Textbook for Vocational Training – Vocational Foundations of Metal Working

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Textbook for Vocational Training – Vocational Foundations of Metal Working

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Preface

The textbook "Metalworking techniques" contains the basic vocational knowledge for all trainees of metalworking professions.

By the consequent consideration of the principle of unity between theoretical and practical knowledge, it can be used as an educational manual by the trainees both during theoretical lessons and practical vocational training.

The textbook explains the most important manual metalworking techniques in a clear and comprehensible way. It describes design and function of the tools required for these techniques as well as their manipulation.

Numerous figures facilitate the trainees to understand correctly the explained problems. In order to find out easily the most essential facts, rules were indicated which are marked with a vertical beam ▌ preceding the text. The chapters contain test questions, which are oriented to the main points of the educational aims for metalworking professions. At the same time, the trainees are able to check their knowledge independently.

At the end of each chapter, the subject is summarized, as indicated in the contents.

Important labour safety and fire protection rules are marked with a double beam ‖ in order to find them out at a glance.

1. Checking and marking−out

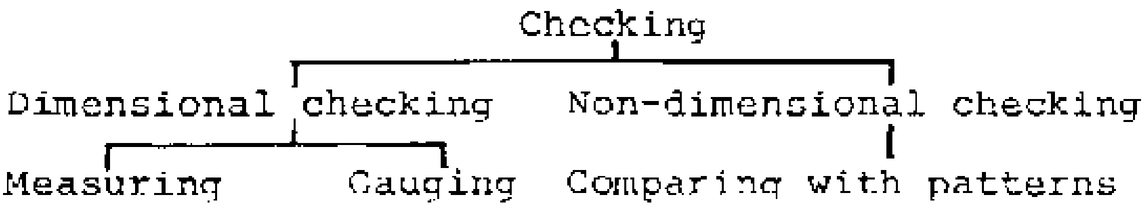
1.1. Checking

Workpieces are made mostly in several working operations according to the data in an engineering drawing. To ensure that the dimensions and shapes given in the drawing are maintained, the workpiece shall be checked during the work and after each operation. The result of checking must coincide with data indicated in the drawing.

Thorough checking ensures that the parts of a product fit perfectly when they are assembled.

Certain properties, as for example the surface condition often play a decisive part for the quality of a product. These properties must also be checked.

The checking processes are divided into dimensional and non−dimensional ones. The dimensional checking processes comprise measuring and gauging, and the non−dimensional comprise comparing with patterns.



1.1.1. Measuring

Measuring serves to check the dimensions of a workpiece. It is carried out by means of measuring tools which are provided with a graduation. The measuring tools are divided into length measuring tools and angular measuring tools.

Length measuring tools

The internationally binding unit of measurement for the graduation of measuring tools for length measurement is the metre (m). It is subdivided into centimetre (cm) and millimetre (mm) with the following relationship:

1m = 10 . 10 cm = 100 cm;
1 cm = 10 mm;
1m = 1000 mm

The simplest length measuring tools are steel rule, folding rule and steel tape rule.

The steel rule (fig. 1.1/1) has a length of 300 mm or 500 mm.

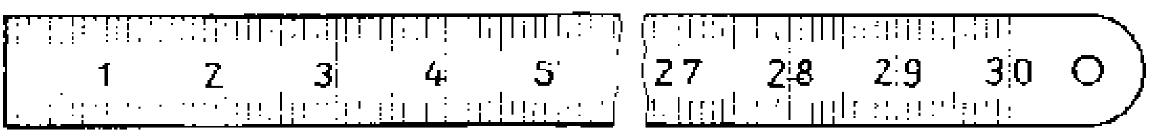


Figure 1.1/1 Steel rule, 300 mm long

The lengths of the folding rule (fig. 1.1/2)

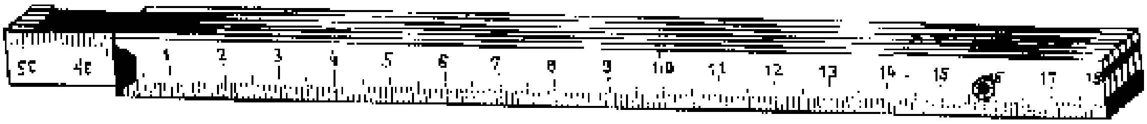


Fig. 1.1/2 Folding rule, folded

Folding rule, folded and the steel tape rule (fig. 1.1/3) are 1000 or 2000 mm. All three measuring tools show graduations in centimetre and millimetre. The reading accuracy is 1 mm, half millimetres (0.5 mm) can be estimated.

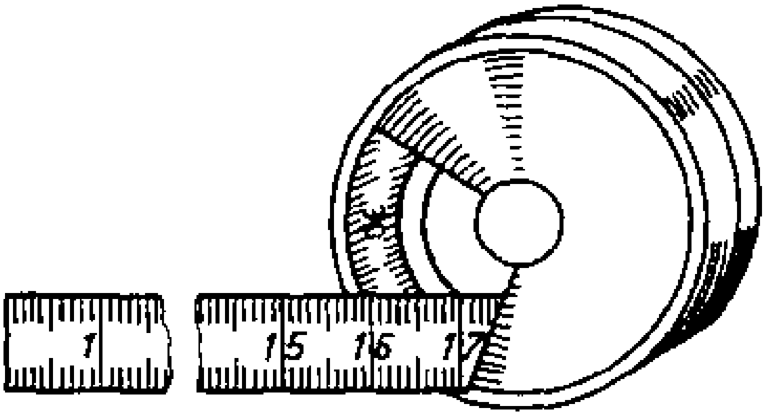


Fig. 1.1/3 Steel tape rule

To avoid measuring errors, the following rules shall be observed during measuring:

- The zero mark of the rule must end with the edge of the workpiece (fig. 1.1/4). The rule shall be applied rectangularly to the edge from where is measured (fig. 1.1/5). Always look perpendicular to the dimension to be read off (fig. 1.1/6).

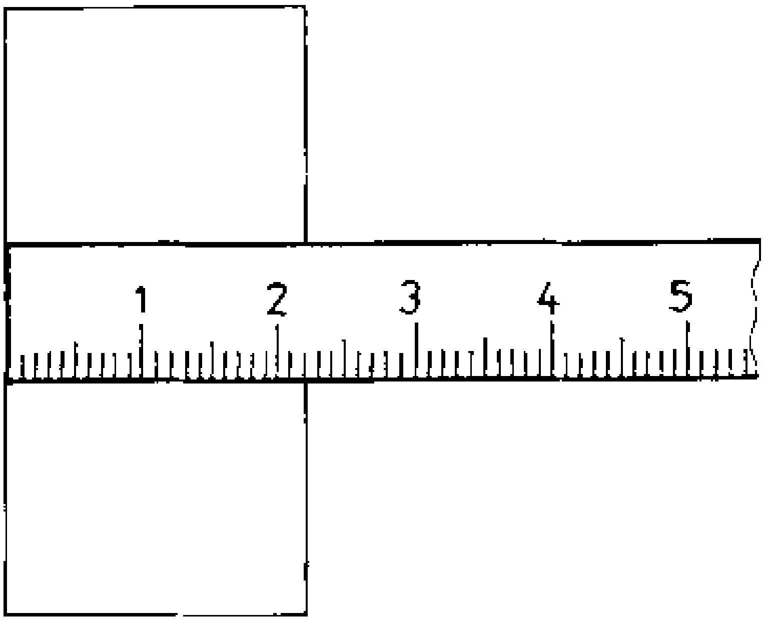


Fig. 1.1/4 Correctly applied rule, starting point of the rule and workpiece edge coincide

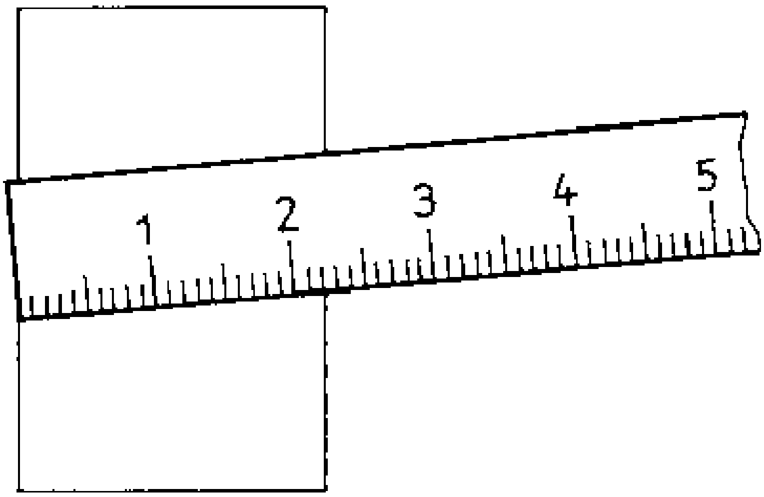


Fig. 1.1/5 Rule is applied obliquely, a wrong size is read off

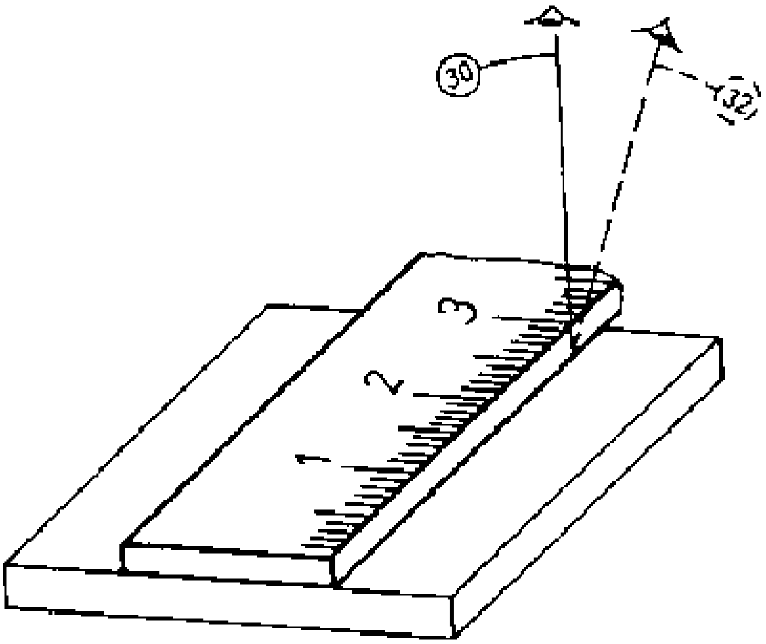


Fig. 1.1/6 Reading error because of oblique visual angle

Task:

1.1. Compare the dimensions to be read off in figs. 1.1/4 and fig. 1.1/5! Which dimensional variation do you find in fig. 1.1/5?

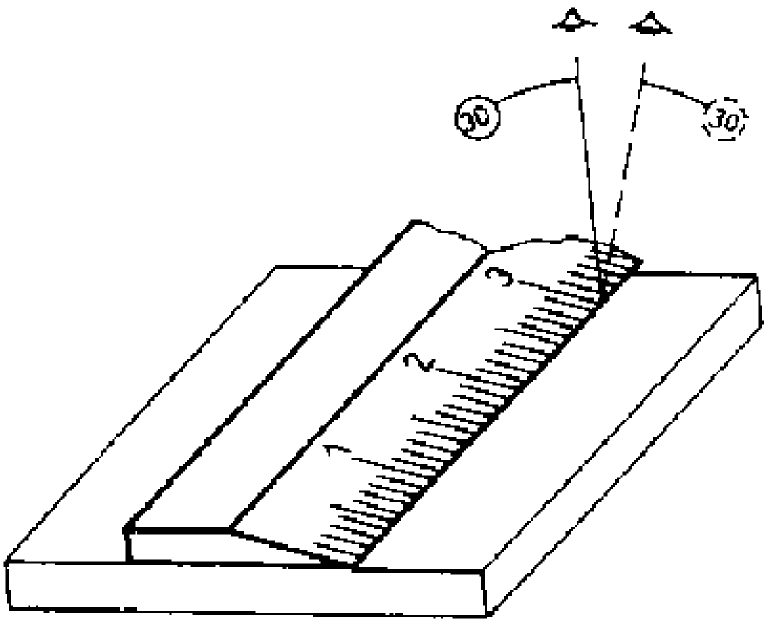


Fig. 1.1/7 If the graduation is on a bevelled surface (bevel), the reading error shown in fig. 1/6 can be avoided.

Measuring with the steel rule: For measuring short lengths, the steel rule is given preference in metalworking. It is handier and its graduation is preciser than the ones of folding rule and steel tape rule.

When a workpiece with bevelled or rounded edge shall be measured, a back square is to be used as reference edge for the rule (fig. 1.1/8).

Measuring with folding rule and steel tape rule: In metalworking, these measuring tools are only used for measuring long lengths and for such workpieces which shall not meet high demands of measuring accuracy, for example for measuring rough dimensions (lengths of unmachined work−pieces).

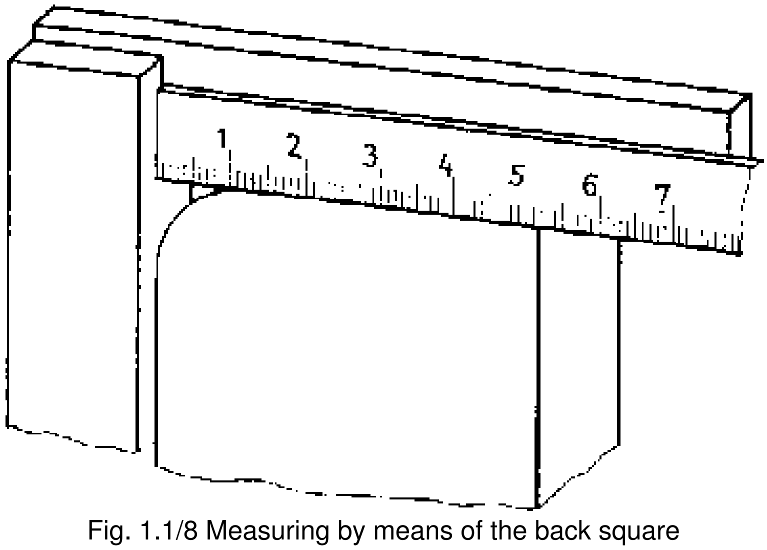


Fig. 1.1/8 Measuring by means of the back square

When measuring with the folding rule, make sure that it is completely extended, otherwise a longer length then the really existing one is measured (figs. 1.1/9 and 1.1/10).

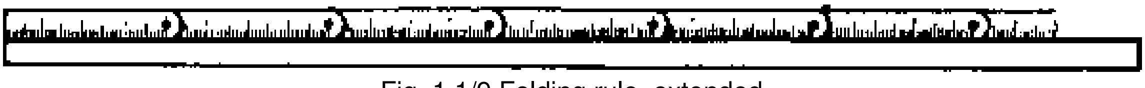


Fig. 1.1/9 Folding rule, extended

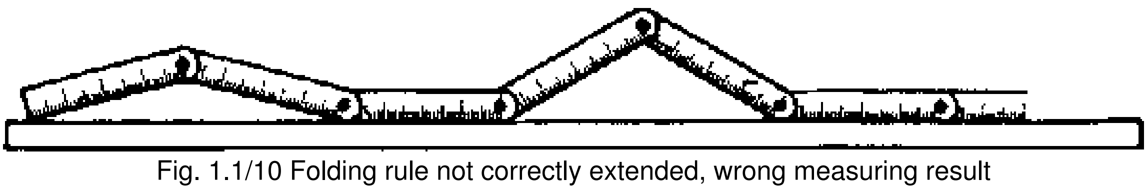


Fig. 1.1/10 Folding rule not correctly extended, wrong measuring result

Steel tape rules have often a small sheet−metal angle which makes it easy to apply it at the workpiece edge (fig. 1.1/11).

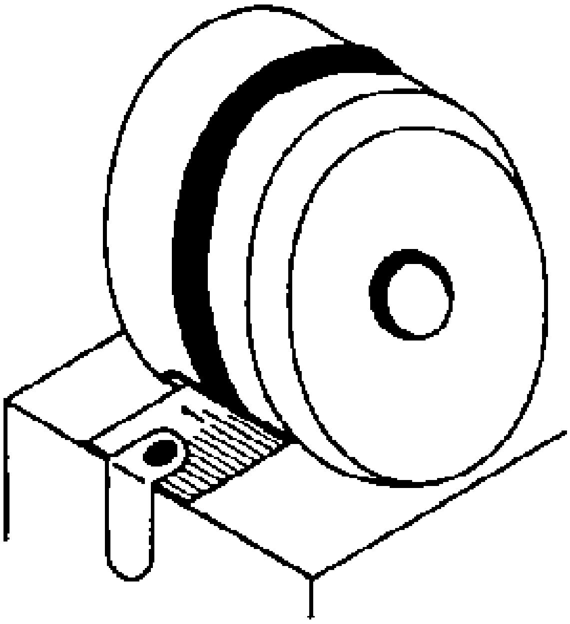


Fig. 1.1/11 Steel tape rule applied to a work−piece edge

Measuring with the vernier caliper: While steel rule, folding rule and steel tape rule belong to the non−adjustable measuring tools, the vernier caliper is an adjustable measuring tool. It allows a precise measurement of 0.1 mm. Its measuring range amounts either to 160 mm or to 320 mm. The vernier caliper is used when dimensions on relatively small workpieces shall be determined as precisely as possible. The vernier caliper consists of a beam with fixed jaw and a sliding member with sliding jaw (fig. 1.1/12). A clamping screw or clip serves to clamp the sliding member. The jaws, for example, allow to measure the diameter of a bolt (external measurement, fig. 1.1/13). The upper parts of the jaws are shaped as measuring edges (cf. fig. 1.1/12). By using them, for example, the diameter of a hole can be determined (internal measurement, fig. 1.1/14). At the back end of the beam, the depth gauge is provided (cf. fig. 1.1/12) which allows the measurement of the depth of a hole (depth measurement, fig. 1.1/15). The graduation on the beam of the vernier caliper is given in millimetres (mm) (main graduation). Another graduation is on the sliding member which is designated as vernier. The vernier has 10 parts over a length of 9 mm. Thus it is possible to read off the tenth of a millimetre. When both jaws touch each other, the zero mark of the vernier and the zero mark of the main graduation are exactly one upon the other (fig. 1.1/16a). When the zero mark of the vernier coincides with a mark of the main graduation, the zero mark of the vernier indicates the precise dimension in whole millimetres. With the measurement shown in fig. 1.1/16b, the diameter of the bolt is exactly 15 mm. In fig. 1.1/16c, the zero mark of the vernier lies between two marks of the main graduation. In this case, the dimension to be determined should be between 17 and 18 mm. Now the mark is looked for on the vernier, which coincides with a mark of the main graduation. In fig. 1.1/16c, this is the fifth mark of the vernier; the zero mark is not counted in this connection. Thus, the precise dimension is 17.5 mm.

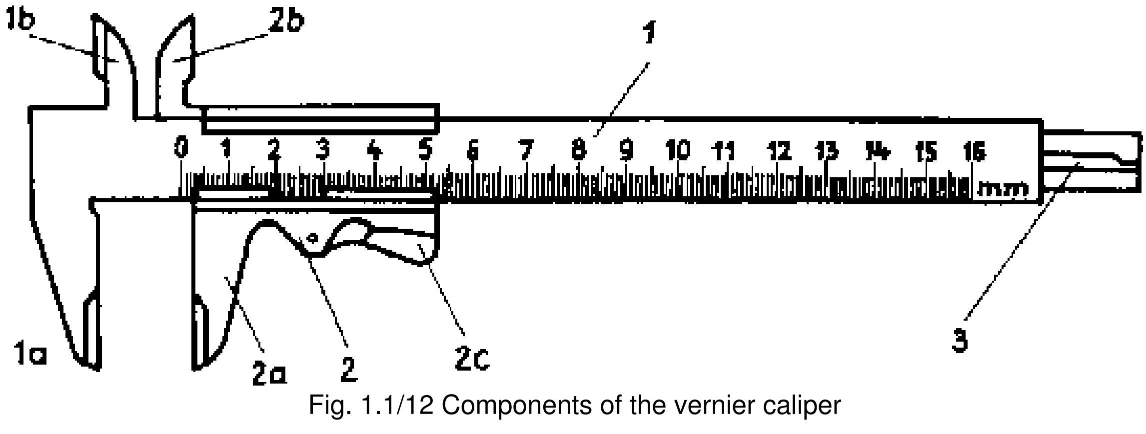


Fig. 1.1/12 Components of the vernier caliper

1 Beam, la Fixed jaw, 1b Fixed measuring edge, 2 Sliding member, 2a Sliding jaw, 2b Sliding measuring edge, 2c Clamping clip, 3 Depth gauge

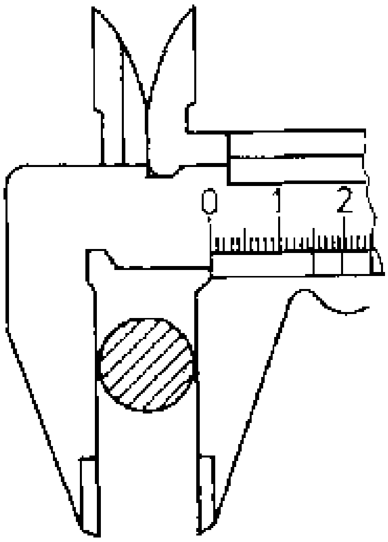


Fig. 1.1/13 External measurement

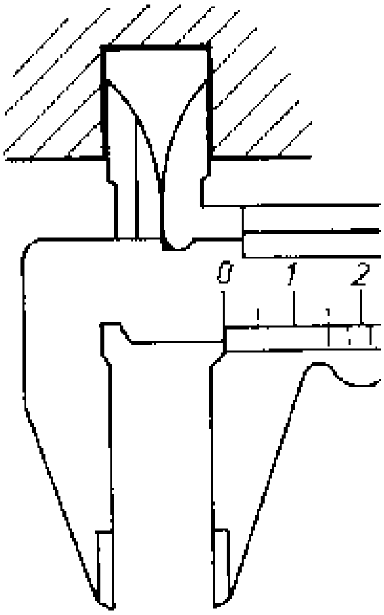


Fig. 1.1/14 Internal measurement

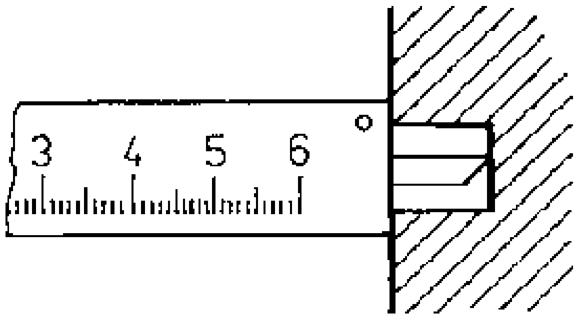


Fig. 1.1/15 Depth measurement

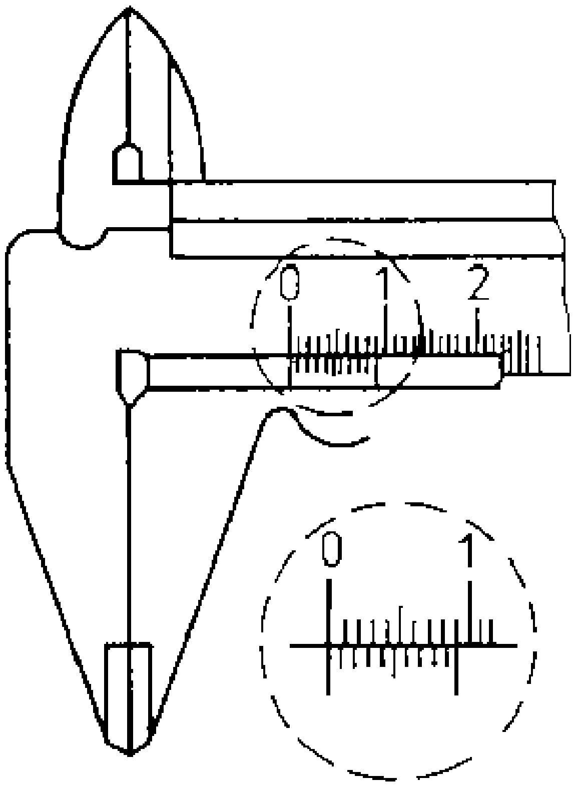


Fig. 1.1/16 a

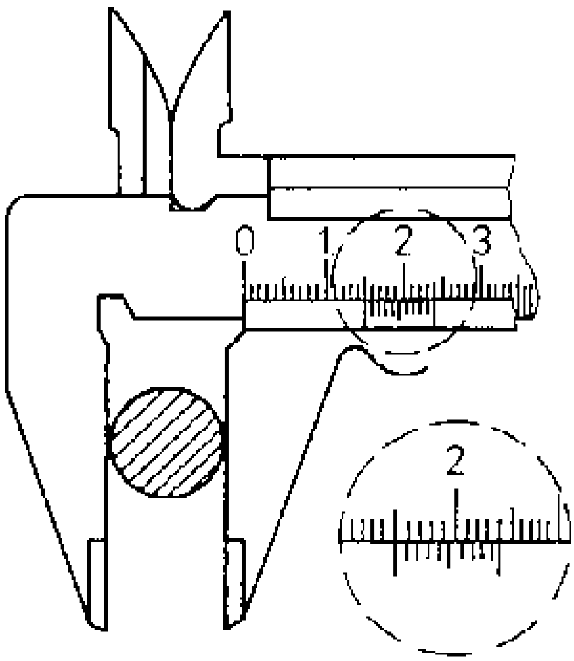


Fig. 1.1/16 b

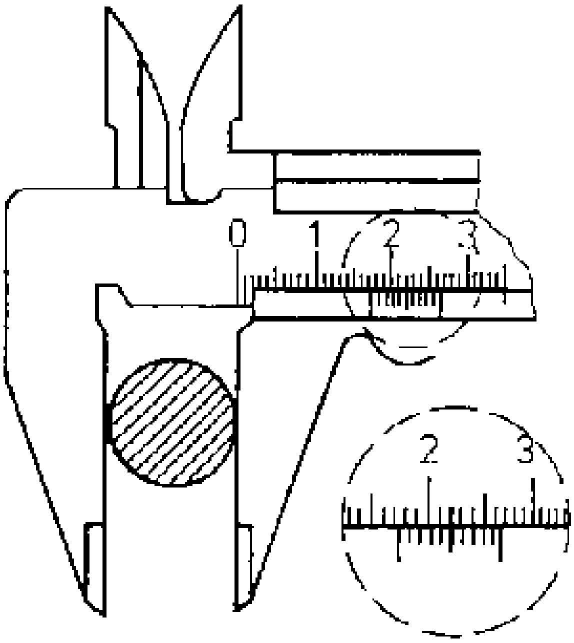


Fig. 1.1/16 c

How dimensions are read off:

Determine the whole millimetres on the beam (left of the zero mark of the vernier);

Look for the coinciding marks of vernier and main graduation;

Count the vernier part marks (without zero mark) until both marks coincide (tenth millimetre);

Add whole millimetre and tenth millimetre;

Task:

1.2. Set the following dimensions on the vernier caliper:

18.0 mm; 7.0 mm; 13.2 mm; 5.7 mm!

1.3. Determine the settings in fig. 1.1/17!

When measuring with the vernier caliper, the workpiece is applied at the fixed jaw. Then, the sliding jaw is slightly pressed against the workpiece. Now the dimension can be read off.

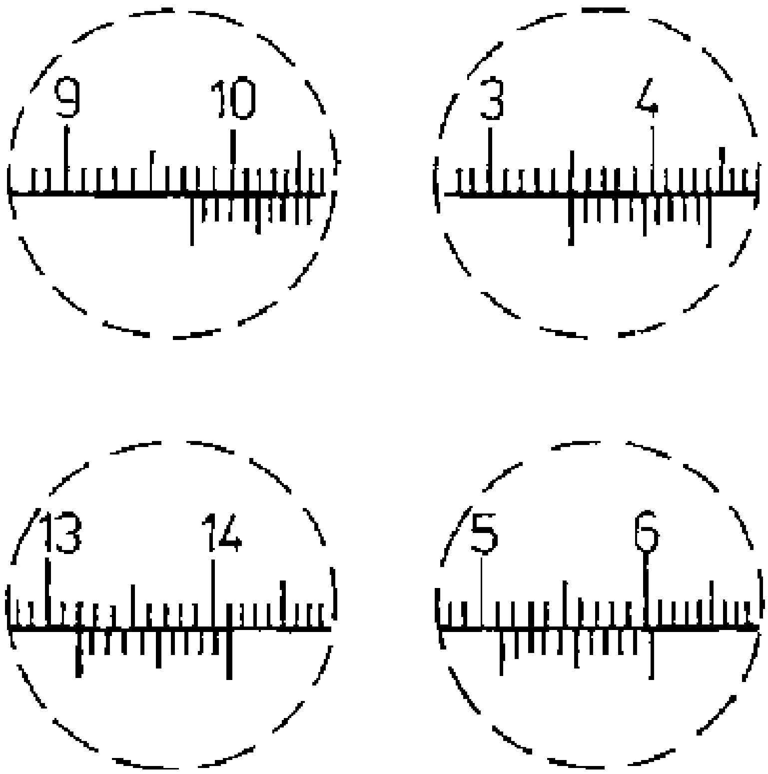


Fig. 1.1/17

<u>Measuring errors</u> when measuring with the vernier caliper can result for example from

- – inaccurate reading off (human errors);
- – application of variable measuring force during pressing the jaw (measuring force error);
- – tilting the sliding jaw; this occurs when it is measured at the ends of the jaws (tool error);
- – temperature effects; different materials –different thermal expansion (environmental error).

▌ The selection of the adequate length measuring tool depends on the length to be checked and the dimensional accuracy required.

Task:

1.4. List in a survey measuring range and measuring accuracy of the length measuring tools you know!

<u>Tools for angular measurement</u>

The generally applied unit of measurement for the graduation on tools for angular measurement is the degree (°). It is subdivided into minutes (') and seconds ("), with the following relationship:

1° = 60'; 1' = 60"; 1° = 3600"

Angles, for which an accuracy of 1° is demanded, are measured with the <u>simple goniometer</u>. Even half degrees (0.5°) can be well estimated.

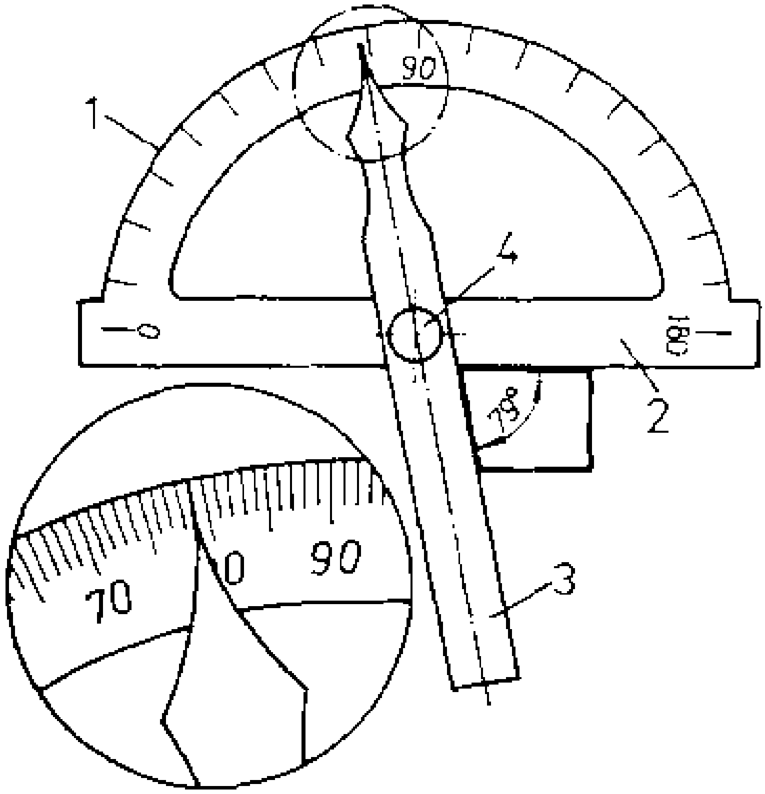


Fig. 1.1/18 Direct angular measurement with the adjustable goniometer

1 Angle scale, 2 Stop, 3 Movable jaw with pointer, 4 Clamping screw

With this goniometer, the graduation in angular degrees is arranged semicircularly. A movable jaw is provided for applying it at the work–piece. This jaw ends in its upper part into a tip (pointer) (fig. 1.1/18). Thus, the goniometer belongs to the adjustable measuring tools.

When the workpiece is placed at the right side of the jaw at the stop and the jaw applied at the workpiece edge and clamped there, the angular degree can be immediately read off on the angular scale (direct angular measurement).

The angle to be checked in fig. 1.1/18 is 65°. When the angle of the workpiece to be checked is included between stop and left side of the jaw, the size of the angle shall be calculated as follows:

180° – indicated degrees = size of the angle

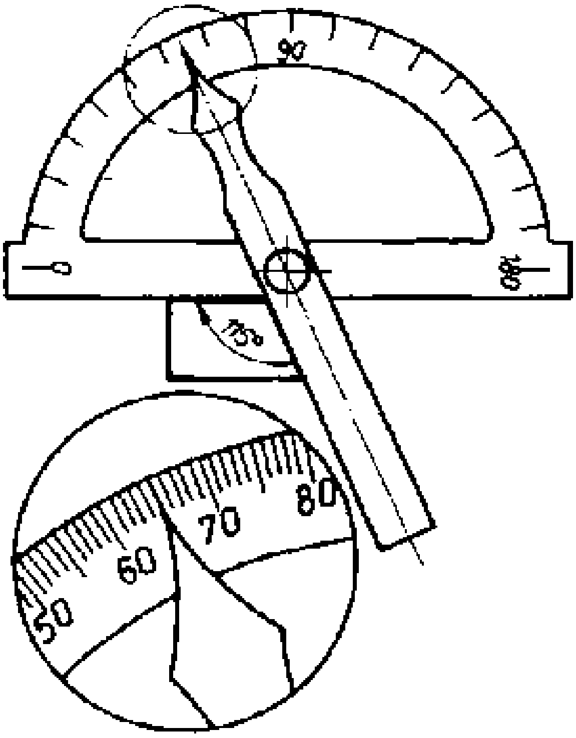


Fig. 1.1/19 Indirect angular measurement

This case is an example of indirect angular measurement. In fig. 1.1/19, the angle to be checked is

180° − 54° = 126°.

When checking with the goniometer, it is distinguished between direct and indirect angular measurement.

Task:

1.5. After having put a workpiece angle to the left side of the jaw, 37° are read off on the goniometer graduation. Which is the size of the angle to be checked?

In order to manufacture quality products it is necessary that the verifier avoids all errors which he can influence by himself. Moreover, the accuracy of checking tools shall be checked in frequent intervals.

When measuring with the goniometer, the same measuring errors can occur as with the vernier caliper.

Task:

1.6. Quote measuring errors and explain which errors can be avoided!
1.7. Which facts do you take into consideration during measuring?

For checking the most frequently existing angular sizes 90 and 45, an angle gauge is used instead of the goniometer (cf. chapter 1.1.2., section profile gauges).

1.1.2. Gauging

When gauging, it is distinguished between <u>limit gauges</u> and <u>profile gauges</u>.

<u>Limit gauges</u>

In many cases it is more time−saving to use checking tools without graduation for checking the dimensions of a workpiece. These checking tools are called gauges. The checking method is also called gauging.

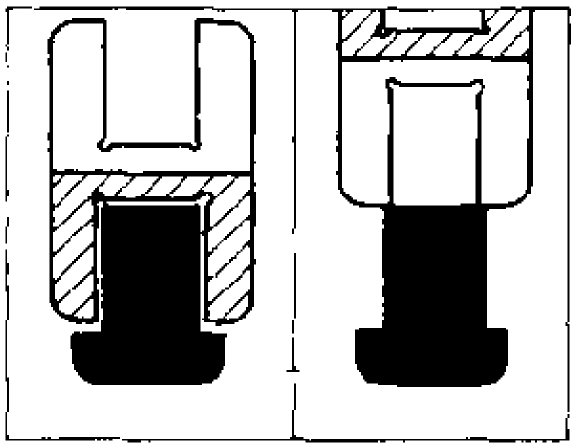
Gauging means comparing with a dimensionally accurate counterpart whether a certain dimension was maintained at a workpiece or not.

Gauging is especially advantageous when a large number of workpieces with the same dimensions shall be manufactured. According to the different types of the workpieces to be checked, there are also different kinds of gauges available. For example, lengths of workpieces can be checked with the flat gauge (fig. 1.1/20). The plate gauge (fig. 1.1/21 serves to check the thickness of plates and sheets and the wire gauge (fig. 1.1/22) to check the gauge of wires.

<u>Profile gauges</u>

Profile gauges serve to check whether a work–piece deviates from a given shape or not.

This given shape can be for example a right angle (90°), or a certain radius.



a b

Fig. 1.1/20 Checking with the flat gauge

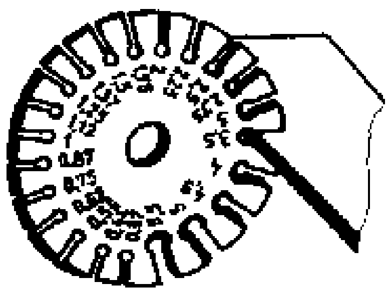


Fig. 1.1/21 Checking with the plate gauge

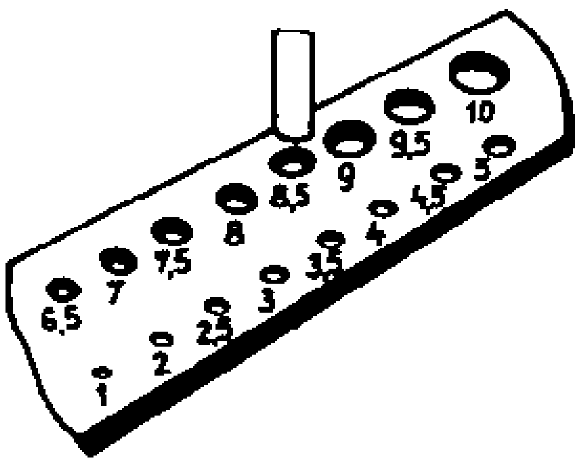


Fig. 1.1/22 Checking with the wire gauge

For example, the thin steel try square is used for checking right angles (fig. 1.1/23), and the radius gauge for checking radii (fig. 1.1/24).

In both cases, the light gap testing method is applied (fig. 1,1/25 and fig. 1.1/26). In doing so, the workpiece is held against the light with the profile gauge applied. A uniform light gap indicates a good working result.

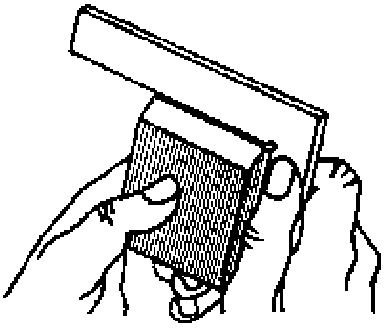


Fig. 1.1/23 Checking with the thin steel try square

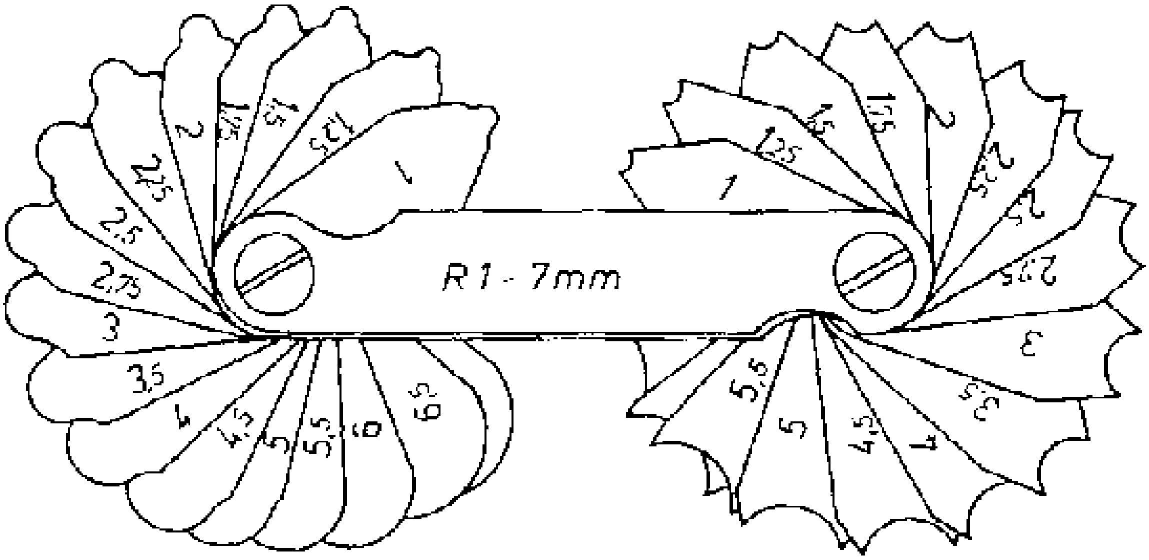


Fig. 1.1/24 Radius gauge

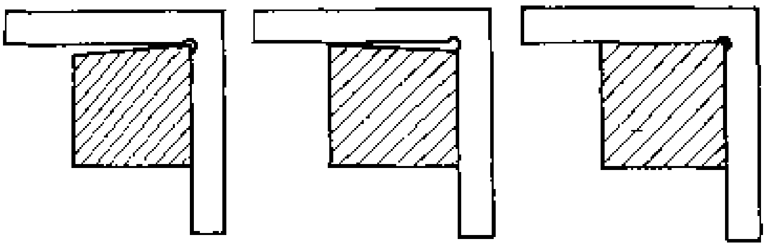


Fig. 1.1/25 Judgement of an angle with the light gap testing method

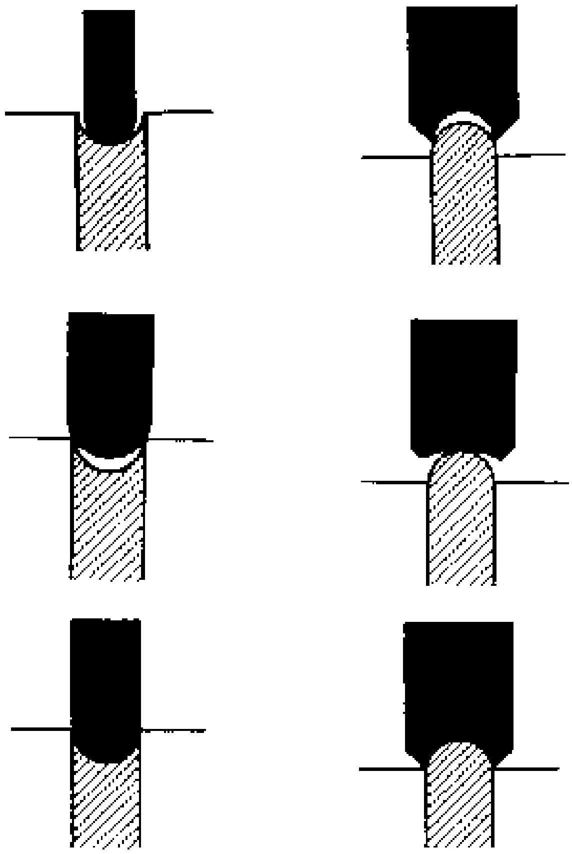


Fig. 1.1/26 Judgement of a radius with the light gap testing method

Task:

1.8. Give reasons why in certain cases it is more useful to apply gauges instead of measuring tools!

1.1.3. Care and storage of the checking tools

Checking tools must be handled especially carefully. They are sensitive and expensive.

▌ Put down checking tools always on a clean cloth or a felt plate! Do not touch the measuring surface because the sweat of your hand causes rusting!

Do not slide the measuring surfaces of vernier calipers, angles etc. over the work–pieces, just put them on the latter; otherwise the measuring surfaces wear and become uneven!

Clean the measuring tools after use, grease thinly with vaseline and store them in wooden boxes or cases!

Store checking tools always separated from other tools.

1.1.4. Comparing with patterns

▌ Comparing with a pattern belongs to non–dimensional checking.

It comprises for example

- Checking by eye (visual checking)
- Checking by ear (listening)
- Checking by the fingers (feeling) (cf. table 1.1.)

Comparing with patterns requires much practical experience.

Visual checking: By visual checking, both the shape of a workpiece and its surface condition can be compared with a pattern.

Listening: By the sound of a workpiece one can hear whether it Is undamaged or shows a crack (fissure). Also hard steel can be distinguished from soft steel by the sound, and quiet running of motors can by judged by listening.

Feeling: When a workpiece is worked with the file a file stroke is produced. When a certain requirement is put to the quality of the filed surface, this file stroke should not be felt. By feeling (thumb one's glass) it can be found out whether the file stroke is still to be felt or not.

Tasks:

1.9. Allocate further checking tools you know to the table. Indicate their application!

1.10. Arrange the known checking tools according to non−adjustable and adjustable checking tools!

1.11. Which kinds of measurements can be made by means of the vernier caliper? State at least one example for each kind!

Summary

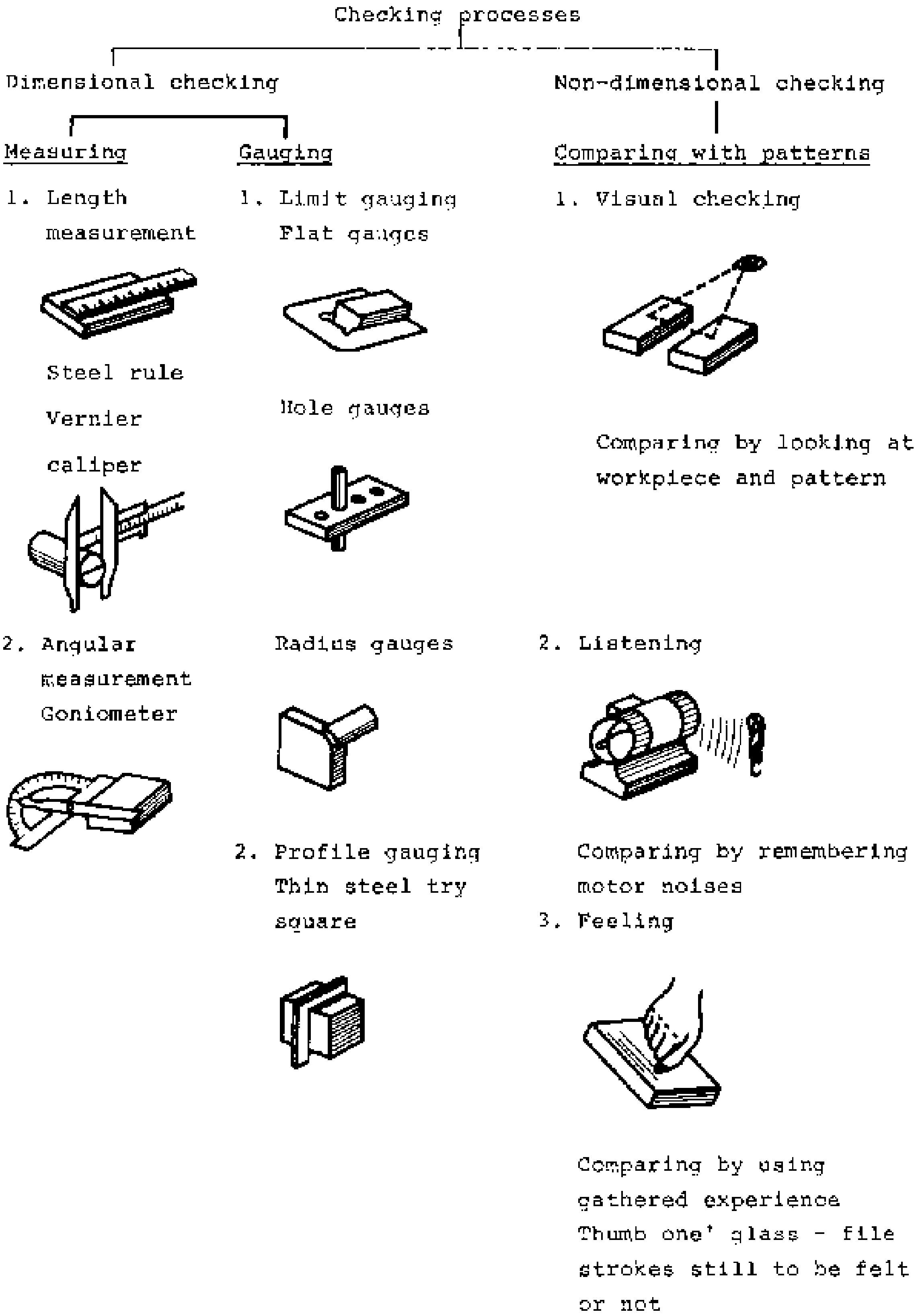


Table 1.1.

1.2. Marking–out

Marking–out is an important preparation for working a workpiece. In this connection, shapes and dimensions of the workpiece as well as penetrations, holes etc. which are to be worked, are exactly transmitted from the engineering drawing to the surface of the workpiece (fig. 1.2/1).

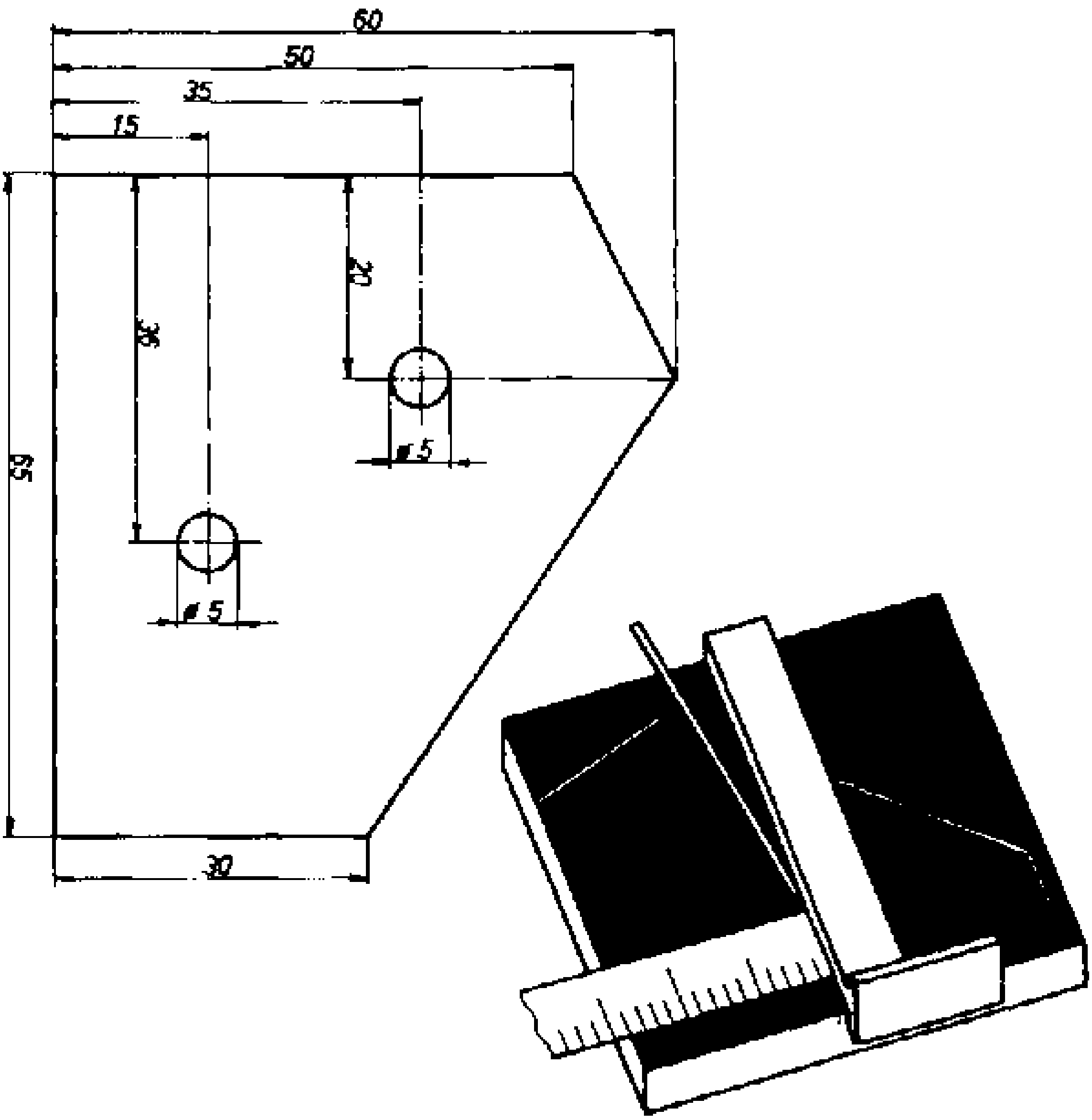


Fig. 1.2/1 Marking–out according to drawing

▌ Careful and precise marking–out according to the production influences the production time and the quality of workpiece to a high degree.

Workpieces can become useless by wrong marking–out. Valuable materials and working time are wasted.

1.2.1. Marking–out methods

The marking–out methods can be divided into three groups:

Marking–out from reference edges or reference lines	Marking–out from a reference face	Marking–out with stencil

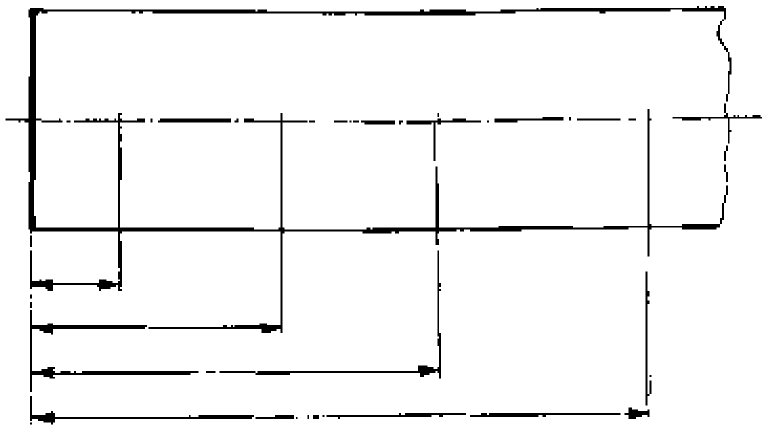
Such a division does not exclude that several marking–out methods are combined or that marking–out is carried out from several reference edges, lines or faces according to how complicated the workpiece is.

▌ Those edges, lines or faces are designated as reference edges, reference lines or reference faces which are used to mark off the dimensions and to which all dimensions are refered.

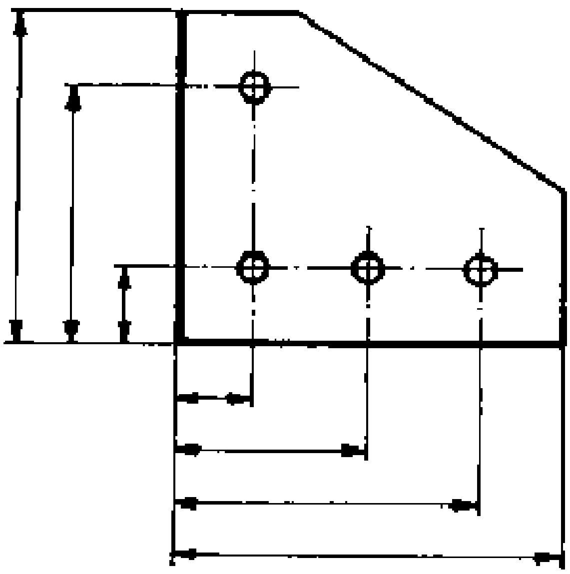
<u>Marking–out from a reference edge or reference line</u>

When marking–out, one proceeds in most cases from one reference edge or from two reference edges (fig. 1.2/2). If there is no suitable reference edge at the raw piece, it can be made by filing or shearing or a reference line is marked out. In some cases, one proceeds from a reference edge and from a reference line (for example, centre line, fig. 1.2/3). The most usual marking−out tools for this marking−out process are scriber, steel rule, back square or thin steel try square and steel straightedge (figs. 1.2/4a and b). The steel rule is used for marking−off the dimensions. It is always applied at the reference edge or reference line with the dimension to be marked off (graduation mark) and the dimension is marked out at the zero edge. In doing so, the steel rule and the back square can be applied at the same reference edge (fig. 1.2/4a) or at two reference edges which are at right angles to each other (fig. 1.2/4b).

Fig. 1.2/2



a) Dimensioning from a reference edge



b) Dimensioning from two reference edges

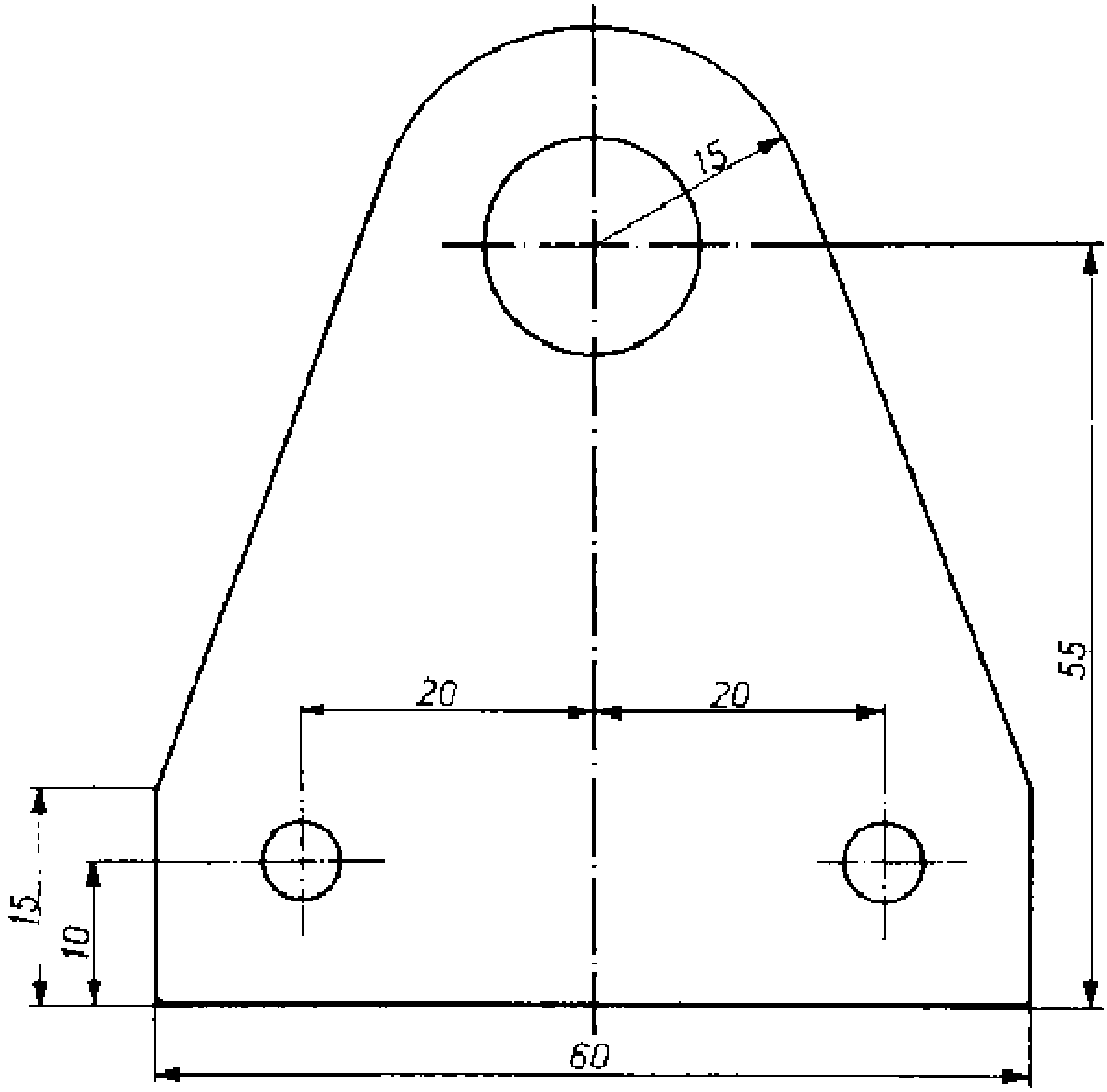
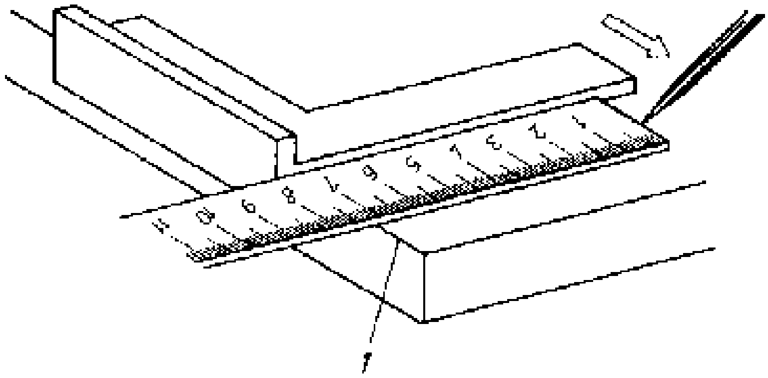


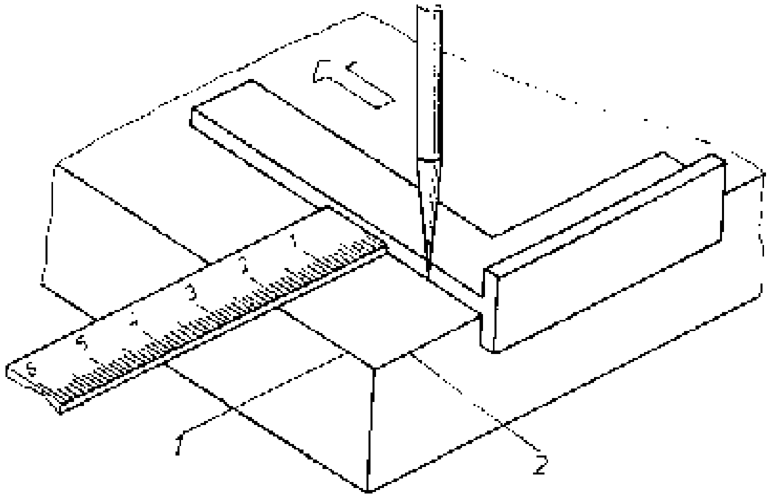
Fig. 1.2/3 Dimensioning from a reference edge and from a centre line

Scribed lines are drawn along the back square or thin steel try square or along a steel straightedge. If parallel scribed lines shall be marked out to previously worked straight reference edges, scribing gauges are used, which are adjusted at the required distance with the steel rule (fig. 1.2/5).

Fig. 1.2/4



a) Marking–out from a reference edge; Marking at the zero edge of the steel rule



b) Marking−out from two reference edges; Marking at the back square

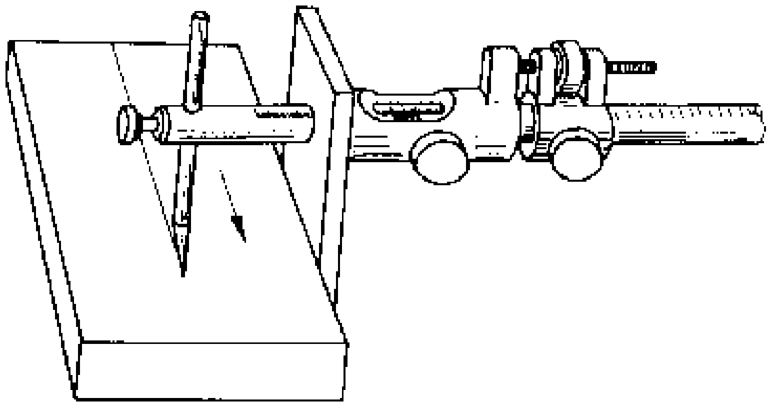


Fig. 1.2/5 Marking out with the scribing gauge

If divisions shall be marked out on a straight line or on a circular arc, dividers are used. The leg opening of the dividers is adjusted according to the desired division by means of the steel rule. The first point of the division is marked by a punch mark (cf. section 1.2.3.) and then the other division points are marked off with the dividers on the scribing line (fig. 1.2/6 and 1.2/7).

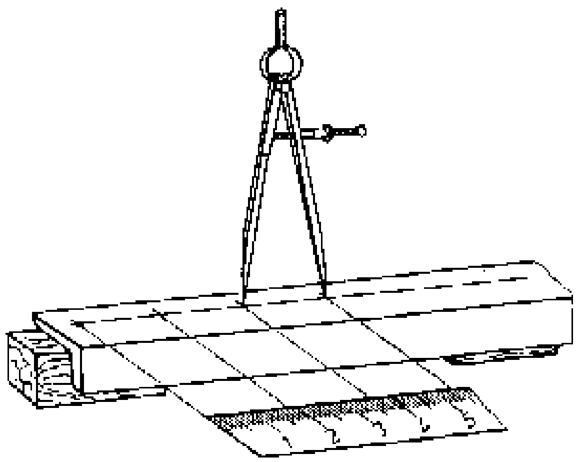


Fig. 1.2/6 Division of a straight line; after marking−out the division, the total length is again checked with the steel rule

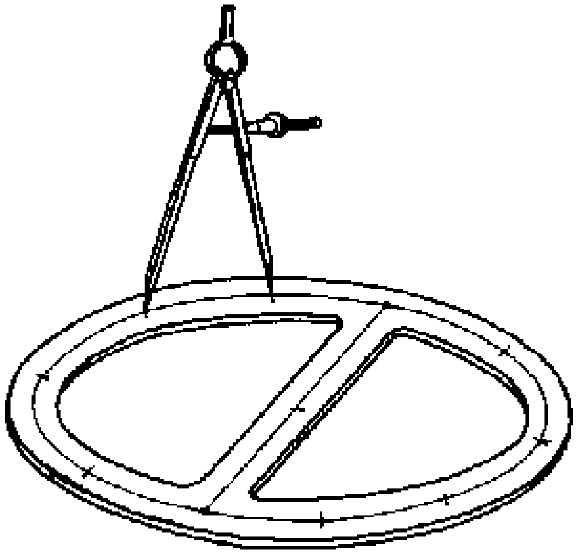


Fig. 1.2/7 Division of a circle; the last dividing marking−out line shall coincide with the first one

Task:

1.12. Give reasons why all following dimensions (exception: division) shall be marked off always from the reference edge!

Circular arcs are marked out by means of the dividers or in case of very large radii, by means of the beam compass (fig. 1.2/8). Prior to that, the circle centres shall be marked out and punched.

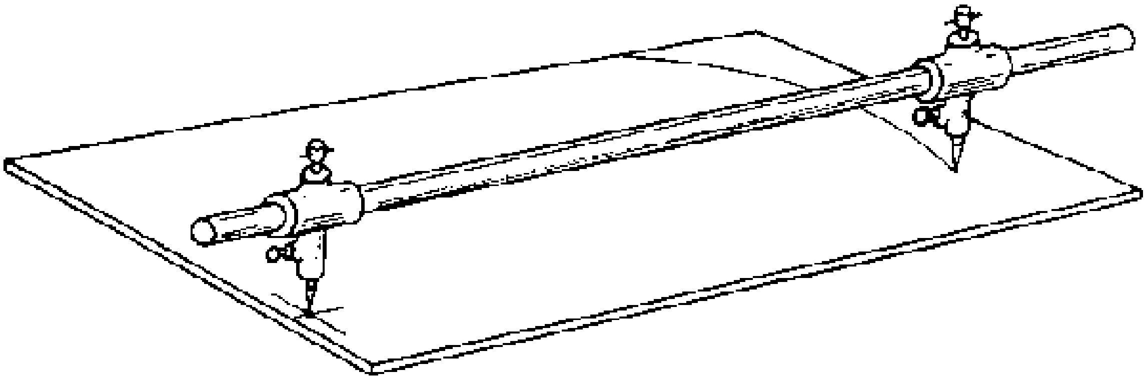


Fig. 1.2/8 Beam compass

Marking−out from a reference face

A marking−out plate and a scribing block are required to mark out from a reference face (fig. 1.2/9a, b). The scriber of the scribing block is adjusted to the desired dimension at a height gauge and then the dimension is transmitted to the workpiece. By means of the scribing block, one obtains only parallel markings to the reference face of the workpiece. Often clamping or supporting devices are required.

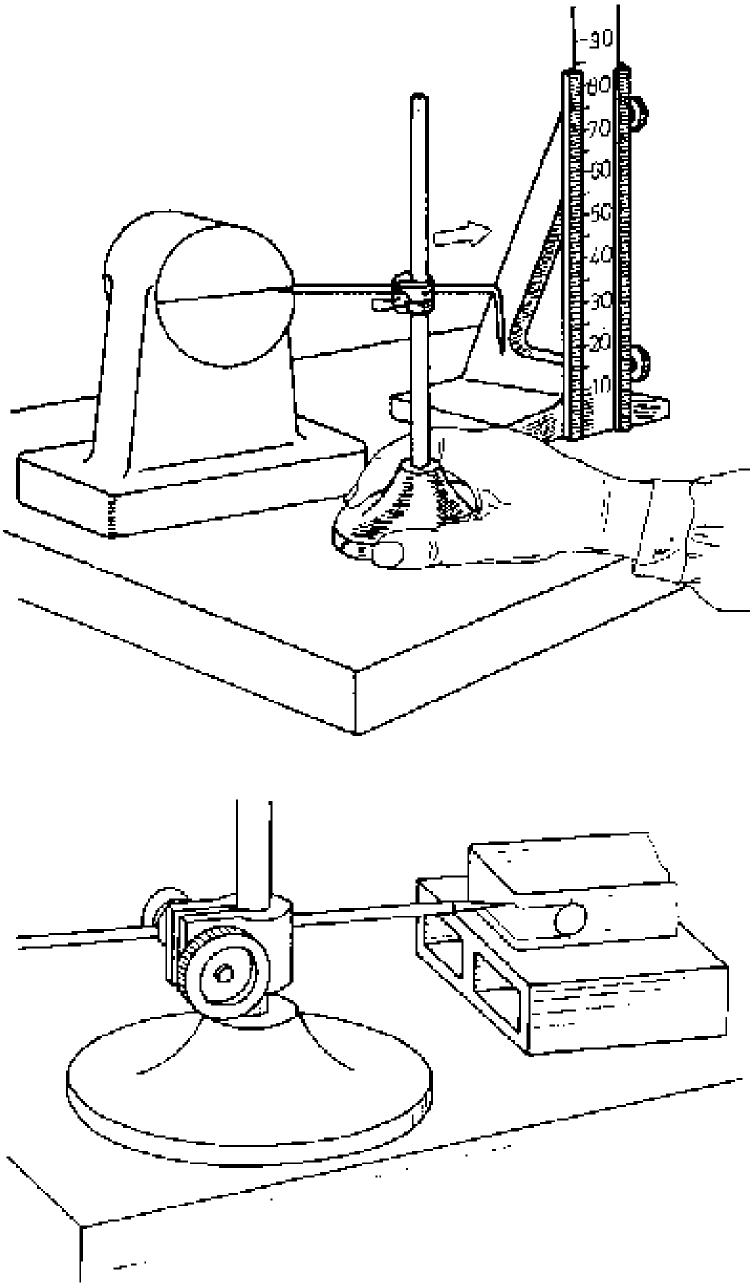


Fig. 1.2/9 Marking−out with the scribing block

If a very small height cannot be adjusted at the scribing block, a parallel strip is laid under the workpiece (fig. 1.2/10). Parallel strips have a square or rectangular shape. Their dimensions are held in such a way that the scribing height can be easily calculated.

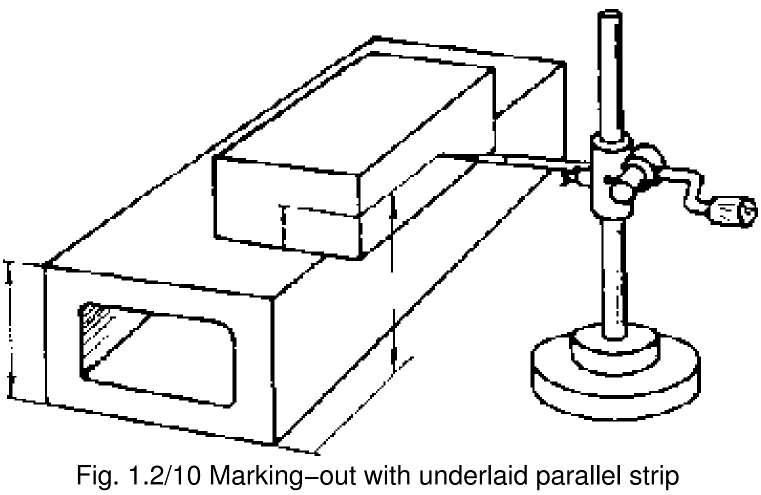


Fig. 1.2/10 Marking−out with underlaid parallel strip

Task:

1.13. The height of the parallel strip h_1 amounts to 50 mm, the height of the scribed line at the workpiece to 22 mm. To which height must the scribing block be adjusted?

Marking–out with stencil

Marking–out stencils are used when a large number of uniform workpieces with complicated shapes shall be marked out (fig. 1.2/11). In such a way, the time needed for marking–out per piece can be considerably reduced.

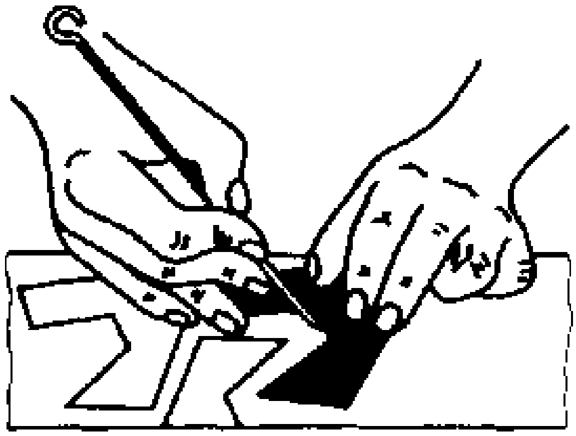
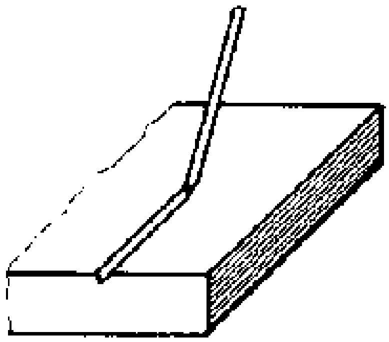


Fig. 1.2/11 Marking–out with stencil

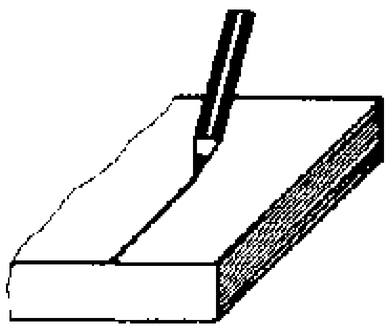
1.2.2. Tools, auxiliary means and material

Scribers can be either harder or softer than the material of the workpieces to be marked out. If the scriber is harder than the material surface, the scribed line is scribed into the workpiece material (steel scriber, fig. 1.2/12a). If the scriber is softer, it leaves a visible, deposited line, as for example pencil on aluminium (fig. 1.2/12b) or brass scriber on steel.

Fig. 1.2/12



a) Scribed line scratched into the material



b) Scribed line drawn on the material

The line scribed into the material can be disadvantageous for the durability of the work−piece because it causes a notch effect. So it is better to use a pencil, for example, for thin sheets. The same applies when the work−piece shall be bent at the marking−out line.

Visibility aids: If the workpiece shows previously worked surfaces and the marking−out line is only poorly visible, whiting or cupric sulphate ($CuSO_4$) can be applied upon the surface prior to marking−out. The coated layer is scratched by the tip of the scriber and the line will be well visible due to the contrast.

1.2.3. Punching

In order to be able to recognize clearly a scribed line up to the end of working, prick punch marks are set on the scribed line. This is carried out by means of aprick punch which intrudes with its tip into the workpiece metal after a light hammer blow. The punch marks are put in larger distances on straight lines than on curved scribed lines. Crossings and transitions of straight lines to curves are always punched.

If you worked precisely, the prick punch marks must be half visible at the end of working (fig. 1.2/13). Punch marks are not only made to mark the scribed lines but also to determine insertion points for the dividers and hole centres.

▌ Punching serves to mark scribed lines, insertion points of dividers and hole centres.

Prick punches with tips of 40 are used for marking scribed lines and centre punches with a tip of 60 are used to mark hole centres (fig. 1.2/14).

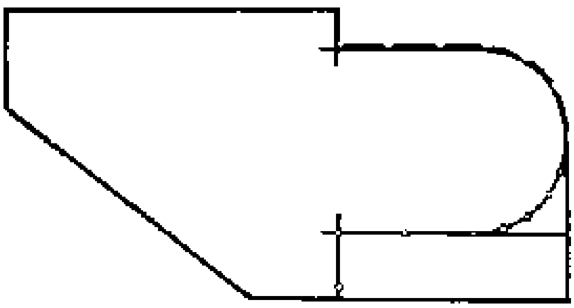


Fig. 1.2/13 Prick punch marks on scribed lines; after finishing, half punch marks are visible

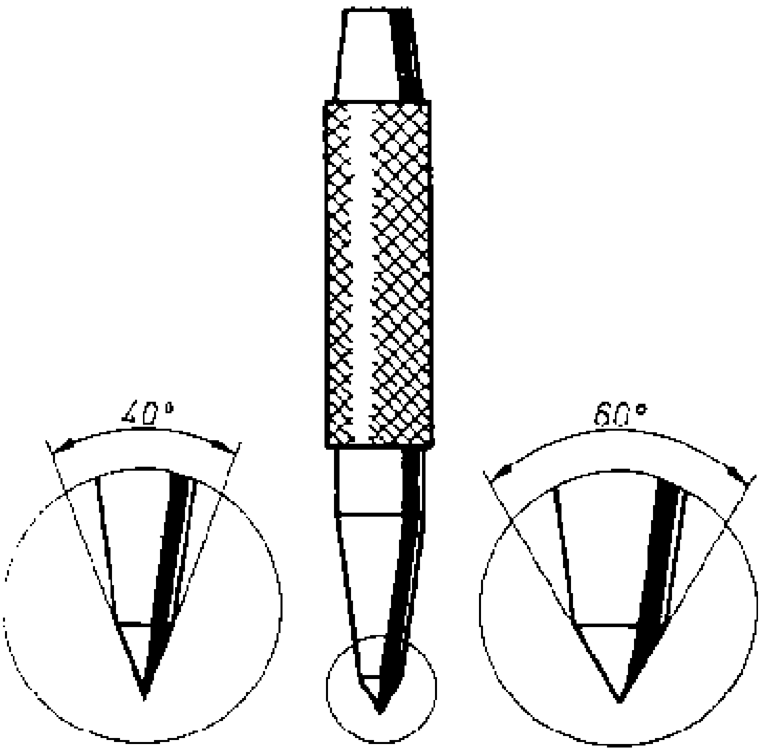


Fig. 1.2/14 Tips of prick punches (40°) and centre punches (60°)

1.2.4. Rules on marking–out and punching

To be able to mark out appropriately, the material of the scriber must be adjusted to the workpiece surface:

steel scriber	– for raw and roughed work–pieces
brass scriber	– for finished workpieces
graphite (pencil)	– for notch–sensitive and protective finished work–pieces (light metal, tin–plate sheet)

Scribers must be pointed to obtain a precise scribed line.

Especially important is the correct guiding of the scriber (fig. 1.2/15).

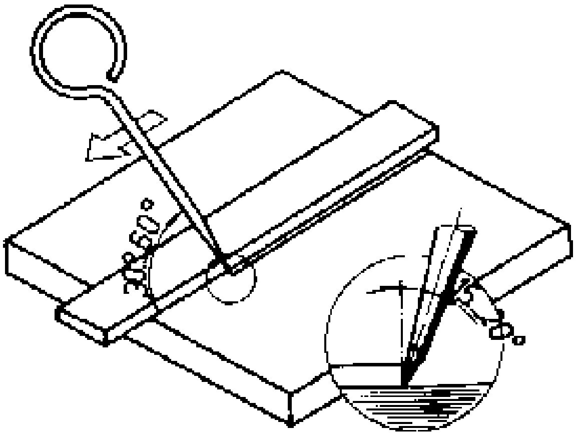
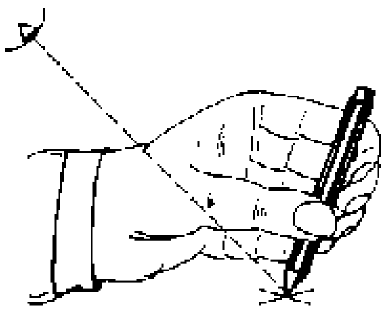


Fig. 1.2/15 Guiding of the scriber

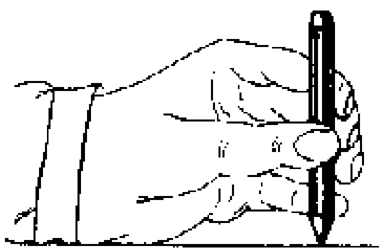
When using the scribing block, grip its lower part after the height was adjusted and guide it along the workpiece with light pressure against the marking–out plate in such a way that the scriber can carry out the marking! Sliding the scribing block is facilitated by the grooves in the cast–iron marking–out plate.

When punching, the prick punch marks shall be put exactly on the scribed line! Place the punch obliquely and help with your hand! Prior to blowing, erect the punch (fig. 1.2/16).

Fig. 1.2/16 Manipulation of the centre punch



a) Application of the centre punch



b) Erection of the centre punch for the blow

Labour safety:

When scriber and dividers are not used any longer, their points shall be protected by a plastic cap or a slipped over cork so that nobody is at risk!

Summary

Marking−out process	Marking−out tools and auxiliary means
1. Scribed lines which proceed from reference edges and reference lines	Scriber, back square or thin steel try square, steel rule, dividers and beam compass, scribing gauge
2. Scribed lines which proceed from a reference face	Scribing block, height gauge, marking−out plate, if necessary clamping and supporting arrangements, parallel strips
3. Scribing lines which are made by means of stencils	Scriber, stencils

The selection of the scriber depends on the material and the further working (for example bending) of the workpiece. Following to marking−out, scribed lines and hole centres are punched for a better marking.

Tasks:

1.14. In which cases a pencil is used instead of the scriber for marking−out?
1.15. How must the finished workpiece edge look in case of exact punching?

2. Cutting−off

Many workpieces obtain their final shape and desired surface condition by cutting−off of material. In this connection, the workpiece can be <u>divided</u> into different parts, however, only chips can be removed as well (<u>metal removal</u>). In each case, the workpiece dimensions are reduced by cutting−off processes.

Task:

2.1. Quote some cutting−off processes you know from your everyday's life. Judge whether a dividing or metal removing process is carried out.

2.1. Cutting−off by means of the chisel

Chiselling is one of the oldest cutting−off processes. Nowadays, it is only used where another kind of machining the workpiece is not possible or not worthwhile as for example with repair works, snagging operations, or for jig−and−fixture manufacture.

2.1.1. Design and function of the chisel

<u>Chisel design</u>

Cutting edge, shank and head are distinguished at the chisel (fig. 2.1/1).

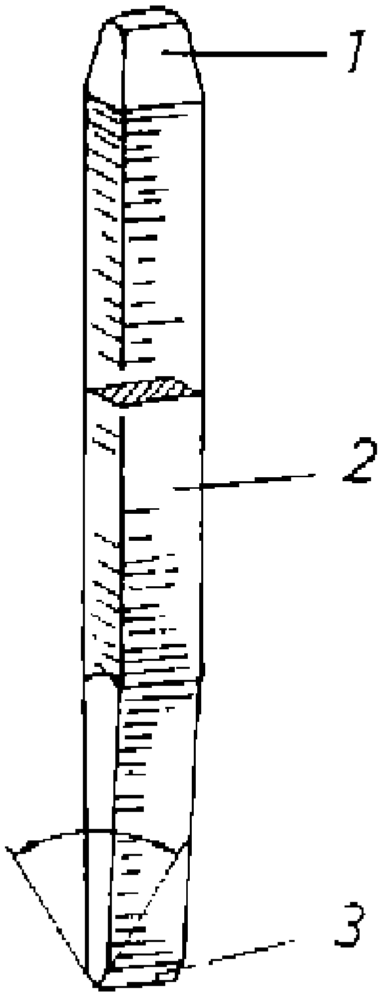


Fig. 2.1/1 Flat chisel design

1 Cutting edge, 2 Shank, 3 Head

Cutting edge: When looking at the chisel from the narrow side you will see that the cutting edge is wedge−shaped. The angle, which is included by the two oblique faces of the cutting edge (cutting surfaces, also called cheeks) is called the wedge angle (fig. 2.1/2). It is decisive for the cutting effect of the tool.

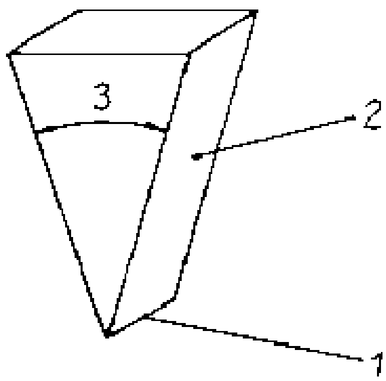


Fig. 2.1/2 Wedge angle at the cutting edge of the chisel

1 Cutting edge, 2 Cutting surfaces (cheeks), 3 Wedge angle

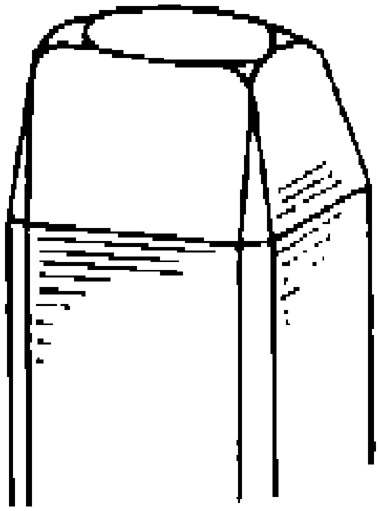
The cutting edge of the chisel is hardened.

▌ Only cutting edges, which are harder than the material to be cut off, can penetrate into it.

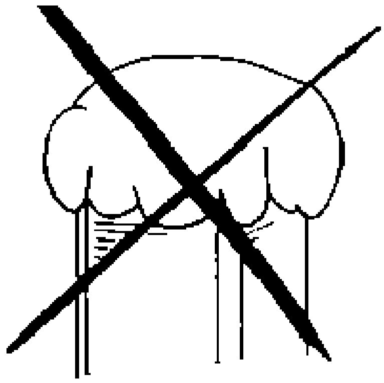
Shank and head: The shank of the chisel should be long enough to grip it well. The ball−shaped ground head receives the hammer blows, which drive the chisel into the workpiece. If the chisel shank is too short so that the chisel head protudes only a little beyond the hand, hand injuries can result. Too long chisels tend to bouncing and, therefore, they can be guided only poorly; in addition, they tend to break away.

Upon long use of the chisel, a burr is formed at its head (fig. 2.1/3) which can make the hammer slip easily.

Fig. 2.1/3



a) Perfect chisel head



b) Chisel head with burr

Labour safety:

Metal parts, which rebound from the burr of the chisel head, can give rise to severe eye injuries. For this reason, the burr shall be definitely removed prior to starting work.

Function of the chisel

The way of holding the chisel is decisive for the function of the chisel.

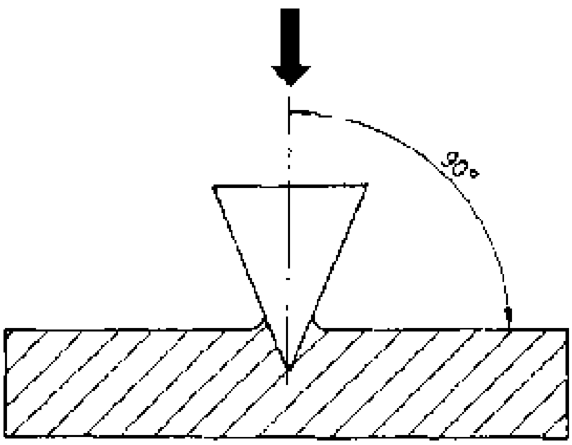


Fig. 2.1/4 Position of the chisel cutting edge during cutting–off. The force acts perpendicularly to the workpiece surface.

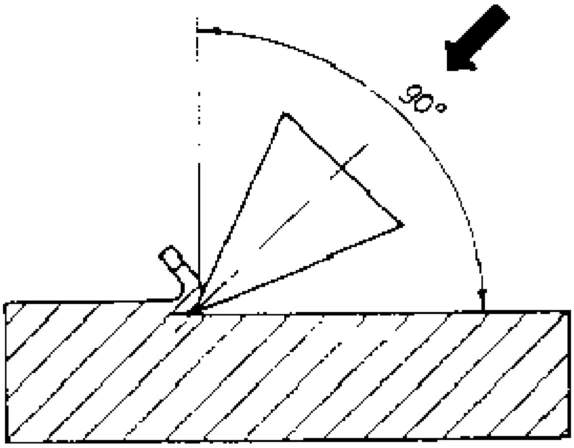


Fig. 2.1/5 Position of the chisel cutting edge during stock removal. The force acts in an angle of less than 90° to the workpiece surface.

When the chisel is held perpendicularly to the workpiece surface, it divides the work−piece. When it is held inclined to the work−pieces surface it removes chips (fig. 2.1/4 and fig. 2.1/5).

Dividing: First, the cutting edge notches the material, then it upsets it and with further penetration, the material is separated (fig. 2.1/6).

Subsequently, the workpiece edges, which are deformed by upsetting, must be straightened out. This results in a loss of material which must be taken into account when calculating the rough length of the workpiece (fig. 2.1/7).

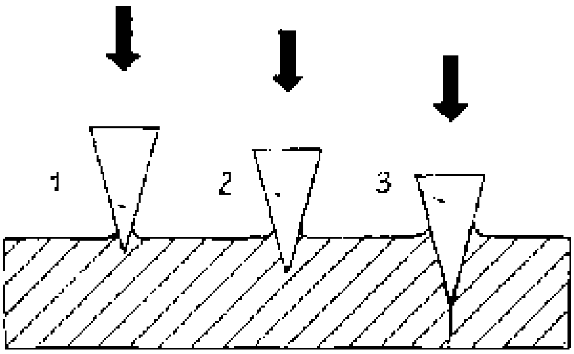


Fig. 2.1/6 Principles of cutting−off with the chisel

1 Notching 2 Penetrating and upsetting 3 Rupturing

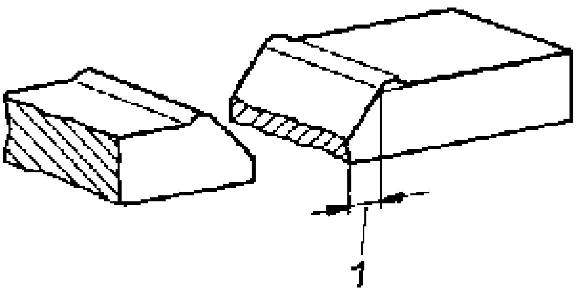


Fig. 2.1/7 Deformation of the workpiece edges at the cutting−off point

1 Material loss

Metal removal: Also in this case, the material is notched, upset and ruptured. Due to the inclined holding of the chisel (normally, it shall have an angle of 30° to the workpiece surface), the cutting−off material is removed as a chip.

Labour safety:

When the material is brittle small keen chips can jump off. To avoid accidents, the eyes must be protected and a protective grating provided.

Energy of motion and cutting−off effect: The energy of motion which is converted into cutting−off operation at the wedge−shaped chisel cutting edge results from the hammer weight and the velocity with which it hits the chisel. In this connection, it shall be taken into account, that hammer weight and chisel weight are in an adequate relation to each other. In general this means:

▌ The hammer weight shall be twice that of the chisel.

Wedge angle and cutting−off effect: Cutting edges with smaller wedge angle penetrate the material easier and faster than cutting edges with large wedge angle, with the same application of force and the same edge length of the chisel cutting edge (fig. 2.1/8). However, the hardness of the material to be cut off shall also be taken into account when selecting the appropriate tool cutting edge. For hard materials (for example steel), a cutting edge with larger wedge angle than for softer materials (for example aluminium) shall be used.

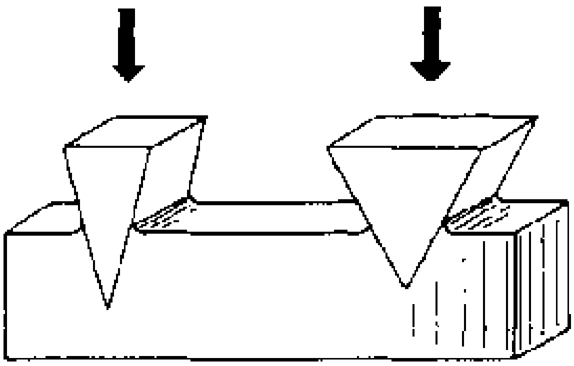


Fig. 2.1/8 Penetration depth of cutting edges with different wedge angles with the same action of −forces and same length of the cutting edge

Time and force can be saved and the tools remain serviceable for a longer period when selecting the chisel cutting edge with the appropriate wedge angle.

Basically, remember always

▌ Small wedge angle ? large cutting−off effect
Large wedge angle ? small cutting−off effect
Hard materials ? large wedge angle
Soft materials ? small wedge angle

Task:

2.2. Chisels with wedge angles of 30° to 50° are used for soft materials, chisels with wedge angles of 60 to 70° are used for hard materials.

Which size of the wedge angle shall be used for cutting−off aluminium and which for cutting−off steel?

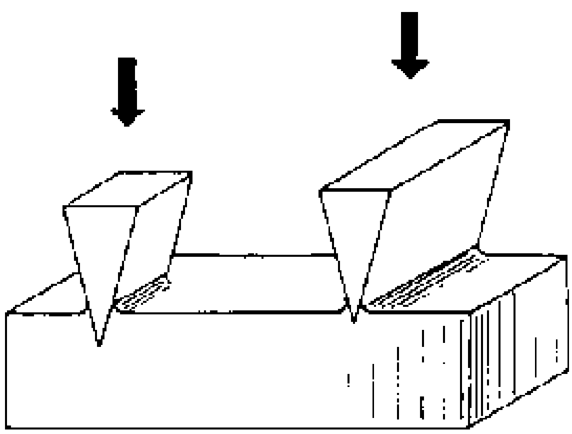


Fig. 2.1/9 Penetration depth of cutting "edges with different cutting edge length with the same action of forces

and the same wedge angle

Cutting edge length and cutting−off effect: Cutting edges with short edges penetrate the material easier than cutting edges with long edges, with the same application of force and the same wedge angle (fig. 2.1/9). For this reason, if possible, chisels with short cutting edges are selected for dividing large workpiece cross−sections. For dividing thin sheets, however, it is more time−saving, to use chisels with long cutting edges.

Task:

2.3. Reflect, which cutting edge length you would select to cut large masses of material, for example, for chiselling grooves!

2.1.2. Working with the chisel

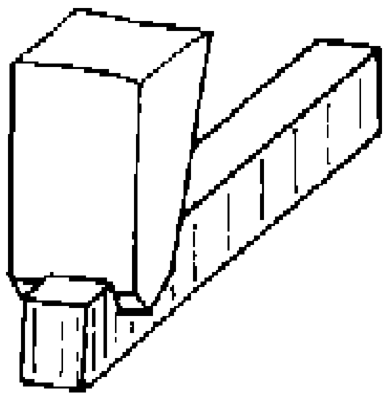
The workpiece shall not deflect or bounce. For this reason, light workpieces or sheets are placed up on a thick unhardened steel plate or clamped into the vice. In the following, three of the many possibilities to cut−off with the chisel are explained.

Cutting−off of flat steel

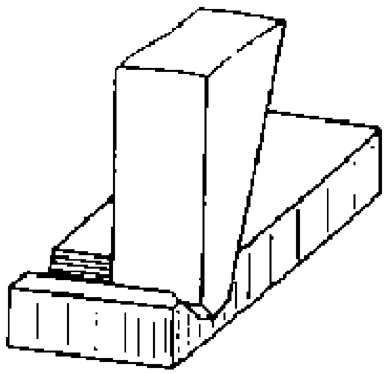
The flat steel is placed up on a shim, which, if possible, rests over a leg of the bench so that it does not bounce. First, the workpiece shall be notched by light hammer blows up on the head of the chisel at the point to be cut−off. In this connection, take into account:

- If the chisel cutting edge is wider than the workpiece, it must evenly project over both sides (fig. 2.1/10a).

Fig. 2.1/10 Cutting−off of flats



a) The chisel cutting edge projects evenly



b) The chisel must be shifted

- If the chisel cutting edge is narrower than the workpiece, the chisel must be shifted several times so that the whole width of the workpiece is notched (fig. 2.1/10b).

After notching, the hammer blows become more powerful.

Cutting−off of square sections

Square sections are evenly worked from all sides. First, the four sides of the section are notched, then the workpiece is upset successively at the four sides, and finally, the chisel is driven successively from all four sides until the workpiece is cut (fig. 2.1/11).

▌ Cutting from all sides saves force, material and time.

Task:

2.4. Justify the statement given in the above rule!

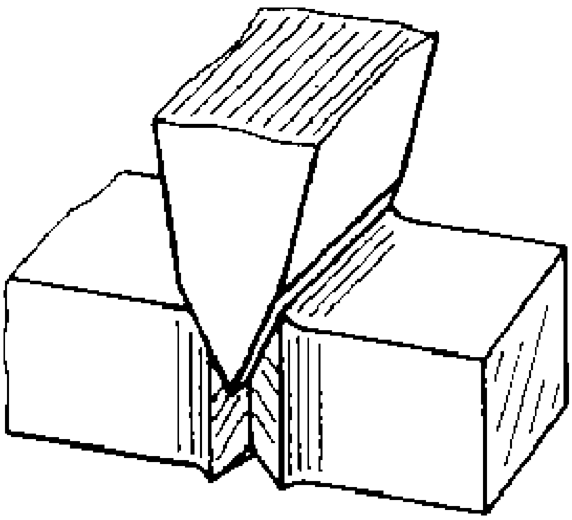


Fig. 2.1/11 All over notched sectional steel

Cutting−off of sheet−metal strips

When a strip shall be cut from a sheet metal, it is useful to clamp the sheet metal into the vice. The chisel can be better guided when laying on a vice jaw and cannot slip off (fig. 2.1/12). The sheet metal shall be clamped in such a way that it cannot bounce at the cutting−off point, that means long sheet−metal strips must be relocated several times.

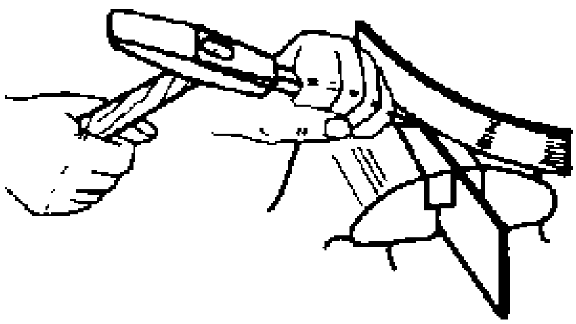


Fig. 2.1/12 Cutting−off of a sheet−metal strip

The chisel is held obliquely against the sheet−metal, so that the whole edge length of the cutting edge does not penetrate at the same time (fig. 2.1/13).

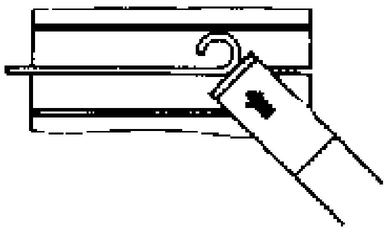
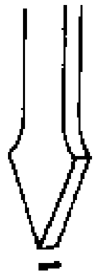
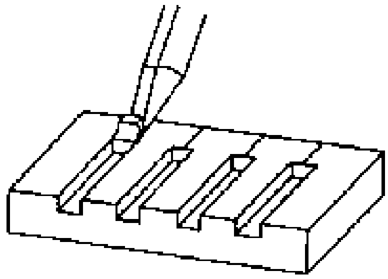
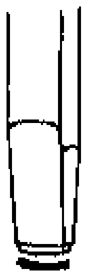
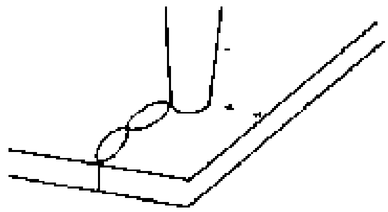
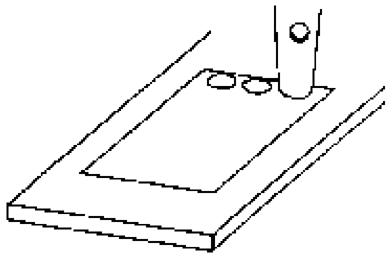
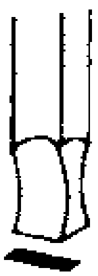
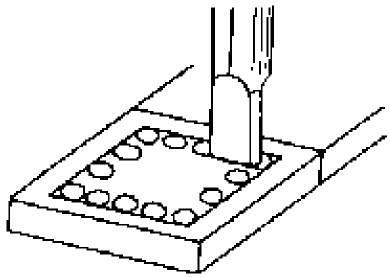


Fig. 2.1/13 Position of the chisel during cutting−off of a sheet−metal strip, which is clamped into the vice

2.1.3. Types of chisels and their application

For all chiselling operations previously mentioned, the flat chisel was used. The following table shows further common types of chisels and their application:

Type of chisel	Application
Cross–cut chisel	Chiselling of grooves into plane workpieces. Subsequently, the left webs can be cut off by means of the flat chisel. This way, a layer can be chiselled off from a large face.
	
Round chisel	Chiselling a rounding or punching out holes with large diameters
	
Punching chisel	Chiselling a hole into thin materials
	
Caulking chisel	Caulking the webs between the holes drilled along the scribed line. This way, penetrations can be produced.
	

Summary

<u>Function of the chisel</u>

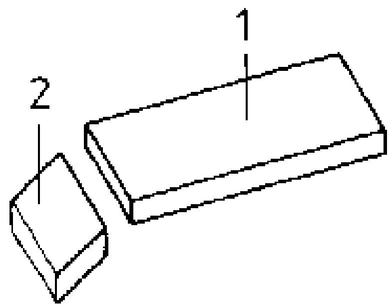
The chisel serves both for dividing and for metal removing.

Tasks:

2.5. Describe the way the chisel is held when dividing and when metal removing!
2.6. Influence of wedge angle and cutting edge length on the cutting−off process?
2.7. Influence of the hardness of the material to be cut−off on the selection of the chisel cutting edge?

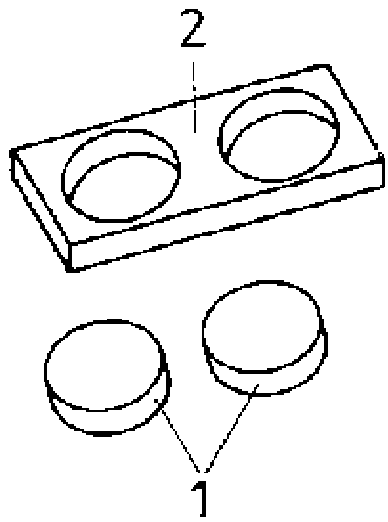
2.2. Cutting−off by means of the shear

Fig. 2.2/1



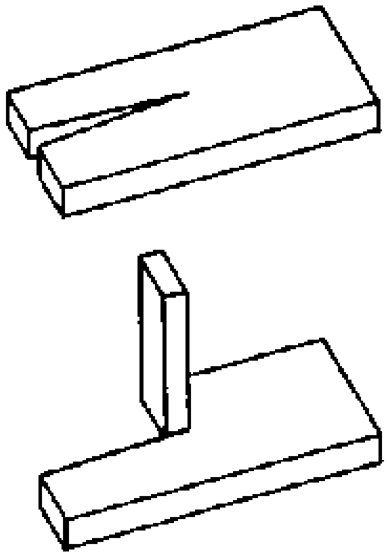
a) Cutting−off

1 Useful workpiece
2 Waste piece



b) Blanking

1 Useful workpiece
2 Waste piece



c) Cutting−in

In manual metalworking, sheet−metals and strip steel are often divided by means of snips. In this connection, parts of the workpiece can be cut off or blanked or the workpiece is cut in (fig. 2.2/1). The cutting−off points (cuts) can be randomly long and of different shapes.

2.2.1. Design and function of the snips

<u>Design</u>

The snips consist of two shear jaws which end in a handle each. They are swivelling connected with each other by a screw or rivet (fig. 2.2/2). Since the handles are longer than the shear jaws, they are able to multiply the acting manual force (lever action) during cutting−off. The shear jaws are ground wedge−shaped (cutting edge). Since the cutting edges are highly loaded during the cutting−off process their wedge angles must be relatively large (approximately 80).

The large wedge angles ensure the resistance of the cutting edges.

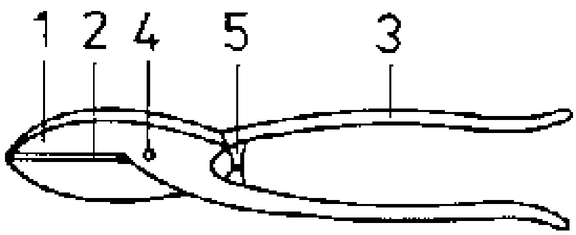


Fig. 2.2/2 Parts of the snips

1 Shear jaw, 2 Cutting edge, 3 Handles, 4 Screw, 5 Blow limit

Task:

2.8. Compare the snips with the paper−scissors you know. Justify the different relation of length of shear jaws and handles as well as the different size of the wedge angles!

<u>Action</u>

When the handles are pressed together, the wedge−shaped cutting edges move towards and slide along each other until the blow limit ends the cut (cf. figs. 2.2/2 and 2.2/3).

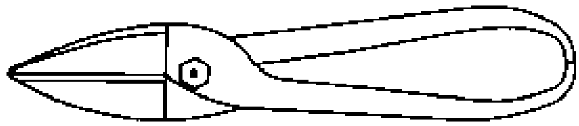


Fig. 2.2/3 Snips with bad blow limit.

This kind of blow limit often results in bruises of the hand

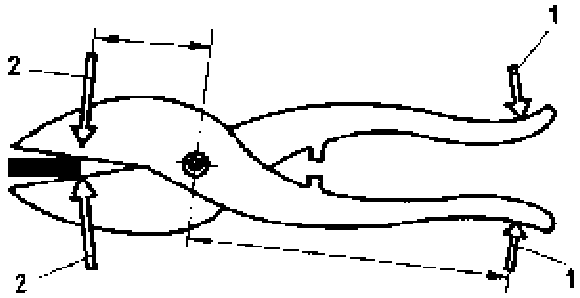


Fig. 2.2/4 Lever action at the snips

1 Hand force, 2 Shearing force

In doing so, the workpiece laying between the shear jaws is divided by the shearing force (cf. fig. 2.2/4). Cutting–off by means of the shear is also called shearing.

Three phases are distinguished during the shearing process:

– The cutting edges of both shear jaws notch the material.

– The cutting edge of the upper shear jaw penetrates deeper into the material. A smooth shoulder of the cut is formed.

– In the last phase, the material breaks. A rough fracture surface is formed.

These three phases can be recognized at the cutting surface (figs. 2.2/5 to 2.2/7).

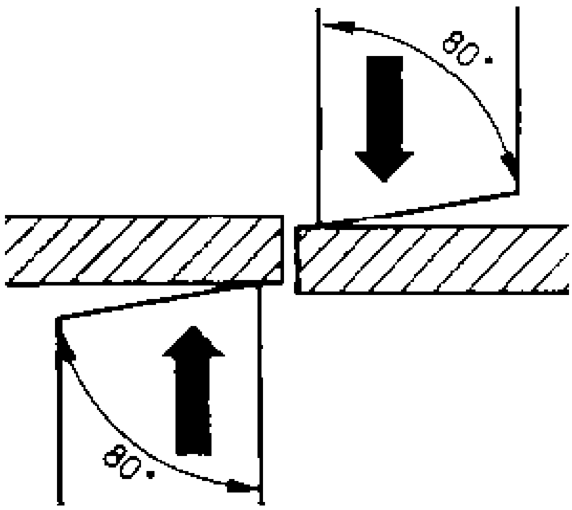


Fig. 2.2/5 Wedge angle at the cutting edges of the snips

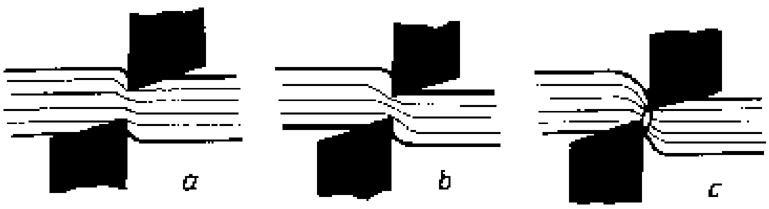


Fig. 2.2/6 Steps of the shearing process

1 Notching, 2 Cutting, 3 Rupturing

Task:

2.9. Compare the cutting surface of a sheared workpiece with the cutting surface of a chiselled workpiece. Conclude from that on rework and material loss in case of the two processes!

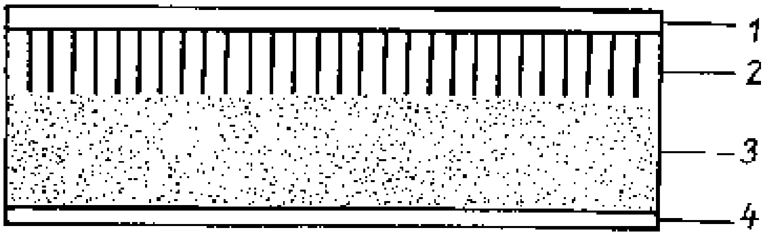


Fig. 2.2/7 Cutting surface of a sheared workpiece

1 Upper notch, 2 Smooth shoulder of the cut, 3 Rough fracture surface, 4 Lower notch

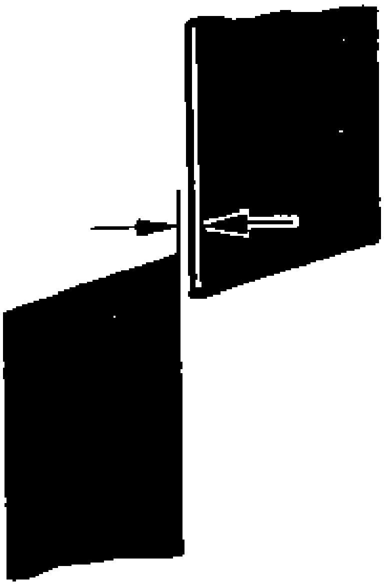


Fig. 2.2/8 Cutting gap between the shear jaws

For perfect cutting−off by shear, a spacing between the cutting edges (cutting gap) must be provided (fig. 2.2/8). It depends on the thickness of the sheet metal to be sheared and amounts on an average to appr. 0.02 mm. If the cutting gap is too small, the cutting edges ream each other and the material to be cut off is squeezed. If the cutting gap is too large, poor cutting surfaces are formed. When shearing thin sheets, these can bend and be drawn−in between the shear jaws (fig. 2.2/9).

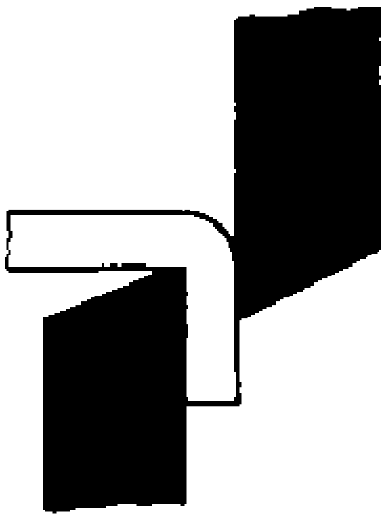


Fig. 2.2/9) Workpiece bent due to too large a cutting gap

▌ When cutting with the snips, a relatively smooth cutting surface is formed at the workpiece. Only little reworking is necessary. The material loss is small. Only sheet metals of such thickness are divided by means of the snips which allow manual shearing.

2.2.2. Working by means of the snips

When working with the snips, the workpiece is held with one hand and the other hand guides the shear. When applying the shear, pay attention to the correct opening angle of the shear jaws.

When too large an opening angle of the shear−jaws is selected, the workpiece will be pushed out of the shear (fig. 2.2/10).

Only when the shear jaws form an angle of approximately 15°, the workpiece is held and can be sheared (fig. 2.1/11).

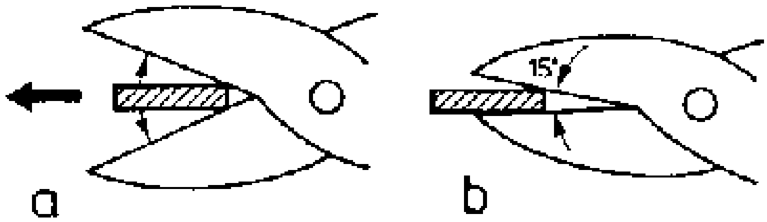


Fig. 2.2/10 a, b) Opening angle of the shear jaw

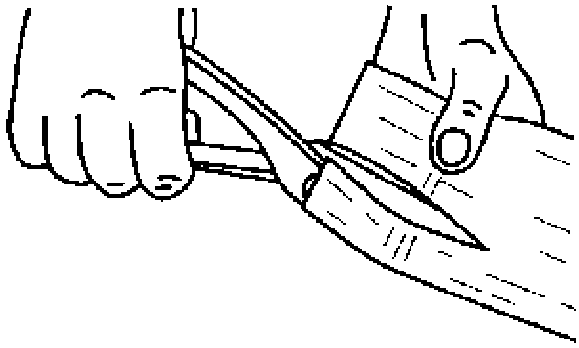


Fig. 2.2/11 Cutting with the snips

However, when too small an opening angle is selected, the force−saving effect of the long handles is reduced.

▌ The opening angle of the shear jaws shall not be larger than 15°.

Both straight and curved cuts can be carried out by means of the snips.

<u>Straight cuts</u>

If, for example, a sheet−metal strip shall be sheared from a plate, the plate shall be held with one hand (fig. 2.2/11) or pressed against the bench. If this is not done, the plate will rotate during shearing and thus become a risk of danger (fig. 2.2/12).

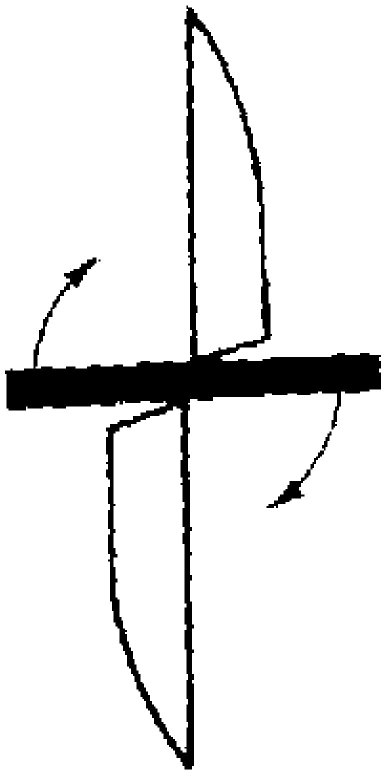


Fig. 2.2/12 Rotary motion of a sheet hanging free in the snips

The shear is not fully pressed together during shearing, but opened shortly before it closes, slightly lifted and pushed forward. Since the tips of the shear jaws act only with little shearing force up on the material, a poor cut will result when the shear is fully pressed together.

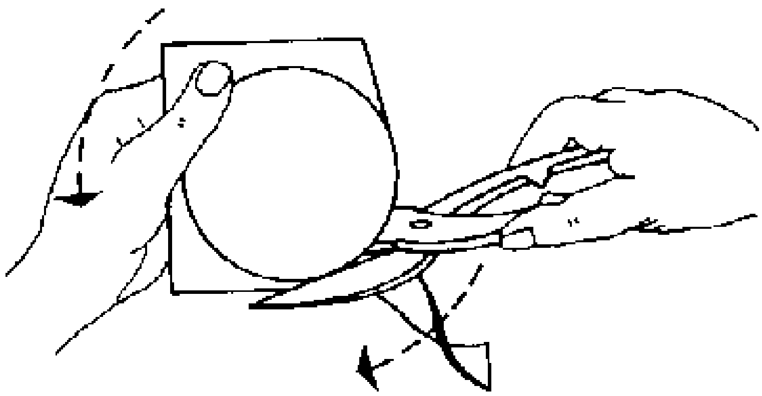


Fig. 2.2/13 Performing a circular cut

Curved cuts

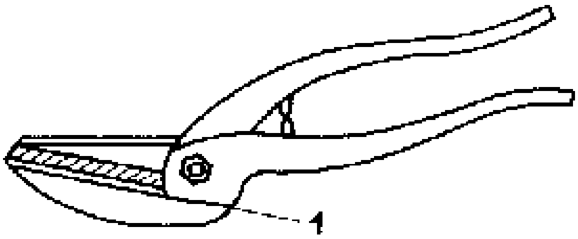
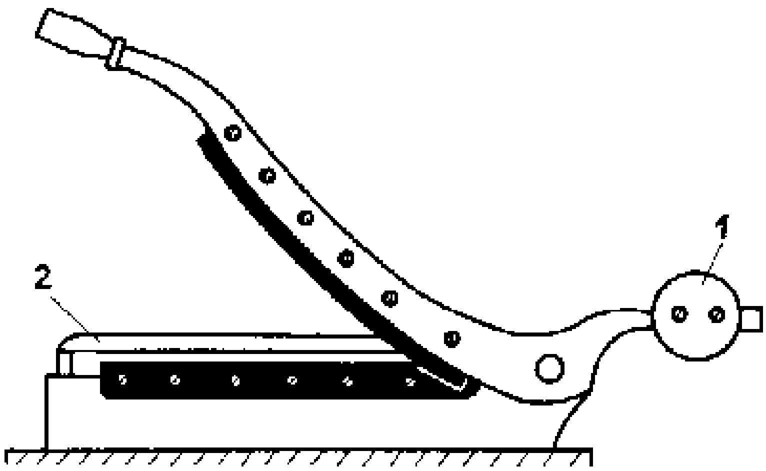
The sheet metal must be kept down and simultaneously guided for carrying out curved cuts. Both for shearing small curves and carrying out circular cuts, the sheet metal shall always be guided in such a way that the shear works clockwise, otherwise the upper shear jaws would cover the scribed line (fig. 2.2/13).

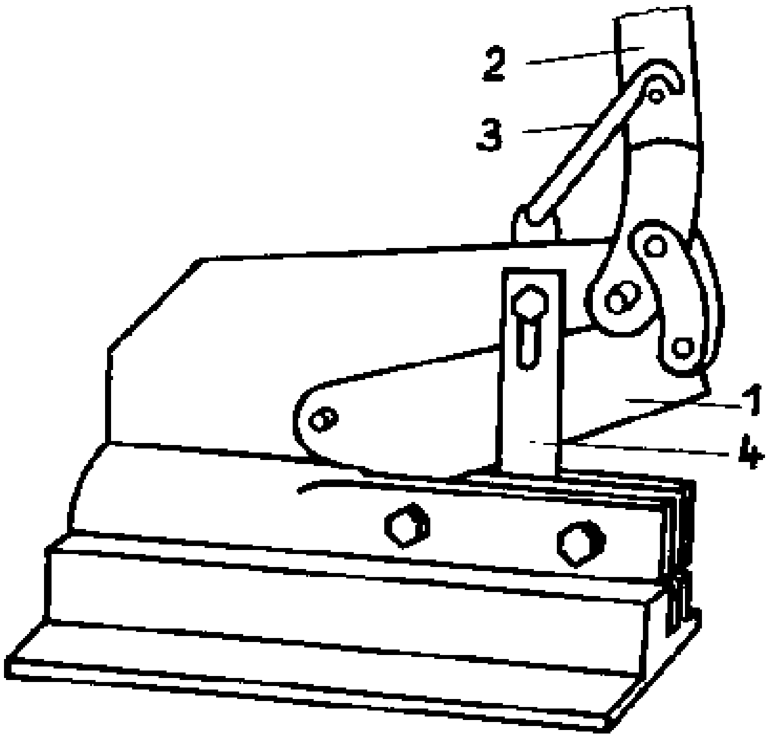
Sheet–metal thicknesses which can be cut by means of the snips:

Material	Sheet thickness
Steel	0.7 mm
Copper	1.0 mm
Brass	0.8 mm
Aluminium according to hardness	1.0... 2.5 mm

2.2.3. Types of shears and their application

Apart from the snips, the following types of shears are used in manual metalworking:

Type of shear	Application
Through shear	For long straight cuts. The sheet metal lies under the hand during shearing, therefore, there is less risk of injuries. Sheet−metal thicknesses as for snips
1 Sheet−metal layer	
Circle snips	For carrying out short curved cuts. Is only used for inside curves. For outside curves the straight shear permits better guidance. Sheet−metal thicknesses as for snips. 
Guillotine−shear	For efficient carrying out long straight cuts. By means of a counterbalance weight the upper shear blade can be slightly lifted. Adjustable stop straight edge allows shearing of strips of a certain width. Sheet−metal thicknesses as for snips or somewhat thicker
1 Counterbalance weight 2 Bar for clamping the sheet metal	
Hand−lever shear	For shearing thick plates and sections. The upper shear jaws are moved by a lever with simple or double transmission. A blank holder prevents the workpiece to be drawn− in between the shear jaws.

1 Shear jaws 2 Hand lever 3 Lever locking 4 Blank holder	

Labour safety:

!! Use shears for the admissible sheet–metal thickness only! (Each hand–lever shear has a plate with the data on sheet–metal thicknesses and profile cross–sections which can be divided by shear). Levers at the hand–lever shear must be secured against falling down!

The sheet metal shall be held down firmly for making long cuts with the snips, otherwise there would be a risk of injury by rotation of the sheet metal!

Summary

– Whereas it is possible both to divide and to remove metal by means of the chisel, cutting–off by shear means only dividing the workpiece.

– Whereas considerable material loss occurs when dividing by means of the chisel due to the required reworking, reworking and the corresponding material loss are low when dividing by means of shear.

– Whereas just <u>one</u> wedge–shaped cutting edge penetrates into the material when chiselling, the cutting process by shearing is carried out by <u>two</u> counteracting wedge–shaped cutting edges.

– Whereas workpieces of different thickness can be cut by chiselling, only workpieces of a relative small thickness (according to the material O.7...2.5 mm) can be cut by shearing.

2.3. Cutting–off by means of the saw

Sheets or plates and strip steels which cannot be cut off by means of the snips because of their thickness as well as tubes and bars with different cross–sections (profiles) can be cut off by sawing. As with cutting–off by means of the shear it is possible to cut–off or cut–out parts of the workpiece or to cut it in. Unlike shearing, the material is cut–off by metal removal when sawing. The most usual cutting–off process in manual metalworking is cutting–off by means of the hand hacksaw.

2.3.1. Design and function of the hand hacksaw

Design

The hand hacksaw consists of a metal frame with handle and holding fixture (fig. 2.3/1 into which the saw blade is chucked.

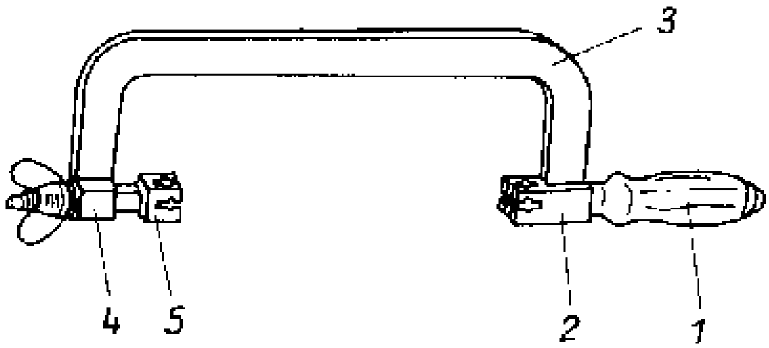


Fig. 2.3/1 Design of the hand hacksaw

1 Handle, 2 Fixed clamp dog, 3 Frame, 4 Guide, 5 Movable clamp dow with thumb screw

The saw blade of hardened tool steel is provided with a continuous row of wedge−shaped saw teeth at one side or at both sides (fig. 2.3/2).

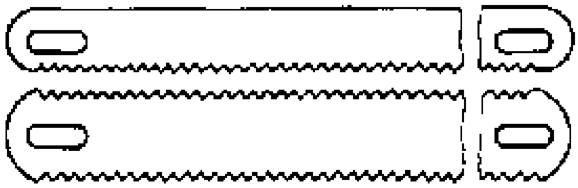


Fig. 2.3/2 One−side and two−sided toothed saw blade

The wedge−angles of the saw teeth must be large enough so that they do not break out when cutting the material (mostly 50°, with harder materials also somewhat larger). The space between the teeth receives the chips which are cut from the material with the teeth. It is called the chip space (fig. 2.3/3). Saws with large, medium−sized and little chip spaces are available. The size of the chip spaces results first of all from the number of the teeth arranged over a certain length of the saw blade (25 mm) (fig. 2.3/4). The distance from tooth tip to tooth tip is called the spacing.

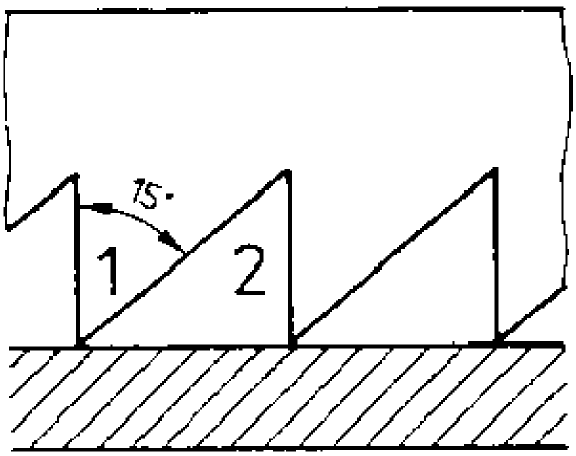
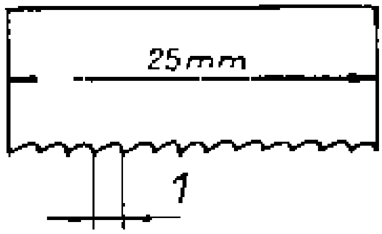


Fig. 2.3/3 Wedge angle at the saw tooth

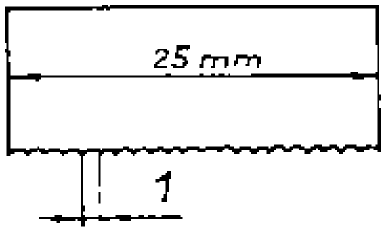
1 Wedge angle, 2 Chip space

Fig. 2.3/4 Spacings



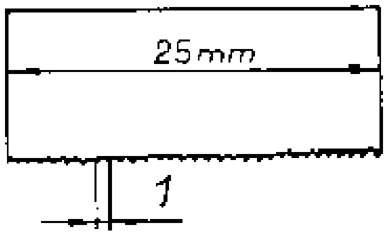
a) Rough: 14... 16 teeth over 25 mm length

1 Spacing



b) Medium: 22 teeth over 25 mm length

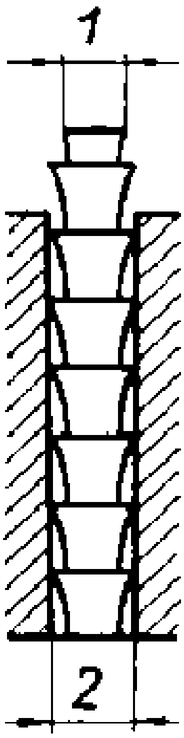
1 Spacing



c) Fine: 32 teeth over 25 mm length

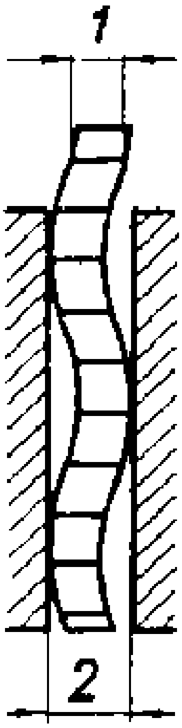
1 Spacing

Fig. 2.3/5 Clearly cutting of the saw blade



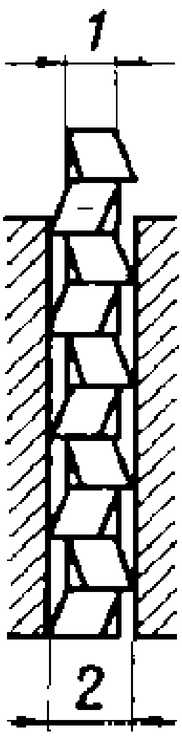
a) Upset teeth

1 Saw−blade width, 2 Width of kerf



b) Wave−set teeth

1 Saw−blade width, 2 Width of kerf



c) Teeth, set to the left and right

1 Saw−blade width, 2 Width of kerf

Rough spacing ? large chip spaces
Fine spacing ? small chip spaces

To avoid jamming of the saw during cutting−off, the tooth row must be wider than the saw blade. For this purpose, the tooth row is upset or waveset or the teeth are set to the left and right (fig. 2.3/5). Thus, a sufficiently wide kerf is formed, in which the saw blade can cut in an unimpeded way.

Action

When sawing, the saw blade is pressed into the material and simultaneously moved in cutting direction. In this connection, several teeth remove simultaneously chips and produce this way the kerf (fig. 2.3/6). When the saw teeth leave the kerf, the chips collected in the chip spaces fall out. When soft materials are cut, the teeth penetrate deeper into the material with the same force, and the chips are larger than with hard materials. Large chips spaces are required, which carry the chips out of the kerf. For this reason, for soft materials the spacing must be rougher than for hard materials.

For soft materials ? rough spacing
For hard materials ? fine spacing

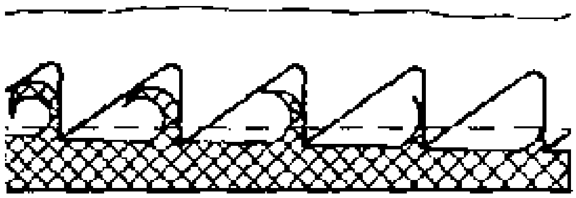


Fig. 2.3/6 Chip formation during sawing

Task:

2.10. List in a table for which materials you have to work, you will use rough, medium or fine spacings!

In case of long kerfs, the single saw tooth leaves it only after a long cutting path. Many chips are collected in the chip space. For this reason, the chip spaces must be sufficiently large so that they do not become clogged. This means, for long cuts saws with rougher spacing must be used than for short cuts.

For long cuts ? rough spacing
For short cuts ? fine spacing

Since with short cuts fewer teeth act up on the material at the same time, the single saw tooth is heavier loaded with the same manual force than with long cuts (fig. 2.3/7).

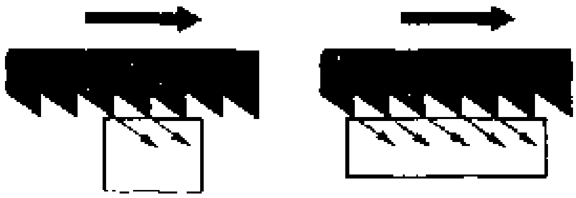


Fig. 2.3/7 Influence of the length of cut upon the load of the individual saw tooth

To preserve the saw teeth, saw short cuts with less hand force than for long cuts.

For short cuts ? less hand force
For long cuts ? large hand force

Task:

2.11. Justify why the return travel of the saw shall be performed without any pressure!
2.12. Compare shearing and sawing with regard to material loss and necessary rework!

2.3.2. Working by means of the hand hacksaw

<u>Chucking of the saw blade</u>

Hand hacksaws work on push, that means the teeth penetrate into the material when the saw is shifted. However, this is only carried out when the saw blade is chucked in such a way that the saw teeth show into the push direction (fig. 2.3/8).

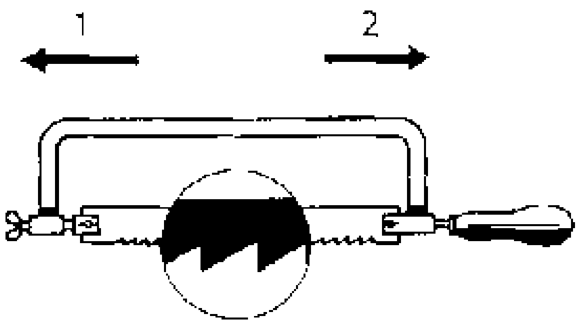


Fig. 2.3/8 Correctly chucked saw blade

Task:

2.13. Describe by means of fig, 2.3/8 how the saw blade must be chucked so that the saw can work on push!

In order to carry out certain parting cuts, it is often required to change the saw blade position to the saw frame. For this purpose, the clamp dogs of the hand hacksaw are cross wise slotted. Thus, they allow four ways of chucking the saw blade (fig. 2.3/9).

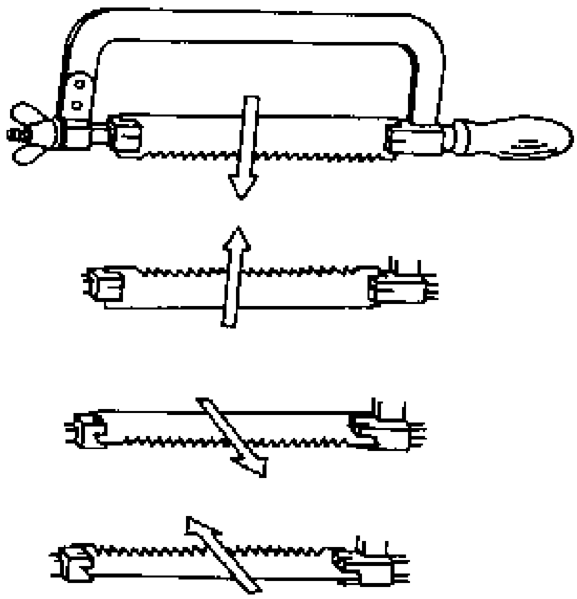


Fig. 2.3/9 Position of the saw blade to the frame

When fastening the saw blade in the clamp dogs, it shall be taken into account that the used steel pins, rivets or hooks do not project beyond the clamp dogs because otherwise there would be a risk of accidents (figs. 2.3/10 and 2.3/11).

Clamping the workpiece

The vice serves to fasten the workpiece during sawing. The workpiece is clamped as short as possible, so that it does not bounce. Work–pieces clamped that they bounce do not allow a clean cut and in addition to this, the saw can easily slide off.

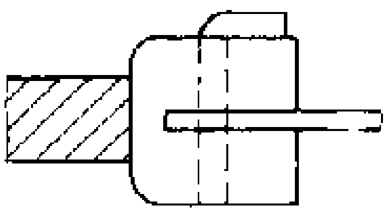


Fig. 2.3/10 Correctly fastened saw blade

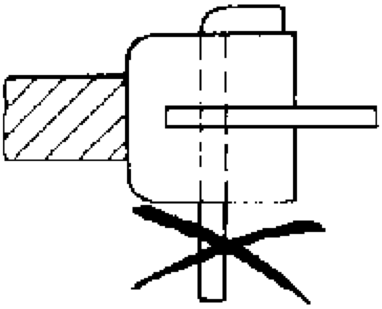


Fig. 2.3/11 Wrong! Risk of accident when the saw slides off

The workpiece is always clamped in such a way that the scribed line is visible some millimetres to the left from the chuck jaws of the vice (fig. 2.3/12).

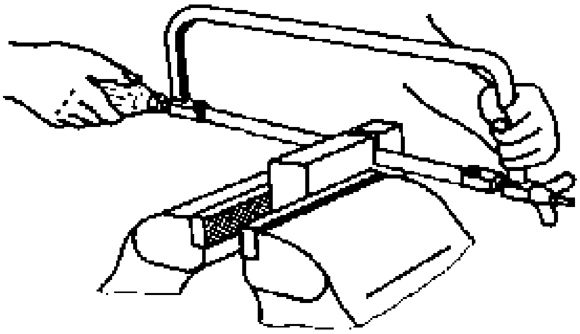


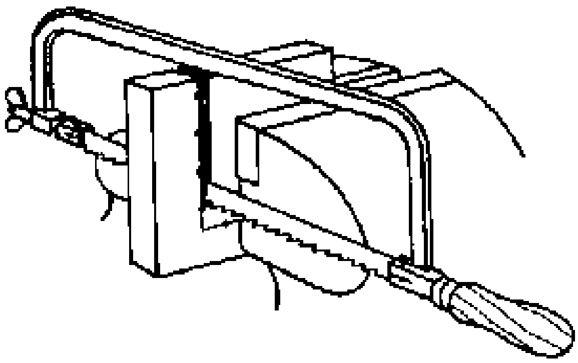
Fig. 2.3/12 Correctly clamped workpiece. The scribed line is left to the vice jaws

Tasks:

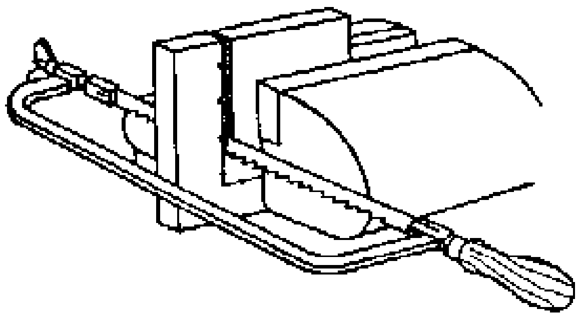
2.14. Think over why it is useful to saw left from the vice!
2.15. Describe by means of fig. 2.3/12 how the saw is gripped!

In case of long cuts, it is necessary to reclamp the workpiece often to prevent bouncing. Moreover, in case of long cuts it is often required to rechuck the saw blade (fig. 2.3/13).

Fig. 2.3/13 Correct handling of the saw for a long cut



a Saw until the frame is put on



b then the saw blade shall be re−chucked

Long saw cuts on sheets are carried out by means of angle−plates (fig. 2.3/14). Sawing along the vice jaws is not workmanlike and results in a quick destruction of the saw blade (fig. 2.3/15).

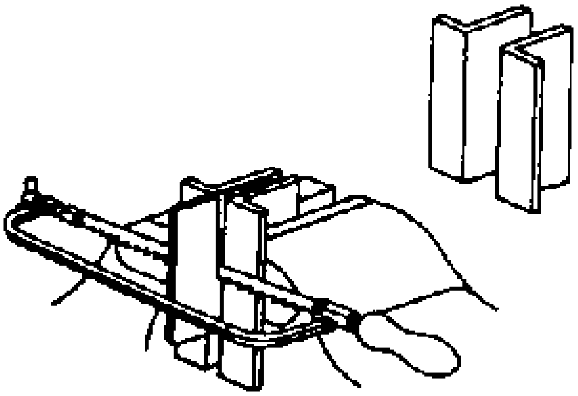


Fig. 2.3/14 Chucking of the workpiece by means of chucking angles

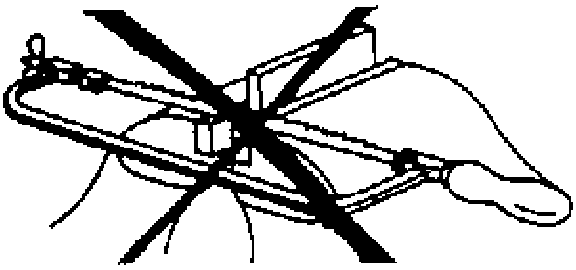


Fig. 2.3/15 Wrong! Do not saw along the vice jaws!

<u>Starting to saw</u>

When there is not yet a kerf which guides the saw, the latter tends to deviate from the desired direction.

To obtain a clean starting cut, first a kerf shall be filed with the triangular file 0.5 mm next to the scribed line at the side of the waste piece (fig. 2.3/16). This kerf provides a first guidance for the saw.

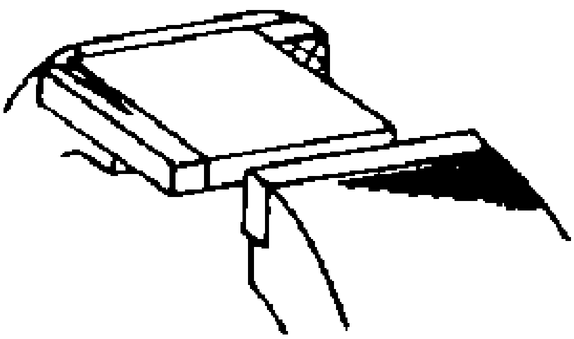


Fig. 2.3/16 File notch next to the scribed line

When starting sawing, first only short saw strokes shall be carried out, and the saw shall be picked up in a small angle to the workpiece, so that only small chips are removed. Basically, sawing is started at the rear workpiece edge (fig. 2.3/17). Subsequently, the saw is guided to and fro in a slightly rolling movement over the total length of the saw blade.

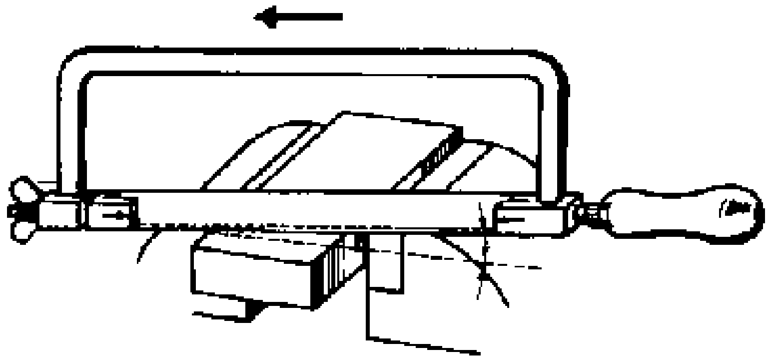


Fig. 2.3/17 Start sawing at the correct angle from the rear workpiece edge!

Sawing of flat steel and angle steel

Flat steel shall be always clamped into the vice in such a way that it can be sawn from its wide side.

Task:

2.16. Justify this requirement by means of the fig. 2.3/7!

Further advantages; The kerf is not deep, so that the saw blade cannot jam. The saw blade gets a good guidance by the long cut.

Angle steel shall be reclamped so that it is always sawn in a long kerf (fig. 2.3/18).

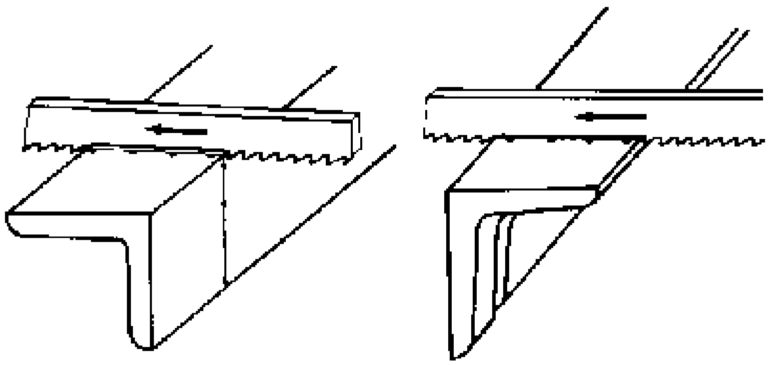


Fig. 2.3/18 Sawing of angle steel

Sawing tubes and pipes

Since tubes and pipes, particularly thin−walled ones, can easily be deformed under the pressure of the vice, it is useful to clamp them into an auxiliary jig. This is a wooden block into which a hole was bored corresponding to the diameter of the tube and which was subsequently divided by a longitudinal cut (fig. 2.3/19).

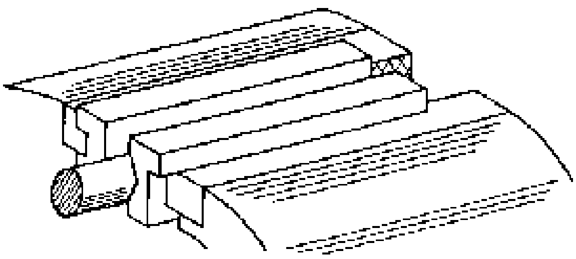


Fig. 2.3/19 A pipe is clamped into the vice by means of auxiliary equipment

Never saw a tube through at a stretch! The teeth could be caught in the inner wall of the tube and break out. So you should saw short before the inner wall, then turn the tube in push direction until the saw still has guidance in the kerf and saw again short before the inner wall. Turning and sawing is repeated until the tube is cut−off (fig. 2.3/20).

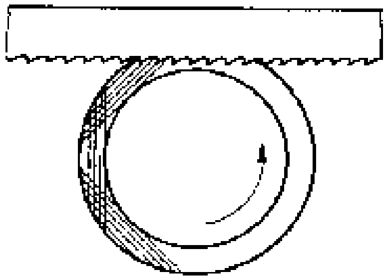


Fig. 2.3/20 Cutting surface when sawing a pipe

2.3.3. Types of saws and their application

Further usual hand saws with which metals can be sawn, are fine saw and fretsaw.

The fine saw (fig. 2.3/21) is lightweight and can be easily guided. It is used for sawing screw−head slots and guidance slots.

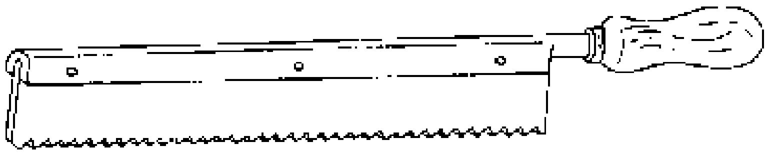


Fig. 2.3/21 Screw head saw − works with push

The fretsaw (fig. 2.3/22) works on pull. It is handled only with one hand. Because of the widely projecting saw frame, manifold shapes and openings can be sawn of materials of little thickness.

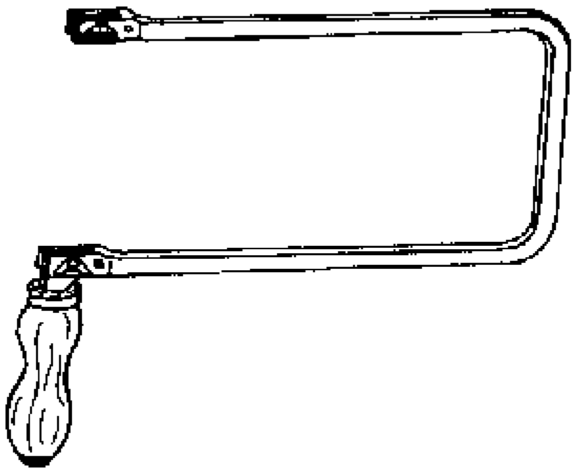


Fig. 2.3/22 Fretsaw − works on pull

Metalworking workshops are often equipped with power hacksaws to cut−off thick workpieces. Their operating motion corresponds to that of the hand hacksaw, however, they work on pull.

The motion of the saw blade is taken from a rotating crank web via a connecting rod (fig. 2.3/23). By means of an adjustable weight piece, the pressure of the saw frame can be changed.

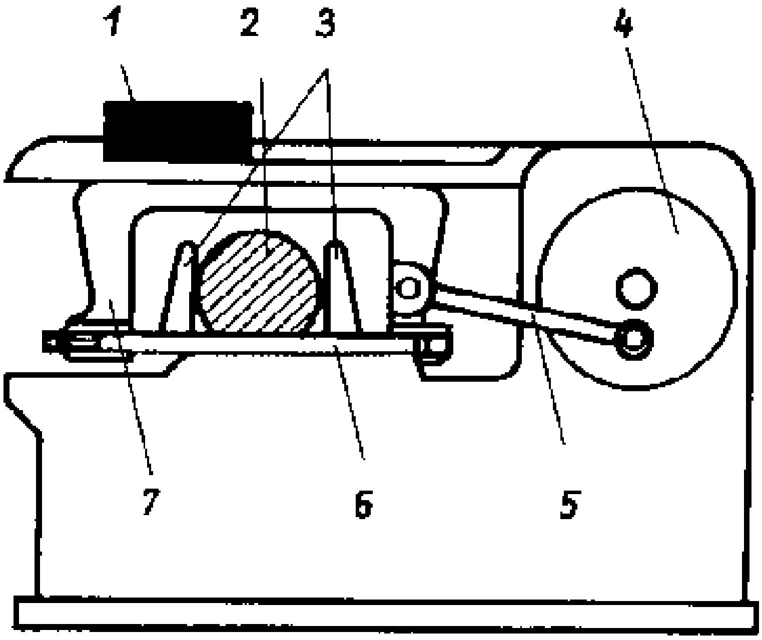


Fig. 2.3/23 Hacksaw machine – works on pull

1 Weight piece, 2 Workpiece, 3 Clamping jig, 4 Crank – web, 5 Connecting rod, 6 Saw blade, 7 Hacksaw frame

Machine saws work with high cutting speeds. The resulting friction between tool and work–piece produces such a great heating of the tool, that it must be cooled. Otherwise it would be too much worn out and become quickly useless.

A coolant pump delivers the coolant (drilling oil emulsion) from a storage tank to the kerf. Simultaneously, the coolant greases and washes the chips away.

▌ When working with the sawing machine, the maintenance and operating instruction shall definitely be observed!

Labour safety for working with the hand saws:

II Before starting work, check whether the handle of the saw seats firmly! Reduce the pressure for the last saw strokes so that no injuries occur when the saw passes the work–piece!

Do not touch the tooth edge with the fingers, the keen burr can cause injuries!

Never remove chips with the bare hand!

Labour safety for working with the sawing machine:

Working at sawing machines gives rise to great accident hazards because the movable parts of the machine can seize loose clothes and the saw blade can cause severe injuries at the hands in case of carelessness. For this reason, the regulations on accident prevention shall be definitely observed:

Wear tight clothes, put off jewelleries and watches!

Keep sufficient distance to movable parts!

Don't let you distract from your work!

Summary

– Sawing is a metal removing cutting–of process whereby the workpiece in most cases is divided into a useful piece and a waste piece.

– The material loss is slightly larger than with sawing reworking, however, is nearly as low as with shearing.

– The saw blade spacing shall be selected according to the material hardness and the kerf length.

– Flat steel and sections shall always be clamped in such a way that long cutting surfaces are obtained!

– Hand hacksaws and fine saws work on push; fretsaws and hacksaw machines work on pull.

– When working with hand saws and sawing machines, the labour safety regulations shall be definitely observed!

Saw blade with rough spacing → Soft materials and long kerfs

Saw blades with fine spacing → Hard materials and long kerfs

2.4. Cutting–off by means of the file

By cutting–off with the file, only small quantities of material are removed. In most cases, filing means reworking: Cutting surfaces are deburred and smoothened. Workpiece edges are rounded. In many cases, workpieces obtain their final shape and the required surface finish. The workpieces can show plane or curved surfaces.

2.4.1. Design and function of the file

<u>Design</u>

The most files consist of the <u>file blade</u> and the <u>tang</u> where the <u>handle</u> is attached (fig. 2.4/1). The file blade is characterized by a number of small wedge–shaped teeth which are cut–in or milled into the blade (fig. 2.4/2a,b).

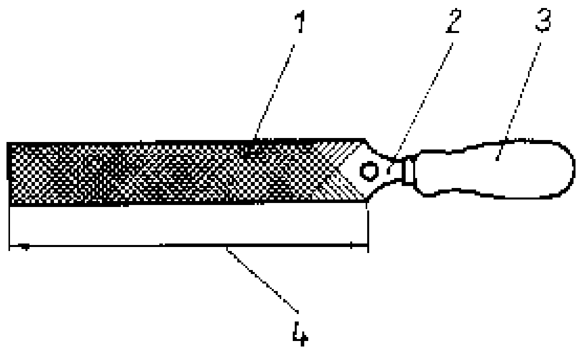


Fig. 2.4/1 Flat file

1 Blade, 2 Tang, 3 Handle, 4 Nominal length

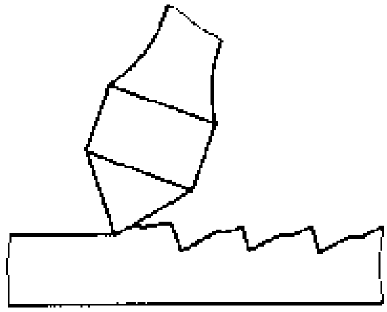


Fig. 2.4/2a Cutting of the file teeth with a special chisel; This results in notches and elevations which form together the file tooth.

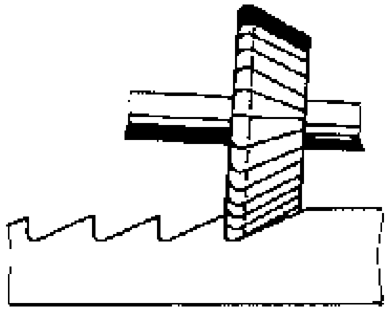


Fig. 2.4/2b Milling of the file teeth with a special milling cutter.

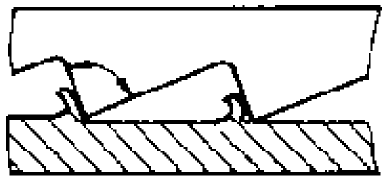


Fig. 2.4/3a Wedge angle and chip space on a cut file

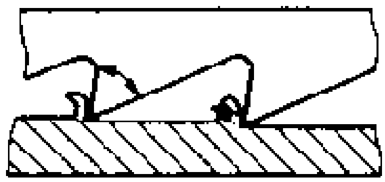


Fig. 2.4/3b Wedge and chip space on a milled file

In case of cut files, the wedge angle of the file tooth is larger than in case of milled files (fig. 2.4/3a,b). On the other hand, milled files have larger chip spaces. Single−cut and double−cut files are distinguished (fig. 2.4/4 and 2.4/5). The majority of the usual files is double−cut. The file cuts run always obliquely across the file blade. The vertical distance from cut to cut (also in case of milled files they are called cuts) is called the tooth spacing (figs. 2.4/6 and 2.4/7).

Large tooth spacing
large chip space

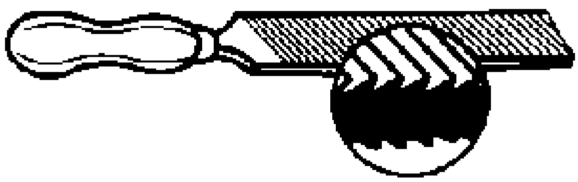


Fig. 2.4/4 Single−cut file

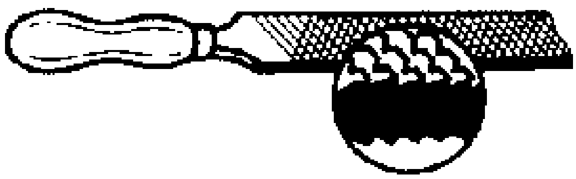


Fig. 2.4/5 Double−cut file

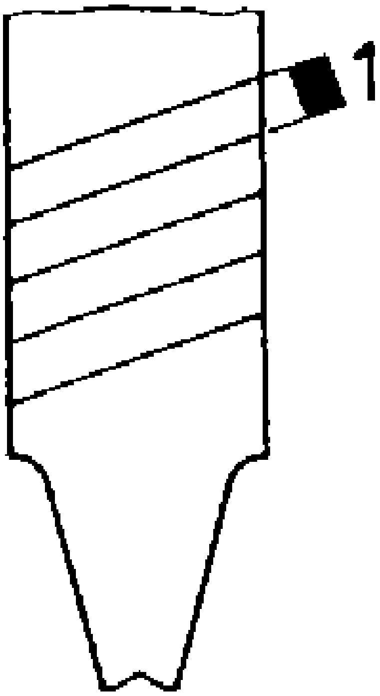


Fig. 2.4/6 Tooth spacing with a single−cut file

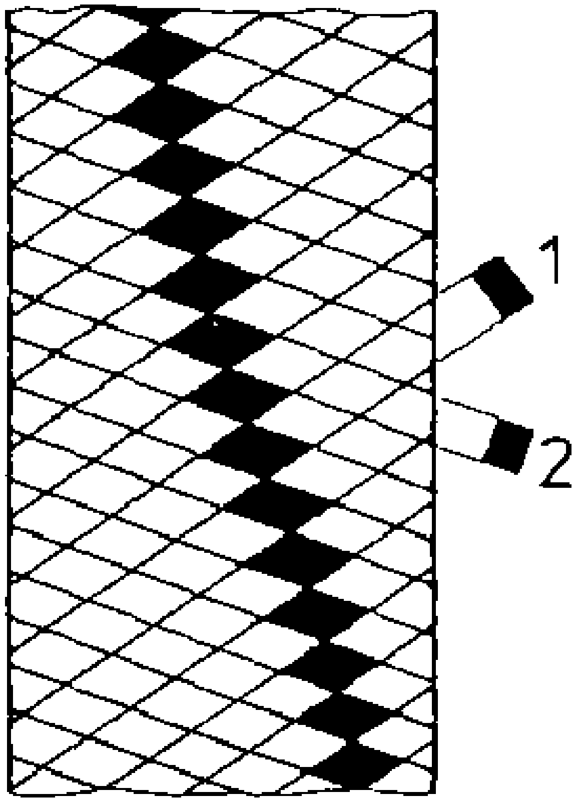


Fig. 2.4/7 With double−cut files, different tooth spacings of overcut and upcut result in oblique running tooth rows.

1 Overcut, 2 Upcut

<u>Action</u>

When the file is pressed upon the workpiece and simultaneously pushed forward, the teeth penetrate into the material and remove chips over the whole cutting path. Part of the removed chips can only fall out when they are pushed beyond the workpiece. Because of the oblique position of the tooth rows, the chips are also removed laterally from the chip spaces.

Task:

2.17. Justify why the file blade must be hardened!

Single−cut files penetrate much more difficult into the material than double−cut files. For this reason, they are used for soft materials (aluminium, copper). Since larger quantities of chips are produced with soft materials, relatively large chip spaces are necessary. Therefore, milled files are prefered. Double−cut files are used best for hard materials (steel, cast iron).

For soft materials ? single−cut milled files
For hard materials ? double−cut files

The selection of the appropriate files depends both on the workpiece material and on the required surface finish (rough or smooth surface).

Double−cut files with small tooth spacing obtain a smooth surface. Single−cut files produce smooth surfaces also with large tooth spacing. However, single−cut files are rarely used, so it can be generally said for double−cut files:

small tooth spacing ? smooth workpiece surface
large tooth spacing ? rough workpiece surface

Files with large tooth spacing are called rough files. Files with small tooth spacing are called finishing files.

Whether the workpiece is roughened or finished depends not only from the required surface finish but also from the stock−removal allowances. When more than 0.5 mm material shall be removed, rough files are used. Work−pieces with stock−removal allowances of less than 0.2 mm are worked with fine finishing files. For better distinguishing the tooth spacing of the different files, the files are provided with tooth spacing numbers. Files with the tooth spacing numbers O to 2 belong generally to the category of rough files, files with the tooth spacing numbers 3 to 5 belong to the category of finishing files.

Task:

2.18. Have a look at the tooth spacings of several files, compare them and assign them to one of the two main groups (rough or finishing files)!

2.4.2. Working with the file

Working with the file requires some skill, which can only be achieved by frequent practising.

Champing of the workpiece

The workpiece is clamped into the vice for filing. If possible, the latter shall be fastened above a workbench foot. As with clamping workpieces for chiselling and sawing, it shall also be taken into account when clamping the workpiece for filing, so that it does not bounce during the work. However, the file shall not slide over the vice jaws.

Long workpieces shall only be filed over the vice and then reclamped (fig. 2.4/8).

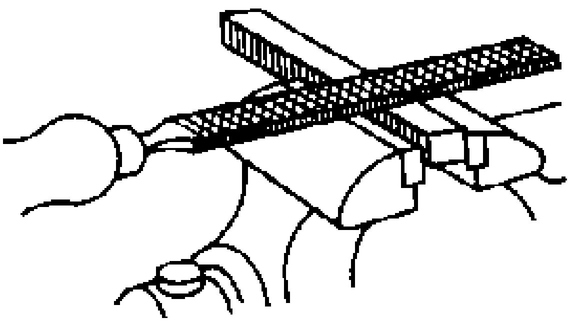


Fig. 2.4/8 Clamping of long workpieces

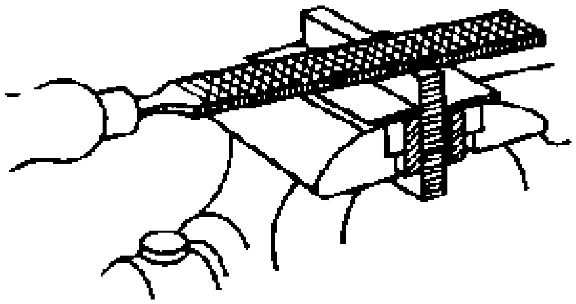


Fig. 2.4/9 Clamping of finished workpieces with protective jaws of soft material

In most cases, filing is a finishing operation. Finished surfaces of the material shall not be damaged. To avoid damaging of the workpiece surfaces by the hardened vice jaws, finished workpieces are clamped by means of protective jaws of aluminium, copper or lead (fig. 2.4/9). Small workpieces can be held by hand in a hand vice (fig. 2.4/10a, b).

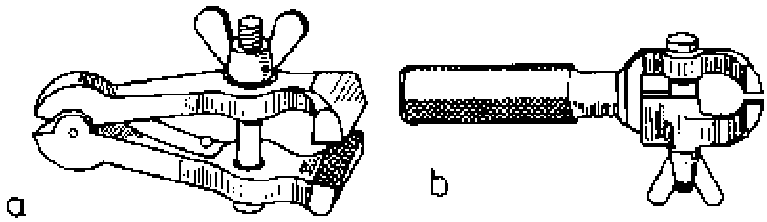


Fig. 2.4/10 Hand vice

Often the corners shall be broken at the work−pieces that means these corners must have an angle of 45° to the plane of the workpiece. Such workpieces are clamped by means of the angle hand vice. The jaws of the angle hand vice are positioned in an angle of 45°. With oblique position of the clamped workpiece and with horizontal guiding of the file, the desired corner angle can be obtained (fig. 2.4/11).

To work the surface of thin sheet−metal parts with the file, the workpiece is nailed on a file board. The file board consists of two T−shaped composed wooden parts and its lower part is chucked into the vice (fig. 2.4/12).

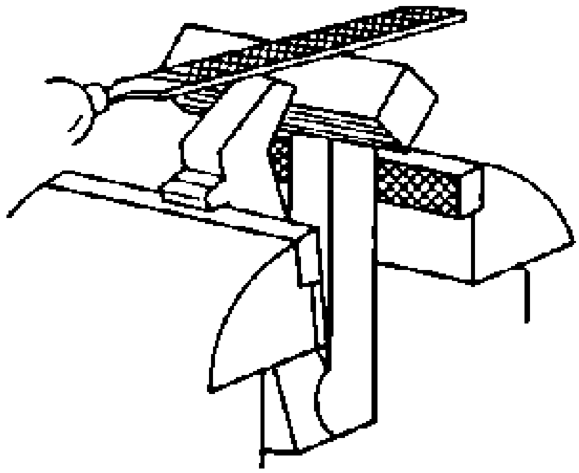


Fig. 2.4/11 Clamping with the angle hand vice for breaking the corners

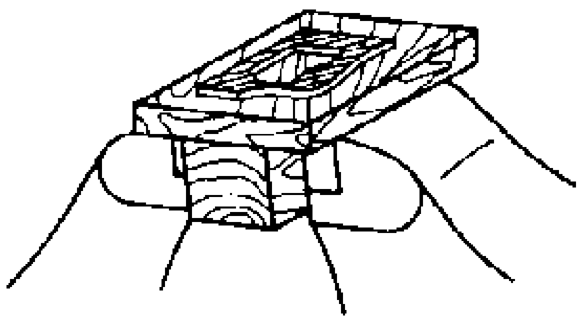


Fig. 2.4/12 Clamping of a thin sheet−metal part with the file board

Posture during filing

The correct posture during filing is especially important. A wrong posture reduces the performances and leads quickly to tiredness. The height of the vice is decisive for the correct posture. The height is correct when the worker stands upright, the clenched fist under the chin and the elbow touching the vice jaws (fig. 2.4/13). The position of the feet is also important during filing. The left foot is put in front and forms an angle of approximately 30° with the direction of filing, the right foot is put back and forms an angle of approximately 75° (fig. 2.4/14). During filing, the body weight rests on the left foot, the right knee remains straightened (fig. 2.4/15).

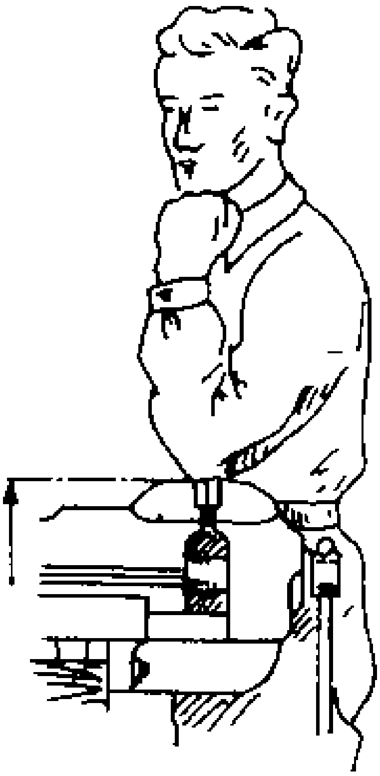


Fig. 2.4/13 Correct height of the vice

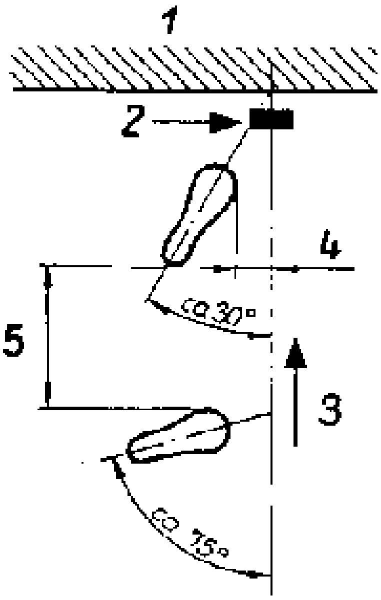


Fig. 2.4/14 Position of the feet when filing

1 File bench, 2 Workpiece, 3 Direction of filing and of view, 4 Distance approximately one foot−width, 5 Distance approximately one file−length

How to guide the file

The guidance of the file depends on its size. The file handle lies always in the right hand.

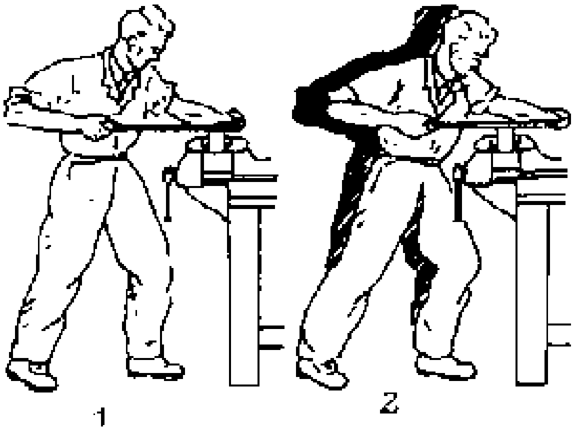


Fig. 2.4/15 Posture when filing

1 Starting posture, 2 Posture during advance

– Large files are always guided and moved with the right hand, the thumb lies on the handle, the left hand keeps the file in horizontal position (fig. 2.4/16).

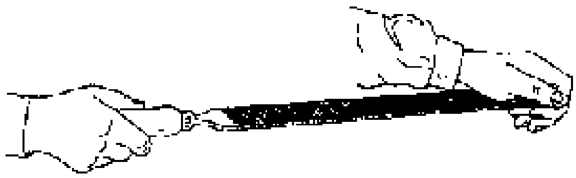


Fig. 2.4/16 How to guide a large file

– Medium–sized files are only slightly guided with thumb and forefinger of the left hand (fig. 2.4/17).

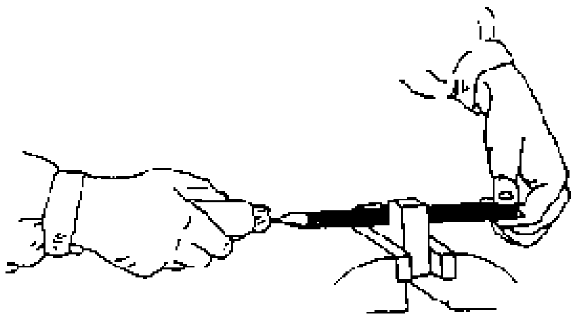


Fig. 2.4/17 How to guide a medium–size file

– Small files are pressed with some fingers of the left hand against the workpiece (fig. 2.4/18).

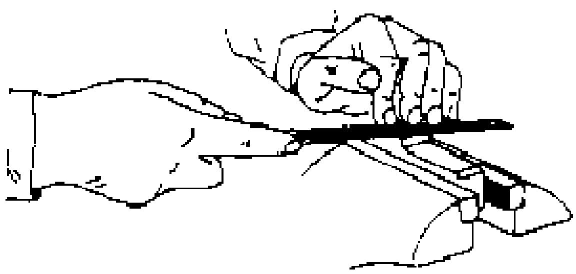


Fig. 2.4/18 How to guide a small file

– Needle files are guided only with one hand, the forefinger lies on top (fig. 2.4/19).

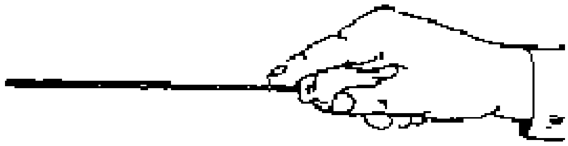


Fig. 2.4/19 How to guide a needle file (smallest type of files, cf. page ...)

When filing small penetrations, the file is gripped at the handle with both hands (fig. 2.4/20).

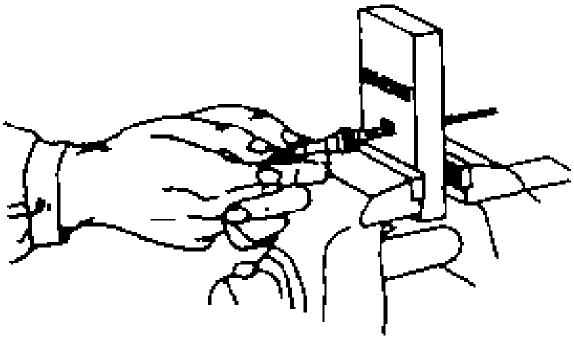


Fig. 2.4/20 Filing of small penetrations

The pressure exerted during the forward−pushing movement of the file is released during the backward movement. Both movements result −similar as during sawing with the hand hacksaw − in a somewhat waving movement. In addition, the movement of the file must be adapted to the relevant required shape of the surface.

Outside radii are roughened in transverse stroke and finished in longitudinal stroke (fig. 2.4/21 and 2.4/22). In this connection, the end of the file is moved from bottom to top.

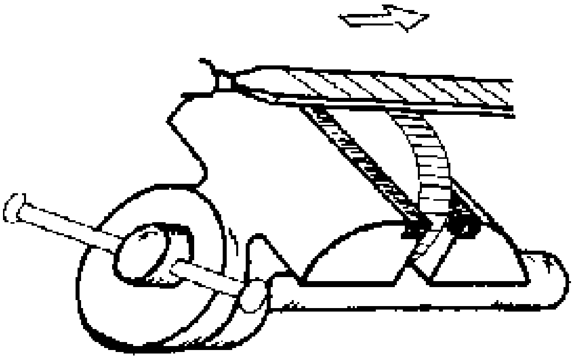


Fig. 2.4/21 Roughing of an outer rounding

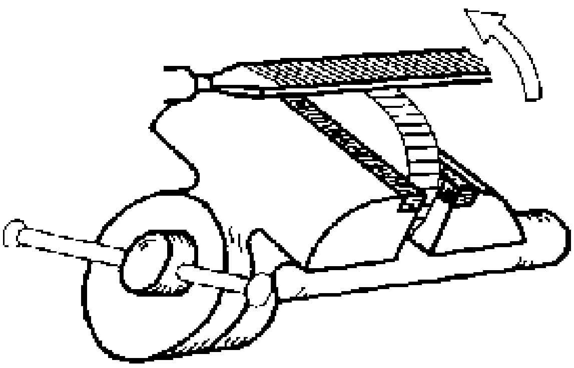


Fig. 2.4/22 Finishing of an outer rounding

Inside roundings are also roughened in transverse stroke. Subsequently, finishing is carried out by drawing In longitudinal direction (figs. 2.4/23 and 2.4/24).

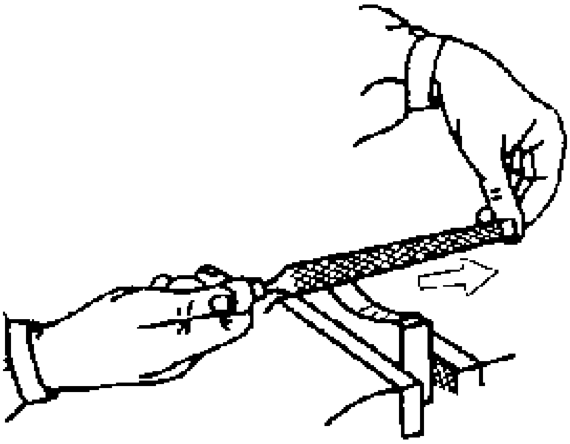


Fig. 2.4/23 Roughing of an inside rounding

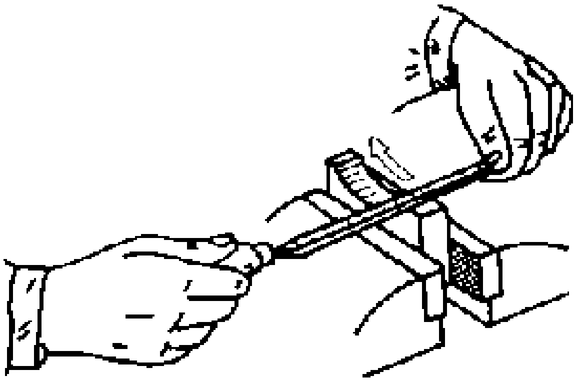


Fig. 2.4/24 Finishing of an inside rounding

Faces with high requirements on flatness are crosswise roughened and finished in longitudinal stroke (figs. 2.4/25 and 2.4/26).

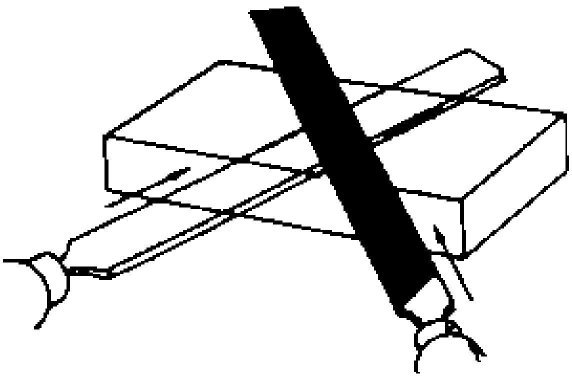


Fig. 2.4/25 Roughing of a flat surface in cross stroke

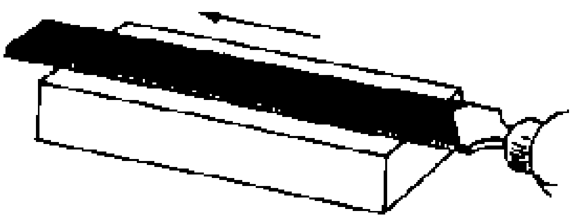


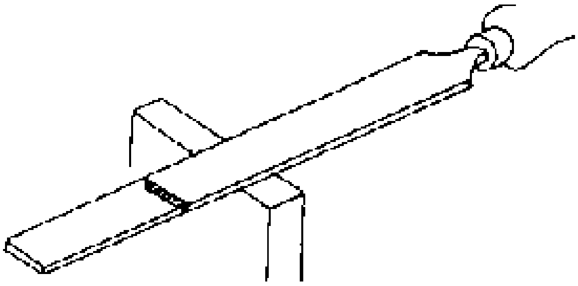
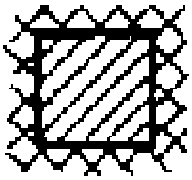
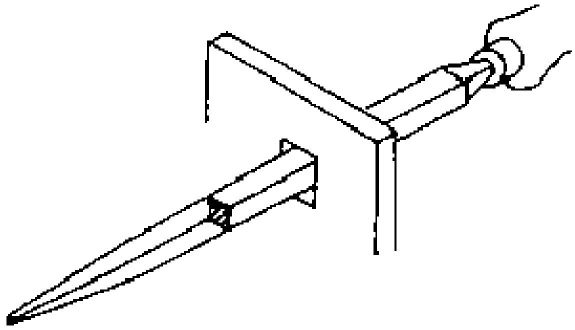
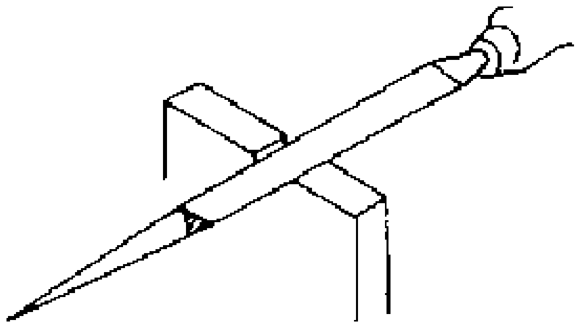
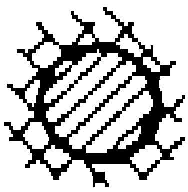
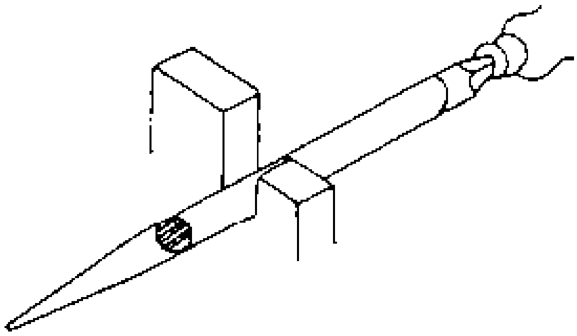
Fig. 2.4/26 Finishing in longitudinal stroke

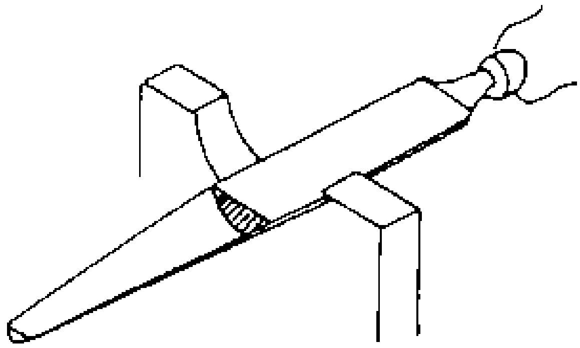
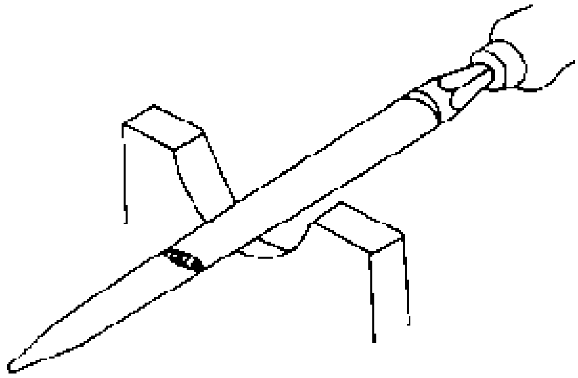
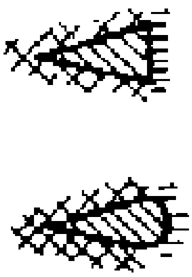
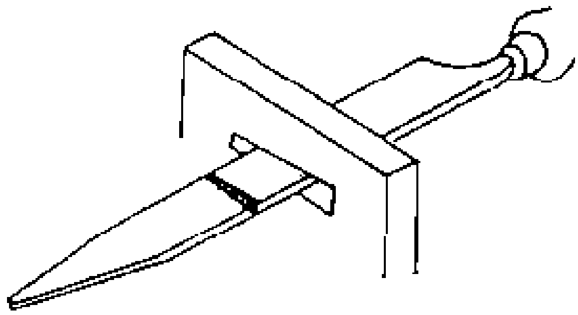
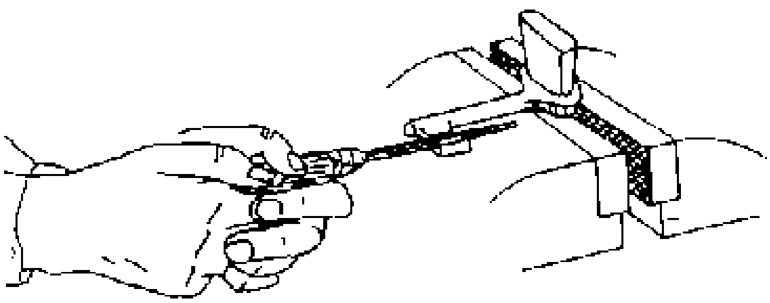
2.4.3. Types of files and their application

Task:

2.19. Repeat the types of files you know already in connection with the production and the action of the file!

Apart from the previously explained types of files there is a variety of differently shaped files provided for the different file works. The following table shows a selection:

Type of file	Application
Flat file	For normal flat faces
	
Square file	Rectangular openings or slits
	
Triangular file	Openings or slits, which are not rectangular
	
Round file	Small openings and slits with small radius
	
Half–round file	Round openings and slits with large radius

	
Crossing file	Round openings and slits with very large radius
	
Knife file	Small openings
	
Needle file with different profiles	Very small openings and slits
	

All files mentioned in the table are available with different tooth spacing for the different file works (for example roughing or finishing).

Moreover, all files are available in different nominal lengths (length of the file blade, cf. fig. 2.4/1), according to the size of the workpiece to be worked (cf. following table).

Type of file	Tooth spacing	Nominal length
Flat file	0...5	
Square file Triangular file	1...5 1...5	100...450

Round file Half–round file	0...5 0...5	
Knife file	2...5	100...250 mm
Crossing file	1...5	80...200 mm
Needle file	1...3	50...100 mm

2.4.4. Care of the files

– Do not throw files one upon another, the teeth could break out!

– Finishing files shall be often cleaned! In doing so, the file shall be brushed with the file brush in direction of the overcuts. Brush only in pulling direction (fig. 2.4/35)! Large chips are scratched out by means of a sharpened brass sheet (fig. 2.4/36).

– Do not file hardened workpieces! The teeth become blunt quickly.

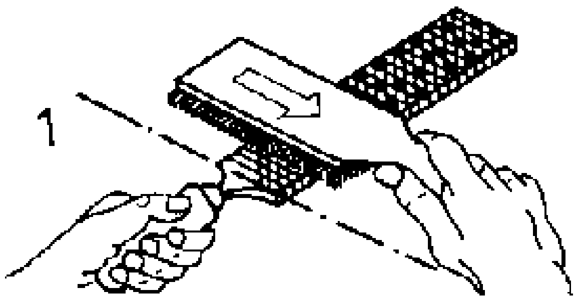


Fig. 2.4/35 Cleaning with the file brush

1 Overcut

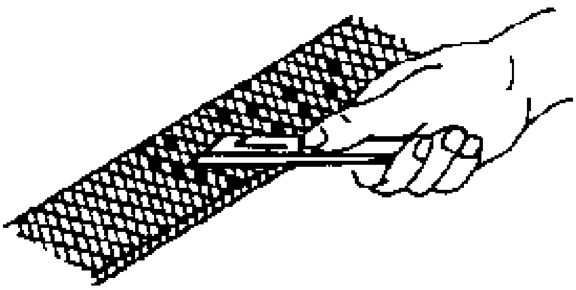


Fig. 2.4/36 Cleaning with the file cleaner

Use files with tight–seating and undamaged handles only! Do not wipe away chips with the bare hand!

Summary

– Filing is a metal–removing cutting–off process, by which the surface of the workpieces is worked.

– The selection of the file depends on the material, surface finish, stock–removal allowance, shape and size of the workpiece surface to be worked.

– The material of the workpiece determines the use of cut or milled, single–cut or double–cut files.

– The given stock–removal allowance and the required surface finish determine whether it should be roughened or finished.

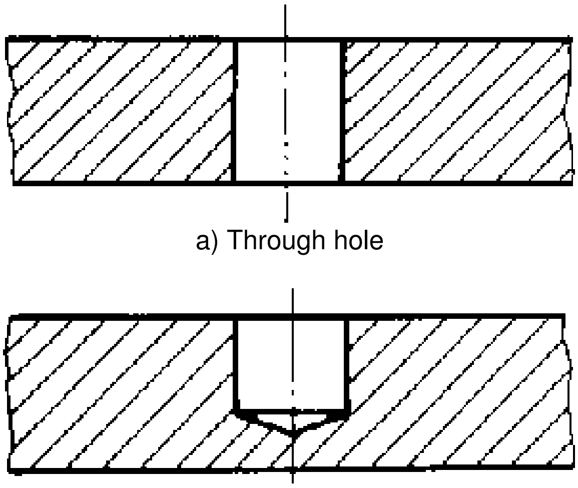
– The shape of the file depends on the shape of the surface to be worked.

– The size of the face to be worked is decisive for the nominal length of the file to be used.

2.5. Cutting–off by means of the drill

Circular holes are produced in a workpiece by cutting off with the drill. These holes serve to accommodate screws, rivets, pins, shafts and other cylindrical components. Drilling of holes can also prepare for example, penetrations (compare caulking). A hole running through the workpiece is called a through hole. When it is drilled only to a given depth, it is a blind hole (fig. 2.5/1). Drilling is – like sawing and filing a metal–removing cutting–off process. The twist drill is used in most cases to drill metals.

Fig. 2.5/1



a) Through hole

b) Blind hole

2.5.1. Design and function of the twist drill

Design

The twist drill is composed of a shank and a cutting edge (fig. 2.5/2). The shank serves for chucking the drill into the holder of the drilling machine (cf. section 2.5.2). The shank is parallel in case of smaller drill diameters, and tapered in case of larger drilling machines. The taper shank is separated from the cutting edge by the neck (cf. fig. 2.5/2).

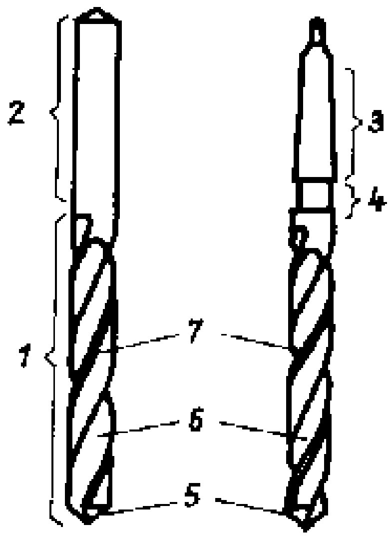
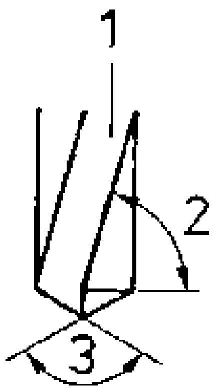


Fig. 2.5/2 Twist drill design

1 Cutting edge, 2 Parallel shank, 3 Taper shank, 4 Neck, 5 Main cutting edges, 6 Flutes (for chip transport), 7 Land

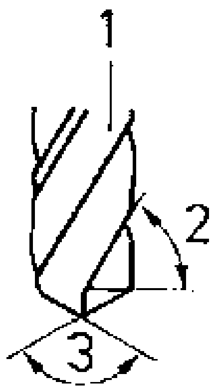
The end of the cutting edge narrows to two wedge−shaped main cutting edges. Two helical flutes serve to remove the chips. The flutes are designed in such a way that the heat generation is kept low.

Fig. 2.5/3 Flute, wedge angle and point angle at the drill cutting edges



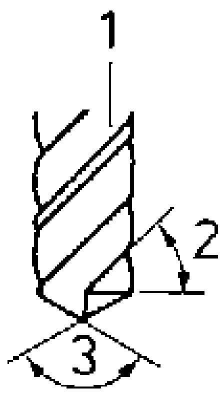
a) Drill type H for very hard materials (for example, marble)

1 Flute, 2 Wedge angle, 3 Point angle



b) Drill type N for steel, cast iron

1 Flute, 2 Wedge angle, 3 Point angle



c) Drill type W for aluminium, tin, lead

1 Flute, 2 Wedge angle, 3 Point angle

As with all cutting−off tools, the wedge angle is of importance also at the drill, where it depends on the shape of the flutes (fig. 2.5/3).

Steep flutes ? large wedge angle
Flat flutes ? small wedge angle

The point angle is easier to recognize at the drill than the wedge angle. It is formed by the two main cutting edges and is in an inverse relation to the wedge angle (cf. fig. 2.5/3).

Task:

2.20. Repeat the relation between wedge angle and material. Conclude to the relation between point angle and material!

Generally, the point angle which can be recognized easier is used to select the drill according to the material to be worked. For example, drills with a point angle of 130...140° are used for drilling aluminium and drills with a point angle of approximately 118 are used for drilling steel.

High−speed steel and super high−speed steel are especially well suited as material for drills. Drills can be provided with carbide lips.

Task:

2.21. Justify the application of these materials for drills!

Principle of drilling

The main cutting edges of the drill cause circular metal cutting of the material, whereby the drill must penetrate deeper and deeper into the workpiece. To do this, two motions are required: a rotary cutting motion around the axis of the drill and a straight−line feed motion along the drill axis (fig. 2.5/4).

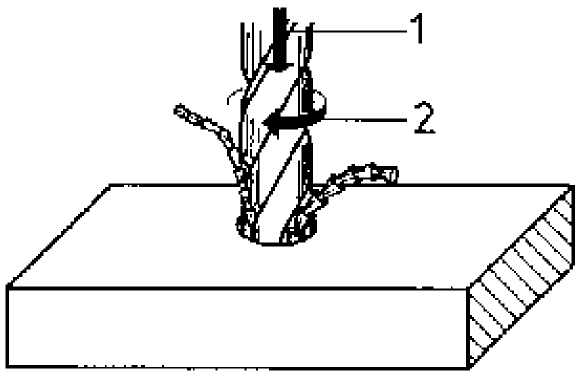


Fig. 2.5/4 Cutting and feed motions during drilling

1 Cutting motion, 2 Feed motion

Rotary cutting motion and straight−line feed motion allow the metal−cutting of the material during drilling. In addition to the point angle of the drill, also the number of revolutions, which are performed by the drill in a unit time (usually one minute) are of importance for the suitable working of the material. These revolutions are called rotational speed and are indicated as revolutions per minute (rpm or min^{-1}). The speed is transmitted to the drill by the drilling machine. It is selected according to the material of the workpiece and the drill diameter.

A general rule is:

For soft materials and small drill diameter ? high speed
For hard materials and large drill diameter ? low speed

Task:

2.22. Reflect why lower speeds are used for hard materials and large drill diameter than for soft material and small drill diameter!

2.5.2. Working with the bench−type drilling machine

In metalworking workshops, often the bench−type drilling machine is used.

Design of the bench−type drilling machine

The bench−type drilling machine consists of the following assemblies (fig. 2.5/5):

– Electric motor as drive

– Cone–pulley transmission or toothed gearing to transmit the rotary motion from the electric motor to the drill spindle and to change the speed (generally, three different speeds are adjustable)

– Drill spindle with feeding mechanism and drill chuck to receive the drill

– Drilling–machine table to receive the workpiece

– Column as carrier of the single assemblies

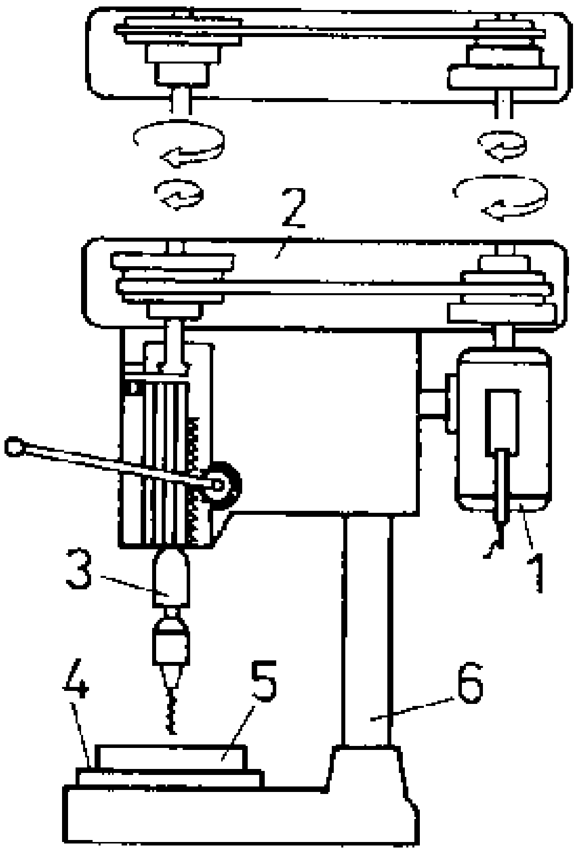
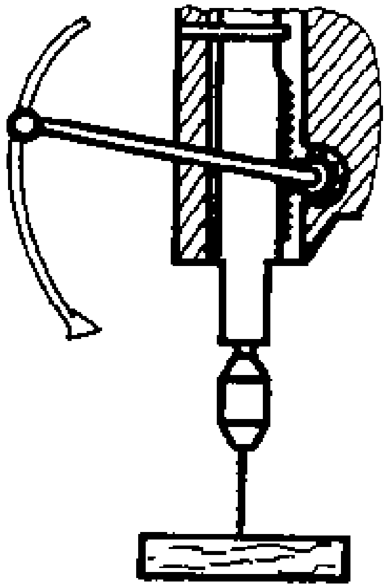


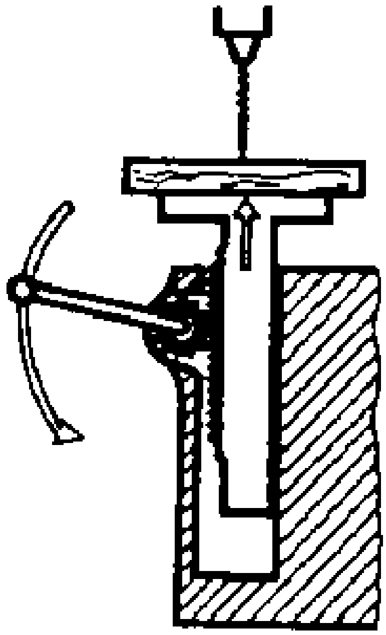
Fig. 2.5/5 Bench–type drilling machine

1 Electric motor, 2 Cone–pulley transmission, 3 Drill spindle, 4 Drilling–machine table, 5 Workpiece, 6 Column

Fig. 2.5/6 Feeding mechanism



a) at the drill spindle



b) at the drilling−machine table

Whereas the cutting motion of the drill is mechanically generated (by the electric motor via gearing and drilling spindle) the feed motion is performed by hand force via lever, toothed gear and geared rack. In most cases, it is carried out by the drilling spindle with the drill, in case of small machines also by the table with the workpiece (fig. 2.5/6a, b).

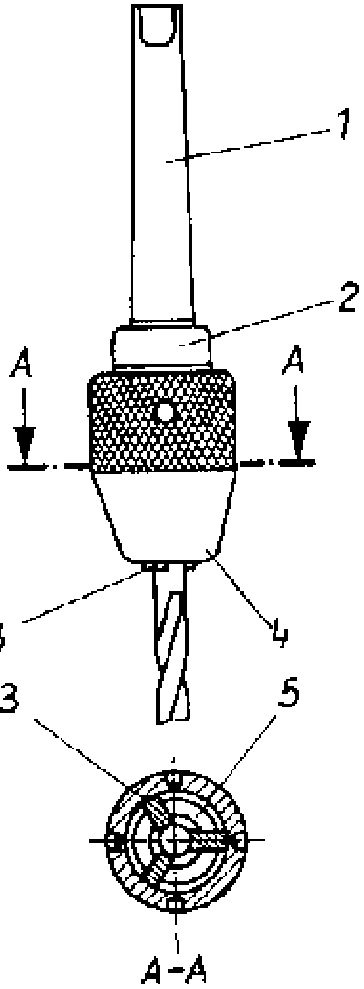


Fig. 2.5/7 Two−jaw chuck

1 Taper shank, 2 Chuck body, 3 Jaws, 4 Sleeve, 5 Intermediate chuck, 6 Locking screw

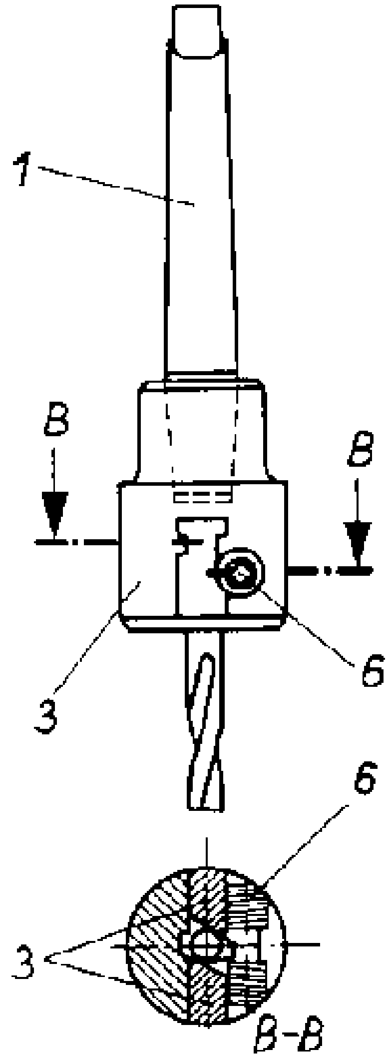


Fig. 2.5/8 Tree−law chuck

1 Taper shank, 2 Chuck body, 3 Jaws, 4 Sleeve, 5 Intermediate chuck, 6 Locking screw

Chucking device for the drill

A chucking device serves to connect the drill with the drilling spindle. Usual chucking devices for drills with parallel shank are the three−jaw chuck and the two−jaw chuck (figs. 2.5/7 and 2.5/8).

The three−jaw chuck is used for drills with a diameter to approximately 10 mm, the two−jaw chuck serves to chuck drills with a diameter larger than 10 mm. Drills with taper shank can be directly inserted into the taper drilling spindle. When the taper shank is smaller than the taper hole of the drilling spindle, drill sockets are used (fig. 2.5/9).

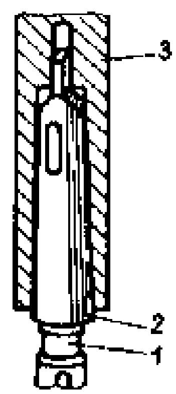


Fig. 2.5/9 Inserting a drill with drill socket

1 Drill, 2 Drill socket, 3 Spindle sleeve of the machine

Chucking the drill

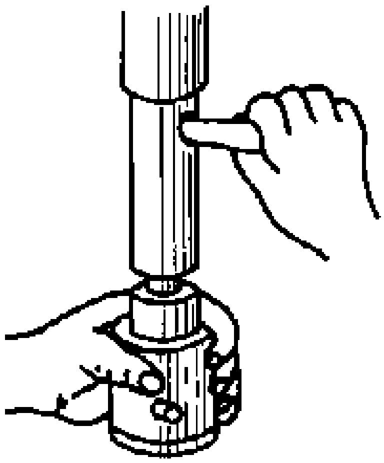
When chucking, the shank of the drill is inserted into the drill chuck to the stop and tightened with the key. When the drill was not tightened correctly, it could jam in the drill hole because of friction.

Driving in and driving out of the drill chuck

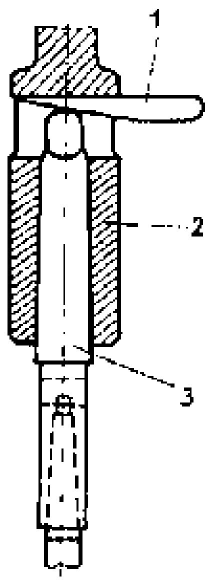
Worn out drill chucks must be exchanged. Often, another type of drill requires another drill chuck or a drill socket is required instead of the drill chuck. For driving in the drill chuck, the taper shank of the chuck is slowly inserted into the taper bore of the spindle until a counterpressure is felt and then slightly blown with the flat hand from below towards the socket. Prior to driving in, the taper shank of the chuck and the bore of the spindle shall be cleaned with a cloth or a brush. A drill drift is used to drive out the drill chuck. The drill drift is a flat steel wedge, which is inserted into the slit of the drilling spindle. The drill drift is moved up and down while it is pushed forward. Usually, the drill drift shall be handled with one hand and the other hand shall hold the drill chuck. When the hand force is not sufficient, a rubber or wooden hammer can also be used. Prior to that, the table must be adjusted short under the drill chuck and covered with cleaning cloths. When the drill chuck falls on an un−padded drill table, it can be distorted.

In the same way as drill chucks, also drill sockets or drills with suitable taper shank are driven in or out (figs. 2.5/9 and 2.5/10).

Fig. 2.5/10 Removal of the drill by means of the drill socket



a) How to handle the drill socket



b) Longitudinal section of the spindle sleeve

1 Drift, 2 Drill spindle, 3 Increased drill socket

Clamping of the workpiece

Small flat workpieces can be hold with the hand vice (fig. 2.5/11).

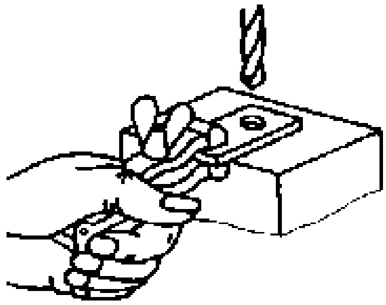


Fig. 2.5/11 Clamping with the hand vice

Larger workpieces are clamped into the machine vice (fig. 2.5/12). The vice is to be fixed with lock screws on the drill table, so that it is firmly placed on the table.

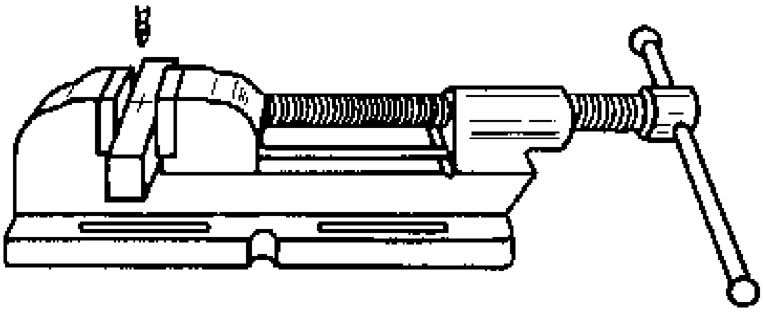


Fig. 2.5/12 Clamping in the machine vice

Workpieces, which cannot be clamped because of their shape or size, can directly be clamped on the drill table. For this purpose, the drill table is provided with grooves with lock screws (the vice is also fixed this way). If necessary, the lock screws can be shifted, thus offering many possibilities for clamping workpieces.

Commonly used is clamping by means of lock screws and tie bar. If possible, the lock screw shall seat as close to the workpiece as possible. Since the tie bar must lie horizontally, shims (steel plates of different thickness (fig. 2.5/13) or a step block (fig. 2.5/14)) must be used additionally.

Cylindrical workpieces of larger diameters are clamped by means of a tie bar or a Vee−block.

The tie bar must be long enough so that it can be fastened with two lock screws, and the Vee−block with the workpiece lies between them (fig. 2.5/15).

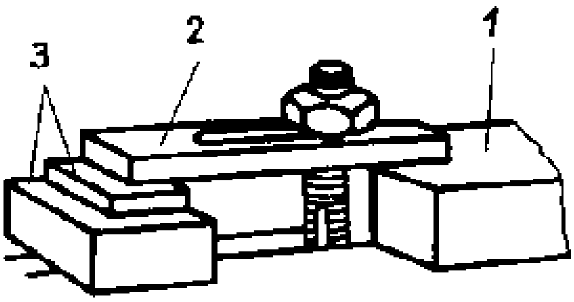


Fig. 2.5/13 Clamping with tie bar and shims

1 Workpiece, 2 Tie bar, 3 Shims

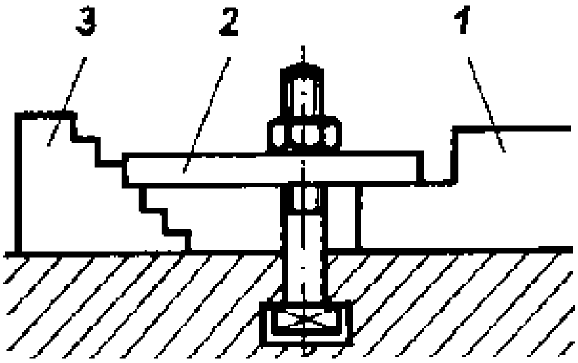


Fig. 2.5/14 Clamping with a tie bar and step block

1 Workpiece, 2 Tie bar, 3 Step block

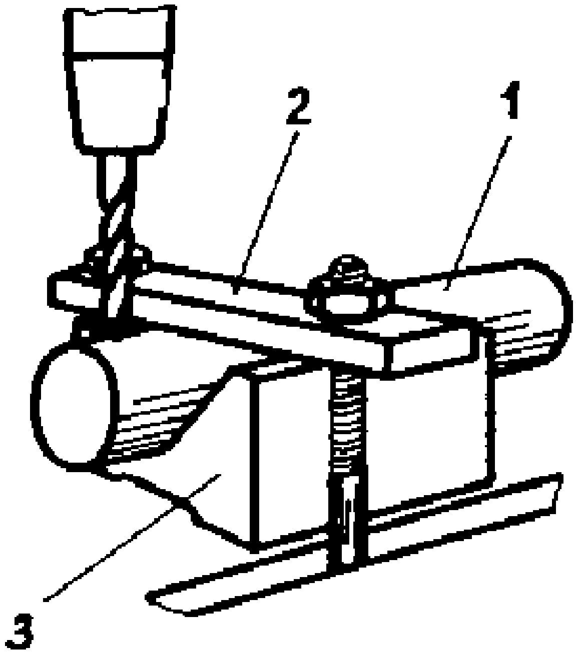


Fig. 2.5/15 Clamping with tie bar and Vee−blocks

1 Workpiece, 2 Tie bar, 3 Vee−block

2.5.3. Operation and care of the drilling machine

− Only work with perfectly ground drill! Drills with blunt cutting edges wear out too quickly. Drills with unequally long cutting edges produce too large holes.

− Check the drill shank and the drill chuck for cleanliness prior to chucking the drill! Clean with a brush, if necessary! Chips sticking at the chuck or at the shank can cause chattering of the drill.

− Check whether the drill puts on correctly only when the drilling spindle rests! Check again whether the drill hole seats well shortly after starting drilling!

− Adjust the speed of the drilling spindle according to the material and the drill diameter!

− Actuate the hand lever for the feed during drilling! When the drill penetrates the material, reduce the feed and draw the drill back with running motor!

− In case of deep holes, interrupt the feed often, draw back the drill, switch off the machine, cool the drill, remove the chips!

− For cooling (particularly for steel, aluminium, copper), brush the drill with soap water or drilling oil emulsion!

Because of the frictional heat generated during drilling, the water evaporates and cools the drill this way. The residual soapy or oily components of the agent form a sliding film on the drill which reduces simultaneously the frictional heat.

Grey cast iron is not cooled!

– Holes with large diameter are spot–drilled with a small drill.

– After drilling, table and drill support must be cleaned with a chip broom or a brush.

Wear a head shield and tight–fitting clothes when working at the electrical drilling machine!

Clamp the workpiece firmly before drilling!

A poorly clamped workpiece can be dragged along by the drill (danger of accidents and risk of tool breakage).

Do not remove chips with the bare hand or by blowing away, but use a hand–brush or a brush!

2.5.4. Drilling machines and their application

Hand drills are practically used for repairs or assembly jobs. Drills with a diameter up to 10 mm can be chucked into these machines.

In case of the manually driven hand drill, the cutting motion is transmitted by hand force from the crank via bevel gears to the drilling spindle with the drill chuck. Mostly, two different speeds (fast motion, slow motion) can be selected. With the machine shown in fig. 2.5/16 the speed can be changed by resetting the handle and the hand crank. The thrust for feeding is generated by pressure of the breast on the breast plate.

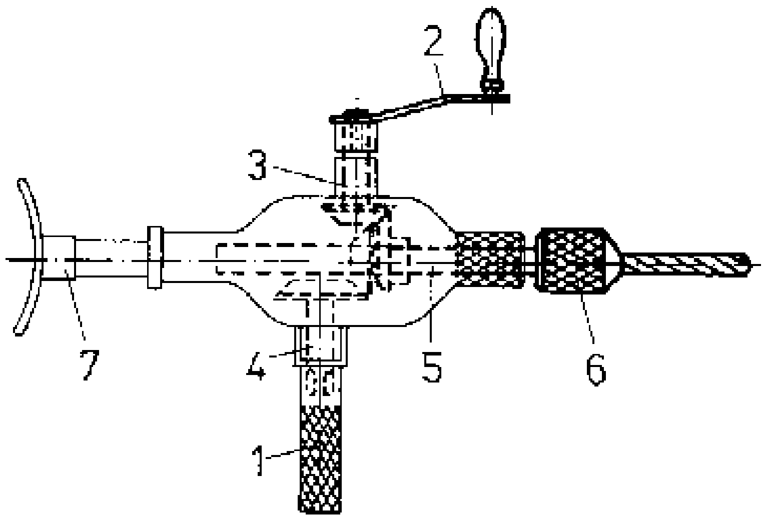


Fig. 2.5/16 Hand drill manually driven

1 Handle, 2 Hand crank, 3 Slow motion, 4 Fast motion, 5 Drill spindle, 6 Drill chuck, 7 Breast plate

In case of the electric hand drill (fig. 2.5/17), the cutting motion is generated by an electric motor and transmitted via a change–speed gear (mostly, for two speeds) to the drilling spindle with the drill chuck. The thrust for feeding is exerted with the right hand via the handle, the left hand clasps the handle and guides the hand drill.

Column drilling machines (fig. 2.5/18) basically, consist of the same assemblies as bench–type drilling machines, larger workpieces, however, can be worked on them and larger holes can be drilled.

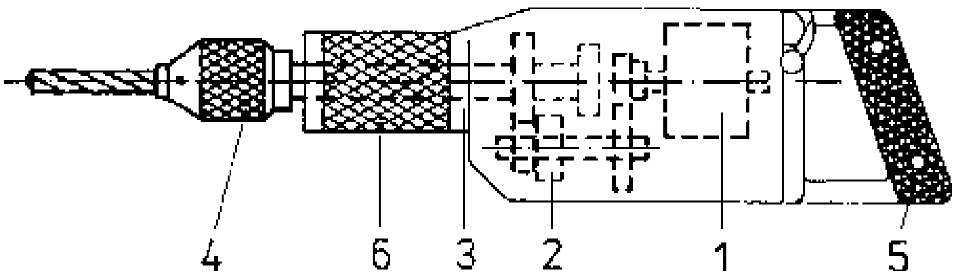


Fig. 2.5/17 Electric hand drill

1 Electric motor, 2 Change−speed gear, 3 Drill spindle, 4 Drill chuck, 5 Handle, 6 Neck

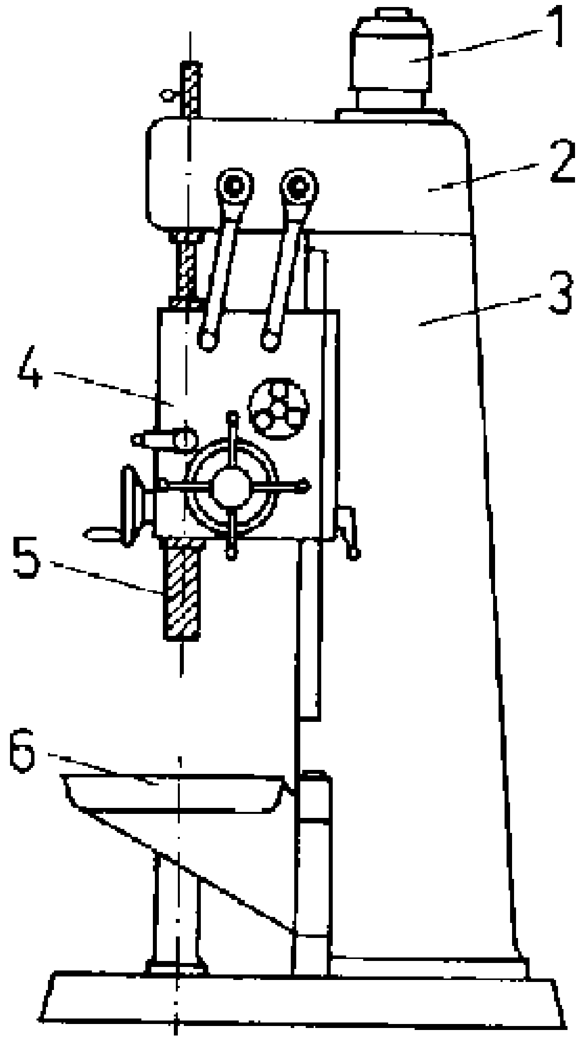


Fig. 2.5/18 Column drilling machine

1 Electric motor, 2 Change−speed gear, 3 Column, 4 Spindle head, 5 Drill spindle, 6 Drill table

By means of a change−speed gear the motor speed can be converted to the desired speed of the drilling spindle. With modern machines, up to 32 speeds can be selected. The drilling spindle receives the thrust for feeding via a feed gear or via a handwheel. The mechanical feed can automatically be switched off (limitation of feed depth).

Column drilling machines are equipped with a cooling facility for constant cooling of the drill.

Summary

– The selection of the drill depends on the size of the hole to be drilled (hole diameter = drill diameter) and on the workpiece material.

– The speed of the drilling machine is chosen according to the drill diameter and the material of the workpieces.

Tasks:

2.23. Reflect why holes with large diameter should be spot–drilled with a smaller drill.
2.24. Compare a twist drill for steel with a twist drill for light metal. Indicate the differences!
2.25. List the drilling machines and their applications you know!

Drill and workpiece must always be firmly chucked resp. clamped during drilling (accident hazard)!

2.6. Cutting–off by means of the countersink and the counterbore

When the heads of screws or rivets shall not project beyond the workpiece surface, the drill holes must be enlarged, counterbored or countersunk. Whether it is counterbored or countersunk, depends on the shape of the screw or rivet head (figs. 2.6/1 and 2.6/2). Counter–boring and countersinking serve also to debur the edges of holes or to chamfer them. Countersinking or counterboring is a metal–removing cutting–off process like drilling. A very usual tool is the countersink.

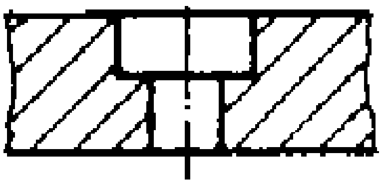


Fig. 2.6/1 Counterbore for filister head screw

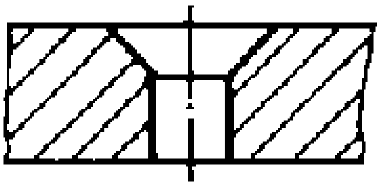


Fig. 2.6/2 Countersinking for countersunk rivet

2.6.1. Design and function of the countersink

Design

Fig. 2.6/3 shows a countersink, which can be used both for countersinking and for deburring a hole. The countersink consists of a shank and a somewhat larger cylindrical head. The head is provided with several wedge–shaped cutting edges which meet at the point of the countersink. Together they form the point angle.

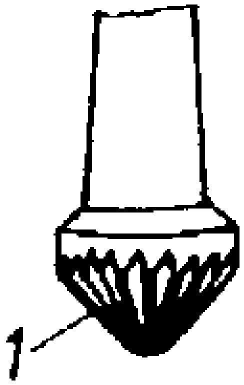


Fig. 2.6/3 Countersink

1 Head with cutting edges,

This point angle must correspond to the cone shape (included countersink angle) of the screw or rivet head, which shall be received by the countersunk hole. Usual included countersink angles for screws and rivets are angles of 60°, 75°, 90° and 120°.

Due to the larger number of cutting edges, the flutes with the countersink are smaller than with the twist drill. However, they are sufficient, because less material is removed than during drilling.

Countersinks with somewhat larger flutes must be used for working light metals.

Countersinks consist of the same material as drills.

Action

Like the twist drill, the countersink makes a rotary cutting motion and a straight−line feed motion. In doing so, small chips are removed from the workpiece. For countersinking, a lower speed is used than for drilling because the small flutes cannot remove sufficient chips with higher speeds. Generally, the larger number of cutting edges of the countersink results in a better surface finish than with drilling.

2.6.2. Working with the countersink

Countersinks are chucked into the drilling machine like drills. Basically, the same rules apply for working with the countersink as with the drill. First of all, important are:

– correct selection of tool and speed,
– firmly fixing the tool and workpiece.

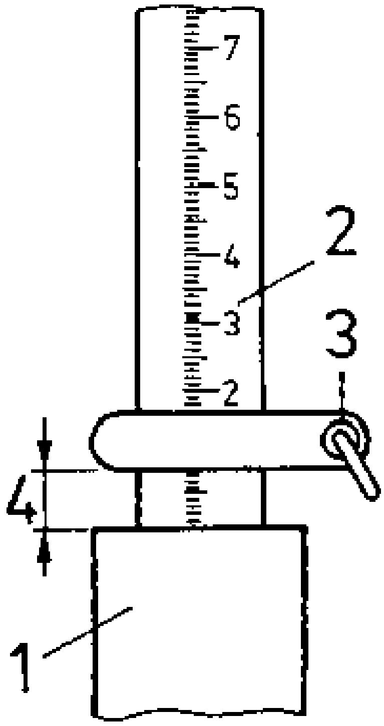


Fig. 2.6/4 Adjusting the depth of countersinking at the column drilling machine

1 Spindle head, 2 Drill spindle sleeve with millimetre graduation, 3 Adjustable stop, 4 Depth of countersinking

Adjustment of the countersinking depth

Countersinking should be carried out on firmly mounted drilling machines (bench−type drilling machine or column drilling machine). In most cases, these machines allow the adjustment of the countersinking depth. For this purpose, for example, the drilling spindle socket can be provided with a millimetre graduation and an adjustable stop. After having the countersink placed on the workpiece surface, the stop is adjusted to the desired countersinking depth (fig. 2.6/4). The feed is now limited by the stop. When the drilling machine has no adjusting facility, the work must be frequently interrupted and re−measured.

Deburring

Often drilled holes have a bur (flanges at the edge of a hole). This bur is removed by means of the countersink. Mostly, a small chamfer (bevelling) is countersunk in the edge of the hole. For deburring and chamfering, the depth of the countersink is adjusted in such a way that the chamfer can be felt with the finger and is perceptible with the eye (figs. 2.6/5 and 2.6/6).

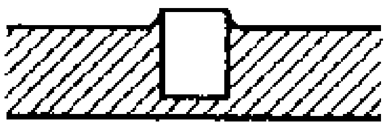


Fig. 2.6/5 Hole with burr

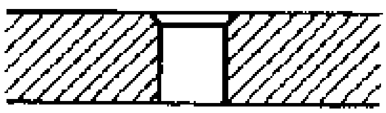


Fig. 2.6/6 Deburred and chamfered hole

Enlarging

Holes can be enlarged by countersinks by means of the countersink tool.

Task:

2.26. Which fact determines the shape of the countersink?

When a hole shall be countersunk for a flush rivet, the countersink can have a larger diameter than the head of the flush rivet. In case of too deep countersinking, the flush rivet seats below the workpiece surface. A countersink for a flush rivet in due form is shown in fig. 2.6/2.

Contrary to flush rivets, countersunk screws have a small cylindrical shoulder which shall be received by the countersink. In case of such countersinks, the countersink tool must have the same diameter as the cylindrical shoulder of the countersunk screw (fig. 2.6/7).

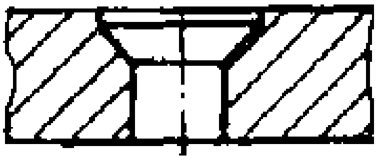
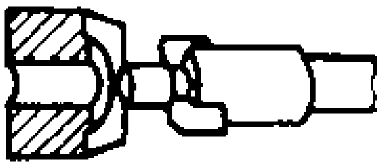
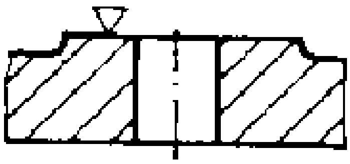
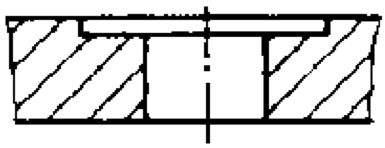
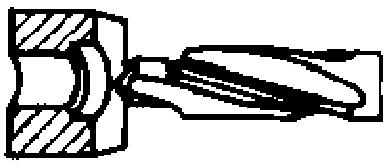
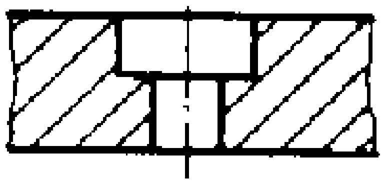
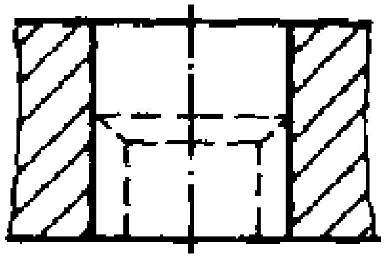
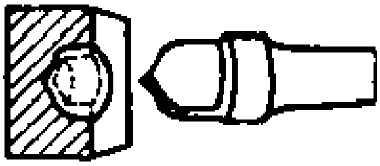
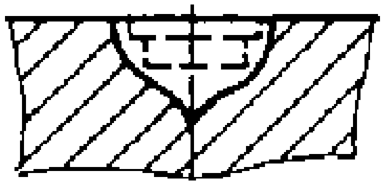


Fig. 2.6/7 Countersink for countersunk screw

2.6.3. Types of countersinks and counterbores and their application

Apart from the most frequently used countersink, there is a wide variety of other types of countersinks and counterbores. The shape of their cutting edges depends on the shape of the desired countersink or counterbore. The following table shows some usual types of countersinks and counterbores.

Type of countersink or counterbore	Application
Spot facer Double−edged counter−bore, the cutting edges are rectangular to the tool axis. The spot facer is provided with a guide.	Producing even seats for screw heads (The seats can be raised or somewhat spot faced).
	 
Counterbore Multiple−edged counterbore, cutting edges rectangular to the tool axis, also equipped with a guide	Producing counterbores for filister−head screws
	
Twist countersink Further developed twist drill, but with 3 cutting edges, cutting edges acute−angled to the tool axis	Producing countersinks for countersunk screws

	
Shaped counterbore Counterbore with not−straight line cutting edges	Producing domed and unregularly shaped! counterbores
	

Summary

− Drilled holes are further worked by cutting off with the countersink or counterbore. They can be deburred, chamfered, bevelled or enlarged.

− The cutting edges with the spot facer and counterbore are rectangular to the tool axis (guidance with guide required).

− The cutting edges with the countersink and twist countersink are acute−angled to the tool axis (good guidance, also without guide possible).

− Shaped counterbores have unregularly shaped cutting edges.

Countersinks or counterbores with straight−line cutting edges		Counterbore with unregularly shaped cutting edges
Cutting edges rectangular to tool axis	Cutting edges acute−angled to tool axis	
Spot facer; counterbore	Countersink; twist countersink	Shaped counterbore

Task:

2.27. Mention at least one example of application for each type of countersink or counter−bore!

Observe the labour safety rules for working at drilling machines!

2.7. Cutting−off by threading

Workpieces can be connected and loosened by means of threads. For this purpose, always an external thread and an internal thread are required, whose courses of the thread engage. Typical examples for the connection by threads are bolt and nut (fig. 2.7/1). The screw bolt of the bolt is provided with the external thread. The nut is provided with the internal thread. However, the internal thread can also be directly in a workpiece (fig. 2.7/2).

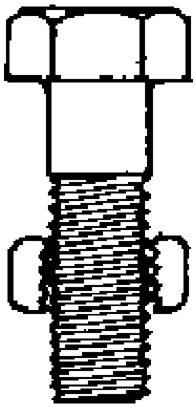


Fig. 2.7/1 Bolt and nut (cross−section)

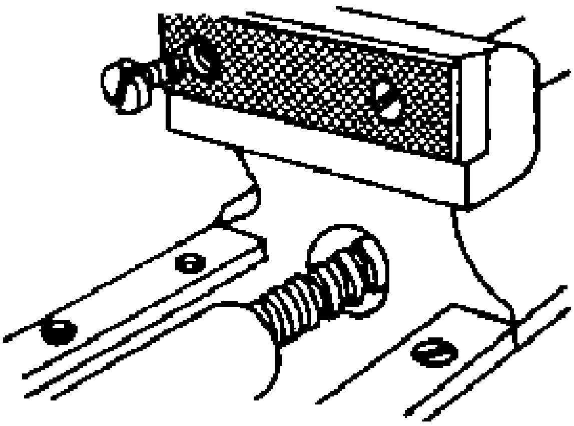


Fig. 2.7/2 Fastening screw head and thread for transmitting motions

As the thread in the mentioned examples serves for fastening, these threads are called fastening threads.

Task:

2.28. Name examples of application for fastening threads!

By means of threads, parts of machines and devices can be moved. For example, the movable clamping jaw of the vice is provided with an internal thread, the screw spindle carries the external thread (fig. 2.7/2). The clamping jaw is moved by turning the screw spindle. Such threads are called threads for transmitting motions.

Task:

2.29. Which examples for threads for transmitting motions are known to you?

Nowadays, threads can be cut by machines. However, thread cutting by hand is required when machines cannot be used for technical or economical reasons (production costs), for example in case of individual production and repair jobs.

Thread cutting is a metal−removing cutting−off process, whereby courses of the thread are cut out of a bolt or of a drilled hole.

When cutting internal threads, the thread tap is used and when cutting external threads, the thread cutting die is applied.

2.7.1. Design and function of the thread tap and the thread cutting die

Design of the thread tap

The thread tap can be compared with a screw, which is provided with flutes (fig. 2.7/3). At the same time, the wedge−shaped cutting edges are formed by working in flutes (fig. 2.7/4).

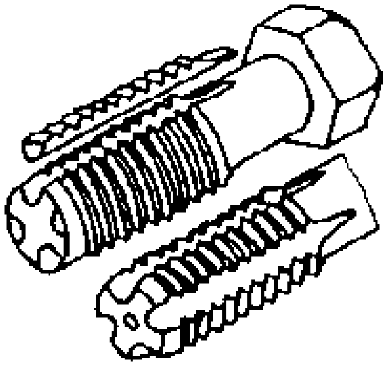


Fig. 2.7/3 Tap developed from the screw

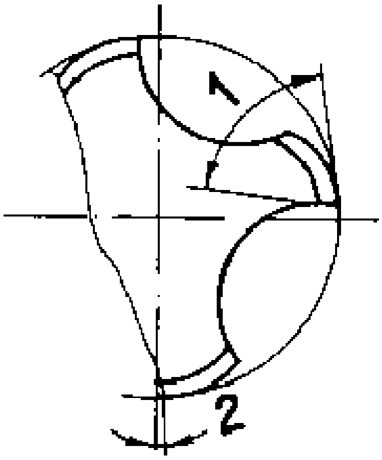


Fig. 2.7/4 Wedge angle at the cutting edges of the tap

1 Wedge angle, 2 Land

To obtain metal removing of the material by these cutting edges, they must be worked such, that only the cutting edge and a small bevel cut the material. In case of thread taps with large diameters, the cutting action must be distributed to several cutting edges. These taps have several flutes. There are taps with 3, 4, 5 and 7 flutes. The larger number of flutes with larger tap diameter is also required because of the larger quantity of chips, which must be carried away. The lower part of the thread tap is a little tapered so that it can easily start cutting (start). The upper part of the thread tap, the shank, ends in a square (fig. 2.7/5). This serves to chuck the thread tap into the tap wrench (figs. 2.7/11 to 2.7/13, section 2.7.2.).

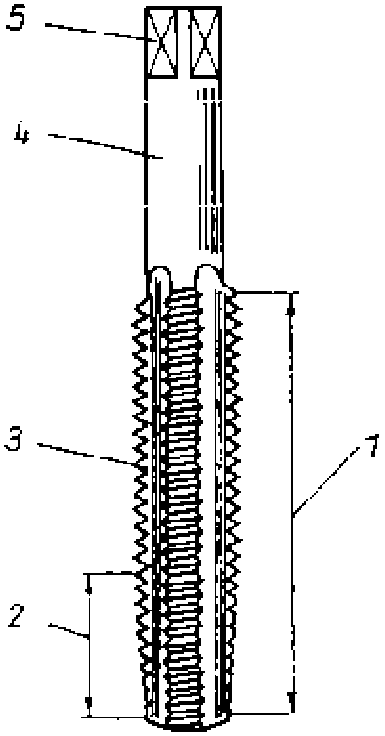


Fig. 2.7/5 Tap

1 Threaded part, 2 Start of the cut, 3 Flutes, 4 Shank, 5 Square end

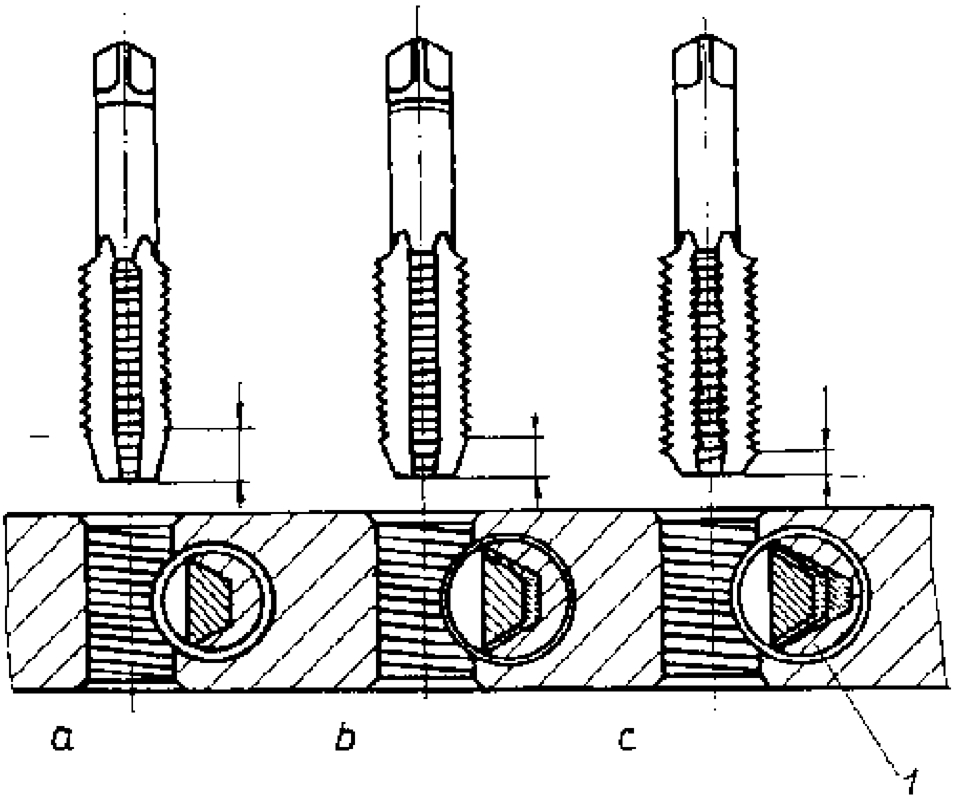


Fig. 2.7/6 Serial tap

a) Entering tap for roughing out, b) Plug tap, c) Third tap
1 Thread profile

To cut an internal thread, mostly a serial tap is used. The serial tap consists of entering tap, plug tap and third tap. The individual taps differ in how they work out the thread profile. The entering tap for roughing out has a little worked out thread profile only, plug tap shows a somewhat better worked out profile and the third tap has the required thread profile (figs. 2.7/6 and 2.7/7). The third tap smoothens the thread simultaneously.

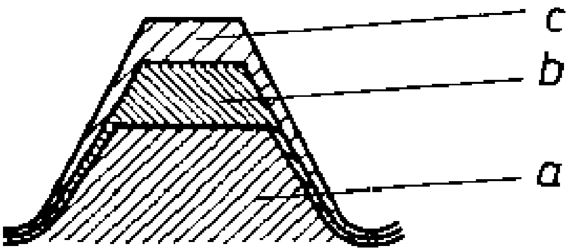


Fig. 2.7/7 Thread profiles for taps

a) Entering tap for roughening out, b) Plug tap, c) Third tap

The thread taps of a set are marked as follows, so that they are always inserted in the right order:

Entering tap for roughing out	– one ring around the shank
Plug tap	– two rings around the shank
Third tap	– without ring

The service life of the thread taps is increased by distributing the cutting action to several tools. When one tap is left out, the other ones are overloaded (risk *of* breakage)! Moreover, the strength of the thread is impaired.

Tapping of short through holes can be carried out by means of the hand tap. This tap combines the No. 1 tap for roughing out, the No. 2 tap and the No. 3 tap in one tool. Since the start has to carry out always the main cutting action, it is especially long at the hand tap (fig. 2.7/8).

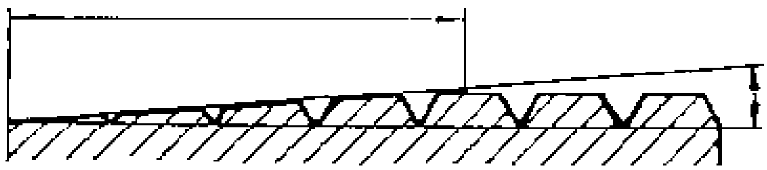


Fig. 2.7/8 Hand tap

Design of the thread–cutting die

The thread–cutting die can be imagined to be developed from the nut into which flutes were worked in (fig. 2.7/9). The number of the flutes corresponds to that of the thread tap. Like with the thread tap, the cutting edges of the thread–cutting die must be ground correspondingly, to obtain the efficient wedge angle of the cutting edges (fig. 2.7/10). The thread of the thread–cutting die is countersunk at both sides. The start, formed this way, has the same function as the start of the tap: it carries out the main cutting action during cutting the thread. The cutting edges of the following courses of the thread cut the thread finally and smoothes it. Thread–cutting dies are provided with holes at their circumference. These serve to receive the thread–cutting die in the die holder for threading (figs. 2.7/14 and 2.7/15) (section 2.7.2.).

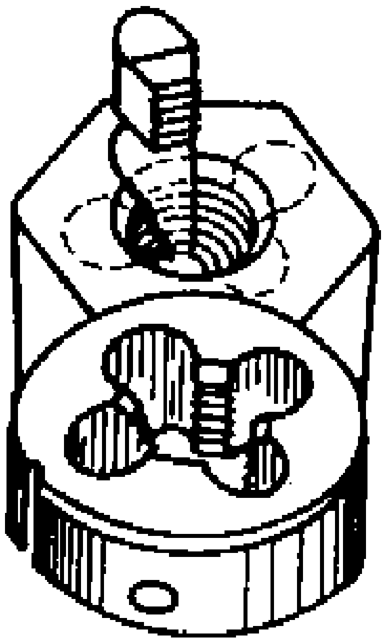


Fig. 2.7/9 Thread−cutting die, developed from the nut

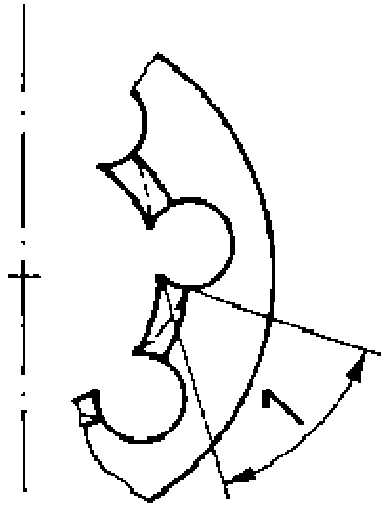


Fig. 2.7/10 Wedge angle at the cutting edges of the thread−cutting die

Function of tap and thread−cutting die

As during drilling, countersinking and counterboring, a rotary cutting motion and a straight−line feed motion are carried out during threading. In doing so, the tool screws itself into the material and removes chips. The main cutting action is done by the start of the tool. The middle part of the thread smoothes the courses of threads and the last part serves to guide the tool.

When tapping with the thread typ, mostly, three operations are necessary: roughing−out, tapping, finish tapping (exception: hand tap).

Threading with the thread−cutting die is always carried out in one operation.

Task:

2.30. In which cases can the hand tap be used for tapping?
Conclude to the application of the thread−cutting die as hand tool!

2.7.2. Working with thread tap and thread−cutting die

Chucking of the tool

The thread tap is inserted into a wrench for tapping. There are several types of wrenches available. One−hole wrench, ball wrench and adjustable wrench are typical ones.

− One−hole wrenches (fig. 2.7/11) can only be used for a certain size of the square.

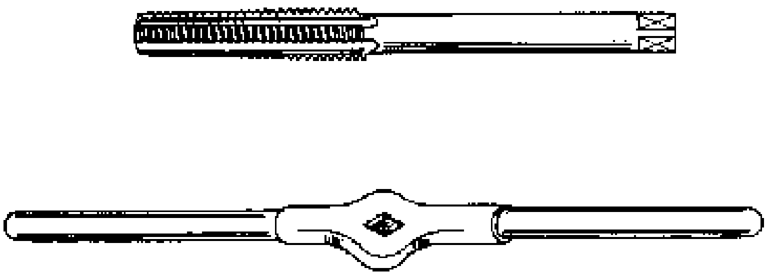


Fig. 2.7/11 Single−hole wrench

− Ball wrenches (fig. 2.7/12) can receive four different sizes of the square.

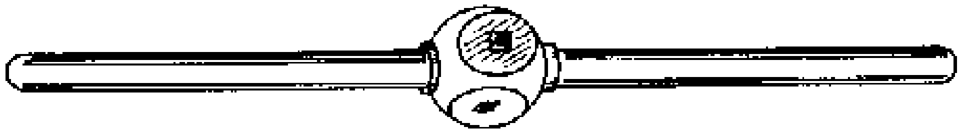


Fig. 2.7/12 Ball wrench

− Adjustable wrenches (fig. 2.7/13) have movable jaws, which can be adjusted to any desired size of the square by means of a knurled handle.

Fig. 2.7/13 Adjustable wrench

Thread−cutting dies can be chucked into the die holder for threading. The die holder for threading is provided with threaded pins. After inserting the thread−cutting die, the threaded pins are tightened in such a way that they engage in the holes of the thread−cutting die (fig. 2.7/14). In case of some die holders for threading, the thread−cutting die must be inserted into a capsula. Then this capsula is fastened in the die holder for threading by means of fixing pins (fig. 2.7/15).

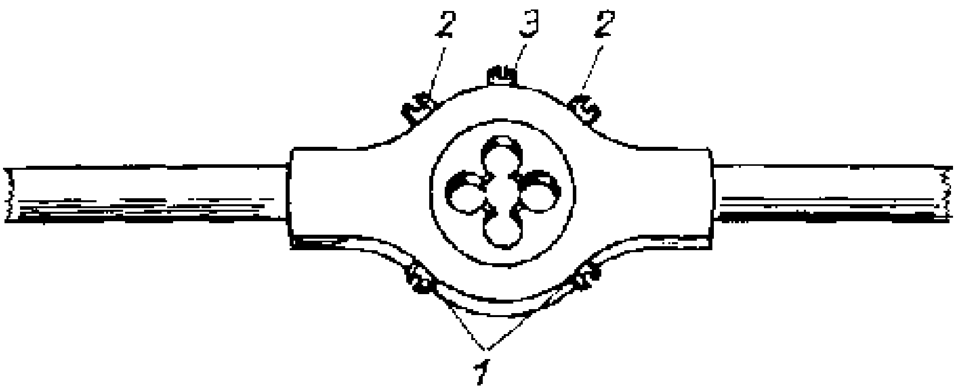


Fig. 2.7/14 Die holder for threading with thread−cutting die

1 Fixing pin, 2 Pressure pins, 3 Expanding pins Slotted thread−cutting dies can slightly be altered in width by means of pressure pins and expanding pin

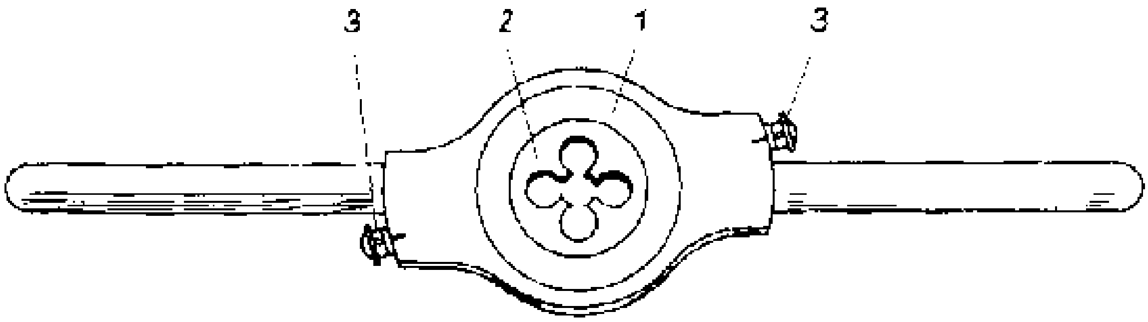


Fig. 2.7/15 Die holder for threading with jacket and thread−cutting die

1 Jacket, 2 Thread−cutting die, 3 Fixing pins

Apart from thread−cutting die and die holder for threading, external threads can also be cut by <u>die stocks</u>. These consist of two bolt dies which are pressed together via a pressure part by means of a clamp bolt (fig. 2.7/16).

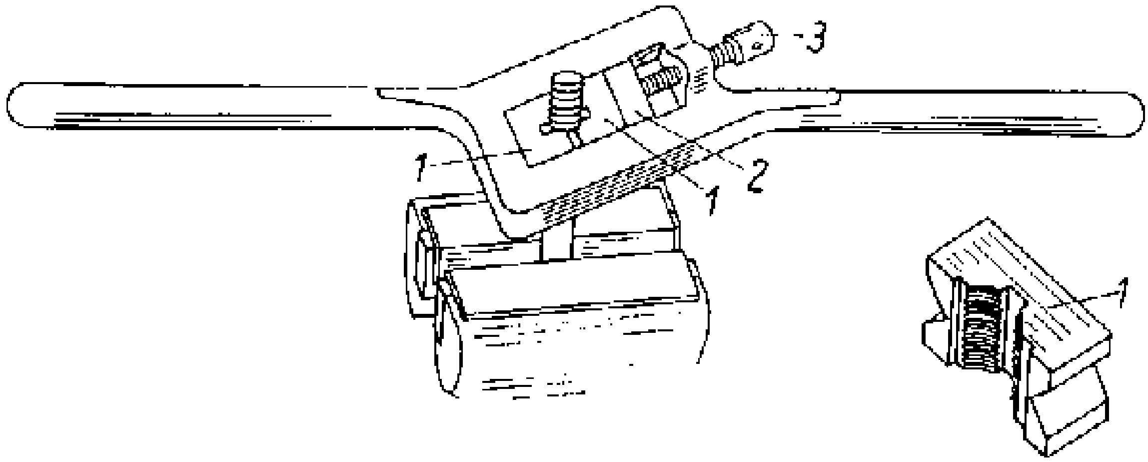


Fig. 2.7/16 Die stock with bolt dies

1 Bolt dies, 2 Pressure part, 3 Clamp bolt

<u>Tapping of internal threads</u>

Internal threads are tapped into drilled holes. The drilled hole for an internal thread is called <u>tapping−size hole</u>. The diameter of the tapping−size hole (minor diameter of the internal thread) depends on the desired diameter of the internal thread and on the workpiece material. As always a small part of the material (in case of soft material somewhat more than with hard material) is squeezed into the courses of the thread of the thread tap during tapping, the tapping−size hole must be drilled slightly larger than the minor diameter of the internal thread.

Example:

The outside diameter of a thread − also called nominal diameter, because the thread is named after it − amounts to 5 mm, the inside diameter (minor diameter of the thread) to 3.9 mm. In case of soft material, the minor diameter of the internal thread must amount to 4.1 mm; in case of hard material, a diameter of 4.2 mm must be chosen (fig. 2.7/17).

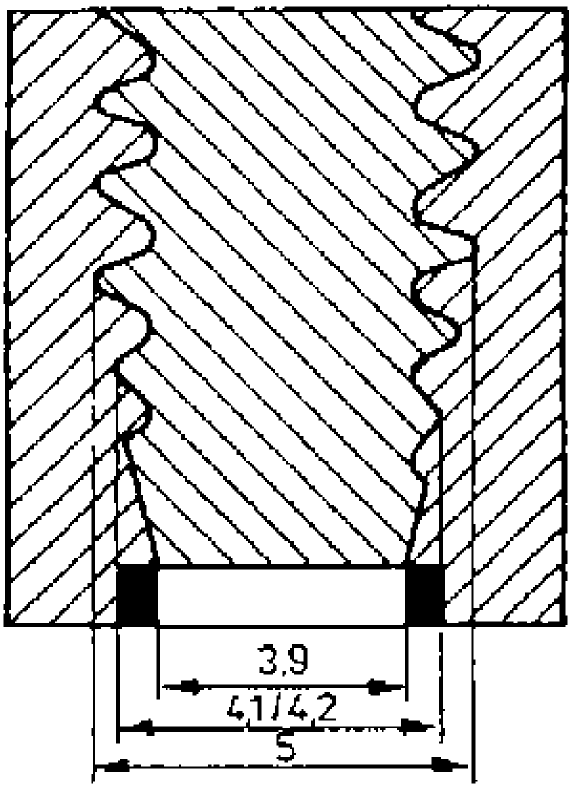


Fig. 2.7/17 Diameter of thread and tapping hole

5 mm = nominal diameter of the thread
3.9 mm = minor diameter of the thread
4.1 mm or 4.2 mm = diameter of the tapping hole

To facilitate the selection of the appropriate twist drill for tapping the tapping−size hole, the respective diameters of tap and tapping−size hole were listed in a table for soft and hard materials (cf. section 2.7.3).

When internal threads are tapped into blind holes, the length of the start at the tap drill must be taken into account. The length of the start is generally taken as the 0.7 fold of the nominal diameter of the thread. It must be taken into account for the determination of the depth of the" blind hole (tapping−size hole):

▌ Depth of the tapping−size hole = thread length +0.7. nominal diameter of the thread.

Example:

A thread with the nominal diameter of 4 mm and the thread length of 20 mm shall be tapped into a blind hole. Determine the depth of the blind hole (tapping−size hole) to be drilled:

Depth of the tapping−size hole

= 20 mm + (0.7 . 4 mm)
= 20 mm + 2.8 mm
= 22.8 mm

Task:

2.31. Determine the depth of the tapping−size hole for a thread with the nominal diameter of 5 mm and the thread length of 35 mm!

Each tapping−size hole must be countersunk with a 60° countersink. In such a way, placing the thread tap is easier. Through holes are countersunk at both sides.

When tapping with the serial tap, the correct sequence of the taps is to be taken into account.

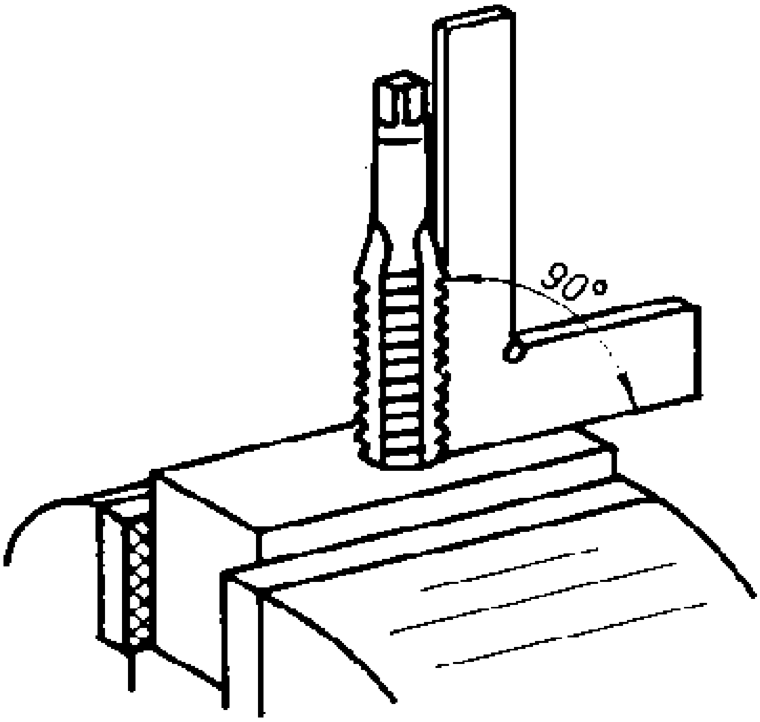


Fig. 2.7/18 Checking of the perpendicular position of the No. 1 tap

To guarantee that the No. 1 tap for roughing out engages perpendicularly into the tapping−size hole, its position is first checked by means of a thin steel try square (fig. 2.7/18). After placing the wrench, it is carefully (with little feed) started. When tapping further, it shall be taken into account, that after two or three turns a half reverse rotation must be carried out always (fig. 2.7/19).

This way, the chips are broken and slide easier out of the flutes. At the same time, a lubricant can be fed. No. 2 and No. 3 taps are first turned in by hand only. Only when a safe guidance is felt in the roughed out courses of the thread, the wrench is placed. Also when tapping with No. 2 tap and No. 3 tap, it is alternating turned forward and reversely (cf. fig. 2.7/19).

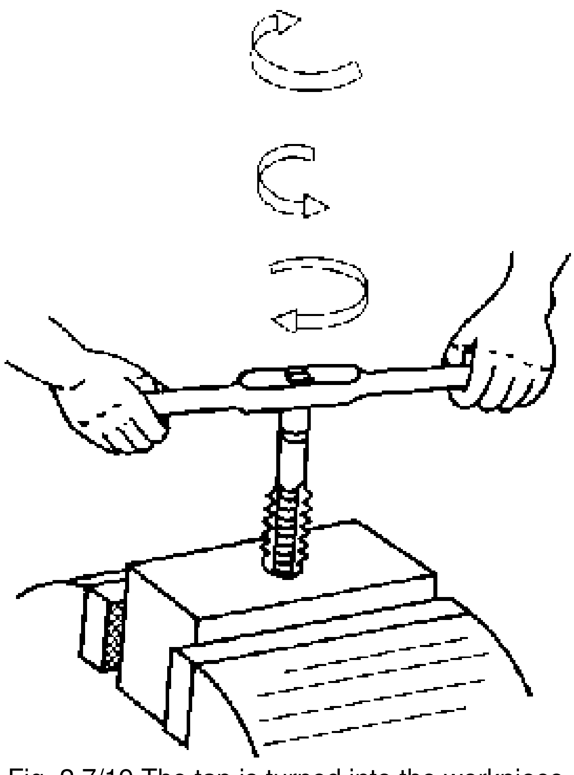


Fig. 2.7/19 The tap is turned into the workpiece

Cutting of external threads

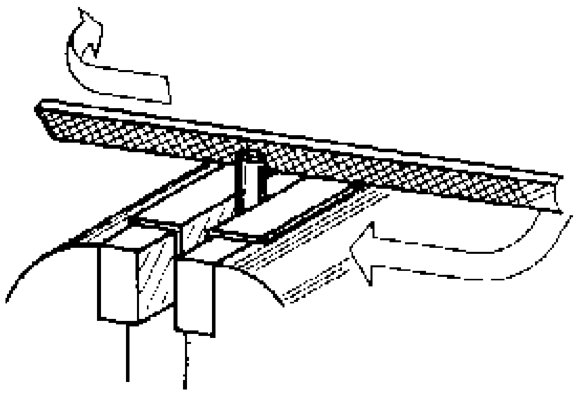
External threads are cut on bolts. As also in – this case, as with tapping internal threads, some material is squeezed into the courses of threads of the cutting tool, it is useful to select the bolt diameter a little smaller than the thread to be cut shall be.

Example:

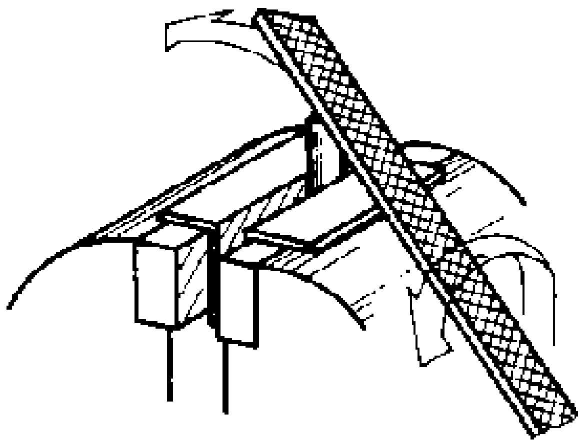
> When a thread with a nominal diameter of 6 mm shall be cut, the bolt shall be selected with a diameter of 5.8 mm.

With less bolt diameter, the thread cannot be fully cut–out, because there is not enough material available. When the bolt diameter is larger than 6 mm, too much material is squeezed and the courses of the thread break out.

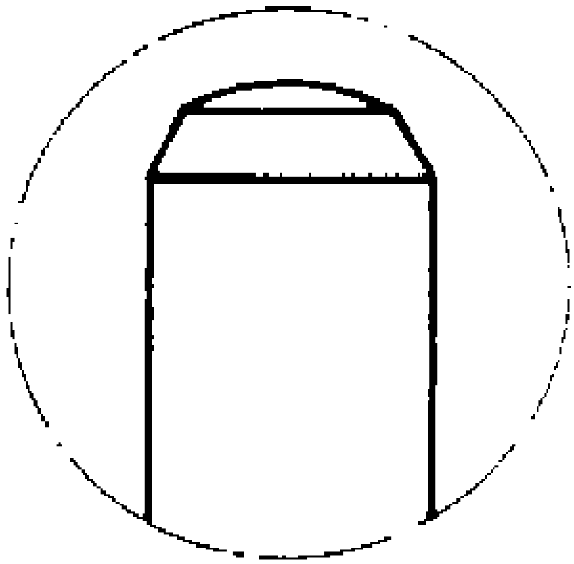
Fig. 2.7/20 Preparation of the bolt head



a Chamfering



b Crowned filing



c Finished bolt head

To let the thread−cutting die start cutting the bolt rectangularly to the bolt axis, the bolt head must be chamfered and filed crowned before threading. When chamfering the file is slewed clockwise during the working stroke. When filing crowned, the file is slewed around the longitudinal axis and guided in a curve (fig. 2,1/20). The same rules apply for cutting with the thread−cutting die as for tapping with the thread tap:

− Place the thread−cutting die rectangularly
− Reverse rotation of the thread−cutting die from time to time to remove the chips and feed lubricant.

Furthermore, it shall be taken into account:

− When starting cutting, grip die holder for threading near to the thread−cutting die and cut with slight pressure (fig. 2.7/21a).

− Continue cutting without pressure, grip the die holder for threading at the outer ends (fig. 2.7/21b).

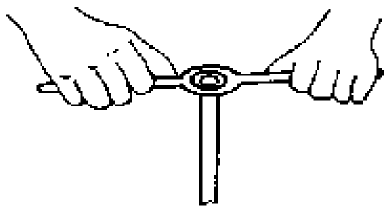


Fig. 2.7/21a Guiding the die holder for threading when cutting is started

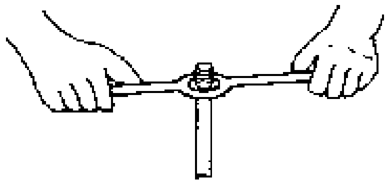


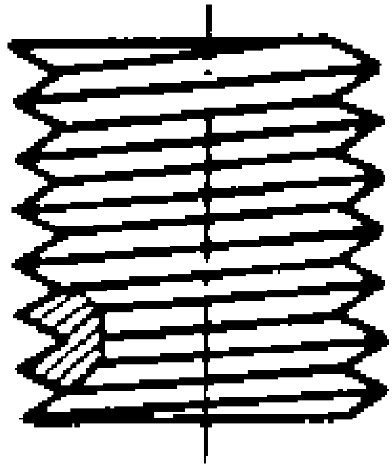
Fig. 2.7/21b Guiding the die holder for threading when cutting is continued

2.7.3. Thread profiles and minor diameter of the internal thread

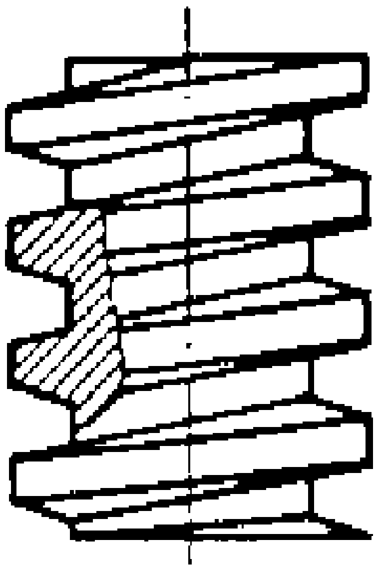
Typical thread profiles are for example

− V−thread (fig. 2.7/22a)
− Acme thread (2.7/22b)
− Buttress thread (2.7/22c)

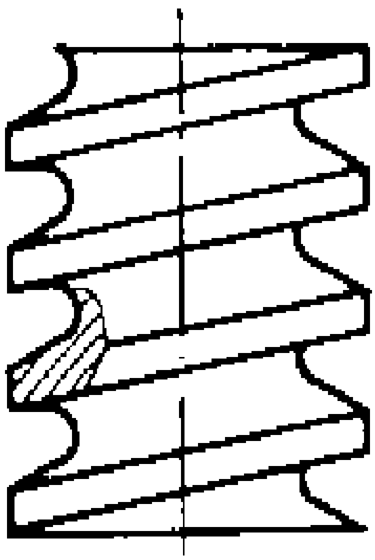
Fig. 2.7/22 Thread profiles



a) V−thread



b) Acme thread



c) Buttres thread

Application of the thread profiles:

– V−thread as fastening thread

– Acme thread } as threads for transmitting motions
– Buttress thread

Only V–threads can be cut by hand.

According to the measuring unit wo which the measures of the thread are refered, metric threads and Whitworth screw threads are distinguished. The measures of the metric threads are refered to the measuring unit metre and indicates as millimetre. The designation M 10 for example, characterizes a metric thread with a major diameter (nominal diameter) of 10 mm.

The measures of the Whitworth screw thread refer to the measuring unit inch ("). They are given as proper fraction. Typical are, for example, 1/4" and 1/2". (1" = 25.4 mm)

However, in many fields of technology, nowadays the metric thread is used internationally. In some cases, for example for tube connections, the Whitworth screw thread is still partly used.

Minor diameter of internal thread for some metric and Whitworth screw threads (in mm):

Thread	Tapping–size hole in Grey cast iron (GG) Bronze (Bz)	Tapping–size hole in Copper (Cu) Brass (Ms) Steel (St) Tin (Zn)
M 3	2,4	2,5
M 4	3,2	3,3
M 5	4,1	4,2
M 6	4,8	5,0
M 8	6,5	6,7
M 10	8,2	8,5
1/4"	5,0	5,1
1/2"	10,25	10,5

Task:

2.32. An internal thread M6 shall be tapped into a steel workpiece. Which drill do you use for drilling the tapping–size hole?

When no table is at hand while working in a workshop, the approximated minor diameter of the internal thread can be calculated by the following rule of thumb:

Minor diameter of the internal thread = Nominal thread diameter 0.8 mm

Example:

Determine the minor diameter of the internal thread for M3!
3 . 0.8 = 2.4 mm
The minor diameter of the internal thread for M3 must be approximately 2.4 mm!

2.33. Check the minor diameter of the internal thread by means of the rule of thumb. What do you find out?

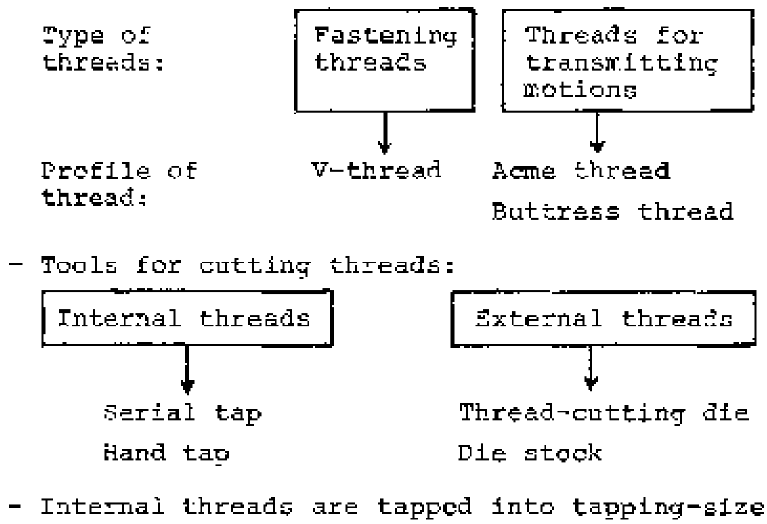
Labour safety

Always check prior to cutting the thread whether the workpiece is firmly clamped. Do not remove chips from bolts and holes by hand (hand injuries at the keen bur of the thread) and do not blow them away (eye injuries)!

Always use a brush or chip broom to remove the chips!

Summary

– Threads differ according to their type and profile



– Tools for cutting threads:

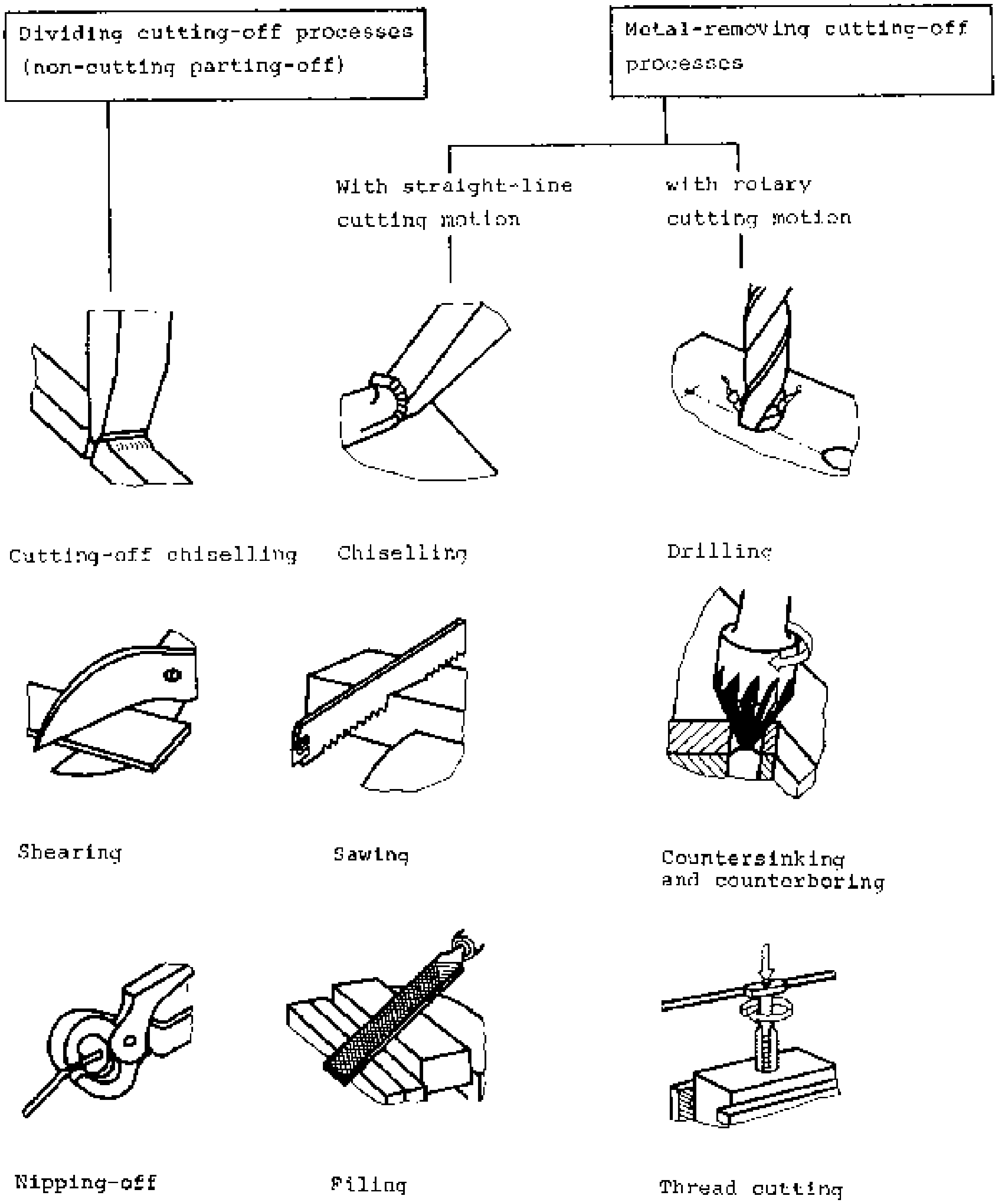
– Internal threads are tapped into tapping–size holes

– External threads are cut on bolts

– The minor diameter of the internal thread must be slightly larger than the minor diameter of the thread

– The diameter of the bolt must be slightly smaller than the nominal diameter of the thread

2.8. Survey on the cutting–off processes and cutting–off tools



– All cutting–off tools are equipped with wedge–shaped cutting edges.

– The position of the cutting edge towards the working motion of the tool determines whether it is divided or metal is removed.

– The cutting edges of tools must always be harder than the material which they shall penetrate.

– Tool cutting edges with small wedge angle are used for soft materials, tool cutting edges for hard materials must have a larger wedge angle.

Task:

2.34. List in a survey the application of the cutting–off processes you know!

3. Metal forming

Whereas material is lost with all cutting−off processes (waste pieces, chips), the original volume of material is completely preserved during shaping by metal−forming processes (fig. 3/1).

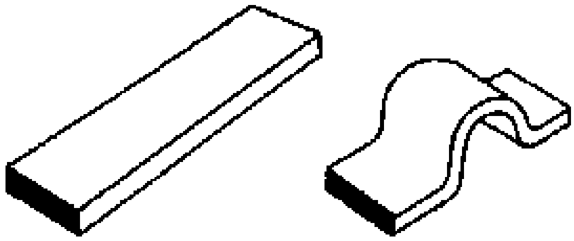


Fig. 3.1 Changing the workpiece − shape by bending

However, not all materials can easily be formed.

Task:

3.1. Try to bend a thin wooden strip, a piece of rubber and a piece of wire by hand. What do you find out?

Hence, metal−forming processes require a plasticity of the material. That means, upon the action of an external force, the material particles must displace against each other and remain in this position.

This plasticity is more or less inherent to most metal materials. Warming up facilitates the displacement of the material particles, particularly in case of thick workpieces.

The most metal materials are cold and hot mouldable.

3.1. Metal forming by bending

Bending is one of the most important metal−forming processes for metal materials. Sheet metal is bent to tube clips (cf. fig. 3/1), casings for machine parts, containers and funnels. Wire is formed to hooks, eyes and rings. Tubes and bars with different sections can also be bent into the desired shape.

Sheets, wires and flat bars can be cold bent. Workpieces with large cross−section are hot bent in most cases. Manual bending is only carried out in case of production of individual parts, repairs and small series (small number of uniform workpieces). In case of large series and mass production (continuously repeated production of uniform products), bending machines are used.

3.1.1. Behaviour of the materials during bending

The action of a bending force on the workpiece causes stress in the material. Tensile stresses are produced at the outside of the bending point and compressive stresses at the inside (fig. 3.1/1). The tensile stresses cause stretching, the compressive stresses upsetting of the material. Only the material layer in the centre of the workpiece preserves its original length. It is called the "neutral layer". To illustrate stretching and upsetting, dotted lines" were drawn on a workpiece. Fig. 3.1/2 shows the workpiece after bending.

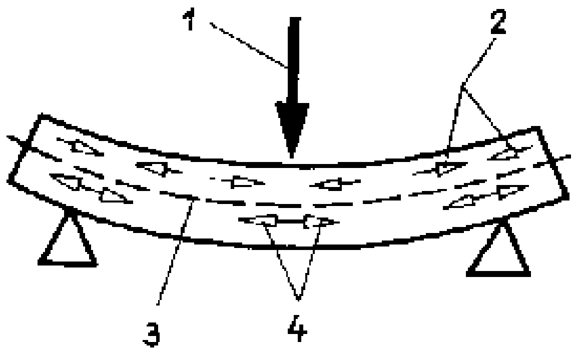


Fig. 3.1/1 Tensile and compressive stresses are produced in the workpiece due to the effects of a bending force

1 Bending force, 2 Compressive stresses, 3 Neutral layer, 4 Tensile stresses

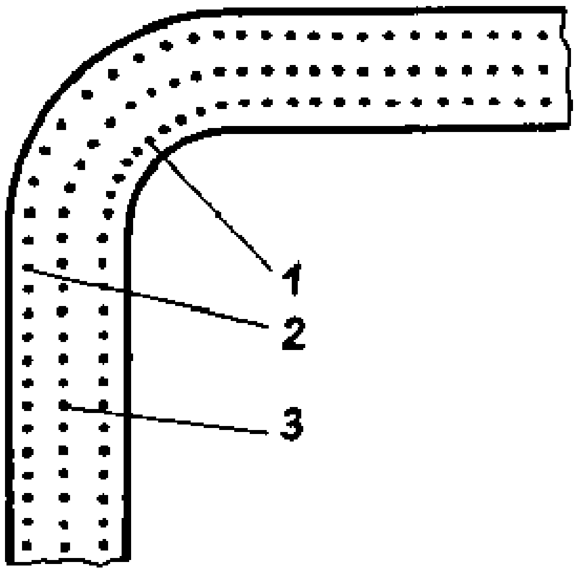


Fig. 3.1/2 Change of the material layers in a bent workpiece

1 Stretched material, 2 Neutral layer, 3 Upset material

Task:

3.2. Describe and justify the arrangement of the dots within the lines given in fig. 3.1/2!

Since the length of the neutral layer does not change, it forms the basis for dimensioning the length of a workpiece to be bent. The length of the workpiece not yet bent is called the stretched length.

To dimension the stretched length, proceed from the engineering drawing of the bent work-piece (fig. 3.1/3).

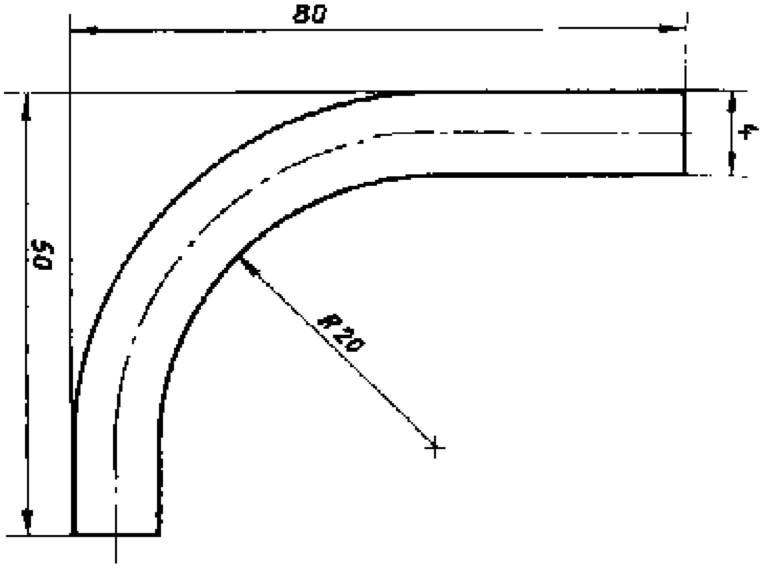


Fig. 3.1/3 Engineering drawing of a bent workpiece of flat steel

Calculation example: The length of a bent workpiece is composed of straight and curved partial lengths. In case of the rectangularly bent workpiece selected as an example, these are two straight lengths (l_1 and l_3) and a quarter bend length (l_2 (cf. fig. 3.1/4).

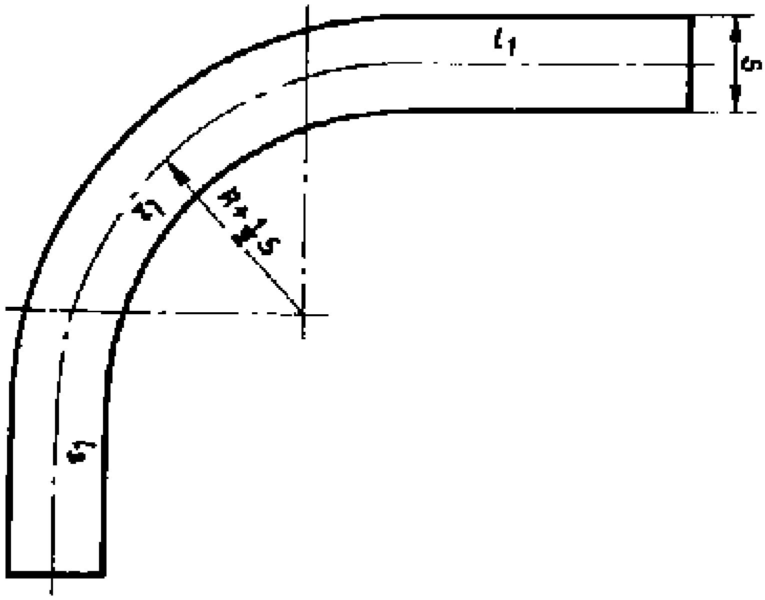


Fig. 3.1/4 Representation of the partial lengths of a bent workpiece and of the radius of the neutral layer

Therefore, the total length is

$L = l_1 + l_2 + l_3$

First, the straight lengths l_1 and l_3 are determined.

$l_1 = 80 - s - R$	R: Bend radius
$l_1 = 80 - 4 - 20$	s: Workpiece thickness
$l_1 = 56$ mm	
$l_3 = 50 - s - R$	In the drawing, it is indicated
$l3 = 50 - 4 - 20$	R = 20 and s = 4 (fig 3.1/3).
$l_3 = 26$ mm	

The length of the quadrant l_2 shall be determined as follows:

Circumference: 2? · r

?: Ratio of the circle

? = 3.14

As the length of the neutral layer shall be calculated, half of the material thickness must be added to the radius R.

Radius of the neutral layer

l_2 = 34.54
l_2 ? 35 mm

$L = l_1 + l_2 + l_3$
L = 56 + 35 + 26
L = 117 mm

The stretched length of the workpiece amounts to 117 mm.

When the stretched length (117 mm) is compared with the sum of the two leg lengths given in the drawing (80+ 50 = 130 mm) (fig. 3.1/3), you find out:

The stretched length is always shorter than the given lengths of the bent workpiece.

This statement can be confirmed by further examples (cf. task 3.3). Therefore, it is important for economical reasons, to always determine exactly the stretched length.

The formula for R_N, given in the example

shall only be applied, when the bend radius (R) is at least five times the material thickness (s), that means

R = 5s or R > 5s

The sign > means "larger than".

From experience, in case of a small bend radius, the neutral layer runs nearer to the inside of the bend. In this case, R_N is:

Therefore, the following shall be taken into account for the calculation of the stretched length of a workpiece to be bent:

With R ? 5s applies: ;

With R < 5 s applies: .

Task:

3.3. A rectangularly bent workpiece with the following dimensions shall be manufactured:

Length of the legs each 60 mm;
Bend radius R = 3 mm;
Workpiece thickness s = 3 mm.

Draw an engineering drawing of the bent workpiece and calculate the stretched length of the workpiece!

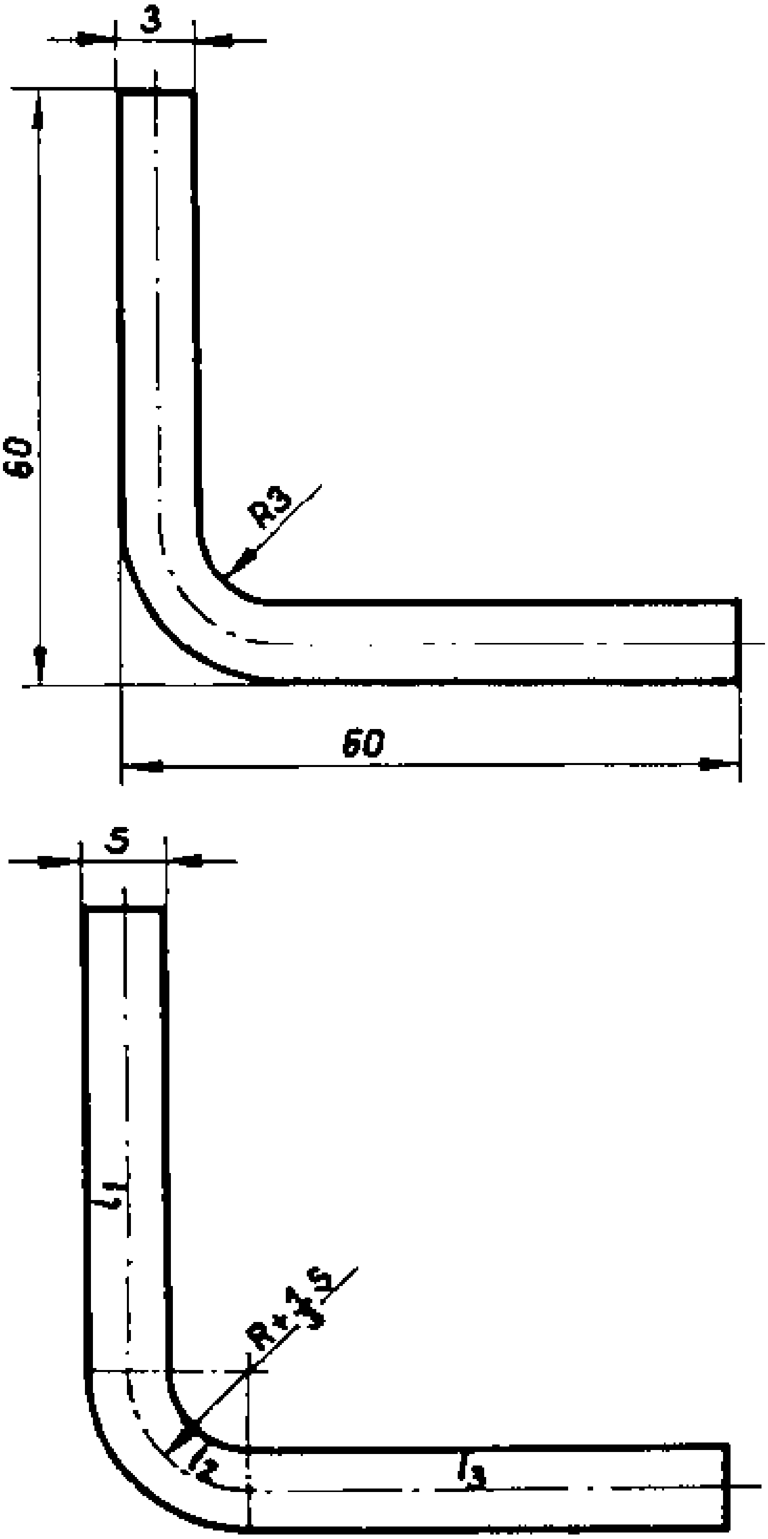
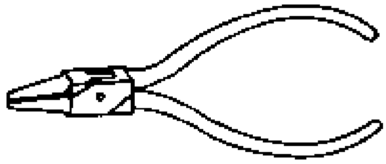
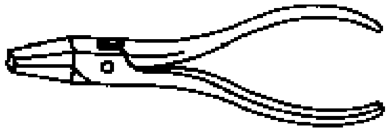


Fig. 3.1/6



a) Circular tongs



b) Flat tongs

3.1.2. Bending tools

It is suitable to use flat tongs or circular tongs for bending wires (fig. 3.1/6). Large workpieces are clamped into the vice (if necessary, with shims) (fig. 3.1/7). When the jaw width of the vice is not sufficient, sheet−metal clamp dogs shall be used (fig. 3.1/8).

The bending force is produced with the locksmith's hammer. When the workpiece surface shall not be damaged, wooden or rubber hammers shall be used (cf. fig. 3.1/10).

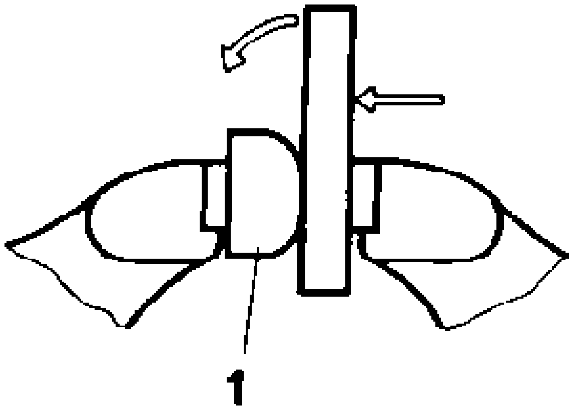


Fig. 3.1/7 Bending in the vice

1 Shim

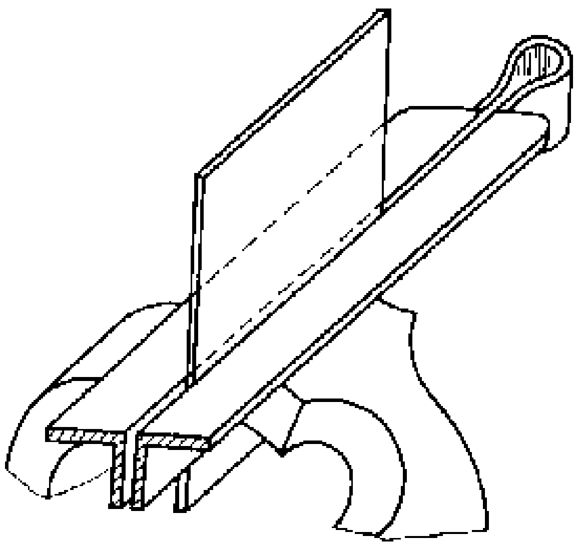


Fig. 3.1/8 Clamping by means of the sheet−metal clamp dog

For marking out the bending point, principally only the pencil shall be used.

Scribers can damage the workpiece due to the occurring notch effect so that the workpiece breaks at the scribed line.

3.1.3. Bending works

Basically, cold bending and hot bending are distinguished. Whether it must be cold or hot bent depends on the cross–section of the work–piece to be bent. Cold bending was selected for the bending operations explained in the following.

Angular bending

When sheets are bent angularly, attention must be paid to the direction of rolling, in particular in case of cold rolled sheets. This direction can be recognized in the fine rolling ridges (fig. 3.1/9). There is a risk of breakage, when the forming edge lies in the rolling direction.

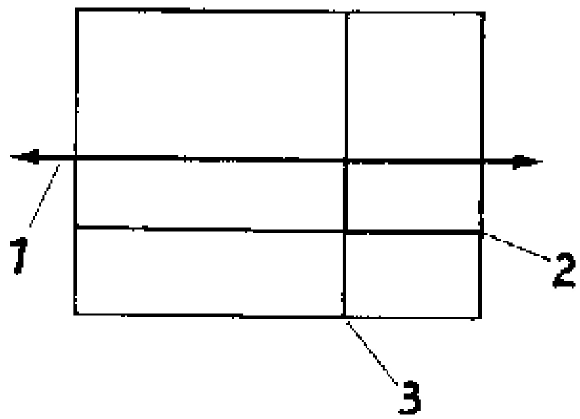


Fig. 3.1/9 Rolling direction and forming edge

1 Rolling direction, 2 Forming edge wrongly chosen, the sheet can break, 3 Correctly chosen forming edge

Therefore applies:

Cold rolled sheets shall always be bent in such a way that the forming edge lies at right angles to the rolling direction.

Sheets, strip and flat steels are clamped into the vice for angularly bending. In case of light metal workpieces, protective dogs shall be used (cf. fig. 3.1/7).

When the workpiece shall obtain a long free leg, it is hammered with the wooden hammer close to the forming edge until the desired angle is reached. In doing so, the left hand grips the free end of the workpiece and presses it over the edge of the vice jaw (fig. 3.1/10). When you hammer from too far above the forming edge, the workpiece is distorted (fig. 3.1/11).

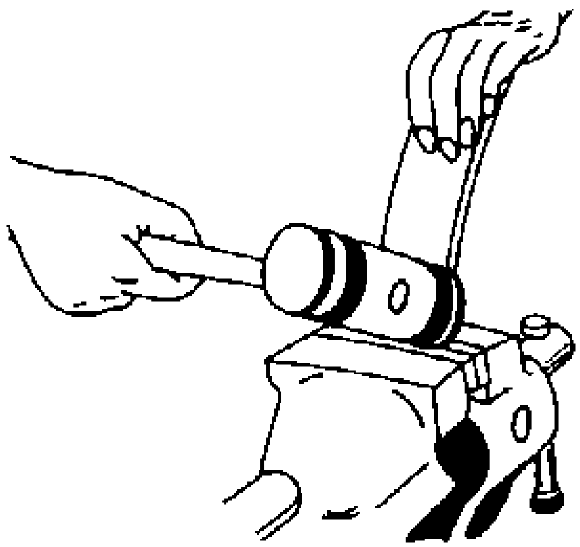


Fig. 3.1/10 Bending of a long free leg of the workpiece

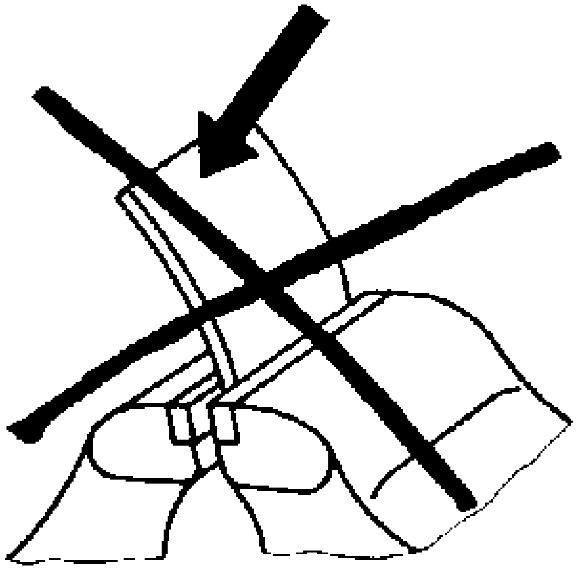


Fig. 3.1/11 Wrong bending! The leg is distorted

When a short leg is required, a hardwood block is used which shall have the width of the work−piece. The block is placed on the workpiece closely above the forming edge and worked with the locksmith's hammer until the workpiece has the desired angle (fig. 3.1/12). Bending of a cornered clip is illustrated in fig. 3.1/13. Long forming edges are bent by means of bending machines (fig. 3.1/14).

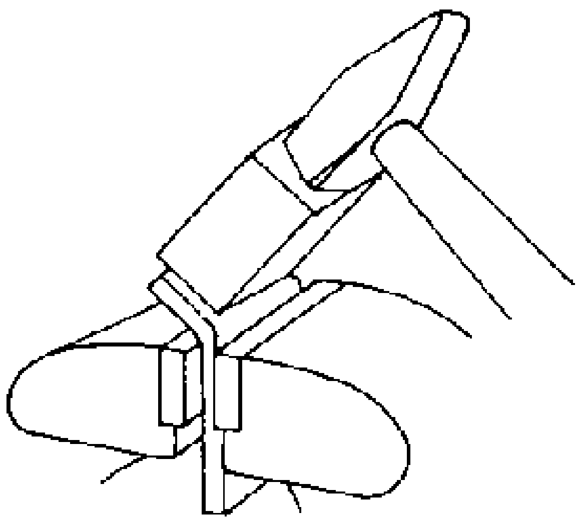
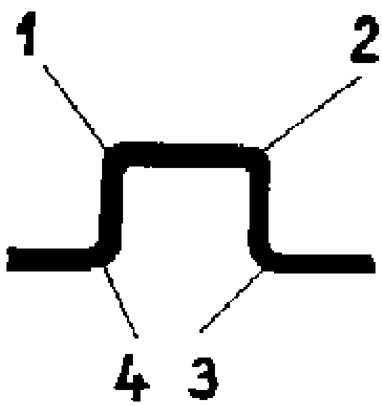


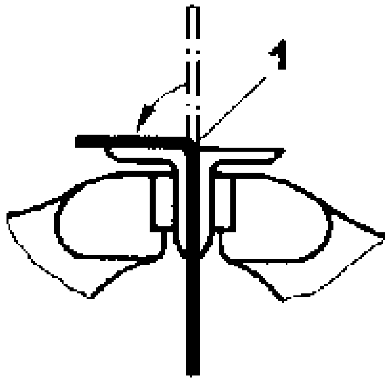
Fig. 3.1/12 Bending of a free short leg

Fig. 3.1/13 Bending of a cornered clip



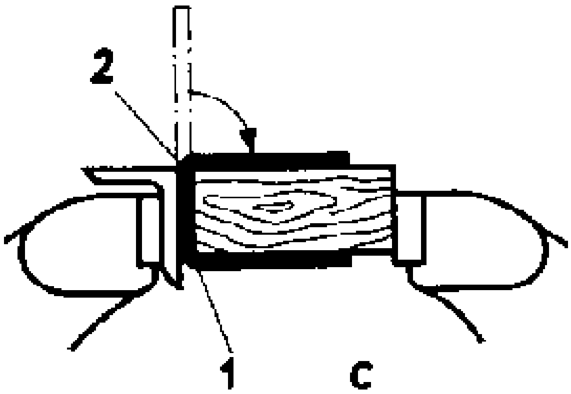
a) Profile of the clip

1, 2, 3, 4 Forming edges

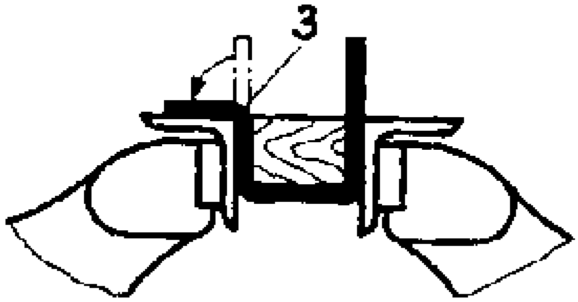


b) Forming edge

1 bent over an angle



c) Forming edge 2 bent over hardwood shim



d) Clamp the U−piece by means of a suitable shim and bend the forming edges 3 and 4 over the angle.

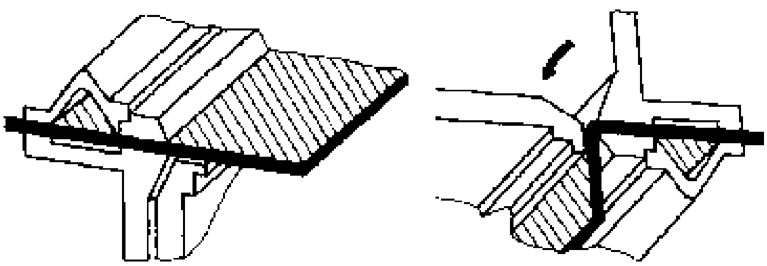


Fig. 3.1/14 Bending by means of the bending machine

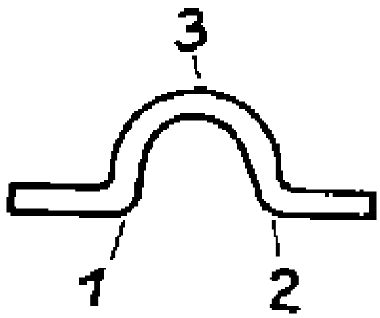
Roll bending

Bending of sheets, bending of wire, and bending of tubes is differed with roll bending.

Roll bending of sheets is carried out by means of arbors in the vice. These are round profiles of metal or hardwood, whose curves must correspond to the required roundings of the workpiece.

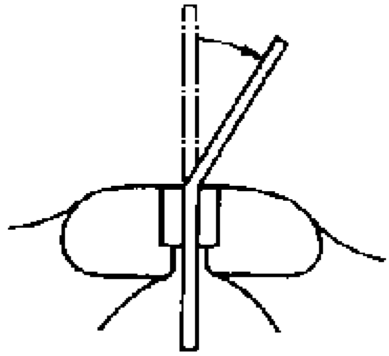
Bending of a half−round clip is illustrated in fig. 3.1/15. Bending of a wire eye: Wire eyes must often have a certain diameter. For this purpose, the stretched length which is required for the eye shall be determined before the wire is cut.

Fig. 3.1/15 Bending of a half-round clip

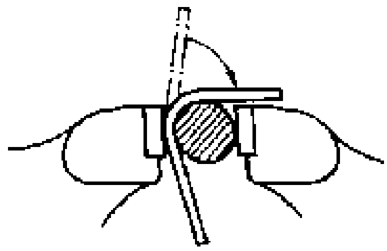


a) Profile of the clip

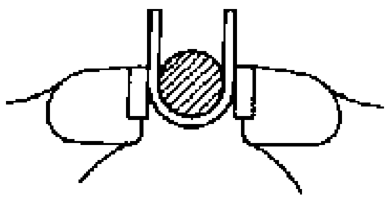
1, 2 Forming edges, 3 Centre of the clip 1, 2 and 3 are to be marked out on the stretched length of the workpiece



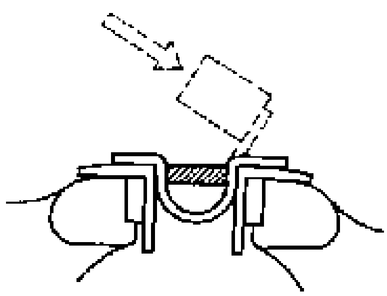
b) Pre-bending of the clip centre



c) Rounding over the arbor



d) Rounding by pressing the vice jaws



e) Clamp the U-piece by means of hardwood shim and bend the clip feet angularly

The formula for the circumference of the circle (d · *?*) is the calculation basis.

Wire length for the eye: L = d · *?*

(d = Required diameter of the wire eye ?: Ration of the circle = 3.14)

When, for example, the wire eye shall have a diameter of 4 mm, the stretched length of the eye must amount to approximately 12.7 mm, because

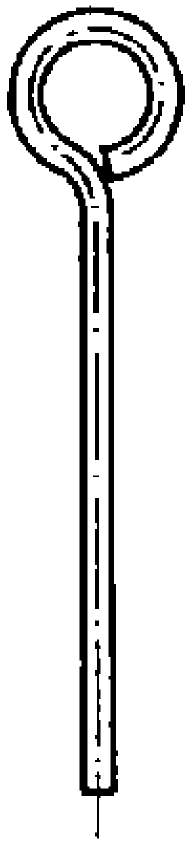
L = d · ?; L = 4 · 3.14; L ? 12.7

Task:

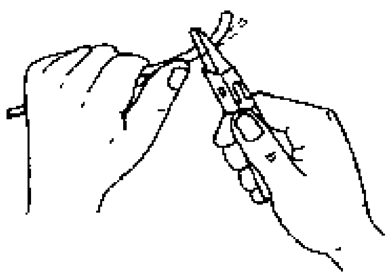
3.4. Calculate the stretched length of the wire piece for an eye with the diameter a) 6 mm; b) 10 mm; c) 12 mm!

Fig. 3.1/16 illustrates bending of a wire eye by means of the round tongs.

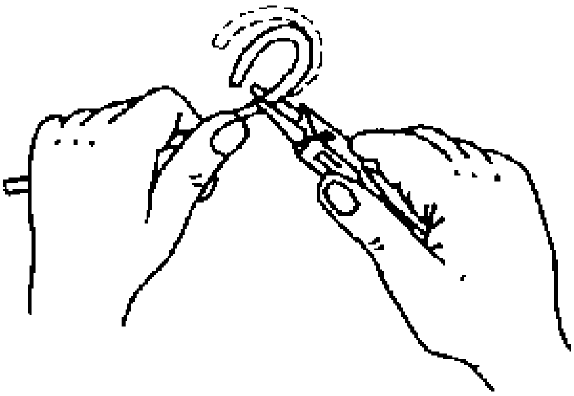
Fig. 3.1/16 Bending of a wire eye by means of the circular tongs



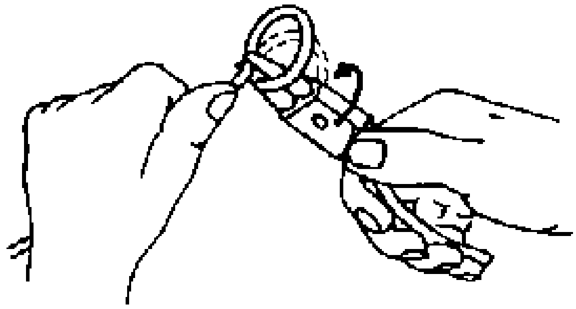
a) Profile of the eye



b) Rounding of the wire



c) Rounding by replacing of the tongs in short distances



d) Centring the eye

Bending of tubes: To avoid buckling of tubes during bending, they are filled with dry sand and closed by a plug before bending (fig. 3.1/17).

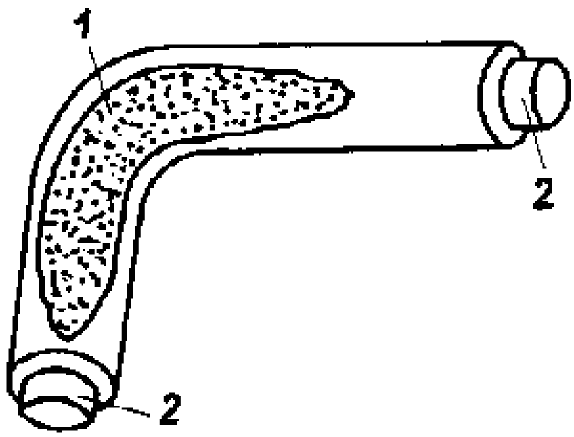


Fig. 3.1/17 Bent tube (part section) with sand filling

1 Sand, 2 Plug

To obtain a perfect rounding, it shall also be taken into account, that the inner radius of the tube bend shall not be smaller than three times the tube diameter. In case of seam−welded tubes, the weld must be in the neutral layer.

Task:

3.5. Justify the necessity of the rule mentioned above!

Tubes with diameters of 13 mm or 1/2" can be cold bent. A simple bending fixture as shown in fig. 3.1/18 is very economical.

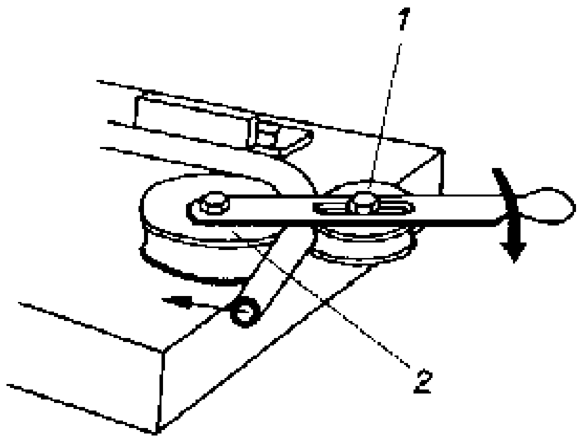
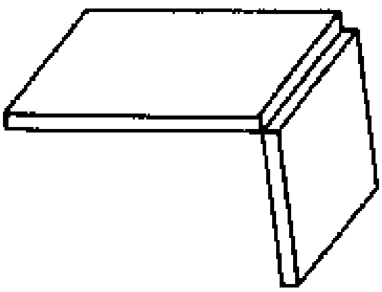
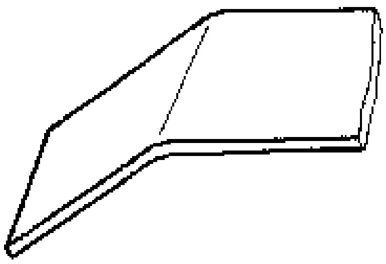
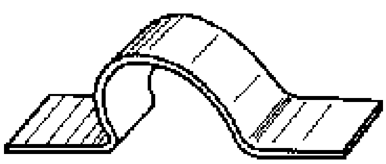


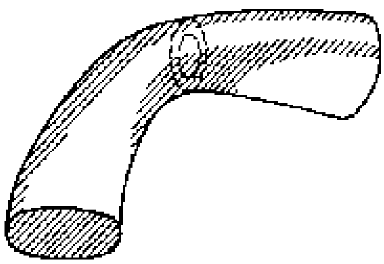
Fig. 3.1/18 Tube bending in a bending fixture

1 Roller, exchangeable and adjustable 2 Exchangeable roller

3.1.4. Bending faults

The following table provides a survey on the most frequent bending faults.

Bending faults	Causes
Fracture at the forming edge 	Material too brittle; rolling direction not taken into account; scriber used for marking−out
Sharp forming edge 	Workpiece was obliquely clamped; hardwood was wrongly placed; it was hammered only from one side
Bad rounding of the 	Sheet too much pre−bent; Diameter of the arbor did not correspond to the required diameter of the rounding; no attention was paid to the centre of rounding during pre−bending and radiusing
Bad rounding of the wire eye	Wire length for the eye was wrongly calculated; eye was not pre−bent; eye was not centred

	
Bad rounding of the tube, bursted weld 	The tube was not correcrtly filled with sand; the bend radius was too small; the weld seam was not in the neutral layer

Summary

– During bending, the workpiece is stretched at the outside of the bend due to tensile stresses and upset at the inside of the bend due to compressive stresses.

– The neutral layer maintains its original length.

– The stretched length of the workpiece is calculated according to the neutral layer of the bent workpiece,

– The rolling direction is to be taken into account in case of bending cold rolled sheets, otherwise there is a risk of breakage.

– Sheets shall not be injured by scribers, otherwise there is also a risk of breakage.

3.2. Metal forming by straightening

A distorted, wavy or bulged workpiece can get back its original shape by straightening.

Therefore, straightening is only necessary, when the workpiece has lost its shape because of improper storage or bad working.

> Whereas tensile and compressive stresses are produced in the material by bending, straightening aims at an elimination of undesired compressive and tensile stresses of the material.

3.2.1. Straightening works

The following straightening works are distinguished in manual metalworking:

– straightening by peening,
– straightening by bending,
– straightening by drawing out

The selection of the straightening process and therefore the choise of the straightening tools depend on the workpiece to be straightened.

<u>Straightening of sheet metals</u>

Sheet metals are straightened by peening on a straightening plate. Hardwood or rubber hammers serve as tools. The strains in a wavy or bulged sheet metal are compensated by peening.

When the sheet metal has wavy edges, it is hammered upon the supported parts of the sheet metal from the outside to the inside whereby the hammer blows follow always closer towards the middle (3.2/1).

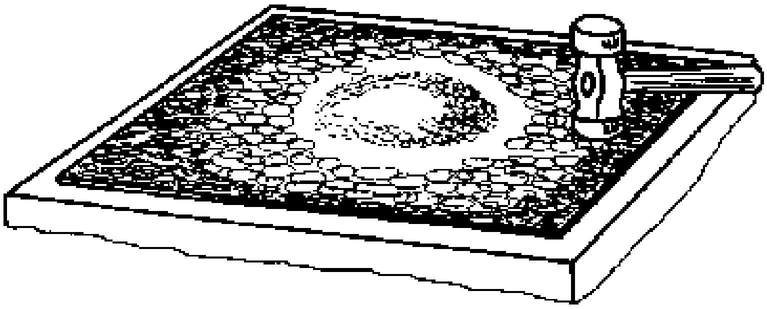


Fig. 3.2/1 Elimination of a wavy edge

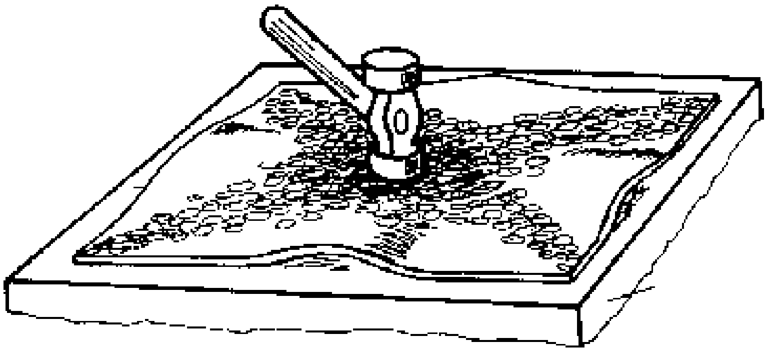


Fig. 3.2/2 Elimination of a dent

When the sheet metal shows a dent, the hammer blows are carried out from the inside to the outside and spiral−shaped around the dent. In doing so, the hammer blows follow always closer towards the edge (fig. 3.2/2).

Never hit the dent or the wavy edge directly when straightening by peening!

Straightening of flat steels and angle sections

As sheet metals, curved flat steels and angle sections are straightened as well by peening on the straightening plate. The locksmith's hammer serves as tool in this case. To compensate the strains, even blows with the pane of the hammer are carried out at the inside of the curve (fig. 3.2/3).

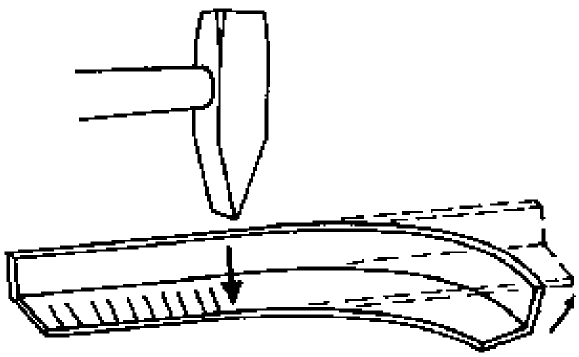


Fig. 3.2/3 Straightening of a curved angle section

Task:

3.6. Justify, why the section can be straightened this way!

Flat bars which are warped at their broadside are straightened by bending on the straightening press (fig. 3.2/4).

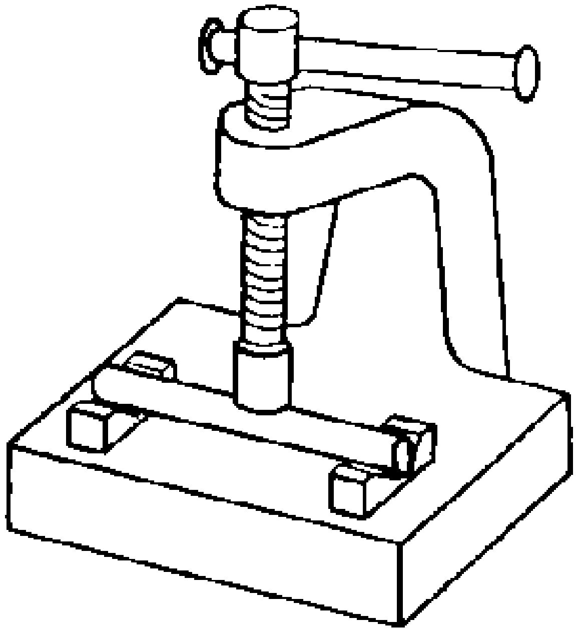


Fig. 3.2/4 Straightening of a flat bar in the straightening press

Straightening of strip steels

Warped strip steels can be straightened by bending by means of a vice and swivel hook.

The workpiece is clamped into the vice with its unwarped part and then straightened by means of the swivel hook as illustrated in fig. 3.2/5.

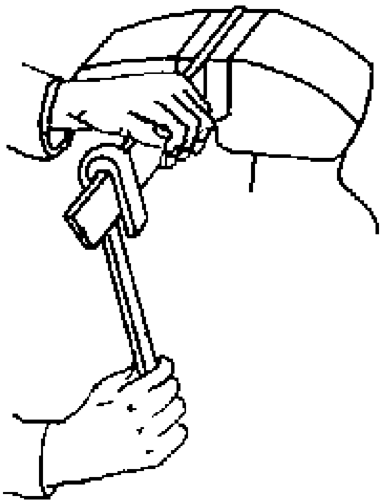


Fig. 3.2/5 Straightening of a sheet−metal strip by means of the swivel hook

Task:

3.7. Describe straightening with the swivel hook by means of fig. 3.2/5!

In case of longer strip steels, it is necessary to reclamp frequently and to straighten in small sections.

Straightening of wires

Warped thin wires can be straightened by stretching. In doing so, curves are eliminated by tensile forces.

Long wires are clamped into the vice with one end and wound once around a round timber near to the tensioned point. While the round timber is drawn back from the vice with the left hand − the wire runs between forefinger and middle finger − the wire is guided by the right hand (fig. 3.2/6).

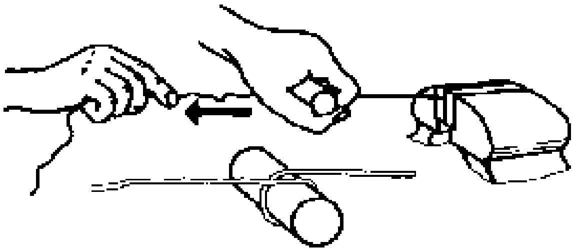


Fig. 3.2/6 Straightening of a wire by pulling across a round timber

Short pieces of wire are clamped into the vice with one end and the other end into the hand vice. Also in this case, hand force is used for straightening.

Labour safety:

> To avoid accidents, it must be checked prior to straightening whether the workpiece is firmly clamped and the straightening plate is firmly fixed.

Summary

Straightening serves to eliminate tensile and compressive stresses in the material. In doing so, the workpiece gets back its original shape. Straightening plate and hammer are used for straightening

– sheet metal with the wooden or rubber hammer

– flat steel or angle section with the locksmith's hammer; or with vice and swivel hook or with round timber or hand vice

– strip steel with the swivel hook

– wires with the round timber or hand vice.

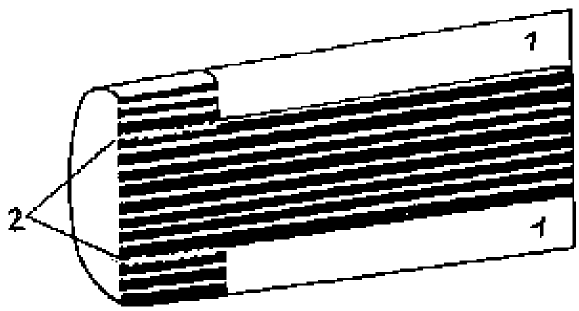
To bend back broadsided bent flat steels, it is suitable to use a straightening press.

3.3. Metal forming by forging

Forging is a hot metal–forming process, which is mainly used for forming steel.

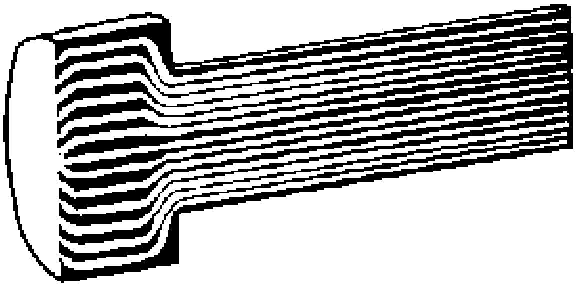
During forging, the heated workpiece is formed by the effect of impacts. In manual metalworking, this is done by short hammer blows. This way, for example, chisels, hatchets, tongs or small parts of machines can be manufactured. Larger workpieces are only formed on large forging machines.

Fig. 3.3/1



a) Bolt formed by metal–cutting; a considerable loss of material results; the strength is reduced by interrupting the direction of fibres

1 Material loss, 2 Risk of breakage



b) Forged bolt; little loss of material; the direction of fibres is preserved, the strength is increased.

As with all metal forming processes, no loss of material occurs with forging. Moreover, forged workpieces have often a higher strength than uniform workpieces formed by metal removal (fig. 3.3/1).

3.3.1. Behaviour of the material during forging

All material forming processes base upon the displacement of material particles, also called "flowing" of the material. Upon the action of force of the tool, the material flows towards the direction of the lowest resistance. Because the material flow is hindered by friction at the workpiece surface and the bearing surface, for example a cube is formed to a barrel−shaped form (fig. 3.3/2).

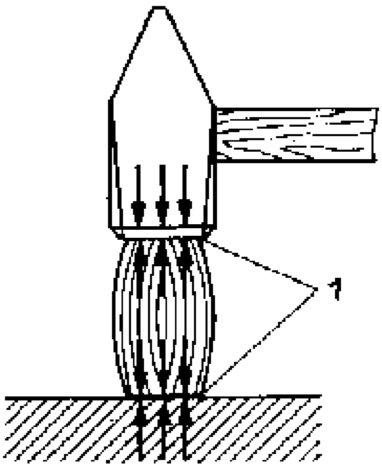


Fig. 3.3/2 Effect of friction during forging

1 Friction

By an appropriate arrangement of the individual blows, the material flow can be directed in such a way, that the desired finished part is produced from the raw piece.

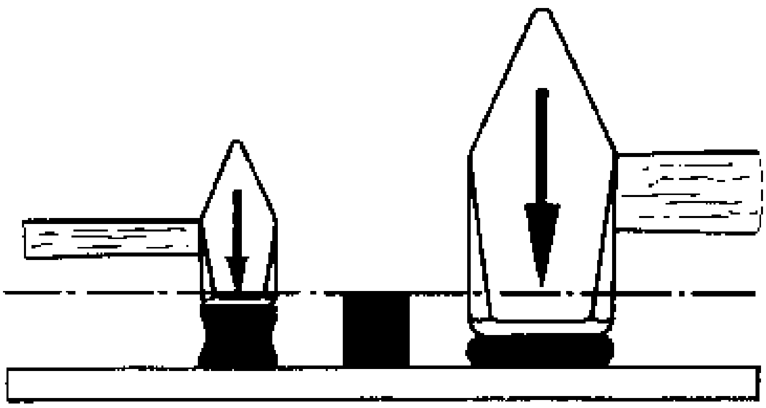


Fig. 3.3/3 Influence of the tool (hammer weight) upon forming

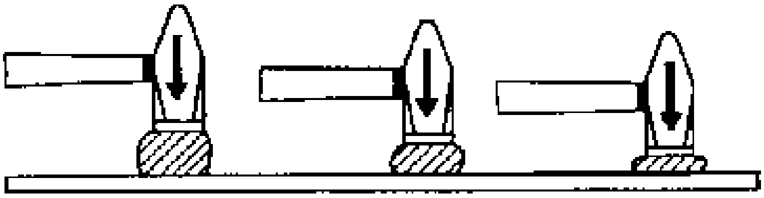


Fig. 3.3/4 Influence of the material temperature upon its plasticity

The heavier the acting force – that means, the hammer during manual forging – the more the workpiece is deformed (fig. 3.3/3). If the impact is not large enough to act up to the middle of the workpiece, the friction at the front surfaces is overcome. The material starts to flow at these points and becomes always wider (cf. 3.3/3). With increasing temperature, the plasticity of the metals increases. Fig. 3.3/4 shows how the steel cube is differently formed with equal force action but different heating up. As the relation between heating up and plasticity is not equal for all metals, the best forging temperatures were found out by tests for every forgeable metal.

Table of some forging temperatures:

Material	Best temperature range in °C
Mild steel	850 ... 1200
Tool steel	800 ... 1050
High–speed steel	1000 ... 1200

The temperature of the heated steel is visible by its annealing colour.

Annealing colour of the steel	Temperature in °C (rounded values)
Black–brown	500
Brown–red	600
Dark re d	700
Cherry–coloured	800
Bright red	900
Yellow–red	1000
Dark yellow	1100
Bright yellow	1200
White	1300

Decisive for the quality of the forged work–pieces is also the duration of heating.

When for example, steel is held on increased temperatures for a long time, the strength and also the plasticity are reduced. For this reason, the following rule applies for forging steel:

> Steel, particularly tool steel and alloyed steels, are slowly heated up to red heat, and then quickly heated to forging temperature and forged. Mild steels can be directly heated up to forging temperature.

After forging, the workpieces must be slowly and evenly cooled down, otherwise stresses arise in the material.

3.3.2. Forging devices and tools

For forging, the following is necessary

– Facilities to heat the workpieces
– Tools and supports to form the desired work–pieces

Facilities for heating

In manual metalworking, the smith's hearth with open coal fire (fig. 3.3/5) is used to heat the workpieces.

The fuels (hard coal or coke) are burnt in the fire pan and the forgings heated in it. The blower supplies the air required for burning.

By resetting a nozzle by means of the nozzle lever, the air current of the blower can be varied.

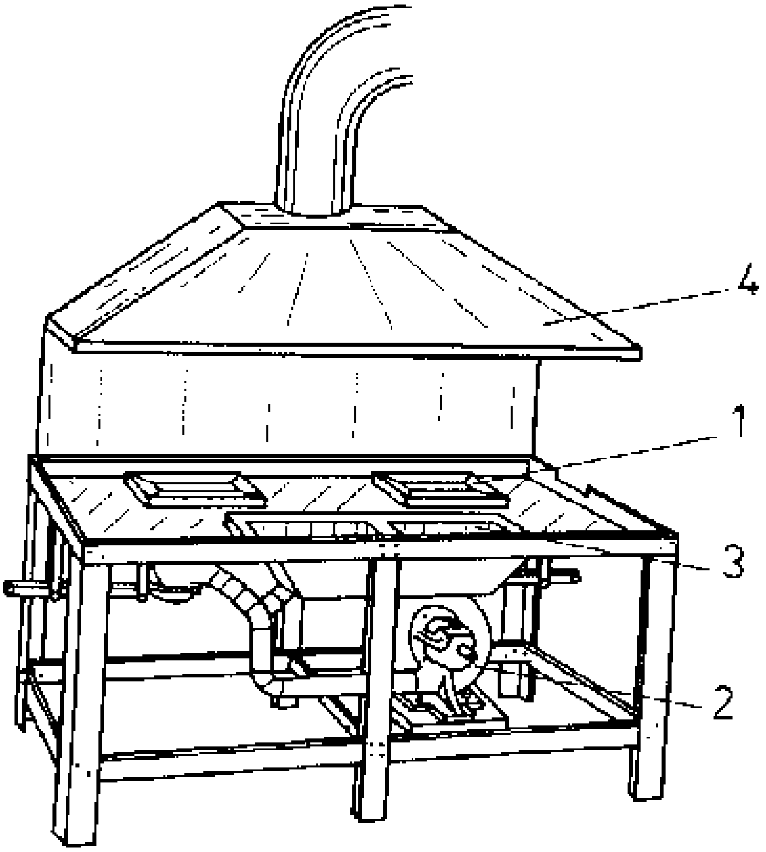


Fig. 3.3/5 Smith's hearth with two fire pans

1 Fire pan, 2 Blower with electric motor, 2a Nozzle lever, 3 Quenching tank, 4 Hood

The stronger the air current, the heavier the burning and the higher the temperature.

By quenching the outer layers of the coal, the heat is maintained in the glowing core. When heating workpieces in the smith's hearth the following shall be taken into account:

Do not expose the workpiece directly and not too long to the blower air!

Otherwise the steel will scale and crumble during forging. Therefore, coal must lay always over the air nozzle in order to distribute the air current.

Never heat the workpiece with fresh coal!

The heated steel absorbes sulphur out of the coal, a sulphur–iron compound is created, which melts already with red heat.

The steel becomes brittle when red hot. For this reason, fresh coal must always be laid at the edge of the fire, where the sulphur can burn. Only such "burnt out" coal is suitable for steel heating.

Other heating facilities: For repair and assembly works outside the workshop, portable forges are used instead of the forge fire (fig. 3.3/6). In up−to−date smith's shops, the workpieces are heated in closed ovens, which are electrically or gas−heated (fig. 3.3/7). In such ovens the forging temperature can be controlled more precisely.

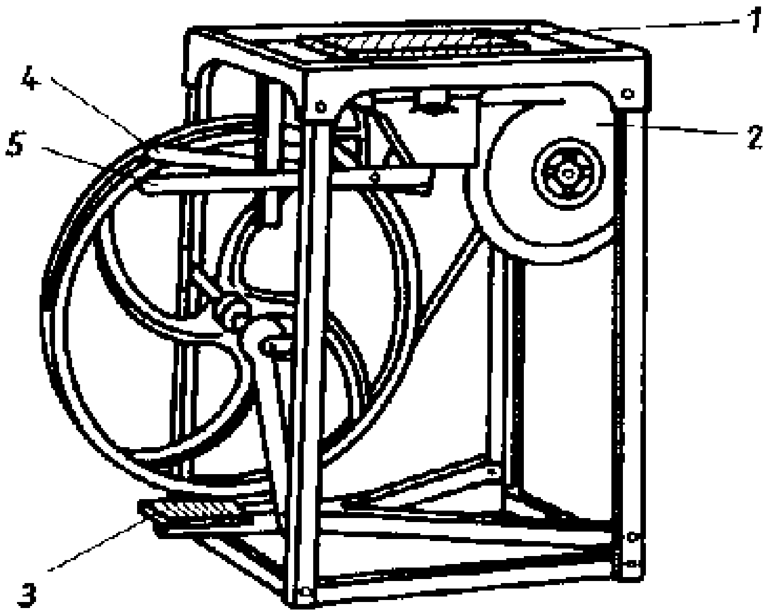


Fig. 3.3/6 Portable−type forge

1 Fire pan, 2 blower, 3 Treadle, 4 Nozzle lever, 5 Slag lever

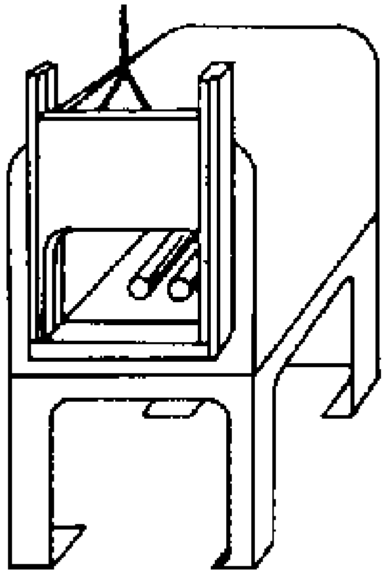


Fig. 3.3/7 Electrically or gas−heated preheating oven

Tools and supports for forging

The blacksmith's anvil serves as support for manual forging (fig. 3.3/8). It consists of cast steel and is mounted on a hardwood block which is secured against splintering by steel strips.

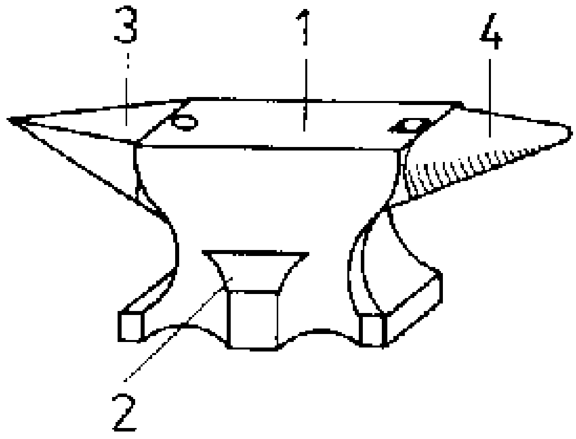


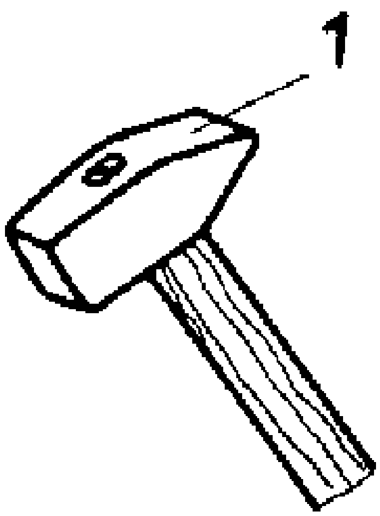
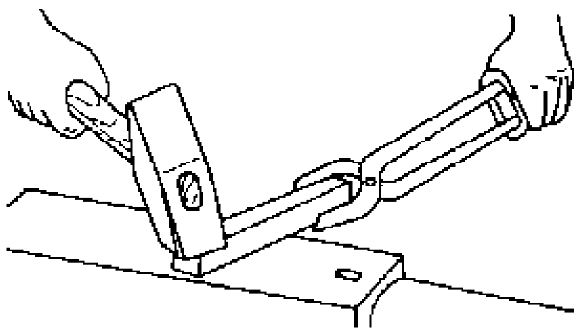
Fig. 3.3/8 Blacksmith's anvil

1 Anvil, 2 Upset anvil, 3 Square beak, 4 Anvil beak, anvil square hole serves to receive accessories of the anvil, pritchel hole for punching

The weight of the anvil must be at least the 10 fold mass of hammer and workpiece in order to prevent bouncing.

The most important forging tools are the <u>forging hammers</u>.

Survey on the most common forging hammers

Hammer	Application
<u>Hand hammer</u> (weight 1 ... 2 kg)  Fig. 3.3/9 1 Hammer peen	The blacksmith holds it in his hand 
<u>Aboutsledge Sledge with straight peen</u> (weight 3 ... 15 kg)	The journeymen of the blacksmith hold them with both hands; a first journeyman holds the aboutsledge, a second one the sledge with straight peen

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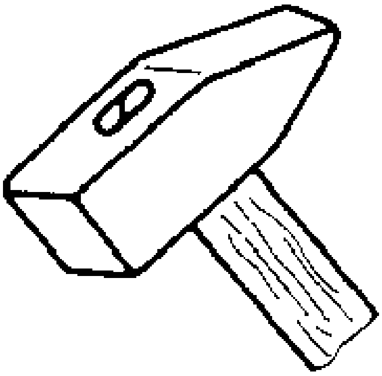

Fig. 3.3/10
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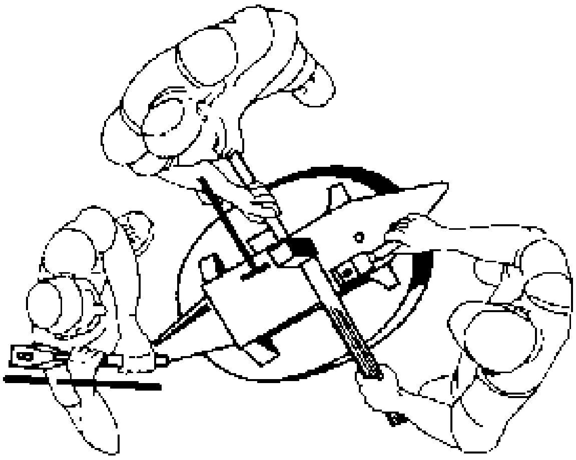
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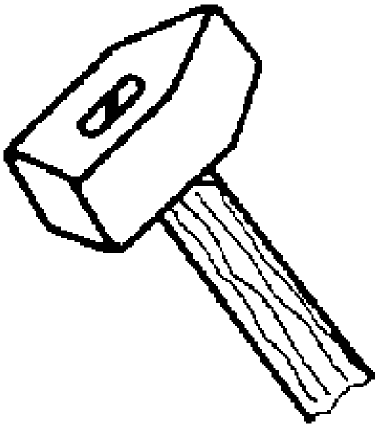

Fig. 3.3/11

1 hand hammer, 2 aboutsledge, 3 sledge with straight peen.
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These are put upon the workpiece and transmit the blow force of the hand hammer. The head is formed spherically, so that the impinging hand hammer does not slide off.
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<u>Auxiliary hammers</u>

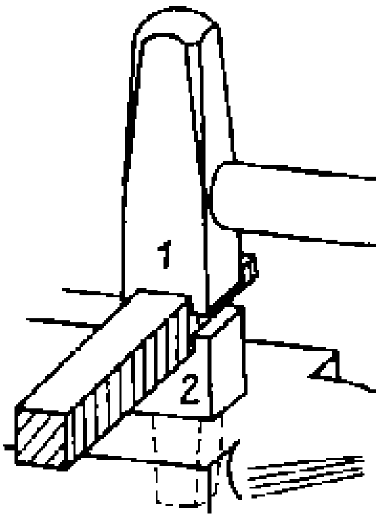

Fig. 3.3/12 Top swage 1 with die−forging die 2
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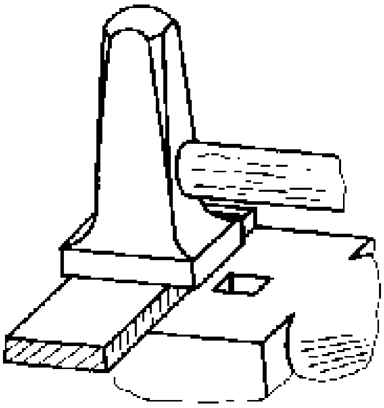
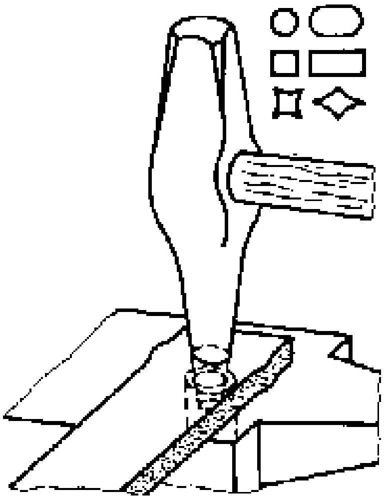
 Fig. 3.3/13 Blacksmith's flatter	
 Fig. 3.3/14 Blacksmith's handled punch	

Task:

3.8. Compare hand hammer, aboutsledge and sledge with straight peen by means of figs. 3.3/9 to 3.3/11. Emphasize common features and differences!

Auxiliary tools for forging are <u>tongs</u>. The mouths of the different tongs are adapted to the shapes of the workpieces which they must grip. The clamping ring at the tongs is important. The workpiece gripped by the mouth is firmly clamped by shifting the clamping ring.

Three out of the variety of tong shapes are introduced in the following: flat tongs (fig. 3.3/15), wolf mouth tongs (fig. 3.3/16) and rivet tongs (fig. 3.3/17).

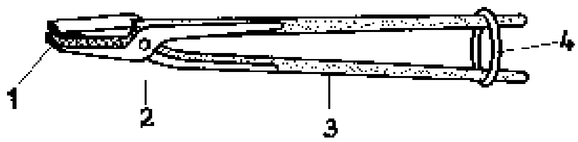


Fig. 3.3/15 Flat tongs

1 Mouth, 2 Eye, 3 Leg, 4 Clamping ring

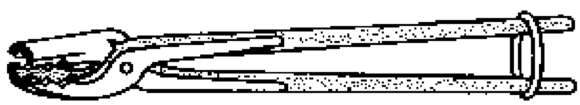


Fig. 3.3/16 Wolf mouth tongs

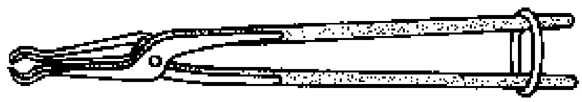


Fig. 3.3/17 Rivet tongs

3.3.3. Forging works

In case of forging works smith forging and drop forging are distinguished.

Smith forging

When smith forging, the workpiece is free−formed between anvil and hammer. The desired shape is obtained by the hammer shape and the type of hammer blows. In the following, some typical forging jobs are introduced:

Forging job	Explanation
Upsetting	By upsetting, the cross section of the workpiece is enlarged and the length reduced. Workpieces can be upset at any point which was heated before. Short workpieces are upset by the blacksmith on the anvil face, and long work−pieces on the upset anvil with the help of a journeyman (cf. fig. 3.3/18). Application: preparation for forming of bolt and rivet heads
Stretching	Basically, the workpiece is enlarged and the cross−section reduced by stretching. To avoid flattening of the work−piece, first it shall be worked with the hammer peen and then finished with the hammer face (cf. fig. 3.3/19a, b). Stretching includes also the processes of flattening, sharpening and pointing.
Flattening	When flattening, the workpiece is stretched with the hammer peen across the longitudinal axis, the width is increased, the thickness decreased and the length hardly changed. Application: Drawing−out of the mouth of forging tongs (cf. fig. 3.3/20).
Sharpening	When sharpening, it is blown with the hammer face (cf. fig. 3.3/21): The workpiece must be reversed after some time! Application: Manufacturing chisels, crowbars, pickaxes
Pointing	As with sharpening, it is blown with the hammer face! The work−piece point lays at the edge of the anvil. The workpiece must be reversed after each blow! Application: Nails, wall hooks
Shouldering	When shouldering a workpiece, its cross−section is reduced at one point only. The shoulder can be at the end or in the middle of the workpiece. It can be shouldered at one side, at two sides or at all sides. In most cases the set hammer is used for shouldering (cf. fig. 3.3/23). Application: Shoulders in tongs, wall hooks, gib−head keys, journals at profile bars

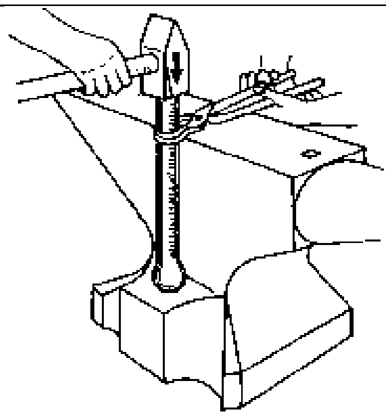


Fig. 3.3/18

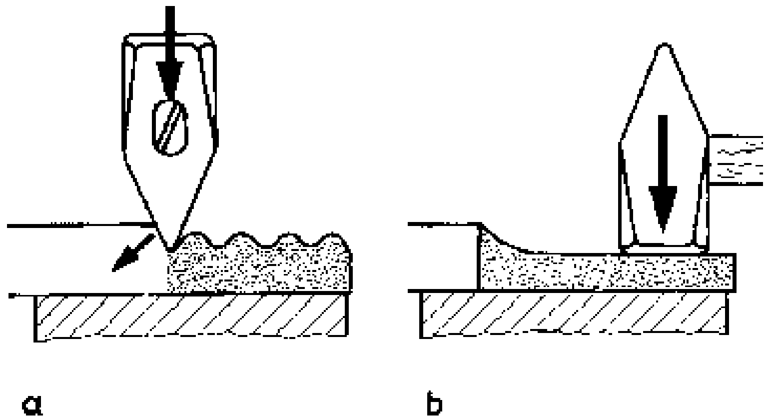


Fig. 3.3/19

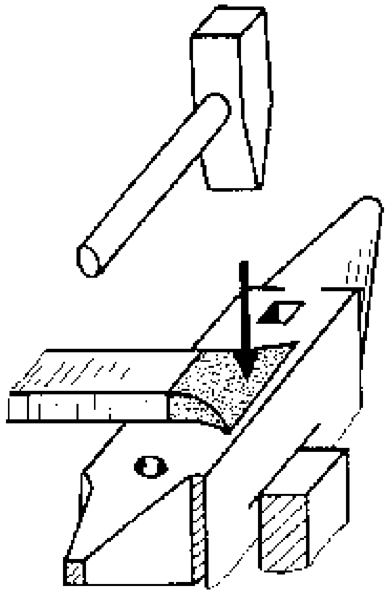


Fig. 3.3/20

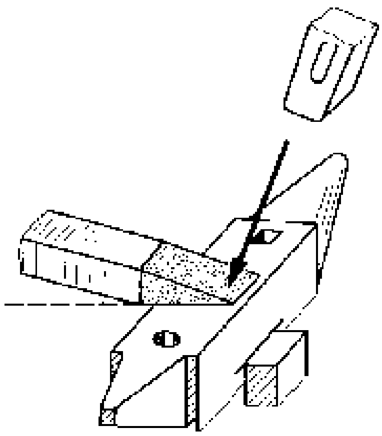


Fig. 3.3/21

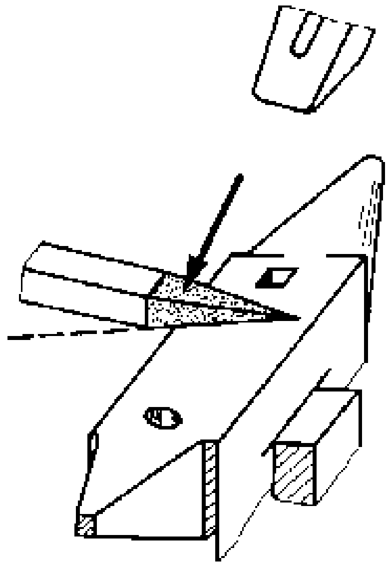


Fig. 3.3/22

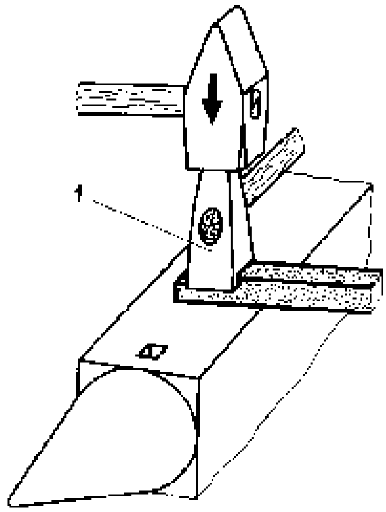


Fig. 3.3/23

Task:

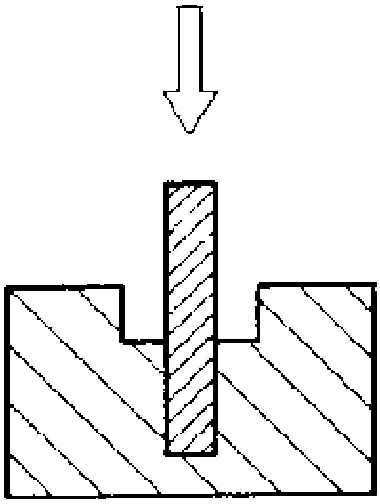
3.9. Find out more forging jobs and list them in a survey together with the application of the relevant tools.

Die forging

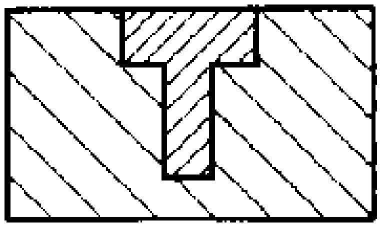
When many uniform workpieces shall be forged, it is often advantageous to use an auxiliary device, the die−forging die.

The die−forging die is a mould (it can be solid or split) which receives the heated blank. First, the workpiece protrudes beyond the mould and then with manual manufacturing it is driven into the mould by means of the forging hammer (when using machines − by means of the power hammer) until it fills the cavity of the mould. Fig. 3.3/24 shows an example of forging with the rivet−forging die. The rivet−forging die is a solid mould, the cavity of which has the shape of the rivet. After the steel bolt which is cut to the respective length was inserted into the die, the hammer blows form the heated upper part of the bolt to a rivet head in the die. Another simple die−forging die for manual manufacturing is shown in fig. 3.3/12.

Fig. 3.3/24 Rivet−forging die



1 Inserted bolt



2 Formed rivet

Task:

3.10. Which kind of forging work is done by means of this die−forging die? Describe the die−forging die!

Labour safety:

Use only intact hammers! The hammer shanks must be well fit−in and wedged.

Use only well fitting blacksmith's tongs! Otherwise the workpiece can slide off during forging.

The tongs must always be secured by a clamping ring.

The workpiece must fully rest on the anvil face. Otherwise rebound blows can beat the workpiece out of the tongs.

Wear goggles when working slightly rusted or scaled workpieces!

Put aside the finished parts so that there is no accident hazard! You cannot see the heat of a workpiece which does not anneal any more, but you can be burnt severely when touching it.

Summary

− Forging is hot−forming by the effect of impact. In doing so, the most suitable forging temperature shall be used for the respective metal. This temperature can be judged from the annealing colour.

Task:

3.11. What shall be taken into account during heating in the smith's hearth?

− The most typical forging works of smith forging are upsetting, stretching and shouldering.

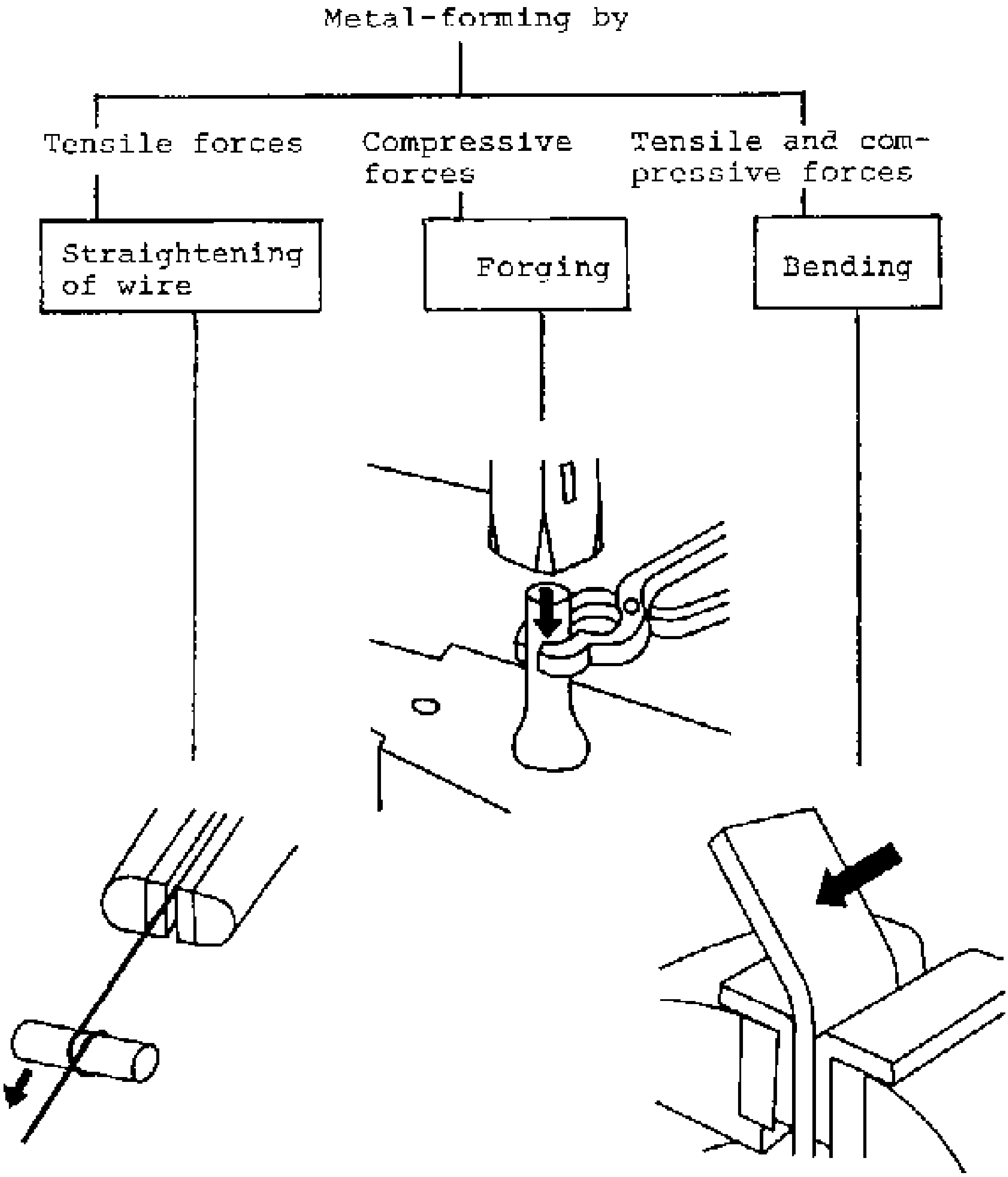
Task:

3.12. What are the characteristic differences of these three forging works?

– When die forging, the workpiece shape is given by the cavity in the die–forging die. This process is economical only when a large quantity of a workpiece is required.

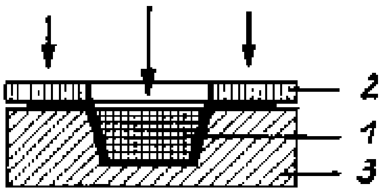
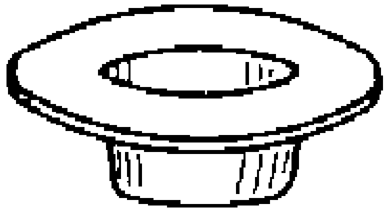
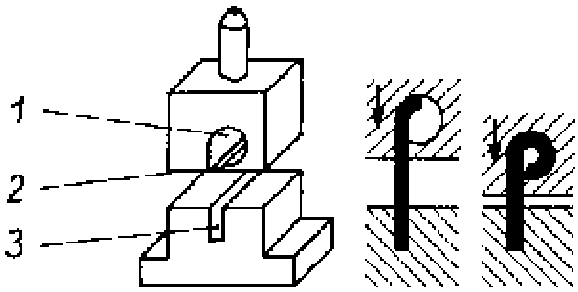
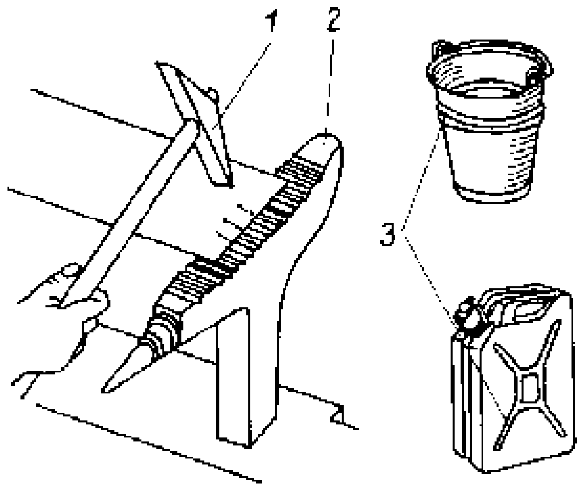
3.4. Survey on the metal–forming processes

During metal–forming, tensile forces, compressive forces or both tensile and compressive forces influence the workpiece.



With many metal–forming processes, tensile and compressive forces act simultaneously. This group of metal–forming processes comprises for example most of the straightening works as well as the following processes:

Metal– forming process	Explanation

Deep−drawing 1 Male die 2 Blank holder 3 Female die part 	The male die draws the work−piece into the female die part, the blank holder grips the edge; compressive force is generated by the press. Application: Forming of sheets to hollow parts (for example to pots) 
Rolling 1 Rolling cylinder (upper forging die) 2 Running−in slot 3 Lower die with receiving slot 	When the upper forging die and the lower die are compressed in the press the upper part of the workpiece is rolled in. During manual rolling, a jig corresponding to the rolling cylinder is set into the anvil. By hammering upon the protruding part of the workpiece, the other end of the workpiece rolls into the die. Application: Rolling−in of edges at vessels, hinges, tubes
Creasing 1 Creasing hammer 2 Creasing iron 3 Examples 	Creases can be manufactured manually (cf. fig. 3.4/6) or by means of the creasing machine. Application: Stiffening of sheet−metal parts (buckets, cans, cover plates, ornamental mouldings)

4. Joining

Apart from cutting−off and metal−forming processes, workpieces can also be given a new shape by joining single parts. In doing so, <u>non−permanent</u> and <u>permanent joints</u> are distinguished. For example, the screw joint belongs to the non−permanent joint types and the riveted and the soldered joint to the permanent joints.

Task:

4.1. Indicate other non−permanent and permanent joints you know!

4.1. Joining by screws

Parts of a workpiece, a unit, a device or a machine are joined to each other by screwing in such a way that the joint can be disconnected at any time without destructing the joint parts or the screws (fastening elements).

Such a joint is necessary in those cases where a part must be exchanged repeatedly.

For example, wheel and shaft of a bicycle are joined by screws. When the tyre of a wheel must be repaired, the wheel can easily and quickly be removed from the shaft.

4.1.1. Screw forms, nut lockings and screwing tools

The variety of shapes and tasks of the work−pieces, units, devices and machines require different kinds and shapes of screws. Different tools are also necessary for tightening and loosening these screws.

Kinds of screw joints and screw shapes

Basically, two types of screw joints are distinguished. With the first type, the parts to be joined are provided with threads and can be screwed together. This type is mainly used in pipe laying works (fig. 4.1/1).

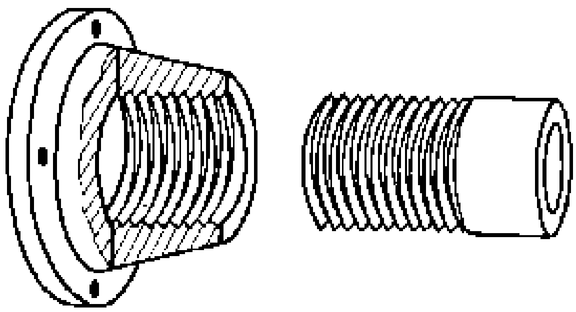


Fig. 4.1/1 Screw joint in a pipe

The second type consists normally of bolt, nut and washer and the parts to be joined (fig. 4.1/2a). When the seating surface for the screw head at the workpiece is not worked, a washer is also required for the screw head (fig. 4.1/2b). When a nut cannot be used because of lack of space or of other reasons (risk of accidents), the last part to be joined is threaded. This thread replaces the nut (fig. 4.1/2b).

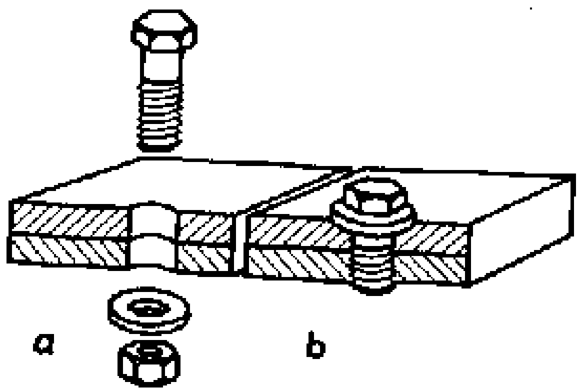
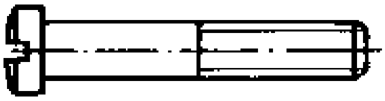
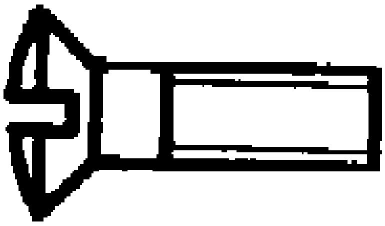
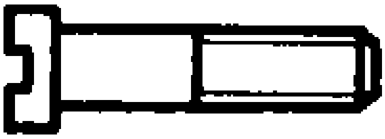
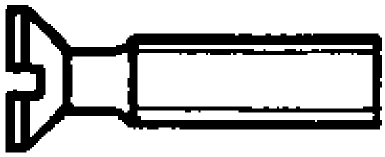
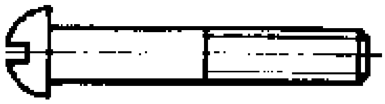
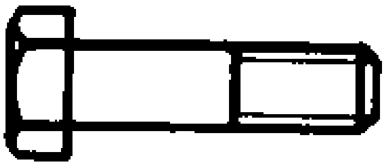
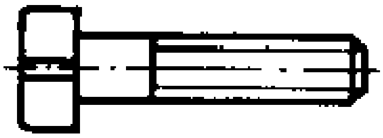
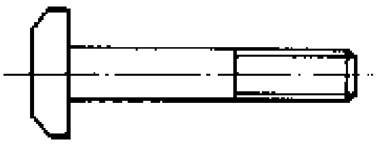
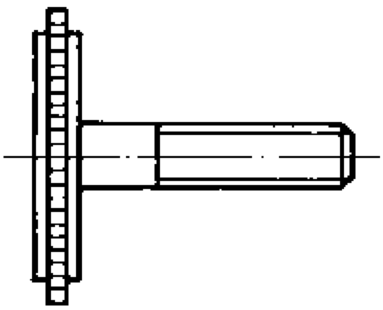
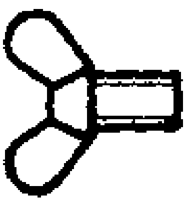


Fig. 4.1/2 a) Screw joint with bolt, washer and nut b) Screw joint with bolt, washer and thread in the lower component

The following survey shows the typical screw shapes which are used to join metal parts with washer and nut.

Designation of the screw	Figure

Lens screw	
Lens countersunk screw	
Filister−head screw	
Countersunk screw	
Button−head screw	
Hexagon screw	
Square bolt	
Hammer bolt	
Knurled−head screw	
Thumb screw	

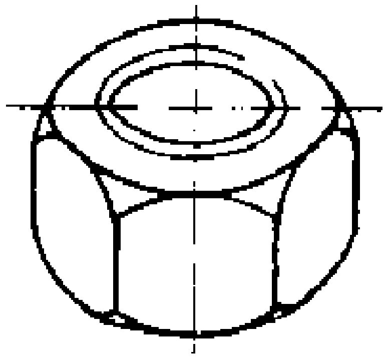
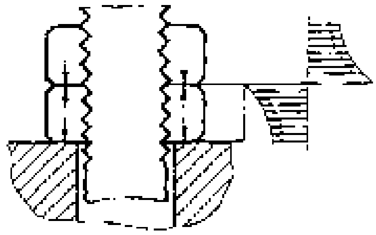
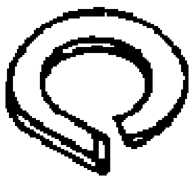
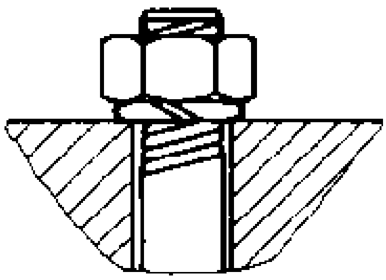
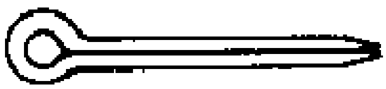
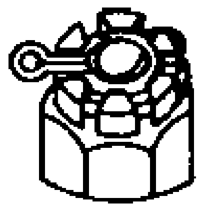
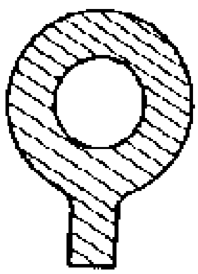
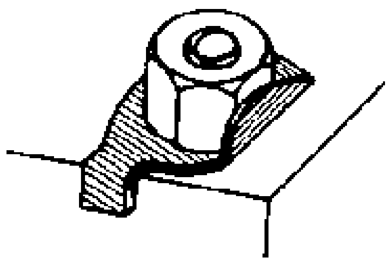
Task:

4.2. Find out examples for the application of the different screw shapes!

The representation chosen in figs. 4.1/3 to 4.1/12 with outside thick and inside thin solid line corresponds to an international agreement.

Nut lockings

When screw joints are on moved parts, it can happen, that the screws are loosened by vibrations. Therefore, the screw must be secured additionally. Typical nut lockings are:

Nut locking	Application
Lock nut	The lock nut is firmly screwed on the other nut. The resulting friction prevents independent loosening.
	
Lock washer	The lock washer ends exert pressure against the surfaces to be secured and keeps the thread under a permanent stress.
	
Cotter pin	When cottering, the bolt is bored. With its shape the inserted bolt holds in place the hexagon castle nut at the castellation.
	
Locking plate	Locking plates hold the nut or the screw head in place by means of their bent tangs.
	

Task:

4.3. Find out where such nut lockings are used at tools, devices and machines!

Tools

The screw driver serves to tighten and loosen all screws heads of which are provided with a slot. A wrench is required for hexagon and square bolts as well as for nuts. In general, knurled−head screws and thumb screws are tightened by hand.

Screw driver and wrench must fit the size and shape of the screw head!

The plates of the screw driver (fig. 4.1/17)

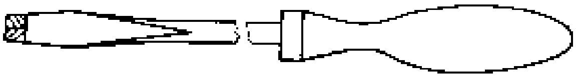


Fig. 4.1/17 Screw driver

Screw driver must run parallel in their lower part and fill the whole depth of the slot (fig. 4.1/18a). Wedge−shaped ground plates damage the slots and the screws become useless (fig. 4.1/18b).

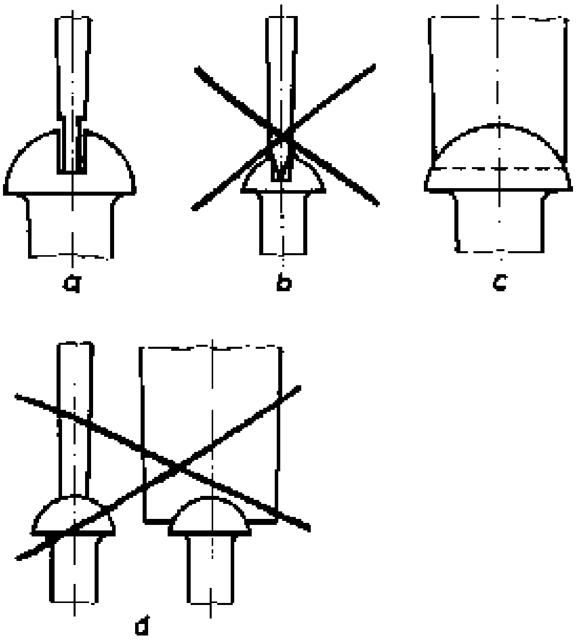
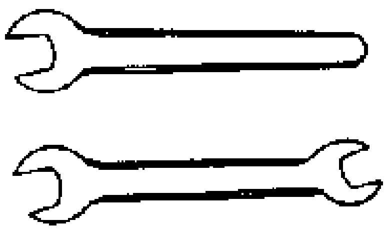


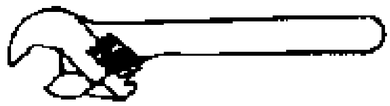
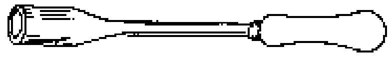
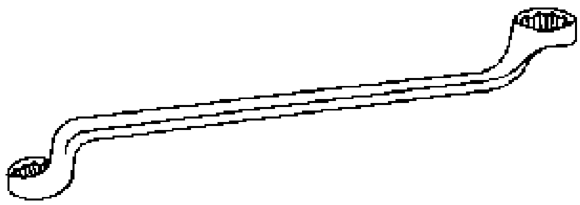
Fig. 4.1/18 Appearance of screw driver plate a) to d)

The width of the plate must be slightly smaller than the diameter of the screw head (fig. 4.1/18c). Too small plates break during tightening the screws, too wide plates cannot seize countersunk screws properly in their slots (fig. 4.1/18d).

Wrenches must have the wrench opening matching the screw head so that they can seize adequately. Adjustable wrenches can be adjusted to the correct opening.

The following survey shows the most common wrenches and their application.

Wrench	Application
Single−end wrench Double−end wrench	The wrench must be turned by 60° until it can be inserted again in starting position.
	

Adjustable wrench	Application as described above
	
Socket wrench	Socket wrenches are used when screws are accessible in axial direction; they need not be changed during tightening and time is saved in this way.
	
Offset box wrench	When screw joints are accessible with difficulty; their manipulation is convenient and do not widen.
	

The length of the wrench must be chosen in such a way that the respective screws can be tightened with sufficient tightness.

Increasing the length of the wrench (for example by slipping a tube over the wrench) is not allowed because the screws can break in case of too large a force.

4.1.2. Remarks on screwing

<u>Tightening of bolts and nuts</u>

– First place the slightly greased bolts or nuts by hand and screw them into the first courses of the thread, only then use the corresponding tool!

– When a nut on a through bolt shall be tightened, hold the bolt head in place with a second screw driver, otherwise the bolt can be turned together with the nut and it cannot be checked whether the nut is tightened!

– When a cover or a fish plate shall be fastened by several screws observe the order shown in the figs. 4.1/24 and 4.1/25 for tightening the screws! This way deformation of the machine parts can be avoided.

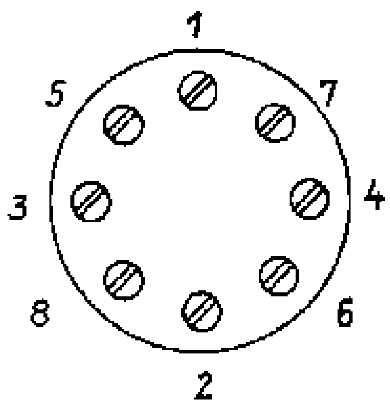


Fig. 4.1/24 Order for tightening the screws of a round cover

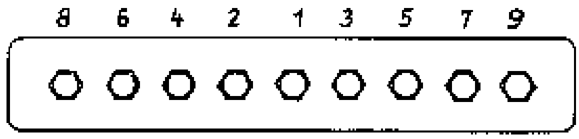


Fig. 4.1/25 Order for tightening the screws of a fish plate

Task:

4.4. Define a rule for tightening screws with a group of screw joints by means of figs. 4.1/24 and 4.1/25!

Loosening of bolts and nuts

– First all bolts and nuts are slightly loosened, then they are completely removed!

– Rusted–in bolts are brushed with oil, petroleum or graphite solution.

– Slight hammer blows on the bolt head or at the side of the nut slacken the courses of the thread and facilitate loosening.

Labour safety:

Use fitting tools only! Too wide wrenches, too large or too small screw drivers slip off and result in injuries.

Do not put screw drivers into the pockets of your working cloth (danger of injuries when stooping)!

Take care when using oil (risk of slipping) and petroleum (risk of fire)!

Summary

– Components can be joined non–permanently with each other by screwing.

– In metalworking the parts of a screw joint are in general bolt, washer and nut.

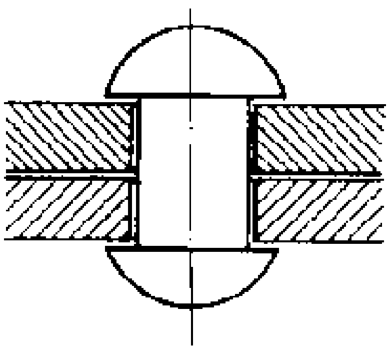
– Nut lockings are additionally required for screw joints on moved parts.

– In case of a group of screw joints, the screws shall be tightened in a given order that the components do not warp.

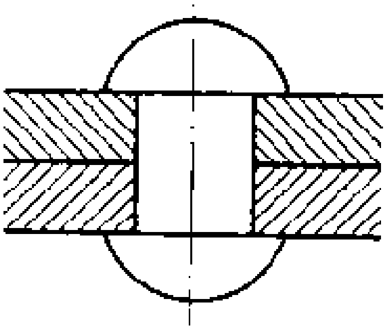
4.2. Joining by riveting

Components are permanently joined with each other by riveting. Either the riveted parts can move countercurrent to each other – movably riveted (examples: shears, pliers) or they are firmly compressed by the rivet – tightly riveted (examples: bridges, planes) (fig. 4.2/1).

Fig. 4.2/1



a) movable riveting



b) tight riveting

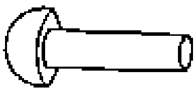
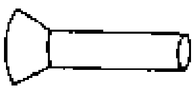
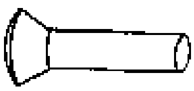
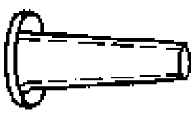
4.2.1. Types of rivets and riveting tools

Rivets are suitable for joining most different materials. Apart from metals, they are also used for example for leather, pasteboard and synthetic materials. In these cases, however, hollow rivets (cf. fig. 4.2/5) are used whereas in metalworking, nearly exclusively solid rivets (cf. figs. 4.2/2 to 4.2/4) are applied.

Solid rivets are mainly used in machine building, vehicle and boiler construction as well in jewellery design.

According to the different fields of application a variety of rivet shapes and fitting tools is available.

Rivet shapes

Designation and representation	Application
Button−head rivet 	For especially firm rivetings, for example steel structures
Countersunk rivet 	When the surface of the components shall be flat
Oval rivet 	Especially for steel staircases or steel ladders whereby the tread face shall be non−skiddy
Tubular rivet (hollow rivet) 	For riveting leather, pasteboard and synthetic materials

Design of the rivets

A solid rivet consists of the manufactured head and the rivet shank. After the rivet was put through the hole of the components which lie one above the other the rivet shank end which protrudes from the hole is upset and formed to the driven head (fig. 4.2/6).

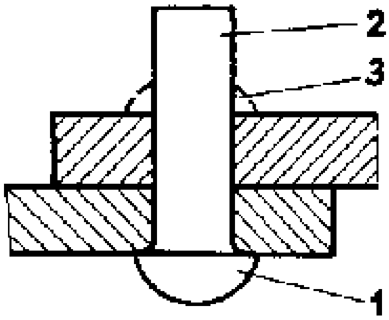


Fig. 4.2/6 Parts of the rivet

1 Manufactured head, 2 Rivet shank, 3 Driven head

Upsetting and forming of the rivet shank is only possible when the rivet material is adequately formable. Therefore, rivets consist of steel, copper or aluminium.

Riveting tools

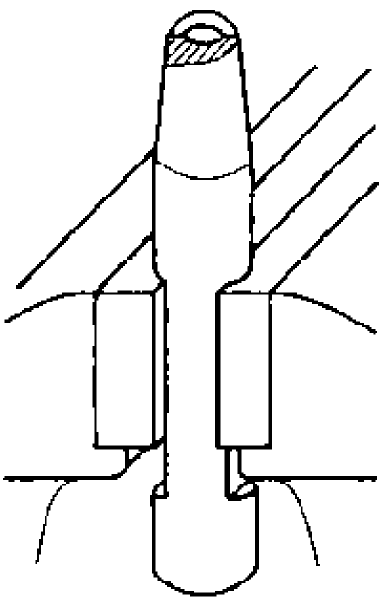
The tools for manual riveting comprise a support, or a holding−up hammer, which is clamped into the vice, a rivet extractor and a rivet header (fig. 4.2/7).

Task:

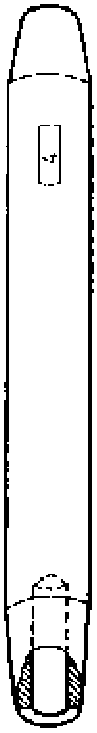
4.5. Describe the design of the riveting tools according to fig. 4.2/7! Explain the condition of the supporting surfaces of holding−up hammer and rivet header for countersunk rivets.

Rolling−up tools are used for tubular rivets (eyelet tongs, fig. 4.2/8).

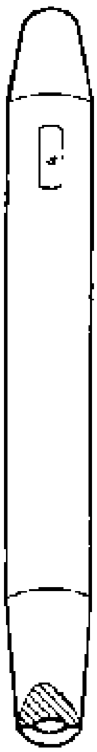
Fig. 4.2/7 Riveting tools



1 Holding−up hammer



2 Rivet extractor



3 Rivet header

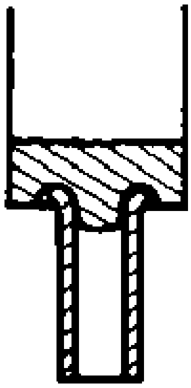


Fig. 4.2/8 Rolling–up tool for eyelets

A hand hammer serves as impact tool. Working with the pneumatic hammer is more efficient (fig. 4.2/9).

For rivets, which are driven in hot condition (only rivets with a diameter of more than 8 mm), additionally rivet tongs which grip and hold the heated rivet are required.

In general, in manual riveting is cold driven.

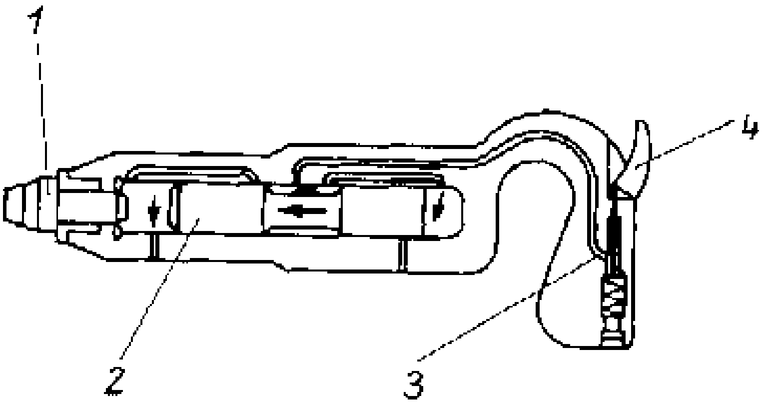


Fig. 4.2/9 Pneumatic hammer

1 Striker, 2 Piston, 3 Cone valve for compressed air, 4 Push

4.2.2. Preparations for riveting

Calculation of the shank diameter of rivets

Thick steel beams require rivets with larger shank diameter than thin sheets. When the shank diameter is too small for the riveted joint, the rivet can be sheared off. Therefore, the shank diameter (d) of the rivet must always be matched with the thickness of the components to be joined – this is called rivet grip (s).

In general, the following applies:

The shank diameter (d) of the rivet must amount to at least of the grip (s).

Example: When the rivet grip (s) is 20 mm, a rivet with a shank diameter of at least must be chosen.

Task:

4.6. A component of 10 mm thickness shall be riveted together with a component of 6 mm thickness. Which minimum diameter of the rivet shank must be selected?

Calculation of the rivet shank length

Also the rivet shank length must be selected according to the thickness of the parts to be joined (rivet grip s).

Also the allowance for the driven head must be taken into account when calculating the shank length.

The length of the rivet shank (1) results from the rivet grip (s) and the allowance for the driven head (z).
$l = s + z$

The driven head allowance (z) for button−head rivets with a rivet grip up to 20 mm amounts to: 1.5 times rivet shank diameter (d); more than 20 mm rivet grip: 1.7 times rivet shank diameter (d). The driven head allowance for countersunk rivets amounts to 0.5 times rivet shank diameter (d).

Example:

Calculate the rivet shank length for a rivet with driven button−head.

Given:

rivet grip s = 20 mm
rivet shank diameter d = 6 mm

To be calculated: rivet shank length l

Solution:

$l = s + z$
$z = 1.5 . d$
$z = 1.5 . 6$ mm
$z = 9$ mm
$l = 20$ mm + 9 mm
$l = 29$ mm

The rivet shank length amounts to 29 mm. Task:

4.7. Two components, each 8 mm thick, shall be joined by means of a button−head rivet with a shank diameter of 5 mm.
Which rivet shank length is required?

<u>Preparation of workpieces</u>

Prior to riveting, the rivet holes must be marked out and drilled. When drilling it shall be taken into account that the diameter of the rivet hole must be slightly larger than the diameter of the rivet shank, because the rivet shank widens during riveting.

Task:

4.8. Justify why the diameter of the rivet shank varies during riveting?

The following table shows the associated values:

Diameter of the rivet shank, mm	Diameter of the rivet hole, mm
1	1,1
1,4	1,5
1,7	1,8
2	2,2
2,3	2,5
2,6	2,8
3	3,2

4	4,3
5	5,3
6	6,4
7	7,4
8	8,4

It is suitable to drill the two parts to be joined simultaneously, so that the rivet holes coincide precisely. When button−head rivets are used, the holes are deburred only after drilling, for countersunk rivets, they must additionally be countersunk.

Task:

4.9. Repeat what shall be taken into account when countersinking holes for countersunk rivets! Compare fig. 2.6/2 for this purpose!

4.2.3. Working with riveting tools

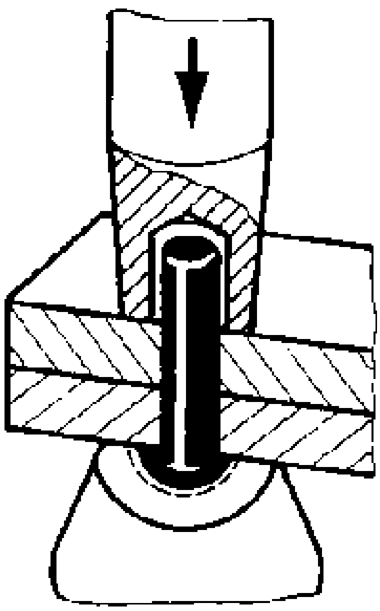
When riveted joints with button−head rivets shall be manufactured, the tools shown in fig. 4.2/7 are used for this purpose. Additionally, tacking screws and hand vices or clamp dogs are required which hold the components accurately to fit.

First, the rivet is guided from bottom to top through the holes of the components which rest one upon the other and are supported with the manufactured head in the holding−up hammer. The rivet extractor is pushed over the free end of the rivet shank. Some heavy hammer blows upon the rivet extractor permit that the manufactured head and the components rest firmly one upon the other. This process is called extraction of the rivet (fig. 4.2/10a).

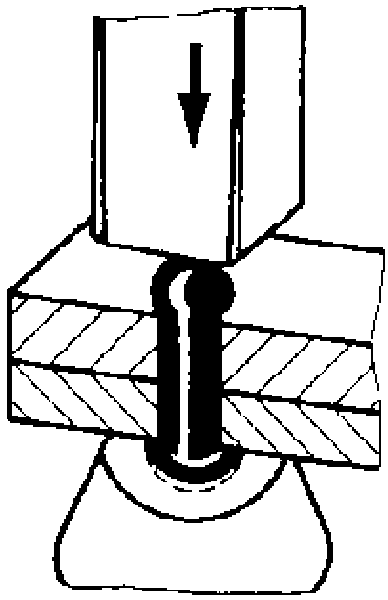
Now, some perpendicular heavy blows upon the rivet shank follow, whereby the rivet shank is upset (fig. 4.2/10b). After upsetting, the driven head is pre−formed by some lateral blows with the hammer face (fig. 4.2/10c). In doing so, the hammer face shall be guided around the driven head with uniform blows.

The rivet header shall be set perpendicularly on the pre−formed driven head. Some heavy blows upon the rivet header serve to finish the rivet (fig. 4.2/10d).

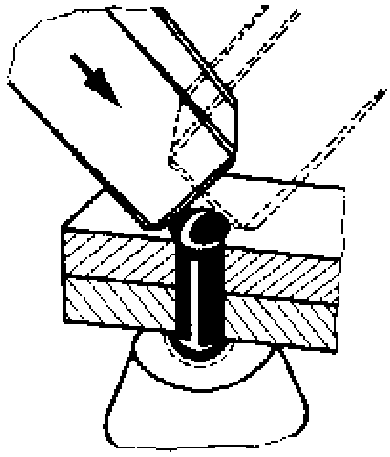
Fig. 4.2/10 Riveting



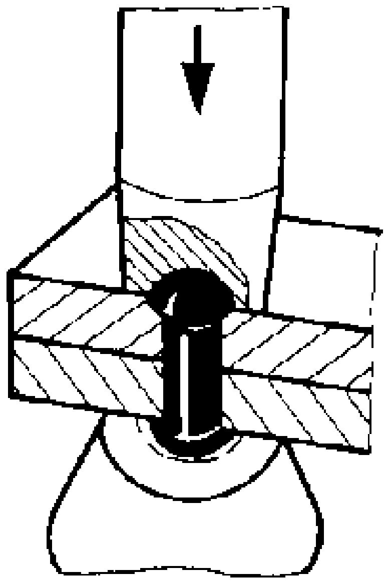
a) Extraction of the rivet



b) Upsetting of the rivet



c) Preforming of the driven head

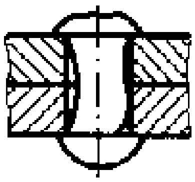
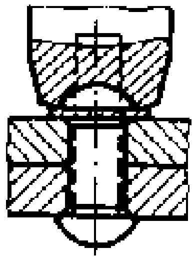
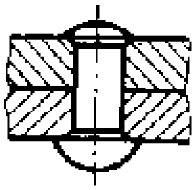
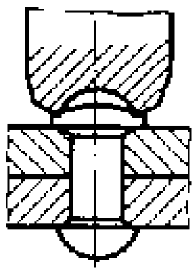
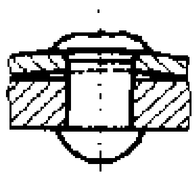


d) Finishing of the driven head

4.2.4. Riveting faults

When the preparation for riveting or riveting itself was not carefully performed, riveting faults can arise which reduce the quality of riveting or make riveting useless.

The following survey shows some possible riveting faults.

Representation of the fault	Reason
	Rivet hole too large, the shank warps; the driven head is not finished
	Rivet shank too long; excessive material forms a ring around the head
	Rivet shank too short; driven head not finished
	Rivet head pre–formed too flat
	The upper sheet is not tightened sufficiently; the shank is upset between the sheets

Task:

4.10. Find out more possible riveting faults!

4.2.5. Kinds of riveting and rivet arrangements

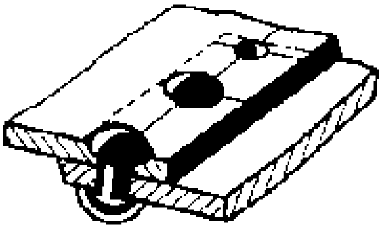
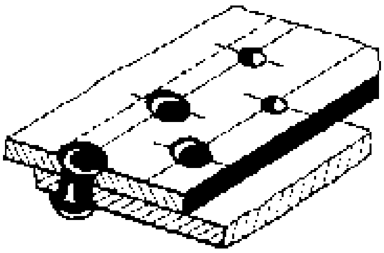
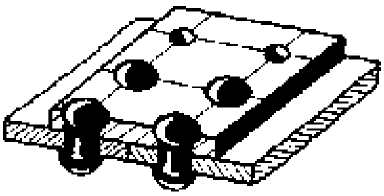
The large group of tightly riveted joints can be subdivided according to their purpose:

- Tight–riveting – this joint must take up large forces; for this reason, rivets with large shank diameters are used; application in steel construction, machine and vehicle building.
- Close–riveting – above all, this joint must be leakproof; important strength is not required; many rivets with small diameters are used; application in tank construction

– Tight– and close–riveting	– this joint must be leakproof and take up large forces; many rivets with large diameter are used; application in pressure–vessel and boiler construction

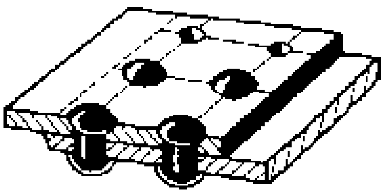
Apart from the mentioned kinds of riveting, there is also *a* variety of rivet arrangements. Which arrangement of rivets is chosen depends on the particular purpose of the workpiece.

Typical rivet arrangements are:

Rivet arrangement	Application
Single–row lap 	Often used for simple tight riveting, for close–riveting as well as for tight–and–close–riveting
Double–row lap as staggered riveting 	For increased demands on tightness and strength. Staggered riveting causes also a better leakproofness than double–row parallel riveting
Single–row, single–strap rivet butt joint 	Butt strap can be slightly thicker than the abuted plates, the joint is strengthened this way; double–strap riveted butt joint is also possible, in this case the butt straps are slightly thinner than the plate thickness

Task:

4.11. Draw the section and top view of a double–row parallel lap riveting. Justify why the staggered riveting permits better tightness.



Summary

– A permanent joint is produced by riveting (loosening is possible only destruction of the rivet).

– Types of riveted joints:

Movable riveting

Tight riveting
- Tight riveting
- Close-riveting
- Tight- and-close-riveting

Task:

4.12. Indicate the preparations which are necessary for riveting!

4.13. Indicate the four working steps when driving a button–head rivet and the faults which must be avoided during each step!

4.3. Joining by soldering

Soldering joins two parts of metal or metal alloys permanently. Binding agent is a fused–in filler metal, the solder. It penetrates the pores of the heated contact faces. After cooling down, the workpiece parts adhere at each other cue to the adhesive force.

Above all, zinc, tin, lead, copper, steel and the precious metals are suited for soldering.

Soldering and brazing can be distinguished.

When soldering, the working temperature is below 450 °C.

Soldering is applied for example by the plumber, in electrical engineering and jewellery design.

When brazing, an increased temperature (above 600 °C) is used. These brazing joints have an increased strength. Brazing is used especially in bicycle construction, pipe and tube making and tool making.

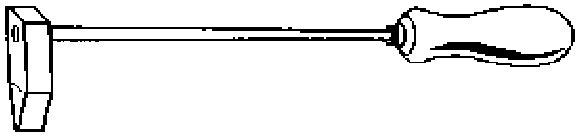
Since soldering is mainly applied in manual metalworking, the following sections refer only to soldering.

4.3.1. Workpieces and auxiliary means

Soldering iron

For soldering, the spot to be soldered must be heated and the binding agent be brought to flow. For this purpose, a soldering iron is mostly used –when soldering. Soldering irons without own heat source and soldering irons with own heat source are available.

Fig. 4.3/1



a) Hammer soldering iron 1 Soldering iron made of copper, 2 Handle

b) Pointed–top soldering iron

Soldering irons without own heat source are heated by means of a wood or coal fire or by means of a gas flame or a soldering blowlamp. However, they cool down quickly. For this reason, it can be soldered always for a short time only, then the iron must be heated repeatedly. According to the shape of the iron, which is made of copper as all soldering irons, the hammer soldering iron (fig. 4.3/1a) and the pointed–top soldering iron (fig. 4.3/1b) are distinguished. The shape of the iron is chosen according to the soldering works to be done.

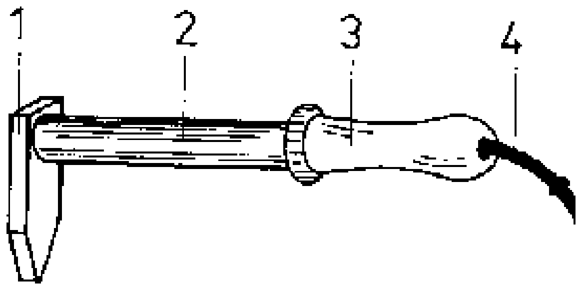


Fig. 4.3/2 Electrically heated soldering iron

1 Soldering iron, 2 Heating, 3 Handle, 4 Supply cable

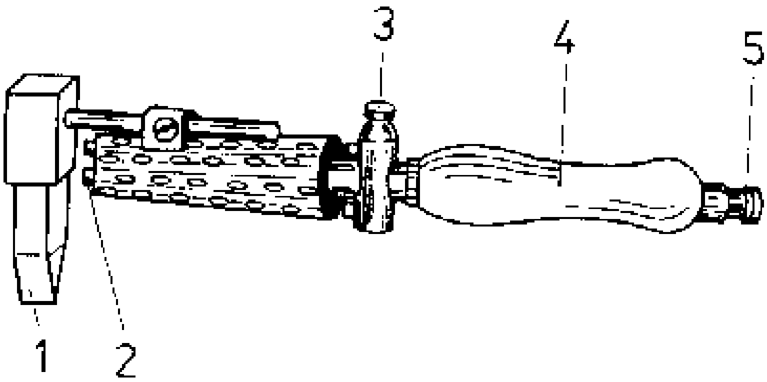


Fig. 4.3/3 Gas–heated soldering iron

1 Soldering iron, 2 Nozzles, 3 Adjusting screw, 4 Handle, 5 Connecting piece

Soldering irons with own heat source feature the advantage that the work need not to be often interrupted. Soldering irons are electrically, gas or fuel heated (figs. 4.3/2, 4.3/3 and 4.3/4). However, these soldering irons –particularly the gas or fuel heated soldering irons – are heavier and often bulkier.

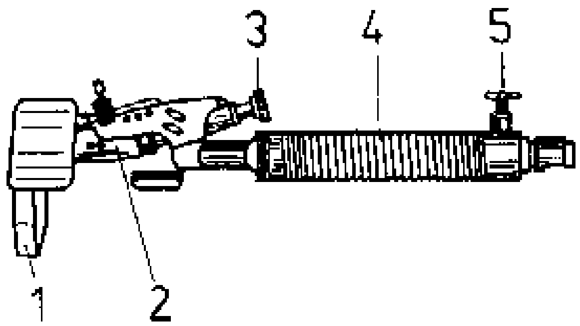


Fig. 4.3/4 Fuel–heated soldering iron

1 Soldering iron, 2 Nozzles, 3 Adjusting screw, 4 Handle used as fuel tank, 5 Inlet piping connection

Soldering iron holder: When soldering, it is often necessary to put away the soldering iron. It is useful to put it on a soldering iron holder. The soldering iron holder (figs. 4.3/5 and 4.3/6) prevents burns on work benches and does not allow too large a heat dissipation.

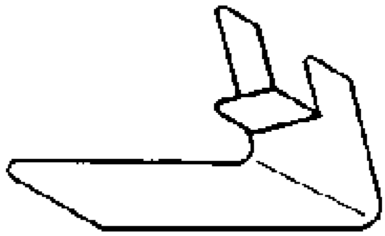


Fig. 4.3/5 Soldering iron holder of sheet

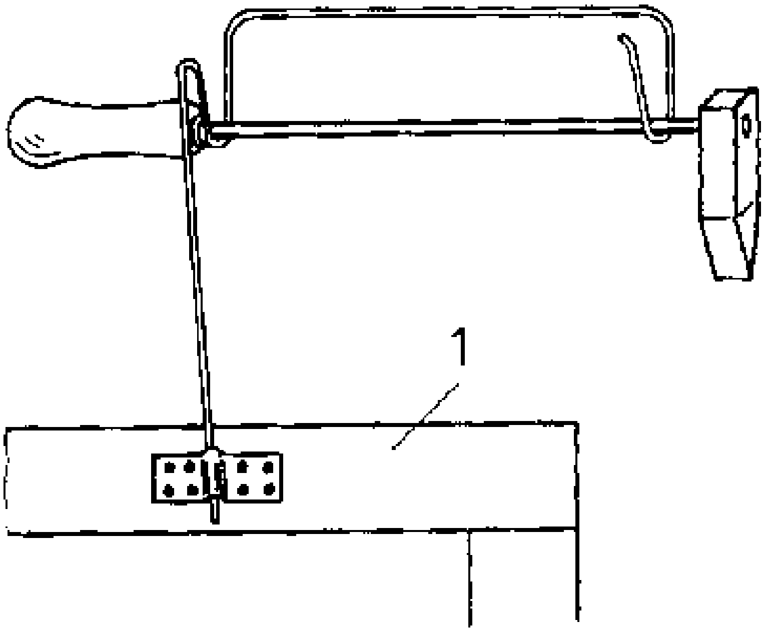


Fig. 4.3/6 Soldering iron holder of wire

1 Table edge

Solder

The solder for (soft−)soldering is mostly an alloy of tin and lead. The number of tin parts and of lead parts contained in a solder depends on the type of soldering work and the material of the workpiece to be soldered.

Survey on the tin solders and their application

Designation	Parts of		Application
	tin	lead	
Tin solder 30	30	70	Rough building plumber work
Tin solder 33	33	67	Soldering tin sheet or zinc−coated sheet
Tin solder 40	40	60	Soldering thick brass sheet or tin−plate sheet
Tin solder 50	50	50	Soldering thin brass sheet or tin−plate sheet
Tin solder 60	60	40	Soldering easily meltable metals, soldering electric connections
Tin solder 90	90	10	Soldering tin boxes in which human foods are put

All tin boxes for foods shall only be soldered with tin solder 90! Plumbous compounds are poisonous and a larger proportion of lead can be detrimental to human beings.

Flux

When metals are heated, an oxide layer forms on their surface. Since the lead cannot flow on this oxide layer and, therefore, cannot be taken up by the workpiece, a flux must destroy the oxide layer.

Hydrochloric acids, soldering fluid, soldering paste or colophonium are used as flux.

Flux	Application
Hydrochloric acid (diluted)	Only for zinc sheets and zinc−coated sheets, not for electric installations
Soldering fluid (consisting of hydrochloric acid and zinc)	Nearly for all soldering works, except for electric installations
Soldering paste (main components: colophonium and ammonium chloride (salmiac)	Nearly for all soldering works except in radio engineering
Colophonium (acid−free)	Only for brass and copper; especially suited for electric installations

How to make soldering fluid: Diluted hydrochloric acid is filled into an acid−proof container and small pieces of zinc sheet are added. When bubbling stops, soldering fluid has formed.

Be careful when handling hydrochloric acid, it can cause etchings! Wear goggles!

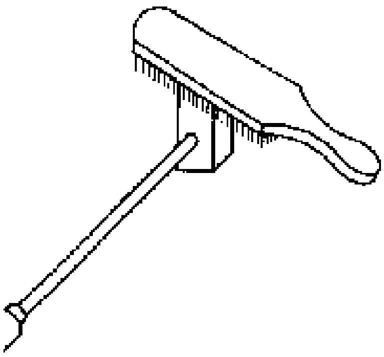
The soldering tool for soft soldering is the soldering iron, auxiliary means are solder and flux.

4.3.2. Working with the soldering iron

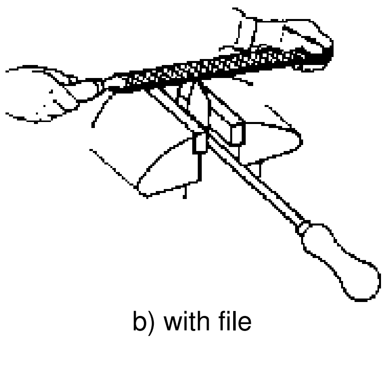
Preparation of the soldering iron

When the soldering face of the soldering iron is heavily contaminated, it must be first cleaned with the wire brush and then with the file (fig. 4.3/7). Subsequently, the soldering iron is heated (fig. 4.3/8). The oxide layer formed on the heated soldering iron is removed by rubbing on the salmiac stone (fig. 4.3/9) or dipping into a flux. Then, the soldering face of the iron shall be coated with solder − tin−coated (fig. 4.3/10).

Fig. 4.3/7 Cleaning of the soldering face of the soldering iron



a) with wire brush



b) with file

Tin−coating the soldering face of the soldering iron facilitates soldering.

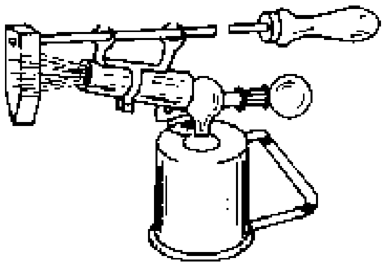


Fig. 4.3/8 Heating of the soldering iron with soldering blowlamp

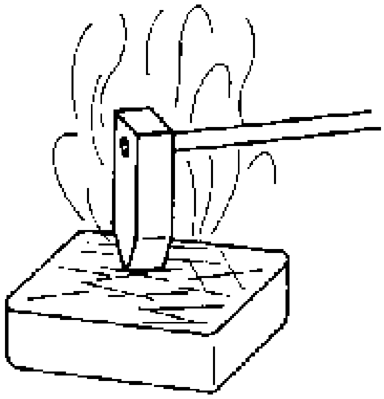


Fig. 4.3/9 Removal of the oxide layer with salmiac stone

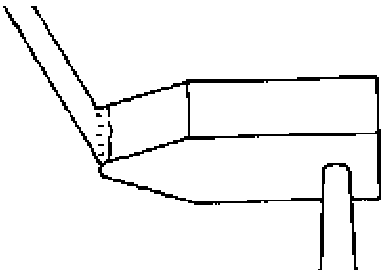


Fig. 4.3/10 Tin−coating of the soldering face

Task:

4.14. Why must the oxide layer be removed from the soldering face prior to tin−coating?

Preparation of the soldered joint

First, the metal surfaces which shall be joint by a solder must be carefully cleaned. Tools for this purpose are file and scraper. For fine cleaning, also emery paper or emery fabric can be used.

Do not touch the cleaned metal surfaces with your hand, because the hand sweat prevents the flowing of the solder!

The flux is coated on the cleaned metal surfaces, then these surfaces are tinned!

Tinning of the metal surfaces to be joined increases the strength of the soldered joint.

Soldering a joint

The parts to be joined must be firmly pressed together in order not to be displaced during soldering. For pressing, wooden blocks (soldering blocks) are used, because they have a poor thermal conductivity, or wire (figs. 4.3/11 and 4.3/12).

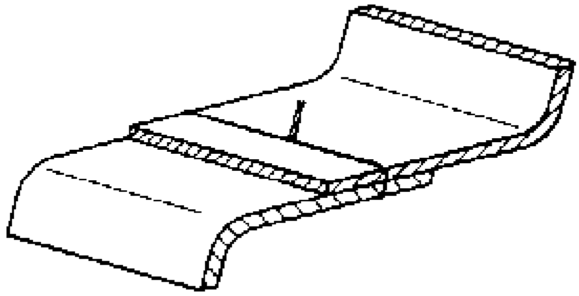


Fig. 4.3/11 The parts to be joint held with wire

When a long joint, a seam, shall be soldered, the seam is first tacked. During tacking, the parts to be joined are provided with soldered points in short distances (fig. 4.3/13). Then, the whole seam shall be finished.

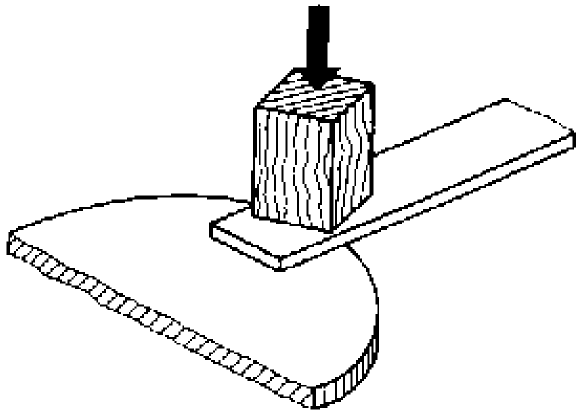


Fig. 4.3/12 The parts to be joint held with the soldering wooden block

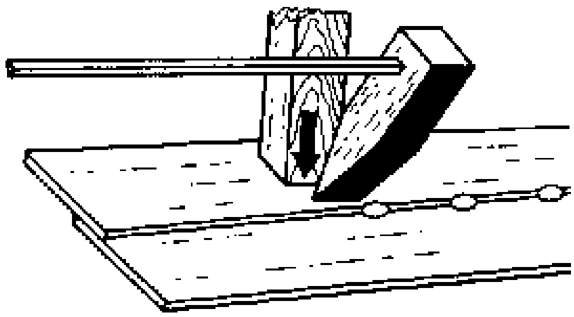


Fig. 4.3/13 Tacking of a solder

Tacking and finish–soldering shall be performed as follows: The soldered joint shall be heated with the soldering iron until the solder on iron and soldered joint starts to flow. When the solder adhering at the iron is not sufficient, more solder must be taken up with the hot iron and transmitted to the soldered joint.

In doing so, take into account, that the solder is flowing easily. When the solder is applied in a viscous or pasty condition on the soldered joint it does not penetrate into the surface of the metals and the soldered joint has no strength (figs. 4.3/14 and 4.3/15). Solders become viscous or pasty when the soldered joint was not sufficiently heated, it is called then "dry joint".

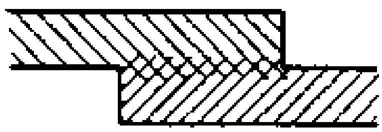


Fig. 4.3/14 Correctly soldered joint; the solder has penetrated into the surface of the metal parts

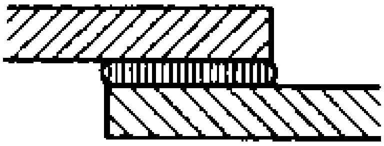


Fig. 4.3/15 "Dry soldered joint"; this joint has no strength and will loosen with the slightest load

After soldering, the soldered joint shall be cleaned: it is rubbed with warm water or spirit and excessive solder is scraped off.

Making an unobjectionable soldered joint includes:

– tinning the soldered face of the iron
– tinning the soldered joint
– tacking and finish−soldering the joint with easily flowing solder

Labour safety:

Put off the soldering iron in such a way that it cannot fall down or cause fire. Clean your hands carefully from residual flux after finishing the work; this is especially important when using hydrochloric acid or acid−containing fluxes!

Task:

4.15. Why is special care necessary when hydrochloric acid is used?

Do not hold small workpieces with the hand! The heat is dissipated in the workpiece and reaches also the end which is hold! Soldering blowlamp or gas torch shall be arranged in such a way that their flame cannot be reached by chance!

Summary

– Soldering – as riveting – produces a permanent joint. The joint is generated by adhesion between solder and the metal surfaces to be joint.

– When soft−soldering, the soldering iron is used.

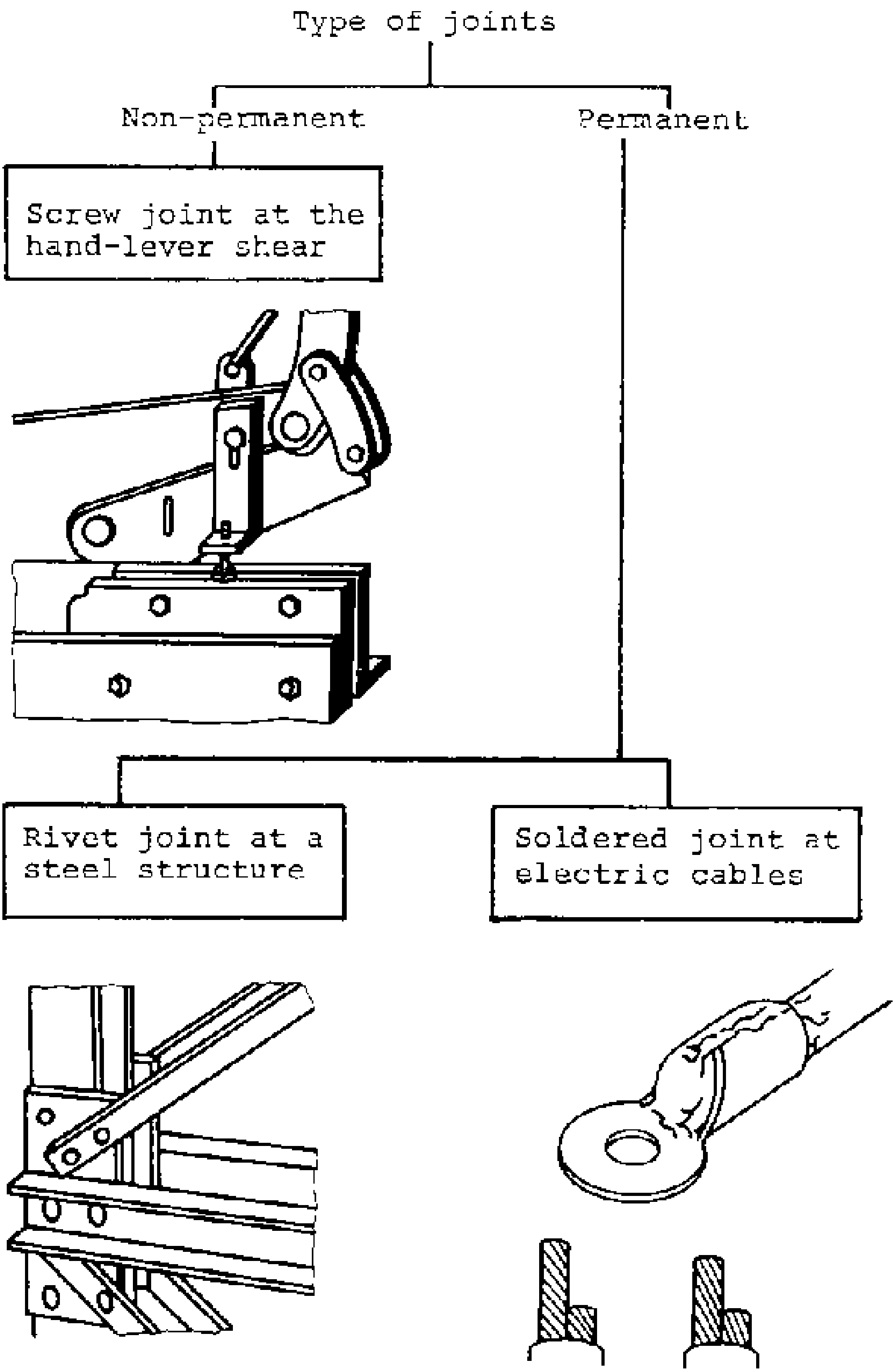
Tasks:

4.16. Indicate the tasks of the soldering iron!

4.17. Characterize shortly the preparation of the soldering iron and the soldered joint for soldering!

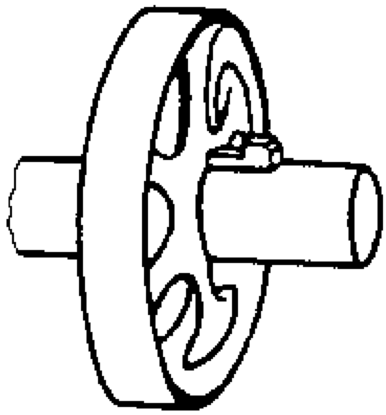
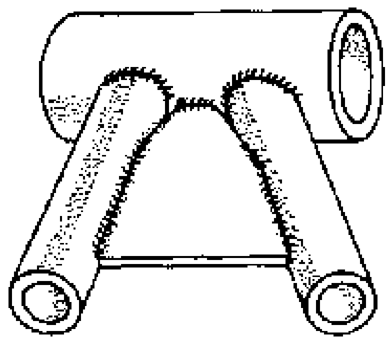
4.18. Justify why the solder must be easily flowing for soldering!

4.4. Survey on the joining processes



Further joining processes are:

Joining process	Explanation

Key and spring joints	They join for example pulleys and toothed gears with centres and shafts. Joint is <u>non–permanent</u> 
Welded joint	Joining by fusing the weld junctions with filler metal (welding wire); very high temperature (approximately 3000°C), thus a very strong joint results. Mainly used in steel construction, boiler making and ship building. Welding processes have partly replaced riveting and soldering processes in modern industry. Joint is <u>permanent</u> 

Solution to the tasks

1.1. The dimensional variation in fig. 1.1/5 amounts to 0.5 mm.

1.3. 97.4; 35; 132; 51.2

1.4.

Measuring tool	Measuring range	Measuring accuracy
Steel rule	300 mm 500 mm	1 mm
Folding rule	1000 mm 2000 mm	1 mm
Steel tape rule	1000 mm 2000 mm	1 mm
Vernier caliper	160 mm 320 mm	0.1 mm

1.5. 180° – 37° = 143°. The angle amounts to 143°.

1.6. Individual errors, measuring force errors, tool errors, Environmental errors. Apart from environmental errors, all the other mentioned errors can be avoided.

1.7. – Put the workpiece correctly between the measuring faces!

– Do not exert force when measuring!

– Read off accurately!

– Check the measuring tools for accuracy in frequent intervals!

1.8. Gauges are used when a large number of workpieces with equal dimensions or equal shapes shall be manufactured. Checking by means of gauges is time–saving.

1.9. Length measuring tools: folding rule, steel tape rule for measuring increased lengths

Limit gauge: gauge for measuring the sheet thickness

1.10. Non–adjustable checking tools: steel rule, folding rule, steel tape rule, flat gauge, wire gauge, thin steel try square, radius gauge

Adjustable checking tools: vernier caliper, goniometer

1.11. External measurement, for example diameter of a bolt

Internal measurement, for example diameter of a hole

Depth measurement, for example depth of *a* hole

1.12. Only when you start from the reference edge, precise marking–out is possible. The marking–out errors are added by chain dimensions.

1.13. The scribing block shall be adjusted to 77 mm.

1.14. A pencil instead of the scriber is used for marking–out notch–sensitive materials, as for example aluminium, as well as for marking–out forming edges at thin sheets.

1.15. Half of the prick punch marks must be visible at the edge.

2.1. Cutting bread or fruit with the knife –dividing; cutting paper with the scissors –dividing; working wood with the file or with the saw – metal removal.

2.2. For aluminium 30° to 50°
for steel 60° to 70°

2.3. A chisel with short cutting edge is selected.

2.4. When cutting from one side, the material would be too much deformed at this cutting point; this consumes power. Additionally, an increased filing allowance (material loss) and more rework (time) are required.

2.5. When dividing, the chisel stands upright, when metal removing, it is oblique to the workpiece surface.

2.6. Chisel edges with small wedge angle penetrate easier into the material than chisel edges with large wedge angle. Chisel edges with short cutting edge length penetrate easier into the material than chisel edges with long cutting edge length.

2.7. Chisel edges with large wedge angle are used for hard materials, cutting edges with small wedge angle for soft materials.

2.8. The shear jaws with paper–scissors are longer than the legs, because in this case less power is required, but a high cutting performance should be achieved. Additionally, the cutting edges of the paper–scissors have small wedge angles, because they are not as highly loaded as the cutting edges of the snips.

2.9. When chiselling by upsetting, the cutting surfaces are deformed; rework by filing is necessary. A considerable loss of material is produced. When shearing, the cutting surface is smooth; no or only minor rework necessary. No or only minor loss of material.

2.10.

Spacing	Materials
Rough	Soft steel, soft aluminium, copper, zinc, plastics, compression−moulding materials
Medium	Half −hard steel, hard light metals (for example hard aluminium), brass
Fine	Hard steel

2.11. Since the saw does not perform a cutting−off operation during the return travel, power can be saved and the saw preserved.

2.12. During sawing, the material loss is slightly larger by metal removal in the kerf than with shearing. Because smooth cutting surfaces are produced with both processes, only minor rework is required.

2.13. The saw blade shall be chucked in such a way that the saw teeth show towards the thumb screw.

2.14. When the saw passes the workpiece no injuries can occur.

2.15. The right hand grips the handle, the left hand the frame.

2.16. When flat steel is sawn from the broad side, the individual saw teeth are less stressed and the saw blade is preserved by the simultaneous action of many teeth.

2.17. The file teeth must be harder than the material to be worked, otherwise the teeth cannot penetrate into the material.

2.19. Depending on the kind of manufacturing cut and milled files; single−cut and double−cut files are distinguished. Depending of the action rough files and finishing files are distinguished.

2.20. Hard material − large wedge angle −small point angle;
Soft material − small wedge angle −large point angle.

2.21. The material of the drill must be harder than the material of the workpiece otherwise the drill cutting edges cannot penetrate into the material.

2.22. When drilling in hard material and with large drill, the friction between tool and material is larger and more frictional heat is generated, the consequence is higher wear. The low speed contributes to keep the wear as low as possible.

2.23. With large drills, the friction in the material is too large, the drill wears too fast. The large drill is saved by pre−drilling with a smaller drill.

2.24. Twist drills for steel have steeper flutes and a smaller point angle (118°). Twist drills for light metal have flatter flutes and larger point angles (130...140°).

2.25.

Drilling machine	Application
Manually driven hand drill	for repairs and assembly works
Electric hand drill	for repairs and assembly works
Bench−type drilling machine	for small workpieces and drilling small holes
Column drilling machine	for larger workpieces and drilling larger holes

2.26. The shape of the counterbore or countersink is determined by the point angle. The point angle is selected according to the included countersink angle of the screw or rivet head.

2.27.

Spot facer	?	even seat for screws
Counterbore	?	counterbore for filister−head screws
Countersink	?	deburring and chamfering of hole edges countersink for countersunk screws
Twist countersink	?	countersink for countersunk screws
Shaped counterbore	?	unregularly shaped counterbores

2.28. Fastening of the metal hook at the wooden coat−hanger;

Fastening of the water tap at the feed pipe; Screw coupling to connect water hoses.

2.29. Feeding device at the bench−type drilling machine

Lifting jack

2.30. Hand taps are used for short through holes. The length of the tap with the thread−cutting die corresponds to the short through hole.

2.31. Depth of the tapping−size hole

= 35 mm + (0.7 . 5 mm)
= 35 mm + 3.5 mm
= 38.5 mm

2.32. To tap an internal thread M6 into steel the minor diameter of the internal thread must amount to 5 mm. Therefore, a twist drill with a diameter of 5 mm must be used to drill the tapping−size hole.

2.33.

M 4 − 4 . 0.8 mm = 3.2 mm
M 5 − 5 . 0.8 mm = 4.0 mm
M 6 − 6 . 0.8 mm = 4.8 mm
M 8 − 8 . 0.8 mm = 6.4 mm
M 10 − 10 . 0.8 mm = 8.0 mm

In case of increased diameter, the rule of thumb is not correct. In this case it must be as follows:

Nominal diameter of the internal thread x 0.8 mm + 0.2 mm

M 8 − 8 . 0.8 mm + 0.2 mm = 6.6 mm
M 10 − 10 . 0.8 mm + 0.2 mm = 8.2 mm

2.34.

Cutting−off processes	Application
Chiselling	Dividing or metal−cutting of workpieces of different thickness for repairs, plastering or preparatory works
Shearing (snips)	Dividing of sheets and strip steels of small thickness
Sawing (Hand hacksaw)	Metal−cutting of sheets with increased thickness as well as tubes and bars with different sections
Filing	Metal−cutting of work−piece edges and work−piece surfaces
Drilling	Metal−cutting of holes in workpieces of different thickness
	Metal−cutting of hole edges (enlarging, deburring, chamfering)

Countersinking and counterboring	
Thread cutting	Metal–cutting of courses of threads into drilled holes and bolts.

3.1. The wooden strip breaks. The piece of rubber can be bent, however, it returns to its original position. Only the wire maintains the new shape from bending.

3.2. At the outside of the bending – stretched material, the dots are arranged further apart.

At the inside of the bending – upset material, the dots are closer to each other.

Along the centre line the dot spacing remains unchanged.

3.3. (Engineering drawing cf. fig. 3.1/5)

$l_1 = 60 - 3 - 3$
$l_1 = 54$ mm

$l_1 = l_3$
$l_3 = 54$ mm

$l_2 = 6.28$
$l_2 = 6$ mm

$L = l_1 + l_2 + l_3$
$L = 54 + 6 + 54$
$L = 114$ mm

The stretched length of the workpiece amounts to 114 mm.

3.4. L = d . *?*

a) L = 6 . 3.14
L = 18.8 mm

b) L = 10 . 3.14
L = 31.4 mm

c) L = 12 . 3.14
L = 37.7 mm

3.5. During bending, no tensile and compressive stresses are produced in the neutral layer. The seam cannot burst.

3.6. The shorter side is stretched by peening until the two sides are equally long, then the section is straight again.

3.7. While the left hand guides the swivel hook, the right hand grasps the lower end of the lever and turns it into the opposite direction of the warped sheet–metal strip until it is straightened.

3.8. Hand hammer and aboutsledge "have the same shape: peen across th the shank. The aboutsledge, however, is larger than the hand hammer. In case of the sledge with straight peen, the peen shows towards the hammer shank.

3.9. Further forging jobs are for example:

Forging job	Tool
Bending off	with the hammer face on the anvil edge
Roll bending	with the hammer face on the anvil beak

Stretching of flat steels	with the hammer face, top fuller and bottom fuller

3.10. By means of the die−forging die shown in fig. 3.3/12 a square−section specimen is shouldered at two sides. The die−forging die is split. It consists of the top swage (upper die) and the die (lower die), which is inserted into the hardie hole of the anvil.

3.11. Coal must always be placed over the air nozzle. When the workpiece has direct contact with the blower air it can scale.

Place fresh coal always at the edge of the fire, otherwise a sulphur−iron compound is formed.

3.12.

Upsetting	?	length reduced, cross−section enlarged
Stretching	?	length increased, cross−section reduced
Shouldering	?	cross−section reduced at certain points, in most cases at the end of the workpiece.

4.1.

Non−permanent joint: Nail fastening in wooden boxes
Permanent joint: Adhesive−bonded joint with paper or board

4.2. Countersunk screws are everywhere used where protruding screw heads would disturb for reasons of space or function or where they could be an accident hazard.

Hexagonal bolts and square−headed bolts are used particularly for large and heavy machine parts, because they are very robust.

Thumb screws or knurled−head screws are used for machine parts which must be often loosened or reset.

4.3. The locking by hexagon castle nut and cotter pin for example is often used in the steering mechanism of motor vehicles. Lock washers are used for example to lock the fastening screws on rails.

4.4. In case of a group of screw joints, either the opposite or the screws in the middle shall be tightened first and then the outer screw pairs!

4.5. The shape of the manufactured head is worked into the holding−up hammer and the shape of the driven head into the rivet header. Both tools must have an even seat for countersunk rivets. The rivet extractor contains the hollow form for accepting the rivet shank.

4.6.

$s = 10\ mm + 6\ mm$
$s = 16\ mm$

$d = 4\ mm$

The shank diameter of the rivet must amount to min. 4 mm.

4.7.

$l = s + z$
$s = 2 . 8\ mm$
$s = 16\ mm$
$z = 1.5 . d$
$z = 1.5 . 5\ mm$
$z = 7.5\ mm$
$l = 16\ mm + 7.5\ mm$
$l = 23.5\ mm$

The rivet must have a shank length of 23.5 mm.

4.8. The compressive force during rivet driving causes flowing of the material; the material flows into the direction of the lowest resistance, i.e. it widens.

4.9. The included countersink angle of the rivet shall be taken into account when countersinking for the countersunk rivet.

4.10. Other possible rivet faults can be:

– The rivet head is laterally displaced when the hammer blows during upsetting are not guided perpendicular upon the rivet shank.

– When the hole edges are not deburred, the shank rounding is upset at the workpiece.

– When the rivet header is too small, the driven head becomes too small.

– When the rivet header is too large, it penetrates into the workpiece and the driven head cannot be formed correctly.

4.11. (Fig. 4.2/19)

During staggered riveting the gaps in the first row are closed by the rivets in the second row.

4.12. Preparations for riveting:

– Calculation of the shank diameter and shank length of the rivet
– Marking−out and drilling of the rivet holes
– Deburring or countersinking of the rivet holes
– Clamping of the components

4.13.

Working steps during riveting	Fault
1. Setting of the rivet Extracting	When the rivet is poorly set the shank is upset between the sheets
2. Upsetting of the rivet	The driven head is displaced when it is obliquely upset.
3. Preforming of the driven head	In case of a driven head preformed too flat the edge of the head is squeezed off by the rivet header
4. Finishing of the driven head	In case of too large a rivet header the driven head is not correctly finished, in case of too small a rivet header the driven head is squeezed off.

4.14. The oxide layer prevents the soldering face of the soldering iron to take up the solder, therefore it must be removed prior to tin−coating.

4.15. Hydrochloric acid is etching. It can injure the hands.

4.16. Tasks of the soldering iron:

– melting the solder and taking it up
– heating the soldered joint to working temperature
– transmitting the liquid solder to the soldered joint

4.17. Preparation of the soldering iron:

– cleaning the soldering face (wire brush, file)
– heating the soldering iron
– removing the oxide layer with a salmiac stone

– tin−coating the soldering iron

Preparation of the soldered joint:

– cleaning the soldered joint (file, emery paper)
– coating the flux
– tinning the soldered joint

4.18. Only easily flowing solder can penetrate into the surface of the metals and join them firmly this way after cooling.