Textbook for Vocational Training – Technology of Metal Working – Part 1

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Preface

The present textbook imparts knowledge of the technology of metal working. The manufacturing methods of initial shaping, forming, separating, joining, coating and changing the properties of materials are dealt with in great detail. This textbook is intended for trainees in trades of the metalworking industry.

In a clearly arranged way, the means of work, the operations involved and the applications regarding the individual manufacturing methods are described. A large number of comprehensive illustrations ensure that the subject−matters of the textbook can be grasped easily, that they are represented vividly and are closely related to practice. The necessary expert knowledge of technological processes is imparted to the trainee so that he will be in a position to tackle the problems involved unaided and in a creative manner. The acquired knowledge will enable him to use the most important manufacturing methods in practice. Rules to be kept in mind and summaries are given for focal points.

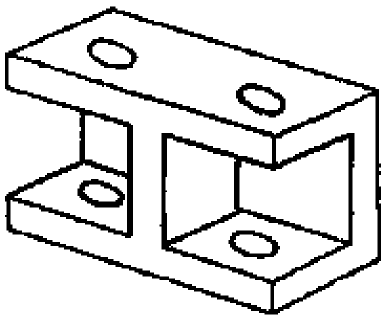
Information about work safety is marked by two vertical lines on the left margin of the text in question. The questions put at the end of the Chapters serve for checking the knowledge actually acquired.

1. Introduction

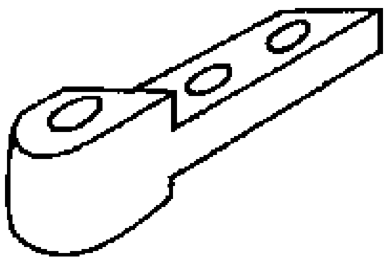
1.1. Fundamental Terms

For the production of machines, devices, plants and other technically usable objects, components, so−called machine elements, are used (fig. 1.1.).

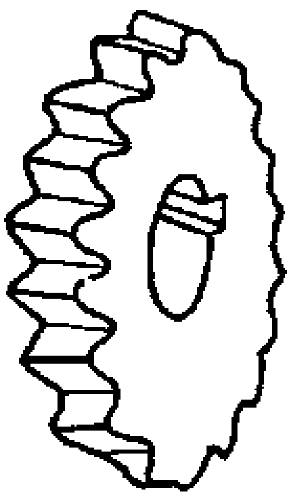
Figure 1.1.



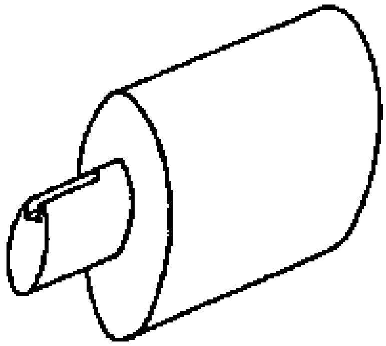
1 Bearing



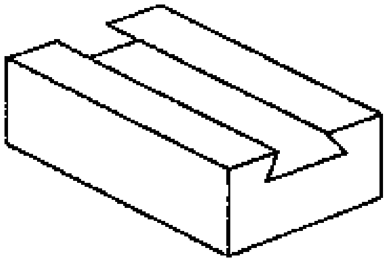
2 Lever



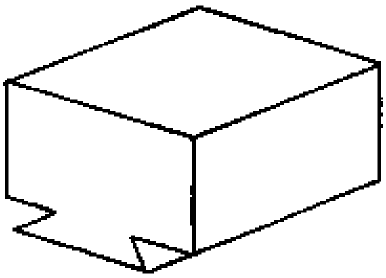
3 Gear



4 Shaft



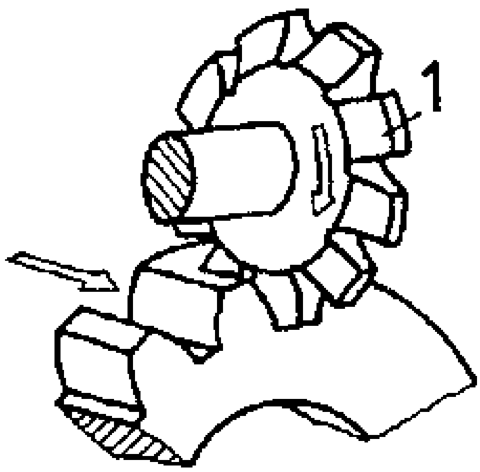
5 Machine guide (lower part)



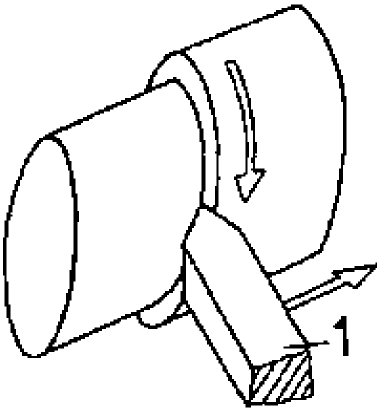
6 Machine guide, (upper part)

These individual parts are shaped by different manufacturing methods, for example, the shaft of a gear mechanism is turned in a lathe while the toothed wheel is milled (fig. 1.2.).

Figure 1.2. Manufacturing methods turning and milling



a Milling the tooth shape of a gear 1 Milling cutter



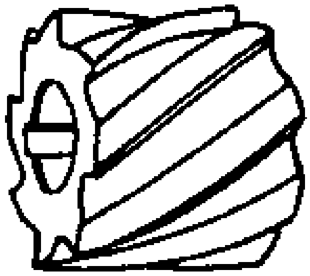
b Turning a shaft in a lathe 1 Tool

These procedures, namely "turning", and "milling", are termed as manufacturing (producing). For manufacturing the shaft, the so−called workpiece, a lathe termed as manufacturing equipment and a lathe tool termed as means of production are required.

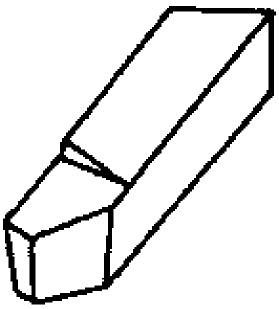
The means of production include the tools (Fig. 1.3.), the jigs and fixtures (Fig. 1.4.) (holders for tools and workpieces) and testing media (Fig. 1.5.) (measuring instruments and gauges).

Figure 1.3. Examples of the means of work "tools"

a Drill

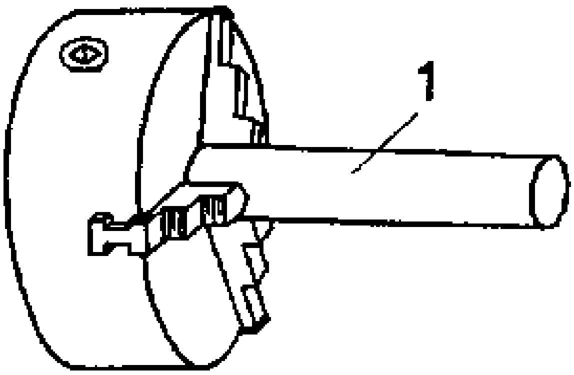


b Milling cutter

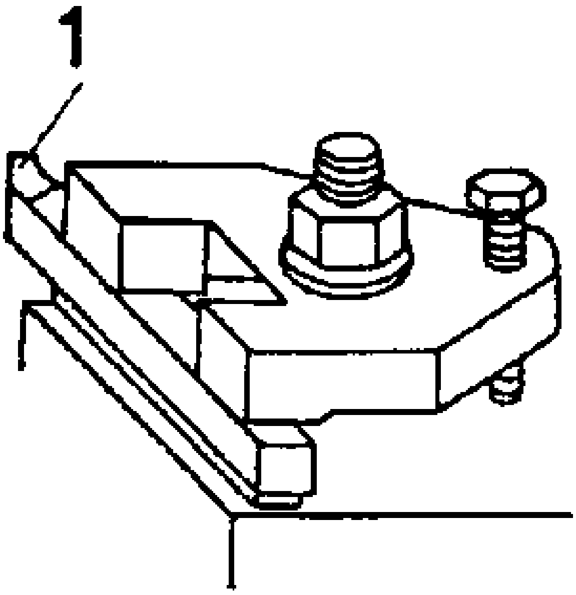


c Turning tool

Figure 1.4. Examples of the means of work "jigs and fixtures"

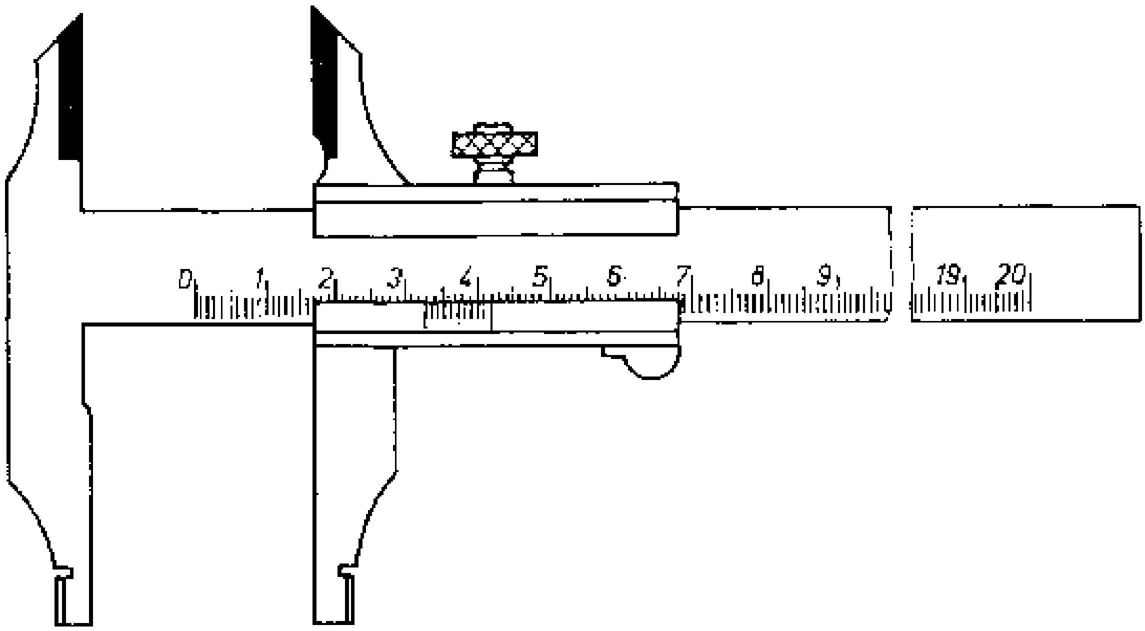


a Workpiece holder (three–jaw chuck for turning) 1 Workpiece

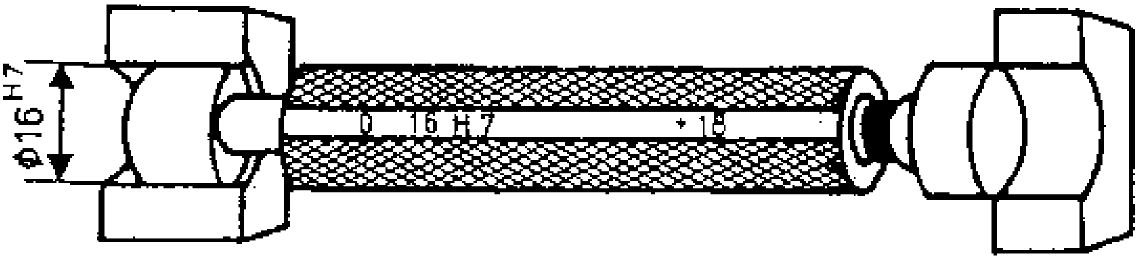


b Tool clamping device (clamping claw for turning tool for turning in a lathe) 1 Tool

Figure 1.5a Examples of the means of work "testing media"



a Vernier caliper



b Plug limit gauge

When pieces of the manufacturing equipment such as the lathe or the milling machine are used for machining, then these metal−working machines are also called machine tools.

It is also possible to arrange several machines one after the other or side by side. These arrangements are called plants. During the process of machining, frictional forces occur between tool and workpiece which lead to an undesired heating of these two elements. This rise in temperature can be restricted or prevented by a coolant or a lubricant. In manufacturing, these are called auxiliaries.

Before and during manufacture, the workpieces pass through different stations; initially they are cut from bar stock, for example, and then the blank is processed by different methods into the finished part.

Fundamental designations for items relating to the process of manufacture are given in Table 1.1.

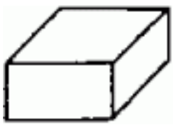
Keep in mind:

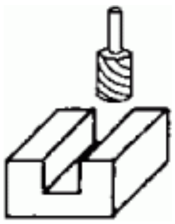
The manufacturing technology is the totality of all material−technical elements which serve for the production of use−values. It represents the unity of

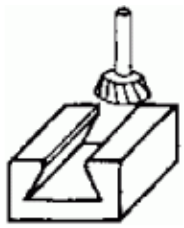
- manufacturing equipment (in the form of machine tool or plant)
- manufacturing means (in the form of jig and fixture, tool or testing media)
- manufacturing auxiliares and
- manufacturing methods (e.g. turning in a lathe, milling, etc.)

Table 1.1. Designations used during the course of manufacture

Procedures







		Operation 1	Operation 2
Conditions	Initial condition	Intermediate condition	Final condition
Shapes	Initial shape	Intermediate shape	Final shape
		Instantaneous shapes	Finished shape
Workpiece designations	Blank or raw piece	Semi−finished piece or semi−finished part	finished part

1.2. Classification and Systematic Representation of the Manufacturing Methods

The production of geometrically determined solid bodies is based on the preset action of tools on workpieces.

The manufacturing task to be solved, starting from the construction drawing, calls for different tools which take effect on the objects to be produced. For example, the guide piece shown in Fig. 1.6. can be manufactured by the following sequence of operations (manufacturing method):

1. Preparing the blank from bar stock by sawing or abrasive cutting
2. Burring by filing
3. Drilling as a preparation for preparing the opening
4. Slotting or reaming the opening
5. Milling the lateral grooves

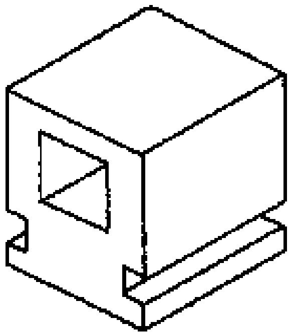


Figure 1.6. Guide piece

In the representation of the above process, the production of the bar stock – from casting to rolling – has not been mentioned. The marking and testing procedures also have not been described in this connection.

The operations have been described only roughly and they can be replaced by other operations. This shows that for the production of objects many manufacturing methods can be applied. The most economical methods are evaluated by technologists and specified in the technological documents. They must be strictly observed at any time (technological discipline).

The great variety of manufacturing methods remains in full view when classifying them according to certain points of view.

Such a systematic representation facilitates the selection of suitable methods for the manufacture of certain objects.

A distinction is made between 6 main groups.

1. Main group initial shaping

This main group is characterized by the first (i.e. original or initial) production of the coherence of particles of matter, e.g. casting of liquid metal into a prepared mould (Fig. 1.7.)

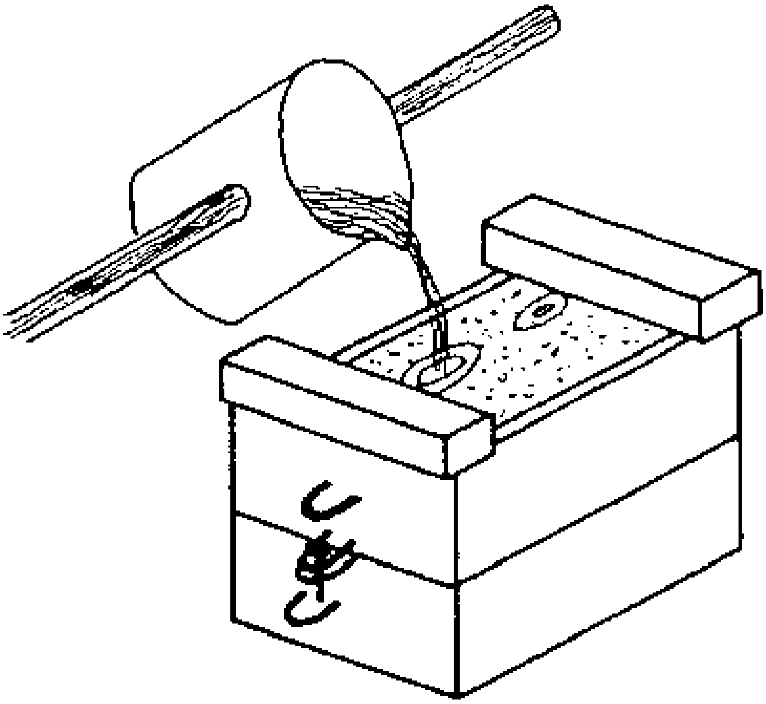


Fig. 1.7. Initial shaping (example of casting)

Apart from the liquid initial state, this can also be performed from the solid state or – in special cases–from the gaseous state.

2. Main group forming

Forming is defined as the re–shaping of the initially shaped workpieces into other intermediate or final shapes. In this process, the coherence of the particles of matter is not lost and the mass is retained, e.g. extruding of heated steel.

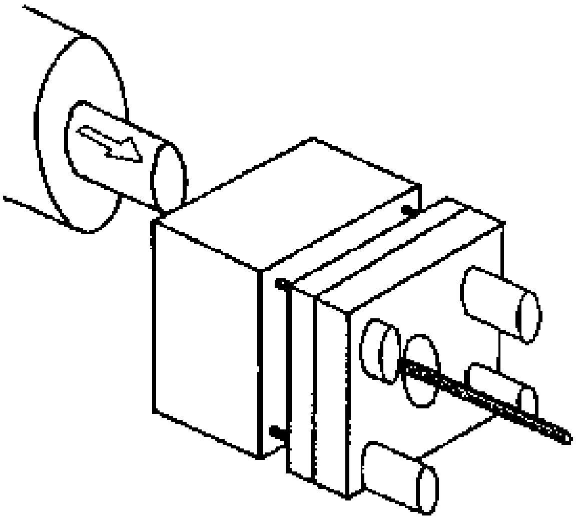


Figura 1.8. Forming (example of extruding)

3. Main group separating

By separating, a change in shape is attained because the coherence of the particles of matter is locally removed, e.g. cutting (Fig. 1.9.).

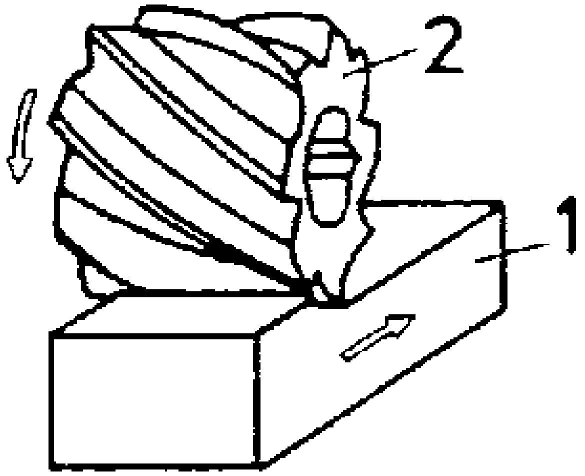


Figure 1.9. Separating (example of chip−forming method − milling)

1 Workpiece
2 Milling cutter

4. Main group joining

This main group is characterized by the fact that workpieces, made by initial shaping, forming or separating as individual parts, are assembled or mounted into a sub−assembly, unit or device or into a machine by screwing or bolting, for example (Fig. 1.10.).

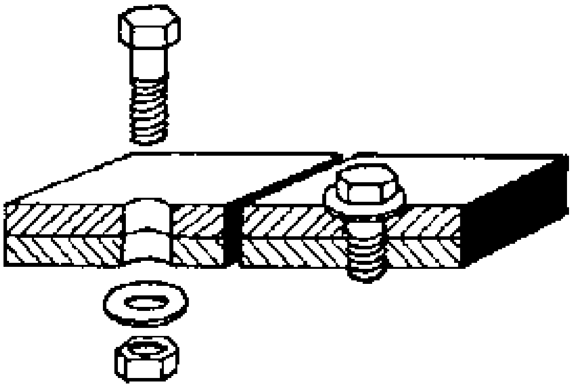


Figure 1.10. Joining (example of bolting)

5. Main group coating

A firmly adhering layer of a shapeless material is applied to a workpiece, e.g. by spraying (Fig. 1.11.).

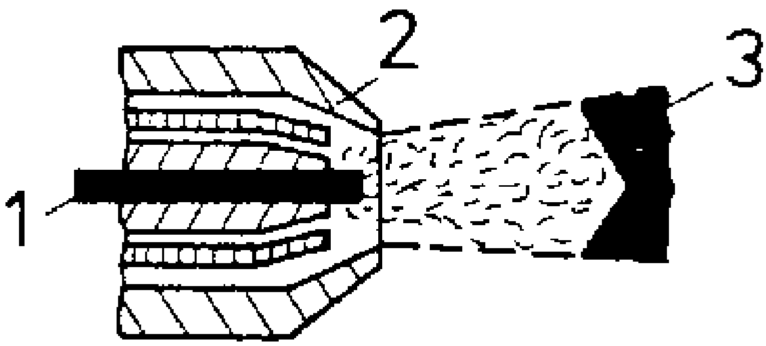


Figure 1.11. Coating (example of sprying)

1 Coating material
2 Nozzle,
3 Workpiece

6. Main group changing the properties of materials

The properties of a solid body (workpiece) are changed by rearrangement, elimination or introduction of particles of matter, e.g. by carburization (Fig. 1.12.).

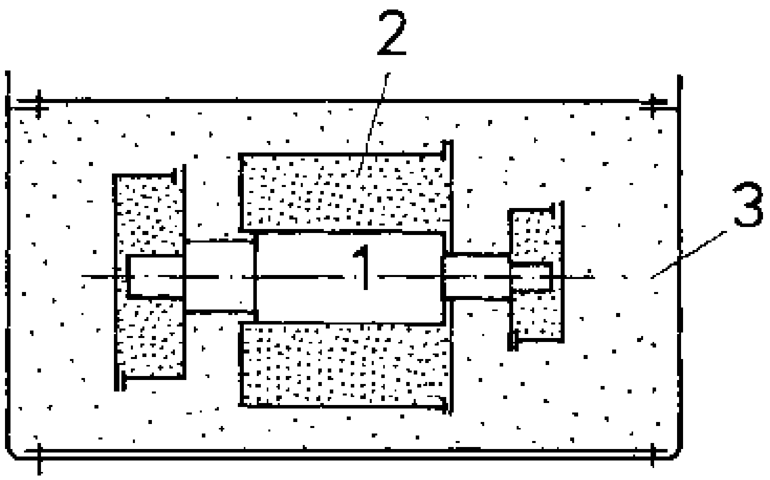


Figura 1.12. Changing the properties of materials (example of carburizing)

1 Workpiece
2 Case−hardening compound
3 Sand

Keep in mind:

The great variety of manufacturing methods becomes surveyable by a systematic representation. An essential point of view of the systematic representation is the term coherence. This coherence is related to the particles of matter of a solid body and the components of a composite body. The shape (creating a shape, changing a shape and retaining a shape) and the particles of matter are further points of view of systematication.

Six manufacturing main groups are divided into manufacturing groups under which manufacturing processes are subsumed (Table 1.2.).

Table 1.2. Survey of manufacturing methods classified according to main groups

Manufacturing main group	Manufacturing group	Manufacturing method (examples)
initial shaping	– from the solid state – from the liquid or pasty state;	sintering, pressing of thermosetting plastics; casting, injection of plastics
	– from the gaseous state	high−vacuum metal depositing
forming	– by pressure;	rolling, forging, extruding;
	– by tensile and compressive forces;	sheet−metal drawing, strand drawing;
	– by tensile force;	stretch−drawing;
	– by bending force;	bending;
	– by shearing force	twisting
separating	– by cutting;	wedge cutting, shearing, tearing;
	– by chip−forming	drilling, turning, milling, grinding;

	– by stock removal	eroding, etching, blasting, flame–cutting;
	– by dismantling	unscrewing, pressing out;
	– by cleaning	brushing, blasting, washing, pickling;
	– by evacuating;	evacuating an electron tube
joining	– by putting together;	placing, inserting, shifting one into another;
	– by filling;	filling of fluorescent tubes, impregnating electric windings;
	– by pressing on and in;	keying, screwing and bolting, clamping, shrinking on;
	– by initial shaping	casting, re–casting;
	– by forming;	folding, lapping, rivetting;
	– by combining substances	welding, soldering glueing
coating	– from the solid state	grinding, melting;
	– from the liquid or pasty state;	dip feed, pouring on, spraying on, brushing on, welding on, spray painting;
	– from the gaseous or vaporous state	coating by evaporation, deposition by thermal de composition;
	– from the ionised state of the substance to be deposited	electrodepisiting, electrolytic transformation
changing the properties of materials	– by rearrangement of particles of matter;	annealing, hardening, tempering, hardening and tempering;
	– by elimination of particles of matter;	tempering;
	– by the introduction of particles of matter	nitrating, carburizing

2. Production Means, Machines and Plants

The processing of the material or of a blank through various stages until the workpiece is finished is effected by a large number of manufacturing processes. In this connection,

- the material is brought into a certain shape (e.g. by casting),
- a given shape is changed (e.g. by bending),
- the structure of the material is changed (e.g. by hardening),
- the surface is coated (e.g. by painting).

The high strength of metallic materials necessitates the use of tools for processing them. Tools directly act on the material or the workpiece. The effect of tools is due to forces and movements carried out.

Low forces and simple sequences of motions can be carried out by hand. The hand tools are small, of light weight and have manual elements (e.g. handles) for safe and reliable handling. The efficiency is limited by the hand and arm forces. The main field of application of hand tools is in single–piece production and assembling.

Since no special sources of energy are required (e.g. electrical current) hand tools can be used everywhere.

The industry of today calls for higher efficiency (e.g. large numbers of parts) and accuracy which cannot be reached by hand. Human force is replaced by machine work. The tools used on machines in their design correspond to the higher stresses involved. They are sturdy and compact. In the place of manual elements, there are provisions for holding and clamping them in machines, e.g. clamping pins, tool shanks.

The forces occurring in machining must be taken up, the position and motion of tool and workpiece must be secured. Depending on the size and shape of the workpiece and the type of tool, different clamping tools are used.

The desired result of work is achieved by firmly and safely clamping.

The machines used in manufacturing technology in general have the same tasks:

– holding and moving the tool
– holding and moving the workpiece

This results in the same design in the main groups in general; externally, the machines are very different.

Production machines can be interlinked technically; that is to say, a workpiece passes through several machines, one after the other, on special transport equipment. Such interlinked machines are also called machine lines or flow lines.

There are pieces of production equipment which are no machines, that is to say, they do not operate with tools. They have to fulfil special functions in production. Such equipment is mainly required for initial shaping and forming (e.g. melting furnaces and annealing furnaces) and for coating (e.g. baths).

2.1. Hand Tools

There is a great variety of hand tools. They are very different in appearance and application. Hand tools are not clamped in machines.

2.1.1. Tools for Marking

Before machining or working, the workpieces frequently are marked. By marking positions the on the workpiece are indicated where work has to be done. For example, a workpiece is to cut out of a plate.

Before cutting, the workpiece must be marked on the plate (Fig. 2.1.1.)

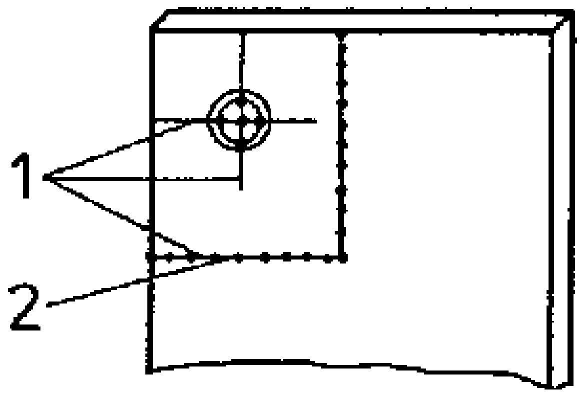


Figure 2.1.1. Plate with marking

1 Scribed line,
2 Punch mark

For this purpose, various marking–off tools are used. The scriber consists of steel. The points are hardened. The scriber is moved along a steel rule. The scriber point must properly contact the rule. As a result, a line becomes visible on the surface of the workpiece (Fig. 2.1.2.).

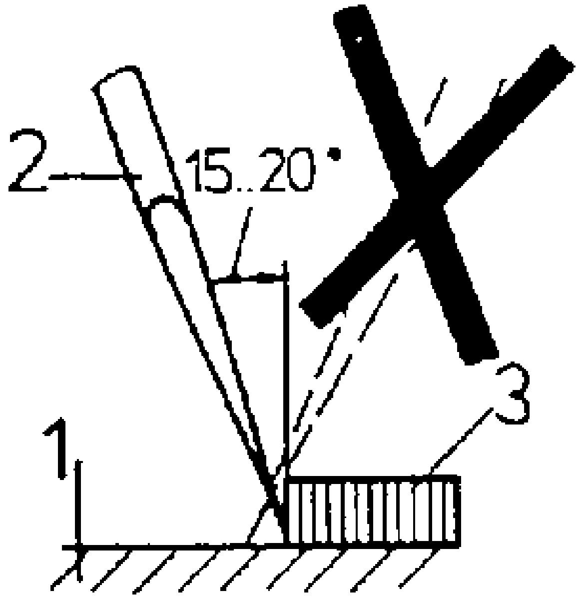


Figure 2.1.2. Guiding the scriber

1 Workpiece, 2 Scriber, 3 Rule

The surface gauge, also known as scribing block, consists of a stand with an adjustable holder for a scriber. On a plane and clean marking–off plate, the height to be marked off is adjusted with the help of a height gauge. The workpiece is also placed on the surface plate. The scribing block is moved along the workpiece in such a manner that a line is carved by the scriber in the workpiece (Fig. 2.1.3.). Surface gauges are particularly suitable for marking–off large and heavy workpieces and form marking–off many equal parts. In soft and thin parts, the scribed line – the scratch in the surface – may lead to destruction. Therefore, scribers of brass are also used. They do not scratch but are worn and, thus, leave a line. In exceptional cases, lead pencils are used and for coarse markings chalk or oil–paint pencils. Compasses in different designs are used for marking off circles and arcs (Fig. 2.1.4.).

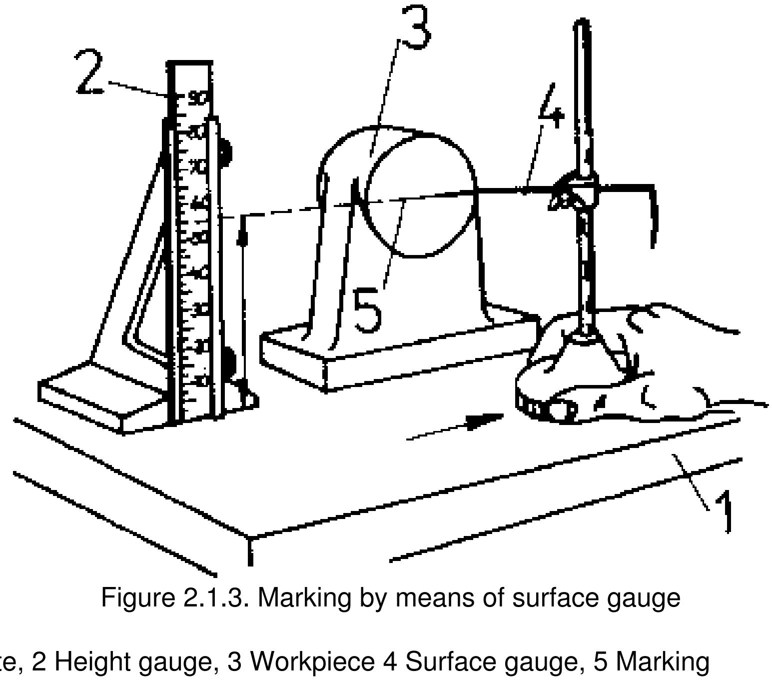


Figure 2.1.3. Marking by means of surface gauge

1 Surface plate, 2 Height gauge, 3 Workpiece 4 Surface gauge, 5 Marking

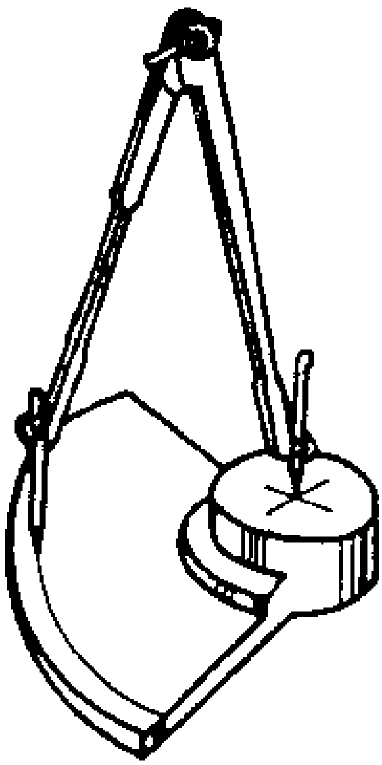


Figure 2.1.4. Use of compasses with adjustable points

Dividers must be reground when their points have become blunt. Compasses with adjustable points enable the adjustment and the replacement of the points.

Frequently, the centre of cylindrical workpieces, e.g. shafts, must be marked. This is rapidly and reliably done by applying a centre square two times along which the scriber is moved (Fig. 2.1.5.).

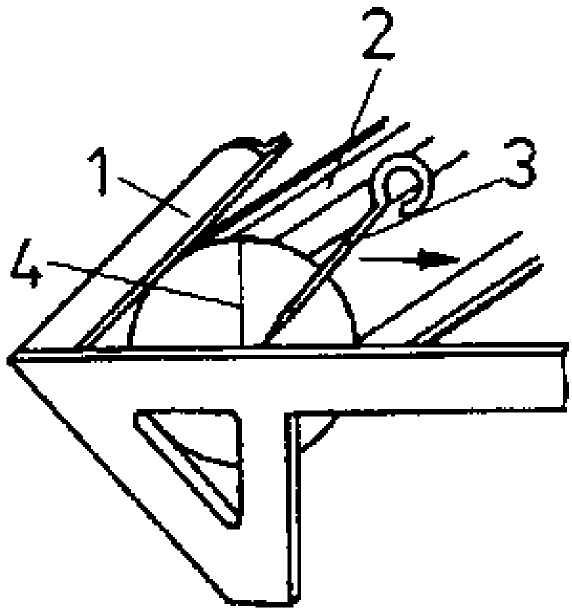
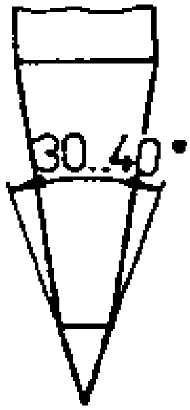


Figure 2.1.5. Marking by means of the centre square

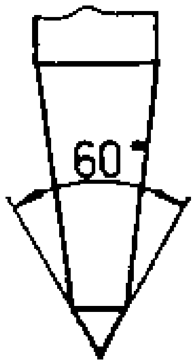
1 Centre square,
2 Cylindrical workpiece,
3 Scriber, 4 Marking

Centre punches are tools of steel with a hardened point. The point is ground in different ways (Fig. 2.1.6.).

Figure 2.1.6. Centre punch



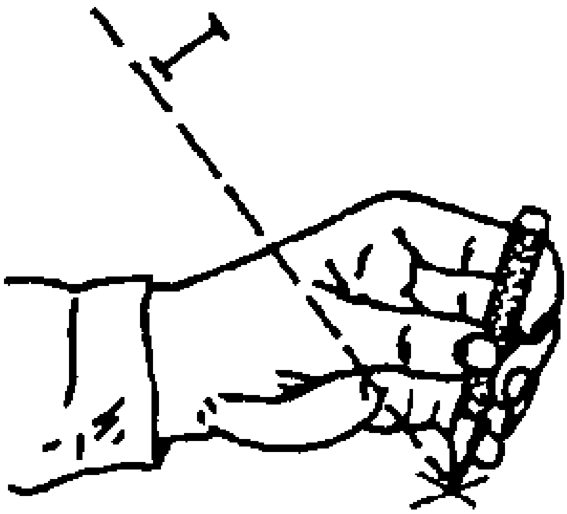
1 Marking−out punch,



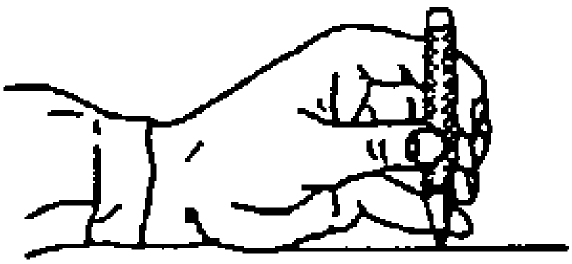
2 Centre punch

The punch us applied in an oblique manner to the workpiece; the point must be seen. When the point is applied to the correct position, the punch is kept vertically. The hand should rest on the workpiece. By a hammer blow on the head of the punch, a depression is produced in the workpiece which is of the shape of the point of the punch.

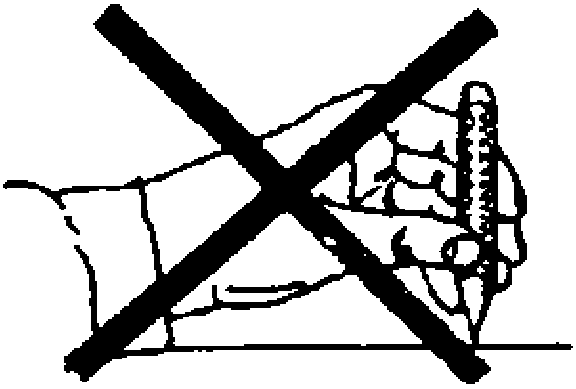
Figure 2.1.7. Punching



a Application



b Setting up and striking



c Wrongly holding the punch (hand is not placed on the support)

I Viewing direction

The centre punch (point angle 60°) is also used for marking the centres of holes to be drilled. This helps to retain the point of the compass. In addition, the point of the drill can be applied accurately. By means of the marking−out punch (point angle between 30° and 40°), scribed lines are provided with punch marks at equal spacing in order to ensure that the lines are easily seen. After machining, the still visible halves of the punch marks serve for checking (checking marks).

Marking−out templates are of a high accuracy.

Their use is only economical for complicated contours and high quantities of parts to be produced. When marking by means of the scriber, the marking−out template must be firmly retained in place or clamped.

On certain surfaces, the scribed lines are hardly perceivable. Very rough and rusty surfaces, therefore, are provided with a coat of whiting and, after drying, scribed.

− The points of scribers and compasses must be protected by caps or cork stoppers in order to avoid injuries!

− The heads of punches must not show any burr otherwise hands may be injured and particles flung off are a danger to the eyes!

<u>Keep in mind:</u>

Tools for scribing are used to mark the position on workpieces where machining operations are required. Scribed lines and punch marks are obtained.

2.1.2. Hammers

Hammers of various sizes and shapes are used for many purposes. Due to the kinetic energy released by the blow of a hammer, forces are obtained which cannot be achieved by hand.

The locksmith’s hammer is the most widely used type in workshops (Fig. 2.1.8.).

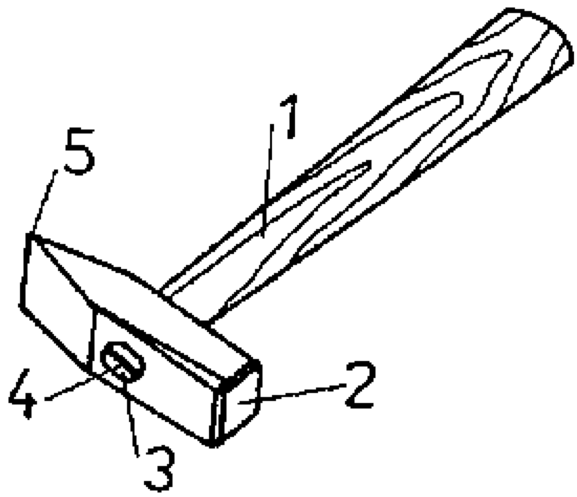


Figure 2.1.8. Locksmith’s hammer

1 Hammer handle,
2 Hammer face,
3 Eye,
4 Steel wedge,
5 Hammer pane

Its mass is anything between 250 and 1,000 grammes. Forging hammers of the same shape usually have a mass of 2 kg.

The hammer head of tool steel is hardened at its face and pane. The hammer handle must fit properly in the hammer eye; the connection is secured by a wedge driven in place obliquely.

Sledges having a mass of up to 15 kg are required for heavy work where powerful blows are necessary.

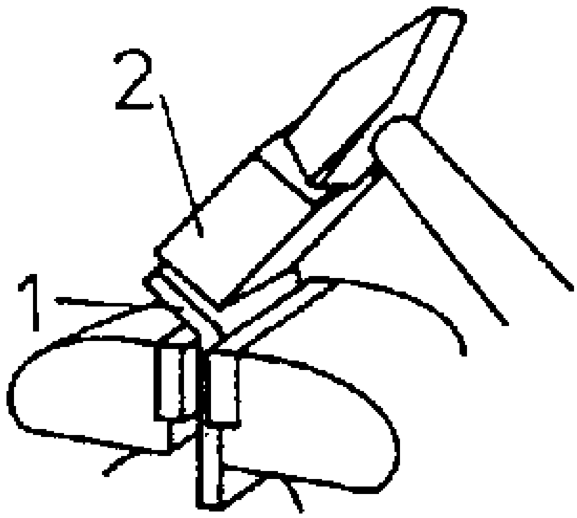


Figure 2.1.9. Striking with pad

1 Workpiece, 2 Pad

In various operations, e.g. in bending, the hammer blows directly on the workpiece. The hard hammer head way damage the workpiece, however. In order to avoid such damage, a suitable gad of hardwood or light metal is placed on the workpiece to dampen the blows (Fig. 2.1.9.).

It is favourable in certain cases, the use hammers with heads of wood, rubber, plastics, lead or copper.

– Only work with hammers whose handle is properly fitted!
– Immediately replace rough, cracked or split hammer handles!

– The end of the hammer handle must be clean!

<u>Keep in mind:</u>

For many and very different operations, hammers are used which largely differ in shape and mass. Hammers must fit tightly on their handles.

2.1.3. Tongs

Tongs or pliers are used for keeping or holding parts to be subjected to different operations, e.g. assembling, soldering or bending. The jaws are frequently adapted to the shape of workpieces and usually have small teeth. This ensures slip–free retaining the workpiece. A few types of tongs or pliers are used for dividing thin parts such as wire.

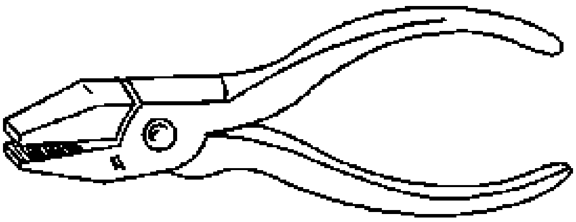


Figure 2.1.10. Flat nose pliers

Flat nose pliers (Fig. 2.1.10.) are available in different sizes including such for assembling operations having particularly long thin noses. Taper nose pliers have semi–circular jaws which are tapering (Fig. 2.1.11.). They are particularly suitable for gripping and keeping small parts.

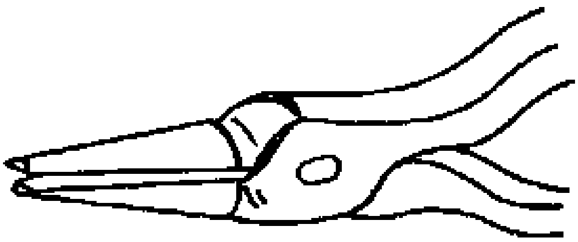


Figure 2.1.11. Taper nose pliers

They are used for operations involved in the construction of electrical appliances. Rod–shaped workpieces such as sections, round stock and pipes can be reliably gripped by means of flat–nose and taper–nose pliers provided these parts have small diameters. For keeping parts with larger diameters, parts of different shapes are available. Their jaws are internally toothed in semi–circular form.

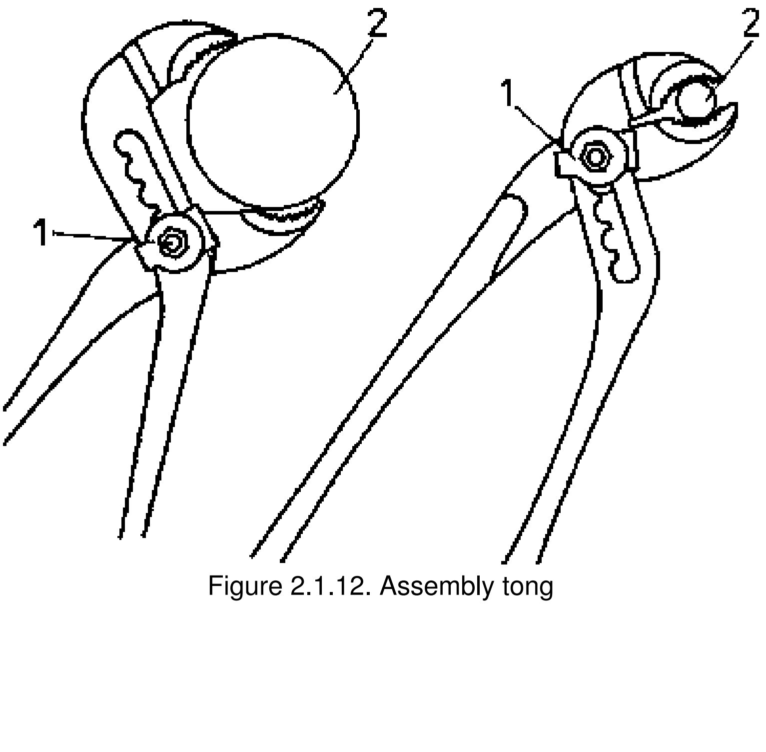


Figure 2.1.12. Assembly tong

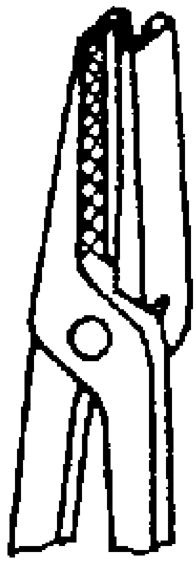
1 Adjustable joint, 2 Workpiece

The assembly tong (fig. 2.1.12.) has an adjustable joint so that the width between the jaws can be changed. Long handles ensure a high force applied by the rongs.

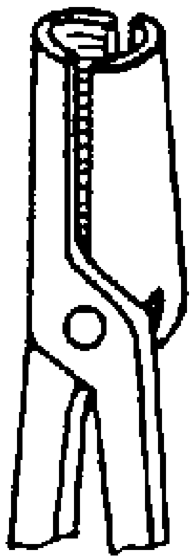
Main field of application is the assembling of pipe lines.

In forging, the bot forgings or parts to be forged must be kept safely. For this purpose, the smith himself prepares special tongs (Fig. 2.1.13) which are adapted to the forging to be produced with respect to shape and size. Frequently, clamping rings are drawn over the handles. After gripping the forging, the clamping rings are driven back so that they clamp the tongs in the closed position. Consequently, the smith is in a position to guide the tongs more easily because he is not compelled to press the handles (Fig. 2.1.14.).

Figure 2.1.13. Shapes of the mouth of blacksmiths' tongs

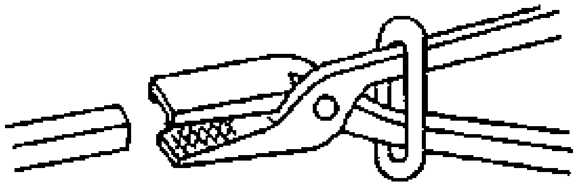


1 Straight lip tongs

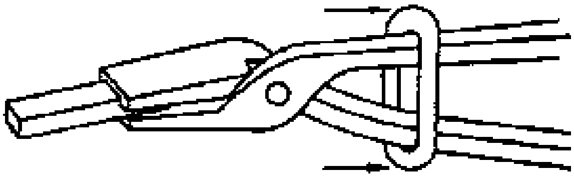


2 Double pick up tongs

Figure 2.1.14. Blacksmiths' tongs with clamping ring



1 Gripping the part to be forged, clamping ring is loose,



2 Holding the part with the clamping ring tightened

Tongs for separating have chamfered jaws. These are pincers (Fig. 2.1.15.)

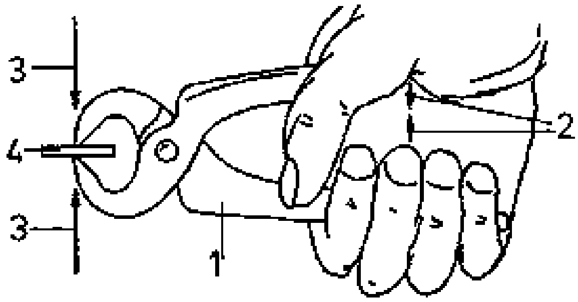


Figure 2.1.15. Pincers

1 Pincers, 2 Hand force, 3 Force exerted by the pincers. 4 Workpiece and side cutting pliers (Fig. 2.1.16.).

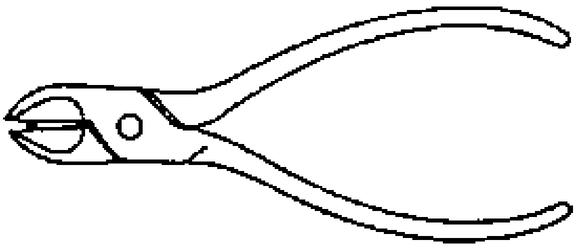


Figure 2.1.16. Side cutting pliers

Larger cross−sections can be cut by means of bolt clippers (Fig. 2.1.17.). High forces become effective at the short tong jaws because of the very long handles (up to 1 metre) and the crank lever joint.

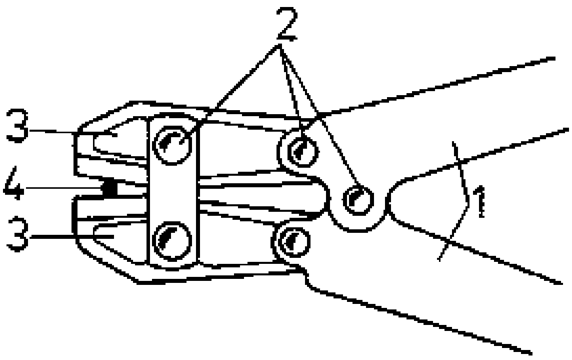


Figure 2.1.17. Bolt clippers

1 Handles,
2 Double joint,
3 Cutting jaw
4 Workpiece

Combination pliers can be used indifferent ways (Fig. 2.1.18.).

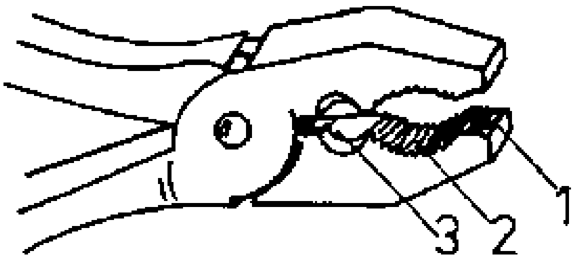


Figure 2.1.18. Combination pliers

1 for flat workpieces,
2 for round and bar stock
3 for cutting off

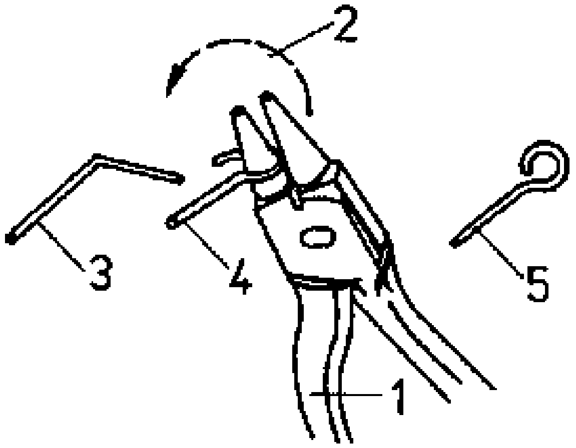


Figure 2.1.19. Round nose pliers

1 Round nose pliers, 2 Rotary motion,
3 Pre−bent part,
4 Part during bending
5 Bent eye

Round nose pliers (Fig. 2.1.19.) are used to bend wires, especially eyelets in electrical conductors. Due to the tapering jaws of the round nose pliers, the bending radius becomes smaller towards the tip.

Do not use tongs or pliers to tighten and loosen screws or nuts!

Keep in mind:

Tongs and pliers are used for holding, bending and separating. By means of the principle of the lever, high forces are achieved.

2.1.4. Hand Shears

Hand shears are used for various operations in sheet−metal working such as cutting off, cutting in and out. As in the case of tongs, hand shears take advantage of the lever action (Fig. 2.1.15.). For thin sheet metal up to a thickness of 1 mm, there are three types of hand shears in various versions.

The hand plate shears (Fig. 2.1.20.) are used for shearing off small strips and corners and for cutting in.

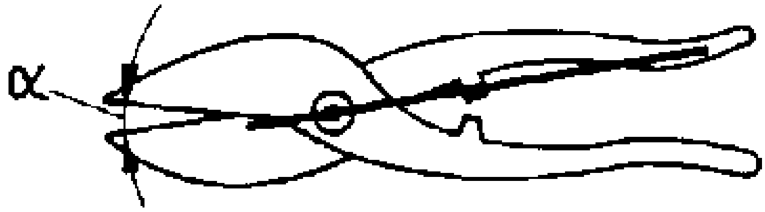


Figure 2.1.20. Hand plate shears

Plate shears are used for cutting straight cuts of particular length in plates manually. The slightly bent up upper shearing jaw facilitates this work. The plates are retained by the holding−down device; the hand cannot get to the point of shearing.

Hand−lever shears are mounted on frames and have a long lever arm (Fig. 2.1.21.). By means of this type of shears, plates having a greater thickness can be separated. The permissible thickness is marked on the hand−lever shear. The holding−down device prevents the tilting of the plate during shearing. There are a few versions of hand−lever shears which lend themselves to the cutting of ' sectional bars.

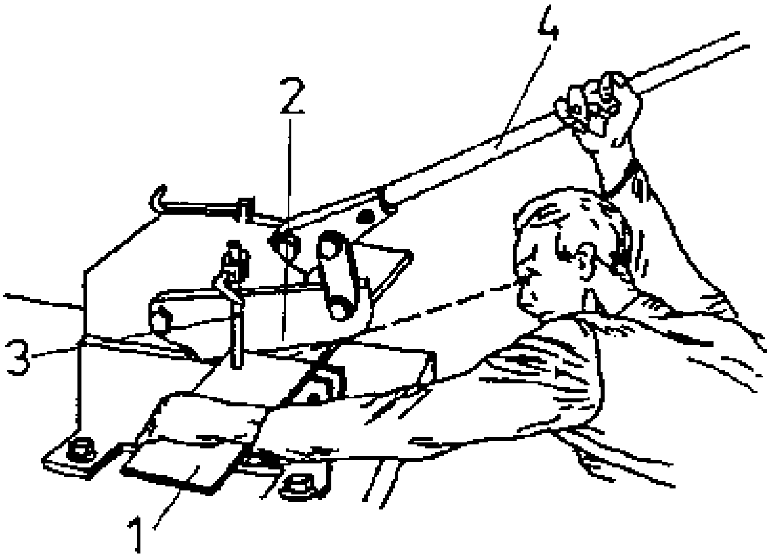


Figure 2.1.21 Hand−lever shears

1 Workpiece, 2 Jaw, 3 Blank holder 4 Lever arm

The shorn areas on the workpieces only comply with simple quality requirements. In most cases, these surfaces must be finished, e.g. by filing.

− Shorn parts of plate have sharp edges!
− Take care in working and transport!
− Shear plates of the permissible thickness only otherwise the shearing jaws will break!
− Secure long hand levers after working by hanging on.

<u>Keep in mind:</u>

Hand shears are used for separating sheet metal and plates. The areas shorn only comply with simple quality requirements.

2.1.5. Chisels

In metal working, chiselling has been replaced to a high degree by machining. Manual chiselling is only employed where the use of machines is not possible or uneconomical. Thus, plates and sections are separated by chiselling when they are too thick for shears. Castings and weld seams are cleaned by means of chisels; rusty bolts and rivets are trimmed by chisels. The main field of application of chisels is in assembling, especially outside workshops and factories. Chisels are forged of tool steel and the chisel tip is hardened. The cutting edge is shaprened by grinding. Flat chisels are most widely used (Fig. 2.1.22.).

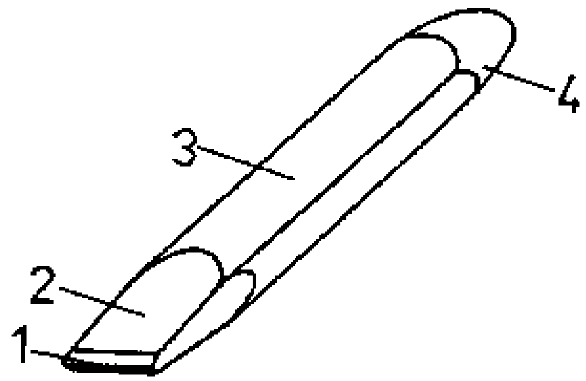


Figure 2.1.22. Flat chisel

1 Cutting edge,
2 Wedge.
3 Shank,
4 Head

For chiselling steel, the cutting edge is ground to form an angle of 70. For working softer materials, the cutting edge must be ground to form a more acute angle, namely, for copper and brass about 45°, for aluminium or lead about 30°. The chisel shank without wedge and without head must be longer than the width of a hand. When the shank is shorter, the chisel cannot be kept properly in hand. Long shanks must be so stable that they are not resilient when a blow is applied so that they cannot slip. The chisel head is spherical. After a longer period of chiselling, the head of the chisel becomes wider. This widening must be ground off in time. It represents a danger due to particles which may be flung off. Also, the hand may slip off and be injured.

Chiselling is divided into two methods: cutting and chip removing. For cutting, the chisel is applied vertically and driven into the material (Fig. 2.1.23.). Consequently, a notch is produced.

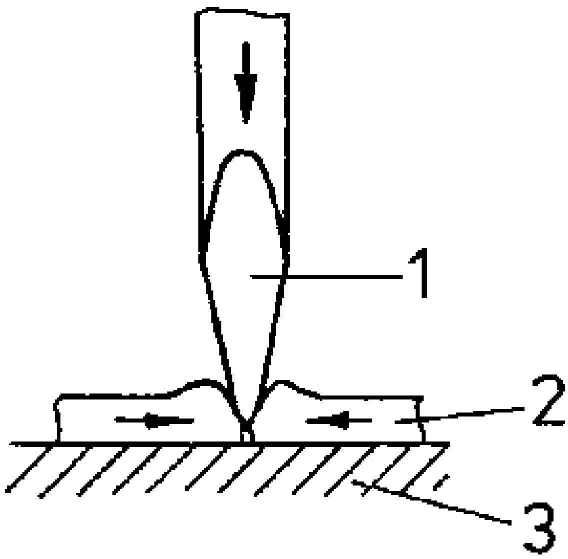


Figure 2.1.23. Chisel in cutting

1 Chisel, 2 Separated workpiece, 3 Support

When the notch is deep enough, the wedge presses the material apart so that it ruptures. In case of larger cross–sections, notches are driven into the material from all sides of the site of separation and then the part is broken (Fig, 2.1.24.).

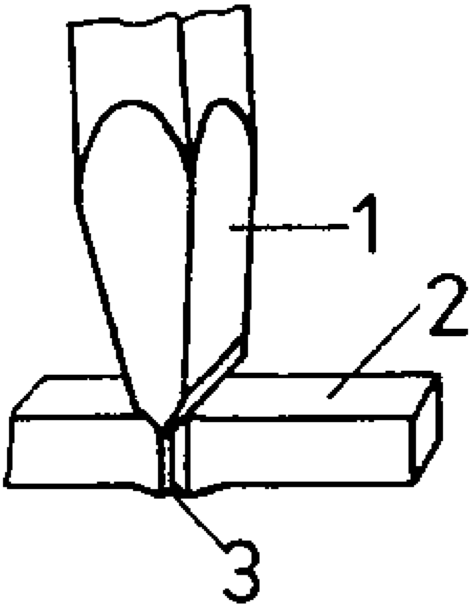


Figure 2.1.24. Chisel in notching

1 Chisel, 2 Workpiece, 3 Notch

Chip removing means that small particles of the material – the chips – are chiselled off. The chisel is applied obliquely. (Fig. 2.1.25.). In case of massive material, this method of chiselling is fatiguing and time consuming.

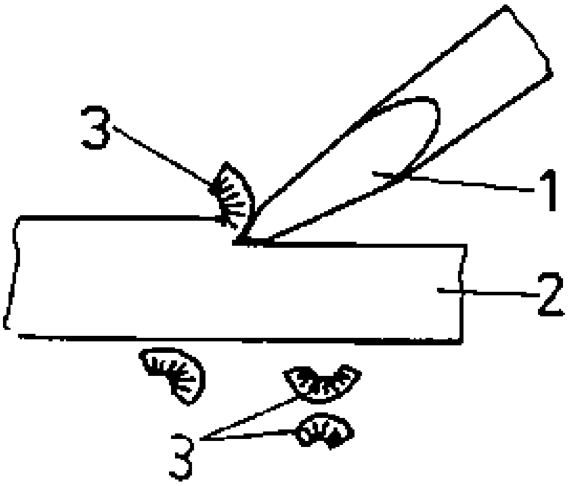


Figure 2.1.25. Chisel in detaching chips

1 Chisel,
2 Workpiece,
3 Chip

The round chisel has an arc–shaped cutting edge. As a consequence, the chisl will not penetrate into the material in its full width. The notch produced in the workpiece is short (Fig. 2.1.26.).

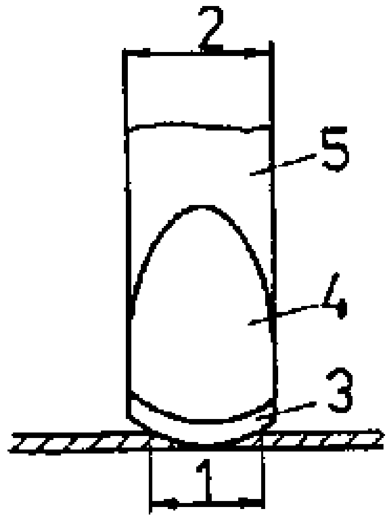


Figure 2.1.26 Notching by means of the round chisel

1 Notch, 2 Width of the chisel,
3 Arc−shaped cutting edge,
4 Wedge, *5* Shank

In this way, arc−shaped sites of separation and holes can be chiselled. At first, notches are driven in side by side. Then, the chisel is applied between these notches so that a continuous notch is achieved (Fig. 2.1.27.).

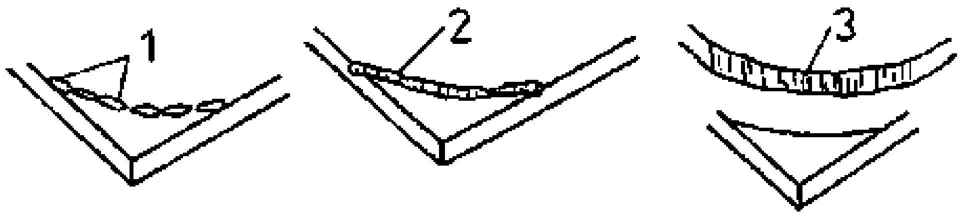


Figure 2.1.27. Chiselling an arc

1 Notches side by side, 2 Continuous notch, 3 Arc chiselled off

In this notch, the chisel is applied so that it is slightly displaced until the material is separated. Holes can be produced in soft materials such as leather, cardboard, plastics or rubber and metal foils by means of a so called punch (see Fig. 2.1.28.).

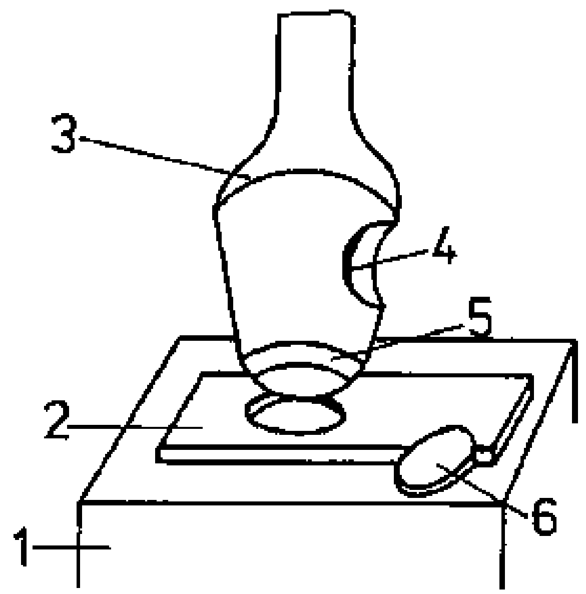


Figure 2.1.28. Piercing holes by means of a punch

1 Support,
2 Workpiece,
3 Shank, 4 Discharge opening, 5 Cutting edge, 6 Part cut out

Punches of this type have a circular cutting edge of different diameters.

The material is punched on a support. These supports consist of hardwood and, sometimes, of lead or light metal. On supports of steel, the cutting edge would be destroyed quickly. The part cut out is removed from the punch through the collecting opening.

The cross−cut chisel has a short cutting edge. It is mainly used to produce grooves using the chip−removal method. In order that the cross−cut chisel does not jam, the wedge becomes narrower laterally towards the tip; it is relieved by grinding (Fig, 2.1.29.).

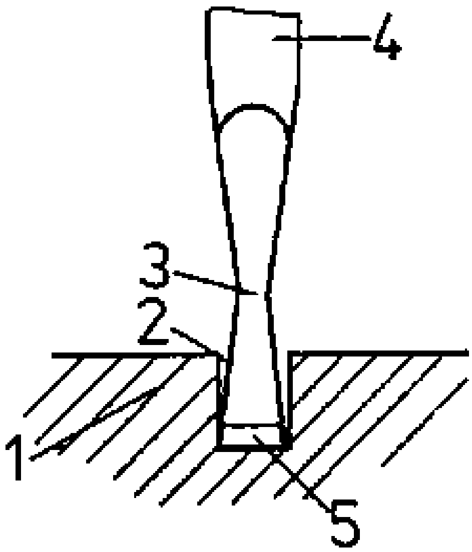


Figure 2.1.29. Grooving by means of the cross−cut chisel

1 Workpiece, 2 Portion relieved by grinding of the wedge, 3 Wedge of the cross−cut chisel, 4 Shank, 5 Cutting edge

Grooving chisels are used (Fig. 2.1.30.) to produce grooves in concave surfaces and sometimes also in plane surfaces.

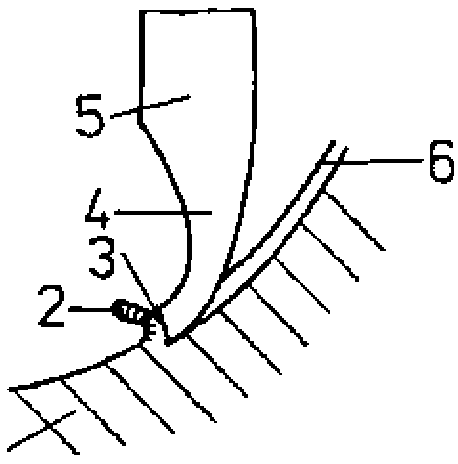


Figure 2.1.30 Grooving in a curved surface

1 Workpiece, 2 Chip,
3 Cutting edge, 4 Curved wedge, 5 Shank, 6 Groove

The curved wedge can be well adapted to the curved surfaces and ensures proper striking with the hammer. Nevertheless, grooving calls for great skill. The grooving chisel is mainly used to produce lubricating grooves in bearings having a large diameter.

– Chisels must possess a sufficiently long shank 1

– Grind off enlargements at the chisel head in time!

– Reliably and safely clamp the workpieces to be chiselled!

– Protect other people from chips flung about by the arrangement of protective sheets or the like!

<u>Keep in mind:</u>

For chiselling, two methods are employed: cutting of sheet metal and detaching chips from massive workpieces. The cut surfaces usually must be reworked or finished.

2.1.6. Drifts

Small openings in sheet metal can be produced by means of drifts. Drifts are also required in cases when a hammer cannot be used because the face or pane of the hammer are too large. Drifts are forged of tool steel. The shank has a circular or hexagonal cross–section. The head is slightly crowned. The lower part of drifts is offset in various diameters or it is tapered. Drifts are mainly used to drive pins out of holes. The drift is applied to the pin. By applying hammer blows on the drift, thepin is driven out of the hole (Fig. 2.1.31.).

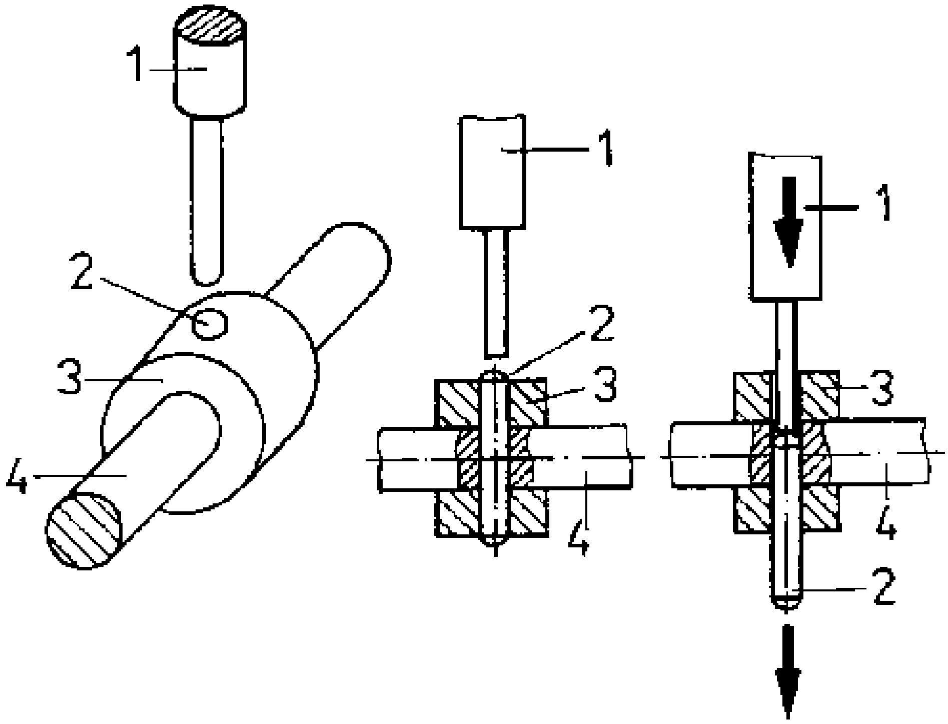


Figura 2.1.31 Driving out a pin by means of a drift

1 Drift, 2 Pin, 3 Bush, 4 Shaft

The diameter of the drift must be slightly smaller than the diameter of the pin. Drifts which are too thin will deform the pin, become bent or will break. Drifts which are too thick will jam in the hole and damage it.

Drifts are also required for bending small parts. An example is shown in Fig. 2.1.32. where plate strips have to be bent which are much smaller than the hammer face.

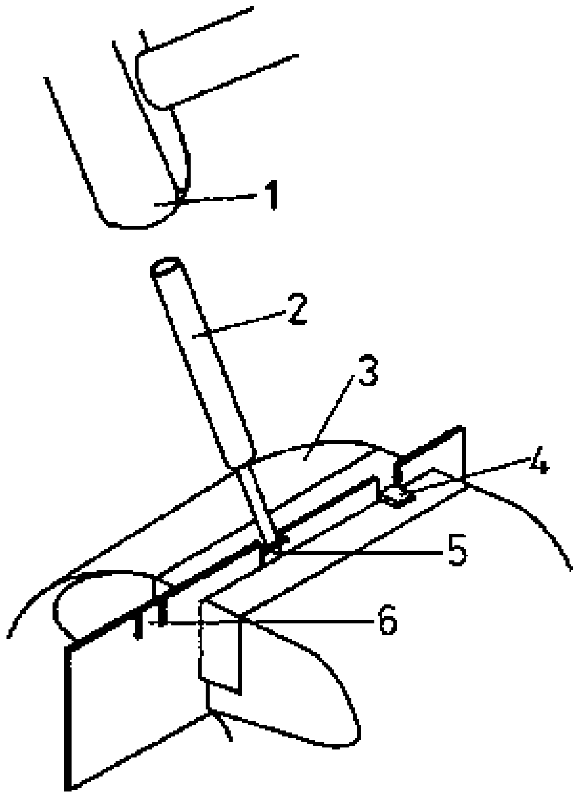


Figure 2.1.32. Bending by means of a drift

1 Hammer,
2 Drift,
3 Vice,
4 Bent strip,
5 Strip being bent,
6 Cut strip

2.1.7. Hand Hacksaw

The hand hacksaw (Fig. 2.1.33.) is used to separate metallic workpieces such as steel, castings or brass. It is not well suited for sawing wood.

The parts of the hand hacksaw consist of mild steel. The handle is made of wood and must be provided with a sheet−metal ring which prevents the handle from bursting. The saw blades consist of tool steel which is particularly hard due to alloying elements such as tungsten.

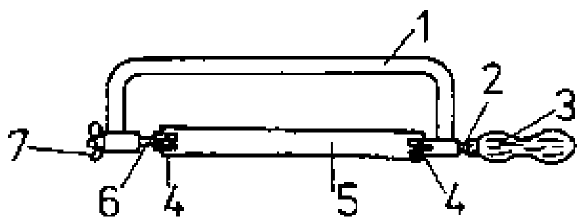


Figure 2.1.33. Hand hacksaw

1 Bow with fixed dog, 2 Tang,
3 Handle, 4 Pin,
5 Saw blade,
6 Movable dog,
7 Wing nut,

Hand hacksaw blades will not be sharpened when they have become blunt. They are replaced by new ones.

When loosening the wing nut, the movable clamp dog is also loosened. As a consequence, the pins can be drawn out of the two dogs and the saw blade removed from the slots in the dogs. The new saw blade is inserted into the slots. The teeth point forward in the direction of the wing nut. After having fitted the pins, the wing nut is tightened by hand.

During their manufacture, the hand hacksaw blades are corrugated mechanically. As a consequence, the teeth are not arranged exactly one after another but they are slightly offset laterally. This ensures that the saw kerf becomes wider than the saw blade and the latter cannot jam.

For sawing with the hand hacksaw, the workpiece must be properly clamped. This is usually achieved with the help of a vice. The saw is operated with both hands; the operator stands close by the vice (Fig. 2.1.34.).

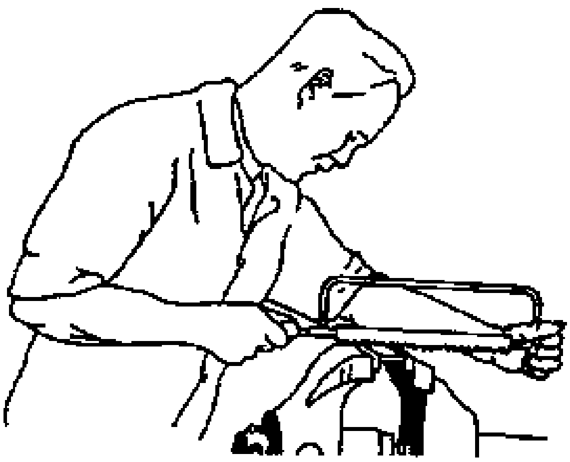


Figure 2.1.34. Working with the hand hacksaw

Since chips are detached only when the saw is pushed, pressure should not be applied to the saw when it is moved back. This will save the saw blade and energy.

In order to observe the correct dimensions in sawing, the saw must be guided close by the scribed line, i.e. beyond the part to be produced. When sawing directly on the scribed line, the part will become too small.

It is favourable to saw a notch at the point where the saw is to be applied. A triangular file is to be used for this purpose. This will ensure that the saw blade will not slip. The saw blade is applied to the notch so that the saw is slightly inclined forward (Fig, 2.1.35.).

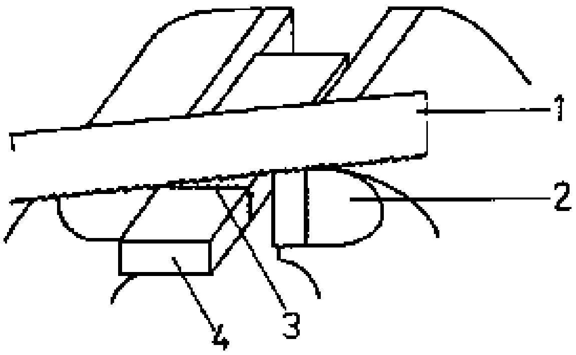


Figure 2.1.35. Applying the hand hacksaw

1 Saw blade, 2 Vice, 3 Marking, 4 Workpiece

Start sawing carefully until the saw kerf is large enough for the saw blade to be guided reliably. When sawing manually take care that the saw kerf is as long as possible. Rectangular material is sawn at the longer side (Fig. 2.1.36.).

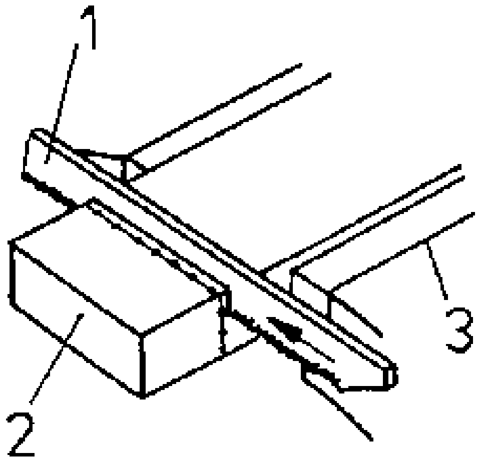
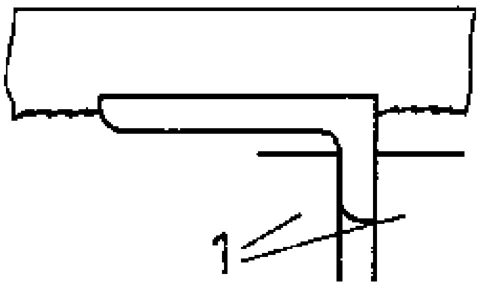


Figure 2.1.36. Sawing *a* rectangular profile

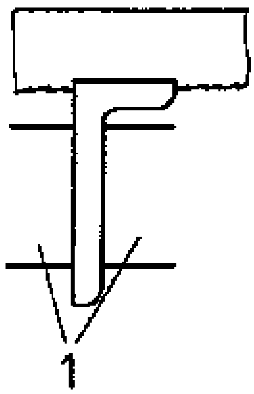
1 Saw blade, 2 Workpiece, 3 Vice

Angular sections and U−sections are sawn by several cuts while the saw is to be reset (Fig. 2.1.37.).

Figure 2.1.37. Sawing an angular profile



a) First cut,



b) 2nd cut after re−clamping

1 Vice

Pipes are also sawn by several cuts in order to avoid breaking out of the saw blade (Fig. 2.1.38.).

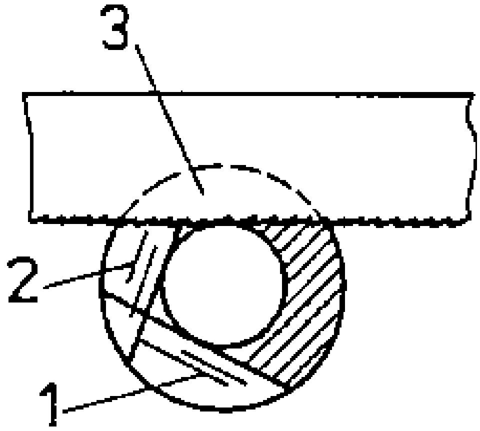
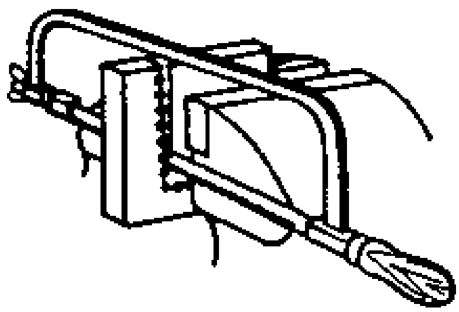


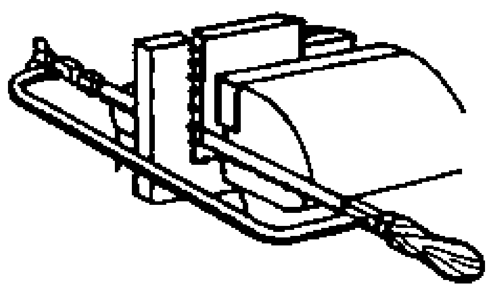
Figure 2.1.38 Sawing a pipe

1 First cut, 2 Second cut, 3 Third cut

For very deep cuts, sawing is continued until the saw frame contacts the workpiece. Then, the saw blade is reset in such a manner, that the blade is across the frame. The teeth point in the direction of the wing nut. When continuing sawing, the frame can be guided along the workpiece (Fig. 2.1.39.).

Figure 2.1.39 Sawing deep cuts


a) First cut


b) Second cut after re−clamping the saw blade

– Only use saws with a proper handle!

– Guide the saw with both hands!

– Tension the saw blade by tightening the wing nut so that the blade is properly taut!

– For sawing, the workpieces must be held reliably and safely!

– Saw blades where parts are broken out must be replaced by new ones!

<u>Keep in mind:</u>

By means of hand hacksaw, metallic materials of medium and smaller dimensions are divided. Saw blades for hard materials have small teeth while saw blades for softer materials have larger teeth and larger chip spaces. Working according to the rules of good workmanship calls for

– reliable clamping of the parts,
– guiding the saw with both hands,
– correct body posture,
– correct fitting and tensioning of the saw blade.

2.1.8. Files

Files are used for very many purposes. Mainly surfaces are worked which may be plane and curved. Further, openings are finished, radii and chamfers are filed, bevels are filed and workpieces deburred.

The structure of a file is shown in Fig. 2.1.40. The file blade is forged of tool steel.

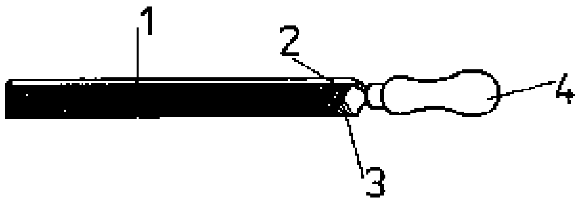


Figura 2.1.40. Structure of a file

1 File blade, 2 Overcut, 3 Upcut, 4 Handle

The spacing of the cuts of a file (Fig. 2.1.40.) determines the size of the file teeth. The size of the teeth is decisive for the quality of the surfaces filed.

A distinction is made between:

– rough–filed surfaces: The ridges left by the tool are clearly perceptible on the surface.

– finish–filed surfaces: The ridges left by the tool are well visible on the surface, but they cannot be felt.

– fine–finished surfaces: The ridges left by the tool are hardly or absolutely not visible on the surface.

In accordance with this, the classification of files is, depending on the size of teeth and hence on the spacings of the cut of file, as follows:

– rough files with 5 to 20 cuts per 1 cm of length,

– finishing files with 20 to 45 cuts per 1 cm of length,

– fine–finishing files with 45 to 71 cuts per 1 cm of length.

For working soft materials, milled files are also used. The teeth are arranged obliquely or in the form of an arc on the file blade. To improve the removal of chips, chip–breaking nicks or grooves are arranged. These grooves break the larger chips so that the file moves smoothly. Milled files are expensive because of the manufacturing process. Cut and milled files are not suitable for the working of wood, horn and soft plastics. The chip space is clogged by the chips – the file no longer removes chips properly. Therefore, rasps with a special shape of teeth are used for these purposes (Fig. 2.1.41.).

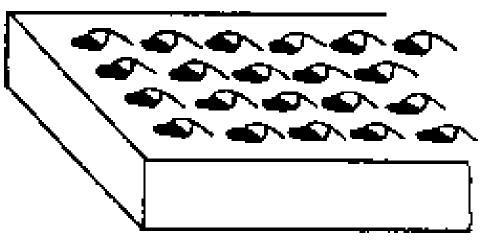


Figure 2.1.41. Rasp cut

1 Rasp tooth

Files are available in different sizes and various cross−sections in order to meet the requirements of workshop practice.

As for sawing, the workpiece, must also be clamped reliably for filing. Usually, the latter is clamped in a vice. To attain the correct body posture and thus the correct guidance of the file, the vice must have the correct height (Fig. 2.1.42.).

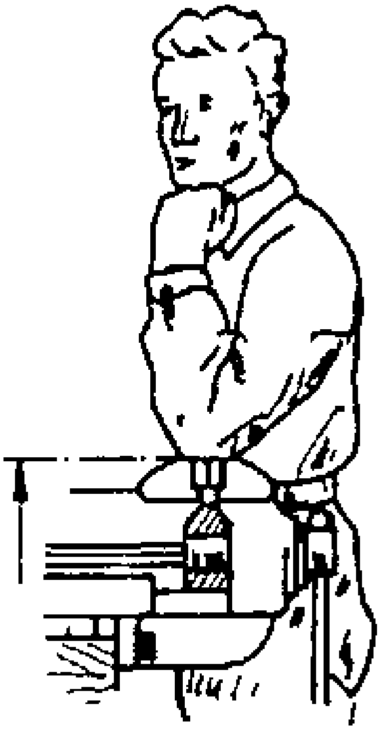
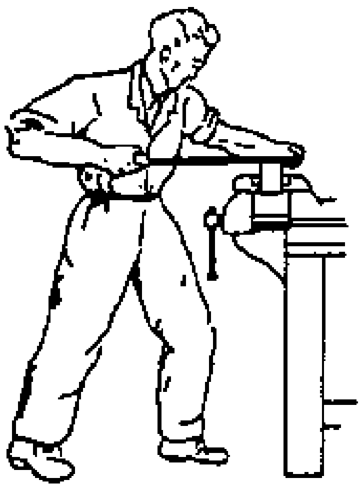
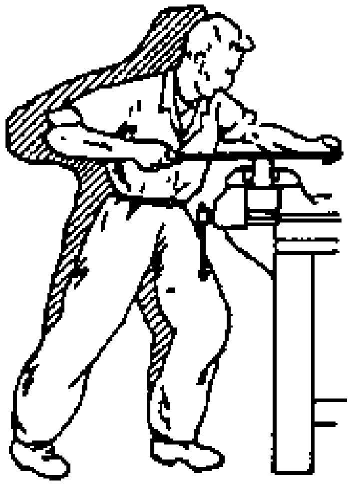


Figure 2.1.42 Correct working height of the vice

Figure 2.1.43 Body carriage in filing



1 Initial position



2 Beginning of feed

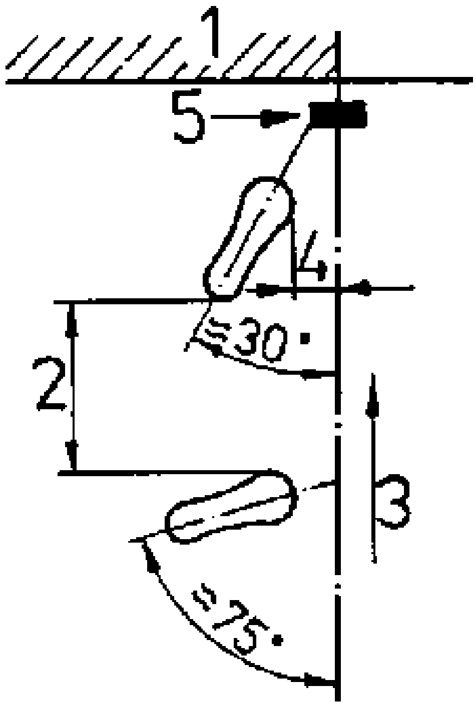


Figure 2.1.44 Position of the feet in filing

1 Filing bench, 2 about the length of a file, 3 Direction of filing and viewing, 4 Distance equal to the width of a foot, 5 Workpiece

For heavy filing work and the removal of large amounts of chips (rough filing), the filing movement of the arms in supported by the body and, for this purpose, the position of the feet of the operator is of particular importance (Figs. 2.1.43 and 2.1.44.).

Figure 2.1.45 How to hold large files

Depending on their sizes, files are guided and kept in different ways (Figs. 2.1.45., 2.1.46. and 2.1.47.).

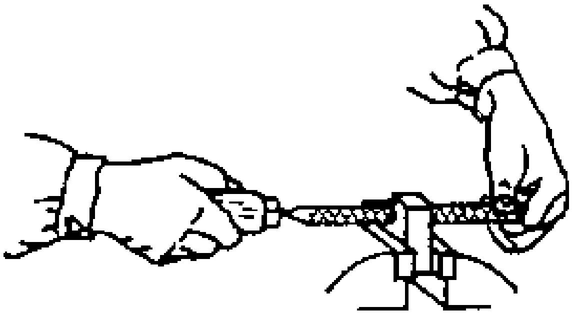


Figure 2.1.46. How to hold medium−size files

Figure 2.1.47. How to hold small files

The chip spaces of the files must be cleaned at shorter intervals. For this purpose, the file brush is drawn in the direction of the upcut. When the chips stick, then they must be pushed out of their seats by means of a pointed strip of sheet metal, i.e. of steel or brass, also in the direction of the upcut.

– Never file with a file without handle!
– Before and during filing check the proper firm fit of the file handle!
– Do not use files to apply blows – they will burst!
– Do not wipe filings with your bare hand!

<u>Keep in mind:</u>

Files are tools for chip removal, mainly from surfaces and the surfaces of openings. Depending on the size of the file teeth, rough−filed, finish−filed and fine−finished surfaces are achieved. A wide field of application of files is ensured by different sizes and different cross−sections of files. For filing, the following information should be observed:

– properly tight clamping of the parts to be filed

– correct body posture

– correct gripping and guiding of the file

– cleaning the chip spaces of the file at shorter intervals.

2.1.9. Wrenches and Screw−drivers

For tightening and loosening screws, bolts and nuts, suitable tools must be used. The different types of screws, bolts and nuts call for different tools which ensure working according to the rules of good workmanship.

The most frequently occurring shape of screw−heads and nuts is the hexagon. The size of hexagon−head screws, bolts and nuts is standardized, especially the width across flats ‘s’ and the corner dimension ‘e’ (Fig. 2.1.48.).

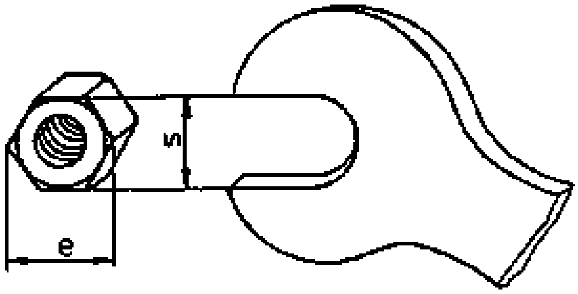


Figure 2.1.48 Hexagon nut and wrench

s Width across flats, e Corner dimension

According to these dimensions, the suitable wrenches, also known as spanners, are made on a commercial scale for screws, bolts and nuts. The commonly used wrenches are shown in Figs. 2.1.49., 2.1.50., 2.1.51. and 2.1.52.

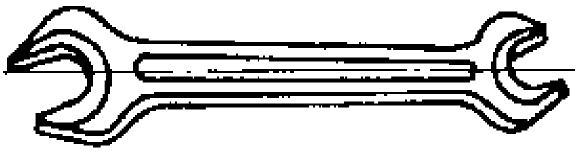


Figure 2.1.49 Double−ended spanner

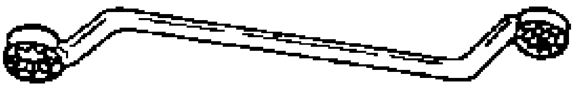


Figure 2.1.50 Offset double socket wrench

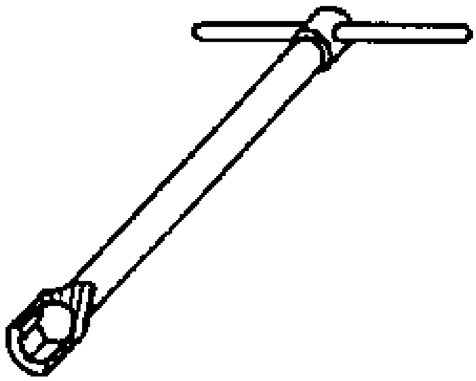


Figure 2.1.51. Hexagon box spanner

Figure 2.1.52. Hexagon pin wrench

The length of the wrenches depends on the thread diameter: the larger the thread diameter, the longer the wrench. The length of the wrenches is designed in such a way that the screw or nut can be properly tightened by hand force. For loosening and tightening screws with slotted head, screw−drivers must be used (Fig. 2.1.53.)

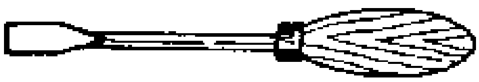
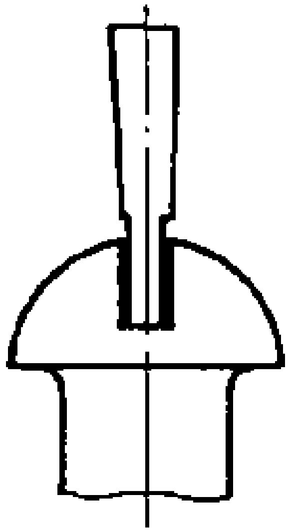


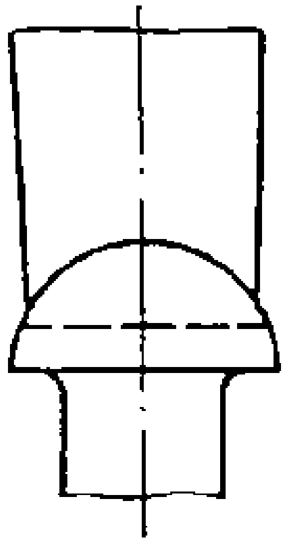
Figure 2.1.53. Screw−driver

They have to be selected according to the size of the slot (Fig. 2.1.54.).

Figure 2.1.54. Correctly selected screw−driver



1 Correctly ground screw−driver blade



2 Correct width of the screw−driver blade

Screw−drivers which are too small will be bent or distorted, damage the screw or will not tighten the screw properly.

− Pay attention to the correct width across flats of the wrench!
− Do not use tongs or pliers for tightening and loosening screws and nuts!
− Always select the suitable screw−driver for slotted−head screws!
− Do not use screw−drivers as chisels!

2.2. Machine Tools

The majority of all workpieces is made or tooled on machines. The tools used for these purposes act in different ways on the workpiece and are largely differing, depending on the manufacturing method. A general classification results from the manufacturing main groups.

2.2.1. Machine Tools for Initial Shaping

The tools used for initial shaping are moulds in which the material is formed into a specified shape (Fig. 2.2.1.).

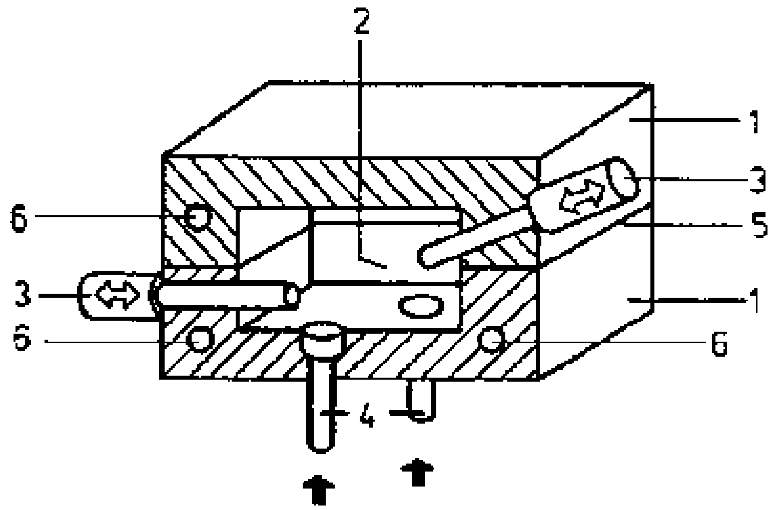


Figure 2.2.1. General construction of a mould

1 Half of a mould, 2 Interior space = engraving, 3 Slide, 4 Ejector (pins), 5 Plane of partition, 6 Cooling channel

Although they are used in different ways, the metal moulds used in initial shaping have common features:

– Usually, they consist of two mould halves so that the mould can be opened and closed (complicated moulds consist of several parts)!

– The engraving, which corresponds to the desired workpiece shape, is worked into the halves of the mould.

– The surfaces of the engraving are polished in order to ensure a smooth surface of the initially shaped part.

– Frequently, the surface of the engraving is hard–chromium plated in order to ensure a long service life.

– The shaped parts are pressed out of the mould by means of ejectors (pins or strips).

– Depressions and cavities in a workpiece are achieved by sliding members; before filling material, they are pushed into the mould and after moulding they are withdrawn from the shaped part.

By means of cooling ducts, the moulds are usually cooled with water. In moulds for pressing plastics, heating cartridges are incorporated. The materials are filled in different ways, depending on the process (Fig. 2.2.2.).

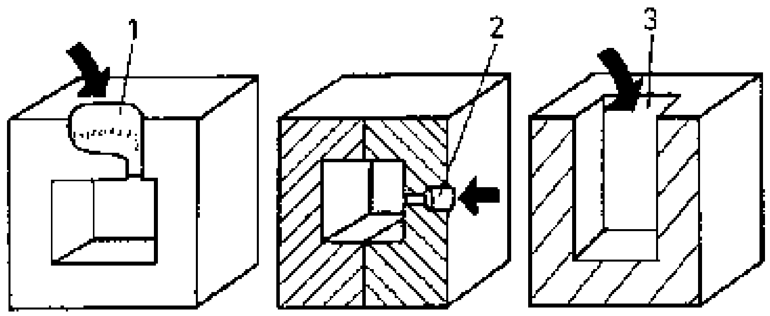


Figure 2.2.2. Ways of filling moulds

1 Ingate of funnel shape, 2 Injection duct or runner, 3 Mould that is open on top

– Through funnel–shaped ingates in casting by gravity,

– Through injection holes, so–called runners, in die casting and injection moulding of plastics,

– By filling the open mould in sintering and pressing of plastics.

The moulds must withstand high mechanical and thermal stresses, therefore, they are made of

– hot working steels

– light alloys (usually aluminium with copper) for low–melting materials (e.g. lead, tin).

Almost all of the moulds are made individually so that their production is rather time–consuming and, hence, they are expensive.

<u>Keep in mind:</u>

Tools for initial shaping are moulds. They are split so that the shaped part can be removed easily. The cavity inside the mould – the engraving – imparts the shape to the material filled in, cavities inside the workpiece are made by means of sliding members. Moulds are tools for casting machines and pressing thermosetting plastics.

2.2.2. Machine Tools for Forming

Forming tools act on the workpieces, applying the required forces on the latter and thus changing the shape of them. The high load on the tools calls for a sturdy construction.

The acting tool parts are made of

– cold working steels for cold forming
– hot working steels for hot forming
– hard metals for particularly high loads.

To increase the strength and the service life, the acting surfaces of the tools are

– subjected to heat treatment (hardening and tempering)
– frequently hard–chromium plated
– partly polished,

A typical group of forming tools are rolls. Their common features are

– the rotating movement
– the compressive forces acting on the workpiece
– the arrangement in pairs in normal cases (Fig. 2.2.3.).

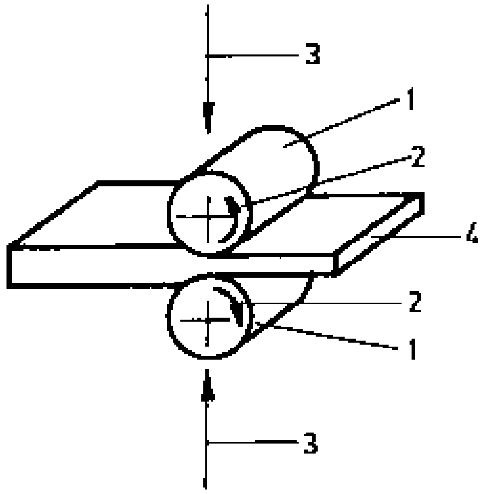


Figure 2.2.3. Forming by means of rolls (principle)

1 Working surface,
2 Rotating working motion,
3 Forming force,
4 Workpiece

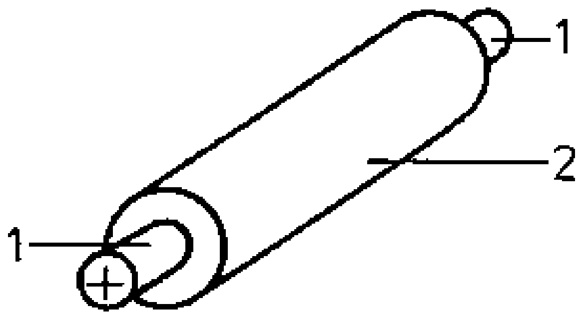
Depending on the forming process, the rolls are distinguished by

– their main dimensions, namely, diameter (20 to 1,500 mm) and length (10 to 1,800 mm)

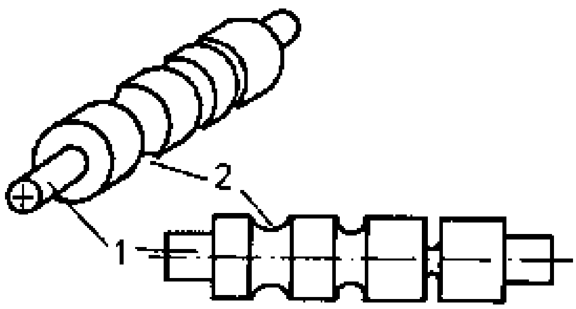
– the shape of their effective area

– the surface of their effective area (Figs. 2.2.4a, b, c).

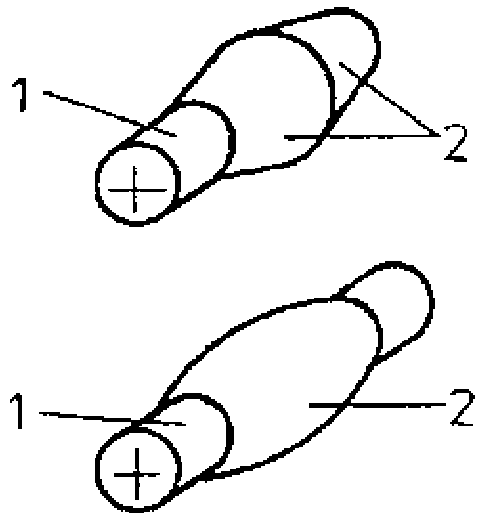
Figure 2.2.4. Rolls for forming



a) Cylindrical roll



b) Grooved roll with passes



c) Formed rolls

1 Mounting end,
2 Working surface

Another comprehensive group of typical forming tools for different processes also exhibits a number of similar constructional features:

– They consist of two main components, the upper part (upper die) and lower part (bottom die).

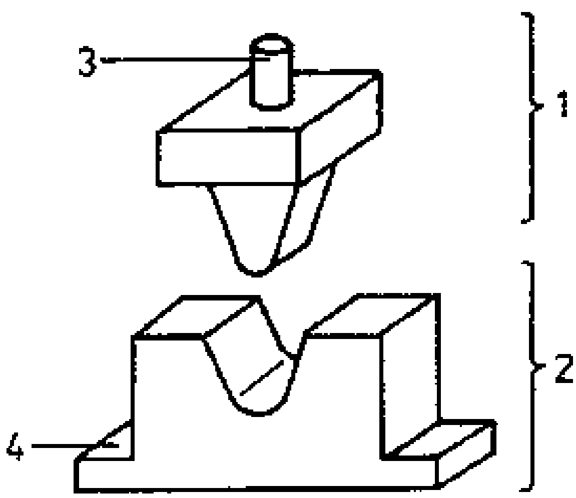
– The upper die is accomodated in a ram by means of a clamping pin.

– The bottom die is fastened on a press bed.

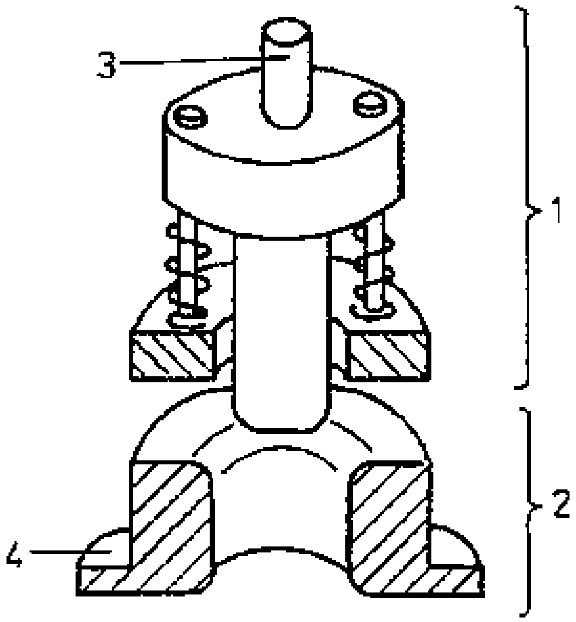
– The force of the press is applied by the upper die in a straight motion to the workpiece, shaping it in this operation.

A selection of such tools is shown in Fig. 2.2.5.

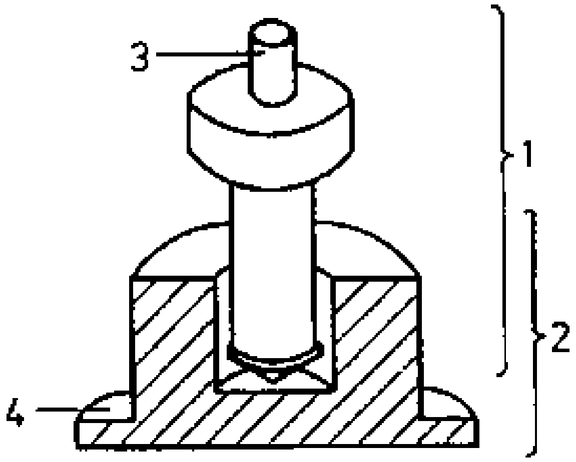
Figure 2.2.5. Typical two-part forming tools



a) Bending tool



b) Deep drawing tool



c) Extruding tool

1 Upper part,
2 Lower part,
3 Mounting pin,
4 Clamping edge

A few special features are exhibited by tools for forging, the drop−forging dies (Fig. 2.2.6.).

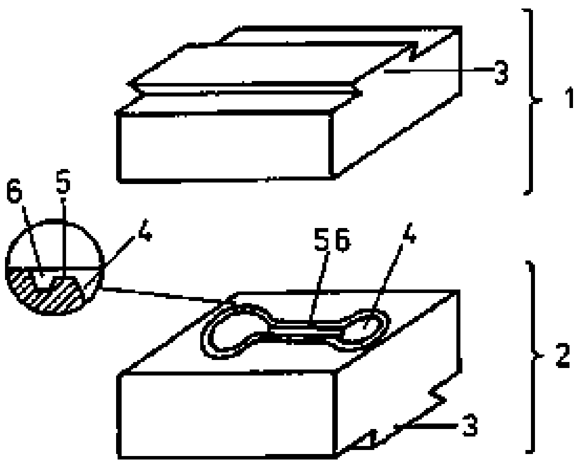


Figure 2.2.6. Drop−forging die

1 Upper part,
2 Lower part,
3 Dovetail,
4 Engraving,
5 Burr groove,
6 Flash rings

They also consist of upper die and bottom die, but they are held in the machines by dovetails. The effective surfaces have the form of engravings. Drop−forging dies are additionally provided with a burr groove and channel both of which have to accomodate the excess material left in forging.

Special forming tools are employed on horizontally operating presses. They also consist of two main components one of which is also accomodated by the press ram (Fig. 2.2.7.).

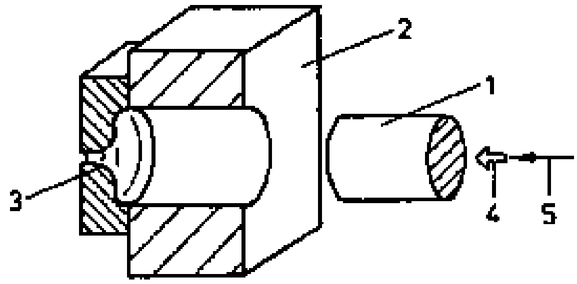


Figure 2.2.7. Horizontally operating forming tool (extruding)

1 Press ram, 2 Receptacle for the blank,
3 Press ring with working surfaces, 4 Ram motion,
5 Pressing force

Keep in mind: Forming tools act on the workpieces by virtue of their effective *area.* The shape of the workpiece is changed by the forming forces. Typical features of tools are roll−shaped tools and two−part tools which are employed on presses.

2.2.3. Machine Tools for Separating

The separating or cutting of workpieces or the cutting−off of parts from workpieces in order to change their shape is carried out according to different principles. This group of tools is classified accordingly.

Tools for cutting

In cutting, a wedge penetrates the material vertically and divides the latter. Usually two workpiece parts are brought about without detaching chips (Fig. 2.2.8.).

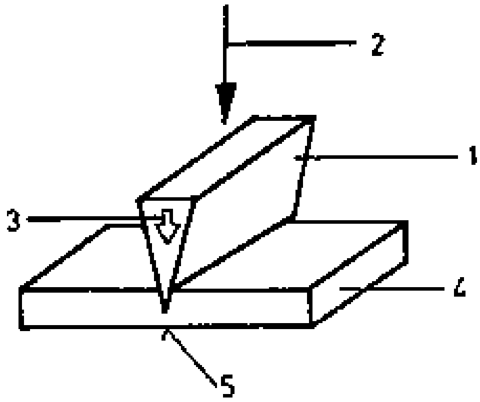
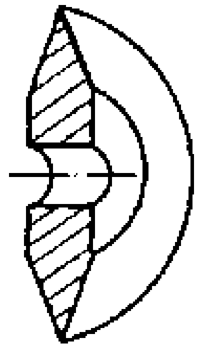


Figure 2.2.8. Principle of wedge cutting

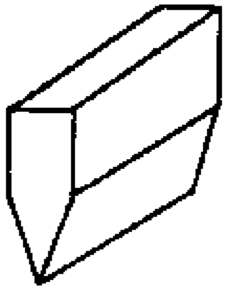
1 Wedge, 2 Cutting force, 3 Cutting motion, 4 Workpiece, 5 Point of separation

This principle determines the construction of cutting tools. The pointed wedge is made of tool steels, hardened and sharpened by grinding. In a tool, the wedges are incorporated in the form of strips and rolls (Fig. 2.2.9.).

Figure 2.2.9. Cutting roller in sectional view (1) and cutting strip (2)



1



2

Cutting strips are inserted in plates of hardwood, plastics or light metal according to the specified cutting procedure. The plate is bolted to a block with a clamping pin. This tool (Fig. 2.2.10.) is accomodated in a press ram. As the lower part of the tool, plane plates of hardwood, hard rubber, plastics and, in a few cases, of lead are placed on the press bed.

Cutting rolls are held by axles or pins so that they are free to rotate. The machine usually moves the roll along the site of cutting and along a straight line, at the same time pressing the roll into the material.

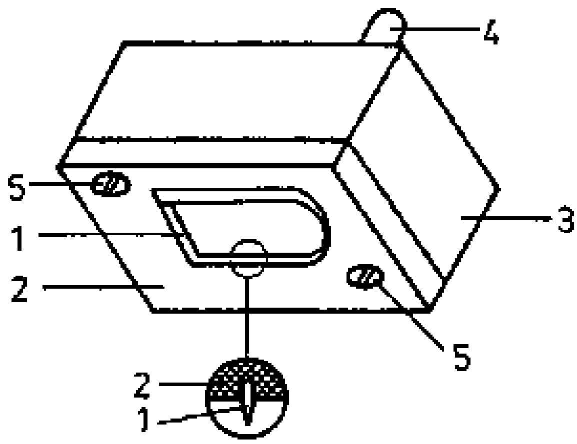


Figure 2.2.10. Cutting tools'

1 Cutting strip,
2 Retaining plate,
3 Block,
4 Clamping pin,
5 Fastening screw

Tools for shearing

In the process of shearing, the material is divided by the shearing edges. The shearing edges move past one another at a small distance – the shearing gap b – applying the required shearing force (Fig. 2.2.11.).

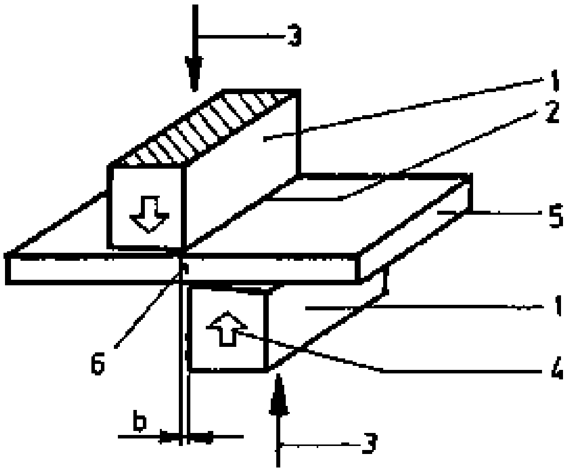


Figure 2.2.11. Principle of shearing

1 Shearing cheek,
2 Shearing edge,
3 Shearing force,
4 Shearing motion,
5 Workpiece,
6 Point of shearing
b Shearing gap

The shearing jaws are arranged at

– shearing jaws for straight shearing sites
– shearing dies for angular and curved shearing sites
– shearing plates for angular and curved shearing sites

Shearing jaws, dies and plates are made of tool steels, hardened and the shearing edges are ground. Shearing jaws are employed on machine shears. Shearing dies and shearing plates are the dividing parts of shearing tools which

– consist of the main components upper die and bottom die,
– are employed in presses.

The simplest design are non–guided shearing tools (Fig. 2.2.12.).

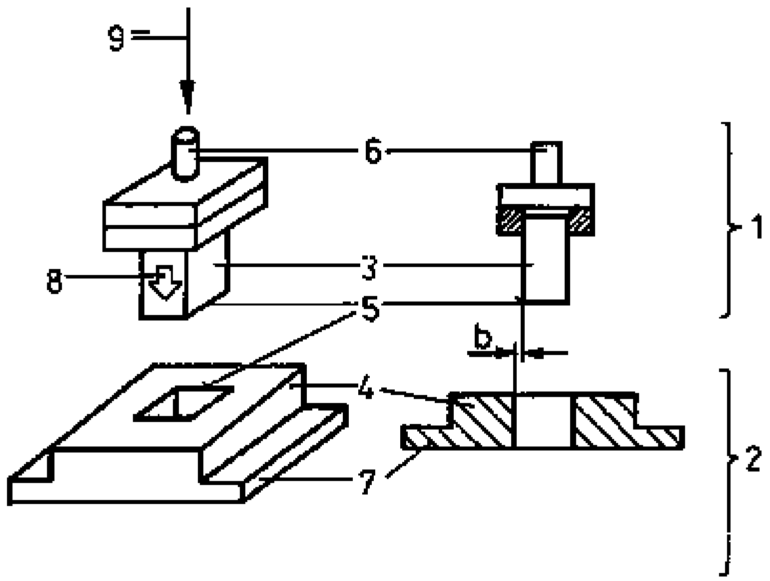


Figure 2.2.12. Shearing tool, simple design

1 Upper part, 2 Lower part, 3 Shearing punch, 4 Shear plate, 5 Shearing edge, 6 Clamping pin, 7 Clamping edge, 8 Shearing motion, 9 Shearing force, b Shearing gap

They are quite simple, but they can comply only with low quality requirements with respect to the shorn parts.

Higher quality requirements regarding the dimensional accuracy of the workpieces and the cleanliness of the shorn surfaces will be achieved by means of shearing tools whose shearing die is guided (Fig. 2.2.13.).

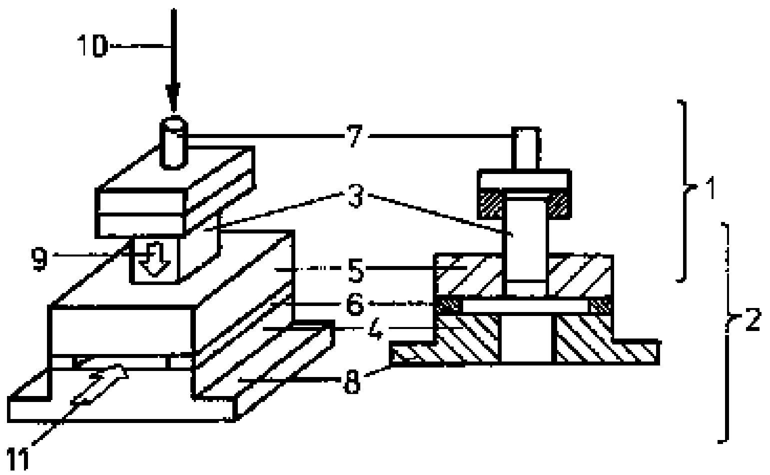


Figure 2.2.13. Shearing tool with plate guide

1 Upper part, 2 Lower part, 3 Shearing punch, 4 Shearing plate, 5 Punch guiding plate, 6 Guide strips for the material, 7 Clamping pin, 8 Clamping edge, 9 Shearing motion, 10 Shearing force, 11 Material (sheet−metal strip)

<u>Chip−detaching Tools</u>

Chip−detaching tools used on machine tools (production machines) are used by many trades. They vary largely with respecto to size, applications and design.

<u>Keep in mind:</u> The basic shape of all chip−detaching tools is the wedge with cutting edge.

The tool wedge detaches chips, thus changing the shape or surface of the workpieces subjected to this process. In this process, the machine performs the necessary motions and applies the required forces. The cutting edge is subjected to high loads and, in addition, it must dissipate the heat generated in metal removing (Fig. 2.2.14.).

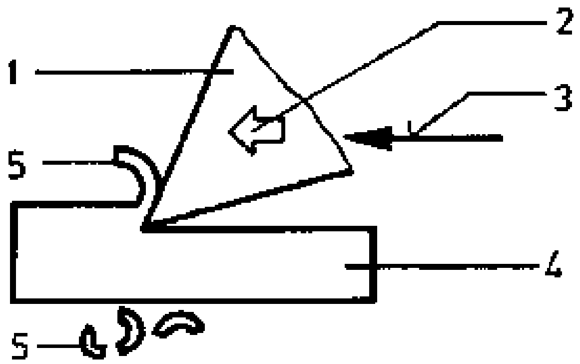


Figure 2.2.14. Principle off chip removal

1 Wedge,
2 Cutting motion,
3 Cutting force,
4 Workpiece,
5 Chip

In view of the high loads involved, the chip−detaching tools or the wedge must be made of special cutting materials. For this purpose, the following materials are used

− unalloyed hardened tool steels, temperature−resistant up to 150°C,

− alloyed tool steels, temperature−resistant up to 300°C due to the addition of chromium, tungsten, molybdenum,

− high−speed steels, high−alloyed with chromium, molybdenum, tungsten vanadium, cobalt and temperature−resistant up to 600°C,

− hard metals of metallic compounds (e.g. tungsten carbide, titanium carbide) and metalls (e.g. cobalt, nickel) are temperature−resistant up to 1,200°C, but they are brittle and hence sensitive to impacts,

− cutting ceramics of pure aluminium oxide with hard metal carbides and sintered with heat−resistant metals (e.g. molybdenum, vanadium and tungsten); temperature−resistant up to 1,200°C but brittle and thus sensitive to impacts,

− super−hard cutting materials (e.g. diamond, boron nitride) for special tools, rarely used in normal workshop operation.

Hard metals and cutting ceramics are not manufactured into complete tools. Hard metals that can be ground are soldered in the form of plates on the tools or clamped in place in series and mass production.

Cutting ceramics cannot be ground because of its particular hardness. Therefore, reversible plates with several cutting edges are made and clamped on the tool. When one cutting edge has become blunt, the plate is turned so that a new cutting edge can be used.

The wedge of the cutting edge of a chip−detaching tool is specified by certain angles. These angles must be observed when the tool is produced and sharpened, and they are determine by

− the material to be tooled
− the particular chip−detaching method to be used and, hence, the type of tool to be employed
− the specified surface finish of the workpiece
− the cutting material used.

The wedge angle ? of the tool is between the cutting face and the surface below the cutting edge (Fig. 2.2.15.).

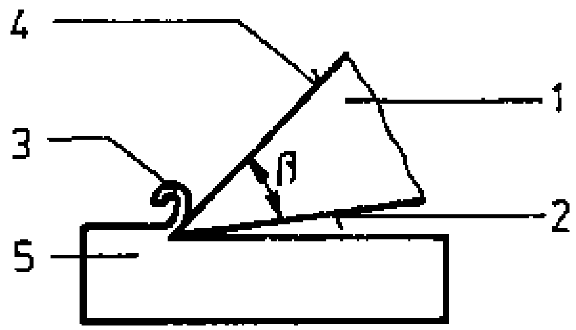


Figure 2.2.15. Cutting−wedge angle “?“ at the cutting tool

1 Wedge, 2 Flank (surface below the cutting edge), 3 Chip, 4 Cutting face (rake face), 5 Workpiece cutting−wedge angle

A small wedge angle imparts a good cutting effect to the tool but the cutting edge only bears low loads and withstands only a relatively low temperature. This shows that tools with a small wedge angle are only suitable for tooling soft materials.

A large wedge angle reduces the cutting effect and calls for a high cutting force. The wedge is more stable and capable of cutting tough and medium−hard materials.

Apart from the wedge angle, the position of the cutting wedge with respect to the workpiece plays an important part. Geometrically, the position of the wedge is determined by a vertical (imaginary) line on to the workpiece surface. Between cutting face and the imaginary line, the rake angle ? (Fig. 2.2.16.) is formed.

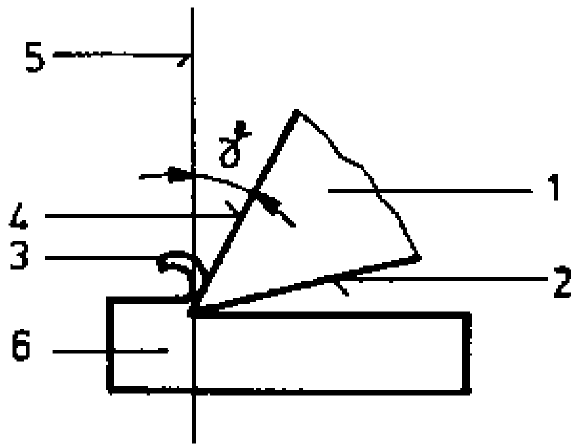


Figure 2.2.16. Rake angle “?“ at the cutting tool

1 Wedge, 2 Flank, 3 Chip, 4 Rake face,
5 Auxiliary−line,
6 Workpiece,
? rake angle

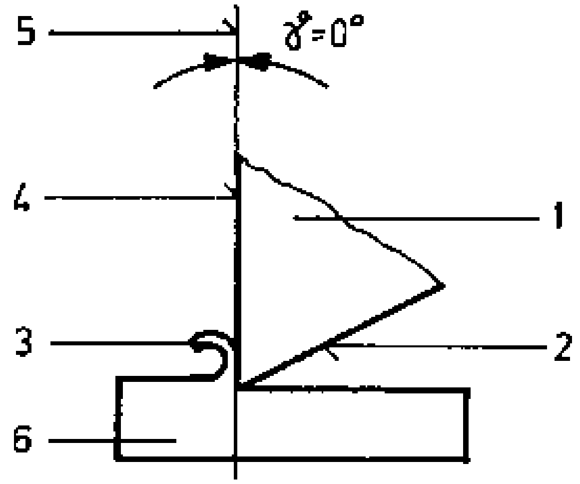


Figure 2.2.17. Wedge having a rake angle ? of 0°

1 Wedge,
2 Flank,
3 Chip,
4 Rake face,
5 Auxiliary line,
6 Workpiece

The smaller the rake angle ?, the lower the cutting effect will be.

In a few chip–detaching tools, the rake angle ? = 0° (Fig. 2.2.17.).

Only a few tools have a negative rake angle (Fig. 2.2.18.). These tools do not cut, they scrape and are particularly suitable for improving the surface of the workpiece while the shape is scarcely changed.

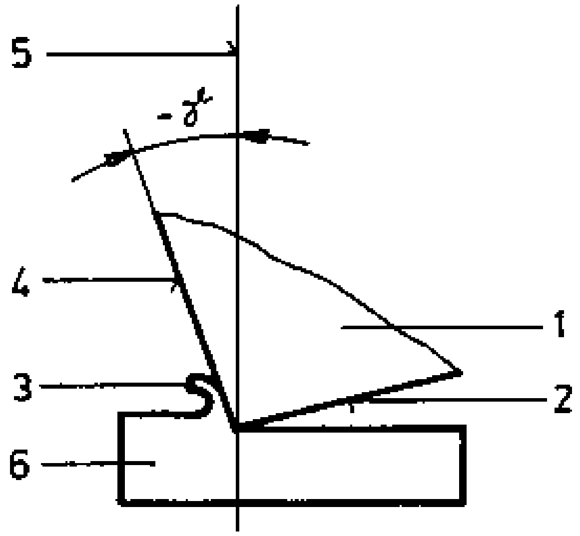


Figure 2.2.18. Wedge with a negative rake angle of – ?

1 Wedge,
2 Flank,
3 Chip,
4 Rake face,
5 Auxiliary line,
6 Workpiece

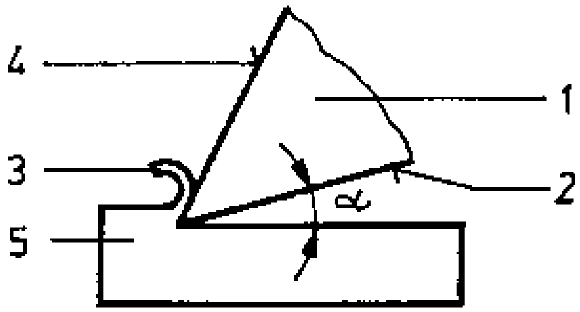


Figure 2.2.19. Wedge with an angle of clearance "?"

1 Wedge,
2 Flank,
3 Chip,
4 Rake face,
5 Workpiece, ? angle of clearance

Another angle – the angle of relief ? – is formed between the surface below the cutting edge of the wedge and the surface of the workpiece (Fig. 2.2.19.).

This angle of relief ? must be present otherwise the surface below the cutting edge would contact the surface of the workpiece.

The friction that would be produced would destroy the tool and damage the workpiece surface. As a standard value, ? = 5 is specified.

The cutting angle ? results from the position of the cutting force with respect to the workpiece surface. The angle of relief ? and the wedge angle ? are added: ? + ? = ?

Keep in mind:

The cutting–edge geometry of a chip–detaching tool is determined by

– the angle of relief ?

– the wedge angle ?
– the rake angle ?

The sum of these three angles is 90°: ? + ? + ? = 90° (see Fig. 2.2.20.).

The motions required for the performance of the chip–detaching process are dependent on the manufacturing method. These motions are carried out both by the tool and the workpiece on the machine.

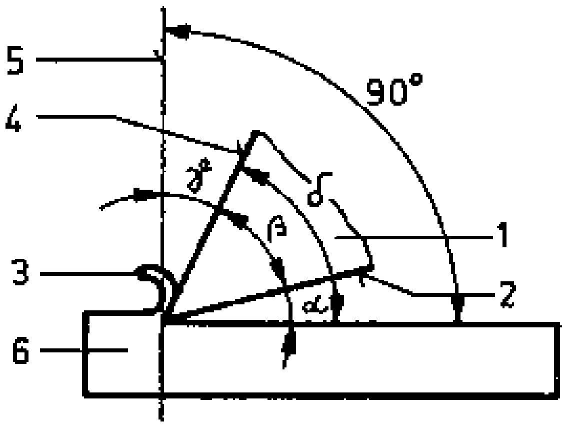


Figure 2.2.20. The angles at the cutting wedge

1 Wedge,

2 Flank,
3 Chip,
4 Rake face,
5 Auxiliary line,
6 Workpiece,
? angle of clearance,
? cutting−wedge angle,
? rake angle
? cutting angle

There is a special group of tools included in the range of simple chip−detaching tools, namely turning tools, planing tools and slotting tools, depending on the manufacturing process used. These tools consist of a shank with the head which carries the wedge with the cutting edge (Fig. 2.2.21.).

The tool is clamped on the tool holder of the machine (Fig. 2.2.22.).

The cross−sectional shape of the shank (square, rectangular, round) and the length are standardised for the tools commercially made. Planing and slotting tools usually have a more sturdy shank. The tool head differs in dependence on the use off the tool.

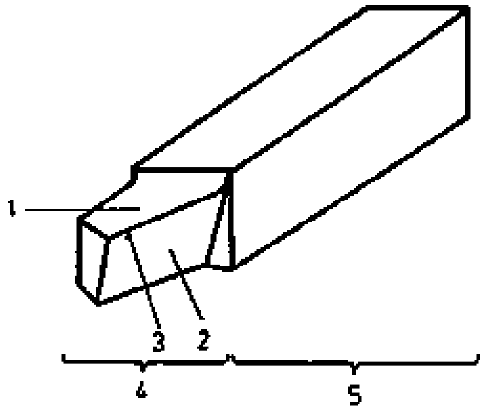


Figure 2.2.21. Lathe tool

1 Rake face,
2 Flank,
3 Cutting edge,
4 Head,
5 Shank

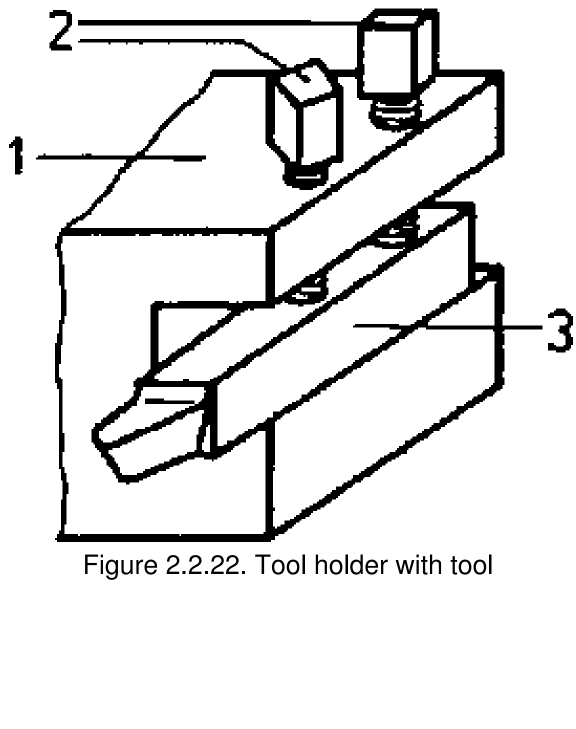


Figure 2.2.22. Tool holder with tool

1 Tool holder,
2 Clamping screws,
3 Tool shank

Further, saw blades should be mentioned in this connection.

According to the sawing methods for dividing metallic materials, three basic types are made and employed:

– machine saw blades for hacksaw machines in standardized lengths of 350 mm to 750 mm

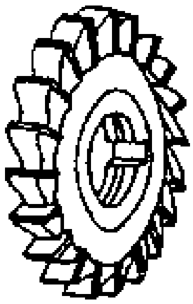
– band–saw blades for band–saw machines in widths between 5 mm and 25 mm and thicknesses from 0.65 to 1.25 mm.

– circular saw blades for circular sawing machines and milling machines having a diameter of anything between 20 and 315 mm, available also with hard–metal tipped cutting edges having a diameter of from 150 to 300 mm. Larger circular saw blades having a diameter of up to 630 mm have inserted tooth segments.

Milling cutters of many types are factory–made. Milling cutters are multiple–cutting edge tools with rotating cutting motion which is always performed by the tool. Milling cutters are classified and named according to various points of view (Table 2.1.).

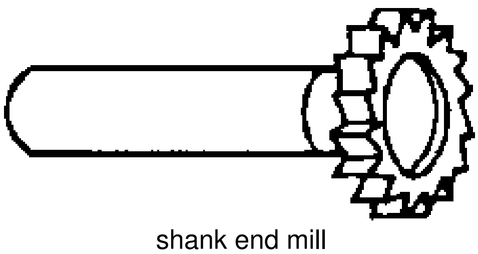
Table 2.1. Classification of milling cutters

– according to the shape



side and face milling cutter

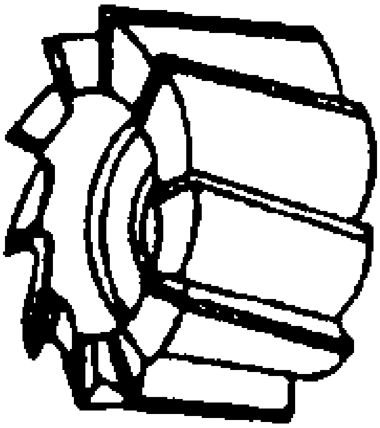
plain milling cutter



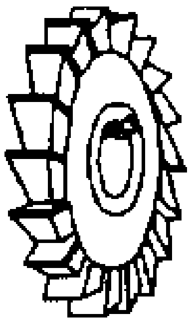
shank end mill

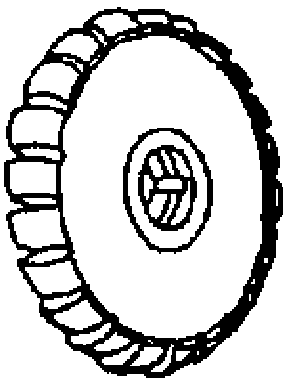
– according to the arrangement of the cutting edges

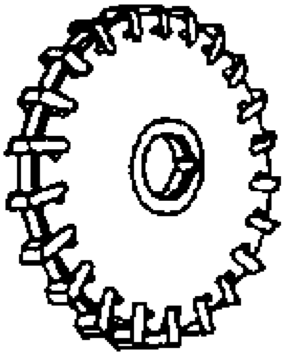

with peripheral cutting edge


with peripheral and face cutting edges end face mill

– according to production

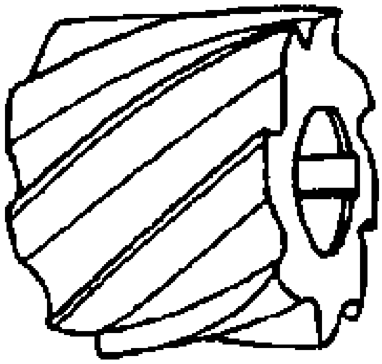

milled


relieved

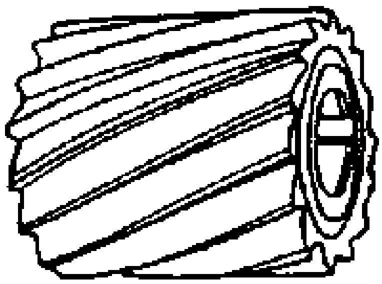


composite

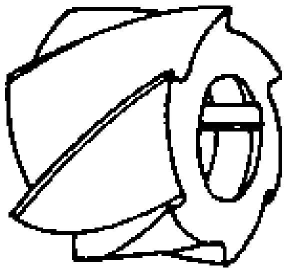
– according to the number of teeth z (with the same diameter)



type N for medium hard and tough materials



type H z > type N for hard materials



type W z < type N for soft materials

– according to use, e.g.:

grooving cutter
thread–milling cutter
radius cutter
gear cutter

The cutter edge, which frequently is rather long, is subjected to high loads during the cutting operation, In order to reduce this load on the cutting edges, to ensure a smooth operating of the cutter and to keep the detached chips as small as possible,

– milling cutters are helically toothed

– the cutting edges of milling cutters are corrugated in high–speed roughing cutters (Fig. 2.2.23.).

– chip–breaking nicks are ground into long milling cutter edges (Fig. 2.2.24.).

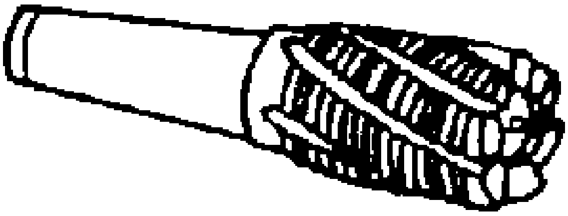


Figure 2.2.23. Heavy–duty roughing cutter with corrugated cutting edges

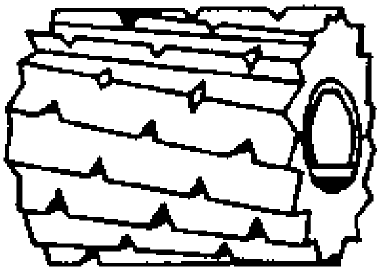


Figure 2.2.24. Milling cutter with chip–breaking grooves

In milling machines, the cutters are clamped at their shank or accomodated by a cutter arbor and secured by means of a feather key (Fig. 2.2.25.).

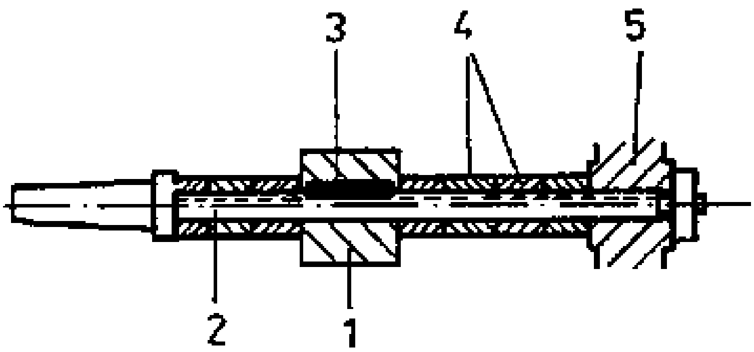


Figure 2.2.25. Cutter arbor with milling cutter

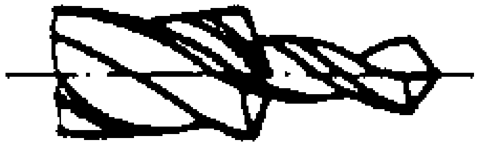
1 Milling cutter,
2 Cutter arbor,
3 Feather key,
4 Spacer ring,
5 End support

> Keep in mind:
>
> Milling cutters are multiple–cutting edge tools with rotating cutting motion. They are used for different operations where usually high rates of metal removal are required.

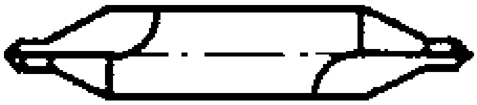
Many workpieces are provided with drill–holes of different diameters and depths. For this purpose, different tools are employed (Fig. 2.2.26.).

Figure 2.2.26. Drilling tools

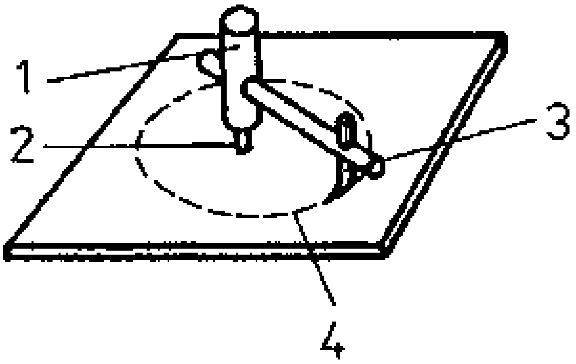
a) Twist drill



b) Multistep drill



c) Centring drill



d) Circle cutter

1 Boring bar,
2 Guide pin,
3 Chisel,
4 Cutting circle

By means of centring drills, parts to be turned are centred in order that they can be clamped between so−called centres (see clamping accessories).

The most widely used drill type is the twist drill by means of which holes having a diameter of up to 80 ram can be drilled (Fig. 2.2.27.).

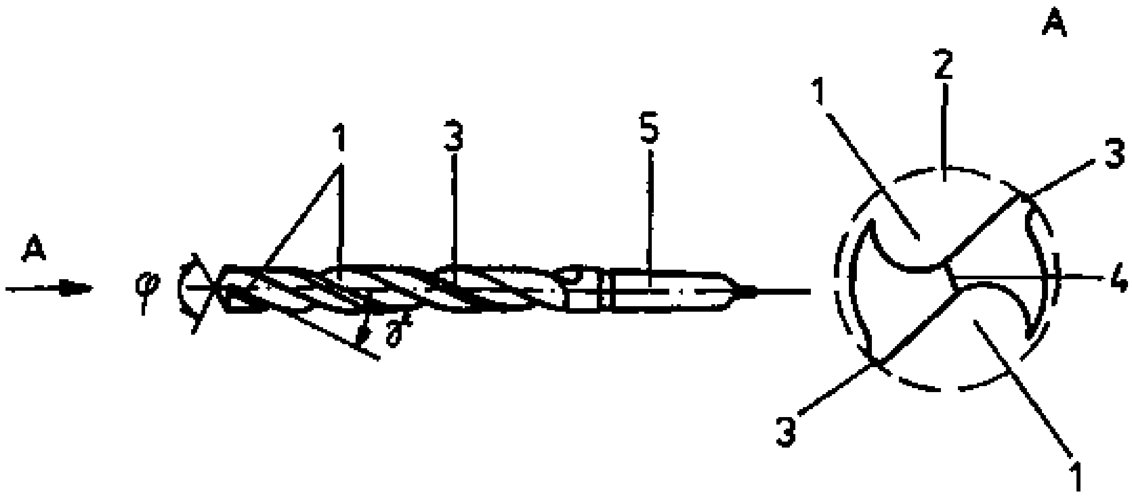


Figure 2.2.27. Twist drill

1 Helical flute, 2 Drilling capacity, 3 Land, 4 Chisel edge, 5 Drill shank, ? point angle ? flute helix angle = rake angle

In order to drill all material s according to the rules of good workmanship.

− twist drills having different flute helix angles = rake angles are available

– the point angles of the drill are ground according to the requirements of the materials in question.

For deep holes from a depth of about 150 mm, deep−hole drills, also known as D−bits, are used. Deep−hole drills are long twist drills with cooling channels through which a coolant is pressed during drilling. This means that the point of the drill is reliably and continuously cooled and the chips are flushed out of the hole. Deep−hole drills require special chucks with provisions for coolant supply and, frequently, they also call for special machines.

Stepped holes can be produced by means of multi−step drills in one pass.

Twist drills with cylindrical shank are clamped in drill chucks while twist drills with a taper shank are accomodated in the drilling machine spindle, usually with an additional sleeve.

Besides the usual workshop drills, special drilling tools are employed for special jobs, mainly on special machines.

Special drilling tools are required for

– drilling holes of a very small diameter (below 0.1 mm)
– drilling holes of great depth (more than 300 mm)
– drilling holes of large diameters (over 60 mm)
– drilling holes in very thin workpieces, e.g. sheet metal.

Circular cutters are used for cutting round parts out of sheet metal or for the production of large drill holes in plates. The tool employed is fitted in a boring bar where it can be adjusted in its diameter.

<u>Keep in mind:</u>

For the production of holes, different drilling tools are used.

These are twist drills in the usual workshop practice. Twist drills are two−edged tools designed for rotating cutting motion. The cutting edge geometry required for different materials is achieved by the flute helix angle = rake angle of the drill and by grinding the suitable point angle of the drill.

The surface quality and the dimensional stability of drilled holes is improved by means of reamers because twist drills produced rough surfaces only. In reaming, only a small amount of chips is detached. Reamers are multi−edged tools with peripheral cutting edges and rotating cutting motion (Fig. 2.2.28.).

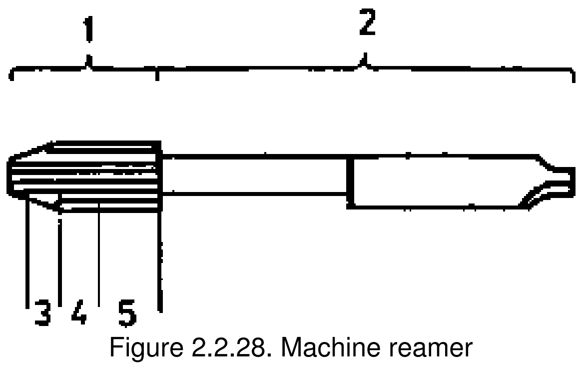


Figure 2.2.28. Machine reamer

1 Cutting−edge part, 2 Shank,
3 Bevel lead, 4 Smoothing part, 5 Guide part

The cutting edges are distributed irregularly around the circumference in order to ensure a smooth removal of chips.

The cutting edges of the reamer are arranged in a straight or twisted manner and grouped in three sections having different functions:

– the bevel lead (also known as starting taper) this part of the cutting edges performs the detaching of chips (Fig. 2.2.29.)

– the smoothing part; it smoothes the reamed portion while only a very small amount of chips is removed

– the guiding part; is ensures the proper motion of the reamer in the hole.

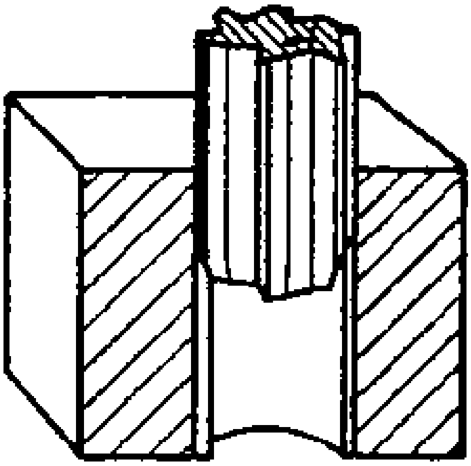


Figure 2.2.29. Chip removal in reaming

In reamers for through–holes, the bevel lead of the reamer is longer than in reamers for blind holes. When sharpening the reamers by grinding, the diameter is reduced. When producing very large numbers of workpieces, adjustable blade reamers are employed (Fig. 2.2.30.).

Figure 2.2.30. Adjustable reamer

The inserted blades enable the adjustment of the diameter.

By means of taper reamers (Fig. 2.2.31.). cylindrical holes are reamed (even manually) into tapering holes.

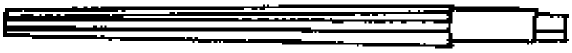


Figure 2.2.31. Taper reamer

<u>Keep in mind:</u>

Reamers are multi–edged chip–detaching tools with rotating cutting motion for improving the dimensional accuracy and surface quality of drilled holes. The small amount of chips detached is due to the action of the bevel lead of the reamer.

Holes must be further prepared for the accomodation of screws, bolts and rivets. For this purpose, countersinks and counterbores are used, especially for

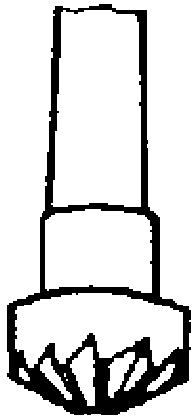
– deburring

– production of place contact surfaces, especially in castings

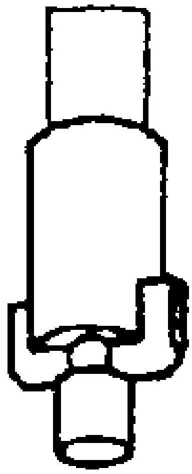
– production of depressions (countersinks and counterbores) for the accomodation of rivet heads and screw heads.

Countersinks and counterbores are two–edged and multi–edged chip–detaching tools with rotating motion (Fig. 2.2.32.).

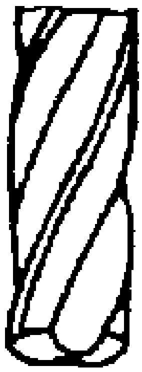
Figure 2.2.32. Types of countersinks and counterbores



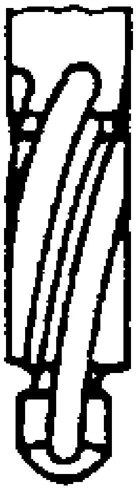
a) Countersink



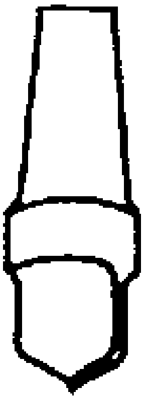
b) Flat counterbore



c) Counterbore with spiral flutes



d) Headed counterbore



e) Formed counterbore

Countersinks are available with a point angle of 60°, 75°, 90° and 120°.

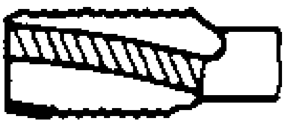
Countersinks with a guide pin operate smoother because the pin guides the countersink in the present holes properly. Some of the guide pin types can be screwed out. This means that pins of different diameters can be used, and countersinks without pin can be gound more easily.

Many threads are produced by chip−detaching by means of different methods and the respective tools:

– by milling using thread−milling cutters
– by turning using thread tools
– by thread cutting by means of special tools.

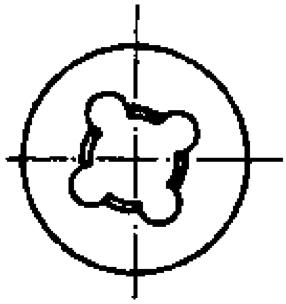
Thread−producing tools are shown in Fig. 2.2.33.

Figure 2.2.33. Thread−cutting tools

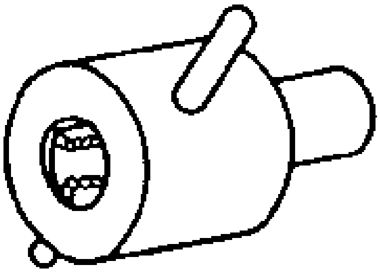


a) Machine tap

b) Thread tap with spiral flutes



c) Threading die for external thread



d) Die head for external thread

Thread taps for internal threads can be derived from screws in their construction. A thread tap is brought about by milling in chip grooves, also known as flutes, and relieving by grinding the individual threads (Fig. 2.2.34.).

Taps are used on lathes, drilling machines and thread cutting machines and also in the manual procedure of thread cutting.

The design of a threading die for the production of external threads can be derived from a nut (Fig. 2.2.35.).

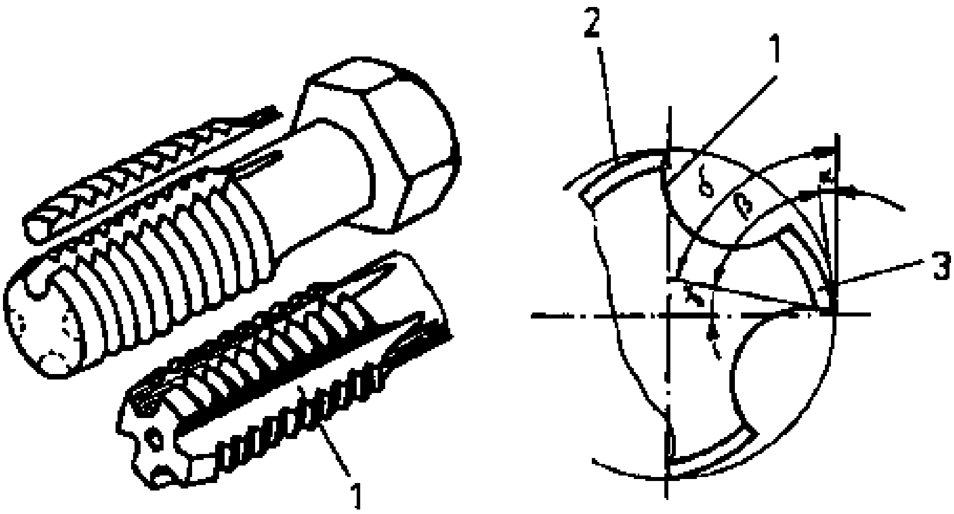


Figure 2.2.34. Thread tap of screw bolts

1 Chip groove, 2 Relieving by grinding, 3 Cutting edge

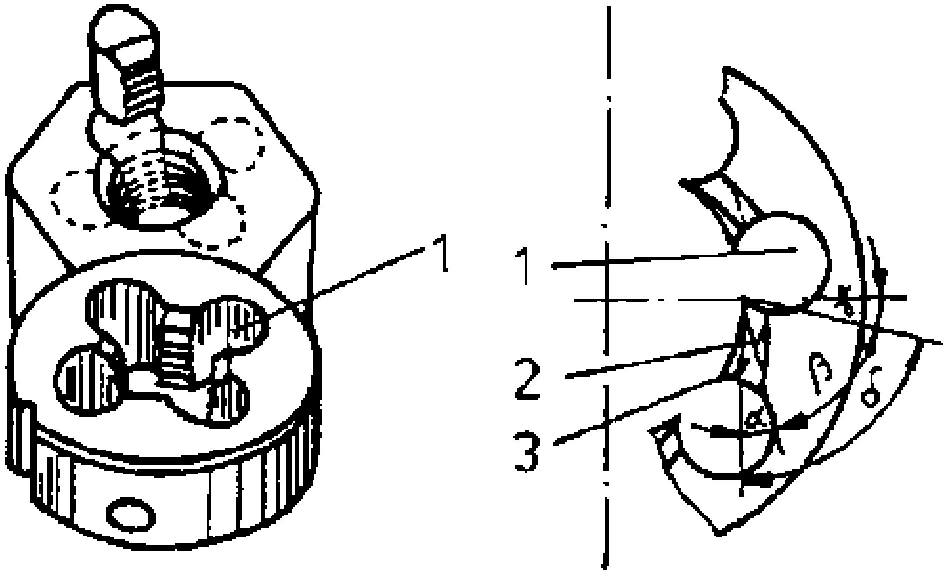


Figure 2.2.35. Threading die of a nut

1 Chip groove, 2 Relieving by grinding, 3 Cutting edge

Threading dies are used for manually cutting threads and on lathes and, in a few cases, on drilling machines. Thread chasers (Fig. 2.2.36.) are employed on small lathes together with the necessary thread−chasing attachments.

As abrasive, very hard (mineral) materials are used. They are produced chemically, rarely they are obtained as a natural deposit. The abrasives are ground and screened so that different grain sizes are obtained. The sharp edges of the abrasive grains are cutting edges of indefinite geometry (because a specification of their angles is not possible).

The abrasives generally used are: boron carbide B_4C, noble corundum, semi−noble corundum, normal corundum, emery, black corundum, silicon carbide greed and black SKS as well as diamond for special grinding tools.

The grain size of the abrasive grains is specified in hundredths of a millimetre, and it is usually anything between 3.15 and 0.05 mm, e.g. grain size 40 means 40/100 mm, namely, a 0.4 mm large grain. The binding agents for the production of grinding wheels and the like are ceramics, magnesite, silicate, rubber, natural resins and artificial resins.

For rotating grinding tools, the maximum permissible speed or the maximum permissible circumferential speed is indicated by the manufacturer which must not be exceeded for reasons of safety. The respective data must be marked on the grinding tool which is to be used on machines. These data are

− the type of the grinding tool
− the dimensions of the grinding tool
− the abrasive
− the grain size of the abrasive
− the hardness of the grinding tool
− the texture
− the permissible rotational speed or circumferential speed
− the standard number.

Before mounting on the grinding machine, the grinding tool must be checked for damage and a resonance test must be performed. After clamping the grinding tool, the latter must perform *a* longer test run while it is covered and not subjected to any load.

<u>Keep in mind:</u>

Grinding tools consist of abrasive grain and binding agent and have pores as the chip space. The technical data of a grinding tool are standardized. They must be marked on the grinding tool by the manufacturer. When working with grinding tools, the work safety regulations must be taken into consideration!

2.3. Clamping Tools

For the machining of workpieces, the firm and reliable clamping is necessary for almost all manufacturing methods. Machine tools must also be clamped properly. Depending on the size and shape of workpieces and machine tools, different clamping tools and devices are used.

2.3.1. Vices

In manual work, e.g. in filing or sawing, a parallel vice is used which is bolted to the work bench (Fig. 2.3.1.). The movable vice jaw is moved by means of a thread and spindle. The handle which acts as a lever ensures the application of high clamping forces.

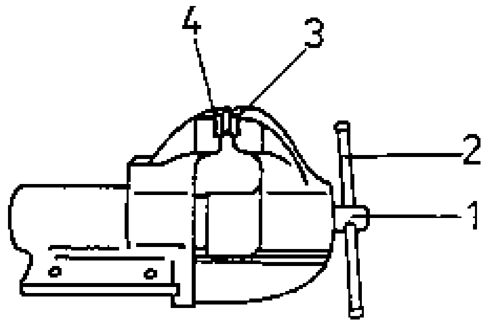


Figure 2.3.1. Parallel vice

1 Spindle, 2 Locking handle, 3 Movable jaw, 4 Fixed jaw

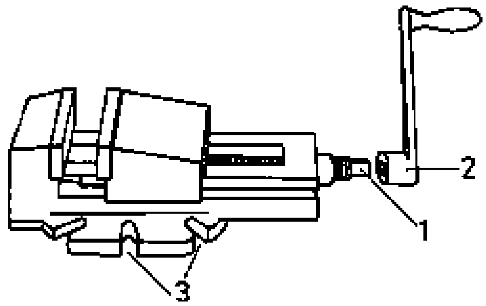


Figure 2.3.2. Machine vice

1 Spindle, 2 Handle, 3 Grooves for clamping

For operation on machine tools, machine vices are required. They are of different sizes and of a compact construction in order to hold workpieces relably when the high machine forces are acting. Machine vices (Fig. 2.3.2.) have a plane supporting surface and grooves for fastening them to the machine table by means of locking screws. Machine vices are provided with a detachable handle. Heavy machine Vices can be operated hydraulically or pneumatically and, in this way, attain high clamping forces.

For drilling small and medium−size workpieces, the latter are clamped in hand vices (Fig. 2.3.3.).

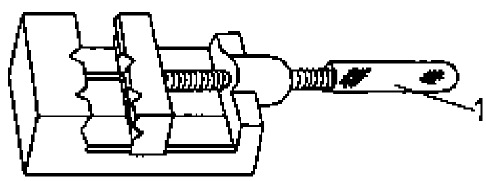


Figure 2.3.3. Hand vice

1 Handle

They are placed on the machine table and are kept and guided by hand. The extended spindle with knurled surface is used as handle.

For operations involved in pipe installation, e.g. sawing, the pipes are clamped in transportable pice vices to advantage (Fig. 2.3.4.).

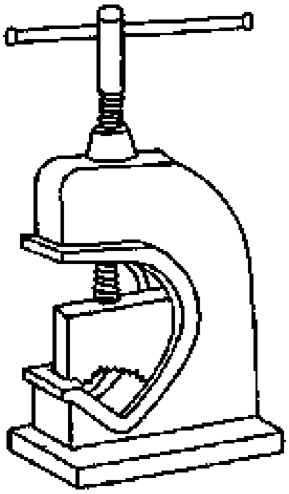


Figure 2.3.4. Pipe vice

2.3.2. Hand Vice

Small parts are clamped in a hand vice; in this way they can be held and guided properly (Figs. 2.3.5. and 2.3.6.).

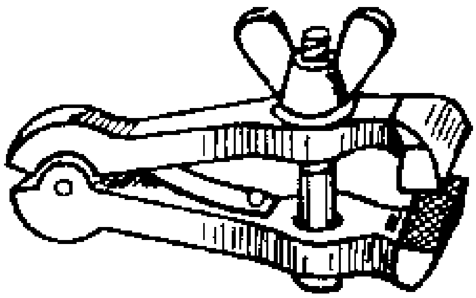


Figure 2.3.5. Filing vice

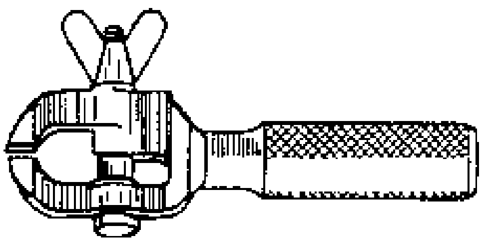


Figure 2.3.6. Small hand vice

For filing chamfers and bevel edges, workpieces are clamped in a saw sharpening vice and together with the latter in a universal vice (Fig. 2.3.7.)

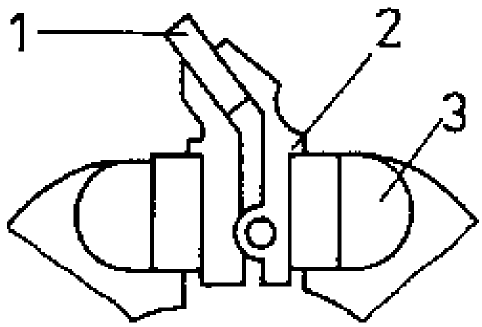


Figure 2.3.7. Clamping in a vice fixture

1 Workpiece,
2 Fixture,
3 Vice

This ensures safe clamping and a good guidance of the file.

2.3.3. Chucks

On machine tools, especially on lathes, cylindrical parts usually are clamped in three−jaw chucks (Fig. 2.3.8.).

The stepped jaws are capable of clamping internally and externally (Fig. 2.3.9.).

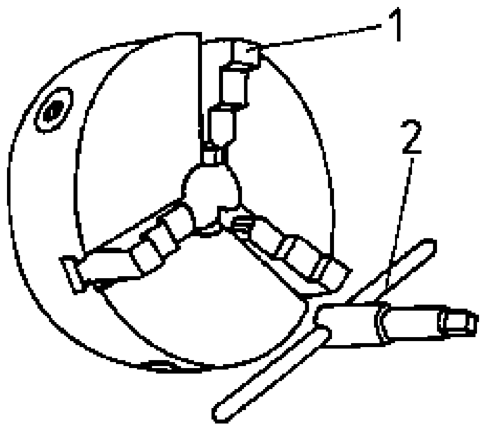


Figure 2.3.8. Three−jaw chuck

1 Clamping jaw,
2 Chuck spanner

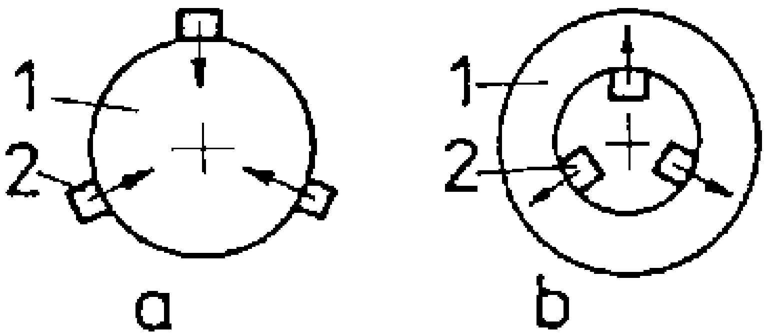


Figure 2.3.9. Clamping from outside a) and from inside b)

1 Clamping jaw,
2 Workpiece

The jaws are moved and clamped by means of a chucking spanner.

After clamping, chucking spanners must be removed in any case!

Power chucks are actuated hydraulically or pneumatically.

Tools with a cylindrical shank such as twist drills, counterbores and reamers are clamped in drill chucks (Fig. 2.3.10.). By turning the clamping ring, three chucking jaws are moved which are pressed against the tool shank. The chuck is properly tightened and released by means of the chucking spanner.

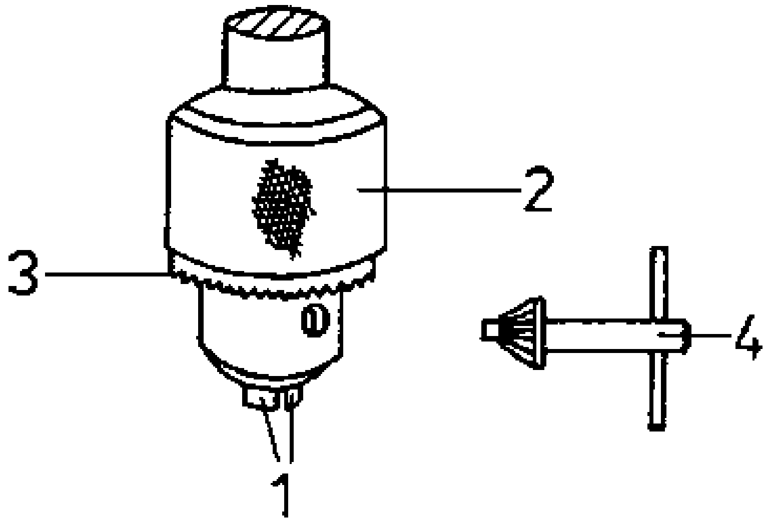


Figure 2.3.10. Drill chuck

1 Clamping jaws,
2 Clamping ring,
3 Teeth
4 Chuck spanner

2.3.4. Clamping Cones

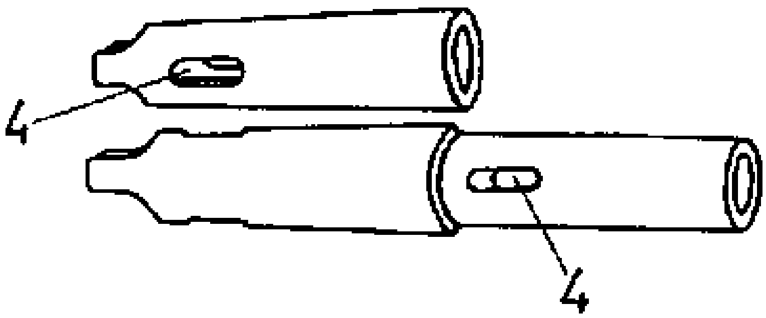
Cones with a small taper, i.e. with a small change in diameter, are called adhering cones. When an adhering cone is pressed into a fitting taper hole, it makes proper contact with the surfaces around it, thus ensuring a connection which can be subjected to high loads. Adhering cones with standardized dimensions are used as clamping elements.

Some tools, e.g. twist drills having a diameter over 12 mm, have a taper shank (Fig. 2.3.11a). It is inserted into the spindle of the drilling machine (Fig. 2.3.11d.). For releasing the connection, a taper drift is required. It is carefully driven into the slot of the spindle and presses on the driving–out lug of the taper shank.

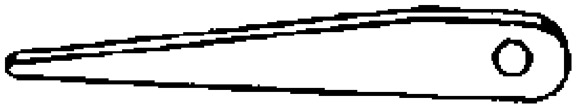
In this way, the shank is pressed out (Fig. 2.3.11c.). For adapting the various diameters, taper sleeves (Fig. 2.3.11b.) in standardized sizes are used.

Figure 2.3.11. Clamping cones

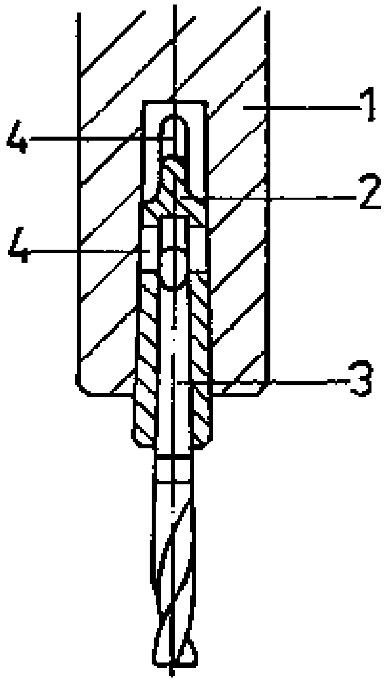
a) Tool with taper shank



b) Taper sleeves



c) Taper drift



d) Spindle with sleeve and tool

1 Spindle, 2 Sleeve,
3 Taper shank,
4 Slot for taper drift

2.3.5. Centre Points

For machining cylindrical workpieces, frequently re−clamping is required, e.g. first turning and then cylindrical grinding. For this purpose, it must be ensured that the workpieces are clamped and re−clamped exactly centrically. To this end, the workpiece is provided on both ends with a centring hole which is standardized as to shape and size (Fig. 2.3.12.).

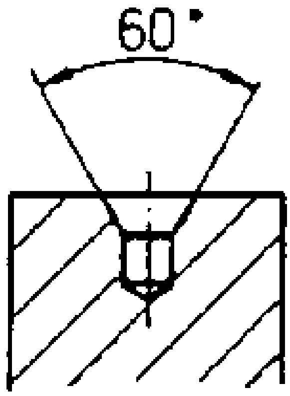


Figure 2.3.12. Centring hole

The workpiece is clamped by means of centre points, also called centres shortly, which are applied to these centring holes. The internal taper of the centring hole and the taper point ensure that the workpiece is clamped exactly centrically (Fig. 2.3.13.).

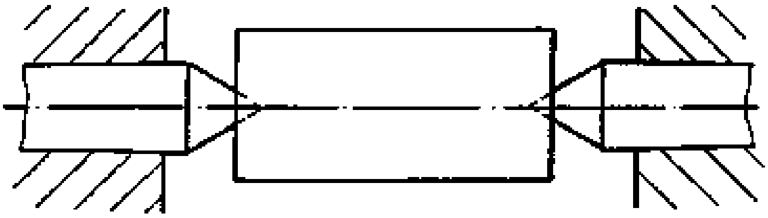
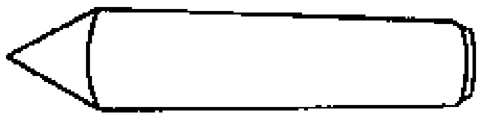
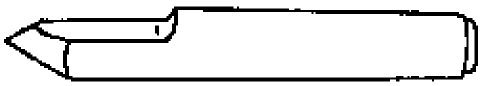


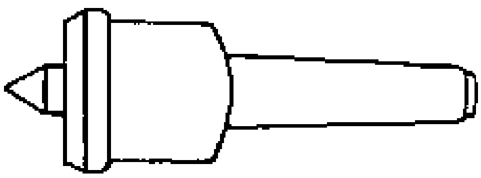
Figure 2.3.13. Clamping between centres

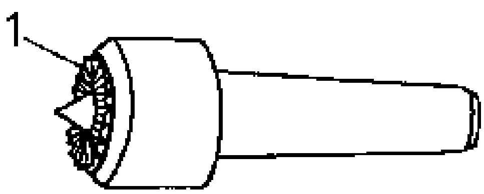
For clamping, the points are provided with standardized adhering cones (Fig. 2.3.14.).

Figure 2.3.14. Shapes of centres


a) Fixed centre


b) Half centre


c) Running centre



d) Drive centre

1 Drive edge

Dead, live and half centres secure the position of the workpiece but they do not transmit any rotary motion. In case of drive centres, small cutting edges are pressed into the workpiece and rotate it. When higher forces are involved, a driving plate and a clamping heart must be employed (Fig. 2.3.15.).

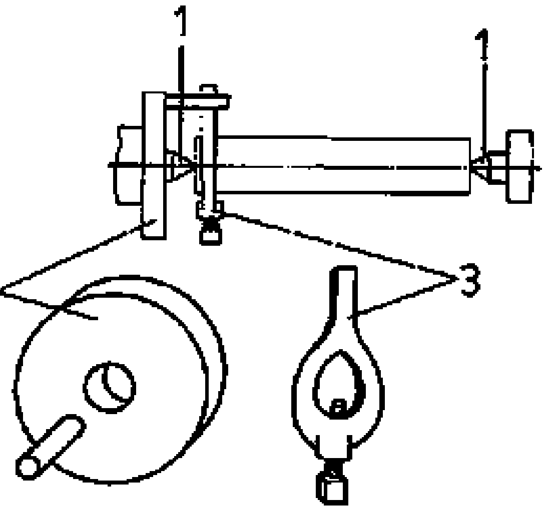


Figure 2.3.15. Clamping between centres with driver

1 Centre,
2 Driver disk,
3 Clamping heart

2.3.6. Clamping Tables and Accessories

The majority of machine tools are provided with clamping tables (Fig. 2.3.16.) for holding the workpieces.

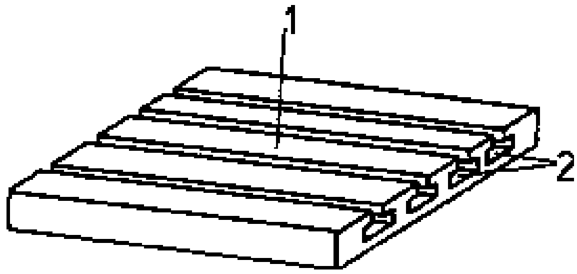


Figure 2.3.16. Clamping table

1 Mounting surface,
2 T−groove

These tables are provided with T – shaped grooves for the accomodation of the clamping screws. These screws are used to clamp the workpieces by means of holding straps and special clamps or other devices for holding work, e.g. machine vices. (Figs. 2.3.17. and 2.3.18.).

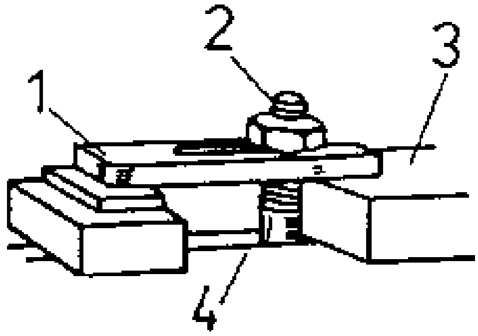


Figure 2.3.17. Clamping with holding iron

1 Holding iron,
2 Clamping screw,
3 Workpiece

4 Drilling table

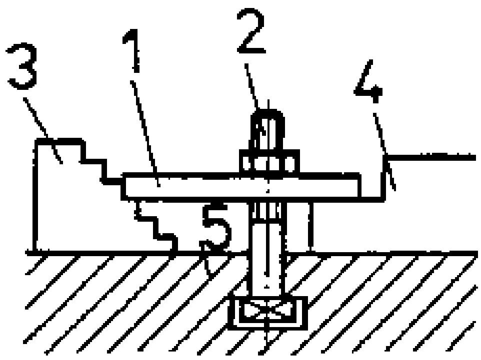


Figure 2.3.18. Clamping with holding iron and clamping stairs

1 Holding iron,
2 Clamping screw,
3 Clamping stairs,
4 Workpiece,
5 Drilling table

By means of clamping angles (Fig. 2.3.19.), vertical clamping surfaces are provided. Round tables (Fig. 2.3.20.) with workpieces clamped in place can be rotated about a vertical axis. By means of the graduation in degrees, specified angles can be adjusted.

For parts of intricate shape, which cannot be clamped between jaws, faceplates (Fig. 2.3.21.) are used. The clamping jaws can be moved or withdrawn individually. The oblong holes can be used for holding work by means of clamping screws.

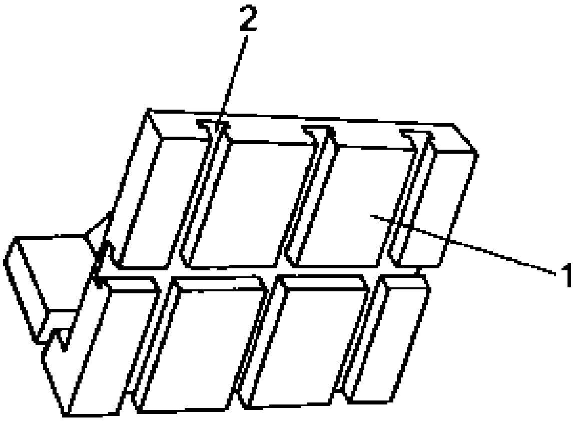


Figure 2.3.19. Clamping angle

1 Mounting surface, 2 T−groove

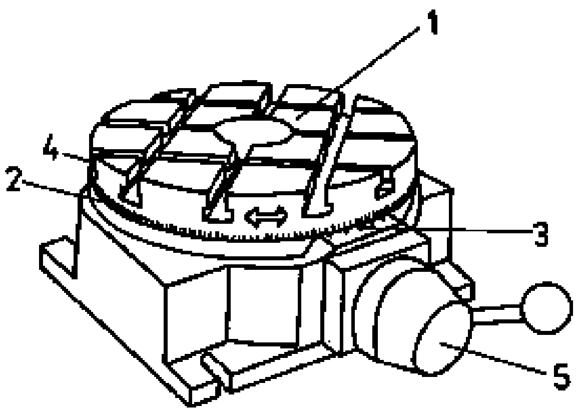


Figure 2.3.20. Round table

1 Mounting−surface, 2 Scale in degrees, 3 Setting scale, 4 T−groove, 5 Arresting device

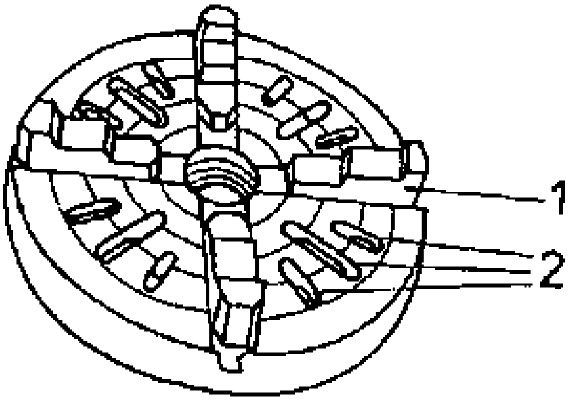


Figure 2.3.21. Faceplate

1 Clamping jaw,
2 Slot

Clamping prisms (Fig. 2.3.22.) are required for clamping cylindrical workpieces especially for drilling.

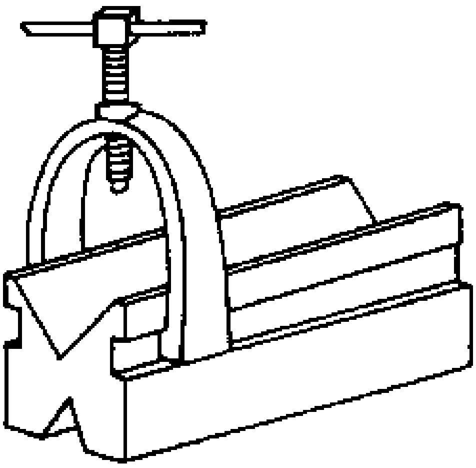


Figure 2.3.22. Clamping prism

Screw clamps (Fig. 2.3.23.) are used for fastening parts which can be easily separated. Parallel clamps (Fig. 2.3.24.) clamp several parts together by virtue of their large clamping surfaces, e.g. plates of certain dimensions.

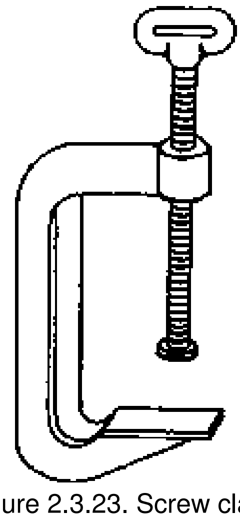


Figure 2.3.23. Screw clamp

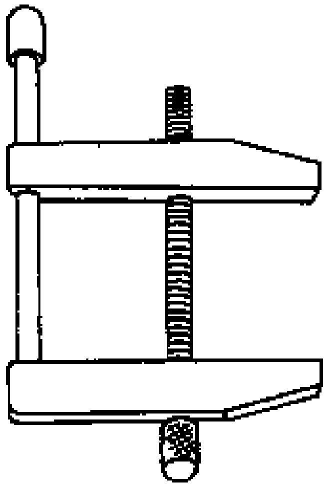


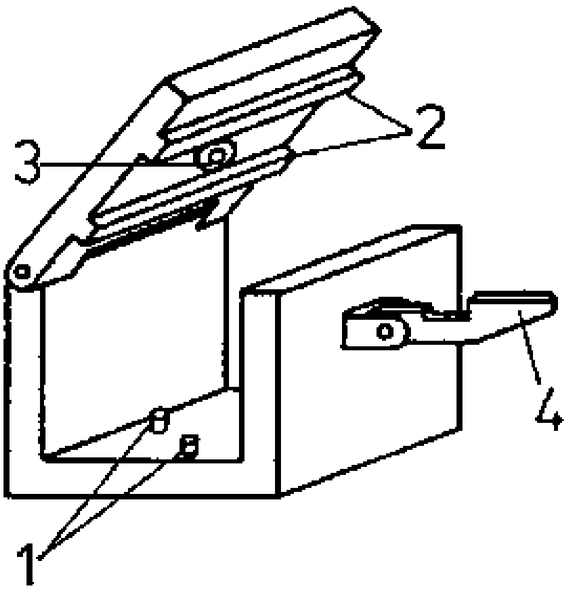
Figure 2.3.24. Parallel clamp

For machining workpieces in large series and in mass production, jigs and fixtures are employed. They are built for one type of work in any case and

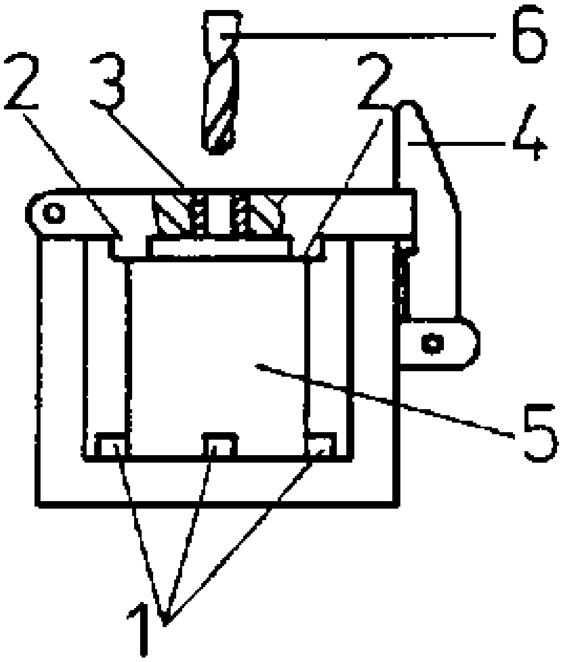
- – secure the correct position of the workpiece during machining,
- – clamp the workpiece and
- – frequently guide the rool.

When using jigs and fixtures, marking and adjusting the workpiece is not necessary; the times required for clamping are cut down considerably. Fig. 2.3.25. shows a simple jig for drilling.

Figure 2.3.25. Simple jig for drilling



a) Dig, open without workpiece



b) Jig, closed with workpiece

1 Pins for locating the workpiece
2 Strips for clamping the workpiece
3 Drill bush (guides the tool)
4 Lock, 5 Workpiece, 6 Tool (twist drill)

Keep in mind:

Workpieces and tools must be reliably and safely clamped for machining. Depending on shape and size of the workpiece and the method of machining, various clamping devices are used.

2.4. Machines and Plants of Manufacturing Engineering

2.4.1. Machines and Plants for Initial Shaping

In foundries, machines and plants are employed for three main tasks:

– production of sand moulds
– casting the moulds
– cleaning of castings.

The foundry sand required for sand casting is mechanically screened and mixed with special agents and moisted in special mixers. The moulding sand, also known as foundry sand, is conveyed to moulding machines by means of conveyors: the moulding machines compact the sand moulds by shaking and pressing.

Special sand mixtures are pressed in core producing machines into cores for sand moulds; these cores are sometimes burnt in gas or electric furnaces.

The design of the casting machines is determined by the method of casting, namely, gravity casting, die casting, centrifugal casting. Ingot–mould casting machines close and open the attached two–part metal mould (ingot mould) for casting by gravity (Fig. 2.4.1.).

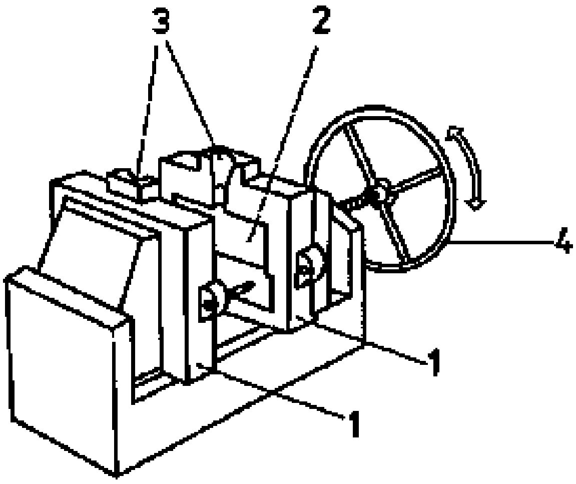


Figure 2.4.1. Ingot−mould casting machine (ingot mould open)

1 Half of the mould, 2 Engraving, 3 Ingate, 4 Hand wheel with threaded spindle

Die−casting machines, which usually operate as automatic machines,

– collect the liquid casting material
– close the mounted mould for die casting
– keep the mould for die casting closed with a high pressure
– press the liquid casting material into the mould at high pressure and high speed
– open after casting the mould for die casting and eject the cast part at the same time.

Centrifugal casting equipment must comply with high work safety requirements. The heart of such a plant are vertically or horizontally mounted rotating clamping tables where the moulds are fastened. During casting, the plants are enclosed by stable protective walls. Small centrifugal casting machines for the casting of bearings (Fig. 2.4.2.) are secured by means of steel hoods.

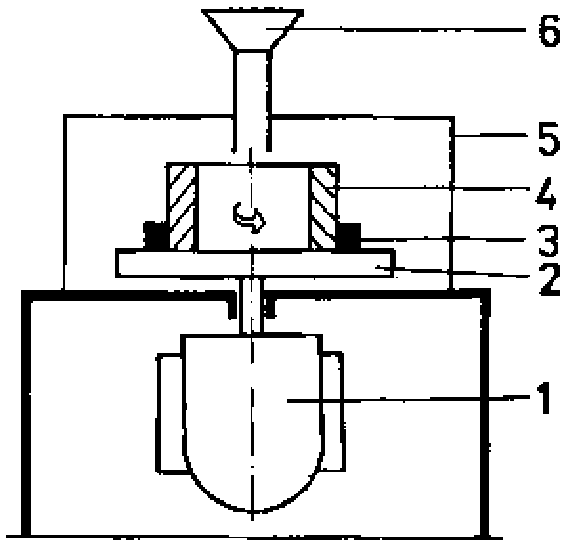


Figure 2.4.2. Centrifugal casting machine

1 Motor, 2 Clamping table, 3 Clamping device, 4 Mould, 5 Protective hood, 6 Ingate

For sintering, hydraulic presses (see forming) are employed on which the sintering moulds are fastened. For the after−treatment of the sintered workpieces, sometimes impregnating plants are required.

Moulded parts of thermoplastic material are produced in large batches on automatic injection moulding machines (Fig. 2.4.3.).

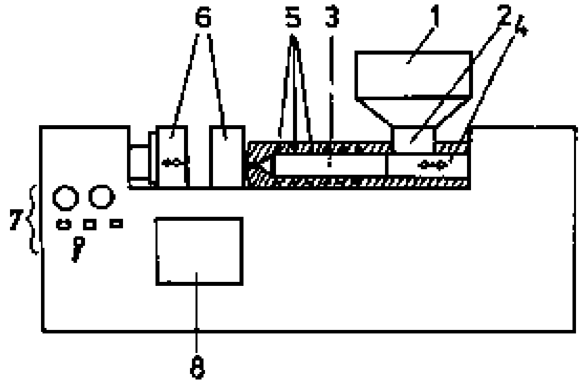


Figure 2.4.3. Automatic injection moulding machine for plastics

1 Reservoir, 2 Dosing device, 3 Working cylinder 4 Piston, 5 Electrical heating, 6 Injection mould, 7 Fittings, 8 Discharge opening for mouldings

The reservoir contains the solid initial material, e.g. granules. Through the dosing mechanism, the required amount of granules gets into the heating zone of the working cylinder where it is liquefied. The piston presses the liquefied plastic material into the mould. The mould is hydraulically opened, the moulded part ejected and the mould closed. Moulded parts of thermosetting plastics are produced on hydraulic presses (see initial shaping) with moulds clamped in place.

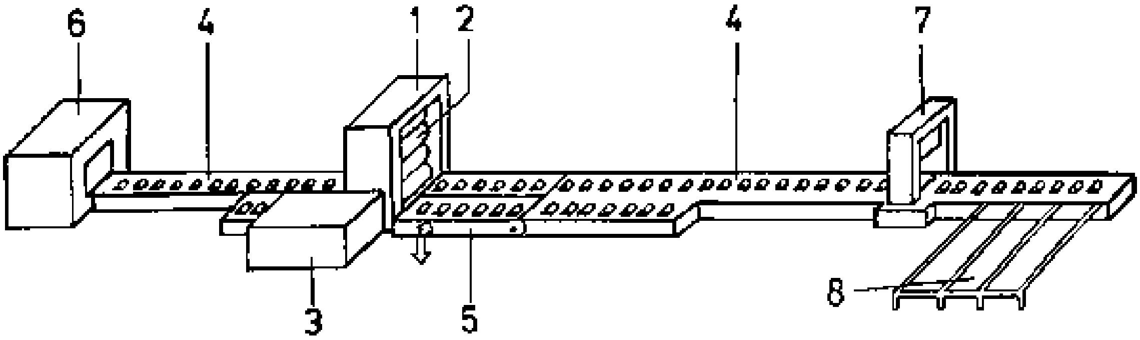


Figure 2.4.4. Rolling mill

1 Roll stand, 2 Rolls, 3 Motor and gear, 4 Roll table, 5 Lifting device, 6 Heating oven, 7 Machine shears or abrasive−wheel cutting−off machine, 8 Cooling bed

2.4.2. Machines and Plants for Forming

Very comprehensive and heavy plants are required in rolling mills for the production of sections and sheets and plates. Fig. 2.4.4. shows a simplified equipment for general information. The heart of a rolling mill is the stand of rolls with the rolling mill pulling motor and the gear mechanism. The rolls incorporated in the roll stand are adjustable with respect to the distance between them. The number of rolls characterizes the type of the roll stand (two−high rolling stand, three−high rolling stand, four high stands); the roll diameter is used for the designation. For example: A 600 three−high stand has three rolls with a roll diameter of 600 mm. Roll tables consist of electrically driven and controllable rolls. On the roll tables, the material to be rolled is moved to and away from the roll stands. In front of and behind the roll stand, the roll tables are designed as a seesaw in order to convey the material to be rolled also between the upper pair of rolls. In electrically or gas heated annealing furnaces, the rolling stock before rolling is heated to the favourable forming temperature (for steel this is about 850°C). After rolling, the rolled section or plate is cut to the specified lengths by means of large abrasive−wheel cutting−off machines or power−driven shears. After cutting, the rolling stock is deposited on grid−type cooling beds and allowed to cool down.

For the rolling of pipes and rings, special rolling mills are used.

For the majority off forming processes, presses are used. Presses are of different sizes and produce different pressing forces; they are classified and designated according to their mode of operation (Figs. 2.4.5. to 2.4.9.)

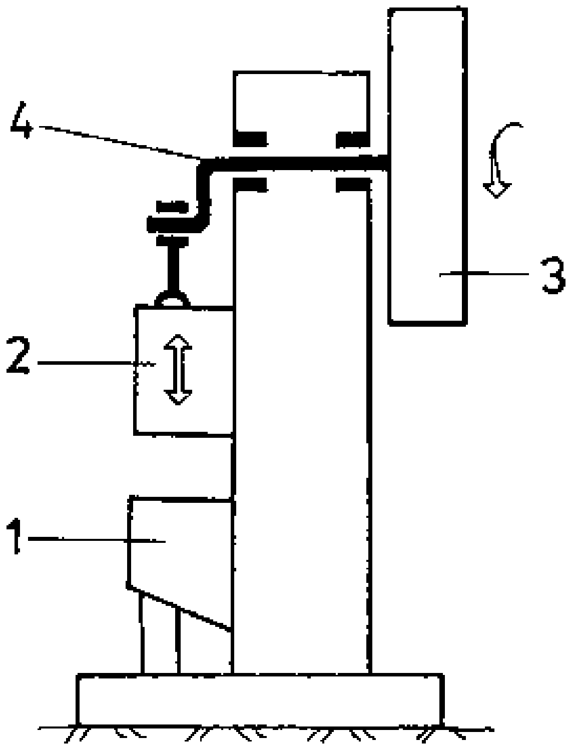


Figure 2.4.5. Eccentric press (up to 100 Mp)

1 Press table,
2 Ram, 3 Flywheel,
4 Eccentric shaft

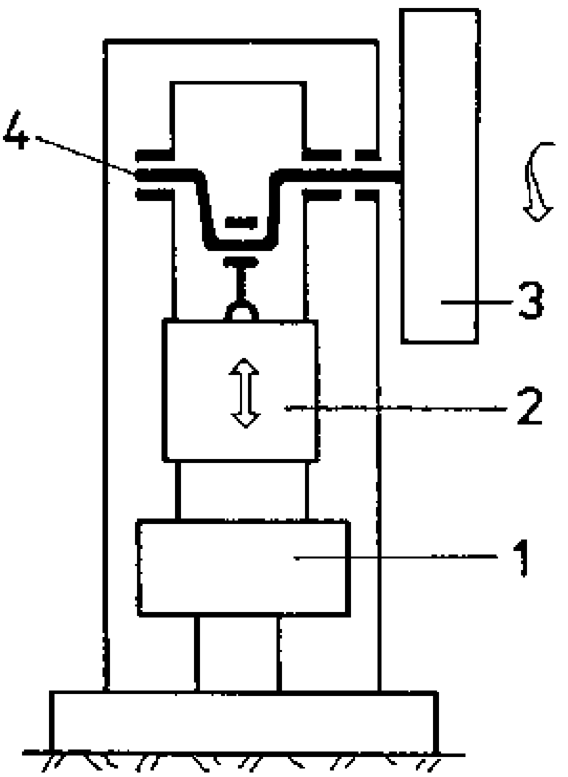


Figure 2.4.6. Crank–driven press (up to 3000 Mp)

1 Press table, 2 Ram,
3 Flywheel.
4 Crankshaft

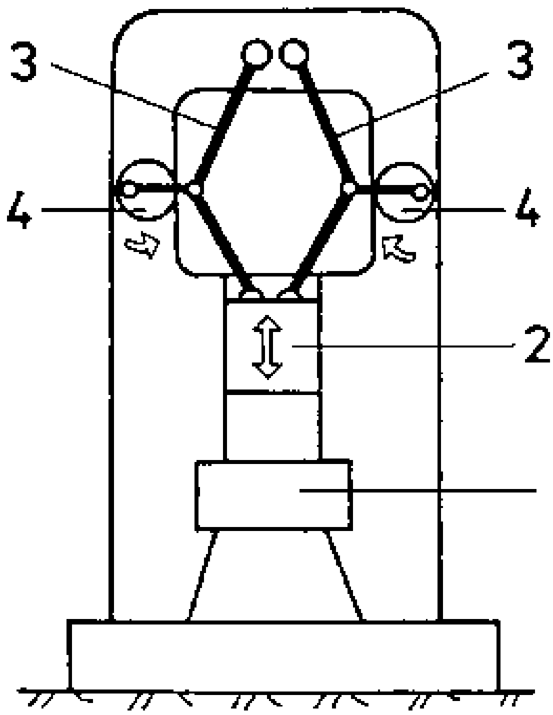


Figure 2.4.7. Toggle plate press (up to 2000 Mp)

1 Press table, 2 Ram, 3 Toggle, 4 Eccentric disks for driving the toggle lever

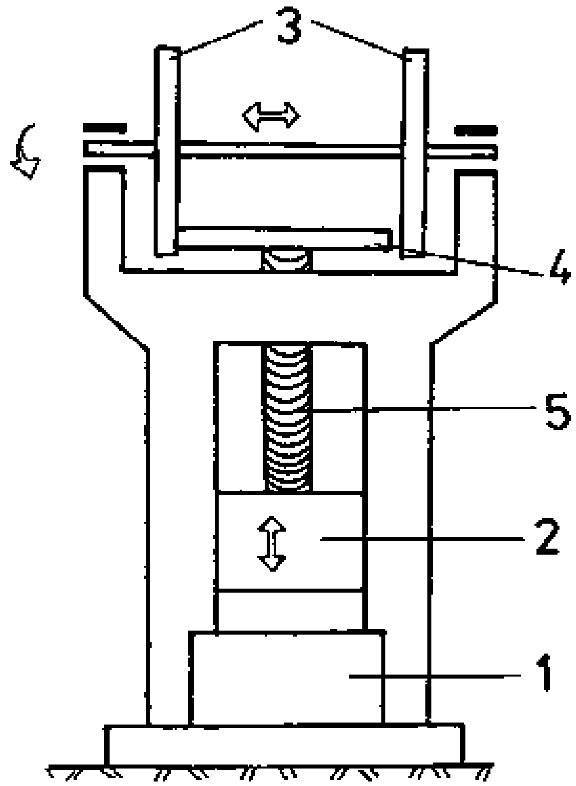


Figure 2.4.8. Friction−gear spindle press (up to 3000 Mp)

1 Press table, 2 Ram, 3 Driving friction wheels, 4 Friction disk, 5 Spindle

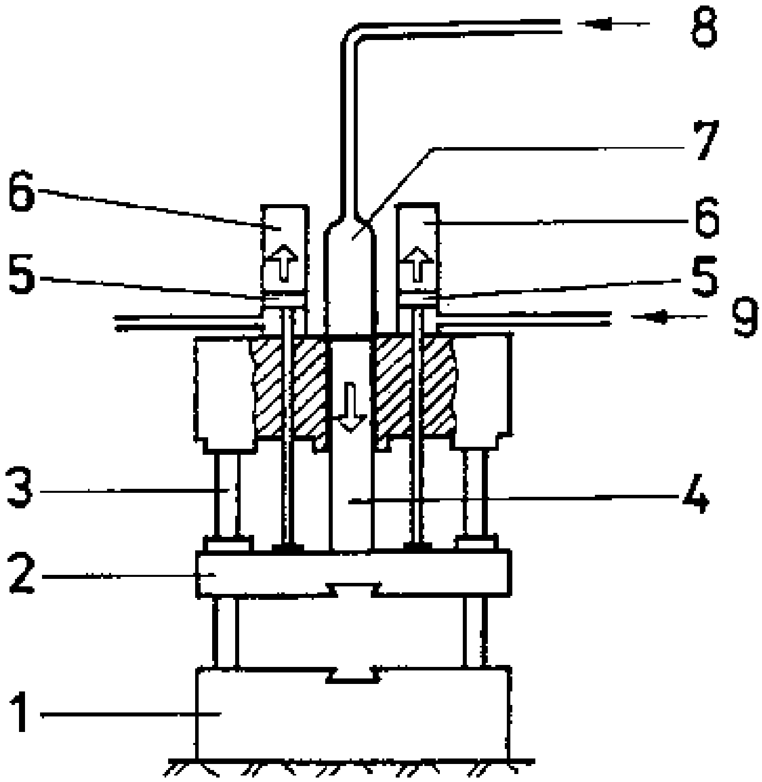


Figure 2.4.9. Hydraulic press (up to 25,000 Mp)

1 Press table,
2 Ram, 3 Guide column, 4 Working piston, 5 Return piston,
6 Return cylinder,
7 Working cylinder,
8 Hydraulic oil

Besides the typical presses that operate vertically, there are also horizontally operating presses used for certain processes, e.g. extrusion. For large series and mass production, e.g. in car body factories, presses are interlinked into production lines. For this purpose, feeding and discharging devices are attached to each press while all presses are connected by conveyor installations for transporting the workpieces. For forging, presses and power hammers (Fig. 2.4.10. to 2.4.12.) are used.

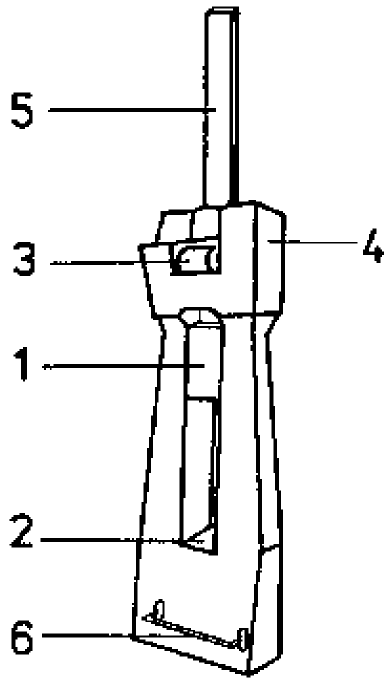


Figure 2.4.10. Board drop hammer

1 Hammer, 2 Anvil,
3 Contact roll, 4 Drive,
5 Board, 6 Foot control

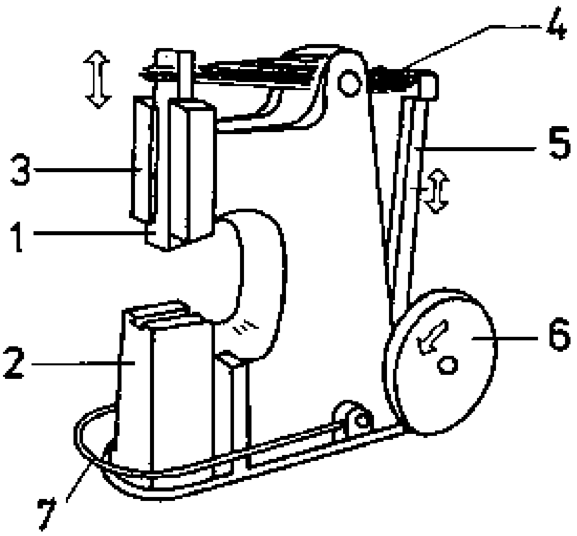


Figure 2.4.11. Spring hammer

1 Hammer,
2 Anvil
3 Guide,
4 Parcel of leaf springs, 5 Push rod, 6 Drive, 7 Foot control

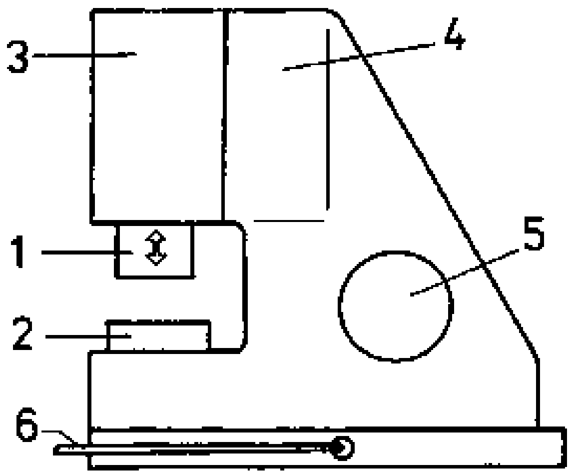


Figure 2.4.12. Air hammer

1 Hammer,
2 Anvil,
3 Working cylinder,
4 Compression cylinder,
5 Drive, 6 Foot control

In case of the so−called monkeys, the heavy hammer is lifted mechanically; the dropping hammer or monkey performs the forming operation. The working capability of the monkeys is limited by the mass of the hammer and the height of fall.

A higher working capability is chieved by accelerated hammers.

The monkey is lifted mechanically and additionally accelerated when falling. Accelerated hammers attain high numbers of impacts; consequently, one can forge quicker.

2.4.3. Machines and Plants for Separating

For cutting and shearing, mainly eccentric presses or crank−driven presses are used. The cutting or shearing tools are mounted on these presses. Shearing machines for plates usually operated on the principle of crank−driven presses.

For the chip forming methods, machine tools are used which are classified and designated according to the methods and built in various size, types and designs. Every machine tool

– accommodates one or several chip−forming tools in tool holders
– accommodates one or several workpieces by means of work−holding devices
– carries out the specified working motions of workpiece and tool at the preset accuracy
– provides the forces required for the chip removal.

Machine tools may also be designed as semi−automatic and automatic machines. For large series and mass production, machine tools are interlinked into production lines. Special−purpose machines are used for particular operations. Of the great variety of machine tools, below typical representatives are described.

Drilling machines are used for drilling, deburring, countersinking, reaming and also for thread cutting (Fig. 2.4.13.). The workpiece is clamped on the machine table; The tool is held by the drilling spindle. The drilling spindle rotates at different adjustable speeds and can be moved vertically downward manually or mechanically.

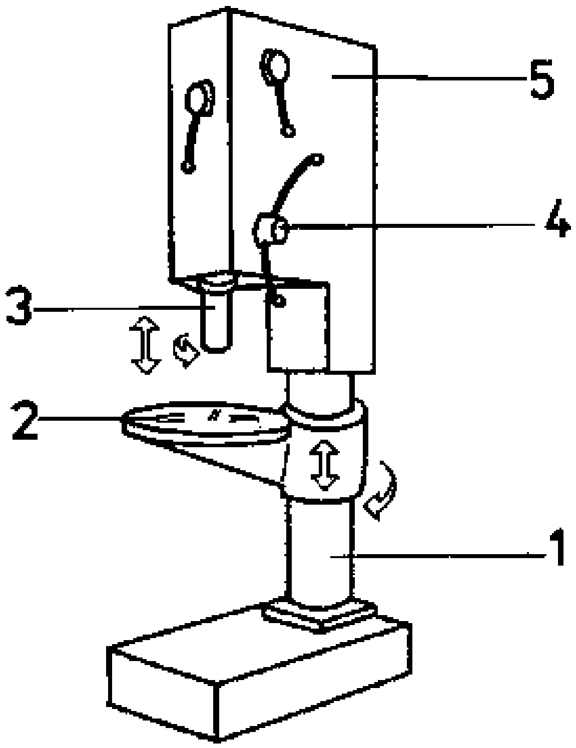


Figure 2.4.13. Upright drilling machine

1 Column, 2 Machine table, 3 Drilling spindle, 4 Lever and switch for vertical spindle motion, 5 Casing with motor and gearing

Milling machines are grouped in two basic types. Horizontal milling machines (Fig. 2.4.14.) hold cylindrical cutters and side and face milling cutters on the horizontally mounted milling spindle. The speed of the milling spindle is adjustable. The three−part table, on which the workpieces can be mounted, can be moved longitudinally, transversely and vertically.

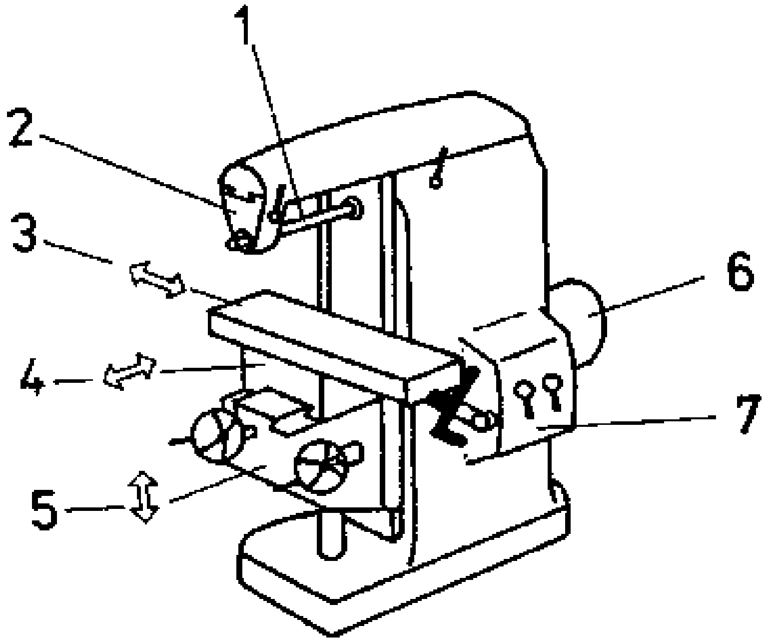


Figure 2.4.14. Horizontal milling machine

1 Horizontal milling spindle, 2 End bearing,
3 Longitudinal table, 4 Transverse table, 5 Lift table, 6 Motor, 7 Gearing for table motions

Vertical milling machines (Fig. 2.4.15.) possess a milling head with a vertically mounted milling spindle which accomodates end mill cutters or face−milling cutters. The milling head can be adjusted obliquely in a few types of machines. The workpieces are clamped on the three−part machine table.

Universal milling machines can be used for milling both vertically and horizontally.

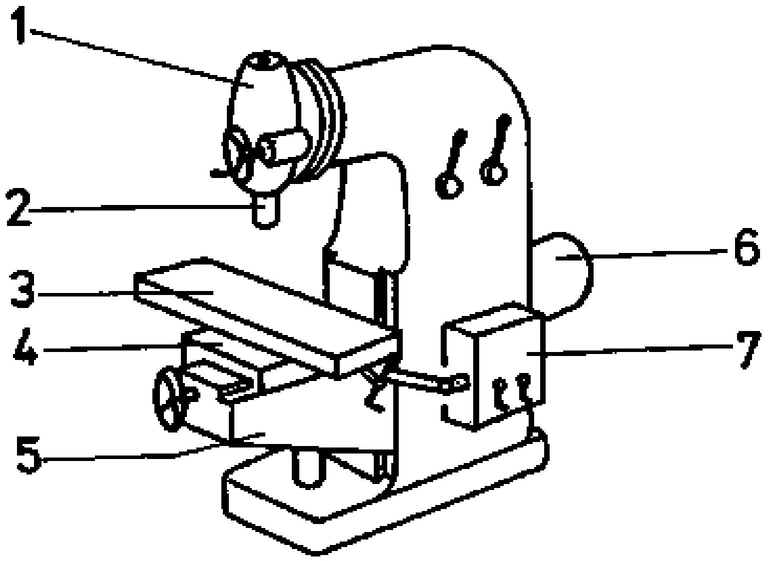


Figure 2.4.15. Vertical milling machine

1 Milling head, 2 Milling spindle, 3 Longitudinal table, 4 Transverse table, 5 Lift table, 6 Motor,
7 Gearing for table motions

The typical lathe is the lead screw and feed screw lathe on which different turning operations as well as drilling, reaming and thread cutting can be carried out (Fig. 2.4.16.).

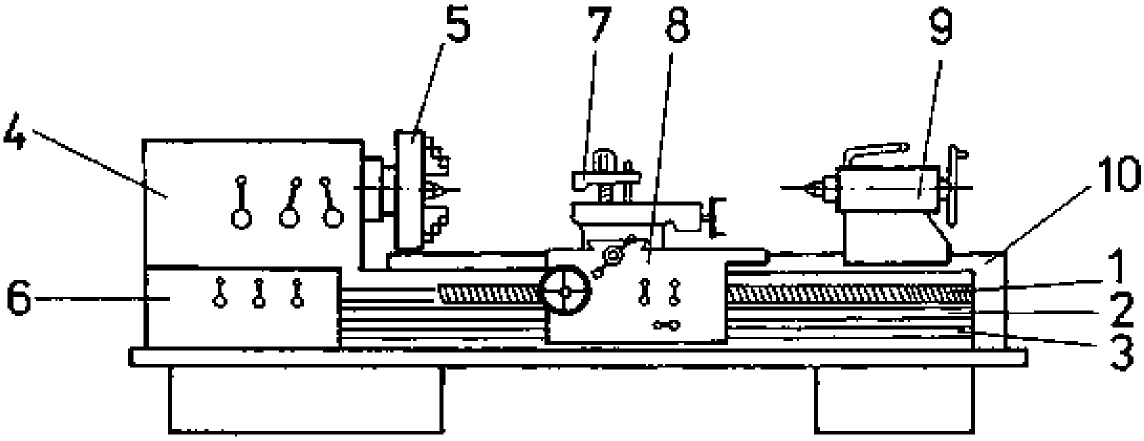


Figure 2.4.16. Lead screw and feed screw lathe

1 Lead screw, 2 Feed screw, 3 Control screw, 4 Headstock (motor and gearing), 5 Three−jaw chuck, 6 Gear for tool slide, 7 Tool post, 8 Tool carriage 9 Tailstock, 10 Machine bed

The carriage holds the tool for turning − tha lathe tool. The carriage enables the manual and mechanical motion of the tool in longitudinal and transverse directions. The feed screw is used for the mechanical tool motion for normal turning operations, the lead screw ensures the exact tool motion for thread cutting.

For clamping the workpiece, the three−jaw chuck is used which can be replaced by a faceplate. The tailstock serves for clamping workpieces between centres and for accommodating the tool for boring and reaming.

Shaping machines (Fig. 2.4.17.) are available in horizontal and in vertical design. The tool − the shaper tool − is accommodated in the tool post at the ram and moved to and fro (or up and down).

The vertically adjustable machine table holds the workpiece and moves laterally during shaping.

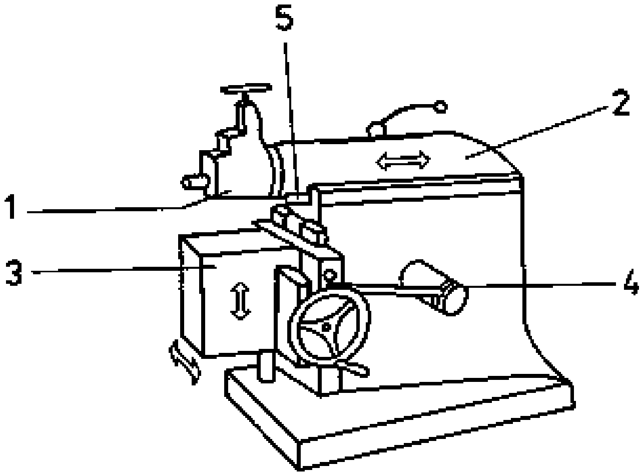


Figure 2.4.17. Horizontal shaping machine

1 Tool post, 2 Ram, 3 Machine table, 4 Table drive, 5 Tool

In planing machines (Fig. 2.4.18.), the machine table performes the planing motion (to and fro). The tools are held by vertically and horizontally arranged tool posts by which they are also moved. Cylindrical grinding machines (Fig. 2.4.19.) clamp cylindrical workpieces between centres and rotate them slowly during grinding. The rapidly rotating grinding wheel moves together with the driving unit longitudinally with respect to the workpiece and can be adjusted across the workpiece.

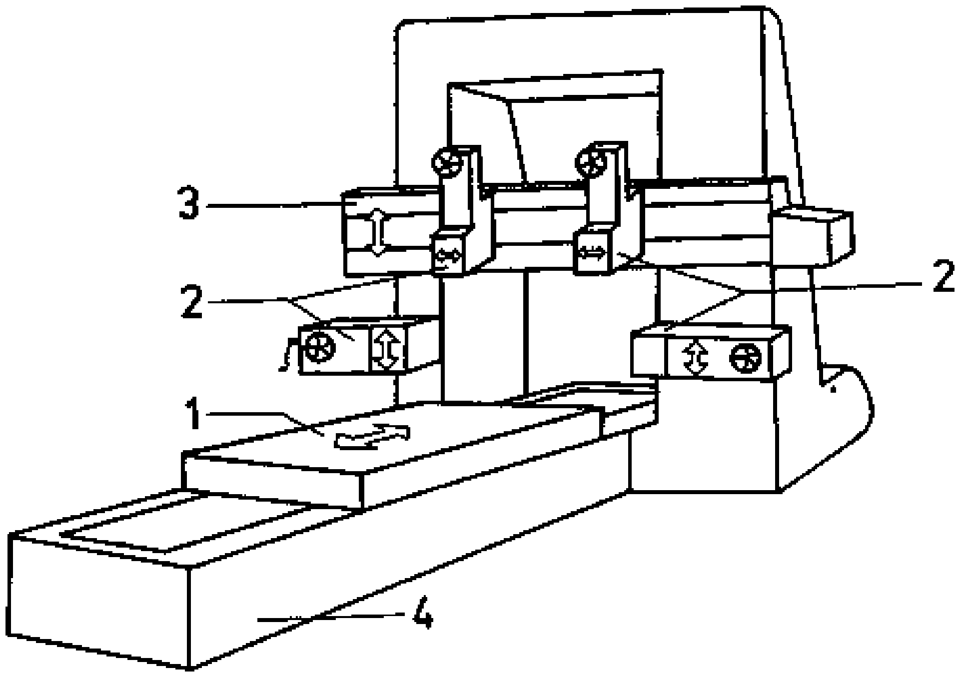


Figure 2.4.18. Planing machine

1 Machine table, 2 Tool holder, 3 Cross member 4 Machine bed

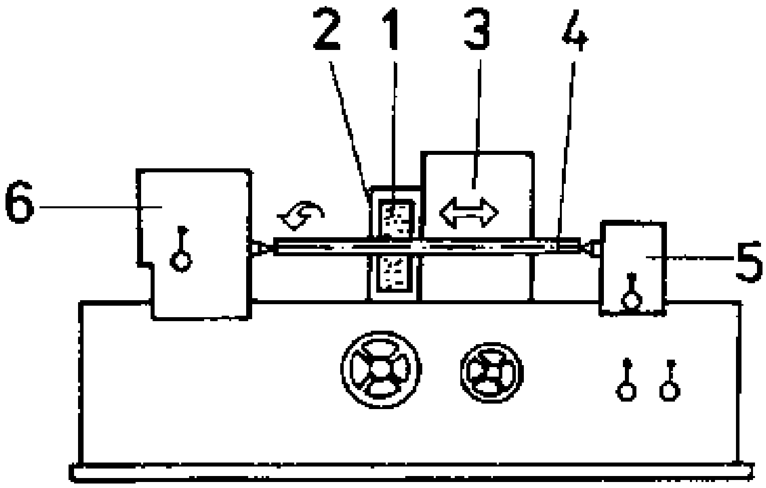


Figure 2.4.19. Cylindrical grinding machine

1 Grinding wheel,
2 Protective hood, 3 Grinding wheel drive,
4 Workpiece,
5 Tailstock,
6 Workpiece drive

Flat grinding machines (Fig. 2.4.20.) hold workpieces on the machine table which can be moved longitudinally and transversely. The rapidly rotating grinding wheel is vertically adjustable together with the driving unit.

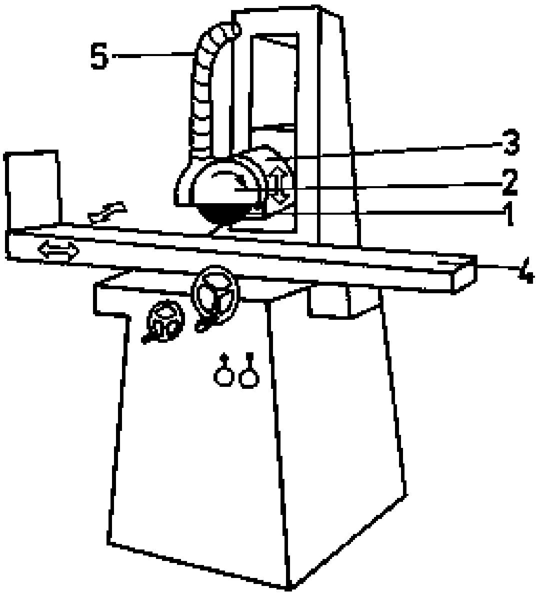


Figure 2.4.20. Flat grinding machine

1 Grinding wheel, 2 Protective hood, 3 Grinding wheel drive, 4 Machine table, 5 Exhaust device

For sawing metallic workpieces, three types of machine saws are used (Figs. 2.4.21. to 2.4.23.).

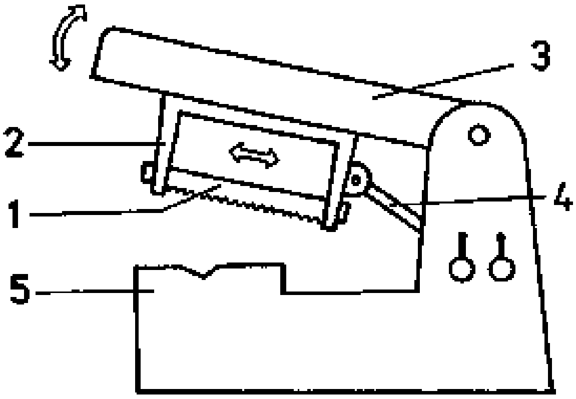


Figure 2.4.21. Power hacksaw

1 Saw blade, 2 Bow, 3 Slewable bow guide, 4 Push rod, 5 Machine table

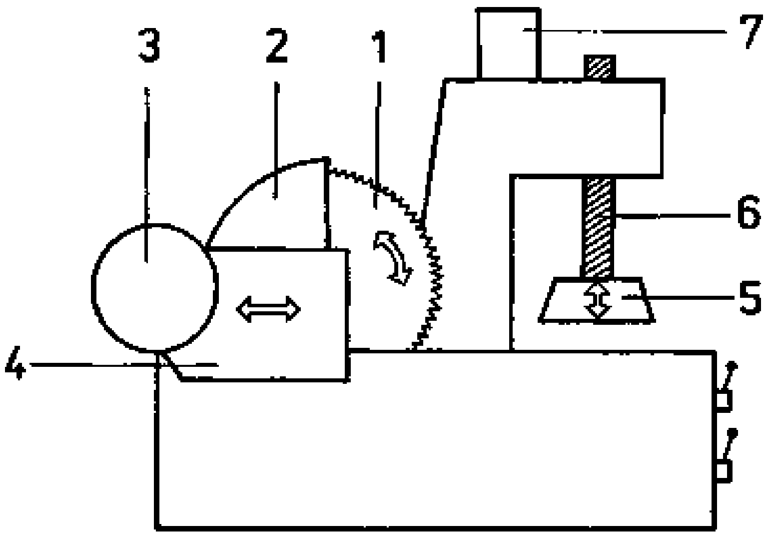


Figure 2.4.22. Circular sawing machine

1 Circular saw blade, 2 Protective hood, 3 Motor, 4 Tool slide, 5 Clamping jaw, 6 Spindle, 7 Motor for spindle drive

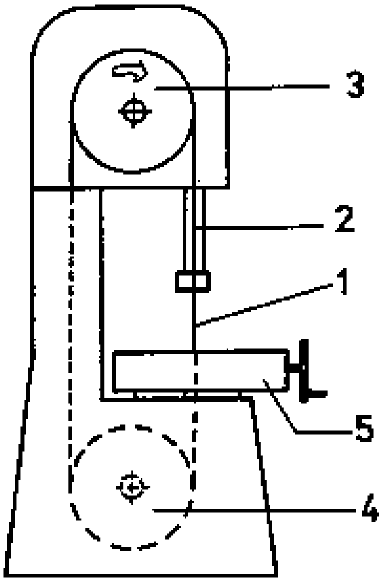


Figure 2.4.23. Band saw

1 Saw band, 2 Guide,
3 reversing pulley,
4 Drive pulley,
5 Machine table

For the main groups of manufacturing methods joining, coating and changing the properties of materials many plants are available which are very specific and offer only closely limited possibilities of application.

<u>Control questions</u>

2.1. What are the faults due to the fact that the scriber is not properly drawn along the steel rule?

2.2. Why are the centres of holes to be drilled punched particularly clearly?

2.3. Explain the advantages of control punch marks!

2.4. Why have marking−off table to be clean and plane?

2.5. What are the dangers due to loosely fastened hammers?

2.6. How are hammer and handle safely connected?

2.7. Why must face and pane of hammers be hardened?

2.8. Why is the cutting edge of chisels for working soft materials ground so that the angle is more acute?

2.9. How is the jamming of the cross−cut chisel avoided when producing grooves?

2.10. Describe the changing of a saw blade!

2.11. How is the safe engagement of the saw blade prepared?

2.12. Why is the saw guided close by the scribed line?

2.13. What are the reasons for which the teeth of the saw blade must point ahead?

2.14. Explain the difference between roughened, finished and fine−finished surfaces!

2.15. What are the dangers of accident involved in filing without handle?

2.16. Why are moulds made of high−value materials?

2.17. Explain the necessity of slide valves!

2.18. Why are moulds cooled?

2.19. What are the requirements specified for an engraving?

2.20. Explain the typical main components of a typical forming tool!

2.21. What are the common components that you find in the tools shown in Fig. 2.2.5.?

2.22. Determine the wedges of the cutting edges at available chip−forming tools!

2.23. Why are milling cutters used which have the same diameter but different tooth sizes and different numbers of teeth?

2.24. What are the types of milling cutters by means of which large workpiece surfaces can be tooled economically?

2.25. What are the effects produced by different point angles of a twist drill on the length of the cutting edges of the drill?

2.26. What are the reasons for which the point of a twist drill must be ground uniformly on the both sides?

2.27. What are the advantages offered by reamers with helical cutting edges?

2.28. Before working at the workpiece, frequently a test hole is reamed by means of a reamer. What is the purpose of this additional operation?

2.29. What are the types of screws that call for holes with counterbore or countersink?

2.30. Why must the guide pin of a counterbore or countersink be only a little smaller than the diameter of the readily drilled hole?

2.31. Why are large−pore grinding wheels used for grinding soft materials?

2.32. How is a machine vice fastened to the machine table?

2.33. Explain the clamping and releasing of a twist drill with taper shank!

2.34. What is the purpose for which a clamping heart is used?

2.35. What may be the consequences when a workpiece is not clamped properly tight?

2.36. What are the advantages offered by working with jigs and fixtures?

3. Manufacturing Methods of Initial Shaping

Initial shaping is the production of a body of shapeless material.

Shapeless materials are powder, chips, grains, liquid materials (melts), liquids, vapours and gases. The state of aggregation of the shapeless material is used as a characteristic for the classification of the methods of initial shaping. The following Table 3.1. gives a survey of the manufacturing groups and manufacturing methods of initial shaping.

3.1. Initial Shaping from the Solid State

Methods of this manufacturing group are used to shape formless solid substances into solid bodies – that is, into workpieces – by the creation of an adherence.

Initial shaping

- from the solid state
  - sintering
  - pressing of thermosetting plastics
- from the liquid state,
  - casting by gravitational force
    - sand casting
    - shell moulding process
    - investment moulding
    - chell casting
  - casting with pressure
    - pressure casting
    - injection of thermoplastics
    - extrusion of thermoplastics
  - casting with centrifugal force
    - centrifugal casting
    - centrifugal moulding casting
  - liquid pressing
- from the ionized state
- from the gaseous state

Table 3.1. Survey of the initial shaping methods

3.1.1. Sintering

By sintering, usually small workpieces with a high surface quality and small tolerances are produced; reworking is not required with the exception of fine operations. Due to the high process costs, sintering is only economical when

– more than 10,000 parts are made,
– other manufacturing methods are more expensive,
– materials and material structures are required which can only be achieved by sintering.

<u>Means of work</u>

Press moulds. For every workpiece, which is to be made by sintering, a press mould of high accuracy must be produced. Press moulds are open on top and have a space which is to be filled; the mating part is called plunger or heading tool (Fig. 3.1.1.).

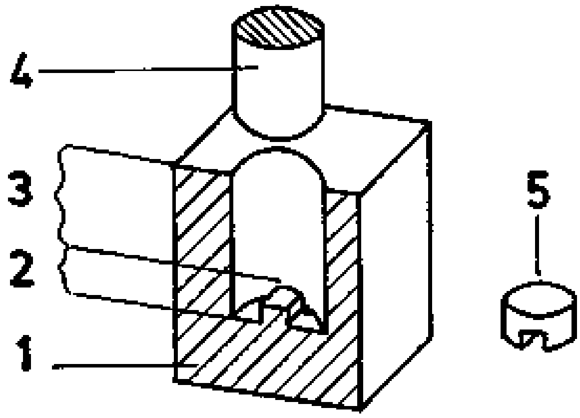
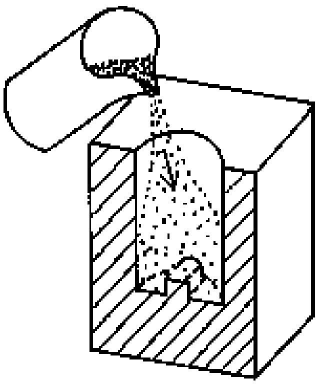
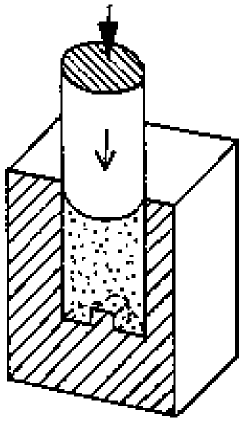


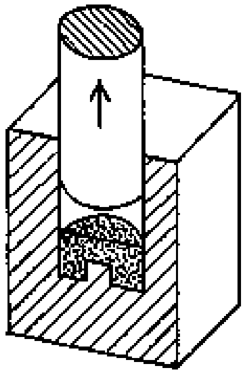
Figure 3.1.1. Press mould for sintering (sectional view)

1 Mould,
2 Pressing space,
3 Filling space,
4 Plunger,
5 Pressed part – sintered part

Figure 3.1.2. Pressing operation in sintering


1 Filling the mould


2 Pressing



3 Raising the plunger

Hydraulic presses. The press moulds are mounted on the press bed, also known as platen, the plunger is fastened to the ram of the press. The press provides the necessary pressures. Sintering furnaces. For sintering, special furnaces are used. The internal space of the furnace is filled with a protective gas which does not react chemically or it is evacuated (vacuum). Sintering furnaces are heated electrically.

Procedure

A dosed amount of powder is filled into the press mould. By the plunger, the powder is compressed at a very high pressure (200 to 1,000 MPa). In this way, a pressing or compact is produced which has the shape of the press–mould engraving and exhibits a low adhesion (Fig. 3.1.2.). The compact made in the press mould is heated in the sintering furnace. At 2/3 to 3/4 of the melting temperature of the powdered material, the compacted powder particles are sintered so that a workpiece of a properly firm adhesion is produced. Sometimes, especially in case of low–melting powdered materials, pressing and sintering is carried out at the same time. For this purpose, the press mould must be capable of being heated.

Use

Sintering is a manufacturing method of great variety whose field of application is continuously increasing.

– Many intricately shaped small parts for the construction of instruments and apparatuses can be made by sintering in large series, e.g. bearing bushes, gears, levers.

– For sintering powder mixtures, can be prepared which cannot be alloyed by melting. Sliding contacts for electric motors and current collectors are sintered from copper and carbon powder. Bearing bushes and parts for guides with very good sliding properties are sintered from iron powder and large amounts of graphite. Permanent magnets for small electric devices and magnetic locks are sintered from iron, nickel and aluminium and then they are magnetised.

Very hard metals which can hardly be machined, e.g. chromium and vanadium, are sintered into hard metals together with metal carbides (metal–carbon compounds), e.g. titanium carbide and tungsten carbide.

Hard metals are required for cutting tips of cutting tools, as dies for the production of wires and for moulds that can be subjected to high loads.

– Sintering is economical when metals and metallic compounds having high melting temperatures are used. High melting metals, e.g. tungsten, molybdenum, titanium, metal carbides and metal borides (chemical compounds of metals with boron) are used to sinter ceramic cutting tips for lathe tools, nozzles, electric contact parts and components for gas turbines and jet power plants.

– A particularity is the sintering of porous metal parts. During pressing, the power contains a special addition which volatilises during the heat treatment. Consequently, small cavities (= pores) are produced in the sintered part. Porous sintered parts are used as ferrite aerials in small radio sets and as filters which are highly resistant, e.g. for fuel.

– Porous sintered parts are sometimes treated by impregnating. As impregnating substance, oil is used for bearing bushes and bearing parts. Impregnated sintered bearings gradually give off the oil and, thus, do not require any maintenance. Cores for electric coils and electric magnets and parts for miniature motors of sindered iron are soaked with artificial resin. Due to the artificial resins which have insulating properties the development of electric eddy currents is avoided and, thus, the detrimental heating of the components.

Summary

Sintering is defined as a process in which sintered parts are produced of powder of metals, metallic compounds and other materials by pressure and heat. For this purpose, press moulds are used on highly efficient hydraulic presses and special sintering furnaces employed. Sintered parts have a high accuracy of shape, a clean ans smooth surface and small tolerances.

3.1.2. Pressing of Thermosetting Plastics

Besides metal parts, parts of thermosetting plastics have proved to be very useful in many fields. Thermosetting plastic parts are made of shapeless materials and have a high accuracy of shape and very smooth surfaces. Pressing of parts of thermosetting plastics is only economical when large numbers are produced.

Means of work

Compression moulds for thermosetting plastics

Depending on the shape of the part to be produced, the moulds are made of two or more parts and have an intricate shape.

By means of cores (in the ejecting direction) and mould slides (not in the ejecting direction), cavities can be obtained in the part of thermosetting plastics – even internal threads in certain cases. The part is removed from the compression mould be means of ejectors. The plunger is the mating part of the mould (Fig. 3.1.2.). Hydraulic presses. Certain types of hydraulic presses are used especially for the pressing of thermosetting plastics. They are designed to heat the mounted compression mould without any difficulty. In addition, they are provided with control and regulating devices so that they can operate semi–automatically.

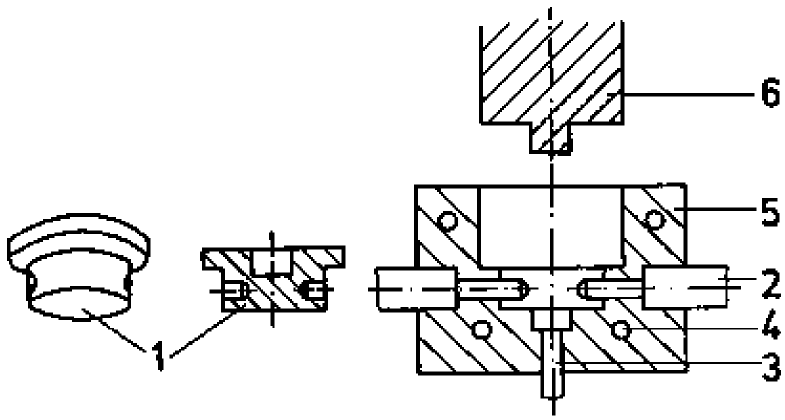


Figure 3.1.3. Compression mould for thermosetting plastic

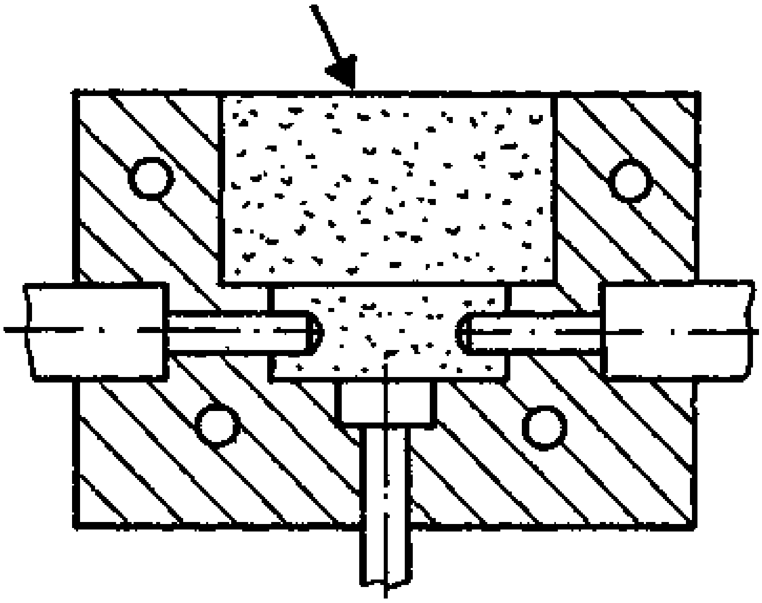
1 Workpiece, 2 Slide, 3 Ejector, 4 Heating, 5 Mould, 6 Plunger

Procedure

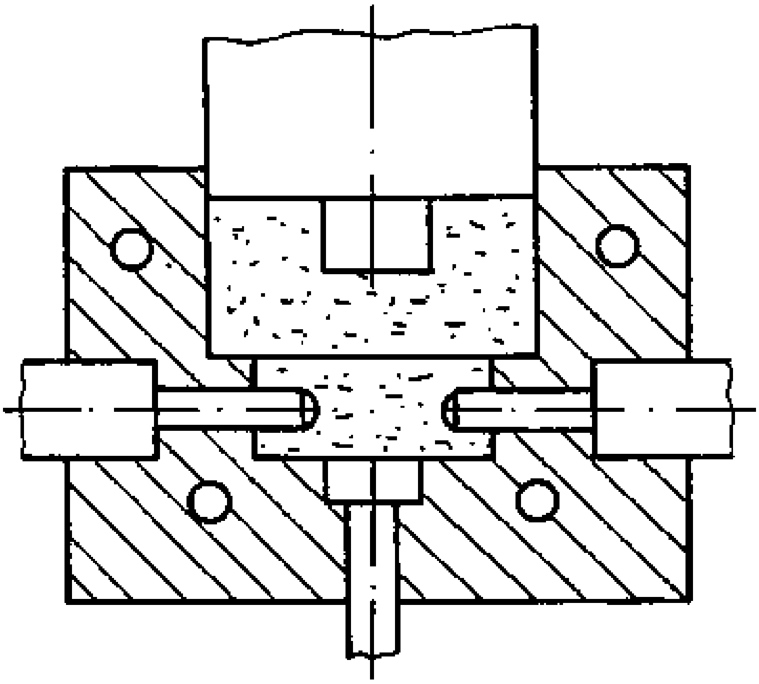
The raw material for thermosetting plastics is available as a progenitor in the form of powder, flakes, chips or grains. These raw materials can be pressed into tablets. A dosed amount of the basic material is filled into the heated compresion mould. By the pressure exerted by the plunger and the heat of the mould, the basic material is chemically changed and liquefied. It fills the mould and hardenes during a certain period – thus, the part of thermosetting plastic is produced in the mould. The ready parts is taken out of the mould or ejected

(Fig. 3.1.4.).

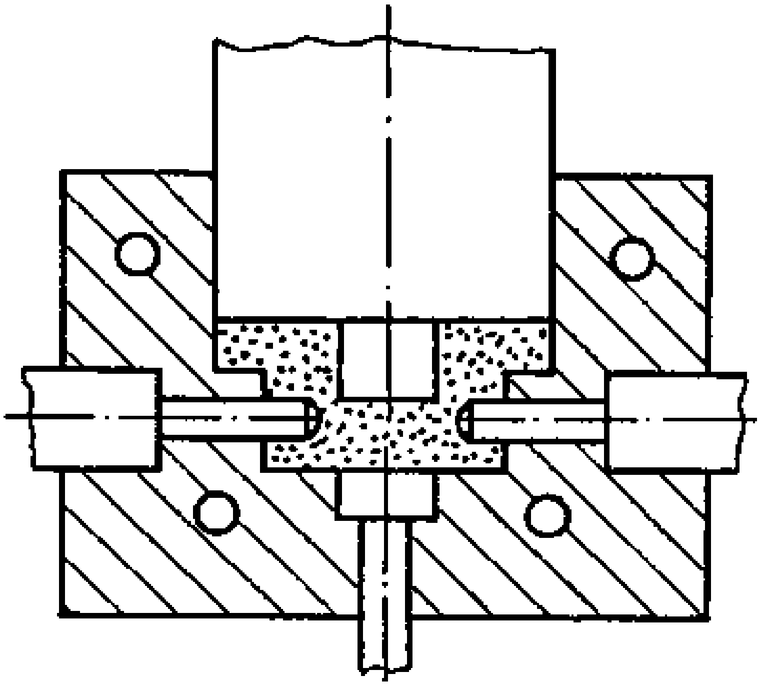
Figure 3.1.4 Procedure of pressing thermosetting plastics



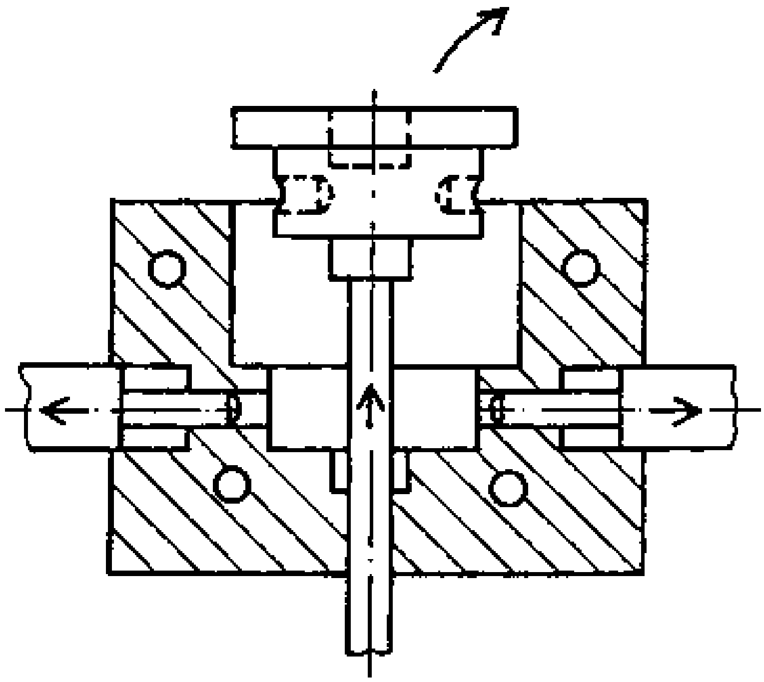
1 Filling



2 Start of pressing



3 End of pressing, curing



4 Ejecting

Application

Pressed parts of thermosetting plastic have a wide field of application.

– Thermosetting plastics are insulators; advantage is taken of this property by electrical engineering. Small and mediumsize housings for electrical devices and apparatuses and basic bodies for electrical components are produced in one pass.

– Differently coloured thermosetting plastics are used as circuit elements, e.g. control bottons, control levers and operating elements, e.g. handles, small hand wheels, balls etc.

– By means of fillers, which are added to the raw materials before pressing, certain properties can be achieved. Thus, glass or textile fibres added increase the strength.

Parts of thermosetting plastics with pressed in fibres are used in precision mechanics, in machine building, as gears, impellers and levers.

– Composite pressing is a special form of application. In this process, metal parts are placed in the compression mould which are included in the part of thermosetting plastics during the pressing operation (Fig. 3.1.5.).

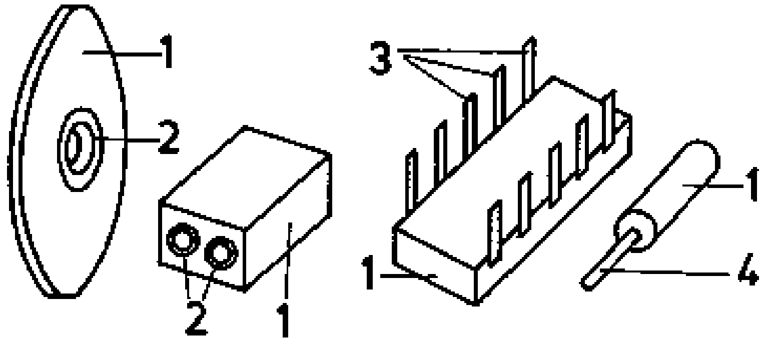


Figure 3.1.5. Composite mouldings

1 Thermosetting plastic, 2 Metal bushes, 3 Metal lugs, 4 Metal rod

Summary

By pressing thermosetting plastics, workpieces of intricate shape can be producing in one pass. The expensive compression moulds become economical when high numbers of compression mouldings are produced; for this purpose special hydraulic presses are required. Parts of thermosetting plastics have a wide field of application in electrical engineering, in precision mechanics and as housings.

3.2. Initial Shaping from the Liquid State

For the manufacturing methods of this manufacturing group, the material has the form of a melt, i.e. it is in the liquid state. The liquid material is filled in moulds where the melt takes the shape of the interior space of the mould and, during cooling, solidifies and attains a firm adherence.

3.2.1. Casting by Gravitational Force

The gravitational force acts everywhere on earth. On the basis of a natural law it causes objects to fall downward and liquids to flow from top to bottom. Advantage of this gravitational force is taken to fill moulds from top with liquid material.

3.2.1.1. Sand Casting

By the method of sand casting, metallic workpieces of intricate shapes and up to a mass of 300 tons are produced.

In single–piece production, expenditures are high and they can be cut by the use of machines when large series of workpieces are manufactured.

Means of work:

Patterns. Before preparing the sand mould, multipart patterns of wood, plastic or light alloy have to be made in most cases. The shape of the patterns closely resembles that of the workpiece to be cast. Differences are due to the core marks in the pattern. The patterns are larger than the actual workpieces by the shrinkage allowance. The dimension of the shrinkage is called shrinkage rule; it is due to the fact that the material contracts when it cools down from the casting temperature to the room temperature. Thus, steel has a shrinkage rule of 2%.

This means that a dimension of 100 mm in length at casting temperature is shortened by 2 mm during cooling down to room temperature, hence, to 98 mm. The shrinkage rule is dependent on the material. In order to use patterns correctly, they are marked by colours. This colour identification is standardized, e.g. patterns for steel castings are marked red, for cast–iron blue, for light alloys green. Core marks are marked black. Cores. For the production of cavities in castings, cores made of sand and a bider (loam, cement, artificial resin) are required. Cores have the shape of the desired cavity with the core marks (Fig. 3.2.1.). Cores are placed into the sand moulds with the core marks.

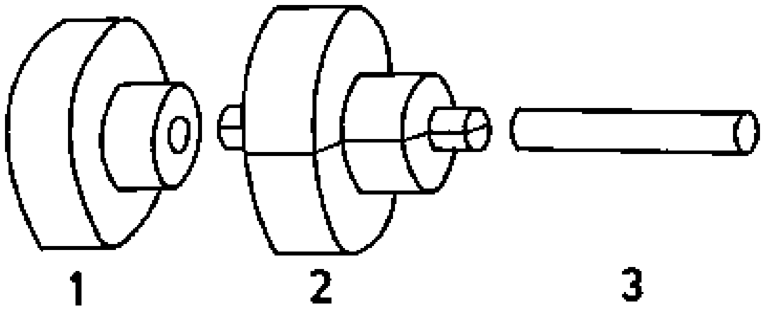


Figure 3.2.1. Casting, pattern, core

1 Casting to be produced, 2 Two–part pattern, with core marks, 3 Core

Foundry sand. The foundry sand is a mixture prepared in accordance with the casting material to be used. The main constituent is silica sand with admixtures of clay and loam. As binder, additions of cement, graphite and coal dust are used.

Tools for the moulder. The most important tools for the construction of sand moulds are tamper, trowel and lancet.

For piercing air holes, venting wires are used; the patterns are drawn out of the mould by means of pattern screws (Fig. 3.2.2.).

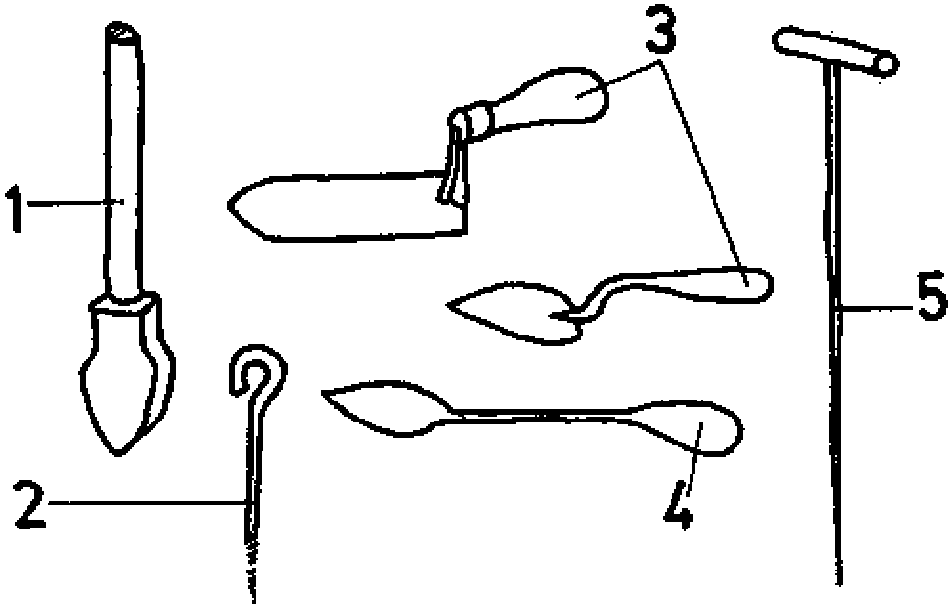


Figure 3.2.2. Moulder's tools

1 Tamper, 2 Pattern screw, 3 Trowels, 4 Lancet, 5 Air venting wire

Moulding machines. In series production, machines can be used for mould construction. They compact the foundry sand by shaking and pressing. Foundry flasks. As an external means of fastening sand moulds, foundry flasks, also known as moulding boxes, without cover and bottom are used. By means of guide pins, they can be placed exactly one above another (Fig. 3.2.3.).

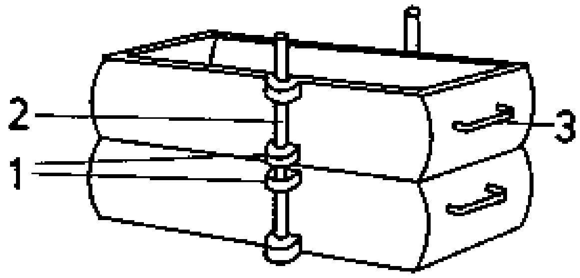


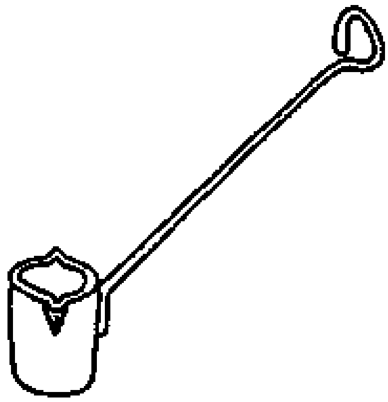
Figure 3.2.3. Foundry flasks

1 Bushing, 2 Guide pin, 3 Handle

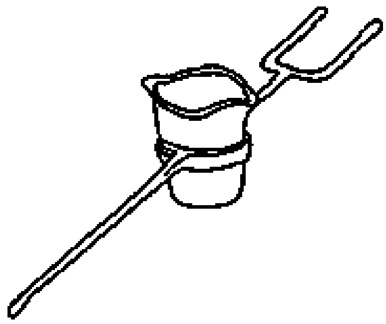
Foundry furnaces. For melting the metals, furnaces of different construction and various capacities are required. They are heated electrically, with gas, coke or electric arc.

Pouring ladles. The required amount of melt is poured from the melting furnace into pouring ladles and cast into the moulds (Fig. 3.2.4.).

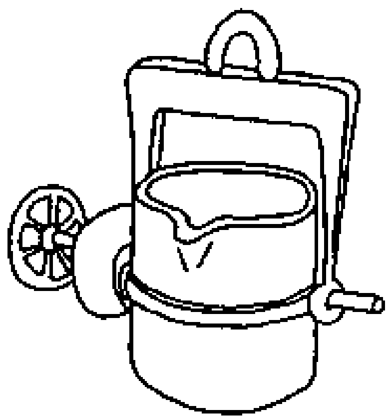
Figure 3.2.4. Pouring ladles



1 Hand ladle



2 Bull ladle



3 Crane ladle

Procedure

Mould construction. One half of the pattern and a suitable foundry flask is placed on a plane plate (Fig. 3.2.5.). The foundry flask is filled with foundry sand, layer by layer, and each layer is tamped so as to compact it. The foundry sand must be compacted uniformly in the flask.

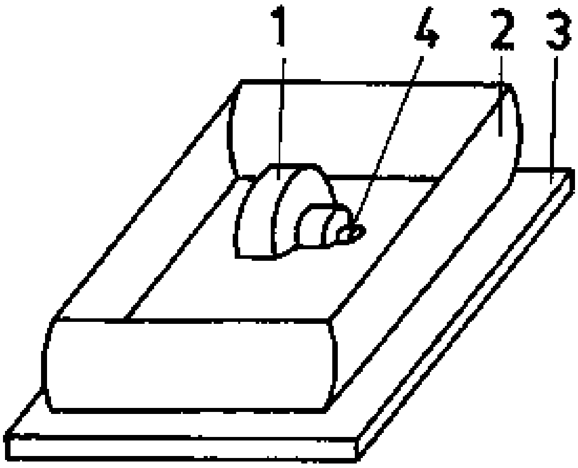


Figure 3.2.5. Plate with foundry flask and pattern half

1 Pattern half,
2 Foundry flask,
3 Plane plate
4 Core mark

After filling the foundry flask, the upper surface is smoothened. Thin air ducts are pierced by means of the venting wire. They are designed to allow the gases produced in casting to escape.

The filled foundry flask is turned over. A second flask is put on and the second half of the pattern is put in place (Fig. 3.2.6.).

When filling and tamping, the slag catcher, the gate and the riser outgate are attached. After filling, the upper surface is smoothened. At the gate, the spure is formed and the head attached the riser outgate. Sprue and riser funnel are drawn out (Fig. 3.2.7.).

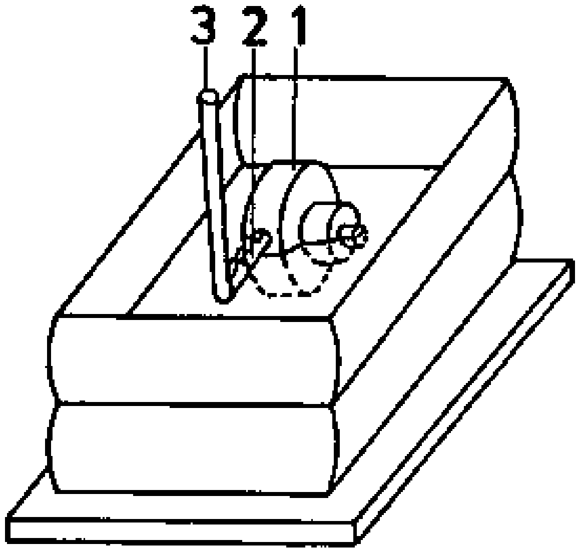


Figure 3.2.6. Flask put on top of the lower flask with the 2nd pattern half, ingate cone and slag catcher pattern

1 Pattern half,
2 Slag catcher pattern,
3 Ingate cone

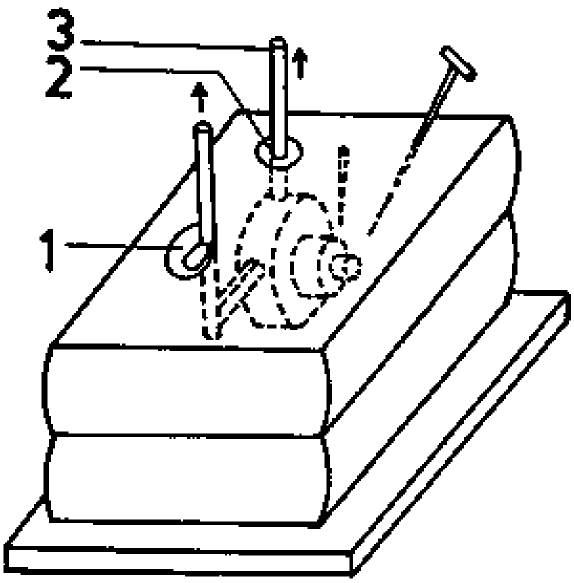


Figure 3.2.7. Ready top flask

1 Ingate,
2 Riser head,
3 Riser cone

The upper half of the mould is lifted and deposited in the turned over position. The pattern halves are drawn out of the mould halves by means of pattern screws (Fig. 3.2.8.).

The core is placed in the lower half of the mould. It rests on the core marks of the pattern (Fig. 3.2.9.).

The lower flask is placed on a pig bed made of loose foundry sand. The top flask is placed on the lower one. After loading the mould with metal blocks, the mould is ready (Fig. 3.2.10.).

The metal blocks prevent the top flask from floating on the liquid casting material.

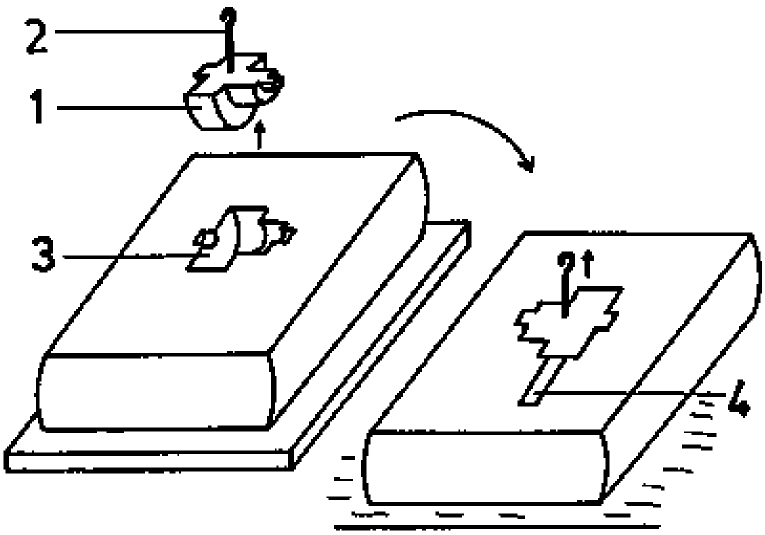


Figure 3.2.8. Top flask removed and drawing the pattern halves

1 Pattern, 2 Pattern screw, 3 Sand mould, 4 Slag catcher

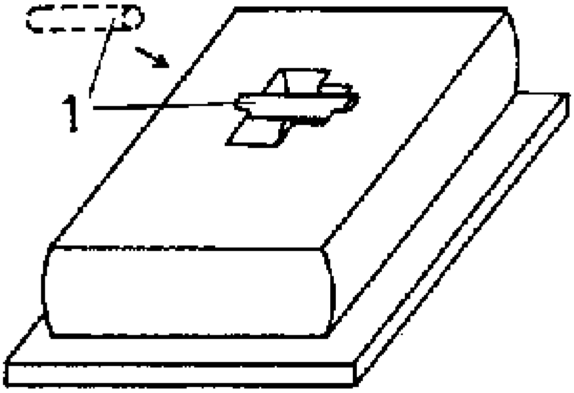


Figure 3.2.9. Fitting the cores

1 Core

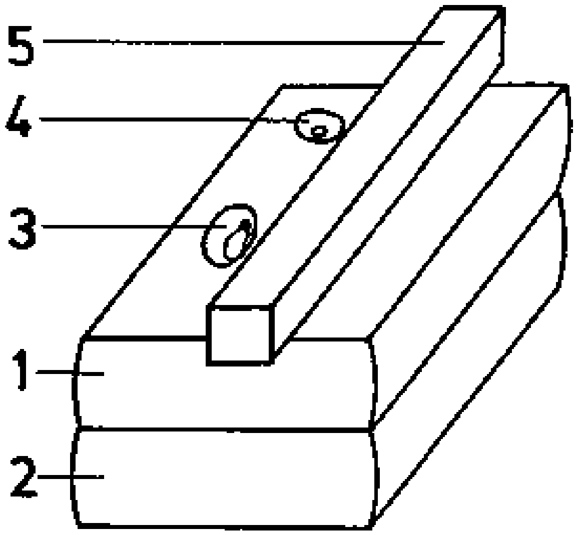


Figure 3.2.10. Ready sand mould

1 Top flask,
2 Lower flask,
3 Ingate funnel,
4 Riser head,
5 Metal block

Casting. In a foundry, several departments have to cooperate. In the melting department, the material to be cast is molten in the desired composition and at the correct melting temperature in foundry furnaces. In the moulding shop, the sand moulds including the cores are prepared ready for casting. In the casting bay, the moulds are filled. For this purpose, the liquid material is poured from casting ladles into the gate of the mould. Through the sprue and gate, the liquid material passes through the slag catcher into the cavity of the mould. The slag catcher is designed to collect slag that may float on the material to be cast so that it cannot get into the cavity off the mould. The slag is trapped in the comb–like devices of the slag catcher.

The mould is filled when the cast material has reached the upper edge of the sprue and the riser head. When cooling, the material solidifies and contracts for the shrinkage rule. During this process, cavities may be formed in cross–sections which are subject to particular risks in casting.

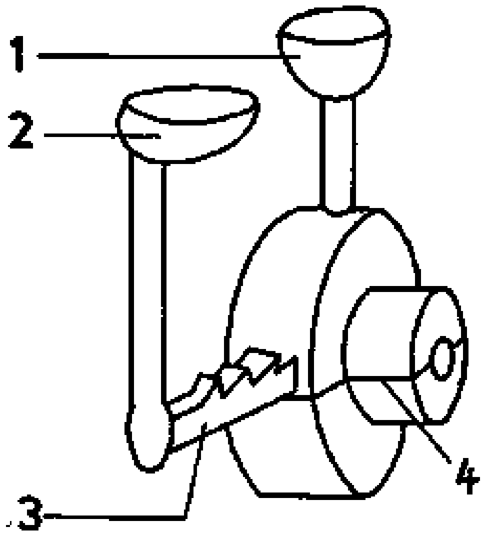


Figure 3.2.11. Ready casting

1 Riser, 2 Ingate,
3 Slag catcher,
4 Casting seam

For this reason, riser outgates or rising gates are attached to these points from which liquid−pasty material can be drawn, i.e. added during this period.

After the solidification of the casting, the sand mould is destroyed and the foundry sand can be regenerated partly.

The casting produced in this way must be cleaned (Fig. 3.2.11.).

Cleaning of castings. Cleaning the castings comprises three main operations:

− The removal of gate and risers by striking them off, sawing off, grinding off or separating by means of the flame−cutting torch,

− The removal or foundry sand remains and core remains by sand−blasting or ginding,

− The removal of cast seam and burr by grinding chiselling or filing.

Application

By the method of sand casting, all of the technologically important metals are cast. The castings made by sand casting have large tolerances and rough surfaces. Corners and edges are rounded. The castings are blanks for further machining processes. In case of parts of intricate shapes, usually only the functioning surfaces made so as to be accurate to the desired size and of a better surface quality. For example, in a large cast casing, only the locating or mounting surfaces of the casing, the mounting surface of the casing cover and bearing holes will be reworked. The surfaces of the interior space and the exterior surfaces will only be cleaned (Fig. 3.2.12.).

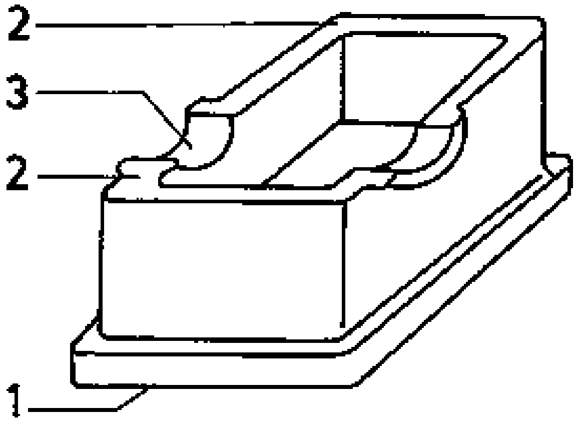


Figure 3.2.12. Functioning surfaces in a casing

1 Mounting surface, 2 Supporting surface for the cover, 3 Bearing hole

The following survey shows important materials for casting and examples of workpieces cast. Cast−iron: machine columns (e.g. drilling machines), machine beds (e.g. lathes), machine tables for machine tools, casings for motors and gear mechanisms, wheel bodies for large toothed wheels, engine blocks, pistons for engines and motors and hydraulic cylinders, components for furnaces (grates, oven doors), fittings for pipe installation.

Cast steel: wheels for rail vehicles, flywheels e.g. for presses, levers, clutch bodies, vice parts, pressure vessels, highly loaded machine parts.

Brass (Alloy of copper and zinc): ship's propellers, fittings for water mains.

Bronze (alloy of copper, tin and other metals): bearing bushes, pump casings, parts of valves bells.

Aluminium alloys: housings for medium−size and small electric motors, light−weight casings, enclosures for machines of the food industry, sea−waterproof parts for ship's equipment. In addition to metallic materials, plastics and artificial resins can be cast by the method of sand casting.

Summary:

In the method of sand casting, liquid metals (materials to be cast) are poured in sand moulds where they solidify. Cavities in the castings are achieved by means of cores which are placed in the moulds. The method of sand casting calls for the cooperation of smelters, (material to be cast) core−making workers and moulders (moulding shop), foundry workers (casting) and workers cleaning the castings. Workpieces made by the method of sand casting may have very intricate shapes and high weights (masses). They are further machined at their functioning surfaces.

3.2.1.2. Shell Moulding Process

The shell moulding process offers castings of higher accuracy size than sand casting and, in addition, very thin−walled workpieces can be made in this process. Labour expenditure is lower but the costs are higher.

Means of work:

Patterns. As in sand casting, the patterns are of two or more parts but they are exclusively made of light alloy. The parts of the pattern are fastened to a metal plate and, together with the latter, electrically heated (Fig, 3.2.13.).

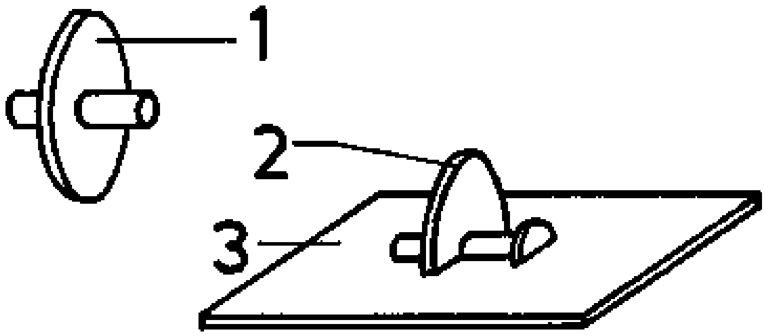


Figure 3.2.13. Part and pattern for the shell moulding process

1 Workpiece to be produced,
2 Pattern half,
3 Pattern plate

Moulding sand. For the shell moulding process, fine and very clean silica sand is mixed with synthetic resin as a binder.

The other means of work are similar to those used in sand casting.

Procedure

Mould production. By means of the heated pattern parts, the mould is made of foundry sand. For this purpose, the mixed moulding sand is placed on the heated pattern (also known as master) and pressed on it in a layer of about 20 mm thickness. Due to the heat of the master, the synthetic resin included in the sand is cured, forming a solid layer – the moulding shell. After the short time during which the heat is allowed to act, the shell can be removed from the master part (Fig. 3.2.14.).

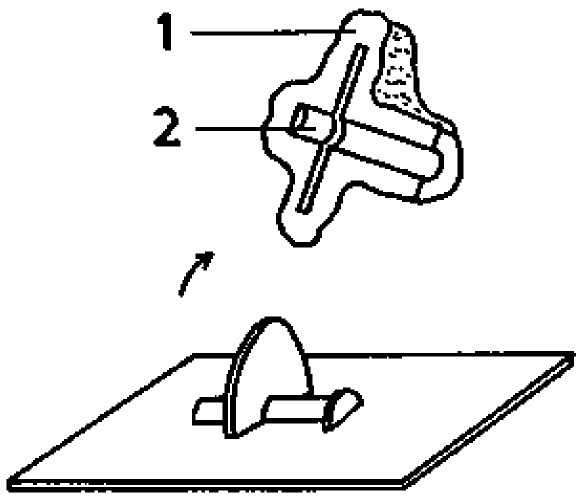


Figure 3.2.14. Lifting the shell from the master (pattern)

1 Moulding shell,
2 Interior shape

In the interior of the shell, there is an exact impression of the pattern or master. For curing and thus further solidifying, the shells are heated in furnaces to a temperature of about 300 C for a few minutes only. After curing and hardening, the shells belonging together are glued – in this way, a complete mould is obtained.

Casting. The moulds glued together are placed in boxes and fastened by an addition of sand pressed in the space between box and mould. The mould is then filled with liquid material by means of ladles (3.2.15.).

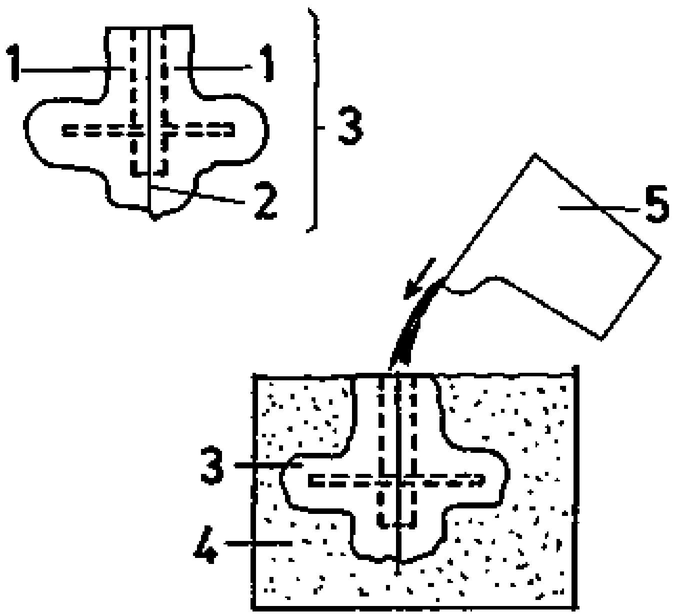


Figure 3.2.15. Ready mould

1 Moulding shell, 2 Glued point, 3 Mould, 4 Sand, 5 Pouring ladle

After the solidification of the material cast, the moulds are destroyed. The moulding sand cannot be used again. The workpieces obtained are cleaned easily and the finishing operations required are not expensive.

Application

The shell moulding process is only suitable for casting metals of low to medium melting temperatures. In case of higher temperatures, the synthetic resin included in the moulding sand would burn and, consequently, the mould be disintegrated. Mainly light alloys are cast.

− Workpieces having thin cross−sections and ribs can be cast readily in a good quality, e.g. cylinders for motor−cycles, compressors (e.g. for the compression of air) and for cooling apparatuses.

− Thin−walled housings, wall thickness from 3 mm, in medium sizes with clean surfaces and holes are cast for motor−cars, various devices and small units.

− Machine parts of intricate shape, e.g. gears and gear clusters with small tolerances call for insignificant finishing by machining operations only and are cast as blanks.

Summary: The shell moulding process enables the casting of workpieces of intricate shapes with thin ribs and thin walls. The castings have sharp edges and smooth surfaces. The shells are made of a mixture of fine sand and cured synthetic resin, glued together to obtain complete moulds which are for casting.

3.2.1.3. Chill Casting

The casting in metal moulds is particularly economical for large series and mass production. The shape of the workpieces to be cast is similar to that of sand castings; but the weight of the castings is only up to about 50 kg.

In contrast to sand casting, the heavy physical labour (mould construction) and the time for transport (foundry sand) are consideraly reduced. Casting can be effected with the help of machines and, thus, semi−automatically.

Means of work

Ingot moulds. Depending on the material to be cast, ingot moulds − also known as chills or permanent metal moulds − are made of steel, cast−iron, light alloy or ceramic materials. The shape of the workpiece to be produced is prepared in the form of an engraving (as in other moulds) and then the engraving is polished. Ingot moulds usually are two−part (split) ingot moulds, sometimes they are made of more than two parts and can accomodate cores (see Fig. 2.4.1.).

Further means of work are melting furnaces, pouring ladles and tongs.

Procedure:

The ingot mould is mounted on the casting machine. Ingot moulds of metal are preheated by a gas flame. The mould is closed and locked in order to prevent it from opening during casting. Then the pouring ladle is used for casting. The liquid material solidifies in the mould − the workpiece is produced. The ingot mould is opened and the casting removed with the help of tongs (sometimes ejectors are employed for discharging).

Application

− For machine building, small and medium−size machine parts are cast in ingot moulds. Light alloys are particularly suitable for this purpose. Cast−iron and copper alloys lend themselves to the production of workpieces of simple shapes, such as disks or rolls, only. Steel cannot be used because of the excessively high melting temperature.

− In steel works, slabs or slab ingots are cast in ingot moulds (Fig. 3.2.16.).

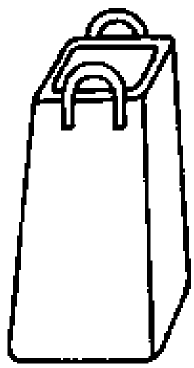


Figure 3.2.16. Ingot mould for steel mill

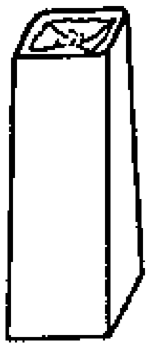


Figure 3.2.17. Slab

Means of work

Pressure−casting moulds. Depending on the shape of the workpiece, the construction of the pressure−casting mould is intricate. Usually it consists of several parts, has a slide and an ejector and cooling ducts through which a coolant passes during casting. The necessary precision in the construction of moulds calls for highly qualified experts. The demands on the materials for the pressure−casting moulds are exacting because they are subjected to high stresses in casting due to the changing temperatures and the liquid casting material under pressure. Therefore, high−alloyed high−temperature resistance steels, hardenable cast−iron, beryllium−copper (an alloy of copper with 5 % of beryllium) and silicon−brass (an alloy of copper, zinc and silicon) are used. The mirror−finished engravings of the moulds for pressure casting are subjected to a special treatment to improve their strength, for example, they are hardened, nitrided, hard−chromium plated. Mould lubricant. Before casting, the engraving of the pressure casting mould is sprayed or coated with a mould lubricant. Mould lubricants are mixtures of wax, hard wax, vaseline (pure technical fat) and graphite. They protect the engravings and ensure proper ejection of the castings.

Pressure−casting machines. Pressure casting can only be carried out with the help of machines. When using semi−automatic or fully automatic machines, the productivity is increased.

Procedure

In pressure casting, the following operations are involved on the pressure−casting machines:

− spraying the engraving with mould lubricant,

− closing the mould and inserting or screwing in the slides,

− arresting the mould in order that it cannot get open during casting,

− filling the mould at a casting pressure of up to 50 MPa in 0.1 to 0.3 seconds (in this way the liquid material to be cast reaches a speed of up to 70 m per second); in the cooled pressure−casting mould, the material solidifies very rapidly,

− unscrewing or drawing out the slides,

− unlocking and opening the mould; at the same time, the casting is pressed out and thrown out of the mould by the ejectors (Fig. 3.2.19.).

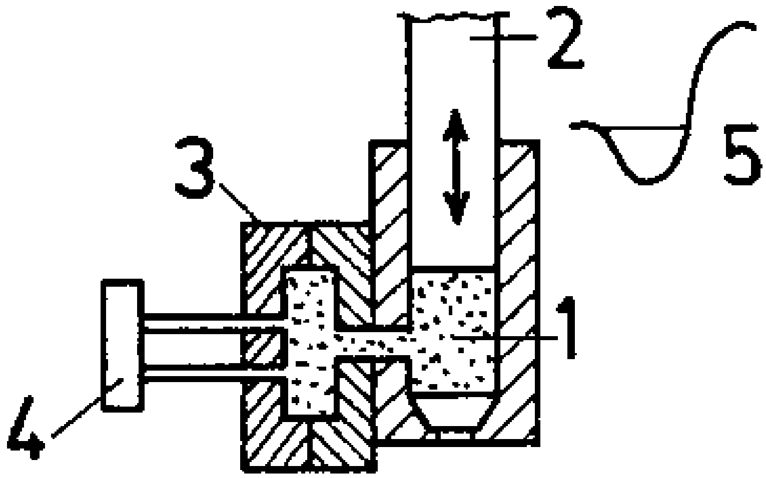


Figure 3.2.19. Cold−chamber pressure casting

1 Pressure chamber,
2 Piston, 3 Mould,
4 Ejector,
5 Filling device

Application

Pressure casting is a precision casting method by means of which tolerances as small as 0.01 mm can be attained. Due to the pressure and the high velocity of flowing in of the material to be cast, workpieces with thin walls (about 0.5 mm), narrow ribs and ready female threads can be cast. Reworking − removing the gate and the cast seam −is insignificant. However, metals and metal alloys having low or medium melting temperatures can only be cast. The reason for this is the fact that the moulds, which are subjected to high casting temperatures, would have a short service life only. Another reason is the rapid solidification of the material cast. The rapid cooling in the cooled pressure−casting mould produces an effect on the material: the material becomes brittle. Consequently, the workpieces made by pressure casting are not formable. They break when subjected to bending or blows or impacts (castings made by pressure casting of high−temperature melding hard metals would become dead hard and burst under low loads).

– In the chemical industry, chemically aggressive substances are used, e.g. acids. Measuring devices and parts of apparatuses frequently must be resistant to these substances. When their shapes are intricate (and when glas cannot be used for certain reasons), they are made of lead or lead alloys by pressure casting.

– For accumulators, e.g. motor–car batteries, grid plates of lead and other materials are cast.

– Small parts for precision mechanics such as levers, gears, check plates and pawls can be cast of tin and zinc alloys at the desired accuracy; this also applies to small and medium–size housings, e.g. for carburetters of engines.

– Many casings of power–current switches, wire plugs and small motors are castings of aluminium alloys made by pressure casting.

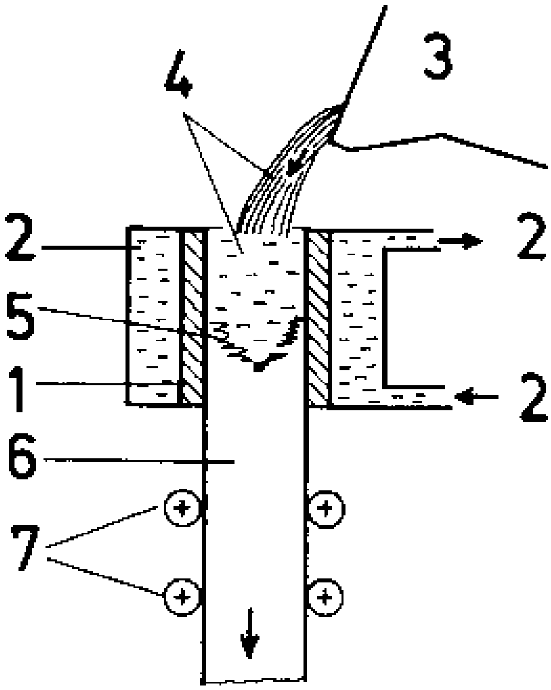
– Camera bodies, frames and enclosures for office machines are parts cast by pressure casting of magnesium alloys.

Summary

Pressure casting is a method of precision casting for large series production. The material to be cast is pressed into pressure–casting moulds of intricate shape by machines of special design. Workpieces made by the method of pressure casting excel in a clean and smooth surface, small tolerances and thin walls.

Besides limited cleaning work, there is scarcely any finishing operation required for castings made by the method of pressure casting.

Slab ingots (Fig. 3.2.17.) are large steel blocks, e.g. 400 × 400 × 1800 mm, which are further formed in rolling mills. The ingot moulds of steel used for this purpose are lined internally with a refractory substance in order that the liquid steel poured into it will not be welded to the mould. After solidification of the cast steel, the ingot moulds are lifted by a crane. Before further treatment by rolling or forging, the gate and the head of the slab must be separated.



1 Ingot mould,
2 Cooling water,
3 Pouring ladle,
4 Liquid material cast, 5 Sump,
6 Strand, 7 Guide rollers

Figure 3.2.18. Principle of continuous casting

– A special method of chill casting is continuous casting. The material cast from top into a cooled special ingot mould solidifies in the central part of the ingot mould – the sump.

The continuous casting produced is lowered by means of a drop table and guide rolls (Fig. 3.2.18.). The long casting produced in steel works is cut into blocks for rolling. Simple sections (round, square, rectangular) are made of non–ferrous metals and light alloys.

– Special ingots moulds are used to cast ceramic substances (porcellain) and synthetic resins.

Summary

Chill casting is the casting in permanent moulds which usually are made of metal. The permanent (or ingot) moulds can be cast on chill casting machines. Ingot–mould castings have simple shapes and their weight is limited. Slabs and sectional steel bars can be made in special processes.

3.2.2. Casting with Pressure

When casting with pressure – a method also called die casting –, the liquid material is not poured into the moulds but pressed into the moulds at high velocity due to the pressure applied.

3.2.2.1 Pressure Casting Method

By the method of pressure casting, small and medium–size workpieces of intricate shape and very smooth surfaces and small tolerances are cast provided high numbers are required.

3.2.2.2. Injection of Thermoplastics

Thermoplastics are chemically produced synthetic materials which can be liquefied by heating (similar to metals). In practice, however, melting cannot be repeated as often as desired. From the chemical industry, thermoplastics are available mainly in the form of granules for re–processing. Granules are materials in the form of grains having the size of rice. These granules are processed by injection. Injection of thermoplastics resembles pressure casting; the machines used are automatic injection moulding machines (Fig. 3.2.20.).

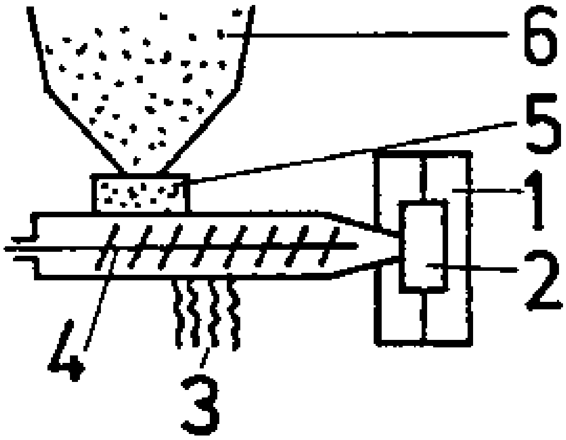


Figure 3.2.20. Plastics injection device

1 Mould, 2 Injection–moulded part,
3 Heating,
4 Transport screw,
5 Dosing device,
6 Container for granules

The great variety of types of thermoplastics ensures application in almost all technical fields. Thermoplastics lend themselves to the production of objects with a smooth surface and intricate shapes such as casings, enclosures, vessels, covers, appliances, and mouldings of different colours.

Special values of strength can be achieved by fillers, e.g. glass fibres.

3.2.2.3. Extrusion of Thermoplastics

By means of hydraulic extruders, thermoplastics are processed into endless strands (Fig. 3.2.21.).

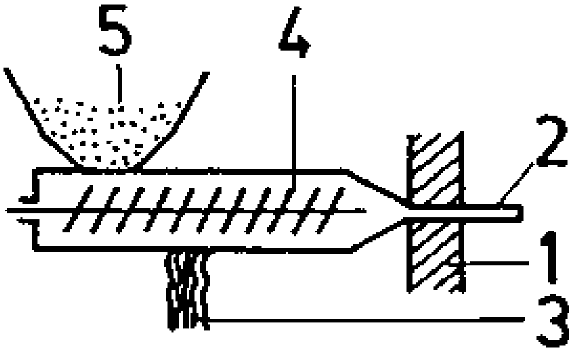


Figure 3.2.21. Extrusion of thermoplastics

1 Die, 2 Strand,
3 Heating,
4 Transport screw,
5 Container for granules

In this way, hoses for liquids having different diameters and insulating hoses for electrical lines are produced.

By means of special machines, wires and braces are provided with an insulating sheath. Thermoplastics which cannot be bent are used to extrude pipes, rods and various sections.

3.2.3. Casting with Centrifugal Force (Centrifugal Casting)

When an object is tied to a cord and then moved in a circle at this cord, a centrifugal force occurs at this object (Fig. 3.2.22.). Seen from the circle, it acts towards the outside. The centrifugal force is generated in any rotational motion and is used in centrifugal casting in the rotating moulds.

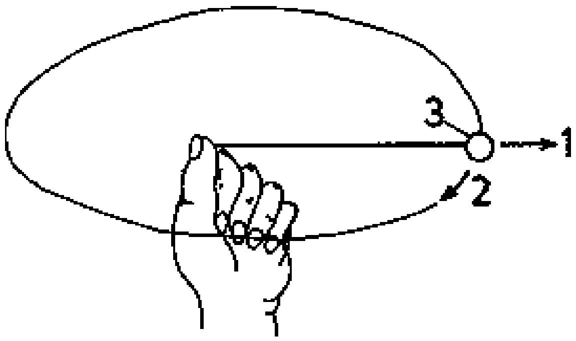


Figure 3.2.22. Effect of centrifugal force

1 Centrifugal force, 2 Direction of circular motion, 3 Object with cord

Means of work

Centrifugal–casting moulds. Because of the centrifugal forces involved, sturdy ingot moulds are used as moulds for centrifugal casting. These moulds usually are two–part moulds in order to facilitate the removal of the ready casting. Centrifugal–casting plants. Depending on the shape and the dimensions of the workpiece to be cast, centrifugal–casting machines for horizontally or vertically clamping the moulds are employed.

Procedure

The ingot moulds are mounted on the centrifugal–casting machine and caused to rotate. Through an inlet, the liquid material to be cast is poured into the mould and thrown to the wall of the mould due to rotation where the material solidifies (Fig. 3.2.23.).

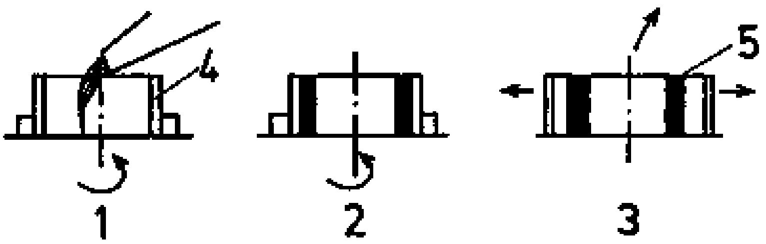


Figure 3.2.23. Procedure in centrifugal casting

1 Pouring the material, 2 Subjecting to centrifugal action and solidifying, 3 Removing the casting, 4 Ingot mould, 5 Casting

Application

Centrifugal casting is mainly used to produce cylindrical parts with a cylindrical cavity. In spite of the expenditure involved, centrifugal casting offers various advantages. Preparation and insertion of cores for the cavities are omitted. Another essential advantage consists in the fact that the material cast is compacted during solidification by the centrifugal force so that good strength properties are obtained. Entrapped gas or air in the casting which maylead to cavities in the workpiece cannot occur. Proper centrifugal casting. The moulds – ingot moulds – are cylindrical. The workpieces cast are also cylindrical and have a cylindrical cavity. In this way, pipes, bushes and rims are cast (Fig. 3.2.24.).

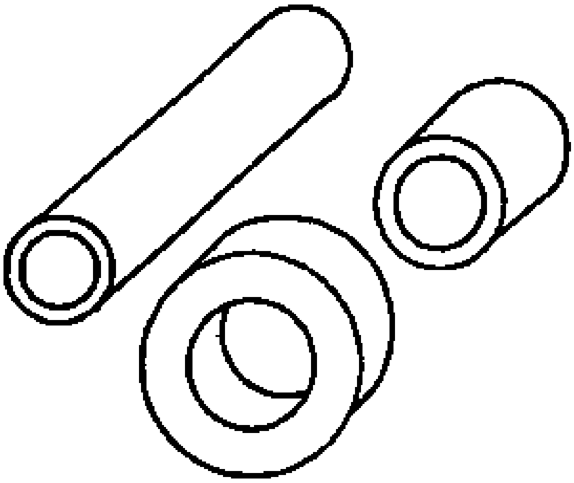


Figure 3.2.24. Workpieces of true centrifugal casting

At a limited speed of the mould and, thus, reduced centrifugal force, workpieces with a bottom, e.g. kettles, can be produced.

Improper centrifugal casting. In contrast to true centrifugal castings, the cast workpieces are not fully cylindrically externally but they have collars, shoulders or grooves while they are cylindrically hollow internally (Fig. 3.2.25.).

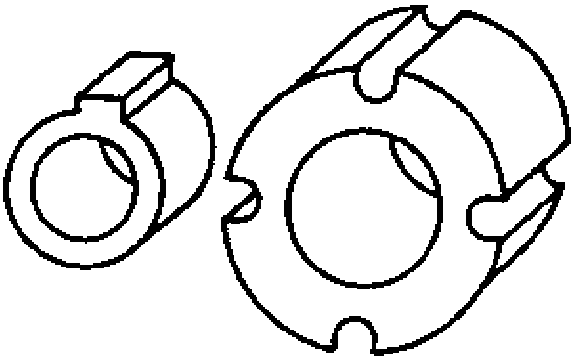


Figure 3.2.25. Workpieces of improper centrifugal casting

Centrifugal moulding casting. In centrifugal moulding casting, the shape of the workpiece is as desired. The ingot moulds are mounted on the table of the centrifugal–casting machine and filled from a central gate (Fig. 3.2.26.).

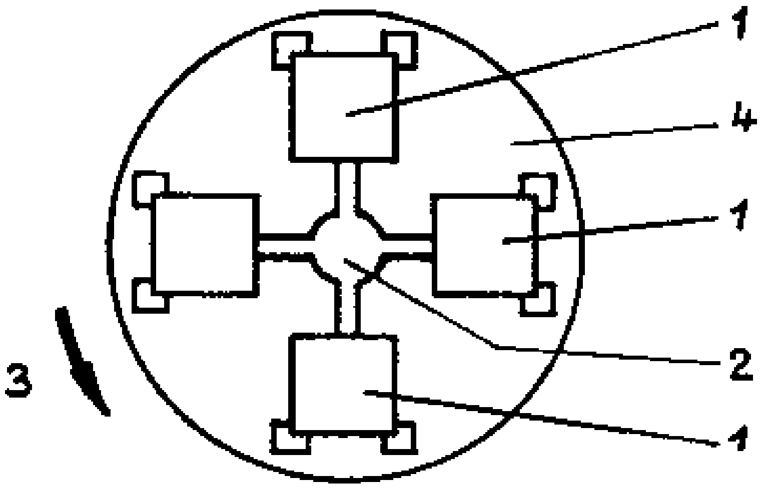


Figure 3.2.26. Principle of centrifugal moulding casting

1 Mounted moulds, 2 Central ingate, 3 Rotation, 4 Rotating equipment

The moulding type of centrifugal casting is used to obtaine workpieces with firm structures and without entrapped air or gas.

Casting of slide bearings. Slide bearings for the accomodation of shafts have to comply with different requirements. They have to take up bearing forces – that is, they must be stable. At the same time, they must offer good sliding properties in order that, between bearing and shaft, friction is limited to a minimum and heat and wear also.

These requirements are best met by composite bearings (Fig. 3.2.27.). They consist of a stable external bush or shell of a supporting metal, e.g. steel, having a high strength.

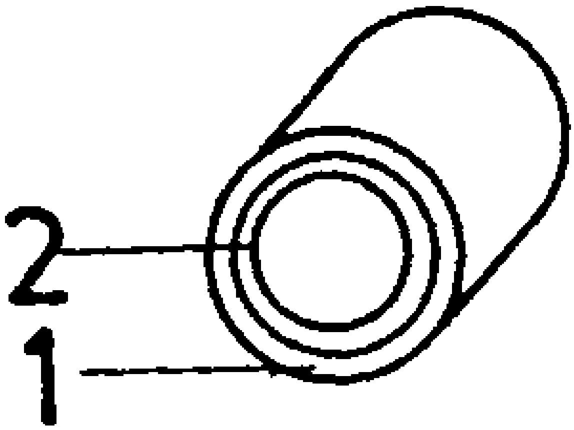


Figure 3.2.27. Composite bearing

1 Supporting bush
2 Bearing metal

Internally, a layer of bearing metal, e.g. brass (an alloy of copper and zinc) is applied to the bush by the method of centrifugal casting. In this procedure, the bush or shell constitutes the centrifugal–casting mould.

Summary

Centrifugal casting takes advantages of the centrifugal force provided by the rotating ingot moulds. The workpieces, which usually have a cylindrical shape, can be cast without core and with a cylindrical cavity. A particular advantage of this method is the compaction of the material due to the action of the centrifugal force.

Control questions

3.1. Why do compression moulds for sintered parts require a filling space?

3.2. What are the advantages of sintered metal filters?

3.3. What is the function of a slide in a compression mould? How does it function?

3.4. What are the advantages offered by compound pressing?

3.5. Explain the term “shrinkage rule”!

3.6. Why is the correct casting temperature important to the successful casting?

3.7. What is the task of the riser outgate or riser?

3.8. What are the particular advantages of the shell moulding process?

3.9. Describe the preparation of a shell for the shell moulding process!

3.10. Describe the casting of continuous castings!

3.11. Why have pressure–casting moulds to be produced at high accuracy and precision?

3.12. Give reasons for the fact that the material subject to pressure casting becomes brittle!

3.13. Why is the casting of cavities by centrifugal casting of particular advantage?

3.14. How can a worn composite bearing be remetalled economically?

4. Manufacturing Methods of Forming

Forming is a procedure by means of which workpieces are produced by plastically changing the shape of a solid body (blank). In this process, mass and internal bond of the matter do not change.

When, after the release of the load, the material remains in the changed shape, one speaks of a plastic deformation or permanent deformation. When the material returns into its original shape after relieving the load, it has been subject to an elastic deformation.

The workpieces produced in this manner are usually subjected to further treatment by other forming methods or separating methods. The following Tables show a comparison of the manufacturing methods of forming – separating – joining (Table 4.1.) and offer a survey of the forming methods (Table 4.2.).

Table 4.1. Comparison of Forming – Separating –Joining

	Forming	Separating	Joining
Shape	changing	changing	changing
Mass	retaining	reducing	increasing
Adhesion of matter	retaining	canceling locally	increasing

Table 4.2. Survey of the forming methods

Forming by pressure	– hammer forging – die forging – rolling – flow–forming
Forming by tensile and compressive forces	– deep drawing – drawing
Forming by tensile force	– stretch–drawing – stretch–expanding
Forming by bending force	– die bending – draw–profiling – bending–off – straingtening
Forming by shearing force	– twisting – displacing

4.1. Forming by Pressure

4.1.1. Hammer Forging

The workpiece produced by hammer forging show coarse dimensions and a limited accuracy (Fig. 4.1.1.).

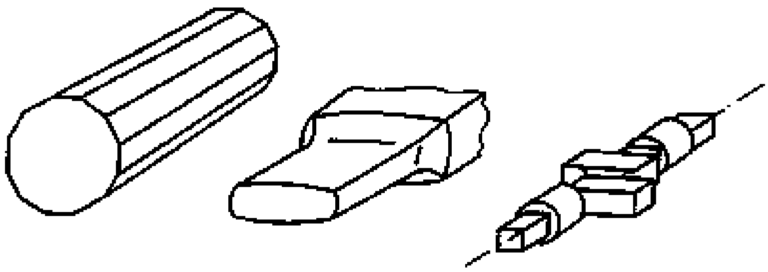


Figure 4.1.1. Workpieces produced by hammer forging

They have a high strength; usually they are made in small numbers and poor surface quality. Simple and cheap tools ensure high profitability. The strength of the workpieces usually is higher than that of comparable castings. The workpieces produced in this way are not ready for mounting, they call for further treatment (e.g. turning in a lathe, milling, grinding).

Means of work

Hammer forging tools. These are mainly saddles of different shapes between which the workpiece is upset (Fig. 4.1.2.). For holding the workpiece, special devices, tongs and grippers are employed. Hammer forging machines. The straight motion of pressure or impact must be produced with a high force action. For this purpose, vertically or horizontally working presses or hammers are used. The presses can be operated mechanically or hydraulically.

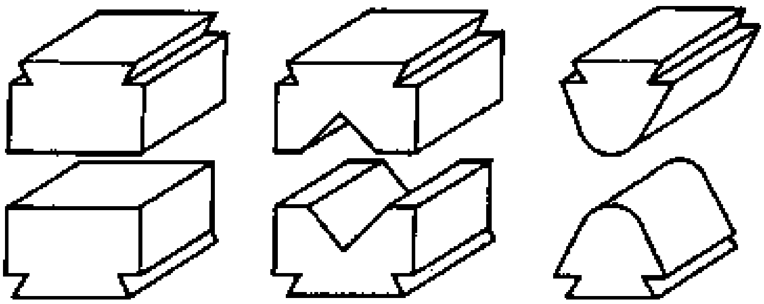


Figure 4.1.2. Saddles for hammer forging

In manual hammer forging, the workpiece is formed between hammer and anvil.

Procedure

For hammer forging, the workpiece is in the hot state. For this purpose, the steel to be worked is heated to a temperature of more than 1,200 C. The shape of the blanks is changed by several upsetting operations between the saddles successively performed (Fig. 4.1.3.).

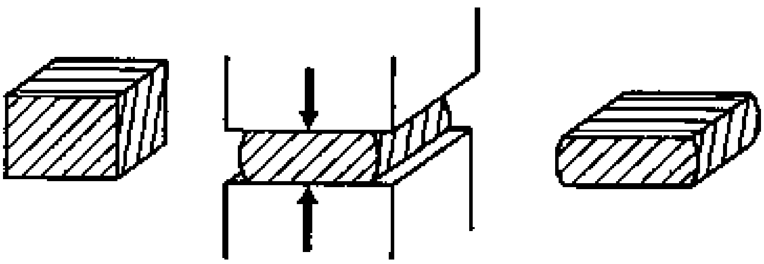


Figure 4.1.3. Forging procedure

Between the upsetting operations, both the position and the type of the saddle can be changed.

When this upsetting operation is performed by pressing exerting the force slowly, then a great depth action is obtained. In hammer forging, where hammer blows are applied to shape the work, the surface of the workpiece is additionally compacted.

Cold upsetting is applied to workpieces up to 20 mm in thickness because high forces are required for this method.

Application

Simple, roughly shaped workpieces are obtained by the process variants of upsetting, drawing and piercing.

Upsetting. Production of cornered or round sections with or without head (Fig. 4.1.3.). Drawing. By drawing out blanks in a forge, cornered or round sections with collars, shoulder of small thicknesses and larger lengths are produced (Fig. 4.1.4.).

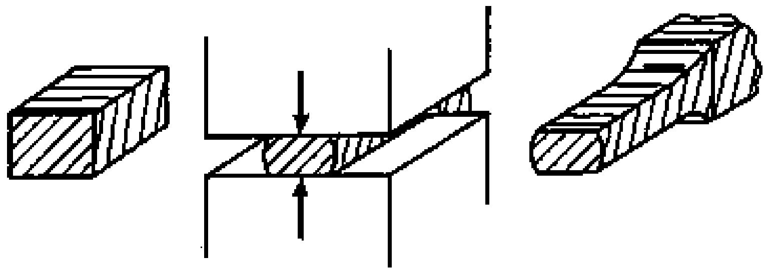


Figure 4.1.4. Drawing out

Piercing. This method is used to produce rings or blankswith preformed holes (Fig. 4.1.5.).

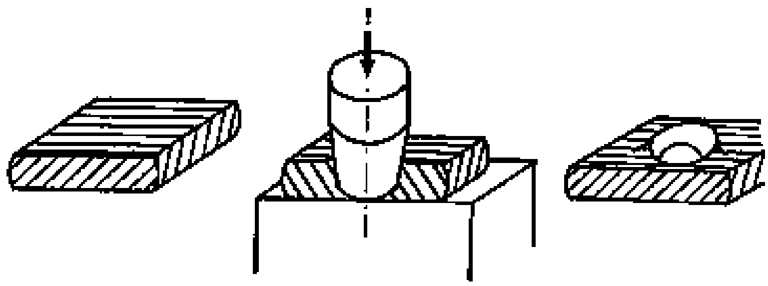


Figure 4.1.5. Piercing

Examples of workpieces produced by these process variants are marine shafts, medium−size and large crankshafts, levers, axles, rolls, shroudings, high−pressure housings, drums, fittings and connecting rods.

Besides steel, non−ferrous metals (e.g. aluminium, copper, magnesium and their alloys) are also used.

Summary:

Hammer forging is a hot forming process in which the workpiece is formed between two surfaces (saddles) by compressive forces. The compressive forces can be produced slowly by presses or suddenly by hammers. The workpieces produced have large dimensions but a low accuracy and their numbers are small; they must be reworked in any case.

4.1.2. Drop Forging

Compact workpieces which are subjected to high stresses (such as gears, screw heads, levers, connecting rods and spanners) are produced by drop forging, also known as die forging. This process is almost exclusively a hot forming process. The blanks for the drop forging process are pieces cut off from semi−finished products or hammer−forged blanks. In contrast to hammer forging, the shape of the workpiece is prepared in the tool (the die). This also means that the tools are expensive but they offer the advantage of an improved dimensional accuracy and accuracy of shape of the workpieces produced. Further advantages are

– small machining allowances,
– close tolerances,
– good utilization of the material,
– high strength of the workpieces, and
– simple working techniques.

Simple shapes are shown in Fig. 4.1.6.

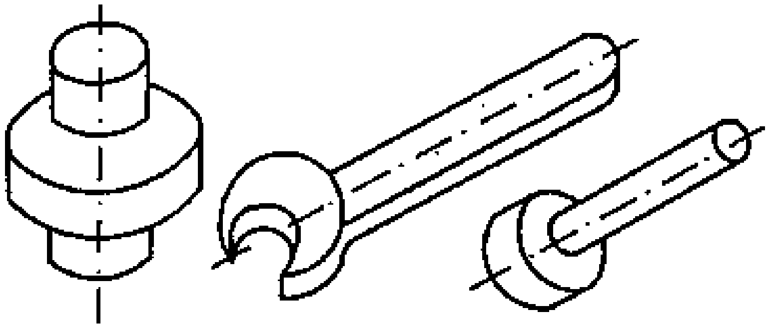


Figure 4.1.6. Workpieces produced by drop forging

Means of work

Tools for drop forging are closed or half−open dies in which the shape of the workpiece is recessed and that in the two parts of the die (Fig. 4.1.7.).

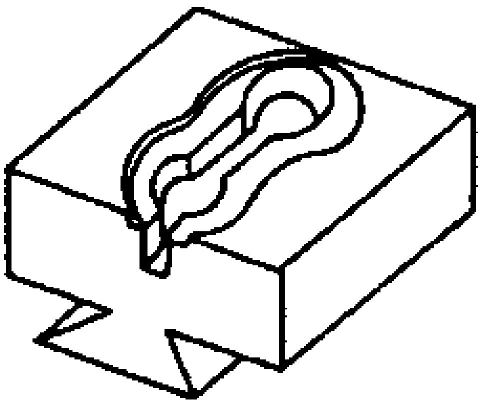


Figure 4.1.7. Die

They consist of high−alloyed, high temperature resistant steels and are polished. The engraving is made by chip−forming methods (e.g. electroerosion) or by forming. Excessive material is allowed to escape through flash grooves provided in the die. The flash or burr formed in this way is removed by a chip−forming method after the forging process.

When the shape of the workpiece cannot be achieved in one operation, multistep dies are used (Fig. 4.1.8.).

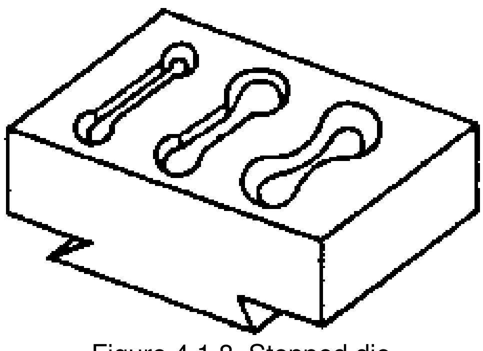


Figure 4.1.8. Stepped die

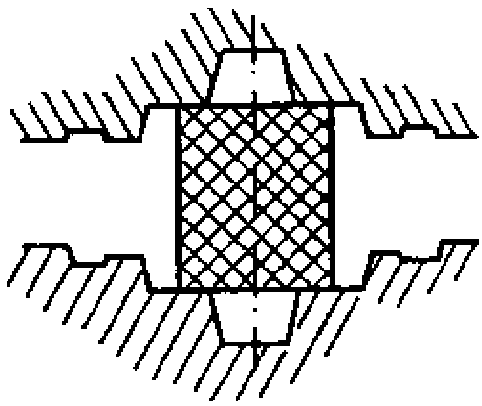
To save high grade steel, the engraving or impression is also made in the form of an insert for the die.

All engravings must be provided with a so−called draft, i.e. the angle of tapper on the side walls to permit the removal of the forging from the dies. As in hammer forging, the machines used mainly are mechanically acting presses or hammers.

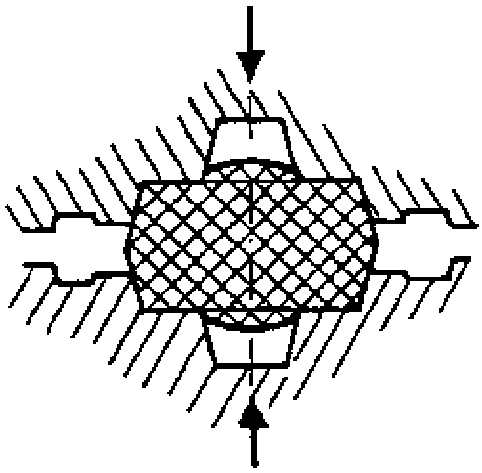
<u>Procedure</u>

Blanks for the forming process in the die are pieces cut−off from semi−finished products or parts pre−formed in any other way. Usually, the blanks are formed on all sides in the die by high pressure or strong blows of the machine tool and in the hot state. The blank, therefore, must comprise the volume of the workpiece plus an allowance that should be accurately calculated.

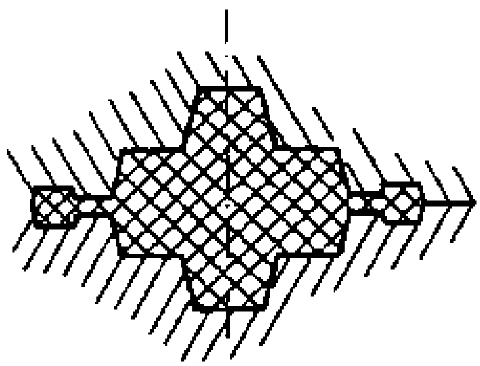
Figure 4.1.9. Procedure of drop forging



1 Upsetting



2 Filling the engraving



3 Filling the burr grooves

This allowance forms the burr in the parting line of the die. The burr of the final shape is removed by cutting.

In the space of the engraving, the workpiece is shaped by various intricate processes. At first it is upset, then flows into the free spaces of the engraving and then fills the flash grooves (Fig. 4.1.9.).

Application

Workpieces that are subjected to high stresses are produced by the process variants of pressing and striking; good accuracy to size and truth of shape are ensured.

Pressing to shape. This process is particularly suitable for compact workpieces with or without burr such as toothed wheels, screw heads and parts of couplings and clutches. It is also suitable for oblong and flat workpieces such as spanners, socket wrenches, snap gauges or connecting rods. The procedure is the same as that described in Fig. 4.1.9.

Striking. This process variant is also known as coining or stamping and it is particularly suitable for the production of coins, medals, badges, ornaments, quality marks, other signs and numbers; these parts are produced in closed dies without the formation of burr (Fig. 4.1.10.).

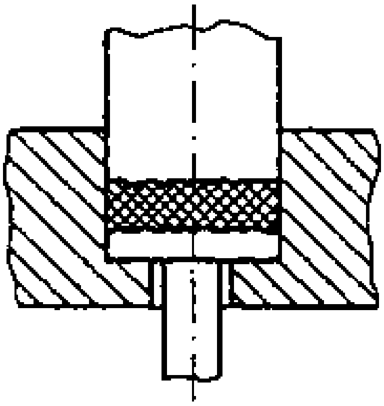


Figure 4.1.10. Coining

Summary:

In drop forging, a blank is shaped in *a* hot state in a closed or half−open die. The two halves of the die are pressed together by mechanically operating presses or hammers. The burr produced in the partition line of the die is finally removed by a chip forming method. The parts produced are capable of being highly stressed as parts of machines and their accuracy to size and truth of shape are good. The high tool costa are compensated by the good utilization of the material and the high strength obtained.

4.1.3. Extruding

In extruding, strands of uniform but different cross−sections are produced e.g. in semi−finished products. Pipes and cups of different head shapes are also produced, e.g. sleeves, flanges or cups (Fig. 4.1.11.). These workpieces are attained when material is pressed through a mould cavity or other tool openings.

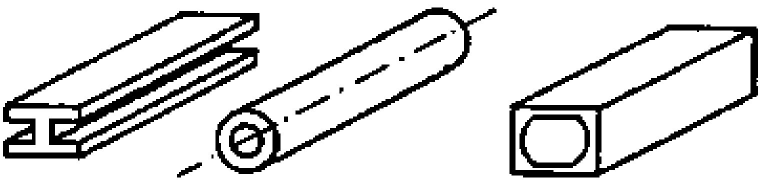


Figure 4.1.11. Extruded workpieces

Means of work

The tools are lower die and punch; the tools may also be called top force and bottom force. Press dies must withstand high pressures and intense friction. The shape of the punches is influenced by the buckling stress and the flow of the material.

The machines required are presses which can produce very high pressures. They operate mechanically or hydraulically (e.g. eccentric presses, toggle plate presses or hydraulic presses). The pressures for extruding are about 2,000 N/mm^2.

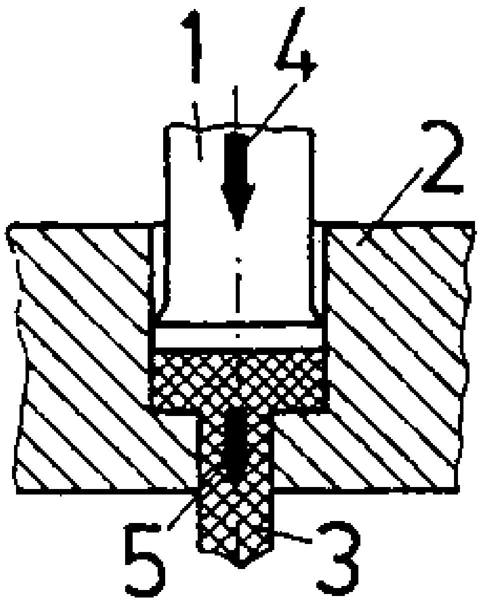
Procedure

The blank is placed in the tool opening. Due to the high pressure exerted, the material flows in the direction of the least resistance. The adhesion of the material is not lost, however. When the material only flows through the openings of the bottom die, then motion of the punch and flow of material have the same direction. Motion of the punch and flow of material are opposite to each other when the material flows through an openings between punch and bottom die (see Fig. 4.1.12.).

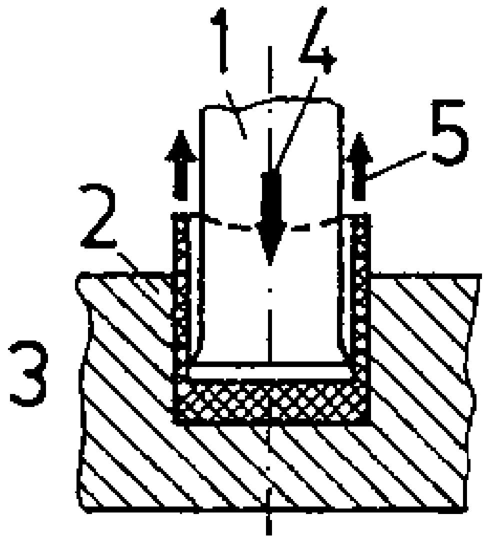
When using several stamps or divided bottom dies, very intricate shapes can be pressed. The method is performed in the cold and in the hot state of the material.

Recently, semi−hot pressing at a temperature of anything between 600 to 800°C has been carried out. In this way, favourable tolerances, limited scale and reduced energy consumption can be achieved (consumption of energy about 70 %).

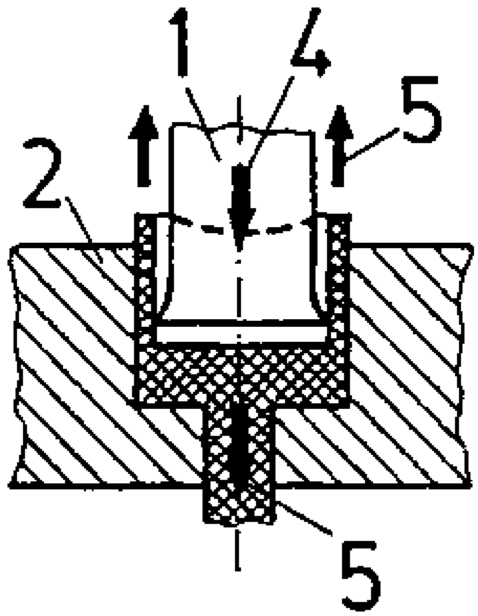
Figure 4.1.12. Flow of material and punch motion in flow−extrusion



a Uniform flow−extrusion



b Opposite flow−extrusion



c Mixed flow−extrusion

1 Punch, 2 Die, 3 Material, 4 Punch motion, 5 Flow of material

Application

Sometimes a distinction is made between flow−extrusion and strand−extrusion. By the former method, pipes and cups or the like and produced, while the latter method is employed to produce strand−like semi−finished products.

Flow−extrusion. Depending on the motions of material and punch, a distinction is made between uniform, opposite and mixed flow−extrusion (Fig. 4.1.12.).

By these variants of the method, mainly symmetrical, cup−shaped or hollow parts of different shapes are produced.

Strand−extrusion. Strands of different sections are produced by uniform or opposite strand−extruding or by solid or hollow strand extrusion (Fig. 4.1.13.).

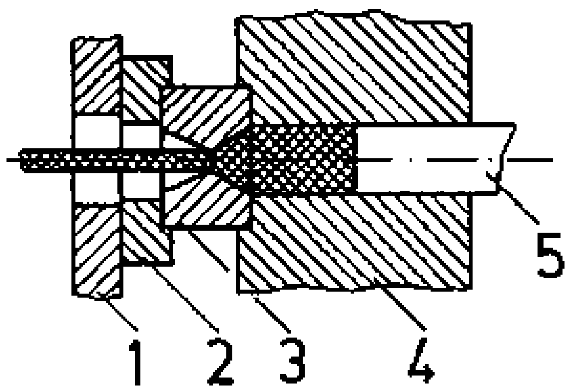


Figure 4.1.13. Uniform strand−extrusion

1 Holder,
2 Die holder, 3 Die, 4 Support, 5 Punch

Summary:

Extruding is a pressure−forming method in which the material starts flowing, due to the pressure exerted by the punch, without that the adhesion of the material is lost.

By different bottom die openings or gaps between bottom die and punch, mainly strands, hollow bodies and pipe−shaped workpieces are produced.

Depending on the relationship between punch motion and material motion, uniform, opposite or mixed pressing methods are achieved.

A distinction is made between strand−extruding and flow−extruding.

4.1.4. Rolling

In this pressure−forming process, roll−shaped tools (rolls) are rotating, transmitting a motion to the workpiece and shaping it. Rolling in general leads to a reduction of the cross−section and an extension of the length of the workpiece. When the workpiece is moving straight ahead, the method is called longitudinal rolling. When the workpieces are rotating, the method is called transversal rolling.

4.1.4.1. Longitudinal Rolling

Flat materials (plate), rings, sectional rods, pipes or workpieces with grooves (e.g. gears) are shaped between two or more rolls (Fig. 4.1.14.).

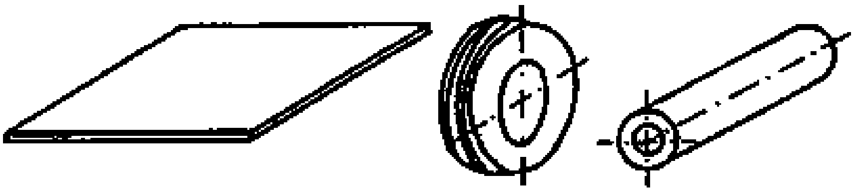


Figure 4.1.14. Longitudinally rolled workpieces

Means of work

Rolls are the tools. Two rolls form a roll pass at the point where they meet (Fig. 4.1.15.).

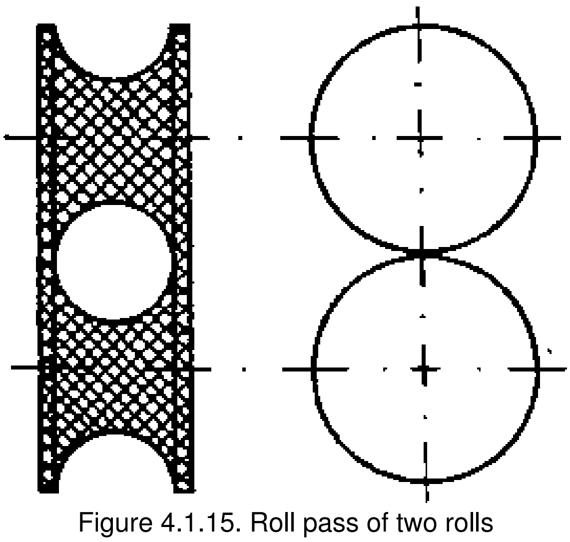


Figure 4.1.15. Roll pass of two rolls

The roll pass can be open or closed and form different profiles (sectional shapes). In the rolling machine, the work rolls are complemented by backing up rolls, roll holders and drive. Rolling machines are classified according to the diameter of the rolls, the type of material to be rolled or the arrangement of the rolls.

A rolling train is composed of rolling machine, feeding devices and additional devices. The individual units are arranged one after the other. Between the rolling machines, roll tables (feeding devices) are arranged. On the roll tables − also known as roller gear bed −, the material to be rolled can be moved forward and backward.

Frequently, the material to be rolled must be tilted; for this purpose, tipping devices are provided. Bloom shears or bar−cutting machines arranged between the rolling machines cut the material rolled into the desired lengths.

Further, defective ends are cut off by the bloom shears; Fig. 4.1.16. shows a simple rolling train.

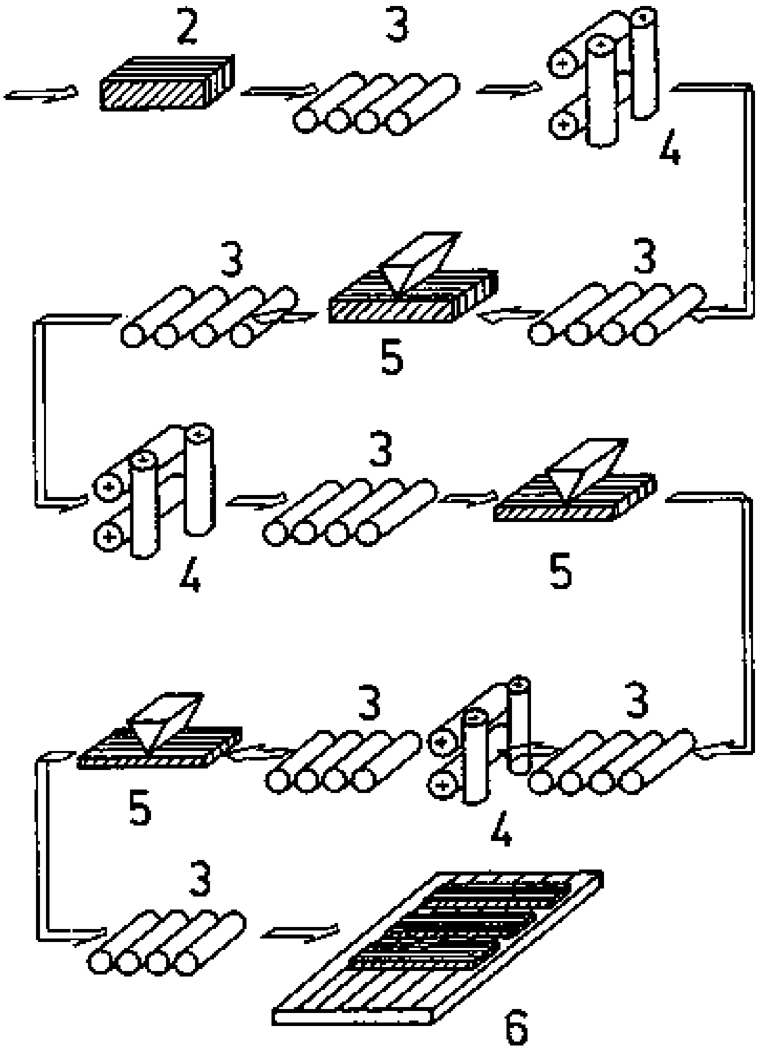


Figure 4.1.16. Rolling train

1 from the pit−type furnace, 2 Bloom, 3 Roll table, 4 Rolling machines, 5 Shears, 6 Cooling bed

<u>Procedure</u>

The rolls rotate about their own axis moving in opposite directions, at the same speed. The workpiece is moved up to the roll gap, gripped by the friction between the surfaces of the rolls and of the workpiece and drawn into the roll gap. The cross section of the workpiece is changed according to the geometry of the roll pass.

The extension of the material causes the different speeds of the material in spite of the same circumferential speeds of the rolls (Fig. 4.1.17.).

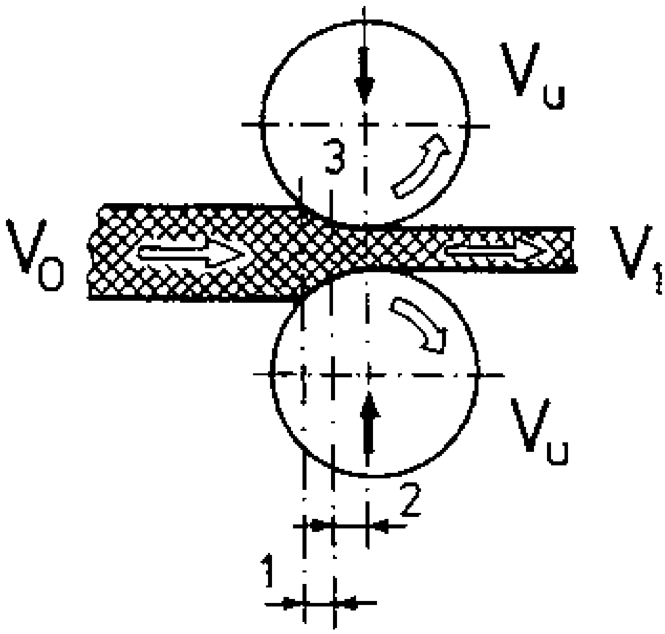


Figure 4.1.17. Procedure in rolling

1 Back–pressure zone,
2 Advance zone,
3 Non–slip point

v_0 workpiece speed before rolling
c_1 workpiece speed after the rolling procedure
v_u circumferential speed of the rolls

As compared to the circumferential speed of the rolls, the material flow at a slower speed in the back–pressure zone and at a higher speed in the forward slipping zone. This process is carried out in the cold and in the hot state.

The final shape of thw workpiece is frequently obtained only after several rolling passes. Then, several rolling machines performing different rolling actions form a rolling train.

Application

In accordance with the different workpieces to be rolled, a distinction is made between flat roll passes, shape rolls, pipe rolls, and groove rolls. Flat pass rolls. They are used to shape plates, bands or rods from blooms and slabs of any description. Sectional semi–finished products can also be rolled in this way (Fig. 4.1.18.).

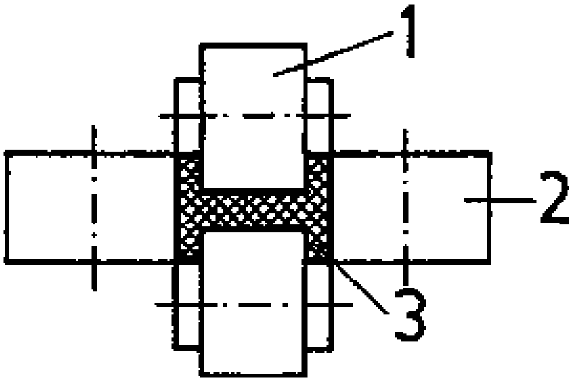


Figure 4.1.18. Flat rolling

1 Working rolls,
2 Towing rolls,
3 Workpiece

Shape rolls. Flat or annular sections are shaped in closed roll passes (Fig. 4.1.19.).

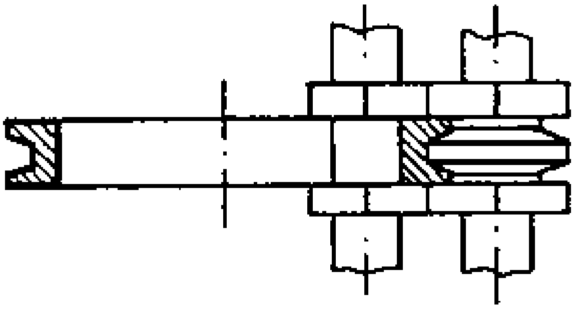


Figure 4.1.19. Shape rolling

Pipe rolls. Pipes can be produced by means of pilgrim rolls. The pre−shaped hollow body is rolled in steps over a mandrel.

The rolls are grouped in a rolling part and an idling part. In idling, the workpiece is advanced and then rolled in the rolling part (Fig. 4.1.20.).

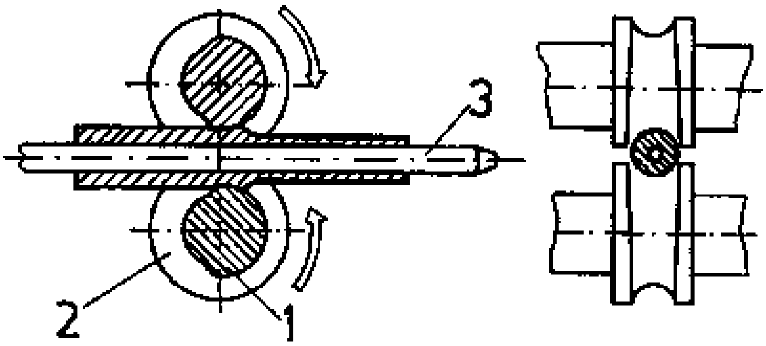


Figure 4.1.20. Pilgrim rolls

1 Rolling part, 2 Idling part, 3 Mandrel

Groove rolls. Longitudinal grooves and splines, e.g. in gears and multiple splined shafts, are shaped by the profiles of the rolls (Fig. 4.1.21.).

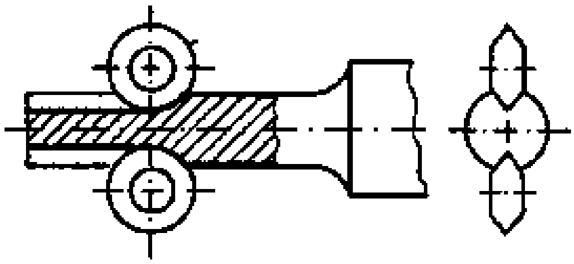


Figure 4.1.21. Groove rolls

4.1.4.2. Transversal Rolling

Shaped parts (e.g. balls, threaded bolts, twist drills), surface profiles (e.g. serration, knurls) pipes or smooth surfaces are shaped between the rolls while the workpiece performs a rotary motion.

<u>Means of work</u>

As in longitudinal rolling, the rolls form the roll pass which determines the shape of the workpiece. In the place of the rolls, <u>flat jaws</u> can be employed (Fig. 4.1.22.).

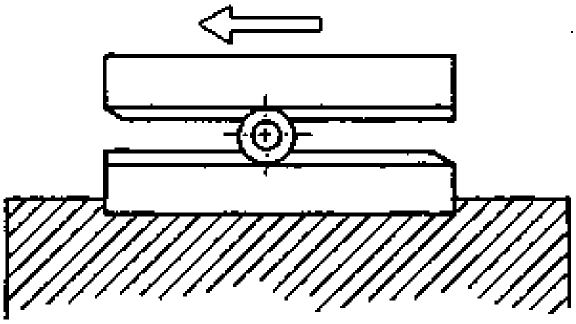


Figure 4.1.22. Rolling with flat cheeks

Frequently, the rolls must be arranged obliquely. This means that high demands are made on the rolling machines.

Procedure

Since the longitudinal axis of the workpiece usually is parallel to the axes of rotation of the rolls, the workpiece is causes to rotate (Fig. 4.1.23.).

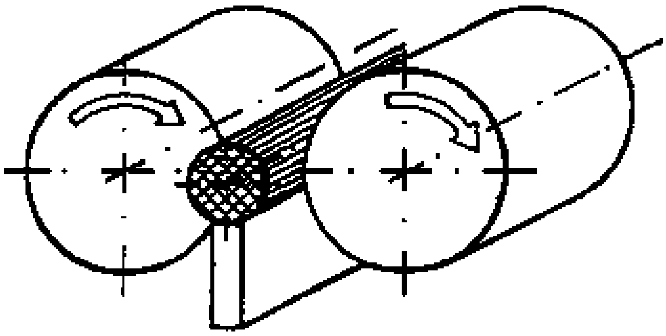


Figure 4.1.23. Procedure in transversal rolling

For a continuous rolling operation, the rolls are arranged obliquely; consequently, a longitudinal motion is imparted to the workpiece.

Application

In accordance with the final shapes to be achieved, a distinction is made between surface profile transverse rolls and skew rolls.

Surface profile transverse rolls. Screw threads, serrations, gripping surfaces or other profiles are transmitted from the rolls to the workpiece (Fig. 4.1.24.).

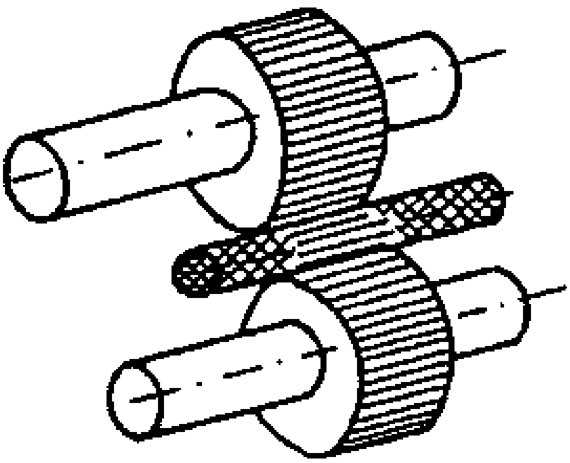


Figure 4.1.24. Surface profile transverse rolls

Skew rolls. Rolls arranged at an angle with respect to each other cause the round blanks to move ahead with a helical motion. The tapered part of the roll at first causes a constriction of the material and then an expansion of the workpiece. Consequently, the material ruptures in the core zone where it is widened and smoothed by a mandrel (Fig. 4.1.25.).

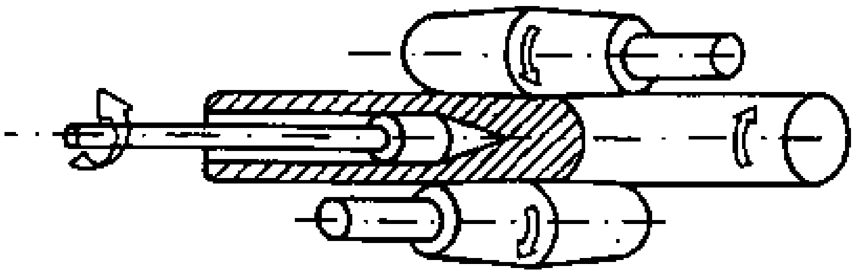


Figure 4.1.25. Skew rolls

Summary:

Workpieces are shaped between rolls (roll−shaped tools). The rolls form a so−called roll pass (profile) at their abutting surfaces and they are driven. When the longitudinal axis of the workpiece is vertical to the axes of the rolls and when the workpieces perform a straight longitudinal motion, the method is called longitudinal rolling. In transverse rolling, the longitudinal axis of the workpiece runs parallel to the roll axis. Consequently, the workpieces perform a rotating motion.

Between the rolls, the cross−section of the workpieces is reduced. As a consequence, the length is extended. Profiles on the rolls are transmitted to the workpiece.

Several rolling machines with additional equipment can be arranged in the form of a rolling train or rolling line. This ensures higher degrees of forming of the workpiece. Flat parts (e.g. plates), sections and pipes are rolled.

4.1.5. Flow−forming

Rotationally symmetric hollow bodies (produced by deep drawing or extrusion) are shaped in axial direction over a mandrel by rotating rolls. The wall thickness of the workpiece can be accurately controlled. Thin−walled pipes and vessels (e.g. milk cans, cettles, cylinders) are produced (Fig. 4.1.26.).

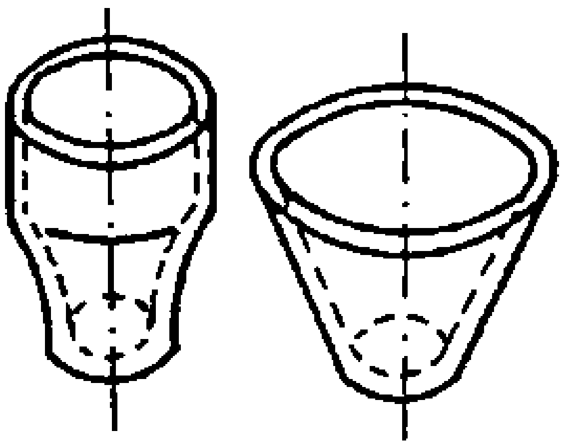


Figure 4.1.26. Workpieces produced by flow−forming

Means of work

The tools are pressure rolls. They have the form of double cone rolls. Their surfaces are very smooth because they influence the surface of the workpiece. Since pressure rolls can take high forces they must be made of high−alloy polished steel and properly mounted. For flow−forming, lathes and drilling machines with additional equipment are used.

Procedure

The workpiece running on a mandrel is driven. The pressure roll is rotating and is moved as feed in axial direction.

The wall thickness of the workpieces is reduced in this way while their outer surface is enlarged (Fig. 4.1.27.).

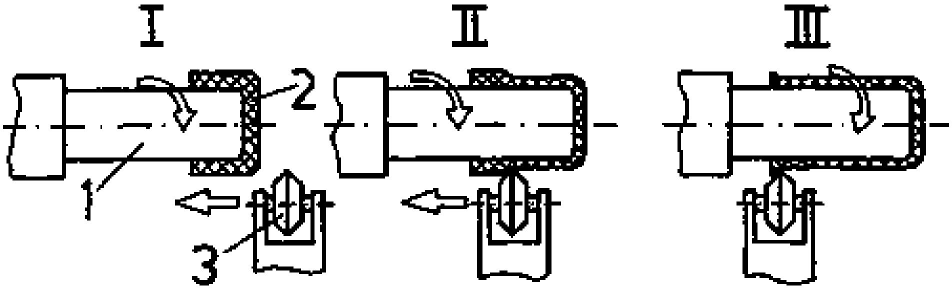


Figure 4.1.27. Procedure of flow−forming

1 Mandrel, 2 Workpiece, 3 Pressing roll, I Initial position, II Intermediate stage, III Finished part

Tapered and curved outer surfaces can also be formed. The blanks required for this process are rotationally symmetric hollow bodies which are produced by extruding, deep drawing or turning on a lathe (Fig. 4.1.28.).

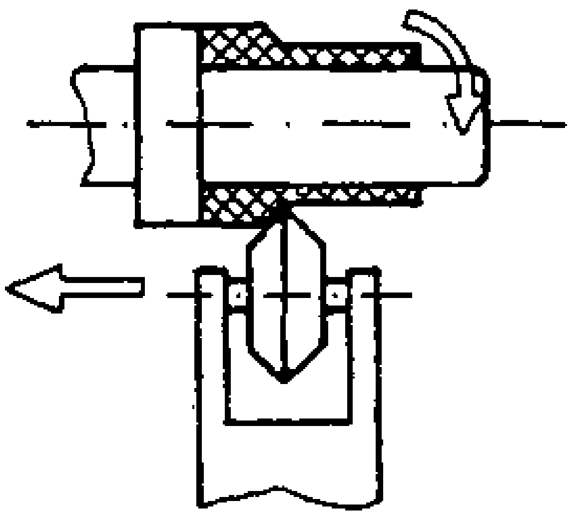


Figure 4.1.28. Flow−forming of a pipe

<u>Application</u>

The main method is the flow−forming; variants derived from this method are transverse−smooth rolling and surface profile flow−forming. Flow−forming. Reducing the wall thickness of pipes, cups, hollow bodies even of those having a tapered or curved outer surface. Depending on the flow of the material, a distinction is made between uniform of opposite flow−forming (Fig. 4.1.29.).

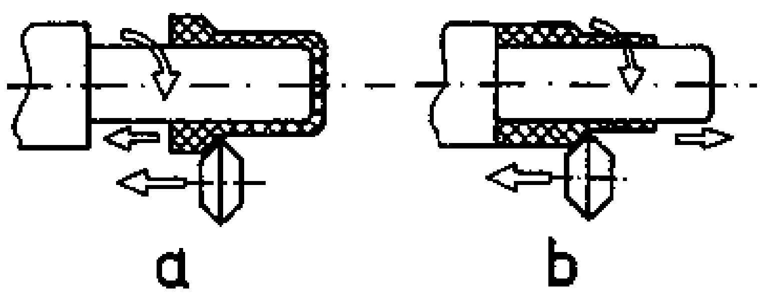


Figure 4.1.29. Flow−forming

a Uniform flow−forming, b Opposite flow−forming Surface profile flow−forming. This process may be compared with surface profile transverse rolling. The difference is the fact that the workpiece is driven in rolling.

Summary:

Rotationally symmetrical hollow bodies are running on a mandrel.

A pressure roll as the tool reduces the wall−thickness of the workpieces which, consequently, is extended. This method is called flow−forming; a variant derived from it is the surface profile flow−forming by means of which, for example, gripping surfaces are transmitted to the workpiece.

4.2. Forming by Tensile and Compressive Forces

4.2.1. Drawing

Strand−shaped workpieces (e.g. wire or strands with different sections) are drawn through the shaping opening of the tool. The cross−section of the workpiece is reduced and its length extended. Rolled, extruded or longitudinally welded pipes are changed in their diameter.

Means of work

The drawing tool consists of a drawing die with an opening of the desired shape (Fig. 4.2.1.).

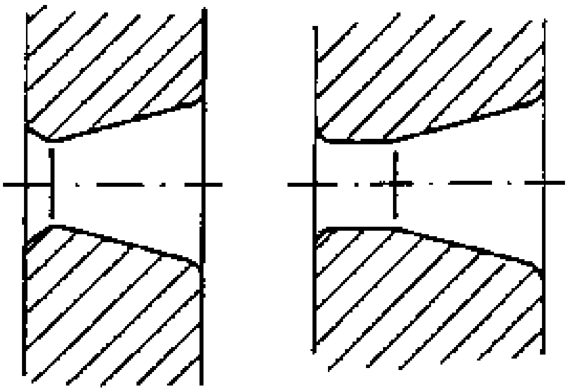


Figure 4.2.1. Drawing dies

It is made of high−alloy steel, hard metal or diamond. The friction caused by the strand sliding through the die is reduced by a film of lubricant.

For reducing the friction further, two drawing rolls are used in the place of the drawing die. The drawing rolls form a closed roll pass and they are mounted so that they can be rotated freely (Fig. 4.2.2.).

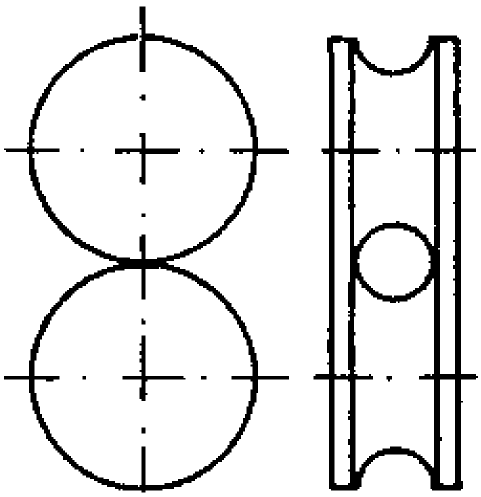


Figure 4.2.2. Drawing rolls with roll pass

If great store is set by an exact internal diameter of the pipe, a stationary or a rotating mandrel is used. For expanding the tubes, tapered mandrels are employed.

The tensile force is produced by a drawing machine. Both wire drawing machines and rod drawing machines are used. In a drawing machine, several drawing dies can be arranged.

Procedure

The workpiece, pointed before starting the drawing process, is inserted into the drawing die and gripped by the drawing tongs of the drawing machine. When drawing the workpiece through the die, high compressive and axial tensile stresses lead to the shaping of the workpiece. The stresses involved must be considerably smaller than the permissible stresses of the material (Fig. 4.2.3.).

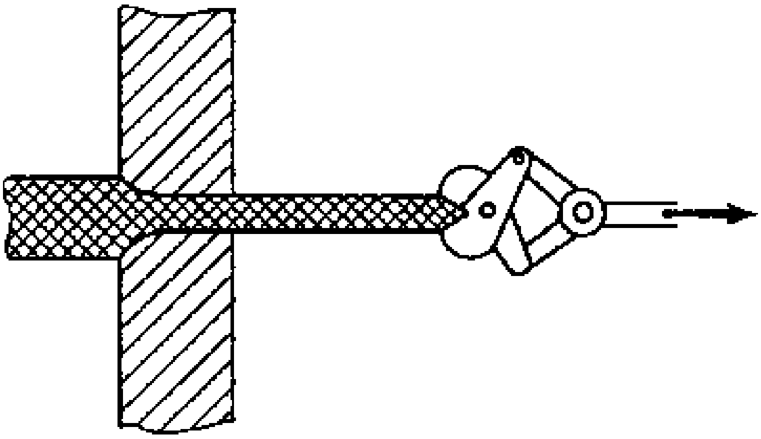


Figure 4.2.3. Procedure of drawing

In this way, the degree of forming is limited in one drawing pass. Therefore, several draws are reduced in many cases. Pipes can also be formed by drawing rolls.

Application

Solid profiles (wire, strands of different sections) or hollow profiles (pipes or other hollow profiles) are made by the variants of the method of strand drawing and hollow−profile drawing.

Strand drawing. By drawing through a drawing die or a pair of drawing rolls, rods, wires or solid profiles with circular section, square section, hexagonal section and the like are made of the pre−rolled material (Fig. 4.2.4.).

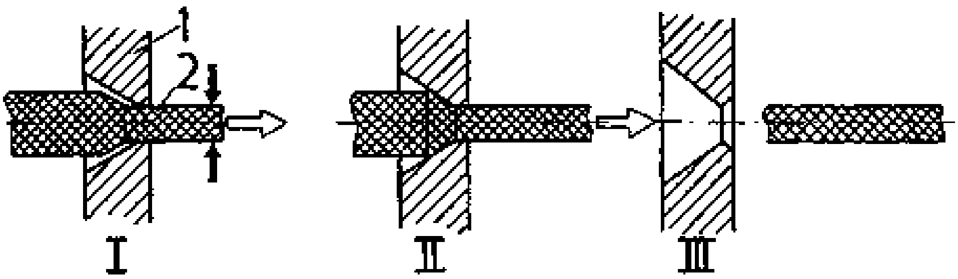


Figure 4.2.4. Procedures of strand−drawing

I Beginning of drawing, II during the drawing procedure. III finished workpiece

1 Drawing die, 2 Workpiece

Hollow−profile drawing. By means of drawing dies or drawing rolls, rolled, extruded or longitudinally welded pipes are drawn in the hollow, plug or strand drawing method into round, square, rectangular, oval or other hollow sections.

Summary:

When drawing material through a drawing die, in general the cross−section of the workpiece is reduced. High degrees of forming must be achieved by several drawing passes. The friction involved can be reduced by lubricants or drawing rolls.

The products drawn are solid sections with different shapes and hollow profiles.

4.2.2. Deep Drawing

Plane sheet blanks of steel, car body sheet or plates of copper, aluminium and other alloys are shaped into hollow bodies or other curved formed sheet−metal parts.

Pre−shaped sheet−metal parts can be also deep−drawn into other three−dimensional shapes (Fig. 4.2.5.).

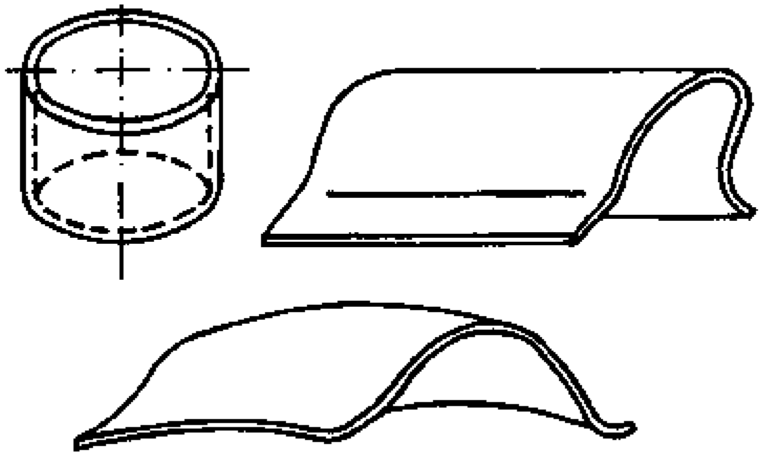


Figure 4.2.5. Deep−drawn workpieces

Means of work

The deep−drawing tool is partly complicated and consists of the basic elements punch, draw−die and blank holder (Fig. 4.2.6.). Column guide, ejector and other parts may additionally be incorporated in the deep−drawing tool.

For deep drawing, special deep−drawing presses with separate drive for punch and blank holder have been developed. Single acting presses can also be used when special additional attachments are provided. Deep−drawing presses operate mechanically, hydraulically or pneumatically.

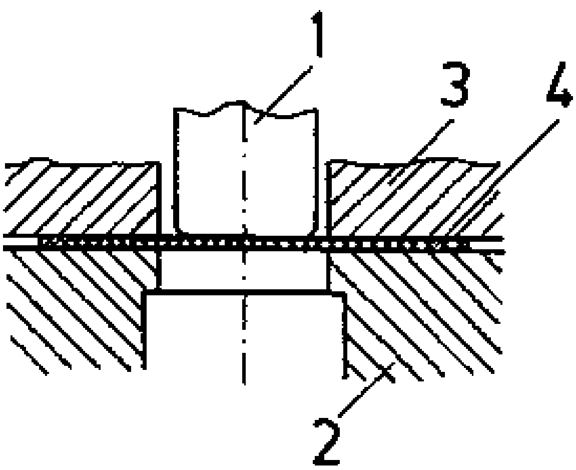


Figure 4.2.6. Deep−drawing tool

1 Punch,
2 Drawing die,
3 Blank holder,
4 Sheet metal

Procedure

The starting material is a plane sheet blank. Due to the compressed air of the drawing punch in the workpiece, tensile, compressive and bending stresses are induced. The punch draws at the same time the sheet blank through the die into the desired final state (Fig. 4.2.7.).

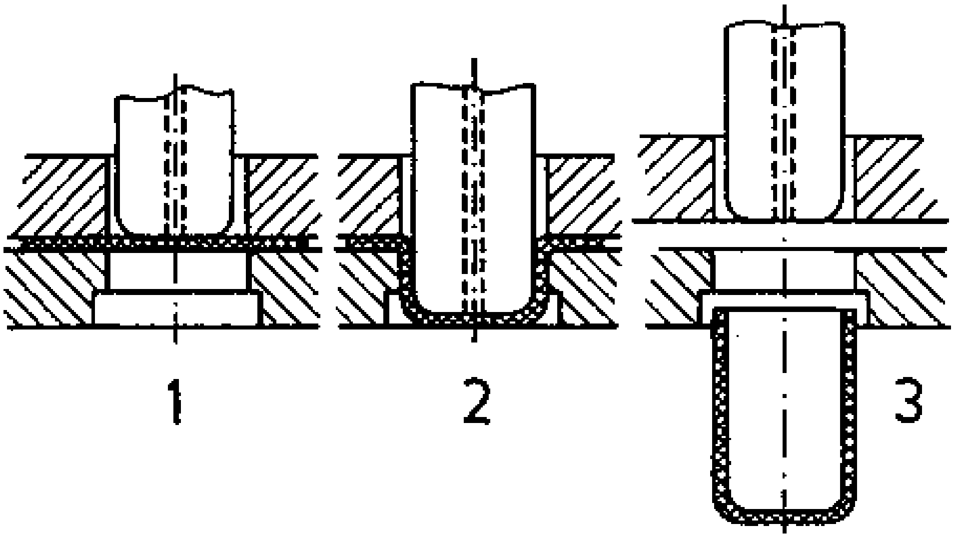


Figure 4.2.7. Procedure of deep drawing

1 Initial position, 2 Intermediate stage, 3 Finished part

In the bottom of the part to be drawn, no change of shape takes place. Changes of shape with a reduction of the sheet thickness occur in the range of the bottom radius. When the change of form or the deep–drawing force is excessive, the bottom may be torn off. The cylindrical part of the workpiece is subjected to an intense elongation of the material. At the same time, the “excessive material”, which exists between the plane sheet blank and the cylinder, must be incorporated in this range (Fig. 4.2.8.).

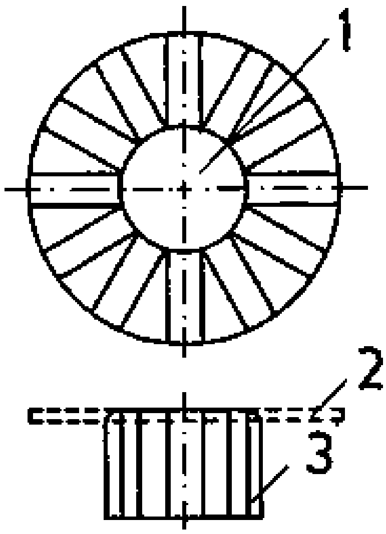


Figure 4.2.8. Material conditions in drawing

1 excessive material to be incorporated
2 Initial shape,
3 Final shape

The compressive stresses involved can lead to the formation of folds.

A compressive stress applied vertically to the bottom surface by the blank holder prevents this formation of folds. Due to the great stress on the material, mostly drawing in several steps is necessary.

Application

Hollow bodies with circular, rectangular or any other base surface and different outer surfaces can be produced.

In form punch deep drawing, the interior shape of the hollow body that is open at one side is given in the punch (Fig. 4.2.7.).

Die deep drawing. The exterior shape of the part to be drawn is given in the die. The compressive force is transmitted via the punch or an active medium (Fig. 4.2.9.).

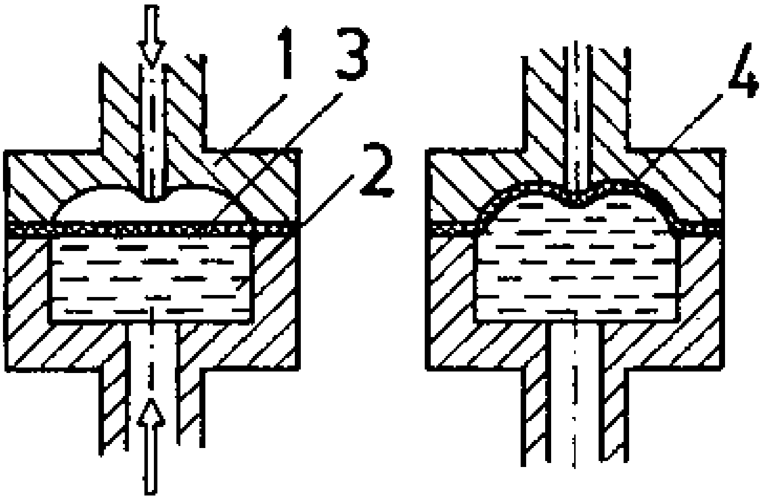


Figure 4.2.9. Deep drawing over an active medium

1 Die, 2 Active medium, 3 Sheet initial shape, 4 Sheet final shape

By virtue of this variant of the method, outer surfaces of intricate shape (e.g. car body parts) can be produced. A number of typical parts to be deep drawn are as follows:

Flanges, cups, caps, pots, boxes, sleeves, bushes, sheet−metal parts of airplanes, curved sheet−metal parts for ship−building, tank bottoms for tank cars and car body parts.

Summary:

Deep drawing is carried out in a deep−drawing tool consisting of punch, drawing−die and blank holder. The deep−drawing die exerts an influence on the external shape of the workpiece while the punch can be used to shape the interior shape. The blank holder prevents the formation of folds in the drawing process. During deep drawing, high stresses are induced in the material which may lead to the tearing off of the bottom. Therefore, drawing in several steps or stages is the usual procedure. The formation of folds is due to compressive stresses and the incorporation of the “excessive material”. Curved or hollow sheet−metal parts such as car bodies, vessels, caps, pots and boxes are produced.

4.3. Forming by Tensile Force

4.3.1. Stretching

By enlarging the surface of plates or sheet−metal due to the application of tensile forces from several directions, flatly dished sheet−metal parts (e.g. such of car bodies) are made.

Means of work

Shaping punch, clamps in stretch−drawing or expanding jaws or elastic means (rubber) in stretch−expanding are the tools.

Presses which act mechanically, pneumatically or hydraulically are used as machine tools.

Procedure

The flat sheet blank is firmly held by the clamps at the edges for stretch−drawing. Due to the compressive force of the punch, the material is stretched and changed in its shape at the same time (Fig. 4.3.1.).

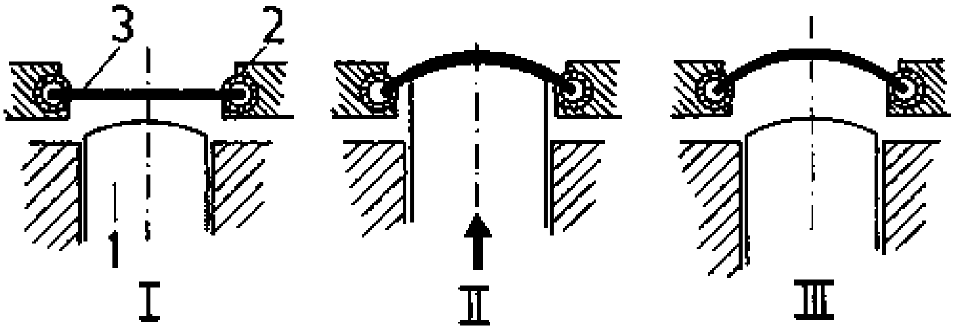


Figure 4.3.1. Procedure of stretching

I Initial position, II Intermediate position, III Finished part

1 Shaping punch, 2 Clamps, 3 Sheet metal

Application

By the variants of the method of expanding and drawing as well as embossing, convex hollow bodies (container parts), plate bodies with ducts for refrigerators or heatings, extensions at pipe ends and dished sheet−metal parts of different shapes (eg. car bodies, aeroplane parts) are produced.

Summary:

In stretching, a convex part is shaped of sheet metal by means of a shaping punch. The sheet blank is clamped at its edges. As a consequence, the surface is enlarged and the thickness of the sheet reduced.

4.4. Forming by Bending Force

4.4.1. Die Bending

Sheet−metal parts are pressed into a die while simple or multiple angles or certain shapes are transmitted to the sheet. In this way, sectional plate parts, channels, pipes and hinge parts can be produced (Fig. 4.4.1.).

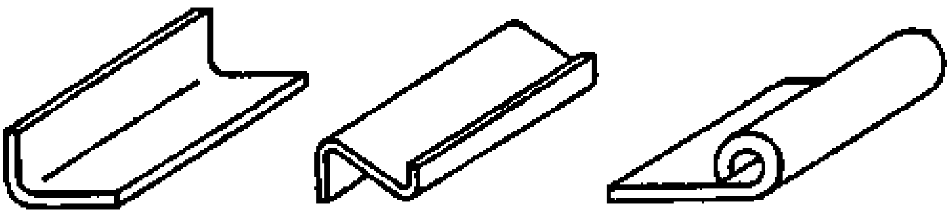


Figure 4.4.1. Workpieces produced by die bending

Means of work

Bending tools consist of the die and the bending punch. The die contains the final shape of the workpiece plus elastic recovery of the material (Fig. 4.4.2.). For longer parts to be bent, bending ledges as accessories of the bending−off press are used. The exchangeable punch can also be an accessory of bending−off presses.

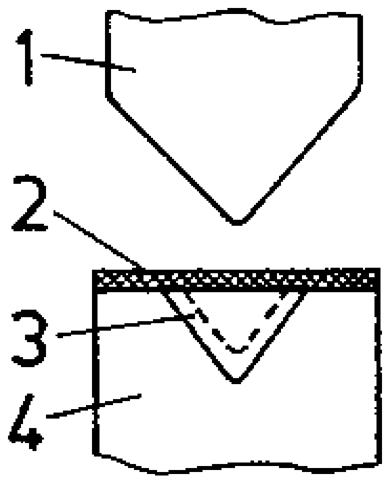


Figure 4.4.2. Die−bending tools

1 Bending punch, 2 Sheet blank, initial shape, 3 Final shape of the sheet metal, 4 Die

As bending machines, eccentric, crank−driven, friction−screw and hydraulic presses. Special bending−off presses are provided with exchangeable bending ledges, bending punch and stops.

Procedure

The plane or pre−formed sheet blank is placed in the die. The part to be bent is produced by pressing the bending punch into the mould contained in the die (Fig. 4.4.3.).

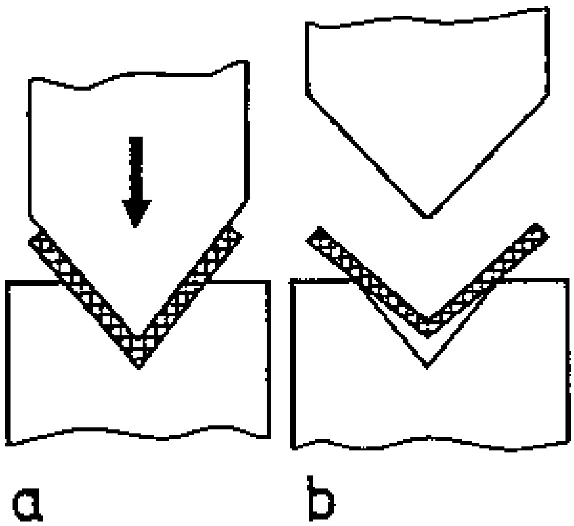


Figure 4.4.3. Procedure of die bending

a Workpiece in bending, b Finished workpiece showing the elastic recovery

During bending, the material is subjected to tension at the outside and pressure on the inside. The neutral layer located about the middle of the part is not subjected to any stress.

Since the tensile stress causes an elongation and the compressive stress an upsetting, the length of the neutral layer is retained. Therefore, it can be used for calculating the stretched length of the sheet blank. The length of the sheet blank, thus, results from the sum of the straight longitudinal sections and the sum of the sections of the neutral layer in bends.

The length of the neutral layer in bends is depending on the bending radius “R_N” and the bending angle “?“ (Fig. 4.4.4.)!

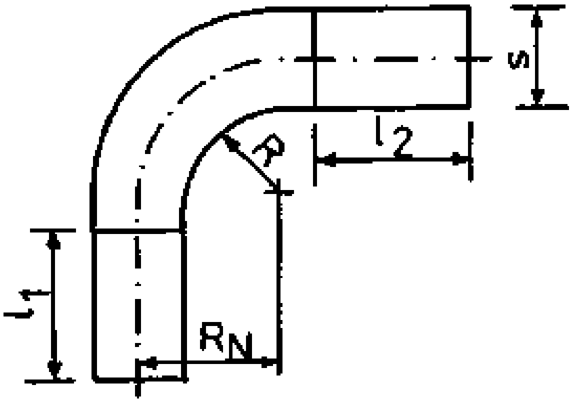


Figure 4.4.4. Characteristics in the bend

R_N bending radius of the neutral layer
R radius of the curvature
S Thickness of the part bent
l_1 and l_2 straight longitudinal sections

$$L_N = \frac{\pi \cdot R_N \cdot \alpha}{180^\circ}$$

The radius of the neutral layer “R_N” is resulting from:

$$R_N = R + \frac{1}{2}s$$ for R ? 5 • s and

$$R_N = R + \frac{1}{2}s$$ for R < 5 • s.

It should be noted that the workpiece is subject to elastic recovery, i.e. it is resilient because of its elasticity. Therefore, the bending angle must take into consideration this elastic recovery (Fig. 4.4.3.).

The elastic recovery can be reduced by considerably increasing the final bending force.

Application

Sheet blanks or pre−formed parts are bent by the variants of the method of angular bending, shape bending, flanging and roll bending.

Angular bending (bending off). V, U and Z angles or other forms are bent into sheet metal or other workpieces.

Shape bending. Sections present in a die are transmitted to sheet metal without changing the thickness of the sheet. It is used for the production of hoods, parts of containers, car body parts and parts of chemical plants.

Flanging. This method is also known as crimping and is used to produce depressions in sheet−metal parts. This increases the strength of cans, containers or car bodies (Fig. 4.4.5.).

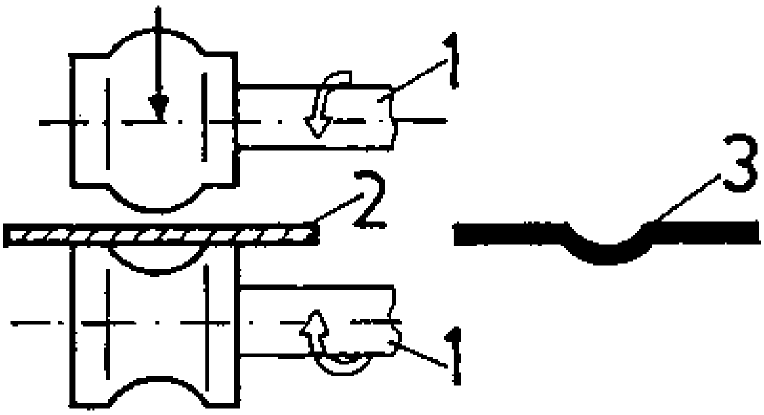


Figure 4.4.5. Crimping

1 Pair of rollers for crimping, 2 Initial shape of sheet metal, 3 Final shape of sheet metal

Roll bending. Sheet metal radii in hinges or eyes are bent be pressing in a roll tool (Fig. 4.4.6.).

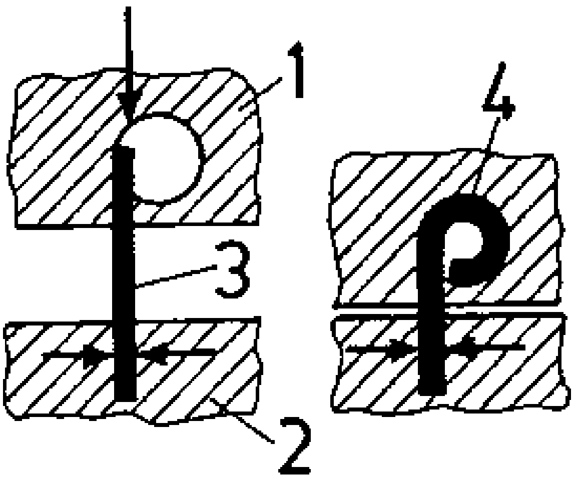


Figure 4.4.6. Roll bending

1 Die, 2 Clamping, 3 Initial shape of sheet metal, 4 Final shape of sheet metal

Summary:

Die bending is also a sheet−metal forming method. The shape to be bent (e.g. a V angle) is given in a die. The parts are pressed into the die by the pressure exerted by a punch and, thus, assume the given shape. The parts are subject to elastic recovery, this must be taken into account.

In the radii bent, the material is subjected to tension at the external edge and to compression at the internal edge. The neutral layer is not subjected to such a stress. Since the neutral layer, therefore, retains the original length, it is used for calculating the length of blanks to be bent.

The variants derived from the method, namely, angular bending, shape bending, crimping and roll bending, are employed to produce hoods, car body parts, containers and many other parts.

4.4.2. Draw−profiling

Strips or hoops of sheet metal are shaped into profiles by draw−profiling in their sections. In this way, ornamental bands, guide fillets or profile ledges for the construction industry (e.g. hand−rail of stairs) are produced. A few examples are given in Fig. 4.4.7.


Figure 4.4.7. Workpieces produced by draw−profiling

Means of work

The tools are bending dies or pairs of rolls which form a profile as roll pass. Since complicated profiles cannot be produced in one operation, frequently several dies or pairs of rolls are arranged one after another.

Draw machines are used for this method as machine tool.

Procedure

The prepared strips of sheet metal are drawn through the opening of the drawing die. In the die, the strips of sheet metal are shaped into the profile provided by the die opening while the thickness of the sheet metal is not changed (Fig. 4.4.8.).

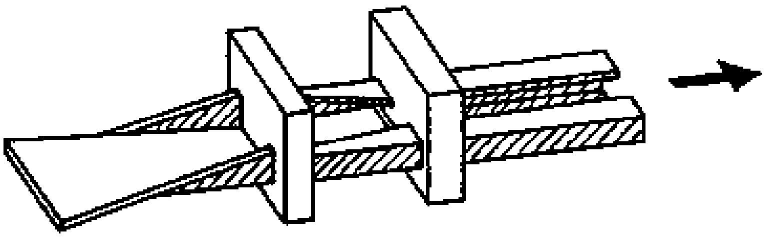


Figure 4.4.8. Procedure of draw−profiling

To reduce the remarkable tensile forces involved and the load on the material, pairs of rolls are used which provide the profile in the form of the roll pass. The number of dies or pairs of rolls to be arranged in succession is dependent on the complexity of the profile to be achieved.

Application

In accordance with the tools used, a distinction is made between sliding draw−profiling and rolling draw−profiling.

Sliding draw−profiling. Drawing dies are used. In accordance with the high tensile occuring, simple profiles are shaped of thin sheet metal. Examples are different profiles in the construction industry and automotive industry required for doors, windows, ornamental borders and cover strips.

Rolling draw−profiling. The reduction of the forming force by the use of draw−rolls enables the production of more complicated profiles and the shaping of sheet metal of higher thicknesses. Several pairs of rolls arranged in succession are conducive to this procedure. In this way, stronger profiles are provided for the construction industry, automotive industry and the construction of various equipment (Fig. 4.4.9.).

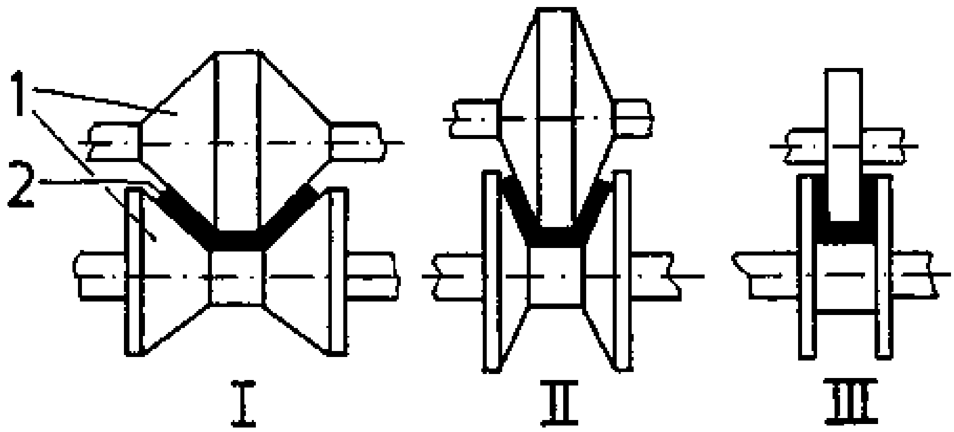


Figure 4.4.9. Rolling draw−profiling

1 Profiled rolls, 2 Workpiece

I, II, III roll pairs arranged one after the other

Summary:

When drawing strips of sheet metal through the profiled opening of dies, profiled fillets or strips are obtained. When using pairs of rolls, the forces can be reduced.

4.4.3. Bending Off

By bending off about a pivot, short plate profiles, pipes or springs can be bent (Fig. 4.4.10.).

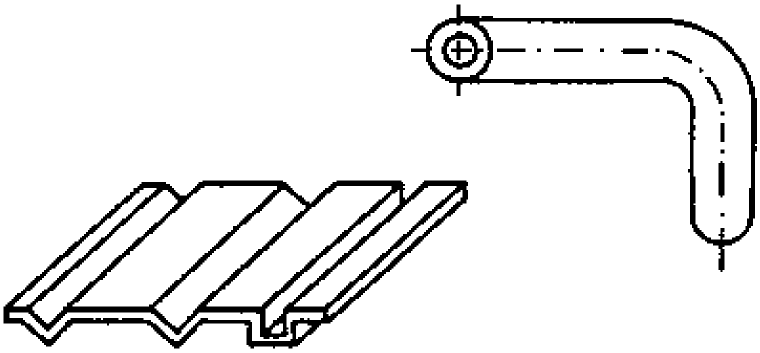


Figure 4.4.10. Examples of bending off

Means of work

As for bending off sheet metal, bending tools of intricate shape are used. They consist of bending cheek, lower cheek, upper cheek, support and stop (Fig. 4.4.11.).

Devices with bending rolls are used for bending pipes.

The bending forces required are produced by bending−off machines.

Smaller bends are also made manually on the bending−off bench.

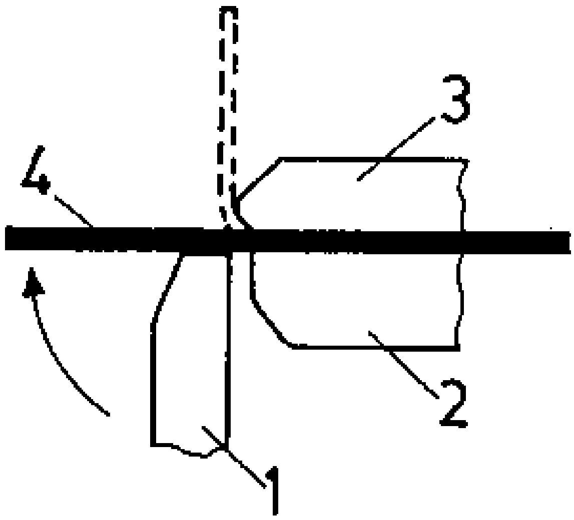


Figure 4.4.11. Bending−off tools

1 Bending cheek,
2 Lower cheek,
3 Upper cheek,
4 Workpiece

Procedure

By means of the slewable bending cheek, the sheet metal is bent round the edge the upper cheek over the entire width and at the same time (Fig. 4.4.11.).

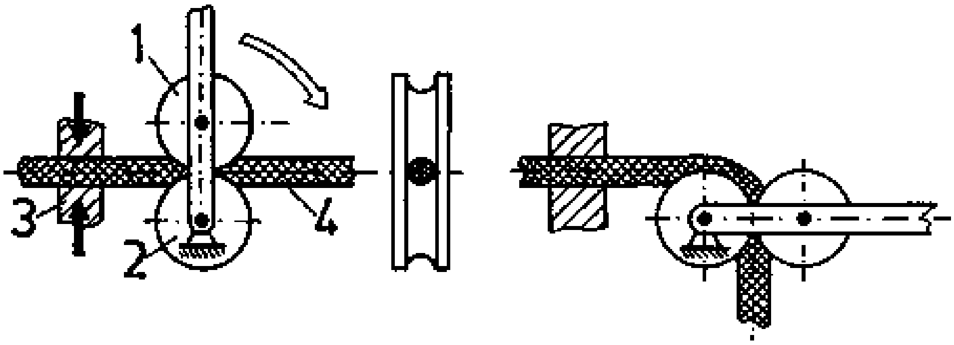


Figure 4.4.12. Procedure in pipe bending

1 Bending roll, 2 fixed roll, 3 Clamping 4 Pipe

For bending pipes, a bending roll is moved about the stationary roll. The two rolls form a closed roll pass. In order to avoid deformations of the cross−section of pipes, the pipes are frequently filled (e.g. with sand) (Fig. 4.4.12.).

Application

Swing−bending. Short sheet−metal profiles or pipe bends are made by means of bending−off machines or other equipment.

Coiling. Production of spiral springs with a radial pitch.

Winding. Production of helical springs for tension or compression and axial pitch. Round bending. Production of hoops or radii of plates, rods or profiled parts. Straightening. Straightening of rolled semifinished products, straightening of distorted sheet metal, straightening of distorted shafts, axles or sections.

Summary:

Bends with very small or larger radii are produced by bending off about a pivot. For this purpose, bending tools with bending cheek, upper cheek and lower cheek are used. For the bending of pipes into coils and the like, a special device with rolls is used.

4.5. Forming by Shearing Force

4.5.1. Displacing and Twisting

Parts of workpieces are displaced or twisted across the main axis in parallel motion. Displaced profiles, stops or shoulders or twisted profiles of a decorative effect are obtained (Fig. 4.5.1.).

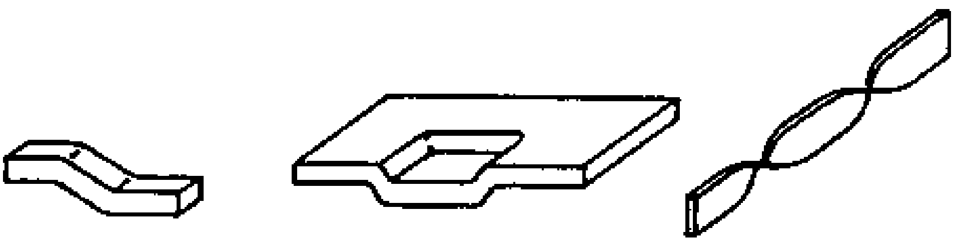


Figure 4.5.1. Examples of Displacing and Twisting

Means of work

Hammers or presses, twisting forks and clamping devices are the means of work which, sometimes, are quite simple.

Procedure

By the parallel displacement of parts of material or by the twisting of the cross−section, considerable shearing stresses or torsional stresses are produced in the workpiece. Frequently, these stresses must be removed by annealing. Fig. 4.5.2. shows the displacement and Fig. 4.5.3 the twisting.

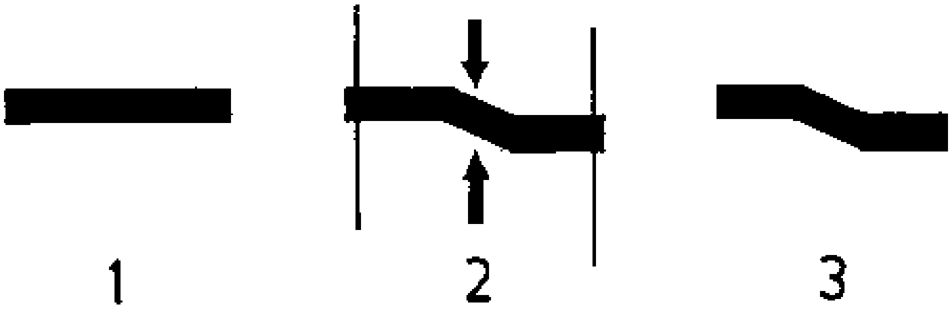


Figure 4.5.2. Procedure of displacing

1 Initial shape of the workpiece, 2 Action of the tool, 3 Final shape of the workpiece

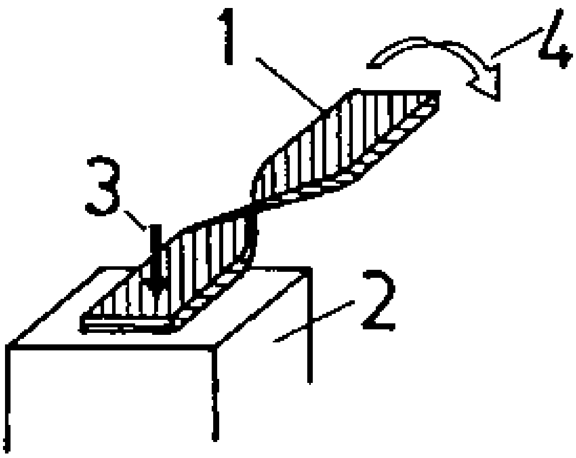


Figure 4.5.3. Procedure of twisting

1 Workpiece, 2 Support,
3 Clamping force,
4 Torque

Application

The displacement of workpieces is used for stiffening, stops or lap joints. Hand−rails or columns are twisted for decorative purpose. Crankshaft. pins are twisted against one another. This procedure is effected immediately after forging in many cases.

Summary:

The material can be displaced parallely or twisted. In this way, offsets or twisted profiles are obtained.

Control Questions

4.1. Why is hammer forging mainly carried out in the hot state and what is the temperature required for this purpose?

4.2. What are the advantages offered by drop or die forging?

4.3. What do you understand by step die and what is the purpose for which it is used?

4.4. How is the volume of the blank determined that is to be die−forged?

4.5. How is the relationship between punch motion and material flow in uniform, opposite and mixed flow−extrusion?

4.6. How can energy be saved in extruding?

4.7. Describe the basic shapes of workpieces which are produced by rolling!

4.8. Explain the terms of roll pass and rolling train!

4.9. What are the changes that can be achieved in a workpiece by flow−forming?

4.10. What are the measures by which friction can be reduced when drawing, namely, the friction between drawing die and workpiece?

4.11. Describe the method of strand drawing!

4.12. What are the tasks of the blank holder in deep drawing?

4.13. What are the basic parts of the deep drawing tool?

4.14. What are the causes of fold formation on deep drawing?

4.15. What are the parts for which die deep drawing is particularly suitable?

4.16. Why is stretching a method of forming by drawing?

4.17. What are the parts that can be produced by stretching?

4.18. What are the parts of which a bending tool consists?

4.19. What are the stresses to which a material is subjected in bends?

4.20. How can the length of a blank to be bent be determined?

4.21. What is a crimp and what is the reason for which parts of sheet metal are subjected to crimping?

4.22. What are the possibilities of profiling thicker plates and producing more complicated profiles?

4.23. What are the parts of which a bending tool for bending off sheet metal consists?

4.24. How are pipes bent without changing their section significantly?

4.25. What is the difference between displacement and twisting?