

Textbook for Vocational Training – Metal Cutting Machine Tools

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Textbook for Vocational Training – Metal Cutting Machine Tools

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Preface

This textbook is intended to help you acquire the skills of a machine operator, the vocation of a skilled worker. You will work with metal cutting machine tools. But to operate them correctly and properly you will have to learn much and acquire knowledge. In using this textbook we recommend you the following:

- First, read the chapters of the introduction
- Then read the special chapter about the machine on which you are trained.
- Take this textbook to your work place and compare the passages you have read in this book with what you see at the machine.

If you are trained to operate several machine tools you can extend your knowledge and widen your skills by reading the other chapters of this book. You will soon realize that you have already acquired a fair knowledge

and that learning becomes more and more easy.

1. Introduction into the theory of machines

In this section you shall get acquainted with the

- criteria used to subdivide machines
- types of machines existing
- major tasks assigned to each machine
- common aspects and differences among the various kinds of machines.

1.1. Types of machines

There is a great number of various machines. They all serve man, for instance,

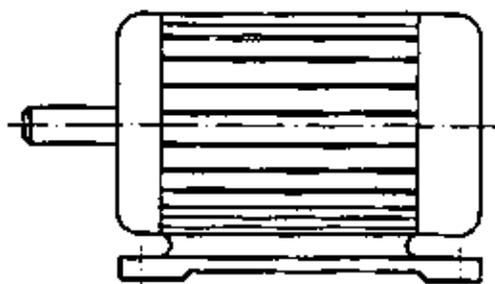
- for transporting material
- for lifting loads
- for machining workpieces
- for cultivating soil and crops
- for generating electrical energy
- for transmitting information and for many other purposes.

All these machines can be subdivided into whether they shall be used for performing a job, for driving other machines, or for processing information.

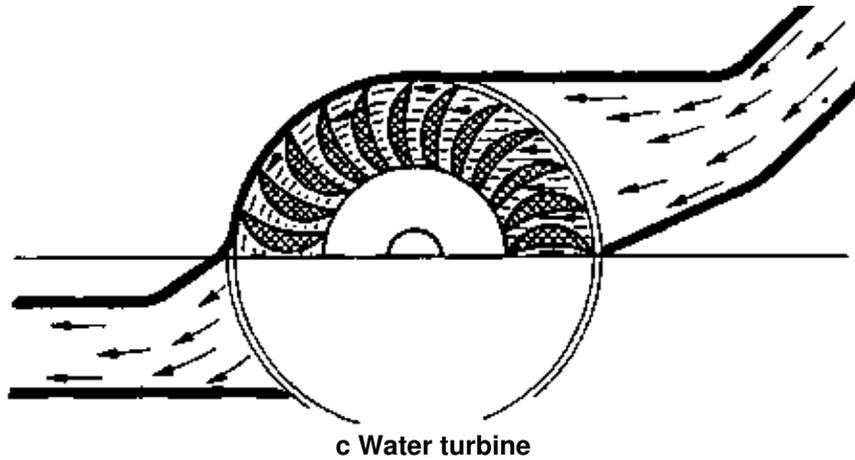
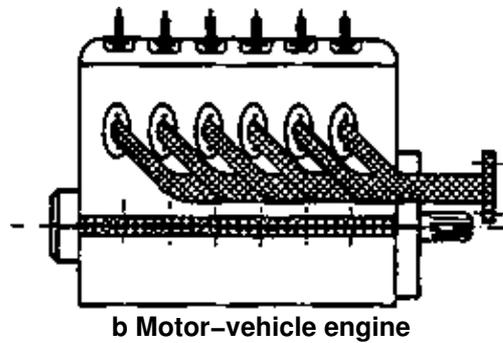
Prime movers

Prime movers are all those machines that transform energy. Examples are electric generators, electric motors, water and steam turbines, vehicle engines, steel propulsion units of aircraft (Figure 1/1). Prime movers are mostly connected with other machines, i.e. they drive other machines. Electric motors, for instance, take energy from an electric source and transform it into a rotating movement which, in turn, is transmitted to another machine, say, a drilling machine so that the tool rotates and performs work. Motorcar engines transform the energy contained in fuel first into heat and then into a rotating movement that is transferred to wheels, so that the automobile drives.

Figure 1/1 Examples of prime movers



a Electric motor



Machines doing mechanical work

These are all those machines that perform work.

Examples are the following: machine tools, transport machines, lifting gear, agricultural machines (Figure 1/2).

Machines are driven by prime movers, with which they are connected. Machine tools are mostly driven by electric motors, motorcars by diesel engines or Otto engines, and also agricultural machines for arable farming.

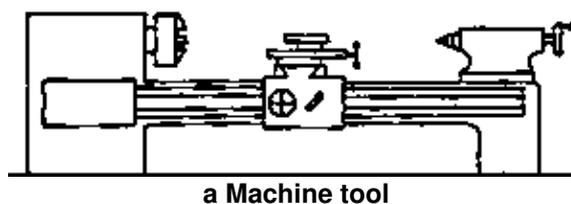
Machines for mechanical work are the older type of machines.

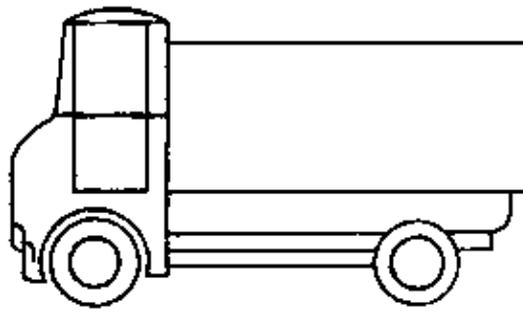
Originally they were driven by man himself, or by animals. Some of these machines, such as hand drills, are still driven today by the muscular strength of man.

Information processing machines

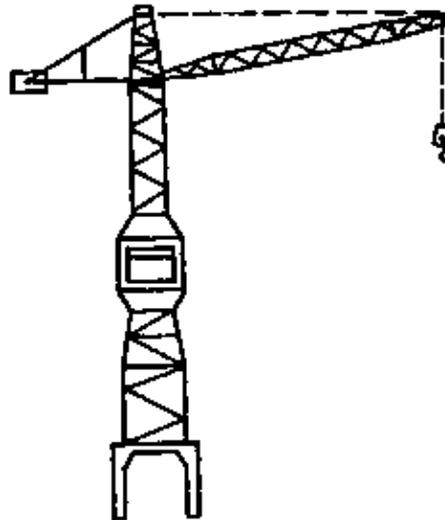
All machines that transfer, store and convert information are called information processing machines. Examples are: machines for the collection and processing of data, auxiliary machines for information processing, calculating and computing machines. Information processing machines are the more recent type of machines. Originally man was only capable of passing information to other people, or putting information into machines to operate them. Nowadays there are machines to be used by man for these operations (Table 1/1).

Figure 1/2 Examples of machines doing mechanical work (operator)





b Vehicle



c Crane

This textbook deals only with metal-cutting machine tools, i.e. a type of machine that performs mechanical work.

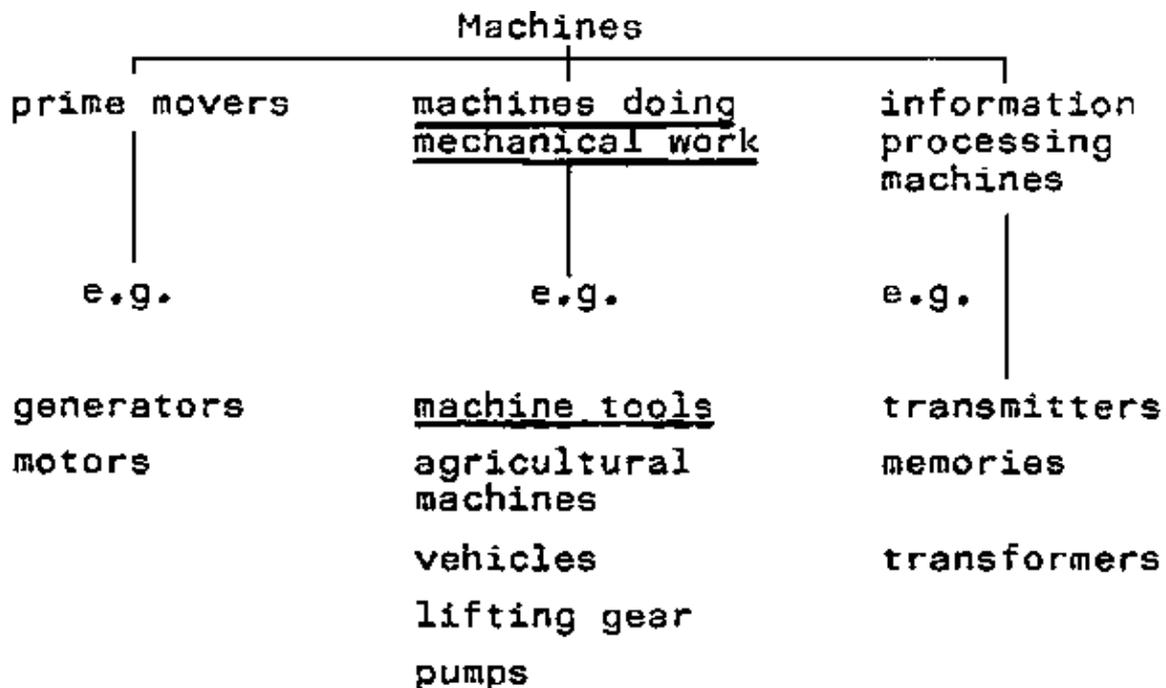


Table 1/1 Types of machines

1.2. Basic structure of machines

When looking at different types of machines performing mechanical work it can be recognized that different mechanism of machines perform the same or similar functions (Figures 1/3 and 1/4).

Driving mechanisms, i.e. generally the prime movers, drive the entire machine. Many driving mechanisms are designed in a way that they can be conveniently used for different purpose if the power requirements are the same.

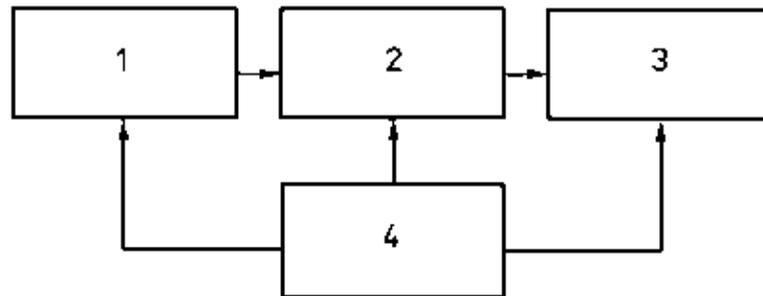


Figure 1/3 Basic structure of an operator (schematic representation)

1 Driving mechanisms, 2 Mechanisms of transfer, 3 Mechanisms of work, 4 Mechanisms of control.

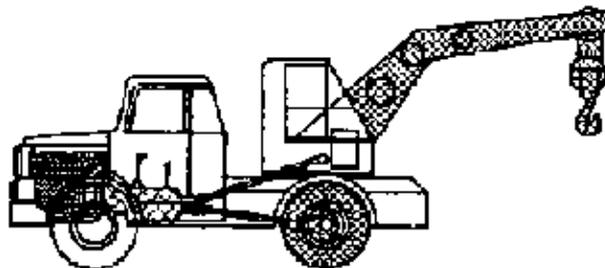
Mechanisms of transfer, e.g. gears consisting of cogwheels or belt drive, transmit the driving motion and driving forces from driving mechanisms to the mechanisms of work.

Mechanisms of work act on the workpiece. They modify its shape or position.

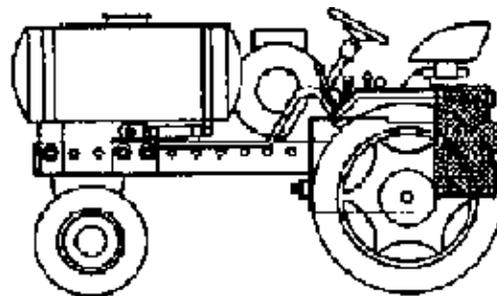
Mechanisms of control control the interaction between mechanisms, either independently according to programmes, or operated by man.

None of these mechanisms can be used separately; the harmonious interplay by man is it that they can be used for technological purposes.

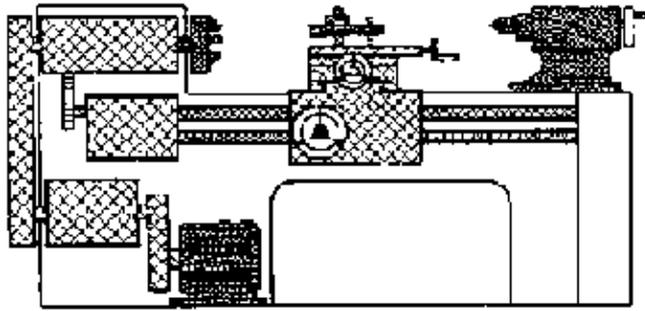
Figure 1/4 Examples showing the basic structure of operators



a Vehicle with crane



b Agricultural machine



c Machine tool

Control questions

1. Name the types of machines and examples of these types.
2. What are the criteria used to subdivide machines?
3. What are the common characteristics shared by machines of different types?
4. What are the characteristics distinguishing machines of different types?

2. Metal cutting machine tools

In this section you shall get acquainted with

- what is generally understood by metal-cutting machine tools
- the types of metal cutting machine tools available
- the basic structures of metal cutting machine tools
- the way of servicing and maintaining metal cutting machine tools

2.1. Survey of the tasks and types

Metal cutting machine tools are machines performing mechanical work. They use machine-driven tools. During operation they cut metal chips from the workpiece. This metal cutting characteristic has given them their name (Table 2/1).

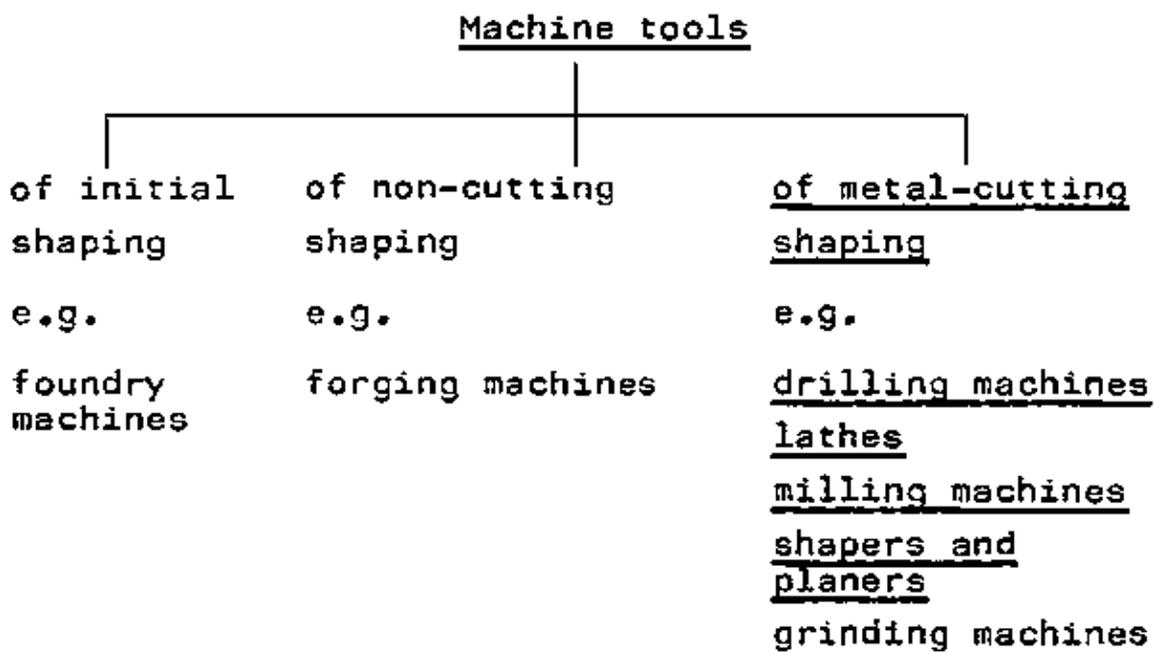


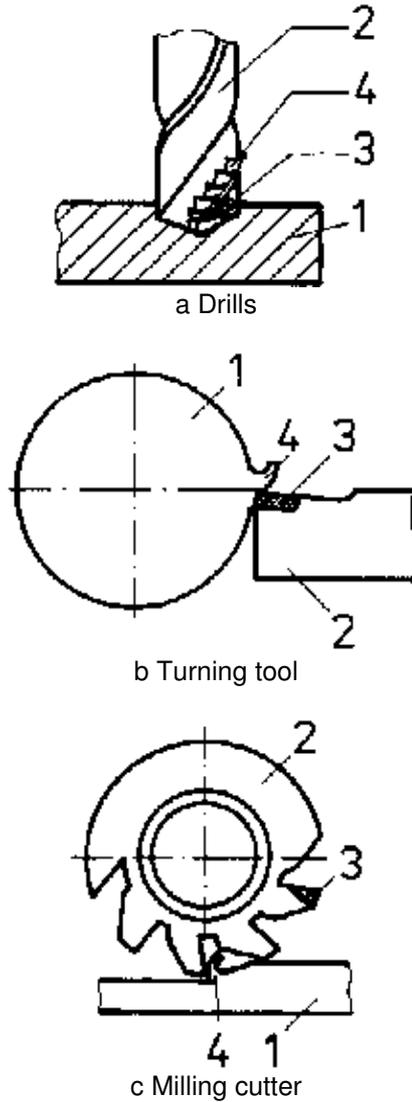
Table 2/1 Types of machine tools

Tasks of metal cutting machine tools

Metal cutting machine tools have the task of shaping workpieces by cutting chips from them. Thus they decrease the volume of workpieces. The cut off metal chips are scrap.

During the process of cutting metal chips the tools cut off material from the workpiece. The workpiece puts up resistance against the impact of tools, for the materials are solid and firm. For the purpose of overcoming this resistance, the tools should be harder and firmer than the workpiece (Figures 2/1 and 2/2).

Figure 2/1 Metal cutting machine tools cut chips from workpieces



1 Workpieces, 2 Tools, 3 Cutting sections, 4 Chips

Figure 2/2 Types of metal chips cut off





b Stringy chip

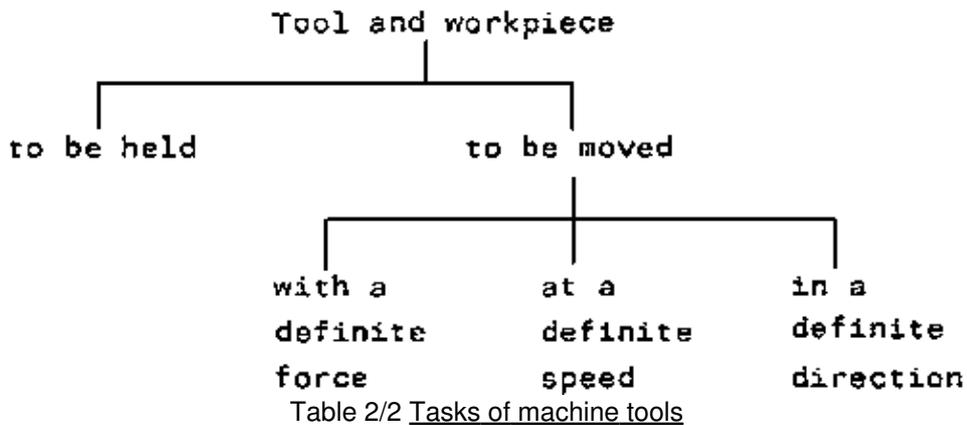


c Screw chip



d Discontinuous chip

During the metal cutting process workpieces and tools are held and rotated by the machine tools (Table 2/2).
 To this end the machines are equipped with adequate fixtures.



Machine tools are designed differently according to the nature of workpieces and according to the kind of machining.

There are:

- Drilling machines
required for machining and finishing drills
- Lathes
required for making and machining rotationally symmetrical parts
- Milling machines, shaping and planing machines
required for making and machining parts with flat and shaped surfaces.

- Grinding machines required for machining flat, shaped and rotationally symmetrical parts.

2.2. Basic structure of metal cutting machine tools

All metal cutting machine tools are made up of the following components:

- The machine frame, or the base frame, on which all the other components are mounted and which give the machine shape and support.
- The driving motors and the gears, the work holders and the tool holders.
- Appliances for control, for measuring and supervision of the course of machining.

The machine frames, or base frames, have to be designed in a way that they can carry the other components without being bent or distorted. During metal cutting forces are developed that have to be fully absorbed. To achieve a good degree of rigidity, many machine frames are provided with ribs or contours to serve as stiffening factors (Figure 2/3).

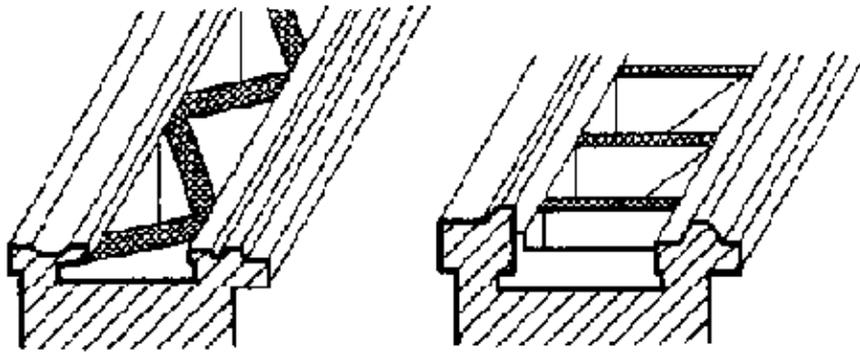


Figure 2/3 Stiffening parts at machine frames

Slides, or guideways are also mounted on the machine frame, on which work holders and tool holders may slide freely. The guideways are shaped differently, dependent on the kind of forces developed during metal cutting. Many machines are provided with special covers for the guideways (Figure 2/4).

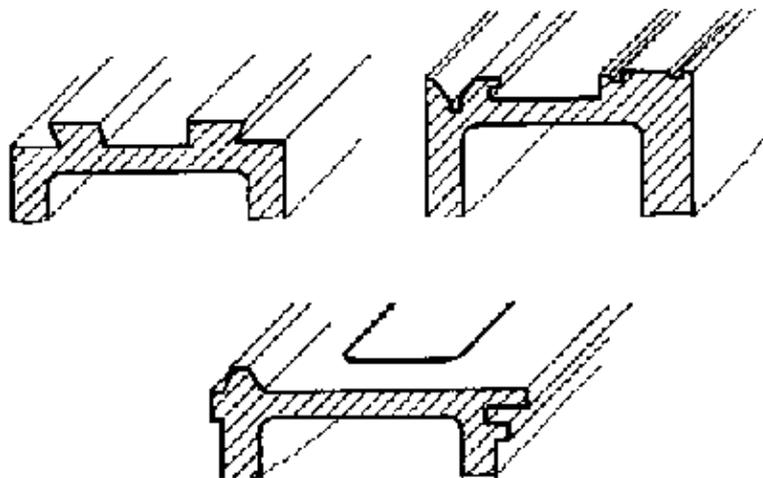


Figure 2/4 Guideways on metal cutting machine tools

The gears are mostly the most sensitive component of a machine. Their functionality depends on whether they are

- technically correctly connected
- sufficiently lubricated and whether the
- lubricant is renewed in time.

The manufacturer of the machine provides instructions on how gears have to be connected, when the lubricant has to be changed and what kind of lubricant has to be used in what quantity.

The work and tool holders move on the guideways of the machine frame. They are intended to put workpiece and tools into the correct positions. The accuracy with which a machine tool operates depends on how work holders and tool holder are actuated. If the guideways are unclean, or used up, or not lubricated, the work holders and tool holders cannot ensure a good guideway, so that the results of work are inaccurate.

Devices for control, measuring and supervision are to be found at the technically developed machines. They are firmly integrated into the machines, or additionally built into them as an exchangeable device. The following operations can be carried out, e.g., by such devices:

- Switching on and off at the beginning and end of an operation
- Measuring the results of work
- Readjustment of tool
- Interchange of tool or workpiece
- Positioning (resetting) of tool
- Engagement of gears.

2.3. Standardization of metal cutting machine tools

Purpose of standardization

Standardization means unification. For metal cutting machine tools it would mean that individual components and parts are uniformly manufactured for different machines. As a result there are convenient conditions reached for

- the design
- the manufacture
- the use
- the maintenance
- the repair of these machines.

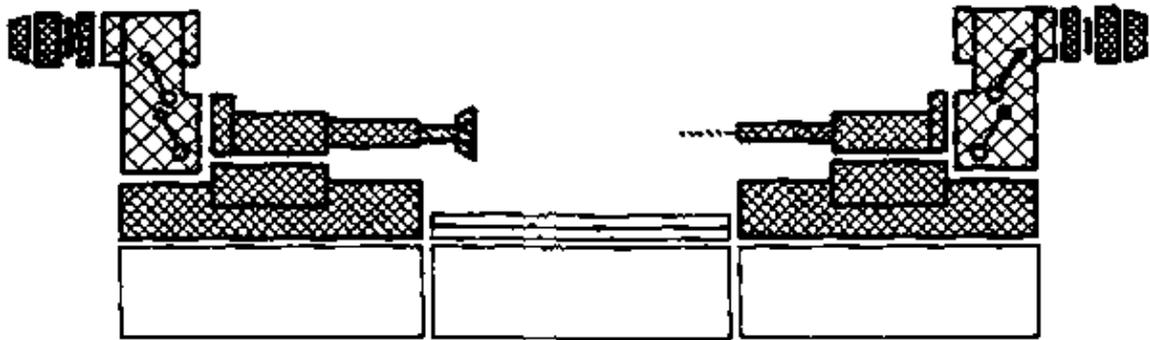
Examples of standardization in metal cutting machine tools

On the basis of the components of the machine (Figure 2/5) it is possible to build various types of metal cutting machine tools. All components are designed in a way that they fit to each other. The system to design machines is called unit construction principle (or: module construction principle). As soon as a new production is started the components of the machine can be composed in a different manner. Thus the machine can be used in many ways.

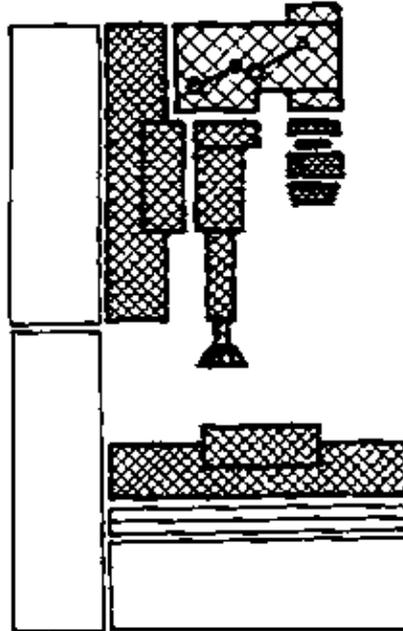
Further examples of standardization are the following:

- Electric motors to be used for various machines;
- Clamping devices for workpieces suitable for different machines;
- Tools of different type to be clamped with the same clamping devices;
- Parts of gear to be interchanged against new ones in case of maintenance.

Figure 2/5 Machine tools composed of modular units



a Horizontal drilling and milling machine



b Vertical milling machine

2.4. General instructions on servicing and maintenance of metal cutting machine tools

The machine operator who keeps his machine operational over a long period by proper and timely servicing and maintenance according to instructions contributes to the property of the enterprise and thus to that of the entire people. Special attention has to be paid therefore to the instructions and regulations on servicing and maintenance of machines.

The operation of the machine according to regulations is the foremost requirement for a long service life of a machine. Those workers are only permitted to operate a machine who are well acquainted with its mode of operation and have learnt how to operate it. If somebody was trained for certain operations only, he should stick to carrying out exclusively these trained operations and should not try to carry out any others.

No use of force, since all operations have to be carried out with a moderate amount of effort. If difficulties arise in operating a machine it is possible that there are defects that have to be eliminated. Remember, force does not remove any defects, it rather multiplies them only.

Regular cleaning prolongs the service life of a machine. It is important to clean the movable components, such as guideways, spindles, all components in contact with coolants.

Regular lubrication increases also the service life of a machine. The lubricating schedule has to be strictly observed. This schedule is part and parcel of every machine and includes the points of lubrication, the lubricants and the lubricating intervals.

2.5. General instructions and rules on work safety

Clothing

1. Working clothes must fit tightly. Sleeves and pockets are not allowed to stick out; belts and scarves shall not dangle.
2. The hair has to be protected and covered by an adequate clothing so that the machine cannot catch it. The ends of a head-scarf are not allowed to dangle.
3. Prior to the beginning of work it is required to take off finger-rings, bangles, wrist-watches and necklaces.
4. Footwear has to be solid and stable. Sandals, or high-heeled shoes increase the danger of accidents. Non-slip shoes are required.

Operation of machines

5. The operation of machines is allowed only for those workers who are wellacquainted with their attendance, or have been instructed to carry out certain operations.
6. Prior to starting up of a machine it is essential to clamp safely workpieces and tools. Clamping tools are to be taken off.
7. Protective devices and appliances are not allowed to be removed.
8. Metal chips are not allowed to be removed by hand, but suitable instruments shall be used only.
9. Machine has to be stopped prior to measuring of workpieces.
10. During the breaks and the removal of defects the machine has to be disconnected.
11. It is not permitted to sit on the machine, or to lean against it.
12. Maintenance works, e.g. cleaning, lubricating, shall be carried out only when the machine is disconnected.

Control questions

1. To what class of machinery belong metal cutting machine tools?
2. Explain the designation "metal cutting machine tools".
3. What are the machine components of a metal cutting machine tool?
4. Name the functions of the machine components.
5. What are the advantages of standardization for the operation of metal cutting machine tools?
6. Name several instructions on servicing and maintenance.
7. Name several instructions on work safety.

3. Drilling machines

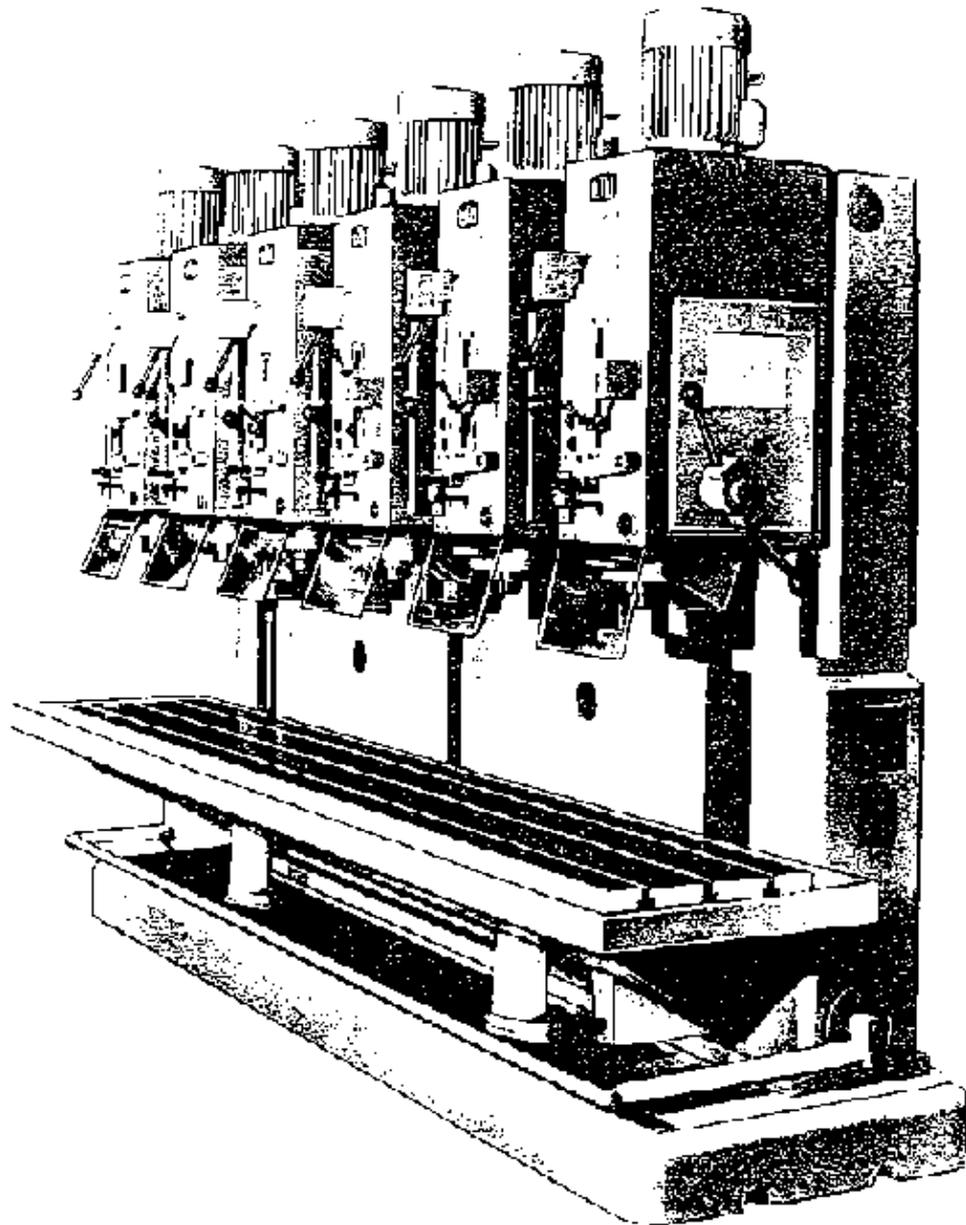


Figure 3/1 Upright column-type drilling machine

3.1. Survey of the types and use of drilling machines

In this section you shall get acquainted with

- the types of machines used for drilling operations
- the kinds of motions made by drilling machines
- the kinds of operations to be performed by drilling machines.

3.1.1. Several types of drilling machines

We distinguish drilling machines

- according to the maximum operating diameter, i.e. there are drilling machines for small, medium and large diameters;
- according to the number of drilling spindles, i.e. there are machines with only one drilling spindle and machines with several drilling spindles;

– according to the arrangement of the drilling spindle, i.e. there are drilling machines with spindles arranged side by side in series and those where the drilling spindles are arranged in tandem and side by side.

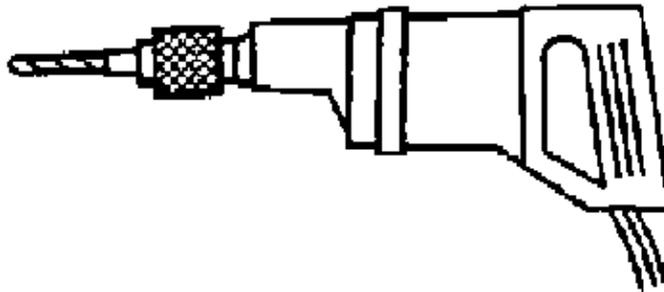
In addition there are drilling machine that can be used universally and there are drilling machines for special purposes.

All drilling machines have to perform the same types of motion. But they have a different design and thus are optimally adapted to their purpose (Table 3/1).

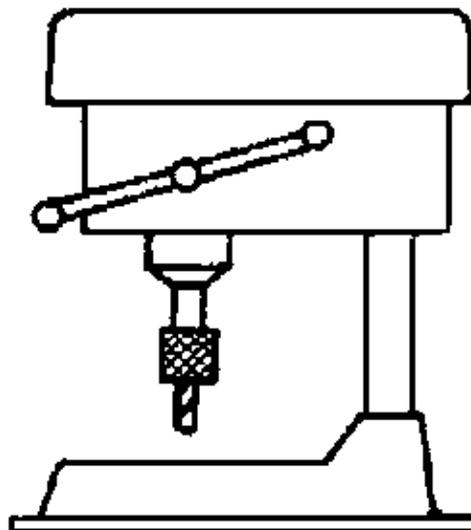
Table 3/1 Classification of drilling machines

Drilling machines

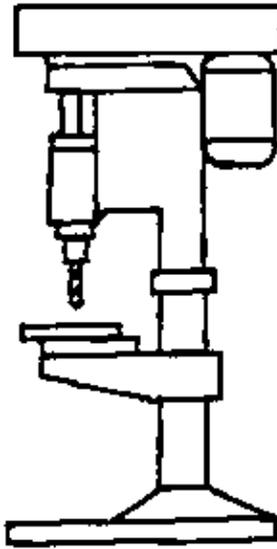
for single–point machining



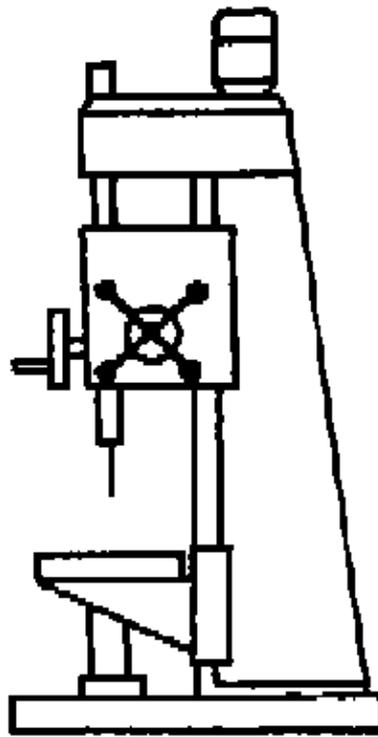
Hand drill



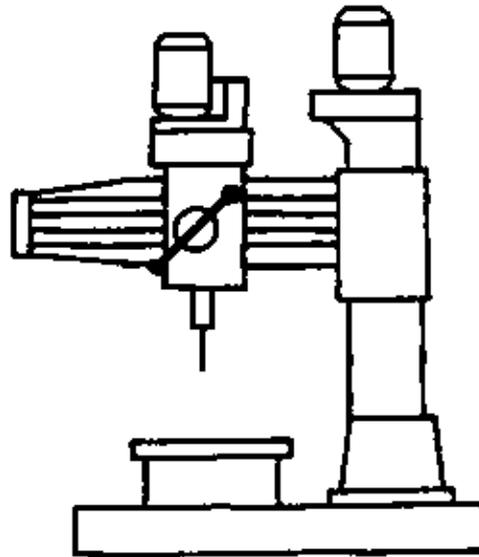
Bench–type drilling machine



Upright pillar-type drilling machine



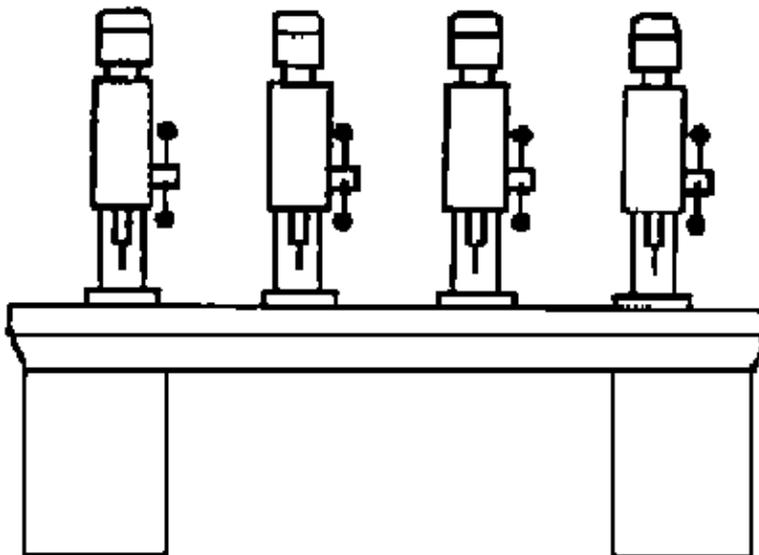
Upright column-type drilling machine



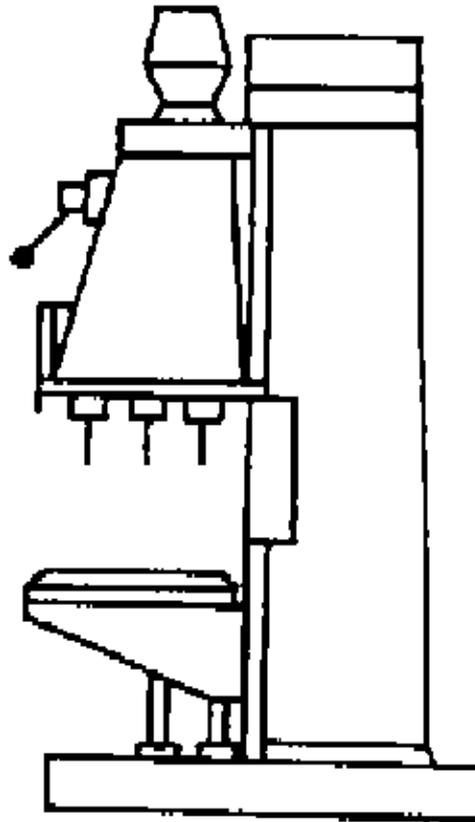
Radial drilling machine

Drilling machines

for multiple-point machining



In-line multiple spindle drilling machine



Multi-spindle drilling machine

3.1.2. Motions of drilling machines

Cutting motion

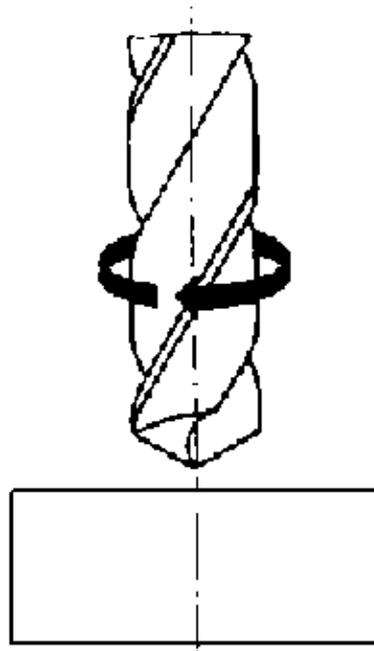


Figure 3/2 Cutting motion during drilling on a drilling machine

The cutting motion of drilling machines is a rotating motion. The cutting motion is performed by the tool. According to the cutting speed to be used for machining the work the tool is rotated at a high number of revolutions, or with a smaller number of revolutions (Figure 3/2).

Feed motion

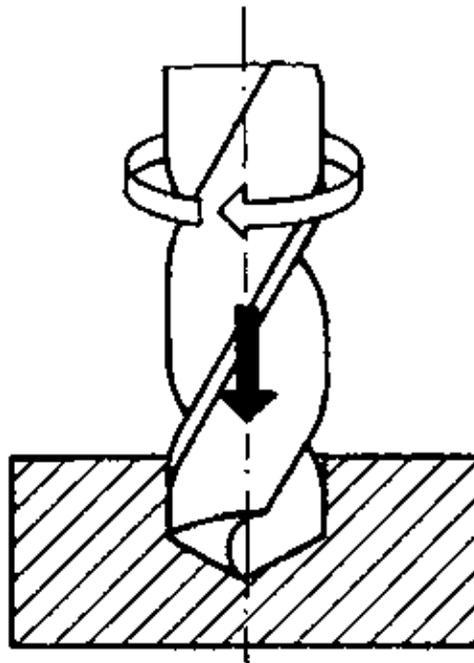


Figure 3/3 Feed motion during drilling on a drilling machine

The feed motion of drilling machines is a straight – line motion. This motion is performed by the tool and proceeds in the direction of the longitudinal axis of the drilling spindle (Figure 3/3),

3.1.3. Examples of operations on drilling machines

Cutting a bottom hole

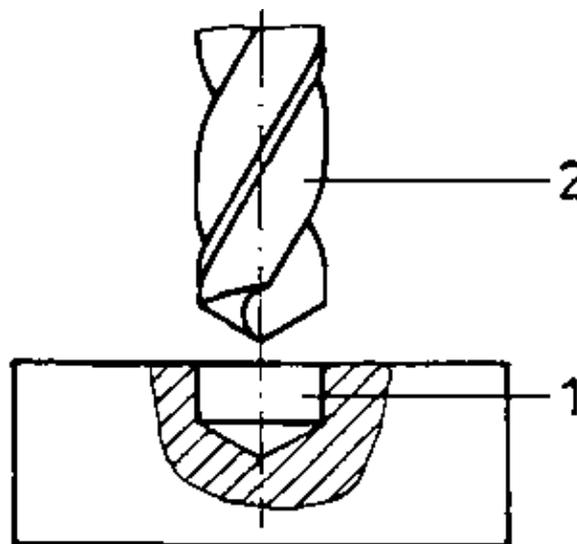


Figure 3/4 Cutting a bottom hole

1 bottom hole, 2 twist drill

Figure 3/4 shows a workpiece with a bottom hole (1).

The bottom hole was cut with a twist drill (2).

Cutting a through bore

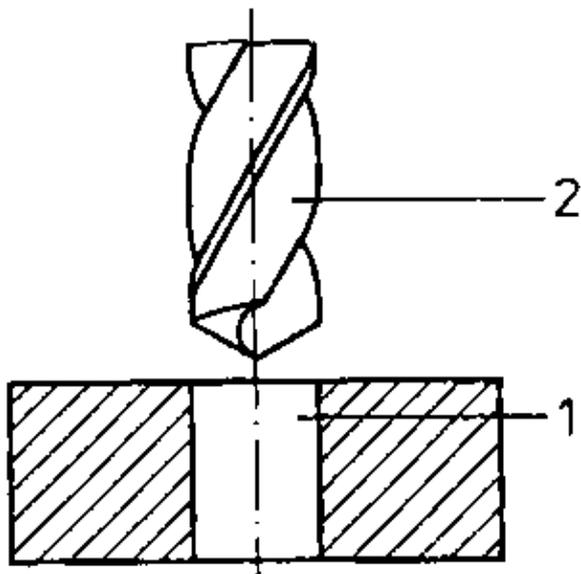


Figure 3/5 Cutting a through bore

- 1 through bore
- 2 twist drill

Figure 3/5 shows a workpiece with a through bore (1). The through bore was cut with a twist drill (2).

Counterboring a through bore

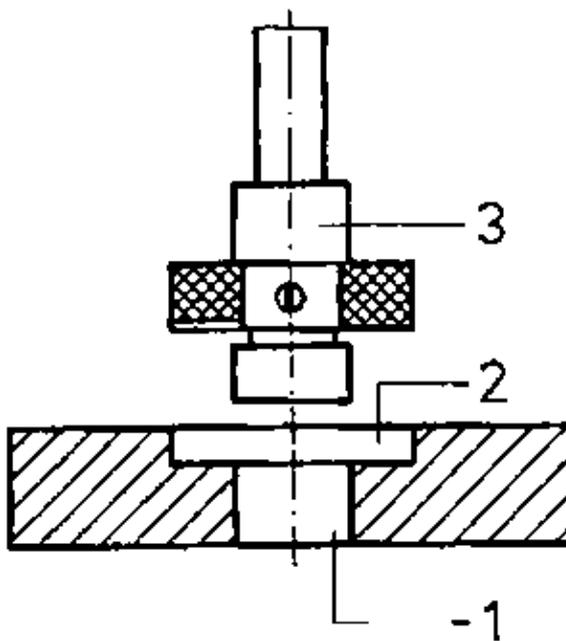


Figure 3/6 Counterboring a through bore

- 1 through bore
- 2 counterbore
- 3 flat counter-bore

Figure 3/6 shows a workpiece with a through bore (1) and a counterbore (2). The through bore was cut with a flat counter-bore (3).

Countersinking a through bore

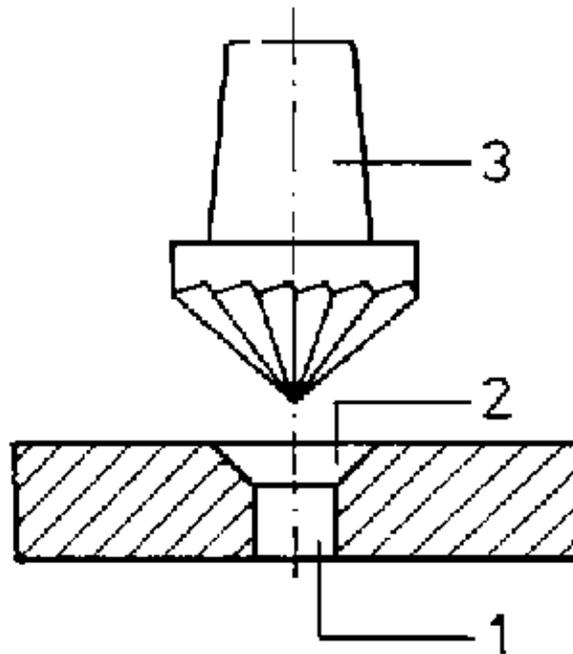


Figure 3/7 Countersinking a through bore

- 1 through bore
- 2 countersink
- 3 taper drill

Figure 3/7 shows a workpiece with a through bore (1) and a funnel-shaped countersink (2). The through bore was cut with a taper drill (3).

Cutting a stepped hole

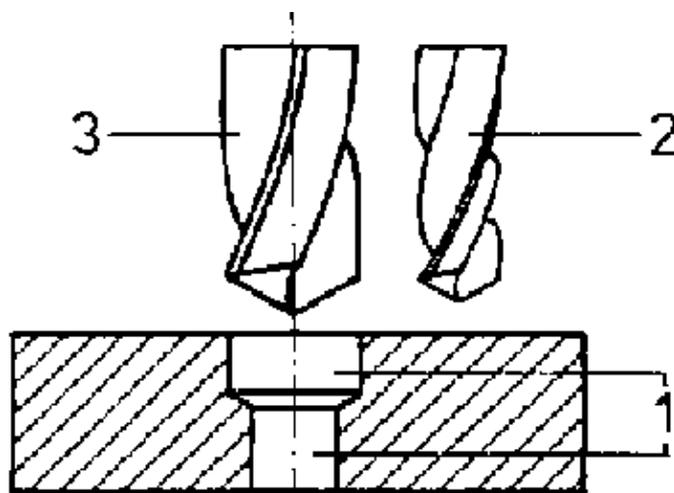


Figure 3/8 Cutting a stepped hole

- 1 stepped hole
- 2,3 twist drill

Figure 3/8 shows a workpiece with a stepped hole (1). The stepped hole was cut in two consecutive stages with two twist drills (2 and 3).

Cutting an internal thread

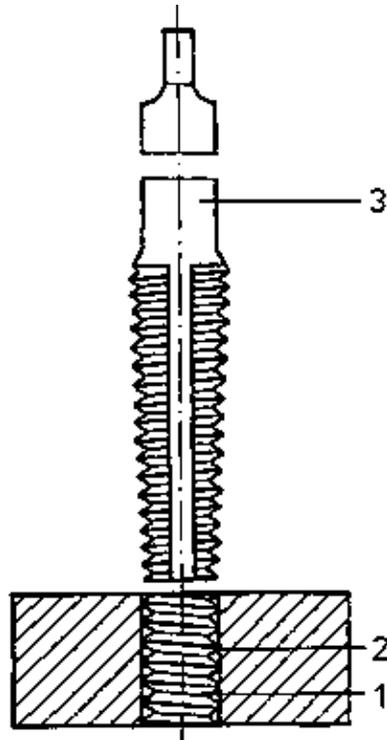


Figure 3/9 Cutting an internal thread

- 1 Through hole,
- 2 Internal thread
- 3 Tap drill

Figure 3/9 shows a workpiece with a through hole (1) and an internal thread (2), The internal thread was cut with a tap drill (3) on the through bore.

Reaming a through bore

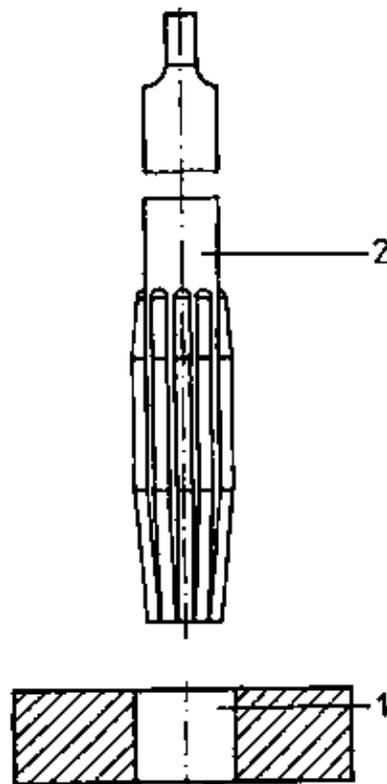


Figure 3/10 Reaming a through bore

- 1 Through bore
- 2 Reamer

Figure 3/10 shows a workpiece with a through bore (1). The through bore was machined with a reamer (2).

Control questions

1. Name several machines which are used for drilling operations.
2. Name workpieces which are preferably machined by these drills.
3. What kinds of motions are to be found during the operation of drilling machines?
4. Name components which in your enterprise are machined by drilling machines.

3.2. Upright column– and pillar–type drilling machines

3.2.1. Structure and mode of operation

In this section you shall get acquainted with

- the machine components of which the upright column–type and pillar–type drilling machines are composed;
- the drive systems that drive the upright column–type and pillar–type drilling machines;
- the mechanism of transmission that convert the motion of motor into the operational motion;
- the interaction between the components of motor and the mechanisms of operation.

Components of a column–type drilling machine

The basic components of the machine are the machine frame (1) with the pedestal (2) and the column (3), the table (4) and the headstock (5). The headstock accommodates the gear (6) for the transformation of motion and the drilling spindle (7). The driving motor (8) is mostly mounted on the headstock (Figure 3/11).

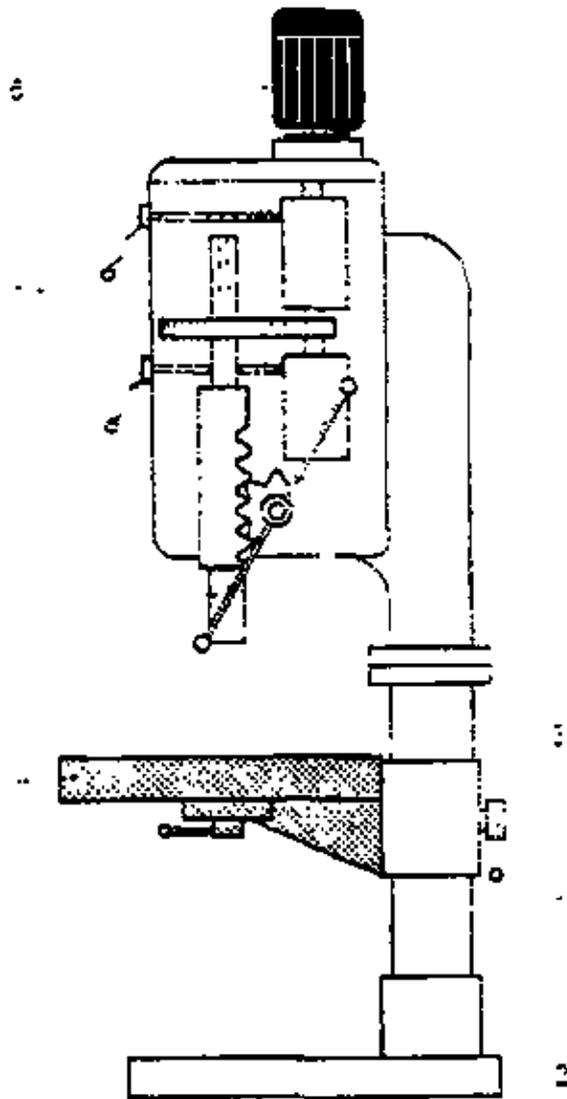


Figure 3/11 Components of a column-type drilling machine

- 1 Machine frame,
- 2 Pedestal
- 3 Column
- 4 Table
- 5 Headstock
- 6 Gear
- 7 Drilling spindle
- 8 Driving motor.

Components of a pillar-type drilling machine

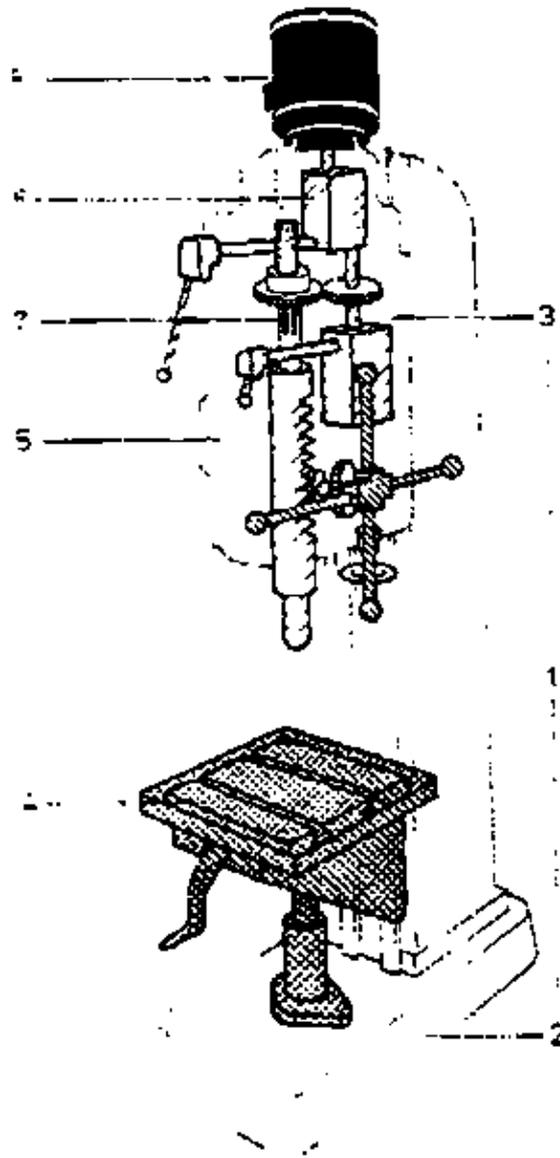


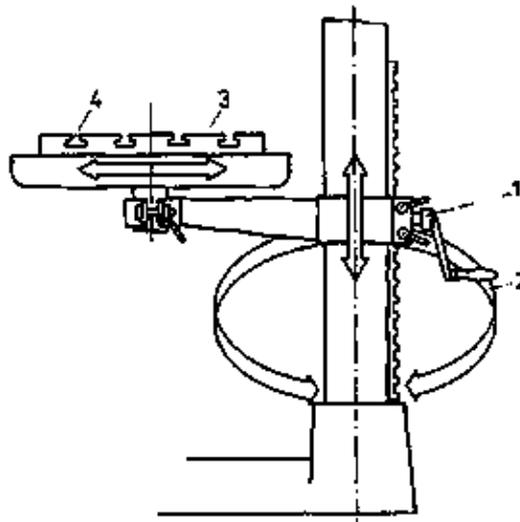
Figure 3/12 Components of a pillar-type drilling machine

- 1 Machine frame
- 2 Pedestal
- 3 Pillar
- 4 Table
- 5 Headstock
- 6 Gear
- 7 Drilling spindle
- 8 Driving motor

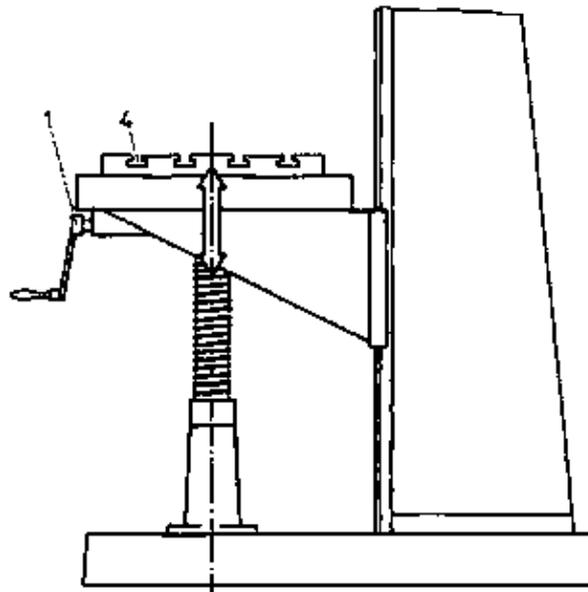
The pillar-type drilling machine has a similar structure compared to the column-type drilling machine. But instead of a round column there is a pillar (3). The other component parts are equal in principle (Figure 3/12).

Common component parts

Figure 3/13 Table at column – and pillar-type drilling machines



a Column-type drilling machine



b Pillar-type drilling machine

1 Table lifting device, 2 Table swivelling around column, 3 Table swivelling around the longitudinal axis, 4 Grooves

The table (2) serves for the support and for fastening the workpieces. The table can be lifted and lowered by means of a table lifting device (1). In the case of round-column drilling machines the table is also slowly arranged around the column and rotates about its longitudinal axis (Figure 3/13).

The machine table is also provided with flutes, or grooves (4) which serve to fasten, or clamp the holding devices for workpieces. The pedestal of the machine gives the stability required for operation. Since the column-type and pillar-type drilling machines are upright slender machines, the pedestal should have an adequate area. The pedestal is fastened to the ground by means of bolts.

Drive for column – and pillar-type drilling machines

Electric motors are used to drive the drilling machines. Column – and pillar-type drilling machines are mostly equipped only with one driving motor to perform all operations (Figure 3/11 and 3/12)

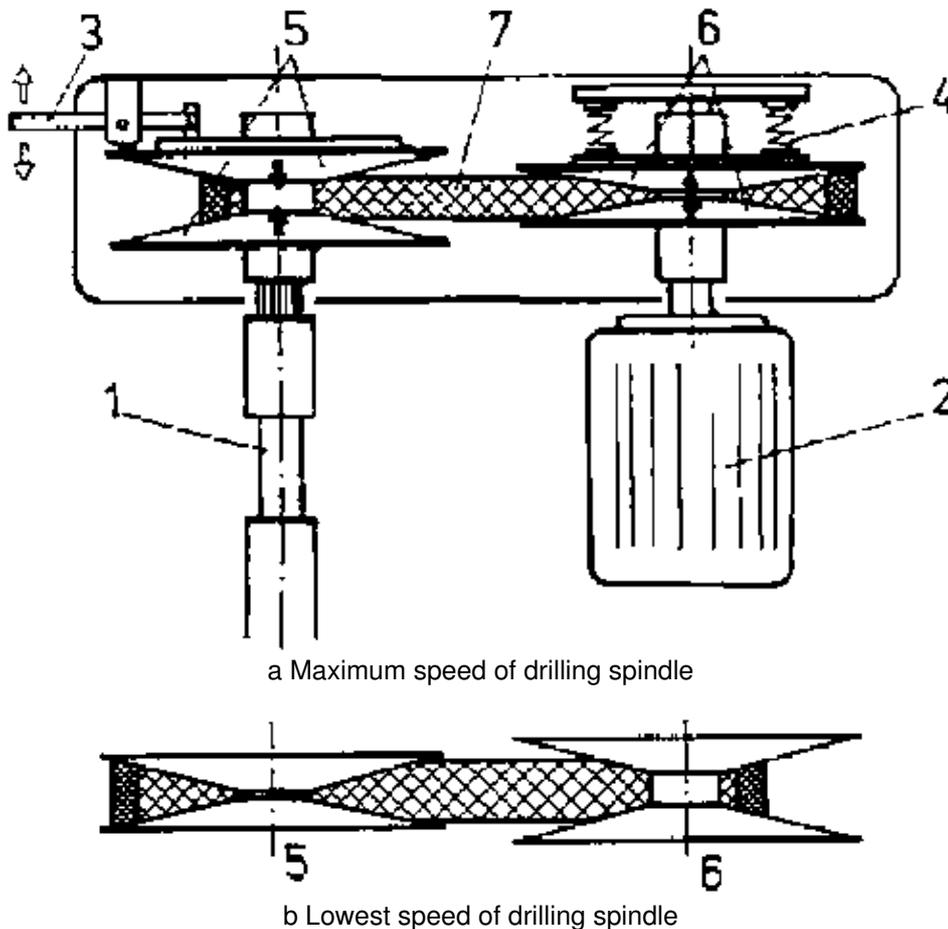
Mechanisms of transfer in column – and pillar-type drilling machines

The drill spindle gear serves for the adjustment of a definite speed for the rotating cutting motion. Since the speed of the driving motor is mostly uniform it is required to obtain the speed of the cutting motion by means of speed regulation. Thus by way of the drill spindle gear the speed of the drilling spindle is either adjustable

in steps, or infinitely variable. (Figure 3/14).

There are drilling machines equipped with a reversible driving motor. The driving motor can be switched on with two different speeds.

Figure 3/14 Drill spindle gear, infinitely adjustable (simplified)



1 Drilling spindle, 2 Motor, 3 Actuating lever, 4 Adjusting spring, 5,6 Belt pulleys, 7 Belt

Table 3/2 Speed graduation of cutting motion with and without motor to be switched over (example)

Speed of motor in rpm	Rotational speed of cutting motion in rpm	
	Series A	Series B
1500	75	120
	190	300
	475	750
3000	150	240
	380	600
	950	1500

As a result the number of switchable speed graduations (Table 3/2) at the spindle gear is doubled. Thus the range of application of the drilling machine is extended. Modern machines are equipped with motors with a speed that is infinitely adjustable.

The mechanisms for hand feed serve to provide the feed motion by hand. They are mostly made up of a hand capstan (3) which via a toothed wheel (4) mates the gear rack (5) at the drilling spindle sleeve (2). (Figure 3/15). When the hand capstan is turned, the toothed wheel moves the spindle sleeve together with the drilling spindle (1) in the direction of the feed motion.

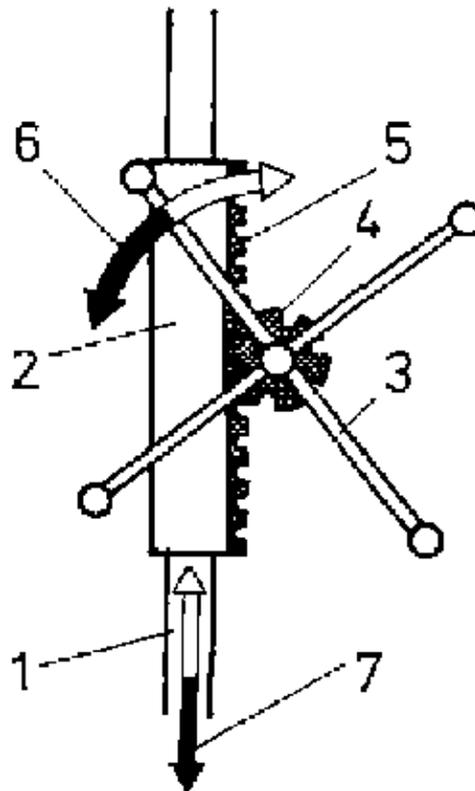


Figure 3/15 Mechanisms for hand feed

- 1 Drilling spindle
- 2 Drilling spindle sleeve
- 3 Hand capstan
- 4 Toothed wheel
- 5 Gear rack
- 6 Direction of rotation of hand capstan
- 7 Direction of motion of drilling spindle.

The feed gear takes the drive of the automatic feed motion from the spindle gear (Figure 3/16). Since the variety of operations require o different feed, the feed gear can be switched. Thus the feed gear makes it possible to adjust the machine to different operations, e.g. to the different diameter of drilling tools.

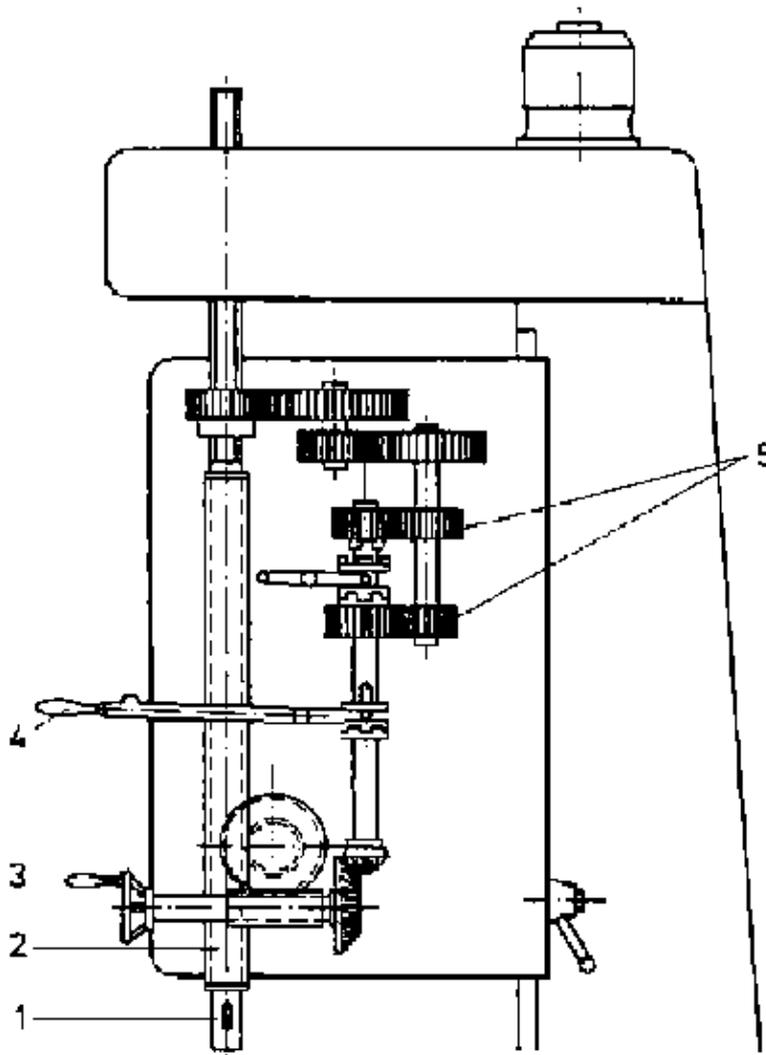


Figure 3/16 Feed gear

1 Drilling spindle, 2 Drilling spindle sleeve, 3 Hand wheel for hand feed, 4 Switch lever for mechanical feed, 5 Notched wheels

The drill depth stop – several machines are equipped with this device – serves to limit the hand feed motion (Figure 3/17).

It is utilized to ensure an equal depth of bottom holes in several equal workpieces. The drill depth stop (4) is connected with the drilling spindle (1). The stop is moved in the direction of the feed motion until it stops at an adjusting component (2). Now it is impossible to move the drilling spindle any further.

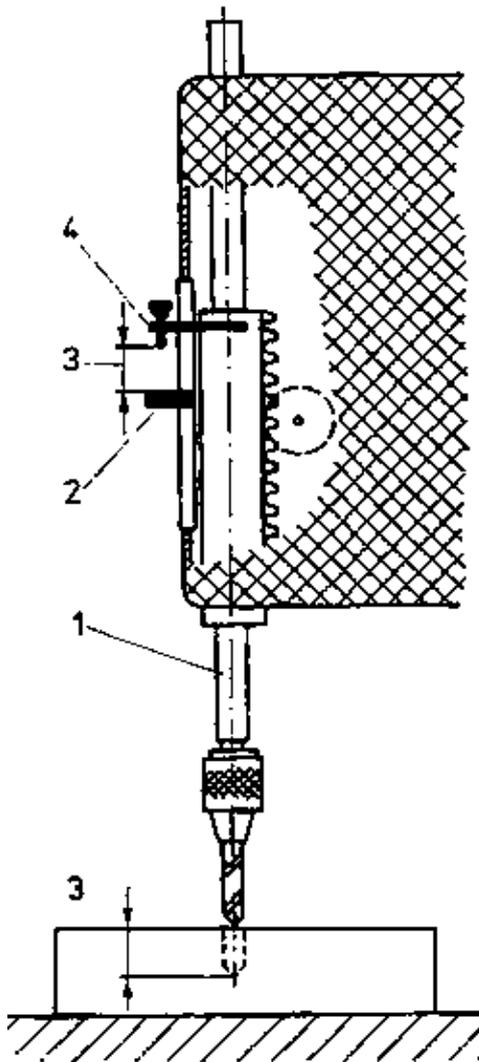


Figure 3/17 Drill depth stop

- 1 Drilling spindle
- 2 Adjusting component
- 3 Drill depth
- 4 Stop

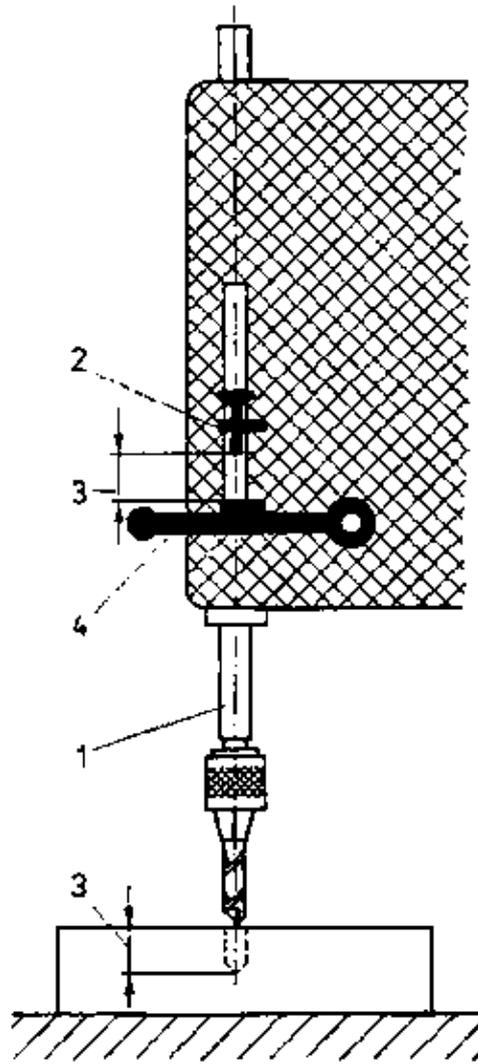


Figure 3/18 Automatic feed disengagement

- 1 Drilling spindle
- 2 Switch lever
- 3 Drill depth
- 4 Switch lever to disconnect power transmission in feed gear.

The automatic feed disengagement is a device which disconnects the automatic feed motion as soon as the drill depth adjusted has been reached (Figure 3/18). Like the drill depth stop it is utilized to cut, e.g. several bottom holes of equal depth.

A switch lever (2) coupled with the drilling spindle (1) is moved in the direction of the feed motion. When the adjusted depth has been reached, the switch lever disconnects the power transfer via a control lever (4) in the feed gear.

Control questions

1. Describe

- the general structure of a column-type drilling machine
- the general structure of a pillar-type drilling machine.

2. What are the functions of the gear with regard to the cutting motion and what are the functions to be fulfilled by the gear for the feed motion?

3. Describe the functions of the hand feed of a drilling machine.

4. What is the benefit of a drill depth stop?

5. Describe the disconnection of the automatic feed by means of the feed disengagement. 6. Make a sketchy drawing to explain the path of power transmission from the driving motor to the workpiece.

3.2.2. Clamping devices for workpieces and their use

In this section you shall get acquainted with

- the functions of clamping devices for workpieces at drilling machines;
- the various kinds of clamping devices
- the way of functioning of clamping devices
- the preferential use of clamping devices for definite workpieces.

Tasks of clamping devices for workpieces

The clamping devices put the workpieces into the position required for machining. They transmit the counter-force to the metal cutting forces onto the workpiece and clamp it tightly.

The forces that emerge during metal cutting are not allowed to displace the workpiece in its clamping device, or to push it out from it.

Any change of position of workpiece in the clamping device results in

- an inaccurate machining of workpiece
- a damage or destruction of workpiece
- an increase in the danger of accidents.

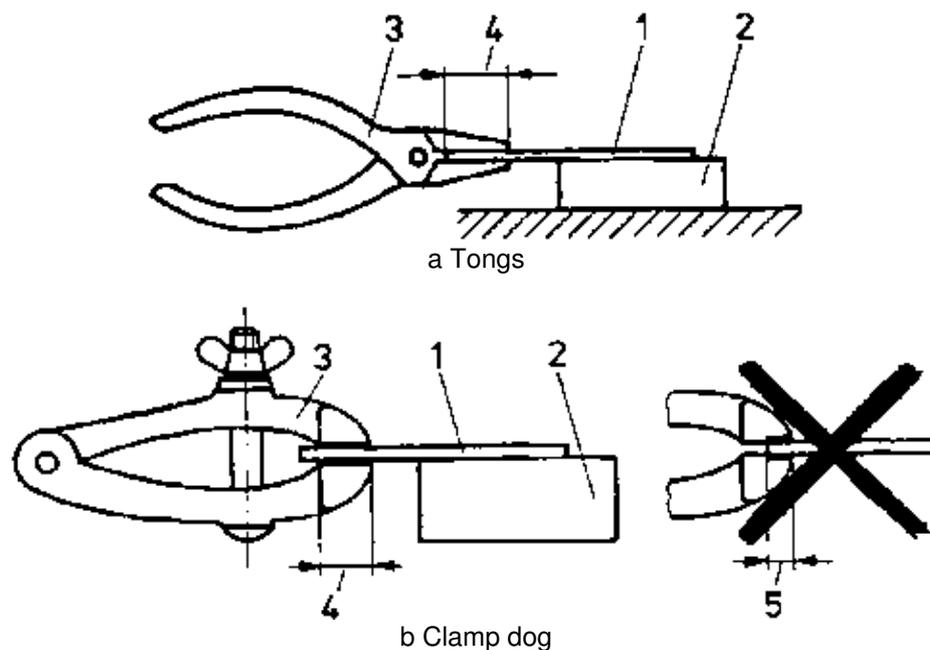
Clamping and unclamping of workpieces shall not require much time; this is a non-productive time.

Clamping devices for holding small workpieces by hand

Workpieces where the forces of machining are small during operation are held by hand. The clamping devices used are

- pliers and
- clamp dogs.

Figure 3/19 Clamping device to clamp small workpieces by hand



1 Workpiece, 2 Support, 3 Clamping device, 4 Area of workpiece clamped by the clamping

device, 5 Workpiece insufficiently clamped.

Clamping devices have to engage the workpiece at a sufficiently large area, because otherwise the machining forces are not fully transmitted from the workpiece to the clamping device, so that the workpiece is torn out from the clamping device (Figure 3/19). It is convenient to utilize a stop against which the workpiece can be leant (Figure 3/20).

Formation of machine table

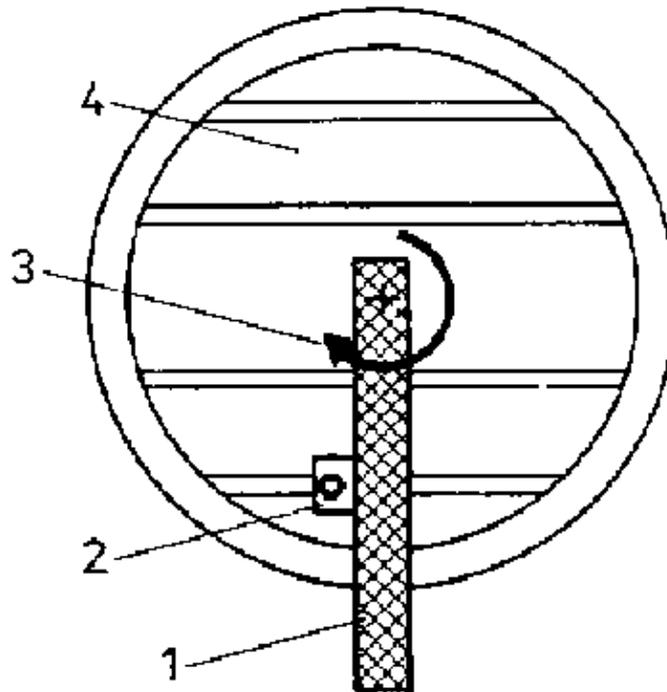


Figure 3/20 Stop for workpiece

- 1 Workpiece
- 2 Stop
- 3 Direction of action of processing forces
- 4 machine table.

Workpieces with flat locating surfaces can be directly clamped on the machine table by using holding clamps. The machine table is designed in a way that it can accommodate drawbolts. The heads of drawbolts are pushed into the T-slots of the motion table (Figure 3/21)

Chips are collected in the T-slots (Figure 3/22). They may get jammed between bolt head and T-slot, so that the drawbolt does not fit well. Therefore it cannot be sufficiently tightened right up and there is the danger that the workpiece becomes loose.

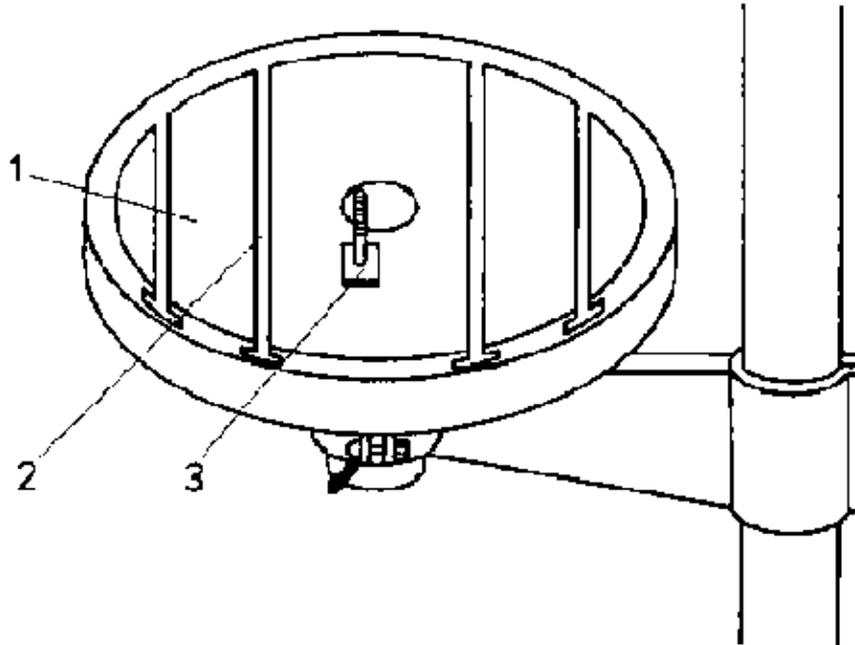


Figure 3/21 Formation of machine table for clamping workpieces

- 1 Table
- 2 T-slot
- 3 Drawbolt with head to be inserted into slot.

T-slots have to be cleaned! Chips impede a safe clamping. There is the danger of accident. Workpiece and tool can be damaged or destroyed.

Clamps or holding straps

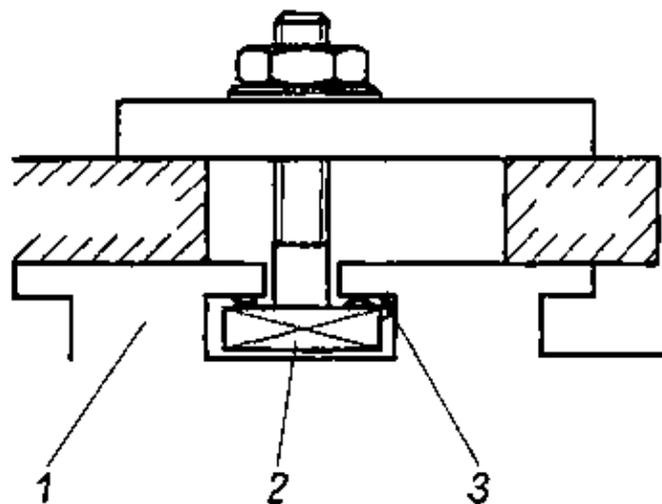


Figure 3/22 Chips in table T-slots impede firm clamping

- 1 Table
- 2 Drawbolts
- 3 Chips which got stuck between slot and screw head.

Clamps or holding straps are used if a workpiece is shaped in such a way that it cannot be directly clamped on the machine table (Figure 3/23). One side of the holding strap lies on the workpiece, whereas the other side is on the clamping support. The clamping support should have a height equal to that point of the workpiece on which the clamp lies. Graduated clamps or holding straps facilitate clamping (Figure 3/24).

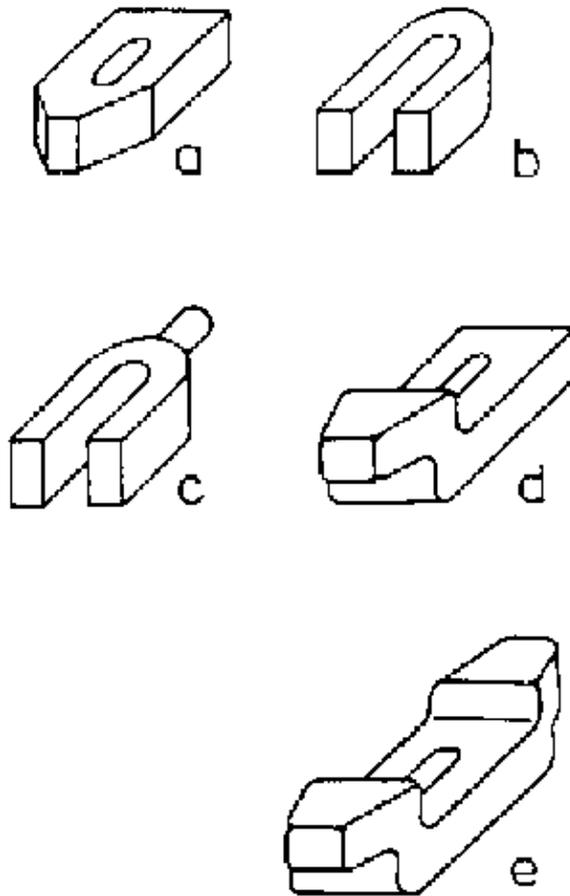


Figure 3/23 Several types of holding straps, or clamps

- a Flat
- b U-shaped
- c Fork-shaped
- d Angularly bent on one side
- e angularly bent on both sides.

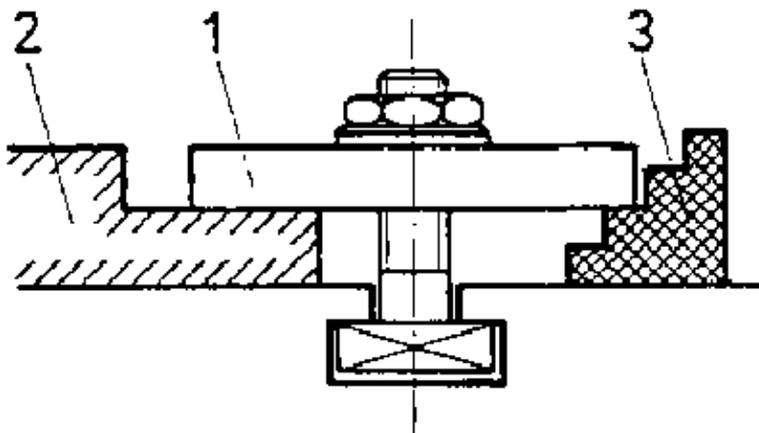
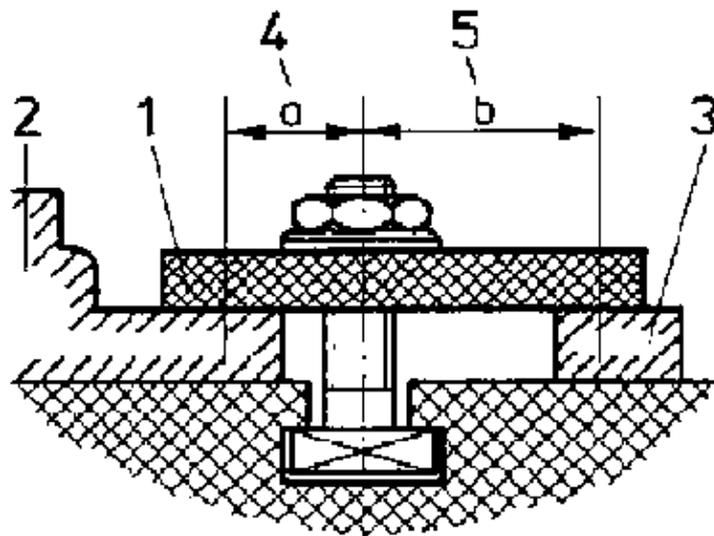


Figure 3/24 Clamping support with steps

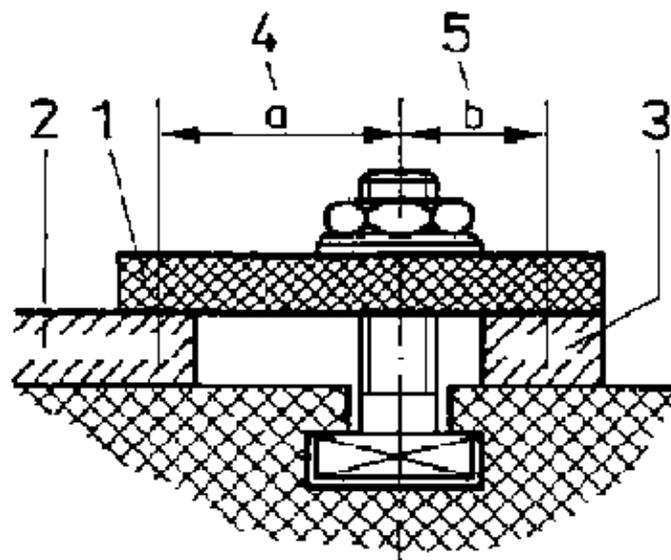
- 1 Holding strap
- 2 Workpiece
- 3 Clamping support

The holding straps are appropriately designed in such a way that the long lever arm lies on the clamping support and the short lever arm on the workpiece. This is a convenient way to utilize lever action for holding and safe clamping of workpieces (Figure 3/25).

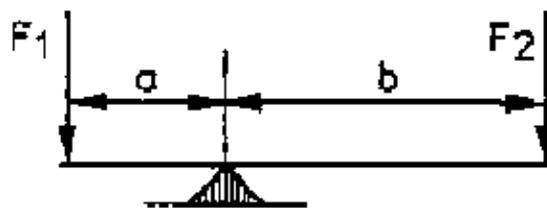
Figure 3/25 Lever action at holding strap



a Favourable



b Unfavourable



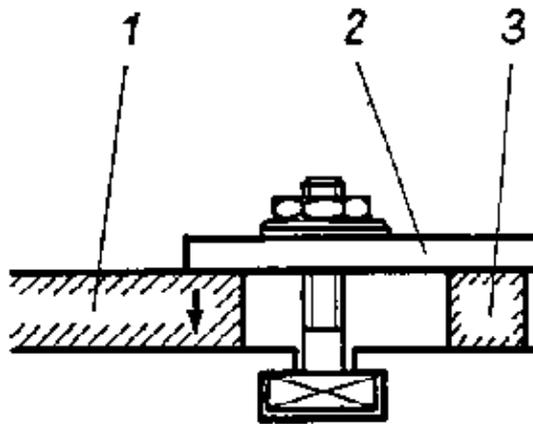
$$F_1 \cdot a = F_2 \cdot b$$

c Lever transmission

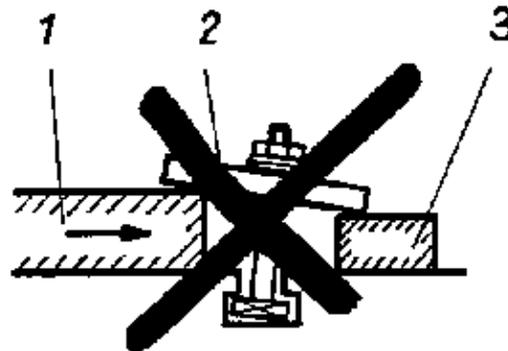
1 Clamping strap, 2 Workpiece, 3 Clamping support, 4 weight arm, 5 Force arm.

If several clamps are used it is advisable to tighten right up all drawbolts in a uniform manner. If the bolts are not uniformly tightened it is possible for the workpiece to be displaced. Thus it is not sufficiently clamped and the machining is defective.

Figure 3/26 Attention when using holding straps



a Holding strap lies parallel to table: correct, workpiece is safely clamped



b Holding strap lies oblique to table: incorrect, workpiece is not safely clamped

1 Workpiece, 2 Holding strap.

To be observed when using clamps or holding straps!

- All drawbolts have to be tightened right up in a uniform way!
- Clamping supports to be selected in a way that the clamps lie parallel to the machine table (Figure 3/26).
- Lever action of clamps to be utilized!

Machine vice

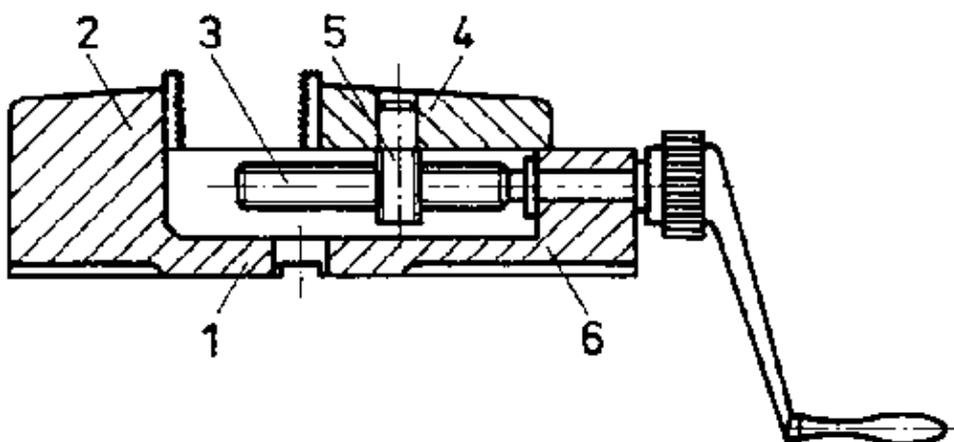


Figure 3/27 Machine vice

1 Base frame, 2 Fixed jaw, 3 Threaded spindle, 4 Movable jaw, 5 Nut, 6 Crank handle.

The function of a machine vice is similar to that of a bench vice attached to a work bench (Figure 3/27). The fixed jaw (2) and the movable jaw (4) are pressed against each other by means of a threaded spindle (3). The movable jaw slides on the sliding surface of the base frame (1). It is connected with a nut (5), in which the spindle is engaged. The threaded spindle is turned via a crank handle (6). On account of its leverage the crank handle increases the manual force of man; it transmits exactly the amount of force, as is required for the safe clamping of workpiece. An extended crank handle would augment the manual force to such an extent that the machine vice would be destroyed or the workpiece deformed (Figure 3/28).

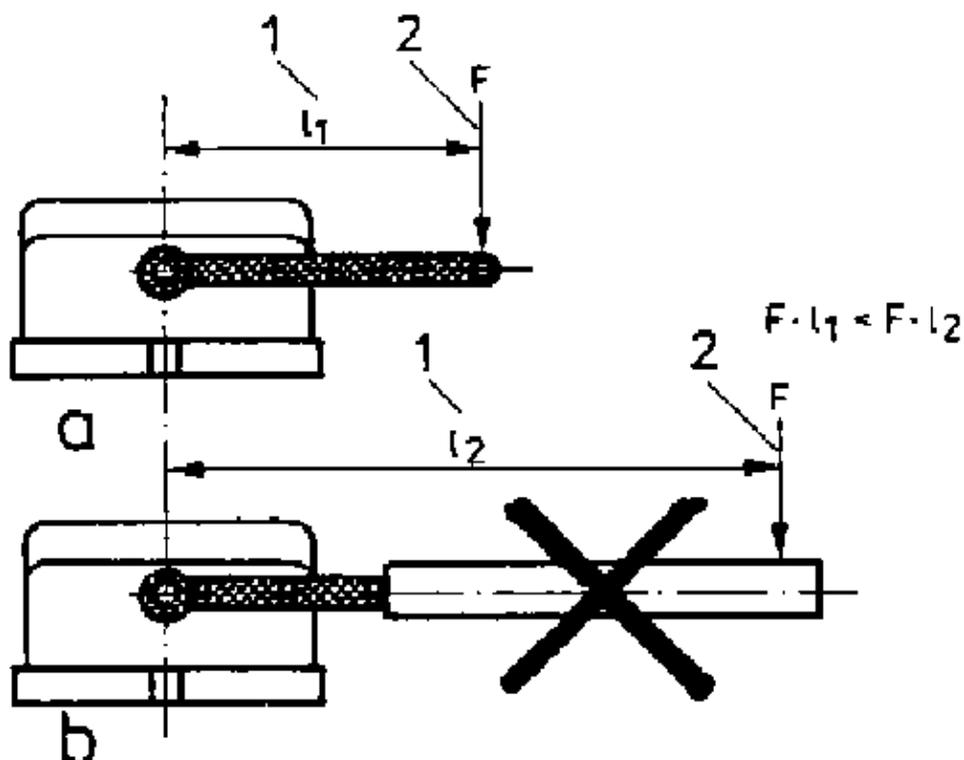


Figure 3/23 Power transmission in the crank handle of the machine vice

- a Crank handle with adequate length
- b Crank handle too long;

- 1 Lever in crank handle
- 2 Direction of manual force.

Crank handles for machine vices should not be extended because of damage to the workpiece and clamping device.

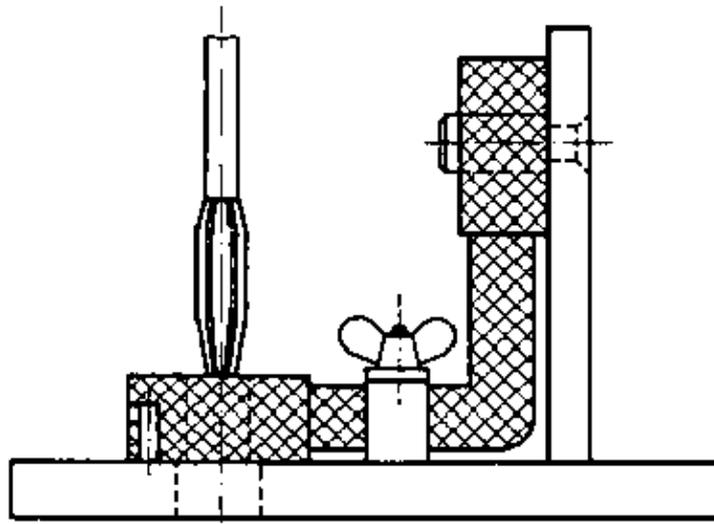
It is also possible to hold the machine vice by hand for operations with small working diameters; for larger diameters, however, the machine vice shall be fastened on the machine table by means of drawbolts.

Clamping fixtures

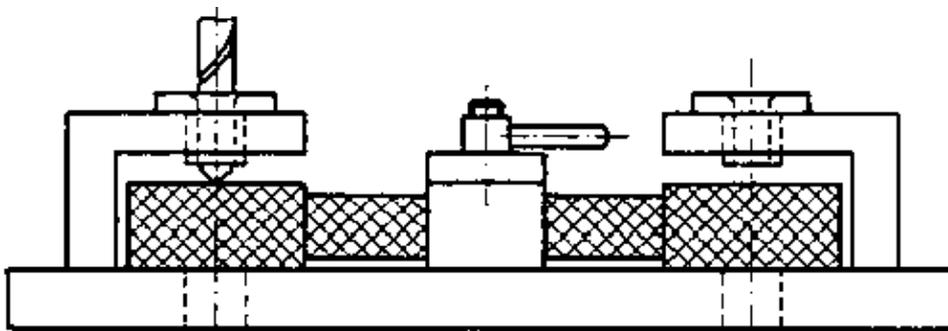
Clamping or holding fixtures serve special ends. For this reason they are very different in their design (Figure 3/29). They are used

- for workpieces which can be clamped only inadequately with holding straps or in machine vices on account of their shape;
- for quantity production of workpieces of identical design to be turned out in great batch numbers, when frequent clamping is required in equal positions;
- for workpieces that can be clamped simultaneously in several numbers;
- for such cases when the tool, e.g. drill, is to be clamped separately.

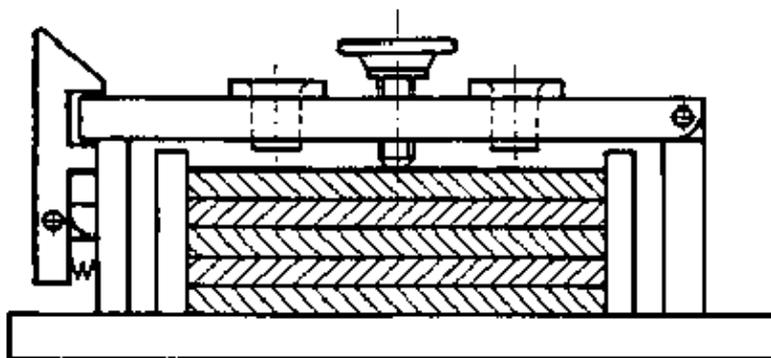
Figure 3/29 Clamping fixtures for operations on. drilling machines



a Clamping fixtures holding the workpiece,



b Clamping fixture holding and conducting the workpiece,



c Clamping fixture for several equal workpieces.

Control questions

1. What are the tasks of clamping devices on column–and pillar–type drilling machines?
2. Name the clamping devices to be used for operation on column – and pillar–type drilling machines.
3. What workpieces can be clamped in using these clamping devices?
4. What has to be observed with the various clamping devices in order to hold the workpieces safely?
5. What influence is exercised by correct clamping of workpieces on the quality of work?

3.2.3. Clamping devices for tools and their use

In this section you shall get acquainted with

- the functions of clamping devices at column – and pillar–type drilling machines
- the types of clamping devices existing
- the way of functioning of clamping devices
- the kinds of clamping devices to be used for definite tools.

Tasks of clamping devices for tools

The clamping devices transmit the rotating cutting motion from the drilling spindle to the tool. They hold the tool vibration–free. They guarantee that the tool runs true.

Clamping devices are designed in such a way that the tool can be clamped and unclamped easily and quickly. During operation it is not allowed for the tools to get loose, because the tool and the workpiece will be damaged, or destroyed.

Cone connection

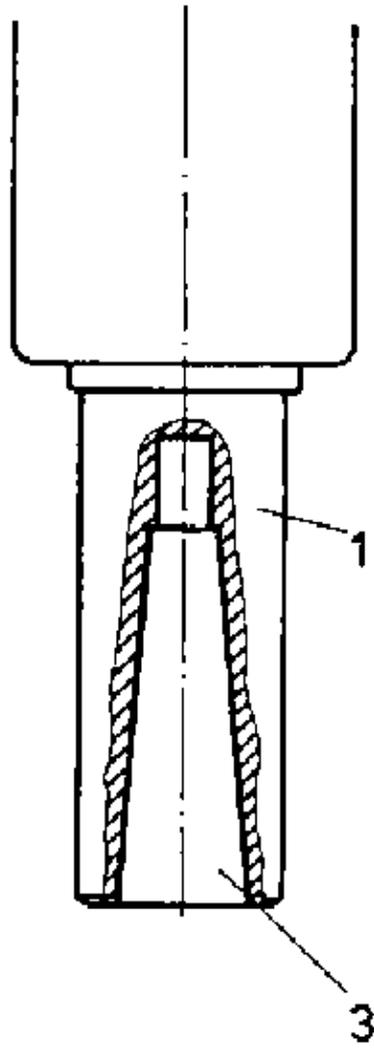
A simple, but firm and reliable kind of clamping the tools into the drilling spindle is the cone connection.

It consists of

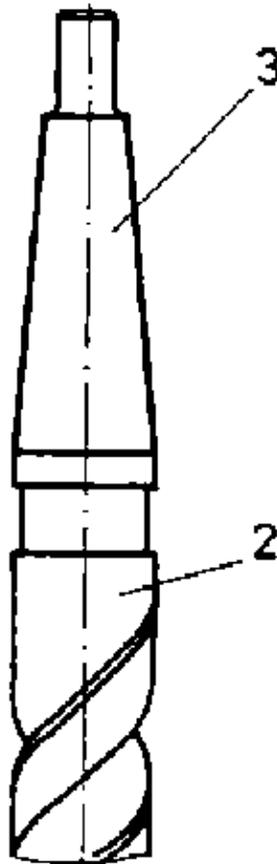
- the internal taper in the drilling spindle and
- the external taper of the tool.

Upon clamping the internal taper of the drilling spindle (1) and the external taper of tool (2) are driven into each other. Between the conical surfaces (3) a great deal of friction is produced due to the action of cone, so that the two cones do not separate from each other under the impact of the machining forces (Figures 3/30 and 3/31).

Figure 3/30 Cone connection to hold tool in drilling spindle



a Internal taper of drilling spindle



b External taper of tool

1 Drilling spindle, 2 Tool, 3 Conical surfaces

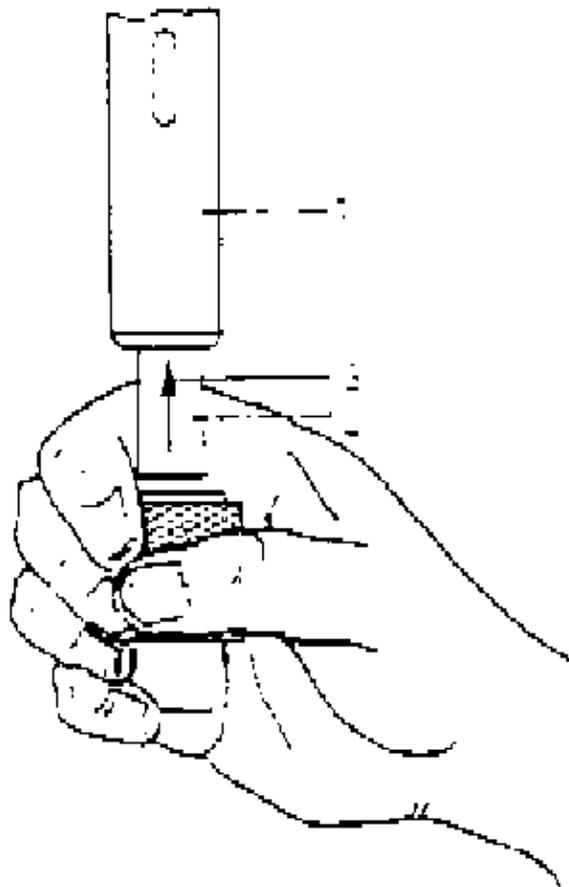


Figure 3/31 Clamping a cone connection

- 1 Drilling spindle
- 2 Tool, or clamping device
- 3 Direction of clamping

A wedge (3) is used for unclamping. The wedge is driven into an opening provided at the drilling spindle (1) so that the tool (2) is pushed out of the internal taper of the drilling spindle (Figure 3/32).

The conical surfaces must be kept clean and free from grease. They shall not be damaged because otherwise they will not fully join with each other. The measurements of the cones are standardized. Intermediate sleeves are used in order to be able to insert small tools with small external cones into spindles with large internal taper (Figure 3/33).

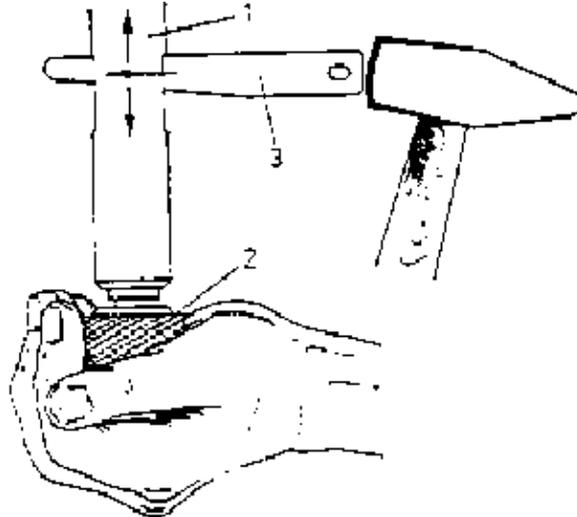
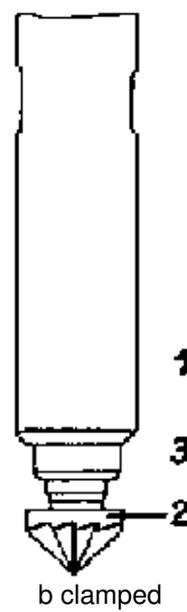
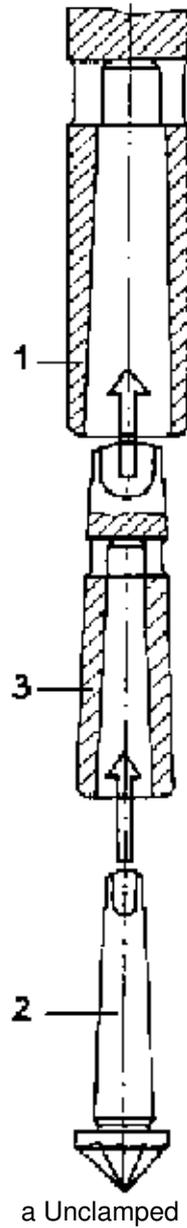


Figure 3/32 Unclamping a cone connection

- 1 Drilling spindle,
- 2 Tool or clamping device
- 3 Wedge for unclamping

Figure 3/33 Cone connection with intermediate sleeves



- 1 Drilling spindle with large internal taper
- 2 Tool with small external cone

3 Intermediate sleeve

Tool clamping chuck

Tools with cylindrical shanks can be clamped into chucks. The tool chuck is clamped into the drilling spindle by means of a cone connection (Figure 3/34).

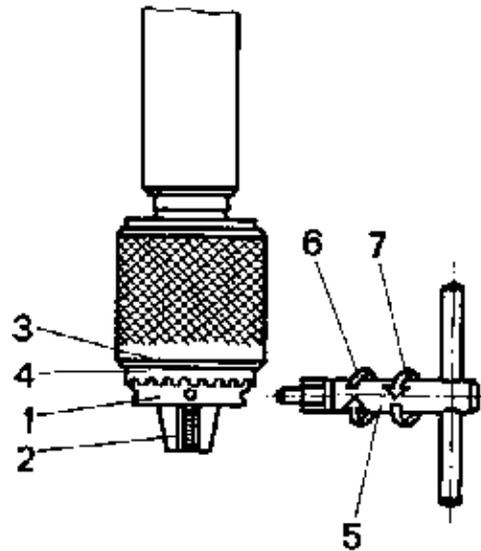


Figure 3/34 Handling a tool clamping chuck

- 1 Base frame
- 2 Clamping jaws
- 3 Sleeve
- 4 Ring gear
- 5 Chuck key
- 6 Direction of rotation during clamping
- 7 Direction of rotation during unclamping

Clamping and unclamping the tool chuck is done in the same way as the cone connection of a tool. The tool with cylindrical shank is held in the chuck by means of three chuck jaws. The chuck jaws can be set apart or together according to the diameter of shank. In doing so, the sleeve of the tool clamping chuck is turned by means of a chuck key.

After clamping or unclamping the chuck key has to be immediately removed! There is the danger of accident when the chuck key is flung out upon start-up of machine.

Upon clamping the sleeve with the chuck key has to be tightened right up, so that the tool shank cannot turn around in the chuck during operation. Otherwise it would be damaged and the tool could no longer be clamped to run true.

Quick change chuck

It is possible with quick-change chuck to clamp and unclamp the tool during the running of the machine (Figure 3/35). Quick-change chuck is used when different tools have to be utilized to carry out different consecutive operations with several workpieces of equal design, e.g. drilling, countersinking, reaming.

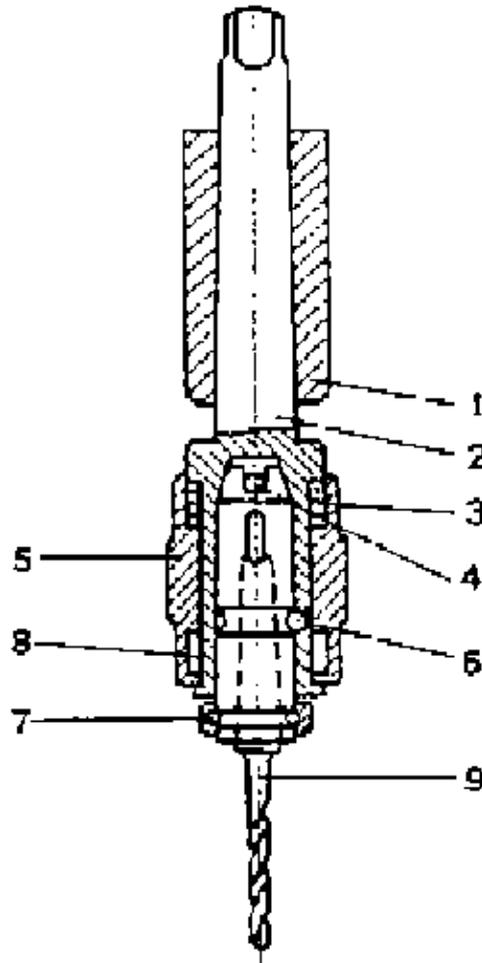


Figure 3/35 Structure of a quick change chuck

1 Drilling spindle, 2 Cone, 3 Spring, 4 Driving pin, 5 Sleeve, 6 Ball, 7 Track ring, 8 Recess, 9 Tool

Quick-change chuck consists of the clamped part to be inserted into the drilling spindle, and the changeable part to be taken up by the tool.

Upon clamping the sleeve (5) is lifted, so that the ball (6) is placed into the recess (8). The changeable part with the tool is put into the clamped part from below. It is kept at the track ring (7). As soon as the driving pin (4) is engaged in the slot of the changeable part, it begins to rotate. Now the track ring (7) is let loose, the spring (3) pushes it down. The ball (6) gears with the changeable part and keeps the clamped part firm.

Since the changeable part is relatively easily held in the clamped part it is advisable to utilize quick. change chucks in operations with clamping fixtures for those workpieces that conduct the tool.

Upon unclamping the changeable part is kept at the track ring, the sleeve is lifted and the changeable part can be taken out at the bottom (Figure 3/36).

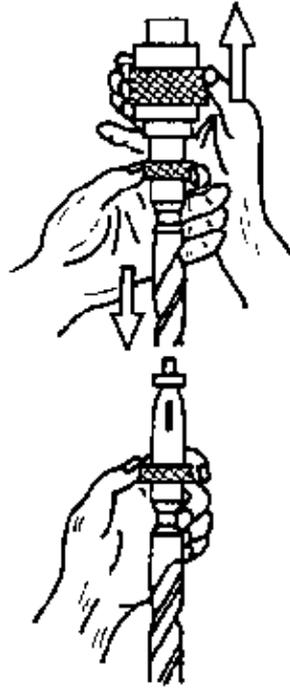


Figure 3/36 Handling a quick change chuck

Control questions

1. Name the tool-clamping devices to be used on column –and pillar–type drilling machines.
2. What clamping devices are used for what tools?
3. Describe the technically correct clamping and unclamping of tools with cone connection.
4. Describe the mode of functioning of a tool clamping chuck.
5. Why is it insufficient in case of a tool clamping. chuck to turn tightly the sleeve only by hand without using the chuck key?
6. What are the results for the quality of workpiece if the tool runs untrue?

3.2.4. Handling of column– and pillar–type drilling machines

In this section you shall get acquainted with

- the setting–up of column– and pillar–type drilling machines
- the operation and attendance of the machines during running
- the errors in operation to be avoided in attendance of the machines.

Setting–up of the machine

Upon setting–up of the machine it shall be provided that the intended operations, e.g. drilling, counter–sinking, reaming, proceed on the basis of adequate machining characteristics.

- Switching the drilling spindle gear

The correct machining characteristic for the cutting motion is set at the drilling spindle gear (Figures 3/11, 3/12, 3/14). This machining characteristic is the cutting speed.

The cutting speed of tool in a drilling machine, e.g. drill or counter–sink, is the speed at which the edge of the tool moves along the workpiece.

The cutting speed depends upon

- the material of the workpiece, e.g. steel, brass, aluminium;
- the material of the tool, e.g. tool steel, high-speed steel
- the machining method, e.g. drilling, countersinking, reaming.

The cutting speed is set for a definite operation. In the case of a toothed-gear drive (Figure 3/14) the transmission required is set. In the event of a cone-pulley transmission the drive belt is put on the corresponding belt pulley.

- Setting the feed gear

Drilling machines are operated with hand feed or with automatic feed. Automatic feed is preferably used if several workpieces of equal design are machined consecutively, or when large diameters are used for machining which require corresponding forces for the generation of the feed motion.

The correct machining characteristic for the feed motion is set at the feed gear (Figure 3/16). This characteristic value is the feed (Figure 3/37).

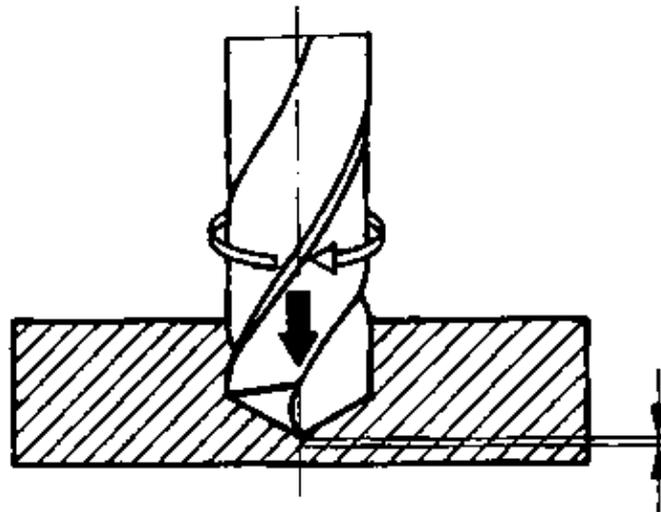


Figure 3/37 Feed during drilling

In operating drilling machines the feed is the distance covered by the tool during one revolution in the direction of the axis of drill (direction of feed).

The speed depends upon

- the material of workpiece, e.g. steel, brass, aluminium;
- the material of the tool, e.g. tool steel, high-speed steel;
- the method of machining, e.g. drilling, countersinking, reaming.

When switching the feed gear the ratio required between cutting motion and feed motion is established.

- Process of gear switching

In drilling machines with toothed gearing the switch levers are put into the position, as indicated. If there is an impediment because two toothed wheels do not engage with each other, the drilling spindle has to be turned slowly by hand until the switch lever is easily movable. With a certain feel you should find out whether the switching operation is impeded by the unfavourable position of toothed wheels, or whether switching can be performed. If there is resistance, force must never be applied.

Heavy damage to machine may arise by errors of switching, e.g. use of force, premature connecting of motor. The instructions for use should be strictly observed!

With drilling machines equipped with cone-pulley drive the following operations are required:

- Protective wire-grating to be removed
- Pulley tensioning device to be loosened
- Belting to be relaxed

- Belting to be shifted to other belt pulleys
- Belt to be tightened
- Tensioning device to be fastened
- Protective wire-grating to be attached.

Danger of accidents! Protective wire grating has to be re-attached at any rate. Machine must not be switched on without protective wire-grating!

- Clamping the workpiece

The workpiece is clamped on the table by using one of the workclamping devices, as indicated in section 3.2.2. In preparing the clamping devices the following hints should be observed:

Table

- to be cleaned from chips and residual coolant, especially in the T-slots;

Machine vice, clamping fixtures

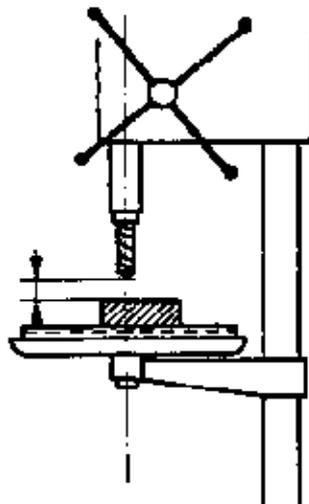
- to be cleaned from chips,
- checking the easy movability of gear spindles (possibly, the threaded screw should be oiled)
- workpiece to be placed, as a test case.

Drawbolts

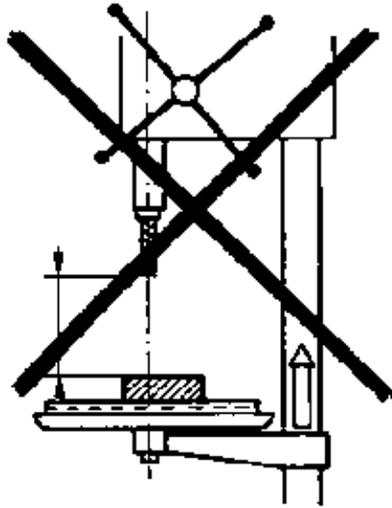
- to be inserted into T-slots for testing
- nuts to be screwed on for testing,

The workpiece is positioned within the operating range of the machine. For this reason it is moved to and from on the table, until the part to be machined lies vertically underneath the tool.

Figure 3/38 During clamping of workpiece attention to be paid to travel required for feed motion



a Distance between workpiece and tool good



b. Distance between workpiece and tool too large, table to be lifted.

The table is lifted by means of the table–lifting device until the distance between the tool being in its upper position of rest and the workpiece is a convenient one (Figure 3/38).

When clamping the workpiece it is essential to observe the distance required for the start–up movement!

- Clamping the tool

The tool is clamped into the drilling spindle by means of one of the tool–clamping devices (compare Section 3.2.3.). The clamping devices have to be free from chips, the tool clamping chuck should be easily movable. For the purpose of clamping in the tool chuck it is only allowed to use the pertaining and suitable chuck key.

After clamping it should be checked whether the tool runs true. Untrue–running tools should again be unclamped from the clamping device and should be reclamped!

Operation of the column – and pillar–type drilling machine

Drilling can be started, as soon as the machine is set and workpiece and tool have been clamped (Table 3/3).

- Switching–on of machine (cutting motion)

Attention should be paid to the fact that the tool is to be found free above the workpiece, or above the clamping fixture for workpiece. In this way the machine can run unimpededly.

- Positioning of tool (positioning motion)

To this end the tool is moved from its upper position of rest to the workpiece. As soon it touches the workpiece, the feed sets in.

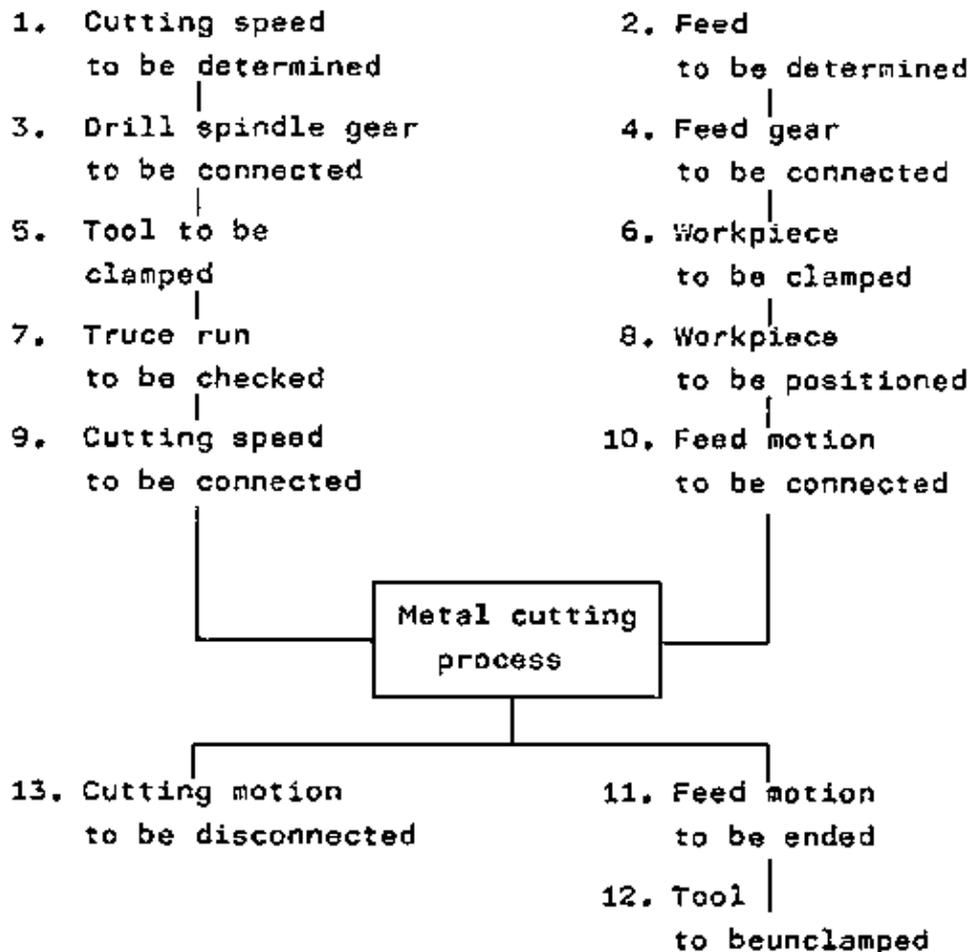


Table 3/3 Setting-in and operating of an upright column – or pillar–type drilling machine

If work is done with a clamping fixture conducting the tool, e.g. a drilling device, the tool has to be carefully inserted into the guideway. In the event of a careless handling there is the danger of a breakage of tool.

- Switching–on of feed motion

After positioning that is mostly done by hand the automatic feed motion is switched on. If work is only done by means of hand feed the right hand operates the feed lever of the machine,

- Ending of feed motion, unclamping of tool, switching–off the machine

After removal of chips the feed motion is switched off. It is automatically switched off in adequately designed machines. The tool is taken out. Only then the cutting motion is switched off.

Switching –on and switching–off the machine during metal cutting operation may cause damage to the tool. For this reason it is essential that

- first the cutting motion, then the feed motion are switched on;
- first the feed motion, then the cutting motion are switched off.

Control questions

1. Explain what has to be understood by cutting speed during drilling operations.
2. Explain what in drilling has to be understood by feed.
3. What handling operations belong to the setting of a column – or pillar–type drilling machine?
4. Explain the functioning of a tool clamping chuck.
5. Describe the shifting of belting in a drilling machine with cone–pulley transmission,

6. Explain the reading of depth of bore at the indicator scale.
7. Describe the setting of the drilling machine for a work that was performed by you.

3.3. Radial drilling machine

In this section you shall get acquainted with

- the machine components the radial drills are composed of
- the way radial drills are functioning
- the kinds of work for which radial drills are used.

3.3.1. Structure and mode of operation

Machine components of a radial drilling machine

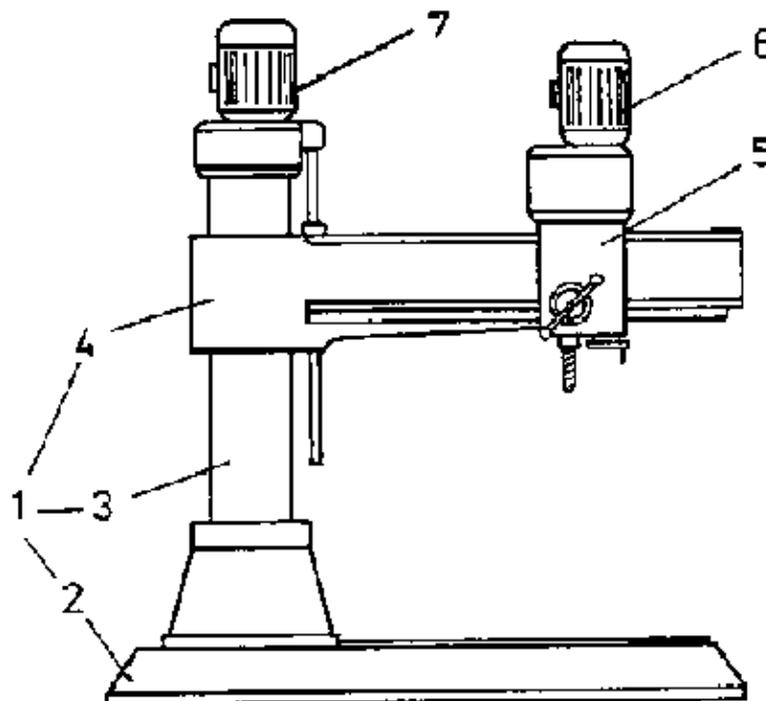


Figure 3/39 Components of a radial drilling machine

1 Machine frame, 2 Baseplate, 3 Column, 4 Arm, 5 Headstock, 6 Motor for cutting and feed motion, 7 Motor for lifting and lowering of arm.

The machine frame (1) with the baseplate (2), the column (3) and the arm (4) provide the main structure of the machine (Figure 3/39). The spindle head, or headstock (5) is mounted on the arm. It accommodates the spindle gear and the feed gear.

The motor for cutting motion (6) and for the feed motion is mounted on the gearing. The motor for lifting and lowering the arm (7) is mounted on the column.

The base plate provides the machine with the stability required. It is also provided with T-slots (cp. section 3.2.2.) required to fasten the work-clamping devices by means of drawbolts.

Mode of operation of a radial drilling machine

Radial drilling machines make it possible to move the headstock in the following directions (Figure 3/40):

- to and from at the arm
- together with arm around the column
- together with arm the column up and down.

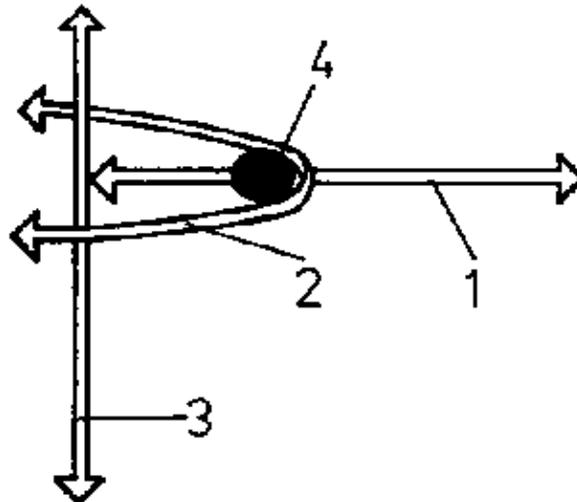


Figure 3/40 Movements of the headstock of a radial drilling machine

- 1 Back and forth movement of arm, 2 Swivelling movement around arm, 3 Upward and downward movement at column, 4 Headstock

As a result of it, it is possible to position the drilling spindle conveniently. This is especially important for the machining of large workpieces, since it is difficult to move them on the machine plate. If a workpiece shall be set by means of a lifting gear, e.g. a crane, onto the machine, the arm can be turned aside, so that it does not provide any hindrance. The clamping of tools is performed in the same way as in column – and pillar–type drilling machines. Since work is frequently done by using tools with large diameters, the cone connection is most common.

Cutting and feed motions of the radial drilling machine, which are performed by the drilling spindle and transmitted to the tool, are equal to those in column – and pillar–type drilling machines.

3.3.2. Use of radial drilling machines

Radial drilling machines can be used for all operations, where the tools perform a rotary cutting motion, e.g. drilling, countersinking, reaming. They are mostly used, however, for large, heavy and bulky workpieces. They are especially found in individual production of large workpieces as well as in small–scale production.

Control questions

1. Describe the structure of a radial drilling machine.
2. Explain the similarities and differences between radial drilling machines and column and pillar–type drilling machines.
3. Name several examples of works to be performed on radial drilling machines.

3.4. Multi–spindle drilling machine

In this section you shall get acquainted with

- the machine components the multi–spindle drilling machines are composed of
- the way of functioning of multi–spindle drilling machines
- the range of application of multi–spindle drilling machines.

3.4.1. Structure and mode of operation

Components of a multi-spindle drilling machine

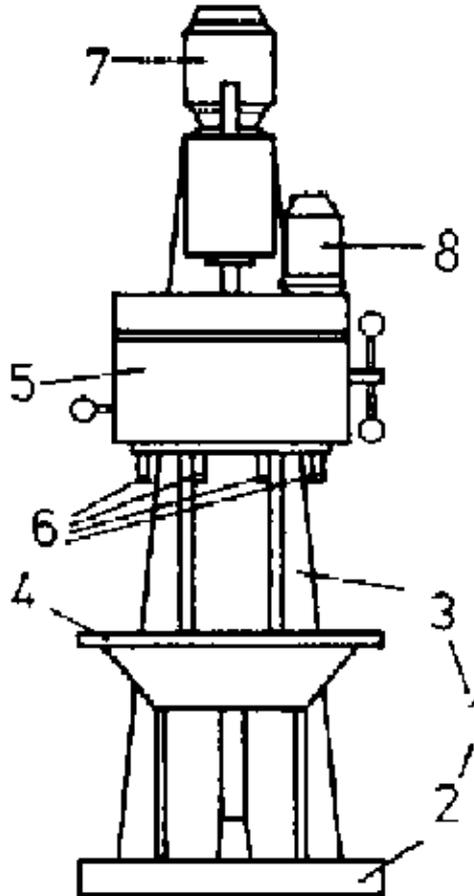


Figure 3/41 Components of a multi-spindle drilling machine

1 Machine frame, 2 Pedestal, 3 Column, 4 Table, 5 Headstock, 6 Drilling spindles, 7 Driving motor for drilling spindles, 8 Feed motor.

The machine frame (1) with the pedestal (2), the column (3), the table (4) and the headstock (5) form the main structure of the machine (Figure 3/41). The headstock accommodates the gearing for the drilling spindles (6). It is of a very complicated design, because each of the drilling spindles has to be driven separately. The drive is performed via articulated or flexible shafts, so that every drilling spindle can be moved to any arbitrary place within the range of application upon setting of the machine.

The motors required for the drive of cutting motions (7) as well as for the drive of feed motion (8) are mostly mounted on the headstock.

Mode of operation a multi-spindle drilling machine

The mode of operation of a multi-spindle drilling machine is similar to that of a pillar-type drill. It is possible to move upwards and downwards headstock and table at the column in line with the height required for the machining of a workpiece.

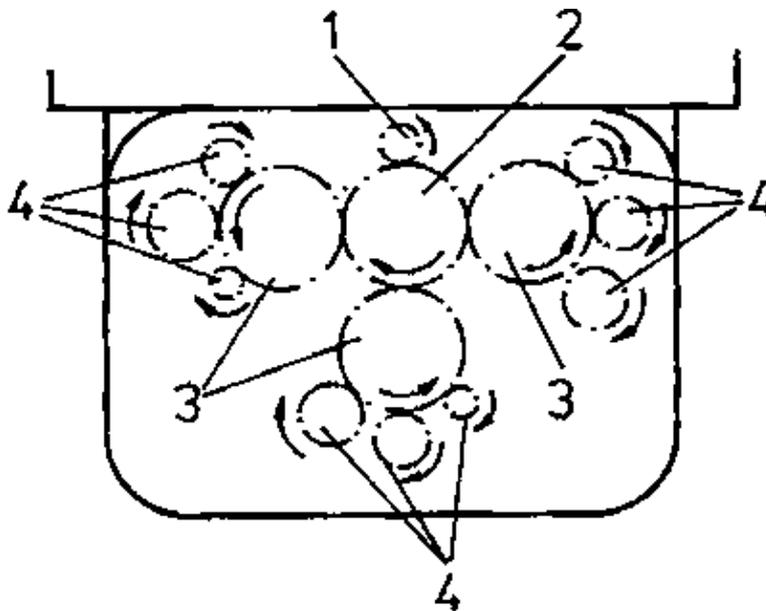
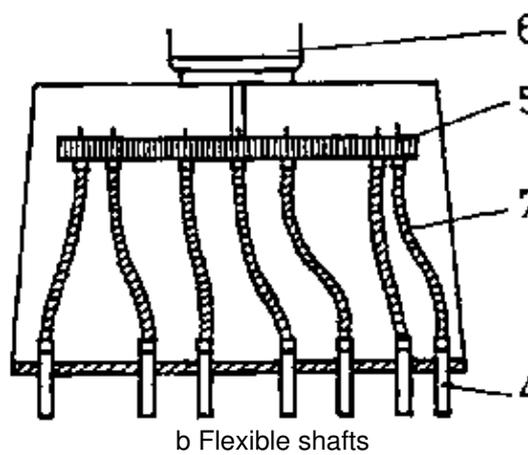
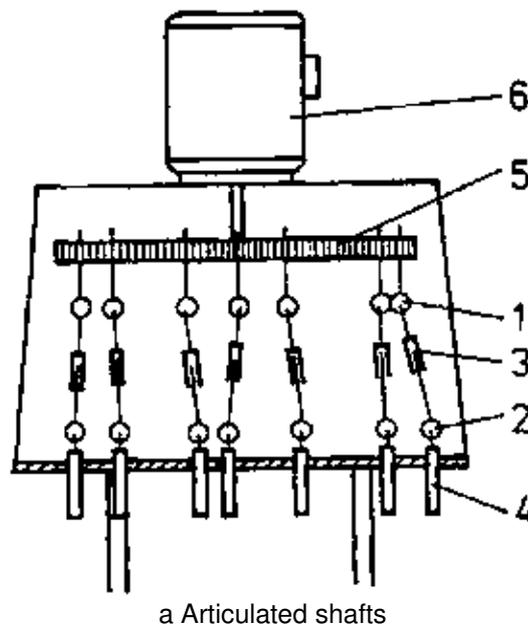


Figure 3/42 Gear to drive the drilling spindles of a multi-spindle drilling machine (simplified)

1 Motor wheel, 2 Main wheel, 3 Intermediate wheel, 4 Wheels of drilling spindles.

Figure 3/43 Drive shafts for drilling spindles (simplified)



1,2 Joints, 3 Telescopic shaft, 4 Drilling spindles, 5 Toothed wheels, 6 Motor, 7 Flexible

shafts.

The spindle gearing takes its driving motions from the drive motor (Figure 3/42). Articulated shafts or flexible shafts transmit the drive motion from the gear to the drilling spindles (Figure 3/43).

Articulated shafts.

An articulated shaft has always two joints (1,2), so that the drilling spindle (4) is vertical independently of its position. A telescopic shaft (3), a shaft modifiable in its length, compensates for the different distances of the drilling spindle to the central drive.

Flexible shaft. A flexible shaft can be bent in such a way that it is possible to take it as an articulated shaft, but with a very great number of joints. Due to its bendability it compensates for the different distances of the drilling spindle to the central drive.

During setting the drilling spindles are positioned and then arrested in the position desired. The positions are dependent upon the points of machining at the workpiece.

3.4.2. Use of multi-spindle drilling machines

Each of the working spindles can be provided with a tool and used for a separate stage of operation. Since there are multi-spindle drills having more than 20 drilling spindles they are also able to perform some 20 operations simultaneously. Those workpieces are suitable, where the points of machining lie approximately at the same height. Convenient work can be performed with devices that provide a guideway to tools. Thus it is possible to attain a high degree of accuracy of distances, e.g. of the bores.

Since all the drilling spindles perform simultaneously the feed motion it is essential to consider the various feed travels already at the moment of setting the machine. The working stages proceed parallel in time, the total time corresponds to the period taken by the longest working stage.

The setting of a multi-spindle drilling machine requires more time than that of a column – or pillar-type drill. This is the reason why multi-spindle drills are primarily deployed in large scale production. The time for setting only once required is thus equally distributed over the number of pieces of the series.

Control questions

1. Describe the structure of a multi-spindle drilling machine.
2. Explain the similarities and differences between multi-spindle drills and pillar-type drills.
3. Name several examples of operations to be performed on multi-spindle drills

3.5. Servicing and maintenance of drilling machines and tools

Please, observe the “General Instructions on the Servicing, Attendance and Maintenance of Metal Cutting Machine Tools” given in section 2.4. of this textbook.

Prior to the beginning of cleaning –, lubricating and control works it is required to switch off the machine!

Cleaning

- Chips and coolant to be removed from the table and in front of the machine. Utilize hand broom and cleaning rag, otherwise there is the danger of injuries.
- Slots in the table to be scraped with a suitable sheet metal,
- Bright components of the machine, e.g. drilling spindle, operating handles, to be polished and slightly greased.

- Filters of coolant pump and coolant container to be cleaned,

Lubricating

- Oil level in gearing to be controlled, oil to be refilled, if required,
- Lubricating points to be oiled or greased according to plan.
- After lubrication it is important to remove oil drops and grease carefully from floor,

Controlling

- Stability of machine to be checked.
- Clearance of drilling spindle to be controlled, bearings to be re-adjusted, if required,
- Switchability of gear to be checked and adjusted, if required..
- Electric connections to be controlled, supply lines to be secured.

Treatment of Tools

- Tools to be put away in such a manner that the cutting edges do not damage each other.
- After use of tools it is required to wipe off chips and residual coolant.
- Blunt tools to be re-ground in time, otherwise a great deal of heat is produced during operation and the tools anneal.
- Tools to be carefully clamped into the clamping devices. Insufficiently clamped tools begin to slip in the devices and are damaged.
- Drive-fitted key to be used to take off tools from the cone connection.

3.6. Work safety in operating drilling machines

Please, observe the “General Instructions and Regulations on Work Safety” (Section 2.5.) of this textbook.

These are the following regulations on protection against accidents during work at drilling machines:

- Never hold small workpieces by hand only, work-clamping devices to be used and workpieces to be firmly clamped, stop to be fastened at the table!
- Chips arising from work not to be removed by hand, but only with suitable chip rake!
- For tool changing machine never to be stopped by hand, but standstill of machine shall first be done!
- Working clothes, especially sleeves and jacket, shall fit tightly to the body, so that they are out of reach of tool!
- The hair of the head and of the beard is not allowed to dangle, suitable clothing has to be used!
- Prior to switching-on of machine attention shall be paid to the protective grating to be applied!

4. Lathes

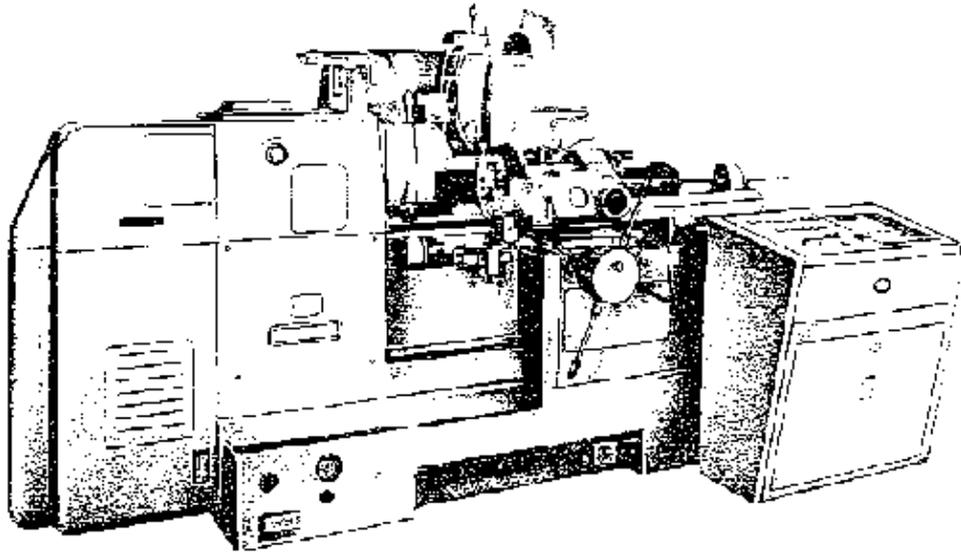


Figure 4/1 Sliding and screwcutting lathe.

4.1. Survey of types and use of lathes

In this section you shall get acquainted with

- the types of machines used for turning operations
- the kinds of operations performed by lathes
- the kinds of work to be machined on lathes.

4.1.1. Several types of lathes

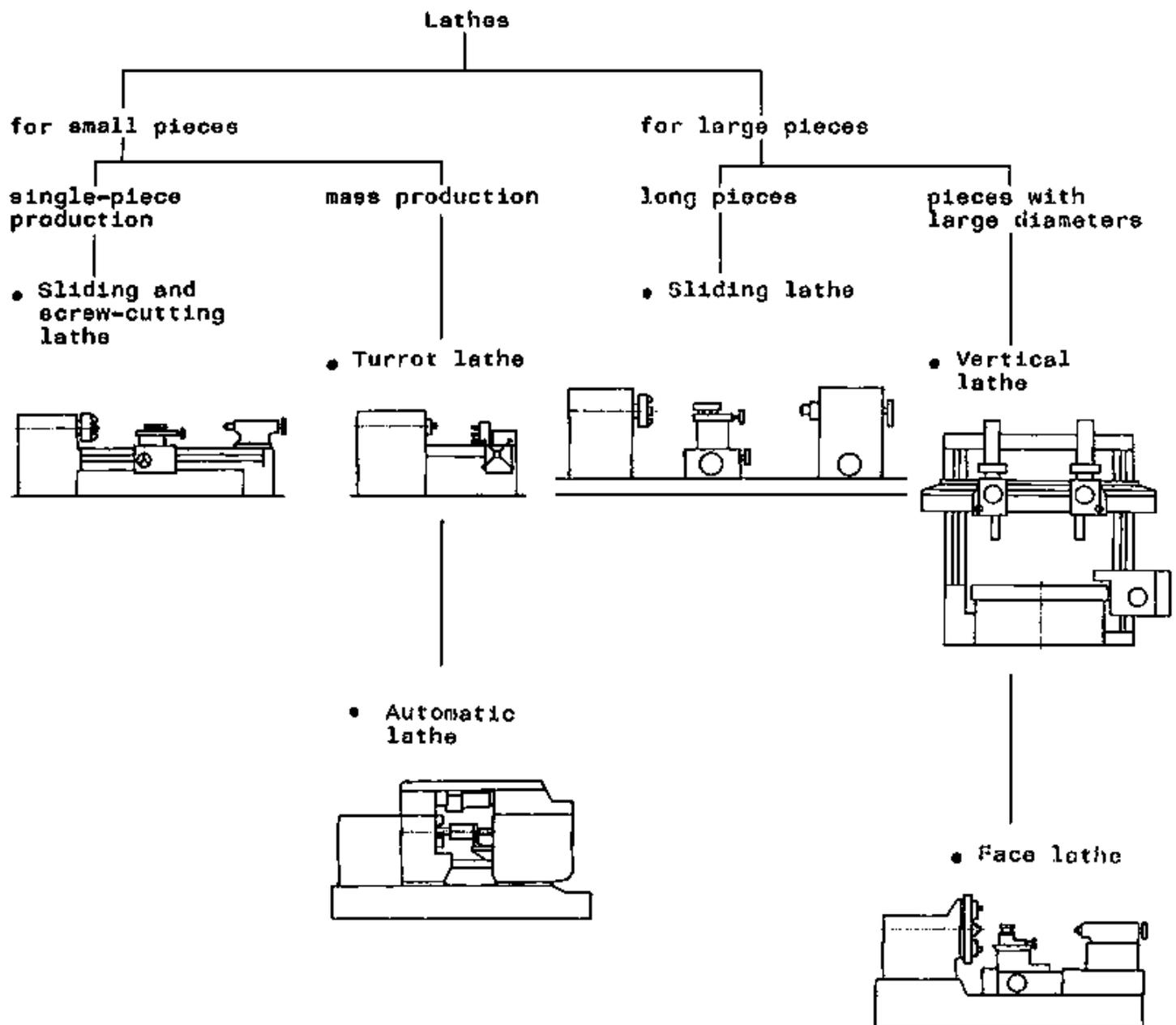


Table 4/1 Classification of lathes

Lathes are built

- for workpieces of different size, i.e. short or long pieces, for workpieces with small or large diameter
- for individual production, i.e. for workpieces to be required only in small numbers
- for mass production, i.e. for units required in great numbers.

All lathes have to perform the same kinds of turning operations. But they have a different design and are thus optimally adapted to their application (Table 4/1).

4.1.2. Motions of lathes

Cutting motion

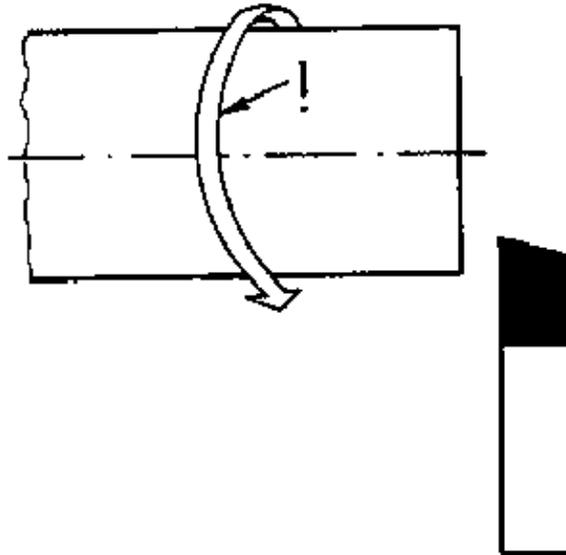


Figure 4/2 Cutting motion during turning

One of the turning operations is the cutting motion, which is a rotary motion. It is performed by the workpiece. In dependence upon the cutting speed to be used for turning the workpiece rotates at a small or a large number of revolutions (Figure 4/2).

Feed motion

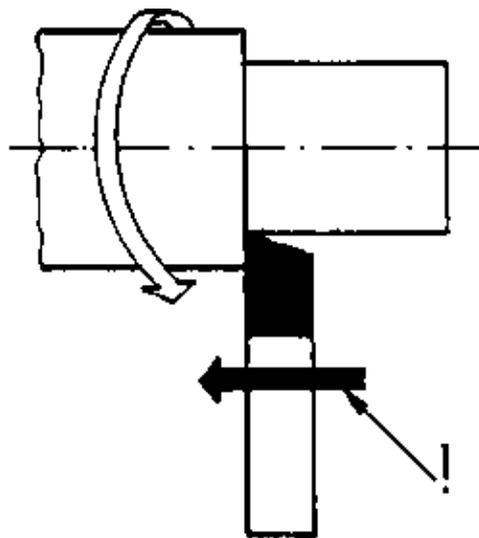


Figure 4/3 Feed motion during longitudinal turning

The feed motion is a straight-lined motion. During cylindrical turning the feed motion proceeds parallel to the longitudinal axis of workpiece. It is carried out by the tool (Figure 4/3). During facing the feed motion proceeds crosswise the longitudinal axis of workpiece and is also performed by the tool (Figure 4.4).

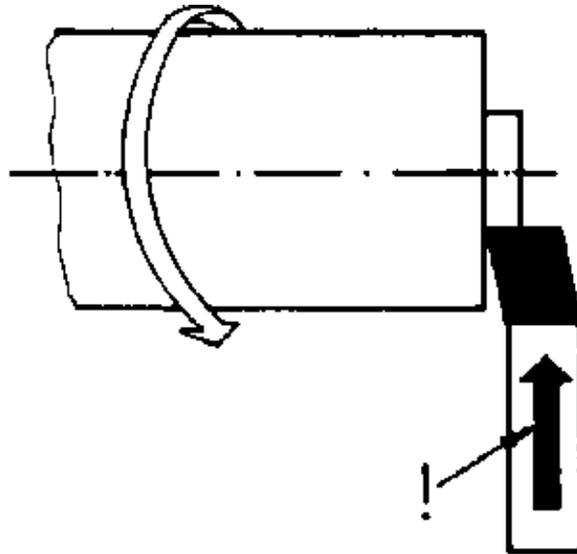


Figure 4/4 Feed motion during facing

During profiling the longitudinal feed and the surfacing feed arise simultaneously. The tools rotate in a camlike way.

In-feed motion

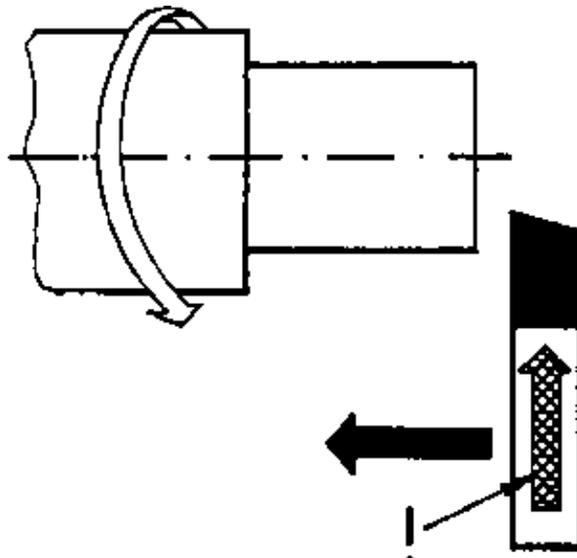


Figure 4/5 In-feed motion during longitudinal turning

The in-feed motion is a straight movement. During cylindrical turning it proceeds crosswise to the longitudinal axis of workpiece. It is carried out by the tool (Figure 4/5). During facing it proceeds parallel to the longitudinal axis of workpiece and is also carried out by the tool (Figure 4/6).

4.1.3. Examples of operations on lathes

Longitudinal turning

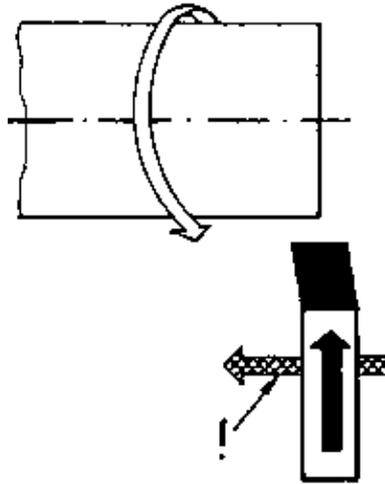


Figure 4/6 In-feed motion during facing

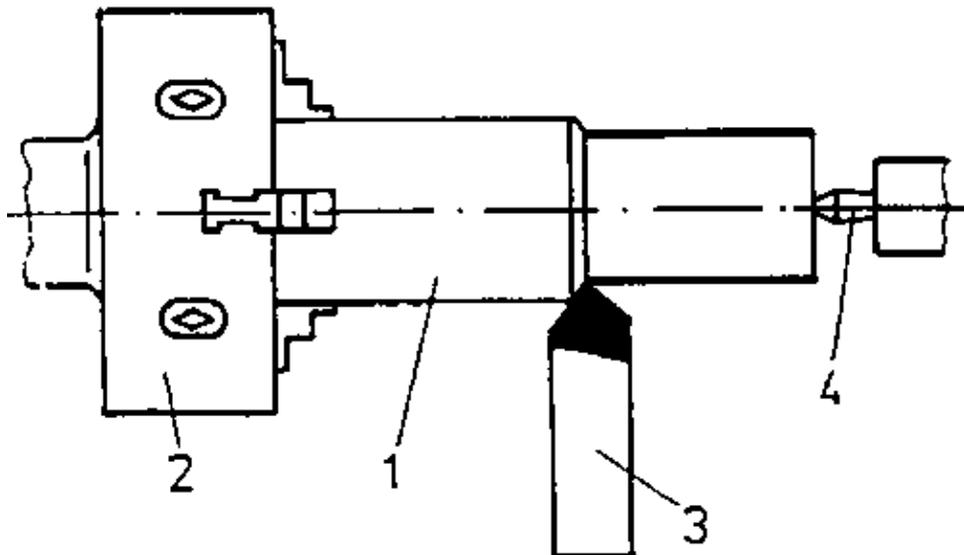


Figure 4/7 Longitudinal turning of a shaft

1 Shaft, 2 Three-jaw chuck, 3 Right-hand straight lathe tool, 4 Tailstock centre.

Figure 4/7 shows a shaft (1) with shoulders. The shaft is clamped in a three-jaw chuck (2). It is supported by the tailstock centre (4). The shaft was machined with a right-hand straight lathe tool (3). The machined surface is marked by a full thick line.

Facing, or surfacing

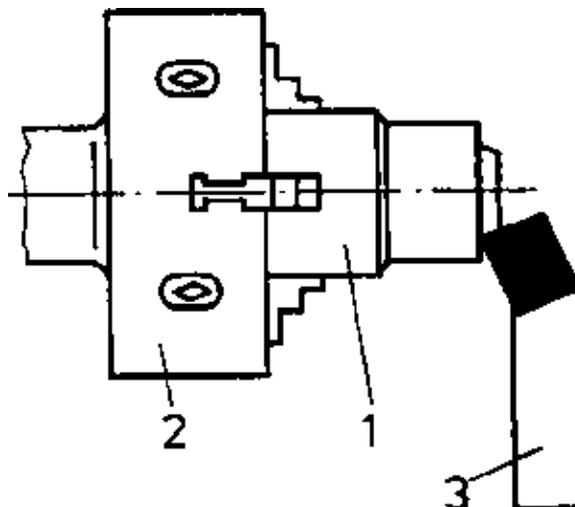


Figure 4/8 Facing a journal

1 Journal, 2 Three-jaw chuck, 3 Right-hand cranked lathe tool.

The figure 4/8 shows the journal (1). The journal is clamped in a three-jaw chuck (2). The journal was machined with a right-hand cranked lathe tool (3). The machined surface is marked by a thick full line.

Thread cutting

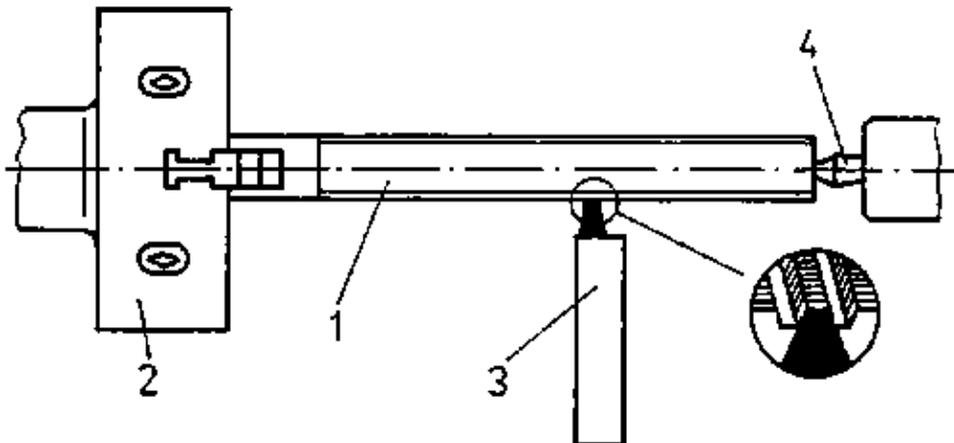


Figure 4/9 Spindle thread cutting

1 Spindle, 2 Three-jaw chuck, 3 Trapezoidal thread-cutting tool, 4 Tailstock centre.

The Figure 4/9 shows a spindle (1) with trapezoidal thread. The spindle is clamped in a three-jaw chuck (2). It is supported by a tailstock centre (4). The thread was cut by means of a trapezoidal thread-cutting tool (3). The surface machined is shown in magnification.

Drilling

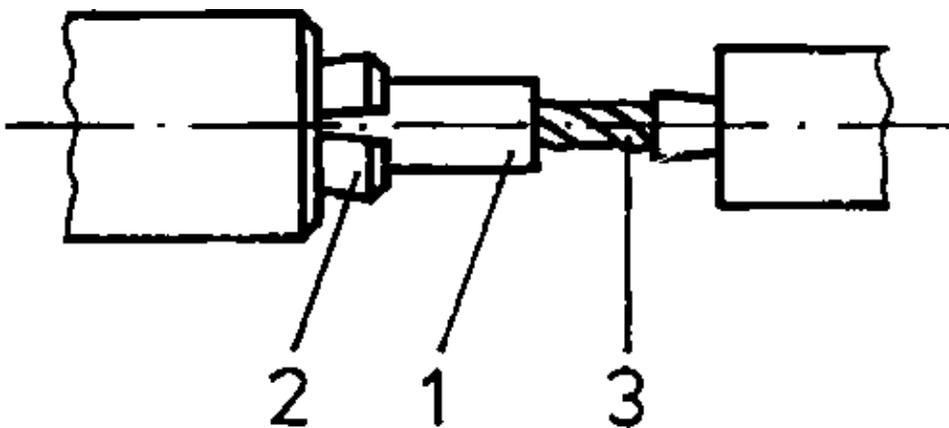


Figure 4/10 Drilling a bushing (or: sleeve)

1 Bushing, 2 Collect, 3 Twist drill

The Figure 4/10 shows a sleeve (1). The sleeve is clamped in a collet (2). The sleeve was drilled with a twist drill (3).

Cutting-off

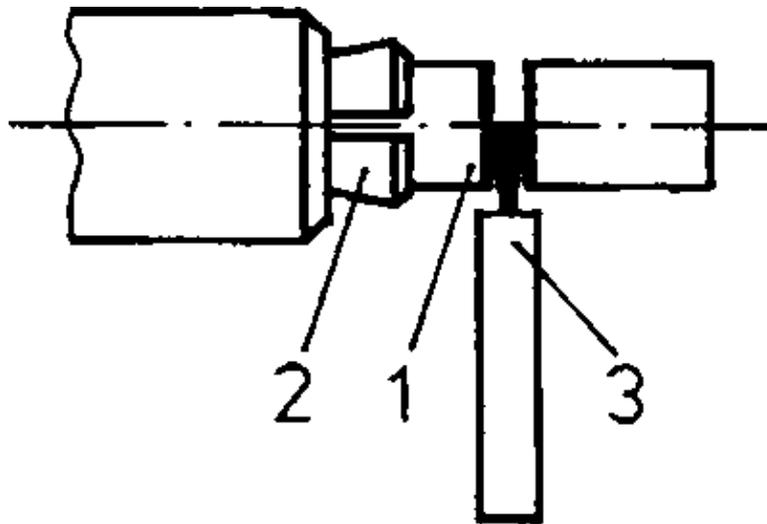


Figure 4/11 Parting-off a bushing

1 Bar, 2 Collet, 3 Twist drill

Figure 4/11 shows a bar (1) from which the sleeve was parted off according to Figure 4/10. The bar is clamped in a collet (2). The cutting chisel (3) was used for parting-off. The parting joint is marked by a thick line.

Internal turning operations

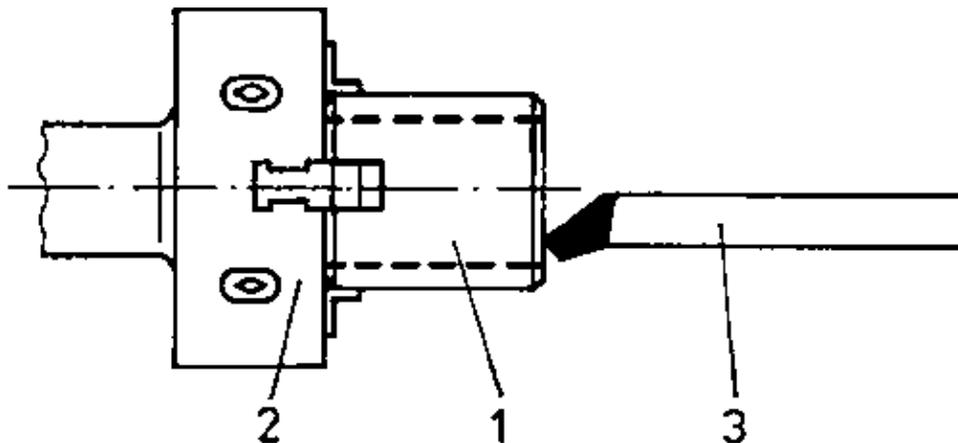


Figure 4/12 Internal turning of a bearing bushing

1 Bearing bushing, 2 Three-jaw-chuck, 3 Boring tool.

Figure 4/12 shows a bearing bushing (1). It is clamped in a three-jaw chuck (2). The bearing bushing was machined with a boring tool (3). The machined surface is marked by the thickly dotted area.

Taper turning

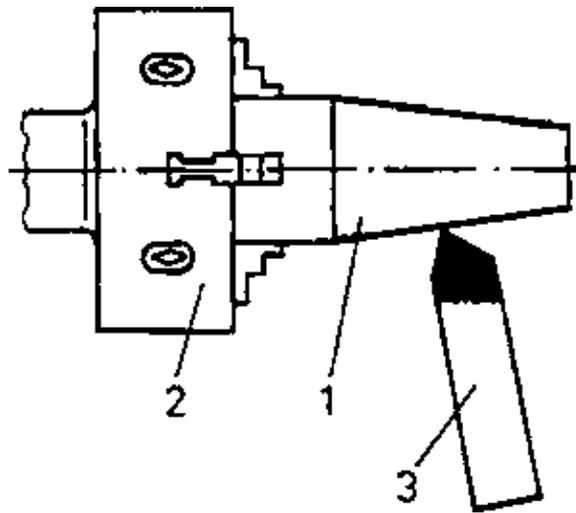


Figure 4/13 Taper turning

1 Bevelled cutter, 2 Three-jaw chuck, 3 Straight lathe tool.

Figure 4/13 shows a bevelled cutter (1). The bevelled cutter is clamped on its cylindrical end in a three-jaw chuck (2). The cone was machined by means of a straight lathe tool (3). The machined surface is marked by thick lines.

Control questions

1. Name several machines to be used for turning operations.
2. Name several workpieces which are preferably machined on these machines.
3. What kinds of working movements arise during turning?
4. Name several machined products that were produced on lathes in your enterprise.

4.2. Sliding and screwcutting lathe

4.2.1. Structure and mode of operation

In this section you shall get acquainted with

- the machine components of which the sliding and screwcutting lathe is composed
- the drive systems that drive sliding and screwcutting lathes
- the mechanisms of transmission that transmit the motion of motors into the working operations
- the interaction between the components of the motor and the mechanisms of operation.

Components of sliding and screwcutting lathe

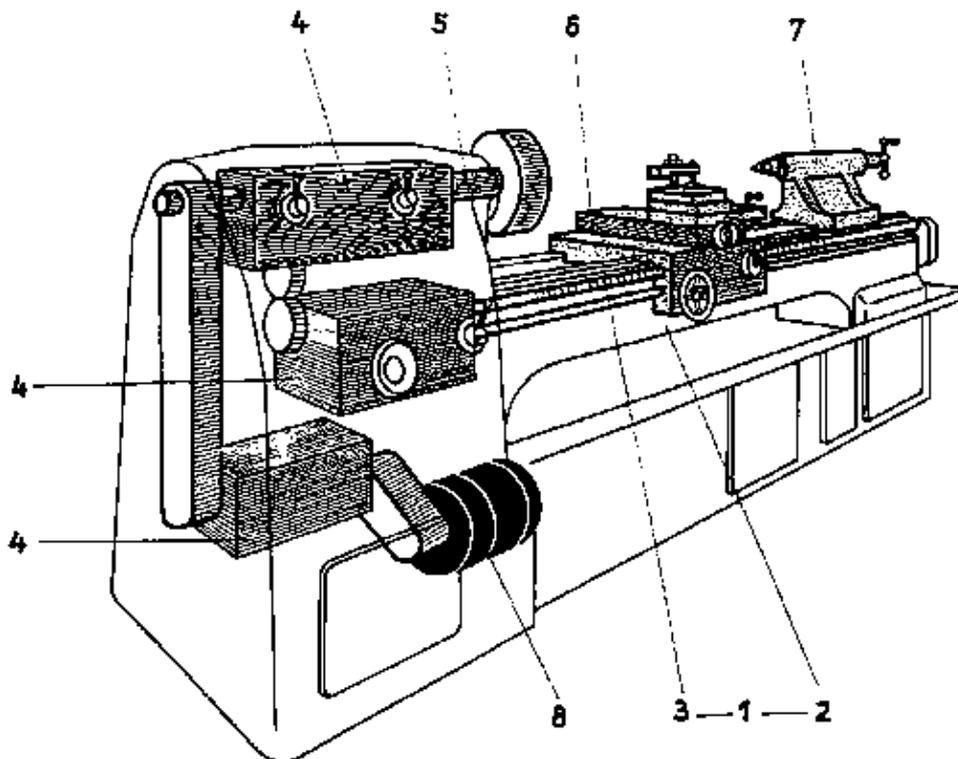


Figure 4/14 Components of a sliding and screwcutting lathe

- 1 Machine frame, 2 Lathe bed, 3 Guideways, 4 Gears, 5 Lathe spindle, 6 Carriage, 7 Tailstock, 8 Motor.

The machine frame (1) with the lathe bed (2) and the guideways (3) provide the main structure of the machine. The machine frame accommodates the gears (4) for the conversion of motions and also the lathe spindle (5)(Figure 4/14).

The carriage (6) and the tailstock (7) slide on the lathe bed. The machine frame has to be rigid, it is not allowed to bend or twist when forces arise in the machine as a result of operations. The machine frame can also contain the boxes for tools, measuring instruments and auxiliary devices.

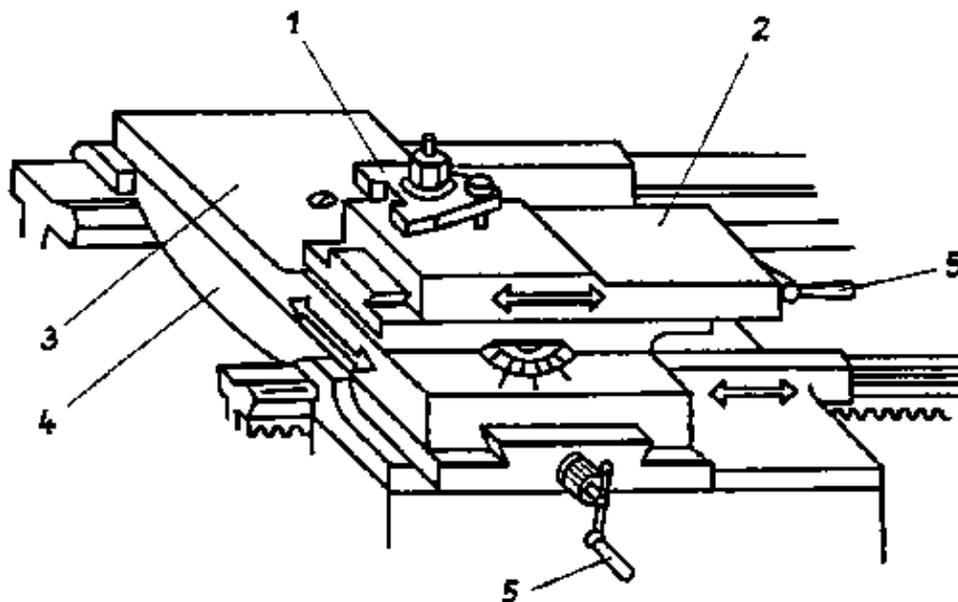


Figure 4/15 Parts of carriage of a sliding and screw-cutting lathe

- 1 Tool holder, 2 Saddle, 3 Cross-slide, 4 Turning carriage, 5 Crank handles.

The carriage (Figure 4/15) consists of the tool holder (1), the saddle (2), the cross-slide (3) and the turning carriage (4).

The slide carriage is provided with all the slideways on which the entire carriage slides. The cross-slide moves on the turning carriage crosswise to the sliding direction of the carriage. The cross-slide holds the tool during facing (Figure 4/8). The saddle is mounted on the cross-slide. It is slewable, so that the tool can be conducted parallel, or at angles to the workpiece axis. The saddle serves to perform short movements, whereas the carriage serves altogether to perform long movements.

Cross-slide and saddle are moved via crank handles (5) and threaded spindles. They carry the tool holder.

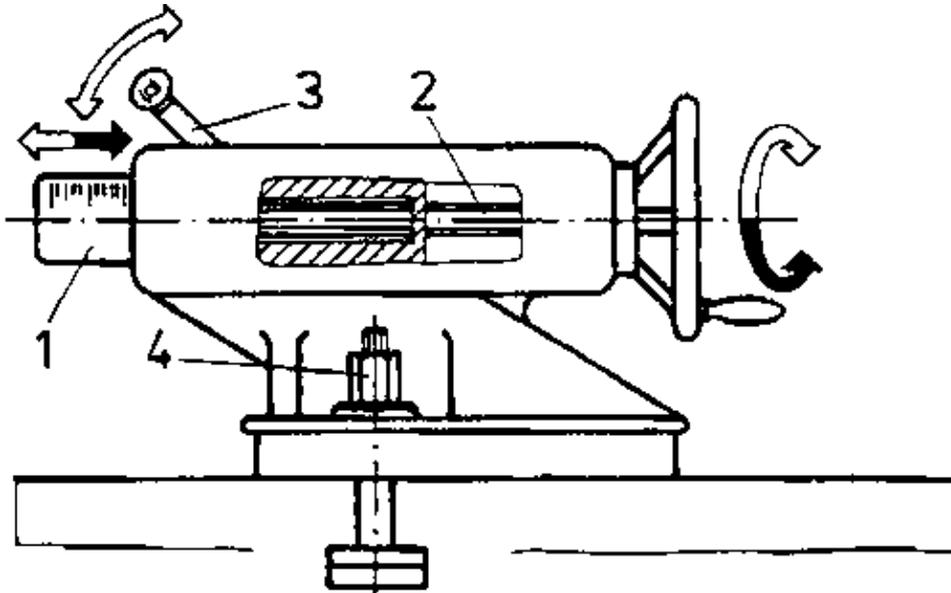


Figure 4/16 Parts of tailstock of a sliding and screwcutting lathe

1 Tailstock spindle sleeve, 2 Threaded spindle, 3 Clamp lever, 4 Clamp nut.

The tailstock (Figure 4/16) can be moved to and from on the machine bed. It contains the tailstock sleeve, or quill (1), which can accommodate the drill tools. The sleeve is actuated by a threaded spindle (2). By means of a clamp lever (3) the sleeve can be clamped at the point desired, so that it can no longer be moved. The tailstock as such can be clamped with a clamp nut (4) on the lathe bed.

Drives of sliding and screwcutting lathe

Electric motors are used for the drive. The electric motor is built into the pedestal of the machine frame and is significantly called foot-mounted motor (Figure 4.17), or it is laterally flanged to the machine frame, then the motor is called flange-mounted motor (Figure 4/18.).

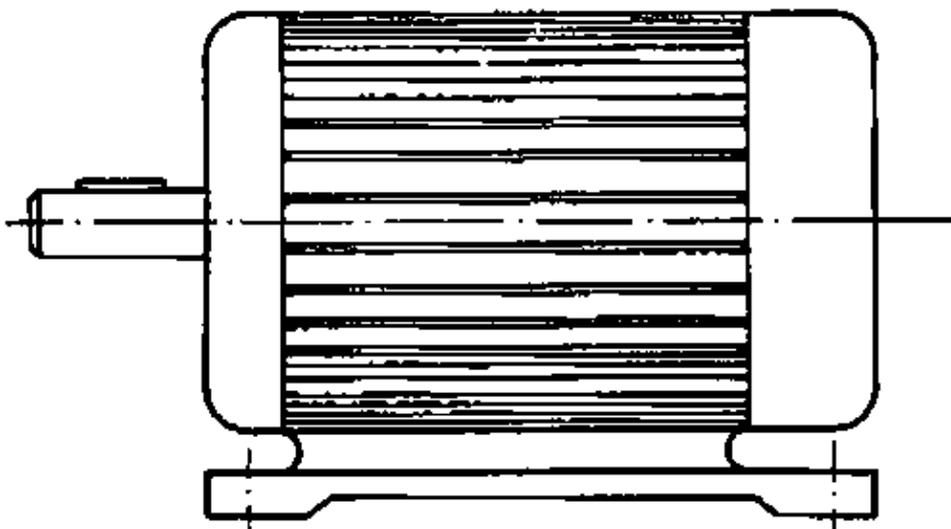


Figure 4/17 Foot-mounted motor of a sliding and screwcutting lathe (built-in motor)

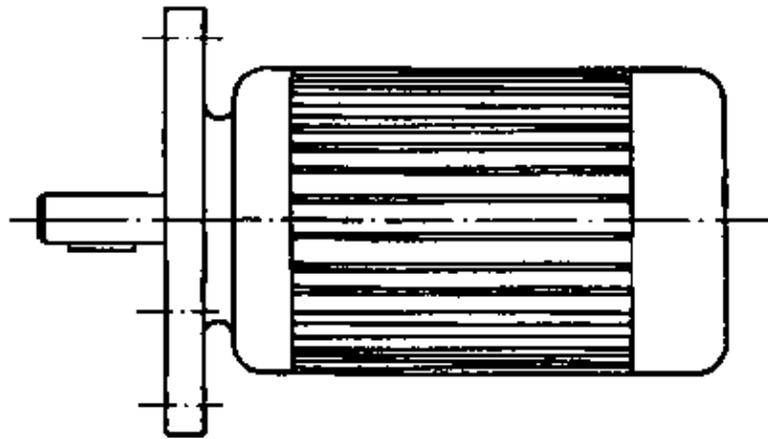


Figure 4/18 Flange-mounted motor of a sliding and screwcutting lathe (flanged motor)

Mechanisms of transfer of a sliding and screwcutting lathe

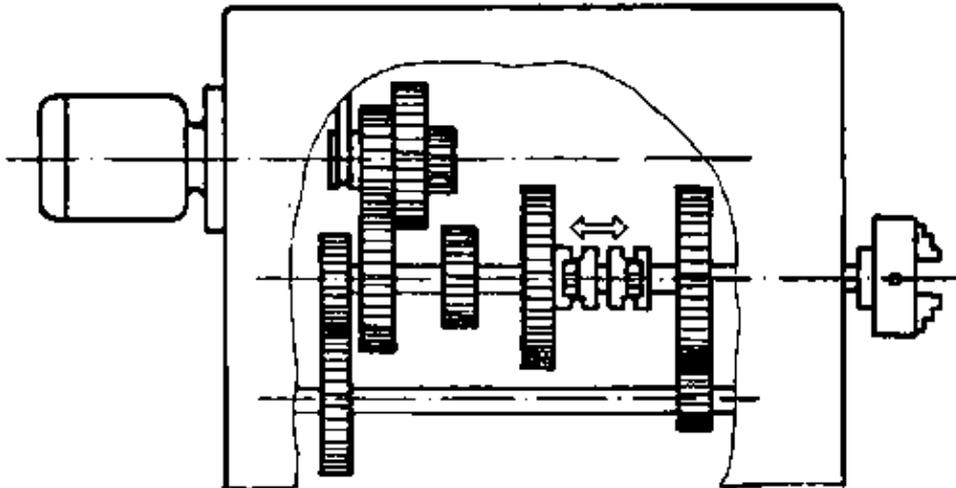


Figure 4/19 Main gear to switch the rotations desired

The main drive serves to adjust the revolutions of the rotating cutting movement (Figure 4/19). The revolutions desired have to be obtained by transmission from the revolutions of motor. while the revolutions of the motor remain constant, the revolutions of the lathe spindle can be changed in steps or infinitely via the gearing.

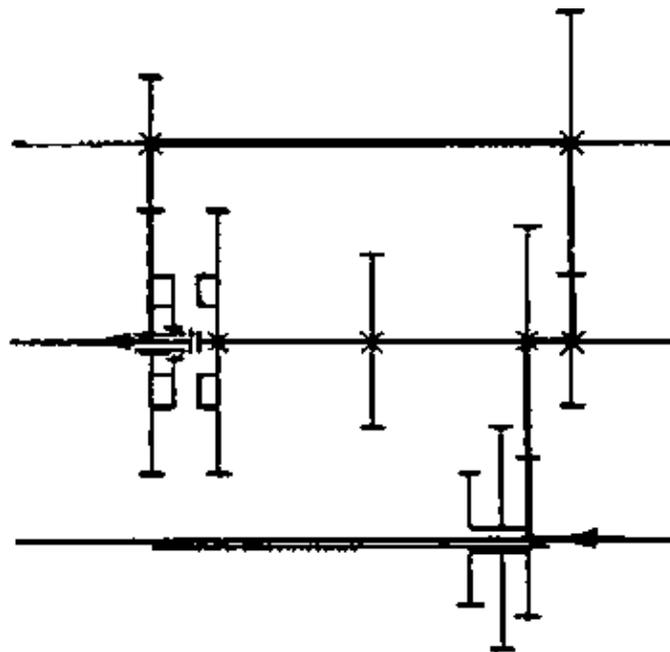


Figure 4/20 Back gear

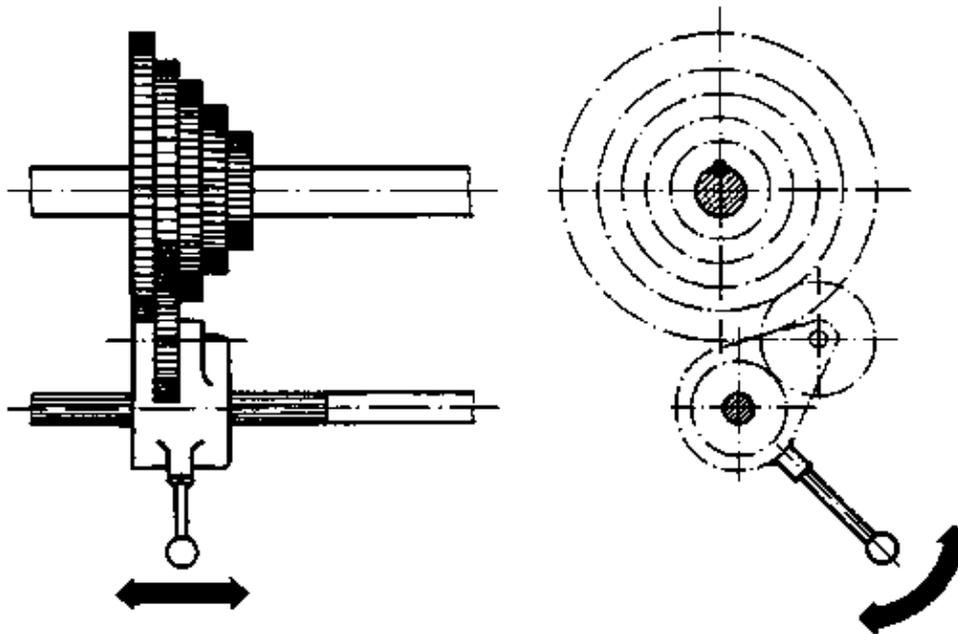


Figure 4/21 Feed gear (Norton-type gear)

Table 4/2 Speed graduation of cutting motion with and without back gear (example)

Rotational speed in rpm		
	Series 1	Series 2
with	15, 21, 30 42,	25, 36, 51,
back gear	60, 85	70, 100, 141,
without	118, 170, 235, 335	200, 288, 410,
back gear	475, 670	580, 820, 1160

The back gear makes it possible to lower the totality of variable revolutions of main drive by one stage (Figure 4/20). As a result the number of speed graduations is doubled (Table 4/2). Thus the range of application of the machine is extended.

The feed gear takes the drive of the feed motion from the main gear. The feed motion has always a definite ratio to the cutting motion (Figure 4/21).

The various operations require a larger or smaller feed. Therefore the feed gear for the engine lathe is equipped with different graduations. With constant revolutions during cutting operation it is possible for the carriage or the cross-slide to move quickly (during rough machining), or to move slowly (during finish-machining). In thread-cutting the feed depends upon the pitch of thread that is to be cut.

- Mechanisms for longitudinal feed

The feed screw (1) transmits the rotary drive motion from the feed gear to the carriage (Figure 4/22). A worm (2) turned by the feed screw slides on it. The worm drives a worm wheel (3). The worm wheel transmits the motion to a rack-and-pinion gear (4). The rack-and-pinion gear transmits the rotary movement of the cogwheel into the straight-lined motion of the carriage.

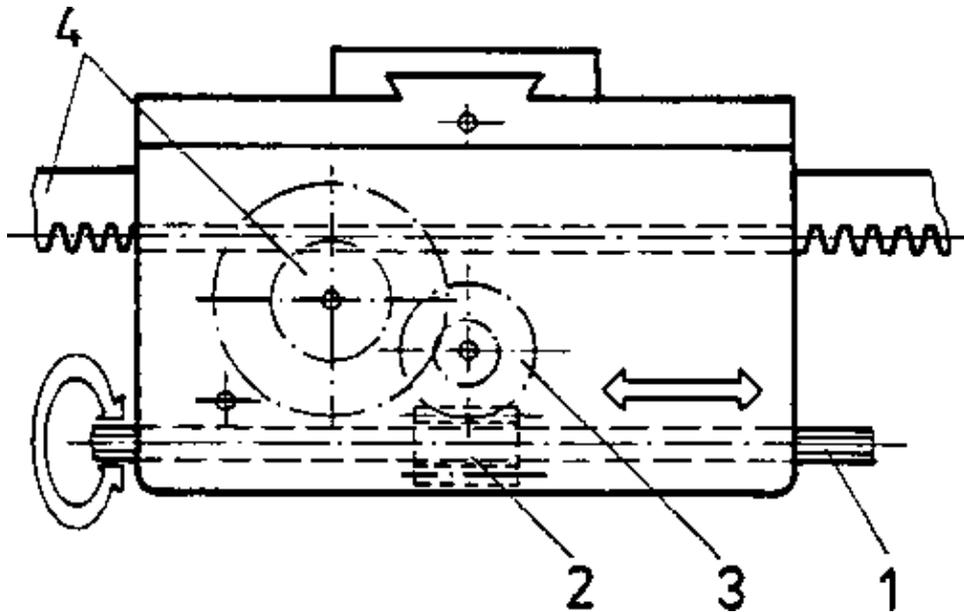


Figure 4/22 Mechanisms for longitudinal feed

1 Feed screw, 2 Worm, 3 Worm wheel, 4 Rack-and-pinion gear

• Mechanisms for surfacing feed

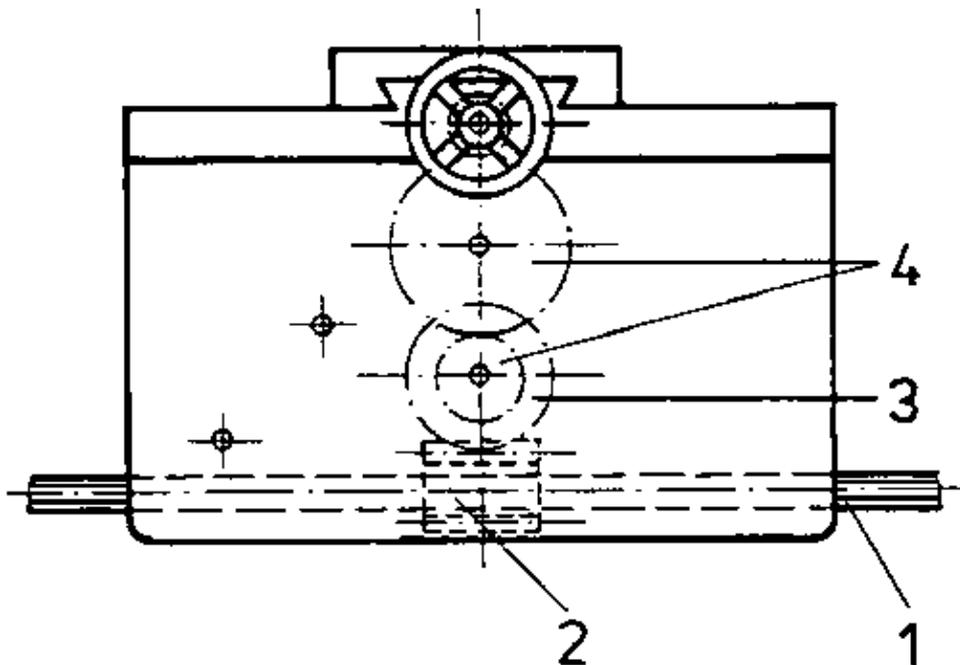


Figure 4/23 Mechanisms for surfacing feed

1 Feed screw, 2 Worm, 3 Worm wheel, 4 Screw gear.

The worm wheel (3) transmits the movement to a screw gear (4). The screw gear transmits the rotary motion of spindle in the cross-slide into a straight-lined motion of the cross-slide (Figure 4/23).

• Mechanisms for feed during thread cutting

The lead screw (1) transmits the rotary drive motion from the feed gear to the carriage. A divisible nut (2) slides on the lead screw. Via a switch lever (3) the nut is opened, when the carriage is supposed to be at standstill (Figure 4/24a). If the carriage is required to move, the nut will be closed (Figure 4/24b). Lead screw and nut operate like a screw gear. They convert the rotary motion of lead screw into a straight-lined motion of carriage.

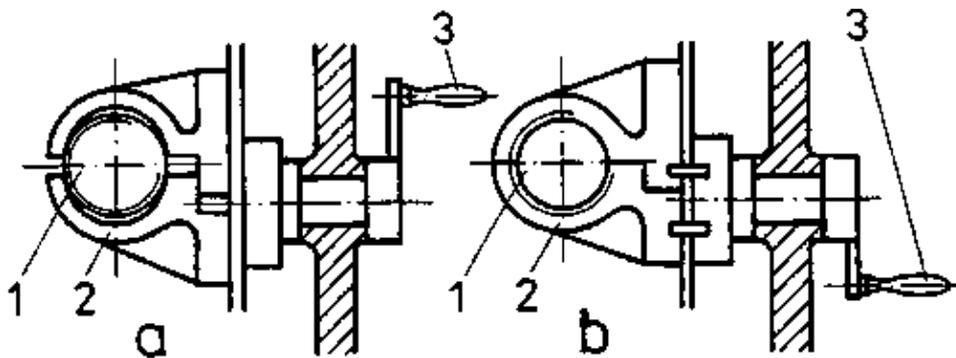


Figure 4/24 Mechanisms for feed during thread cutting

1 Lead screw, 2 Divisible nut, 3 Switching lever

Control questions

1. Describe the structure of a sliding and screwcutting lathe.
2. Describe the mechanisms of transfer that transmit the drive motion of the motor to the lathe spindle.
3. What are the transformations of motions that proceed in the mechanisms of transfer of a sliding and screwcutting lathe?
4. For what purposes is the feed screw used, and for what purposes is the lead screw used?
5. How does the feed motion arise during facing with hand feed?
6. What are the tasks of the back gear?

4.2.2. Clamping devices for workpieces and their use

In this section you shall get acquainted with

- the tasks and functions of work-clamping devices in turning machines
- the types of work-clamping devices available
- the way of functioning of clamping devices
- the preferable use of clamping devices for definite workpieces.

Tasks of clamping devices for workpieces

The work-clamping devices hold the workpieces. They transmit the rotary motion from the lathe spindle to the workpiece.

Forces arising during the process of metal cutting must not shift the position of the workpiece clamped in the clamping device (Table 4/3).

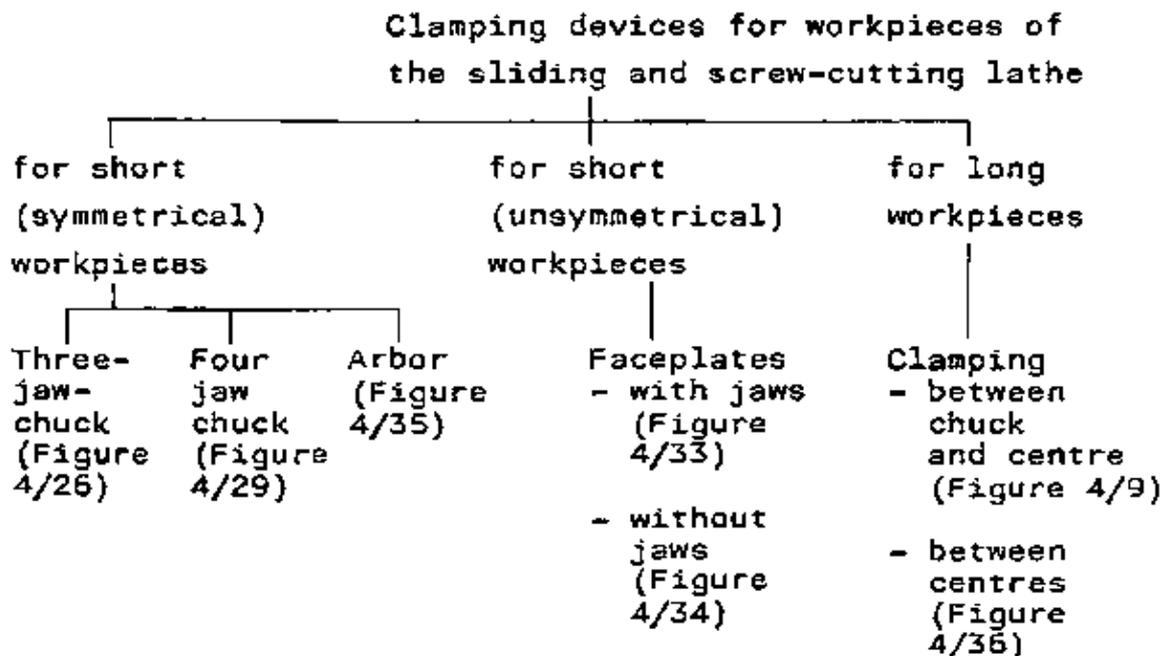
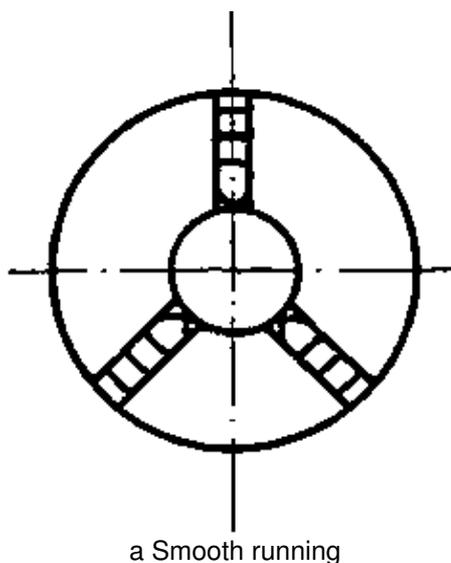


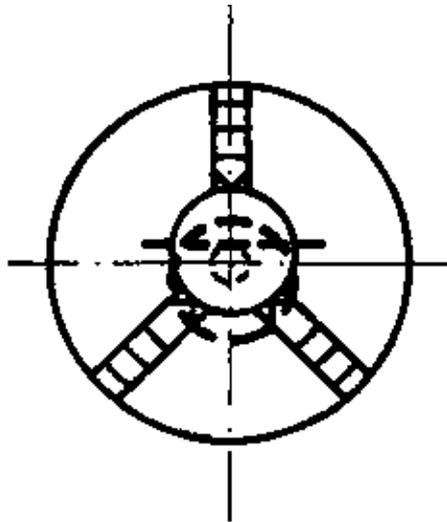
Table 4/3 Survey of the types of clamping devices for workpieces

The work-clamping devices have to provide for the true running of workpieces at the place of machining and have to ensure that they cannot escape the machining forces (Figure 4/25).

Clamping and unclamping the workpieces must not take much time; this is non-productive time.

Figure 4/25 True run of workpiece!





b Untrue running which has to be corrected prior to metal cutting operations

Three-jaw chuck

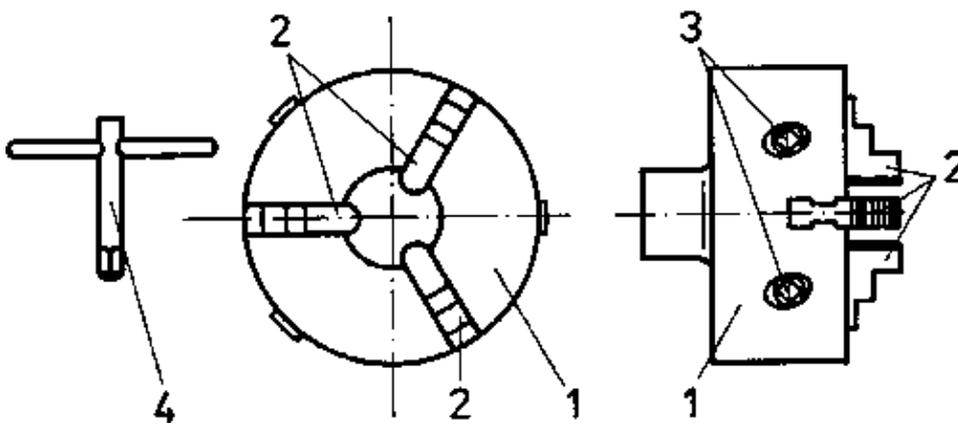


Figure 4/26 Three-jaw chuck

1 Chuck, 2 Clamping jaws, 3 Recess for chuck key, 4 Chuck key.

Three-jaw chucks are most frequently used in sliding and screwcutting lathes. The three-jaw chucks clamp cylindrical workpieces symmetrically. They can be easily operated. With the chuck key (4) to be inserted into the reception for chuck keys (3) the three jaws (2) in the chuck (1) are simultaneously and uniformly moved, so that they at each opening are placed symmetrically to the rotary axis of chuck (Figure 4/27). The chuck key contains a safety device that enables the key to be automatically ejected after clamping and unclamping of workpiece. Otherwise, there would be the danger of accident upon start-up of machine (Figure 4/28).

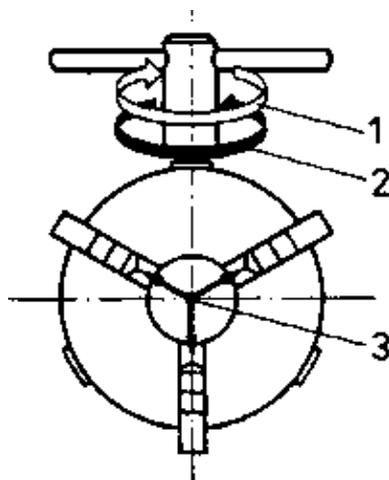


Figure 4/27 Handling the three-jaw chuck

- 1 Closing the jaws during clamping (right turn),
- 2 Opening the jaws during unclamping (left turn).
- 3 Uniform travel of jaws during opening and closing.

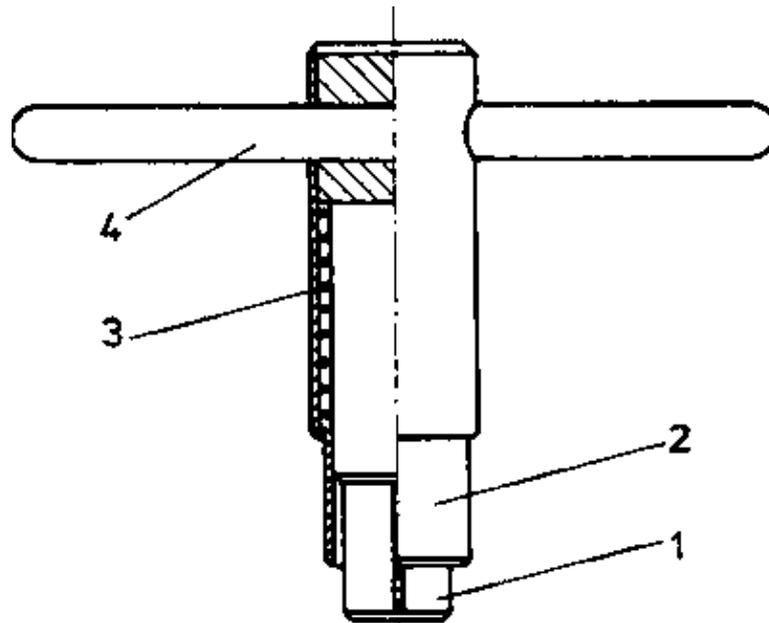


Figure 4/28 Chuck key is automatically ejected otherwise danger of accident

- 1 Square-head key,
- 2 Safety sheath,
- 3 Spring,
- 4 Handle.

Four-jaw chuck

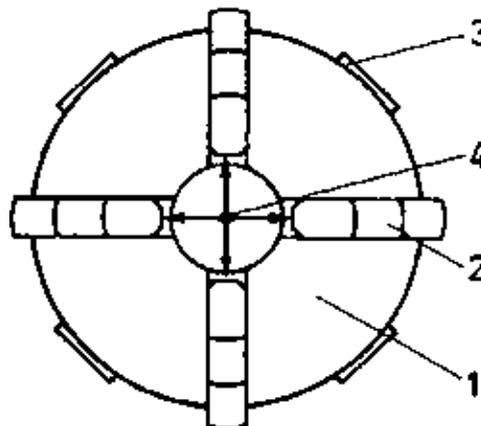


Figure 4/29 Four-jaw chuck

- 1 Chuck body, 2 Clamping jaws, 3 Recess for chuck key, 3 Equal distance of jaws from centre of rotation.

Four-jaw chucks are used in sliding and screwcutting lathes for clamping workpieces with square and octagon surfaces (Figure 4/29), The chuck key is put into the reception for chuck keys (3). By turning the key all four jaws (2) in the chuck body (1) are simultaneously and uniformly moved. The four-jaw chuck functions in the same way as the three-jaw chuck. The surfaces at the edge-type part of workpiece have to be placed symmetrically to the rotary axis, because otherwise the four-jaw chuck would be inapplicable (Figure 4/30).

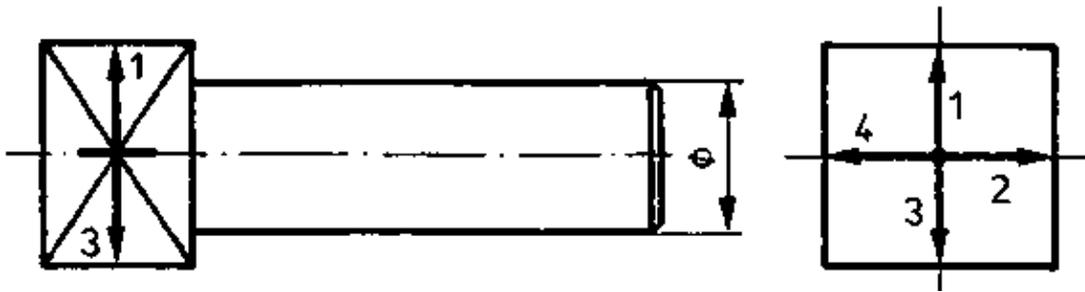


Figure 4/30 Symmetrical position of sides at square of a workpiece

1, 2, 3, 4 Equal distances from centre of rotation

The chuck key is designed in the same way as with the three-jaw chuck.

Faceplates

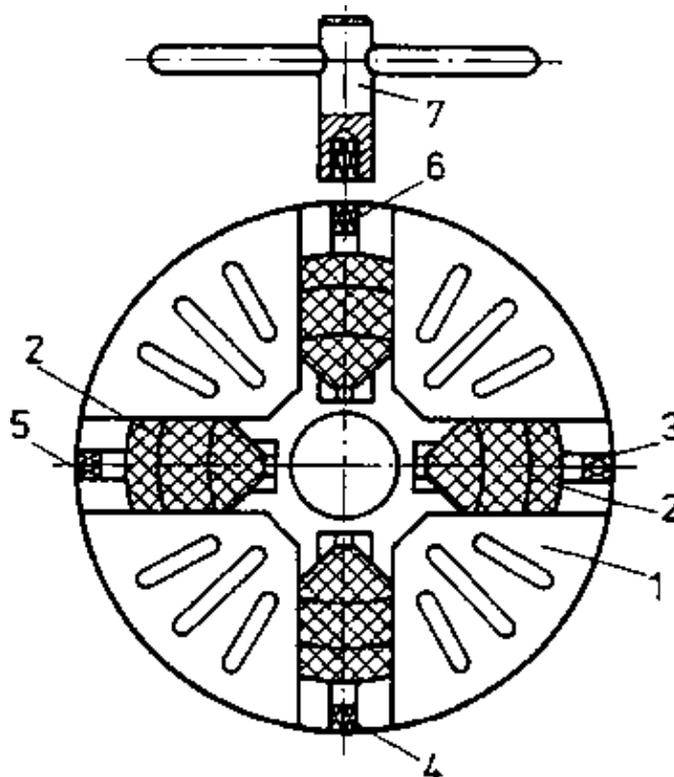


Figure 4/31 Faceplate

1 Body of faceplate, 2 Clamping jaws, individually adjustable, 3, 4, 5, 6 Receptions for socket wrench, for each clamping jaw separately, 7 Socket wrench.

Faceplates are used in sliding and screwcutting lathes for the clamping of workpieces, the surfaces of which lie unsymmetrically to the rotary axis (Figure 4/31).

With the socket wrench (7) to be put into the reception for socket wrenches (3,4,5,6) each of the four jaws (2) of the faceplate can be moved separately. The clamping in the faceplate requires careful work and repeated checking of true run.

The individual jaws have to be adjusted, until the workpiece has a true run (Figure 4/32). If a workpiece shows an unbalance it is required to apply balancing pieces for the balancing of masses (Figure 4/33).

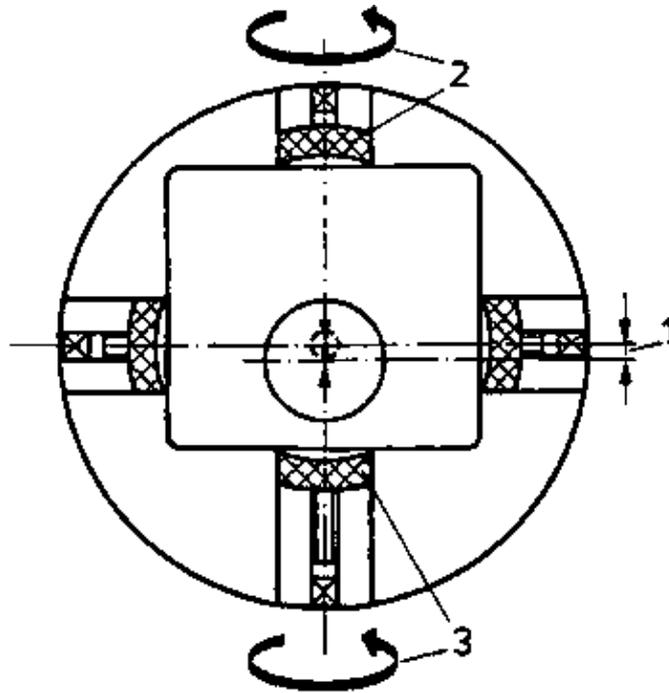
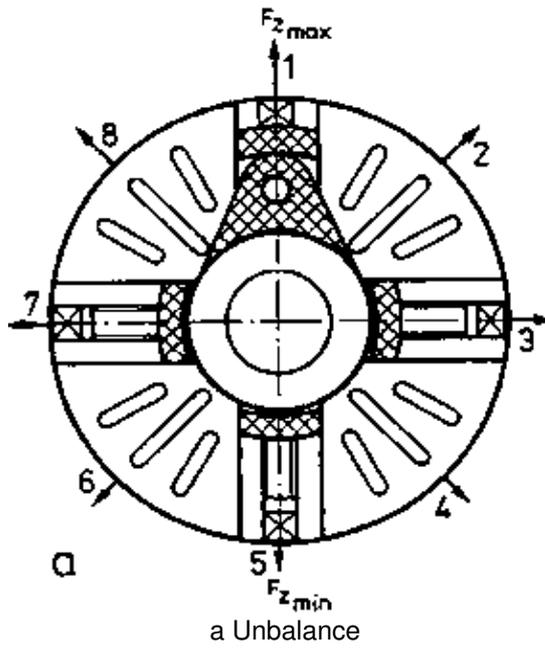
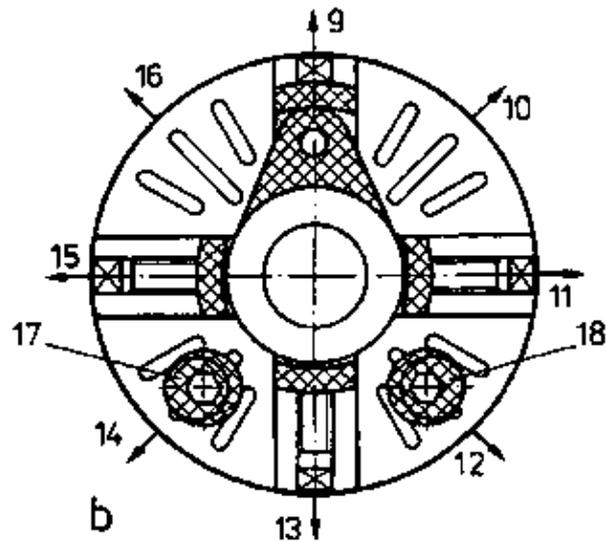


Figure 4/32 Correction of untrue running

1. Unbalance (difference of true run),
- 2 Clamping jaws to be loosened,
- 3 Clamping jaws to be tightened

Figure 4/33 Unsymmetrical workpiece in faceplate





b Correction of unbalance

1 Unequal centrifugal forces, 9 to 16 Equal centrifugal forces due to the effect of mass balancers, 17, 18 Mass balancers

The faceplate can also be used without any jaws. One after the other the jaws are taken out and the spindles are removed. The workpiece is clamped by using auxiliary means, e.g. bolts and nuts, clamping angles, and is directly put on the faceplate. Balancers for the balancing of masses are likewise required for this type of clamping (Figure 4/34).

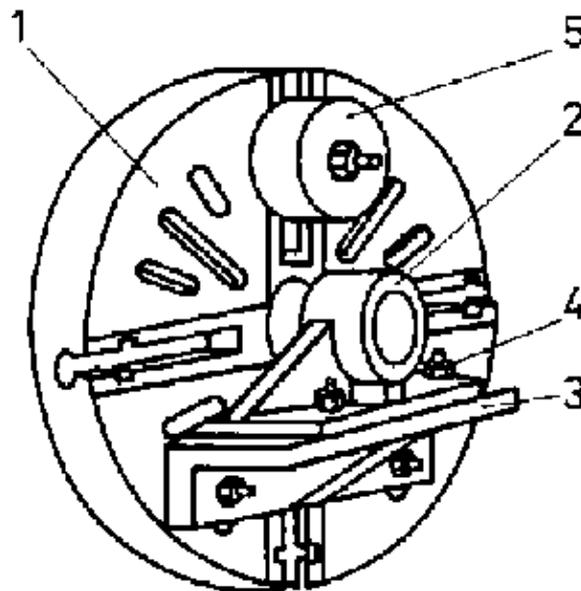


Figure 4/34 Workpiece with clamping angle directly clamped to faceplate

1 Faceplate,
 2 Workpiece,
 3 Clamping angle,
 4 Bolts with nuts,
 5 Mass balancers

Mandrels

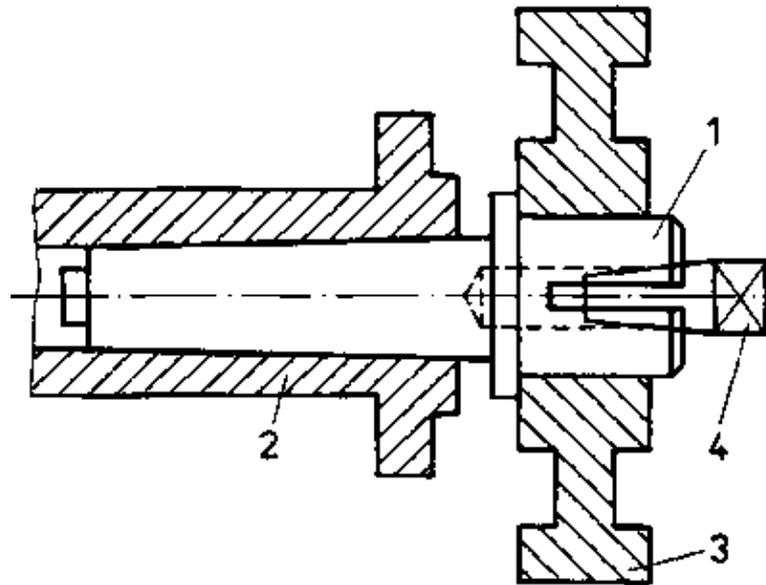


Figure 4/35 Mandrel with workpiece

1 Arbor (mandrel), 2 Lathe spindle, 3 Workpiece, 4 Spreader bolt.

Mandrels serve to clamp symmetrical workpieces with accurate bores (Figure 4/35). The mandrel (1) is inserted into the conical bore of the lathe spindle (2). The workpiece (3) is placed on the cylindrical part of mandrel. The mandrel is slit, so that it can be expanded by means of the spreader bolt (4). Thus the workpiece is tightly clamped. The operations are simple, clamping and unclamping can be done readily.

Mounting on centres

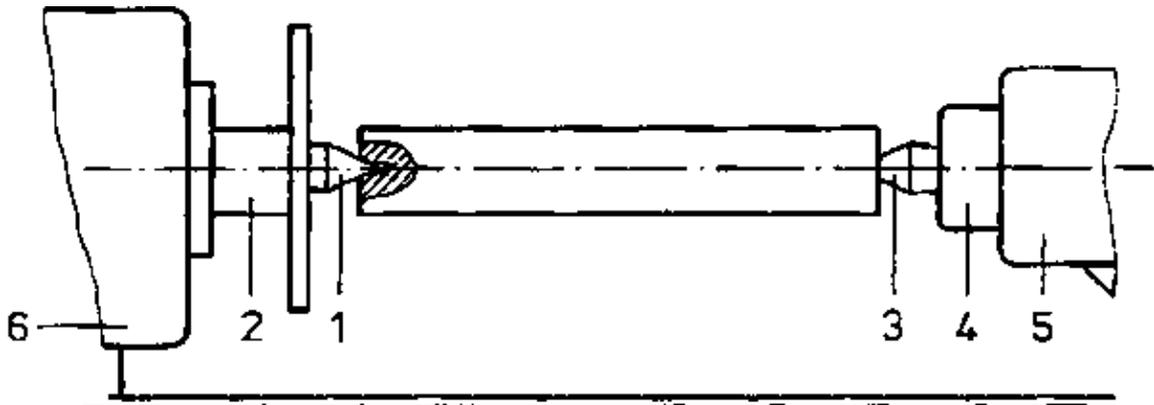


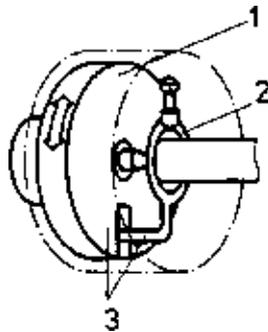
Figure 4/36 Workpiece mounted on centres

1 Centre in lathe spindle, 2 Lathe spindle, 3 Centre in tailstock sleeve, 4 Sleeve, 5 Tailstock, 6 Headstock

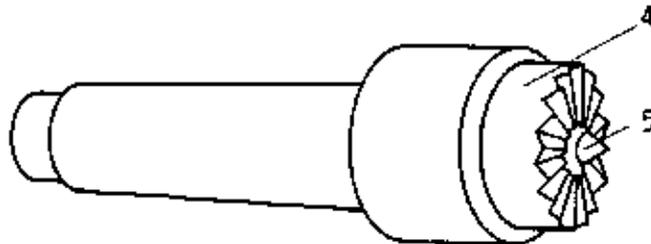
The mounting on centres is used for long workpieces (Figure 4/36). This is done by means of two centres, one of them being inserted into the lathe spindle (2) and the other (3) into the sleeve (4) of the tailstock (5). For clamping and unclamping the sleeve is actuated in such a way by the hand wheel that the centres modify the distance to each other.

The peak in the lathe spindle is insufficient to transmit the rotary movement onto the workpiece. Therefore a work driver has to be used which serves for the transmission of power between the lathe spindle and the workpiece.

Figure 4/37 Driving pin (work driver) for power transmission during turning on centres



a driving pin, two-part, for right- and left rotation of workpiece



b Front-side driving pin

- 1 Part fastened on lathe spindle,
- 2 Part fastened on workpiece,
- 3 Close engagement of parts,
- 4 Driving plate with spur teeth,
- 5 Centre.

Part of the driver is fastened on the lathe spindle, the other part on the workpiece. Both parts engage in each other so intensively that a good drive is ensured (Figure 4/37a).

Front-face drivers engage in the front-side of the workpiece (Figure 4/37b). The workpiece has to be firmly pressed against the front edges of the driving plate (1), so that the edges penetrate into the front-side of the workpiece. There is a centre (2) in the middle of the driver.

Control questions

1. What demands are made on the work-clamping devices?
2. Name clamping devices for workpieces which are used on engine lathes,
3. For what kinds of workpieces are these clamping devices preferably used?
4. Describe the function of a three-jaw chuck.
5. What has to be the design of the driver for mounting between centres in order to avoid any accidents?

4.2.3. Clamping devices for tools and their use

In this section you should get acquainted with

- the tasks and functions of tool-clamping devices in turning lathes
- the types of tool-clamping devices available
- the way of functioning of tool-clamping devices
- those tool-clamping devices to be preferably used for definite workpieces.

Tasks of clamping devices for tools

The tool-clamping devices have to hold the tools firmly. They transmit the feed motions and in-feed

movements to the tool.

Forces arising during the process of metal cutting are not allowed to shift the position of tool in the tool-clamping device. The tool must not vibrate in the clamping device.

There are tools which are clamped on the carriage (Figure 4/7, 4/8, 4/9) and there are tools which are clamped in the sleeve of the tailstock (Figure 4/10).

Tool changing should proceed quickly, so that the various turning operations can immediately follow. Clamping and unclamping the tools shall not require much time, because this is non-productive time.

Single-type lathe tool holder

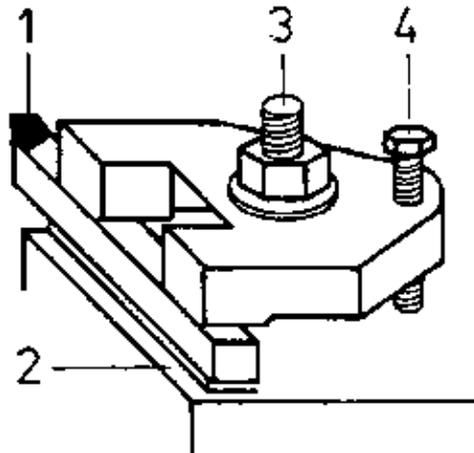


Figure 4/38 Clamping claws

- 1 Lathe tool,
- 2 Saddle,
- 3 Fastening screw,
- 4 Adjusting screw.

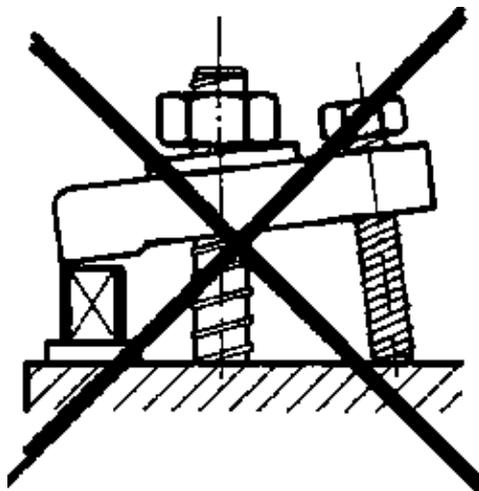


Figure 4/39 Wrongly set adjusting screw

Adjusting screw to be loosened!

It serves for the clamping of a lathe tool on the carriage. It is common practice to use clamping claws (Figure 4/38) and lathe tool holders with adjusting screws (Figure 4/40).

In case of clamping claws the horizontal position of the claw is only set with the help of the setscrew (4). Then the lathe tool is clamped at the retaining screw (3). If the setscrew is wrongly adjusted (Figure 4/39), the clamping claw is in an oblique position and the lathe tool is only insecurely held.

With the lathe tool holder with adjusting screws the lathe tool is firmly clamped with the help of adjusting screws (Figure 4/40). All the adjusting screws have to be uniformly clamped, because otherwise the lathe tool

begins to vibrate (Figure 4/41).

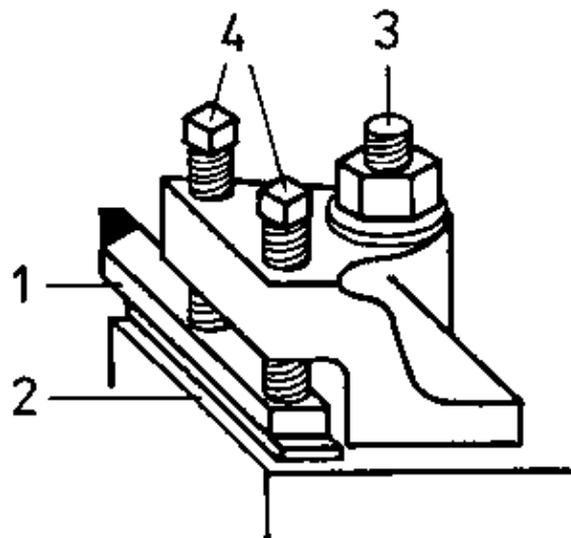


Figure 4/40 Lathe tool holder with adjusting screw

- 1 Lathe tool, 2 Saddle,
- 3 Screw for fastening lathe tool holder,
- 4 Adjusting screws

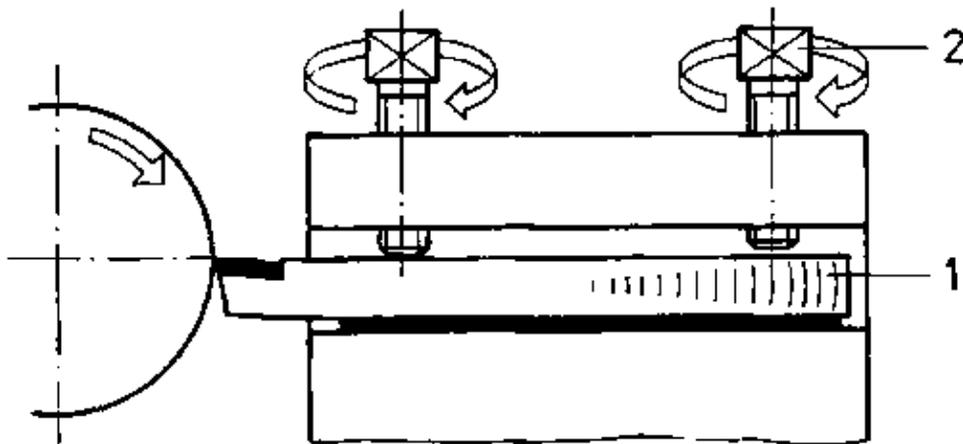


Figure 4/41 Wrongly clamped adjusting screw

- 1 Lathe tool vibrates, 2 Adjusting screw to loosely clamped.

Multiple lathe tool holder

They serve for clamping several lathe tools on the carriage. The lathe tools form part of a sequence of operations. The multiple lathe tool holder is slewable, so that after each operation the next tool can be quickly set. This is especially convenient if several equal workpieces have to be machined one after the other, which are noted for several equal operations.

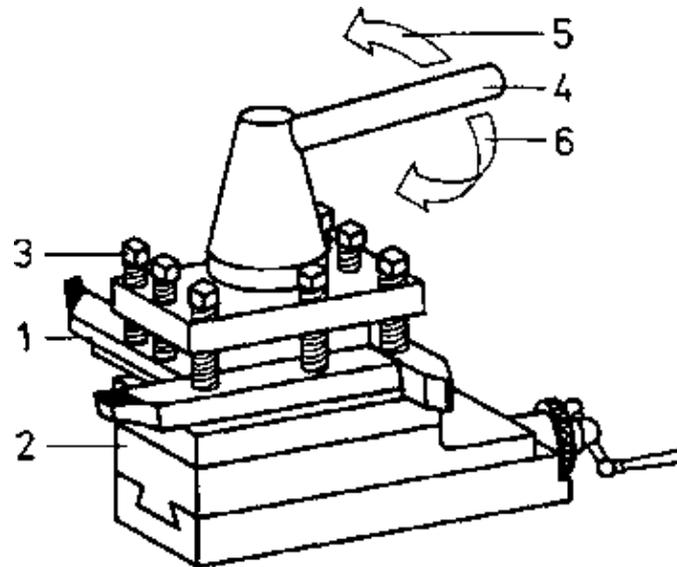


Figure 4/42 Multiple lathe tool holder

- 1 Lathe tool,
- 2 Saddle,
- 3 Adjusting screws,
- 4 Lever to turn the lathe tool holder and for tight clamping,
- 5 Release for tool change,
- 6 After change of tools to be tightly clamped.

The multiple lathe tool holder according to Figure 4/42 can accommodate 4 lathe tools. The adjusting screws serve to clamp the lathe tool firmly (3). If the tool is to be changed, the lever (4) is released. The lathe tool holder is turned until the tool desired has been set. Then again the lathe tool holder is firmly clamped by means of the lever.

Tool holder in tailstock sleeve.

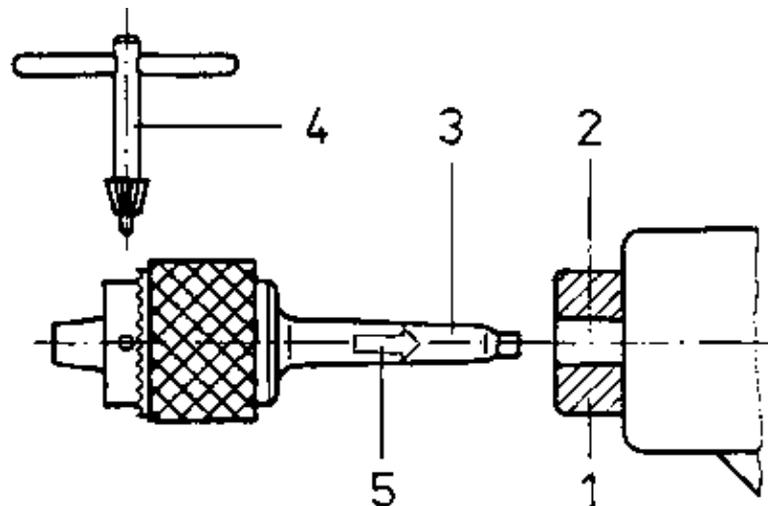


Figure 4/43 Drill chuck with external cone to be set into tailstock sleeve

- 1 Tailstock sleeve,
- 2 Conical bore,
- 3 Conical shaft at drill chuck,
- 4 Drill chuck key,
- 5 Drill chuck with short pressure to be inserted in this direction.

They serve to clamp the tools used to cut bores and to machine them. The tailstock sleeve (Figure 4/43) includes a conical bore (2). The tool holders have conical shafts (3). The outer cones are placed into the conical bore of the sleeve.

Several tools have conical shanks (drills, countersinks, reamers) which can be directly inserted into the conical bore of the sleeve (Figure 4/44). Therefore special tool holders are not required.

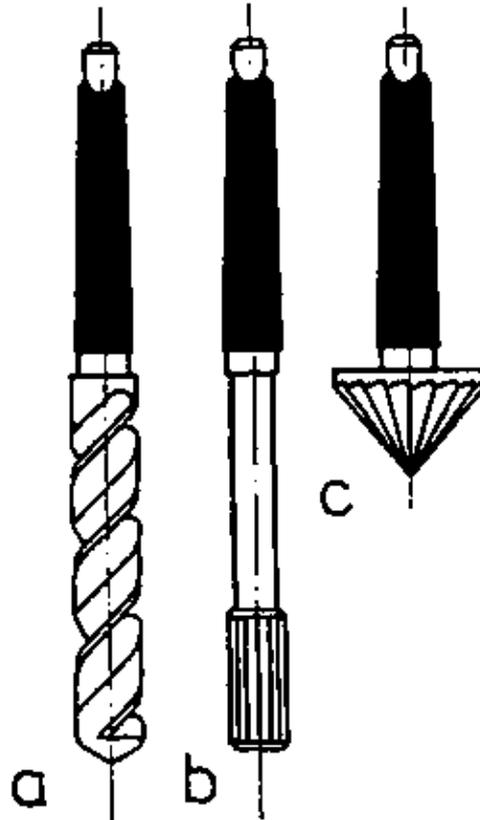


Figure 4/44 Tool with conical shaft

- a Twist drill,
- b Machine reamers,
- c Countersinks.

For the purpose of release from the conical bore the sleeve is turned into the tailstock. A stop inside pushes out the taper shank inserted.

Control questions

1. What demands are put on the tool-clamping devices for lathes!
2. Name tool-clamping devices used for sliding and screwcutting lathes.
3. For what tools and for what operations are these clamping devices preferably used?
4. In what way do these clamping devices influence productivity of labour?
5. Describe the function of a multiple lathe tool holder.

4.2.4. Handling of the sliding and screwcutting lathe

In this section you shall get acquainted with

- the setting of a sliding and screwcutting lathe
- the way of operating the lathe during turning operations
- the errors that have to be avoided during operation of machine.

Setting of the machine

During the setting of the machine it will be provided that the turning operation intended will proceed with a suitable metal cutting characteristics for turning.

Switching the main gear

The correct turning characteristics for the cutting motion are set at the main gear (Figure 4/19). This turning characteristic is the cutting speed.

The cutting speed during turning operations is the speed at which the workpiece travels long the machining place at the tool.

The cutting speed depends on

- the material of the workpiece
- the material of the tool
- the surface grade required for workpiece (fine or rough).

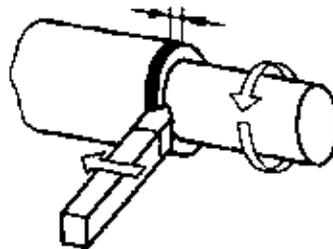
The cutting speed is set for a definite turning operation. At the main gear the number of revolutions required for the cutting motion is set (Figure 4/2).

• Switching the feed gear

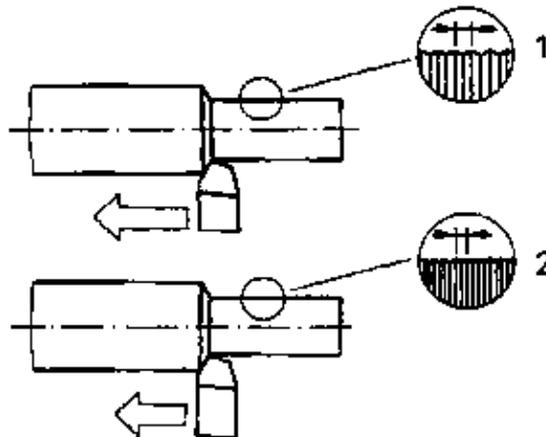
The correct machining characteristics are set at the feed gear (Figure 4/21). This turning characteristic is the feed (Figure 4/45).

During turning operations the feed is the distance travelled by the lathe tool during one revolution of the workpiece along the workpiece

Figure 4/45 Feed upon turning



a Representation of feed



b Influence of feed on surface grade

- 1 Large feed – large surface.
- 2 Small feed – fine surface

The feed is dependent upon

- the material of the workpiece
- the material of the tool

- the surface grade of the workpiece required (fine or rough).

The feed is adjusted for definite turning operations by setting the ratio required between the cutting motion and the feed motion at the feed gear.

- Process of gear switching

Gears are sensitive components of a machine. Due to wrong operations of switching they can be damaged, or they can even be destroyed. According to design gears can be switched

- only during the standstill of machine
- only in the running–out period after disconnecting i.e. shortly before the standstill;
- at any time, i.e. at a standstill, in the running–out period, or during operation.

Upon switching the switch lever is slowly actuated. With a certain feel it is possible to find out whether the switching elements can be freely moved. As soon as any resistance arises it is never allowed to use force.

The technically correct switching of gear keeps the machine operational over a long period, it saves repairs and prevents stoppages. Please, observe instructions for use!

Clamping the workpiece

The workpiece is clamped by means of one of the workpiece clamping devices according to Section 4.2.2. on the lathe. The following has to be observed for clamping:

- during clamping the machine is not allowed to start out of a sudden (motor to be disconnected, or decoupled)
- the clamped workpiece must be able to be turned freely
- the workpiece must be firmly placed in the work–clamping device
- no unbalance shall arise in case of unsymmetrical workpieces, otherwise compensating balancers (Figure 4/33) have to be attached
- chuck keys or other working media have to be removed prior to the connection of machine.

After clamping the workpiece has to be turned around by hand for one full revolution. This shows whether it can be freely moved.

Checking of true running

It has to be checked prior to the onset of metal cutting, whether the clamped workpiece runs true. For this purpose the cutting motion is switched in and

- the true running of blanks is checked by means of chalk, or with a scribe (Figure 4/46).
- the true running of the already roughened workpieces is checked by means of a dial gauge (Figure 4/48).

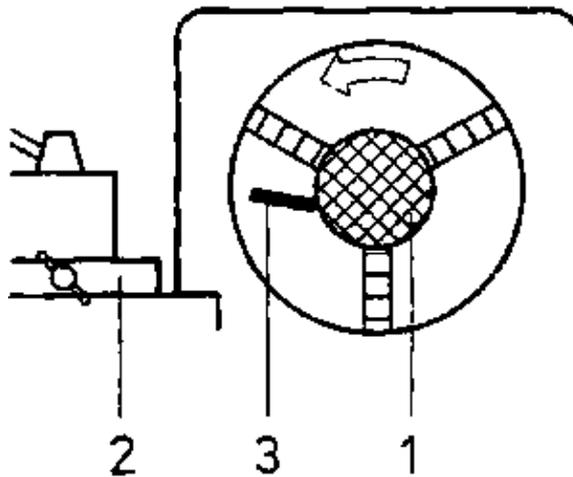


Figure 4/46 Checking of true running of blanks

1 Workpiece, 2 Carriage, 3 Chalk held with the hand supported on the carriage.

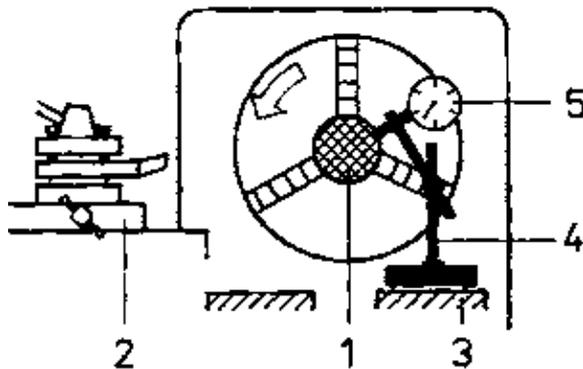


Figure 4/47 Checking of true running of pre-machined workpieces

1 Workpiece, 2 Carriage, 3 Lathe bed, 4 Pillar, 5 Measuring indicator (dial gauge).

If the workpiece does not have a sufficiently true running, it has to be unclamped from the three-jaw or four-jaw chuck and to be re-clamped differently. The eccentric position of workpiece has to be corrected on a faceplate by readjusting the various jaws (Figure 4/32).

Clamping the tool

The tool is clamped on the carriage or in the tailstock sleeve by using one of the tool-clamping devices according to Section 4.2.3.

- Carriage

Upon clamping lathe tools in tool holders the following hints shall be observed:

Lathe tool

- to be clamped with short end, because otherwise it bends and begins to vibrate (Figures 4/48 and 4/49).
- to be clamped at right angle to workpiece, because otherwise the action angle is inconvenient (Figure 4/50).
- to be clamped at centre, otherwise there are unfavourable angles of action (Figure 4/51)

– the shank of tool is allowed to be fully seated, because otherwise changes of position may be possible (Figure 4/41).

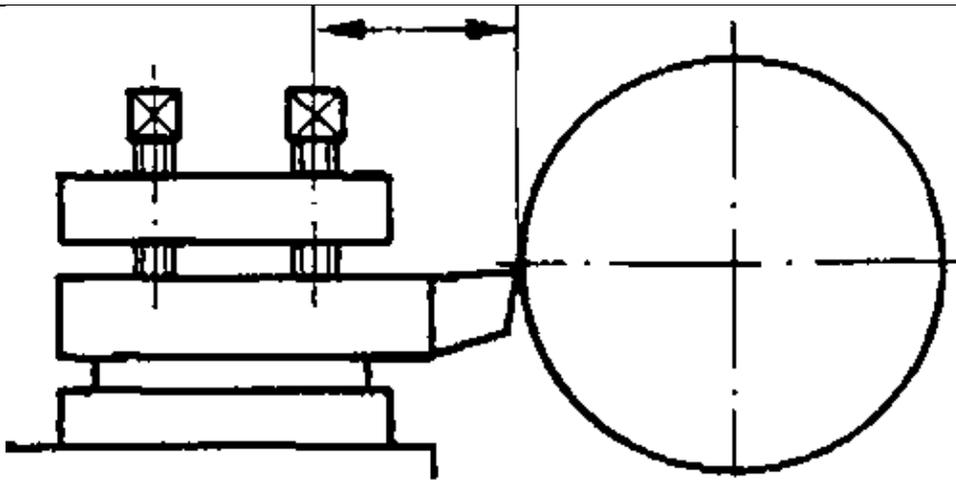


Figure 4/48 Lathe tool to be clamped with short end!

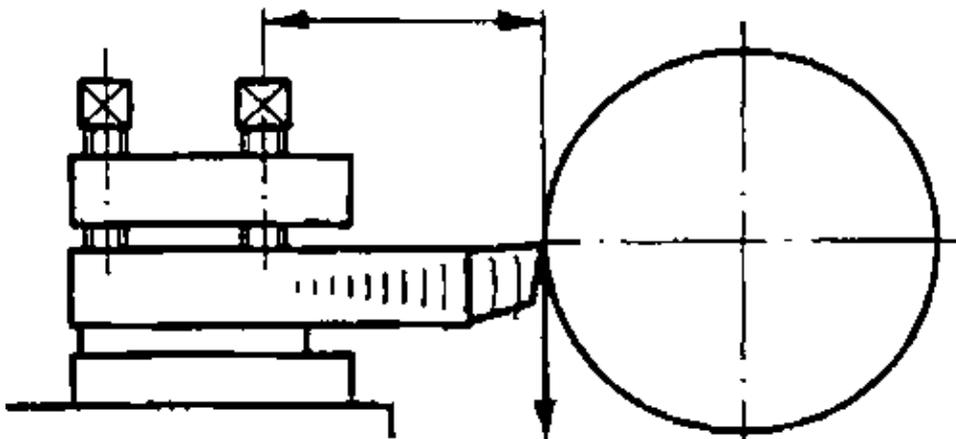
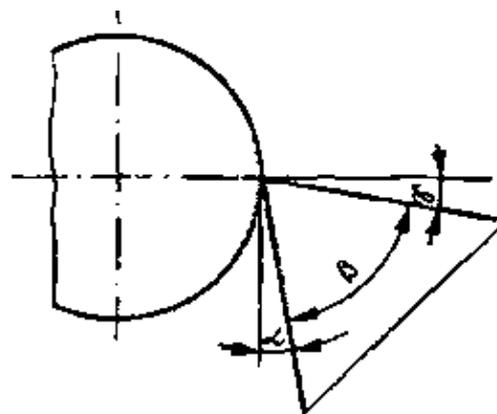
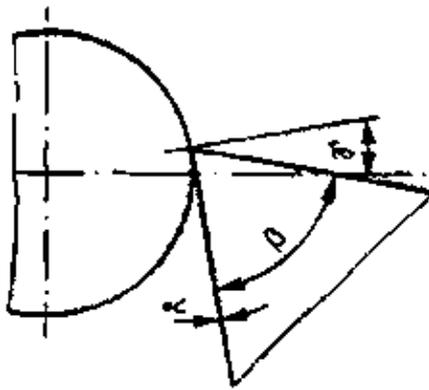


Figure 4/49 Lathe tool wrongly clamped (too long), it bends and vibrates.

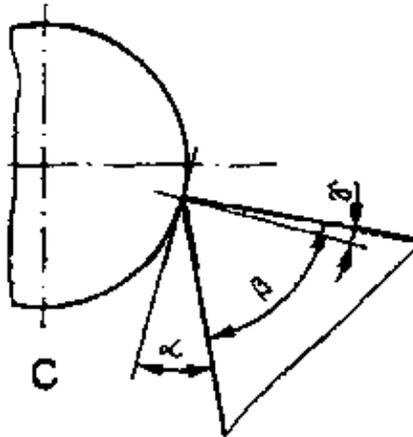
Figure 4/50 Change of action angle upon clamping, apart from centre



a At centre



b Beyond centre (? larger, ? smaller than with lathe tools clamped at centre)

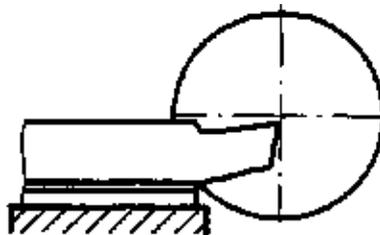


c Below centre (? smaller, ? larger than with lathe tool clamped at centre)

Figure 4/51 Checking the clamping at centre



a Lathe tool at centre



b Test at the workpiece (lathe tool below centre)

The position of lathe tool that is clamped at centre can be checked at the centre in tailstock sleeve, or by a test at the workpiece. (Figure 4/51).

- Tailstock sleeve

When clamping the tools in the tailstock sleeve the following instructions shall be observed:

- Internal taper of sleeve and outer cone of tool to be cleaned by rag,

- Tailstock sleeve to be turned out of tailstock only as is absolutely required, otherwise tool is inaccurately actuated (Figure 4/52)
- In case of long feed sleeve shall be turned back and tailstock to be readjusted.
- If required, tool to be secured against being turned (Figure 4/53).

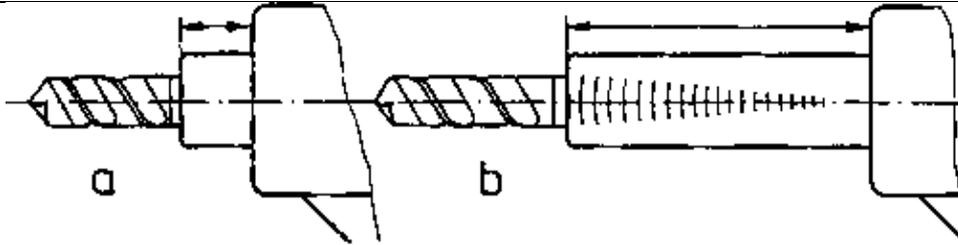
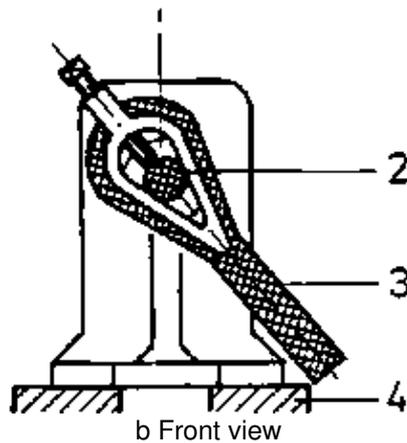
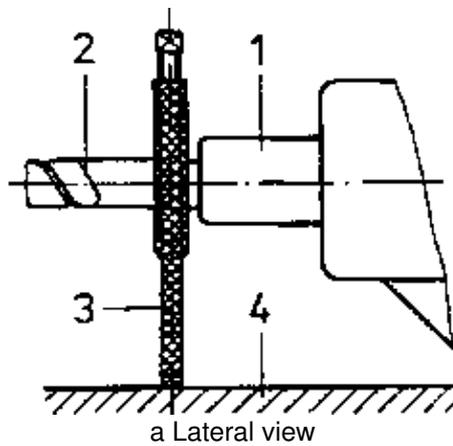


Figure 4/52 Tool to be adjusted in tailstock sleeve

a Good guidance, b Inaccurate guide because tailstock sleeve is turned out too far

Figure 4/53 Tool in tailstock sleeve secured against turning



1 Tailstock sleeve, 2 Tool, 3 Safety device, 4 Support,

Operation of a sliding and screwcutting lathe

After the machine had been set, workpiece and tool have been clamped, it is possible to start with the turning operations (Table 4/4).

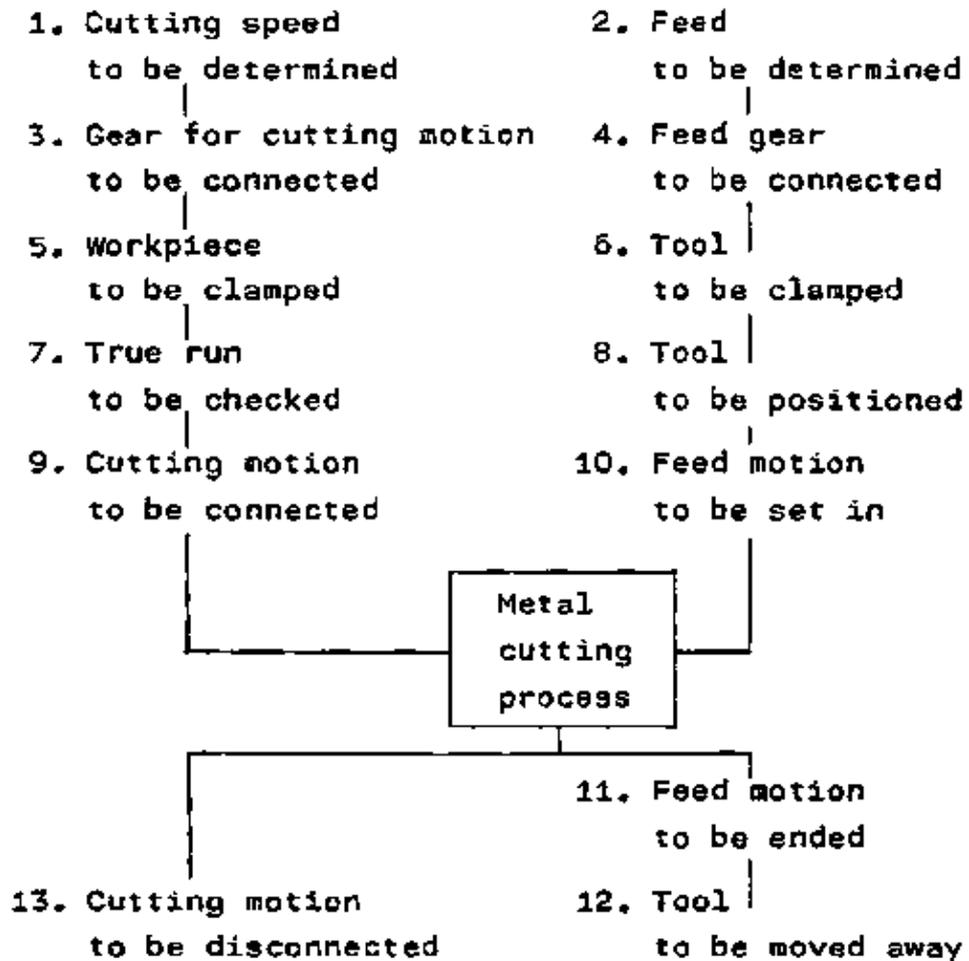


Table 4/4 Setting-in and operating a sliding and screw-cutting lathe

- Switching-on of machine (cutting motion)

Attention shall be paid to the fact that the workpiece runs in the correct rotational direction of the cutting motion. The tool has to be moved forward, together with the carriage, out of the range of rotation of workpiece, so that any undesired contacts are prevented. There is the danger of accidents!

- Positioning of lathe tool

Outside the range of rotation of workpiece the tool has to be moved in the position where the chip removal is to be performed. In doing so, that desired cutting depth has to be adjusted, i.e.

- at the crank handle of the cross-slide the cutting depth for cylindrical turning to be adjusted,
- at the crank handle to the saddle the cutting depth for facing has to be adjusted.

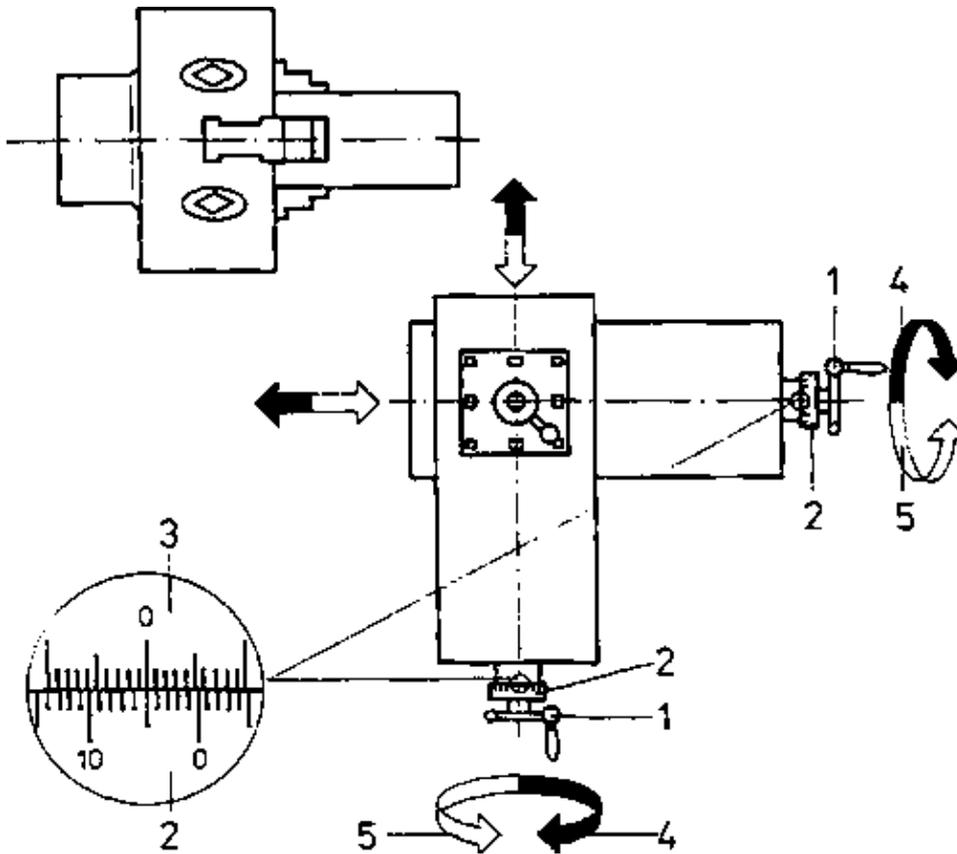


Figure 4/54 Scale rings at crank handles of saddle and cross slide

1 Crank handle, 2 Swivelling scale rings, 3 Fixed ring, 4 Rotational direction upon in-feed, 5 Direction of rotation during disconnection.

Scale rings with graduations of 0.1 mm or 0.05 mm make it possible to read the degree of setting of the tool (Figure 4/54).

- Advancing of tool, beginning of metal cutting

In the case of hand feed the tool is advanced by a uniform turning of the crank handle. The left hand turns the crank for the cross-slide for facing, whereas the right hand, upon cylindrical turning, actuates the crank for the saddle (Figure 4/55). The crank handle for the advancing of the tailstock sleeve is actuated only with the right hand, or even by both hands alternately.

The automatic feed motion is switched on and off at the switch lever of the carriage.

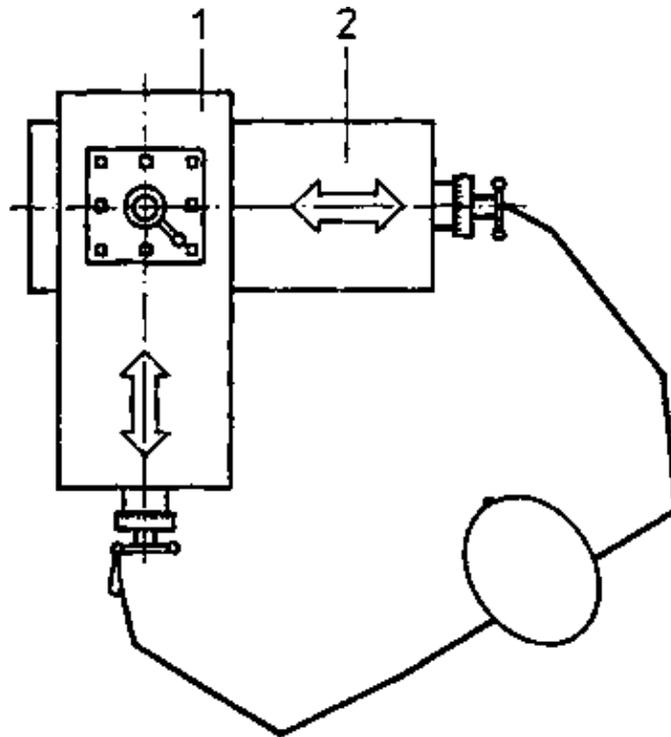


Figure 4/55 Handling the crank handle of saddle and cross slide

1 Cross slide, left hand, 2 Saddle, right hand

- Ending the feed motion, tool to be taken away, disconnecting the machine

After chip removal the feed motion is ended. The tool is moved out, and only then the cutting motion is switched off.

Switching–on and off the cutting motion during metal cutting can result in a breakage of tool. Defects may arise on the tool surface.

If additional operations shall follow, the tool has to be again positioned.

Control questions

1. Explain what you understand by the term 'cutting speed' during turning operations?
2. Explain what you understand by the term 'feed' in turning?
3. What handlings are required for the setting of a sliding and screwcutting lathe?
4. What are the effects of an unbalance of workpiece on the quality of machining?
5. What has to be observed in clamping a lathe tool?
6. What kinds of damage may arise if a gear is not properly switched?
7. Describe the setting of a sliding and screwcutting lathe for those operations you have performed.

4.3. Vertical lathe

In this section you shall get acquainted with

- the machine components of which vertical lathes are composed
- the way of functioning of vertical lathes
- the kinds of operations for which vertical lathes are used

4.3.1. Structure and mode of operations

Components of a vertical lathe (Two-column-type machine)

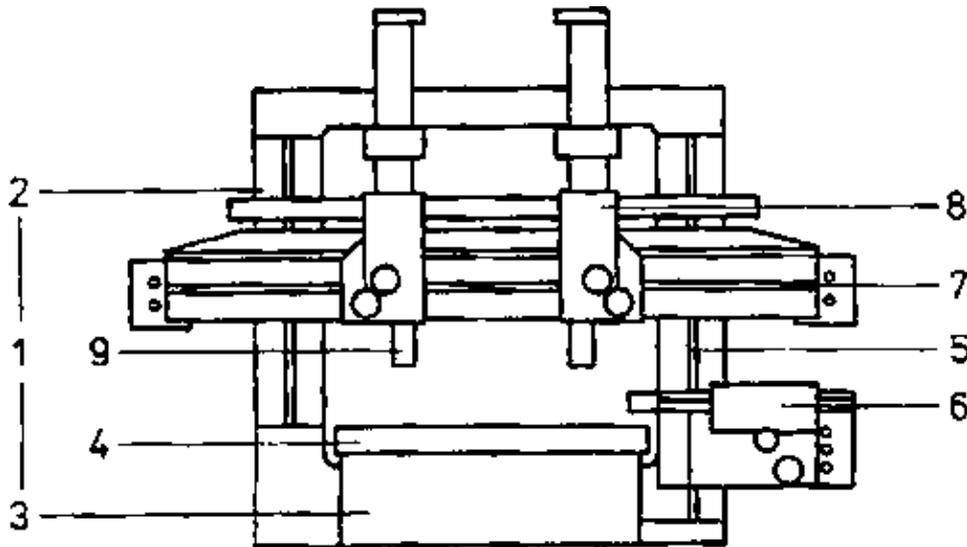


Figure 4/56 Components of a vertical lathe

- 1 Machine frame,
- 2 Pillar,
- 3 Machine bed,
- 4 Rotary table,
- 5 Guideways,
- 6 Saddle,
- 7 Guideways,
- 8 Cross slide,
- 9 Tool holders.

The machine frame (1) with the columns (2) and the machine bed (3) provides the main structure of the lathe. The rotary table (4) is supported on the machine bed. In most cases this is a fixed or sliding table. At the columns there are the guideways (5) for the longitudinal support (6) which moves lengthwise to the rotary axis of workpiece. The guideways (7) for the cross-slide (8) are lateral to the machine bed. The cross-slide moves crosswise to the rotary axis of workpiece.

At the carriages there are the tool holders (9) for the lathe tools. In dependence upon the application of the vertical lathe it is possible to have single-type lathe tool holders, or multiple-type lathe tool holders. Vertical lathes are equipped with several drive motors. There is one motor for the drive of the cutting motion. Frequently it is housed in the machine bed. The other motors serve for lifting and lowering or for the transverse movement of carriages. The motors are mounted into the carriages, or attached to the guide-ways.

Screw drives consisting of threaded spindles and nuts serve as units of motion for the carriages. Hand wheels as operating elements serve to adjust the carriages by hand.

Mode of operation of a vertical lathe

The workpiece is clamped on the horizontal table. Thus the weight of workpiece acts on the table in a vertical way. The true running of the workpiece is corrected by the horizontal shifting on the table. This is more easily possible than on a vertical faceplate (Figure 4/34), because in the latter case a lifting gear would be necessary to hold a heavy workpiece.

The lathe tools are carried and put forward to the workpiece by the carriages. If possible, several lathe tools can be simultaneously put forward from various carriages. Vertical lathes for mass production are equipped with devices and appliances enabling an instant change of tools, e.g. multiple lathe tool holders, or turret lathes.

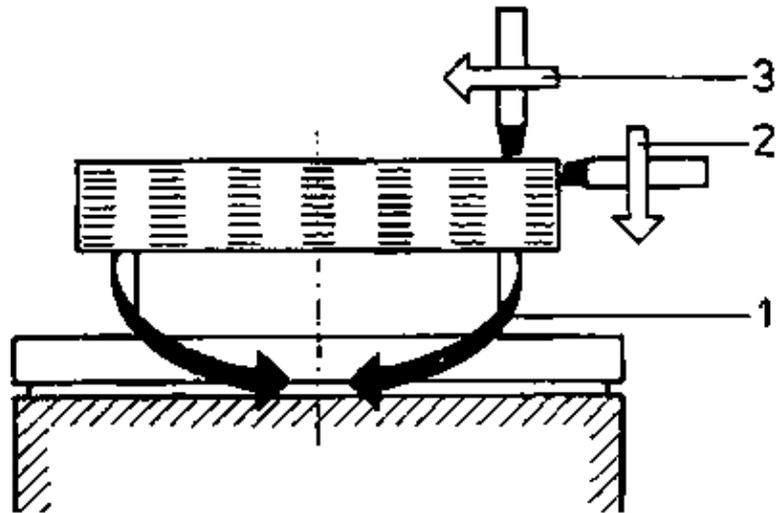


Figure 4/57 Mode of operation of a vertical lathe

1 Cutting motion, 2 Longitudinal feed motion, 3 Face feed motion

Vertical lathes are built for special purposes with diameters of table of 20 m and more.

4.3.2. Use of vertical lathes

Vertical lathes serve for the machining of heavy workpieces. Such workpieces could not be clamped on a vertical faceplate on account of their size, or due to their weight. They would dangle from the holding units and there would be the great danger that they got unclamped. Unsymmetrical workpieces would have to be balanced by using large weight balancers.

Examples of production are the following (Figure 4/58): machine frames, turbine casings, wheel rims of railway wheels, covers of boilers and tanks, sealing surfaces of large valves.

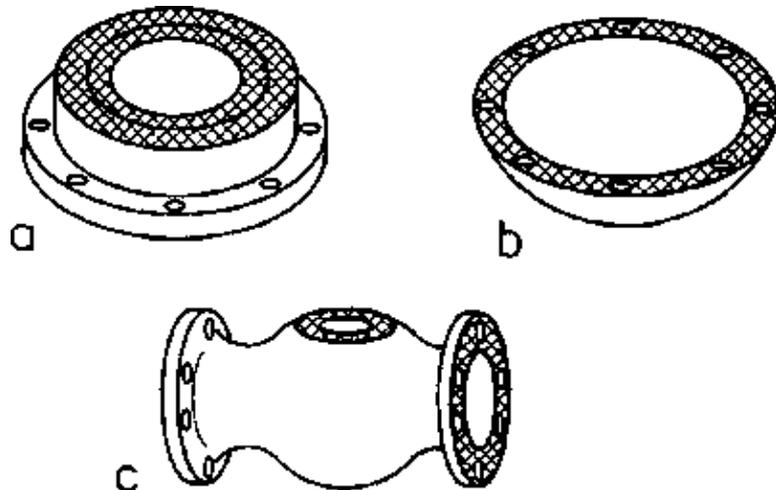


Figure 4/58 Examples of work done on vertical lathes

a Guideway of a machine frame, b Covers of boilers c Sealing surfaces of valve casing

Control questions

1. Describe the structure of a vertical lathe.
2. Describe the mode of operation of a vertical lathe.
3. Name several examples of operations to be performed on vertical lathes.

4.4. Turret lathe

In this section you shall get acquainted with

- the kinds of components of which turret lathes are composed
- the way of functioning of turret lathes
- the kinds of operations for which turret lathes are used.

4.4.1. Structure and mode of operation

Machine components of a turret lathe

Turret lathes are, as to their general structure, similar to sliding and screwcutting lathes. They are provided with a machine frame (1) with the lathe bed (2) and the guideways (3) which form the main structure. The machine frame includes the gears (4) for the transformation of motion (figure 4/59). The driving motors are designed either as flange, mounted motors, or as foot-mounted motors, as in sliding and screwcutting lathes.

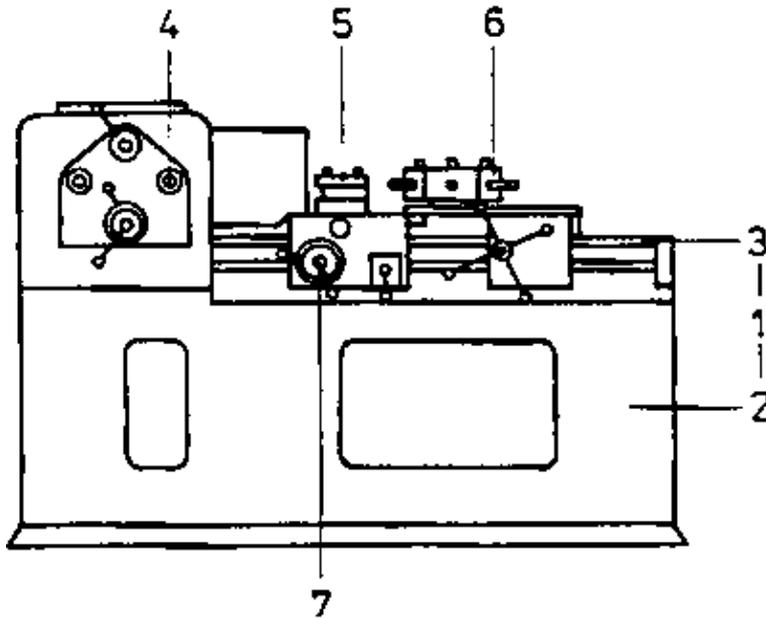
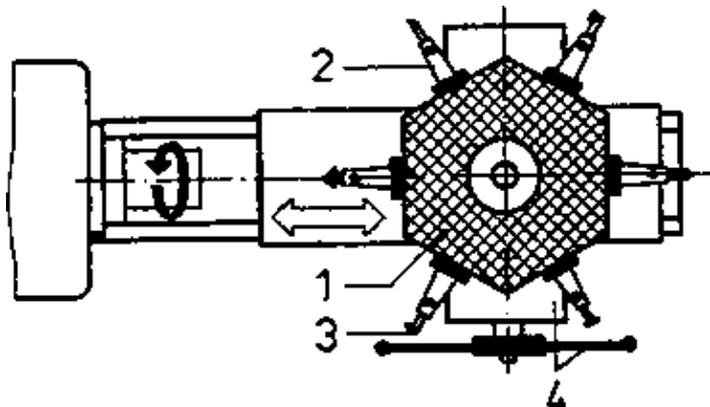


Figure 4/59 Components of a turret lathe

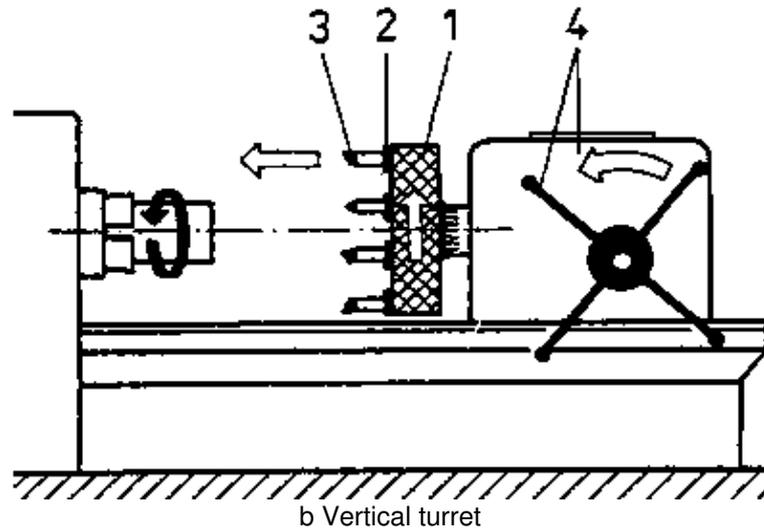
1 Machine frame, 2 Lathe bed, 3 Guideways, 4 Gears, 5 Carriage, 6 Turret head, 7 Operating elements at carriage

The carriages (5) as well as the appliances for an instant change of tools, the turret heads (6), have been especially designed. These latter machine components have given the turret lathe its name (Figure 4/60).

Figure 4/60 Turret head for an instant change of tools



a Horizontal turret



- 1 Swivelling part,
- 2 Tool holders,
- 3 Tools,
- 4 Carriage and controlling element

The operating units of turret lathes are designed in a way that it is possible for the carriages to advance and retract quickly the tools to and from the workpiece. Frequently, for the sake of an instant clamping of workpieces the turret lathe is provided with clamping devices that can be opened and closed during the running of the machine,

Mode of operation of a turret lathe

A bar of the material to be machined is advanced through the hollow lathe spindle. The bar strikes against a stop so that the required length only projects out of the clamping device. The bar is firmly clamped in the clamping device. The long end of the bar has to be separately supported and held, so that it cannot get loose. Danger of accident! (Figure 4/61)

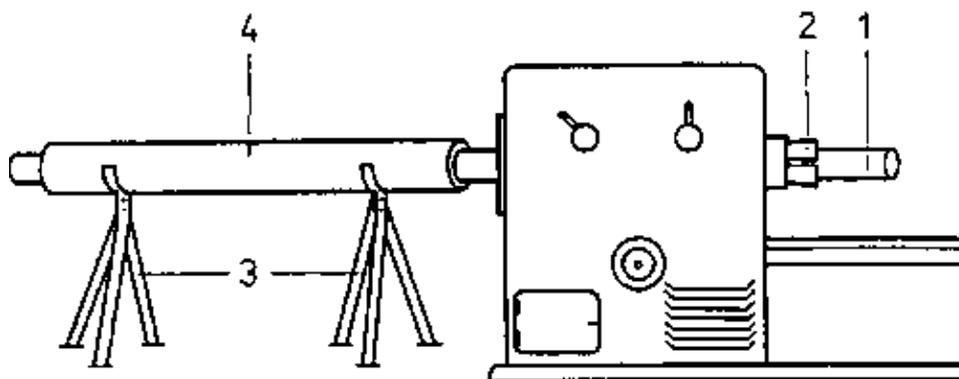


Figure 4/61 Workpiece in turret lathe

- 1 Workpiece, 2 Clamping device, 3 Support, 4 Safety for protection.

The tools required are mounted on the turret head. By turning the operating unit the carriage with the turret head and tools is moved towards the workpiece. One or several tools begin to operate. The tools are clamped in such a way that they cut off exactly the correct quantity of metal chips. This means that the workpiece need not be checked after each operation. The lathe bed is provided with stops. They are intended to limit the feed of the carriages (Figure 4/62). As soon as the carriage was advanced to the stop, the removal of chips is finished. The carriage is moved backwards by turning the operating unit in the opposite direction.

Upon return travel of the carriage the turret lathe is simultaneously rotated. A new tool is being positioned (Figure 4/63). The carriage can again be moved forward up to the stop and the next tool will carry out the next turning operation. Upon return travel the tool is again interchanged.

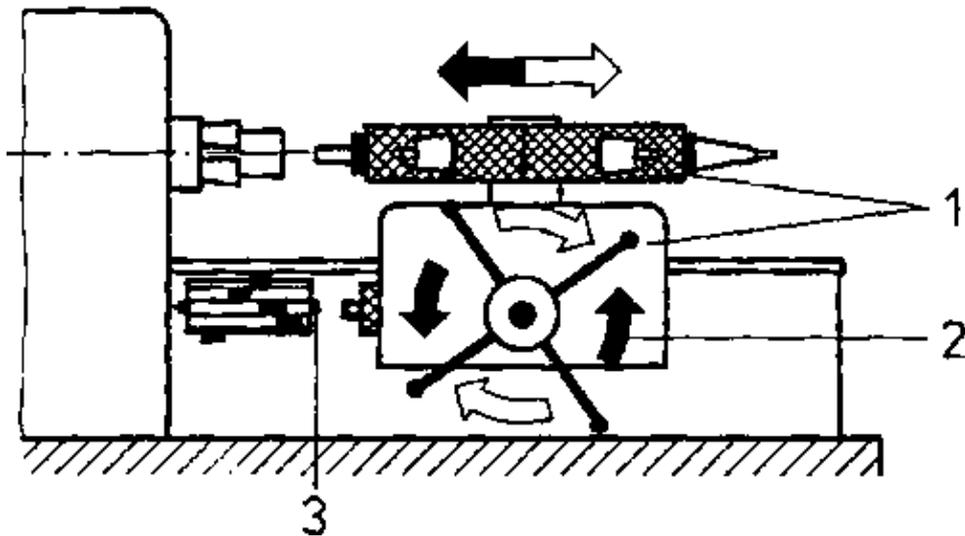


Figure 4/62 Feed of tools for cutting chips

1 Carriage with turret head and tools, 2 Direction of rotation at operating element, 3 Stop for limiting the feed

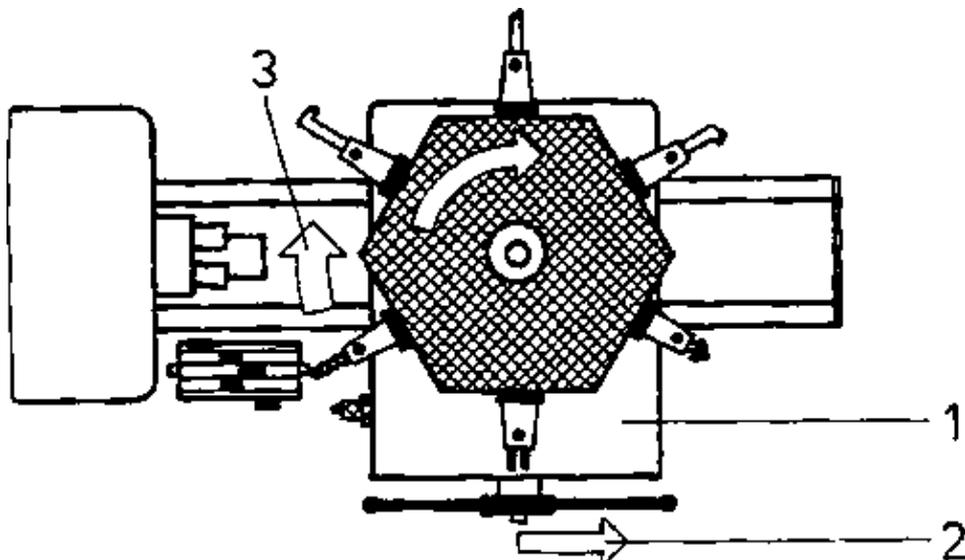


Figure 4/63 Tool change by turning the turret head during back travel of carriage

1 Carriage, 2 Direction of rotation of controlling elements, 3 Tool change

If the turret head is provided with six aides (Figure 4/60), it is possible to have six consecutive working operations. Every side of the turret head can accommodate several tools.

A workpiece can claim altogether so many operations as tools can be accommodated in the turret head.

As the last operation the workpiece is separated from the bar. The clamping device for the workpiece is opened, the bar is readjusted and is again firmly clamped. Now the operation can be started anew. The clamping of tools into the tool holders of the turret head and the setting of stops limiting the feed of carriage is called the setting-up of a turret lathe.

It depends upon the correct setting-up, whether the workpieces are faultless and whether the turret lathe operates economically.

Checks are carried out within certain distances. If there are defects in the workpieces tested, the setting of the turret lathe has to be corrected.

4.4.2. Use of turret lathes

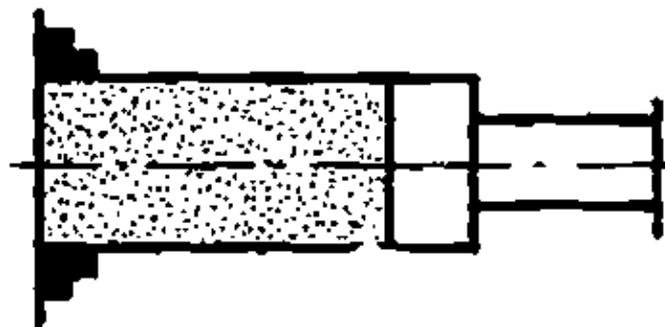
Turret lathes are used for mass production. In most cases the workpieces are small-size units. It is also possible to turn complicated shapes. There are many different designs of turret lathes. Every type of machine is especially suitable for a definite type of workpiece. Since small-size units require to be manufactured economically it is important to select the suitable machines. Prior to the setting of turret lathes it is essential to work out the technology for the workpiece (Table 4/5).

Control questions

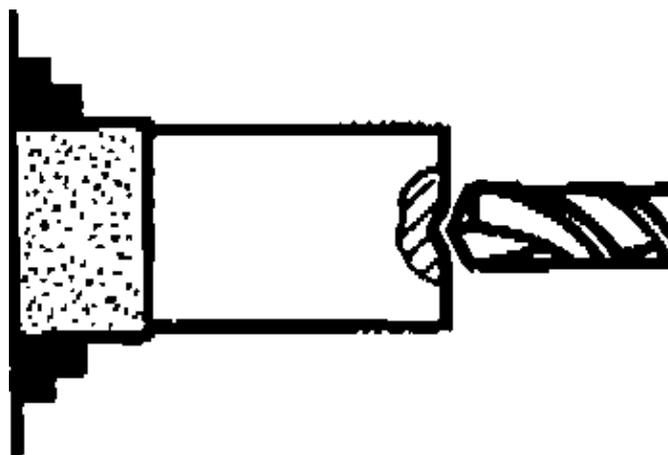
1. Describe the structure of a turret lathe.
2. Describe the mode of operation of a turret lathe.
3. How to effect the change of tools between operations on a turret lathe?
4. What is the reason for the higher productivity of a turret lathe compared with a slide and screwcutting lathe?
5. What devices and appliances are required to control the course of operations of a turret lathe?
6. Name several examples of operations that have been performed on turret lathes.

Table 4/5 Example of a turret lathe

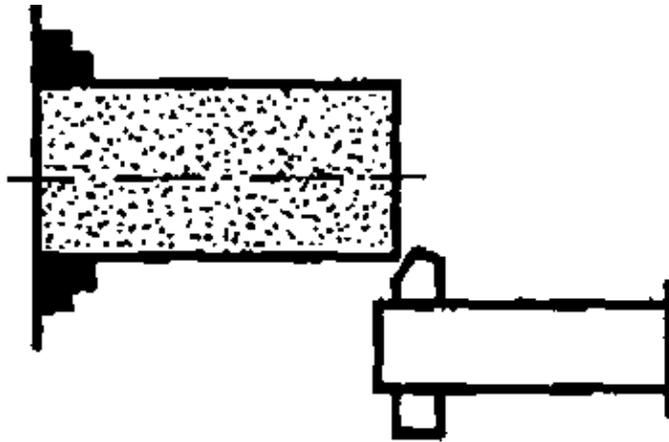
Bushing



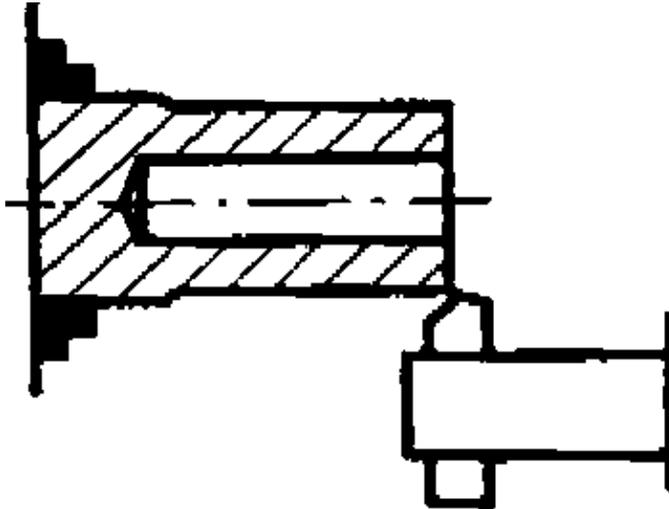
Material to be advanced until stop



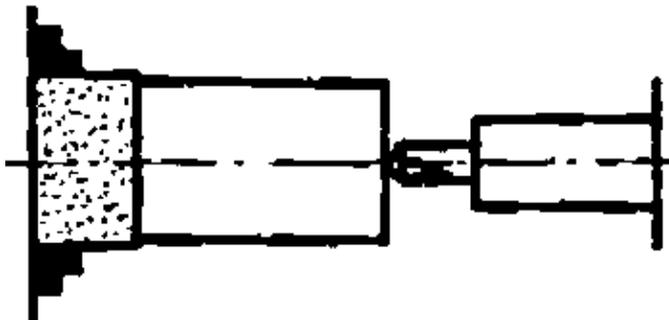
drilling



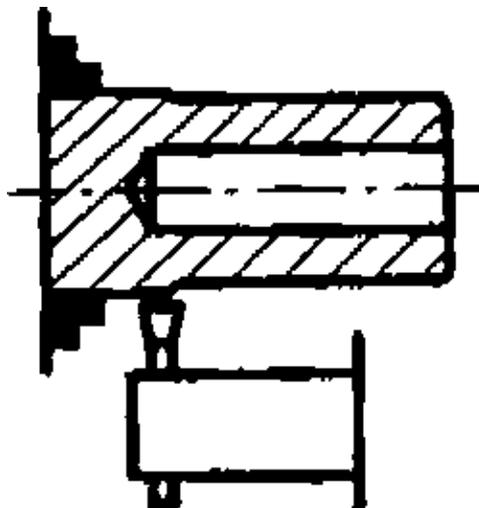
plain turning



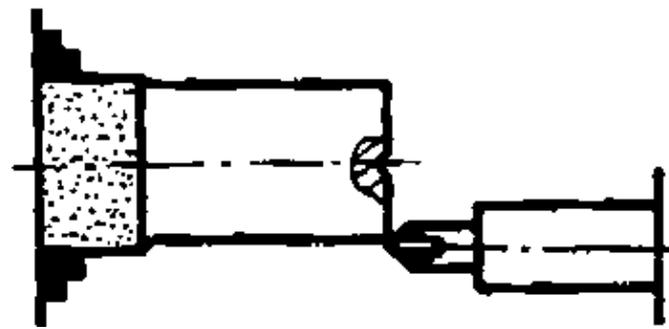
chamfering



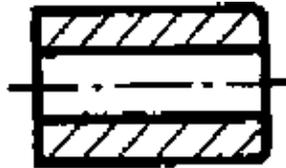
centering



(...)rting off



planing



ready-made work

4.5. Automatic lathe

In this section you'll shall get acquainted with

- the machine components of which automatic lathes are composed
- the way of functioning of automatic lathes
- the kinds of operations for which automatic lathes are used

4.5.1. Structure and mode of operation

Machine components of automatic lathes

Automatic lathes are specialized turning machines. There are many different kinds of automatic lathes. Every type has been designed for definite operations and is particularly suitable for them. Therefore automatic lathes of different type show greater differences in their design than the other turning lathes.

Usual types of automatics are the following:

- Automatic screw machines
- Automatic cutting-off machines
- Automatic turret machines
- Automatic screw and shaping machines
- Automatic chucking machines
- Automatic multi-spindle machines

The machine frame provides also the main structure for an automatic turning machine. The machine frame accommodates also the gears for the transformation of motions from the drive to the cutting motion as well as the feed and in-feed movements. The driving motors are dependent upon the type of automatic turning machine – built into the machine frame, or are laterally mounted (Figure 4/64).

For the sake of an instant clamping and unclamping of workpieces automatic turning machines are equipped with clamping devices that are operated electrically, pneumatically or mechanically.

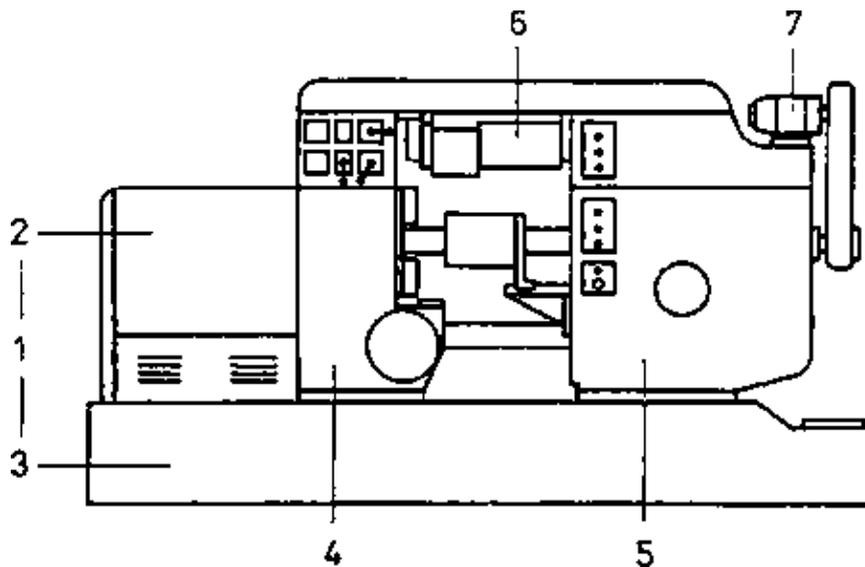


Figure 4/64 Automatic lathe

- 1 Machine frame,
- 2 Pillar,
- 3 Lathe bed,
- 4 Headstock,
- 5 Saddle,
- 6 Cross slide,
- 7 Motor for tool change.

The most important machine components of an automatic turning machine are those required for the control of motions. Cam gears (Figure 4/65) are used as such components for the control. These cam gears are made up of cam units (1,2,3) and the ram (4), or tracer (5). The cam units may be designed as curve drums (1), a curve plate (2) or like an irregular French curve (3). The curve drums and curve plates rotate (6). As a result they move the ram in line with the course of curve (7). This ram transmits its motion onto the tool, so that its motion proceeds proportionally to the curve form.

Irregular curves are mostly rigid. The ram with its carriage slides along it. Thus it follows the course of curve. This movement is transmitted to the tool. For frequently recurring motions, such as the feed motion upon cutting-off a finished part, or upon counter-sinking a bore, it is possible to re-use definite cam gears. However, for specific motions, e.g. the feed motion upon profiling, it is necessary manufacture cam gears separately.

Stops or limit switches are used to limit the sequence of motions. They can be shifted in special holders and be clamped at the spot desired (Figure 4/66). If a motion reaches the stop, then it is terminated, but if a motion reaches the limit switch, the driving motor is disconnected or switched over.

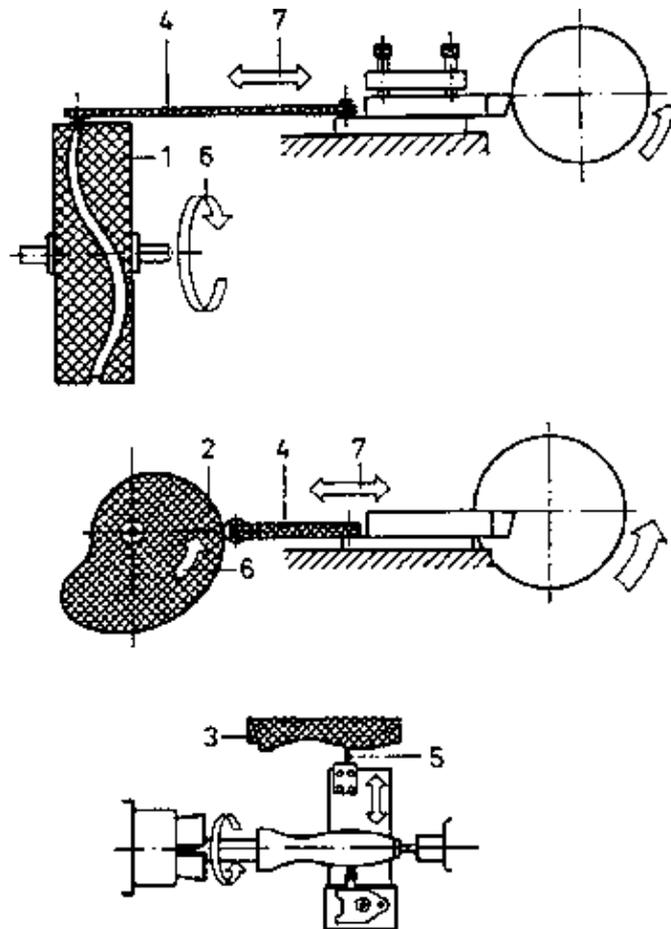


Figure 4/65 Cam paths for automatic lathes

1 Cam drum, 2 Cam plate, 3 Irregular French curve, 4 Ram, 5 Tracer, 6 Direction of motion of curve bodies, 7 Directions of motion of scanning organs

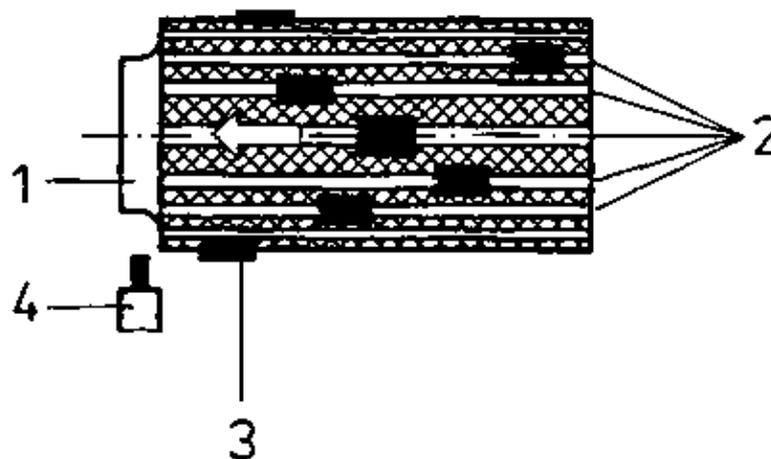


Figure 4/66 Holding fixtures for stops and limit switches

1 Holding device, 2 Grooves to shift stops, 3 Stop, 4 Limit switch.

Cam gears, stops, cams and limit switches are machine components required for the control of automatic turning machines. They are important to attain the quality of workpieces and thus have to be kept clean and to be treated with great care.

Mode of operation of an automatic turning machine

An automatic turning machine performs all stages of operation required for machining a workpiece. The automatic need not be attended to during operation. The job of the skilled worker is to set the automatic machine.

The sequence of operations in manufacturing a component on an automatic turning machine includes the following stages:

- Automatic feed-in of material or workpiece, clamping devices to be opened, material to be feed or blanks to be prepared, clamping devices to be closed
- Advancing and positioning of tools quick advance, slow positioning
- Feed of tools, amount of feed in line with the turning characteristics (Section 4.2.4.);
- Change of tools quick return travel after cutting, change, again forward travel and slow positioning;
- Discharge of ready-made workpieces workpiece to be taken away after parting-off and to be deposited outside the machine.

For the purpose of setting an automatic turning machine it is required to set the clamping devices for workpieces the clamping devices for tools, the components for control, the devices for feeding the material, or blanks and the appliances for the discharge of the finished workpieces.

The sequence of operations is determined by a sequence control. The last operation of a sequence releases the beginning of the first operation of the next stage.

Automatic turning machines operate very quickly. Therefore they have to be carefully set. Any error or defect during setting may result shortly in a great number of defective workpieces.

If a defect arises in a workpiece, the automatic machine has to be checked. The defective stage of operation has to be set anew.

4.5.2. Use of automatic lathes

Automatic lathes are used for mass production (Figure 4/67). The workpieces are equal to those of the turret lathe (Section 4.4.2.). At a turret lathe the skilled operator has to repeat all controlling operations with each workpiece. Therefore the job is monotonous and invariable.

Automatic lathes relieve man from the constant repetition of equal operations. They operate automatically.

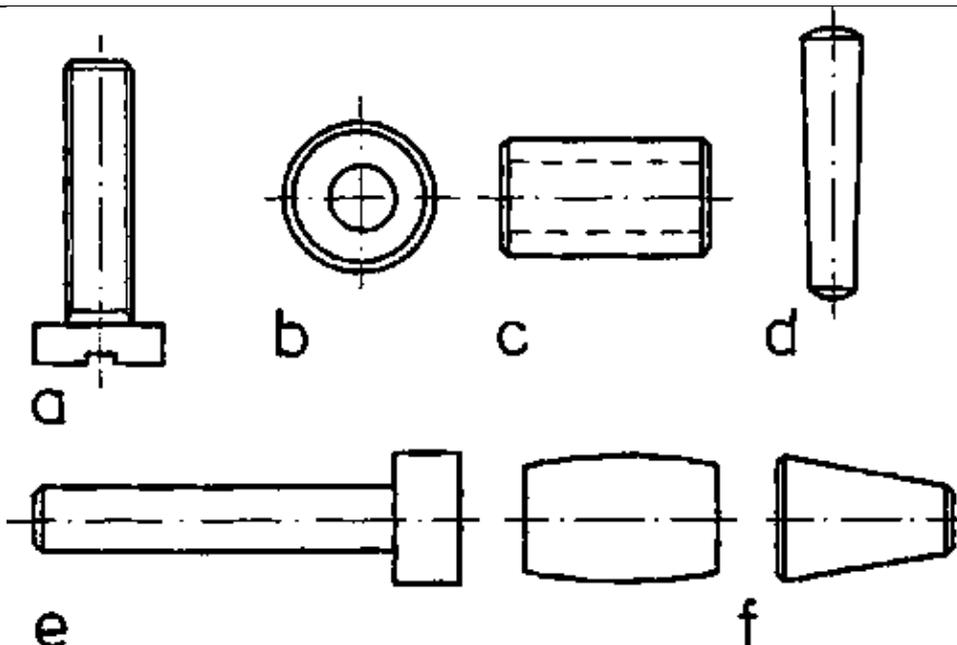


Figure 4/67 Examples of work done on automatic lathes

a Bolts and screws, b Plates, c Bushings and sleeves, d Pins, e Bolts, f Rolling members for antifriction bearings.

Control questions

1. Describe the structure of automatic turning machines
2. Describe the mode of action of an automatic turning machine
3. What is the reason for the higher productivity of an automatic turning machine compared to a turret lathe?
4. What appliances serve for the control of the sequences of operations of an automatic turning machine?
5. Name several examples of operations to be performed on an automatic turning machine,

4.6. Servicing and maintenance of sliding and screwcutting lathes and the tools

Please, observe the “General Instructions on Servicing and Maintenance of Metal Cutting Machine Tools” (Section 2.4. in this textbook).

Prior to the beginning of cleaning, lubricating and controlling operations it is required to disconnect the machine!

Cleaning

– Metal chips and coolant to be removed from the machine, e.g. from the carriage, the machine bed and in front of the machine!

Hand brush and cleaning rag to be utilized because of the danger of injuries.

– Bright components of machine, e.g. guideways on bed and on carriage together with controls, to be cleaned and slightly oiled.

– Filters of coolant pump and coolant container to be cleaned.

Lubricating

– Oil level in gear to be controlled, oil to be refilled, if required;

– Lubricating points to be supplied with oil and grease according to lubricating schedule;

– Spindles at carriage and guideways at carriage and bed to be cleaned, slightly oiled and oil to be uniformly distributed;

– Tailstock sleeve to be screwed out and oiled;

– Jaws of chuck to be widely screwed out and guide grooves to be slightly oiled.

– After lubrication it is required that oil drops and residual grease to be carefully removed from floor.

Controlling

– Clearance of lathe spindle to be controlled!

– Bearings to be readjusted, if clearance is too large.

– Clearance of threaded spindles at carriage to be checked.

Nuts at slides and saddles to be readjusted if clearance is too large.

– Clearance of slides to be controlled!

Guides at slides to be readjusted and clearance to be balanced off.

- Switchability of gear to be tested and adjusted, if required,
- Electric connections to be controlled, supply lines to be secured.

Treatment of tools

- Tools to be deposited in a way that cutting edges do not damage each other.
- After use metal chips and residual coolant to be wiped off!
- Blunt tools to be reground in time in order to maintain them dimensionally stable and to keep surfaces clean.

Upon metal cutting a great deal of heat is generated so that the tools anneal.

- Tools with carbide cutting edges or ceramic tips to be preserved carefully and protected against jolts; for carbide and ceramic tips are sensitive and break easily.
- During metal cutting it is essential to provide for sufficient cooling and lubrication because of the excessive heating of tools and the danger of annealing.

4.7. Work safety in operating sliding and screwcutting lathes

Please, observe the “General Instructions and Rules on Work Safety (Section 2.5) of this textbook. For the operation of sliding and screwcutting lathes there are the following rules for the protection against accidents during work:

- After disconnecting or decoupling it is not allowed to decelerate tool by hand, but the standstill of machine has first to be reached!
- During operations metal chips not to be removed by hand, but only with a suitable chip rake!
- Workpiece to be measured only during standstill, never during turning operations!
- Prior to change of tools machine to be disconnected, or workpiece to be decoupled!
- Chuck key to be immediately taken off after clamping and declamping of workpiece!
- During operations it is not allowed to reach over the rotating chuck and workpiece!
- The sleeves of working clothes and jacket have to cling close to the body, so that they are beyond the reach of workpiece!
- During metal cutting at high speeds it is required to cover the workpiece by a grating, so that flying metal chips can be caught!
- The hair of the head and beard is not allowed to dangle, suitable clothing has to be used!
- Prior to switching–on of machine it shall be provided that the protective casing has been applied!

5. Milling machines

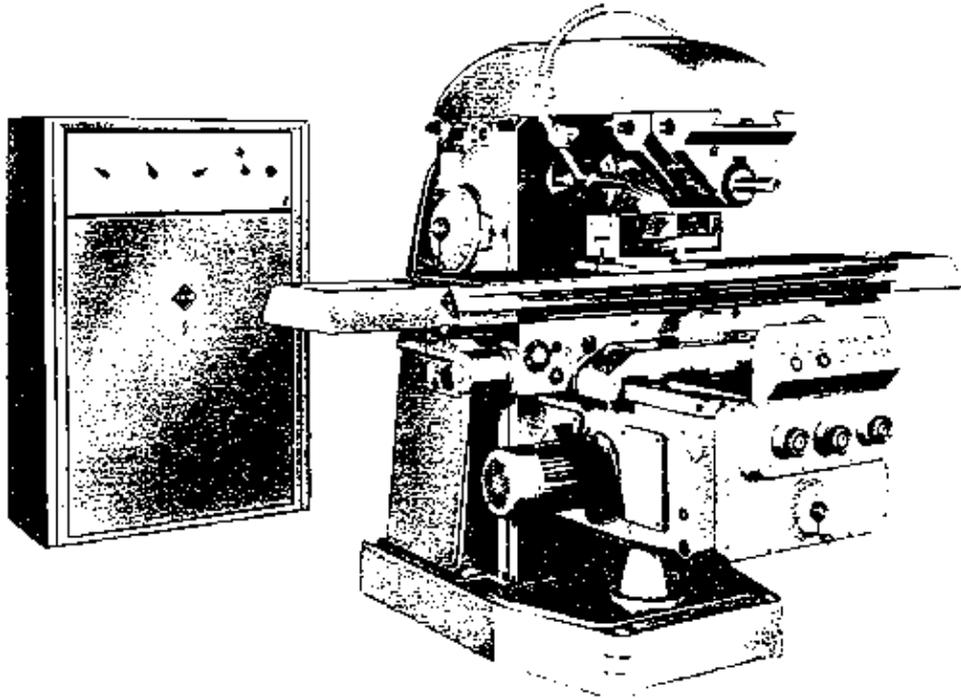


Figure 5/1 Horizontal knee-and-column type milling machine

5.1. Survey of types and use of milling machine

In this section you shall get acquainted with

- the types of machines to be used for milling operations
- the kinds of motions performed by milling machines
- the kinds of work to be performed on milling machines.

5.1.1. Several types of milling machines

Milling machines may be classified

- according to the directions into which the machine table can be moved;
- according to the position of the milling spindle;
- according to the purpose of use.

In addition there is a number of milling machines designed for special purposes.

The horizontal knee-and-column type milling machine is most frequently used because of its universal application. This machine will be described in this textbook in greater detail.

All milling machines have, in principle, to perform the same kinds of motions. But they have different designs and are thus optimally adapted to their application (Table 5/1).

5.1.2. Motions of milling machines

Cutting motion

The cutting motion in milling is a rotating motion. This motion is performed by the tool. In dependence upon the cutting speed for milling the tool rotates either at a high speed, or at a small speed (Figure 5/2 a and b).

Feed motion

Feed motion during milling is performed by the tool. It is

- a straight-lined motion if the machine table with tool moves only in a straight line in one direction (Figure 5/3 a);
- a curved motion when several directions of motion arise for the machine table simultaneously (Figure 5/3 b).

Milling machines
subdivided according to

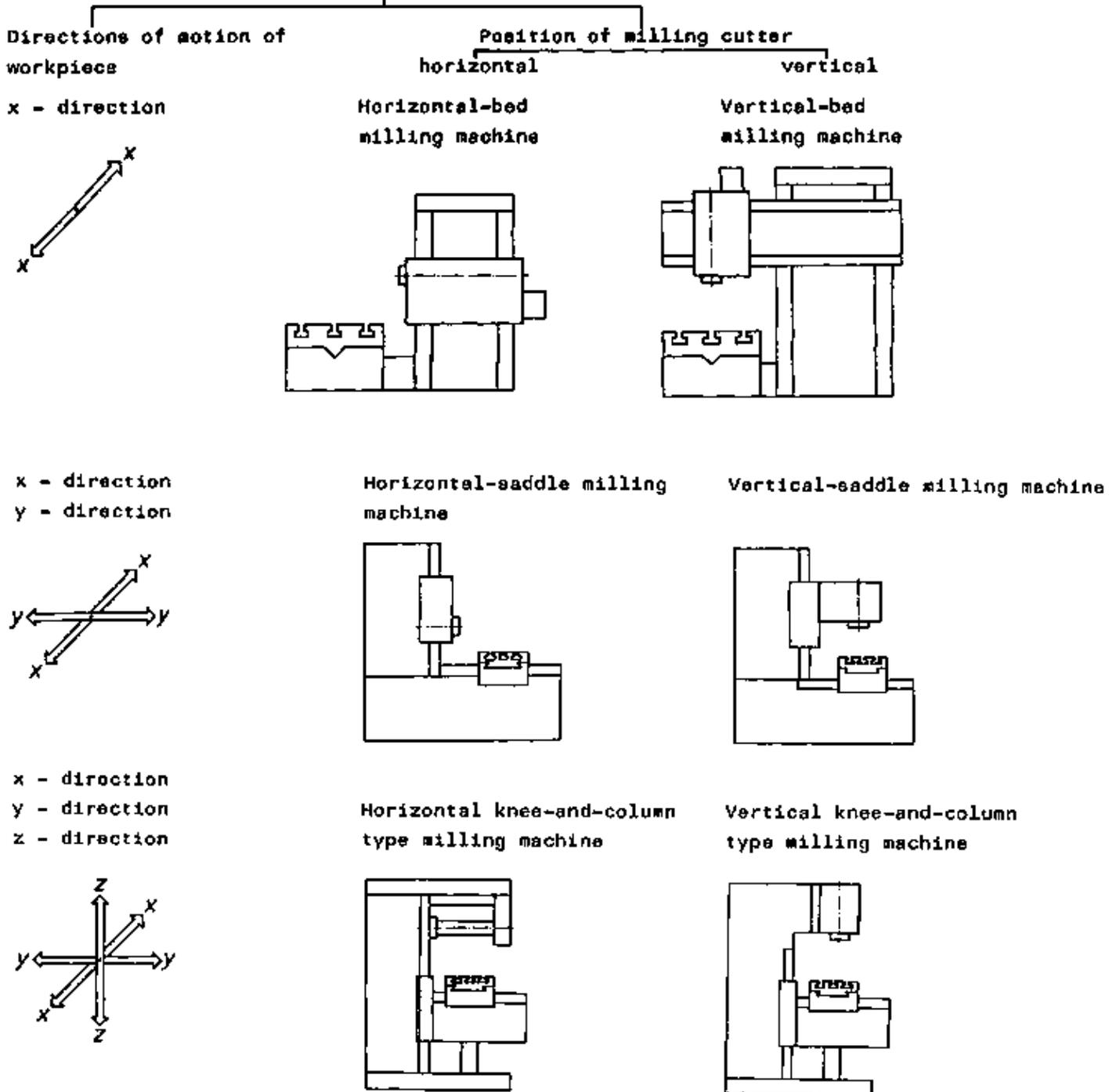
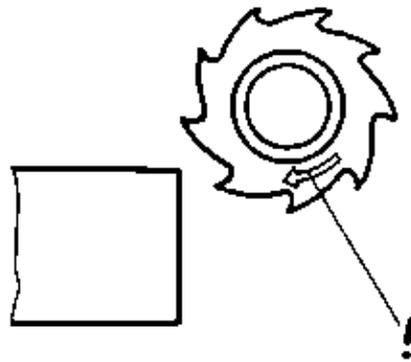
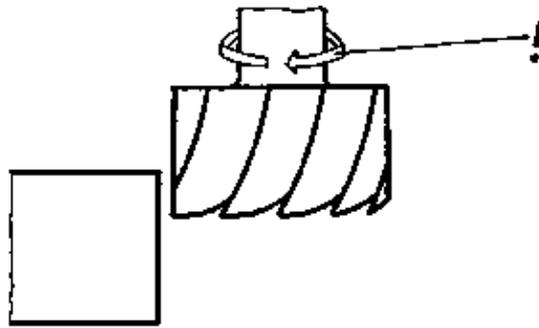


Table 5/1 Classification of milling machines

Figure 5/2 Cutting motion during milling

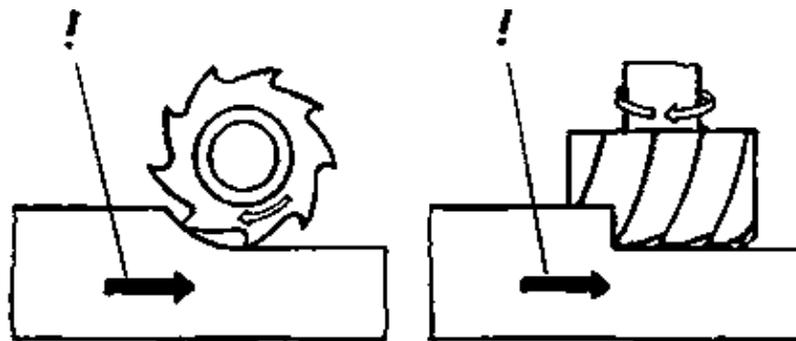


a At a horizontal knee-and-column type milling machine

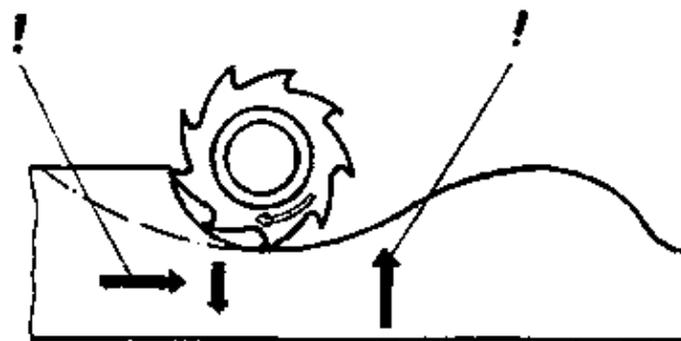


b At a vertical knee-and-column type milling machine

Figure 5/3 Feed motion during milling



a Straight-lined



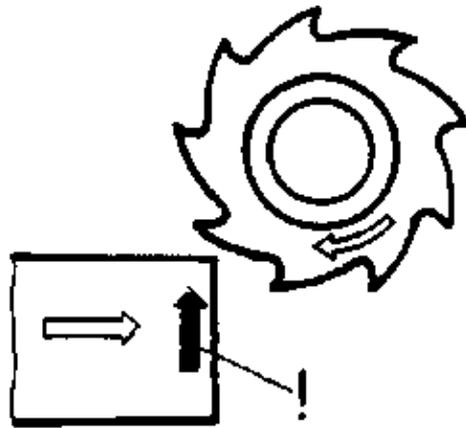
b Cam-like (curved)

In feed-motion

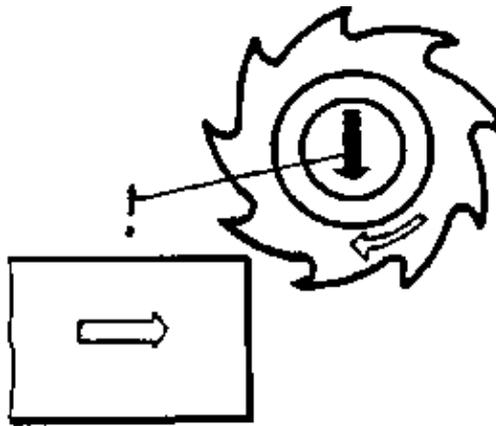
The in-feed motion in milling

- is carried out by the workpiece in knee-and-column milling machines (Figure 5/4 a);
- is carried out by the tool in bed-type and compound-table type milling machines (Figure 5/4 b);

Figure 5/4 In-feed motion during milling



a At a knee-and-column type milling machine



b At a bed-type and compound-table milling machine

5.1.3. Examples of operations on milling machines

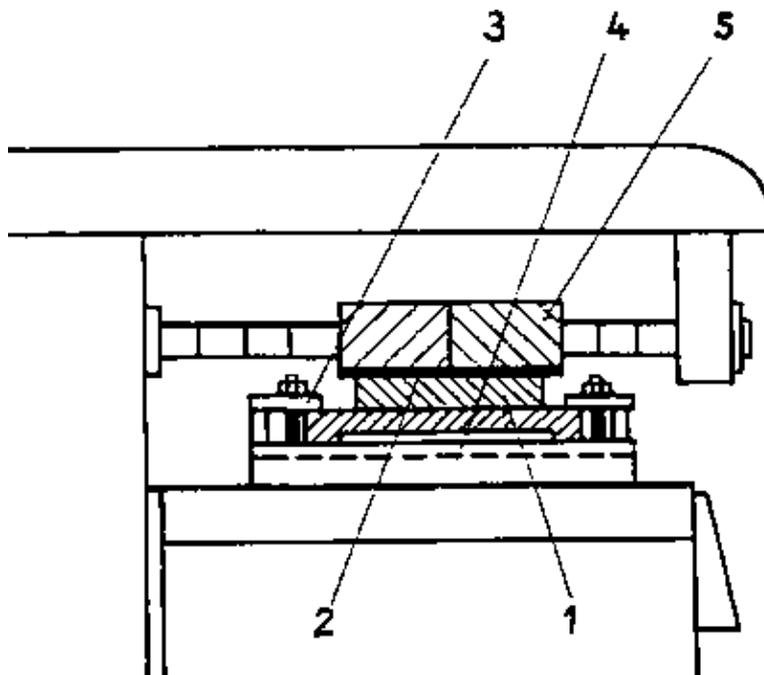


Figure 5/5 Cutting flat surface with a horizontal milling machine

1 Bed plate, 2 Sliding surface, 3 Clamping straps, 4 Machine table, 5 Hobbing cutter.

Cutting flat surfaces on a bed plate with one sliding surface

Figure 5/5 shows a bed plate (1) with a sliding surface (2). The bed plate has been clamped on the machine table (4) by means of clamping straps (3).

The sliding surface was milled by means of hobbing cutters (5).

Cutting flat surfaces on a bed plate with two sliding surfaces

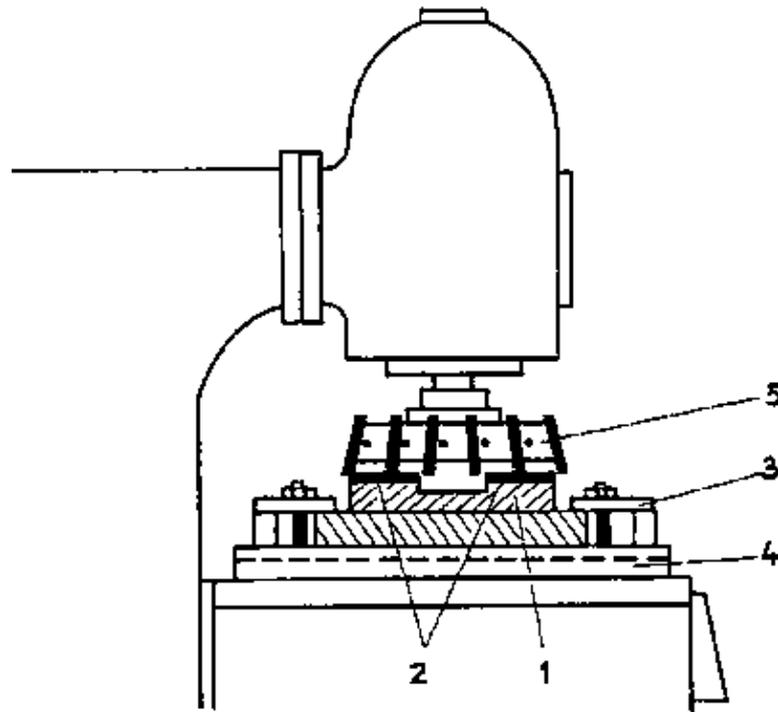


Figure 5/6 Cutting flat surface with a vertical milling machine

1 Bed plate, 2 Sliding surface. 3 Clamping straps, 4 Machine table, 5 Milling head.

Figure 5/6 shows a bedplate (1) with two sliding surfaces (2). The bed plate has been clamped on the machine table (4) with clamping straps (3). The sliding surfaces were milled simultaneously by means of a milling head (5).

Milling a keyslot

Figure 5/7 shows a shaft (1) with a continuous slot (2). The shaft has been clamped in a machine vice (3) by means of a prism (4). The keyslot was milled with a cylindrical cutter (5).

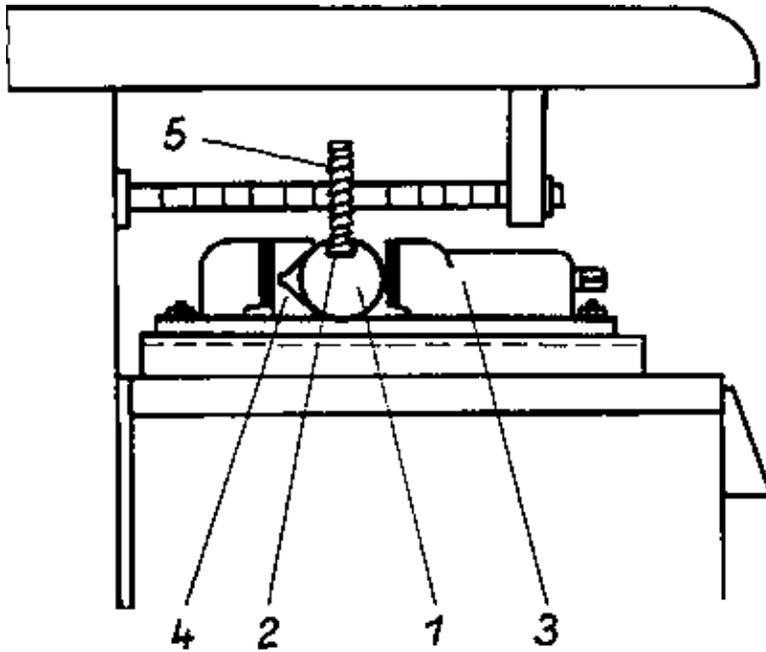


Figure 5/7 Keyslot milling with a horizontal milling machine

1 Shaft, 2 Slot, 3 Machine vice, 4 Prism, 5 Cylindrical cutter.

Milling an elongated slot

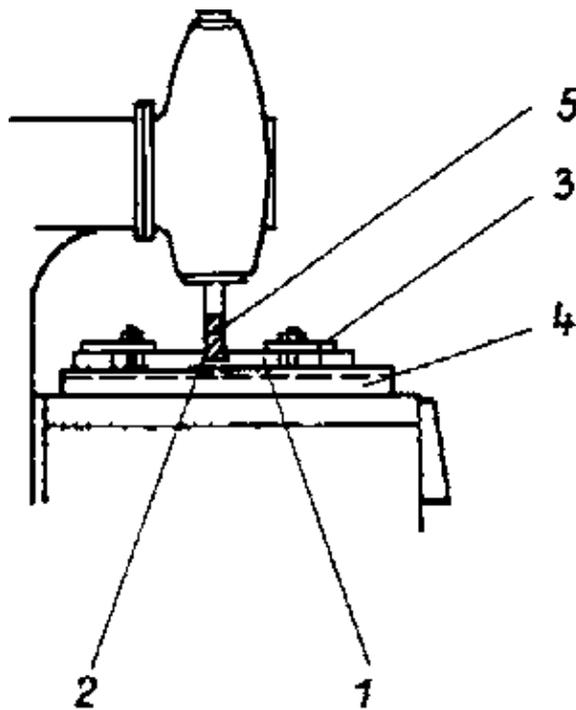


Figure 5/8 Elongated-slot milling on a vertical milling machine

1 Bed plate, 2 Elongated slot, 3 Clamping strap, 4 Machine table, 5 End mill cutter

Figure 5/8 shows a base plate (1) with an elongated slot (2). The base plate has been clamped with clamping straps (3) on the machine table (4). The elongated slot was milled with an end mill cutter (5).

Parting – off a sectional bar

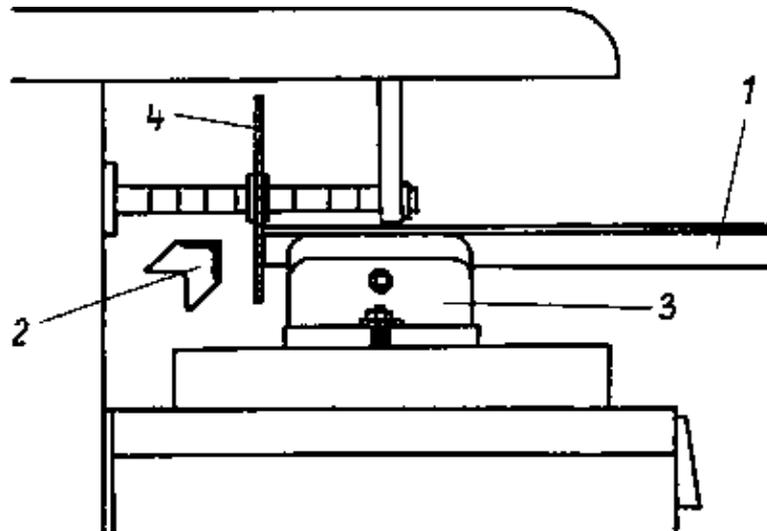


Figure 5/9 Parting-off milling on a horizontal milling machine

1 Angular sectional bar, 2 Parted piece, 3 Machine vice, 4 Circular saw

Figure 5/9 shows an angular sectional bar (1), part of which was cut off (2). The angular sectional bar is clamped in the machine vice (3). The pieces are cut off with a circular saw (4).

Milling angular guiding surfaces at a base plate Figure 5/10 shows a base plate (1) with guideways (2) and angular guiding surfaces (3). The base plate is clamped with setscrews (4) on the machine table (5). The guiding surfaces were milled with an angular mill (6).

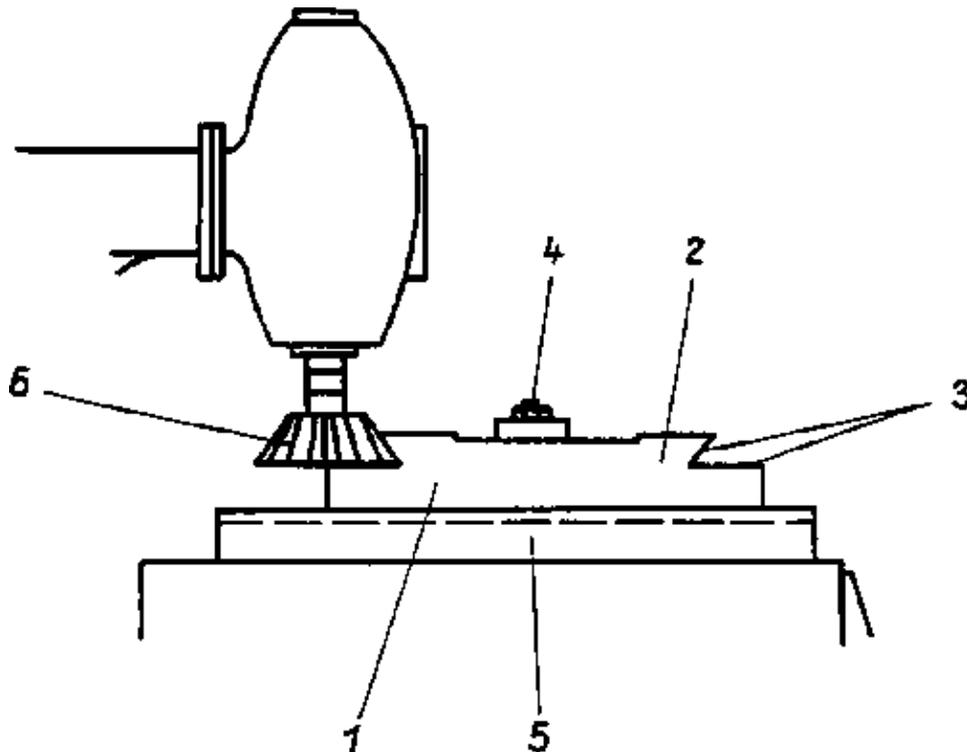


Figure 5/10 Angular milling on a vertical milling machine

1 Bed plate, 2 Slideway, 3 Angular guiding surface, 4 Drawbolt, 5 Machine table, 6 Angular milling tool.

Milling a profile

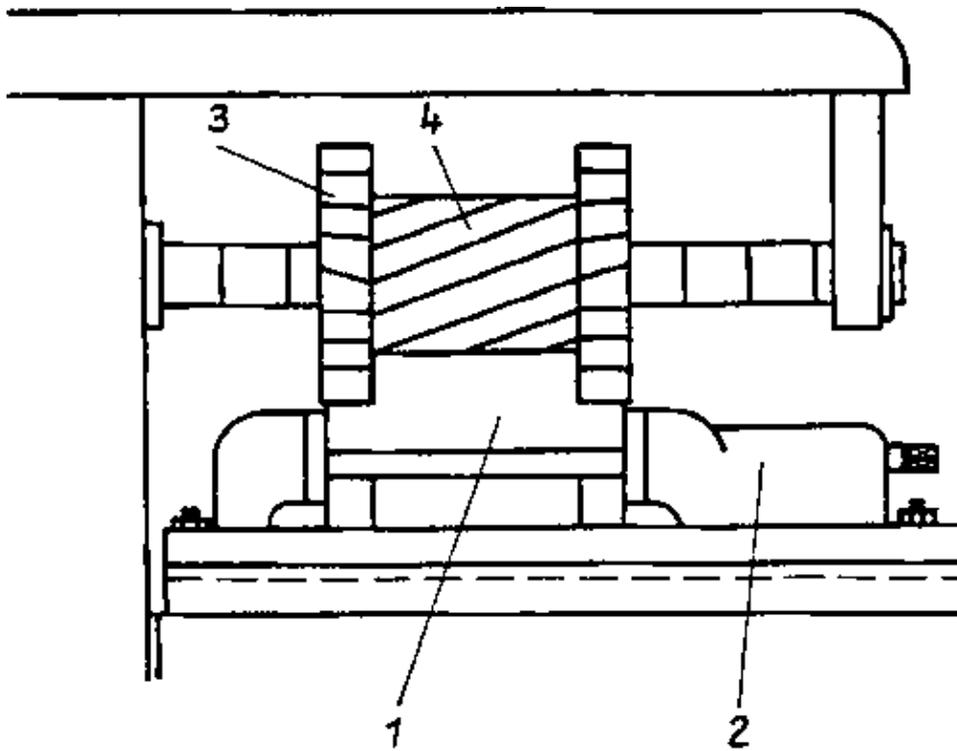


Figure 5/11 Profile milling on a horizontal milling machine

1 Slide bar with T-profile, 2 Machine vice, 3 Cylindrical cutter, 4 Hobbing cutter

Figure 5/11 shows a slide bar with a T-profile (1). The slide bar has been clamped in the machine vice (2). The T-profile was milled by means of a milling gang!

The milling gang consists of two cylindrical cutters (3) and one hobbing cutter (4).

Milling the tothing of a toothed gear

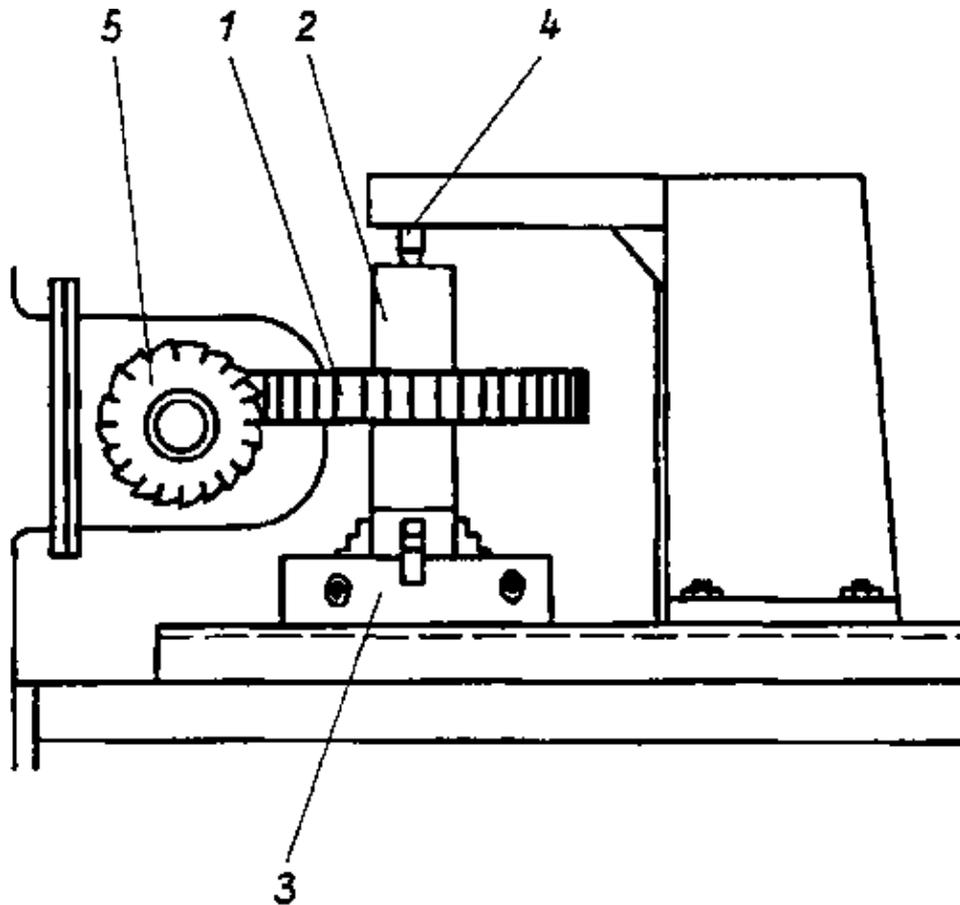


Figure 5/12 Profile milling on a gear hobbing machine

1 Toothed wheel with spur gearing, 2 Conical arbor, 3 Three-jaw chuck, 4 Centre, 5 Gear hobber

Figure 5/12 shows a toothed wheel with spur-gear tothing (1). The toothed wheel is clamped on a conical mandrel (2) between three-jaw chuck (3) and centre (4). The tothing was milled with a gear hobbing cutter (5).

Milling a threaded spindle

Figure 5/13 shows a spindle with a trapezoidal thread (1). The spindle is clamped in a three-jaw chuck (2). It is supported by a centre (3) and the steady rest (4). The thread was cut with a thread-milling cutter (5). The surface machined has been marked by a circle in the magnification.

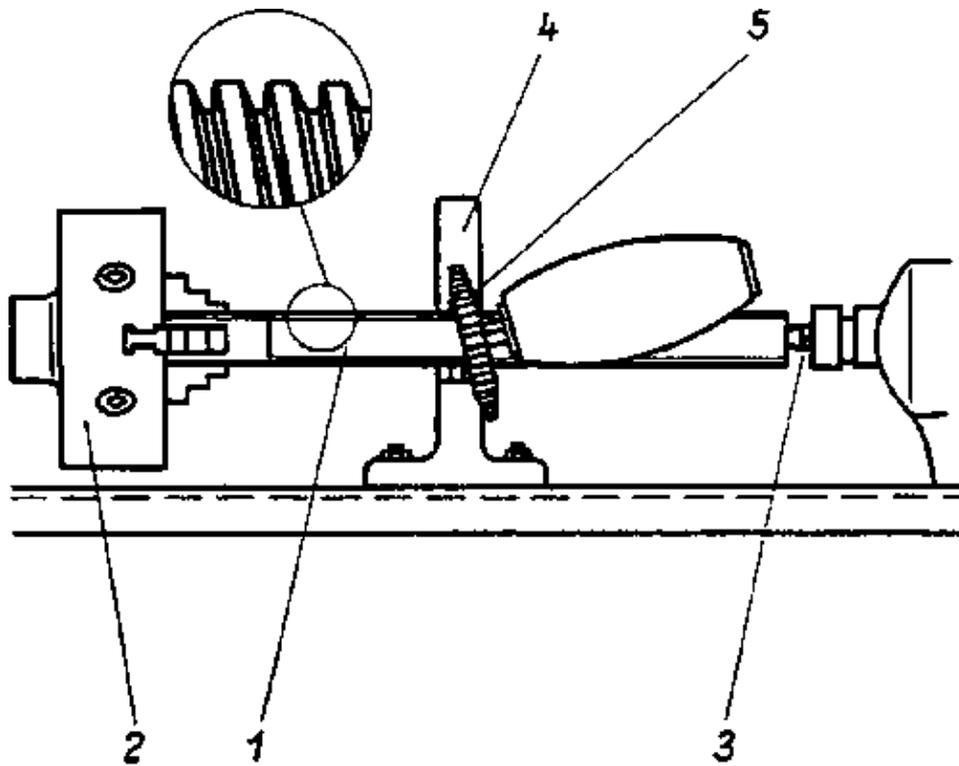


Figure 5/13 Profile milling on a thread milling machine

1 Spindle with trapezoidal thread, 2 Three-jaw chuck, 3 Centre, 4 Steady rest, 5 Thread-milling cutter.

Control questions

1. Name several machines that are used for milling operations.
2. Name workpieces that are preferably milled on these machines.
3. What kinds of motions are obtained during milling?
4. Name milled products that have been manufactured in your enterprise.

5.2. Horizontal knee- and-column type milling machine

5.2.1. Structure and mode of operation

In this section you shall get acquainted with

- the machine components of which horizontal knee-and-column type milling machines are composed.
- the drives to be used for driving horizontal knee-and-column type milling machines
- the kinds of mechanisms of transfer used to transmit the motions of motor into production operations
- the way of interaction between the components of motor with the mechanisms of production

Components of a horizontal knee-and-column type milling machine

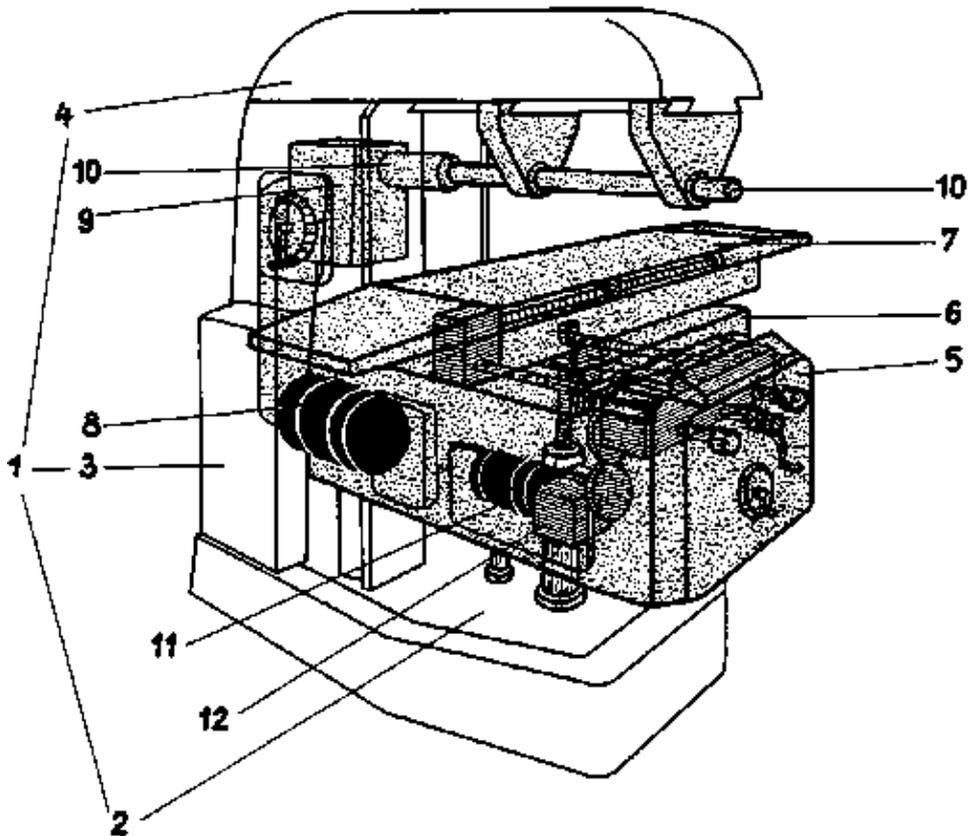


Figure 5/14 Components of a horizontal knee-and-column type milling machine

1 Machine frame, 2 Bed plate, 3 Pillar, 4 Overarm, 5 Knee, 6 Saddle, 7 Machine table, 8 Motor, 9 Gear, 10 Milling cutter, 11 Motor for feed motion, 12 Gear for feed motion.

The machine frame (1) with the base plate (2), the column (3) and the overarm (4) provides the basic structure of the machine. The knee (5) with the saddle (6) and the machine table (7) are mounted on the machine frame (Figure 5/14).

The column accommodates the motor (8) for the cutting motion as well as the gear (9) for the transfer of the motor motion to the milling cutter (10).

In the knee there is the motor (11) for the feed motion and the gear (12) for the transfer of the motion of motor to the saddle and the machine table. There are also machines which have a motor for the drive of the machine table and one for the drive of the saddle.

By means of crank handles it is possible to actuate the machine table and the saddle also by hand, e.g. upon forward travel of the workpiece to the tool (Figure 5/15). The knee can be actuated upwards and downwards (z-direction) at the column (Figure), the saddle slides on the knee parallel to the longitudinal axis of the milling spindle (y-Direction), the machine table slides on the saddle crosswise to the longitudinal axis of the milling spindle (see Table 5/1).

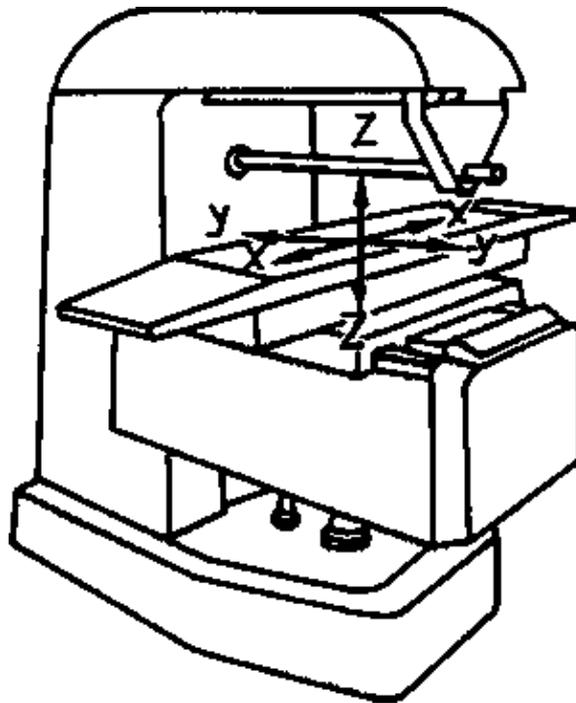


Figure 5/15 Direction of movement of machine table with workpiece

- x Direction: motion horizontal, at right angles to the longitudinal axis of milling cutter;
- y Direction: motion horizontal, parallel to the longitudinal axis of milling cutter;
- z Direction: motion vertical, at right angles to the longitudinal axis of milling cutter.

Drive of a horizontal knee-and-column type milling machine

Electric motors are used for the drive. The motors of several machines are designed in a way that their revolutions can be changed within a certain range. Thus it is possible to adapt the revolutions to the corresponding operations. In addition, it is possible to change their direction of rotation from a right-hand rotation into left-hand rotation and vice versa.

Mechanisms of transfer of a horizontal knee – and-column type milling machine

- Mechanisms for milling spindle drive

The milling spindle drive is accommodated in the column of the machine. According to the design of the machine there are used as milling spindle drives

- change-speed drives with a great number of switching steps (about 20);
- stepless gear with a great actuating range.

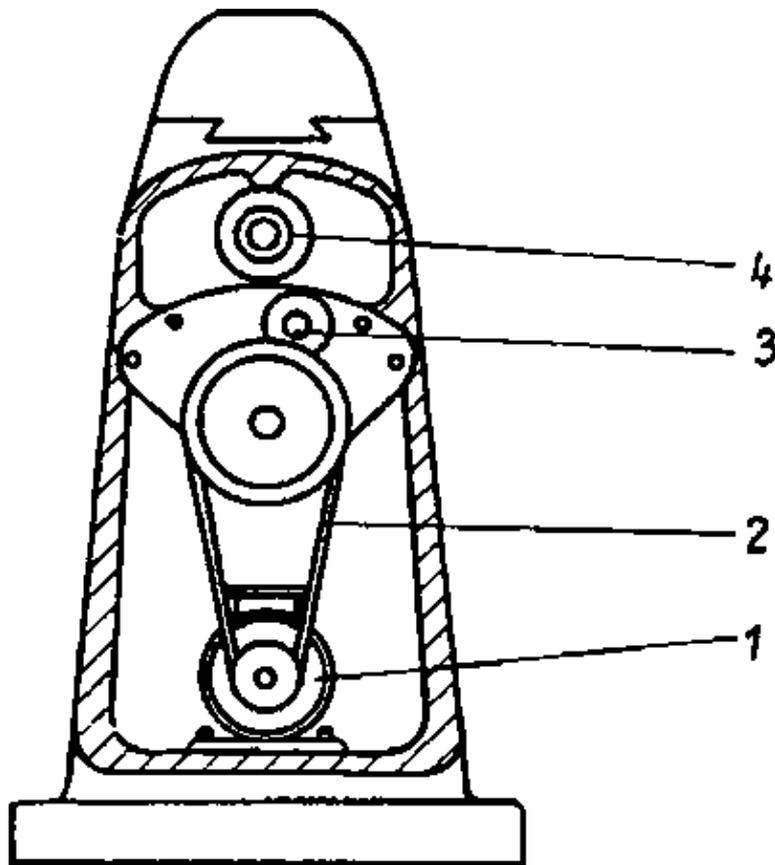


Figure 5/16 View into the open pillar of a horizontal knee-and-column type milling machine

1 motor, 2 Belt drive, 3 Milling cutter gear, 4 Milling cutter support.

The motor (1) can be directly mounted on the milling spindle gear (3) or connected with it by means of belt drive (2). At the milling spindle gear the revolutions of the spindle are set. They are equal to the number of revolutions of tool to be driven via the milling spindle. Infinitely variable gears have the benefit that within the range any desired number of revolutions can be set. Thus the number of revolutions of tool can be optimally adapted to that of the job. However, with a step gear only the speed is switchable which comes closest to the optimal speed. For special requirements machines are designed with an infinitely variable gear and additionally a step gear (Figure 5/17).

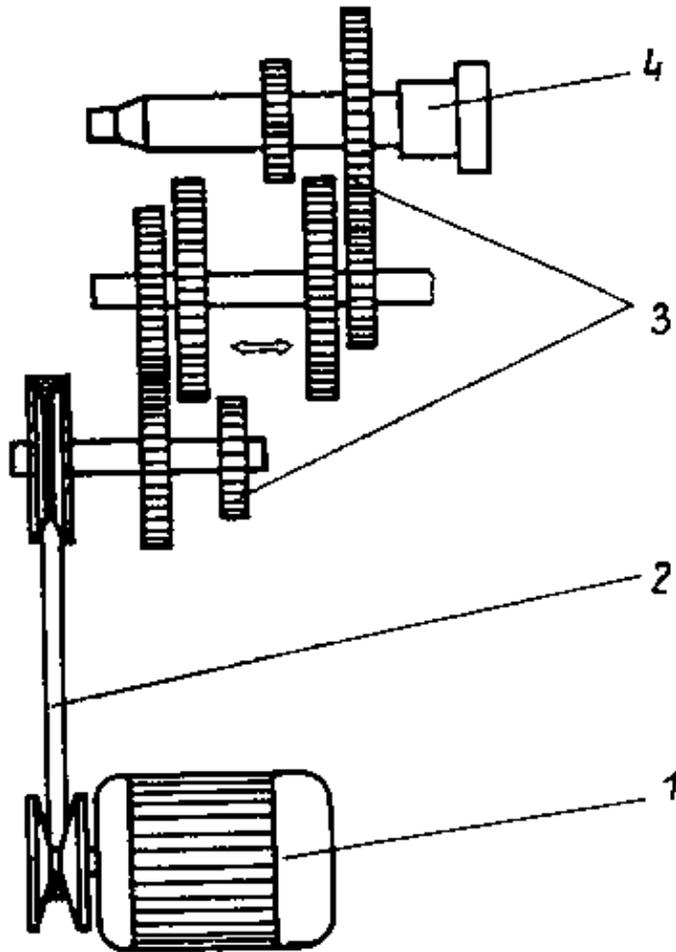


Figure 5/17 Infinitely variable belt drive and step gear of a horizontal knee-and-column type milling machine

1 Motor, 2 Infinitely variable belt drive, 3 Step gear, 4 Milling cutter.

- Mechanisms for feed motions

The feed gear is accommodated in the knee. Like the gear for the milling spindle, there are also used

- step gears with a great number of switching steps (about 20)
- infinitely variable gears with a great actuating range.

Instead of gears for speed transmission it is also possible to use motors with variable speed. The motors are also built into the knee. In the knee there are also the mechanisms for hand feed by way of crank handle (Figure 5/18).

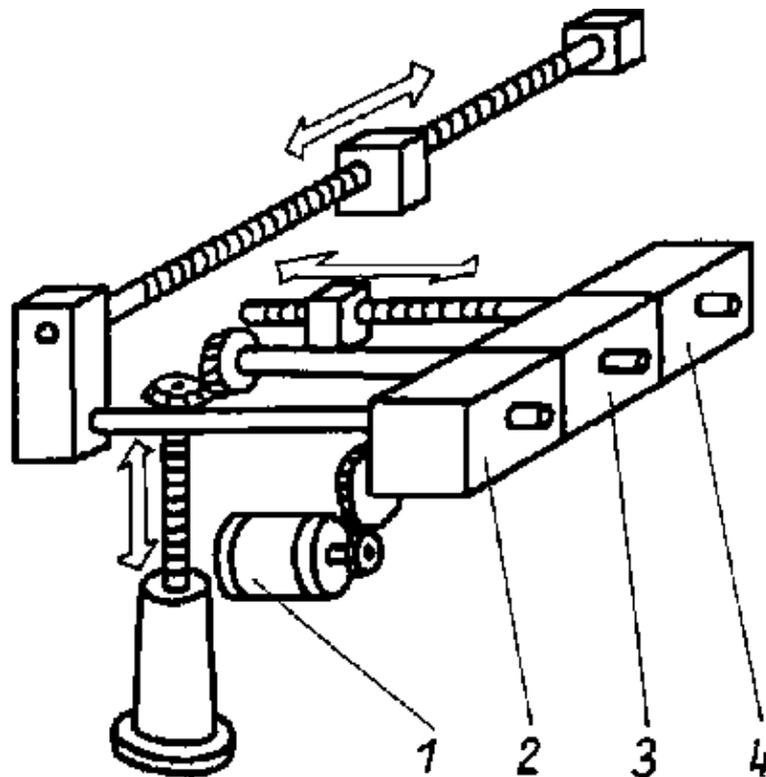


Figure 5/18 Feed gear of a horizontal knee-and-column type milling machine (simplified)

1 Motor, 2 Gear for machine table, 3 Gear for saddle, 4 Gear for lifting and lowering of knee.

As a safeguard against overload the gear is equipped with overload couplings. As soon as a defect arises, the overload coupling switches off the transmission of rotary motion. In this way the machine is protected from damage.

Overloaded couplings are not allowed to be made inoperational! Severe damage to the machine and to the workpiece may be the result together with danger to man.

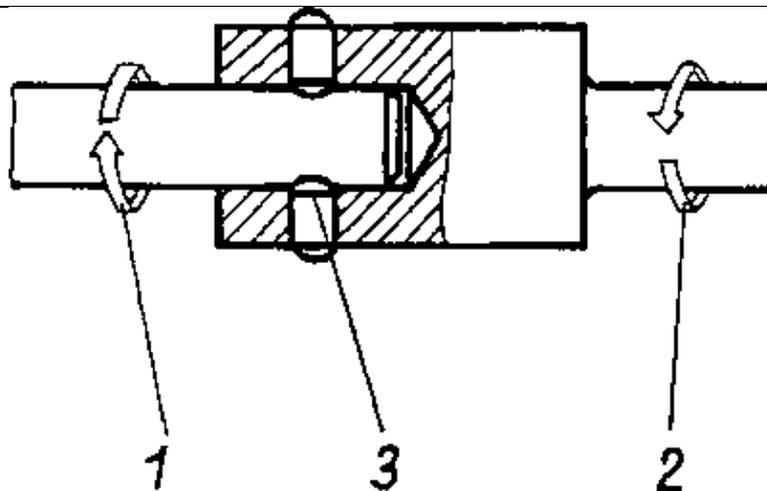


Figure 5/19 Principle of action of a coupling to protect against overload (example)

1 Driving torque, 2 Output torque, 3 Load

To accelerate the forward travel of workpiece to the milling cutter as well as to speed up the return travel after cutting, many machines are equipped with a rapid traverse motion. By means of the rapid traverse motion it is possible to cut back non-productive time. In addition, there are automatic knee lowering devices which lower the knee upon return travel, so that the workpiece can pass unimpededly underneath the cutter (Figure 5/20).

The milling spindle serves to accommodate the tool holder, e.g. the cutter arbor (Figure 5/21). It has a multiple support in the column of the machine. (1,2,3), There is a conical bore (4) at the spindle head for accommodating the tool holder. The entire milling spindle is through-drilled. Through the cavity (5) throughout

there is the spindle (6) which is passed through, with which the outer cone of tool holder is drawn into the internal taper of the milling spindle.

The milling spindle is not allowed to bend or twist during milling operations. This is also the reason why it is of a robust design.

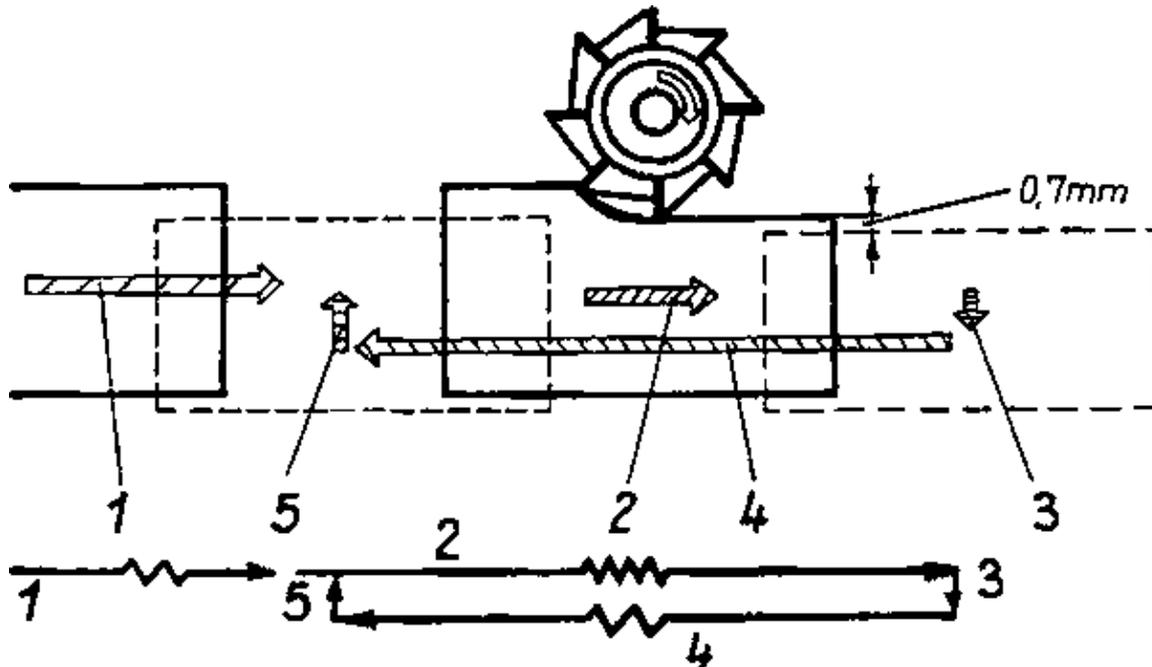


Figure 5/20 Principle of rapid traverse motion and knee lowering

1 Rapid traverse motion during advance travel, 2 Feed during milling, 3 Knee lowering after milling, 4 Rapid traverse motion upon return travel, 5 Lifting knee into initial position.

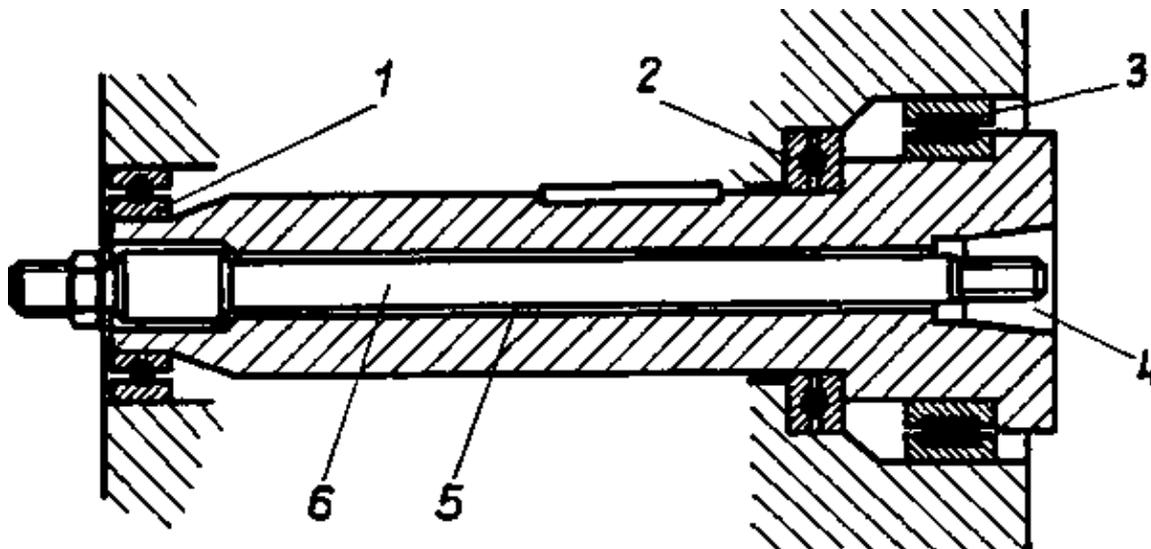


Figure 5/21 Milling cutter (simplified)

1,2,3 Bearings, 4 Conical bore to receive tool holder, 5 Bore through the milling cutter, 6 Spindle to clamp tool holder (Starting spindle for milling cutter)

Control Questions

1. Describe the structure of a horizontal knee–and column type milling machine.
2. Explain the specifics that had given the machine its name.
3. What kinds of transformations of motion proceed in the mechanisms of transfer in a horizontal knee–and–column type milling machine?

4. Why is an as great as possible number of switching steps in the milling machine gear especially favourable for milling operations?
5. Describe the mode of operation of the rapid traverse motion and that of the knee–lowering device.
6. Explain the system of coordination determining the motions of workpieces.

5.2.2. Clamping devices for workpieces and their use

In this section you shall get acquainted with

- the functions of work–clamping devices to be performed at horizontal knee–and–column type milling machines
- the types of work–clamping devices available
- the way of functioning of work–clamping devices
- the kinds of work–clamping devices that are preferably used for certain workpieces.

Tasks of clamping devices for workpieces

The clamping devices hold firmly the workpieces. They transmit the feed motions from the machine table to the workpiece.

Forces arising from metal cutting are not allowed to shift the position of workpiece in the work–clamping device. The work–clamping device have to keep the workpiece in the correct position to the tool. They are not allowed to hinder the tool from metal cutting, because there may be the danger of accident and possible even damage to the tool.

Clamping and unclamping of workpieces is not allowed to take much time, this is non–productive time.

Design of the machine table

Many workpieces with plain support surfaces are directly clamped on the machine table by means of clamping devices (Figure 5/22). The machine table is designed in a way that it can accommodate setscrews. It is provided with T–slots, into which the heads of setscrews are pushed.

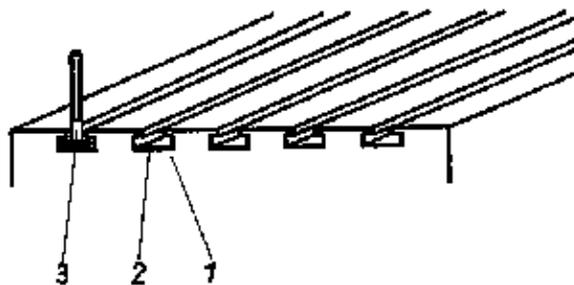


Figure 5/22 Formation of a machine table for clamping workpieces

- 1 Machine table, 2 T–slot, 3 Drawbolts with head to be inserted into the slot

Metal chips are collected in the T–slots (Figure 5/23). They impede the pushing forward of the setscrews; in addition they get jammed between head and slot in a way that the setscrew does not fit tightly enough. There is the danger that the workpiece gets loose.

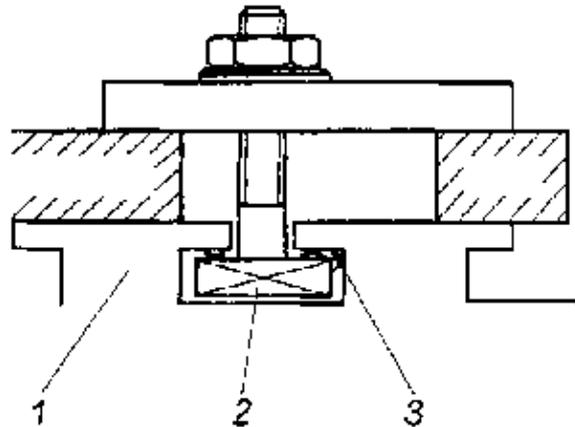


Figure 5/23 Metal chips in the machine–table T–slots impede a tight clamping

1 Machine table, 2 Drawbolt, 3 Chips which got stuck between groove and screw head.

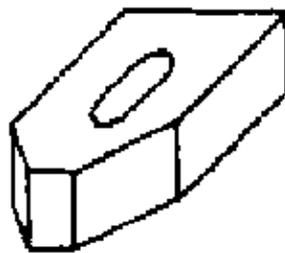
T–slots to be cleaned, because metal chips impede a tight clamping! There is the danger of accidents and there is danger to the tool and to the workpiece.

Clamps

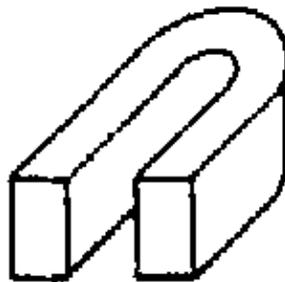
Clamps transmit the forces from the setscrew to the workpiece. In doing so, they press the workpiece firmly against the machine table. Clamps are used for workpieces that are shaped in a way that one side of the strap can safely support the workpiece without impeding the tool (Figures 5/5, 5/6, 5/8, 5/10). In line with the application there are various types of clamps (Figure 5/24).

The side of clamp turned away from the workpiece has to lie on a clamping support. The clamping support has to be as high as that place where the clamp lies on the workpiece (Figure 5/25). Then the clamp lies parallel to the machine table. Several clamps are designed in the form of steps. They can be favourably used (Figure 5/26).

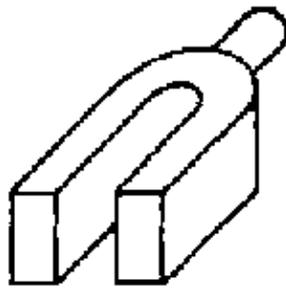
Figure 5/24 Different types of clamping straps



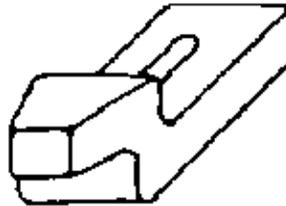
a Flat



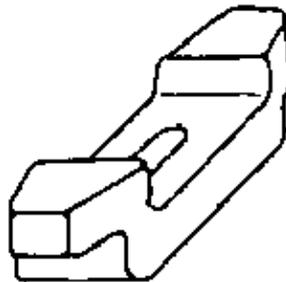
b U-shaped



c Fork-shaped

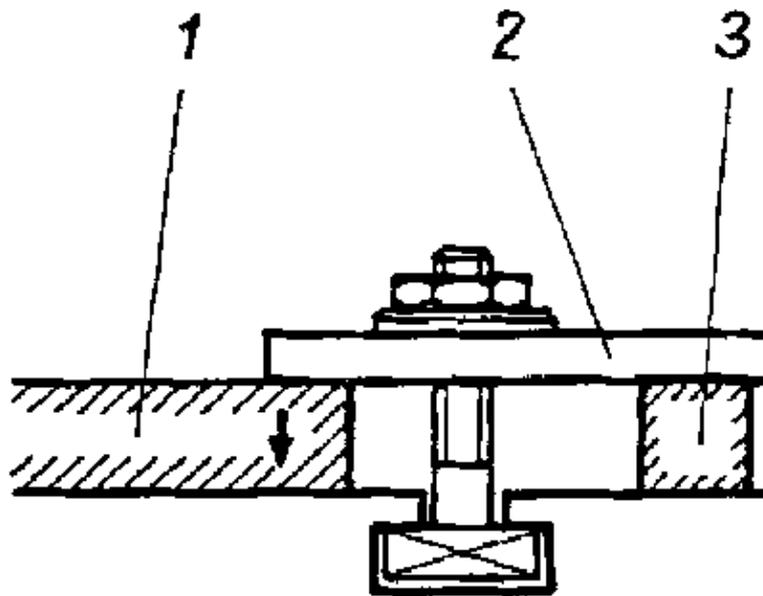


d Unilaterally angularly bent



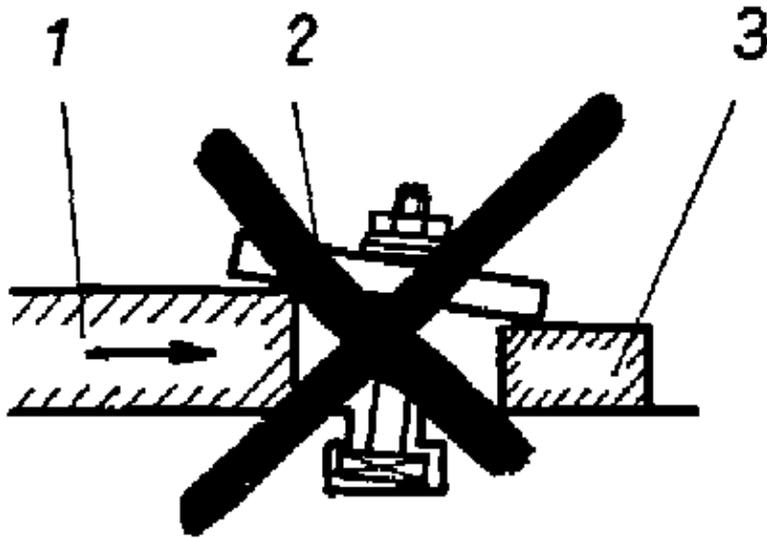
e Bilaterally angularly bent

Figure 5/25 Attention to be paid when using clamps!



a Clamps lies parallel to the machine table: correct, workpiece is safely clamped,

1 Workpiece, 2 Clamps, 3 Clamping support.



b Clamp lies oblique to the machine table: incorrect workpiece is not safely clamped.

1 Workpiece, 2 Clamps, 3 Clamping support.

All setscrews can be firmly tightened up in a uniform manner, so that the workpiece is fully supported on the machine table. The clamp will appropriately be laid in such a way that the long lever arm is supported on the clamp, whereas the short lever arm is supported on the workpiece. Thus the leverage is utilized for the safe clamping of the workpiece (Figure 5/27).

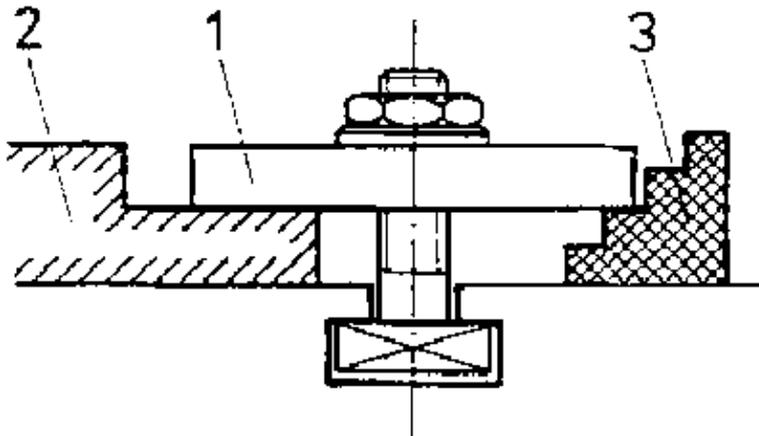
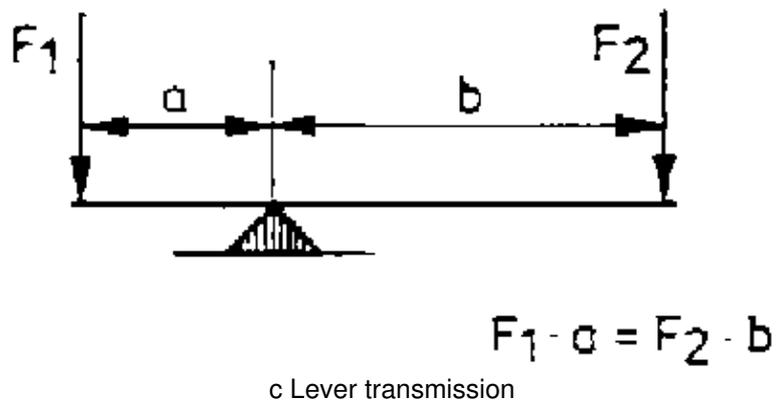
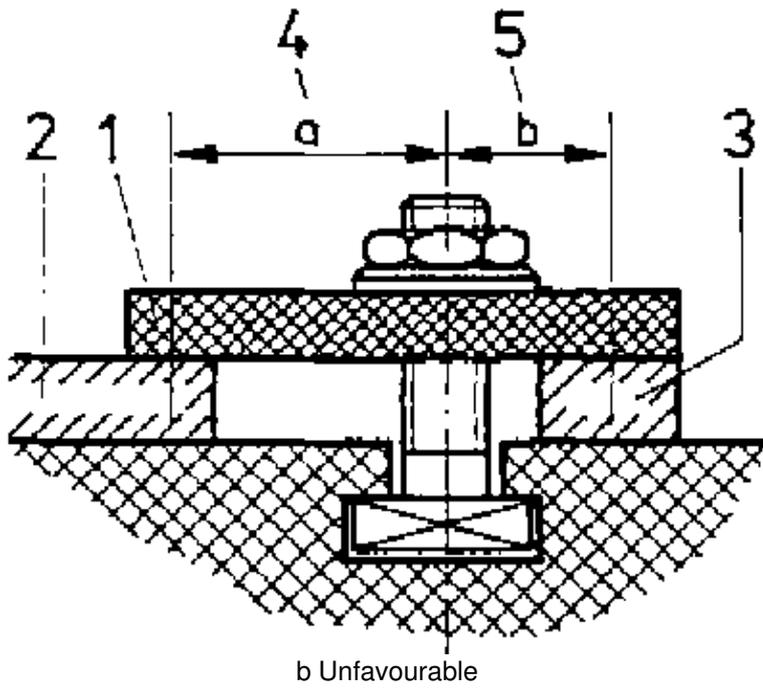
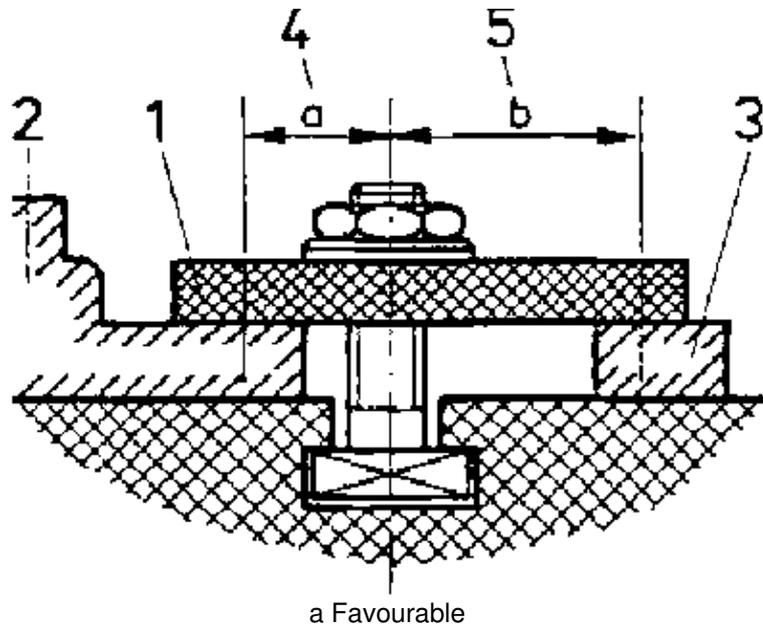


Figure 5/26 Clamping support with gradations

1 Clamp, 2 Workpiece, 3 Clamping support

Figure 5/27 Lever action at clamps



1 Clamp, 2 Workpiece, 3 Clamping support, 4 Weight arm, 5 Force arm

Upon utilization of clamps it is essential

- that all setscrews shall be firmly tightened in a uniform way
- that all clamps lie parallel to the machine table
- that the lever action of clamp is utilized.

Machine vices

A machine vice is mounted on the machine table by setscrews. The workpiece is put into the machine vice and firmly tightened between the jaws (Figures 5.7. 5/9, 5/11). The function of a machine vice is equal to that of a bench vice on the workbench (Figure 5/28).

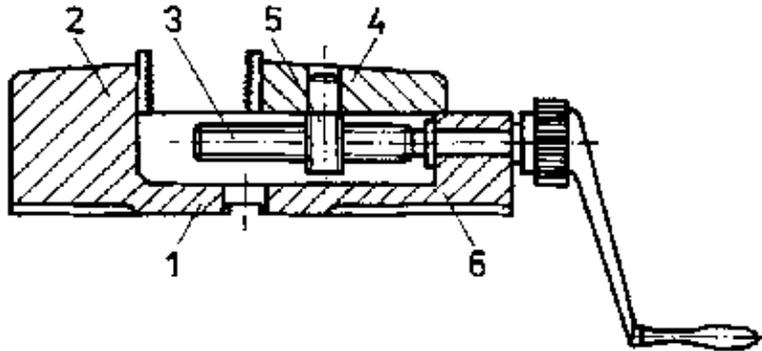


Figure 5/28 Machine vice

1 Main structure, 2 Fixed jaw, 3 Threaded spindle, 4 Movable jaw, 5 Nut, 6 Crank handle

The main structure (1) carries the fixed jaw (2). The threaded spindle (3) is supported in a bore of the main body. A movable jaw (4) moves on the sliding surfaces of the main structure. It is actuated via the nut (5) by the threaded spindle. The crank handle (6) can be placed on the four-cornered shaft of the threaded spindle and can be taken off after the clamping of workpiece.

Crank handle to be detached prior to switching-on of machine and to be safely deposited!

The crank handle, as a result of lever action, increases the manual power of man. The threaded spindle is operated so firmly as is required for the safe clamping of workpiece. By means of an elongated crank handle the manual force of man is still further increased. There is the danger that the machine vice is destroyed or the workpiece deformed (Figure 5/29).

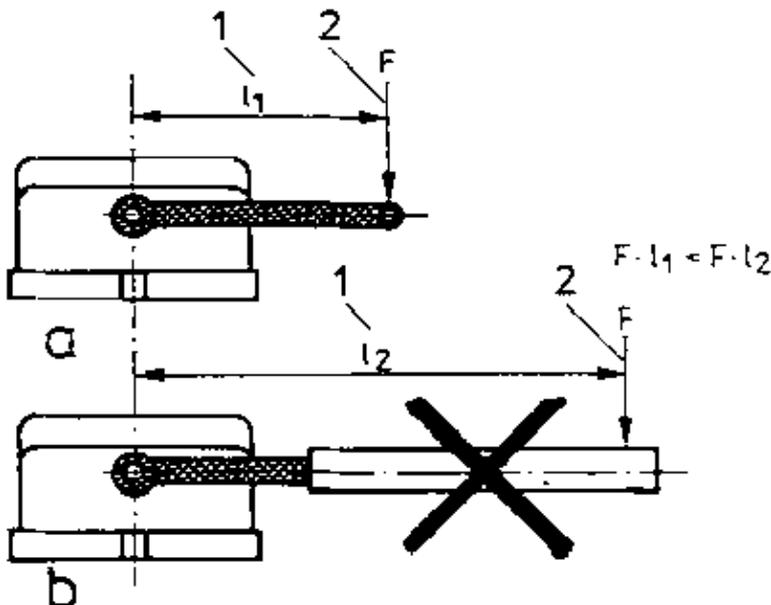


Figure 5/29 Power transmission through the crank handle of machine vice

a Crank handle with adequate length, b Crank handle too long
 1 Lever in crank handle, 2 Direction of manual force

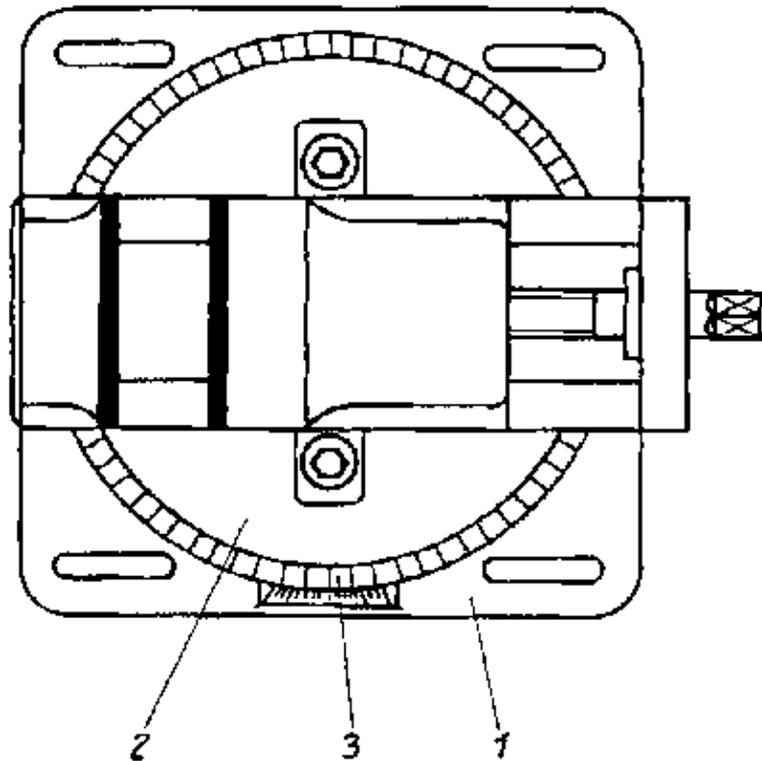


Figure 5/30 Machine vice, swivelling

1 Fixed part, 2 Swivelling part, 3 Scale for reading the angle of rotation

For several milling operations it is required to turn the workplace around or to tilt it. Machine vices of adequate design are used for this purpose. The amount by which the machine vice is turned or tilted can be read from a scale (Figures 5/30 and 5/31). With clamping screws the movable part is firmly clamped, so that it cannot be moved by itself.

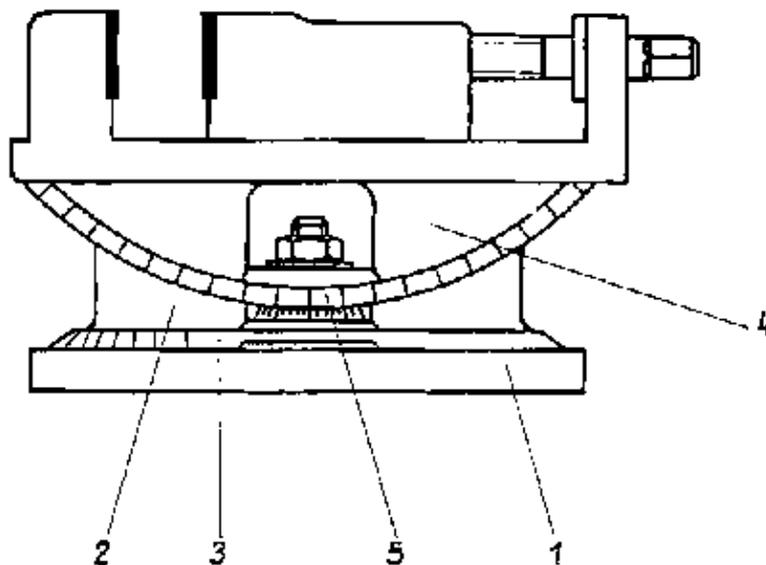


Figure 5/31 Machine vice, swivelling and tiltable

1 Fixed part, 2 Slewable part, 3 Scale to read the angle of rotation, 4 Tiltable part, 5 Scale to read the angle of tilt.

Clamping fixtures

They are used

– for workpieces having such a shape that permits it to be clamped only insufficiently by means of clamps or in machine vices;

- for workpieces to be produced in great quantities (mass production) so that a frequent clamping and unclamping in equal position is required;
- for workpieces of which several can be simultaneously clamped.

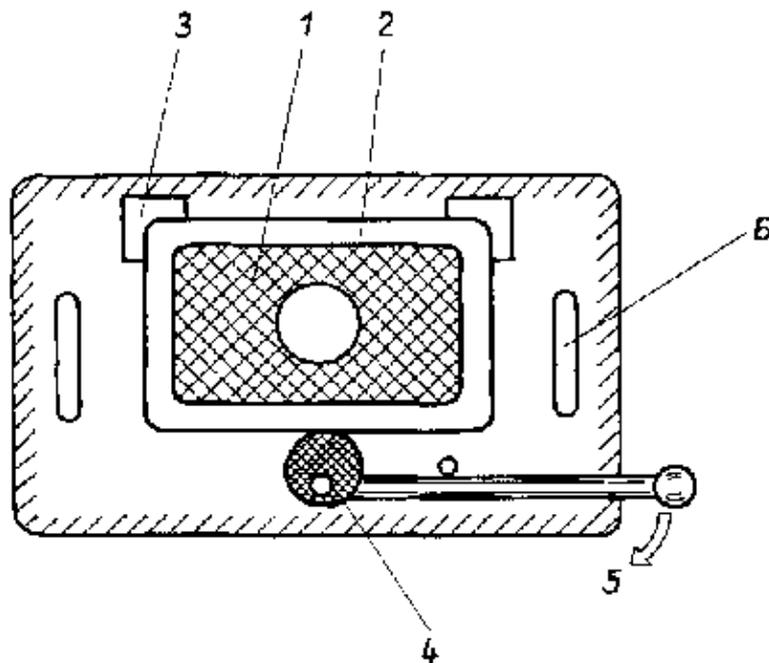


Figure 5/32 Clamping fixture for clamping a cover

1 Workpiece, 2 Machined surface, 3 Holding angle, 4 Eccentric cocking lever, 5 Release of eccentric cocking lever, 6 slots for screws for fastening on machine table.

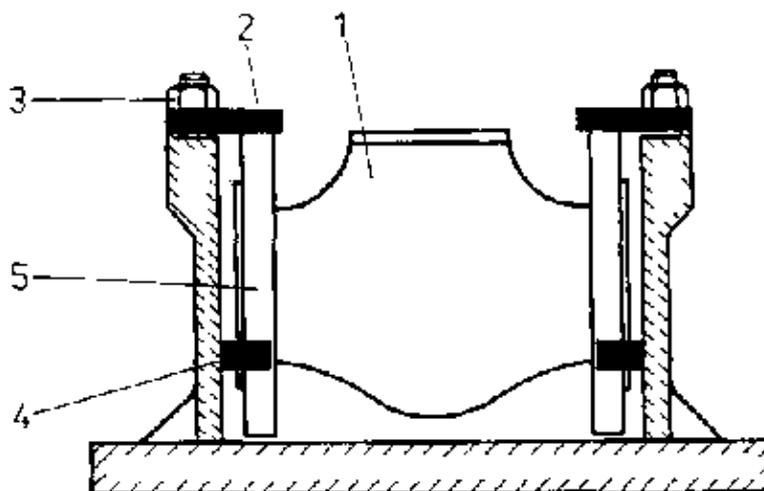


Figure 5/33 Clamping fixture for clamping a valve casing

1 Workpiece, 2 Holding part, 3 Drawbolt, 4 Support, 5 Flange of valve.

Since clamping fixtures serve for special purposes they are also differently designed. The Figures 5/32 and 5/34 show examples of clamping fixtures.

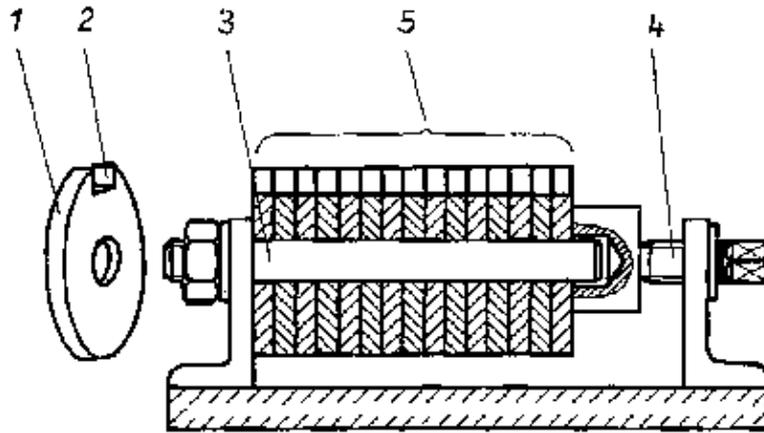


Figure 5/34 Clamping fixture for clamping 15 equal workpieces

1 View of workpiece, 2 Slot to be cut into the workpiece, 3 Holding arbor, 4 Drawbolt, 5 Slot cut in all workpieces in one operation

Jaw chucks

They serve for clamping cylindrical or symmetrical multi-cornered workpieces. Their structure is equal to the jaw chucks of a turning machine (Figures 4/26 and 4/29). The jaw chucks themselves are directly mounted on the machine table, or by means of special devices (Figure 5/35).

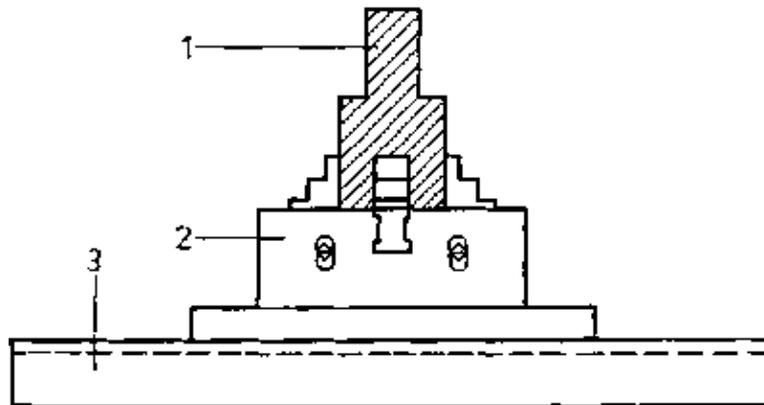


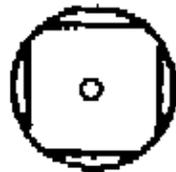
Figure 5/35 Workpiece clamped into the jaw chuck of the milling machine

1 Workpiece, 2 Jaw chuck, 3 Machine table

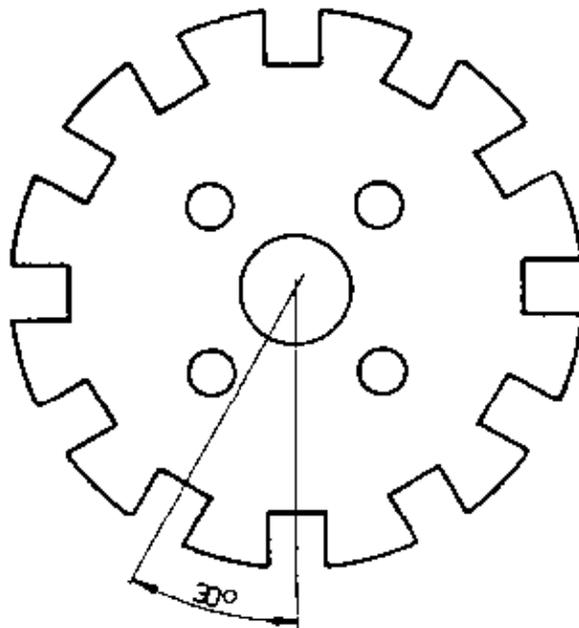
Indexing apparatus

Several workpieces receive symmetrically arranged machining operations, e.g. spindle (Figure 5/36a) is provided at the end with a four-cornered shaft, the disk (Figure 5/36b) is provided with slots, the wheel (Figure 5/36c) is given the toothing. Each side of the four-cornered shaft can be separately milled, it is equally possible to machine each slot of the disk and every tooth of the cogwheel. As soon as one operation is finished, the workpiece has to be turned around. The new machining place is adequately positioned to the tool.

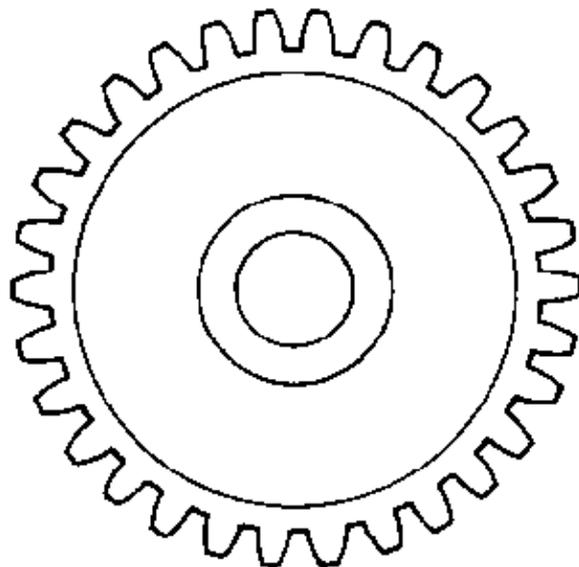
Figure 5/36 Examples of workpieces to be clamped into indexing apparatus for milling



a Spindle with four-cornered shaft



b Scanning disk provided with slots



c Toothed wheel

An indexing apparatus makes it possible to move the workpiece by exactly the fixed distance requi(...) that it can be machined symmetrically.

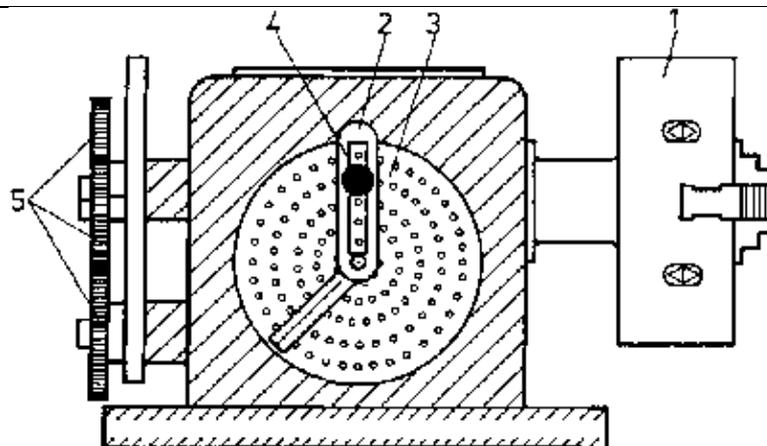


Figure 5/37 Universal indexing apparatus

1 Jaw chuck, 2 Indexing lever, 3 Perforated disk, 4 Indexing pin, 5 Interchangeable gear (Toothed wheels)

The workpiece is clamped into the clamping fixture (1) of the indexing apparatus (Figure 5/37). By turning the indexing lever (2) the workpiece is turned together with the chuck. A gear transmission between lever and chuck (5) provides for the turn of the workpiece by the amount desired, e.g. the workpiece of Figure 5/36b is turned by 30° from slot to slot. The indexing pin (4) retains the indexing lever by allowing the perforated disk (3) to click.

Control questions

1. What are the functions of clamping devices for workpieces on horizontal knee–and–column type milling machines?
2. Name work–clamping devices that are used on horizontal knee–and–column type milling machines!
3. What types of workpieces can be clamped by using these types of clamping devices?
4. What has to be observed in using these individual clamping devices, so that the workpieces are held firmly?
5. What are the benefits and the disadvantages offer by special type clamping fixtures?

5.2.3. Clamping devices for tools and their use

In this section you shall get acquainted with

- the functions of tool–clamping devices on horizontal knee–and–column type milling machines
- the various types of tool–clamping devices available
- the way of functioning of tool–clamping devices
- the types of tool–clamping devices to be used for definite tools.

Tasks of clamping devices for tools

The clamping devices transmit the rotating motion of the milling spindle to the tool. They have to hold the tool vibration–free and firmly.

Milling cutters are multiple–edged tools. During milling several edges attack the workpiece simultaneously. If one edge begins cutting and even then when one edge finishes cutting the load on the milling cutter is subject to changes due to cutting forces. This change has to be fully absorbed by the clamping device. The tool is not permitted to change its position relative to the clamping device and is not allowed to get loose in the clamping device.

Milling cutters are expensive tools. Therefore a safe clamping in the tool holder is especially important. If a milling cutter gets loose, it may be destroyed, the device is damaged, possibly even the workpiece gets spoiled.

Tool–clamping devices have to be treated carefully. Their function influences the quality of milling operations, i.e. the surface grade and dimensional stability.

Cutter arbor

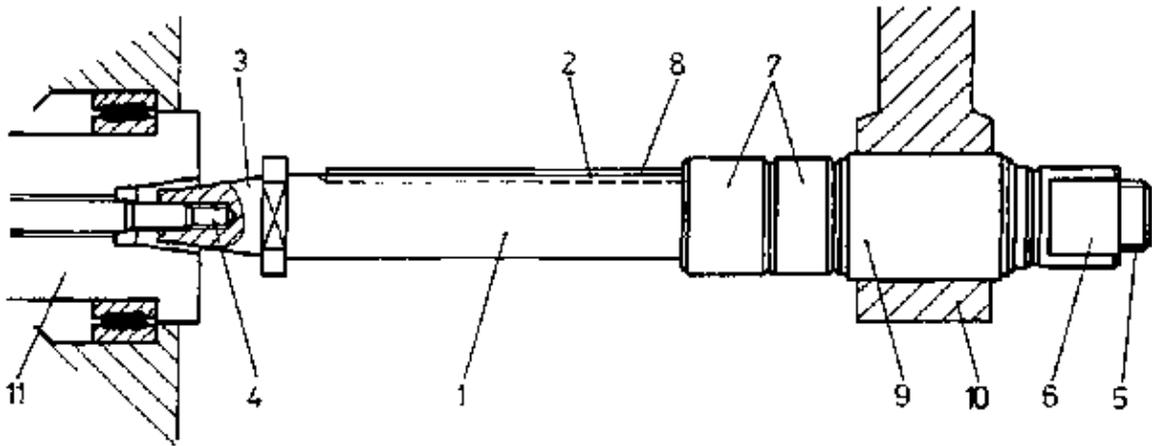


Figure 5/38 Cutter arbor, prior to clamping into milling spindle (simplified)

- 1 Cylindrical metal shaft of arbor, 2 Longitudinal slot (feather slot), 3 Steep taper, 4 Internal thread, 5 External thread, 6 Arbor nut, 7 Arbor rings, 8 Feather, 9 Bush, 10 Overarm, 11 Milling spindle

Cutter arbors (Figure 5/38) are made of the cylindrical metal shaft (1) that has a longitudinal slot (2). At one end it is provided with a cone (3) to be put into the milling spindle. The cutter arbor spindle (Figure 5/21) is screwed into the internal thread (4) of cone and the outer cone of arbor is pulled into the internal taper of the spindle. At the other end of arbor there is an outer thread (5) for the arbor nut (6). The milling cutter is pushed onto the cutter arbor. Differently wide cutter arbor rings (7) keep the milling cutter at the position desired. A feather key (8) transmits the torque from arbor to milling cutter. At the bush (9) the arbor is supported by the overarm (10). The arbor nut presses milling cutter and rings together.

The milling arbor has to run true. There should be no dirt between the cutter arbor rings, milling cutter and bushes. Arbor spindle and arbor nut have to be carefully tightened.

Arbor for shell end mill

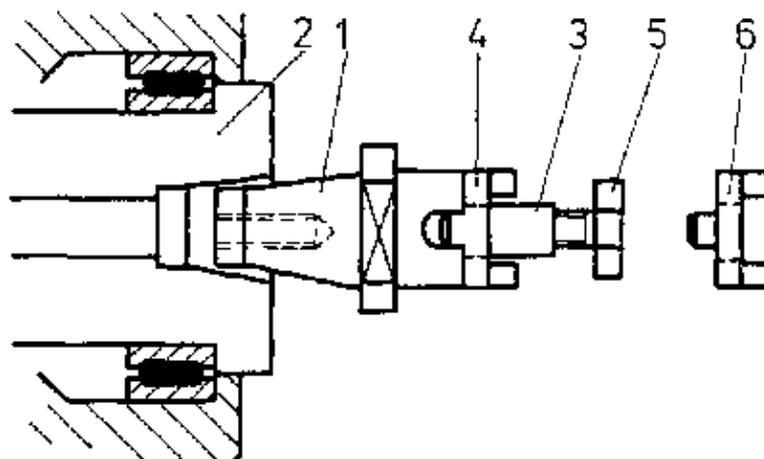


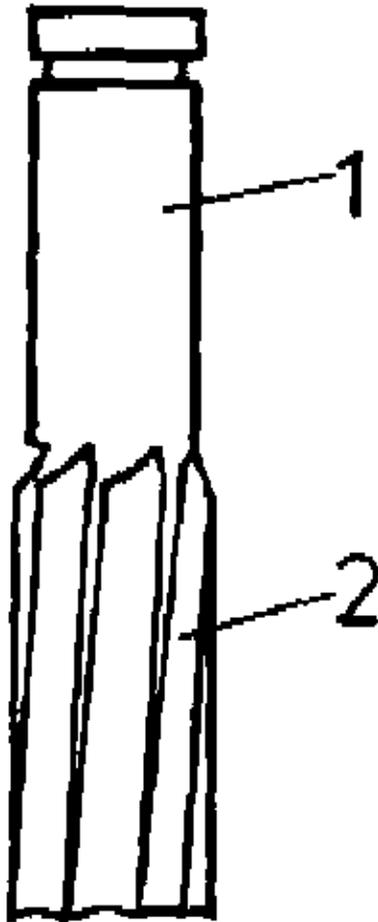
Figure 5/39 Arbor for shell end mill

- 1 Cone, 2 Milling spindle, 3 Cylindrical part to receive cutter, 4 Drive ring, 5 Draw-in bolt, 6 Drive ring, released from end-mill arbor

Arbors for shell end mill (Figure 5/39) are short arbors. They are used when the milling cutter shall be fastened very closely to the milling spindle. They are provided with a cone (1) intended to put them into the conical bore of milling spindle (2). The milling cutter is put on the cylindrical part (3) of the arbor for shell end mill. A driving ring (4) transmits the rotary movement of arbor to the tool.

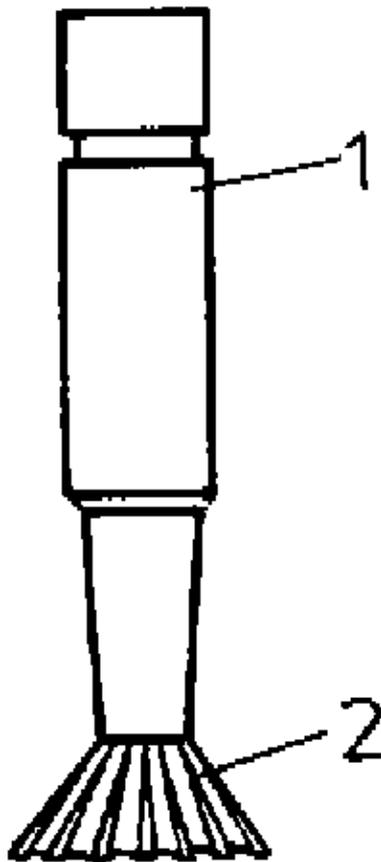
Chuck for milling cutter

Figure 5/50 Milling cutter with cylindrical shank



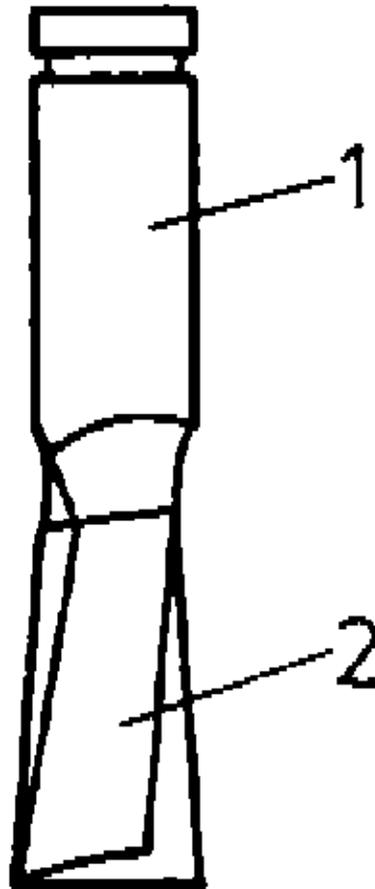
a Shank cutter with cylindrical shank

1 Cylindrical shank; 2 Cutting part



b Angle end mill

1 Cylindrical shank; 2 Cutting part



c Shank-type slotting end mill.

1 Cylindrical shank; 2 Cutting part

Milling cutter chucks serve for clamping milling cutters with cylindrical shaft (Figure 5/40). They are put into the milling spindle. According to the size of cutter the cylindrical shaft has a different diameter. Thus the milling cutter chuck (Figure 5/41) can be used for several diameters provided that collets (4) are inserted. These collets adapt the chuck to the diameter of cutter shaft.

Upon clamping the cutter shaft is put into a suitable collet. The clamping nut (3) is tightened. It presses the collet into the base structure (1). Between cutter shaft and tongs there is frictional connection which transmits the rotary motion from cutter chuck to milling cutter.

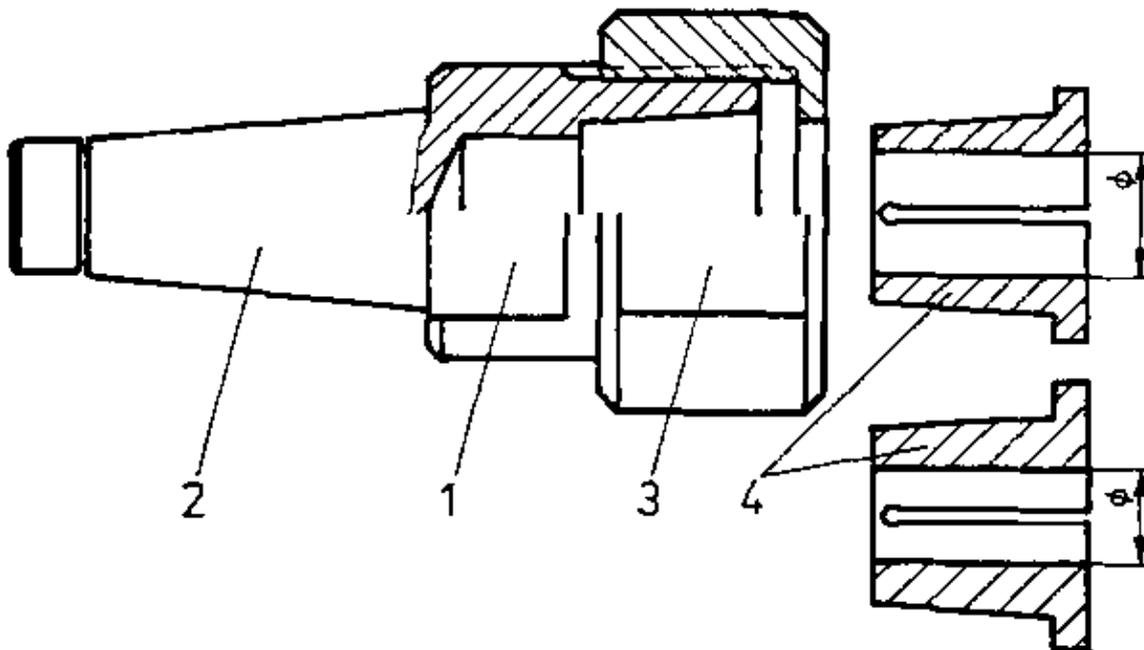


Figure 5/41 Chuck for milling cutter to clamp milling cutters with different shank diameters

1 Base structure, 2 Cone, 3 Clamping nut, 4 Collet.

Direct fastening

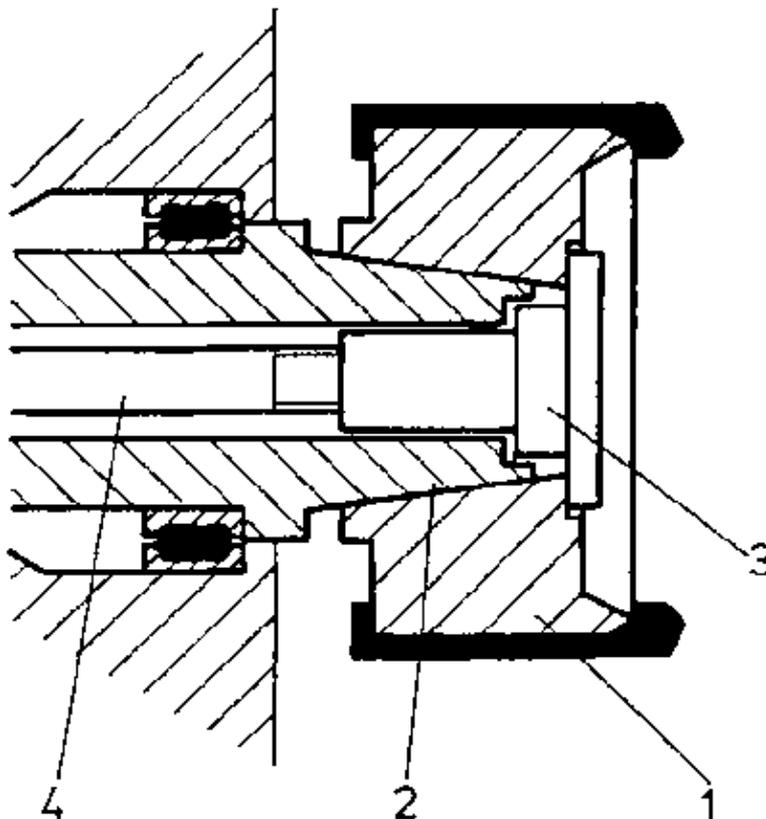


Figure 5/42 Direct fastening of cutter head with internal taper to milling spindle

1 Milling cutter head, 2 Internal taper at cutter head (External cone at milling spindle); 3 Driving pin; 4 Arbor spindle.

By the term 'direct fastening' it is understood that the milling cutter – it is mostly the cutter head – is directly fastened at the milling spindle. A special clamping device, such as an arbor or chuck, is not required (Figure 5/42).

The cutter head (1) is placed onto the cutting spindle with cone. The driver (3) is tightened with the arbor spindle (4) in such a manner that it draws the cutter head firmly onto the cone. At the same time the driver interferes positively into the cutter head.

Control questions

1. What demands are made on tool-clamping devices for milling machines?
2. Name tool-clamping devices which are used on horizontal knee-and-column type milling machines!
3. What types of clamping devices are used for what tools?
4. What is the function of the cutter arbor rings?
5. What is the function of the overarm at the cutter arbor?
6. What are the consequences of an untrue-running milling cutter for the quality of workpieces?

5.2.4. Handling of the horizontal knee-and-column type milling machine

In this section you shall get acquainted with

- the setting of a horizontal knee-and-column type milling machine
- the way the machine is operated during milling
- the kinds of errors to be avoided in operating the machine

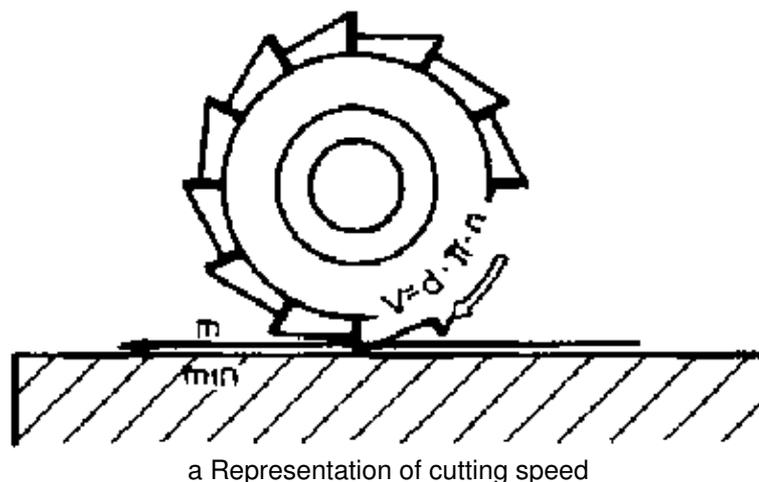
Setting the machine

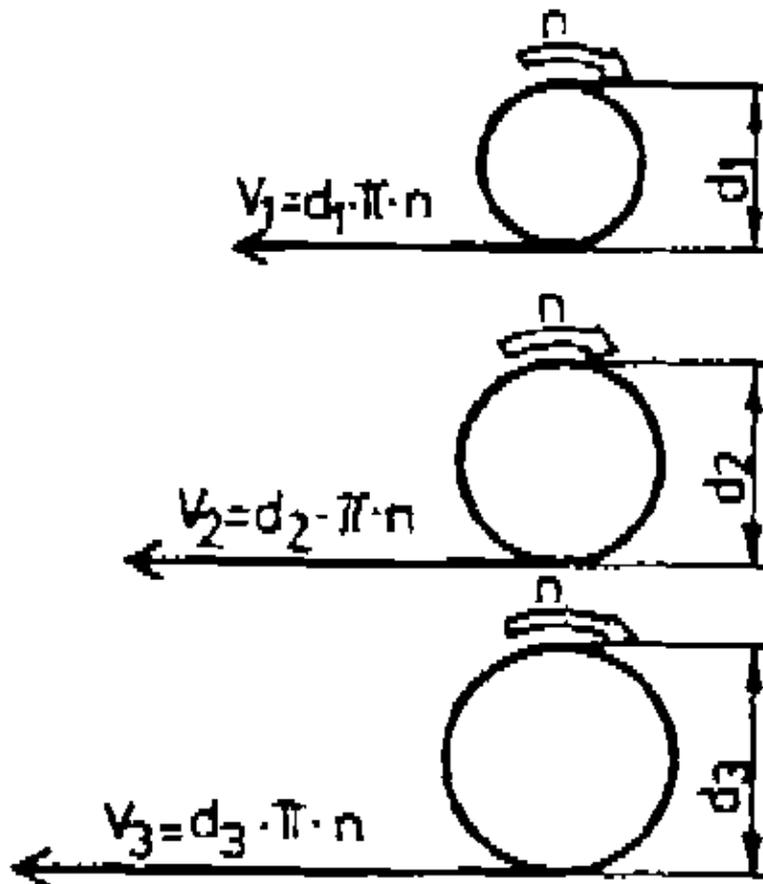
Upon setting the machine all preconditions are created that are required to achieve the appropriate milling characteristics for the milling operations intended.

- Switching the milling spindle gear

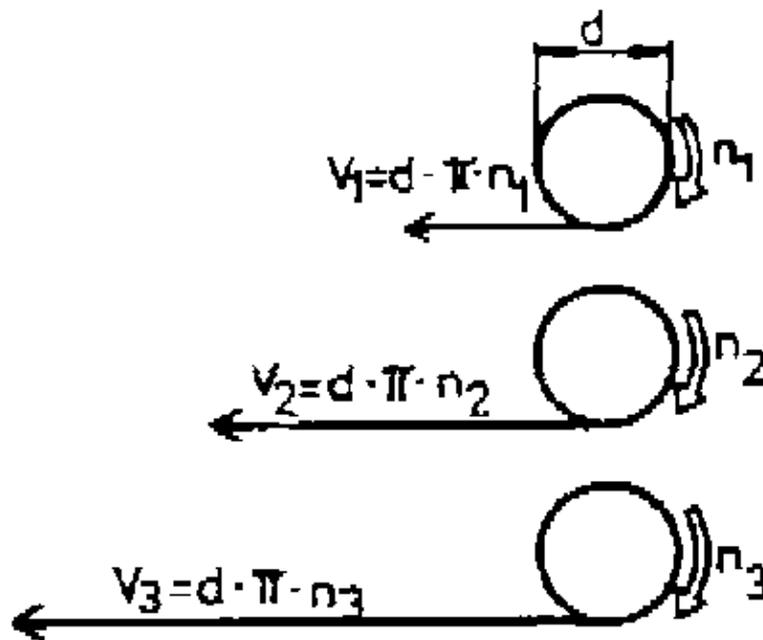
At the milling spindle gear (Figures 5/14, 5/16 and 5/17) the correct machining characteristics for cutting motion are set. This machining characteristic is the cutting speed.

Figure 5/43 Cutting speed during milling





b Influence of milling cutter diameter ($d_1 < d_2 < d_3$)



c Influence of speed ($n_1 < n_2 < n_3$)

The cutting speed upon milling is the speed at which the edges of the milling cutter move along the workpiece (Figure 5/43).

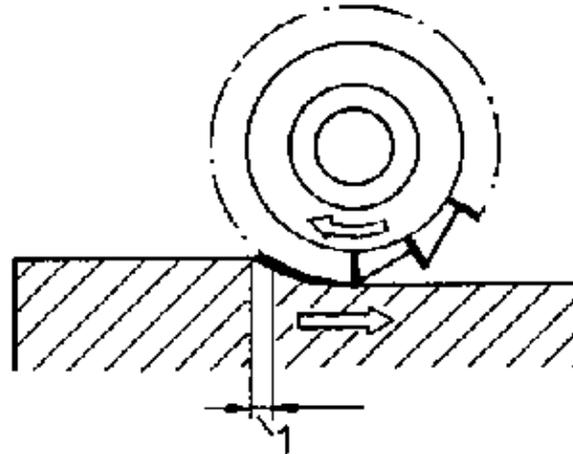
The cutting speed is dependent upon

- the material of the workpiece
- the material and the type of tool
- the surface grade required for the workpiece (fine or rough).

The cutting speed is set for a definite milling operation. The number of revolutions required for the cutting motion is adjusted at the milling spindle gear (Figure 5/2).

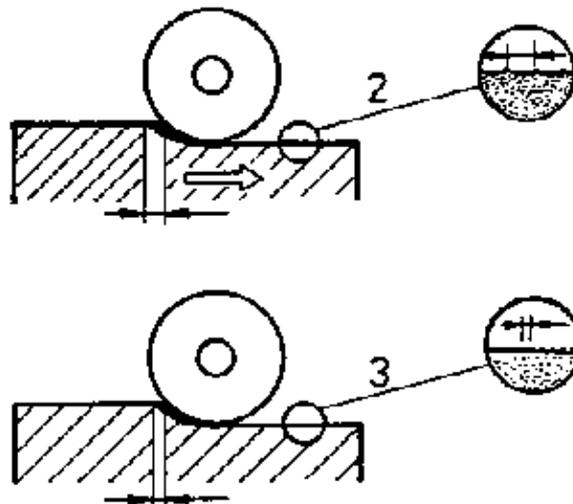
- Switching the feed gear

Figure 5/44 Feed during milling operations



a Representation of tooth feed

1 mm per tooth



b Influence of feed on surface grade

2 Large feed – Rough surface, 3 Small feed – Fine surface

At the feed gear (Figure 5/18) the correct machining characteristics for the feed motion are set. This value is the feed (Figure 5/44).

Feed in milling is the travel by which the workpiece is pushed forward during the operation of one cutter tooth. It is also called tooth feed.

The feed depends on

- the material and the type of tool
- the material of the workpiece
- the surface grade required for the workpiece (fine or rough)

The feed is set for a definite milling operation by setting the necessary ratio between motion and feed motion at the feed gear.

- Process of gear switching

Gears are sensitive components of a machine. On account of wrong handling upon switching gears can be damaged or even destroyed. According to the design gears can be switched:

- only during the standstill of machine
- only in the running–out period after switching off, i.e. shortly before standstill
- at any time, during standstill, in the running–out period, or during operation.

Upon switching the switch levers are slowly moved. With a certain feel it is found out whether the switching units of gear can be easily moved. If resistance comes up it is never allowed to use force.

The correct technical switching of gear keeps a machine operational over a long period, it saves costs for repair and prevents stoppages. Instructions for use shall be observed!

Clamping the tool

The tool is clamped with a clamping device for tools, into the milling spindle according to Section 5.2.3. Upon preparing the tool–clamping devices the following instructions shall be observed:

Milling spindle

- conical bore to be cleaned
- external cone to be cleaned.

Cutter arbor

- cone to be cleaned
- feather bey groove to be cleaned
- cutter arbor nut to be screwed on for testing
- cutter arbor spindle to be screwed in for testing

Arbor for shell end mill

- cone to be cleaned
- milling cutter screw to be inserted for testing

Chuck for milling cutter

- cone to be cleaned
- clamping tongs to be cleaned, especially the slots
- clamping nuts to be screwed on for testing

Direct fastening

- cone of milling spindle to be cleaned
- cone of tool to be cleaned
- cutter arbor spindle to be screwed into driver for testing.

After inserting of clamping devices into milling spindle it has to be checked whether they run true. If required, they have once again to be declamped from milling spindle and, for the purpose of correcting untrue running, to be again clamped and tightly set.

During the process of inserting clamping devices it is essential to put tool down on wooden support. Caution when touching tool, the edges are sharp: danger of injuries!

In the case of cutter arbors the tool has to be mounted on the machine stand as closely as possible. The cutter arbor is then less exposed to bending as in case of a greater distance.

Clamping the workpiece

The workpiece is clamped with a clamping device for workpieces on the machine table according to Section 5.2.2. In preparing the clamping devices the following instructions have to be observed:

Machine table

- to be moved forward laterally out of the operating range of tool
- to be cleaned from metal chips and residual coolant, especially in the T-slots

Setscrews

- to be pushed into the T-slots for testing
- nuts to be screwed on for testing

Machine vice, clamping fixtures, jaw chucks

- to be cleaned from metal chips
- easy movability of threaded spindle to be checked (possibly, thread has to be slightly oiled).

In conformity with the milling operations to be performed on the workpiece it is required to select the most favourable place at the machine table. It should be possible to move fully the workpiece within the range of operations. Between tool and workpiece it is not allowed to create any coercive positions.

Milling operations on horizontal knee-and-column type milling machine

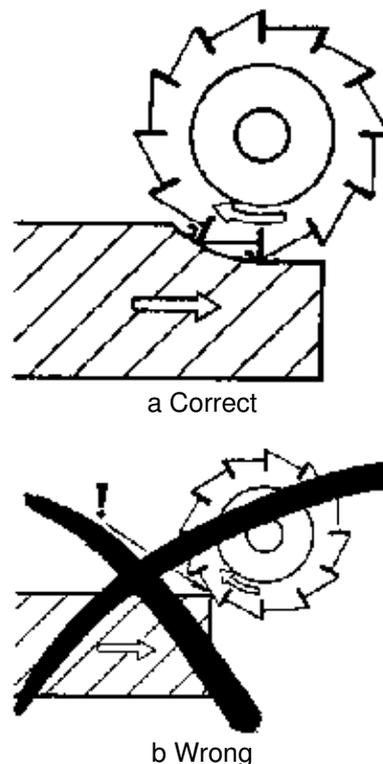
After setting the machine and after having clamped workpiece and tool it is possible to start with milling operations.

- Switching-on the machine (cutting motion)

It has to be provided that the tool rotates in the correct rotary direction of cutting motion. Any false rotary direction will damage or even destroy tool as well as workpiece (Figure 5/45). Prior to switching-on the workpiece has to be moved out of the range of operation of milling cutter, so that it is avoided having any undesired contacts.

Attention! The milling cutter has to be covered by a protective device because of the danger of accidents!

Figure 5/45 Direction of rotation of tool



- Positioning of workpiece

Upon positioning the workpiece is placed into the position from which the removal of metal chips shall be made.

The start-up motion moves the workpiece to the cutter. It is a rapid traverse motion so that the nonproductive times are kept as short as possible. The in-feed motion determines the thickness of the metal layer to be cut off. This motion is determining for the dimensional stability of operations. The adjustment motion serves for the corrections, if any deviations occur from the desired measurement of workpiece. The scale rings (Figure 5/47) at the crank handles of the knee, the saddle and the machine table make it possible to read the amount by which the workpiece has to be feed or readjusted.

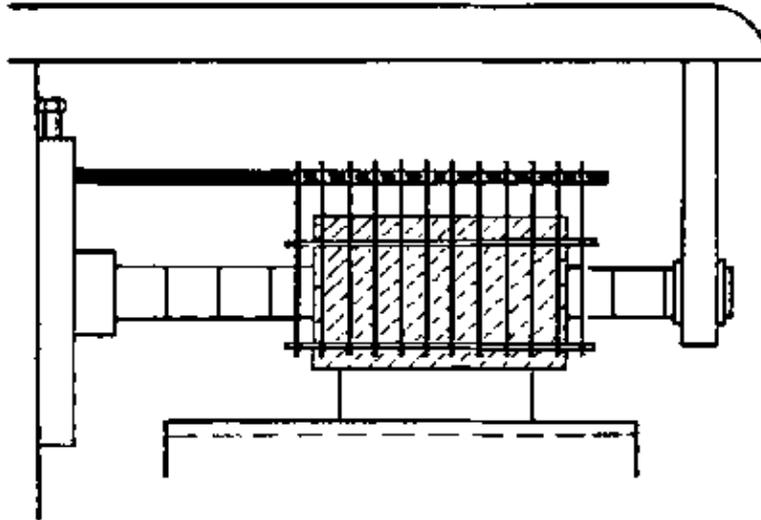


Figure 5/46 Protective device for milling cutter

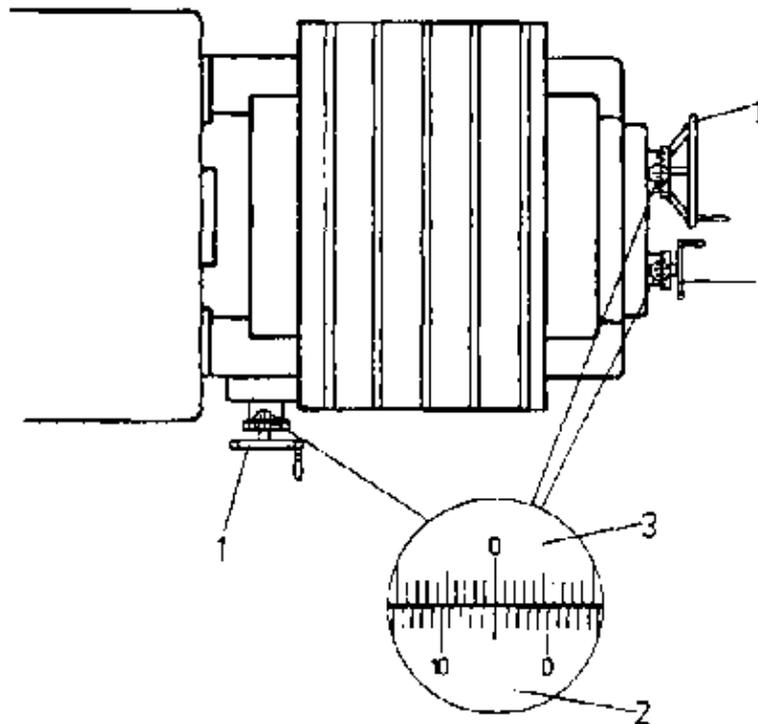


Figure 5/47 Graduated collar ring at crank handles of knee, saddle, machine table

1 Crank handle, 2 Swivelling collar ring, 3 Fixed indicator

• Travel of workpiece, beginning of metal cutting

As soon as the workpiece has been positioned, the feed motion is switched on. Upon milling the travel motion is mostly done automatically by means of the mechanized feeding devices of the machine.

In case of milling operations for complicated parts, e.g. tools, devices a.o. the feed motion can also be generated by hand. The right hand operates the crank handle of the machine table, whereas the left hand

operates the saddle.

- Finishing the feed motion, workpiece to be turned aside, machine to be switched off

As soon as the removal of metal chips is terminated, the feed motion is ended. The workpiece is moved aside. Only then the cutting motion is switched off.

Switching on and off the cutting motion during metal cutting may cause damage to tool and machine. Therefore, first cutting motion, then feed motion to be switched on, first feed motion, then cutting motion to be switched off.

If additional operations shall follow it is essential to position the workpiece anew before the machine is switched off.

- Operation via panels with keys

in order to facilitate operation many machines are equipped with operating panels with keys. The individual motions are released by pressing the pertaining key. Every key carries the symbol of operation.

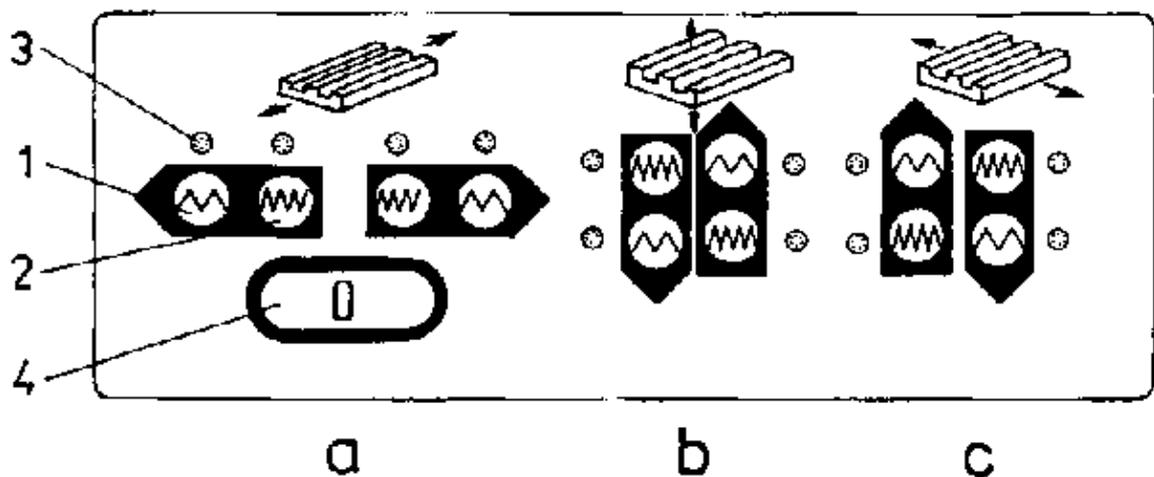


Figure 5/48 Control board with keys for table movement (Example)

- a Keys for longitudinal movement (x-direction),
- b Keys for upward and downward movement of knee (z-direction);
- c Keys for crosswise movement (y-direction);
- 1 Rapid traverse motion, 2 Feed motion, 3 Control lamp, 4 "Off-key

Control questions

1. Explain what has to be understood by the term 'cutting speed' during milling operations?
2. Explain what has to be understood by the term 'feed' during milling operations.
3. What operations are required for the setting of a horizontal knee-and-column type milling machine?
4. What are the effects of unclean milling arbor rings on the clamping of milling cutter on a cutter arbor?
5. What are the effects of the untrue runing of a milling cutter on the quality of machining?
6. Explain the reading of the amount of in-feed motion on a scale ring.
7. Describe the setting of a horizontal knee-and-column type milling machine for milling operations and a milling product which you have produced.

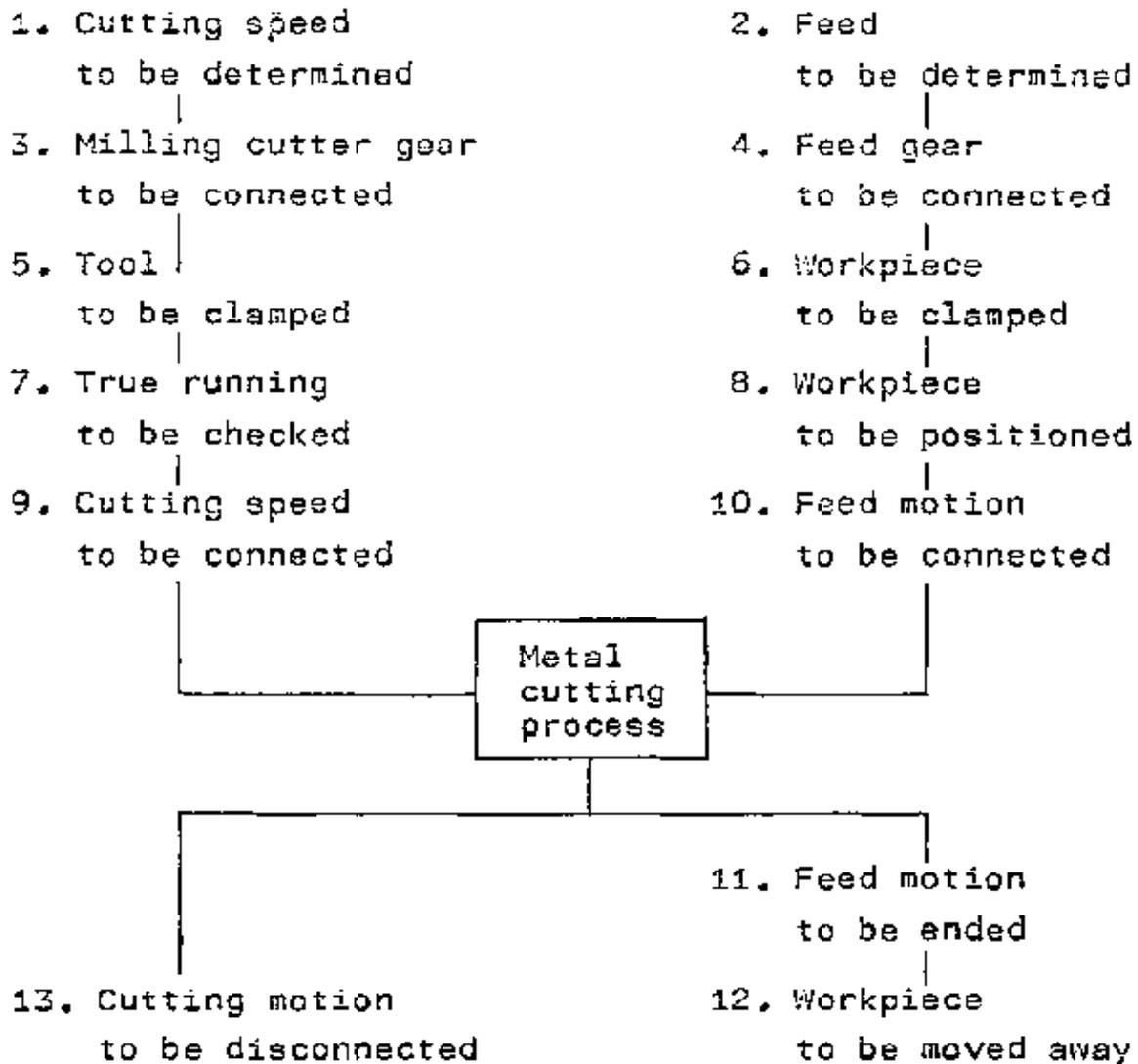


Table 5/2 Setting-in and operating of a horizontal knee-and-column type milling machine

5.3. Vertical knee-and-column type milling machine

In this section you shall get acquainted with

- the components of which vertical knee-and-column type milling machines are composed
- the way of functioning of vertical knee-and-column type milling machines
- the kinds of operations for which vertical knee-and-column type milling machines are used.

5.3.1. Structure and mode of operation

The machine components of a vertical knee-and-column type milling machine

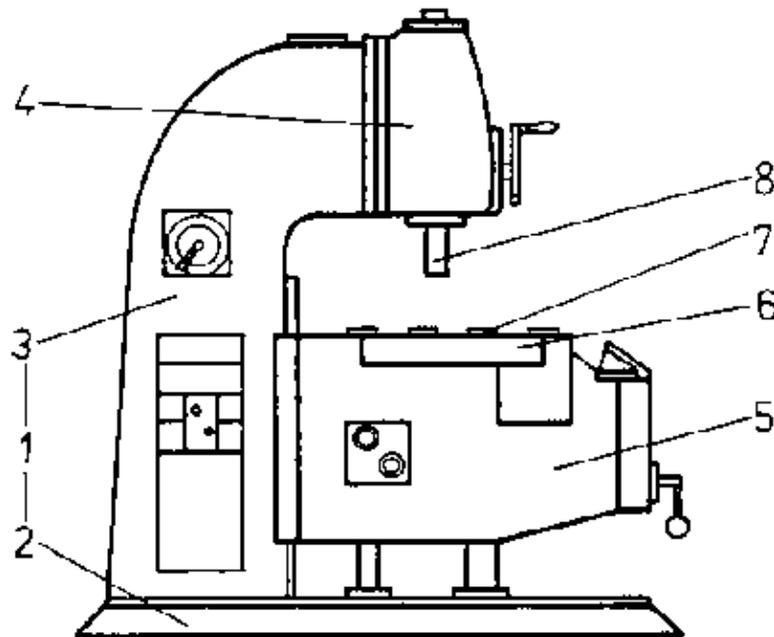


Figure 5/49 Components of a vertical knee-and-column type milling machine

1 Machine frame, 2 Base plate; 3 Column; 4 Milling spindle head; 5 Knee; 6 Saddle; 7 Machine table; 8 Milling spindle.

The machine frame (1) with the base plate (2) and the column (3), the milling spindle head (4), the knee (5), the saddle (6) and the machine table (7) provide the main structure of the machine. The milling spindle (8) lies in a vertical position.

The column accommodates the motor for the cutting motion and the gear for setting the speed of the milling spindle.

The knee includes the motor and the gear for the feed motion. As driving motors there are the same to be found as with horizontal knee-and-column type milling machines and they have the same size.

On account of the great similarity it is possible for the two milling machines to use equal or similar machine components.

This entails providing benefits for the manufacture of the machines.

Mode of operation of a vertical knee-and-column type milling machine

The tool is clamped into the vertical milling spindle. As clamping devices are used arbors for shell end mill, mounting mandrels or arbors, milling chucks; even a direct fastening is feasible.

During milling the tool is turned around its vertical longitudinal axis (cutting motion). The workpiece is clamped on the machine table by using the clamping materials mentioned in Section 5.2.2.

The vertical type of machine is set and operated in the same way as the horizontal knee-and-column type milling machine.

In several designs of machines it is possible for certain purposes to swivel the milling spindle head. In this way the tool can be adapted to the position of a machining surface at the workpiece. A scale with graduation shows the amount of swivelling by which the head of milling spindle has to be turned (Figure 5/50).

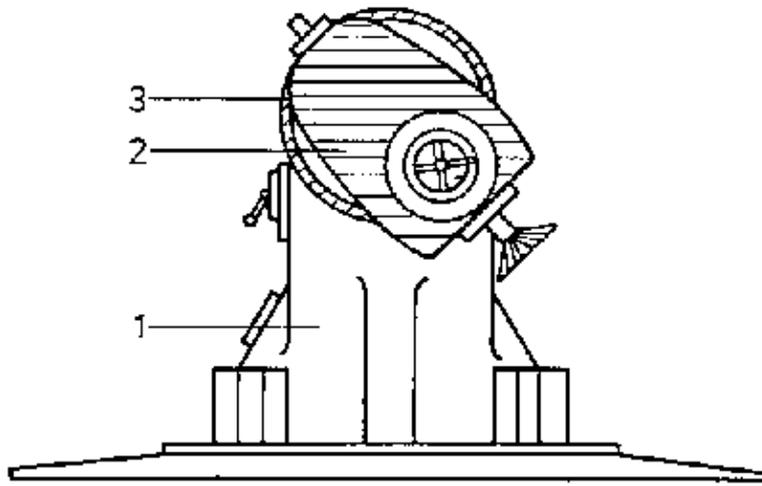


Figure 5/50 Vertical knee-and-column type milling machine with swivelling milling spindle head

1 Column; 2 Milling spindle head; 3 Scale for reading (by how many degrees the milling spindle head was swivelled)

5.3.2. Use of vertical knee-and-column type milling machines

Vertical knee-and-column type milling machines can be used for a great variety of purposes (Figures 5/6, 5/8 and 5/10). They are frequently utilized in machine tool construction. They can be operated with facing cutters and hobbing cutters. Milling heads are frequently used for machining large surfaces (Figure 5/52). These heads are equipped with interchangeable edges (Figures 5/6 and 5/42). If the edges consist of high-quality cutting materials, it is possible to operate at high cutting speeds.

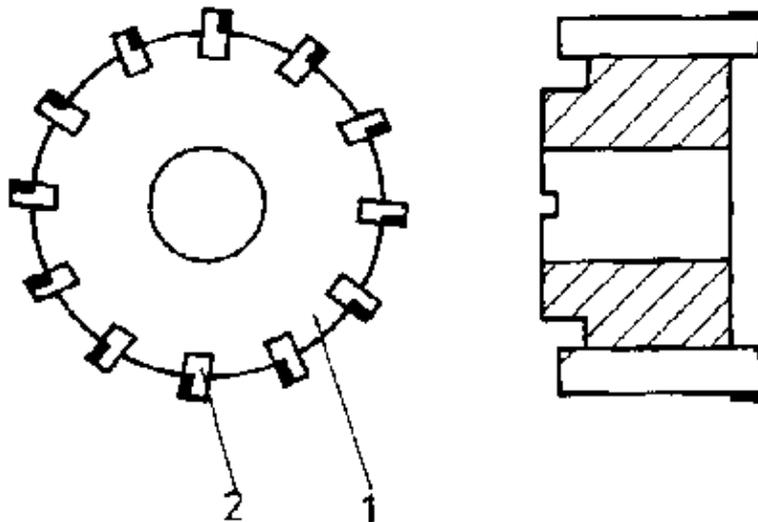


Figure 5/51 Milling head with interchangeable cutting blades (chisels)

1 Basic structure, 2 Cutting blade

Control questions

1. Describe the structure of a vertical knee-and-column type milling machine.
2. Explain the similarities and differences of horizontal and vertical knee-and-column type milling machines.
3. Name several examples of operations and products made on vertical knee-and-column type milling machines.

5.4. Gear cutting machines

In this section you shall get acquainted with

- the mode of operation of gear cutting
- the components of which gear-cutting machines are composed
- the way of functioning of gear-hobbing machines
- the kinds of operations for which gear-cutting machines are used.

5.4.1 Mode of operation of gear cutting

All gear-cutting machines have to comply with the following functions:

- workpiece to be held, positioned, moved forward and fed
- tool to be held, rotated (cutting motion), positioned, moved forward.

In contrast to horizontal and vertical knee-and-column milling machines where only the tool performs the cutting motion, even in gear-cutting machines the tool is positioned and moved forward. For this reason adequate appliances and devices are available.

Single indexing process

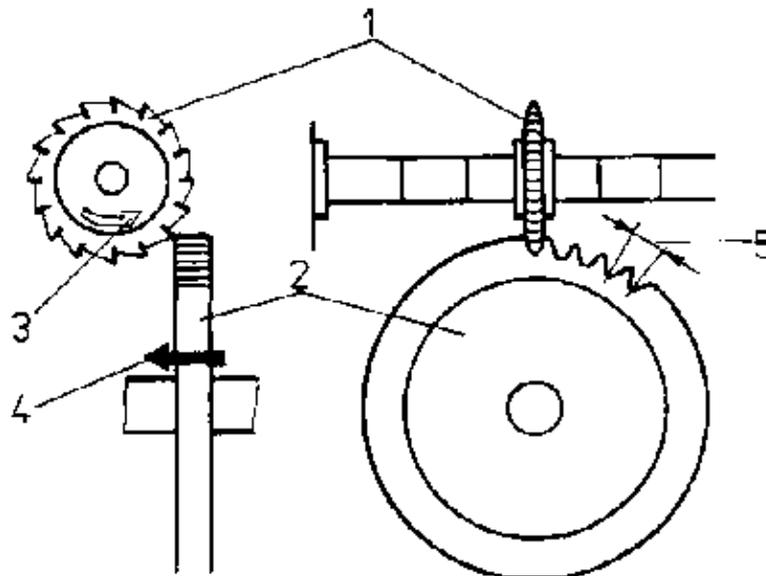


Figure 5/52 Single indexing process

1 Tool, 2 Workpiece, 3 Cutting motion, 4 Feed motion, 5 Partial pitch

In the case of the single-indexing process each tooth is cut individually out of the raw material. The tool, the tooth cutter, corresponds in its profile exactly to the profile of a tooth space. With the help of adequate devices, e.g. the indexing apparatus, the workpiece is fed forward from tooth to tooth, so that a uniform division is achieved around the circumference (Figure 5/52).

Hobbing method

With the hobbing method several teeth are simultaneously cut out of the raw material. The tool, the hobbing cutter, is provided with teeth at the circumference which proceed like threads. As a result, the workpiece is gradually turned further during milling (or hobbing) Figure 5/53. The hobbing cutter and the workpiece rotate in a coercive motion, i.e. the speed of the cutter, the cutting speed, and the speed of workpiece have to be coordinated with each other.

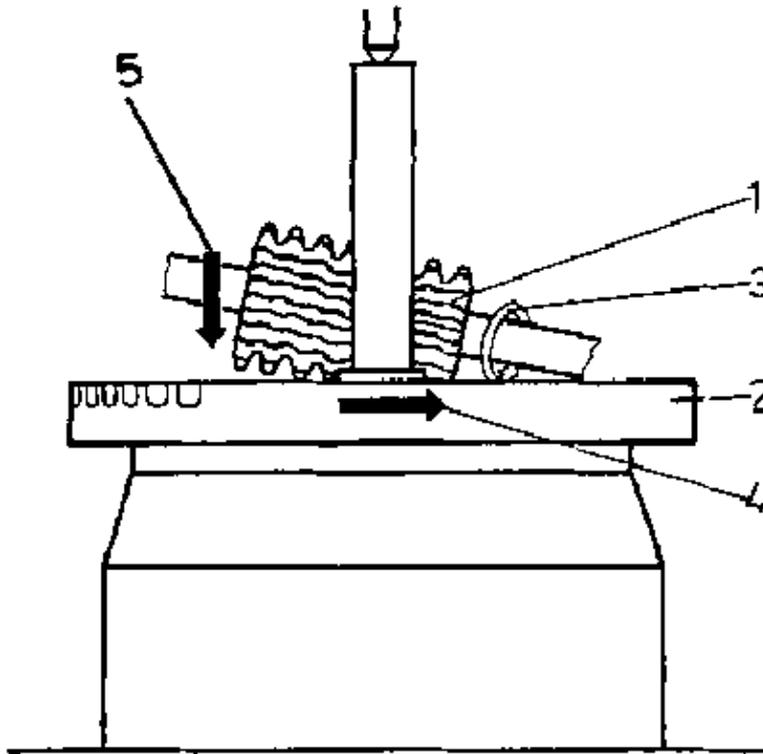


Figure 5/53 Hobbing method

1 Tool, 2 Workpiece, 3 Cutting motion, 4 Feed motion of workpiece, 5 Feed motion of tool.

5.4.2. Components of a gear hobbing machine

Gear hobbing machines are specialized machines. They are exclusively used for the manufacture of tothing. There are gear hobbing machines for only one kind of gear and those for several kinds. The machines are different in size according to the dimensions of the components to be provided with gears.

The gear-hobbing machine (Figure 5/54) shall be treated here in greater detail. It consists of the bed (1), the tool stand (2), the end column (3), the milling head (4), the overarm (5) and the work holder (6).

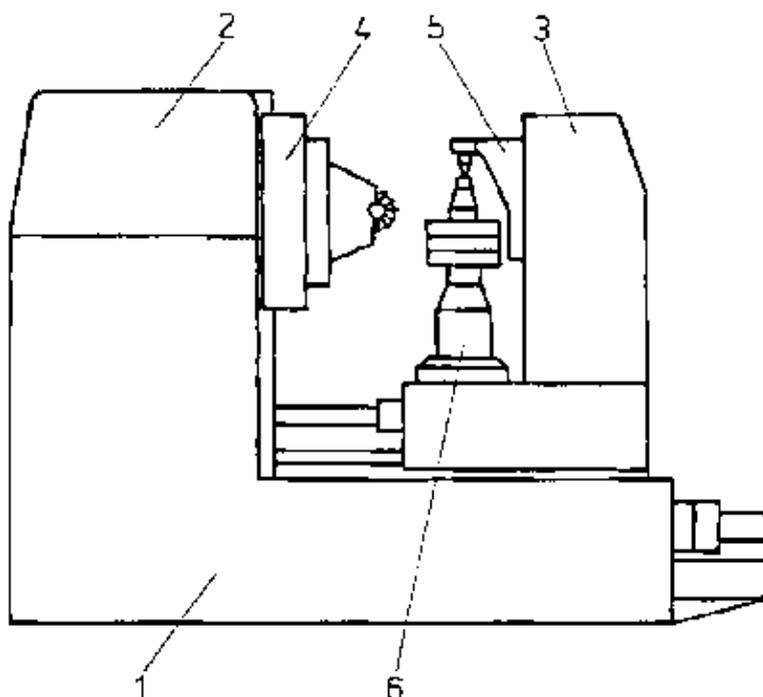


Figure 5/54 Components of a gear hobbing machine

1 Bed; 2 Tool stand; 3 End column; 4 Milling head; 5 Overarm; 6 Work holder.

The driving motor for the milling spindle with cutter is accommodated in the tool stand, or column. The switch gear for adjusting the speed of milling is also accommodated there. The feed motions are taken from the milling spindle gear via feed gear. There has to be constantly a positive drive between the cutting motion and the feed motions. Milling cutter and workpiece have to be always related to each other in a definite situation.

5.4.3. Mode of operation of a gear hobbing machine

The mode of operation of a gear hobbing machine is described according to Figure 5/54.

The workpiece is clamped into a vertical work holder, whereas the hobbing cutter is clamped on the cutter arbor at the milling head. The entire milling head can be actuated upwards and downwards at the tool stand. During milling the cutter begins cutting at the upper edge of workpiece. The workpiece is rotated (rotating feed motion), so that the cutter cuts out the shoulders of gear. At the same time the milling head is slowly moved downwards at the tool stand (straight-lined feed motion). The teeth are continued to be cut and then the gear is completed as the result of interaction of

- the rotating cutting motion of milling cutter
- the rotating feed motion of workpiece
- the straight-lined feed motion of cutter with milling head.

Hobbing cutters gears simultaneously at several tooth spaces. Therefore the method is more productive than the single indexing method where the tooth space is cut out one after the other.

5.4.4. Use of gear hobbing machines

Machine components with teeth are available in a great variety of types. Above all they are to be found in gears and serve for the transmission of motions. In dependence upon the forces to be transmitted the demands on the teeth – dimensional stability, surface grade, indexing accuracy – are different. Generally it can be said that the teeth produced by hobbing are more accurate than those teeth produced by single-indexing methods.

Figure 5/55 Machine components with tothing



a Spur gear with straight tothing



b Bevel gear



c Gear rack



d Worm gear

Control questions

1. Describe the mode of operation

- of the single-indexing method
- of the hobbing method.

2. Explain the structure of a gear hobbing machine.

3. Under what conditions is it possible to use horizontal and vertical knee-and-column type milling machines for the cutting of gear?

5.5. Thread milling machines

In this section you shall get acquainted with

- the mode of operation of thread milling
- the components of which thread milling machines are composed
- the way of functioning of thread milling machines
- the jobs for which thread milling machines are used.

5.5.1. Mode of operation of thread milling

All thread milling machines have to comply with the following functions:

- workpiece to be clamped and to be fed
- tool to be clamped, rotated (cutting motion), positioned, fed-in and advanced.

The motions required for thread milling have to proceed in a positive drive. The most important indicator is the pitch of thread to be milled.

You can distinguish two thread milling methods, i.e.

- long-thread milling
- short-thread milling.

In long-thread milling (Figure 5/55) the thread is cut by means of a thread cutter (3) out of the workpiece (1). The thread cutter has the profile of the thread. It performs the rotary cutting motion (4). The workpiece rotates also in the same direction (2), it carries out the rotating feed motion. In accordance with the pitch of the thread to be milled, the milling head with the cutter is moved along the workpiece (5), According to the lead angle of thread the milling spindle has to be swivelled vis-à-vis the workpiece (Figure 5/13).

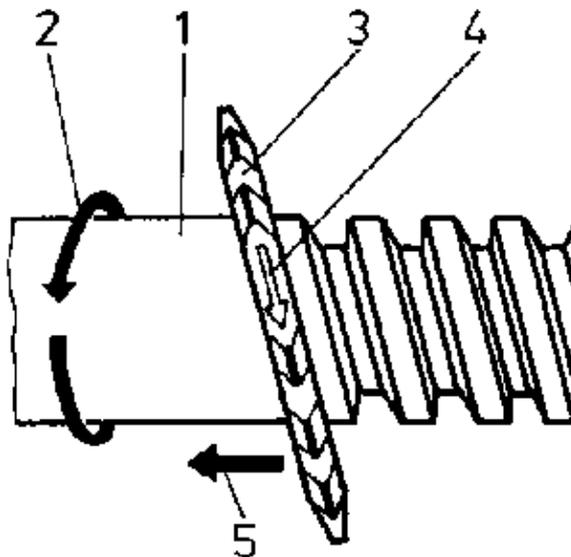


Figure 5/56 Mode of operation of long-thread milling

1 Workpiece, 2 Rotational direction of workpiece, 3 Thread cutter, 4 Rotational direction of tool; 5 Direction into which the carriage at workpiece has to be pushed forward.

In short-thread milling (Figure 5/57) the thread is cut by means of a short-thread cutter (3) all at once over the entire length of thread. The short-thread cutter attacks the workpiece (1) with its entire length. During milling the workpiece is once fully rotated (2), it carries out the rotating feed motion. During this period the milling cutter is moved forward in axial direction by the amount of pitch (5); it carries out the straight-lined feed motion.

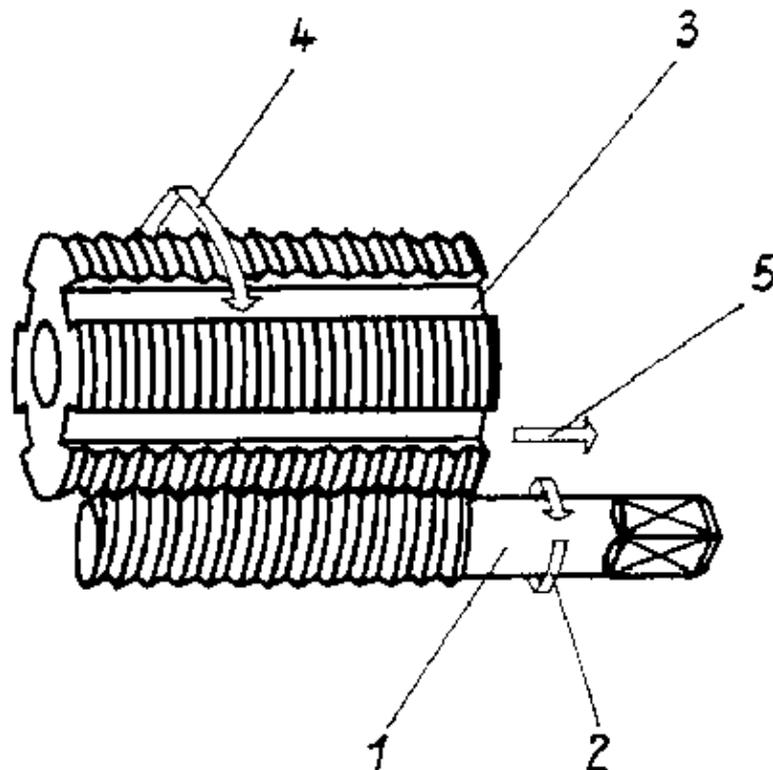


Figure 5/57 Mode of operation of short-thread milling

1 Workpiece, 2 Rotational direction of workpiece (one full rotation), 3 Short-thread cutter, 4 Rotational direction of tool, 5 Direction into which the milling cutter is pushed forward during the full rotation of workpiece.

5.5.2. Components of a long–thread milling machine

From the outside a long–thread milling machine looks like sliding and screwcutting lathe (Figure 5/58). It consists of the bed (1), the workpiece headstock (2), the saddle (3) and the tailstock (4). The workpiece headstock accommodates the gear for the rotating feed motion of workpiece and the straight–lined feed motion of the saddle with milling cutter.

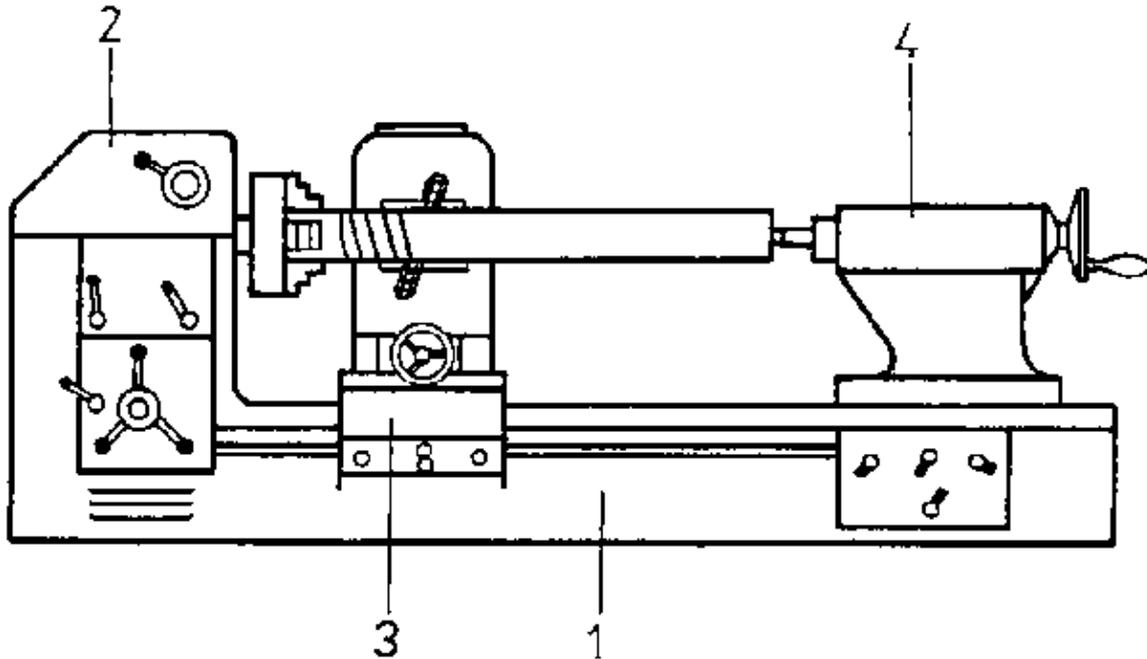


Figure 5/58 Components of a long–thread milling machine

1 Machine bed, 2 Workpiece headstock, 3 Saddle, 4 Tailstock.

According to the thread to be cut it is possible to set the size of the two motions, the feed, at these gears. The motor for the drive of the feed motions is accommodated in the workpiece headstock, or mounted outside.

The milling spindle with cutter is arranged at the saddle. The saddle accommodates the gear for switching the cutting motion.

The motor for the cutting motion is also accommodated at the saddle.

5.5.3. Mode of operation of a long–thread milling machine

The workpiece – it is mostly a long threaded spindle (lead screw) – is clamped into the work–clamping device at the workpiece headstock. At the opposite end the long workpiece is supported by the tailstock. The milling cutter is clamped into the saddle. The speed of the cutting motion is set at the milling spindle gear.

During milling the workpiece is rotated by the machine. The milling cutter is adjusted to the depth of milling desired. The lead screw accommodated in the machine bed pulls the saddle in such a way that it travels along accurately in accordance with the pitch of thread. According to the depth of thread grooves several production stages are required. It is important that the milling cutter continues its cutting exactly at the thread groove during the next consecutive operation. Special appliances provide for the compensation for clearance between lead screw and nut.

5.5.4. Use of long–thread and short–thread milling machines

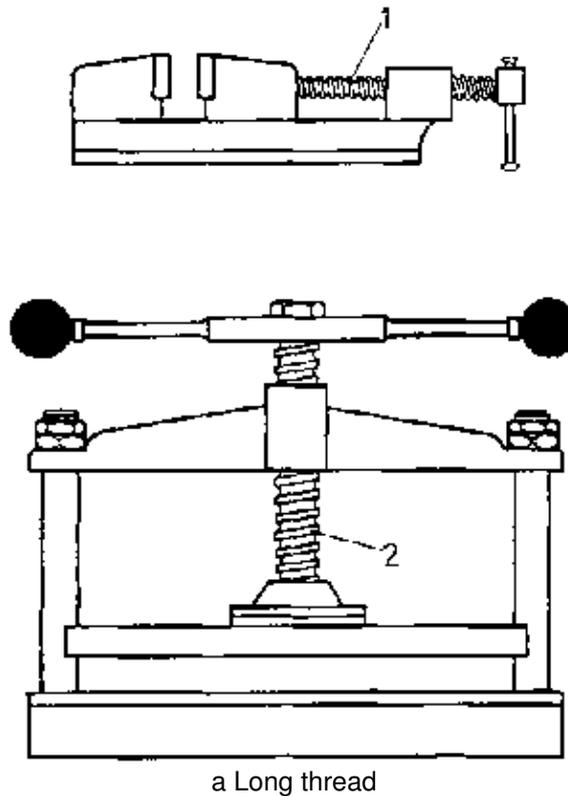
The long–thread milling machine is mainly used for the milling of single–threaded and multi–threaded workpieces, e.g. at

- lead screws,
- vice spindles,
- spindles at lifting gear,
- spindles at presses,
- adjusting spindles at slide rests.

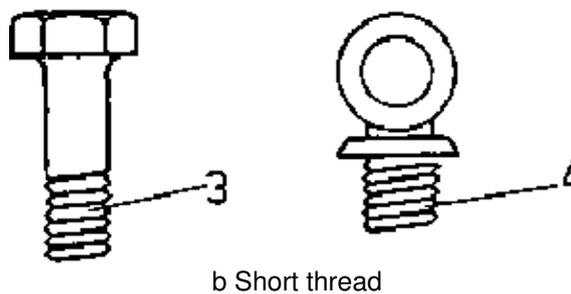
The range of application can be extended with the help of additional devices.

Short-thread milling, although it is more productive compared with long-thread milling, is superseded by the more beneficial thread rolling in mass production. Thread rolling is a chipless method producing threads by metal forming.

Figure 5/59 Examples of operations of a thread-cutting machine



1 Vice spindle, 2 Press spindle



3 Hexagonal head bolt, 4 Carrying bolt.

Control questions

1. Describe the mode of operation of

- long-thread milling
- short-thread milling.

2. Why is it necessary for the two feed motions, workpiece and tool, to have a positive drive towards each other?
3. Explain the structure of a long–thread milling machine.
4. What are the common features and what are the differences between a long–thread milling machine and a sliding and scrawcutting lathe?

5.6. Servicing and maintenance of milling machines and tools

Please, observe the "General Instructions on the Servicing and Maintenance of Metal Cutting Machine Tools" (Section 2.4.).

Prior to cleaning, lubricating and controlling operations it is required to switch off the machine!

Cleaning

1. Metal chips and coolant to be removed from the machine, e.g. from the table and the operating desks and in front of the machine. Hand broom and cleaning rag to be used because of the danger of injuries!
2. Grooves in the table to be scraped with a suitable piece of sheet metal.
3. Bright components of machine, e.g. tool–clamping devices and operating and controlling units, to be cleaned and slightly oiled.
4. Filters of coolant pump and coolant container to be cleaned.

Lubricating

1. Oil level in gear to be controlled! Oil to be refilled, if required.
2. Lubricating points to be supplied with oil or grease according to lubricating schedule.
3. Guideways at knee to be cleaned, to be slightly oiled and oil to be evenly distributed.
4. After lubrication oil and grease splashes to be carefully removed from floor.

Controlling

1. Clearance of milling spindle to be controlled! Supports to be readjusted, if clearance is too big.
2. Guideways at knee to be controlled. Guide bars to be readjusted and clearance to be compensated.
3. Switchability of gear to be controlled and adjusted, if required.
4. Belt tension to be controlled, if there is a belt gear (to be readjusted, if required).
5. Electric connections to be controlled! Supply lines to be safeguarded.

Treatment of tools

1. Tools to be deposited on wooden boards, or on rags.
2. Tools to be deposited in a way that the cutting edges do not damage each other.
3. After use metal chips and residual coolant to be removed, space between teeth to be observed!
4. Blunt tools to be re–ground in time! Otherwise the load on the machine is too high. Great heat arises and there is the danger of a breakage of tools.

5. Tools with carbide edges or ceramic tips to be protected from jolts and percussion; Hard metal edges and ceramic tips are sensitive and break easily.

6. During metal cutting it is essential to provide always for sufficient cooling and lubrication.

5.7. Work safety in operating milling machines

Please, observe the "General Instructions and Rules on Work Safety" (Section 2.5.).

To protect from accidents it is required to observe the following rules in connection with the operation of knee-and-column type milling machines:

1. High-speed milling cutters to be safeguarded by protective devices! There is the danger by metal chips flying around.

2. During work metal chips shall not be removed during milling, but only during stationary milling cutter. The danger is that the instruments for removing metal chips come within the operating range of cutter.

3. Metal chips never to be removed by hand!

4. Workpiece to be measured only when milling cutter is not in operation, but never during milling operations!

5. Prior to change of milling cutter machine to be switched off!

6. Tools for the clamping and unclamping of clamping devices not to be deposited on the machine after use, but only on a separate shelf (table or cupboard).

7. The sleeves of working clothes and jacket have to cling tightly to the body, so that they are out of reach of the machine.

8. The hair of the head or the beard is not allowed to dangle, suitable clothing has to be used.

9. Protective covers and gratings that were taken off for the servicing of machine have always, to be re-attached, before the machine is switched on.

6. Shaping and planing machines

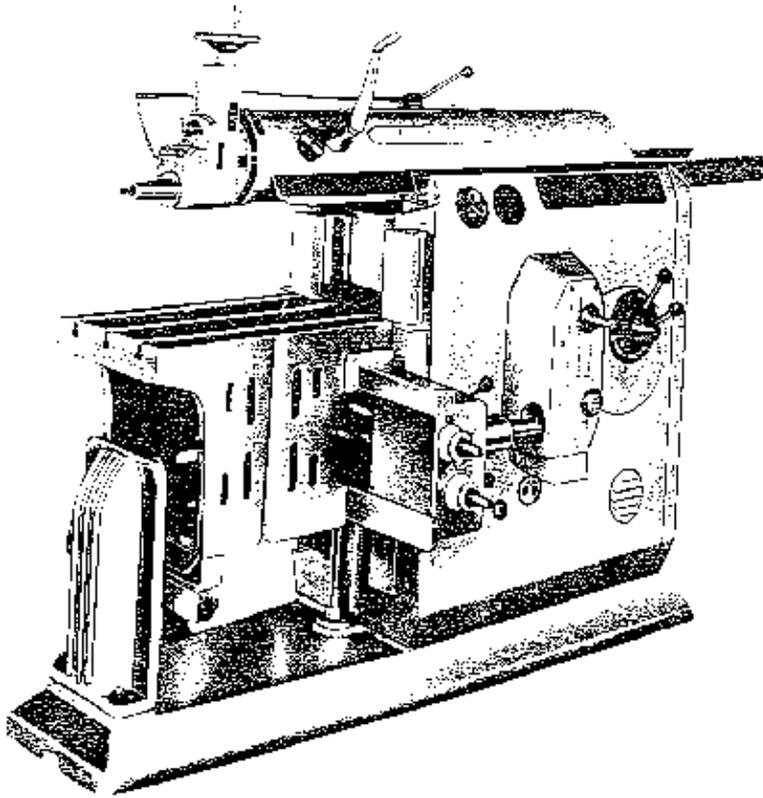


Figure 6/1 Horizontal shaper manufactured in the German Democratic Republic

6.1. Survey of types and use of shaping and planing machines

In this section you shall get acquainted with

- the types of machines used for shaping and slotting operations and those machines used for planing operations
- the kinds of movements performed by shaping machines and those performed by planing machines
- the types of jobs to be executed by shaping machines and those executed by planing machines.

6.1.1. Several types of shaping and planing machines

Shaping machines

Shaping machines are classified as to the level of cutting motion as

- horizontal shaping machines
- vertical shaping, or slotting machines

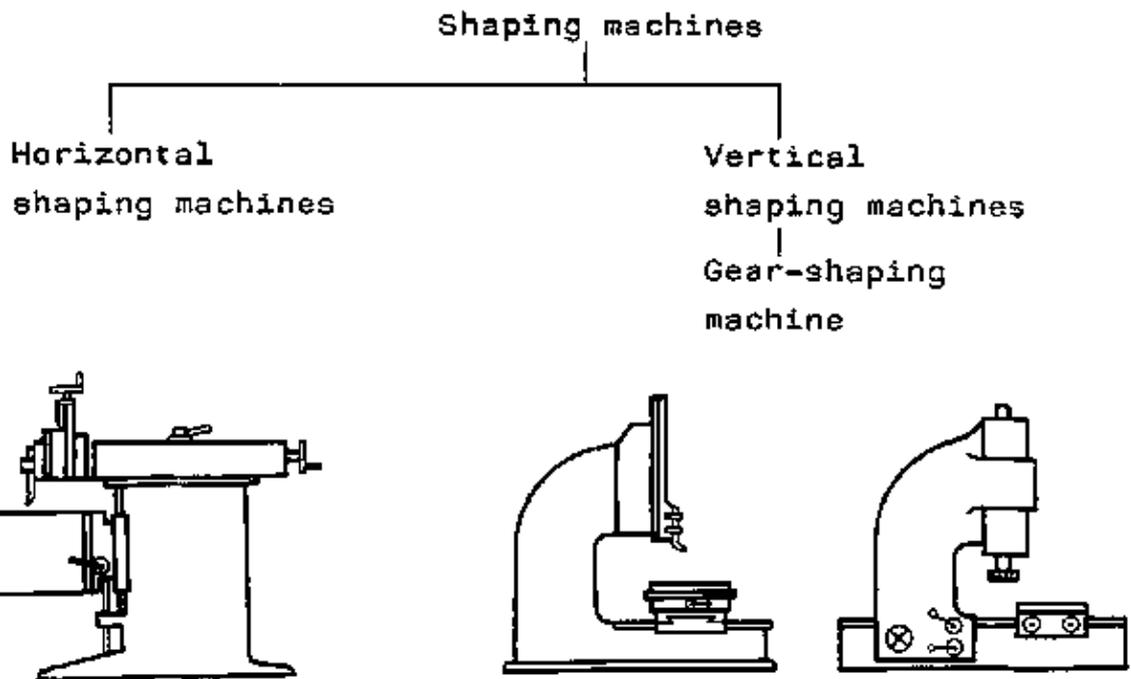


Table 6/1 The types of shaping machines classified according to cutting motion

Planing machines

According to the number of columns you distinguish

- open-side planing machines
- two-column planing machines.

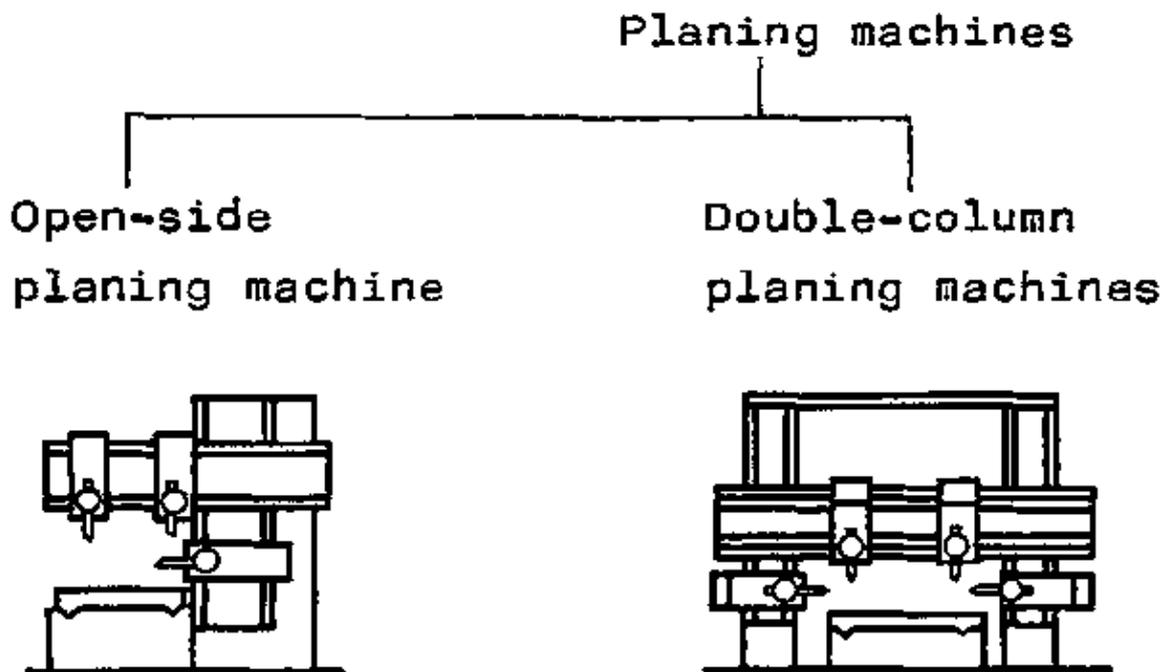


Table 6/2 The types of planing machines classified according to number of columns

6.1.2. Motions of shaping machines

Cutting motion

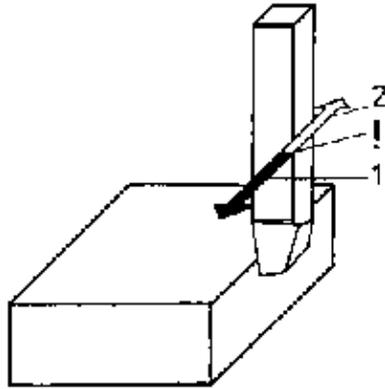


Figure 6/2 Cutting motion during horizontal shaping

1 Forward stroke, 2 Backward stroke

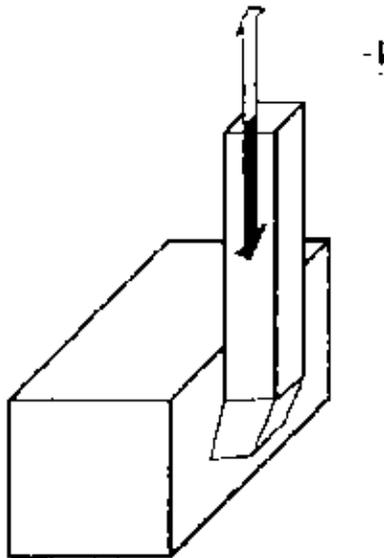


Figure 6/3 Cutting motion during vertical shaping

Cutting motion in shaping is a straight-lined motion. It is performed by the tool. In horizontal shaping this motion proceeds horizontally to and fro, in slotting this motion proceeds upwards and downwards.

Feed motion

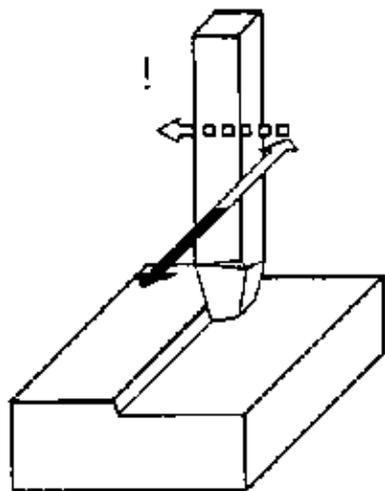


Figure 6/4 Feed motion during horizontal shaping

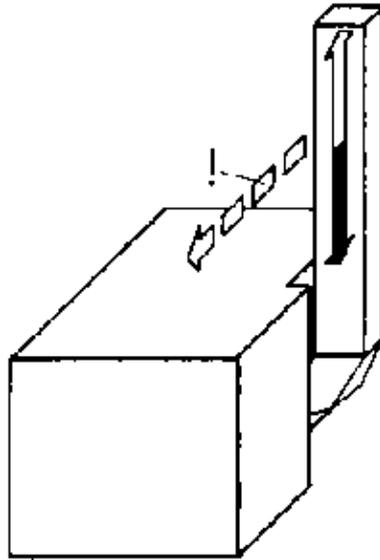


Figure 6/5 Feed motion during vertical shaping

Feed motion in shaping is a straight-lined motion. It is performed by the workpiece and proceeds crosswise to the direction of the cutting motion.

In-feed motion

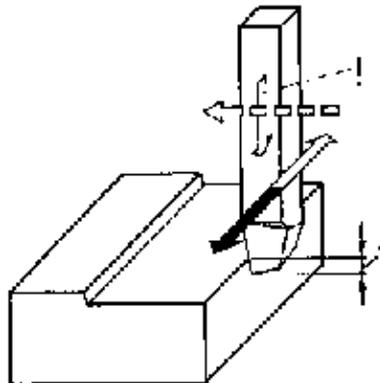


Figure 6/6 In-feed motion during vertical shaping

1 – Feed-in amount

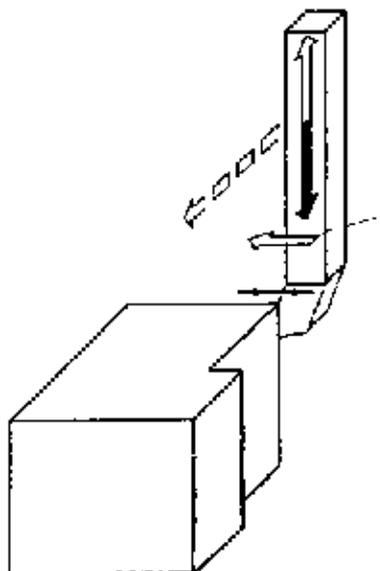


Figure 6/7 In-feed motion during vertical shaping

The in-feed motion in shaping is a straight-lined motion. It is performed by the tool and proceeds crosswise to the direction of the cutting motion and the feed motion.

6.1.3. Motions of planing machines

Cutting motion

The cutting motion in planing is a straight-lined motion. It is performed by the workpiece.

Feed motion

The feed motion in planing is a straight-lined motion. It is performed by the tool and proceeds crosswise to the direction of the cutting motion.

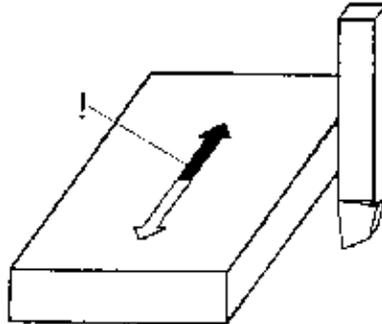


Figure 6/8 Cutting motion during planing

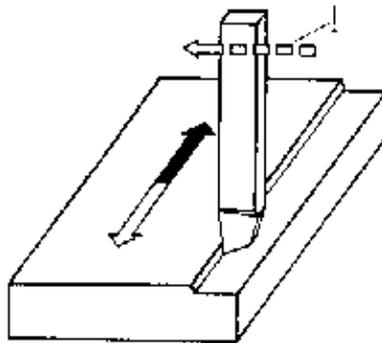


Figure 6/9 Feed motion during planing

In-feed motion

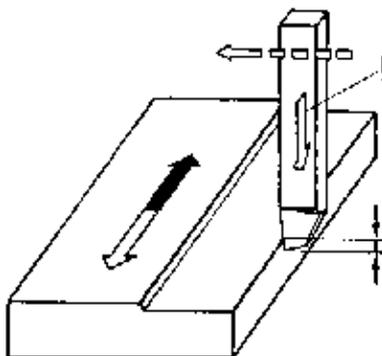


Figure 6/10 In-feed motion during planing

The in-feed motion in planing is a straight-lined motion. It is performed by the tool and proceeds crosswise to the direction of the cutting motion and the feed motion.

6.1.4. Examples of operations on shaping machines

Flat shaping a surface

Figure 6/11 shows a surface with square cross-section (1). The support surface is clamped into a machine vice (2). The surface (3) of the support was machined with a horizontal slotting tool (4). The surface that was last machined is indicated.

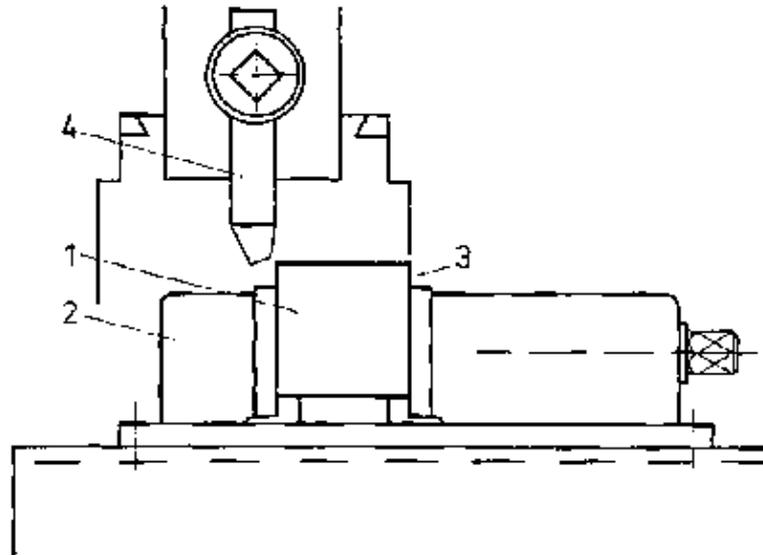


Figure 6/11 Flat shaping a surface

1 Surface with square cross-section, 2 Machine vice 3 Cylindrical surface, 4 Slotting tool.

Groove cutting into a wheel hub

Figure 6/12 shows a wheel (1). The wheel is clamped with setscrew (2) onto the machine table (3). A groove (5) was cut into the hub (4) of wheel.

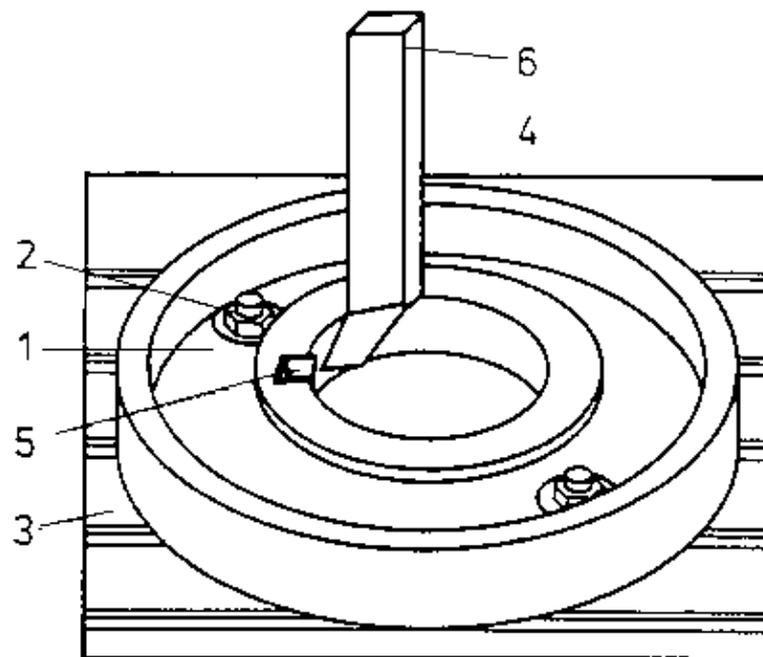


Figure 6/12 Groove cutting into a wheel hub

1 Wheel, 2 Locking screws, 3 Machine table, 4 Hub, 5 Groove, 6 Slotting tool

Shaping the tothing of a tooth wheel

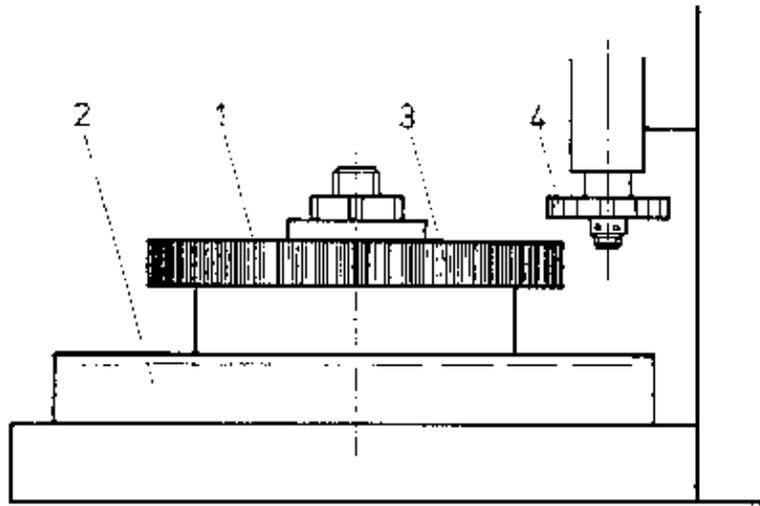


Figure 6/13 Shaping the gearing of a toothed wheel

1 Toothed wheel with spur gearing, 2 Round table, 3 Tothing, 4 Slotting tool

Figure 6/13 shows a tooth wheel with spur gearing (1). The tooth wheel is clamped on the round table (2). The tothing (3) was shaped by means of a slotting tool (4).

Planing a base plate

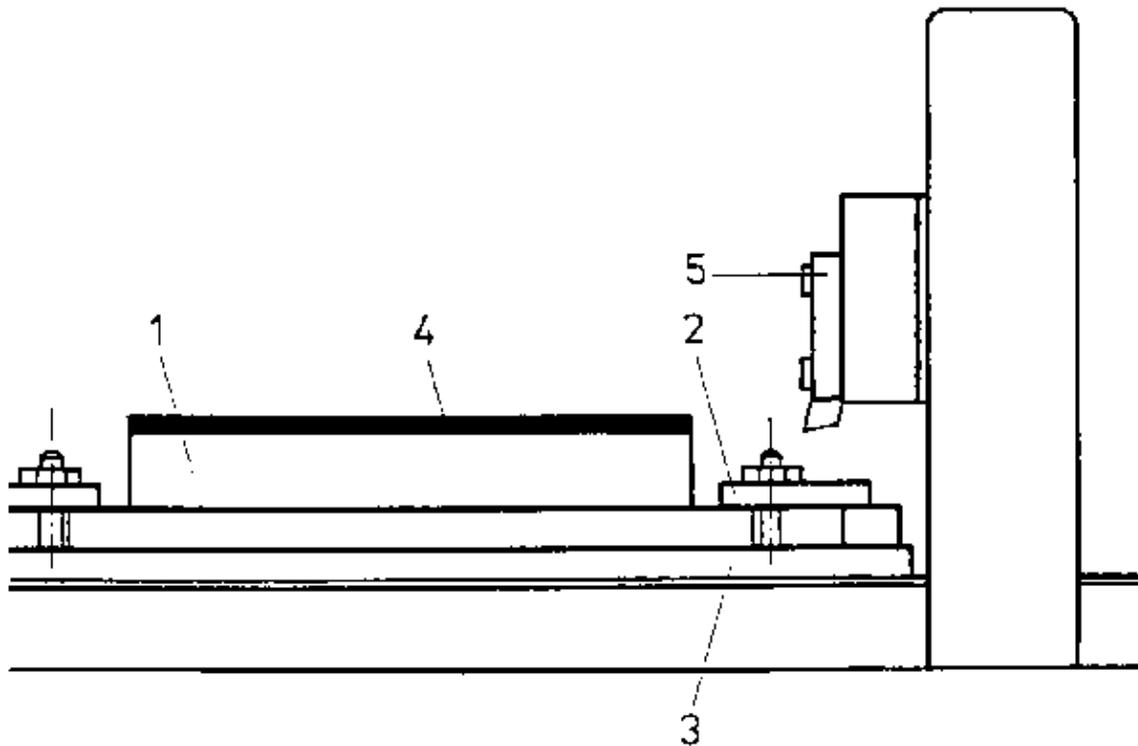


Figure 6/14 Planing a base plate

1 Base plate, 2 Clamping straps, 3 Machine table, 4 Surface planed, 5 Planing tool.

Figure 6/14 shows a base plate (1). The base plate is clamped on the machine table (3) by means of clamping straps (2). The upper surface (4) of the base plate was planed with a planing tool (5).

Planing a casing

Figure 6/15 shows a casing (1). The casing is clamped on the machine table (3) by means of clamping straps (2). A surface (4) on the side of the casing was planed with a planing tool (5).

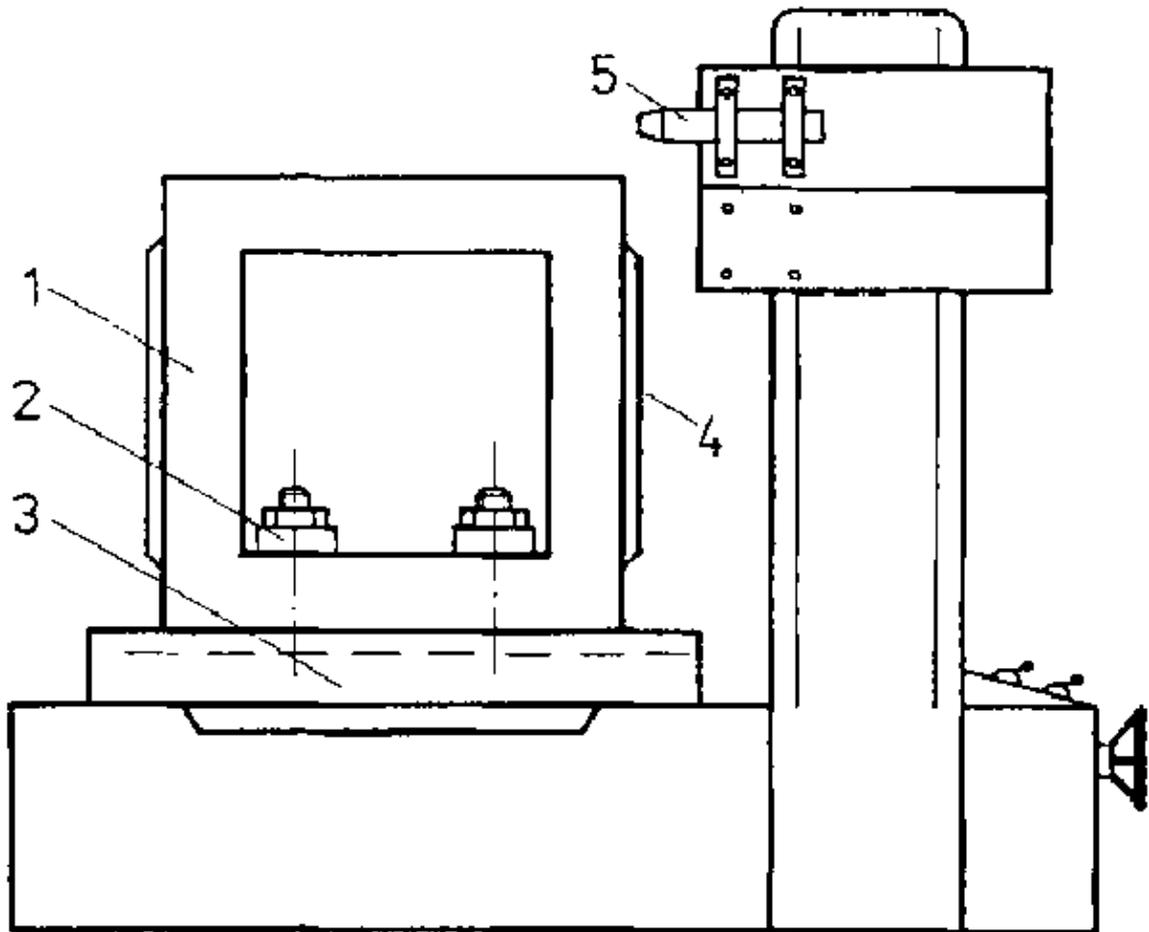


Figure 6/15 Planing a casing

1 Base plate, 2 Clamping straps, 3 Machine table, 4 Lateral surface of casing, 5 Planing tool.

Control questions

1. Name several shapers and planers.
2. Name workpieces that are preferably machined on these machines.
3. What movements are developed
 - during shaping
 - during planing?
4. Name workpieces that have been machined in your enterprise
 - on shapers
 - on planers.

6.2. Horizontal shaper

6.2.1. Structure and mode of operation

In this section you shall get acquainted with

- the machine components of which horizontal shapers are composed
- the types of drives used to drive horizontal shapers

- the types of mechanisms of transfer used to transform motor movement into production movement.
- the kind of interaction between the parts of motor and the production mechanisms.

Machine components of a horizontal shaper

The machine frame (1) provides the basic structure of machine. It consists of a box-type hollow structure. The shaping tool (2) is actuated back and forth on the machine frame. At the front side of the machine frame there is the table (3).

The shaping tool is provided with the tool head (4) and the tool holder (5). It is actuated in firm guideways (6) because the machining forces come up intermittently during shaping. The tool head accommodates the in-feed device (7) for the tool. The table is also moved in firm guideways (8). The table is adjustable up and down and back and forth. For this purpose it is provided with a height adjustment (9) and a lateral adjustment (10).

Inside the machine frame there are the mechanisms for the drive of the shaping tool (cutting motion) and the table (feed motion).

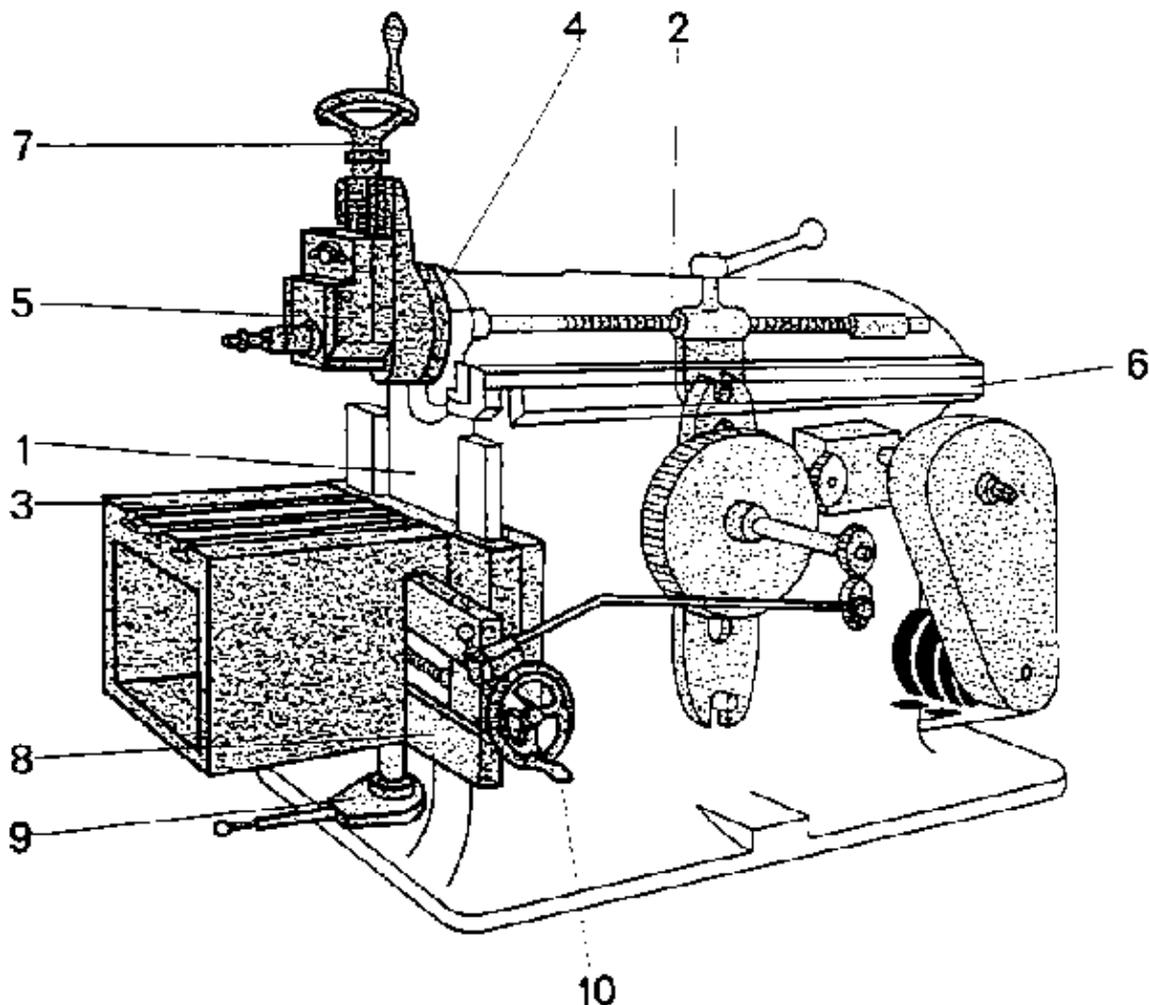


Figure 6/16 Components of a horizontal shaper

1 Machine frame, 2 Ram, 3 Table, 4 Ram face, 5 Tool holder, 6 Guideways for ram, 7 In-feed device for tool, 8 Guideways for table, 9 Height adjustment, 10 Lateral adjustment.

Drive of the horizontal shaping machine

The drive is done by electric motor attached to the rear-side of the machine frame. It is not general practice to have several motors for a separate drive of cutting and feed motions at horizontal shaping machines.

Mechanisms of transfer of a horizontal shaping machine

Horizontal shaping machines have a straight-lined cutting movement performed by the shaping tool actuated back and forth in a straight line. The rotary drive motion of the electric motor is converted into a straight-lined back-and-forth motion via belt gear (1), toothed-gear drive (2) and oscillating crank-gear (3) (Figure 6/17).

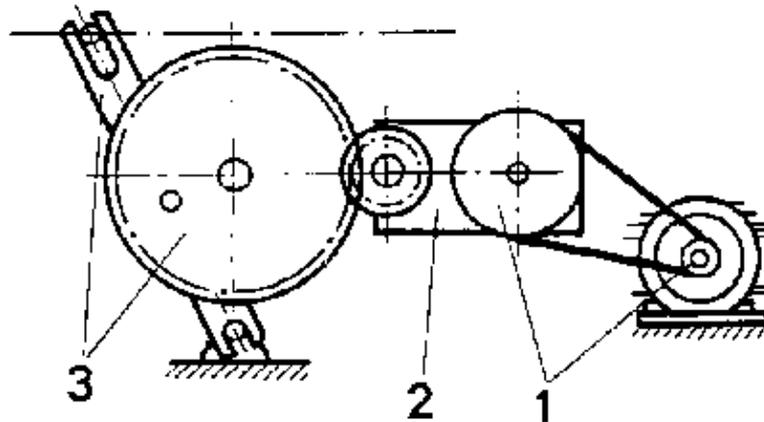


Figure 6/17 Mechanism of transfer (simplified)

1 Belt drive, 2 Toothed gear drive, 3 Oscillating crank-gear.

Mode of operation of a horizontal shaping machine

The mode of operation of the oscillating crank gear is that the tool during the working stroke (forward stroke) is slowly actuated and quickly actuated during no-load stroke (back stroke).

Figure 6/18 shows clearly that the distance to be travelled by the crank pin during working stroke is larger than the distance during no-load stroke. Since the speed of the crank cam is constant, a longer time is required for the working stroke than for the no-load stroke.

The speeds of the crank cam can be adjusted in steps by the gear. This changes also the number of strokes per unit of time. The length of stroke is changed by adjusting the crank pin in the crank cam towards outside (stroke is longer), or towards inside (stroke becomes shorter).

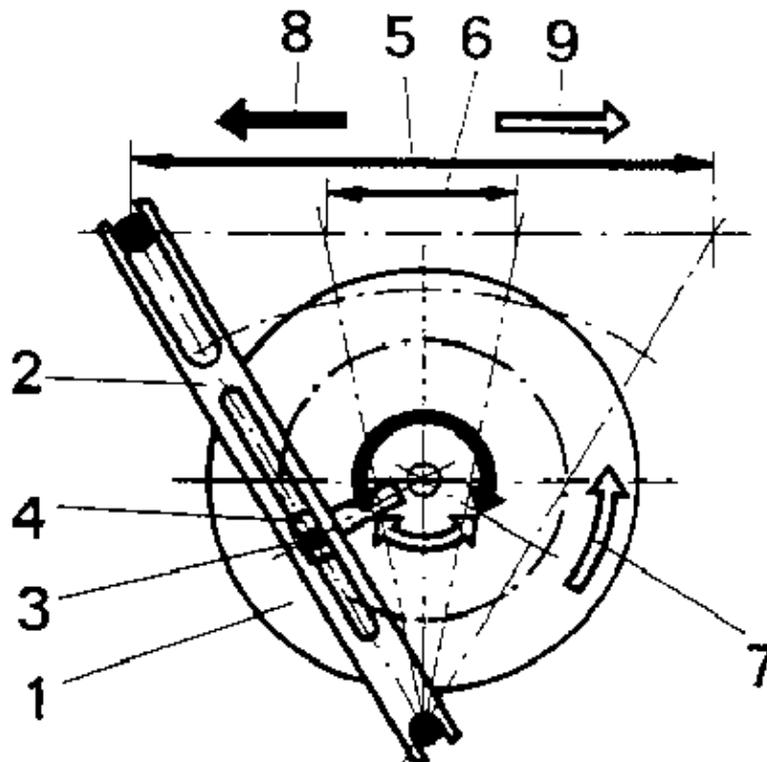


Figure 6/18 Function of the oscillating crank-gear

1 Crank cam, 2 Rocker arm, 3 Crank pin, 4 Sliding block, 5 Largest stroke, 6 Smallest stroke, 7 Rotational direction of crank cam, 8 Direction of working stroke, 9 Direction of no-load stroke.

The automatic feed motion of table (Figure 6/19) is taken off from the crank shaft via stroke disk (1). The stroke disk has the crank pin (2) which is connected with the push bar (3). The push bar actuates a catch mechanism (4) back and forth. According to the position of catch, the switch wheel (5) is turned stepwise left or right in the circle. Stroke disk and crank cam are arranged to each other in a way that the feed motion of table proceeds always during no-load stroke.

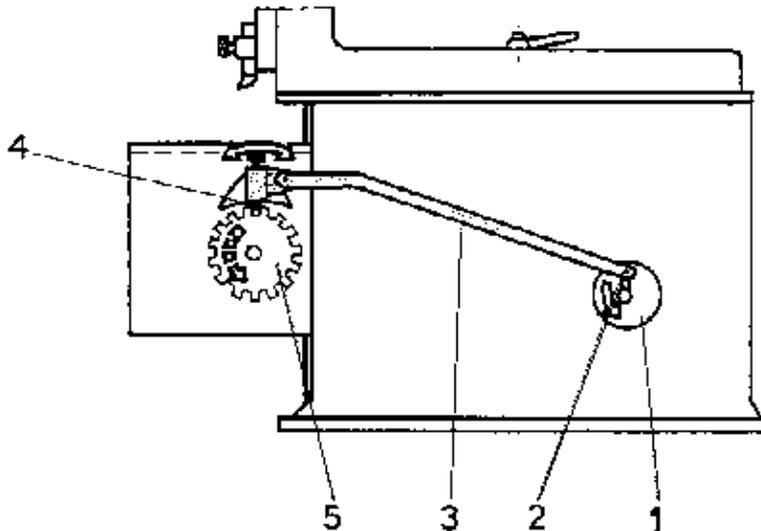


Figure 6/19 Feed device

1 Crank gear, 2 Crank pin, 3 Connecting rod, 4 Catch mechanism, 5 Switch wheel.

Control questions

1. Describe the structure of a horizontal shaping machine.
2. Describe the mechanisms through which the driving movement of the motor is transmitted to the tool.
3. what about the readjustment of the length of stroke?
4. What about the functions of the automatic feed mechanism?
5. Describe how and by what means the size of feed can be changed.

6.2.2. Clamping devices for workpieces and their use

In this section you shall get acquainted with

- the kind of functions fulfilled by work-clamping devices on horizontal shaping machines
- the various kinds of work-clamping devices available
- the way of functioning of work-clamping devices
- the types of work-clamping devices that are preferably used for definite kinds of workpieces.

Tasks of clamping devices for workpieces

The work-clamping devices have to clamp so tightly that the machining forces which set in jerkily are not able to change the position of the workpiece.

During shaping the slotting tool feeds into the workpiece with its entire cutting cross-section. As a result a jerk is produced. The clamping holders have to be solidly built, so that they are able to absorb these jerky forces. They are not allowed to impede the tool during the working stroke and the no-load stroke. A clamping device

should be possibly fastened on the machine table in a way that the workpiece is pressed against a firm part of the holder by the machining forces.

Clamping and unclamping the workpiece are nonproductive times, therefore these operations should not require much time.

Design of the machine table

The machine table is built in a very robust manner. It is provided with T-slots at the upper side into which setscrews can be inserted. With the help of setscrews it is possible to clamp suitable workpieces directly on the table.

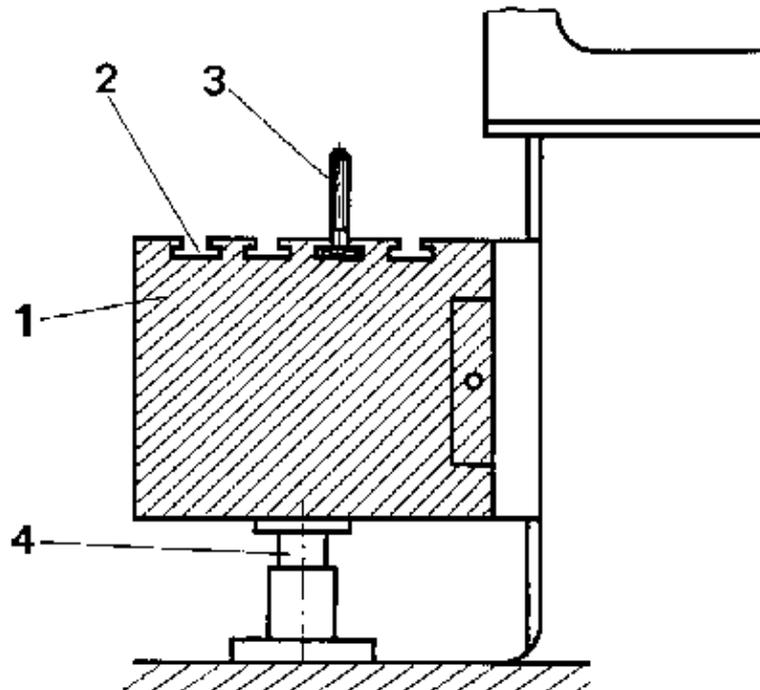


Figure 6/20 Machine table of a horizontal shaper with workpiece held by clamping bolts

1 Machine table, 2 T-slots, 3 Drawbolt with head, fitting to T-slot, 4 Support

Prior to the insertion of setscrews it is necessary to clean the t-slots. Metal chips between screw head and slot give rise to a spring seat, so that the workpiece cannot be sufficiently clamped. In addition it is possible for the setscrews to get jammed so that it is difficult to turn them.

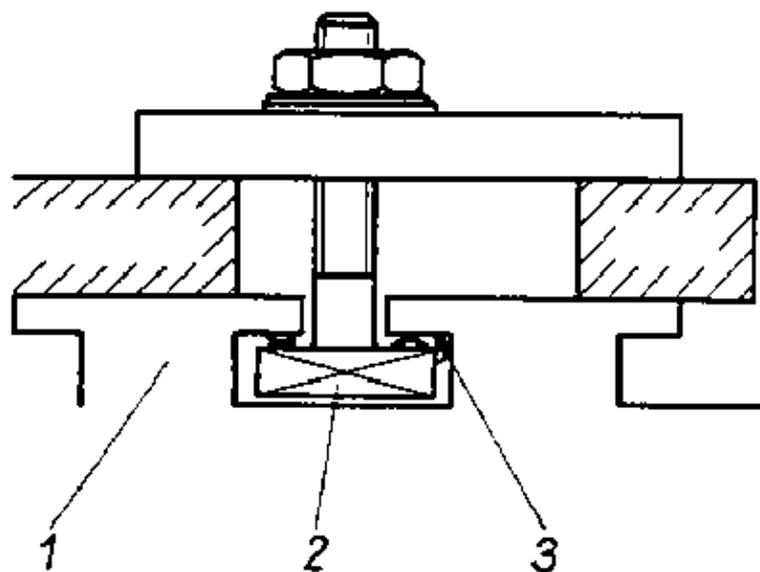


Figure 6/21 Chips in the T-slots of the machine table

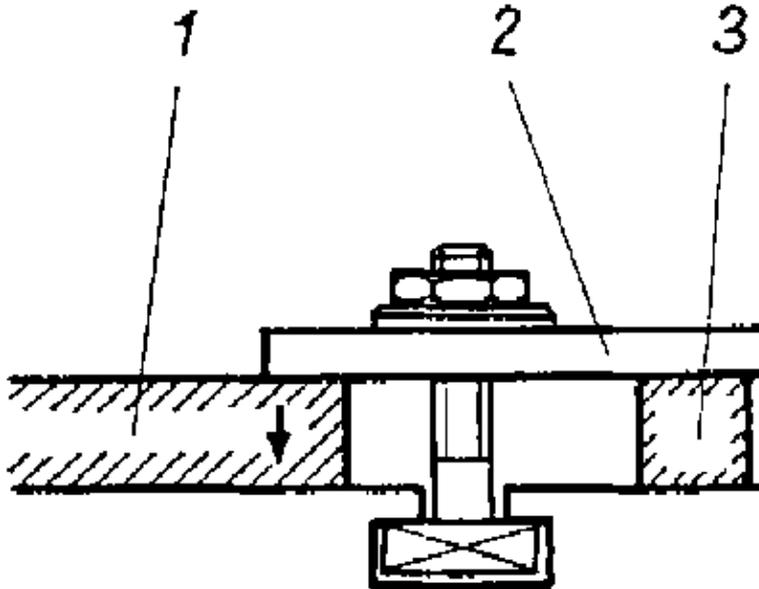
1 Machine table, 2 Drawbolt, 3 Chips impeding the firm clamping of workpiece.

T-slots to be cleaned prior to insertion into setscrews, because there is the danger of accidents! There is damage to tool and workpiece.

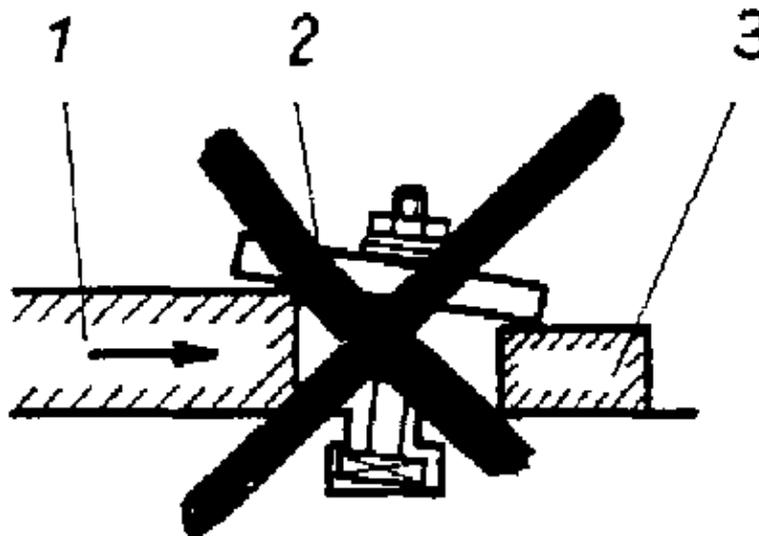
Clamping straps

Clamping straps are used in connection with setscrews. They transmit the forces from the screw to the workpiece and press it firmly against the machine table. The workpiece has to be shaped in a way that several clamping straps can conveniently be positioned on one side without impeding the tool. With the other side the clamping straps are based on clamping supports. The clamping support and the spot at the workpiece on which the clamping strap lies have to be of the same height.

Figure 6/22 Clamping straps to be used correctly!



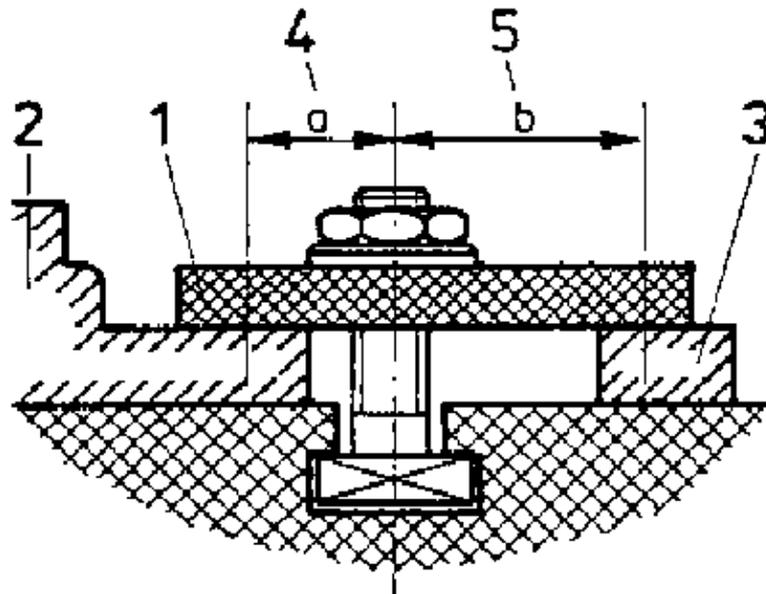
a Clamping strap lies parallel to machine table: Workpiece is safely held



b Clamping strap lies obliquely to machine table: Workpiece is no longer safely clamped.

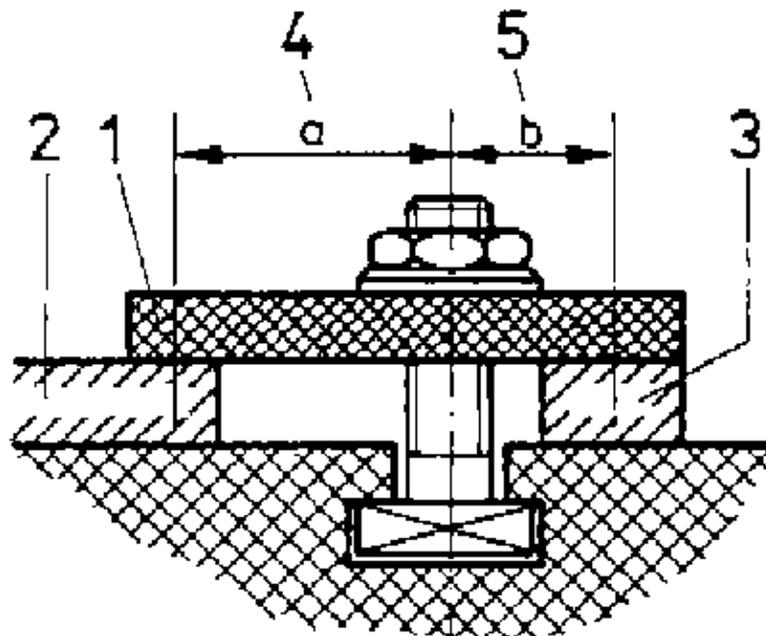
In order to utilize lever action the clamping strap is applied in a way that the long lever comes to lie between setscrew and support, whereas the short lever is between setscrew and workpiece. There are differently shaped clamping straps and clamping supports available to serve various ends.

Figure 6/23 Lever action to be used at clamping strap!



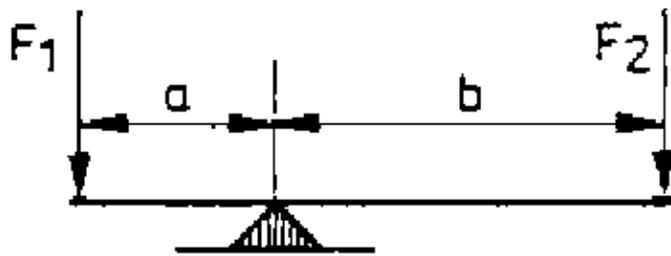
a Good lever action

1 Clamping strap, 2 Workpiece, 3 Clamping support 4 Weight arm, 5 Force arm.



b Poor lever action

1 Clamping strap, 2 Workpiece, 3 Clamping support 4 Weight arm, 5 Force arm.

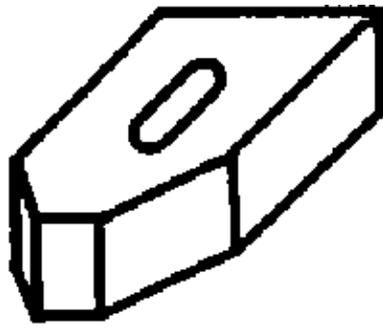


C

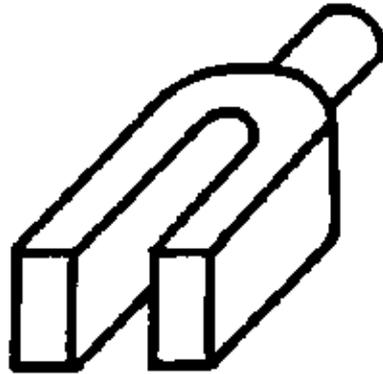
$$F_1 \cdot a = F_2 \cdot b$$

c Lever transmission

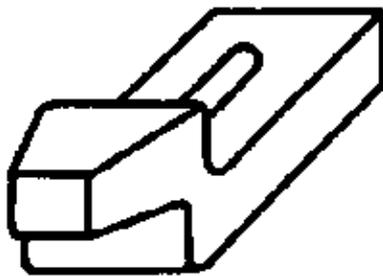
Figure 6/24 Differently shaped clamping straps



a Flat

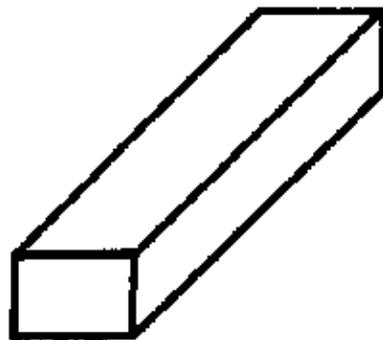


b Fork-shaped

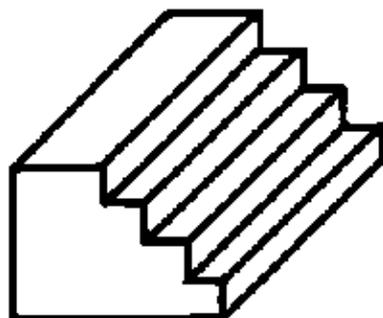


c Angular-bent

Figure 6/25 Clamping supports



a Simple



b With steps

Upon using clamping straps it is essential

- to clamp firmly all setscrews uniformly
- to place the clamping straps parallel to the machine table

- to utilize lever action of clamping strap by observing favourable distances.

Machine vice

The machine vice (Figure 6.26) is mounted on the machine table with setscrews. The workpiece is firmly clamped between the jaws (Figures 6.11; 6.12.). The clamping force is developed by the threaded spindle (1) which actuates the movable jaw (3) of vice via the nut (2). By means of a crank handle (4) that is slipped on the four–cornered shaft (5) the spindle is actuated.

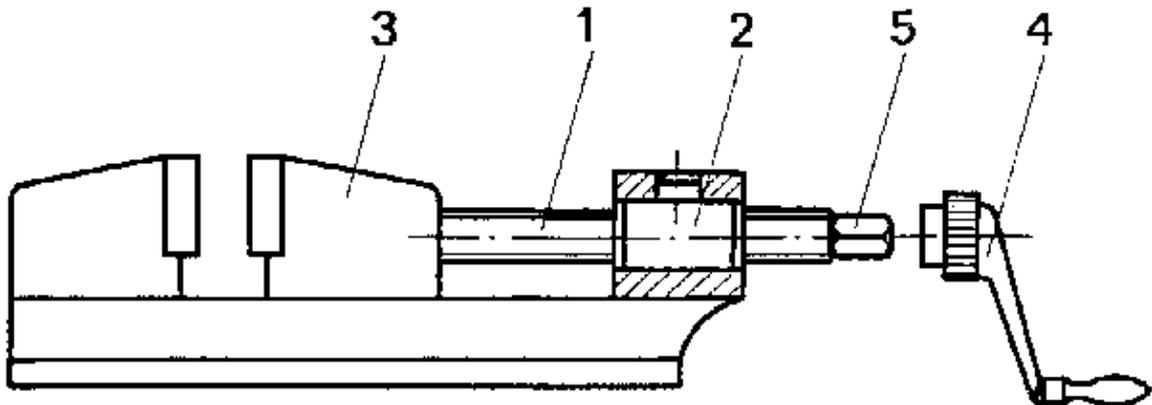


Figure 6/26 Machine vice

1 Threaded spindle, 2 Nut, 3 Movable jaw, 4 Crank handle, 5 Four–cornered shaft.

Attention! Prior to switching–on the machine the crank handle has to be taken off from machine vice and to be deposited safely. There is the danger of accidents!

Machine vices that are rotatable or turnable (Figures 5/30, 5/31) are not used on horizontal shapers because of the jerky cutting motion.

Control questions

1. Name work–clamping devices to be used on horizontal shapers.
2. What types of workpieces can be clamped with these clamping devices?
3. Describe the utilization of lever action in clamping straps.
4. How does a machine vice function?
5. Formulate several rules for the safe clamping of workpieces on horizontal shapers.

6.2.3. Clamping devices for tools and their use

In this section you shall get acquainted with

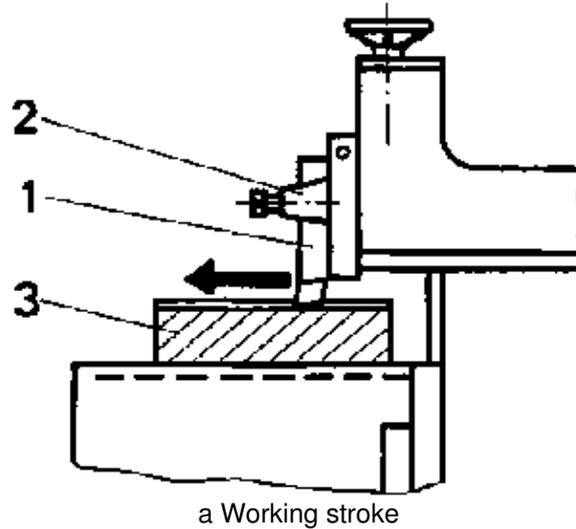
- the various tasks and functions to be fulfilled by tool–clamping devices on horizontal shapers
- the way of functioning of tool–clamping devices.

Tasks of clamping devices for tools

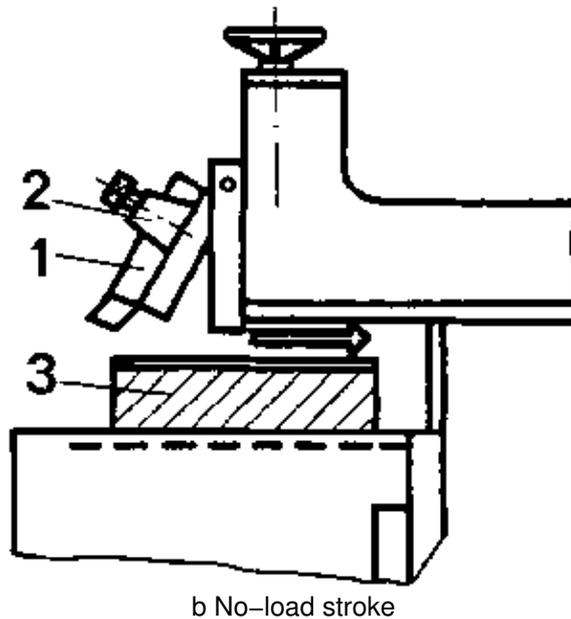
The tool-clamping devices transmits the straight-lined working movement of the ram to the slotting tool. The tool-clamping device has to clamp the slotting tool firmly and without any vibrations.

The slotting tool cuts the metal chips from the workpiece only during the working stroke. Therefore the clamping device is designed in a way that the tool is moved towards the workpiece exclusively during the working stroke. During no-load stroke the tool is lifted so that it does not touch the workpiece and damage the cutting edge. (Figure 6/27).

Figure 6/27 Slotting tool in clamping device



1 Slotting tool, 2 Clamping device, 3 Workpiece



1 Slotting tool, 2 Clamping device, 3 Workpiece

During several shaping operations it is necessary to clamp the slotting tool obliquely. To this end the clamping device can be swivelled. A clamping screw can be loosened, the clamping device is rotated around and the screw is again tightened. (Figure 6/28).

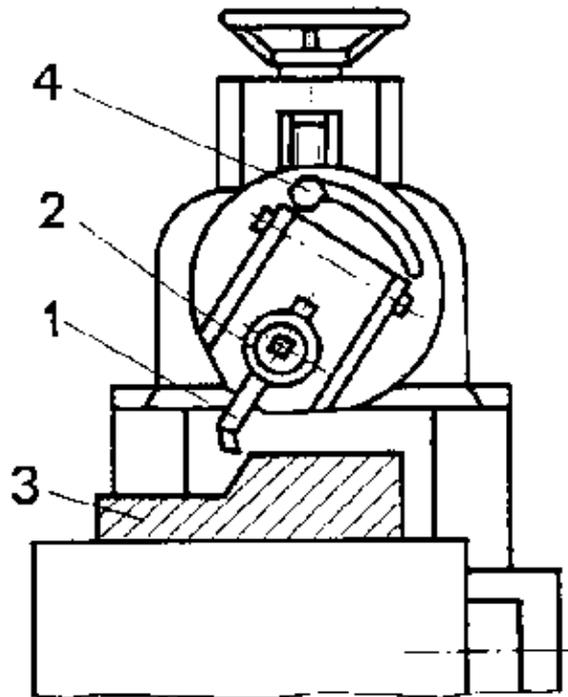


Figure 6/28 Slotting tool swivelled with clamping device

1 Slotting tool, 2 Clamping device, 3 Workpiece, 4 Clamping screw

Function of clamping devices for tools

The function of tool-clamping devices (Figure 6/29) on horizontal shapers is extremely simple. The tool-clamping device consists of a casing (1) and the adjusting screw (2), with which the shaft of tool is pressed against the ram flap (3). Casing and ram flap can be rotated at any arbitrary angle, as described above.

The planing tool is positioned above the feeding device for tool (Figure 6/16.).

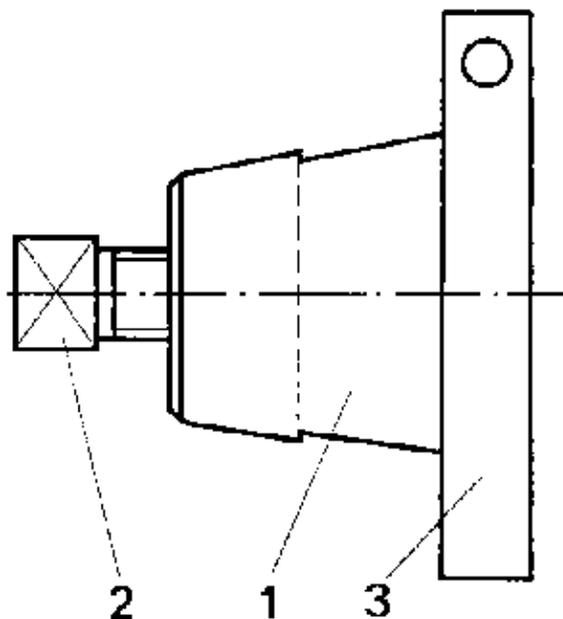


Figure 6/29 Parts of clamping device

1 Casing, 2 Pressure screws (adjusting screw), 3 Ram flap

Control questions

1. What are the tasks of the tool-clamping device at a horizontal shaper?

2. What are the specific aspects of the machining forces in a horizontal shaper?
3. How do the tool-clamping devices function?

6.2.4. Handling of horizontal shapers

In this section you shall get acquainted with

- the setting of a horizontal shaper
- the way of operating the machine during shaping
- the kinds of errors to be avoided when operating the machine.

Setting the machine

During the setting of the machine all basic requirements are created that the shaping operations intended are performed with suitable machining characteristics for shaping.

- Setting the length of stroke

The length of stroke (L) corresponds to the sum of the

- length of the workpiece (l)
- advance of tool up to the beginning of metal cutting (l_a)
- overtravel of tool beyond the workpiece ($l_{\bar{u}}$)

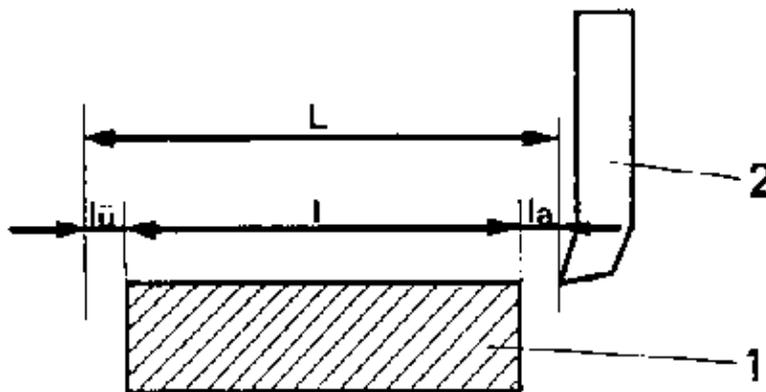


Figure 6/30 Stroke length during horizontal shaping

1 Workpiece, 2 Tool, L Stroke length, l Length of workpiece, l_a Start, $l_{\bar{u}}$ Overtravel.

$$L = l + l_a + l_{\bar{u}}$$

The length of stroke is set by adjusting the crank pin and disk crank with the sliding block (Figure 6/31). Please, observe:

- crank pin towards outside (5) results in a large crank radius and a long stroke
- crank pin towards inside (6) results in a short crank radius and a short stroke.

Advance and overtravel are not allowed to be too short, or too long. In the case of a short advance the tool does not receive sufficient momentum for cutting; in the case of a too short overtravel the tool does not sufficiently protrude from the workpiece. It leaves behind residual chips at the workpiece. But a too long advance and a too long overtravel are unused times and they prolong the period of machining.

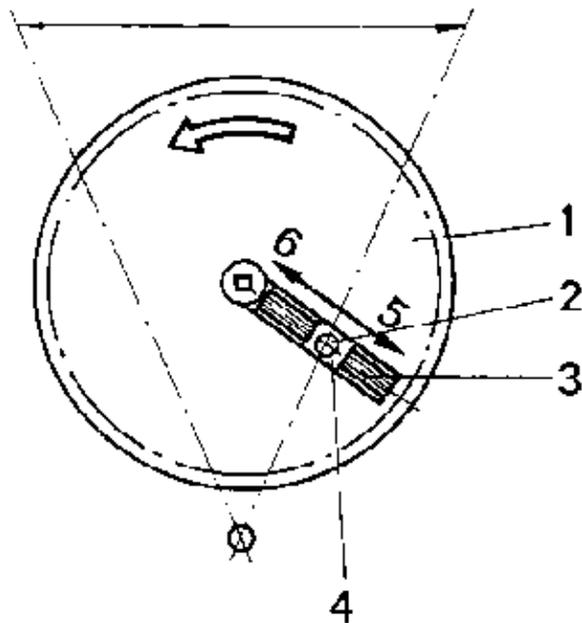


Figure 6/31 Readjustment of crank pin on crank cam

1 Crank cam, 2 Crank pin, 3 Adjusting spindle, 4 Sliding block, 5 Stroke long, 6 Stroke short.

• Adjustment of stroke position

The stroke position is dependent upon the point of workpiece to be machined. The ram is connected with the rocker arm in such a way that its position can be adjusted. To this end a clamping screw has to be loosened. Then the ram is adjusted via a threaded spindle and then the clamping screw is again tightened.

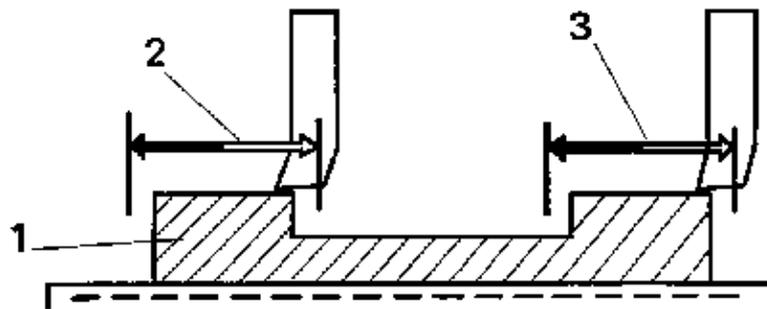


Figure 6/32 Stroke position during horizontal shaping

1 Workpiece, 2 Stroke in front position, 3 Stroke in back position.

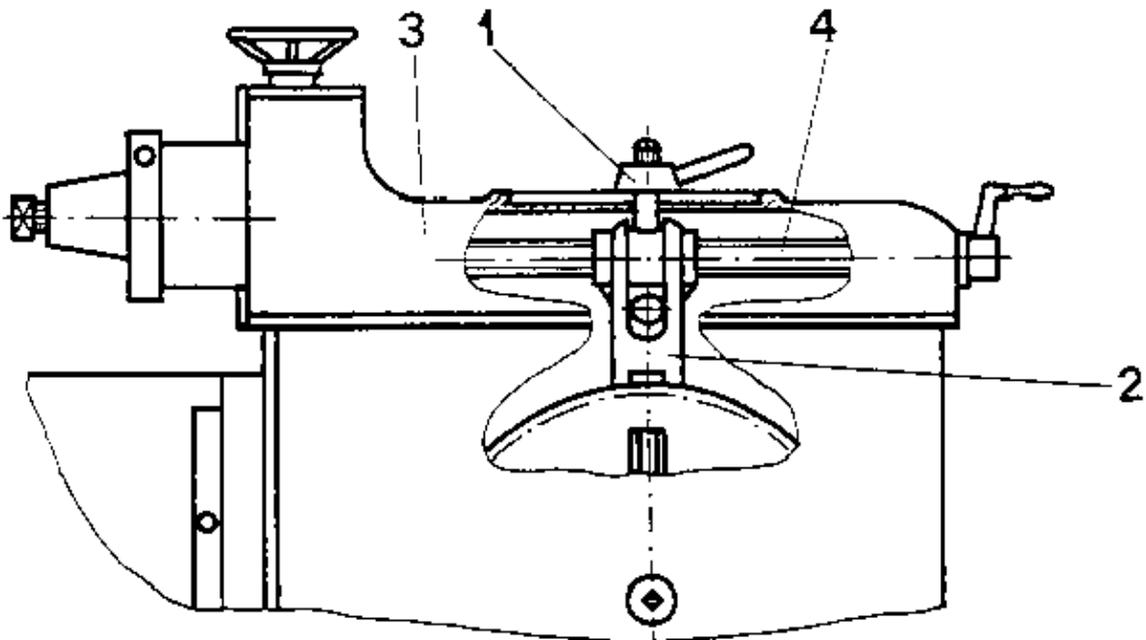


Figure 6/33 Readjustment of stroke position

1 Clamping screw, 2 Rocker arm, 3 Ram, 4 Adjusting spindle with thread.

• Adjustment of number of strokes

The number of strokes adjusted at the toothed gear (Figure 6/17) is essential for the machining characteristic, the cutting speed.

The cutting speed in horizontal shaping is that speed at which the edge of slotting tool moves along the workpiece.

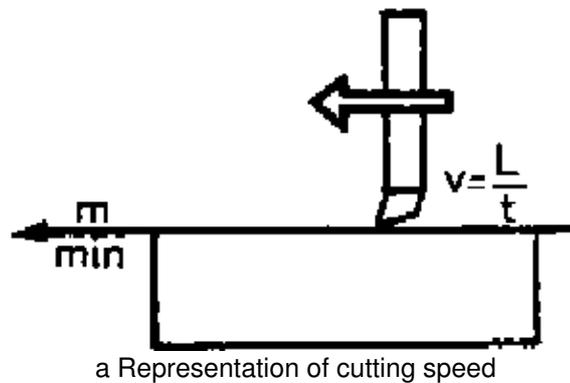
The cutting speed is dependent upon

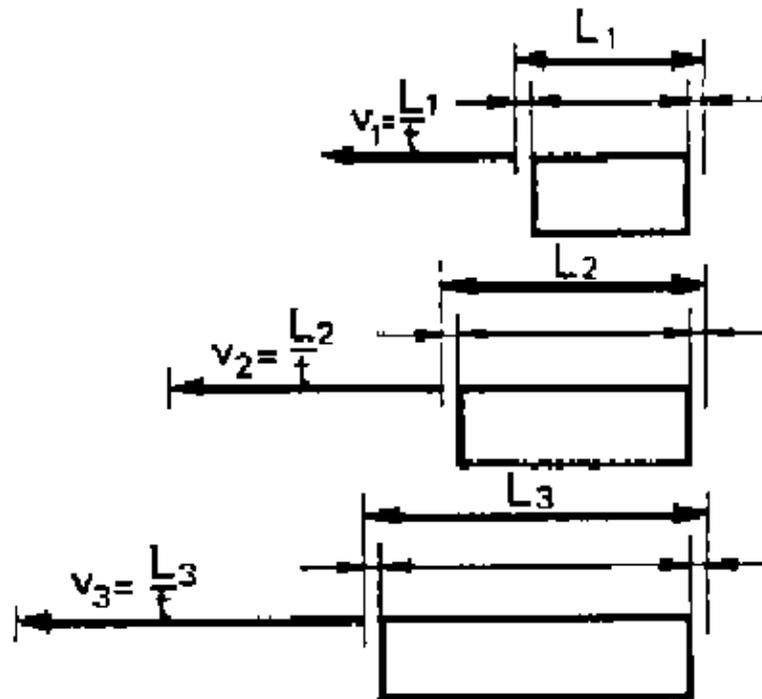
- the material of the workpiece
- the material of the tool
- the surface grade required for the workpiece (fine or rough).

• Adjustment of feed mechanism

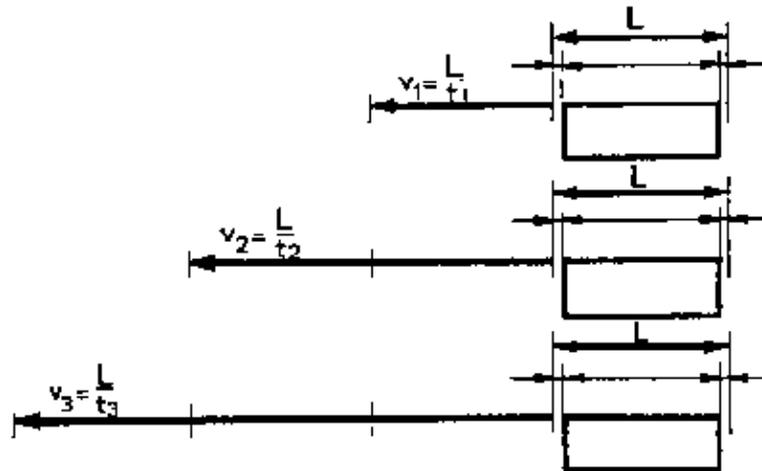
The machining characteristic for the feed motion is set at the feed mechanism (Figure 6/19). This characteristic value is the feed.

Figure 6/34 Cutting speed during horizontal shaping





b Influence of stroke length



c Influence of stroke number, T constant, L constant.

The feed in horizontal shaping is the distance by which the workpiece is advanced per each working stroke and no-load stroke (double stroke).

Feed depends on

- the material of workpiece
- the surface grade required (fine or rough).

The feed is adjusted for a certain shaping operation by adjusting the stroke required for the push bar with the catch at the stroke disk of feed mechanism.

Figure 6/35 Feed during horizontal shaping

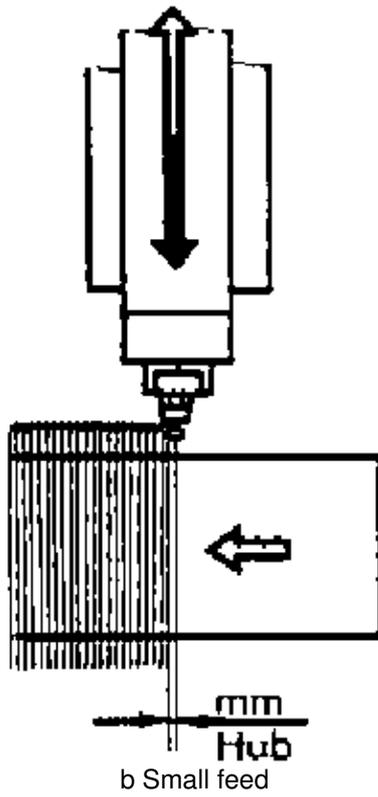
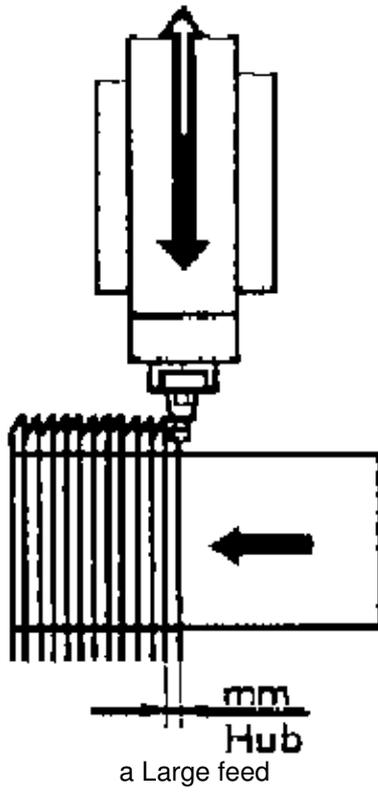
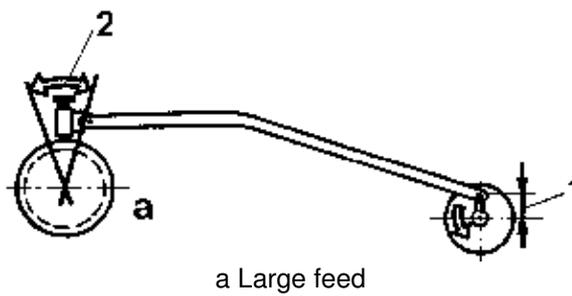
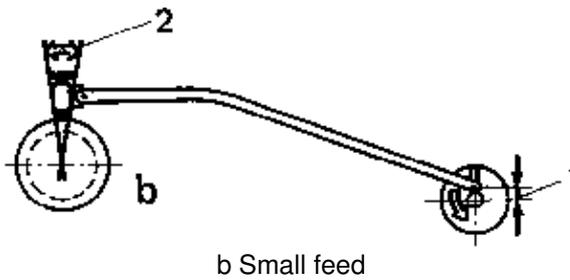


Figure 6/36 Adjusting feed at crank gear of feed device



1 Crank radius at crank gear, 2 Shearing angle of catch mechanism at switch wheel.

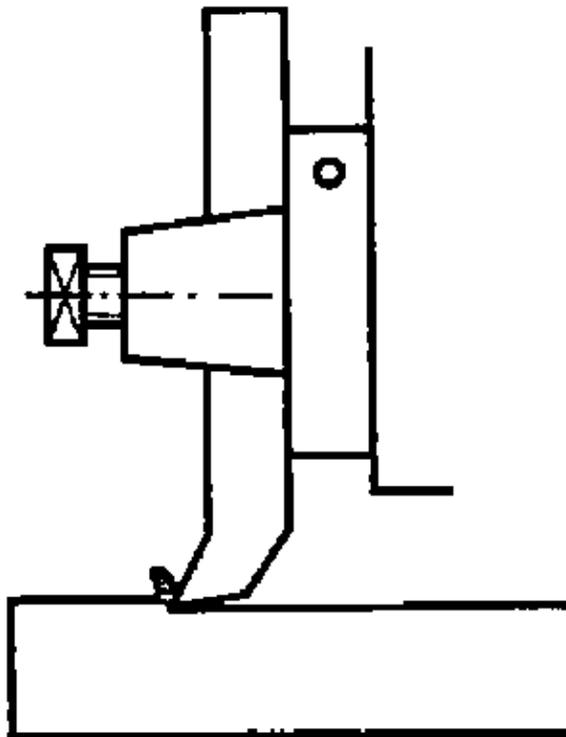


1 Crank radius at crank gear, 2 Shearing angle of catch mechanism at switch wheel.

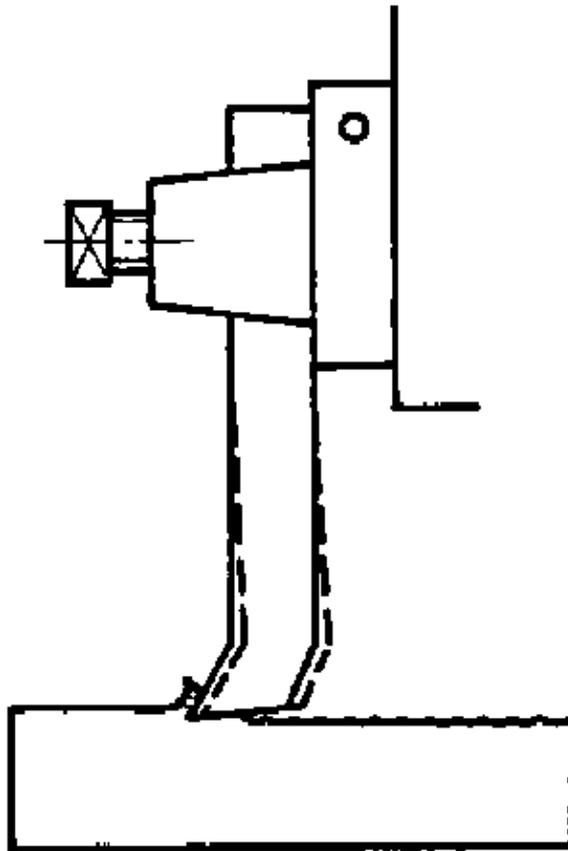
Clamping the slotting tool

The slotting tool is exposed to great loads by the machining forces setting in jerkily. It shall not be clamped with too long an end because it will be springy and will bend (Figure 6/37). As a result there are markings on the workpiece.

Figure 6/37 Planing tool, clamped



a Correct: surface of workpiece is smooth,



b Too long: surface of workpiece has markings of springy slotting tool.

Clamping the workpiece

The workpiece is clamped on the machine table by means of a work-clamping device in conformity with the shape of workpiece according to Section 6.2.2.

During preparations for work-clamping devices the following instructions should be observed:

– Machine table

- to be laterally moved out of range of operation of ram
- to be cleaned from metal chips, especially in T-slots
- testing the firm seat of clamping screws at table adjustment.

– Clamping screws

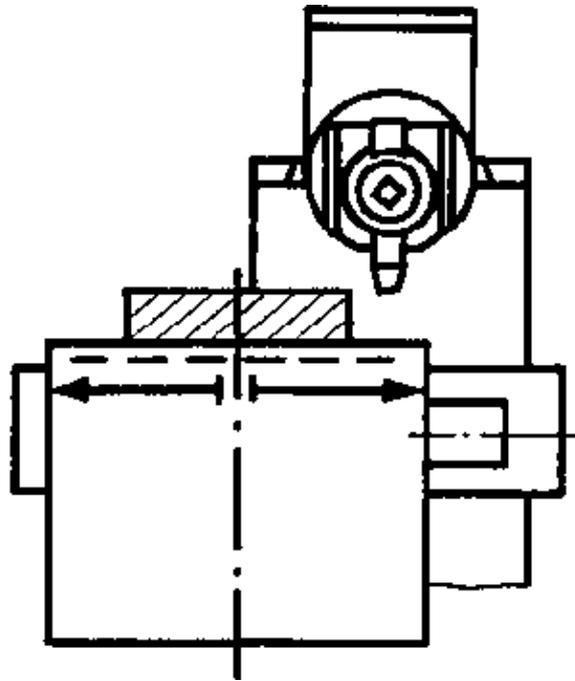
- to be inserted into T-slots for testing
- nuts to be screwed on for testing

– Machine vice

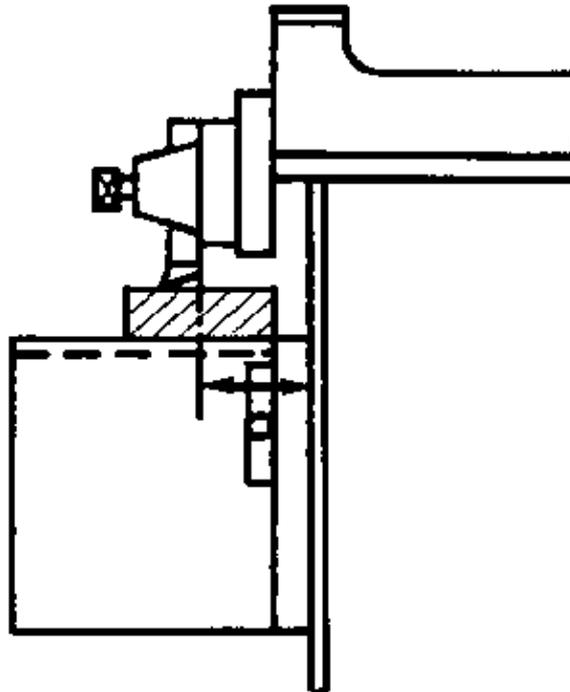
- to be cleaned from metal chips
- testing of easy movability of threaded spindle (to be slightly oiled, if required).

In conformity with the shaping operation to be performed at the workpiece it is essential to choose the most favourable point of the machine table. This point is as far as possible in the centre of table and as far as possible in the vicinity of machine frame(Figure 6/38). At this point the jerks and jolts produced by the machining forces are best absorbed by the machine table.

Figure 6/38 Most favourable point for clamping on machine table



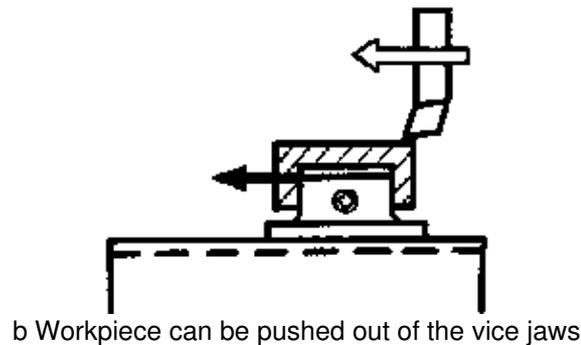
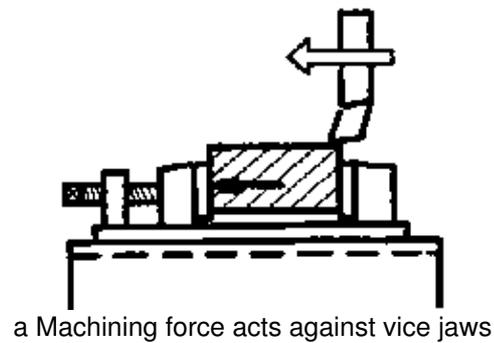
a In centre of machine table



b As near as possible at the machine frame

The machine vice is mounted on the machine table in the direction of the ram stroke, if possible. Then the machining forces will act against the vice jaw (Figure 6/39). If the vice were located cross-wise to the ram stroke, the machining forces would try to move the workpiece out of the jaws.

Figure 6/39 Most favourable clamping in machine vice



Multiple clamping. This method is used on machine tools if two or several equal workpieces shall be clamped and machined in one continuous operation. The workpieces have to be well aligned so that its contours are exactly identical.

Multiple clamping of workpieces increases productivity of labour, since many stages of operation are required only once, e.g. marking, positioning and feeding the tool, testing.

Operation of a horizontal shaper

As soon as the machine is set, tool and workpiece has been clamped, the shaping operation can begin.

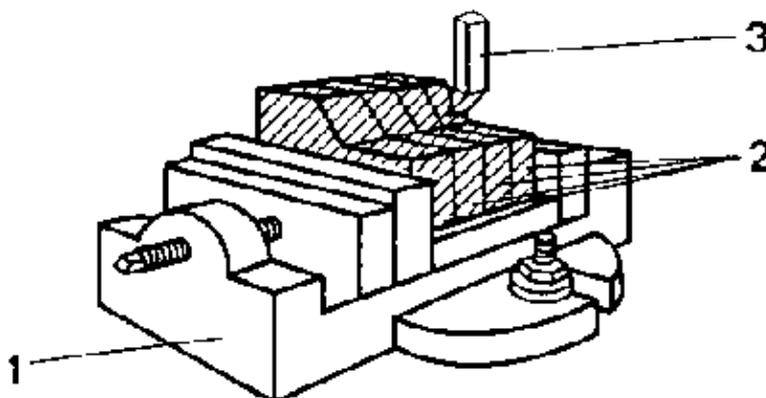


Figure 6/40 Example of multiple clamping

1 Machine vice, 2 Four equal workpieces, 3 Slotting tools.

- Switching–on the machine (cutting motion)

Attention should be paid to the fact that the ram drive – the oscillating crank gear – is disconnected. The workpiece together with the machine table is outside the range of operation of the slotting tool. As soon as the driving motor runs at full capacity the ram drive can be connected.

- Positioning

During positioning the workpiece is slowly moved towards the slotting tool which already performs its cutting motion back and forth. For this purpose the machine table is actuated by hand at the table drive. The depth of cutting is adjusted at the tool head.

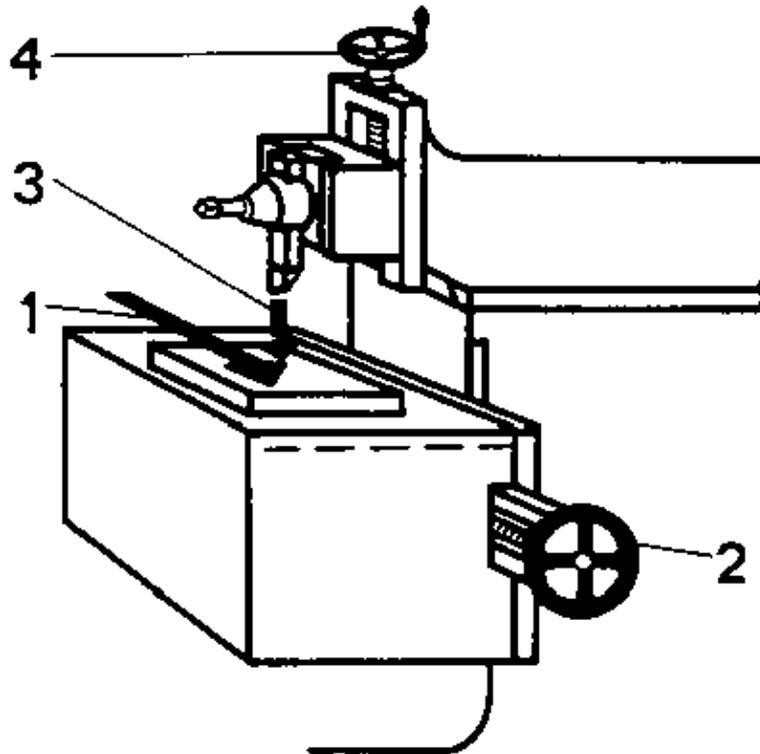


Figure 6/41 Positioning during horizontal shaping

1 Workpiece to be travelled forth, 2 Table drive, 3 Cutting depth to be adjusted, 4 In-feed device for tool

During positioning it is required to move towards the tool so slowly that the metal cutting process begins gradually at the workpiece. A too rapid advance to the workpiece may result in the fact that the tool begins cutting with too large cutting cross-section: breakage of tool, damage to workpiece, danger of accident!

- Switching-on the feed motion

As soon as the workpiece has been positioned the automatic feed motion can be connected. For this purpose the catch is operated at the feed mechanism (Figure 6/19).

- Finishing the feed motion and cutting motion, disconnecting the machine

If the removal of chips is finished the feed motion is ended, the catch released. Then the ram drive is decoupled, if the ram is positioned at its lower point of arrest. Now it is allowed to take out the workpiece, the machine is switched off.

Switching-on and off the driving motor during metal cutting with coupled ram drive can cause damage to tool and machine. Therefore

- first ram drive to be decoupled is no longer in cutting position
- then driving motor to be switched off.

If further stages of operations are intended to follow, the workpiece has to be re-positioned. The depth of metal cutting has to be re-set at the in-feed mechanism.

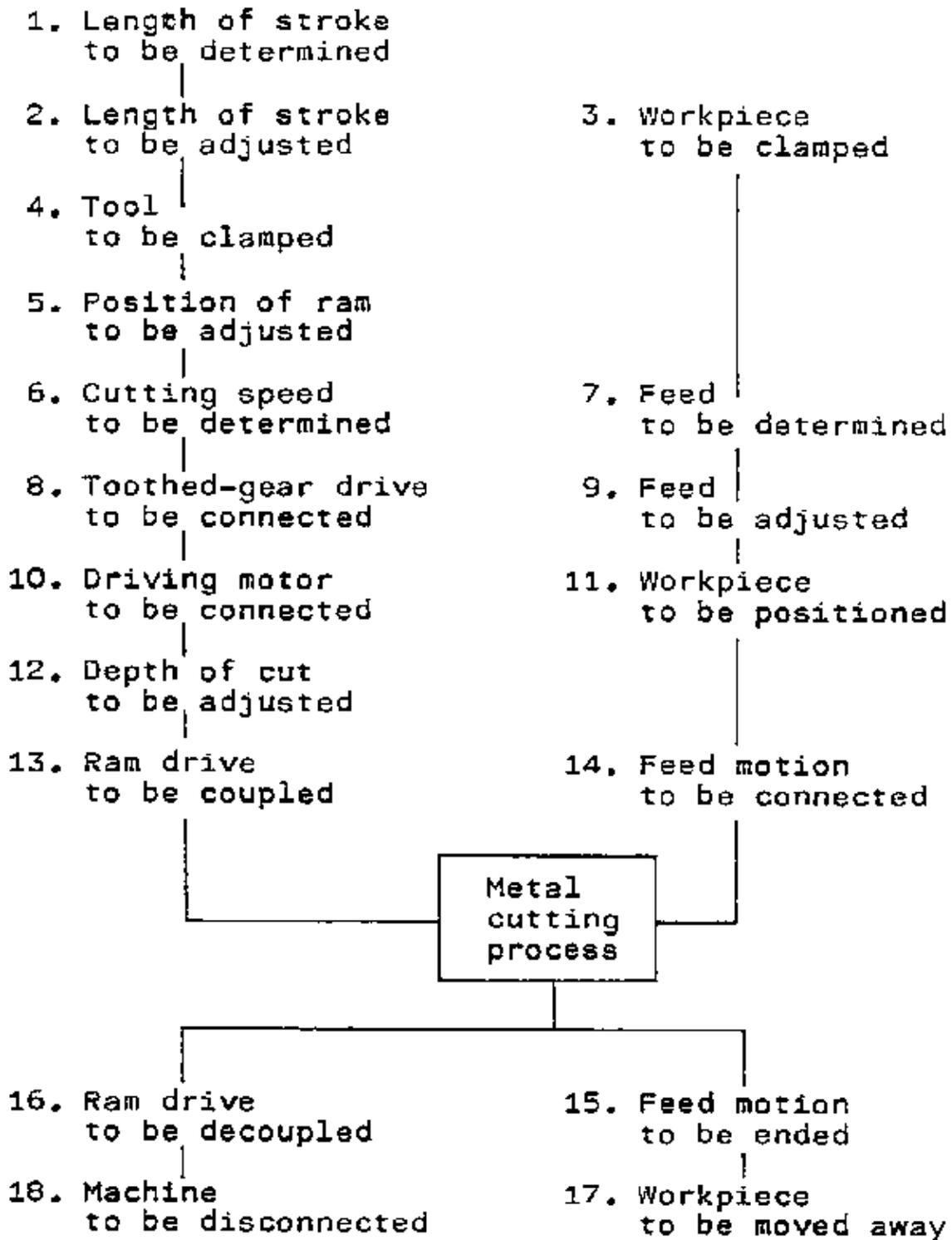


Table 6/3 Setting-in and operating of a horizontal shaper

Control questions

1. Explain what has to be understood by the term 'cutting speed' in horizontal shaping.
2. Explain what has to be understood by the term 'feed' in horizontal shaping.
3. What operations have to be performed to set a horizontal shaping machine?
4. Why are the machining forces best absorbed in the middle of the table?
5. What is to be understood by the term 'stroke length' and 'stroke position' of the slotting tool?

6. Describe the mechanisms of a horizontal shaping machine for shaping operations and products which have been performed by you.

6.3. Vertical shaper

In this section you shall get acquainted with

- the types of machine components of which vertical shapers are composed.
- the way of functioning of vertical shapers
- the kinds of operations for which vertical shapers are used.

6.3.1. Structure and mode of operation

Machine components of a vertical shaper

The machine frame (1) of a vertical shaper consists of the column (2), the bed (3) and the ram guide (4). The ram (5) with the tool head (6) slides in the guideways (7) of the ram guide up and down.

The table (8) of the vertical shaper slides on the bed, it carries the saddle (9) and frequently a round table (10).

The controlling elements are arranged at the operating side of the machine at the saddle and the column.

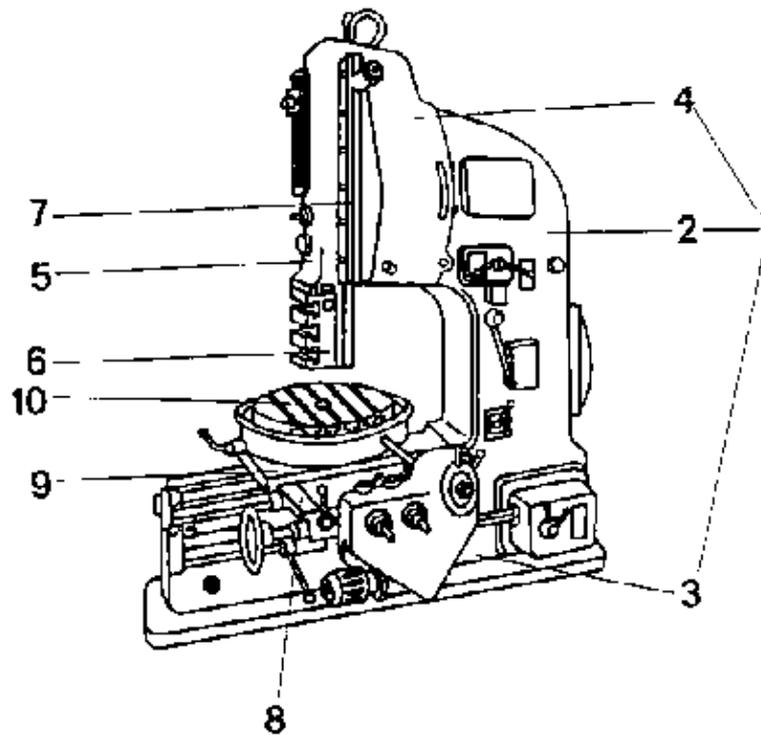


Figure 6/42 Components of a vertical shaper

1 Machine frame, 2 Column, 3 Bed, 4 Ram guide, 5 Ram, 6 Ram face (tool head), 7 Guideways, 8 Table, 9 Saddle, 10 Round table.

In the column there are accommodated the mechanisms of the vertical shaper, i.e.

- the drive of ram (cutting motion)
- the drive of table (feed motion).

Mode of operation of a vertical shaper

The vertical shaper has a straight-lined reciprocating vertically moving cutting motion. This motion is performed by the ram. The ram drive transfers the rotary motion – as in a horizontal shaper – into a reciprocating motion. The transformation of the rotary motion into stepwise straight-lined feed motion of table, or the stepwise rotating feed motion of round table – is performed in the driving mechanisms of table.

Vertical shapers are equipped in the same way as horizontal shapers (Section 6.2.4.). The workpiece is clamped on the table by clamping devices for workpieces according to Section 6.2.2. Attention has to be paid to the fact that the slotting tool has still sufficient over-travel after cutting and will not deposit on table or the clamping tool. If necessary, supports shall be used that increase the distance between table and workpiece.

The slotting tool cuts in the longitudinal direction, so that it can be conveniently used for the machining of openings (Figure 6/43).

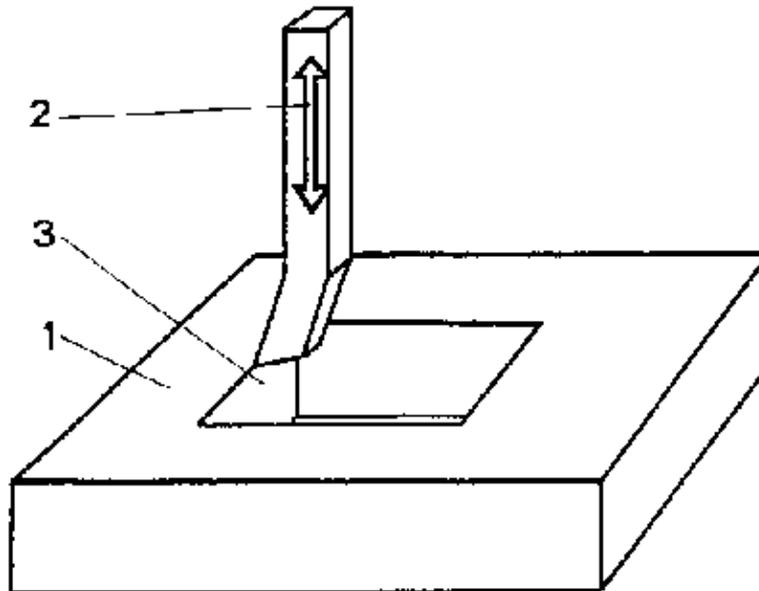


Figure 6/43 Slotting tool of a vertical shaper

1 Workpiece, 2 Slotting tool, 3 Rupture in workpiece to be machined.

6.3.2. Use of vertical shapers

The use of this machine is determined by the specific mode of action of the slotting tool of a vertical shaper. The machine is mainly used for machining the inside surfaces of openings, for the machining of which the use of milling machines would be unsuitable (Figure 6/44).

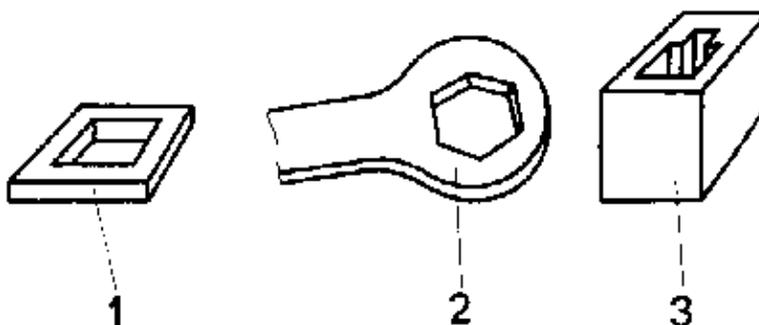


Figure 6/44 Examples of workpieces of vertical shapers

a Cutting plate, b Wrenches, c Pilot segment

Workpieces to be machined are casings of gears, machine columns, box-type supports with openings. In special cases slotting tools are used with profiled edges.

Control questions

1. Describe the structure of a vertical shaper.
2. Explain the similarities and differences between horizontal and vertical shapers.
3. Name several examples of operations which have been performed on vertical shapers.

6.4. Gear shaping machine (gear shaper)

In this section you shall get acquainted with

- the machine components of which gear shapers are composed
- the way of functioning of gear shapers
- the kinds of operations for which gear shapers are used.

6.4.1. Structure and mode of operation

Machine components of gear shapers

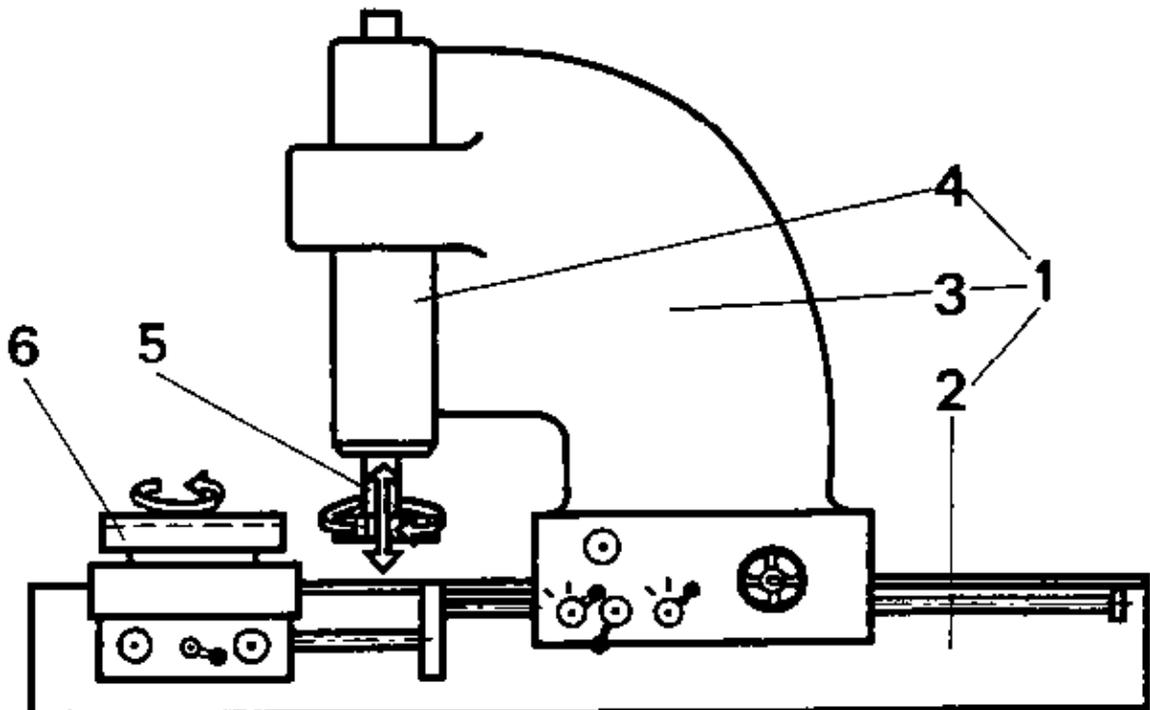


Figure 6/45 Components of a gear shaper

1 Machine frame, 2 Bed, 3 Casing for ram drive. 4 Ram guide, 5 Ram with tool, 6 Table (round table).

Gear shapers are similar in their structure to a vertical shaper (Figure 6/45).

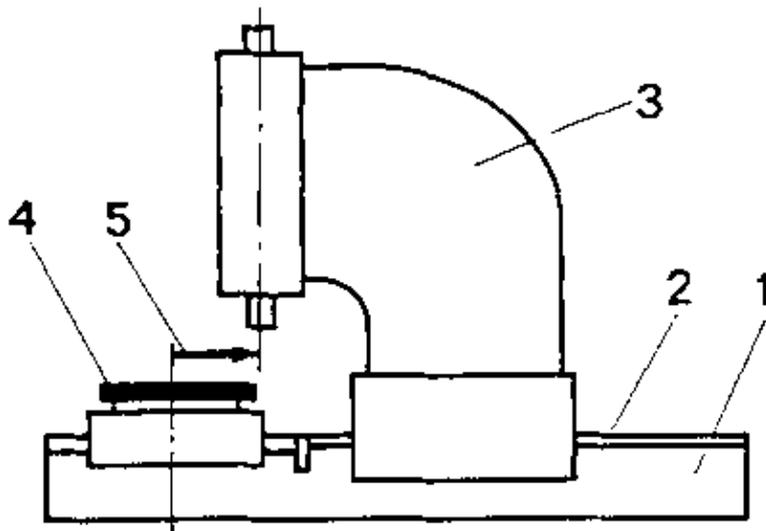
The machine frame (1) consists of the bed (2), the casing for the ram drive (3) and a ram guide (4). The ram (5) slides up and down in the ram guide. Table (6) is supported rotatably on the bed. The mechanisms for the gear shaper are accommodated in the bed and the casing for ram drive. They bring about

- the drive of ram (cutting motion)
- the drive of the table (feed motion).

Mode of operation of a gear shaper

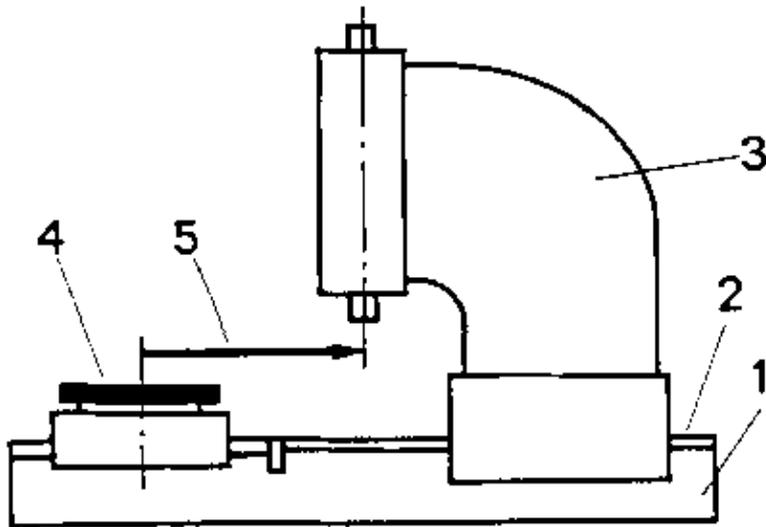
Gear shapers have a vertical, reciprocating back and forth cutting motion; it is performed by the ram. The ram drive transforms the rotary motion of the motor into a back and forth motion.

Figure 6/46 Setting for various diameters of toothed gears



a Small diameter

1 Bed, 2 Guideways on bed, 3 Adjustable casing with raw drive, 4 Round table, 5 Radius of toothed wheel.



b Large diameter

1 Bed, 2 Guideways on bed, 3 Adjustable casing with raw drive, 4 Round table, 5 Radius of toothed wheel.

The casing for the ram drive can be actuated together with the ram on the bed radially to rotary table (Figure 6/46). Thus it is possible to set the gear shaper for various diameters of toothed gears.

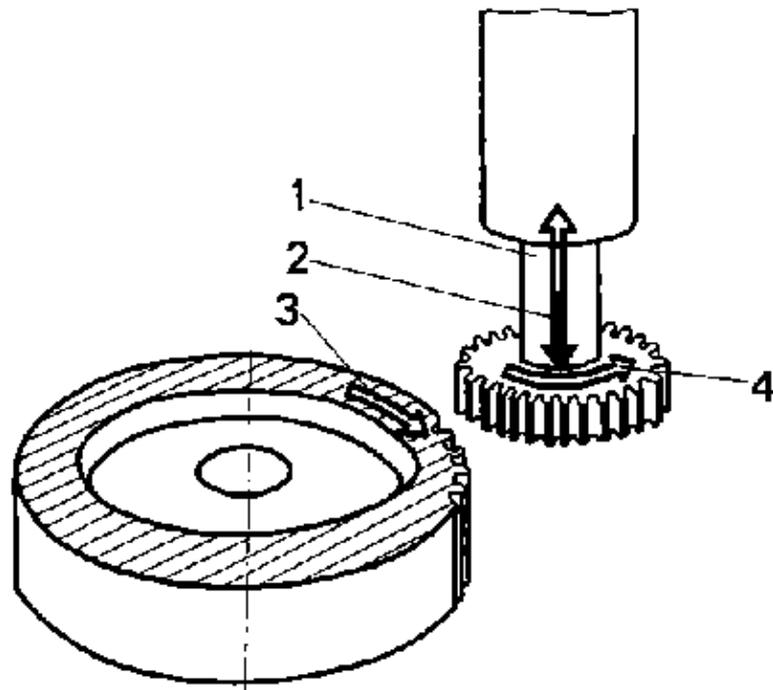


Figure 6/47 Swivel tool in the form of toothed wheel

1 Ram, 2 Cutting motion, 3 Feed motion of workpiece, 4 Feed motion of tool.

The tool collet in the ram is rotatable for gear shaping with a tool which has the shape of a gear (Figure 6/47). Workpiece and tool are rotated, they both carry out a rotating feed motion. Between both feed motions there has to be a positive movement, i.e. workpiece and tool have to engage in each other like two toothed wheels and have to be turned simultaneously. The ram with the gear-like tool actuates up and down and the teeth of tool cut the space out of the workpiece (Figure 6/48).

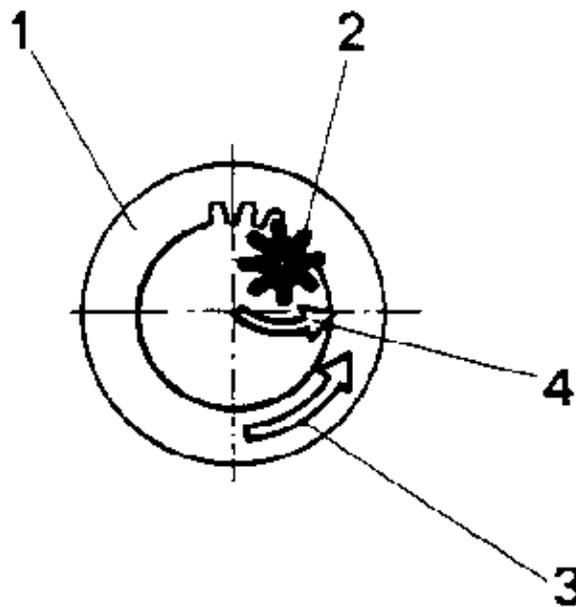


Figure 6/48 Shaping internal toothing

1 Workpiece, 2 Tool, 3 Feed motion of workpiece, 4 Feed motion of tool.

6.4.2. Use of gear shapers

The name is indicative of the use of gear shapers. Tools with different shapes of gear make it possible to produce toothing, or gear, of different gear-tooth profile. Gear shapers are especially suitable for internal toothing because it is impossible for milling cutters to machine inside a toothed wheel. Cylindrical toothing

only can be produced on gear shapers.

Control questions

1. Describe the structure of a gear shaper.
2. Describe the mode of operation of a gear shaper.
3. Name workpieces which have been manufactured on gear shapers.

6.5. Planing machine (planer)

In this section you shall get acquainted with

- the machine components of which planers are composed
- the way of functioning of planers
- the kinds of operations for which planers are used

6.5.1. Structure and mode of operation

Planers are equipped with several carriages which are mounted – according to the design of the machine – on the column (5) or the grate bar support (Figure 6/49). Each carriage is adjustable by itself, so that the machine can operate with several tools at the same time.

Drive of a planer

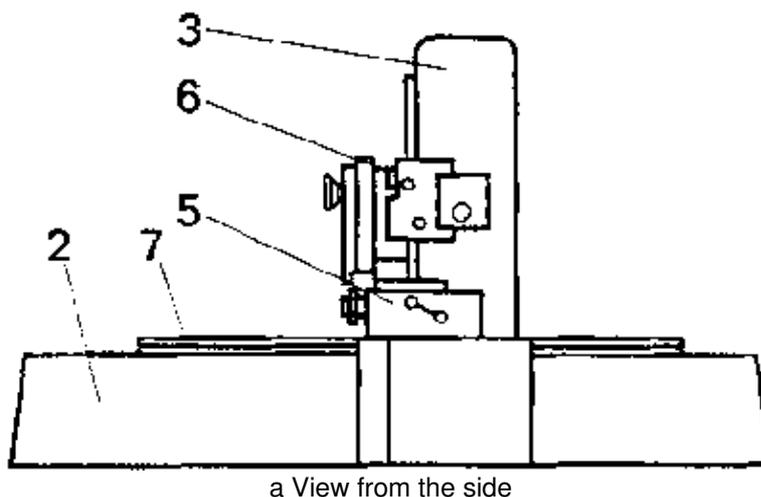
Planers, notable large-size planers, are driven by several electric motors.

Mode of operation of a planer

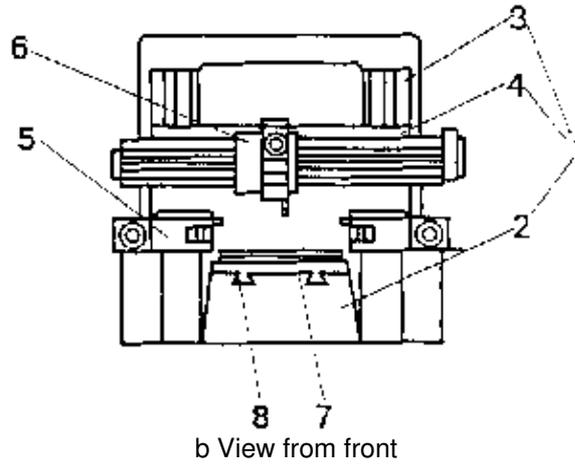
Planers are used for machining large workpieces with long surfaces. The workpieces are clamped on the table of planer by using clamping straps and screws (Section 6.2.2.). The workpiece that reciprocates back and forth on the table of the machine bed carries out the cutting motion.

The tool-clamping devices with the clamped planing tools are found on the carriages. It is thus possible at several surfaces simultaneously, e.g. at the upper surface and at the lateral surfaces to perform planing operations on the workpiece. However, there is one condition: the directions of the cutting movement have to proceed parallel to each other. Even the cutting speeds (Section 6,2.4.) of all tools have to be identical (Figure 6/50).

Figure 6/49 Components of a planer



1 Machine frame, 2 Bed, 3 Column, 4 Grate bar support, 5 Column carriage, 6 Cross slide, 7 Table, 8 Guideways on the bed.



1 Machine frame, 2 Bed, 3 Column, 4 Grate bar support, 5 Column carriage, 6 Cross slide, 7 Table, 8 Guideways on the bed.

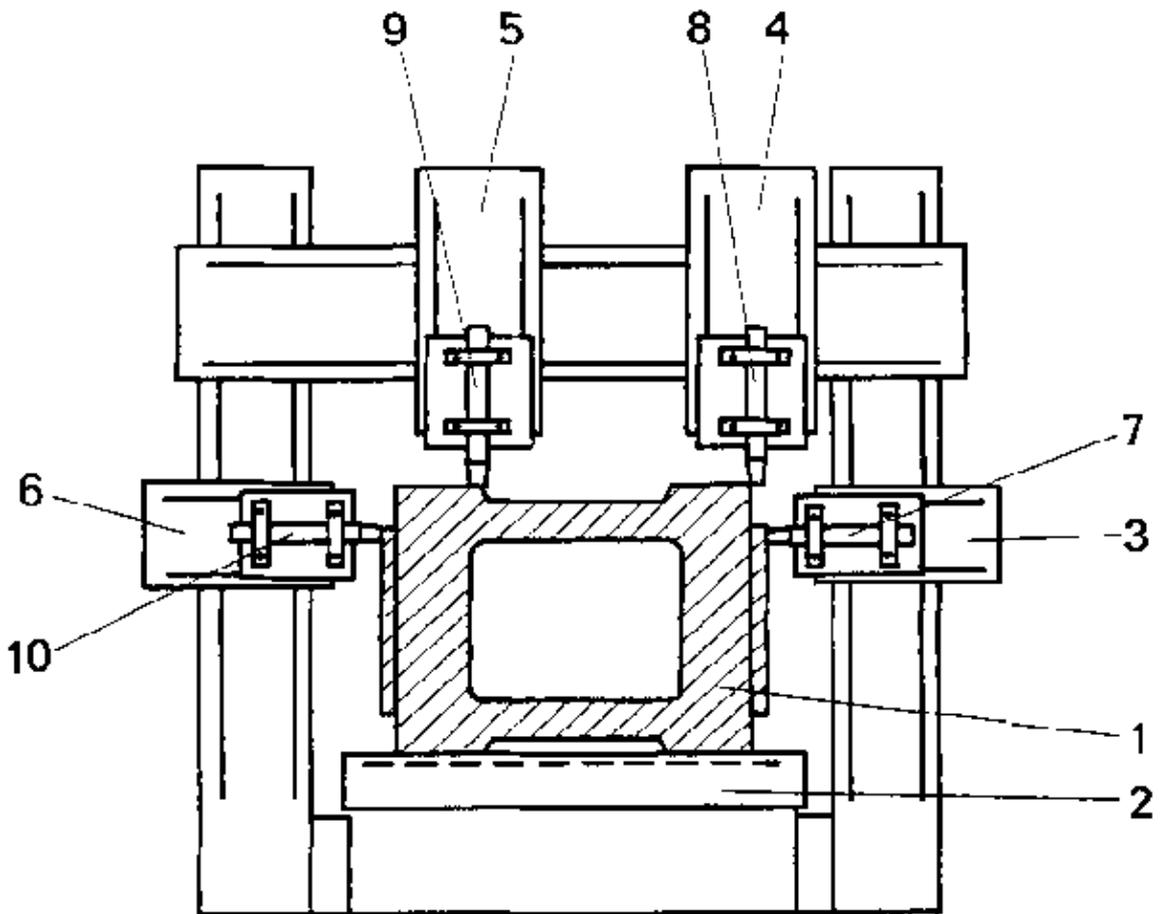
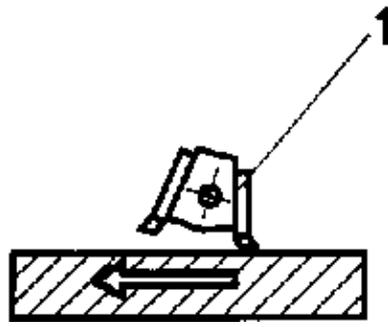


Figure 6/50 Several planing tools operate at the same time

1 Workpiece, 2 Table, 3,4,5,6 Carriages, 7,8,9, 10 Planing tools.

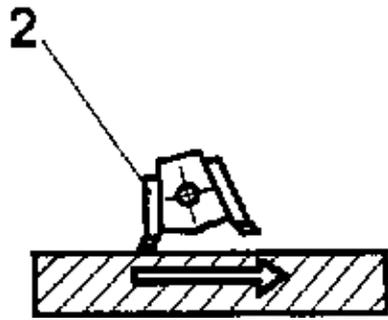
In order to avoid any loss of time and loss of driving energy which would arise during each return stroke as a no-load stroke, several machines are equipped with tool changing mechanisms (Figure 6/51). There is one cutting tool that cuts during the forward stroke, the tool is changed during the overtravel, then the other tool cuts the workpiece during the return stroke. Thus both strokes are working strokes

Figure 6/51 Tool changing mechanism



a Forward stroke

1 Tool for forward stroke



b Backward stroke

2 Tool for backward stroke

6.5.2. Use of planers

Planers are above all suitable for the machining of large workpieces, with long strokes being required for cutting.

Such workpieces are, e.g. machine beds, base plates, machine columns, supports for steel constructions.

The surface grade reached during planing is that finishing operations, e.g. grinding, will be required a to meet high demands.

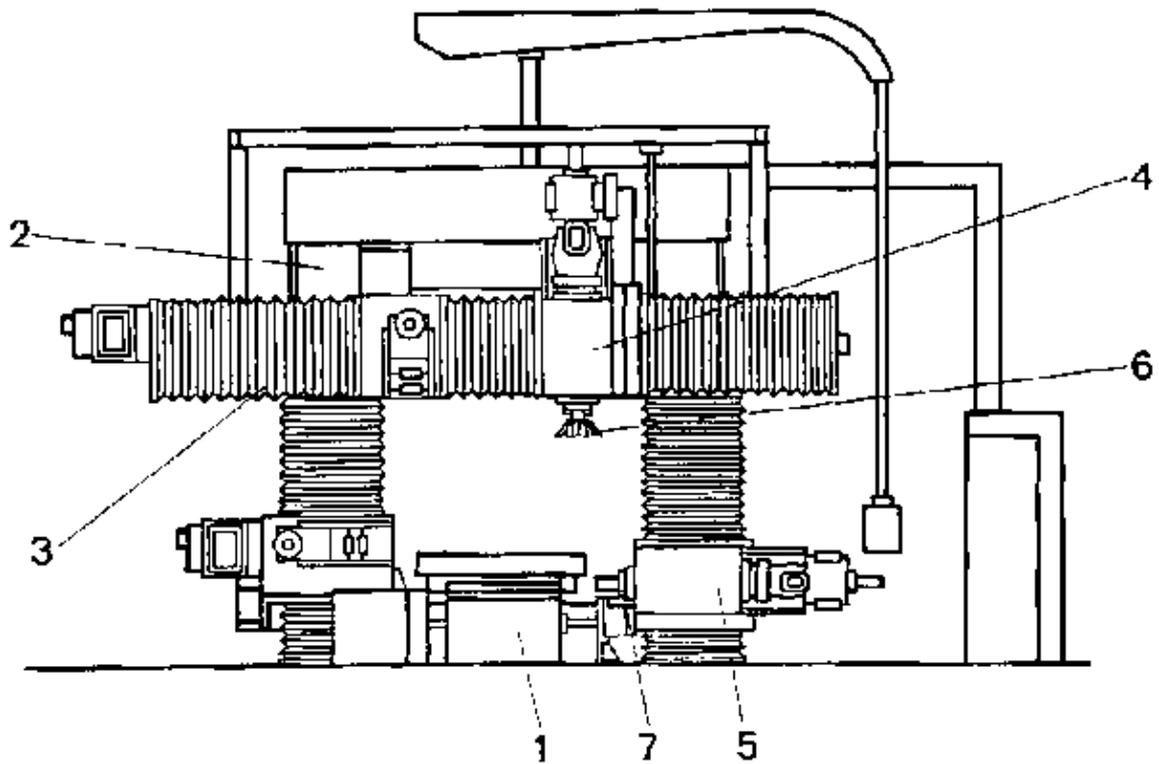


Figure 6/52 Planer with milling carriages

1 Bed, 2 Column, 3 Grate bar support, 4,5 Milling carriages, 6,7 Milling cutter

Several planing machines can also be used for 'milling'. In this case milling carriages are mounted which are equipped with milling spindles and milling cutters. As is general practice in milling, the milling cutters perform the rotating cutting motion and the workpiece with the table performs the straight-lined feed motion. Planing machines in combination with milling machines have a great variety of application and thus are convenient. However, a simultaneous application to planing and milling is not feasible.

Control questions

1. Describe the structure of a planing machine.
2. Explain the ways of functioning of a planing machine.
3. Compare horizontal shapers, vertical shapers and planing machines in terms of their cutting motions and the feed motions. Explain the differences between them.
4. What are the advantages if a planing machine can also be used with milling carriages?
5. Why is it impossible to use planing machines at the same time for planing and for milling?
6. Name examples of workpieces that have been machined on planing machines.

6.6. Servicing and maintenance of shapers and planers

Please, observe the "General Instructions on Servicing and Maintenance of Metal Cutting Machine Tools" according to Section 2.4.

Prior to the beginning of cleaning, lubricating and controlling operations it is required to switch off the machine!

Cleaning

1. Metal chips to be removed from the machine, e.g. from the machine table and in front of the machine, Hand

broom and cleaning rag to be used because of the danger of injuries!

2. Bright components of the machine, e.g. controlling elements, to be cleaned and slightly oiled.
3. Grooves in the table to be scraped with a suitable piece of sheet metal.

Lubricating

1. Oil level in gear to be controlled. Oil to be refilled, if required.
2. Lubricating points to be supplied with oil and grease according to lubrication schedule.
3. Guideways of ram and table to be cleaned, slightly oiled and oil to be evenly distributed.
4. After lubrication oil and grease splashes to be carefully removed from floor.

Controlling

1. Clearance of ram to be controlled in ram guide. Guide bars to be readjusted and clearance to be adjusted.
2. Table guide to be controlled, guide bar to be readjusted, if necessary.
3. Switchability of gear to be controlled. Coupling for ram drive to be controlled and readjusted, if required.
4. Belt tension to be controlled if there is a belt drive available, (to be re-clamped, if required).
5. Electrical connections to be controlled. Supply lines to be safeguarded.

Treatment of tools

1. Tools to be deposited in a way that the cutting edges do not damage each other.
2. Blunt workpieces to be reground in time, otherwise the tools will no longer be dimensionally stable, the surfaces get soiled, the machine is exposed to excessive loads; there is the danger of a breakage of tools.

6.7. Work safety in operating shapers and planers

Please, observe the "General Instructions and Rules on Work Safety", Section 2.5.

In operating shapers and planers the following regulations shall be observed as a protection against accidents:

1. There is no stay allowed in the range of stroke of ram, or the table during the operation of machine.
2. Metal chips arising from work shall not be removed during shaping and planing, but only during the standstill of machine!
3. Metal chips should never be removed by hand!
4. Gratings to be set up as a measure of protection against flying metal chips!
5. Workpiece to be measured only during the standstill of machine, but never during shaping and planing!
6. Machine to be disconnected prior to change of tools!
7. Tools after change never to be deposited on machine, but on a special place of deposit (table or cupboard)!
8. Protective casings, or gratings to be taken off for servicing the machine, shall be re-attached, before machine is switched on!

7. Grinding machines

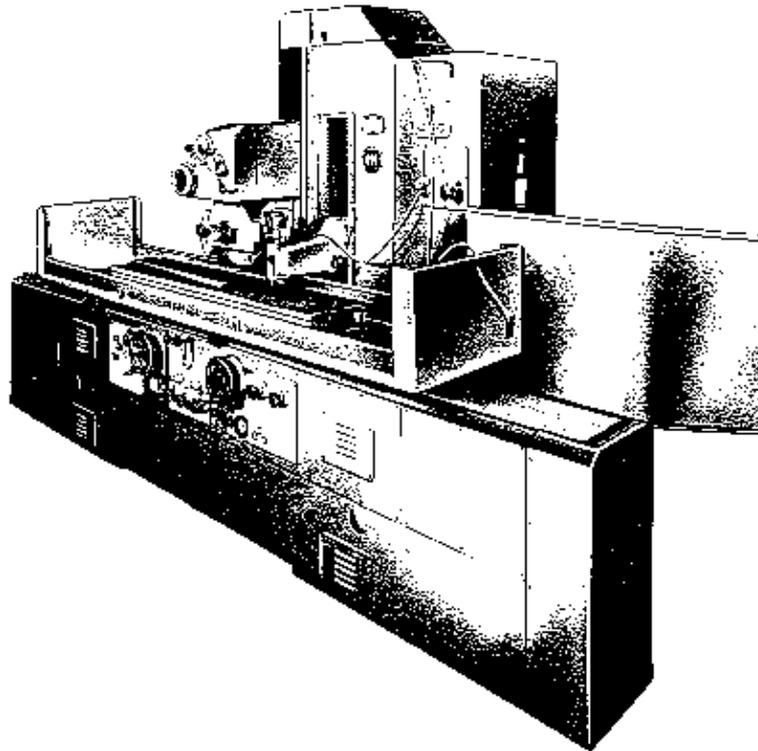


Figure 7/1 Vertical flat grinding machine manufactured in the German Democratic Republic

7.1. Survey of types and use of grinding machines

In this section you shall get acquainted with

- the types of machines used for grinding operations
- the kinds of working motions performed by grinding machines
- the kinds of operations to be carried out on grinding machines.

7.1.1. Several types of grinding machines

Grinding machines are classified

- according to the position of the grinding-wheel spindle
- according to the surface shape of workpieces
- according to the application.

Table 7/1 shall give a survey on the types of grinding machines. In addition, there are grinding machines for special purposes, e.g.

- Thread grinding machines for machining threads, e.g. lead screw
- Gear-tooth flank grinding machines for machining tothing, e.g. toothed-wheels of gears intended to run especially smooth.
- Copy grinding machines for machining dies and gravures, e.g. on pressing tools or drop-forging dies.

- Cylindrical grinding machines, also called honing machines, for machining cylinders for combustion engines.
- Lapping machines for machining finest surfaces of flat parts, e.g. for block slip gauges.
- Ball grinding machines for machining balls for ball bearings.

All grinding machines have, in principle, to perform the same types of working motions. But they have different designs and are thus optimally adapted to their application.

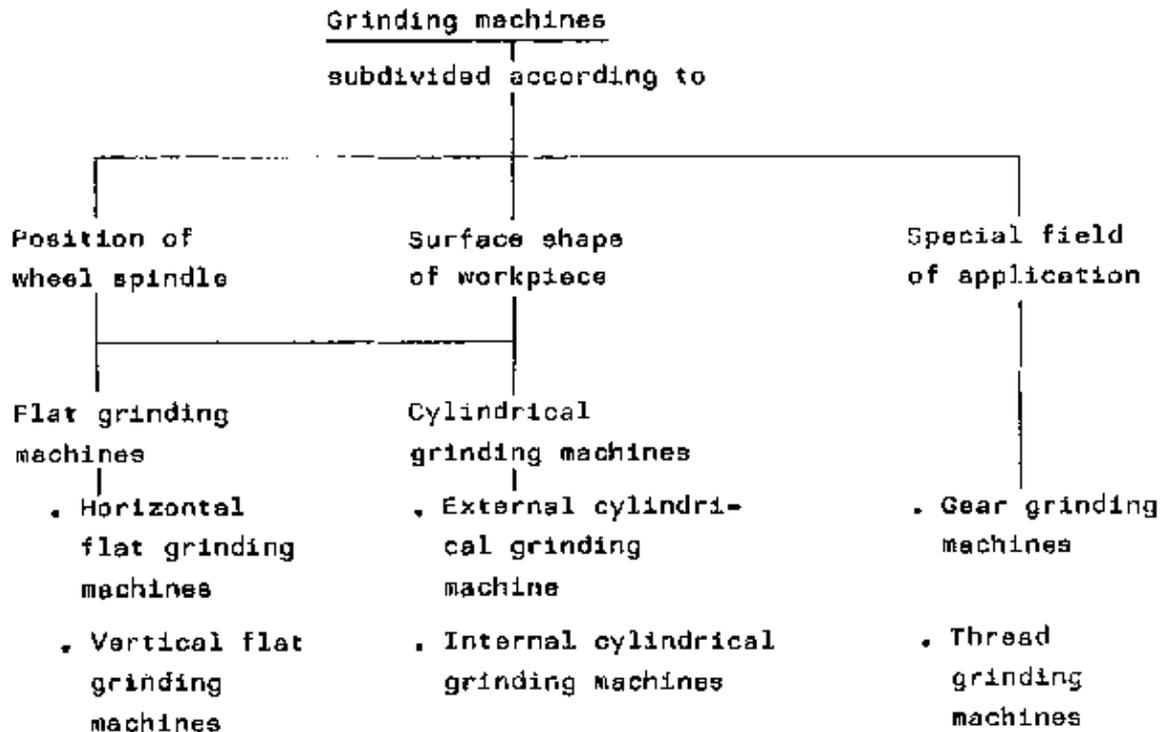
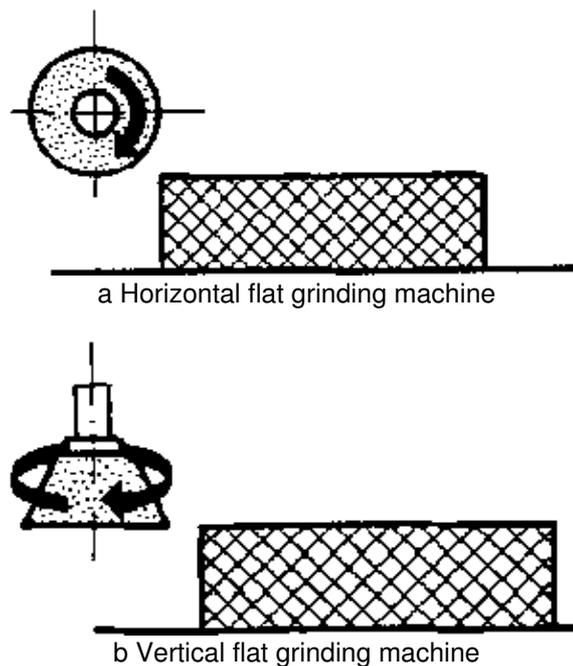
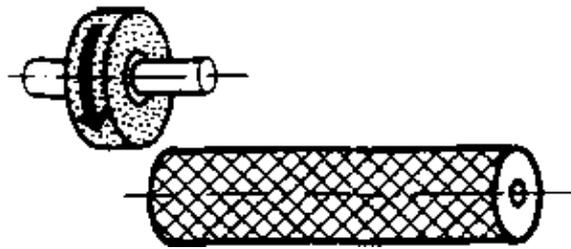


Table 7/1 Classification of grinding machines

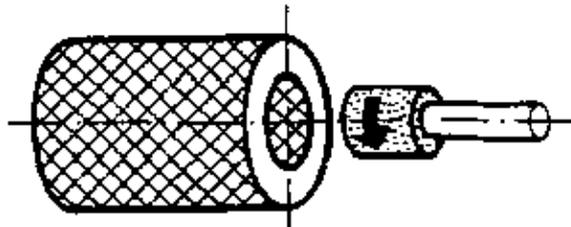
7.1.2. Motions of grinding machines

Figure 7/2 Cutting motion during grinding





c External cylindrical grinding machine



d Internal cylindrical grinding machine

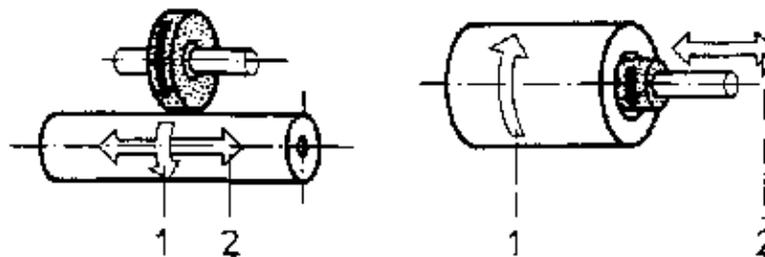
Cutting motion

In grinding the cutting motion is a rotating motion. It is performed by the tool. In grinding high cutting speeds are used; accordingly the tools rotate at a high number of revolutions (Figure 7/2)

Figure 7/3 Feed motion during grinding



a Straight back and forth during flat grinding



b Rotating and straight back and forth during cylindrical grinding

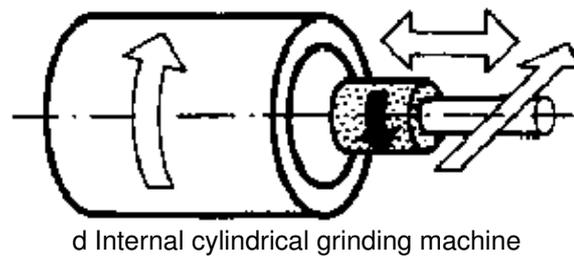
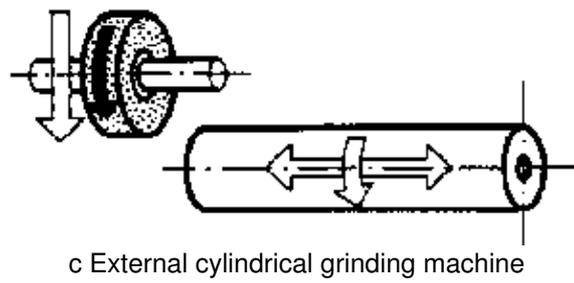
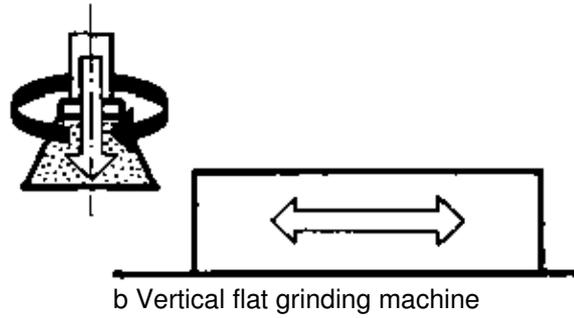
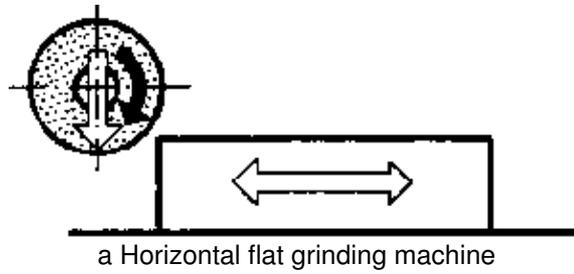
Feed motion

Feed motion in grinding is performed either by the workpiece, or by the tool; it is a straight-lined, or a rotating motion (Figure 7/3).

- It is a straight-lined motion if the grinding table is actuated together with the workpiece. e.g. in horizontal or vertical flat grinding.
- It is a rotating motion of the workpiece rotates during grinding, e.g. in external cylindrical, or internal cylindrical grinding.
- It is a curved motion in the case of the grinding of tooth flanks on tooth-flank grinding machines.

In-feed motion

Figure 7/4 In-feed motion during grinding



The in-feed motion in grinding is performed by the tool (Figure 7/4).

7.1.3. Examples of operations on grinding machines

Horizontal flat grinding of a cutting tip

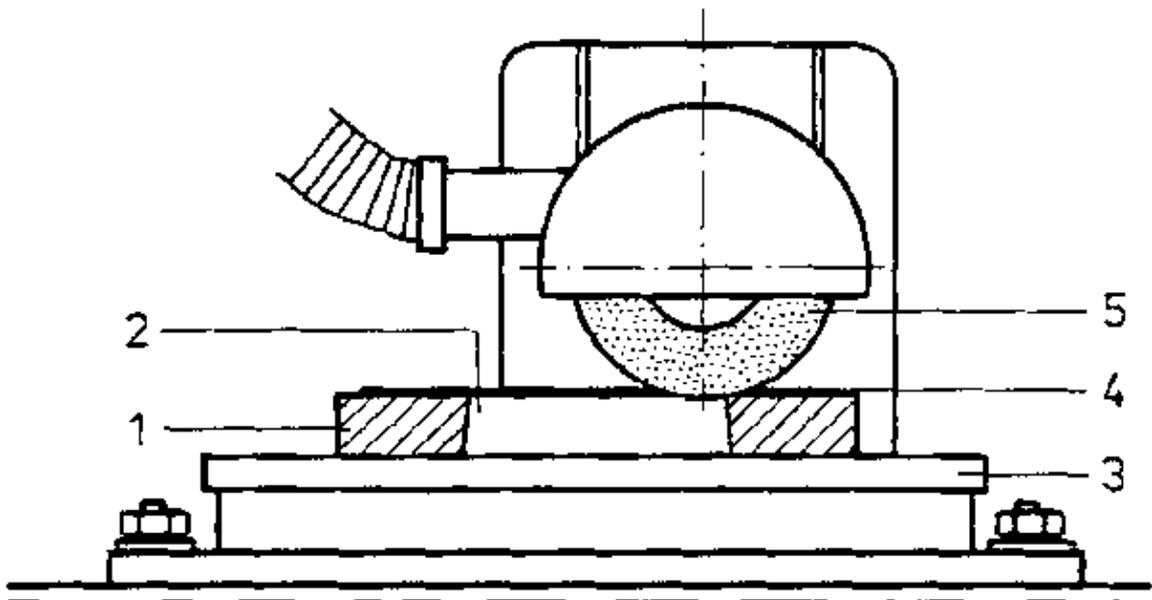


Figure 7/5 Flat grinding on a horizontal flat grinding machine

1 Cutting plate, 2 Rupture, 3 Magnetic clamping plate, 4 Cutting surface, 5 Abrasive tool.

Figure 7/5 shows the cutting tip (1) with an opening (2). The cutting tip is clamped on a magnetic plate (3). The cutting face (4) was ground with an abrasive tool (5).

Vertical flat grinding of a base plate with two sliding surfaces

Figure 7/6 shows a base plate (1) with two sliding surfaces (2). The base plate is clamped with clamping straps (3) on the machine table (4). The sliding surfaces were ground by means of a segmental abrasive tool (5).

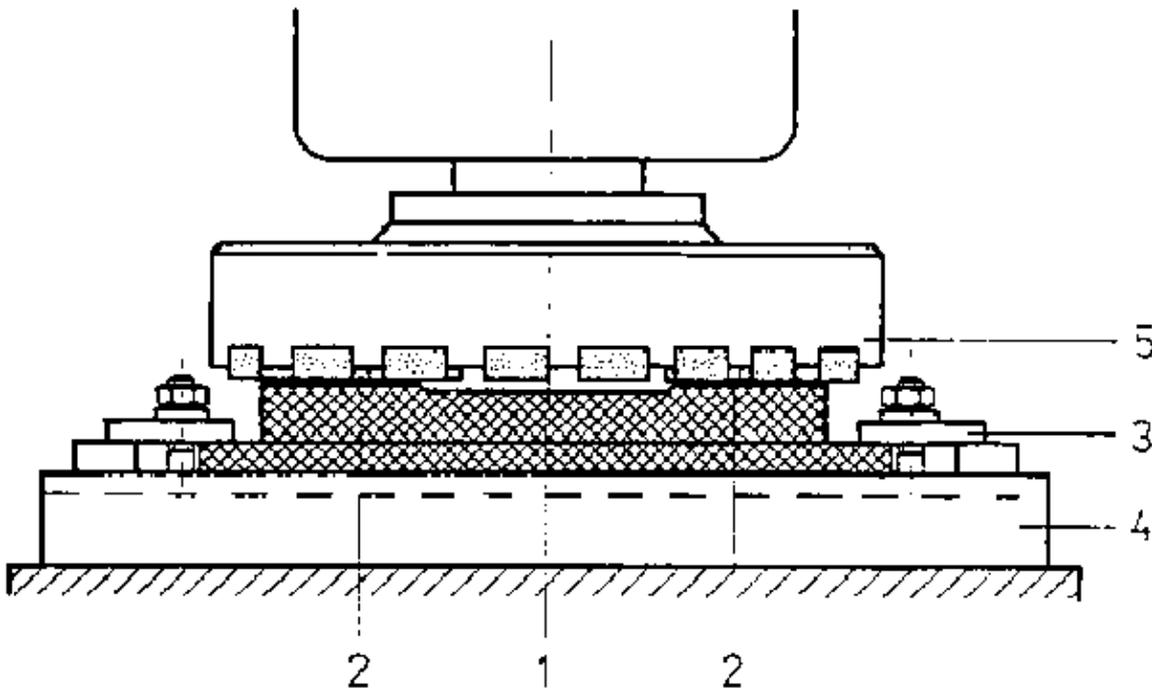


Figure 7/6 Flat grinding on a vertical flat grinding machine

1 Base plate, 2 Guideways, 3 Clamping straps, 4 Machine table, 5 Segmental abrasive tool.

External cylindrical grinding of a shaft

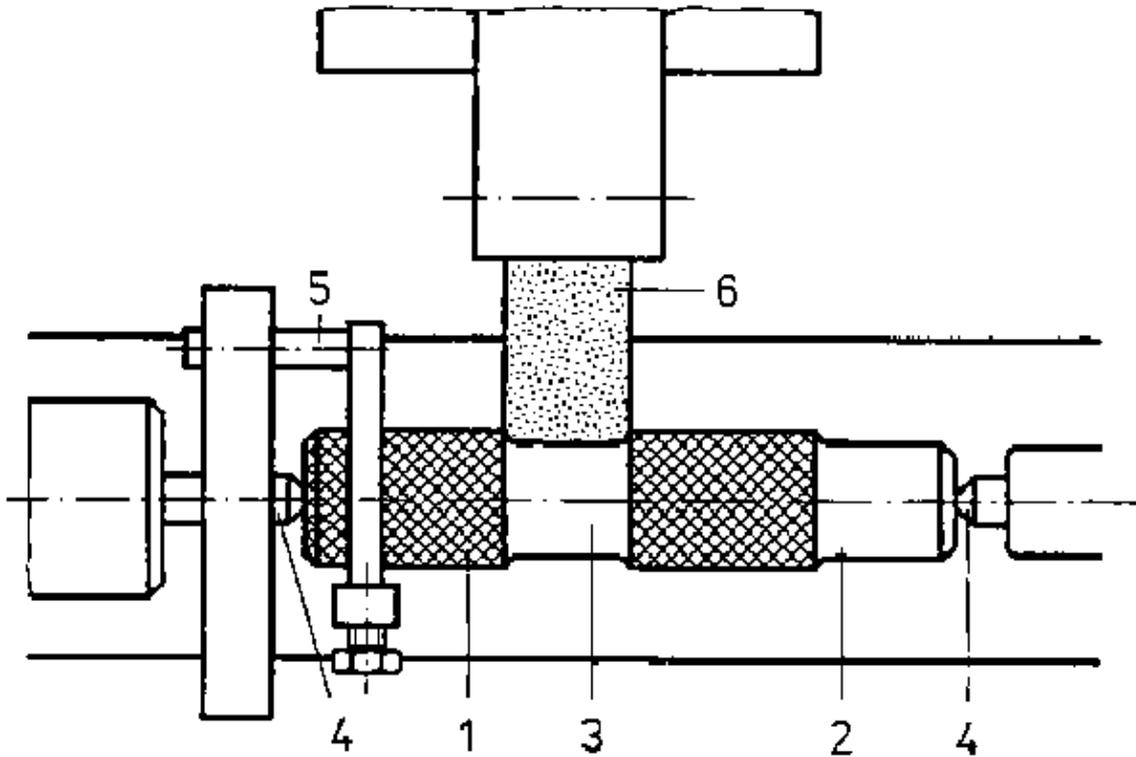


Figure 7/7 External cylindrical grinding on an external cylindrical grinding machine

1 Shaft, 2 End journal, 3 Collar journal, 4 Centres, 5 Driver, 6 Profiled abrasive tool.

Figure 7/7 shows a shaft (1) with end journal (2) and neck collar journal (3). The shaft is clamped between centres (4). It is moved by a driver (5), The journals are ground with a profiled peripheral abrasive tool (6).

Internal cylindrical grinding of a bearing bush

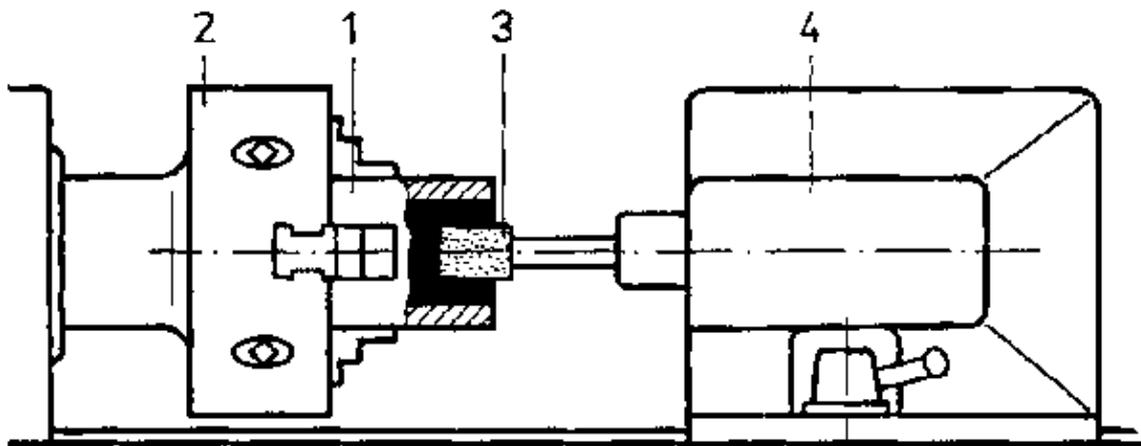


Figure 7/8 Internal cylindrical grinding on an internal cylindrical grinding machine

1 Bearing bush, 2 Three-jaw chuck, 3 Pin-type abrasive tool, 4 Grinding wheel spindle head.

Figure 7/8 shows a bearing bush (1). The bush is clamped into a three-jaw holder (2). The bush was ground with a pin-type abrasive tool (3).

Grinding the tooth flanks of a gear tooth

Figure 7/9 shows a gear tooth with spur-gear toothing (1). The toothed gear is clamped on a conical mandrel (2) between round table (3) and centre (4). The tooth flanks (5) are ground by means of a profile abrasive tool (6).

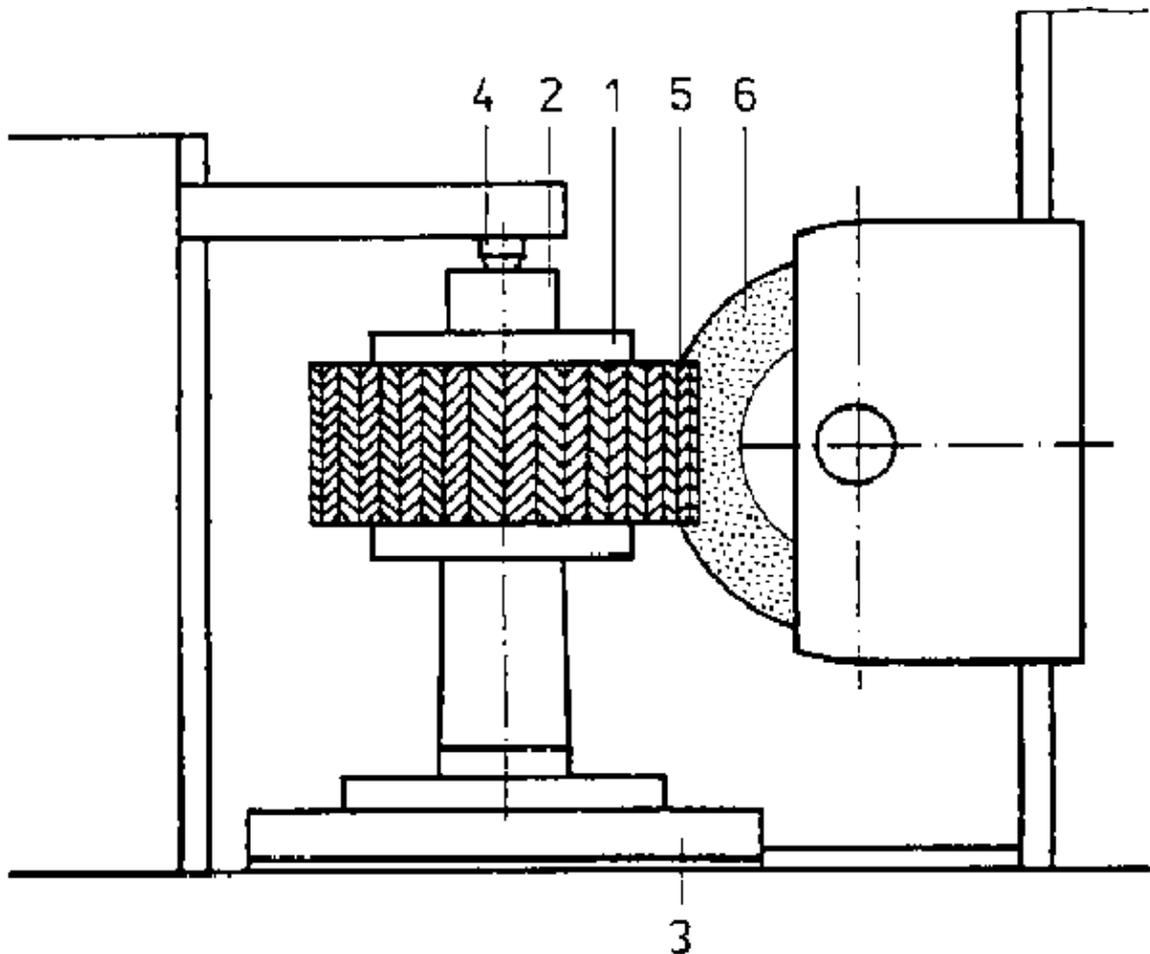


Figure 7/9 Tooth-flanks grinding on a tooth-flanks grinding machine

1 Toothed wheel with spur gearing, 2 Conical arbor, 3 Round table. 4 Centre, 5 Tooth flank, 6 Profile abrasive tool.

Control questions

1. Name several machines to be used for grinding operations.
2. Name workpieces that are preferably machined on these machines.
3. What working motions arise in grinding?
4. Name products which have been machined in your enterprise by grinding operations.

7.2. Horizontal flat grinding machine

7.2.1. Structure and mode of operation

In this section you shall get acquainted with

- the machine components of which horizontal flat grinders are composed
- the types of drive which drive horizontal flat grinders
- the kinds of mechanisms of transfer used to transform the movements of motor into working movements.

– the way how the components of the motor interact with the working mechanisms.

Components of a horizontal flat grinding machine

The machine frame (1) with the bed (2) and the column (3) forms the main structure of the machine. The table (4) slides on the bed. The grinding-wheel spindle head (5) is mounted on the column.

The bed accommodates the motor (6) as well as the mechanisms of transfer (7) required for the motion of table (feed motion).

The grinding-wheel spindle head includes the motor (8) required for the drive of the grinding spindle (9) with the abrasive tool (cutting motion) and the devices for the feed motion of the wheel slide (10). An exhaust (11) for the grinding dust is also provided at the spindle head. The entire grinding-wheel spindle head can be lifted and lowered at the column; it carries out in-feed motions.

All slideways of a grinding machine are provided with covers (12) to protect from grinding dust which otherwise would mix with the lubricant to form a paste.

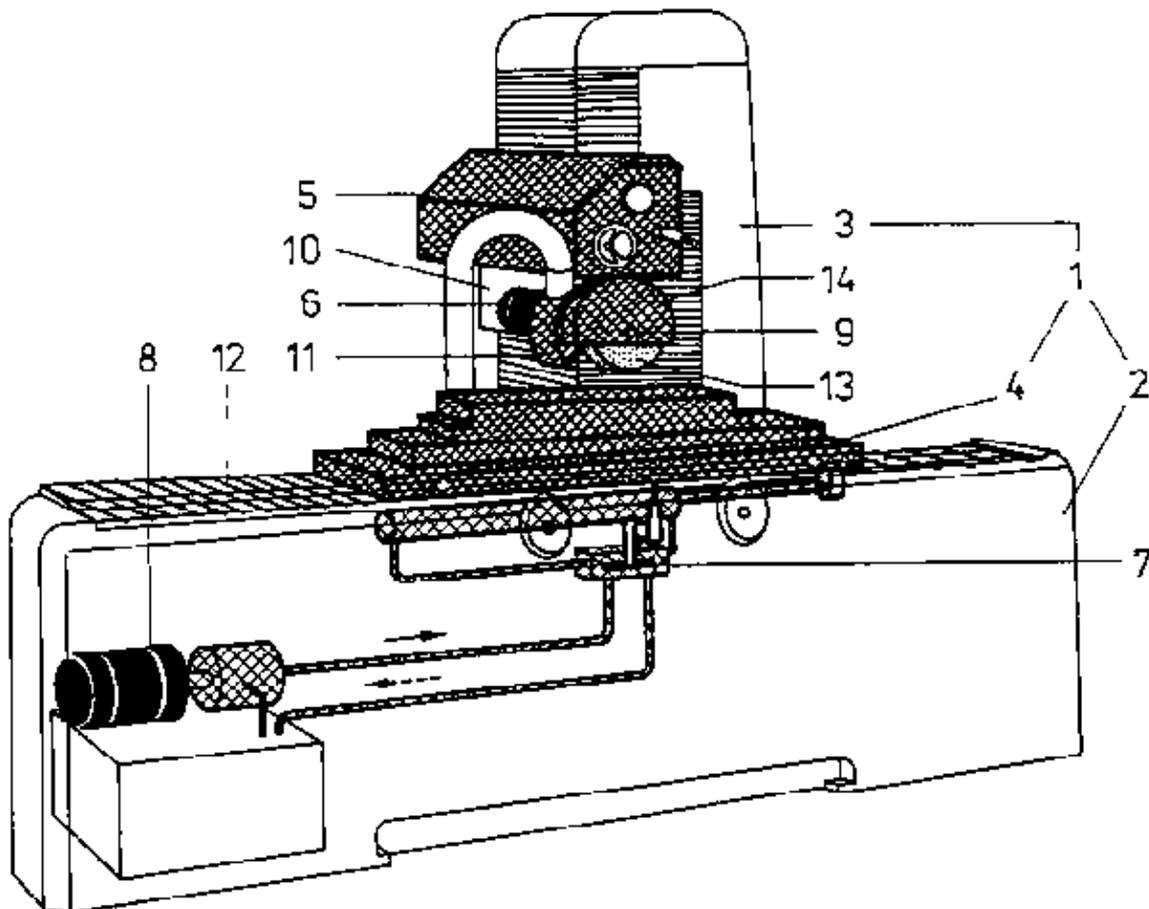


Figure 7/10 Components of a horizontal flat grinding machine

1 Machine frame, 2 Bed, 3 Column, 4 Table, 5 Grinding wheel spindle head, 6 Motor, 7 Mechanism of transfer for table movement, 8 Motor, 9 Wheel spindle, 10 Wheel slide, 11 Exhaust device, 12 Cover, 13 Abrasive tool, 14 Protective hood.

The abrasive tool (13) is encased with a protective hood (14), so that nobody can inadvertently come into contact with the rotating abrasive tool and to avoid that particles of a bursting abrasive tool will injure somebody.

Drive of a horizontal flat grinding machine

For the drive electric motors were used. Each machine has several motors that can be switched independently of each other.

Mechanisms of transfer of a horizontal flat grinding machine

- Mechanisms for the drive of grinding spindle

In most cases the electric motors transmit directly to the mechanisms driven by them, e.g. motor (8) in Figure 7/10 transmits directly to the spindle drive (9). If special demands are made on a smooth run of the abrasive tool, an elastic coupling will be provided between motor and grinding spindle (Figure 7/11), It contains a rubber disk so that the metal parts of motor shaft and those of the grinding spindle do not come into immediate contact with each other, but only via the damping rubber disk. The number of revolutions of the grinding tool is infinitely variable by the motor.

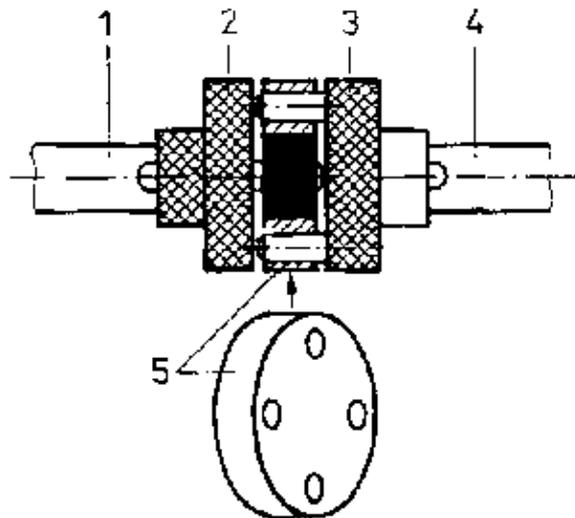


Figure 7/11 Mode of operation of an elastic clutch

1 Motor shaft, 2,3 Half-couplings 4 Grinding wheel spindle, 5 Rubber disk.

- Mechanisms for feed motion

A horizontal flat grinding machine performs feed motions in two directions (Figure 7/12):

- Reciprocating back and forth movement of table (longitudinal feed)
- Transverse movement of grinding wheel slide (transverse feed).

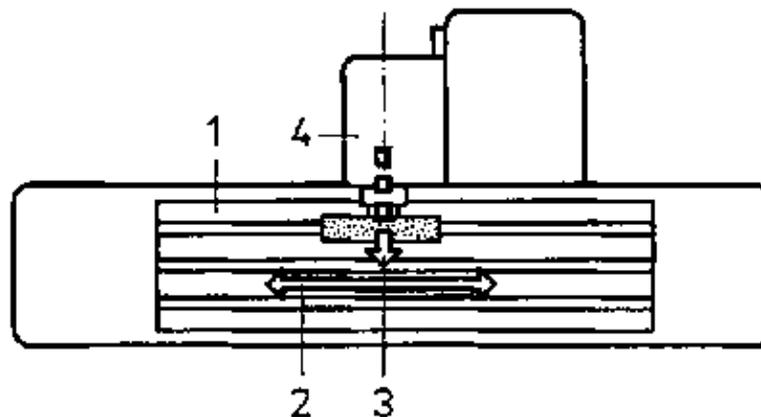


Figure 7/12 Directions of feed motions during horizontal flat grinding

1 Table, 2 Direction of longitudinal feed motion, 3 Direction of transverse feed motion, 4 Grinding wheel spindle head.

Hydraulic systems are mostly used in grinding machines as mechanisms of transfer between motor and table, or slide. Hydraulic mechanisms have advantages for grinding machines (Figure 7/13). Power transmission is done in a smooth and vibration-free manner, so that no uneven spots arise on ground surfaces due to vibrations in the mechanisms of transfer. This hydraulic system is made up of a hydraulic pump (1) as the generator of compression, a control block (2) for the reversal of the compressed current and a hydraulic cylinder (4) to transform the compression into a sliding movement (5) which is transmitted onto the part to be driven, e.g. on the table, or the grinding wheel slide.

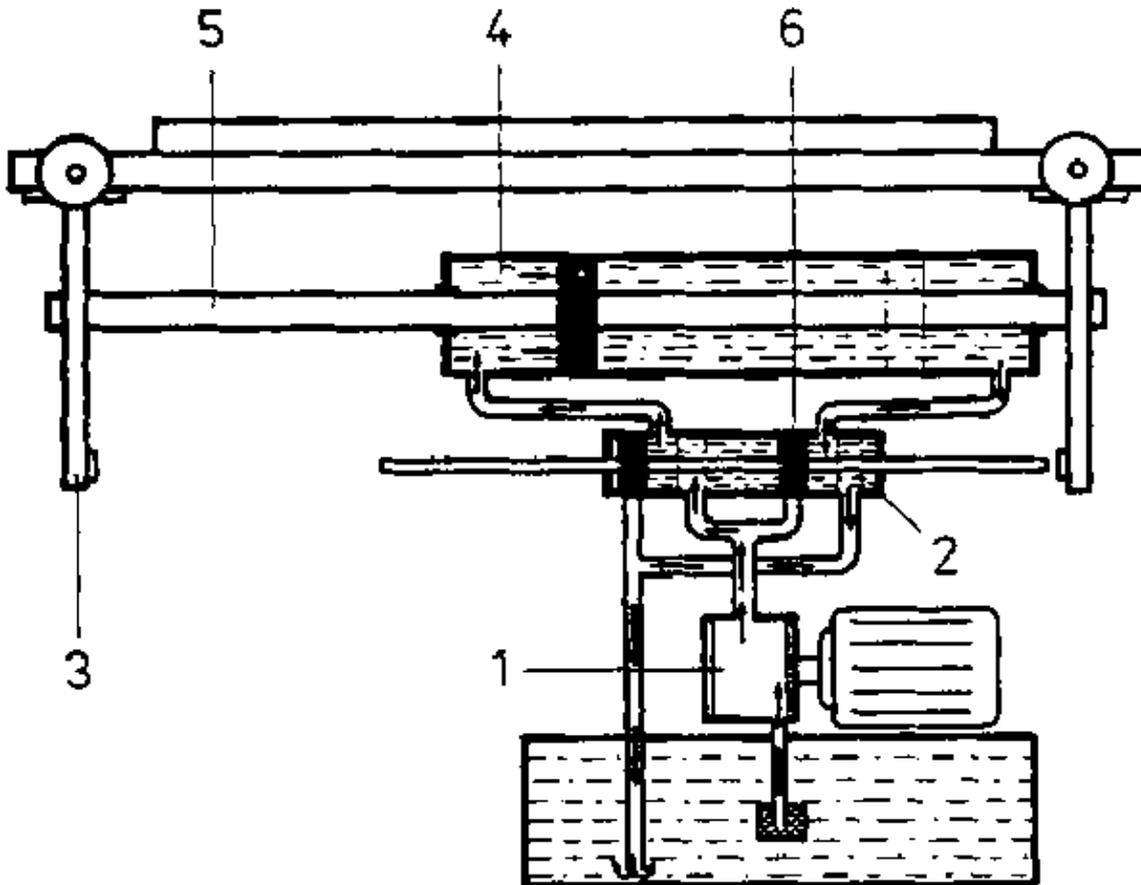


Figure 7/13 Mode of operation of a hydraulic mechanism of transfer

1 Hydraulic pump, 2 Control block, 3 Stops at table to readjust control block, 4 Hydraulic cylinder with piston, 5 Connecting rod, 6 Piston at control block to reverse hydraulic oil current.

Stops (3) on the table limit the feed motion. They act against a piston (6) at the control block, they actuate the lever and control the hydraulic oil current in the control block in a way that the piston is moved into the opposite direction, until the second stop again actuates the lever and reverses the hydraulic oil current. As a result there is a uniform and vibration-free reciprocating back and forth motion of table.

- Mechanisms for holding the abrasive tools

Abrasive tools are the tools of grinding machines. Horizontal flat grinding machines operate mostly with peripheral abrasive tools (Figures 7/5 and 7/7). It is typical of all peripheral abrasive tools that they grind with the peripheral surfaces.

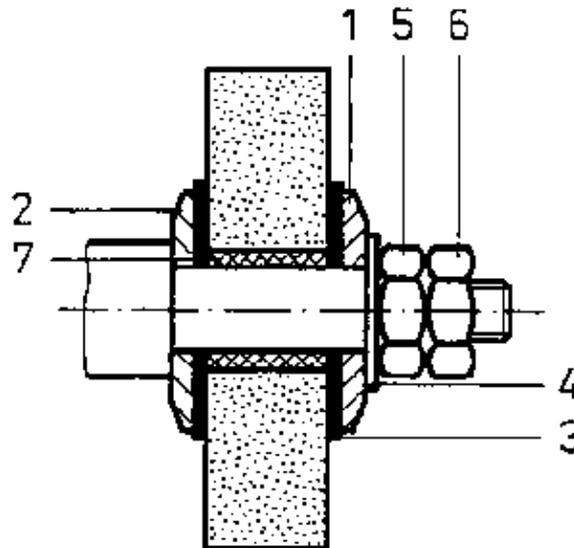


Figure 7/14 Fastening a peripheral abrasive tool on the wheel spindle

1,2 Flanges, 3 Intermediate layer made of soft material (e.g. cardboard), 4 Pressure disk, 5 Nut, 6 Jam nut, 7 Bushung made of soft material (e.g. plastics).

The abrasive tools are fastened on the grinding spindle. The fastening is made of two flanges (1,2), smooth intermediate layers (3), pressure disk (4) and nuts (5,6). In the hole of the abrasive tool there is a bush (7) made of soft material. The intermediate layers and the bushes are provided for the purpose of not squeezing an abrasive tool during fastening on the grinding spindle.

Abrasive tools are exposed to great centrifugal forces. Tools that were squeezed upon clamping burst during grinding and fly around like an explosion. Therefore

- Abrasive tools have to be clamped always in line with the instructions of the machine manufacturer
- Adequate force to be applied upon clamping
- Prior to switching–on the protective devices shall be applied!

Control questions

1. Describe the structure of a horizontal flat grinding machine.
2. Explain the particular aspects that have given the machine this name.
3. Describe the mode of operation of a hydraulic table drive.
4. Why are elastic and damping mechanisms of transfer convenient for grinding machines?
5. What is the purpose of the elastic supports upon clamping an abrasive tool on a grinding spindle?
6. How to counter–act the excessive development of dust during grinding?

7.2.2. Clamping devices for workpieces and their use

In this section you shall get acquainted with

- the various kinds of functions taken by work–clamping devices on horizontal flat grinding machines
- the various kinds of work clamping devices available
- the way of functioning of clamping devices
- the clamping devices which are preferably used for definite workpieces.

Tasks of clamping devices for workpieces

Grinding is mostly an operation of finishing. The workpieces are ground, so that

- the surfaces obtain a high grade and remain smooth,
- the measurements demanded are observed with only a few deviations (tolerances).

Thus the workpieces have to be clamped in a way that they do not distort, and they cannot even change their position. This applies especially to thin workpieces which are subject to easy bending.

The work-clamping devices have to clamp the workpieces firmly, without distorting them.

Design of the machine table

Workpieces with plain supporting surfaces are directly clamped on the machine table. The surfaces to be ground have to be parallel to the supporting surface (Figure 7/15).



Figure 7/15 Workpiece clamped on the table

1 Table, 2 Workpiece, 3 Clamping strap, 4 Table and surface to be machined run parallel.

The table is provided with T-slots for the insertion of clamping screws. The working face of table is ground and plain, so that workpieces are well supported and do not tilt.

Supporting surface of table to be preserved from damage! No striking on table, for every unevenness affects the position of workpiece.

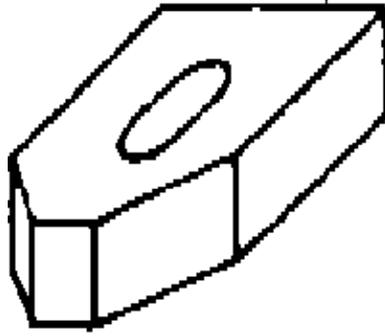
Grinding dust and metal chips are collected in the T-slots. They impede the insertion of the clamping screws. Therefore the T-slots have to be cleaned regularly.

Clamping straps

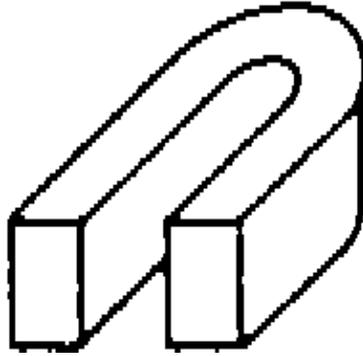
Clamping straps are used together with the clamping screws. They transmit the forces from the clamping screw to the workpiece and press it firmly against the table. It has to be added that the workpiece is required to have adequate shoulders and shapes for the application of clamping straps. Moreover, the clamping screws and straps are not allowed to impede the workpiece (Figure 7/6).

To guarantee a convenient operation, various types of clamping straps have been designed and used (Figure 7/16).

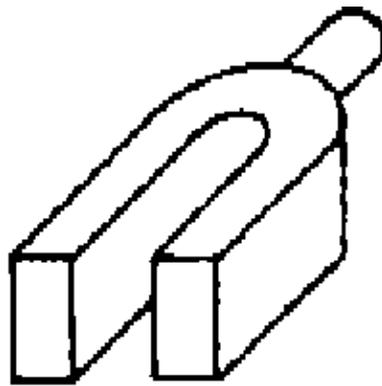
Figure 7/16 Differently shaped clamping straps



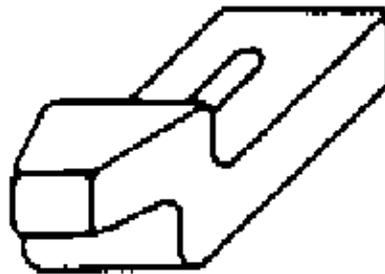
a Flat



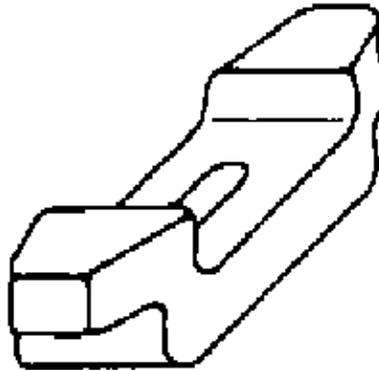
b U-shaped



c Fort-shaped



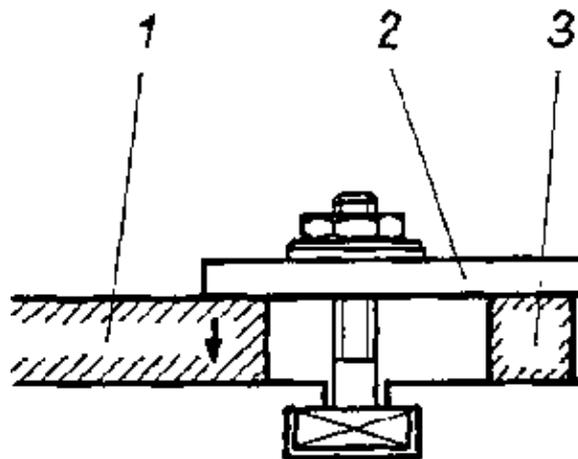
d Unilaterally angular bent



e Bilaterally angular bent

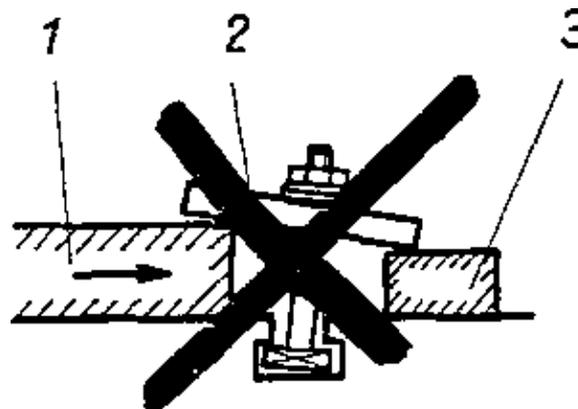
The clamping strap lies with one side on the workpiece, with the other on the clamping support. There should be the same height between the workpiece at the support point and the clamping support, so that the clamping strap lies parallel to the table (Figure 7/17a). If the clamping strap does not happen to lie parallel to the machine table, the clamping screw is unilaterally loaded; thus it cannot be tightened right up and the workpiece can slip out underneath the clamping strap (Figure 7/17b). Graduated clamping supports make it possible to adapt the supporting point to the workpiece (Figure 7/18).

Figure 7/17 Clamping strap to be used technically correct!



a Clamping strap lies parallel to table: correct

1 Table, 2 Clamping strap, 3 Clamping support.



b Clamping strap does not lie parallel to table: incorrect

1 Table, 2 Clamping strap, 3 Clamping support.

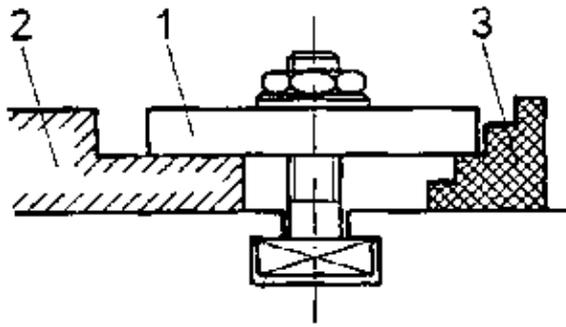
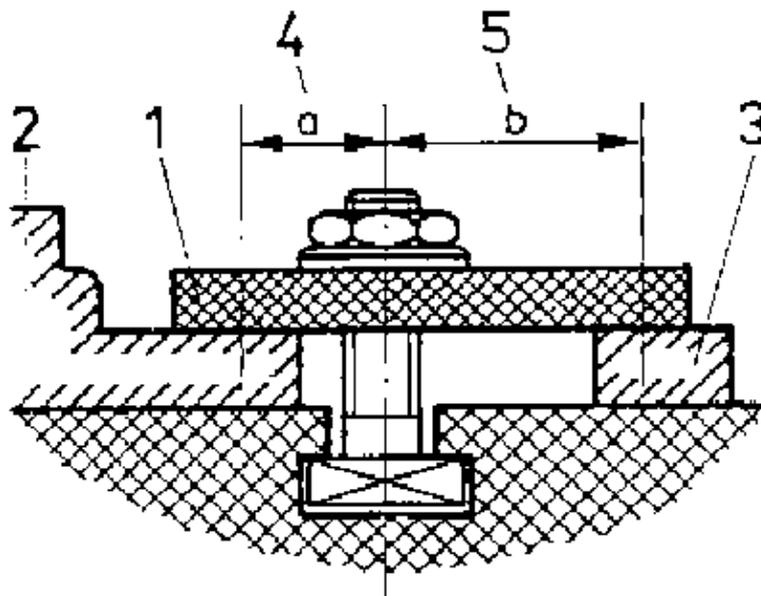


Figure 7/18 Clamping support with a steps

1 Clamping strap, 2 Workpiece, 3 Clamping support.

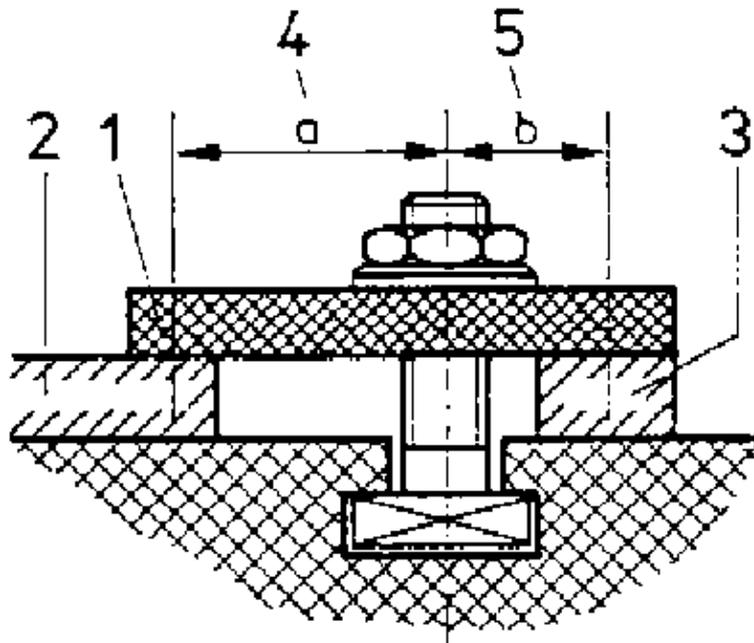
The clamping strap utilizes lever action (Figure 7/19) if it is laid in a way that the distance between clamping screw and support is greater (force arm) than that between clamping screw and workpiece (weight arm).

Figure 7/19 Lever action to be utilized by using clamping strap



a Lever action well utilized

1 Clamping strap, 2 Workpiece, 3 Clamping support, 4 Weight arm, 5 Force arm.



b Lever action poorly utilized

1 Clamping strap, 2 Workpiece, 3 Clamping support, 4 Weight arm, 5 Force arm.



$$F_1 \cdot a = F_2 \cdot b$$

c Lever transmission

To allow a workpiece to be well supported by the table it is required to tighten all clamping screws right up uniformly.

Irregularly tightened-up clamping screws tilt the workpiece on the machine table. Thus the result of work is impaired.

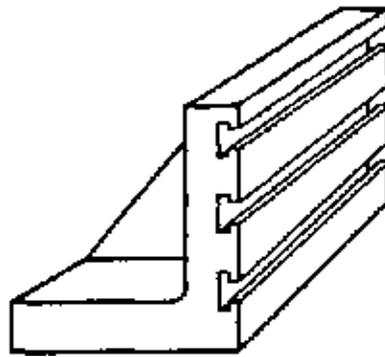
To utilize clamping straps in a technically correct manner means

- to tighten up all screws in a uniform way
- to utilize lever action
- to observe the parallel position to table.

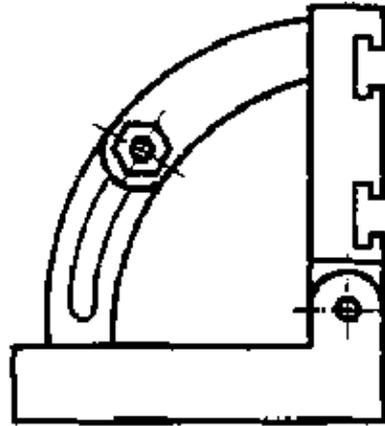
Clamping angles

Clamping angles are used when the surface to be cut by grinding is not parallel to the table. There are fixed and adjustable clamping angles (Figure 7/20). The workpiece is mounted on the clamping angle by clamping devices, such as clamping straps, after the angle plate was itself screwed tight on the table of the grinding machine (Figure 7/21).

Figure 7/20 Clamping angles



a Fixed



b Adjustable

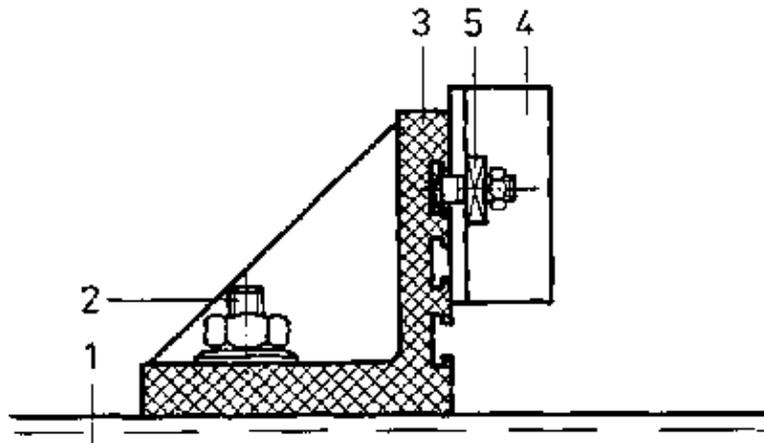


Figure 7/21 Clamping angle with workpiece

1 Table, 2 Drawbolts, 3 Clamping angles, 4 Workpiece, 5 Clamping strap with drawbolts.

Electromagnetic clamping plate

Electromagnetic clamping plates are frequently used on flat grinding machines. They utilize the magnetic forces to keep a workpiece made of steel (Figure 7/22).

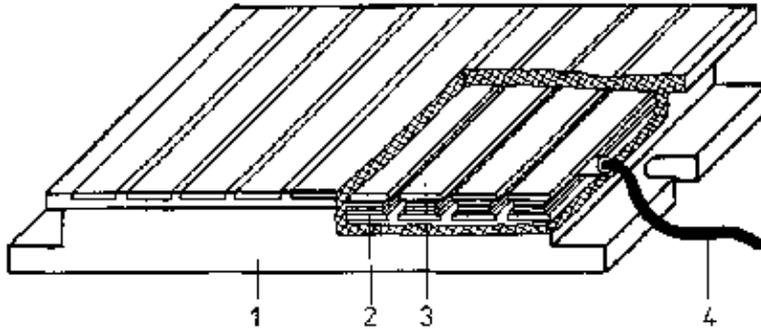


Figure 7/22 Electromagnetic clamping plate, partially broken

1 Casing, 2 Coils, 3 Cores, 4 Supply line for electric current.

There are coils inside the electromagnetic plate. As soon as an electric current flows through the coils a magnetic field is caused in the core of coil which holds the workpiece in place. To release the workpiece, the current is disconnected, the magnetic forces are suspended and the workpiece can be taken off from the clamping plate.

Specially thin workpieces can be well clamped with magnetic clamping plates because they are uniformly attracted and have a firm support without being bent by stressing forces.

It is also convenient that the abrasive tool is not impeded by clamping devices, such as clamping straps, and others.

The clamping plate itself is fastened on the machine table by using clamping devices, such as clamping straps.

Clamping fixtures

It is advisable to use clamping fixtures for those workpieces that cannot be fastened with any other clamping devices, and for those workplaces which are ground in great numbers. Clamping fixtures increase productivity of labour, because they speed up the clamping and unclamping of workpieces (Section 5.2.2.).

Control questions

1. What are the tasks of workpiece clamping devices on horizontal flat grinding machines?
2. Name clamping devices that are used on horizontal flat grinding machines.
3. What types of workpieces can be clamped with these devices?
4. Describe the function of an electromagnetic clamping plate.
5. What is the danger if a workpiece was not sufficiently tightly clamped?
6. What is the influence of a correct clamping of workpiece on surface grade and dimensional stability?

7.2.3. Handling of horizontal flat grinding machines

In this section you shall get acquainted with

- the way of setting a horizontal flat grinding machine
- the way of operating the machine during grinding
- the kinds of errors and faults to be avoided during operation of the machine.

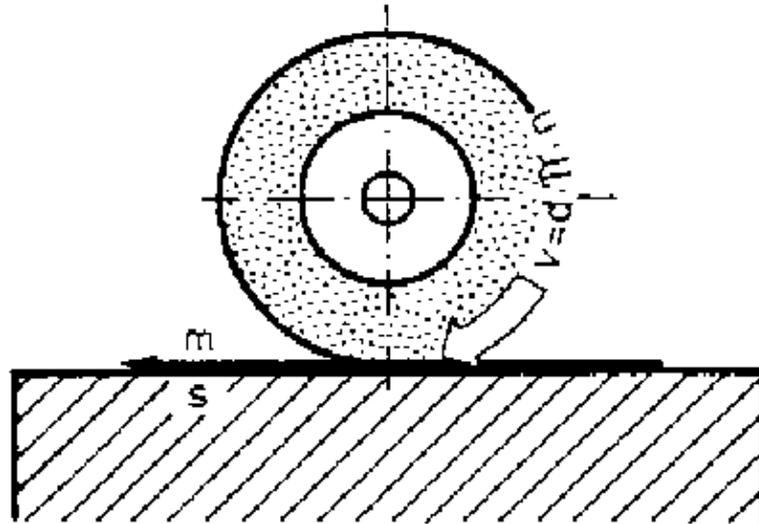
Setting the machine

In setting the machine it is provided that the grinding operations intended shall proceed with suitable machining characteristics for horizontal flat grinding.

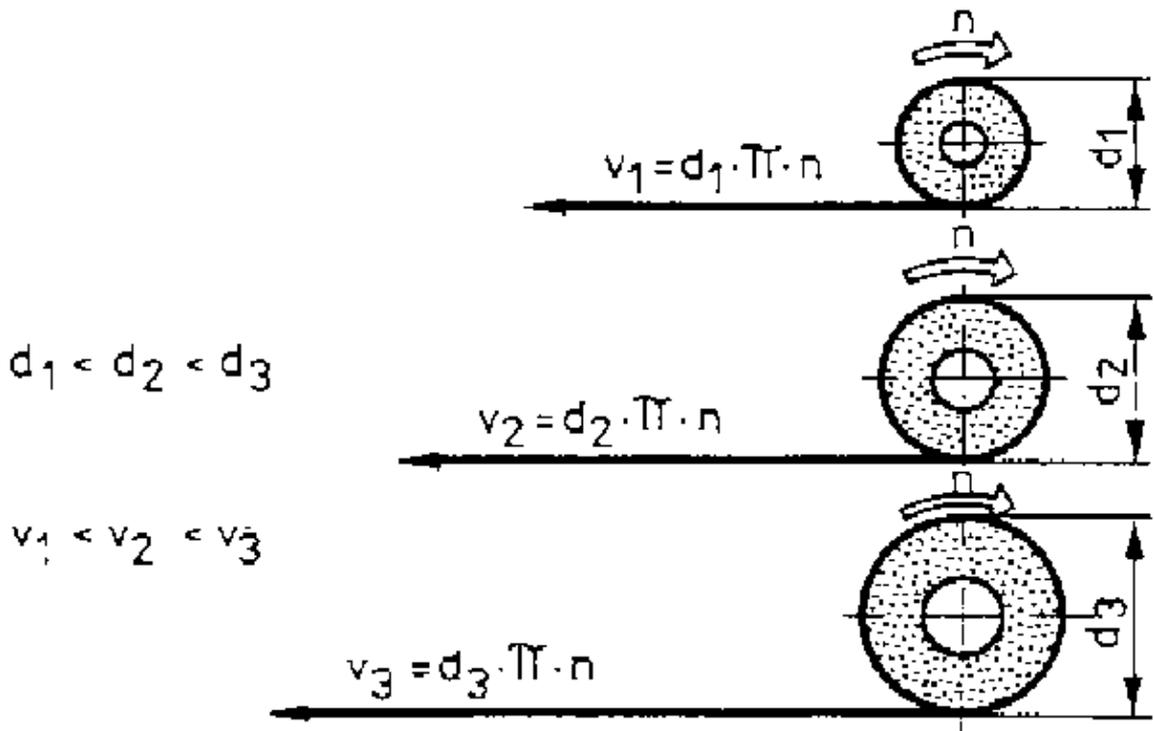
- Setting the –grinding wheel spindle speed

The number of revolutions of the grinding spindle is a variable which co-determines the cutting speed during grinding (Figure 7/23).

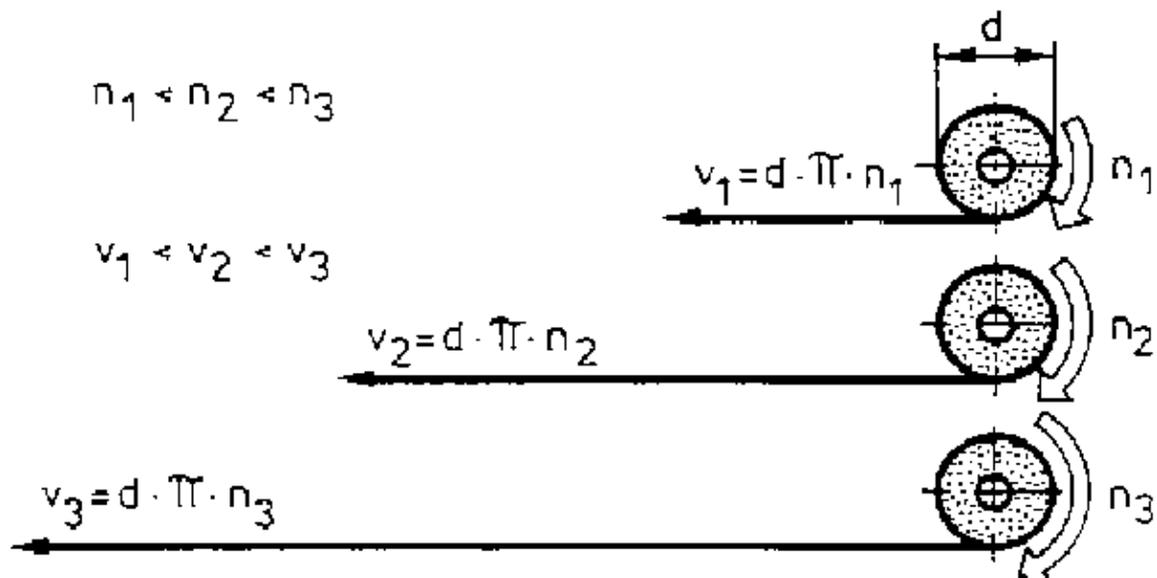
Figure 7/23 Cutting speed during grinding



a Representation of cutting speed



b Influence of abrasive tool diameter, the speed of grinding wheel is constant (n)



c Influence of rotations of abrasive tool, the diameter of grinding wheel (d) is constant.

The cutting speed in grinding is the speed at which the abrasive tool travels along the workpiece.

The cutting speed depends upon

- the material composition of the abrasive tool and
- the material of the workpiece.

The cutting speed should be chosen as high as possible. But the number of rotations as the influence factor on the cutting speed is not allowed to exceed the value that is indicated on the label of abrasive tool as the maximum value.

Any higher number of rotations, as is permissible for abrasive tool, would mean a great danger of accidents!

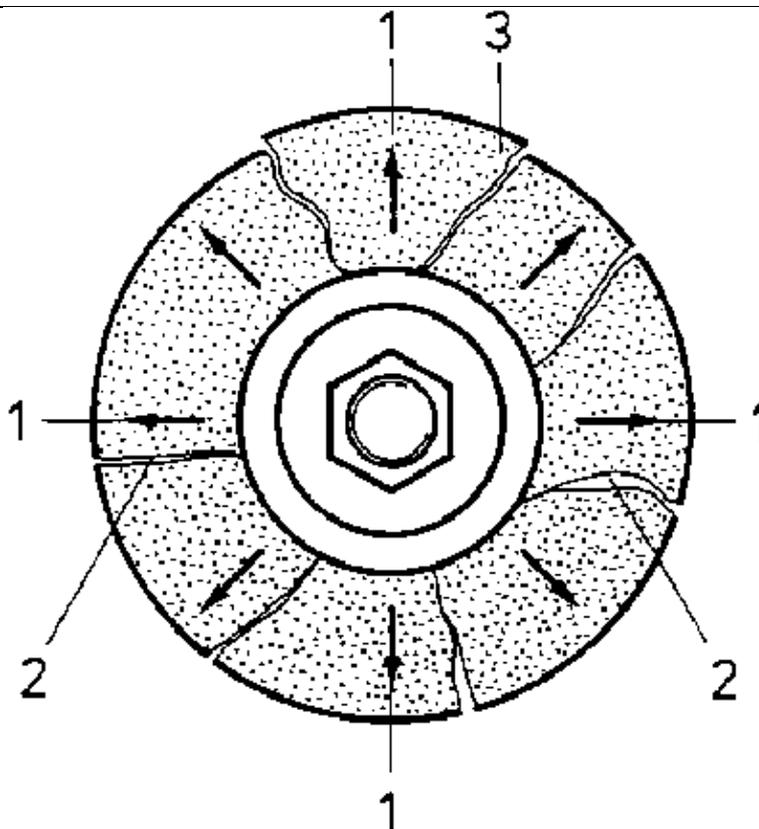


Figure 7/24 Effects resulting from excessive speed of abrasive tool

- 1 Centrifugal forces, 2 Material of grinding wheel loses adhesion, 3 Abrasive tool flies apart.

The grinding wheel spindle speed is adjusted, according to the design of the machine, at the motor for the drive of the grinding spindle (Figure 7/10), if an adjustable-speed motor is available; or it is adjusted by changing the belt at the belt drive.

- Setting the feed motions

Two feed motions have to be set at a horizontal flat grinding machine:

- the longitudinal feed motion of table
- the transverse feed motion of grinding-wheel slide

The longitudinal feed motion of table (L) corresponds to the sum of

- the length of workpiece (l)
- the advance of tool up to the beginning of metal cutting (l_a)
- the overtravel of tool beyond the workpiece (l_u)

$$L = l + l_a + l_u$$

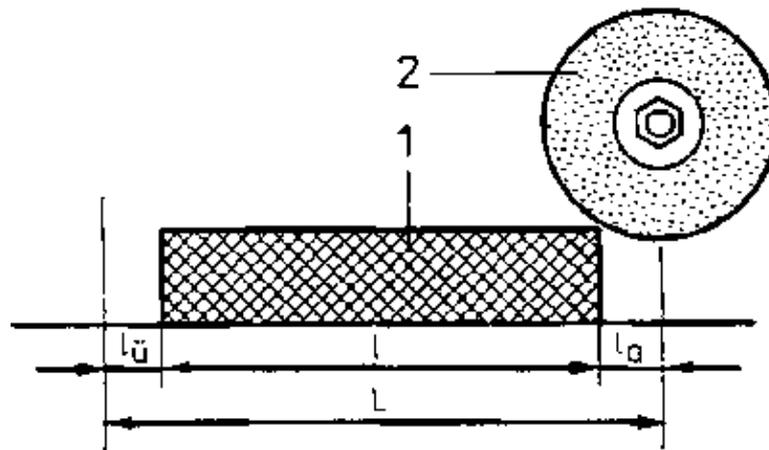


Figure 7/25 Length of feed motion of table

1 Workpiece, 2 Tool, L Length of feed motion, l Length of workpiece, l_a Advance of tool, l_u Overtravel of tool.

The length L shall not be greater than required; therefore advance and overtravel are to be chosen only so great that the abrasive tool protrudes from the workpiece and the transverse feed motion can proceed unimpededly (Figure 7/25). If advance and overtravel are too great, it would mean non-productive time and loss (Figure 7/26).

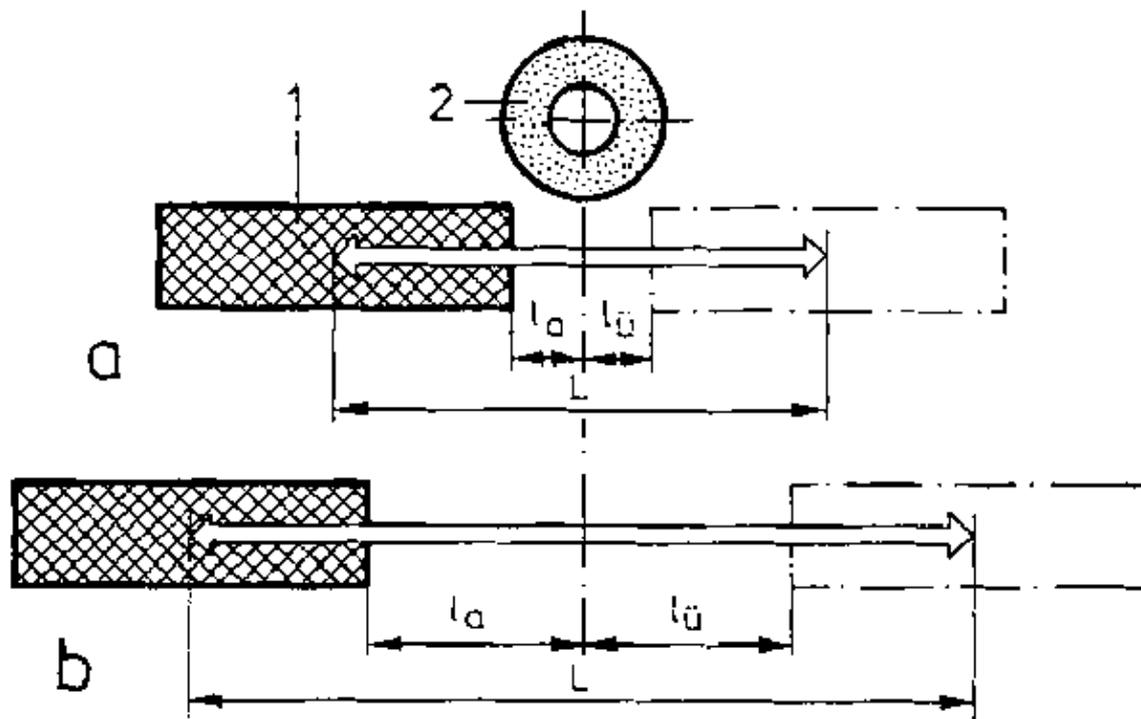


Figure 7/26 Loss as a result of excessive longitudinal feed motion

a Longitudinal feed motion correct, b Longitudinal feed motion too long
 1 Workpiece, 2 Tool, L Length of longitudinal motion, l_a Advance of tool, l_u Overtravel.

The longitudinal feed motion is limited by stops. Setting implies therefore to adjust the stops (Figure 7/13).

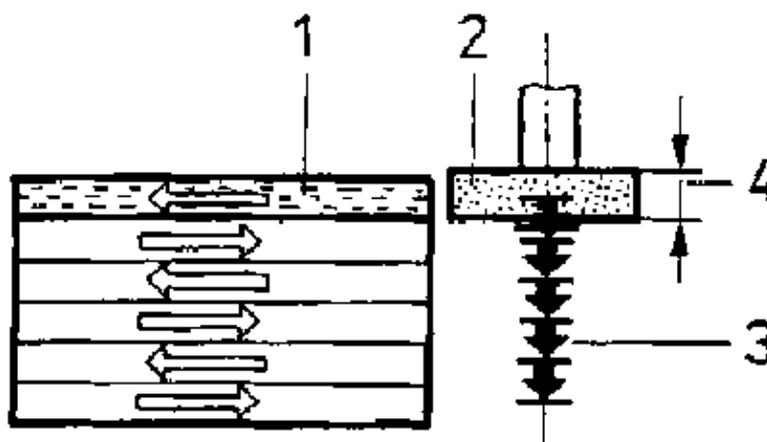


Figure 7/27 Length of transverse feed motion

1 Workpiece, 2 Tool, 3 Transverse feed motion, 4 Width of tool.

The transverse feed motion of the grinding-wheel slide is to proceed always at the end of the longitudinal feed motion (Figure 7/12), The length of this feed motion is dependent upon the width of abrasive tool (Figure 7/27). The feed motion is caused by reversing the table movement.

• Clamping the workpiece

The workpiece is clamped on the machine table with one of the workpiece clamping devices according to Section 7.1.2.

In preparing the clamping devices the following instructions shall be observed:

Machine table

– to be laterally moved out of the range of operation of abrasive tool;

- to be cleaned from grinding dust, especially the T-slots; brush, cleaning rag or vacuum cleaner shall be used, never compressed air to be used for blowing off.

Clamping screws

- to be inserted into T-slots for testing,
- nuts to be screwed on for testing.

Electromagnetic clamping plate

- condition of electric connections to be checked,
- to be switched on for testing and function to be checked,
- to be fastened on machine table with clamping devices

• Multiple clamping

It is convenient in grinding to use always several suitable workpieces especially when an electromagnetic clamping plate is used for the clamping of workpieces (Figure 7/28). However, the workpieces are required to be ground to the same measurements.

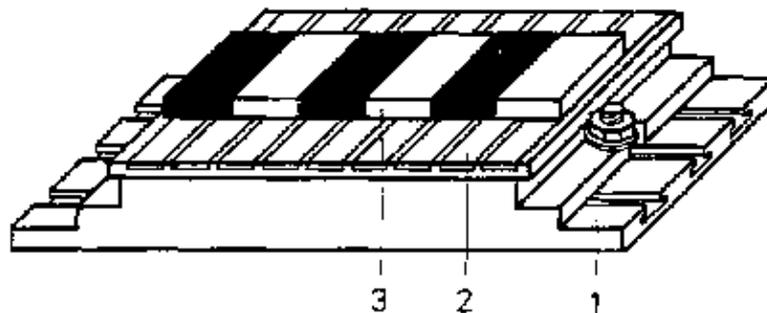


Figure 7/28 Multiple clamping on an electromagnetic clamping plate.

1 Table, 2 Electromagnetic clamping plate, 3 Workpieces.

Operating the horizontal flat grinding machine

After the machine had been set and the workpiece been clamped it is possible to begin with the grinding operations.

- Switching–on the machine (cutting motion) Prior to switching–on the workpiece has to be moved out of the operating range of the abrasive tool; the protective cover of abrasive tool has to be attached.
- Switching–on the exhaust device

The exhaust device provides for the exhaustion of fine grinding dust immediately at the operating point of abrasive tool.

The exhaust device protects the eyes and respiratory tracts of worker. It must always be switched on during grinding operations!

- Positioning of workpiece

During positioning the workpiece with the table is put into the position from which metal cutting (or: chip removal) is to begin.

The start–up movement puts the workpiece to the abrasive tool.

The in–feed movement determines the thickness of the layer to be removed by grinding. It is essential for the dimensional stability of work.

The re–adjustment movement serves to make corrections if deviations arise from the desired measurements of workpiece.

From the graduated dials of the controlling elements, e.g. the hand cranks and hand wheels of the grinding-wheel slide, it can be read what amount has to be fed in, or readjusted (Figure 7/29).

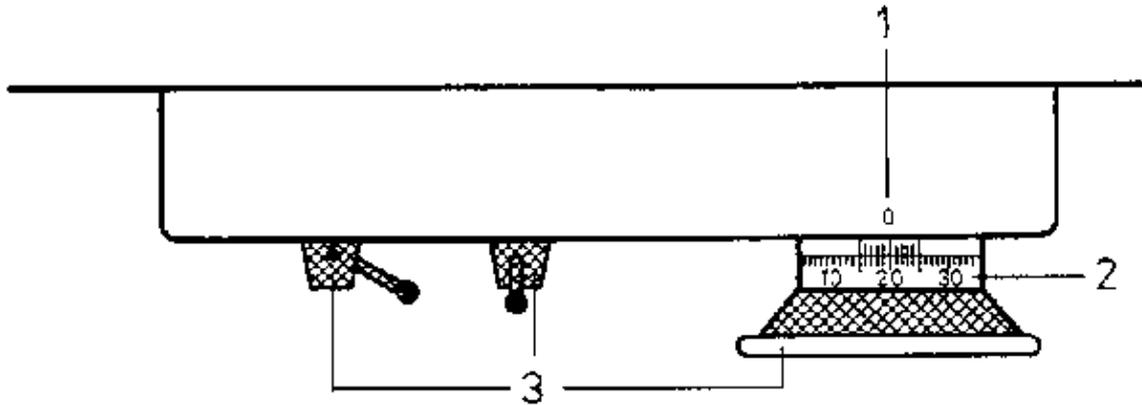


Figure 7/29 Scale collar rings at controlling elements

1 Zero stroke, 2 Scale with graduation, 3 Controlling elements.

- Switching-on the feed motions, beginning of cutting Horizontal flat grinding machines operate with automatic feed. If the automatic feed is switched on the hydraulic mechanisms begin to operate and the table reciprocates back and forth; the grinding wheel slide is advanced.

- Switching-off the feed motions, disconnecting the workpiece

After metal cutting the feed motions of table and the feed motion of the grinding-wheel slide are switched off. The workpiece is travelled back into its original position.

If further operations of metal-cutting are to follow, the abrasive tool with the grinding-wheel slide has to be fed by the desired measure. Again the workpiece has to be positioned.

- Switching-off the exhaust device, disconnecting the machine (cutting motion)

The cutting motion of the abrasive tool is only allowed to be switched off, after the feed motions have been switched off, because otherwise it is possible for the workpiece and the tool to get into a mutual position of constraint.

Please, observe the following sequence! Upon switching-on:

- first cutting motion (and exhaust device), then feed motions to be switched on; upon switching-off:
- first feed motions, then cutting motion (and exhaust device) to be switched off.

Control questions

1. Explain what has to be understood by the term 'cutting speed' in grinding on a horizontal flat grinding machine?
2. What is the influence of the diameter of the abrasive tool on the cutting speed?
3. What are the benefits if several workpieces are simultaneously clamped on an electromagnetic clamping plate?
4. Describe the setting of the automatic hydraulic longitudinal feed motion of table?
5. Why is it necessary to switch on the exhaust device during grinding?
6. Describe the setting of a horizontal flat grinding machine for a grinding job which you have performed.

7.3.1. Structure and mode of operation

Components of a vertical flat grinding machine

The machine frame (1) with the bed (2) and the column (3) form the main structure of the machine. The table (4) slides on the bed. The grinding-wheel spindle head (5) is provided at the column.

The bed accommodates the mechanisms for the feed motions of table. In principle, they are designed in the same way as the mechanisms of the horizontal flat grinding machine (Section 7.2.1.).

The grinding-wheel slide (6) can be adjusted upwards and downwards at the column (in-feed motion). It accommodates the motor (7) for the drive of the vertical grinding spindle with the abrasive tool (cutting motion).

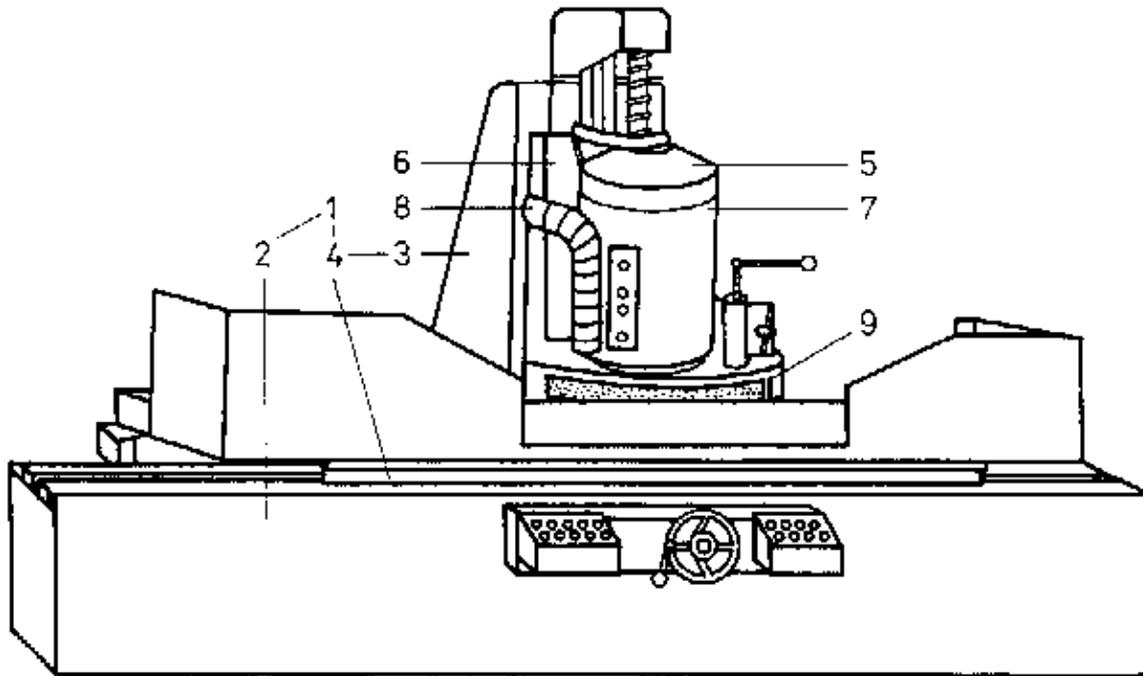


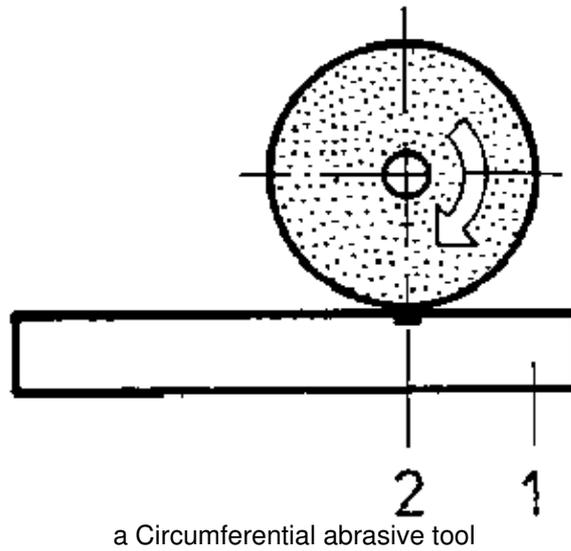
Figure 7/30 Components of a vertical flat grinding machine

1 Machine frame, 2 Bed, 3 Column, 4 Table, 5 Grinding wheel spindle head, 6 wheel slide, 7 Motor, 8 Exhaust device, 9 Protective hood.

The exhaust device (8) for the grinding dust is also mounted on the spindle head. The abrasive tool is encased with a protective hood (9).

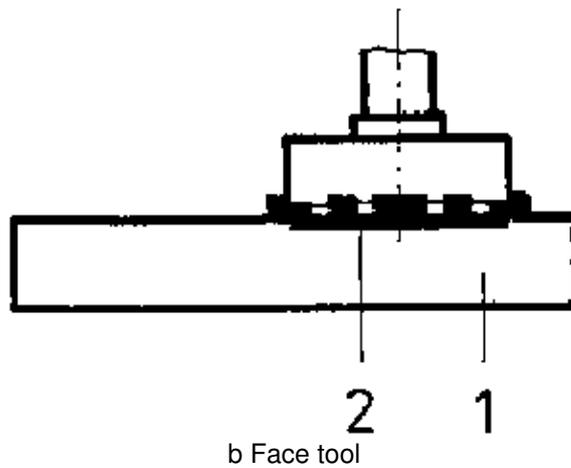
Electric motors are used as driving motors, as with horizontal flat grinding machines. The driving motors for the grinding-wheel spindle of a vertical flat grinding machine needs a higher capacity than that for the drive of the wheel spindle in a horizontal flat grinding machine: the abrasive tool attacks the workpiece with a larger cutting surface than that in a horizontal flat grinding machine. (Figure 7/31).

Figure 7/31 Comparison between circumferential tools and face tools, contact area



a Circumferential abrasive tool

1 Workpiece, 2 Contact area between workpiece and abrasive tool.



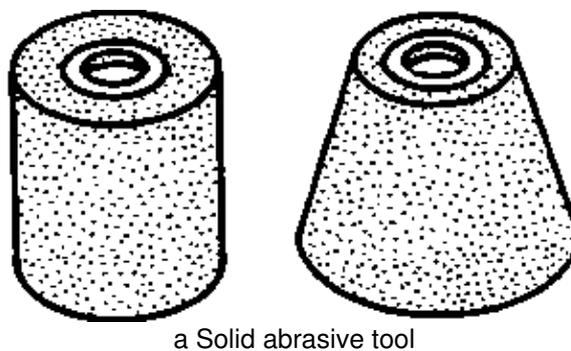
b Face tool

1 Workpiece, 2 Contact area between workpiece and abrasive tool.

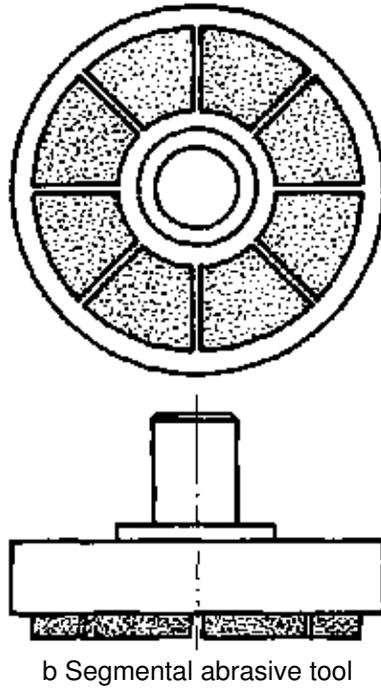
Mode of operation of a vertical flat grinding machine

The vertical grinding-wheel spindle carries the tool, the abrasive cutting tool, Vertical flat grinding machines operate primarily with face tools that may be designed as solid abrasive tools, or as segmental abrasive tools (Figure 7/32).

Figure 7/32 Abrasive tool of a vertical flat grinding machine



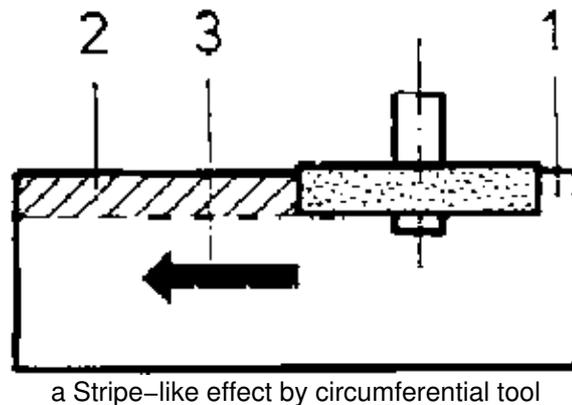
a Solid abrasive tool



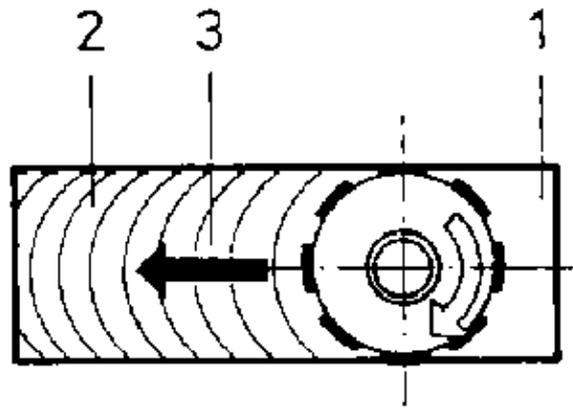
During grinding the tool rotates vertically around its longitudinal axis, it performs the cutting motion. The workpiece is clamped on the machine table by using one of the work-clamping devices (see Section 7.2.2.). The machine table with the workpiece performs the feed motion by allowing the workpiece to move underneath the abrasive tool. The face of the abrasive tool attacks a large part of the workpiece, so that no transverse feed of the grinding wheel slide is any longer required (Figure 7/33), By contrast, a peripheral abrasive tool performs a strip-like machining of the workpiece.

Figure 7/33 Comparison between circumferential and face tools:

Mode of operation



1 Workpiece, 2 Surface of action, 3 Feed motion (direction).



b Large-area effect of face tool

1 Workpiece, 2 Surface of action, 3 Feed motion (direction).

During in-feed the grinding-wheel spindle head is actuated in a vertical direction at the column. Since vertical flat grinding machines cut a large surface of workpiece, heat is created. For this reason the wet grinding technique is operated on these machines. Adequate attachments consisting of motors, pumps, conduits, filters are required. The coolant binds also a large part of the grinding dust.

7.3.2. Use of vertical flat grinding machines

Vertical flat grinding machines are frequently used for rough cuts involving a great deal of chip removal. The face tools attacking a large surface can machine several workpieces in one cutting operation; however, multiple clamping of tools will be required (Section 7.2.3.).

Control questions

1. Describe the structure of a vertical flat grinding machine.
2. Explain the similarities and differences between horizontal and vertical flat grinding machines,
3. Name several examples of jobs which are performed on vertical flat grinding machines.

7.4. External cylindrical grinding machine

7.4.1. Structure and mode of operation

In this section you shall get acquainted with

- the components of which external cylindrical grinding machines are composed
- the types of drive used to drive external cylindrical grinding machines
- the types of mechanisms of transfer used to transmit the motions of motor into working movements
- the interaction between the various components ranging from motor to the machining mechanisms.

Components of an external cylindrical grinding machine

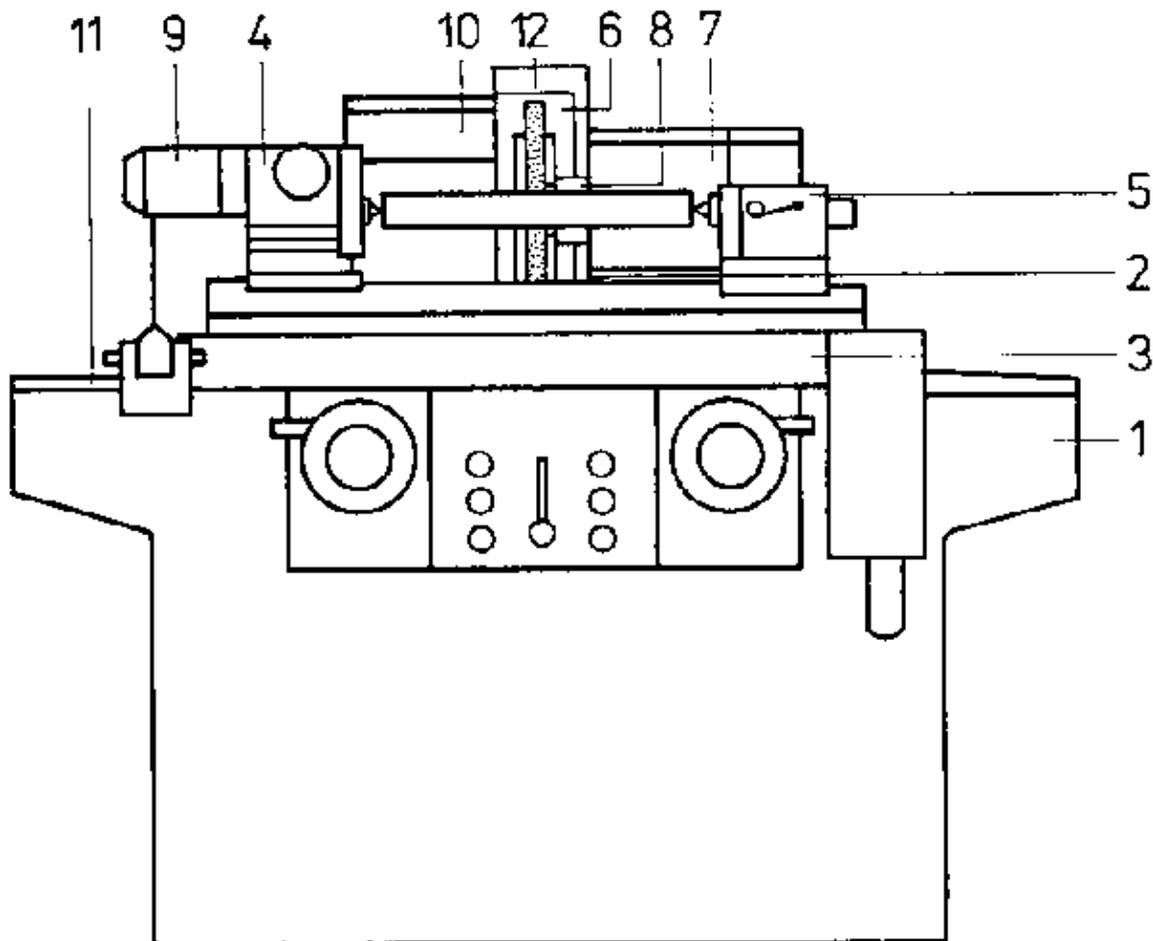


Figure 7/34 Components of an external cylindrical grinding machine

1 Bed for work table, 2 Bed for grinding wheel spindle head, 3 Table, 4 Workpiece spindle head, 5 Tailstock, 6 Grinding wheel spindle head, 7 Motor, 8 Wheel spindle, 9 Motor, 10 Exhaust attachment, 11 Covers, 12 Protective hood.

The main structure of machine is formed by the bed for the work table (1) and the bed for the grinding-wheel spindle head (2). The table (3) carries the spindle head (4) and the tailstock (5). The spindle head (6) is supported by the bed.

The grinding-wheel spindle head includes the motor (7) for the drive of the wheel spindle (8) with the abrasive tool (cutting motion). In addition it accommodates the mechanisms for the in-feed movement of the grinding-wheel spindle head.

The motor (9) for the rotating feed motion of workpiece is mounted on the workpiece spindle head.

The exhaust attachment (10) is mounted on the grinding-wheel spindle head.

The bed accommodates the mechanisms for the feed motion of table. In most cases these are hydraulic systems. In addition there are also the facilities for cooling in the bed.

All guideways are protected by covers (11). The abrasive tool is encased by a protective hood (12).

Drive of the external cylindrical grinding machine

Electric motors are used for the drive. An external cylindrical grinding machine is equipped with at least 5 motors, i.e.

- for the drive of the wheel spindle (cutting motion)
- for the drive of the workpiece spindle (rotating feed motion)
- for the drive of the table (longitudinal feed motion)
- for the drive of the coolant pump,

– for the drive of the exhaust attachment.

Mechanisms of transfer of an external cylindrical grinding machine

• Mechanisms for the wheel spindle drive

The wheel spindle can be immediately connected with the electric motor shaft, or an elastic coupling is provided (Section 7.2.1.).

To adjust the rotations of the abrasive tool it is possible to have an electric motor with adjustable rotations, i.e. speed. A belt drive can also be provided, it has additionally a damping effect.

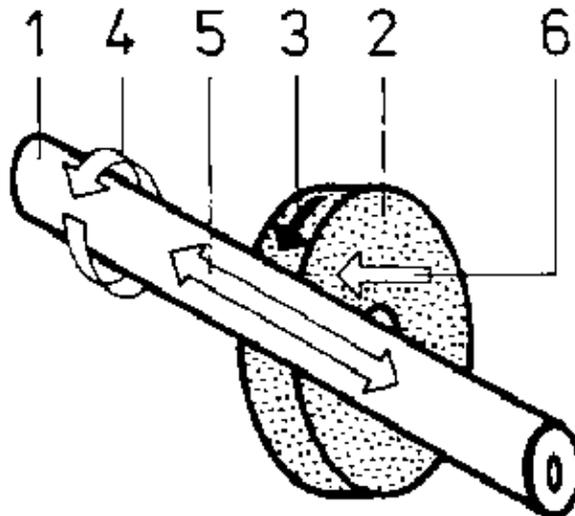


Figure 7/35 Operating movements of an external cylindrical grinding machine

1 Workpiece, 2 Abrasive tool, 3 Cutting motion, 4 Rotating feed motion, 5 Back and forth feed motion, 6 In-feed motion.

• Mechanisms for feed motions

An external cylindrical grinding machine performs feed motions in two directions (Figure 7/35):

- rotating feed motion of workpiece
- longitudinal feed motion of table.

The rotating feed motion is transmitted from the workpiece spindle head onto the workpiece. This feed motion has a low speed, so that a reduction gear is required between the electric motor and the work-clamping device.

Belt drives in steps are used, but it is also possible to use infinitely variable gears.

The longitudinal feed motion of table is generated as a reciprocating back-and-forth movement mostly by hydraulic transfer mechanisms (Section 7.2.1.). The function corresponds to one of a horizontal flat grinding machine.

Control questions

1. Describe the structure of an external, cylindrical grinding machine.
2. Explain the mode of operation of an external cylindrical grinding machine.
3. What are the similarities and differences between flat grinding machines and external cylindrical grinding machines?

7.4.2. Clamping devices for workpieces and their use

In this section you shall get acquainted with

- the functions of work-clamping devices on external cylindrical grinding machines,
- the types of clamping devices available
- the way of functioning of clamping devices
- those work-clamping devices that are preferably used for the various workpieces.

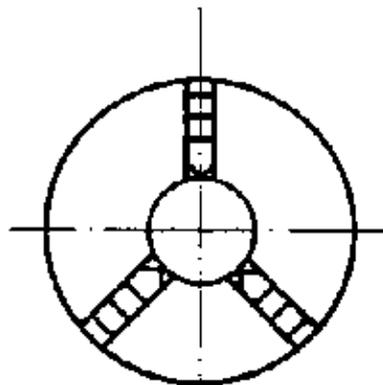
Tasks of clamping devices for workpieces

External cylindrical grinding machines are used for the machining of workpieces or parts with rotationally symmetrical cross sections. The work-clamping devices have the task to transmit the rotating feed motion from the workpiece spindle in the spindle head to the workpiece. They have to hold the workpiece in a way that at the point of machining it is symmetrically rotated in front of the abrasive tool (Figure 7/35).

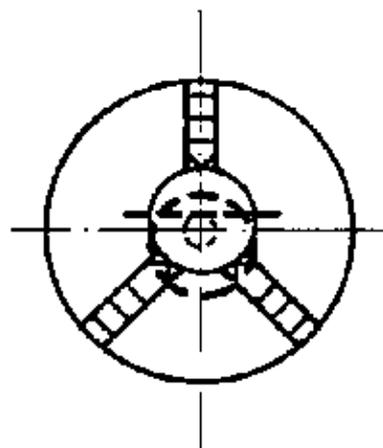
The rotating feed motion is decisive for the dimensional stability of workpiece. The feed motion has to be uniform and free of play.

Forces arising during metal cutting are not allowed to shift the position of workpiece in the clamping device, so that the rotating feed motion may develop an untrue running (Figure 7/36). This demand is especially important for those clamping devices which are used for precision grinding on grinding machines.

Figure 7/36 The workpiece must have a true running!



a Correct true run



b Untrue run which has to be corrected prior to grinding

Jaw chucks

Workpieces that need not be continuously ground and are provided with an adequate shoulder for clamping can be clamped in a jaw chuck. Most frequently three-jaw chucks are used. They clamp cylindrical workpieces symmetrically, they are easy to handle (Figure 7/37).

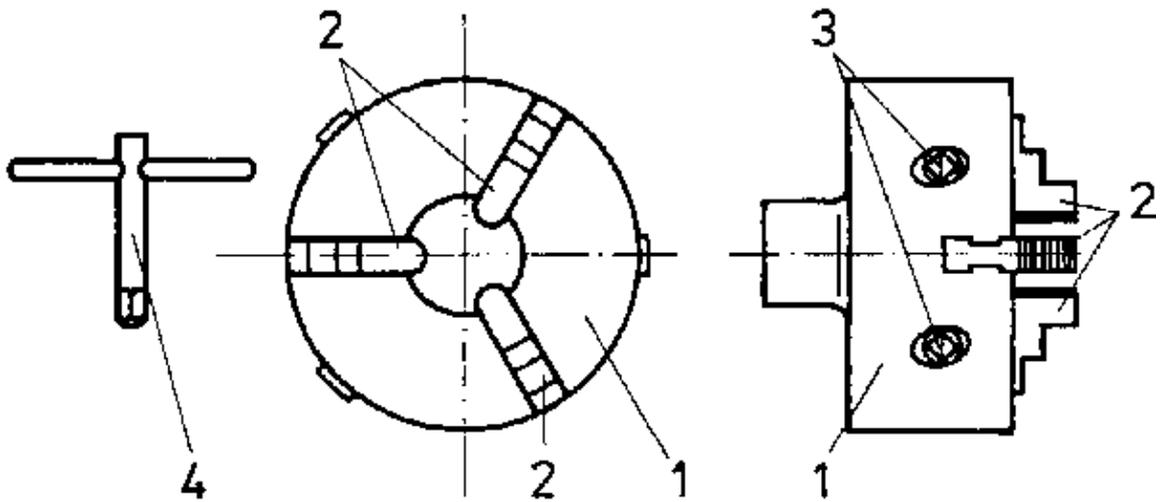


Figure 7/37 Three-jaw chuck

1 Chuck structure, 2 Jaws, 3 Reception for chuck key, 4 Chuck key.

With a chuck key (4) it is possible to actuate all three jaws (2) at the same time uniformly in the chuck (1), so that at each width of opening they are symmetrical to the rotary axis of chuck. The chuck key with its four-cornered shaft is placed into the reception for chuck keys (3) (Figure 7/38). It is provided with a safeguard which draws the key out after the clamping and unclamping of workpiece. This is designed to prevent any danger (Figure 7/39).

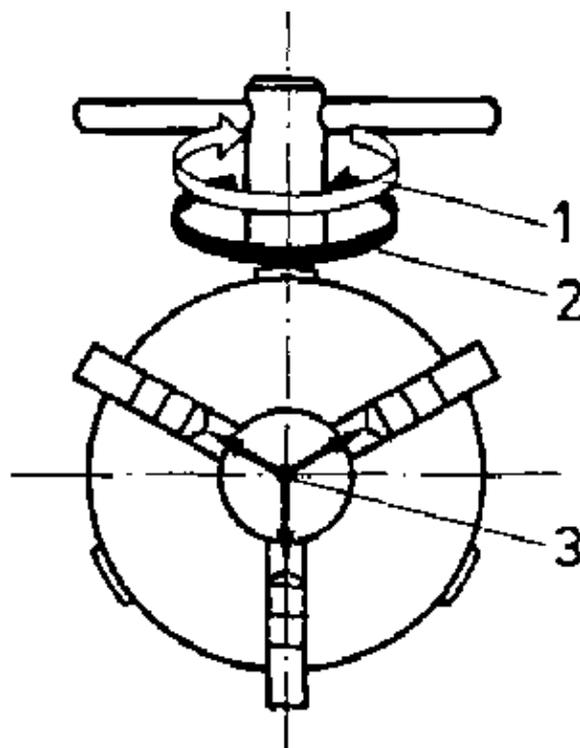


Figure 7/33 Handling the three-jaw chuck

1 Closing the jaws upon clamping (right turn), 2 Opening the jaws upon unclamping (left turn), 3 Uniform travel of jaws during opening and closing.

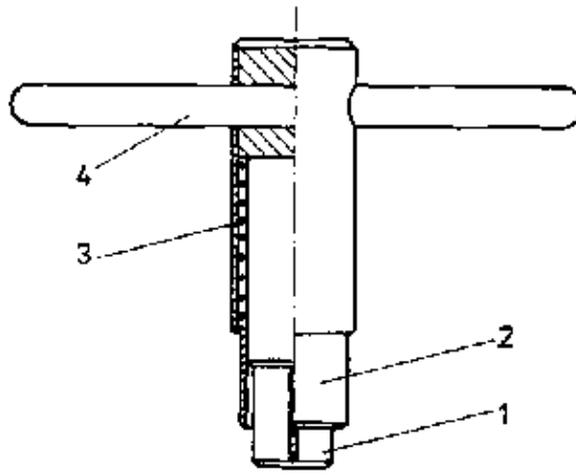


Figure 7/39 Chuck key is automatically lifted up, otherwise danger of accident

1 Four-cornered shaft, 2 Safety sheath, 3 Spring, 4 Handle

Chuck keys are never allowed to be left in the chuck after clamping and unclamping because of the danger of accidents and the danger to machine and workpiece.

Workpieces with square or octagonal shaft for clamping can be fastened in four-jaw chucks. Four-jaw chucks function similarly to three-jaw chucks (Figure 7/40).

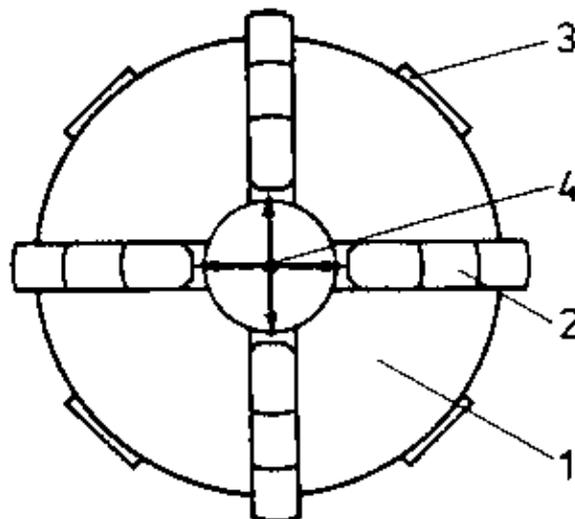


Figure 7/40 Four-jaw chuck

1 Chuck structure. 2 Jaws, 3 Reception for chuck key, 4 Chuck key.

Faceplate jaws

External cylindrical grinding machines can be equipped with faceplate jaws for the sake of machining proportionately large workpieces. The faceplates are used for the clamping of workpieces, with clamping surfaces being unsymmetrical to the axis of the part to be ground (Figure 7/41).

With the socket wrench (7) which with its square shaft can be put into the reception for spanners (3,4,5,6) it is possible to move every jaw of the faceplate separately. By way of an alternative adjustment of jaws the workpiece is aligned, so that the point to be machined will perform an exactly true running (Figure 7/42).

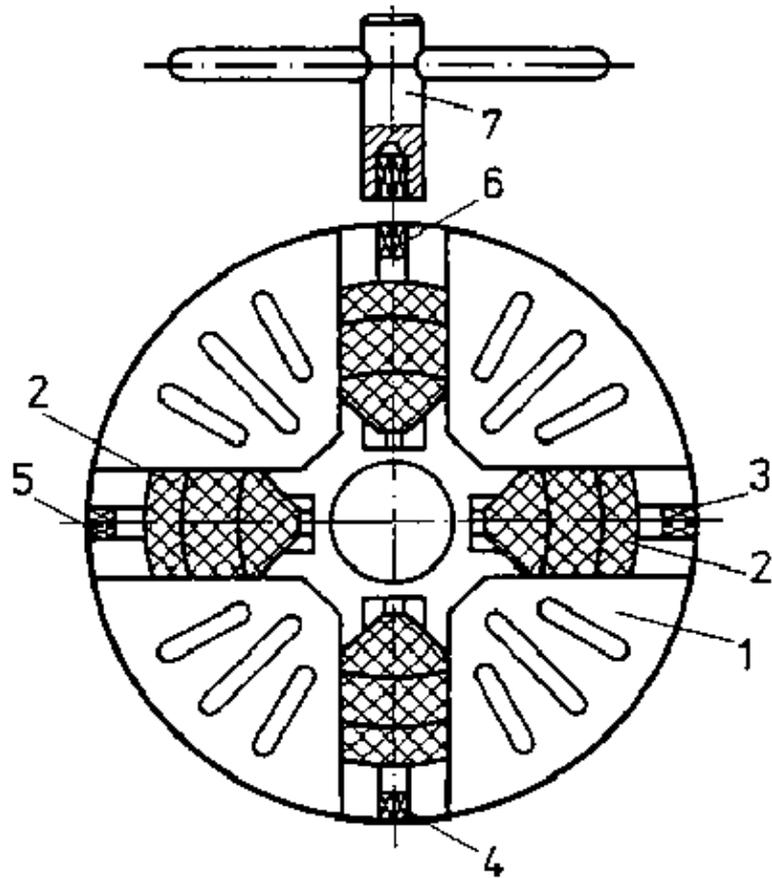


Figure 7/41 Faceplate jaw

1 Body with faceplate, 2 Jaws individually adjustable, 3,4,5,6 Collets for spanner one for each jaw separately, 7 Spanners.

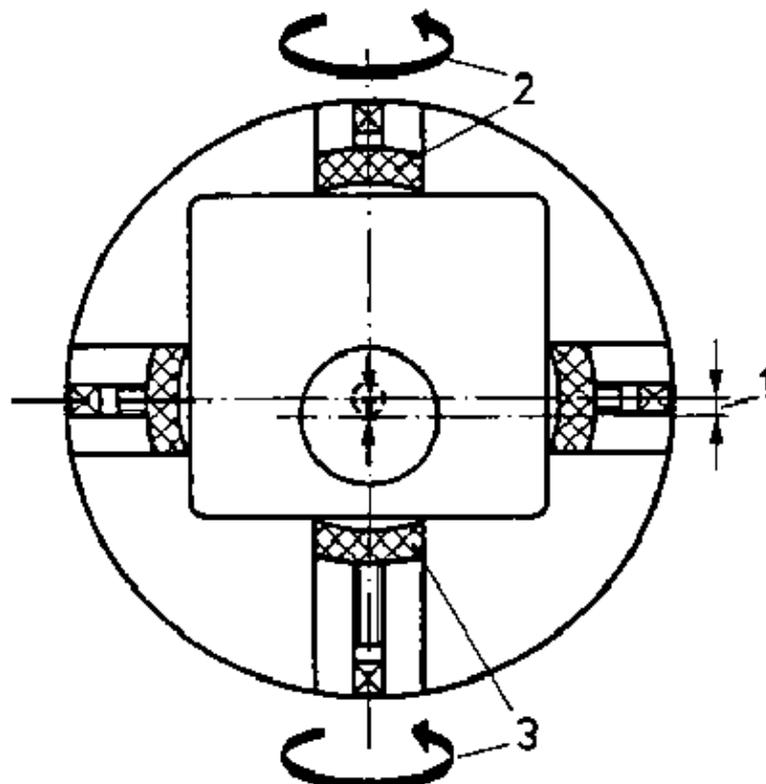
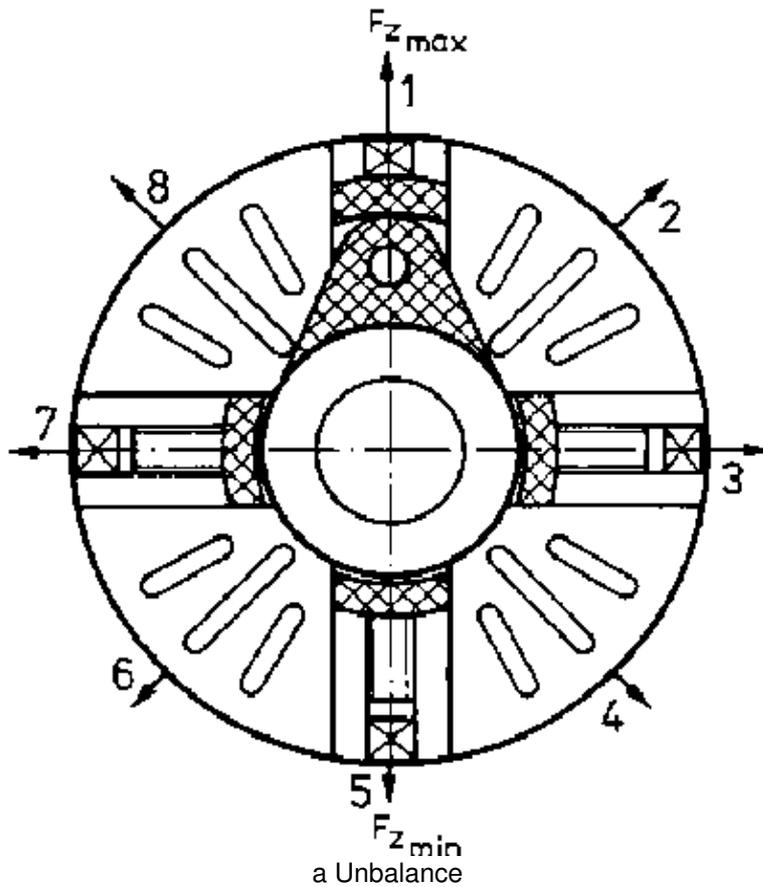


Figure 7/42 Correction of untrue run

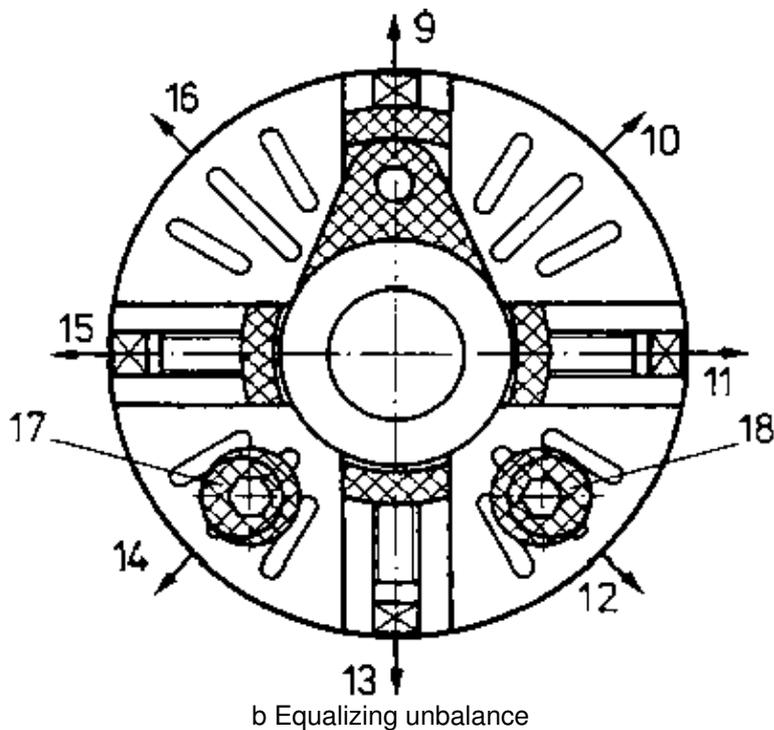
1 Difference of true running, 2 Jaws to be loosened, 3 Jaws to be clamped.

If unbalance is created by an unsymmetrical workpiece it is required to attach weight compensating balancers at the faceplate (Figure 7/43).

Figure 7/43 Unsymmetrical workpiece in faceplate jaw



1-6: Unequal centrifugal forces, 7 - 12: Equal centrifugal forces due to the effect of mass balancers.



1-6: Unequal centrifugal forces, 7 - 12: Equal centrifugal forces due to the effect of mass balancers.

Mandrels

Symmetrical workpieces with exact bores can be clamped on mandrels (Figure 7/44). A mandrel (1) is inserted into the conical bore of the workpiece spindle (2). The workpiece (3) is put on the cylindrical part of mandrel. The mandrel is slit, so that it can be expanded by means of the expanding screw (4). The workpiece is clamped firmly and symmetrically. Clamping and unclamping are done quickly.

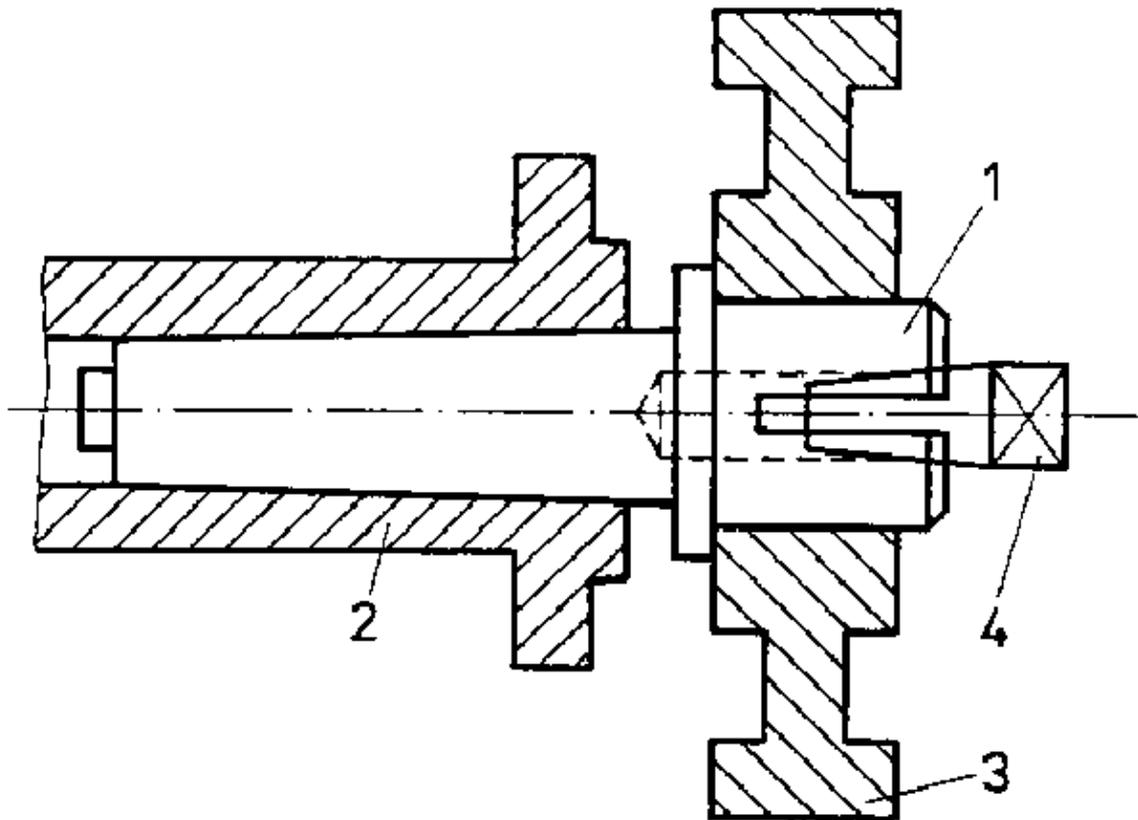


Figure 7/44 Mandrel with workpiece

1 Mandrel, 2 Workpiece spindle, 3 Workpiece, 4 Expanding screw

Mounting on centres

Long workpieces that are to be ground over their entire length are mounted between centres (Figure 7/45). This is done with the help of two centres. One of the centres (1) is placed into the workpiece spindle (2), the other centre (3) into the sleeve (4) of tailstock (5). For clamping and unclamping the sleeve is actuated at the hand wheel (6) in a way that the centres change the distance towards each other (7 and 8).

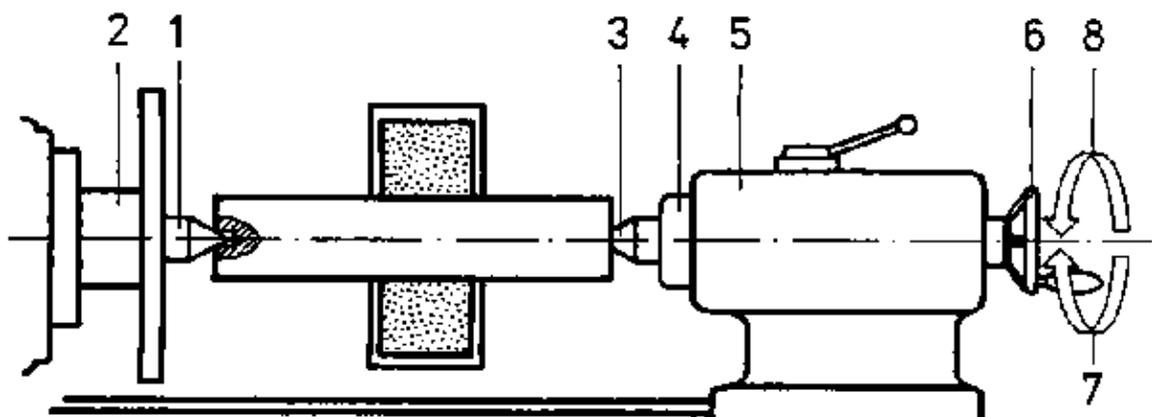
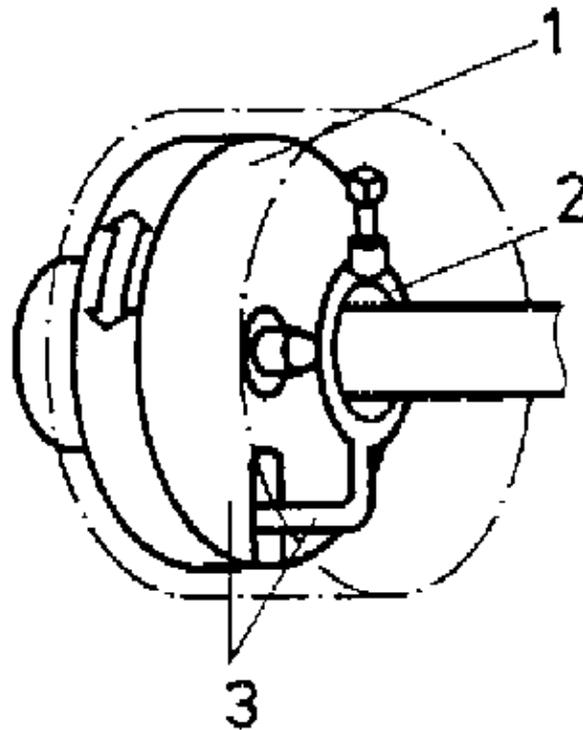


Figure 7/45 Workpiece to be continuously ground mounted between centres

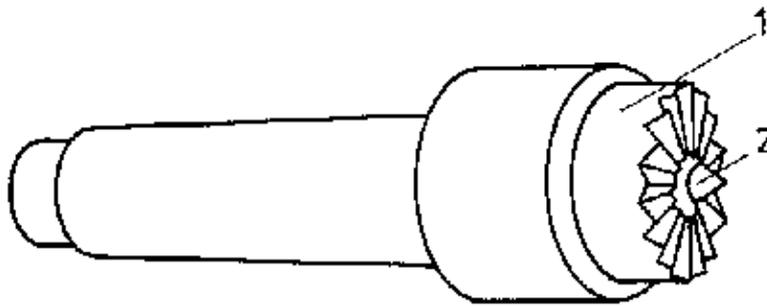
1 Centre put into workpiece spindle, 2 Workpiece spindle, 3 Centre put into tailstock, 4 Tailstock sleeve, 5 Tailstock, 6 Hand wheel, 7 Motion during clamping, 8 Motion during unclamping.

Figure 7/45 Work driver for power transmission during external cylindrical grinding between centres



a Work driver, two-part; to be reset

1 Part to be fastened on workpiece spindle, 2 Part to be fastened on workpiece, 3 Engagement between parts



b Front-side driver

1 Driving plate with spur gears, 2 Centre.

To transmit the rotary machining movement to the workpiece, a driver is used between tool and workpiece. Part of the driver is mounted on the tool spindle, the other part is mounted on the workpiece. Both parts engage each other, so that the drive created is good (Figure 7/46a). After one side of the workpiece had been ground, it is unclamped, the driver is put to the other end and the workpiece is again clamped.

If face drivers are used it is possible for the workpiece to be continuously ground, without the need of reclamping (Figure 7/46b). The workpiece has to be pressed so firmly against the spur-gear of the driving plate (1) that the teeth penetrate into the front side of workpiece. The centre (2) is found in the middle of the driver.

Control questions

1. What demands are made on work-clamping devices?
2. Name work-clamping devices which are used on external cylindrical grinding machines.
3. For what kinds of workpieces are these clamping devices preferably used?
4. Describe the clamping of parts that are to be ground continuously.

5. What is the influence of unbalance of a clamped workpiece on the dimensional stability of work?

7.4.3. Handling of external cylindrical grinding machines

In this section you shall get acquainted with

- the way of setting an external cylindrical grinding machine
- the kind of operating the machine during grinding
- the kinds of errors and faults to be avoided when operating the machine.

Setting the machine

In setting the machine it shall be provided that the grinding operations shall be done on the basis of suitable machining characteristics for external cylindrical grinding.

- Setting the wheel spindle speed

To these operations the same description of handlings are applicable which have been done for the setting of the wheel spindle speed of a horizontal flat grinding machine (Section 7.2.3.).

- Setting the feed motions

Two feed motions have to be set on an external cylindrical grinding machine:

- the rotating feed motion of the workpiece
- the longitudinal feed motion of table with the workpiece.

The rotating feed motion is dependent upon the diameter of workpiece. It has to proceed at a rotational speed which results in a definite feed. The rotation of workpiece is adjusted at the workpiece spindle head. This speed has to be higher with workpieces of smaller diameter than with workpieces of large diameter.

The longitudinal feed motion is dependent upon the length of workpiece. It is set in the same way, as was described for the longitudinal feed motion of horizontal flat grinding machines. Stops at the bed limit the motion (Section 7.2.3.).

- Clamping the workpiece

The workpiece is clamped with a work-clamping device on the external cylindrical grinding machine according to Section 7.4.2. In doing so the following has to be observed:

- The abrasive tool (cutting motion) has to be switched off, or to be moved far back, so that no unwanted contacts are made between workpiece and abrasive tool;
- The rotating feed motion during clamping is not allowed to run on its own (motor to be disconnected);
- the clamping devices have to be free of dust and well fastened;
- No unbalance is allowed to be caused with unsymmetrical workpieces, otherwise it is required to attach weight compensating balancers (Figure 7/43).
- The chuck key or other working media have to be removed prior to switching on the rotating feed motion.

Special attention has to be paid to setting if mounting between centres is done. The workpiece should be cylindrical over its entire length and should have the same diameter at both ends. This is only achieved, however, if both centres have the same distance to the abrasive tool. The tailstock is adjustable, so that this distance can be corrected (Figure 7/47).

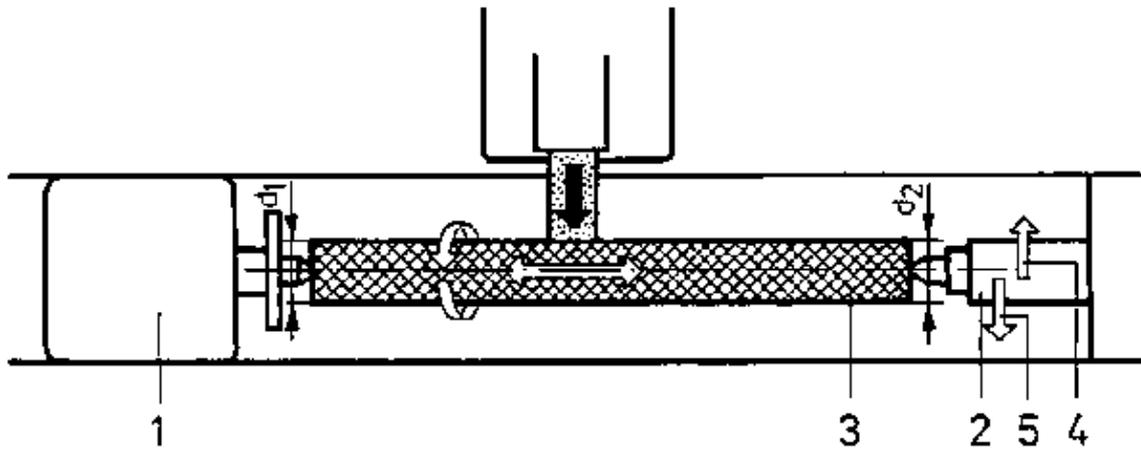


Figure 7/47 Adjusting tailstock head

1 Workpiece spindle head, 2 Tailstock, 3 Workpiece, d_1 Diameter of workpiece at workpiece spindle head, d_2 Diameter of workpiece at tailstock, 4 Direction of readjustment d_2 smaller, 5 Direction of readjustment d_2 larger.

Prior to the switching–en the rotary feed motion it shall be checked whether the workpiece can be turned unimpededly between centres end whether there is a loose contact.

- Checking true running

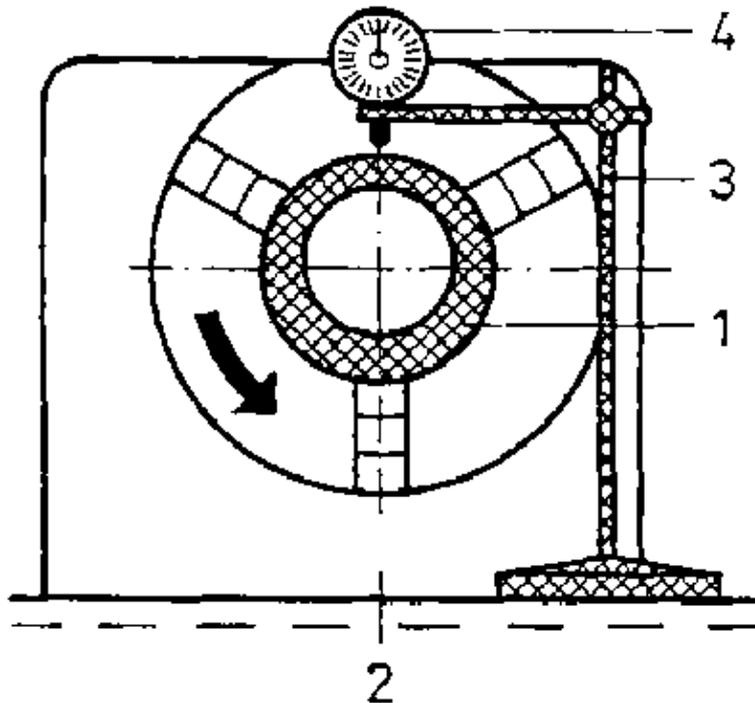


Figure 7/48 Testing true running with dial gauge

1 Workpiece, 2 Table, 3 Column, 4 Dial gauge.

In the interest of the accuracy of the working result it has to be checked whether the clamped workpiece has a true running. To this end the rotary feed motion is switched on. A dial gauge indicates the true running error (Figure 7/48).

Operation of the external cylindrical grinding machine

After the setting of machine and the clamping of workpiece it is possible to begin with the grinding operations* The handling required corresponds essentially to those which are necessary to operate a horizontal flat grinding machine (Section 7.2.3.):

- Switching-on the machine (cutting motion)
- Switching-on the exhaust attachment
- Positioning of workpiece (start-up, in-feed, readjusting)
- Switching-on the feed motions (first rotating feed motion, then longitudinal feed motion)

Chip removal

- Return travel of grinding-wheel spindle head
- Switching-off the feed motions (first longitudinal feed motion, then rotary feed motion)
- Switching-off the exhaust attachment
- Switching-off the machine.

Control questions

1. What importance has the true running of workpiece for the result of grinding operations?
2. How do you check whether a workpiece has a true running?
3. Describe how an unbalance has to be compensated for?
4. Explain how to clamp a long workpiece that has to be continuously ground.
5. How to correct the deviations if a long workpiece to be ground continuously has different diameters at the ends?
6. Describe the setting of an external cylindrical grinding machine for a grinding job that you have done.

7.5. Internal cylindrical grinding machine

In this section you shall get acquainted with

- the machine components of which internal cylindrical grinding machines are composed
- the way of functioning of internal cylindrical grinding machines
- the various kinds of machining processes for which internal cylindrical grinding machines are used.

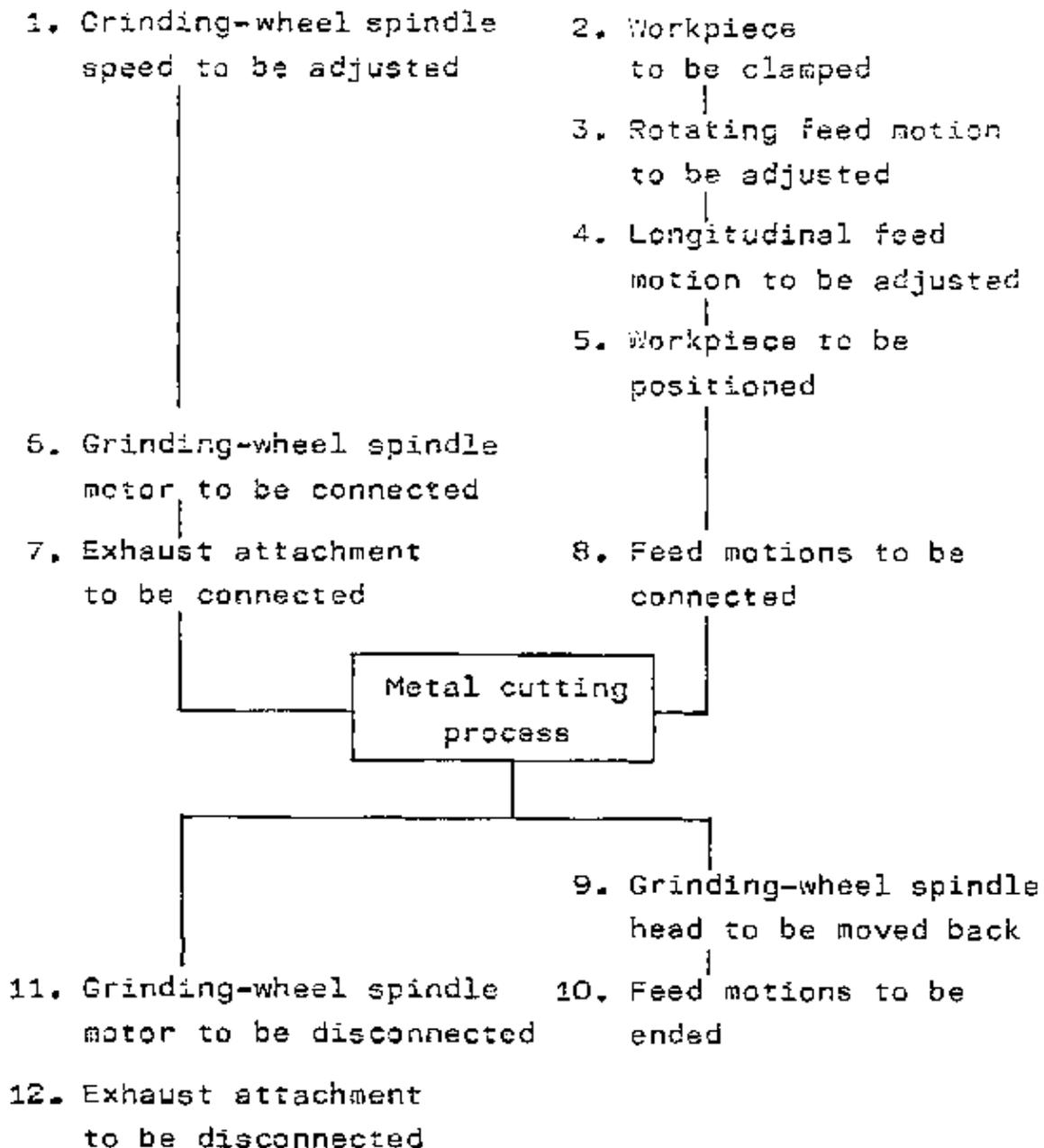


Table 7/3 Setting-in and operating of an external cylindrical grinding machine

7.5.1. Structure and mode of operation

Components of an internal cylindrical grinding machine

The bed (1) is the basic structure of the machine. On the bed there is the spindle head (2) that is firmly mounted, and the grinding wheel spindle head (3) which actuates back and forth on guideways (4).

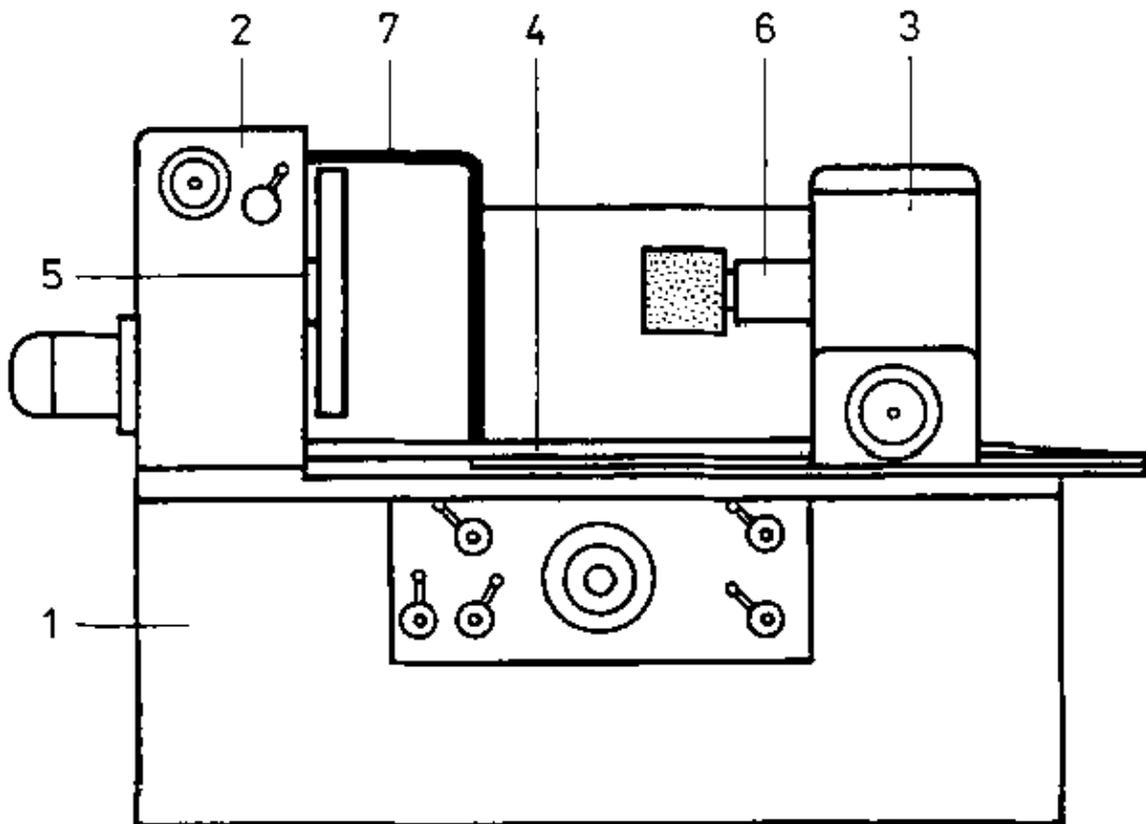


Figure 7/49 Components of an internal cylindrical grinding machine

1 Bed, 2 Workpiece spindle head, 3 Grinding wheel spindle head, 4 Guideways, 5 Workpiece spindle, 6 Wheel spindle, 7 Protective hood.

The tool spindle head contains the tool spindle (5) and the driving motor for the rotary feed motion of workpiece.

The grinding wheel spindle head includes the wheel spindle (6) and the driving motor for the rotating cutting motion of the abrasive tool. It is radially adjustable to the rotary axis of workpiece (in-feed motion).

The bed accommodates the mechanisms for the longitudinal feed motion of the grinding wheel spindle head, These are mostly hydraulic mechanisms. In addition it is possible for the bed to accommodate the appliances (motor, pump, filter, container; for coolant circulation).

The workpiece is encased with a protective hood (7). The abrasive tool of internal cylindrical grinding machines is provided with a protective hood because it is moved into the bore to be ground.

Exhaust attachments are mostly to be attached only with difficulties because they would impede the machining operations. However, since wet grinding is mostly used, the development of dust is relatively small.

Mode of operation of an internal cylindrical grinding machine

The workpiece (1) is clamped by means of a clamping device (2), mostly a jaw chuck (Section 7.4.2.). The clamping device transmits the rotation of the tool spindle to the workpiece. The abrasive tool (4) is on the wheel spindle. The entire grinding wheel spindle head (5) travels to the rotating workpiece in a way that the equally rotating abrasive tool projects into the bore which is ground. The start-up motion (7) leads the abrasive tool to the bore wall. Due to the rotation the entire bore wall is moved past the abrasive tool (Figure 7/50).

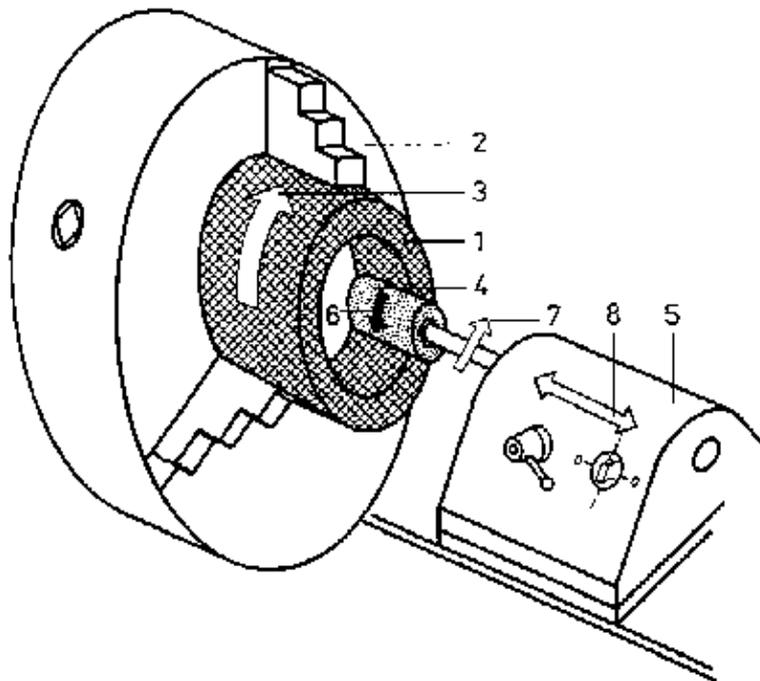


Figure 7/50 Mode of operation of internal cylindrical grinding

- 1 Workpiece, 2 Clamping device, 3 Rotational direction of workpiece. 4 Abrasive tool, 5 Grinding wheel spindle head, 6 Rotational direction of abrasive tool (cutting motion), 7 Direction of start-up movement, 8 Direction of back and forth movement of grinding wheel spindle head.

If the bore is longer than the abrasive tool is wide, the wheel spindle head is actuated back and forth. The abrasive tool cuts over the entire length of bore. The basic requirement for the process of internal cylindrical grinding is that the workpiece is clamped in a way that the bore rotates centrally. If this requirement cannot be met, the rotating wheel spindle has to be used for the process (Figure 7/51). In this process the workpiece is at a standstill. The wheel spindle with the rotating abrasive tool (cutting motion) rotates on a circular path in a way that the entire internal surface of the bore is ground (rotating feed motion). For the purpose of grinding deep bores the grinding wheel spindle head is also actuated back and forth (longitudinal feed motion).

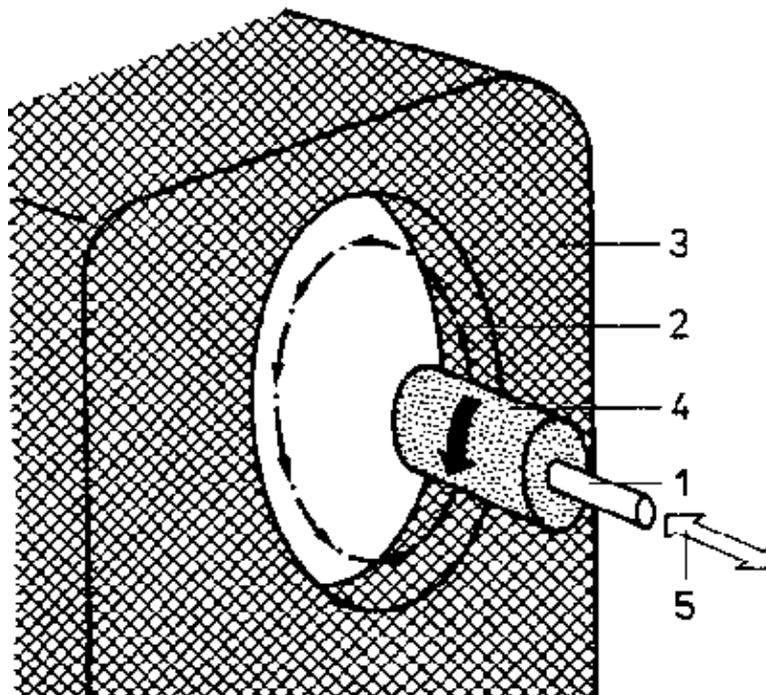


Figure 7/51 Internal cylindrical grinding with rotating wheel spindle

- 1 Wheel spindle, 2 Circular path of rotating grinding wheel spindle, 3 Workpiece, 4 Abrasive tool, 5 Direction of back and forth movement of grinding wheel spindle head.

7.5.2. Use of internal cylindrical grinding machines

Internal cylindrical grinding machines are used for finishing operations of bores. Those workpieces are above all machined, which have already been subjected to the process of hardening. Any other metal-cutting processes, e.g. turning, drilling or reaming, can no longer be applied to these workpieces. But grinding is still possible, because abrasive tools can be provided with an adequately hard abrasive grain. Such workpieces are, e.g. antifriction rings, bearing bushes, cylinders of reciprocating engines, hydraulic cylinders, bores for bearing bushes.

The surface grade achieved with the process by internal cylindrical grinding is average, in general, If an extremely fine surface finish should be reached, other processes have to be subsequently applied, e.g. honing.

Control questions

1. Describe the structure of an internal cylindrical grinding machine.
2. Explain the difference between the two internal cylindrical grinding techniques described.
3. Name several examples of machining operations which have been performed on internal cylindrical grinding machines.

7.6. Servicing and maintenance of grinding machines and tools

Please, observe the "General Instructions on Servicing and Maintenance of Metal Cutting Machine Tools" according to Section 2,4. of this textbook.

Prior to cleaning, lubricating, and controlling operations it is required to switch off the machine!

Cleaning

1. Grinding dust and coolant to be removed from the machine and in front of the machine! Brush, hand broom and cleaning rag to be used, grinding dust to be sucked off, but never to be blown away! It penetrates into finest slots, endangers the eyes and the respiratory tract of worker.
2. Bright parts of the machine, e.g. the controlling elements, the guideways, to be cleaned and slightly oiled.
3. Filters of the coolant pump and coolant container to be cleaned!
4. Dust container of exhaust attachment to be cleaned!
5. Covers that had been removed during cleaning to be again carefully fastened.

Lubricating

1. Only those lubricating devices, e.g. grease nipples, squirt oilers, to be used which are carefully cleaned from grinding dust!
2. Lubricating points to be supplied with oil or grease according to lubricating schedule.
3. Adjusting spindles and guideways to be cleaned, to be slightly oiled and oil to be uniformly distributed!
4. Jaws of chuck to be turned out of jaw chuck as far as possible, guide grooves to be cleaned and slightly oiled!
5. After lubrication oil and grease splashes to be carefully removed from floor!

Controlling

1. Guides of table and spindle heads to be controlled, clearance to be adjusted.
2. State and fastening of abrasive tool to be checked!

Any damaged abrasive tool to is immediately exchanged! Bursting abrasive tools are a great danger to man and machine.

3. Leakage test of hydraulic lines to be carried out, especially the connecting points and at exit points of piston and shafts'.
4. Oil level of hydraulic systems to be checked!
5. Leakage test of exhaust attachments to be carried out!
6. Electric connections to be controlled, Supply lines to be secured.

Treatment of tools

Abrasive tools are brittle. They are easily damaged by jolts, strikes or falls which have to be avoided at any rate!
--

1. Abrasive tools to be protected from falling! No jolting against each other.
2. Worn abrasive tools soon to be sharpened! 31unt abrasive tools cause a higher cutting pressure and thus increased warming.
3. During change of abrasive tool no brute force to be applied!

Elastic supports to be used according to regulations!

7.7. Work safety in operating grinding machines

Please, observe the "General Hints and Regulations on Work Safety" according to Section 2,5. of the textbook.

To protect from industrial accidents there are the following regulations to be observed in operating grinding machines:

1. Grinding dust resulting from machining not to be–blown away from the machine, but to be swept off, or sucked off!
2. Measurements to be done only during standstill, never during grinding!
3. Chuck key to be immediately taken off after clamping and unclamping of workpiece!
4. Protective hood for abrasive tool to be fastened always carefully, never switch on cutting without protective hood!
5. Protective glasses to be worn during observation of grinding process!
6. The sleeves of working clothes and jacket have to cling tightly to the body, so that they cannot be caught by rotating parts!
7. The hair of the head and the beard is not allowed to dangle; it is required to use suitable covers!
8. Protective covers and gratings taken off for the purpose of servicing the machine have always to be re–attached before the machine is switched on.