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Annealing, Hardening, Tempering – Course: Working Techniques of Heat Treatment of Steel. Methodical Guide for Instructors

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Annealing, Hardening, Tempering – Course: Working Techniques of Heat Treatment of Steel. Methodical Guide for Instructors

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Methodische Anleitung für den Lehrenden
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1. Objectives and Contents of the Vocational Training in the Working Techniques "Annealing, Hardening, Tempering"

The trainees shall have full command of the most common working techniques of the heat treatment of simple tools, testing devices and machine parts made of unalloyed steel, after having concluded the training.

– The trainees have knowledge of the purpose, the types and spheres of application of the various heat treatment processes.

– They have command of the structure and the operation of the devices and auxiliary means and are able to use them appropriately by observing labour safety and fire protection regulations.

– They have knowledge of the preconditions for heat treatment with regard to material engineering and material shaping.

– They master the various technological routines of the heat treatment processes of annealing, hardening and tempering of tools, testing devices and small machine parts.

– They are able to carry out quality controls independently.

2. Organizational Preparations

In order to ensure an undisturbed run of the instructions, exercises and instruction works it is necessary to prepare the training very well. The following measures have, among others, to be taken:

2.1. Preparation of Labour Safety Instructions

Prior to the beginning of the exercises, a short–term instruction with regard to the suitable dealing with working means specifying hints on works not involving accidents have to be given. The following features have to be imparted:

– Wear working garments, aprons and handgloves!
– Protect your eyes by means of protective glasses!

– Do not remove safety devices installed at devices!
– Do not touch cyanide salts and nitrites for melting baths with bare hands!
– Cover melting baths after use.
– Only use predried, cleaned workpieces for heat treatment.
– Take care for fire protection.
– Remove oil slicks on the floor immediately.
– Place hot workpieces only at places marked for that.
– Plut in order the tools, devices and auxiliary means after having finished work and keep them clean.
– Do careful hygiene after having finished work.

The knowledge of those hints is to be confirmed by the trainees' signatures in the control book.

2.2. Preparation of Means of Instruction

– The "Trainees" Handbook of Lessons – Annealing, Hardening, Tempering" is to be distributed among the trainees according to their number.

– Charts may be made prior to the instructions as blackboard figures.

– Coloured tables, figures, originals and models of devices and auxiliary means as well as break samples of heat–treated workpieces may be produced as illustrative material and prepared for the instructions (see section 4).

2.3. Preparation of Working Means

– The "Instruction Examples for the Practical Vocational Training – Annealing, Hardening, Tempering" is to be distributed among the trainees according to their number and intended as theoretical basis for the exercises to be carried out.

– Starting materials required for the exercises are to be prepared in an appropriate number by means of the material data given in the "Instruction Examples....

– The workshop is to be checked for a complete equipment with tools, devices and auxiliary means according to the exercises intended.

– Recommended basic outfit:

• smith's hearth with coal shovel, swatter and fire rake, stock of charcoal;
• muffle furnace with temperature gauge;
• inserts with sand and charcoal powder filling;
• melting bath for salt filling;
• hot bath for oil filling;
• quenching tanks for water and oil;
• hooks, spears, tongs, worn–out files, hammers;
• handling devices for small and medium–sized workpieces: sieves and baskets;
• cleaning agents: scouring cloths, sawdust, brooms;
• additives: clay, paper
• quenching media: water – fire–resistant, heatproof lubricating oil;
• melting agents: cyanide salts and nitrites.

The functionability of the devices is to be checked with regard to labour safety and fire protection regulations prior to the beginning of the exercises.

2.4. Planning of Training Phases

Starting from the total hours the periods for the individual training phases of this training unit are to be planned independently from each other.

For the following training phases it is advisable to take a phasing:

– for the introduction into the working techniques in the form of instructions;
– for necessary demonstrations;
– for task–related instructions for the preparation of exercises;
– for the execution of the exercises;
– for recapitulations and control works.

The following factors are to be considered when planning the periods:

– the state of training of the trainees;
– the conditions of training;
– the future employment of the trainees;
– the degree of difficulty of the training phases.

Focal point of each training phase is always the acquisition of mechanical abilities and skills by means of exercises, that feature must be given most of the time.

3. Recommendations for the Execution of the Vocational Training in the Working Techniques "Annealing, Hardening, Tempering"

The following sections include recommendations on how to organize the instructions for the trainees, the demonstrations of the working techniques as well as the exercises and control works.

3.1. The Introductory Instruction

If possible, the introductory instruction is to be carried out in a class room with the trainees. During the instruction it has to be taken into consideration that the trainees shall write necessary supplements or answers to questions in the Trainees' Handbook of Lessons – Annealing, Hardening, Tempering". The instruction can be carried out with regard to the contents given in the Trainees' Handbook of Lessons":

Purpose of heat treatment of steel

In the beginning, the trainees are to be made familiar with the term of "heat treatment" as a sequence of various processes of heating and cooling down. They shall realize that tools, measuring and testing devices as well as various machine parts must have special properties which are only reached by a heat treatment which, however, is to be carried out appropriately.

In this connection, a *demonstration* may be carried out:

A few chisel blows are to be made onto a steel plate of about 4 mm thickness by means of an unhardened flat chisel. Subsequently, this process is to be repeated by means of a hardened flat chisel. All the trainees shall examine the steel plate and the two flat chisels and draw the necessary conclusions. Subsequently, a broken chisel may be used as an example of an unsuitable heat treatment

The consideration of the heat treatment of alloy steels is necessary. The term of "alloy steel" is to be explained or recapitulated, the special properties of those steels have to be mentioned. It must be said that a correct heat treatment can only be carried out if the conditions given by the steel manufacturer are strictly adhered to, therefore, he shall supply tables specifying the appropriate temperature data. If possible, such a table should be shown.

All sections to be dealt with in the following are therefore only to be referred to unalloyed steels!

Types of heat treatment processes

The trainees may be made familiar with the most common heat treatment processes by means of the chart given in the "Trainees' Handbook of Lessons".

Those processes may be explained more in detail by means of the subsequent sections in the Trainees' Handbook of Lessons".

In addition, the special processes of "surface hardening" and "hardening and tempering" should be mentioned, but it is to be indicated that also other variants and processes are used in industry apart from the processes mentioned.

Devices and auxiliary means for heating, transportation and cooling down of workpieces

The devices and auxiliary means suitable for the production of individual parts or small series are to be mentioned and explained by means of appropriate figures, originals and models:

- smith's hearth with coal shovel, swatter and fire rake, stock of charcoal;
- gas burner to temper and flame hardening;
- Furnaces with and without temperature gauges, equipped with one or more compartments;
- melting baths for metal or salt melts as well as hot oil baths;
- sheet−metal inserts for casehardening with sand and carbon−containing powder filling;
- hooks, spears, tongs;
- handling devices such as self−tightening claws and hangers on lifting devices;
- sieves and baskets;
- quenching tanks for water and oil filling.

The effect of the different quenching media is to be explained by means of the chart in the "Trainees' Handbook of Lessons".

A short exercise of conversions is to be made for temperature data if the unit of "degree centigrade" is not used. The conversion into "Kelvin" and "Fahrenheit" is possible according to the following table:

Centigrade	Kelvin	Fahrenheit
0°C	= 273 K	= 32 F
100°C	= 373 K	= 212 F

Since the Fahrenheit units do not run in the same rate as "Centigrade" and "Kelvin", conversion must be effected by means of a self−made numerical line onto which these units are entered.

Principles and types of annealing, hardening and tempering

In the sections included in the "Trainees' Handbook of Lessons" the essential facts related to the mentioned heat treatment processes have been stated.

The individual principles of the procedures as well as the specific features of application are to be discussed step by step. The questions following the sections should immediately be answered in writing by the trainees and entered in the appropriate free places of the "Trainees' Handbook of Lessons".

Those answers must be checked during the discussion by a comparison!
Wrong answers must not be overlooked!

Annealing:

After definition of the term, the possibility is to be made evident to the trainees on how temperatures may be assessed at workpieces without temperature gauges. As to plain carbon steels, the standard colour values may be imparted by means of the table in the "Trainees' Handbook of Lessons".

Those standard values are only to be applied if no exact temperature gauge is existing at the device to heat the workpiece!

Subsequently, the following processes are to be discussed individually:

- stress−free annealing
- soft annealing
- normalizing.

The importance of a correctly effected annealing process is to be demonstrated to the trainees. They must realize that workpieces become useless or require refinishing when the annealing is not effected correctly and expertly. It must be explained that the adherence to the holding time is vital to reach the desired change in structure. Therefore, calculations are to be made by means of the rule:

Holding time = 20 minutes plus half of workpiece thickness

The section "Control of the annealing result" should be made clear by suitable illustrative materials of various break samples.

The trainees are to be made qualified to exactly assess the appearance of the break. Subsequently, the trainees shall answer the complex of questions in the "Trainees' Handbook of Lessons".

Hint:

Now, the introductory instruction may already be finished and simple exercises for "annealing" could be carried out But it is advisable to continue the instruction with regard to "hardening" and "tempering" in order to carry out a complete sequence of exercises by means of the "Instruction Examples for the Practical Vocational Training".

Hardening:

It is recommended to continue the instruction with regard to "hardening" according to the following sequence:

- definition;
- preconditions for hardening by means of heat treatment as to material engineering;
- principle of hardening by means of heat treatment;
- types of hardening by means of heat treatment;
- hardness−related shaping of the workpieces;
- hardening defects;
- specific working hints for practical execution of work;
- hardeness measurement.

After an exact definition it is necessary to mention the material−related preconditions for hardening by means of heat treatment − the trainees must learn that not all unalloyed steels are hardenable, and that is why they must know the carbon content of the workpiece to be hardened!

Subsequently, the three essential hardening processes are to be explained:

- quenching
- interrupted hardening
- hot quenching.

As to the latter process, calculations are to be carried out regarding the holding time in the hot bath. The rule is:

$$\text{Holding time} = \frac{\text{Diameter or thickness in mm. seconds}}{10\text{mm}}$$

The section "hardness−related shaping of workpieces" may be demonstrated by means of illustrative materials showing positive and negative features of shaping. The appropriate figures in the "Trainees' Handbook of Lessons" shall be used for problem discussions.

In the same connection, the discussion on "hardening defects" may be effected, it should not be done without illustrative materials.

As to the work in the workshop, specific practical hints are of special importance. Thus, it is advisable to check the procedures resulting from theory only for their practical use and to explain them more in detail. In this connection, the packing of workpieces should especially be dealt with which protects the work−pieces from scaling or carbon loss. Furthermore, possibilities to cover the workpieces having great cross−section differences are to be mentioned.

Point out: It is also important to ensure a preheating of all parts when hardening several parts in order to save time and quicker reach the hardening temperature. The complex "Hardening" is to be finished with the section of "Hardness measurement". If there are hardness measuring devices available, now deal with their application; at the same time the formation of the hardness number according to Rockwell (HRC 50) is to be explained. Supplementary, demonstrate the simple hardness test by the file test.

Tempering:

Since this process directly follows the hardening process, it must be discussed subsequently. In this connection, the relation between tempering tempering temperature and certain examples of application is of special importance; a chart in the "Trainees' Handbook of Lessons" shows this fact concerning plain carbon steels.

The connection between tempering temperature and hardness may also be illustrated by means of the following table with regard to a tempering test:

Tempering temperature	**Rockwell hardness**
200°C	63.5
240°C	62
260°C	60.5
280°C	58
300°C	56.5
320°C	54.8
340°C	54

A steel was gradually tempered according to the table, and the hardness was controlled each time as to the Rockwell process. It was determined that the Rockwell hardness decreases with increasing temperature, but steel's toughness increases.

The tempering test indicated that the tempering temperatures must be held in very narrow limits. Subsequently, explain the processes of tempering from outside and the tempering from inside.

Hint:

Now, the instruction may be finished and the appropriate exercises will be carried out. The following items as to "surface hardening" and "hardening and tempering" may be imparted in a supplementary instruction given at a later date.

Application of surface hardening and hardening and tempering

The possibilities to harden only the surfaces of workpieces as is possible by means of "flame hardening" and "casehardening" should be mentioned as specific processes of heat treatment. When explaining those **processes,** the material−related preconditions (carbon content) must be especially pointed out. Casehardening is to be demonstrated by means of the term of "carburization", an existing insert with appropriate charge material should be shown as original.

At the end of the instruction, impart "hardening and tempering" as possibility to increase strength and toughness simultaneously in general.

3.2. The Exercises

On principle, the necessary instructions as to labour safety must be given prior to the beginning of the exercises. Then, show the workshop and the existing equipment to the trainees and demonstrate its operation. It is advisable to begin each exercise by a demonstration given by the instructor in connection with an instruction related to the instruction example. Therefore, motivate the trainees to carry out the exercise with good quality. Refer to difficulties which may occur.

The exercise may be effected either thematically completed or in several phases according to the hints given in section 3.

6 exercises can be accomplished for various processes of heat treatment by means of the "Instruction Examples for the Practical Vocational Training".

The material "Instruction Examples..." includes a list of materials (starting material, tools and devices and auxiliary means) and the sequence of operations to execute the exercises as well as a clearly represented workshop diagram.

Hence, the trainees get all the necessary information for being able to systematically execute the exercises. If it becomes apparent during the exercises that the quality of the exercise pieces is not sufficient, more extensive exercises must be carried out; in that case, any waste parts should be used. When the skills have been practised enough, the intended instruction example may be produced.

The instructor must already have produced the exercise piece by himself and he must know the problems occuring in its production!

The focal points of rating to estimate the performance may thus be mentioned definitely – problematic points at the exercise piece can be referred to. During the task–related instruction, the "sequence of operations" and the workshop diagrams of the instruction examples should lie on the tables so that the trainees can write comments in their notebooks.

In order to give a general view at which exercise pieces the knowledge previously imparted should be applied, the individual instruction examples have been described in the following in short:

Instruction examples:

Instruction examples 16.1.: assembly tools

A small spiral spring (wire diameter appr. 1.0 mm) is to be made bendable by soft annealing in a smith's hearth. Bend hooks at the ends by means of tongs and, subsequently, harden and temper the spiral spring again.

(Figure 1)

Instruction examples 16.2.: marking and riveting tools

Prefabricated scriber, centrepunch, rivet header and rivet drawer are to be treated from outside by quenching and subsequent tempering. Use the muffle furnace.

(Figure 2)

Instruction example 16.3.: flat chisel and cape chisel

Prefabricated flat chisels and cape chisels are to be treated by quenching and subsequent tempering from inside. The muffle furnace is used.

(Figure 3)

Instruction example 16.4.: assembly tools

Prefabricated hexagon socket wrenches, box wrenches and screw drivers are to be treated by interrupted hardening and subsequent tempering from outside. Any furnace and separated quenching media are used.

(Figure 4)

Instruction example 16.5.: locksmith's hammer

Prefabricated locksmith's hammers are to be treated by hot–quenching and subsequent tempering from outside. Any furnace and a salt melting bath are used.

(Figure 5)

Instruction example 16.6.: testing means

Prefabricated steel straightedges, back squares and centre squares are to be treated by casehardening and subsequent tempering. A controllable furnace with appropriate insert is used.

(Figure 6)

All trainees can execute the exercises at the same time, if the material preconditions have been guaranteed (enough working means).

In that case, the trainees can execute each individual exercise independently – each trainee should get so much time he needs.

If there are not enough working means available, the trainees must be divided into groups. In this connection, it is advisable to divide these groups according to the use of the various devices:

1st group – work on smith's hearth
2nd group – work on muffle furnace
3rd group – work on any furnace and on melting bath.

If the instruction examples offered will not be used for exercises, it is possible to select other exercise pieces. In this case, it should be taken into consideration that all the working techniques discussed previously may also be practised on those exercise pieces.

Focal points for practical execution

For the execution of the works it is recommended to determine focal points for examination and estimation. Those focal points may be characterized by the following features:

- Do the trainees carefuly prepare their working places?
- Are the prefabricated exercise pieces clean and dry?
- Are the devices for heating operated appropriately?
- Are the correct temperature ranges identified?
- Are the technological sequences adhered to?
- Do the trainees adhere to the regulations on labour safety?

3.3. Examples for Recapitulation and Control

For strenghtening and checking the knowledge acquired, tasks have been assembled in this section, the tasks are given together with the appropriate answers. Tasks also included in the Trainees' Handbook of

Lessons" have been marked with the letter "A".

1. What is heat treatment?
"A" (*a systematic sequence of heating and cooling*)

2. What is the purpose of heat treatment processes?
"A" (*change of properties of unalloyed and alloy steels*)

3. According to which criteria are the heat treatment processes selected?
(*according to the purpose of application and the kind of material of the object to be treated*)

4. Which are the most common processes of heat treatment?
(*annealing, hardening, tempering*)

5. Which requirements have to be made on devices for heating the workpieces?
"A" (*temperature must be reached quickly, kept constant and must be adjustable without difficulty; steady* heating *of workpieces has to be ensured*)

6. Which devices are used for heating?
(*smith's hearth, gas burner, furnaces, melting baths*)

7. What is the advantage do of melting baths compared to the smith's hearth?
(*temperature is exactly adjustable, no danger of overheating, no scaling of workpiece surfaces*)

8. Which requirements have to be made on quenching tanks?
"A" (*quenching media must always be kept cool*)

9. Which main effects can have quenching media?
(*coarse and mild effect*)

10. Which effect has the use of a coarse quenching medium onto the workpiece?
"A" (*great strength and hardness, especially at the case, little elasticity*)

11. Which requirements have to be made on the workpieces being prepared for the annealing process?
"A" (*they must be clean, rust−free and free of scale*)

12. What principle is the basis for annealing?
"A" (*heating of the workpiece and holding of annealing temperature over a certain period, subsequently, slow cooling down*)

13. What is the purpose of stress−free annealing?
"A" (*elimination of stresses existing in the prefabricated workpiece*)

14. What is the purpose of soft annealing?
"A" (*makes further working processes for hardened or carbon steels possible*)

15. What is the purpose of normalizing?
"A" (*equalization of irregularities in the steel structure, achieving a fine−grained structure*)

16. Which rule has to be heeded for holding massive workpieces at annealing temperature?
(*20 minutes plus half of material thickness*)

17. Which holding time has to be considered when a shaft of 84 mm diameter must be annealed?
"A" (*62 minutes*)

18. Ace, to which criteria are annealing defects evaluated?
"A" (*according to the appearance of the broken workpiece*)

19. Which annealing faults may be deducted from a coarse−grained structure?
"A" (*steel was heated too long or at a too high temperature*)

20. What is the purpose of hardening by means of heat treatment?
"A" (*to make steels hard and wear−resistant for certain purposes*)

21. Which minimum carbon content must have a steel for being hardened?
"A" (*0.35% of carbon*)

22. Which effect has a higher carbon content on the mechanical properties?
"A" (*great hardness and strength, little toughness and elasticity*)

23. Which working steps are required for hardening?
"A" (*heating to hardening temperature, holding and sudden cooling down of the workpiece*)

24. What hardening temperature has to be chosen for an unalloyed steel of 0.8% carbon content?
(*780 °C*)

25. What is the characteristic feature of interrupted hardening?
"A" (*quenching is effected for a short time, in most cases first in a powerful and then in a mild quenching medium*)

26. A workpiece having irregular shapes shall be hardened by hot−quenching. Its average thickness is 100 mm. Which time has to be met in the melting bath during the cooling−down process?
(*600 seconds or 10 minutes, respectively*)

27. What has to be considered when dipping the workpieces into melting baths?
(*correct dipping according to shape, only dip dry workpieces*)

28. Why it is advisable to harden workpieces in a carbon−containing packing?
"A" (*workpiece cannot be scaled and absorbs carbon, thus avoiding carbon loss at high heat effect*)

29. What is a simple way to test hardness?
"A" (*by a file test; if the file is slipping, the workpiece is harder than the file*)

30. What is the purpose of tempering?
"A" (*to give the workpiece a useful hardness after hardening*)

31. What effect has the tempering temperature on useful hardness?
"A" (*the higher the tempering temperature, the smaller the hardness*)

32. Why can temper colours facilitate temperature determination?
"A" (*a thin oxide layer inking according to temperature is produced when heating a blank steel*)

33. Which properties can reach workpieces after surface hardening?
"A" (*the workpieces withstand great impact and bending stresses by hard surfaces and a tough core*)

34. Which steels can be treated by flame hardening?
"A" (*unalloyed steels of 0.35% to 0.6% carbon content*)

35. Which steels can be treated by casehardening?
"A" (*tough steels of a carbon content below 0.25%*)

36. Which properties shall be reached by hardening and tempering?
"A" (*at relatively high strength values, a great toughness shall be guaranteed continuously*)

4. Explanations to the Means of Instruction

Apart from models and originals of devices and auxiliary means, break samples of heat−treated workpieces are recommended as additional illustrative material. The following samples should be manufactured:

- steel of little carbon content
- steel of high carbon content
- steel having been heated too long or at a too high temperature
- steel having been heated extremely high so that it is already burned
- hardened and broken flat chisel.

Furthermore, examples for good and bad manufacture should be produced by means of the figures included in the Trainees' Handbook of Lessons". Those examples will show envisaged affects after hardening (cracks).

Existing defects should be made visible by a paint coat on a workpiece having cracks. For demonstrating the annealing colours, a table of colours including the appropriate colours is recommended which can be made as blackboards charts.

Annealing, Hardening, Tempering – Course: Working Techniques of Heat Treatment of Steel. Instruction Examples for Practical Vocational Training

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Annealing, Hardening, Tempering – Course: Working Techniques of Heat Treatment of Steel. Instruction Examples for Practical Vocational Training

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Introductory Remarks

The present material includes 6 instruction examples by means of which different common processes of heat treatment of unalloyed steels can be practised.

In this connection, the following processes are described in detail:

- soft annealing
- quenching
- interrupted hardening
- hot quenching
- casehardening
- tempering from inside
- tempering from outside

All the practising pieces can be produced in a locksmith's shop. The prefabricated practising pieces reach the required properties for use by means of the heat treatment process. In order to facilitate the preparation and execution of the works, the materials, tools and devices, as well as auxiliary accessories necessary for each of the instruction examples have been specified. Apart from the working diagrams attached, the sequences of operations have been described in short.

Hint on temperature data:

Temperature data specified in the sequences of operations and in the working diagrams are given in degrees centigrade.

The following conversion is valid when other units are used:

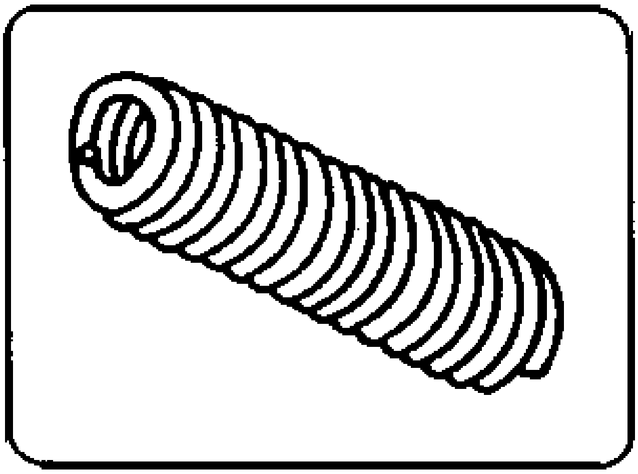
Centigrade	Kelvin	Fahrenheit
0°	273	32
100°	373	212

Instruction Example 16.1.: Spiral Spring

Practise the soft annealing of a spiral spring with subsequent hardening and tempering.

Material

Any hardened spiral spring of approx. 1.0 mm wire diameter



Tools and devices

Smith's hearth, quenching tank, round−nosed pliers

Auxiliary accessories

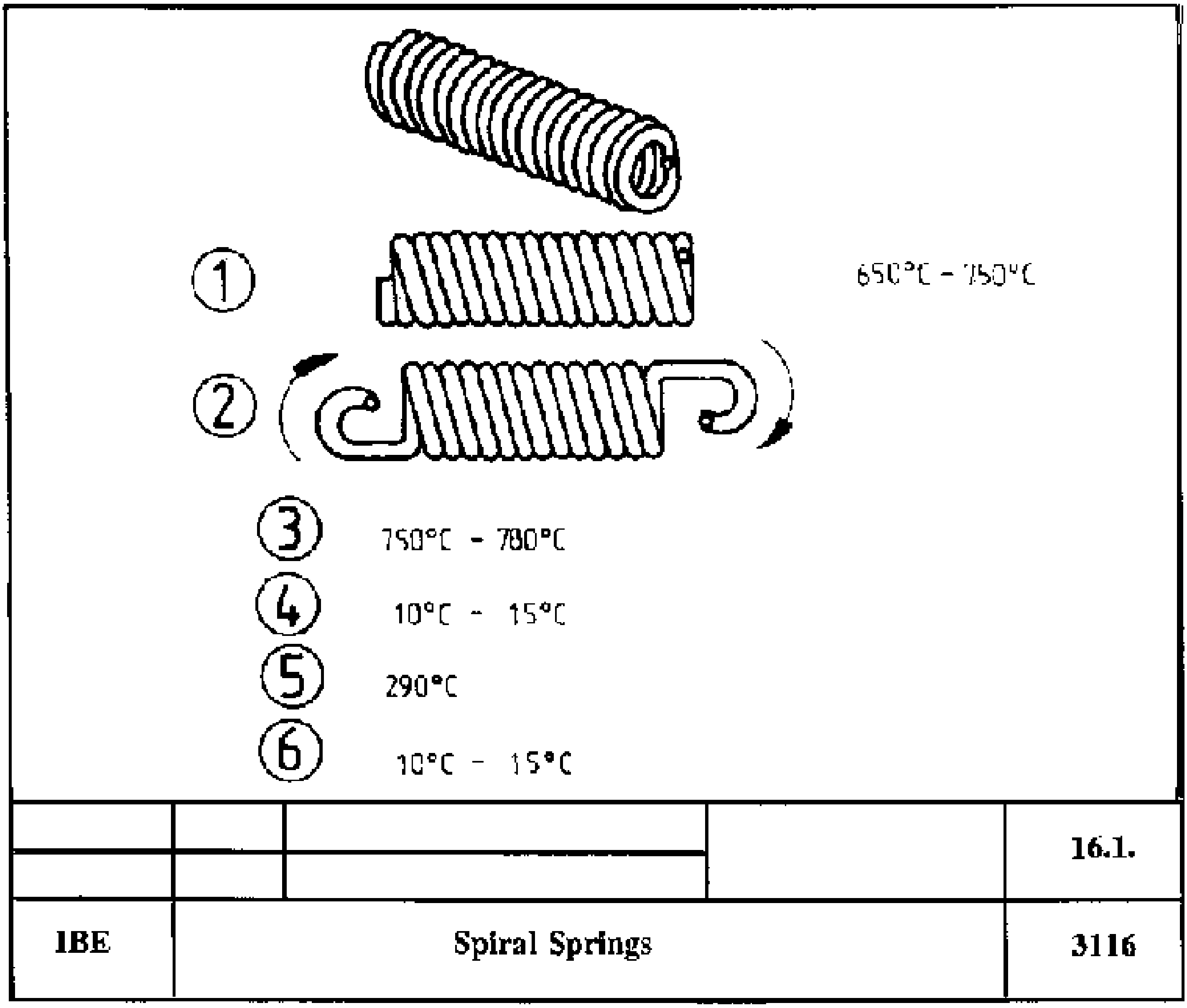
Blacksmith's tongs, coal shovel, swatter, furnace rake, quenching medium (water)

Previous required knowledge

Manual working of materials

Sequence of operations	Comments
1. Prepare workplace	Check for completeness
Make working material available	
2. Fire smith's hearth; wait until charcoal is glowing	Take care for fire protection!
3. Hold spiral spring by means of the blacksmith's tongs just over the fire	Phase 1 Annealing colour: dark−red 650°C to 750°C
4. After having reached annealing temperature, shortly move to and from over the charcoal fire	Increase and decrease distance to fire
5. Let spiral spring slowly cool down	Cool down in air!
6. Bend hooks on the ends by means of the round−nosed pliers	Phase 2 Check for flexibility
7. Heat spiral spring once again up to hardening temperature	Phase 3 Annealing colour: dark cherry red 750°C to 780°C
8. Keep shortly hardening temperature at reaching	Only few seconds
9. Dip spiral spring quickly into water and move it to and from	

	Phase 4 Until complete cooling
10. Control hardness by means of tensile and pressure test	If the spiral spring is too hard, subsequently temper
11. Heat spiral spring once again	Phase 5 Temper colour: dark–blue 290°C
12. After having reached tempering temperature, quickly cool down	Phase 6
13. Control useful hardness by means of tensile or pressure test	



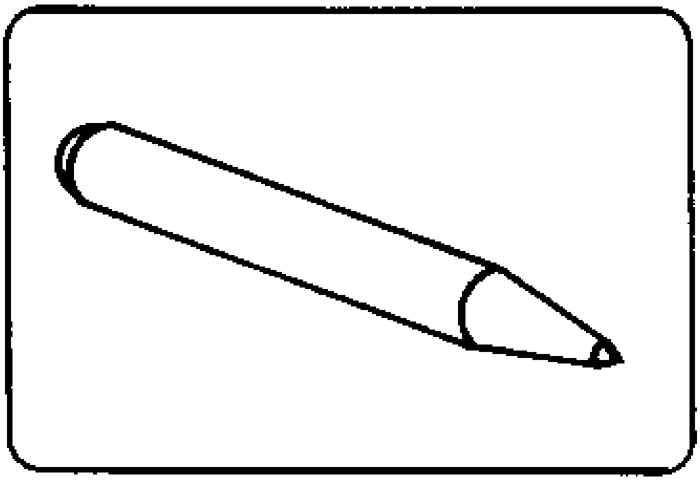
Spiral Springs

Instruction Example 16.2.: Marking and Riveting Tools

Practise the quenching with subsequent tempering from outside.

Material

Prefabricated scriber, sentrepunch, rivet header, rivet drawer made of tool steel with a carbon content between 1.1 and 1.25%



Tools and devices

Muffle furnace, quenching tank, abrasive cloth, file

Auxiliary accessories

Quenching medium (water), scouring cloth (fat–free)

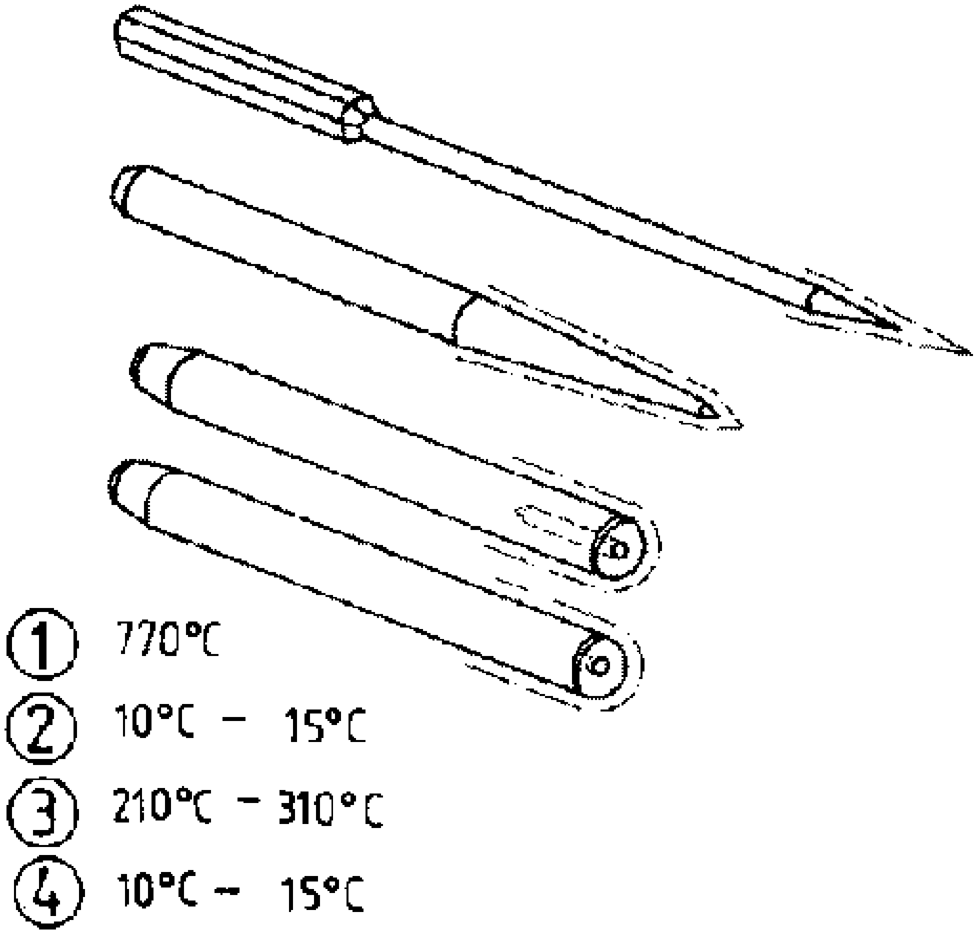
Previous knowledge required

Manual working of materials

Sequence of operations	Comments
1. Prepare workplace Make working material available	Check for completeness
2. Fire muffle furnace, wait until nominal temperature is reached	In case of an existing temperature controller, adjust hardening temperature
3. Place tools with the side to be hardened into the furnace and heat up to hardening temperature	Phase 1 Annealing colour: dark cherry red 770°C
4. Keep scriber at temperature for approx. half a minute; keep centrepunch and riveting tools for approx. 1 minute	
5. Quickly cool down tools, move them to and fro in the quenching tank	Phase 2 Until complete cooling
6. Carry out file test; if hardness is not enough, harden again	Hardness is enough when the file slips!
7. Wipe the tools dry, grind surfaces or points blank	Use abrasive cloth
8. Heat tools up to tempering temperature once again in the muffle furnace:	Phase 3 Observe tempering colours
scriber: white–yellow – 210°C	
centrepunch: violet – 280°C	
riveting took: light–blue – 310°C	
	Phase 4

9. Quickly cool down the tools as soon as reaching the tempering temperature

10. Carry out hardness test — File test with a dry workpiece



		16.2.
IBE	Marking and Riveting Tools	3116

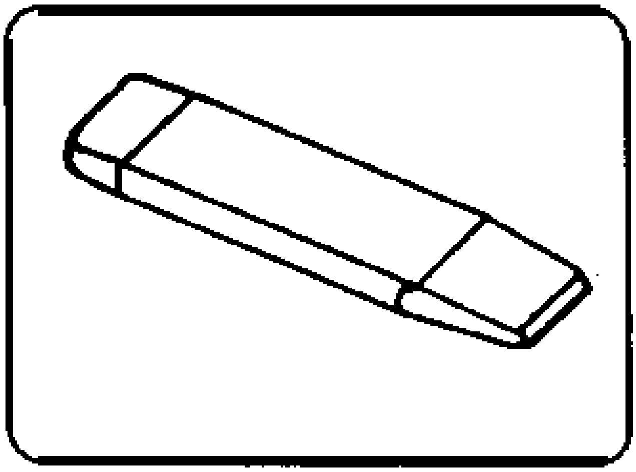
Marking and Riveting Tools

Instruction Example 16.3.: Flat Chisel and Cape Chisel

Practise the quenching with subsequent tempering from inside

Material

Prefabricated flat chisel and cape chisel made of tool steel with a carbon content of 0.9%



Tools and devices

Muffle furnace, quenching tank, abrasive cloth, file

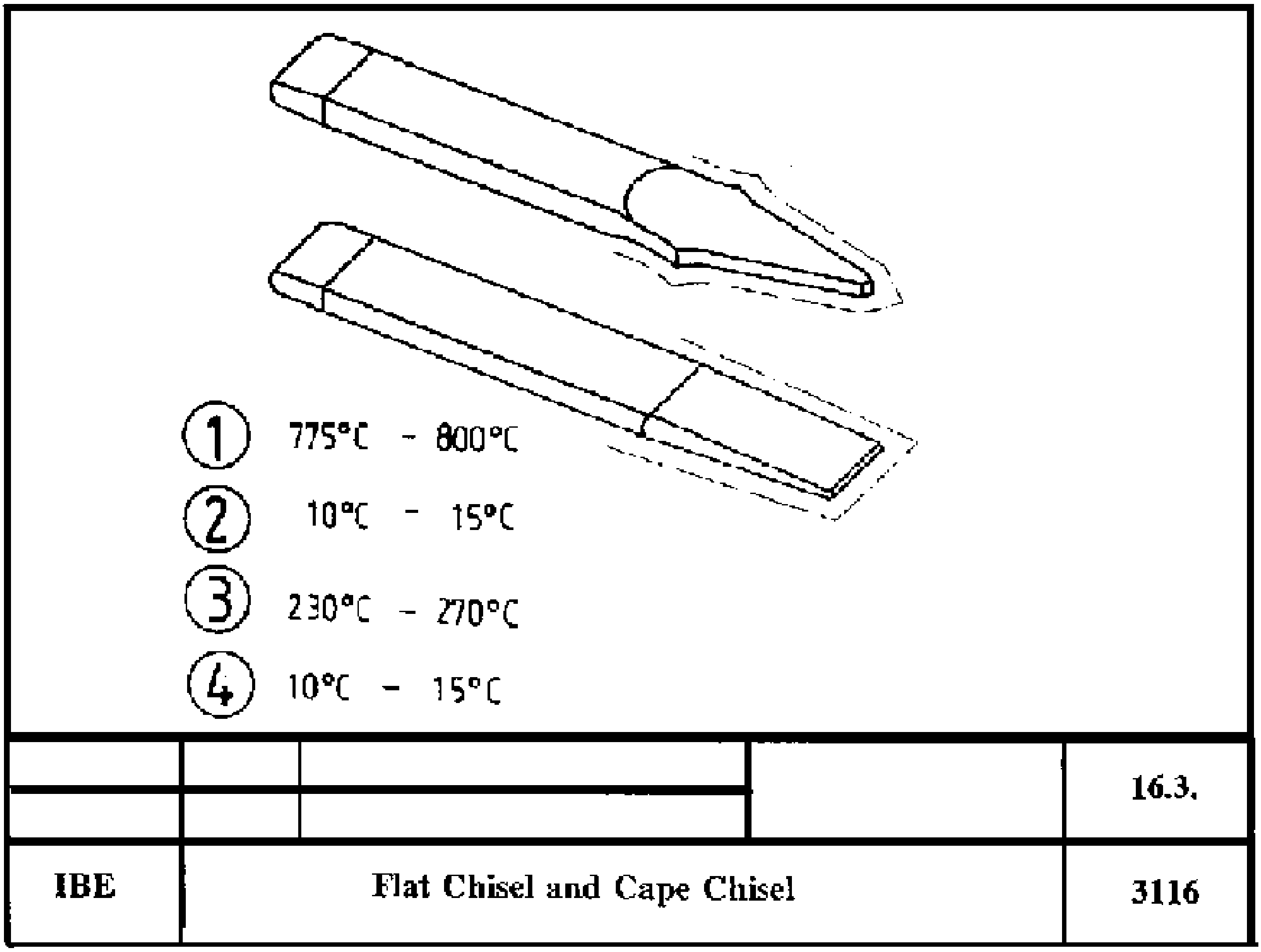
Auxiliary accessories

Quenching medium (flame−resistant, heatproof lubricating oil) or water, scouring cloth (fat−free)

Previous knowledge required

Machining of material

Sequence of operations	Comments
1. Prepare workplace Make working material available	Check for completeness
2. Fire muffle furnace and bring to nominal temperature	In case of an existing temperature controller, adjust hardening temperature
3. Place chisel with face edge into the furnace and heat up to hardening temperature	Phase 1 Annealing colour: cherry red 775°C to 800°C
4. After having reached hardening temperature, keep for approx. 1 minute	
5. Shortly cool down the chisel with the top in the quenching tank	Phase 2 Until hissing fades away!
6. Quickly clean face edge of chisel and grind one point blank	Use abrasive cloth
7. Observe the residual heat running in the direction of the face edge − temper colour becomes visible	Phase 3 Temper colour: yellow 230°C to purple 270°C
8. Quickly cool down chisel when reaching the tempering temperature	Phase 4
9. Clean chisel and carry out hardness test	File test, impact test



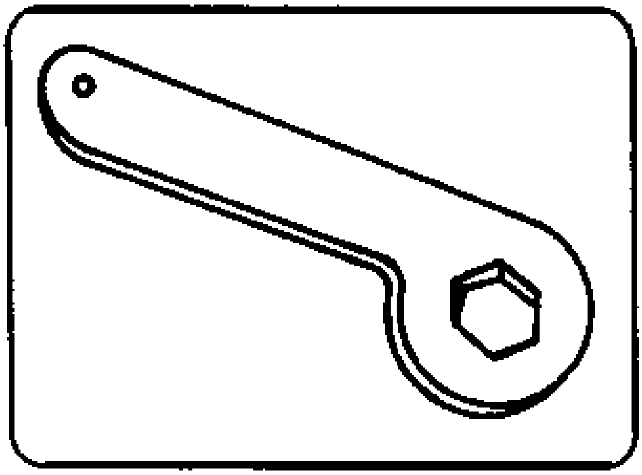
Flat Chisel and Cape Chisel

Instruction example 16.4.: Assembly Tools

Practise the interrupted hardening with subsequent tempering from outside.

Material

Prefabricated hexagon socket wrench, box wrench, screw driver made of tool steel with a carbon content between 1 and 1.1%



Tools and Devices

Furnace, quenching tank (two pieces), abrasive cloth, file

Auxiliary accessories

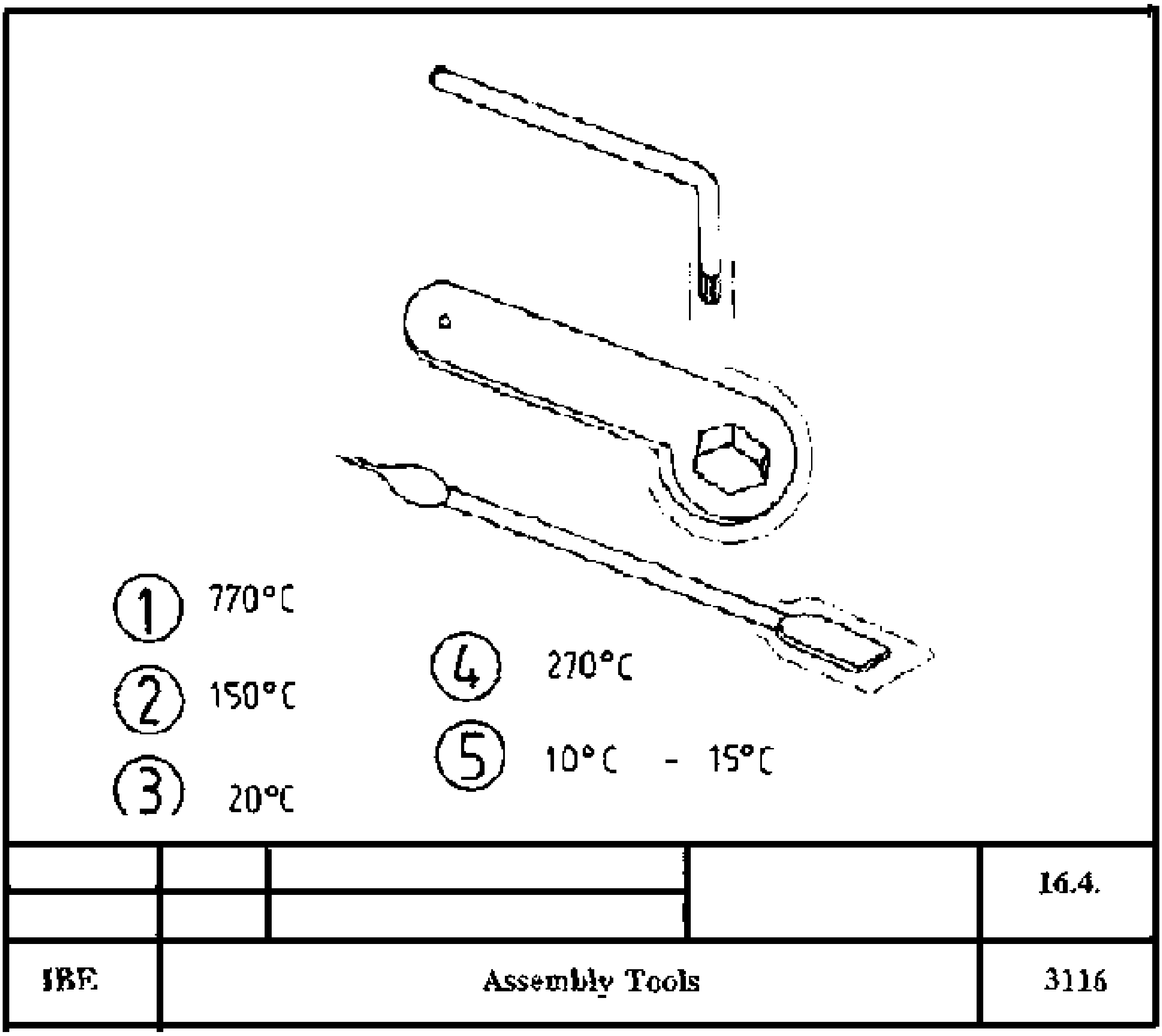
Powerful quenching medium (water), mild quenching medium (lubricating oil heated to 150°C), scouring cloth (fat−free)

Previous knowledge required

Manual working of materials

Sequence of operations	Comments
1. Prepare workplace Make working material available	Check for completeness
2. Fire the furnace and bring to nominal temperature	In case of an existing temperature controller, adjust hardening temperature
3. Heat quenching tank with lubricating oil up to approx. 150°C	
4. Place tools with the side to be hardened into the furnace and heat up to hardening temperature	Phase 1 Annealing colour: dark cherry−red 770°C
5. After having reached the hardening temperature, keep for approx. 1 minute	
6. Dip tools into the quenching tank filled with water, for a short time	Until hissing fades away!
7. Dip tools into the quenching tank with heated oil	Phase 2 Until temperature balance
8. Let tools cool down in air	Phase 3
9. Clean tools, carry out hardness test	File test
10. Grind tools at hardened side blank	Abrasive cloth
11. Heat tools in the furnace once again	Phase 4 Temper colour; purple 270°C
12. After having reached the tempering temperature, cool down tools	Phase 5

13. Clean tools and again carry out hardness test	File test, functional test



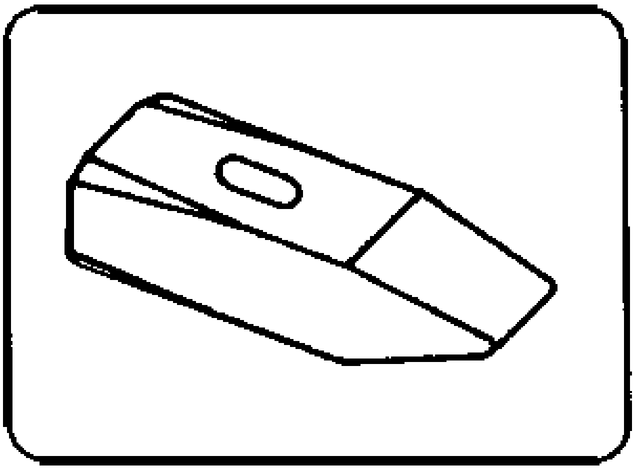
Assembly Tools

Instruction Example 16.5.: Locksmith's Hammer

Practise the hot−quenching with subsequent tempering from outside.

Material

Prefabricated locksmith's hammer made of tool steel with a carbon content between 1 and 1.1%



Tools and devices

Furnace, salt melting bath, quenching tank, abrasive cloth, file

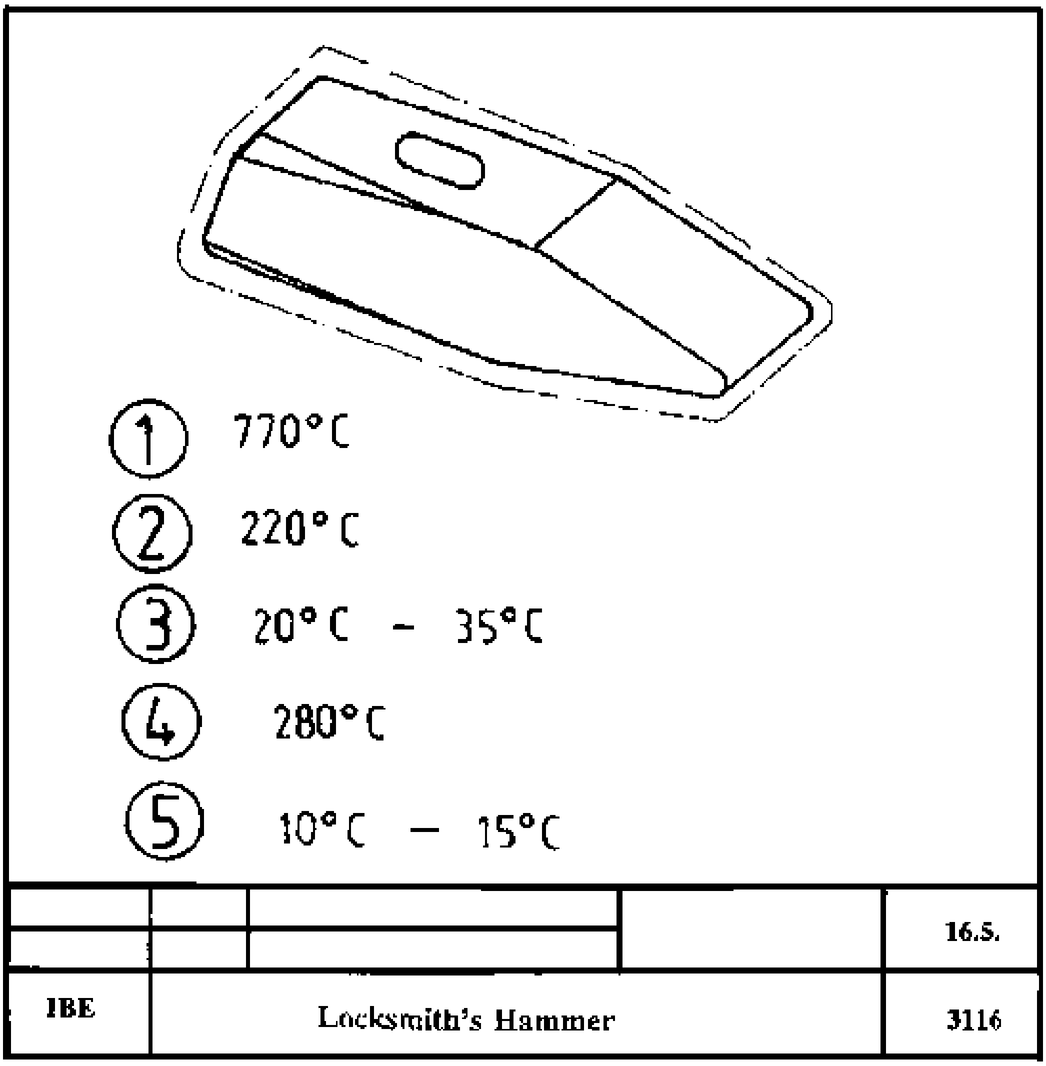
Auxiliary accessories

Quenching medium (lubricating oil) scouring cloth (fat–free)

Previous knowledge required

Manual working of materials

Sequence of operations	Comments
1. Prepare workplace Make working material available	Check for completeness
2. Fire the furnace and bring to nominal temperature	In case of an existing temperature controller, adjust hardening temperature
3. Heat salt melting bath to approx. 200°C	
4. Heat the hammer up to hardening temperature in the furnace	Phase 1 Annealing colour: dark cherry red 770°C
5. After having reached the hardening temperature, keep for approx. half a minute	
6. Cool down the hammer in the melting bath at approx. 220°C until temperature balance	Phase 2 Holding time: max. 2 1/2 minutes
7. Cool down the hammer to lukewarm in the quenching tank	Phase 3
8. Clean the hammer, carry out the hardness test	File test
9. Grind one point of the hammer blank	Abrasive cloth
10. Heat the hammer up to tempering temperature in the furnace	Phase 4 Temper colour: violet 280°C
11. After having reached the tempering temperature, cool down the hammer	Phase 5
12. Clean the hammer and again carry out the hardness	File test Impact test



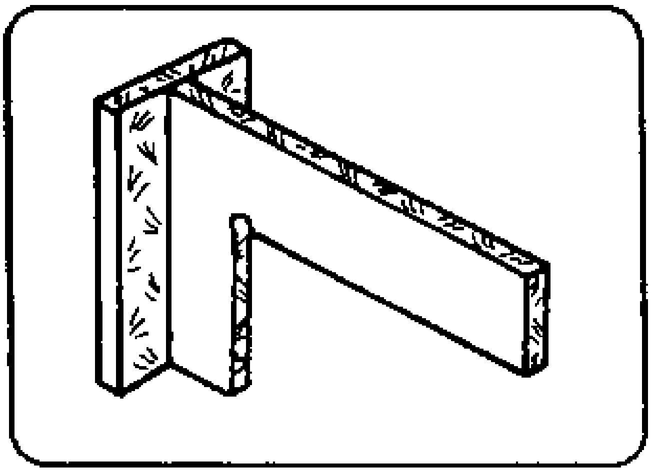
Locksmith's Hammer

Instruction Example 16.6.: Testing Means

Practise the casehardening and tempering of testing means.

Material

Prefabricated steel straightedges, back squares and centre squares made of unalloyed steel with a carbon content between about 0.1 and 0.15 %



Tools and devices

Controllable furnace with temperature gauge, quenching tank, fireproof inserts for sand charcoal filling, emery cloth

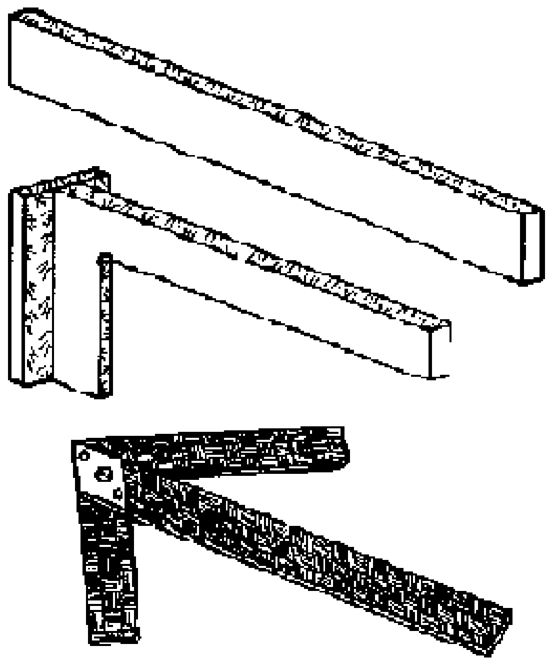
Auxiliary accessories

Charcoal (evenly cut into small pieces), clay, paper, quenching medium (heavily inflammable, heatproof lubricating oil), scouring cloth

Previous knowledge required

Manual working of materials

Sequence of operations	Comments
1. Prepare workplace Make working material available	Check for completeness
2. Wrap testing means into paper, lay into the insert with charcoal, cover the insert and lute by means of clay	
3. Place insert into the furnace and heat; keep for about 5 hours	Phase 1 Starting temperature: 880°C to 920°C; Penetration depth of carbon: approx. 0.5 mm
4. Take the insert out of the furnace, unpack testing devices and let cool down in air	Phase 2
5. Harden the testing means at about 770°C	Phases 3 and 4
6. Temper the testing means at about 220°C	Phases 5 and 6
7. Clean the surfaces of the testing means	



1. 880°C - 920°C
2. 20°C
3. 770°C
4. 10°C - 15°C
5. 220°C
6. 10°C - 15°C

				16.6.
IDE	Testing Means			3116

Testing Means

Annealing, Hardening, Tempering – Course: Working Techniques of Heat Treatment of Steel. Trainees' Handbook of Lessons

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Annealing, Hardening, Tempering – Course: Working Techniques of Heat Treatment of Steel. Trainees' Handbook of Lessons

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Author: Frank Wenghöfer

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Introductory Remarks

The present material has been elaborated for the training in professions which, apart from knowledge in the field of metal working, require command of the usual heat treatment processes. The material includes the description of various heat treatment processes on principle and the necessary devices and auxiliary means with their specific features of application. All working steps have been described by the material group of plain carbon steels (tool steels); given temperature data are not applicable for alloy steels; with regard to that, tables elaborated by the steel manufacturer must be consulted.

In order to promote the learning process, control questions follow the individual sections, the trainees can check their knowledge by answering those questions.

Hints on Labour Safety

- Wear work clothes, aprons and gloves
- Protect your eyes by wearing protective glasses
- Do not remove safety devices at appliances
- Do not touch salts for melting baths with bare hands
- Cover up melting baths after use
- Use only pre–dried and cleaned workpieces for heat treatment
- Take care for fire protection
- Immediately remove oil sticks from the floor
- Lay down hot workpieces only on marked places
- Keep clean tools, devices and auxiliary means and clear them away after finishing of work.

1. Objectives of Heat Treatment of Steel

In practice, heat treatment is a systematic sequence of various processes of "heating" and "cooling".

In this way, special properties of unalloyed and alloy steels can be changed.

Such properties are:

Hardness – Strength – Toughness – Elasticity.

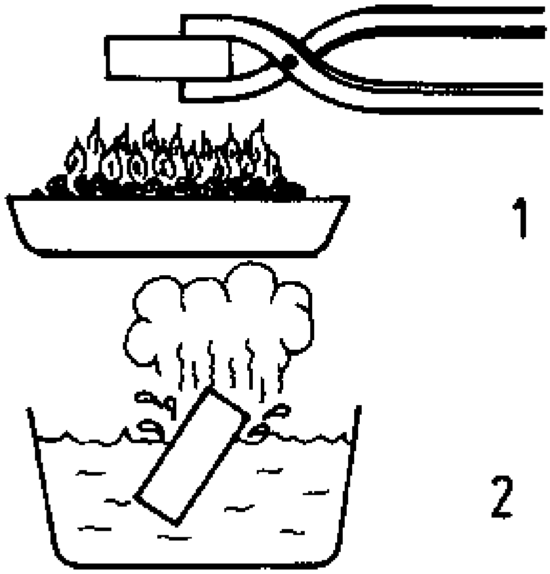


Figure 1 – Principle of heat treatment – *1 heating, 2 cooling*

The appropriate heat treatment process is selected either to increase or to decrease the properties.

Therefore, temperatures to be set during heating, the period of heating and the cooling speed are of special importance. Cooling can be effected either quickly or slowly or in individual stages.

Properties of steels are changed because the crystal structure of steels having a latticed configuration is changed in its internal structure due to temperature factors.

According to the selection of the process, a structural change of the entire workpiece or of certain parts on the surface only can be effected.

Examples:

Tools must be hard and robust so that they are suitable for working other materials. In general, they must, however, only be hard at points by which working is effected:

Chisel:

- cutting edge is hard and wear–resistant
- tang is tough and elastic

If the chisel would be hard throughout, it could break when the hammer is striked onto it!

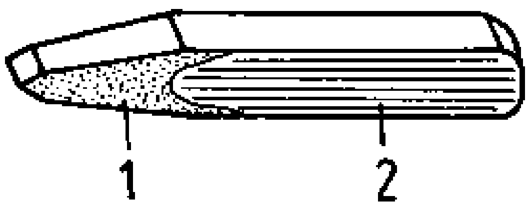


Figure 2 – Cut through a hardened chisel – *1 cutting edge* (*hard*)*, 2 twig* (*tough*)

Measuring and testing means must not be worn out even when they are used frequently. They must especially be wear–resistant on their surfaces.

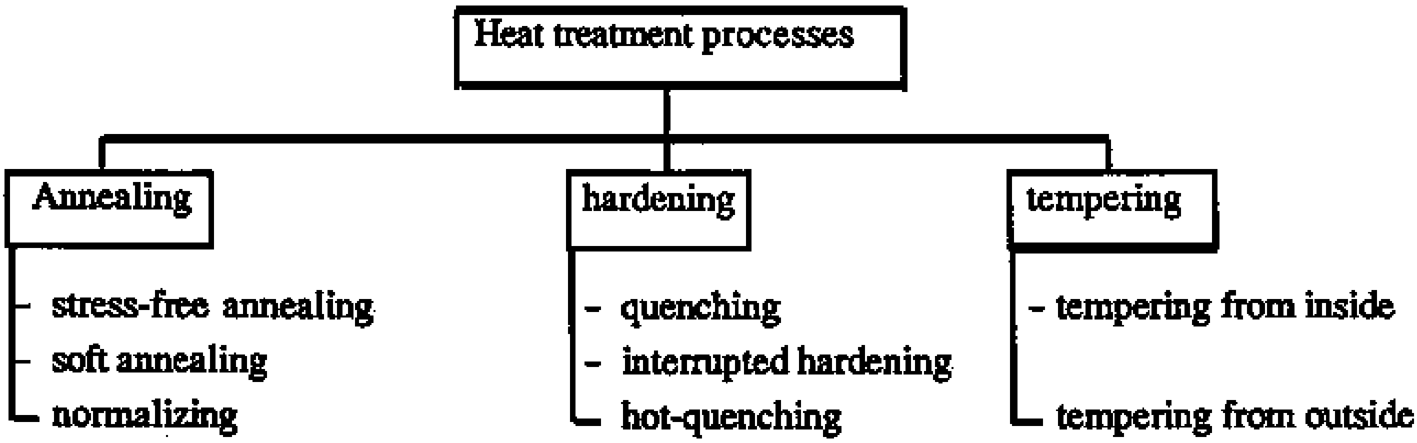
Moving machine parts (ball bearing, shafts, spur wheels) must not be worn out or only to a little extent. They must be hard and wear–resistant, but also tough at the same time.

Alloy steels containing apart from iron also other alloying elements have in general especially distinct properties.

Therefore, an exact heat treatment can only be carried out when the conditions given by the steel manufacturer are strictly adhered to. Precise temperature data for heat treatment processes are therefore supplied with by the steel manufacturer.

2. Kinds of Heat Treatment Processes

According to the purpose of application and the kind of material of the workpiece to be treated, different heat treatment processes are applied. The most common processes are given in the following chart:



Apart from these processes, "surface hardening" and "hardening with subesequent tempering" are used among others when special properties shall be changed.

Hint:

In practice, hardening is directly related to tempering since it follows the hardening process as subsequent method.

What is heat treatment?

What is the purpose of heat treatment processes?

3. Devices and Auxiliary Means

The following requirements are made on devices designed to heat the workpieces:

- Temperature must be reached in the shortest possible time
- Temperature has to be controlled as easy as possible
- Temperature has to be kept constant at the required figure
- The workpiece must evenly be heated in all spheres.

3.1. As to Heating

***Smith's hearth* (*open fire*):**

It is used for heating small parts and tools; in most cases, it is heated by means of charcoal. Pit coal is not suitable due to its sulphur content, fresh timber does not generate enough heat and it bums unevenly. Temperature must be estimated by the temper colours of the workpiece; thus, it is unsafe to assess.

Therefore, assessment can only be made perfectly in darkened rooms (windows are coated with blue paint).

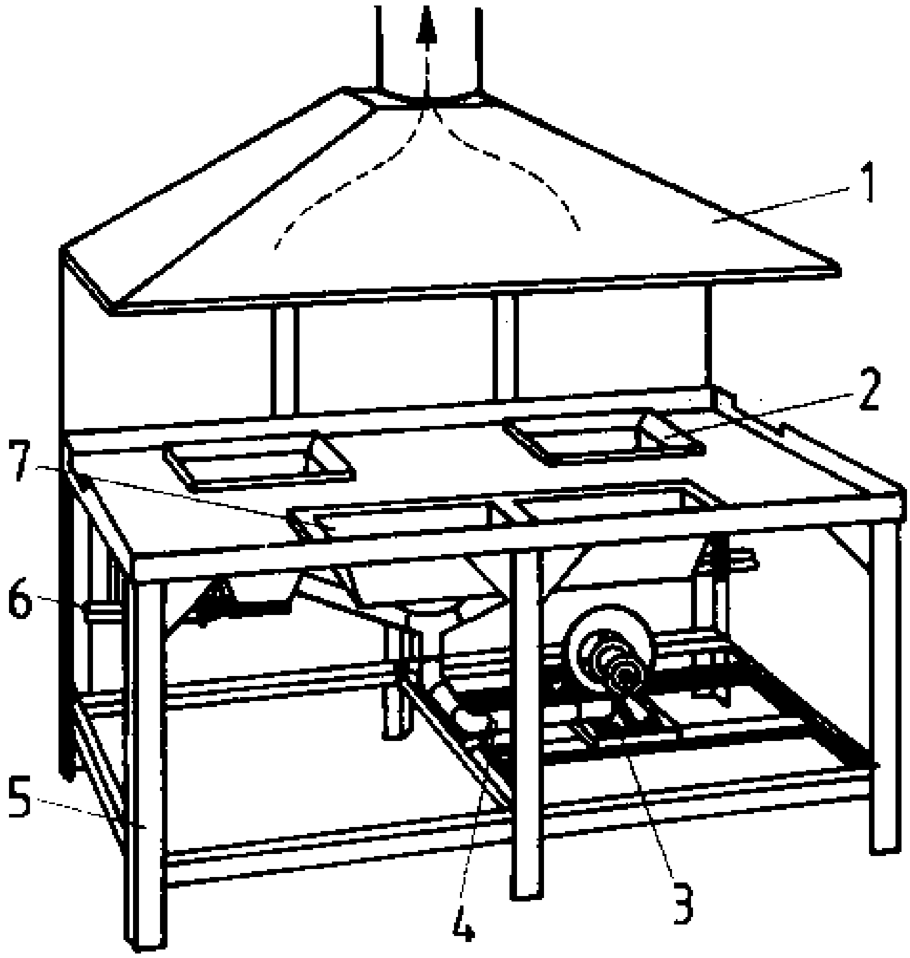


Figure 3 – Smith's hearth – *1 flue, 2 fire case, 3 blower, 4 air supply, 5 frame, 6 nozzles and slag lever, 7 explosion chamber*

Smith's hearth is equipped with firing appliances: coal shovel, swatter and fire rake.

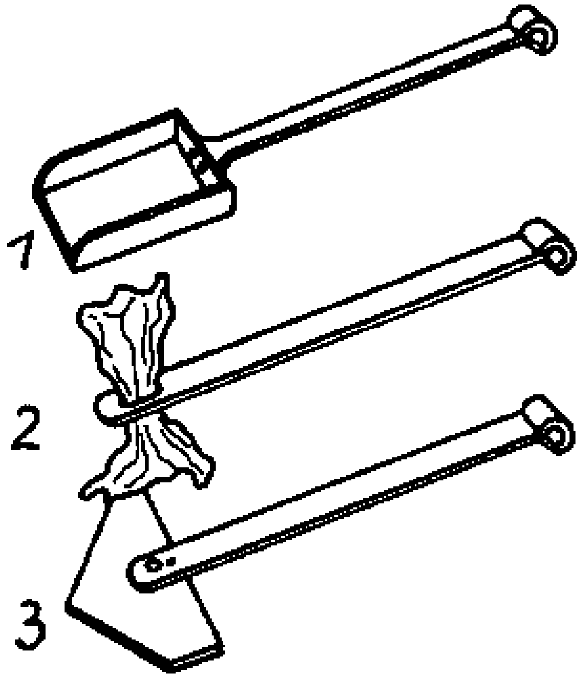


Figure 4 – Firing appliances – *1 coal shovel, 2 swatter, 3 fire rake*

Gas burner:

When tempering small parts and tools, gas burners of the Bunsen type (fuel gas: e.g. propane) are used. In case of flame hardening, special burners designed for gas/oxygen mixtures and, in most cases, equipped with mechanical feeders onto which water sprinklers are mounted subsequently, are applied.

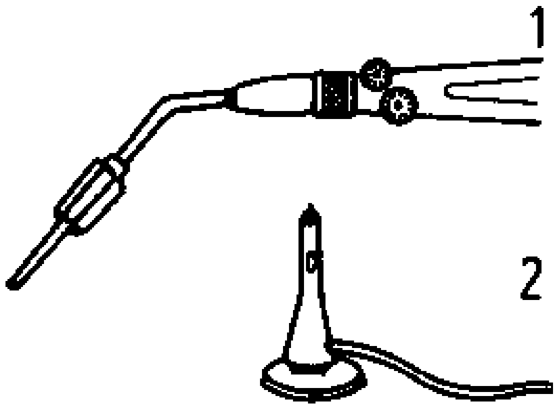


Figure 5 – Gas burner – *1 gas and oxygen burner, 2 Bunsen burner*

Furnaces:

They are used for evenly heating any workpieces; gas, oil or electric power are used as fuel. In furnaces equipped with temperature controllers there is no danger that the workpieces are overheated or changed in their chemical composition. In order to contact the workpieces not directly with the heat source they may be arranged in inserts

(muffles) made of fire clay, graphite or heat–resistant cast iron. Thus, the workpieces are evenly heated as a whole.

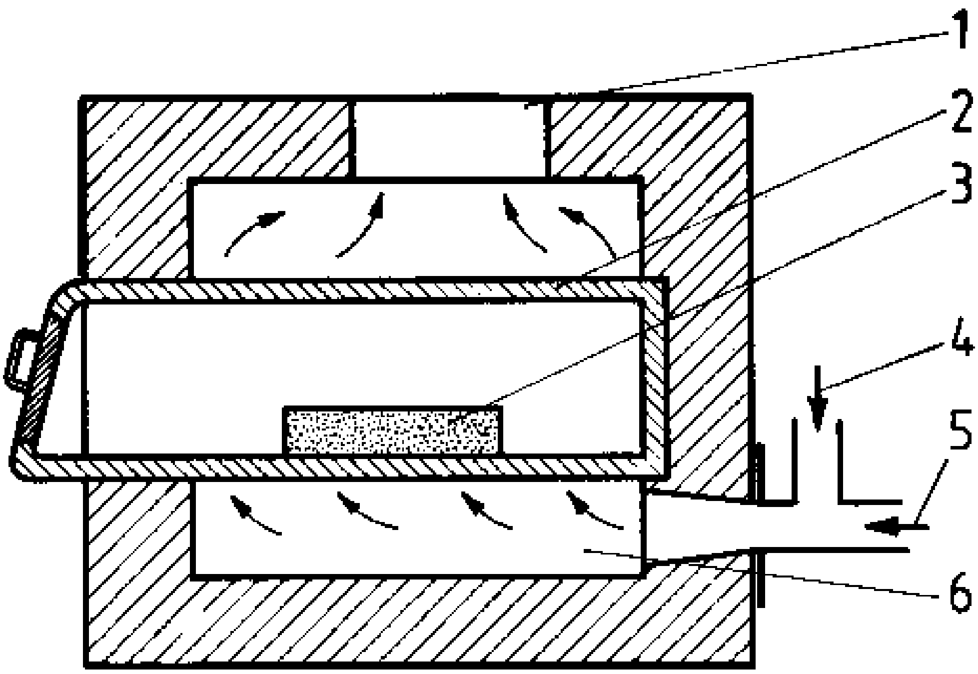


Figure 6 – Muffle furnace – *1 chimney flue, 2 insert* (*muffle*), *3 work–piece, 4 air supply, 5 fuel gas supply, 6 combustion chamber*

Apart from the simple muffle furnace operating at nominal temperatures around 1200°C, the double–chamber furnace equipped with two differently heated chambers (nominal temperatures in the chambers: 1300°C and 900°C, ensuring timesaving hardening and tempering, are applied. Hardening temperature can be controlled by means of electrical or optical measuring instruments. Modern furnaces used in industrial large–series production are designed in such a way that they guarantee an uninterrupted heat treatment. For that purpose, they may be equipped with multi–purpose chambers for annealing, tempering and quenching, ace, to type. They have chambers with certain gas atmospheres and different transport mechanisms.

***Melting baths* (*hot baths*):**

They are used to evenly heat sensitive workpieces (measuring and testing means, cutting tools). By applying fuels such as gas, oil or electric power, metals, metal alloys or salt mixtures are heated, which melt within a limited temperature range; the workpieces are entirely or partly suspended into the melting baths.

Overheating is avoided by means of automatic temperature controllers. In a short time, the workpieces are heated up to bath temperature, scaling of surfaces cannot be affected in the bath.

Whereas lead melting baths can be heated up to 800°C, melting baths can be heated up to 1400°C.

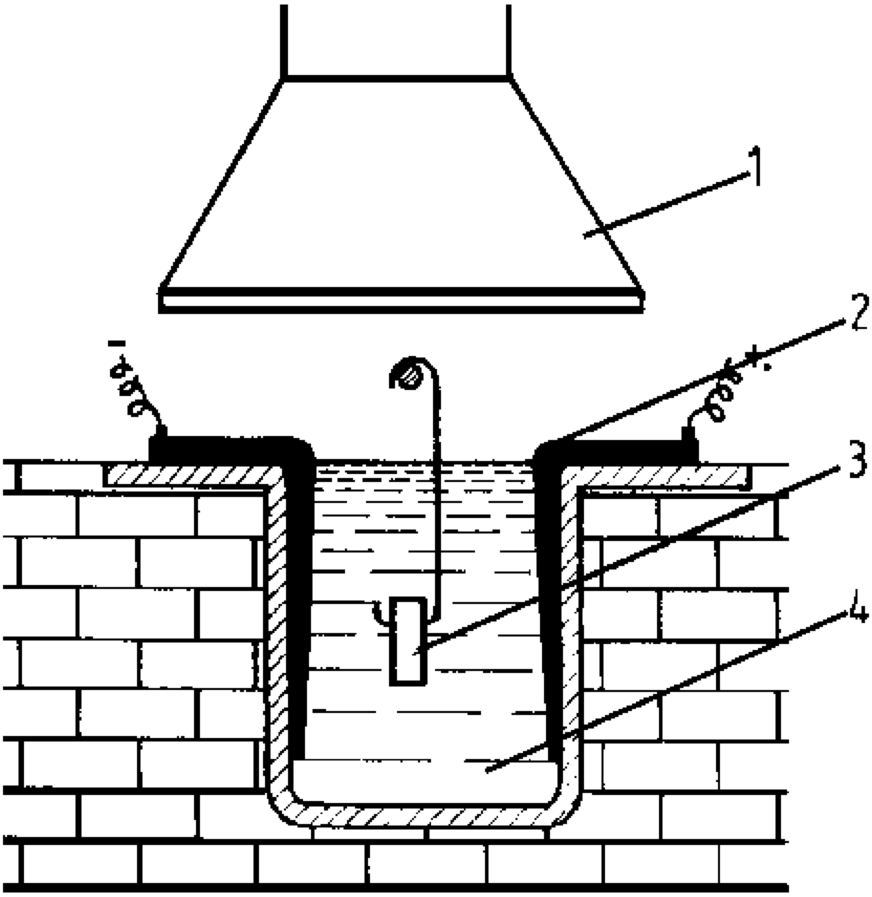


Figure 7 – Melting bath – *1 hood, 2 electrode, 3 workpiece, 4 melt*

Other possibilities for heating:

– When tempering, heated steel plates, heated sand baths or hot oil baths are especially used which ensure a slow and even heating of the work–pieces.

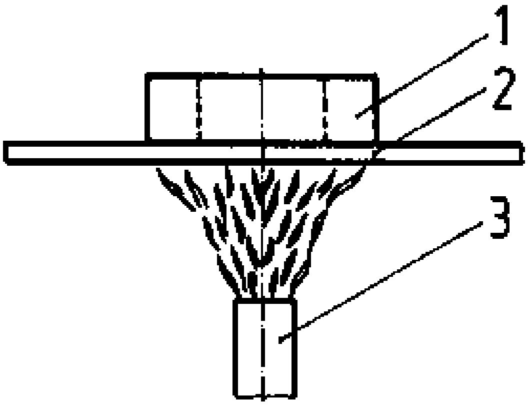


Figure 8 – Heat steel plate – *1 workpiece, 2 heated steel plate, 3 gas burner*

– In case of casehardening, sheet–metal boxes filled with sand and carbon–containing powder and equipped with cover are required. They are sealed by means of clay.

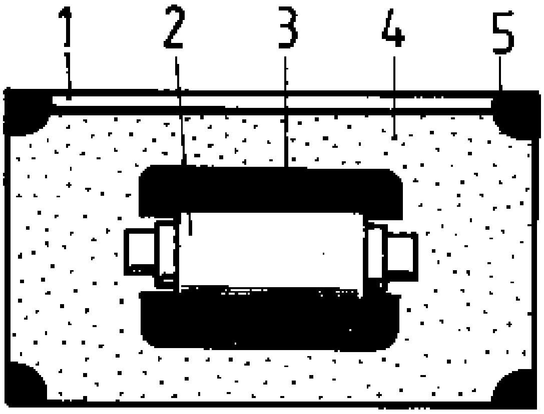


Figure 9 – Box for casehardening – *1 fireproof box with cover, 2 workpiece, 3 carbon–containing powder, 4 sand, 5 clay*

Which requirements have to be made on the devices designed to beat the workpieces?

What are the advantages of melting baths compared to the smith's hearth?

3.2. As to Transport

Hooks and spears:

They are used for operating the smith's hearth and the furnaces, in order to turn and displace the workpieces.

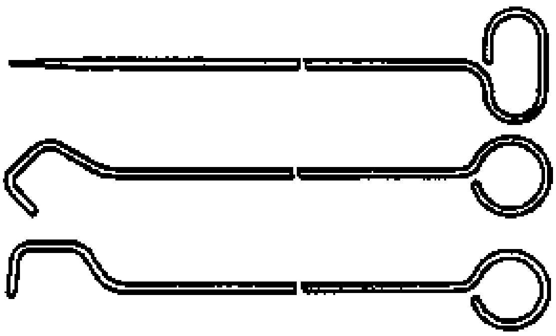


Figure 10 – Hooks and spears

Tongs:

They grip the workpieces when being inserted into the furnaces and when being removed as well as when being suspended into the quenching baths. Their bit–type shape can be formed variously in order to use them properly according to the shapes of workpieces.

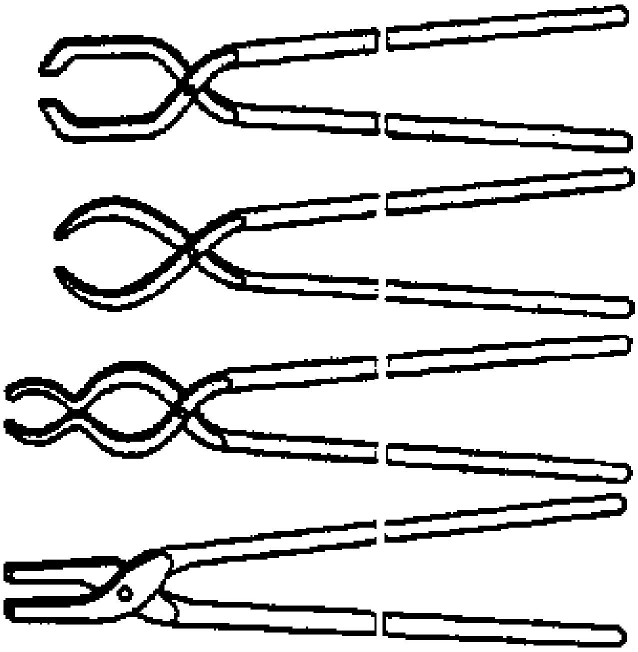


Figure 11 – Tongs

Self–tightening claws:

Large and heavy workpieces can be lifted beyond a lifting device, the clamping jaws are clamped due to workpiece's weight.

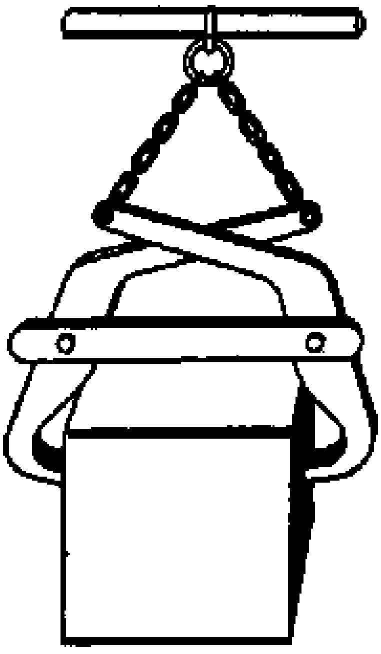


Figure 12 – Self–tightening claw

Hangers:

Heavy workpieces *which* cannot be gripped by means of claws are inserted into the hangers and moved by means of a lifting device.

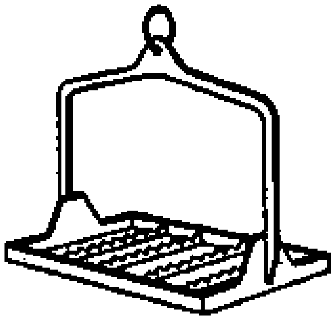


Figure 13 – Hanger

Sieves:

Small workpieces may be placed onto the sieve and moved for being heated in melting baths and for being quenched in quenching tanks, in large quantities.

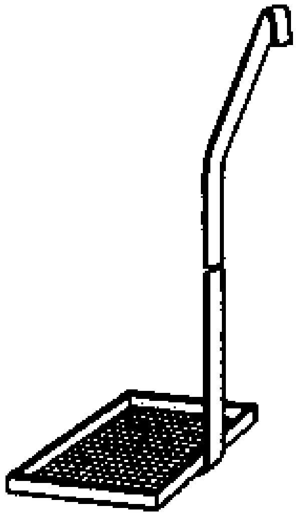


Figure 14 – Sieves

Baskets:

Very small workpieces may be poured into baskets in large quantities and moved for being heated in melting baths and for being quenched in quenching tanks.

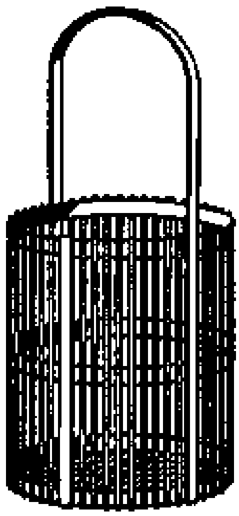


Figure 15 – Baskets

3.3. As to Cooling

Quenching tank:

In order to quickly cool down the workpieces, the tank is filled with water or oil, for example, and it must constantly be kept cool. That is ensured by means of cooling coils, but also by the regular feed of coolant (with simultaneous discharge). Workpieces have to be moved in quenching tanks so that cooling down is effected as quick as possible; thus, steam bubbles quickly come off the workpiece.

> The quicker cooling is effected, the higher is the degree of hardness!

As to mild cooling processes, heated quenching media can also be applied in heated tanks (hot baths).

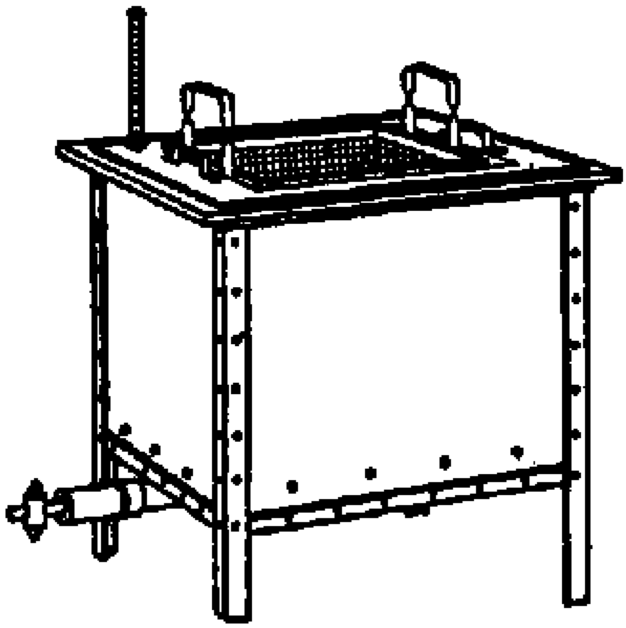


Figure 16 – Quenching tank

Quenching media:

According to the desired properties of the workpieces, rough or mild quenching media are used.

Rough quenching media – great strength and little elasticity of the workpiece to be treated

Mild quenching media – little strength and higher elasticity of the workpiece to be treated

Quenching media	**Effect**
Acidified water	very rough
Salt−containing water (10% salt)	rough
Ice−cold water (2° C)	very powerful
Pure water (20° C)	powerful
Soluble oil emulsion or hot water (40° C)	less powerful
Petroleum, oil, train oil	mild
Compressed air	very mild
Air	very mild

> The rougher the quenching medium, the harder is especially the case of the workpiece!

Temperature data may be given in various units. Apart from the units "degree centigrade" used herein, the units "Kelvin" or "Fahrenheit" may be used.

Conversion table for temperature data

Centigrade	Kelvin	Fahrenheit
0 °C =	273 K =	32 F
100 °C =	373 K =	212 F

Which requirements are made on quenching tanks?

What are the effects of the use of a rough quenching medium onto the workpiece?

4. Annealing

Any processes of heat treatment resulting in a heating of the workpiece up to a certain temperature with subsequent, in most cases slow, cooling, are called annealing.

Since heating must be effected slowly, evenly and drastically, furnaces are granted special favours to be the heat source which are equipped with temperature measuring devices. If there is no possibility to exactly gauge the temperature, it must be estimated by means of the decoloration of the workpiece effected during heating.

Standard values of colours for plain carbon steels:

Temper colour	Temperature	Temperature
Brownish black	520 to 580	793 to 853
Brownish red	580 to 650	853 to 923
Dark–red	650 to 750	923 to 1023
Dark cherry red	750 to 780	1023 to 1053
Cherry red	780 to 800	1053 to 1073
Light cherry red	800 to 830	1073 to 1103
Light–red	830 to 880	1103 to 1153
Yellowish red	880 to 1050	1153 to 1323
Dark–green	1050 to 1150	1323 to 1423
Light–yellow	1150 to 250	1423 to 1523
White	1250 to 1350	1523 to 1623

The identification of colour differences requires a darkened background and experience in estimating!
As to alloy steels, this table is not applicable!

4.1. Principle and Kinds of Annealing Processes

Annealing is effected in three working steps:

1st – Heating of the workpiece to annealing temperature
2nd – Keeping the temperature constant over a certain period of time
3rd – Slow cooling down of the workpiece

Workpieces have to be prepared very carefully, rust and scale have to be removed prior to annealing!

According to the required properties of the workpiece, different annealing processes are used:

Stress–free annealing:

Stresses which may result in distortion of the workpiece are caused by different cooling processes for forged or rolled steel or by cold forming.

Hose stresses can largely be removed by the annealing process.

Proceedings:

– Heating to temperatures between 550 °C and 650 °C;
– Keeping the temperature constant for 30 to 120 minutes in dependence on material thickness;
– Slow and even cooling down in warmed ash or in a furnace.

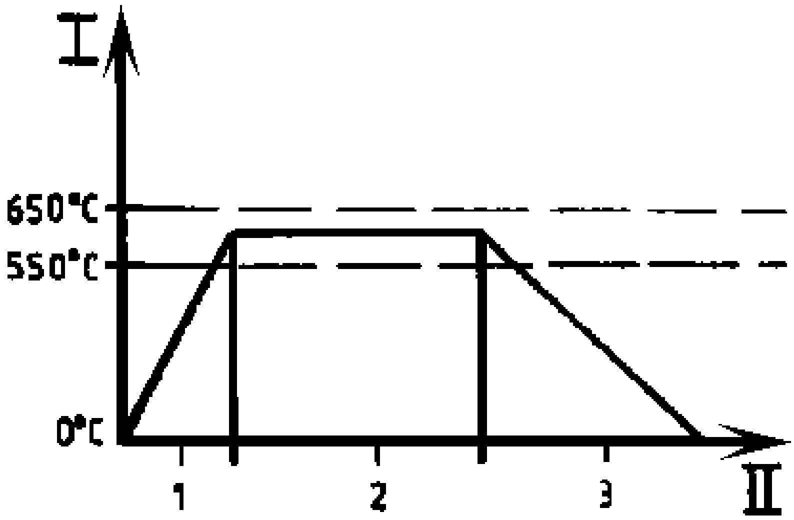


Figure 17 – Temperature/time diagram of stress–free annealing – *1 heating, 2 keeping constant. 3 cooling down* – **I** Temperature, **II** Time

Soft annealing:

Hardened materials or materials rich in carbon (above 0.9%) have a bad free–cutting machinability and cannot easily be cold–formed. In order to make those materials better for being machined, they are soft–annealed.

Proceedings:

– Heating to temperatures between 650 °C and 750 °C; it is also possible to work with changing heating and slight cooling–down processes around 723 °C;

– Keeping the temperature range constant for 3 to 4 hours in dependence on the type of material and material thickness;

– Slow cooling down.

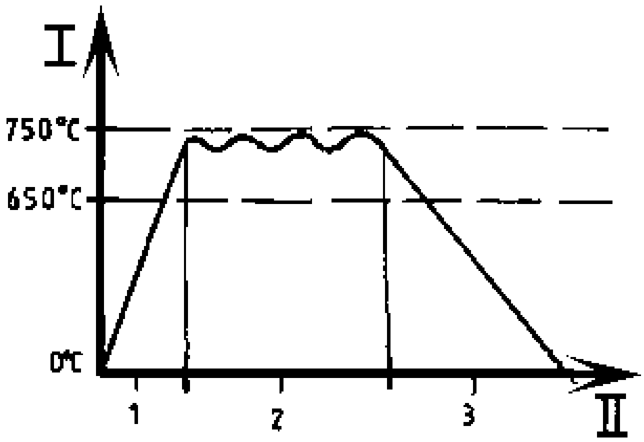


Figure 18 – Temperature/time diagram of soft annealing – *1 heating, 2 keeping constant* (*shuttle*)*, 3 slow cooling down* – **I** Temperature, **II** Time

Normalizing:

When dressing, bending, hammer forging and forging, the material is cold or hot–worked and the structure of the workpiece is distorted and partly solidified, the same goes for areas near welding seams.

The working properties of heavily–stressed workpieces and parts of constructional engineering are therefore unfavourable. By means of normalizing, the structural irregularities will be balanced and a fine–grained structure will be reached.

Proceedings:

– Heating to temperatures between 750 °C and 980 °C according to the carbon content of the material;
– Keeping the temperature constant according to material thickness;
– Slow cooling down in air.

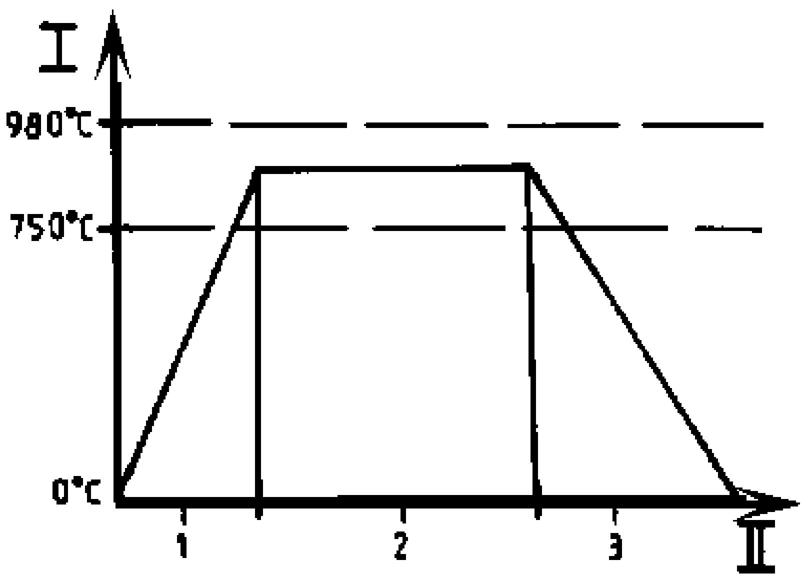


Figure 19 – Temperature/time diagram of normalizing – *1 heating, 2 keeping constant, 3 slow cooling down* – **I** Temperature, **II** Time

4.2. Working recommendations

– In case of a high carbon content, choose low temperatures within the range!

– Holding time for massive workpieces is adjusted ace, to the rule: 20 minutes plus half of material thick ness.

Example for determining the holding time:

A workpiece of 60 mm thickness has to be annealed.

Rule: Holding time = 20 minutes + D/2(without unit)

Holding time = 20 minutes + 60/2

Holding time = 20 minutes + 30

Holding time = 50 minutes

The workpiece has to be annealed for 50 minutes before it is cooled down.

What demands have to be made on workpieces being prepared for the annealing process?

What principle is the annealing process based on?

What is the purpose of stress−free annealing?

What is the purpose of soft annealing?

What is the purpose of normalizing?

What holding time has to be considered when a shaft of 84 mm diameter must be annealed?

4.3. Control of the Annealing Result

Annealing defects can be identified by means of the appearance of the broken workpiece. That is why the test workpiece has to be notched after being annealed and broken across to the rolling direction by a short blow of a hammer.

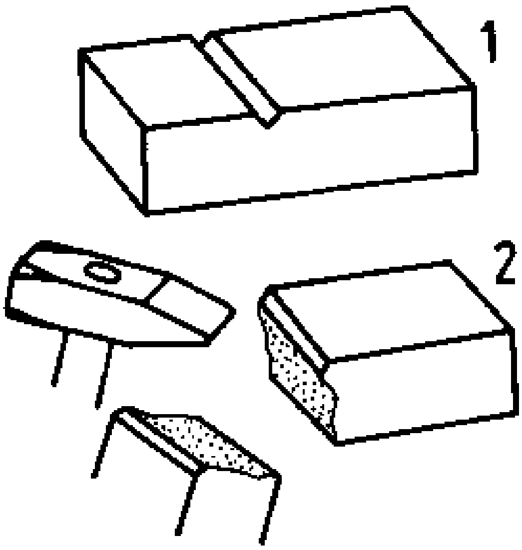


Figure 20 – Control of the annealing result – *1 notching, 2 breaking*

Appearance of break	Kind of material and treatment	Improvement
criystalline fracture, glistening	steel of low carbon content, "structural steel"	no
fine–grained, dead grey, smooth	steel of higher carbon contents, "tool steel"	no
coarse–grained	steel kept too long at annealing temperature or heated too much	normalizing
coarse–grained, very glistening over the entire cross–section	steel heated too much so that carbon is burned out, "burned steel"	waste because structure is destroyed
large– to coarse–grained, glistening edge	steel heated too long and too much, carbon removed from surface, "decarburized surface"	decarburized edge zone to be removed or recarburized by inserting –normalizing

A change of the mechanical properties can first be determined when the workpieces will be worked further.

After what can annealing defects be determined?

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Which defects do suggest a coarse–grained structure?

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5. Hardening

By hammering, bending and cold rolling of iron materials and nonferrous metals a strengthening of the metal structure is already reached, this is called "cold straining". Another kind is the "age–hardening" of light metals which is carried out after the finished heat treatment by storing the materials of several days' duration.

The most important kind is the "hardening by means of heat treatment" by which the structure of steels is changed systematically. This kind of heat treatment is used for making the steels hard and wear–resistant for certain purposes.

5.1. Material–related Preconditions for the Hardening by Means of Heat Treatment

Unalloyed steel is an iron material which can be formed in hot or cold state without special after treatment Unalloyed steel contains, apart from other chemical elements, the element "carbon" in portions of 0.02 to 2.1 per cent, which especially influences the properties "hardness" and "strength".

High carbon content:	– great hardness and strength
	– low toughness and elasticity
Low carbon content:	– low hardness and strength
	– great toughness and elasticity

When the steel is heated, the properties of the steel are changed in dependence on the carbon content

That is why the carbon content of the steel must be known prior to the heat treatment!

Conditions for hardenability:

Carbon content:	above 0.35 per cent – hardenable
	below 0.35 per cent – not hardenable

Steels of a carbon content below 0.35 per cent can be hardened at their surfaces when carbon is added to the steel from outside by means of a special process (casehardening).

What is the purpose of hardening by means of heat treatment?

What minimum carbon content must a steel have for being hardenable?

What influence on the mechanical properties does a high carbon content have?

5.2. Principle of Hardening by Means of Heat Treatment

Three working steps are required for hardening:

- Heating of the workpiece up to hardening temperature (over 723°C) in dependence on the carbon content of the steel;
- Holding the temperature according to the grade of steel and the size of the workpiece;
- Sudden cooling down (quenching) of the workpiece still being at hardening temperature.

In order to reach the correct hardness for the respective steel, the required hardening temperature must be met

Selection of hardening temperatures for unalloyed steels:

Carbon content in percent	0.5	0.6	0.7	0.8	1.0	1.5
Hardening temperature in degree centigrade	830	815	800	780	770	770

The lower the carbon content, the higher must be the hardening temperature!

The holding time up to hardening temperature is dependent on the grade of steel and the size of the workpiece. Small and difficult–to–form parts only require short holding times of a few minutes duration. With increasing size of the parts and a high carbon content, a longer holding time is required.

5.3. Kinds of Hardening by Means of Heat Treatment

Quenching:

Steels which can be hardened without special preparations are hardened by this process. In this case, the steel is heated to hardening temperature and quickly cooled down once a time. As a result, the material is very hard and brittle and it can show serious internal stresses; in case of unfavourable conditions, the workpiece can distort or break.

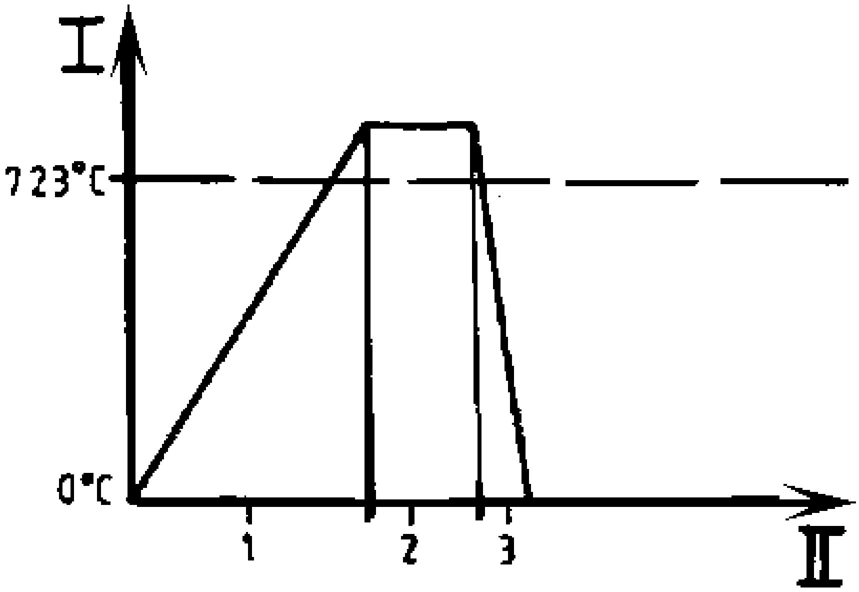

Figure 21 – Temperature/time diagram of quenching – *1 heating, 2 keeping constant. 3 quick cooling down* – I Temperature, II Time

Interrupted hardening:

By this process, steels are treated which are especially sensitive to break and distortion. The material is quenched only for a short time in a powerful quenching medium (water) until hissing is finished, after having been heated up to hardening temperature; subsequently, it is kept in a mild quenching medium (heated oil) until temperature balance. Only then it is further cooled down in air. A favourable variant is therefore the method where the material powerfully quenched is suspended into a hot bath of 200°C until temperature balance; by this, stresses occuring during the cooling–down process and the danger of break formation are effectively avoided.

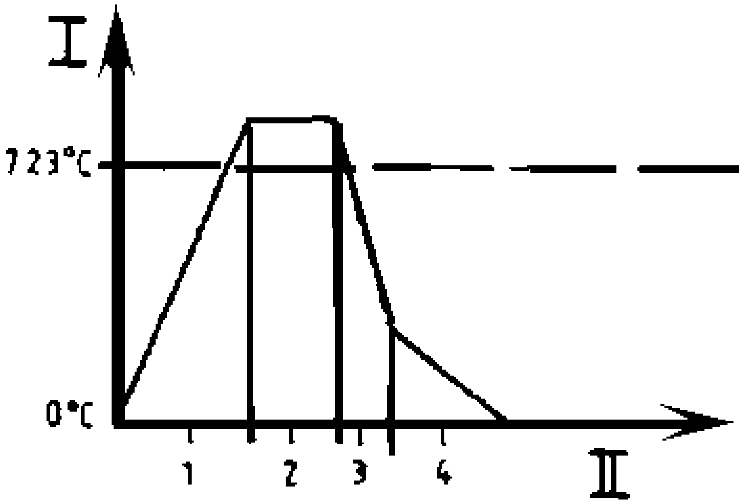

Figure 22 – Temperature/time diagram of interrupted hardening – *1 heating, 2 keeping constant, 3 quick cooling down, 4 slow cooling down* – I Temperature, II Time

Hot quenching:

By this process, workpieces of complicated shapes are treated. After having been heated to hardening temperature, the workpiece is cooled down in a hot bath at temperatures between 180°C and 500°C until temperature balance according to the grade of steel. Then it is cooled down (for any length of time) to ambient temperature by means of which the workpiece subsequently shows minor internal stresses only. Salt melting baths are preferably used as hot baths, the temperature of the bath must be derived from the grade of steel.

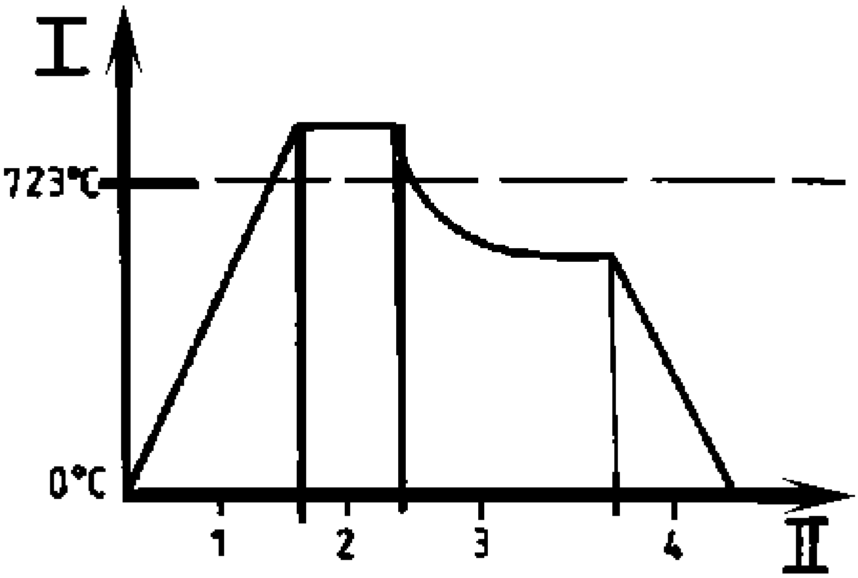

Figure 23 – Temperature/time diagram of hot quenching – *1 heating, 2 keeping constant, 3 retarded cooling down, 4 residual cooling down* – **I** Temperature, **II** Time

Within this mild hardening process the holding time for the workpiece in the melting bath has to be considered for the cooling–down process. The following rule is valid:

For every 10 mm in diameter or thickness, the workpiece must be held in the melting bath for 60 seconds!

Example:

A heated shaft of 75 mm diameter has to be cooled down in a melting bath. What holding time has to be met in the melting bath?

$$\text{Holding time} = \frac{\text{Diameter or thickness in mm} \times 60 \text{ seconds}}{10\text{mm}} =$$

$$= \frac{75 \text{ x } 60 \text{ sec.}}{10}$$

$$= 450$$

The shaft has to be kept in the melting bath for 450 seconds or 7.5 minutes, respectively.

Which working steps are required for the hardening process?

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What feature determines the interrupted hardening?

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5.4. Hardness–related Shaping of the Workpieces

As to small workpieces, hardening is effected in the entire structure; as to greater workpieces, the degree of hardness decreases internally.

Unfavourable shapes of workpieces or working imperfections can cause crack formation after hardening.

The following problematic points can cause defects:

- irregular breakthroughs
- sharp edges
- boreholes directly made into outer surfaces
- abrupt transitions between thick and thin parts

Measures:

Sharp edges have always to be rounded; in case of abrupt transitions, a separated individual–part–hardening with subsequent joining of the individual parts is more favourable.

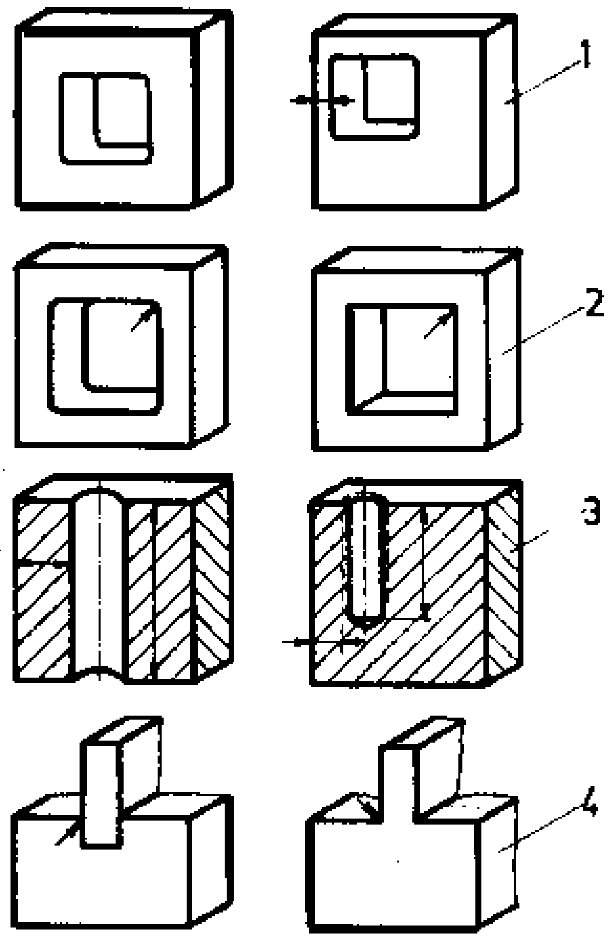

Figure 24 – Workpieces compared to hardness – **I** Favourable shape of workpiece, **II** Unfavourable shape of workpiece – *1 shaping of opening, 2 shaping of internal edges, 3 boreholes, 4 transition points in cross–sektion*

Hints:

Quenching cracks can be determined when a dilute colour paint is coated over the hardened surfaces – existing cracks ink and become visible!

Particularities for hardening in melting baths:

- When suspending into melting baths it has to considered that the workpieces are correctly emerged according to their shape.

– The workpieces must evenly be wetted; air cushions must not be produced! Air cushions slow down the quenching process and cause soft spots in the hardness layer!

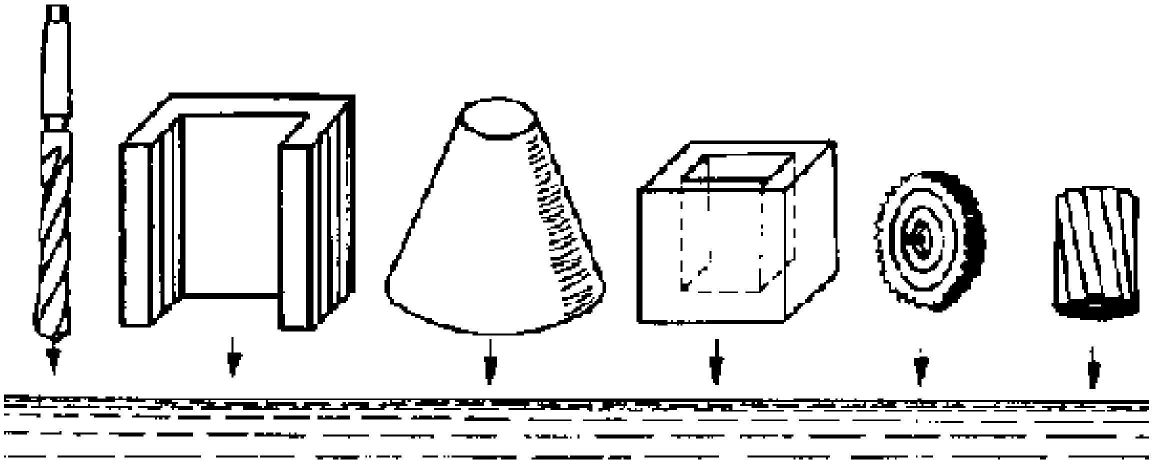

Figure 25 – Correct dipping of various workpieces into a melting bath

– Before being suspended into the melting bath, the workpieces must be predried. Minor amounts of moisture cause, at those great temperature differences, explosive evaporation of water. The vapour throws off the heated bath fluid from the melting tank.

– Vapours produced in the melting baths must be sucked off the hardening room by means of effective suction devices.

5.5. Hardening Defects

Feature	**Causes of defect by**		
	heating	**quenching**	**tempering**
Steel to soft	hardening temperature too low, too little heated, workpiece too much cooled prior to quenching	quenching bath too hot, quenching bath too small, wrong quenching medium, quenching speed too slow, quenching time too short	tempering temperature too high, wrong temper colour, when tempering from inside, too slowly cooled down
Steel irregularly hard	irregular heating, sulphur taking in from fuel gas, scaled workpiece, sticking melting bath when using melting baths	too big tongs' bit, unclean quenching bath, pieces to be hardened lie too crowded, unsuitable covering, wrong move in the bath (vapour bulbs), annealing skin and scale	irregularly heated
Steel too hard	too high hardening temperature	quenching medium too coarse	tempering temperature too low
Distorted work–pieces	due to great cross–section differences heated wrong, unfavourable position in annealing furnace, heated too quickly and unevenly, workpiece partly superheated, covered inadequately or even not, too long kept onto hardening temperature	cooled down too coarsely, emerged wrong	–

Workpieces with cracks	irregularly and too much heated, sharp screwings not covered, not preheated	irregularly quenched – quenched too coarsely – suspended wrong	

5.6. Specific Working Hints for Practical Execution of Work

– Finished parts which have to be protected from scaling or carbon loss are favourably heated in a salt bath or hardened in a packing.

Packing material can be, for low hardening temperature, peashaped–screened and roasted charcoal; in case of higher hardening temperatures, it can be burnt coke grit. It is practicable to wrap the parts into paper, additionally.

> – As to the heating of workpieces of great cross–section differences or sensitive points, protective covers made of sheet metal, asbestos or clay must be laid onto the weaker or more sensitive points in order to protect them from being overheated.
>
> – Prior to hardening, it is practicable to preheat the workpieces to about 500°C and to hold them at that temperature. At the beginning of hardening, the workpieces are quickly heated to hardening temperature and then, they are further machined.

Why is it favourable to harden the workpieces in a carbon containing packing?

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5.7. Hardness Measurement

Hardness is the resistance a body puts up against the forcible entry of a harder body.

The easiest possibility to check this hardness is the use of a used fine file by means of which a file test is carried out If the file slips on the edge and does not penetrate, the material is harder than the file.

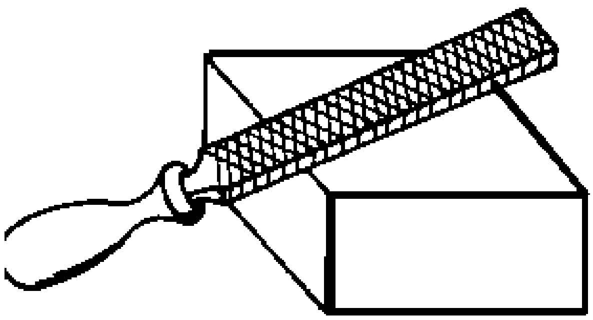


Figure 26 – File test

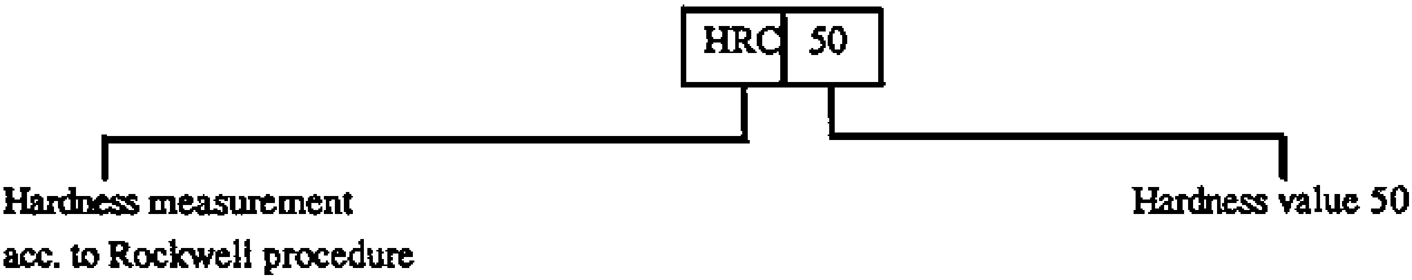
Frequently, the exact hardness is however required for the application of a workpiece. In those cases, the hardness must be determined by means of special testing devices.

According to the kind of power action onto the piece to be tested, we distinguish test procedures with statical or dynamical power action.

Principle of any hardness measurements:

A testing piece penetrates into the material to be tested – a value for the hardness of the material is derived from the deformation produced therefrom.

The produced hardness values are specified without measuring unit, only with a symbol according to the hardening process. Example for a hardness specification:



How can hardness be checked in a simple way?

6. Tempering

The steel becomes hard an brittle by the quenching process after heating. So high stresses can occur in the structure of the material that cracks are produced and the material slivers to pieces like glass.

In order to eliminate those negative effects and give the material the "useful hardness", it is tempered after having been hardened, i.e. it is heated once again. The toughness of the material is increased again at a justifiable decrease of the hardness and strength.

Tempering temperatures relate to the purpose of use of the workpiece.

The higher the tempering temperature, the lower the hardness and the tougher the steel.

When a blank steel is heated, a 0.2 mm thick oxide layer is produced on the surface, this oxide layer becomes discoloured in dependence on the temperature.

Apart from temperature gauges, the temperature can also be estimated by the colour.

Tempering colours for plain carbon steels:

Tempering colours	Temperature °C	Temperature K	Examples for use
Pale yellow	210	483	Steel scriber
Light−yellow	220	493	Measuring instruments
Yellow	230	503	Chisels of any kind
Dark−yellow	240	513	Twist drill, files
Yellowish brown	250	523	Milling cutter, reamers,
Brownish red	260	533	screw taps, metal saw blades
Red/purple	270	543	Screw drivers, woodworking tools
Violet	280	553	Hot−cross chisel, centrepunch, mandrils
Dark−blue	290	563	Springs, surgical instruments
Cornflower blue	300	573	
Light−blue	310	583	Rivets, axes, hand saw blades,
Greyish blue	320	593	scynthes
Grey/greyish green	330	603	Household knives

6.1. Types of Tempering

Tempering from outside:

The cold workpiece is slowly heated by means of appropriate heat sources and after having reached the tempering temperature (between 200°C and 500°C) it is cooled down.

Tempering from inside:

The workpiece is shortly quenched after having been hardened so that only outer layer is cold. The residual heat penetrates from inside, after having reached the tempering temperature it is cooled down.

The same effect can be reached when the workpiece is cooled down only on one side and the heat contained in the other part runs after again.

After hardening the point to be tempered must be finished quickly by means of polishing linen cloth in order to recognize the temper colours!

The approximate value for the tempering time for compact workpieces:

1 to 1.5 hours for 20 mm thickness of workpiece

Hints:

- The tempering effect is a combination of time and temperature. If the tune is enlarged, the temperature can be decreased.
- For tools, longer tempering at lower temperature is better than shorter tempering at higher temperature.
- High−alloy steels require longer tempering times than unalloyed steels.

What is the purpose of tempering?

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Which influence is exercised by the tempering temperature onto the useful hardness?

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Why it is possible to determine the temperature by means of tempering colours?

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7. Surface Hardening

When workpieces shall have a hard, wear−resistant surface, but the core must remain tough, they are only hardened on the surface. Those workpieces can resist to great shock and bending stresses.

7.1. Types of Surface Hardening

Flame hardening:

Unalloyed steels with 0.35 to 0.6% carbon content are quickly heated to hardening temperature and subsequently, they are immediately (without holding time) cooled down.

The thickness of the hardened surface is dependent on the heat supply:

The greater the supply and the smaller the burner speed, the stronger is the hardened layer!

Normal layer thicknesses are 1.0 to 1.5 mm, but they can also be greater.

The burner can be guided over the material surface by hand or by mechanical feeding devides. Tempering is effected at temperatures between 150°C and 200°C for materials which are sensitive to break and crack.

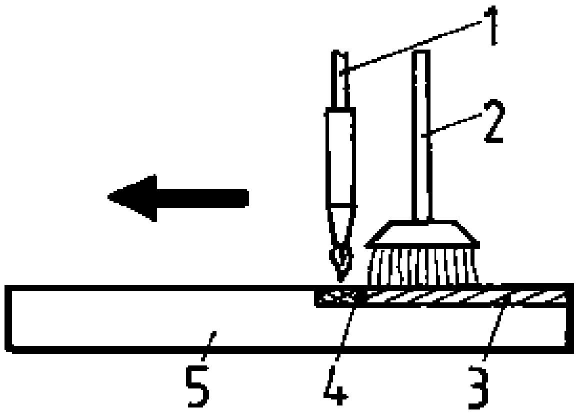

Figure 27 – Flame hardening – *1 gas burner, 2 sprinkler, 3 hardened surface, 4 red–hot surface, 5 workpiece*

Casehardening:

Tough steels with a carbon content of less than 0.25% can be enriched with carbon (carburized) on their surfaces so that they contain 0.75 to 1.1 % carbon and can subsequently be hardened. As to the carburization process, the metallic clean workpieces are inserted in carbon–containing powder (charcoal or leather coal) or they are blown with carbon–containing gases and annealed without air for 4 to 10 hours at temperatures between 880°C and 920°C. Surfaces to be kept soft are covered by means of protective means (clay, refractories) or coppered.

The penetration depth of the carbon is dependent on the application time during carburization. After one hour the layer is about 0.4 mm thick, after 10 hours about 1.2 mm.

The following hardening process can be carried out at temperatures around 770°C by means of various processes.

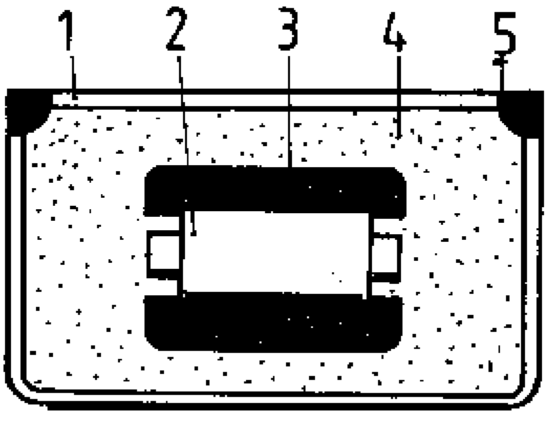

Figure 28 – Casehardening – *1 fireproof case with cover, 2 workpiece, 3 carbon–containing powder, 4 sand, 5 clay*

Which properties can have workpieces after surface hardening?

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Which steels can be worked by means of flame hardening?

Which steels can be worked by means of casehardening?

8. Hardening and Tempering

By this process, the strength of unalloyed steels with a carbon content of generally 0.2 to 0.6% in most cases can be changed in a wide range.

In spite of the low carbon content, those steels can reach higher strength values with higher toughness at the same time.

Proceedings:

1. Heating of the material according to the hardening temperature in furnaces or melting baths between 700 °C to 860° C.

2. Quenching in water or oil to lukewarm.

3. Tempering according to the desired properties at temperatures between 360°C and 670°C and cooling down to lukewarm.

A high tempering temperature decreases the strength and increases the toughness!

Which properties shall be reached by hardening and tempering?

Series of Transparencies – Machine Elements Bearings

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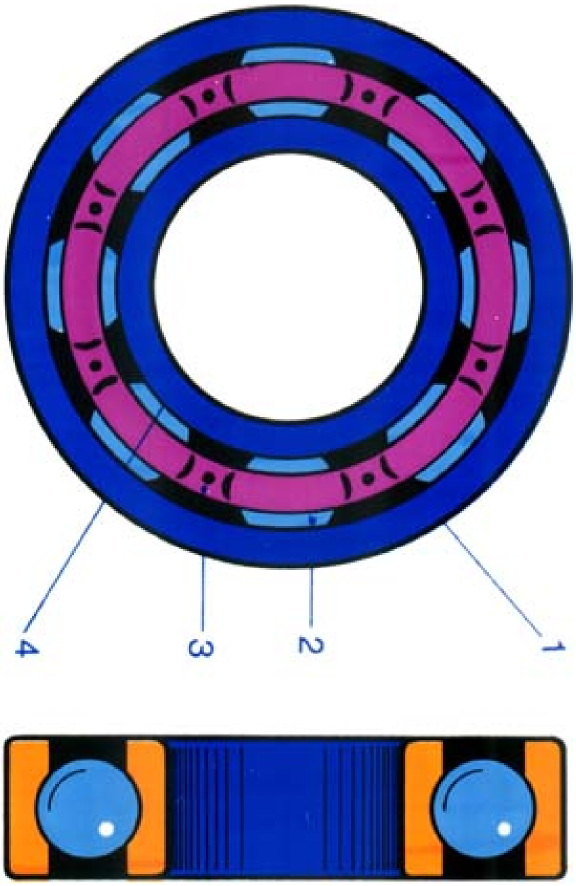
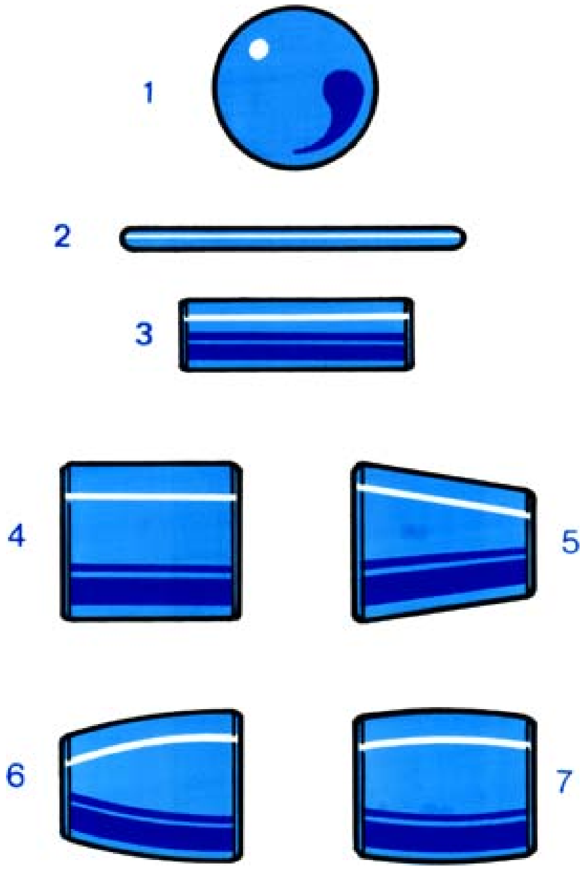
Series of Transparencies – Machine Elements Bearings

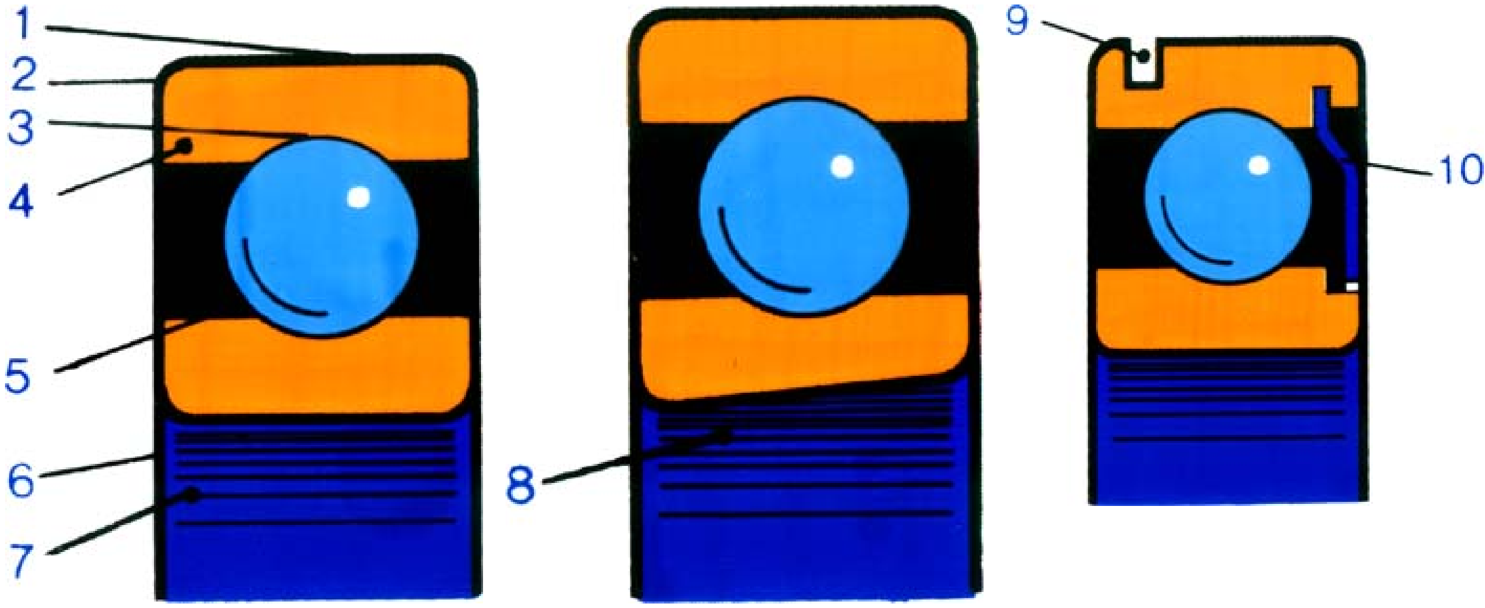


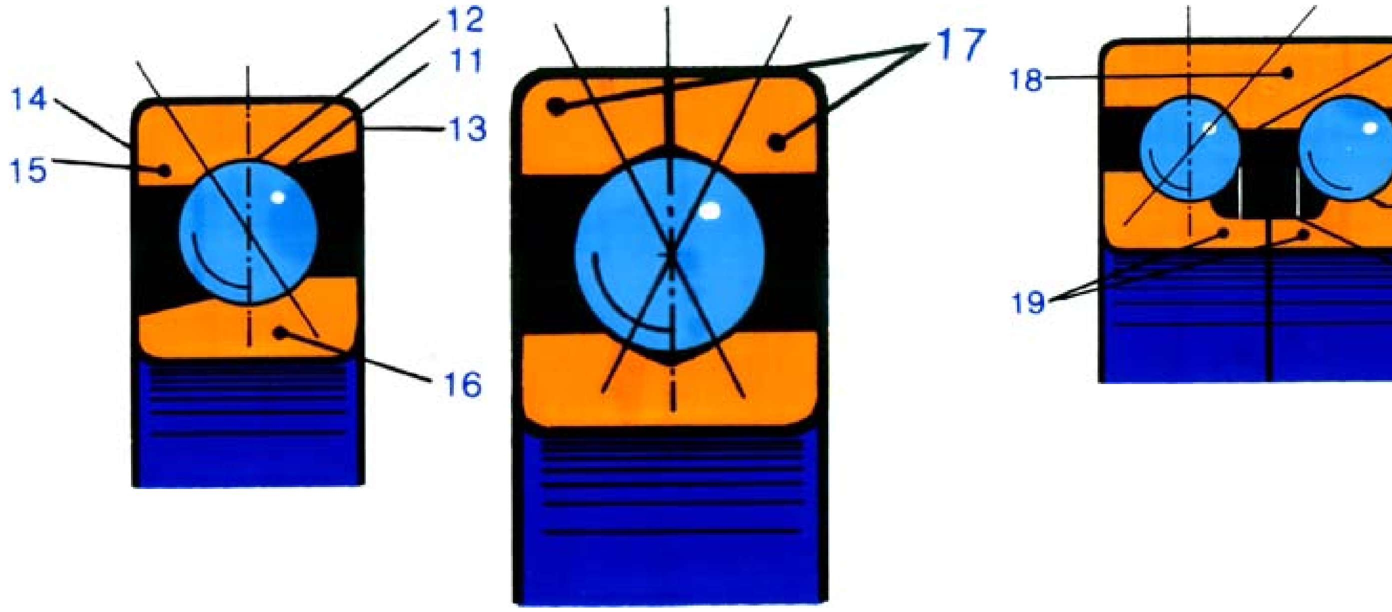
FR–MALF 1.1. Aufbau eines Wälzlagers



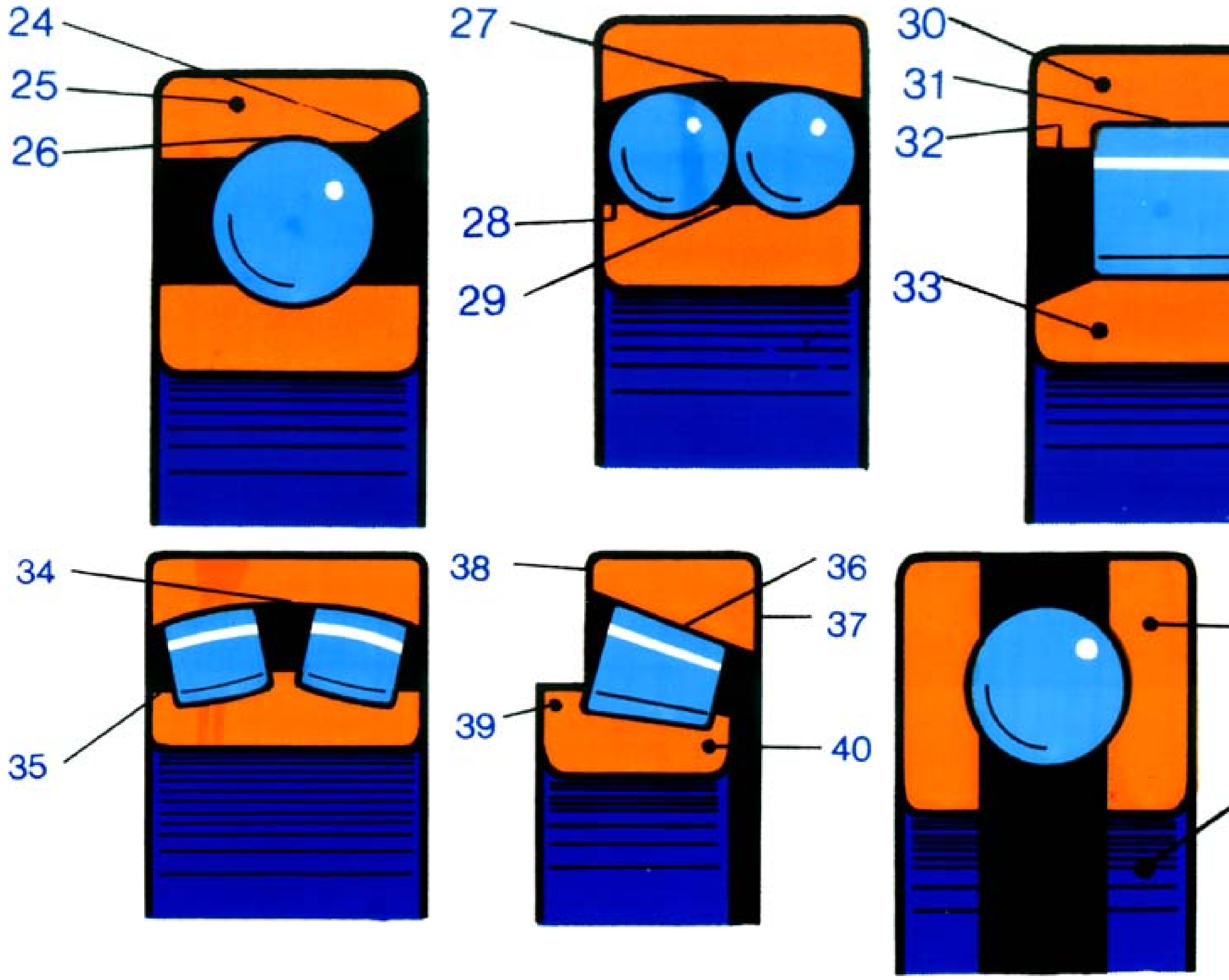
FR–MALF 1.2. Arten von Wälzkörpern

FR–MALF 1.3. Bauformen – Einzelheiten der Gestaltung I





FR−MALF 1.4. Bauformen − Einzelheiten der Gestaltung II



FR−MALF 1.5. Einteilung der Wälzlager

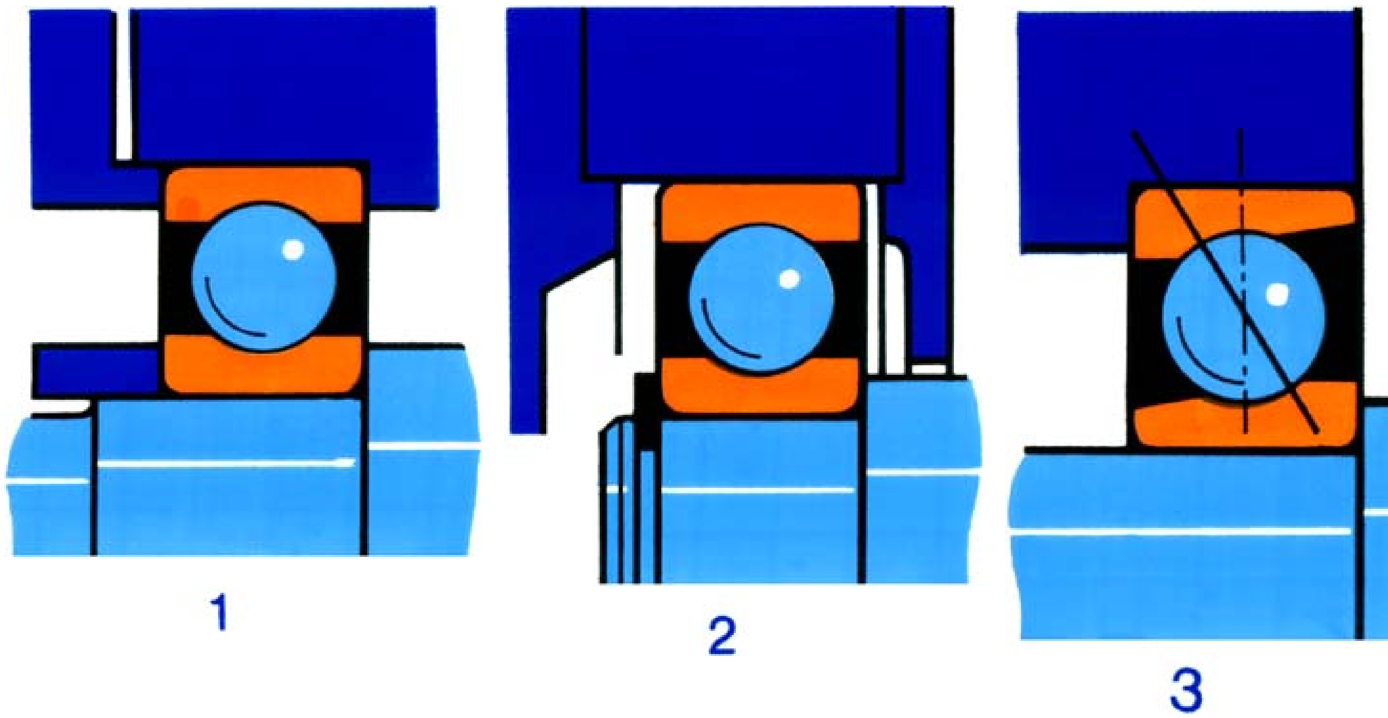
Paliers à roulement

- **Roulements à billes**
  - Roulements rainurés à billes
  - Roulements à billes à contact oblique
  - Roulements à billes à rotule
  - Roulements à billes et à épaulement
- **Roulements à rouleaux**
  - Roulements à rouleaux cylindriques
  - Roulements à aiguilles
  - Roulements à rouleaux coniques
  - Roulements à rouleaux à rotule
- **Butées à billes**
  - Butées à billes à simple effet
  - Butées à billes à double effet
- **Butées à rouleaux**
  - Butées à rouleaux à rotule

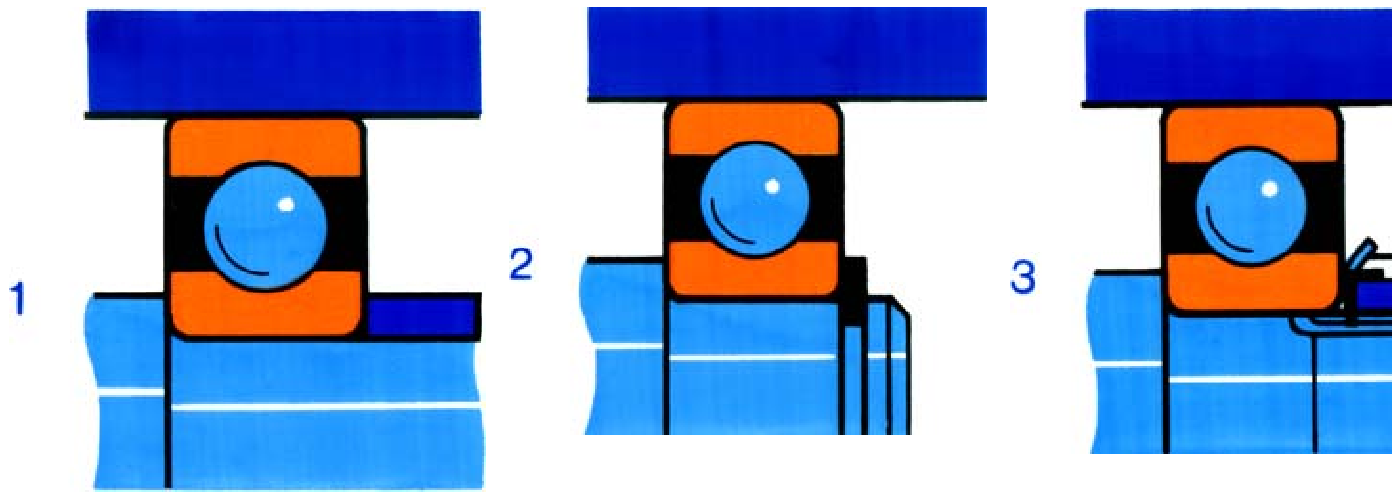
محمل مقاوم للاحتكاك

- **محمل اسيطينات**
  - **محمل قطرى**
    - محمل اسيطينات اسطوانى
    - محمل ابرى
    - محمل اسيطينات مخروطى
    - محمل اسيطينات تأرجحى
  - **محمل محورى**
    - محمل اسيطينات تأرجحى – محورى
- **محمل ذو كريات**
  - **محمل قطرى**
    - محمل اخدودى ذوكريات
    - محمل مائل ذوكريات
    - محمل تأرجحى ذوكريات
    - محمل كتفى ذوكريات
  - **محمل محورى**
    - محمل اخدودى ذوكريات – محورى بفعل فردى الجوانب
    - محمل اخدودى ذوكريات – محورى ثنائى الفعل

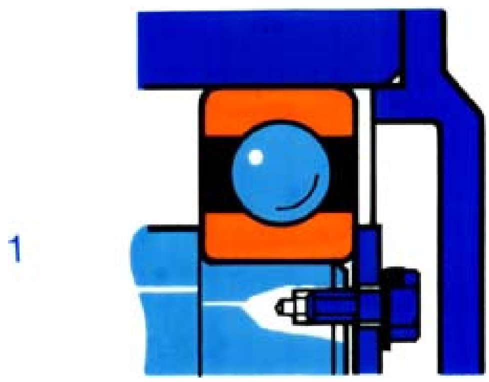
FR–MALF 1.6. Konstruktive Gestaltung der Lagerstelle – Festlager, Loslager, Stützlager



FR–MALF 1.7. Konstruktive Gestaltung der Lagerstelle – Axiale Festlegungen I



FR–MALF 1.8. Konstruktive Gestaltung der Lagerstelle – Axiale Festlegungen II



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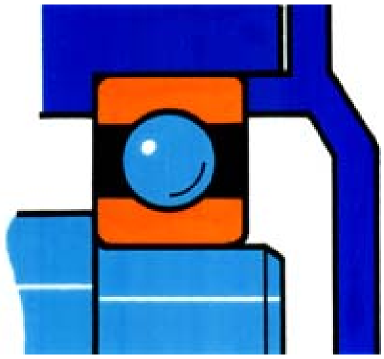
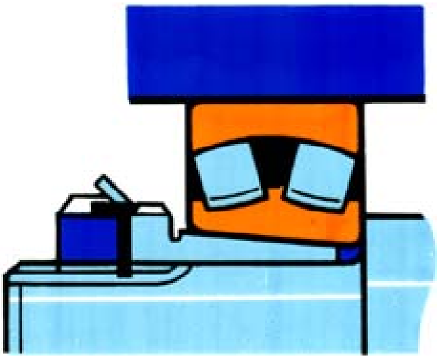
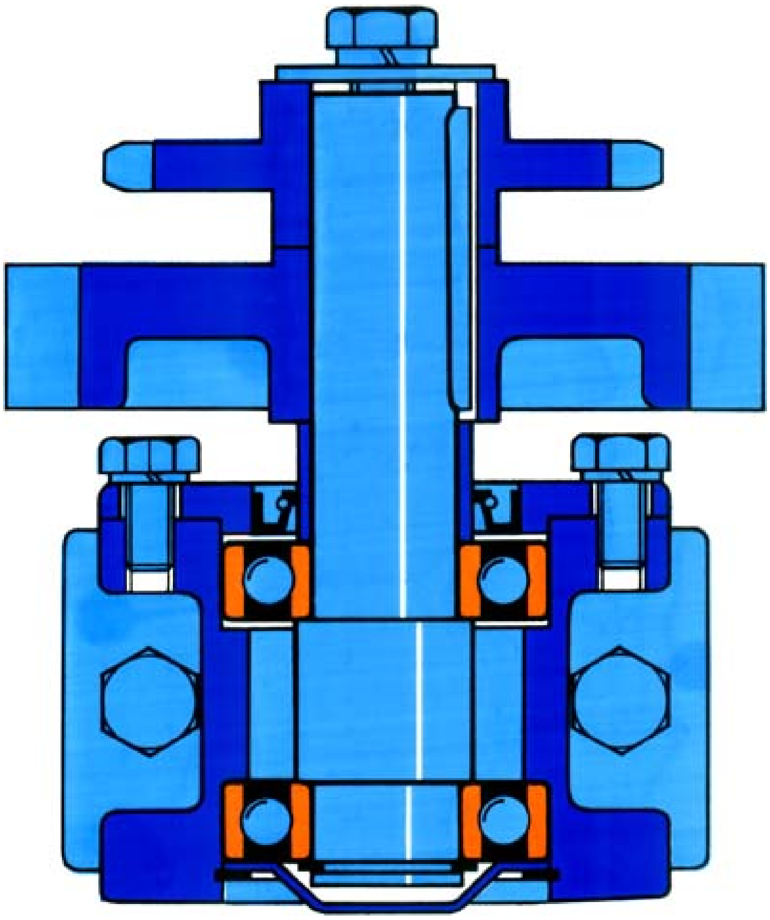


FR−MALF 1.9. Konstruktive Gestaltung der Lagerstelle − Axiale Festlegungen III

1

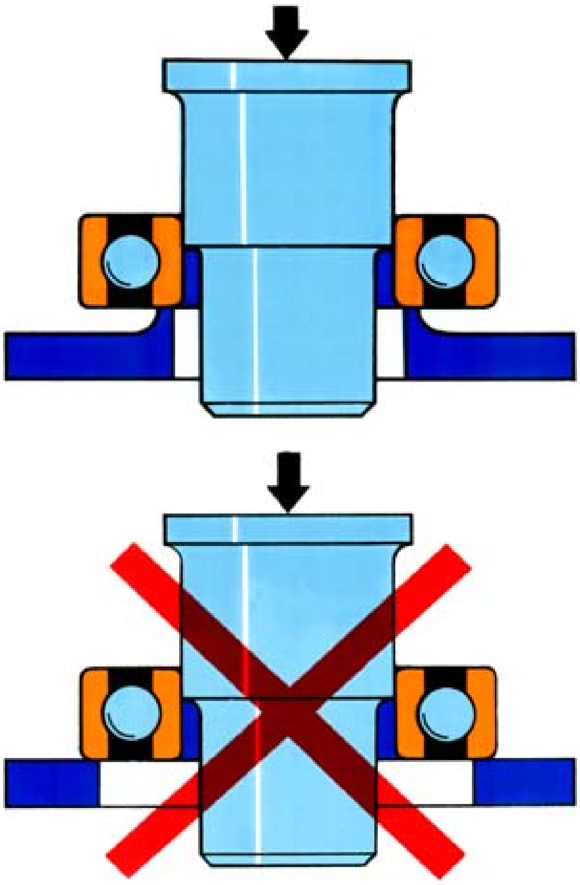
2



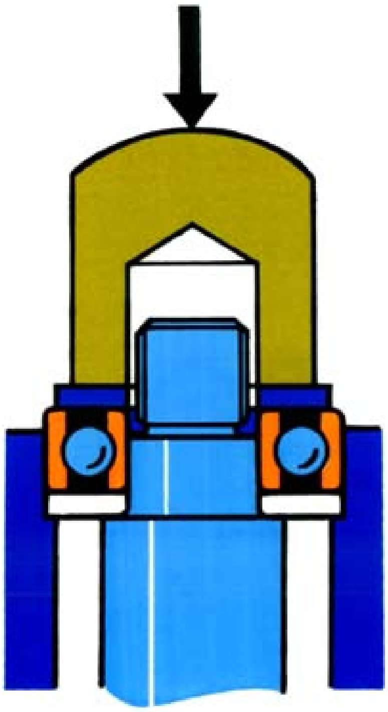


FR–MALF 1.10. Konstruktive Gestaltung der Lagerstelle – Zwischentrieb

FR–MALF 1.11. Einbau – Gegenüberstellung richtig/falsch



FR–MALF 1.12. Einbau – Montagebüchse, Montagescheibe



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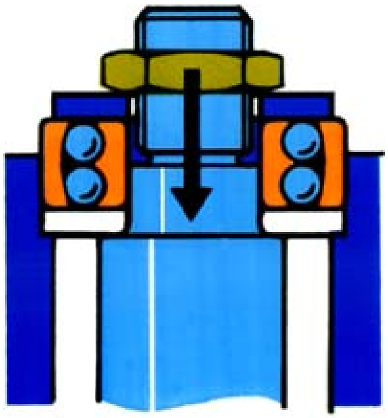

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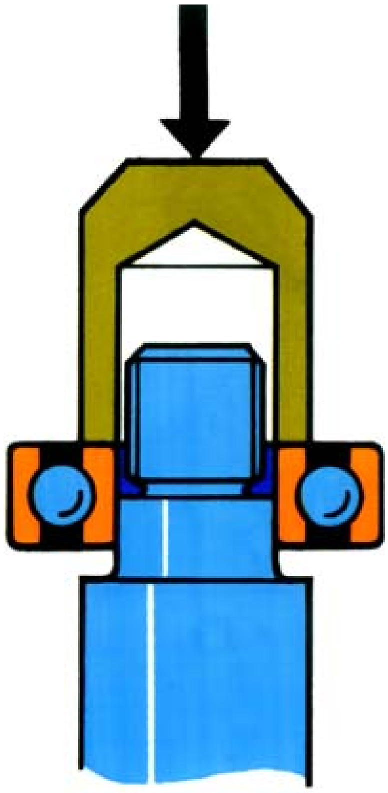

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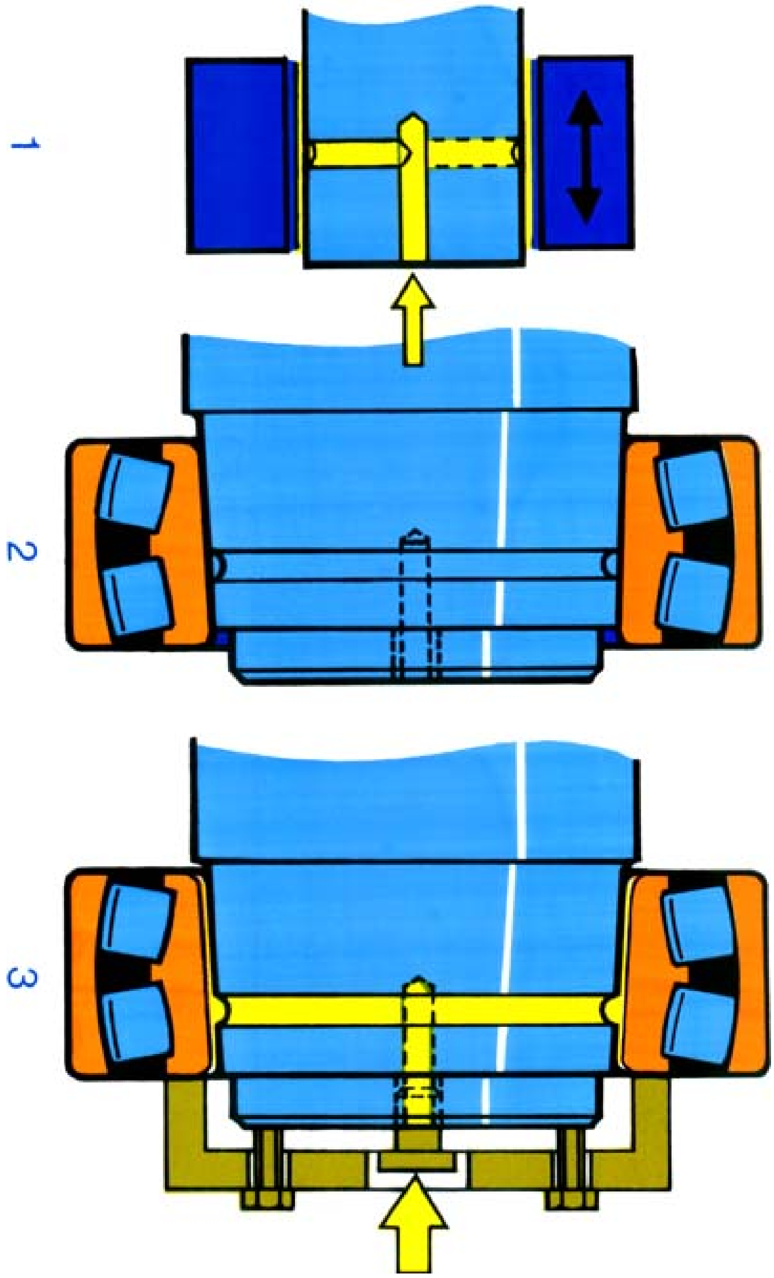
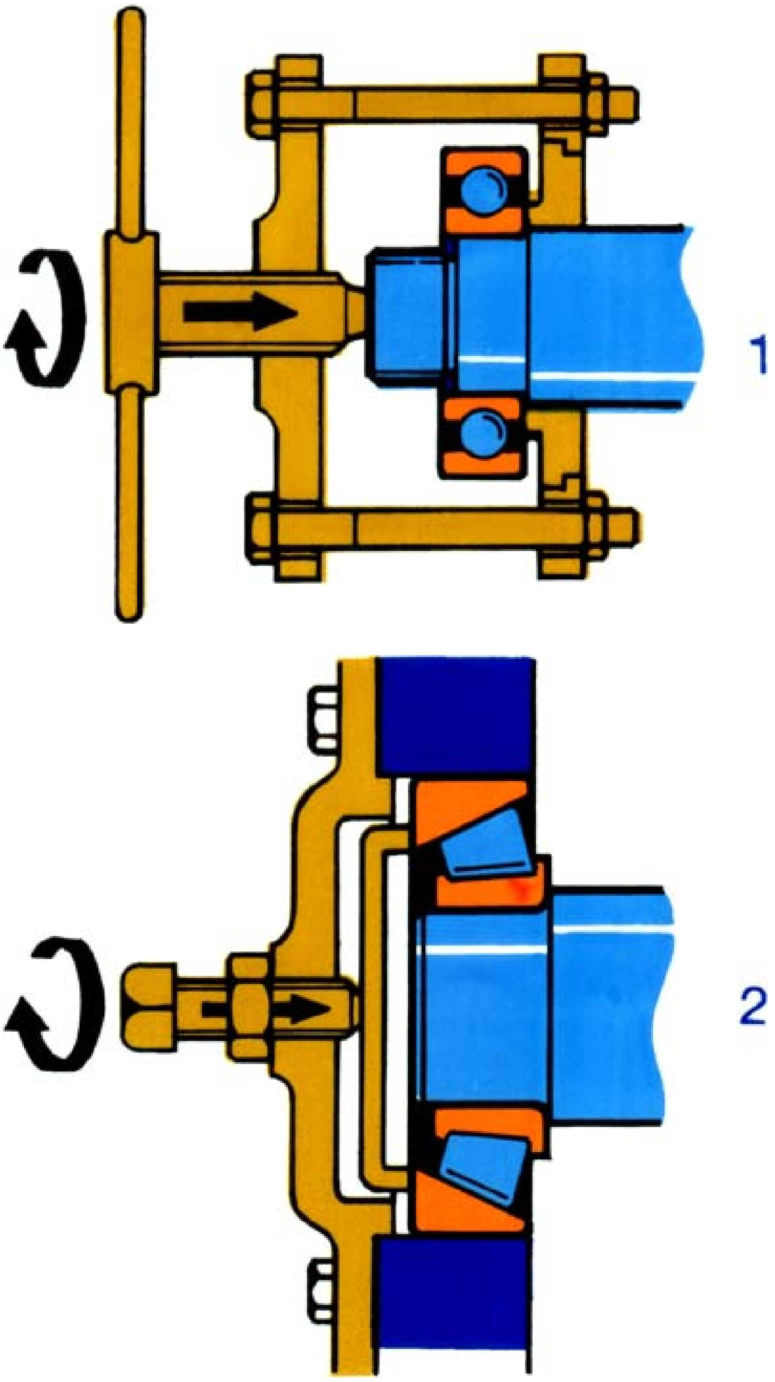
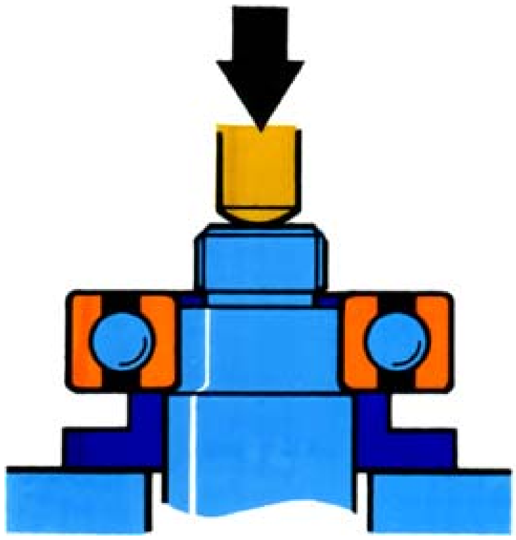


FR−MALF 1.13. Einbau − Hydraulikmontage

FR−MALF 1.14. Ausbau − Abziehvorrichtung. Auspreßvorrichtung



FR−MALF 1.15. Ausbau durch Schlag. Mittels Abziehhülse, hydraulisch



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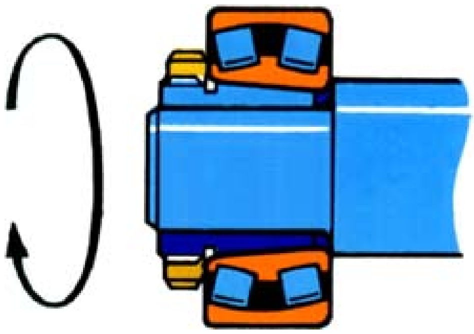

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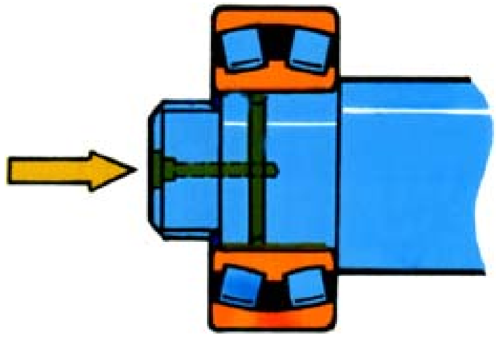

3

Bending – Course: Technique of Working Sheet Metals, Pipes and Sections. Methodical Guide for Instructors

Table of Contents

Bending – Course: Technique of Working Sheet Metals, Pipes and Sections. Methodical Guide for Instructors

Institut für berufliche Entwicklung e. V.
Berlin

Original title:
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"Biegen"

Author: B. Zierenberg

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13187 Berlin

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1. Aims and Contents of Practical Vocational Training in the Techniques of Bending

After having terminated their training, the trainees shall be able to surely master the most common techniques of bending procedures. For that purpose, the following aims have to be achieved:

Aims

– The trainees will have profound knowledge of kinds and fields of application of the working means to be used for bending.

– They will master the different techniques to be used for bending sheet metals, pipes and sections with various tools, appliances and machines.

– They will be enabled to select the appropriate working means according to the kind of material, material thickness and shape of bending.

– The trainees will be capable of adequately employing the tools, appliances and machines while adhering to the health, labour safety and fire protection regulations.

– The will know how to assess the quality of their work themselves.

To reach the objectives so demanded, the following subject matters have to be imparted by the instructor

Contents

– Knowledge:

• Purpose of bending
• Kinds and fields of application of tools, appliances and machines
• Phenomena occurring in the material
• Fundamentals of calculation
• Bending techniques

– Hints on labour safety

– Skills:

• Folding, aiming over, flanging, seaming, crimping, rounding of, and rolling of sheet metals

• Rounding of sections and pipes
• Rolling of sections

2. Organizational Preparations

To ensure a trouble−free course of instructions, exercises, and vocational practice, it is necessary to prepare the training well, with the following measures to be taken:

2.1. Planning the Training in Bending Techniques

Proceeding from the total hour volume, the times for the individual training sections of this vocational unit should be planned in a differentiated manner.

It is recommended to draw up a time schedule for the subsequent training sections:

– for introducing the techniques in the form of instruction
– for necessary demonstrations
– for instructions to prepare the practical exercises
– for executing the practical exercises
– for recapitulation and controls.

While the hours are being scheduled, the following additional factors are to be taken into consideration:

– the trainees' educational level
– the training conditions
– the trainees' future employment
– the degree of difficulty of the training section.

The focus of each training section is always the acquaintance of practical skills and abilities by exercises, which will take the most comprehensive period of time.

2.2. Preparing the Instructions on Labour Safety

Before the practical exercises begin, the trainees are briefly instructed on the adequate handling of working means and given recommendations for an accident−free work. In general, those regulations are valid which are to be observed for manual techniques in hammering and straightening.

Especially, the following key points should be observed:

– Use only proper hammers – the hammer shaft must be tightly wedged with the hammer head.

– Select the correct striking plate with regard to the form of bending – a hard and inflexible surface is required.

– Workpieces to be campled have to be tightly fixed in the clamping fixture so that they are not torn away by the striking impact

– Always strike against the fixed vise jaw so that the vise screw will not be damaged.

– Mind your hands and head when working on presses.

– Work with welding torches must not be performed until the instructor has given the necessary instructions.

– Always observe fire protection – place ready water for fire fighting, do not work close to inflammable materials.

– Only bend sheet metals and sections over 8 to 10 mm thickness and pipes of more than ½" in a heated state.

– Use only dry sand as filler for hot bending of pipes to avoid steam formation.

Knowing about these hints is to be confirmed by the trainees' signing in the control book.

2.3. Providing the Teaching Aids

– The "Trainees' Handbook of Lessons – Bending" is to be distributed among the trainees according to their number.

– Illustrations contained in the “Trainees' Handbook of Lessons” and having a high indicative value should be used as visual aids (e.g. on flip charts, blackboards etc.)

– Workpieces showing well and badly performed bendings may be provided as visual objects.

– Particular tools and appliances not yet known to the trainees should also be used as visual illustrations, the same applies to brochures and photos of bending machines.

– If transparencies on bending are available, they should, in any case, be included in the instruction.

2.4. Providing the Working Means

– The "Instruction Examples for Practical Vocational Training – Bending" as theoretical basis for the practical exercises to be performed should be distributed according to the number of trainees.

– The basic material required for the exercises should be prepared and provided with the help of the specification of materials given in the "Instruction Examples ....." in sufficient quantity.

– The workshop should be checked whether or not it is completely equipped with tools, appliances, machines, measuring and testing means as well as auxiliary means as to the exercises planned.

– Recommended basic outfit:

- Steel rule, steel square, vernier caliper
- Steel scriber, centre punch
- Smooth files, band hack saw, hand–lever shear
- Machinists' hammer, light metal hammer, special hammers for sheet metal working
- Straightening plate, surface plate, vise
- Various intermediate plates and bending mandrels
- Drills and counterbores
- Hand screw press, bending devices, folding bench, rolling device
- Welding torch, dry sand

– Machines to be employed for bending have to be checked as to their serviceability with regard to labour safety before starting the exercises.

– For necessary drilling and counterboring operations, a table–type or column–type drilling machine with appurtenant clamping fixtures is required.

– Check serviceability of this machine prior to the practical exercises with regard to labour safety.

3. Recommendations for Implementing Vocational Training in Bending Techniques

The following sections contain proposals on how to arrange the trainees' instruction, the demonstration of techniques as well as exercises and controls.

3.1. Introductory Instruction

The introductory instruction should be given, if possible, with the trainees in a classroom. Attention is to be paid during the instruction to the trainees' noting down necessary additions or replies to questions in the “Trainees' Handbook of Lessons”. An essential prerequisite for learning the bending techniques is the trainees' mastering the techniques in testing and hammering. This knowledge should be repeated, if necessary.

For your instruction you can use the “Trainees' Handbook of Lessons” with the following focal points:

Purpose of bending

Initially, it would be favourable to explain to the trainees the purpose of bending with the help of visual objects and illustrations. In this connection, it must be made clear that bending is, due to its versatility, used in many fields of manufacture and performed by various techniques. Predominantly, the techniques in folding, turning over, flanging, seaming, rounding and rolling should be discussed.

Selected tools, appliances and machines

Out of the variety of applicable working means it is recommendable to introduce or repeat the following:

– Hammer
– Welding torches
– Angle bending appliances, strip rolling devices, pipe benders
– Screw presses
– Folding bench, rounding device, crimping and flanging machine
– Vise, blacksmith's anvil

These working means may also be dealt with in a question–answer talk with the trainees, as far as the trainees have previous knowledge. Already here, particular characteristic features in their application can be stressed. If tools cannot be shown, the trainees should have a look at the illustrations in the “Trainees' Handbook of Lessons”.

Processes in the material

During this instruction section, the tensile and compressive stresses and their effects occurring during the bending process are to be discussed. The terms "stretching and upsetting" as well as "neutral axis" have to be explained.

In this connection, it is recommended to show the stretching and upsetting zone on a spot of rupture of a square section strongerly bent It is also favourable to make a blackboard drawing as to Fig. 14 of the “Trainees' Handbook of Lessons” to show the neutral axis. Subsequently, the influences of such material properties like "plasticity", elasticity", "strength" and "strain hardening" are to be explained.

The trainees should keep in mind the knowledge so acquired in the form of rules and key sentences. To deepen the knowledge, the trainees have now to answer the questions asked in the ”Handbook of Lessons” following the respective section.

In supplement of the influence data depicted just now, me influences of the bending radius, particularly the minimum bending radius, and the influences of beat reaction for the quality of bending can be discussed.

It is recommendable to put side by side a hot bent and a cold bent square section of 16 × 16. The trainees are to state the differences in quality of bending and derive from it the findings for their own work.

Fundamentals of calculation

Comprehensively dealing with this focus is essential. The trainees are to be explained the necessity of the exact blank of the basic material. As for calculating the blank size, the straight length in dependence of the neutral axis position must be ascertained first.

The formulae required for it are distinctly introduced in the "Trainees' Handbook of Lessons".

With an example of application it is demonstrated that the blank length can be calculated out of a sum of different partial lengths. Here, the trainees should develop more examples for calculation to be solved by them without assistance, if possible.

Bending techniques

The techniques depending on material thickness and form of bending edge, as mentioned in the beginning, are described in the “Trainees' Handbook of Lessons”, in principal.

Versions for each technique are shown, describing the manual making of bends with hammers or with mechanical devices as well as machines. It is not recommendable to describe the techniques all together during the lessons, what is more, it is favourable first to only explain the bending procedures which can be practised in the workshop with the help of existing working means.

That means that following the description of folding sheets practical exercises should be done, applying immediately in practice the knowledge just imparted.

Subsequently, the following techniques will be dealt with in the same way. It would be better, in case of slow learners or those having only a small previous knowledge, to impart the know−how in small, closely restricted sections and then support it with respective practical exercises.

Hints on Labour safety

Give the essential hints at the respective place, when bending procedures to be performed are described. These recommendations are contained in the text and as a compilation in the “Trainees' Handbook of Lessons".

3.2. Practical Exercises

Basically, the necessary hints on labour safety have to be given prior to the practical exercises. Then, the trainees receive their working places and the technical equipment of the workshop is checked as to its serviceability. It is recommended to start any exercise with a demonstration in connection with the teacher's instruction related to the instruction example. Here, the trainees are to be motivated to perform the exercises in good quality. Difficulties to be expected have to be pointed out and evaluation key assessment should be mentioned at the same time.

> It is necessary for the instructor to have previously performed the exercise himself.
> Only in such a way does he know the difficulties that may arise during its execution.

The course of exercise may be in change of instructions on the special techniques and the appurtenant exercises. With the help of "Instruction Examples for Practical Vocational Training − Bending", 6 practical exercises can be done by applying different techniques.

For that purpose, the "Instruction Examples....." contain a material list (base material, tools, appliances, measuring and testing instruments as well as auxiliary means), the sequence of operations to carry out the practical exercises and an illustrative working drawing. The trainees receive all the required information in it to be able to perform the exercises purposefully.

To give a survey, to which practical pieces the knowledge previously imparted is to be applied, the following individual instruction examples are briefly described.

Instruction examples:

Instruction example 14.1.: Mounting angle

Sheet metals of 1 mm and 2 mm thick steel are to be folded in the vise. For that purpose, a sheet with a simple bending edge is to be bent manually.

A second sheet shall receive two bending edges by means of machinist's hammer and intermediate plate'

(Figure 1)

Instruction example 14.2.: Half−round bracket

A sheet steel strip is to be folded and rounded off in the vise with the help of a bending mandrel so that a serviceable half−round bracket is the result. Before bending, the straight length is to be calculated.

(Figure 2)

Instruction example 14.3.: Hasp

During this exercise, a sheet steel is to be rolled on a rolling device as well as round sections to be folded and bent to a round object by means of bending mandrels, so that a serviceable hasp will be the result after assembly.

(Figure 3)

Instruction example 14.4.: Double pipe knee

A steel pipe is to be rounded off twice with a bending device as well as with a machinist's hammer in the vise. In this case, sand filler and local heating are to be applied to. The heating length has to be calculated before.

Instruction example 14.5.: Beaker jacket (Figure 4)

A thin sheet steel is to be folded with the folding press, turned over and rounded off. Subsequently, a jacket seam joint is fabricated.

(Figure 5)

Instruction example 14.6.: Beaker

The previously fabricated beaker jacket is further worked on. After flanging, a bottom piece is connected with the beaker jacket by a bottom seam joint.

(Figure 6)

All trainees can do the exercises at the same time so far as material and equipment are available in sufficient quantity and number.

In this case, the trainees are able to perform any single exercise individually − each trainee should have as much time as needed.

If there are not enough working means, the trainees must be split into groups. Here it is favourable to divide them into groups according to the application of different tools and appliances.

As versions for the exercises to be done, the bendings can be made with various working means as well. In such a way, foldings should not only be made on the vise, but also on the folding press and folding bench. Even so should roundings not only be exercised manually, but also on the rounding−off device, if available.

Should the proposed instruction examples not be used for exercises, it would be possible to select other practising pieces. In this case, attention is to be paid to the fact that all the techniques previously discussed can be practised on these pieces as well.

Focal points for practical execution

It is recommended for the to fix certain criteria for the assessment of the exercises.

These could be the following:

– Do the trainees prepare their working places carefully?
– Is the straight length of workpiece exactly calculated?
– Is the basic material exactly cut to size?
– Are the appropriate working means selected and properly operated?
– Are the workpieces tightly clamped?
– Do the workpieces receive the required form and accuracy to size?
– Are workpieces damaged by improper work?
– Are the trainees able to assess the quality of their work themselves correctly?
– Do the trainees adhere to the labour safety regulations?

3.3. Questions for Recapitulation

To strengthen and check the knowledge and abilities so acquired, the following tasks have been made out in this section and are also contained in the “Trainees' Handbook of Lessons”:

1) What is the purpose of bending?

(To remodel workpieces that must have angular or rounded shapes for a specified purpose of application.)

2) Which techniques are used for bending of sheet metals?

(Folding, turning over, flanging, seaming, crimping, rounding, rolling.)

3) What does the term "neutral axis" mean?

(Transition zone in the bent workpiece where no tensile and compressive stresses occur.)

4) Which material properties must parts to be bent not have?

(They must not be brittle or spring–tempered.)

5) What does the term "spring–back" (elastic recovery) mean?

(Elastic materials spring back after an action of force by a certain measure.)

6) What will happen when a sheet metal is being bent around a bending edge that is in accordance with the streak flow of rolling direction?

(Cracks may occur on the bending's outer edge.)

7) What does the term "strain hardening" mean?

(When tensile and compressive stresses change for several times, the internal stresses grow and result in hardening at the bending point.)

8) Which influence has the bending radius on developing cracks in the workpiece?

(The larger the bending radius, the smaller the risk of cracks.)

9) Which influence has workpiece thickness on bending radius?

(The thicker the workpiece, the larger the bending radius must be.)

10) Which influence has the material heating on the bending procedure in case of thick workpieces?

(With growing heat, the internal resistance within the material decreases, the bending procedure becomes easier and is without risk of crack formation.)

11) What does the term "stretched length" mean?

(Length of workpiece before being bent: is calculated from the neutral axis length.)

12) How does the position of the neutral axis change when workpieces are bent around a radius that is smaller than five times the workpiece thickness?

(It shifts to the internal side of the bending.)

13) How is the stretched length of a workpiece calculated, if several different bendings have to be effected?

(Each bending is calculated individually as a partial length, then the partial lengths are summarized.)

14) To which side have you to hammer when a sheet metal is to be folded on the vise?

(Towards the side of fixed jaw.}

15) Which side of the workpiece has to be scribed with the steel scriber?

(On the bending's internal side.)

16) From which sheet thickness onwards should workpieces be hot−bent?

(From 8 mm sheet thickness onwards.)

17) What is the significance of hardwood or metal intermediate plates for bending on the vise?

(They serve to compensate distances when workpieces with several bending edges are to be folded. They also absorb the impact when you strike with a machinist's hammer.)

18) How are sheets with long bending edges clamped in the vise?

(With sheet clamp or angular sections, both being additionally fixed with a ferrule.)

19) What is to be done before sections are folded?

(Prior to bending, the upsetting zone is to be separated.)

20) How are sheet metals to be turned over?

(They are folded by 90° and turned over with presses or hammers to a bending angle of up to 180°.)

21) How is a sheet metal cylinder flanged manually?

(Slightly flange with the hammer pane (striking face of a hammer) on the bordering tool and finish flanging with the hammer face on a plane striking plate.)

22) By which working steps is seaming marked?

(Turning over with shims, hooking−in, pressing together.)

23) What does “crimping” mean?

(Producing curl−like recesses in sheets to stiffen the metal)

24) How can sheet metals be rounded off in a vise?

(Clamp the sheet with the bending form and turn it overstep by step with the hammer.)

25) With which appliances can sections be rounded off?

(With bending devices, bending dies, section bending machines, swage block.)

26) What is to be noted when pipes of over ½" in diameter are rounded off?

(Pipe must be filled with sand prior to being bent.)

28) What is to be noted when welded pipes are rounded off?

(Welding seam must be lateral to bending radius in neutral axis.)

29) Which length has to be exactly calculated prior to hot−bending?

(The bend length to be heated.)

30) How is the bend length scribed?

(From the dimension length, the dimension leg is scribed to one side on the unbent pipe and the bending leg to the other side.)

31) How may sheet rims be rolled?

(With hammers on round sections, with devices or presses.)

32) How may springs be wound?

(Mechanically with lathes or manually with winding mandrels and wood clamp in the vise.)

Bending – Course: Technique of Working Sheet Metals, Pipes and Sections. Instruction Examples for Practical Vocational Training

Table of Contents

Bending – Course: Technique of Working Sheet Metals, Pipes and Sections. Instruction Examples for Practical Vocational Training

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Preliminary Remarks

This material contains 6 selected instruction examples, by means of which bending of sheet metals and sections with various tools and appliances can be practised. The following techniques are applied for making the practising pieces:

- Folding of sheet metals and round sections
- Turning over of sheet metals
- Flanging and seaming of sheet metals
- Rounding of sheet metals, round sections and pipes
- Rolling of sheet metals

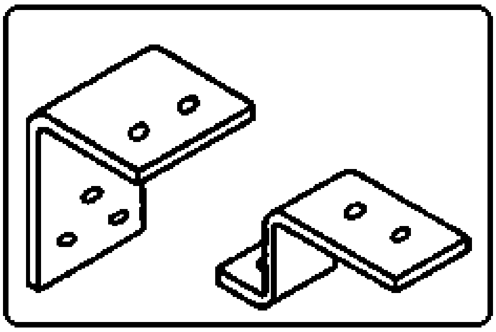
While "mounting angles" and "double pipe knee" exclusively are exercise pieces, the "half–round bracket", the "interlocking sleeve" and "beaker" may be used in the workshop in practice.

To facilitate preparation and execution of work, the materials, tools, measuring and testing instruments as well as auxiliary means necessary for each instruction example are specified. Moreover, the previous knowledge needed to perform the exercises is mentioned.

Based on working drawings and the appurtenant sequence of operations, the exercises can be done independently.

Instruction Example 14.1.: Mounting Angle

Practise the folding of thin sheet metals on the vise with and without hammers.



Material

Sheet steel	(380 MPa) 1
thickness:	1 mm
width:	60 mm
length:	165 mm

Sheet steel	(380 MPa) 2
thickness:	2 mm
width:	20 mm
length:	155 mm

Tools

Steel scriber, centre punch, smooth file 200 mm (flat), light metal hammer, machinist's hammer

Measuring and testing means

Vernier caliper, steel rule, steel square

Auxiliary means

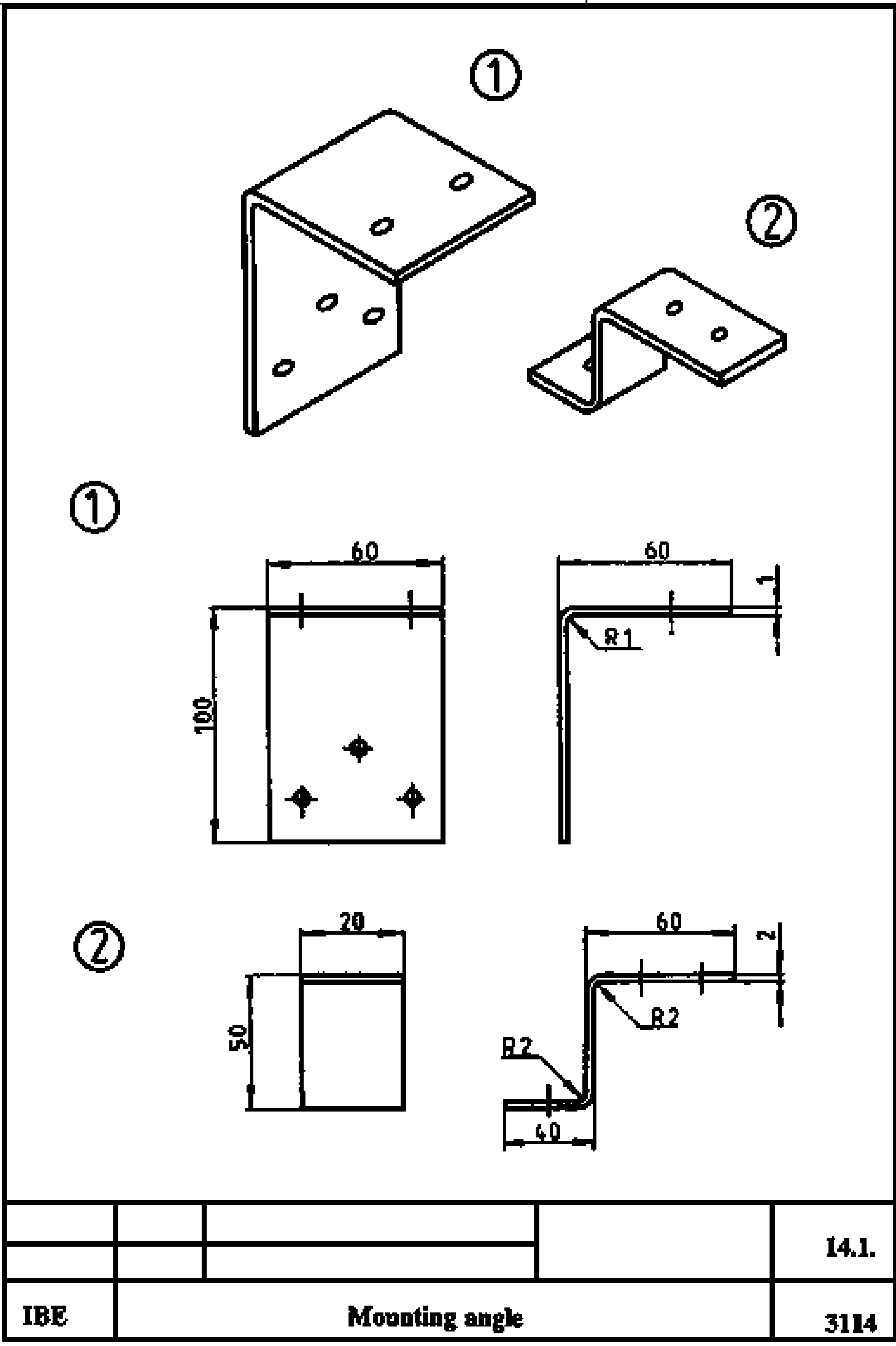
Surface plate, vise, bending plate, intermediate plate 40 × 40

Previous knowledge required

Manual material working: Measuring, testing, scribing, punching, filing, shearing

Sequence of operations	Comments
1. Prepare the working place and make available working material.	Check completeness.
2. Check initial sizes of sheets. If need be, cut to size, deburr and straighten.	
3. Scribe bending edges of sheet (1) and sheet (2).	Scribe on internal sides.
4. Clamp sheet (1) in vise and bend with your ball of the thumb and, if need be, use bending plate.	Strike bending edge with light metal hammer.
5. Clamp sheet (2) in vise and fold first bending edge with light metal hammer.	Strike hammer directly against bending edge. Strike against the fixed vise jaw.

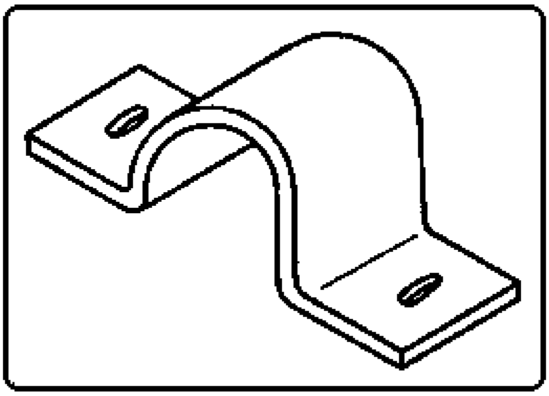
6. Reclamp sheet (2) with intermediate plate in vise and fold second bending edge.	If need be, strike bending edges with hammer face of machinist's hammer.
7. Check bending edges.	– Accuracy to size
	– Angularity
	– Shape
8. Drill the workpiece.	Ask the instructor as for drilling sizes.



Mounting angle

Instruction Example 14.2.: Half−round Bracket

Practise the folding and rounding of sheet metal on the vise with hammer and bending mandrel.



Material

Sheet steel	(380 MPa)
thickness:	2 mm
width:	20 mm
length:	90 mm, approx.

Tools

Steel scriber, centre punch, smooth file 200 mm (flat), machinist's hammer

Measuring and testing means

Steel rule, vernier caliper

Auxiliary means

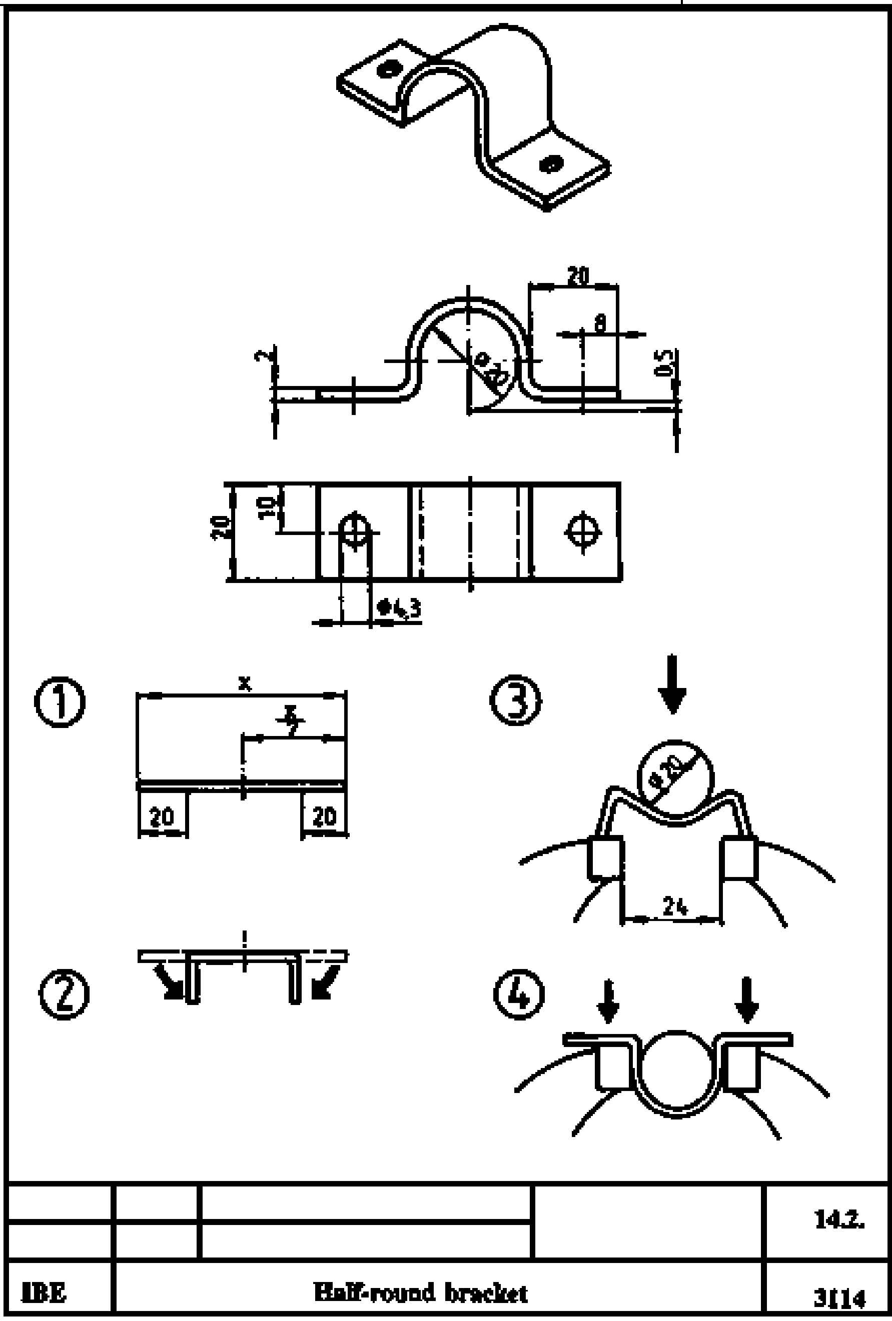
Surface plate, straightening plate, vise, bending mandrel 0 20 mm

Previous knowledge required

Manual material working: Measuring, testing, scribing, punching, filing, shearing

Sequence of operations	Comments
1. Prepare the working place and make available the material.	Check completeness.
2. Check initial size and, if need be, rework, deburr and straighten.	
3. Calculate stretched length (x), cut sheet to this length, deburr and straighten.	Subdivide total length into 5 partial lengths.
4. Scribe centre $\left(\frac{x}{2}\right)$ on one side of sheet and scribe tang lengths on the other external side (20 mm).	Stage (1)
5. Fold clamped tangs.	Stage (2)
6. Place sheet on open vise and put bending mandrel on sheet centre (see scribed line) and strike with hammer.	Stage (3)
	Vise opening:

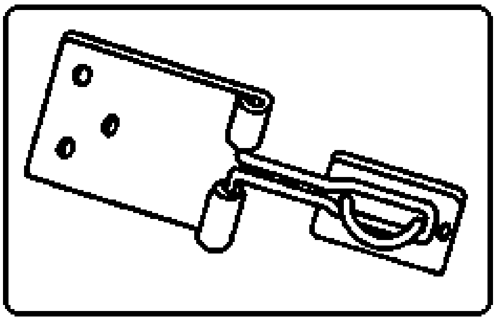
	Diameter of bending mandrel plus two times the sheet thickness.
7. Strike tangs planely in final position and straighten on straightening plate.	Stage 4
8. Check bending.	– Evenness on surface plate
	– Angularity
	– Accuracy to size
	– Shape
9. Drill workpiece.	



Half−round bracket

Instruction Example 14.3.: Hasp

Practise the folding and rounding of round section in the vise as well as rolling of sheet metal with the rolling device.



Material

Sheet steel	(380 MPa) 1
thickness:	2 mm
width:	53 mm
length:	80 mm
Sheet steel	(380 MPa) 2
thickness:	2 mm
width:	32 mm
length:	67 mm
Round section	(380 MPa) 3
diameter	5 mm
length:	280 mm
Round section	(380 MPa) 4
diameter	5 mm
length:	80 mm

Tools

Steel scriber, centre punch, smooth file 200 mm (flat), drill ϕ 5 mm, countersink 75", machinist's hammer, hand–type hack saw

Measuring and testing means

Steel rule, vernier caliper, steel square

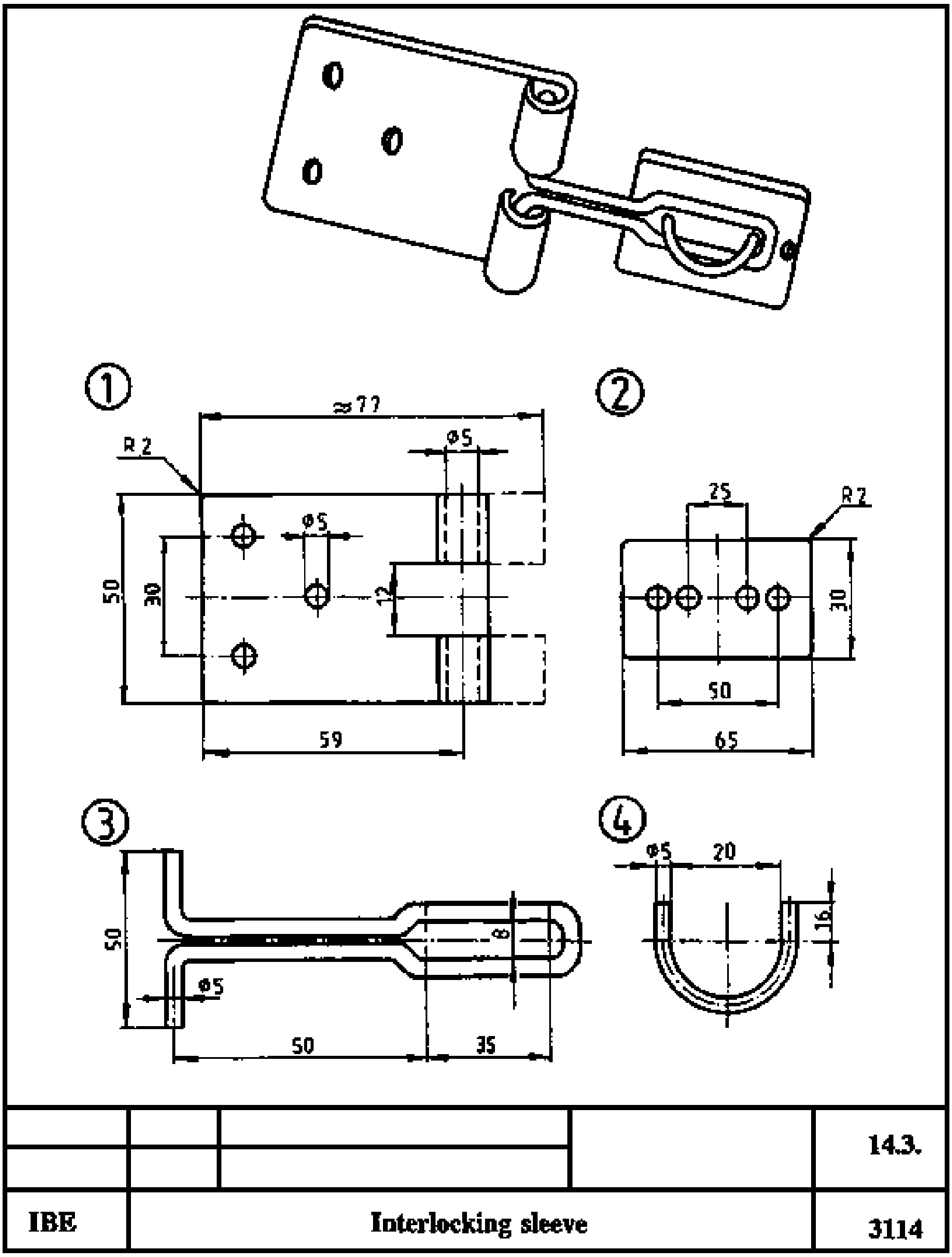
Auxiliary means

Rolling device with bore ϕ 10 mm, vise, bending mandrel ϕ 20 nun, bending mandrel 8 mm (flat)

Previous knowledge required

Manual material working: Checking, measuring, scribing, punching, sawing, filing, drilling, counterboring, rivetting.

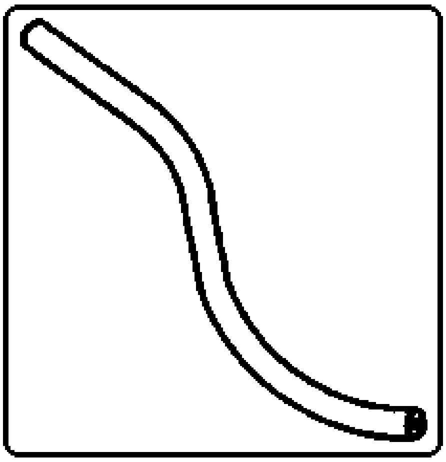
Sequence of operations	Comments
1. Prepare the working place and make available the working material.	Check completeness.
2. Prepare hinge sheet (1) and trim tab (2) as to specified size, counterbore trim tab back for rivetting.	Shearing, deburring, drilling, counterboring.
3. Roll hinge sheet on rolling device, then bend upwards hinge side by 5 mm.	Tightly clamp rolling device, pre–bend sheet and then roll it.
4. Round and fold joint piece 3 as to specified size and subsequently saw it to size.	Apply bending mandrel 8 mm.
5. Round staple (4) as to specified size and subsequently saw it to size.	Apply bending mandrel 0 20 mm.
6. Put joint piece (3) in hinge sheet (1) and press hinge side together.	Joint piece must be moved easily.
7. Insert staple into staple plate (2) and rivet from the back.	
8. Check bendings	– Function
	– Accuracy to size
	– Shape



Interlocking sleeve

Instruction Example 14.4.: Double Pipe Knee

Practise the rounding of a pipe with the pipe bending device and hammer.



Material

Steel pipe	(380 MPa)
diameter	25 mm
length:	about 1000 mm

Tools

Pipe bending device, smooth file 200 mm (flat and round), hand−type hacksaw, welding torch, machinist's hammer

Measuring and testing means

Steel rule, template R 400 and R 89, steel square

Auxiliary means

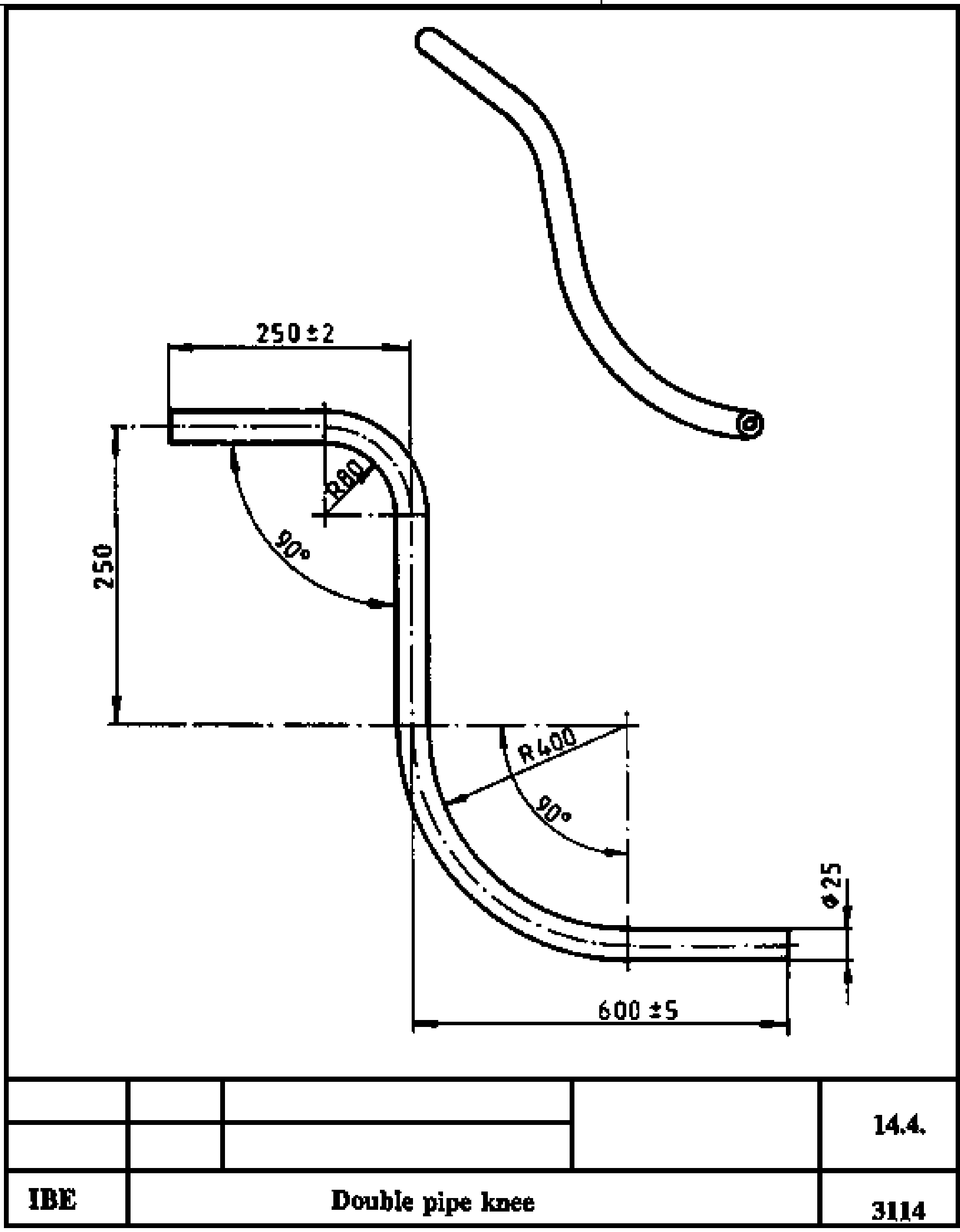
Vise, fine−grained sand, wooden stopper

Previous knowledge required

Manual material working: Measuring, testing, scribing, sawing, filing.

Sequence of operations	Comments
1. Prepare the working place and make available the working material.	Check completeness.
2. Calculate stretched length.	Subdivide total length into 5 partial lengths.
3. Saw pipe to length and deburr it.	
4. Fill pipe with sand and close it with wooden stopper.	Only use dry and fine−grained sand.
	After filling, compress the sand by knocking.
5. Bend radius of 400 without heating in the bending device.	
6. Bend radius of 80 on the vise with the hammer by uniform heating.	Before bending, scribe length to be heated.
7. Check bendings.	– Accuracy to size
	– Angularity

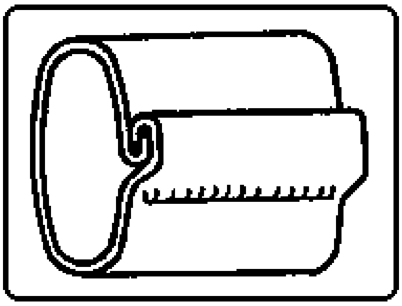
	– Shape



Double pipe knee

Instruction Example 14.5.: Beaker Jacket

Practise the folding, turning over and rounding of sheet metal and fabricating a jacket seam joint.



Material

Sheet steel	(380 MPa)
thickness:	1 mm
width:	102 mm
length:	210 mm

Tools

Steel scriber, smooth file 200 mm (flat), light metal hammer, machinist's hammer, folding bench

Measuring and testing means

Steel rule

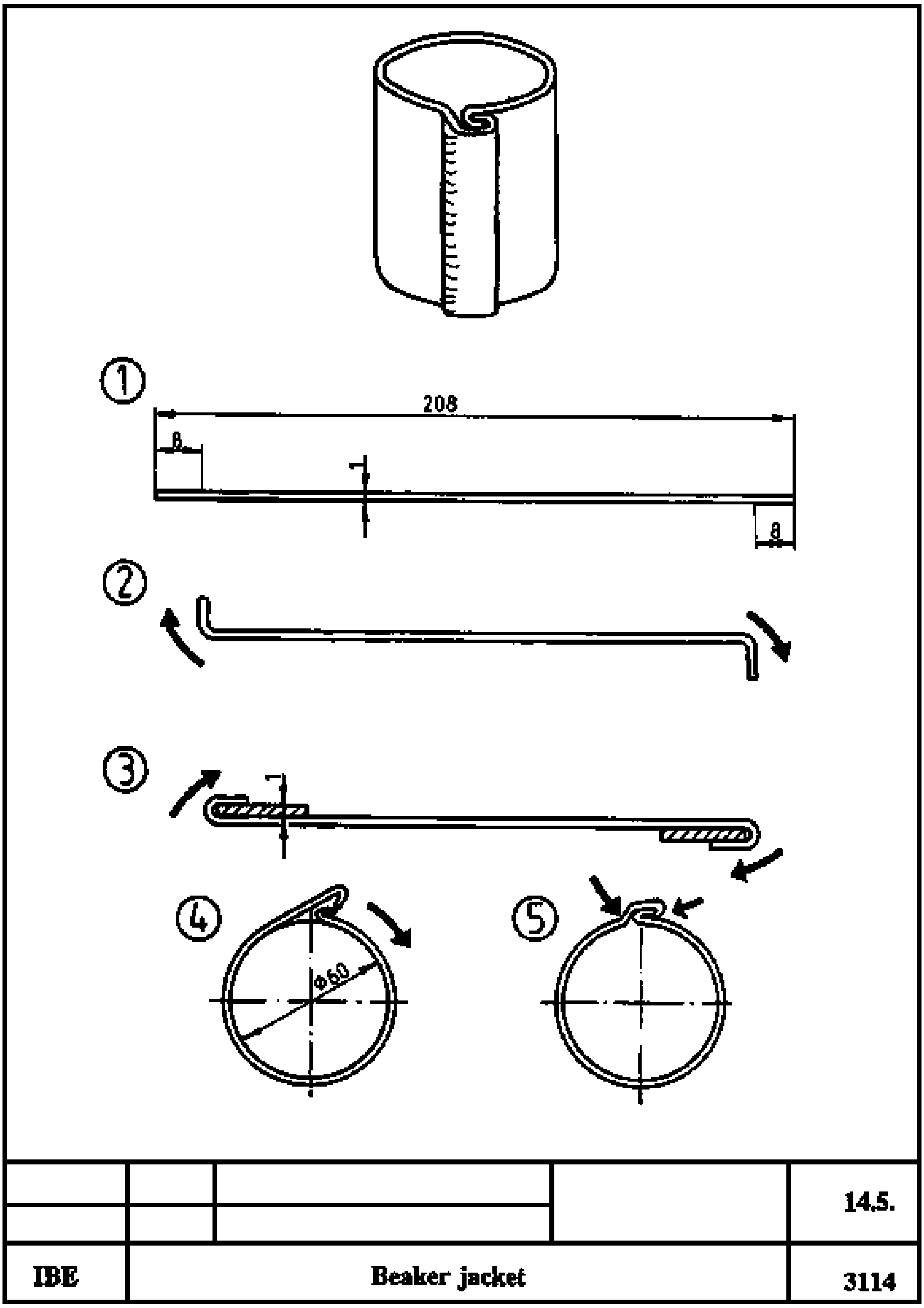
Auxiliary means

Vise, intermediate plate 1 mm, bending mandrel ϕ 60 mm

Previous knowledge required

Manual material working: Measuring, testing, scribing, hammering, filing

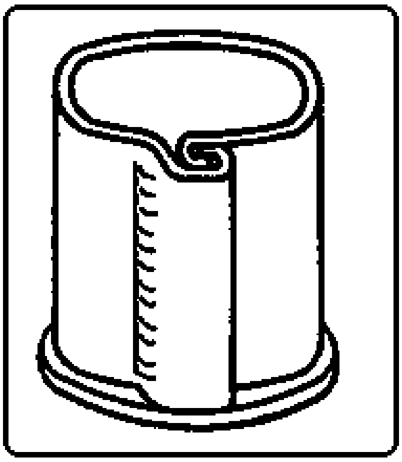
Sequence of operations	Comments
1. Prepare the working place and make available the working material.	Check completeness.
2. Check initial size, deburr and straighten.	Re−work, if need be.
3. Scribe seam width and fold seam on folding bench.	Stages (1) and (2)
4. Turn over the seam with intermediate plate inserted.	Stage (3)
	Insert intermediate plate of 1 mm
5. Gradually round sheet on vise around the bending mandrel.	Stage (4)
	Insert bending mandrel of ϕ 60 mm
6. Hook in the seam without bending mandrel.	Stage (5)
Press the seam together and upset it on the bending mandrel.	Press together with hammer face.
	Upset with hammer pane.
7. Check rounding and jacket seam.	



Beaker jacket

Instruction Example 14.6.: Beaker

Practise the flanging of sheet metal and fabricating a bottom seam joint



Material

Beaker jacket as to Instruction Example 2.5.

Sheet steel	(380 MPa)
thickness:	1 mm
diameter	80 mm

Tools

Steel scriber, smooth file 200 mm (flat), machinist's hammer, hand−type hacksaw

Measuring and testing means

Steel rule

Auxiliary means

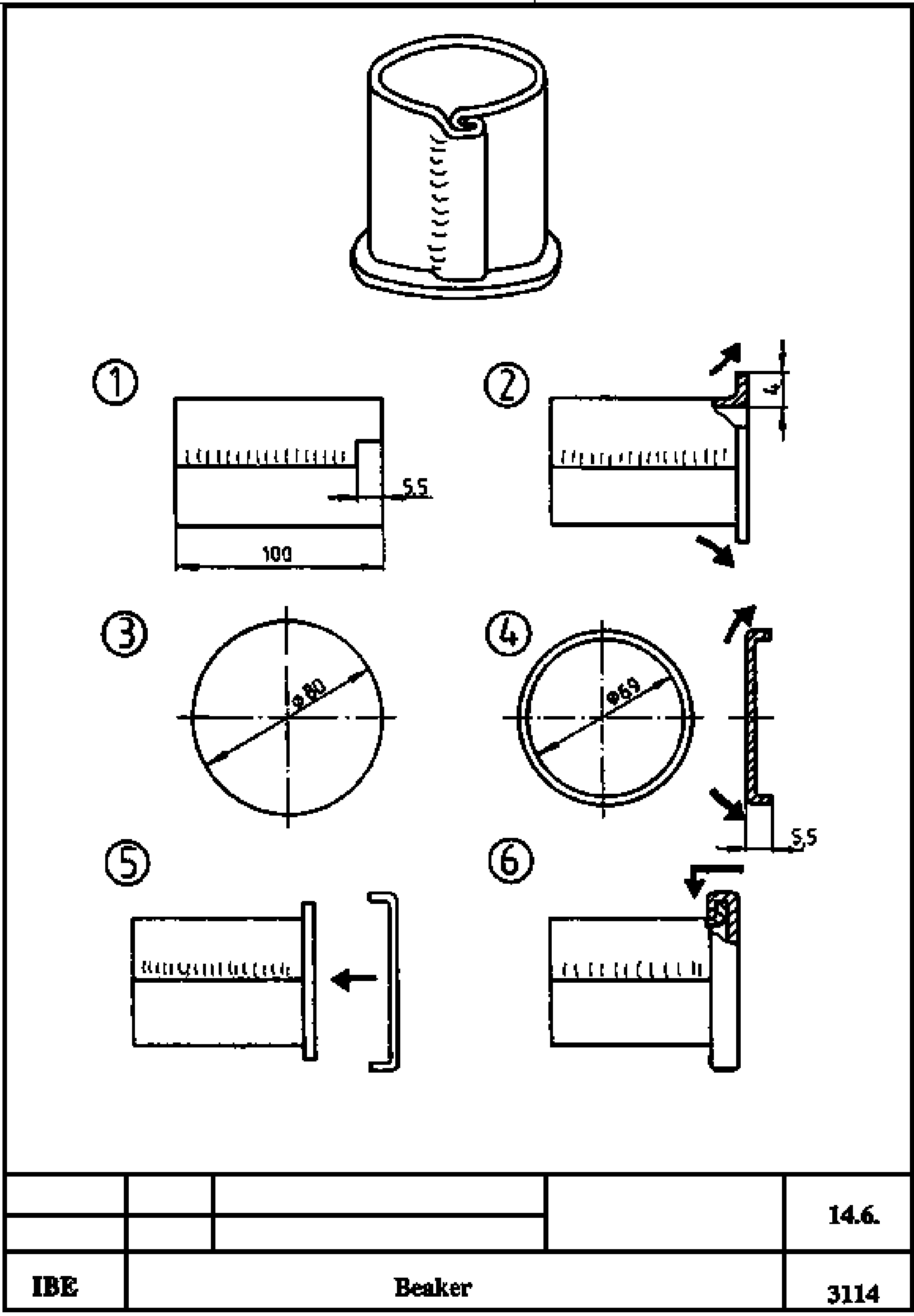
Vise, cylindric striking support ϕ 69 mm, ferrule

Previous knowledge required

Manual material working: Measuring, testing, scribing, hammering, sawing, filing

Sequence of operations	Comments
1. Prepare the working place and make available the working material.	Check completeness.
2. Clamp beaker jacket of Instruction Example 2.5. and shorten seam on one side.	Stage (1)
3. Fabricate outside flanging.	Stage (2)
	Start and finish flanging on anvil.
4. Check diameter 80 mm of bottom sheet	Stage (3)
	Rework, if need be.
5. Scribe bottom sheet for flanging, tightly clamp on cylindric striking support and flange edge.	Stage 4
	Insert ferrule and striking support ϕ 69 mm.
6. Put bottom sheet on beaker (flanged side).	Stage 5

7. Joint bottom sheet and beaker by bottom seam.	Stage 6
	First, fold short bottom sheet piece, then clamp it under the jacket seam and finish folding.
8. Check bottom seam.	Shape.



Beaker

Bending – Course: Technique of Working Sheet Metals, Pipes and Sections. Trainees' Handbook of Lessons

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Bending – Course: Technique of Working Sheet Metals, Pipes and Sections. Trainees' Handbook of Lessons

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Preliminary Remarks

This material is intended for vocational training in jobs where basic skills and abilities in the processing of sheet metals, pipes and sections, are required.

The handbook describes the execution of various bending techniques with tools, appliances and machines. The necessary calculations are explained with the help of examples.

Hints on Labour Safety

In general, the same labour safety rules apply to the bending techniques as to the manual techniques of hammering and straightening.

Especially the following focal points have to be attended to:

– Only use proper hammers – hammer shaft must be tightly wedged with the hammer head.

– Select the correct striking base with regard to the form of bending – a hard and inflexible surface is required.

– Workpieces to be clamped have to be tightly fixed in the clamping fixture so that they are not torn away by the striking impact

– Always strike against the fixed vise jaw so that the vise screw will not be damaged.

– Mind your hands and head when working on presses.

– Work with welding torches must not be performed until the instructor has given the necessary instructions.

– Always observe fire protection – place ready water for fire fighting, do not work in close vicinity to inflammable materials.

– Only bend sheet metals and sections of over 8 to 10 mm thickness and pipes of more than ½" in a heated state.

– Only use dry sand as filler for hot bending of pipes to avoid steam formation.

1. Purpose of Bending

Sheet metals, pipes or sections are remodelled by various techniques in order to give angular or round forms to workpieces to be used for a certain purpose.

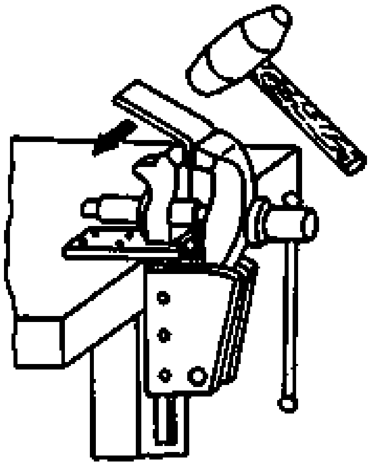

Figure 1 Bending

Due to its versatility, bending is applied in many manufacturing fields:

Folding:	Fabricating short sections, channels, sheet−metal containers or cases as well as frames and supporting structures made of sections.
Turning over:	Fabricating edge stiffenings of containers or cases, preparing saddle joints.
Flanging:	Fabricating sheet−metal joints and edge deformations on containers, preparing saddle joints.
Seaming:	Fabricating sheet−metal joints on containers and pipes.
Crimping:	Fabricating sheet−metal stiffenings on containers and sheet linings.
Rounding:	Fabricating arched sheet metals for containers and pipes as well as curved sections.
Rolling:	Fabricating sheet−metal stiffenings on container rims, hinge joints, cylindrical cavities with flat sections for accommodating pins and spiral springs.

What is the purpose of bending?

____
____
____

Which techniques are applied to bending sheet metals?

____
____
____

2. Selected Tools, Appliances and Machines

Thin cross−sections of sheets, pipes and sections without requiring an exact accuracy to size may be bent by hand with appropriate clamping fixtures.

As for larger and thicker materials, the following tools, appliances and machines are employed:

Hammers:

Such as machinist's hammers, light−metal, wooden and rubber hammers as well as special hammers for manually bending sheet metals.

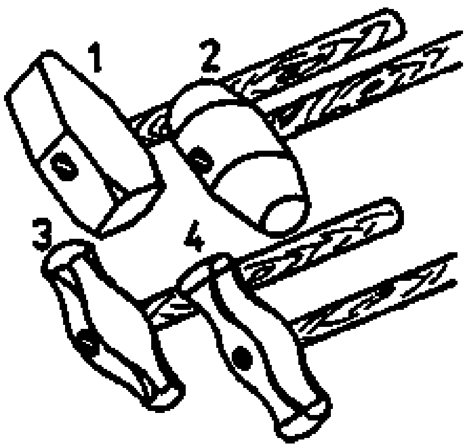

Figure 2 Hammers *1 machinist's hammer, 2 light metal hammer, 3 embossing hammer, 4 sweep hammer*

Pliers:

Such as round−nose and flat−nose pliers to bend small sheets and thin sec−dons on the vise or freely in one's hand.

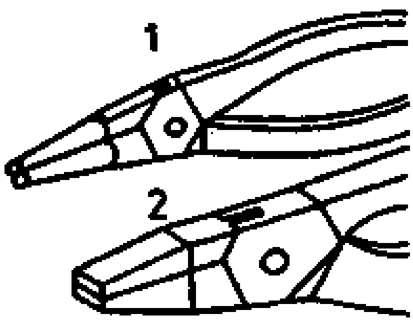

Figure 3 Pliers *1 round nose plier, 2 flat nose plier*

Welding torch:

Such as fuel gas−oxygen welding torches to locally heat the workpiece for hot bending.

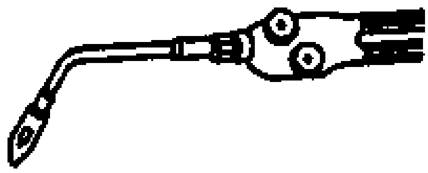

Figure 4 Welding torch

Angle bending device:

This device is used to fold or round flat, square and round section.

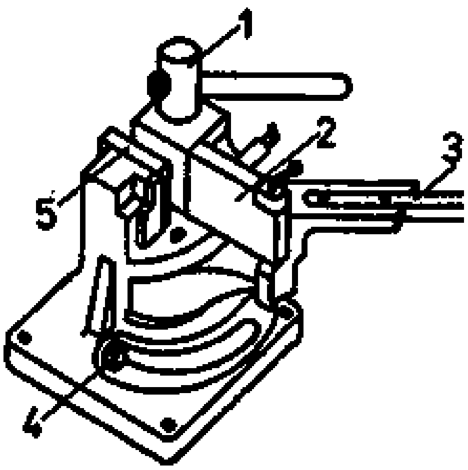

Figure 5 Angle bending device *1 eccentric chuck, 2 moveable bending jaw, 3 bending lever, 4 adjustable dog, 5 fixed bending jaw*

Strip rolling device:

This device is used to round and roll flats, squares and rounds.

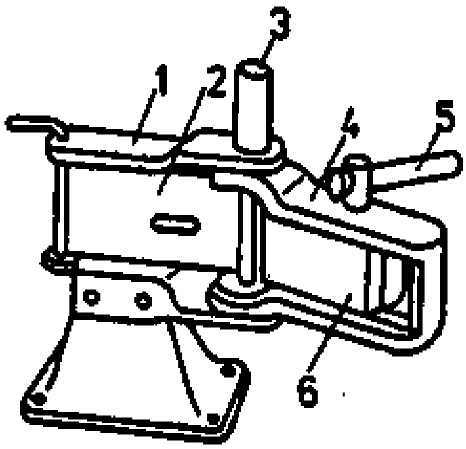

Figure 6 Strip rolling device *1 basic body, 2 adjustable sliding plate, 3 bending mandrel, 4 accommodation for moveable clamping segment, 5 bending lever, 6 clamping segment*

Pipe bending device:

These manually operated or hydraulic devices are used to round pipes.

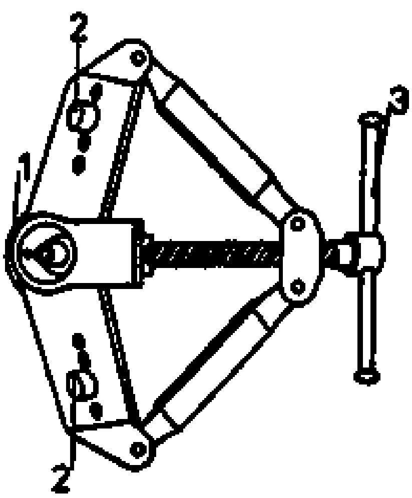

Figure 7 Pipe bending device *1 bending mandrel, 2 dogs, 3 bending screw*

Screw press:

Such as hand−type screw or hydraulic presses with different screw insets and supports to bend sheet metals and sections.

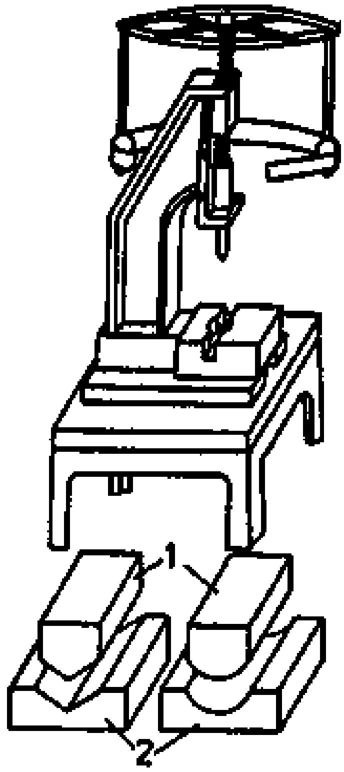

Figure 8 Screw press *1 screw inserts, 2 bases*

Folding press:

Such as table−type and column−type folding presses to fold and partially round sheet metals.

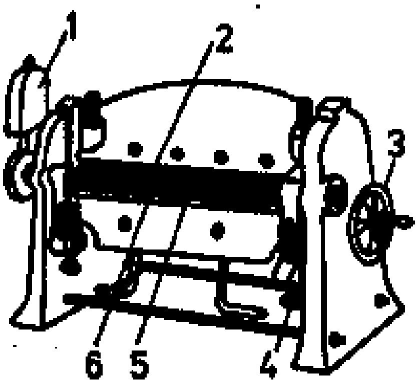

Figure 9 Folding press *1 weight, 2 clamping cheek, 3 crank to adjust top clamping cheek, 4 bolts to adjust bending cheek, 5 bending cheek, 6 bottom clamping cheek*

Rounding device:

Such as hand−operated and mechanical roll bending machines to round and roll sheet metals.

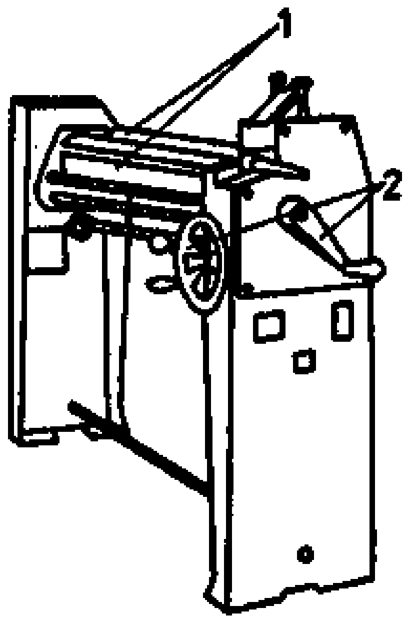

Figure 10 Round device *1 bending rolls, 2 crank to operate bending rolls*

Crimping and flanging machines:

Manually operated and mechanical appliances and machines are used to crimp and flange sheet metals.

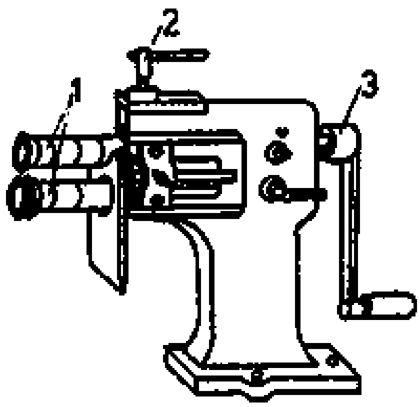

Figure 11 Crimping and flanging *1 bending rolls, 2 adjusting facility, 3 crank to operate bending rolls*

Apart from above tools, appliances and machines, the following clamping fixtures and supports are needed:

Vise:

Such as parallel vises and collet vises with different clamping jaws for manual bending.

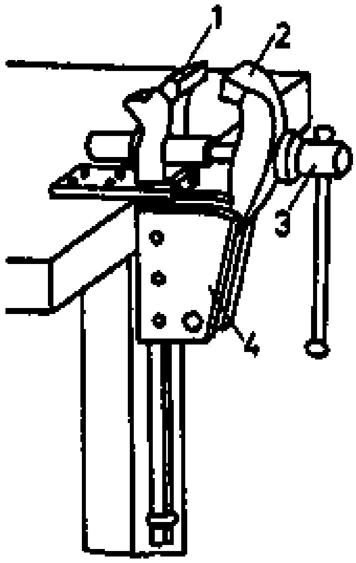

Figure 12 Collet vise *1 fixed jaw, 2 moveable jaw, 3 screw, 4 collet*

Blacksmith's anvil:

Face, round horn and flat horn as well as slip−on striking supports such as creasing stake and double face sledge, hardy and bordering tools for bending work with hammers are used.

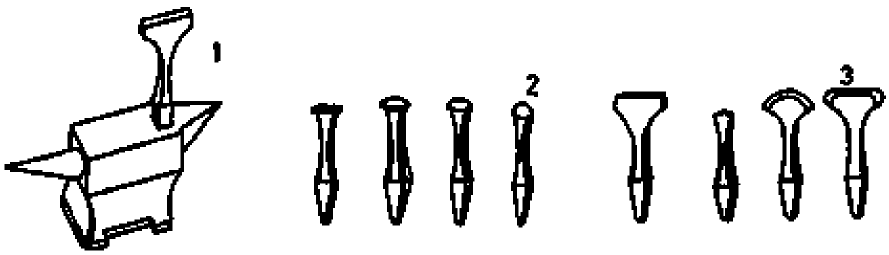

Figure 13 Blacksmith's anvil *1 anvil with slip−on striking base, 2 double face sledge, 3 flanging and hardy iron*

3. Processes within in the Material

Acting bending forces cause stresses in the material affecting a remodelling of the workpiece.

> Tensile stresses occur at external radii of bendings due to stretching the material, while compressive stresses occur at internal radii of bendings due to upsetting the material.

Between those areas where tensile and compressive stresses act, there is a transition zone where no stresses act It is denominated as neutral axis or neutral layer.

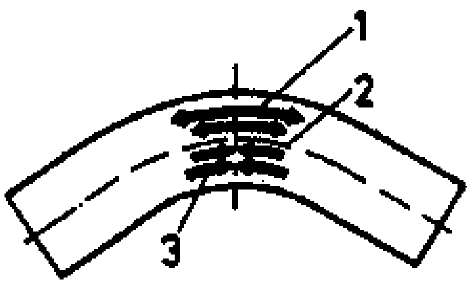

Figure 14 Stresses in the bent workpiece *1 tensile stresses, 2 neutral axis, 3 compressive stresses*

The neutral axis length is needed to calculate the stretched length of the workpiece to be bent

What does the term "neutral axis" mean?

3.1. Influence of Material Properties

Plasticity:

Only can such materials be bent that allow a change of shape. Hardened and brittle materials cannot be bent – they break when strong bending forces act

Spring–tempered materials cannot be bent either – they completely spring back to their initial position after bending forces have acted.

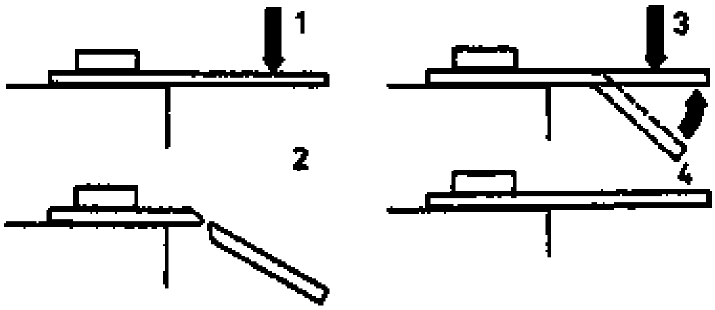

Figure 15 Bending property of various materials *1 bending force acts on brittle material, 2 workpiece fracture, 3 bending force acts on spring–tempered workpiece, 4 workpiece spring–back*

Elasticity:

Elastic materials spring back after application of force by a certain measure – what is called spring–back. This measure must always be taken into consideration when bending.

Hard metals spring more back than soft ones.

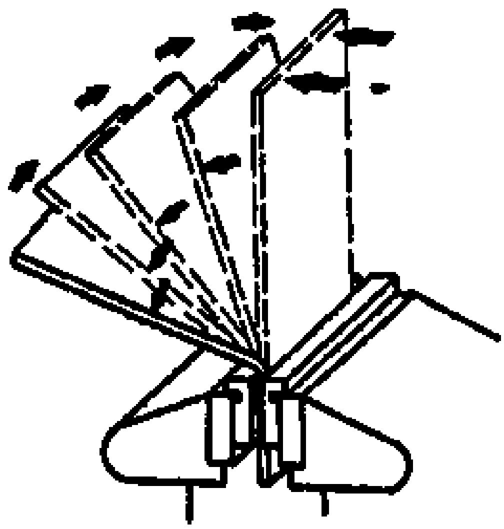

Figure 16 Workpiece spring–back after each force reaction

Strength:

When sheet metals are rolled, a fibre structure comes into being (similar to streaks in wood) which can be seen on the surface of clean sheet metals. To avoid streaks at the external edge of bendings, the bending edge must not be in accord with the streak flow.

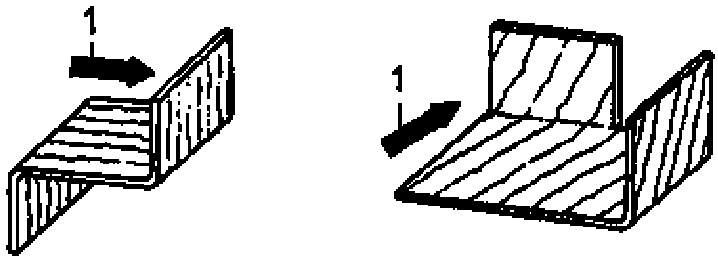

Figure 17 Rolling direction to be considered during bending *1 rolling direction*

Strain−hardening:

When tensile and compressive stresses change for several times during the bending process (to−and−from bending), the material structure is more and more deformed. The increasing internal stresses lead to a hardening at the bending point The more often the change of stresses takes place, the more brittle the material becomes. If deformation continues, it may result in a fracture.

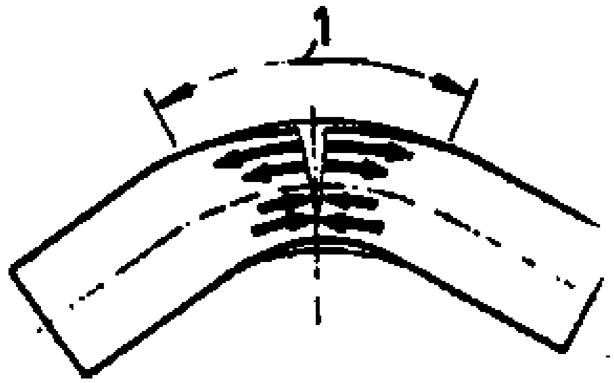

Figure 18 Crack formation at strain−hardened bending points *1 zone of strain−hardening*

Which material properties are not allowed for a piece to be bent?

____
____
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What does the term "spring−back" mean?

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____
____

What will happen when a sheet metal is bent around a bending edge being in accordance with streak flow of the rolling direction?

____
____
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What does the term "strain−hardening" mean?

____
____
____

3.2. Influence of the Bending Radius

To avoid cracks due to bending, the bending radius has to be selected by a size sufficiently large.

The bigger the bending radius, the smaller the risk of cracks.
The thicker the material is, the bigger the bending radius must be.

The bending radius depends on both the shape and thickness of the workpiece as well as the temperature during bending and the kind of material.

Hence, there are fixed minimum radii for all metals and many section forms.

The following minimum bending radii can be applied to as empirical values:

Material	Radius
Copper	0.8 up to 1.2 × thickness
Brass	1 up to 1.8 × thickness
Zinc	1 up to 2 × thickness
Steel	1 up to 3 × thickness

Which influence has the bending radius on the formation of cracks in the workpiece?

Which influence has the workpiece thickness on the bending radius?

3.3. Heat Influence

The more the workpiece is being remodelled, the bigger are the stresses inside the material. Particularly, in bending thicker workpieces with small bending radius, there is such a strong stress on the material that it may crack at the bends' external side.

To avoid this formation of cracks, such workpieces must be heated red−hot. The resistance inside the material decreases with growing heat so that remodelling can be effected without great expenditure of force and without the risk of crack formation.

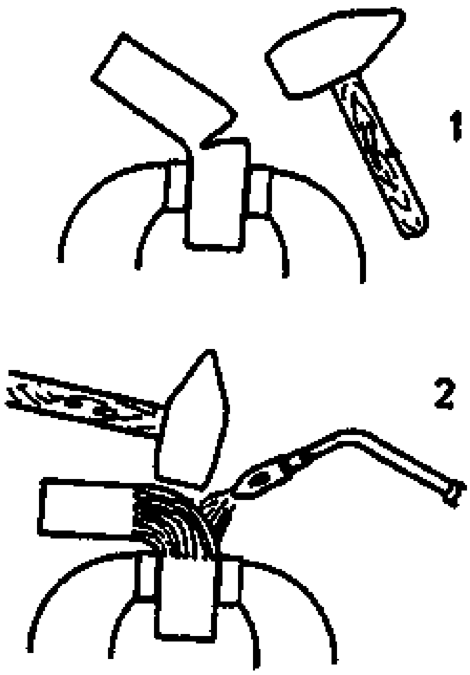

Figure 19 Bending of thick workpieces *1 cold bending leads to crack formation, 2 hot bending makes exact bending procedure possible*

Which influence has the supply of heat on the bending process with thick workpieces?

4. Fundamentals of Calculation

When a workpiece is being bent, its original length may alter by a certain measure.

Therefore, the workpiece has to be cut to size very exactly before being bent The required blank length is called “stretched length” and is to be calculated from the length of the neutral axis.

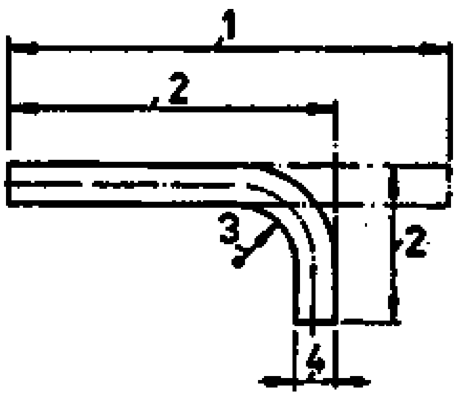

Figure 20 Dimensions on parts to be bent *1 stretched length, 2 leg lengths, 3 bending radius, 4 workpiece thickness*

If the bending radius is bigger than five times the workpiece thickness, the neutral axis runs in the middle of the workpiece. Hence, the neutral axis bending radius is to be calculated with the following formula:

With $R_B > 5 \cdot S$

$$\text{thereforeis } RN = RB + \frac{S}{2}$$

R_N = radius of neutral axis

R_B = bending radius

S = workpiece thickness

If the bending radius is smaller than five times the workpiece thickness, the neutral axis is displaced to the bending internal side during the bending process.

Then the bending radius of the neutral axis can be calculated with the following formula:

With $R_B < 5 \cdot S$

$$\text{thereforeis } R_N = R_B + \frac{S}{3}$$

If workpieces are bent by 360°, the length of bend is calculated with the formula for calculating the circumference:

L_B	=	U	=	D • ?
or L_B	=	U	=	2 • R_N• ?
L_B	=	length of bend		
U	=	length of circumference		
D	=	circle diameter		
?	=	constant with the value of 3.14		

Hence, the following formula is used for a 180° bending:

$$L_B = \frac{D}{2} \bullet \pi$$

or $L_B = R_N \bullet$?

Hence, the following formula is used for a 90° bending:

$$L_B = \frac{D}{4} \bullet \pi$$

$$\text{or } L_B = \frac{R_N}{2} \bullet \pi$$

For any optional bending, the formula of the bending angle is to be considered:

$$L_B = R_N \bullet \pi \bullet \frac{\alpha}{180^\circ}$$

$$\alpha = \text{bending angle}$$

What does the term "stretched length" mean?

How does the position of the neutral axis change when a workpiece is bent around a bending radius smaller than five times the workpiece thickness?

Calculation example:

A flat section is to be bent for several times. Its dimensions are to be seen from the following illustration.

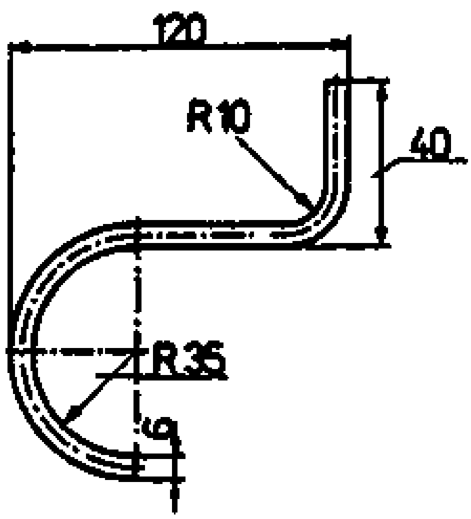

Figure 21 Example for dimensioning a part to be bent

For calculation, the total length is subdivided into 4 partial lengths:

Total length – sum of all partial lengths
L = L1 + L2 + L3 + L4

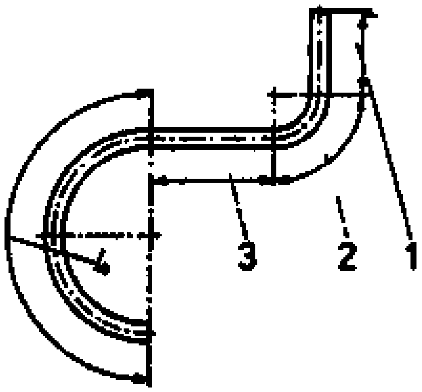

Figure 22 Subdividing the piece to be bent into partial lengths *1 partial length L_1, 2 partial length L_2, 3 partial length L_3, 4 partial length L_4*

The neutral axis of partial length L_1 is calculated as follows:

$L_1 = 40\text{ mm} - S - R_{B1}$

$L_1 = 40\text{ mm} - 6\text{ mm} - 10\text{ mm}$

$L_1 = \underline{24\text{ mm}}$

The neutral axis of partial length L_2 is calculated with the formula derived from that to calculate the circumference for a 90° bending:

$$L_2 = \frac{D}{4} \bullet \pi = \frac{R_{N1}}{2} \bullet \pi$$

Since the bending radius R_{B1} is smaller than five times the section thickness, therefore R_{N1} is:

$$R_{N1} = R_{B1} + \frac{S}{3}$$

$R_{N1} = 10\text{ mm} + 2\text{ mm}$
$R_{N1} = \underline{12\text{ mm}}$

This means for partial length L_2:

$$L_2 = \frac{R_{N1}}{2} \bullet \pi$$

$$L_2 = \frac{12}{2} \bullet 3.14$$

$L_2 = \underline{18.84\text{ mm}}$

The neutral axis of partial length L_3 is to be calculated as follows:

$L_3 = 120\text{ mm} - 2 \bullet S - R_{B1} - R_{B2}$
$L_3 = 120\text{ mm} - 12\text{ mm} - 10\text{ mm} - 35\text{ mm}$
$L_3 = \underline{63\text{ mm}}$

The neutral axis of partial length L4 is calculated with the formula derived from that to calculate the circumference for a 180° bending:

$L_4 = R_{N2} \cdot ?$

Since the bending radius R_{B2} is bigger than five times the section thickness, therefore R_{N2} is:

$$R_{N2} = R_{B2} + \frac{S}{2}$$

R_{N2} = 35 mm + 3 mm
R_{N2} = <u>38 mm</u>

Now, the neutral axis of partial length L4 can be calculated as follows:

$L_4 = R_{N2} \cdot ?$
L_4 = 38 mm • 3.14
L_4 = <u>119.32 mm</u>

With the help of die partial lengths so calculated, the total stretched length of the flat section can be calculated now:

$L = L_1 + L_2 + L_3 + L_4$

L = 24 mm + 18.84 mm + 63 mm + 119.32 mm

L = <u>225.16 mm</u>

The calculated value is always brought up to a round millimetre figure, thus the stretched length of the flat profile is 226 mm.

How is the stretched length of a workpiece calculated, if several different bends are to be made?

5. Bending Techniques

Depending on the form of bend and material thickness, manual and mechanical techniques of cold and hot bending can be applied.

5.1. Folding of Sheet Metals

If sheet metals with as small a bending radius as possible are bent, this process is called "folding". In this procedure, bending angles are fabricated up to 90° on a fixed bending edge.

The sheet has to be clamped in such a way that hammer strikes are directed against the fixed vise jaw during bending.

So, the vise screw is not stressed too strongly.

Always scribe the internal side of the bending with the steel scriber, since the crack (mark) is pressed together after bending and has no fracture effect any more.

The sheet metal is correctly clamped, when the scribed line is in accordance with the fixed vise jaw upper edge.

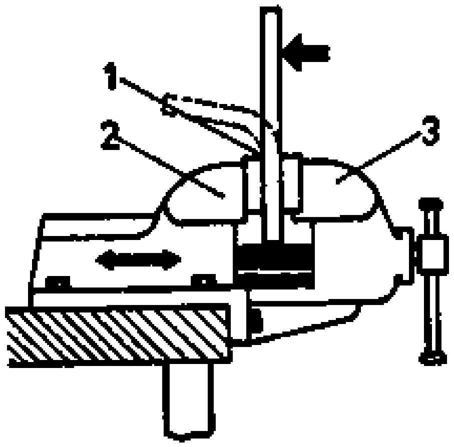

Figure 23 Bending procedure on a vise *1 scribed line, 2 moveable jaw, 3 fixed jaw*

Thin, long sheet metals with short bending edges may be pie−bent by hand or with intermediate plates. Not until then do you strike with the hammer from the exterior towards the bending edge. To avoid the formation of cracks at me bending edge, you should not directly strike on the bending.

Figure 24 Bending of thin, long sheet metals *1 pre−bending by hand, 2 pre−bending with intermediate plates, 3 finish bending with a hammer*

Wooden, rubber or light metal hammers are sufficient for most of the folding works. If, however, strong bending strikes are required, a machinist's hammer together with a hardwood intermediate plate has to be used in order not to damage the workpiece surface.

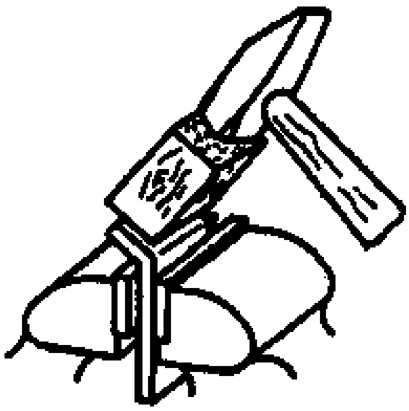

Figure 25 Bending of a thick sheet metal with hardwood intermediate plate and machinist's hammer

Thick sheets with short bending edges can be bent with the machinist's hammer in the vise. In case of hard and brittle sheets, however, a bending radius of at least 2½ times the sheet thickness is to be taken into consideration to prevent the sheet from breaking. This radius can be guaranteed by using appropriate intermediate plates.

Since sheet metals from 8 mm thickness onwards can only be bent with a great deal of manual energy, they are to be bent at a heated state.

If the sheet is to be bent several times, intermediate plates are to be used. The individual bending steps should be so stipulated that even the final bending step can be performed of in high quality.

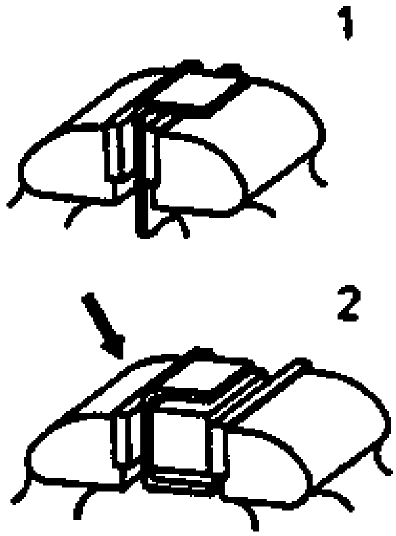

Figure 26 Gradual bending of a workpiece with two bending edges *1 bending of the 1st edge, 2 bending of the 2nd edge with intermediate plate*

Metal sheets with short bending edges may also be bent with the hand screw press. For that purpose, the sheet is to be put between punch and base. With the help of the screw the punch is run down and the sheet is pressed into a base corresponding to the shape.

To compensate spring−back, punch and base are so arranged that the sheet is slightly bent over during the process.

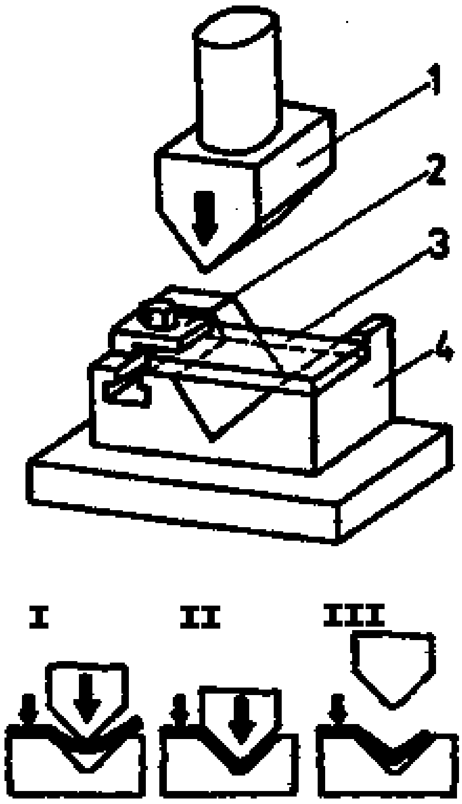

Figure 27 Bending of a sheet metal with the press *1 punch, 2 clamping fixture for the workpiece, 3 workpiece, 4 base* I, II, III bending steps

Thin, soft sheets with long bending edges can be bent by hand with the help of a stable pressure plate. The bending edge should not be scribed with the steel scriber, but with a pencil to avoid formation of crack

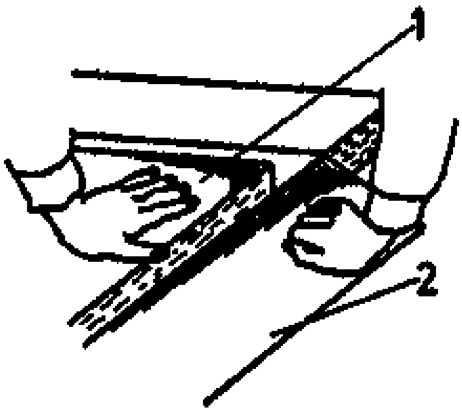

Figure 28 Bending of a soft sheet metal with a pressure plate *1 pressure plate, 2 sheet*

Thin, hard sheets can be bent manually with a hammer when they have long bending edges, by clamping them with additional clamping fixtures on the vise.

The sheet metal is either bent on an intermediate plate over the entire length or with hammer strikes directed from the vise towards the exterior. Finally, the bending edge can be smoothed with an intermediate plate by uniform hammer strikes.

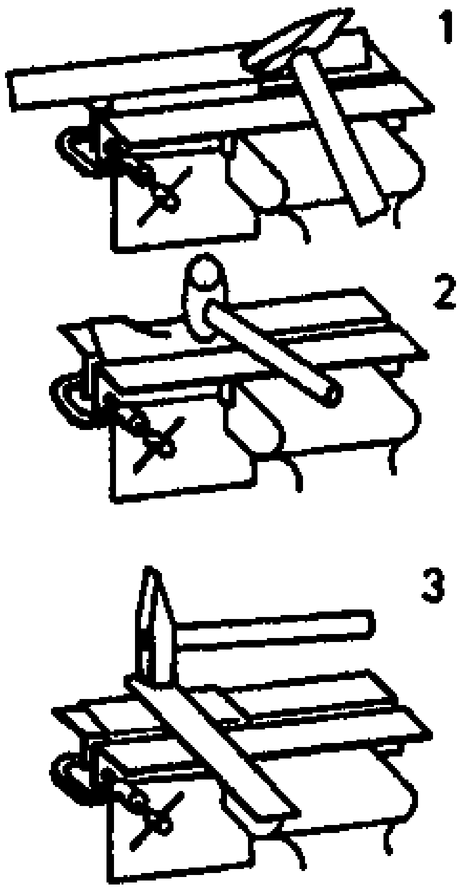

Figure 29 Bending of a hard sheet metal on the vise *1 bending with intermediate plate and hammer over the entire length, 2 continued bending with the hammer, 3 smoothing with intermediate plate and hammer*

Sheet metals with long bending edges can be bent on the folding press very well.

The sheet is put in the folding press in such a way that the scribed line can be seen from above.

The sheet is tightly clamped with the upper clamping cheek, while the bending cheek is so arranged that the sheet thickness is given special attention for bending. Subsequently, the bending cheek is aimed over according to the angle to be bent

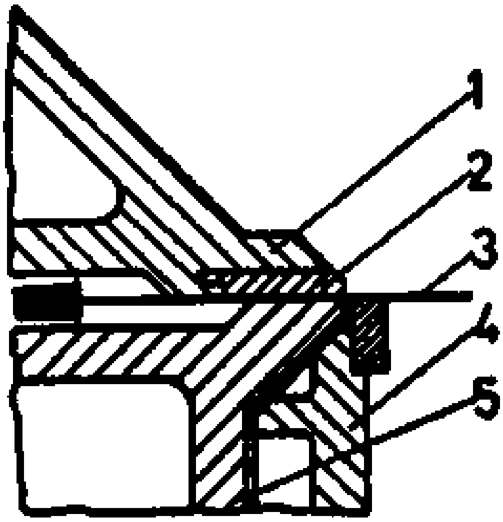

Figure 30 Bending of a long sheet metal in the folding press *1 top clamping cheek, 2 changeable bending rail, 3 sheet, 4 bending cheek, 5 bottom clamping cheek*

When sheets with several bending edges are bent, the respective intermediate plate must be used, with the sequence of bendings to be stipulated in advance so that the final bending edge can be made as to the requirement of good quality as well.

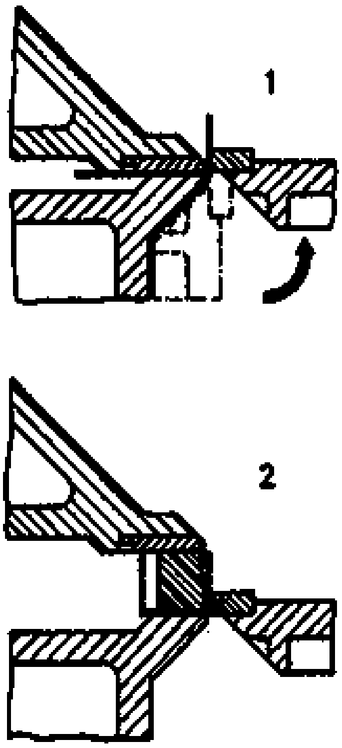

Figure 31 Bending of a sheet channel on the folding press *1 bending of the 1st edge, 2 bending of the 2nd edge with intermediate plate*

Sheets with long bending edges can also be bent with folding presses. The punch presses down on the sheet lying between punch and base and presses the sheet into the respective base recess. According to the desired bending radius, different bending punches are employed.

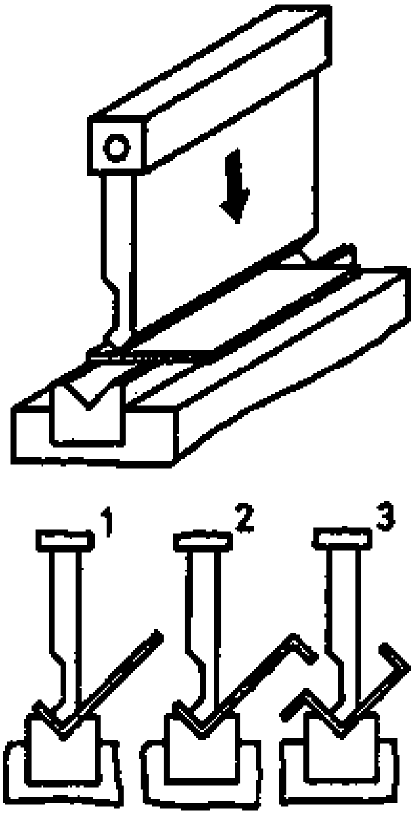

Figure 32 Bending of sheet metals with several bending edges on the folding machine *1, 2, 3 sequence of bending steps*

Sections are folded by separating material off the upsetting zone, with the workpiece being bent on the vise subsequently. Depending on the bending angle, the dimensions of the workpiece zone to be cut out are so stipulated that there will not remain a gap between the surfaces after bending.

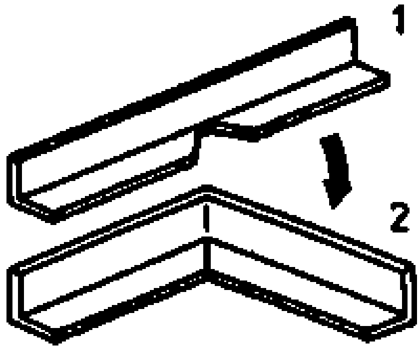

Figure 33 Bending of angular section *1 sawing out the upsetting zone, 2 bending*

To which side is the hammer to be stroken, if a sheet metal is to be folded on the vise?

From which sheet thickness onwards should workpieces be hot bent?

What significance have hardwood or metal shims for bending on the vise?

How are sheet metals with long bending edges to be clamped in the vise?

What must be done before sections are folded?

5.2. Turning−up of Sheet Metals

If angles are to be bent over 90° up to 180°, this procedure is called "turning up", with the workpiece mostly being remodelled in several bending steps.

Sheets are turned up in bending them by the folding technique to an angle of 90° and subsequently bringing them up to 180° with hammers or presses.

The minimum turning−up length depends on the sheet thickness. As for small sheet thicknesses, the sheet rests closely on after being turned up, while in case of bigger sheet thicknesses, a small bead is formed at the place of turn−up.

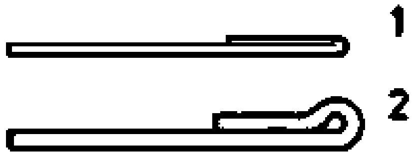

Figure 34 Turning up *1 thin sheet, 2 thick sheet*

How are sheet metals turned up?

5.3. Flanging of Sheet Metals

If sheet rims are bent horizontally or at an angle to the sheet level, this procedure is called as flanging". One distinguishes between external flange and internal flange, both being fabricated manually or mechanically.

Manual flanging is effected by the hammering technique, with the sheet rims being turned up with hammers on respective striking bases (bordering tool and hardy tool). Subsequently, the folds are upset with the machinist's hammer. These two procedures are denominated as "initial flanging" and "finish flanging".

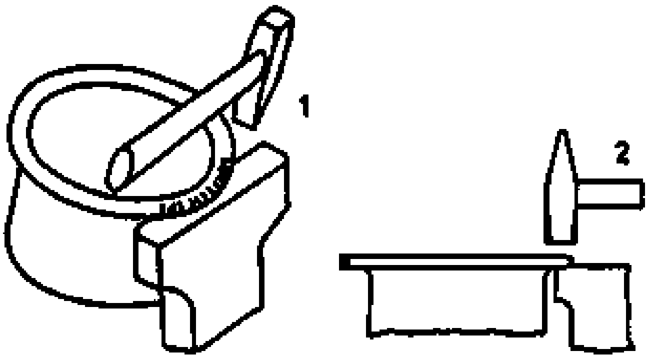

Figure 35 Manual flanging *1 initial flanging, 2 finish flanging*

From the mechanical point of view, flanging is effected with crimping and flanging machines or with flanging devices. The sheet is turned up in several bending steps between a pair of rolls with external and internal roundings until there is the finished rim.

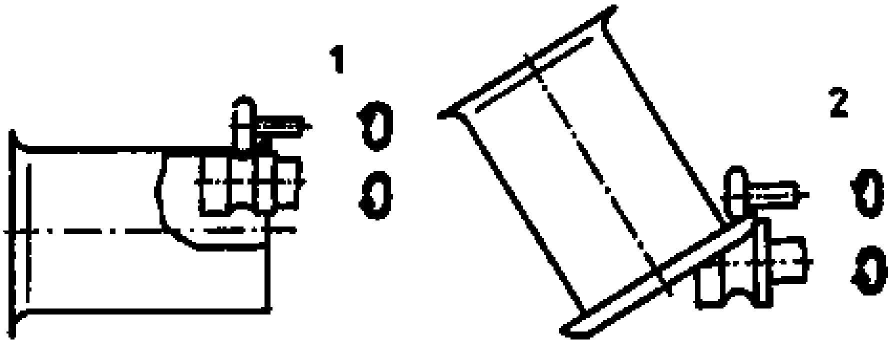

Figure 36 Mechanical flanging *1 initial flanging, 2 finish flanging*

How is a sheet cylinder flanged manually?

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5.4. Seaming of Sheet Metals

If sheet metals to be joint with each other are turned up or flanged, this procedure is called "seaming". According to the function of the scarf joint, there are different kinds*)* of seaming.

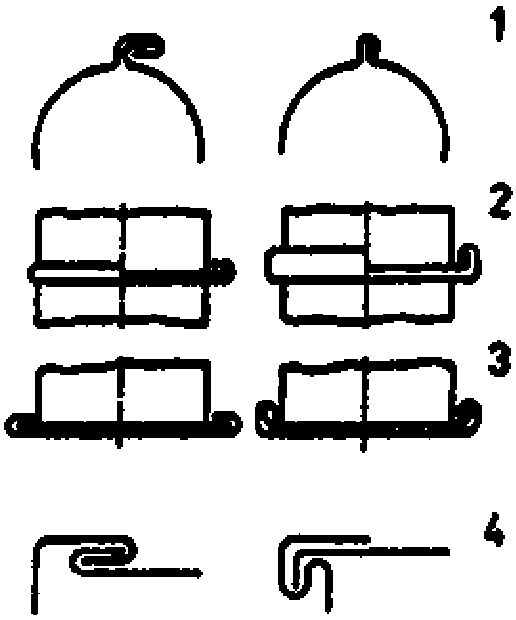

Figure 37 Selected kinds of seaming *1 body seaming, 2 casing seaming, 3 bottom seaming, 4 corner seaming*

Seaming is effected in several working steps. After being folded, turned in or flanged, the sheets are joined by hooking in.

Subsequently, the scarf joint is pressed together and even upset, if need be. To fabricate tight scarf joints, packing rubber may be incorporated or the scarf joint is soldered subsequently.

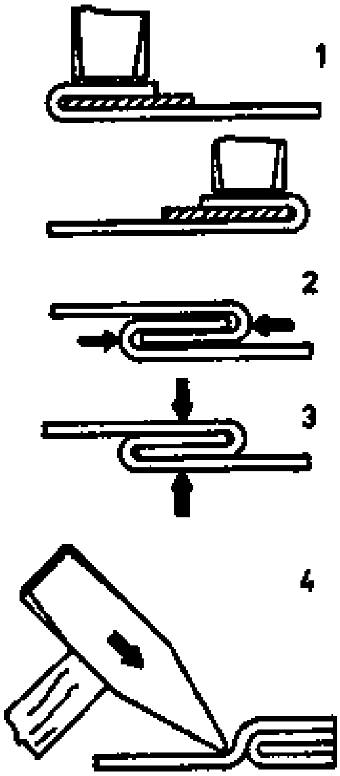

Figure 38 Fabricating a plane seam *1 turning−up with packing rubber, 2 hooking in, 3 pressing together, 4 upsetting*

The following blank lengths are needed for scarf (seamed) joints:

− With single turn−up	3 times the seaming width
− With double turn−up	5 times the seaming width

Sheet thickness	**Seaming width**	**Blank width**	
		Single turn−up	**Double turn−up**
in mm	**in mm**	**in mm**	**in mm**
Sheet steel:			
0.3 to 0.5	5	16	28
0.5 to 0.7	6	19	34
0.8 to 1.2	8	26	45
Light metal sheets:			
to 0.5	6	16	34
0.6 to 0.7	8	26	45
0.8 to 1.4	10	33	56

Mechanically, scarf joints with longitudinal seams can be fabricated on folding presses and folding benches as well as on rolling devices. Round seams on containers and cases are prepared on crimping and flanging machines.

By which working steps is seaming marked?

5.5. Crimping of Sheet Metals

If curl–like recesses are made in plane or rounded sheets, which run from edge to edge or only inside the sheet metal, this procedure is called "crimping".

Manually, crimping is done with a swaging hammer by placing the sheet on the anvil creasing stake and striking it uniformly. So, the hammer strikes the sheet into the creasing stake recesses.

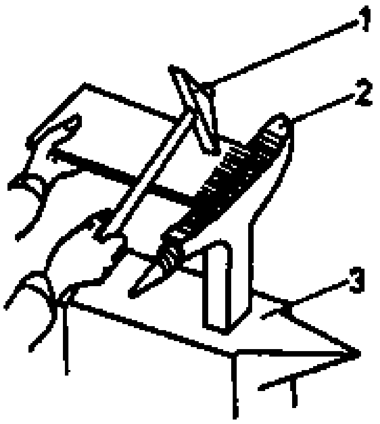

Figure 39 Manual crimping *1 swaging hammer, 2 creasing stake, 3 anvil*

Mechanically, crimping is effected on crimping and flanging machines or crimping devices. The sheet metal is placed between the crimping rolls and formed by turning the rolls.

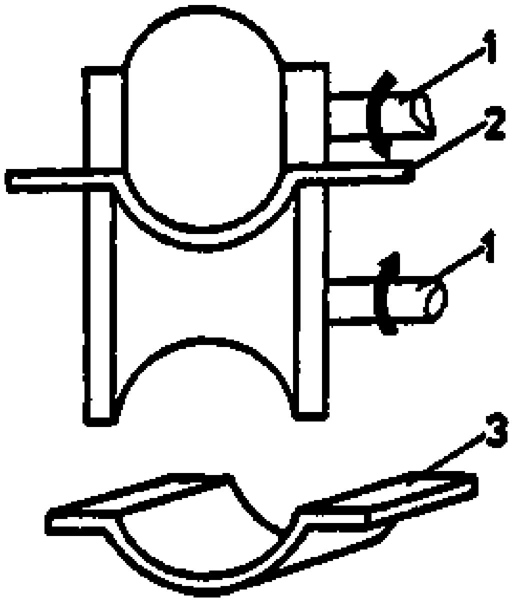

Figure 40 Mechanical crimping *1 seam rollers, 2 sheet, 3 finished piece*

What does the "crimping" process mean?

5.6. Rounding of Sheet Metals

If sheet metals are bent with a bending radius bigger than the smallest possible one, this process is called "rounding" or "bending round". Here, the sheet metal is bent around a bending axis respectively far away from the workpiece surface. The bending angle may be up to 360°.

Short sheets can be bent round on the vise, if the bending die, depending on its kind, is clamped alone or jointly with the sheet The radius of a bending die can be enlarged, when an intermediate plate is put on the bending die and the workpiece is bent over this plate.

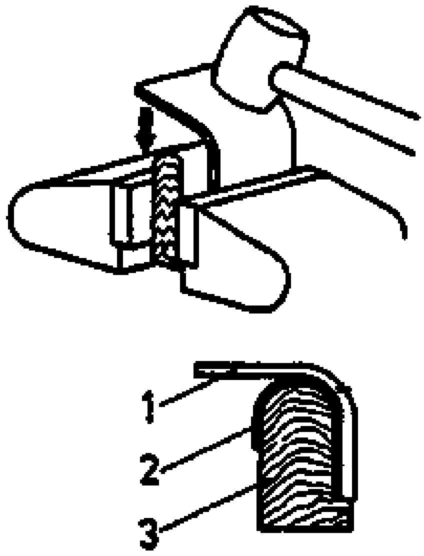

Figure 41 Rounding on the vise *1 sheet, 2 intermediate metal plate for enlargening the bending radius, 3 bending die*

Sheets can be bent round with presses, when bending punches and bases, formed according to the bending radius, are available. The punch is the bending die in this case. Should the need arise, the sheet would have to be bent in several bending steps.

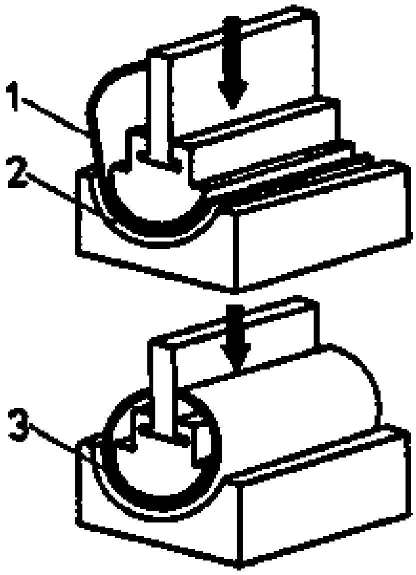

Figure 42 Rounding on the press *1, 2, 3 sequence of bending steps*

Sheets can be rounded on the folding press, when a bending rail (e.g. round sections) with the respective radius is mounted on the upper clamping cheek.

The lower clamping cheek and the bending cheek must be so adjusted that they are away from the bending rail centre of rotation by bending radius plus sheet thickness. In case of bigger bending angles, the sheet has, if need be, to be rounded in several bending steps. However, the bending angle is limited by the adjustibility of clamping and bending cheeks.

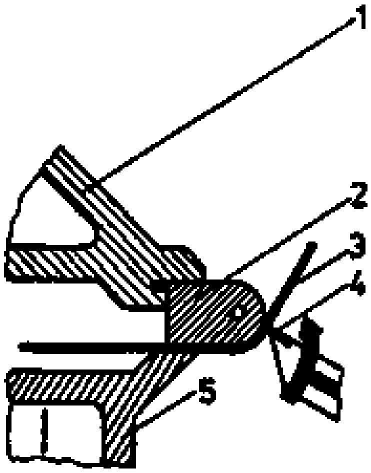

Figure 43 Rounding on the folding press *1 top clamping cheek, 2 changeable bending rail, 3 sheet, 4 bending cheek, 5 bottom clamping cheek*

Long sheet metal can be bent up to the complete circle on the rounding device. Bending force is applied by a pressure roll, pushing the sheet away from the bottom roll and bending it around the top roll. Depending on the bending radius, one or several bending steps are necessary. When the three−roller bending machine is used, the sheet ends are to be pre−bent, otherwise they remain straight by half the length of the distance between bottom roll and pressure roll

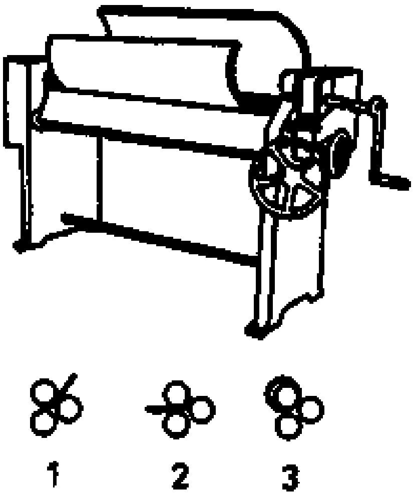

Figure 44 Rounding on the rounding device *1, 2, 3 sequence of bending steps*

How can sheet metals be bent on the vise?

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5.7. Rounding of Sections

Thin round sections may be bent manually or with bending devices. When bending dies are used, attention has to be paid to the fact that, due to spring−back, the radii of bending dies should be smaller than the desired bending radius requires it.

Smaller roundings can be made by turning the workpiece end, gripped with the round nose plier, around the jaws of plier. Bigger roundings are bent on respective bending mandrels of bending devices.

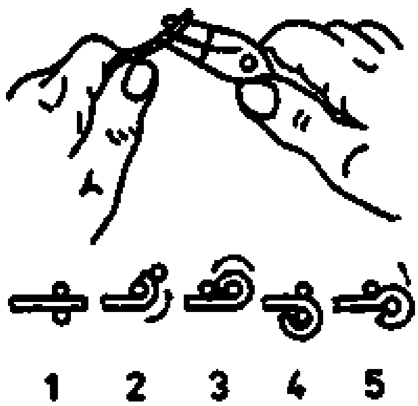

Figure 45 Rounding of thin round sections with the round nose plier *1, 2, 3, 4, 5 sequence of bending steps*

Sections such as flats, angles, tees, and channels may be bent on devices or section bending machines.

Depending on the form of section, the workpieces to be bent are rounded between special profile rolls.

Distortions are avoided by special counter rollers.

According to the kind of profile and size of bending radius, bending has to be effected in cold or hot state.

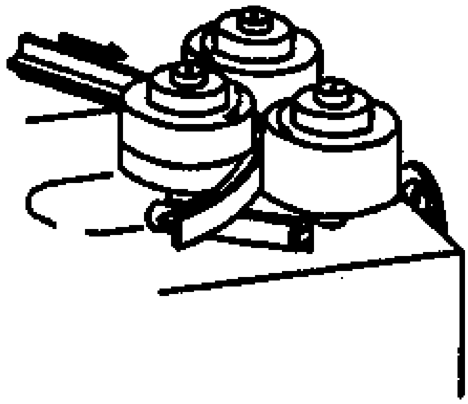
Figure 46 Rounding of angular section with the section bending machine

In bending with bending dies, the workpiece must be tightly clamped at one end and rounded around the bending die with auxiliary tools or hammers. Frequently, this is followed by straightening work.

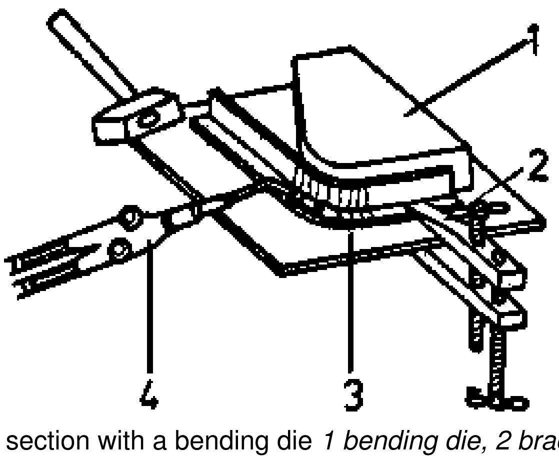

Figure 47 Rounding of angular section with a bending die *1 bending die, 2 bracing, 3 heating zone, 4 welding torch*

Rounding may also be performed over bending dies on swage blocks. The workpiece is tightly clamped in a mounting support and rounded with relevant tools around the contact faces.

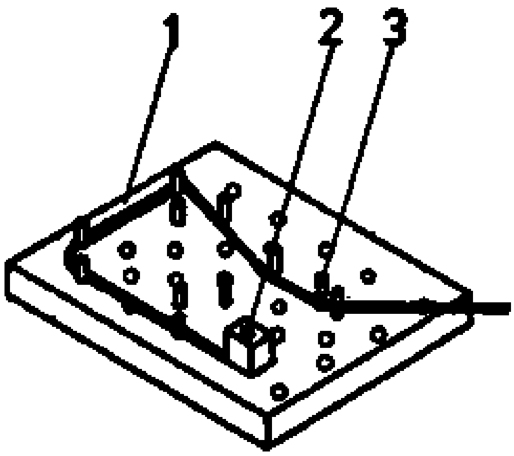

Figure 48 Rounding of round sections on the swage block *1 swage block, 2 bracing, 3 dogs*

Rounding with mechanical bending devices is possible in case of round, square and rectangular cross−sections. The workpiece is fixed in a mounting support and bent with a slide roller to the angle desired.

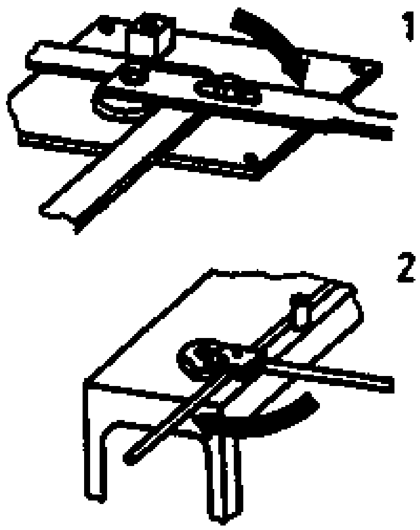

Figure 49 Rounding of sections with bending devices *1 flat section, 2 round section*

Which devices and tools are needed to round sections?

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5.8. Rounding of Pipes

Rounding of pipes requires special measures to prevent them from being flattened at the bending point Counter measures would be:

− Heating to be locally changed on the pipe wall at the bending point during the bending procedure

− Filling the pipe (quartz sand, resin, lead).

Steel pipes having a diameter of more than ½" are to be bent in a heated state with filler. In case of welded pipes, attention has to be paid to the fact that the welding seam is lateral to the bending radius, because the neutral axis is there and thus, the welding seam cannot rupture.

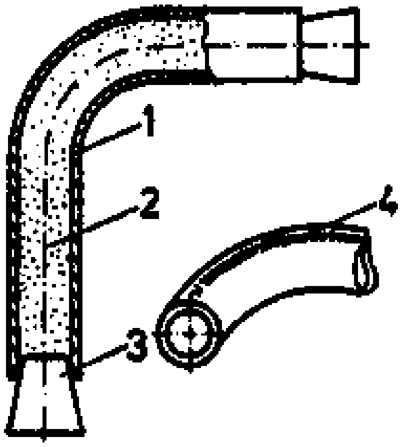

Figure 50 Rounding of pipes *1 steel pipe, 2 sand filler, 3 stopper, 4 position of welding seam lateral to the bending*

Only use dry sand as filler for hot bending.

When being heated, moist sand forms water steam ejecting the locking stopper – risk of getting injured.

Manually, filled pipes can only exactly be bent with pipe bending and other bending devices.

Bending mandrels and bending rollers of appliances and devices should be adapted to the pipe diameter.

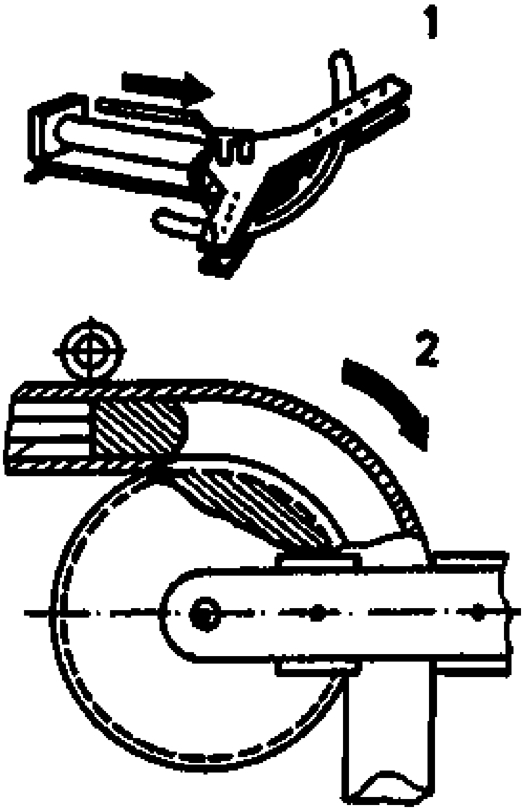

Figure 51 Rounding of pipes with: *1 pipe bending device, 2 bending appliance*

When pipes are hot bent, the pipe zone to be bent is locally heated to a light–red heat (approx. 900 °C). In case of thin–walled pipes the inside of the bending is more heated than the outside so that upsetting at the internal side can be done more easily.

As for pipes with larger diameters, one partial area of the bending zone after the other is heated and bent

Note:

When pipes are bent, a definite minimum bending radius should be adhered to.

Empirical values for steel pipes:

For hot bending:	radius = 2 to 4 × diameter
For cold bending:	radius = 10 × diameter

For hot bending, the bend length is to be calculated previously. It is calculated from the circumference with about 1.5 times the radius, with a bending angle of 90°.

***Example*:**

A steel pipe is to be bent with a bending radius of 75 mm to 90°. The bend length to be heated is calculated as follows:

L	=	1.5 × R	
L	=	1.5 × 75 mm	
L	=	<u>112.5 mm</u>	120 mm selected

The bend length to be heated is divided into two measuring ranges being in a certain relation to each other.

Band length	=	dimension leg	+	bending leg
1	$=$	$\frac{2}{3}$	$=$	$\frac{1}{3}$

The dimension leg corresponds to $\frac{2}{3}$, of the bend length, while the bending leg is $\frac{1}{3}$, of the bend length.

To mark the bend length on the pipe, one has to proceed from the pipe's dimension length being the measure from the pipe beginning to the centre of the pipe end to be bent. Proceeding from the dimension length on the unbent pipe, the dimension leg is scribed to one side and the bending leg to the other one.

Thus, the bend length to be heated has been established.

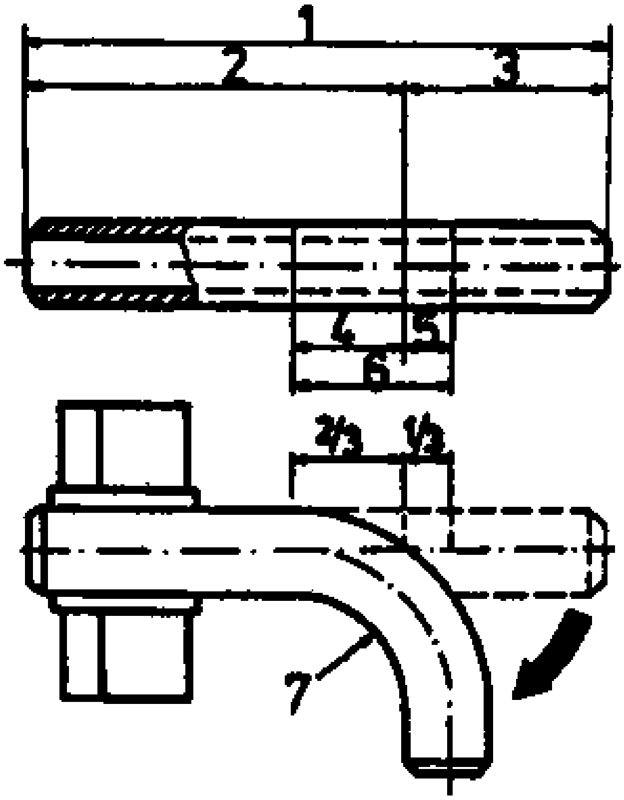

Figure 52 Dimensions on the 90° pipe knee *1 stretched length. 2 dimension length, 3 bending length, 4 dimension leg, 5 bend leg, 6 bend length to be heated, 7 bending radius*

By which means can pipes be rounded?

____
____
____

What is to be noted when pipes of more than ½" in diameter are founded?

____
____
____

What is to be noted when welded pipes are rounded?

____
____
____

Which length is to be exactly calculated prior to hot bending?

____
____
____

How is the bend length scribed?

____
____
____

5.9. Rolling of Sheet Metals

If sheet metals arc so far rounded at their rims that they have a bending angle of 360° and more, this procedure is called "rolling" (or beading). The bending radius is constantly small. Sheet metals may be rolled over a round section manually. For that purpose, they are to be pre−bent over the round section and then brought to the final form over the round section with uniform hammer strikes. If wire is used as a round section, it remains as insert in the bead.

However, it is better to roll sheets on devices.

The device is adjusted to the diameter of the bead and the beaded bar with the respective diameter is inserted (overall bead diameter minus twice the sheet thickness).

Subsequently, the sheet is pushed into the holding slit of the beaded bar and the latter is turned.

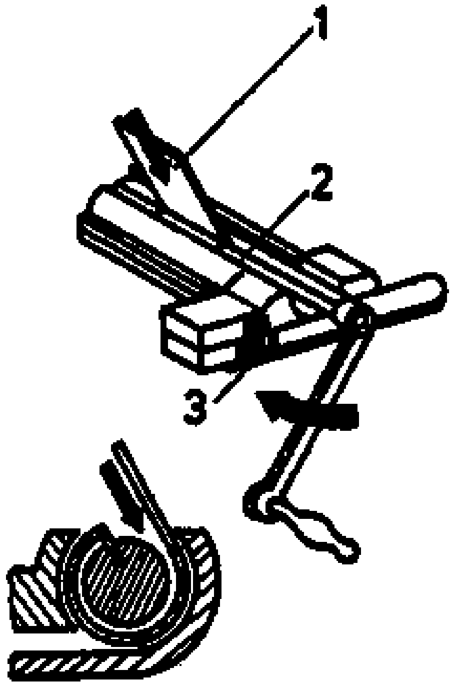

Figure 53 Rolling of sheet rims with a beading device *1 sheet, 2 beaded bar, 3 appliance with control dial*

Sheet metals can also be rolled with presses, if the punch takes over the rolling process by the respective shape arrangement and the sheet is clamped in a fixed base. The sheet metal has to be pie−bent by a small size before the punch is lowered.

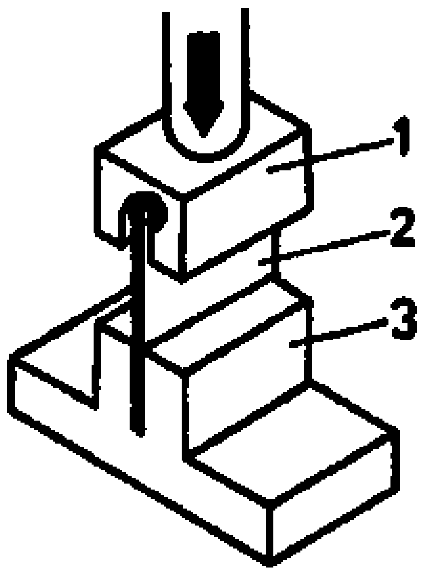

Figure 54 Rolling of sheet rims with presses *1 punch, 2 sheet, 3 base*

By which means can sheet metal rims be rolled?

____

____

____

5.10. Rolling of Sections

Flat sections are manually rolled with the rolling mandrel or on the rolling device. It is important to slightly sharpen the flat section prior to rolling so that after rolling the end sits close and shows a closed eye. After being sharpened the section is pre−bent and then finish rolled. These processes are performed like those for rolling sheet metals.

A special rolling technique is the winding of spiral springs from round sections. For that purpose, steels rich in carbon and having a tensil strength of 700 MPa are used. Mechanically, winding is effected on lathes around a winding mandrel.

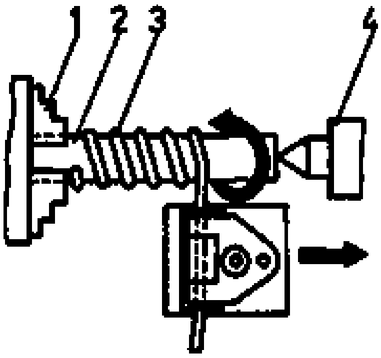

Figure 55 Mechanical winding of a compression spring on the lathe *1 lathe chuck, 2 winding mandrel, 3 compression spring, 4 tailstock with live* centre

Manually, winding is performed on a vise by employing wood clamping screw stocks and winding mandrels.

Tension and compression springs are made by winding spring wire in turns of a coil on a winding mandrel.

Procedure of fabricating a compression spring:

− Threading the spring wire through the winding mandrel hole.

− Clamping the winding mandrel in the wood clamping screw stock on the vise − the winding mandrel can be just turned with the spring wire. When the wire is paid off, its tension must be released, i.e. it is wound in opposite direction to the tension.

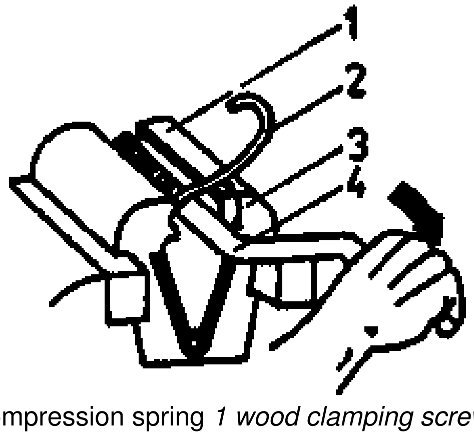

Figure 56 Manual winding of a compression spring *1 wood clamping screw stock, 2 wire tension contrary to winding direction, 3 bevel protractor, 4 winding mandrel*

− Winding the spring − when the spring wire is applied in axial direction, the angle determines the spring lead of helix.

− Carefully open the vise to prevent the spring from bursting open heavily.

− The spring is fitted on a mandrel and face−ground on a grinding wheel − the fully annealed dead coils lie against the springy coils.

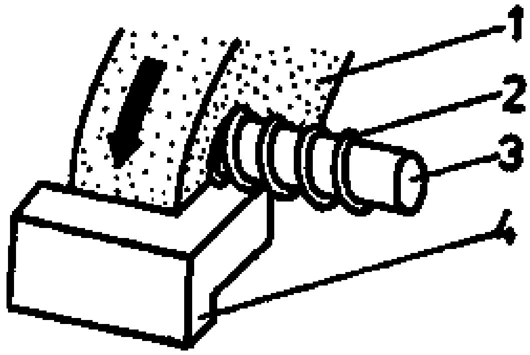

Figure 57 Face−grinding and close−setting of dead coils *1 grinding wheel, 2 spring, 3 mandrel, 4 grinding rest*

Contrary to compression springs, tension springs are closely wound so that the coils are closely−spaced. As for the eyelets, 2 additional coils have to be taken into consideration. When the wire is paid off, its tension is utilized, i.e. it is wound in direction of tension.

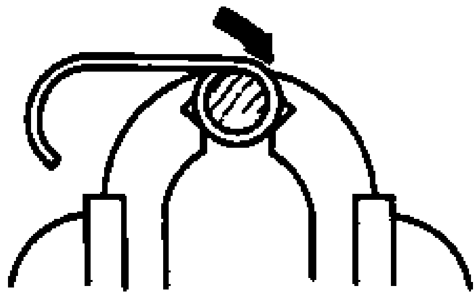
Figure 58 Winding a tension spring in direction of wire tension

After winding, the eyelets are bent off in a clamp.

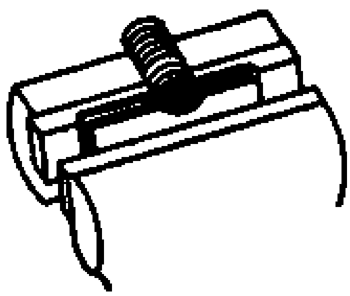
Figure 59 Bending of tension spring eyelets on the clamping plate

Calculation of the compression spring:

A compression spring with 10 active coils with 22 mm medium spring diameter and 30 mm in length is needed.

Hie spring wire is 2 mm thick.

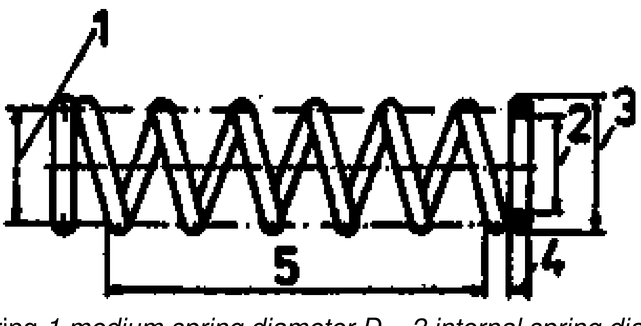

Figure 60 Compression spring *1 medium spring diameter D_m, 2 internal spring diameter D_i, 3 external spring diameter, 4 spring wire diameter D, 5 length of active coils*

First the internal spring diameter must be calculated:

$D_i = D_m - D$
D_i = internal spring diameter
D_m = medium spring diameter
D = wire diameter

Calculation example:

$D_i - D_m - D - 22\ mm - 2\ mm = \underline{20\ mm}$

Afterwards, the diameter of the winding mandrel is to be calculated: $D_w = 0.8 \cdot D_i$

The winding mandrel, due to the wire spring−back, must be smaller than the internal spring diameter:

D_w = winding mandrel diameter

Calculation example:

$D_w = 0.8 \cdot D_i = 0.8 \cdot 20\ mm = \underline{16\ mm}$

Then the wire length is to be calculated: L = ? • $D_m(W + Z)$

In addition to the active coils, 2 times 0.75 of dead coils are to be considered:

L = wire length

= 3.14 (constant)

W = number of active coils

Z = extra for dead coils =1.5

Calculation example:

$L = ? \cdot D_m(W + Z) = 3.14 \cdot 22\ mm\ (10 + 1.5) = \underline{794.5\ mm}$

To be able to hold the wire in the clamp jaw, this length has to be given an extra.

Calculation of a tension spring:

A tension spring of 2 mm spring wire with 25 mm medium spring diameter and 30 active coils is to be wound. 2 coils are additionally needed for the suspension loops.

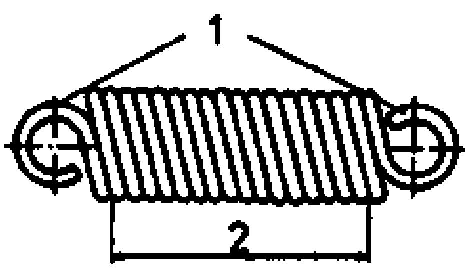

Figure 61 Tension spring *1 hang−up eyelets, 2 length of active coils*

Internal spring diameter

$D_i = D_m - D = 25\ mm - 2\ mm = \underline{23\ mm}$

Diameter of the winding mandrel:

$D_w = 0.8 \cdot D_i = 0.8 \cdot 23\ mm = \underline{18.4\ mm}$

Wire length:

$$L = ? \cdot D_m(W + Z) = 3.14 \cdot 25 \text{ mm } (30 + 2) = \underline{2512 \text{ mm}}$$

By which means can springs be wound?

Chipping – Course: Technique for Manual Working of Materials.
Methodical Guide for Instructors

Table of Contents

Chipping – Course: Technique for Manual Working of Materials. Methodical Guide for Instructors

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1. Objectives and contents of practical vocational training in the working technique of "Chipping"

By concluding their training, the trainees shall have a good command of the working technique of "Chipping". Therefore, the following objectives have to be achieved:

Objectives

– Knowledge of purpose and application of chipping.

– Proper command of the various working techniques of chipping and capability of separating or, resp., cutting workpieces.

– Capability of selecting the appropriate tools and accessories and of using them appropriately.

– Capability of making decisions on quality independently.

The following contents have to be imparted to the trainees:

Contents

– Purpose of chipping
– Tools, accessories and means of protection for chipping
– Action and working techniques of chipping

2. Organizational preparations

In order to guarantee a trouble–free development of the instructions, exercises and practical work it is necessary to prepare this training properly.

The following steps have to be taken:

2.1. Preparations for instructions on labour safety

Prior to the exercises the trainees have to be given a brief instruction on the proper use of tools and equipment. This comprises also hints for accident−free work.

The following points should be emphasized:

- Use proper hammers and chisels only!

- Chisel heads must be free from burrs!

- Protect your hands from accidents by providing the chisel with an impact guard (cover)!

- Wear safety goggles to protect your eyes from injuries!

- Enclose your workplace in the direction of impacts by means of protective gratings or protective screens.

Familiarity with these hints has to be confirmed by the trainees' signatures in a control book.

2.2. Provision of teaching aids

− For demonstration purposes during the instructions a vice should be installed at the place of instruction.

− The "Trainees' Handbook of Lessons − Chipping" is to be handed out to the trainees in sufficient numbers.

− When using the transparencies series of "Chipping", check whether they are complete (transparencies nos. 10.1 − 10.5.) and whether the overhead projector is in working order. (Check the operating conditions at the place of instruction and make sure of the proper mains supply!)

− Surveys etc. which have to be written on the blackboard roust be completed prior to the instruction.

− All the tools and accessories for chipping mentioned in section 3 should be kept ready for illustration purposes.

2.3. Provision of working tools and materials

− Sufficient copies of the "Instruction Examples for Practical Vocational Training − Chipping" must be handed out to the trainees to provide them with the theoretical foundations for the exercises to be carried out.

− The initial materials required for the exercises must be prepared and laid out in sufficient numbers on the basis of materials mentioned in the "Instruction Examples...".

− Each trainee is to be provided with a workbench at which a vice, the required steel supports and good lighting are available.

− The instructor has to check whether the workbenches of the trainees are fully equipped with tools and accessories necessary for the planned exercises.

Recommended basic equipment:

- steel rule, protractor, depth gauge, vernier caliper
- steel scriber, prick−punch, double−point punch
- hammer, hand hacksaw
- flat chisel, cape chisel, half−round grooving chisel, mortise chisel
- bastard and smooth files − 300 mm (flat)
- C−clamps

Bench− or column−type drilling machines and the required clamping tools (machine vice, holding clamps, C−clamps) roust be provided for the necessary preliminary work (drilling) in some of the exercises.

Based on the regulations on labour safety, the instructor has to check that the drilling machines are in good working order prior to the exercises..

2.4. Time schedule

Time planning is recommended for the following training stages

- introduction to the working techniques in the form of instructions
- necessary demonstrations
- job−related instructions to prepare the exercises
- carrying out the exercises
- recapitulations and tests.

The necessary time share depends on the respective training conditions. The biggest time share must be allocated to the exercises.

3. Recommendations for practical vocational training in the working technique of "Chipping"

The following paragraphs comprise proposals on conducting trainee instructions, demonstrations of working techniques, exercises and tests..

Two course variants are recommended:

Variant no. 1

This variant should be chosen for trainees with generally good achievements and receptiveness.

1.1. Introductory instruction for the whole subject, with demonstrations based on the "Trainees' Handbook of Lessons".

1.2. Exercises in chiselling based on the "Instruction Examples 10.1. – 10.5." with subsequent evaluation.

1.3. Final test of theory knowledge based on the "Examples for recapitulation and tests".

Variant no. 2

This variant should be chosen for trainees with little previous knowledge or poor achievements.

2.1. Introductory instruction with demonstrations based on the "Trainees" Handbook of Lessons"

2.2. Exercises in cutting−off chipping based on the "Instruction examples nos. 10.1. – 10.3." with subsequent evaluation.

2.3. Additional instruction in the working technique of chipping chiselling.

2.4. Exercises in cutting−off and chipping chiselling based on the "Instruction examples 10.4. and 10.5." with subsequent evaluation.

2.5. Final test on theory knowledge based on the "Example for recapitulation and tests"

Practical skills should be checked immediately after handing over the finished workpieces. Theory knowledge can be checked constantly; however, it is recommended to have a final test written (item 1.3. to 2.5.) after the exercises.

3.1. Introductory instruction

If possible, this instruction should be conducted in a classroom.

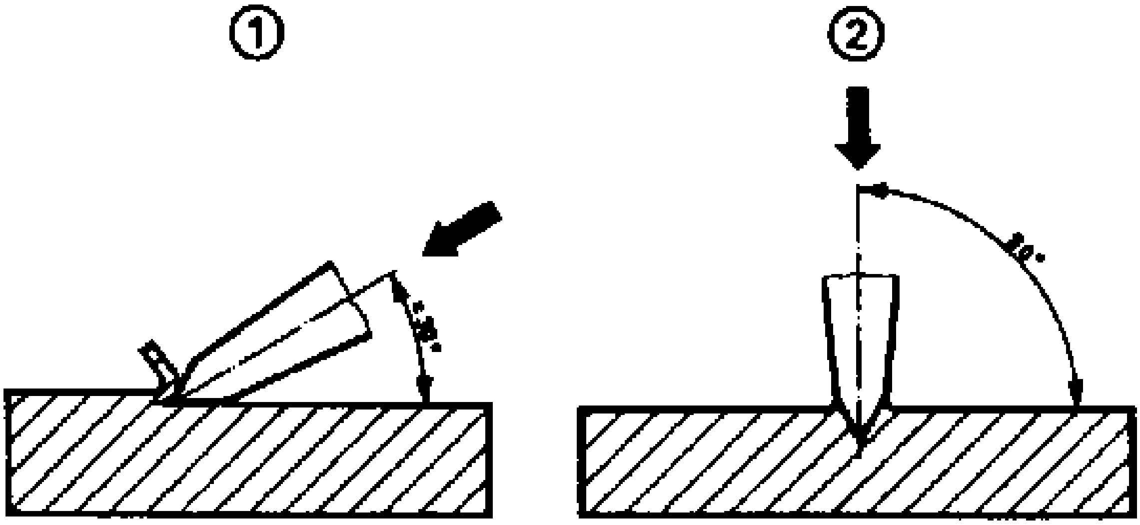
Make sure that the trainees put down necessary and supplementary notes or answers to questions in their "Trainees' Handbook of Lessons".

The instruction can be given based on the main points contained in the "Trainees" Handbook of Lessons".

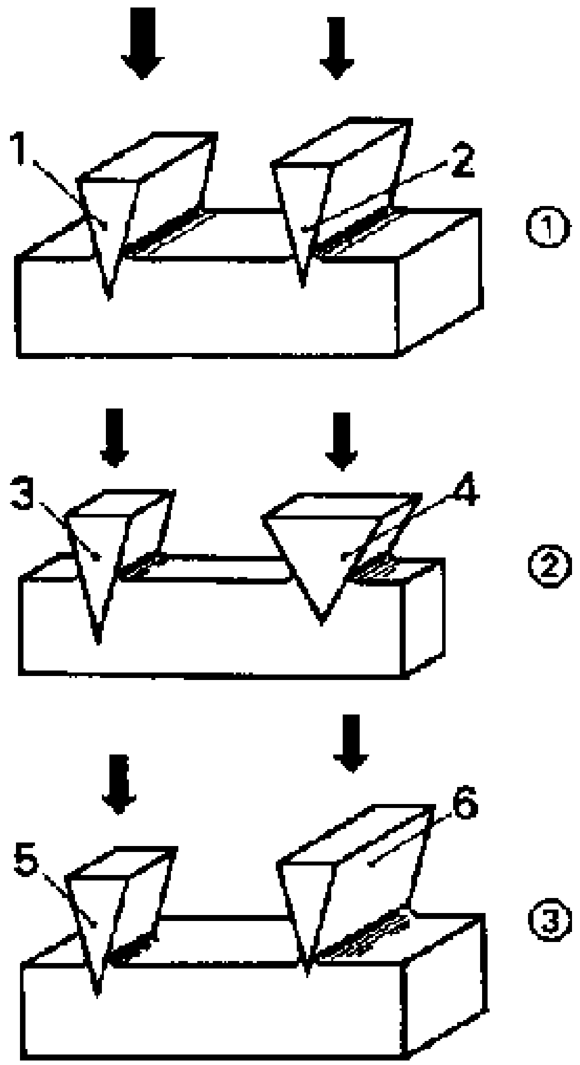
<u>Purpose of chipping</u>:

The trainees have to learn that cutting−off and chipping by chiselling are energy and time−consuming activities. The instructor has to give examples of such cases where it will not be possible to employ machining techniques and where, therefore, chipping is required.

Based on the transparencies nos. 10.1, and 10.2, the instructor can describe the positions and actions of chisels.



Transparency 10.1



Transparency 10.2

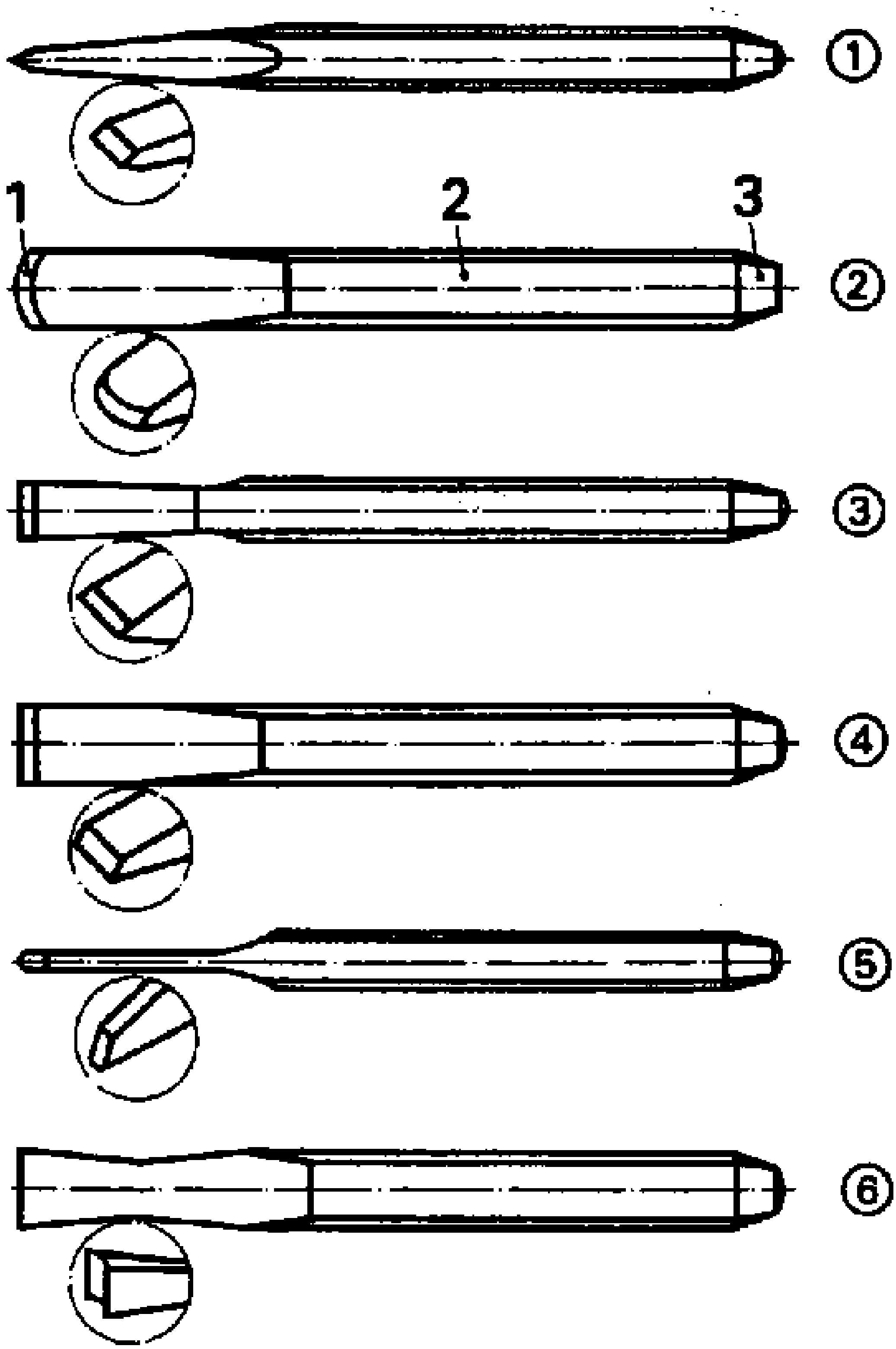
<u>Tools, accessories and protective means for chipping</u>:

The following original tools should be shown and the instructor has to explain when to use them:

- flat chisel (chipping chisel)
- round chisel
- cape chisel
- shear chisel
- grooving chisel
- mortise chisel
- punching tool

If it is not possible to show all the chisels as original tools, transparency no. 10.3. can be used as a teaching aid. The respective illustrations are also contained in the "Trainees' Handbook of Lessons"

When explaining the kinds of chisels the instructor has to mention how chisels are ground.



Transparency 10.3

This includes a description of the relation between the wedge angle of the tool edge and the material properties:

material property	wedge angle
soft (aluminium)	30° – 50°
medium–hard (steel)	60°
hard (tool steel)	

	60° – 70°

Other tools and accessories to be mentioned are:

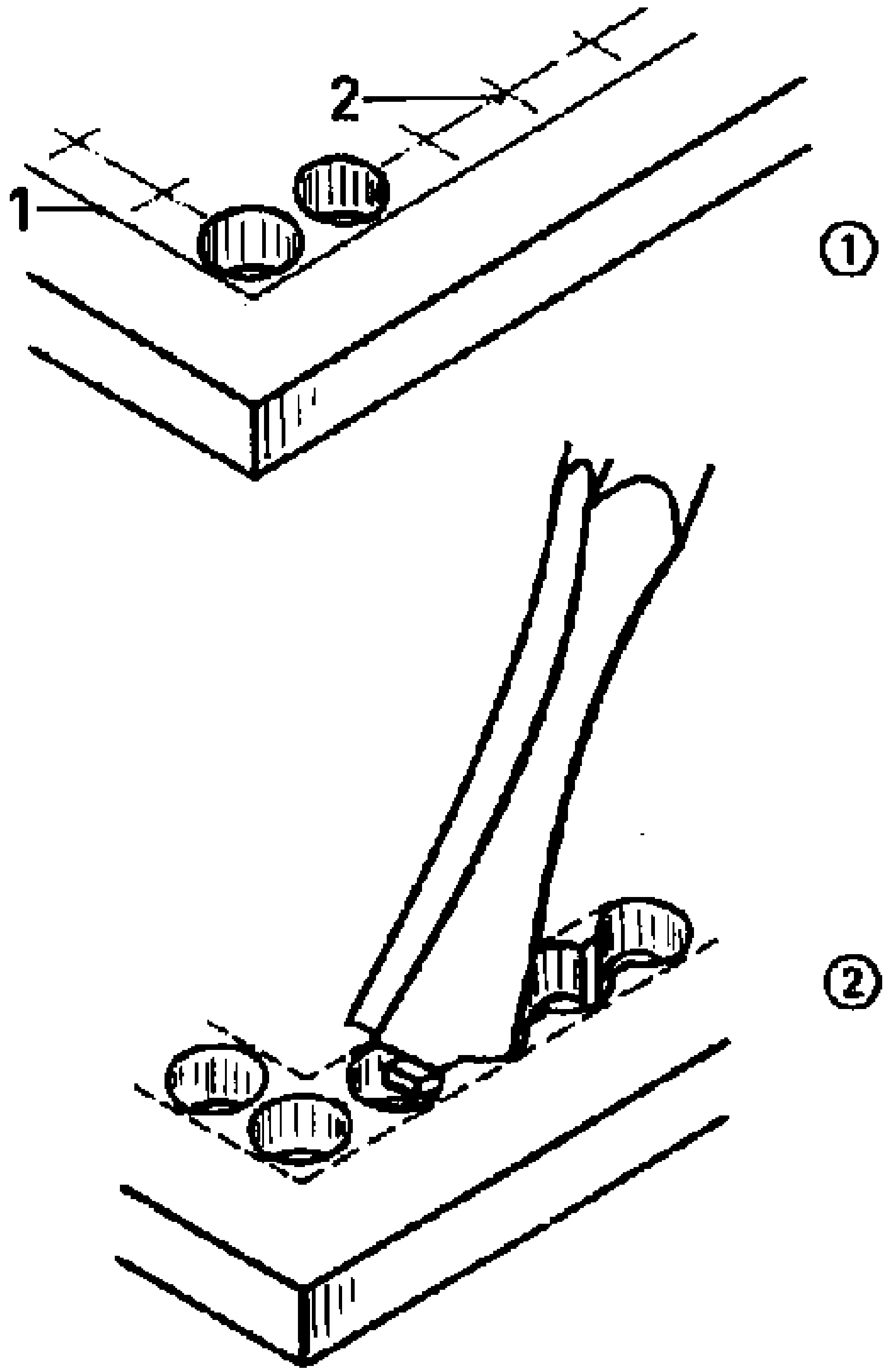
– locksmith's hammer
– supports (steel plates and blocks, anvil)
– vice.

The instructor has to stress that surface plates must never be used as a support, because the chisel edge would destroy the surfaces of the plates. The following means of protection should be mentioned:

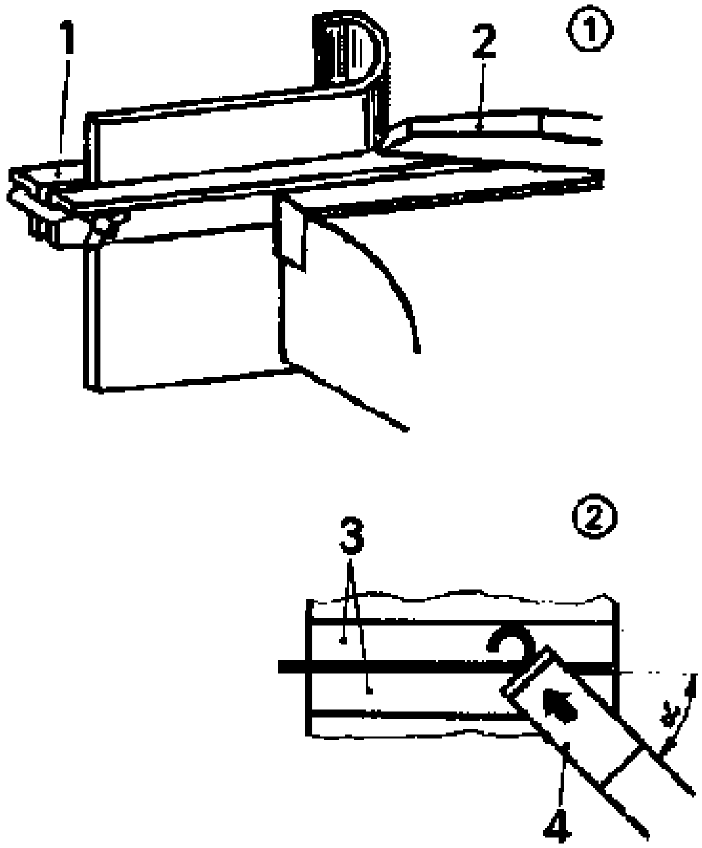
– protective gratings and screens
– safety goggles and impact protection

<u>Action and working techniques of chipping:</u>

This subject can be clearly explained by using transparencies nos. 10.1. and 10.2. as teaching aids. The instructor has to deal in detail with handling the chisel when chipping and cutting–off. This instruction can be supported by the hints contained in the "Trainees' Handbook of Lessons" and the respective illustrations, as well as by using transparencies nos. 10.4. and 10.5. as teaching aids.



Transparency 10.4



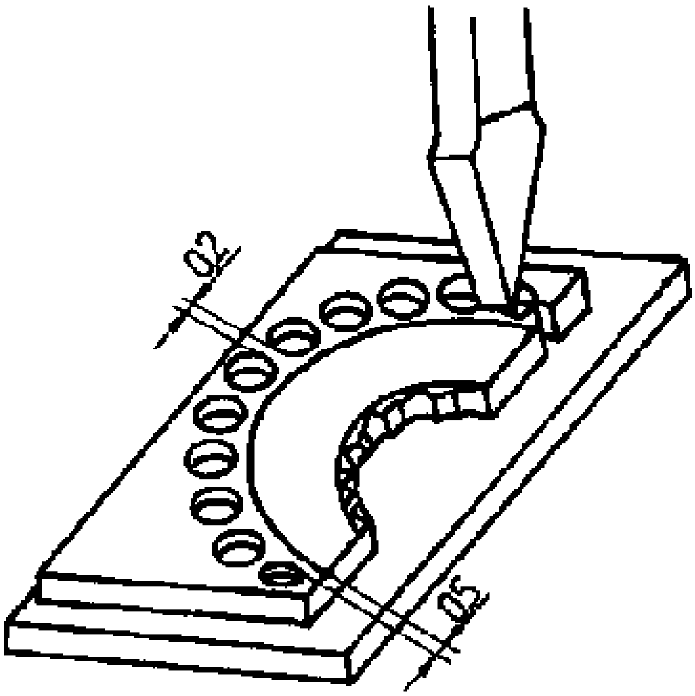
Transparency 10.5

If possible, the instructor has to give a demonstration of chipping and cutting−off chiselling on small−size steel parts. When speaking about cutting−off chiselling of curved contours the instructor has to refer to the preparation of this work by scribing a bore line. He has also to refer to the necessary formulae, and a calculation should be done using the available widths of a double−point punch.

D = diameter of drill
y = width of double−point punch
x = distance of bore line from scribed line

$$D = y - 0.2 \text{ mm}$$

$$x = \frac{D}{2} + 0.5 \text{ mm}$$



Drilling and chiselling out of curved contours

3.2. Exercises

If it has not been possible to include demonstrations in the instructions, this should be done right now prior to the exercises.

Subsequently, the trainees can begin with their first exercises based on the "Instruction examples for practical vocational training".

However, it is necessary to prepare every individual exercise by a brief "job−related instruction" in the course of which the trainees are shown a finished workpiece in order to demonstrate the objectives and purpose of the exercise.

> The instructor roust have made such a workpiece himself in order to be familiar with all the problems which might arise from producing such a workpiece.

Thus, the main points of evaluating the achievements can be clearly defined, and the instructor can inform about difficult areas in the exercise. During these instructions the sequences of operations and the working drawings should be placed on the desks so that the trainees can put down additional notes therein.

All the trainees can perform these exercises simultaneously, provided that the necessary tools etc. are available. In this case the trainees can carry out all the individual exercises by themselves. Each trainee should be given as much time as required.

If there are not enough tools available, the instructor has to form groups of trainees. It is recommended to divide these groups on the basis of applying the various kinds of chisels:

group no. 1 – working with flat chisels only
group no. 2 – working with flat, cape and grooving chisels.

If there are still trainees who cannot take part in these exercises, they should perform additional exercises to consolidate working techniques acquired earlier.

3.3. Examples for recapitulation and tests

This section comprises questions which are to consolidate and test the previously acquired knowledge and skills. Each question is provided with the respective answer. Questions which are also contained in the "Trainees' Handbook of Lessons" are marked with the letter "A".

1. What is the purpose of chipping?

(Cutting−off or chipping of material.)

2. When do we employ the chipping technique?

"A" (If it is not possible to employ mechanical techniques or if these are too costly.)

3. What is the material chisels are made of?

"A" (Unalloyed tool steel with hardened cutting edge.)

4. What are the criteria for selecting chisels?

"A" (The criteria are: kind of work and hardness of material−of the workpiece.)

5. What kinds of chisels do we know?

(flat, round, cape, shear, grooving, mortise and punching chisels (tools).)

6. What is the purpose of using flat chisels?

"A" (Flat chisels are the most common tools for cutting−off and chipping chiselling)

7. What is the purpose of using cape chisels?

"A" (They are used for cutting out horizontal grooves and for cutting−off the webs in bore lines.)

8. What is the recommended wedge angle of cutting edges for working on medium−hard steel?

"A" (60°)

9. Which additional tools and accessories do we need for chipping?

"A" (Hand hammer, supports, vice.)

10. What is the basic principle for selecting the hammer?

"A" (The hammer must have double the weight of the chisel.)

11. Which property must supports have?

"A" (They roust not be hardened so that they can absorb the impact of blows.)

12. Why roust surface plates never be used as supports?

"A" (The penetrating chisel edge would leave notches and uneven spots on the plates so that they could no longer be used for their proper purpose.)

13. What do you have to take into account when chiselling a workpiece in a vice?

(You roust hammer against the fixed jaw of the vice and use a firm counter−support.)

14. Which protective means are used to prevent accidents?

(Protective gratings or screens, goggles and impact protection.)

15. What is the task of protective screens and safety goggles?

"A" (To protect people from being hit by flying chips and fragments of workpieces.)

16. What is the action of chiselling?

(The impact of the hammer on the chisel head is transferred to the cutting edge, which **can** perform its chipping work now.)

17. What is the position of the chisel in a chipping operation?

"A" (The chisel inclination towards the surface of the workpiece is about 30°.)

18. How are metal sheets chiselled which are clamped in a vice?

(The chisel must be in an inclined position − with an angle of inclination of 45°.)

19. What is the position of the chisel in a cutting−off operation?

"A" (Perpendicular to the surface of the workpiece.)

20. How can we chisel off curved contours from thicker workpiece?

"A" (Scribing and punching of a bore line with a double−point punch; drilling; chiselling off the webs with mortise chisel.)

4. Application of the working technique of "Chipping"

Based on the variants mentioned in section 3, the exercises can be designed as a single subject−oriented instruction or in several stages.

Based on the "Instruction examples for practical vocational training − Chipping" the trainees can carry out 5 exercises with an increasing degree of difficulty.

These "Instruction examples ..." also comprise a list of materials (initial material, hand tools, measuring and testing tools, accessories) as well as a sequence of operations associated with the exercise. Also contained is an illustrative working drawing. Thus, the trainees avail of all the necessary information in order to begin their exercise−related work.

If the course of the exercise reveals that the quality of the workpieces does not meet the requirements, the trainees must carry out comprehensive preliminary exercises.

In this case they should use any waste parts. After having practised the skill sufficiently, the envisaged workpiece can be manufactured.

The following hint for organising the work should be taken into account:

> The trainee has to carry out all the necessary work by himself − from cutting the initial material up to the completion of the workpiece.

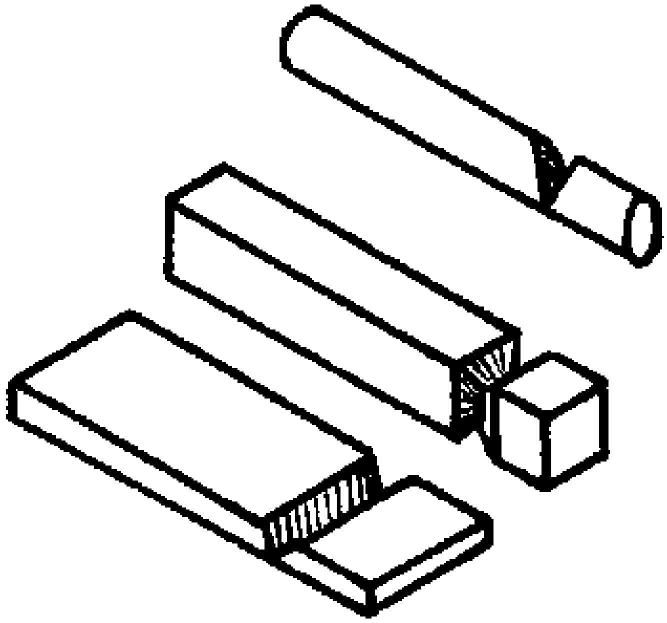
This is the only way to guarantee *a* just evaluation of the achievements.

If the proposed instruction examples cannot be used for the exercises, it will be possible to select other workpieces. In this case the instructor has to make sure that the trainees can practise all the working techniques mentioned earlier.

4.1. <u>Instruction examples</u>

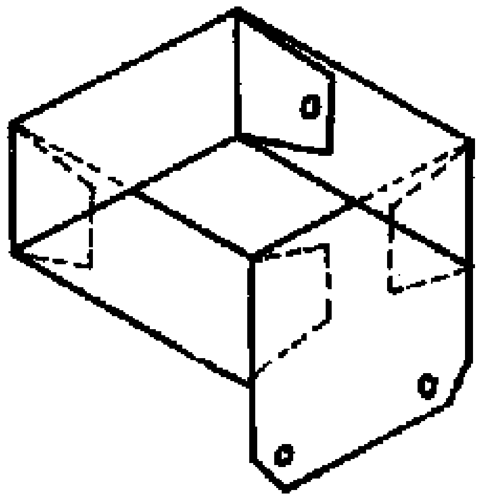
What follows is a brief description of the individual instruction examples in order to give a survey of those workpieces on which the knowledge previously acquired can be practised.

Instruction example 10.1.
<u>Training workpieces for cutting−off chiselling</u>



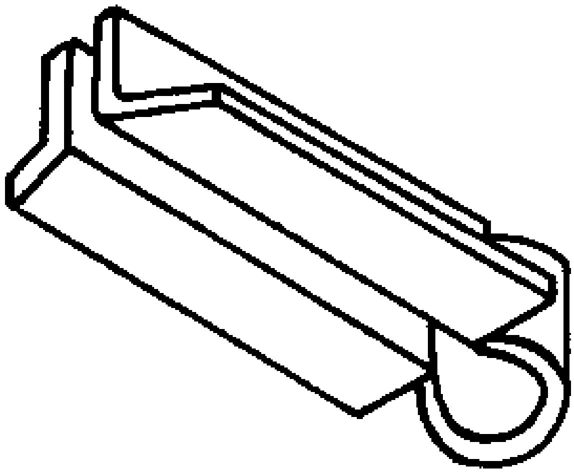
The technique of cutting−off chiselling will be practised at various cross−sections of steel.

Instruction example 10.2.
Case for safety goggles



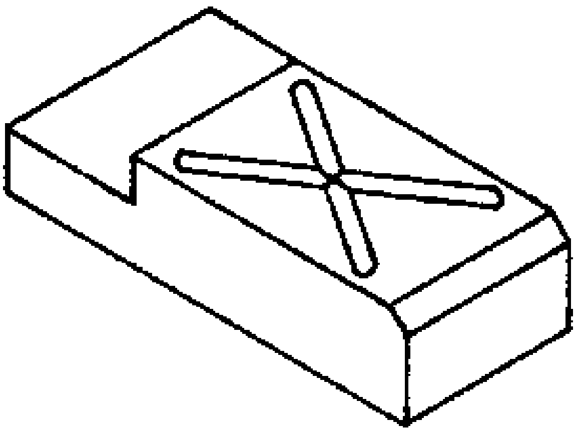
Cutting−off and shearing chiselling practises are employed to form a metal sheet in such a way that it can be bent to form a case. This case for safety goggles must be properly dimensioned. It can be fixed close to the drilling or grinding machines.

Instruction example 10.3.
Dog vice for sheet metal



The trainee has to produce a bore line on angle steel and to chisel off sections and cut−outs. This workpiece can be used for clamping metal sheets in a workshop vice..

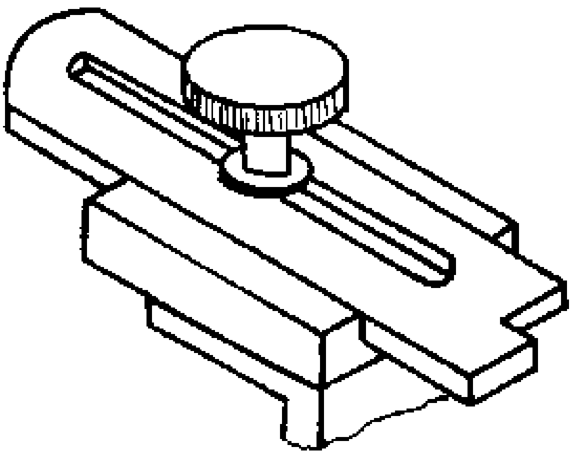
Instruction example 10.4.
<u>Drilling support</u>



The trainees practise the chipping chiselling of surfaces and grooves on cast iron. They employ cape and grooving chisels.

After its completion this workpiece can be used as an accessory for drilling machines.

Instruction example 10.5.
<u>Marking gauge</u>



Several flat steel components serve to practise cutting−off and chipping chiselling by producing break−throughs and by working on surfaces. After its completion this device can be used as an accessory for marking−out operations.

4.2. Criteria for practical training

It is recommended to determine some crucial points of evaluation and supervision. The following criteria can serve as a guideline:

Cutting−off chiselling

– Is the chisel position precisely perpendicular?

– Does the trainee drill the corner points in thin metal sheets and continue by chiselling on a hardened support?

– Does the trainee notch thicker sections from all sides in order to break them?

– Does the trainee prepare long dividing lines by producing a guide notch?

– Does the trainee prepare curved contours, which are to be chiselled off, by providing a bore line?

Chipping Chiselling

– Is the chisel position properly inclined?
– Does the trainee chisel off thin layers at narrow surfaces with the chisel in an angular position?
– Does the trainee chisel off thicker layers in several stages?

5. Captions and legends of the "Chipping" transparencies aeries

Transparency no. 10.1. Position of chisel in chipping and cutting−off operations

(1) chipping chiselling

(2) cutting−off chiselling

Transparency no. 10.2. Principle of wedge penetration (chisel edge) into the material

(1) equal wedge angles – unequal action of force

1 action of higher force

2 action of lower force (smaller depth of penetration)

(2) different wedge angles – equal action of force

3 smaller wedge angle

4 bigger wedge angle (smaller depth of penetration)

(3) different edge lengths – equal action of force and equal wedge angle

5 smaller length of edge

6 bigger length of edge (smaller depth of penetration)

Transparency no. 10.3. Kinds of chisels

(1) flat chisel (chipping chisel)

(2) round chisel (3) cape chisel

(4) shear chisel

(5) grooving chisel

(6) mortise chisel

Transparency no. 10.4. Chiselling–off of thin metal sheets

(1) Scribing and drilling

1 scribed line

2 bore line

(2) Chiselling out of "webs" with a mortise chisel

Transparency no. 10.5. Shearing–off of metal sheets

(1) shearing–off of longer metal sheets by shearing chisel and dog vice for sheet metal (angle steel with clamp)

1 dog vice for sheet metal

2 shearing chisel

(2) shearing process in a vice

3 vice jaws

4 chisel angle of inclination of about 45°

Chipping – Course: Technique for Manual Working of Materials. Instruction Examples for Practical Vocational Training

Table of Contents

Chipping – Course: Technique for Manual Working of Materials. Instruction Examples for Practical Vocational Training

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Author: B. Zierenberg

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Introduction

The present documentation comprises five selected instruction examples by means of which cutting–off and chipping chiselling can be exercised.

Apart from the introductory cutting–off exercise, workpieces are manufactured which can fulfill a special purpose in the workshop:

It is useful to fasten the case for the safety goggles beside drilling and grinding machines, the dog vice for sheet metal and the marking gauge complete the tool outfit of the trainee at his workplace, the drilling support can be used as supplement to the drilling machine accessories.

To facilitate the preparation and execution of the work the materials, hand tools, measuring and testing tools as well as accessories required for each instruction example are given.

Moreover, the previous knowledge is mentioned which is required for the individual exercises.

On the basis of the working drawing enclosed and the appertaining sequences of operations the workpieces can be manufactured.

Explanations as to material indication:

> Marking of the steel is done with the value of tensile strength in the unit of "Megapascal" (MPa).

Instruction example 10.1. Training workpieces for cutting–off chiselling

To practise cutting–off chiselling on different cross–sections without measures given.

<u>Material</u>

– Round steel (380 MPa)

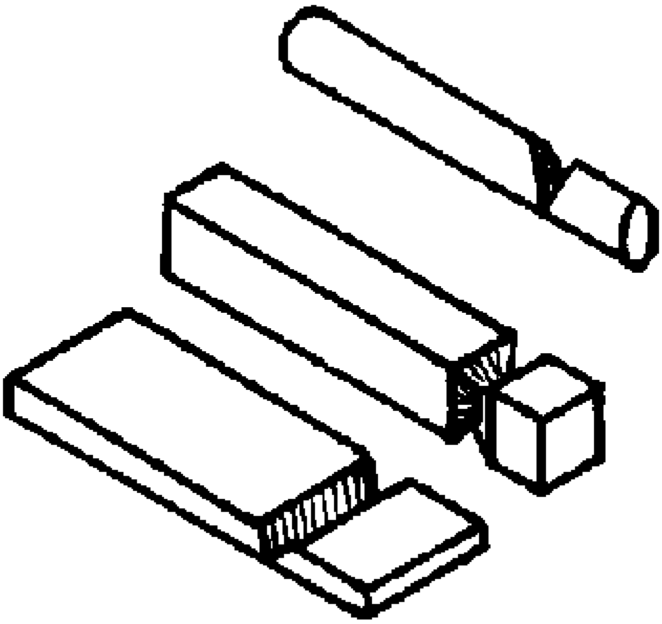
Diameter: 6 to 10 mm

– Square steel (380 MPa)

Thickness: 6 to 10 mm

– Flat steel (380 MPa)

Thickness:	4 mm
Width:	20 to 35 mm



Hand tools

Flat chisel, engineers' hammer

Measuring and testing tools

Eye

Accessories

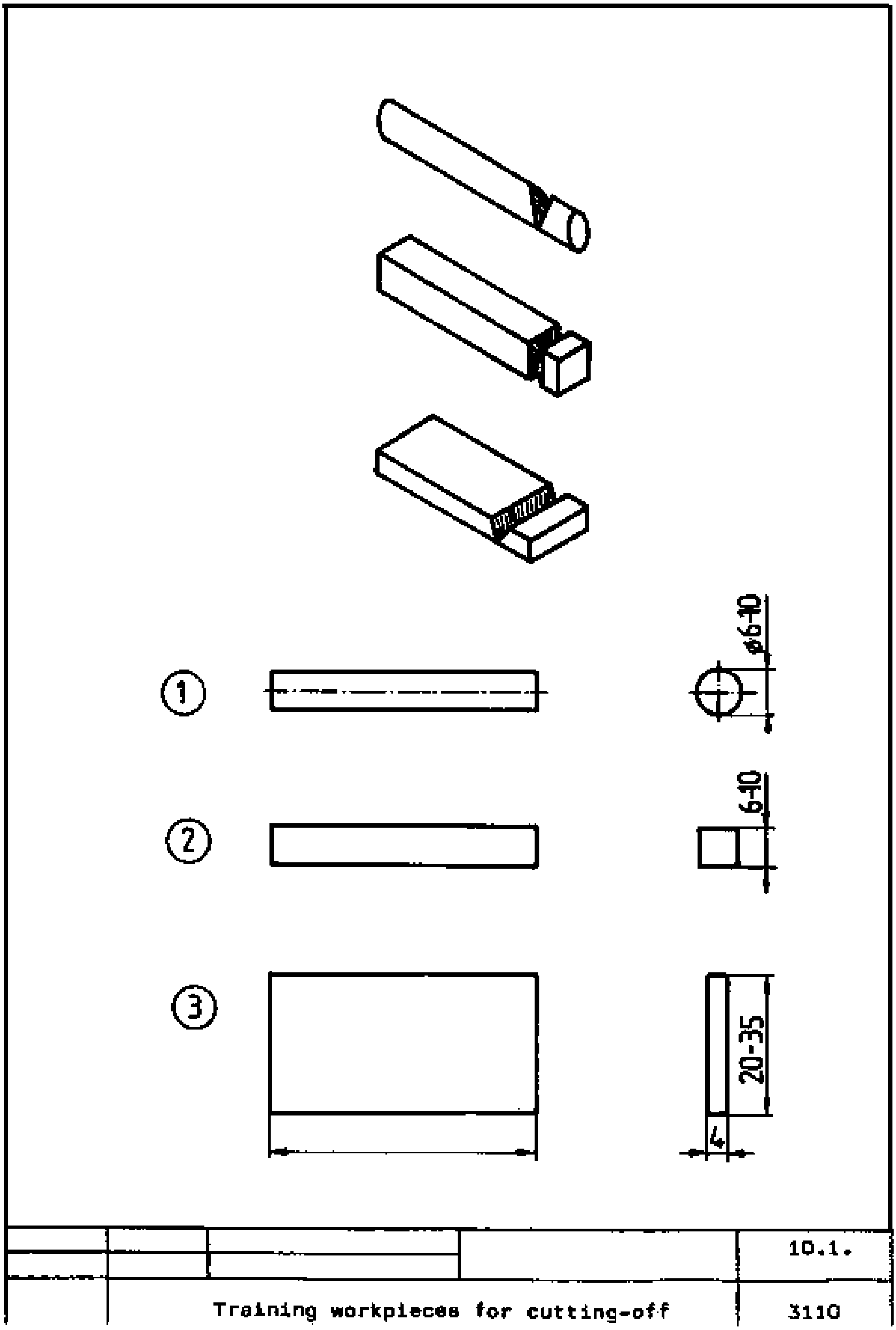
Steel plate or anvil with spacers (sheet plates), protective wall or protective grating

Required previous knowledge

none

Sequence of operations	**Comments**
1. Arrange workplace, prepare working material	– Check for completeness
2. Cutting–off the round steel – chiselling in a single pass	– Part (1) Protect the workpiece against rolling away!
3. Cutting–off the square steel – notching at all sides with the flat chisel, then beating through or breaking	– Part (2)

4. Cutting−off the flat steel – beating through from one side with overlapping chisel neck	– Part (3) – on a support not hardened (spacer)
5. Final check	– Visual check of the cut face



Training workpieces for cutting off

Instruction example 10.2. Case for safety goggles

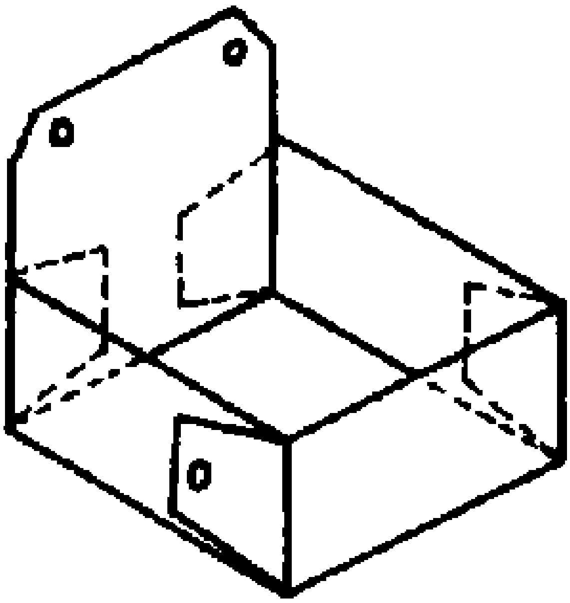
To practise cutting–off and chipping chiselling of sheet steel

Material

– Sheet steel (380 MPa)

Thickness:	abt. 1.5 mm
Width:	320 mm
Length:	360 mm

– 4 x button–head rivet of 4 mm dia.



Hand tools

Brass scriber, steel scriber or surface gauge, flat chisel, engineers' hammer, centre punch, drills with flat point and centre point of 4.1 mm dia. and 8 mm dia., smooth file 250 mm (flat)

Measuring and testing tools

Steel rule

Accessories

Steel plate or anvil and spacer, protective wall or protective grating

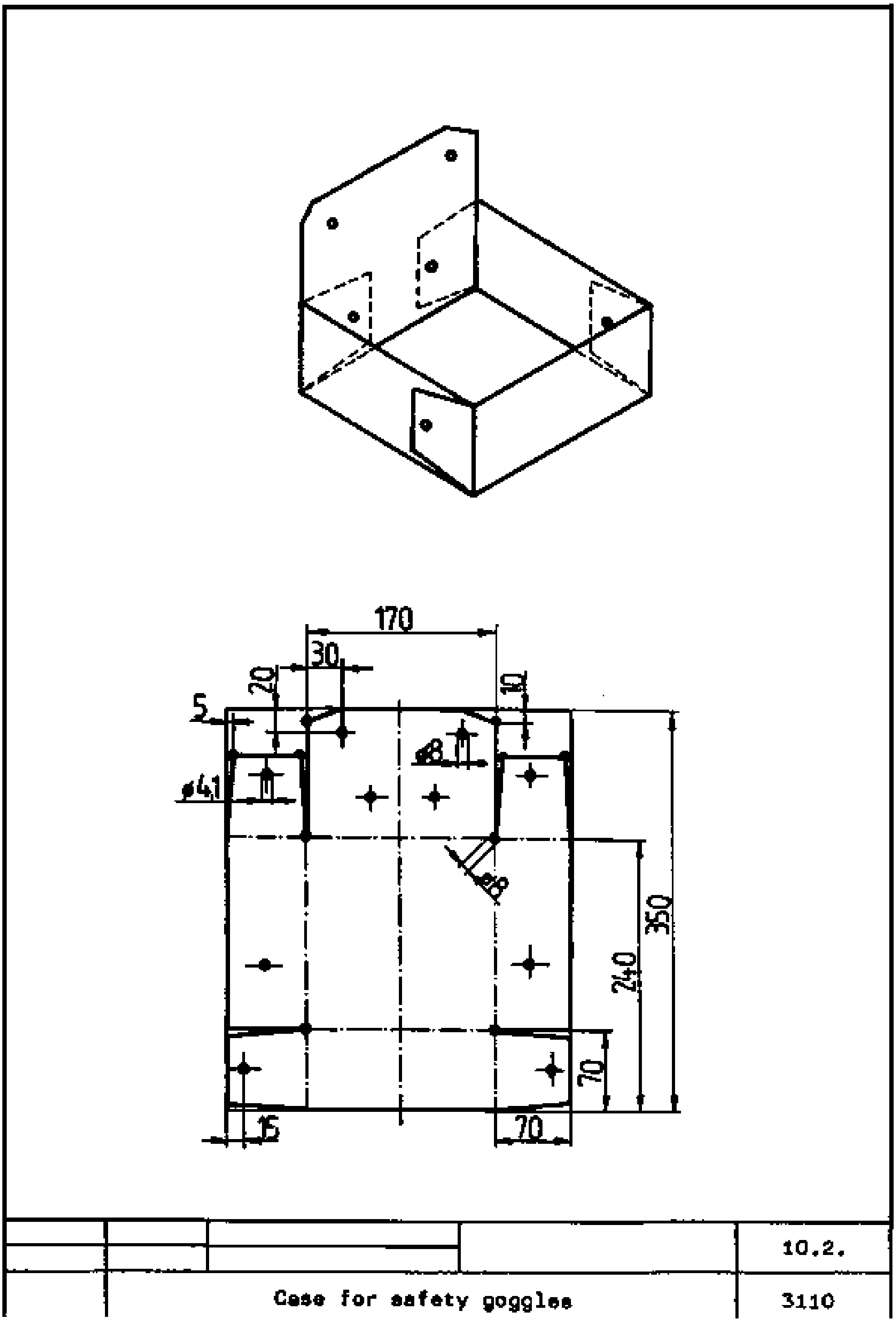
Required previous knowledge

Reading of drawings, scribing, prick–punching, measuring, filing, drilling

Sequence of operations	**Comments**
1. Arrange workplace, prepare working material	– Check for completeness
2. Checking of initial dimensions of the sheet metal, if necessary, reworking	– (shearing, filing)
3. Scribing of the edges to be parted and bent as per drawing, scribing and punching of the holes	– Attention! When using a steel scriber, scribe lightly on the inside of the bending edge – otherwise danger of breaking when bending!

4. Drilling of the holes with the drill with flat point and centre point – corner holes of 8 mm dia., rivet holes of 4.1 dia., deburring of the holes	– Protect workpiece against pulling up and twisting!
5. Chiselling out of the outlines of the case – at one side with overlapping chisel neck along the scribed line	
6. Deburring of the edges	
7. Checking of the edges	– Cleanliness, accuracy to size

Finishing: Bending of the side parts by means of a bending machine and on the vice, riveting of the side parts with button−head rivets of 4 mm dia.



Case for safety goggles

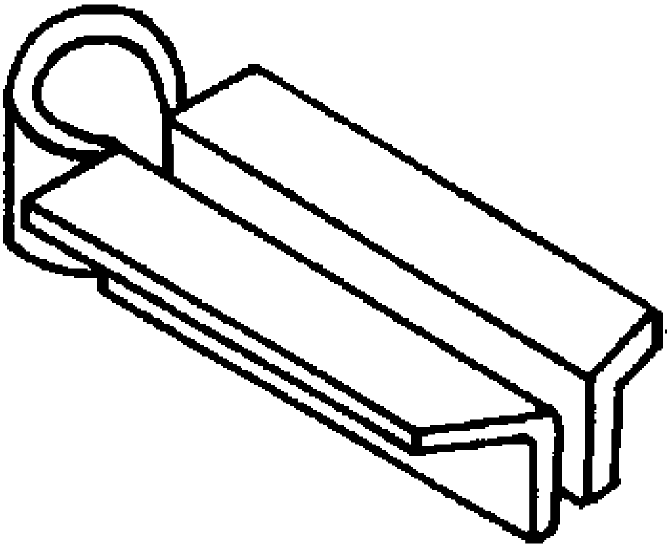
Instruction example 10.3. Dog vice for sheet metal

To practise cutting−off chiselling after drilling out

<u>Material</u>

− Angle steel (380 MPa)

(equal angle or unequal angle)
25 x 25 x 4
Length: not less than 680



Hand tools

Steel scriber, double−point punch (5.2.), engineers' hammer, drill of 5 mm dia., flat chisel, bastard file 200 mm (flat)

Measuring and testing tools

Steel rule, protractor

Accessories

Vice, steel plate or anvil, round material 20 dia., protective wall or protective grating, soluble oil, machine vice

Required previous knowledge

Reading of drawings, scribing, prick−punching, measuring, drilling, filing

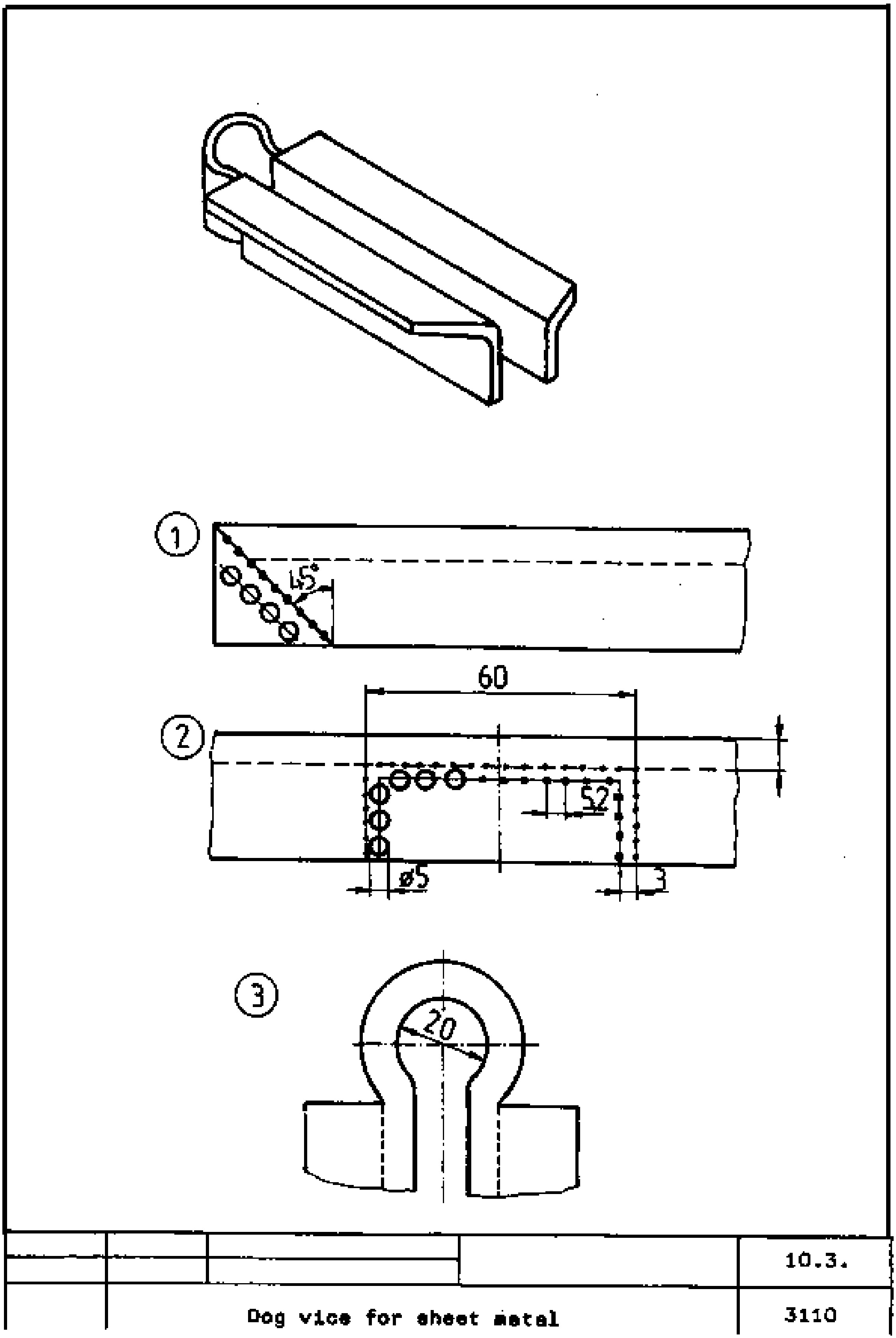
Sequence of operations	**Comments**
1. Arrange workplace, prepare working material	− Check for completeness
2. Scribing of the bevels at the ends of the angle steel in an angle of 45°	− Stage (1) Set check punch marks
3. Scribing of the centre of the angle steel and of the section as per drawing on the outside	− Stage (2) Set check punch marks
4. Scribing of the line to be drilled out (bore line) 3 mm away from the scribed line and punching with double−point punch	− The dimensions on the drawing apply when a 5.2 mm double−point punch is used

5. Drilling out with drill of 5 mm dia. – Attention! Drill must not run off centre!

6. Chiselling along the drilled out line and breaking out of the section

7. Checking of the parted edges

Finishing: Filing of the parted edges, bending of the eye over the round material of 20 dia. according to given data Stage (3)



Dog vice for sheet metal

Instruction example 10.4. Drilling support

To practise chipping chiselling of faces and grooves on cast iron.

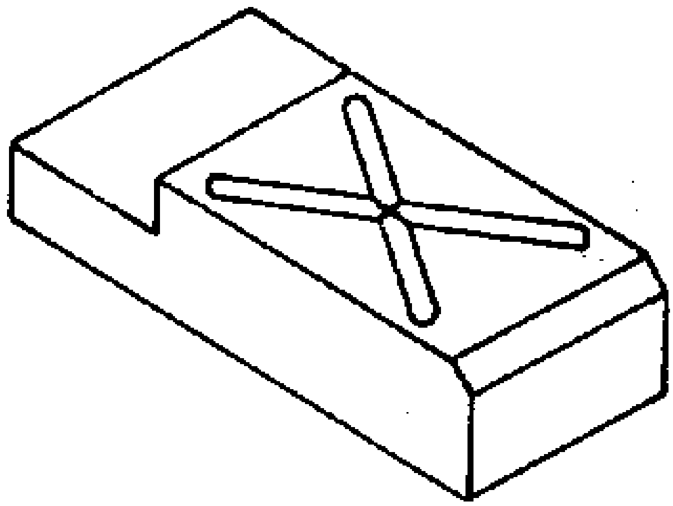
Material

Cast iron

Thickness: abt. 16 mm

Width: 100 mm

Length: 140 mm



Hand tools

Steel scriber, punch, hammer, cape chisel 5 mm, flat chisel, half−round grooving chisel 4 mm

Measuring and testing tools

Steel rule, depth gauge

Accessories

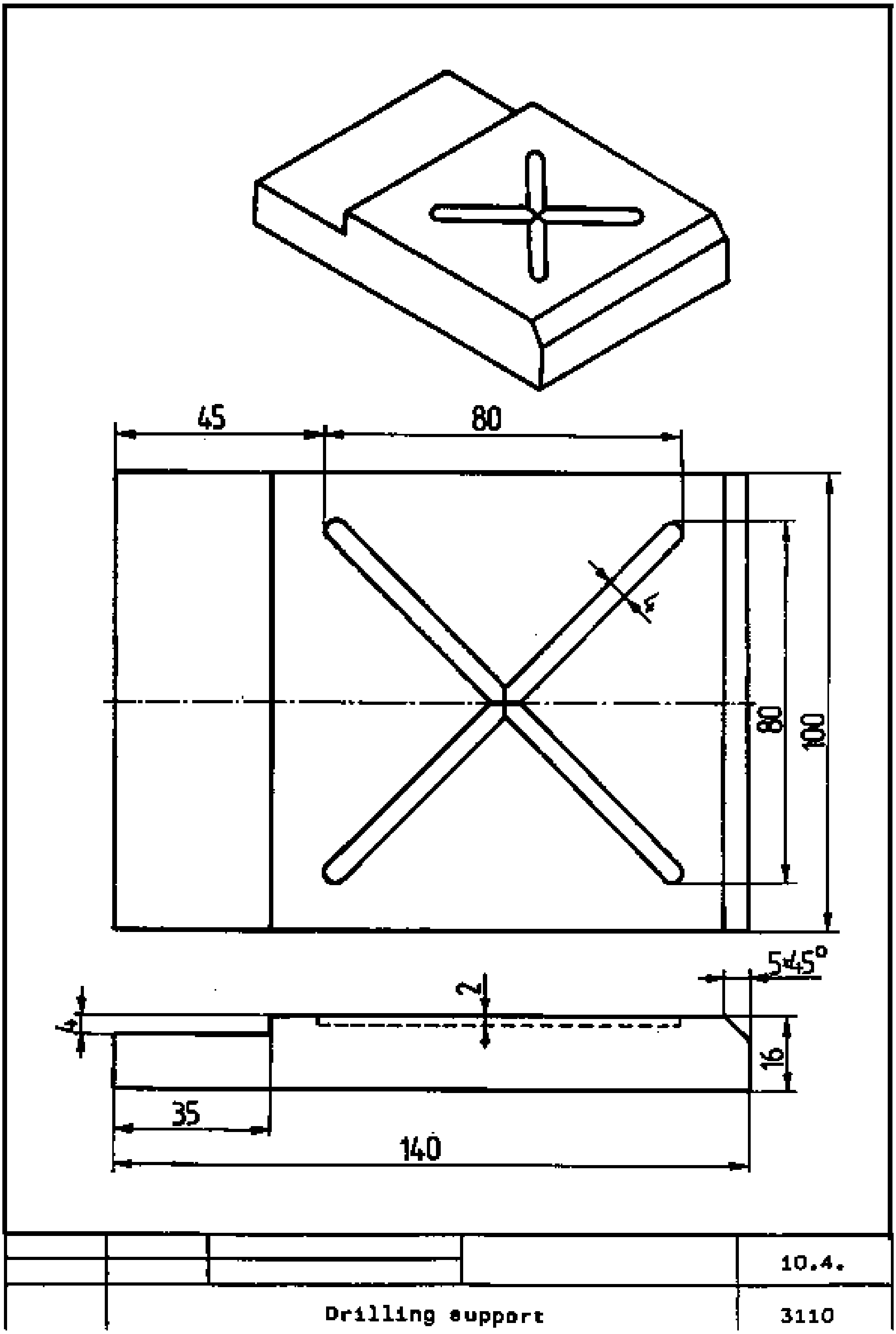
C−clamp, steel plate, protective wall or protective grating

Required previous knowledge

Reading of drawings, scribing, prick−punching, measuring, testing

Sequence of operations	**Comments**
1. Arrange workplace, prepare working material	− Check for completeness
2. Checking of initial dimensions	− Set check punch marks
3. Scribing of the step edge (35 x 100) and of the centre lines of the grooves on this face	
4. Chiselling of the grooves with the cape chisel from both sides, chiselling off of the remained webs by the flat chisel	− approx. 3 chip thicknesses
5. Scribing of the chamfer 5 x 45 and chiselling off with the flat chisel	− approx. 2 chip thicknesses

6. Scribing of the groove cross (centre lines)	
7. First chisel completely one groove with the grooving chisel, then, proceeding from the middle, chisel the second groove towards both sides	– approx. 1 chip thickness
8. Final check	– Straightness of the grooves, uniformity of the plane areas



Drilling support

Instruction example 10.5. Marking gauge

To practise cutting−off chiselling of slots and chipping chiselling of narrow areas

Material

13

– Flat steel (380 MPa)

Thickness: 4 to 5 mm

Width: 24 mm

Length: 180 mm

– Flat steel (380 MPa)

Thickness: 10 mm

Width: 35 mm

Length: 50 mm

– Angle steel (380 MPa)

40 x 40 x 4

Length: 35 mm

– High straight–knurled screw

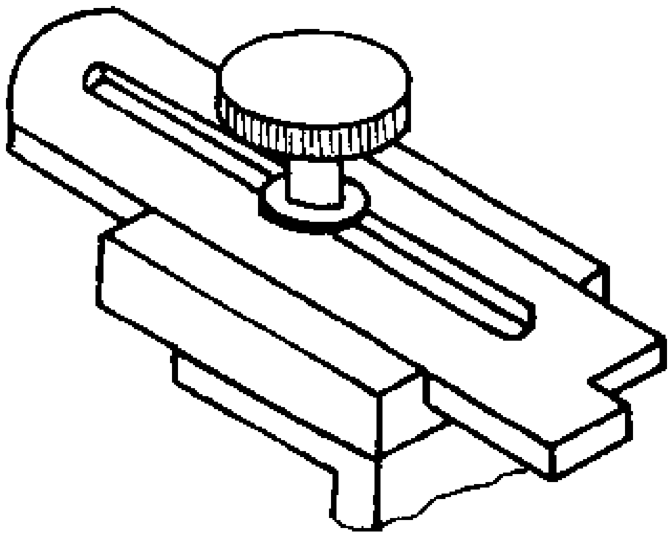
M 6 x 18

– Fillister head screw

M 3 x 10

– Wide washer

Hole diameter: 6,2 mm



Hand tools

Steel scriber or surface gauge, marking and centre punch, hand hacksaw, engineers' hammer, drills 2.5 mm dia.; 3.1 mm dia.; 5 mm dia.; 6 mm dia.; 6.2 mm dia.; nut taps M 3 and M 6, bastard and smooth files 250 mm (flat), mortise chisel, cape chisel, flat chisel

Measuring and testing tools

Steel rule, vernier caliper

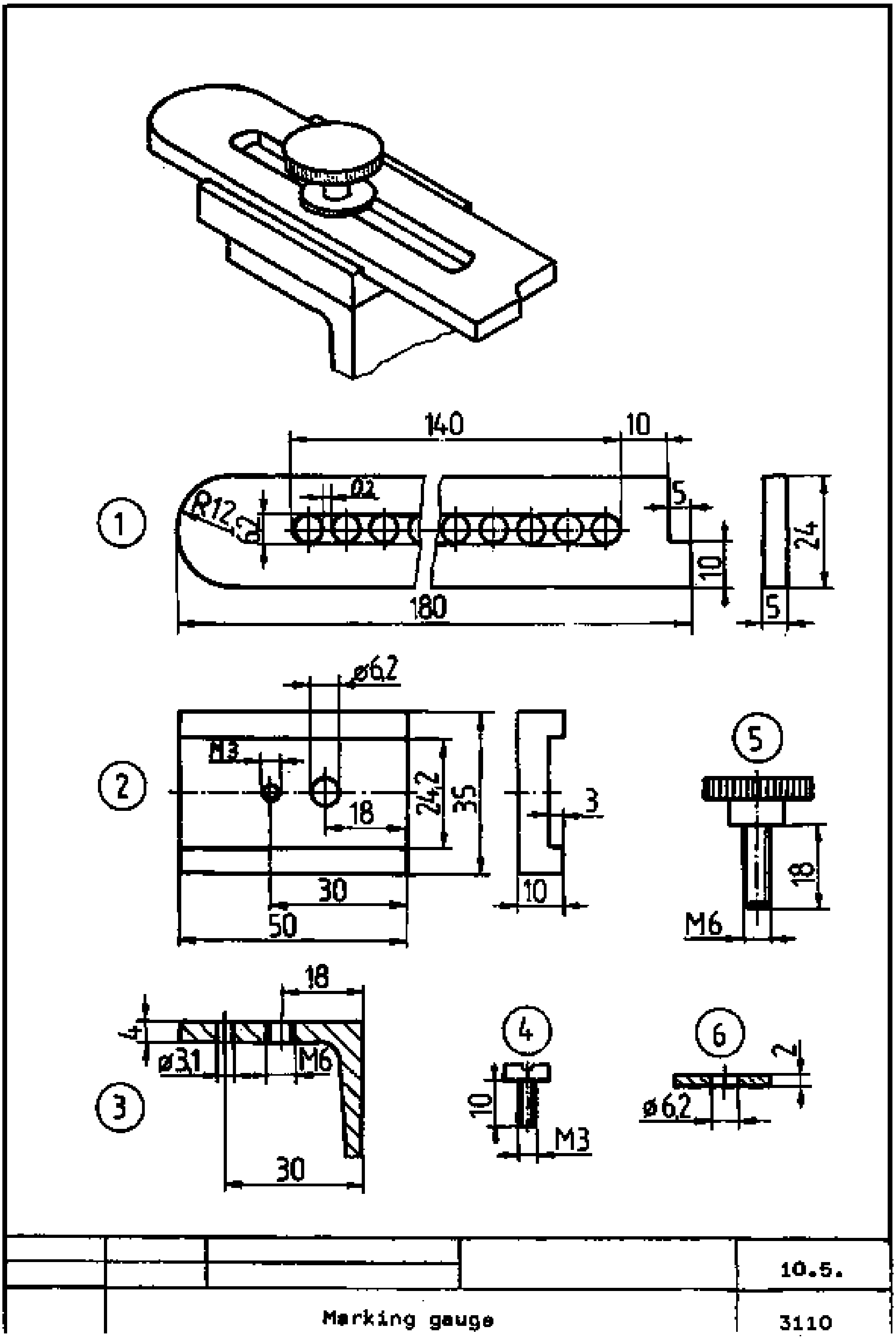
Accessories

Vice, C−clamps, machine vice, steel plate or anvil

Required previous knowledge

Reading of drawings, scribing, prick−punching, measuring, testing, drilling, countersinking/counterboring, sawing, filing, thread cutting

Sequence of operations	**Comments**
1. Arrange workplace, prepare working material	– Check for completeness
2. Scribing of the component (1) and working of the outline to size	– Sawing, filing
3. Punching of the hole centres in the slot, drilling and chiselling out of the slot by the mortise chisel	– Hole 6 mm dia. – Distance between the hole edges 0.2 mm
4. Control of the slot, subsequently finishing by filing	
5. Scribing of the component (2) and working to size of the outer edges	– filing
6. Scribing of the flat groove (24.2), sawing of the groove edges, chiselling of grooves by the cape chisel, chiselling off of the remained webs by the flat chisel	– Pay attention to firm fixing!
7. Checking of the flat groove, subsequently finishing by filing	
8. Working to size of the component (3); Fastening with part (2) and drilling jointly; Boring separately and threading	– sawing, filing – hole 2.5 dia. and 5.0 dia. – boring 3.1 dia. and 6.2 dia. according to the drawing
9. Mounting by means of parts (4), ,(5), (6)	
10. Final check	– Accuracy to size, appearance, good slideability of the slide



Marking gauge

Chipping – Course: Technique for Manual Working of Materials. Trainees' Handbook of Lessons

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Chipping – Course: Technique for Manual Working of Materials. Trainees' Handbook of Lessons

Institut für berufliche Entwicklung e.V.
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Author: Frank Wenghöfer

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Parkstraße 23
13187 Berlin

Order No.: 90–35–3110/2

1. Purpose of chipping

Chipping is working on materials by a wedge–shaped tool (the chisel) in order to separate or chip material. The cutting effect of the chisel is achieved by hammering on the head end of the chisel, which is an energy and time consuming operation.

Chipping therefore, is useful only if other mechanical working techniques cannot be applied or are not worthwhile.

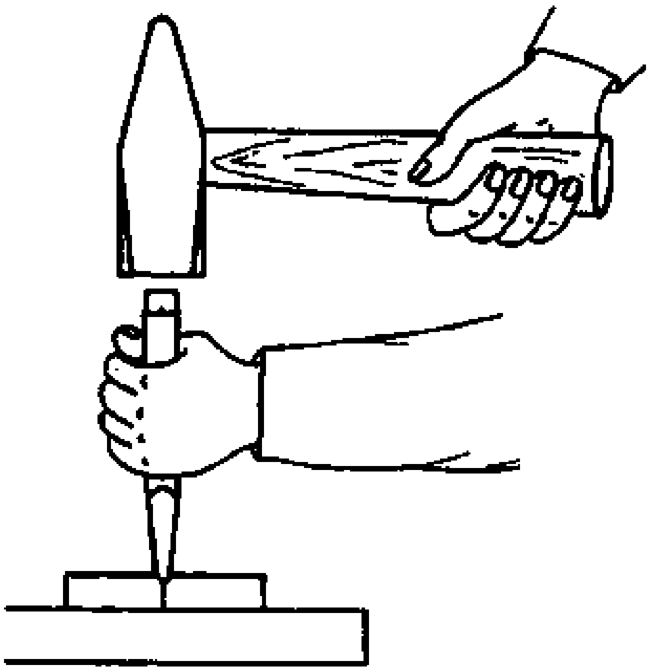

Figure 1 – Chiselling

2. Tools and auxiliary tools for chipping

Main tools are chisels of various kinds. They are made of unalloyed tool steel carbon content (0.9 %). The cutting part is hammered, hardened, ground and tempered (HRC 48). The head of the chisel is unhardened, chamfered towards the upper end and rounded.

Chisels are chosen according to the respective task as well as hardness of material of the workpiece:

– Flat chisel

Most common chisel for separating and chipping with straight, broad cutting edge.

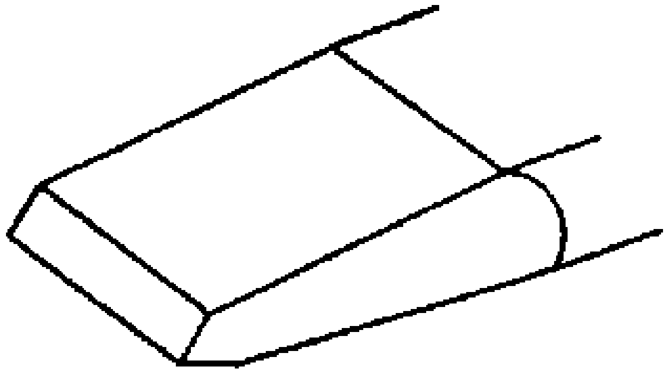

Figure 2 – Flat chisel

– Round chisel

Special chisel for chiselling out big holes or separating curved forms. This chisel has an arched cutting edge.

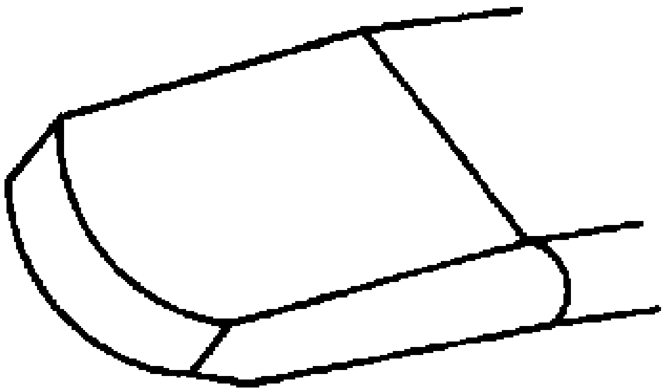

Figure 3 – Round chisel

– Cross–cut chisel

Chisel for chiselling out horizontal grooves or for separating webs in boring lines. The cutting edge is across the width of the chisel, the side surfaces are hollow–ground.

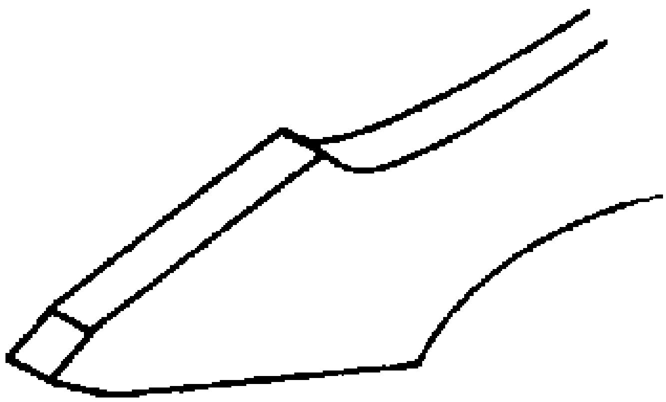

Figure 4 – Cross–cut chisel

– Shear tool

Chisel for shearing sheet metal. It has a straight, broad cutting edge which is at level with one flank and the shank of the chisel.

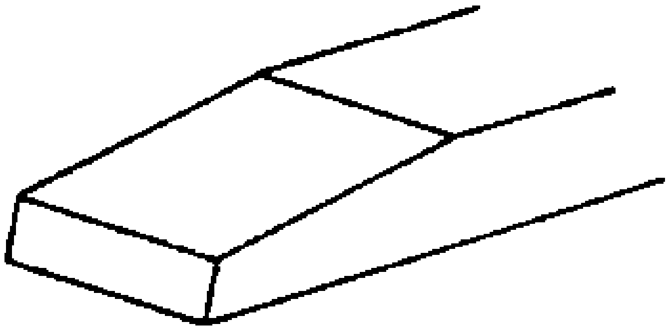

Figure 5 – Shear tool

– Grooving chisel

Chisel for chiselling out grooves in special workpieces (bearing shells). The cutting edge of the chisel is across the shank, the arched back corresponds to the arched forms.

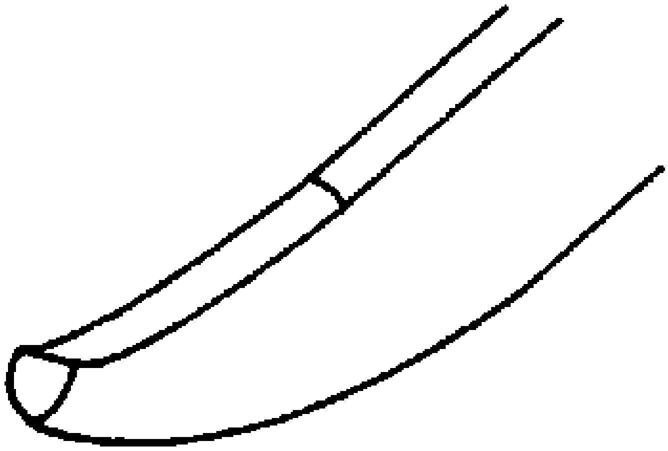

Figure 6 – Grooving chisel

– Cut–out tool

Chisel for cutting out webs with boring lines and drilled deep–holes.

The two cutting edges are hollow–ground; the flanks are relief–ground in order to avoid jamming.

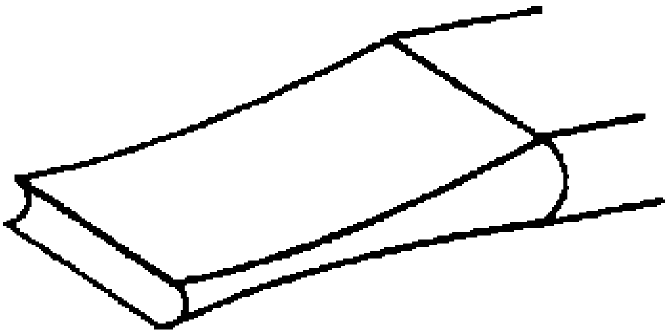

Figure 7 – Cut–out tool

– Hollow punch

Chisel with circular cutting edge for chiselling out holes in thin or soft materials

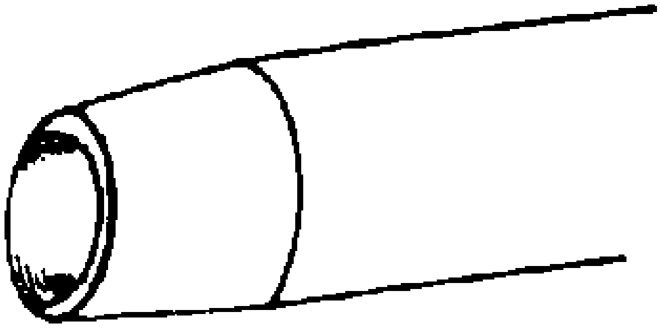

Figure 8 – Hollow punch

The following recommended values apply to the selection of chisels according to the hardness of material:

Constitution of the material	Cutting–wedge angle
Soft (aluminium)	30° – 50°
medium hard (steel)	60°
hard (tool steel)	60° – 70°

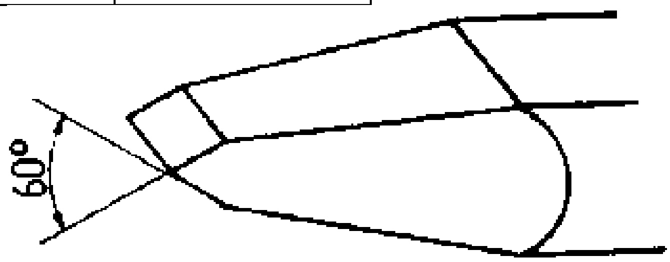

Figure 9 – Cutting–wedge angle at the chisel

When is the technique of chipping applied?

____

____

What material are chisels made of?

____

____

What aspects have to be considered in choosing chisels?

____

____

When do you use a flat chisel?

____

____

When do you use a cross–cut chisel?

____

____

What cutting–wedge angle shall the cutting edges have for working medium hard steel?

____

____

– Hammer

Mostly, hand hammers are used (weight: 400 g); as a general rule:

The hammer should be twice as heavy as the chisel.

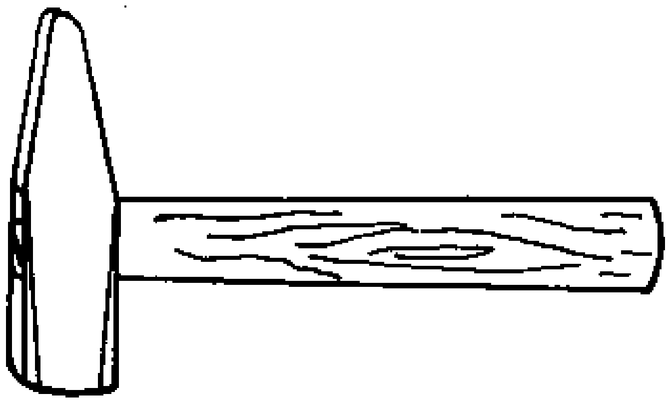

Figure 10 – Hand hammer

– Supports

For absorbing the beating effect, these should be unhardened: steel plates, steel blocks.

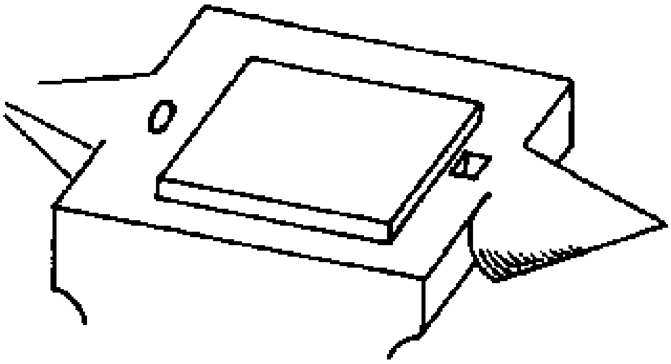

Figure 11 – Anvil with steel support

If the anvil is used, an unhardened intermediate plate is required; when working with the hollow punch, use a wooden support.

Marking–out tables and surface plates must not be used – the chisel edge causes damage that destroys the even surfaces of the plates.

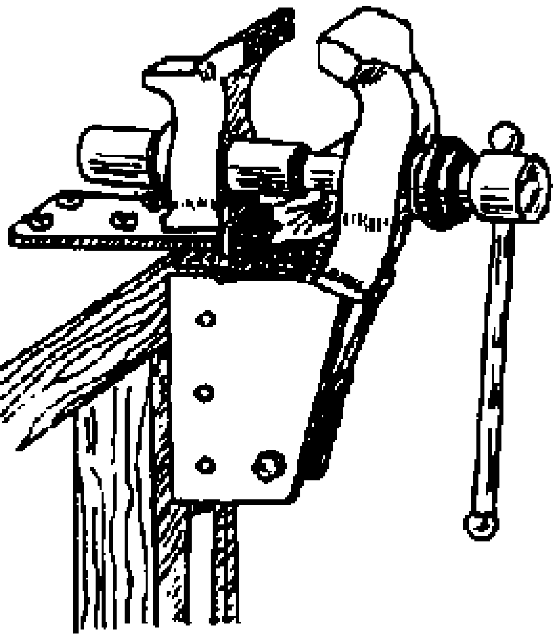

Figure 12 – Collet vice

– Vice

If possible, use a collet vice for clamping smaller parts and work against a rigid counter−support.

Always beat against the fixed jaw of the vice in order to go easy on the screw.

3. Protective means

− Protective lattices and guards:

These are placed in beating direction in order to protect fellow workers standing next to the chiselling place against splashing chips.

Figure 13 − Chiselling in front of the safety lattice

− Safety goggles and beating protection:

The eyes are protected by wearing safety glasses.

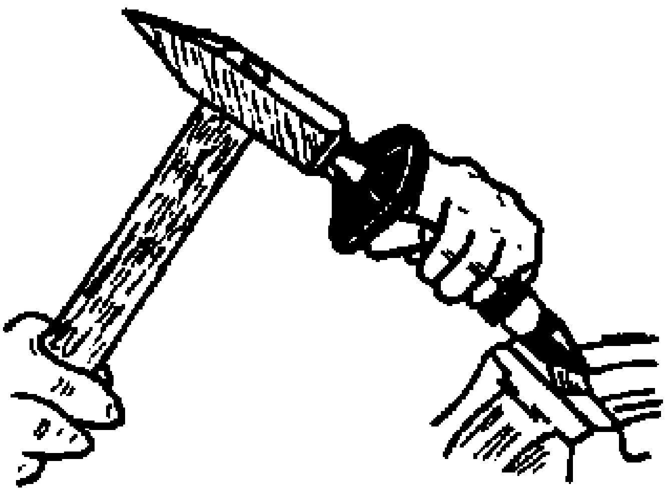

Figure 14 − Chiselling with protective device

A protective device of soft plastic material can be put over the head of the chisel in order to protect the back of the hand against strokes of the hammer that perhaps mise the head of the chisel.

What additional tools and auxiliary means are required for chipping?

What general rule applies to the selection of the hammer?

What qualities must the supports have?

When must marking–out tables and surface plates not be used as supports?

What is the task of protective guards and safety goggles?

4. Operation and techniques of chipping

As a result of the impact of the hammer hitting the head of the chisel, the impact energy of the hammer is transmissed to the cutting edge thus enabling it to do the cutting work.

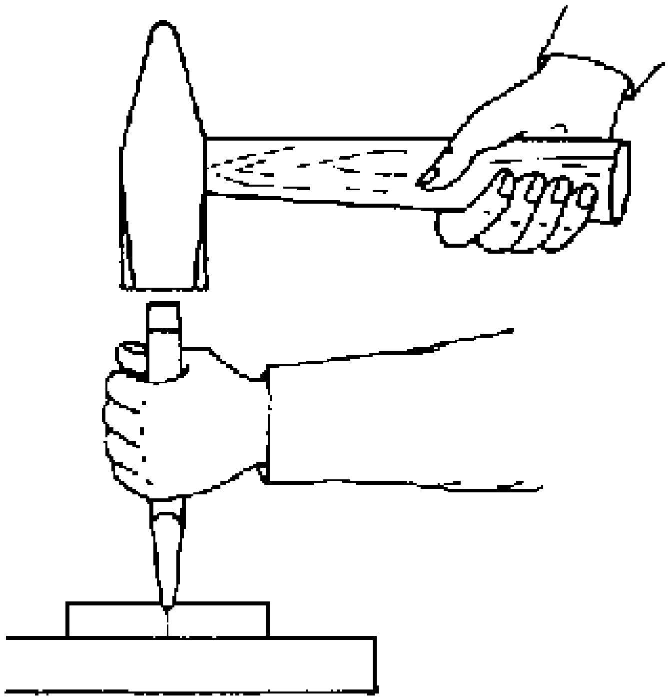

Figure 15 – Chiselling

The strokes of the hammer are directed mainly by the wrist–joint, because this leads to a good accuracy of aim. Harder strokes must be struck out of the shoulder–joint – do not strike the blows out of the upper arm (little accuracy of aim, rapid tiring).

Look at the cutting edge of the chisel in order to watch its effect.

There is a basic difference in holding the chisel with chipping and parting chiselling.

4.1. Chipping chiselling

The chisel has to be applied in a position inclined towards the surface of the workpiece.

The cutting edge penetrates the material and squeezes it.

As a result, a chip is rolled up from the cutting face and sheared off.

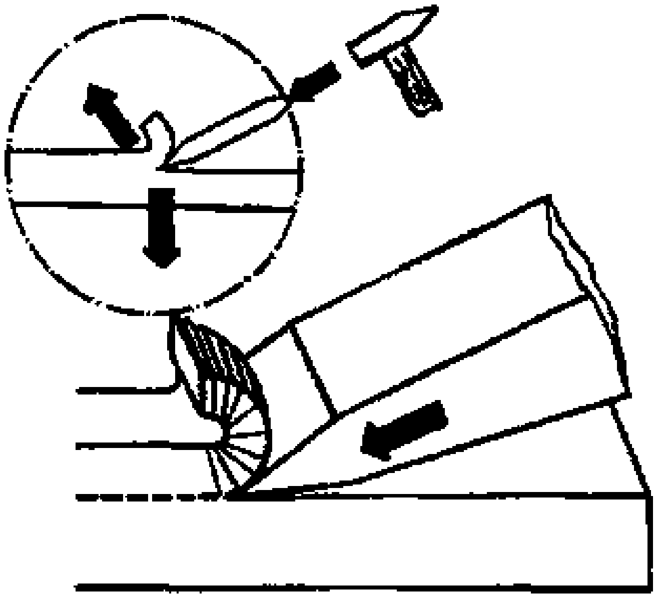

Figure 16 – Position of the chisel when chipping

The angle of inclination is approximately half of the cutting–wedge angle (approx, 30°).

If chips of different thicknesses have to be cut off in order to achieve an even surface, the following has to be observed:

For chips of little thickness hold the chisel steeper (angle of clearance approx. 8°), for thicker chips hold the chisel in a rather flat position (angle of clearance approx. 0°).

<u>Working recommendations</u>

– Thin layers of material at narrow surfaces as well as strips of sheet metal are chiselled off by clamping the workpiece into the vice and holding the chisel in an inclined position (angle of incidence approx. 45°).

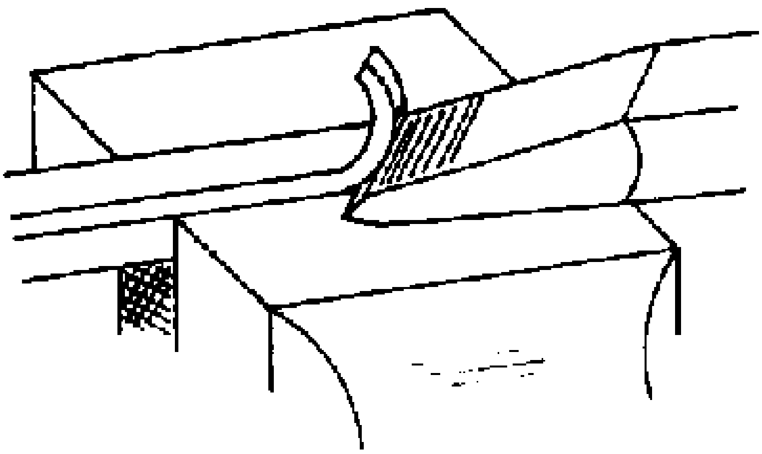

Figure 17 – Chipping of thin layers by a chisel

– Thicker layers have to be removed by several plies, so that the chips roll off more easily.

– Larger surfaces are treated with the cross–cut chisel first which cuts grooves in them. After this, the webs remaining between these grooves are removed with the help of the flat chisel.

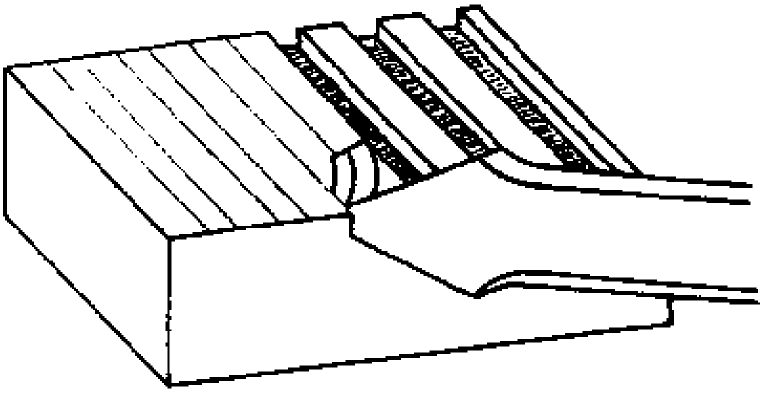

Figure 18 – Chipping of surfaces by a cross–cut chisel

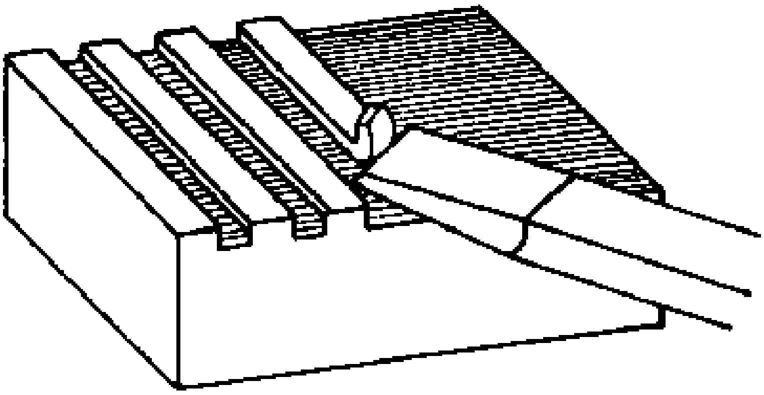

Figure 19 – Chipping of the webs by a flat chisel

How is the chisel applied for the chipping operation?

____

____

4.2. Parting chiselling (cutting–off)

The chisel is put vertically on the surface of the workpiece.

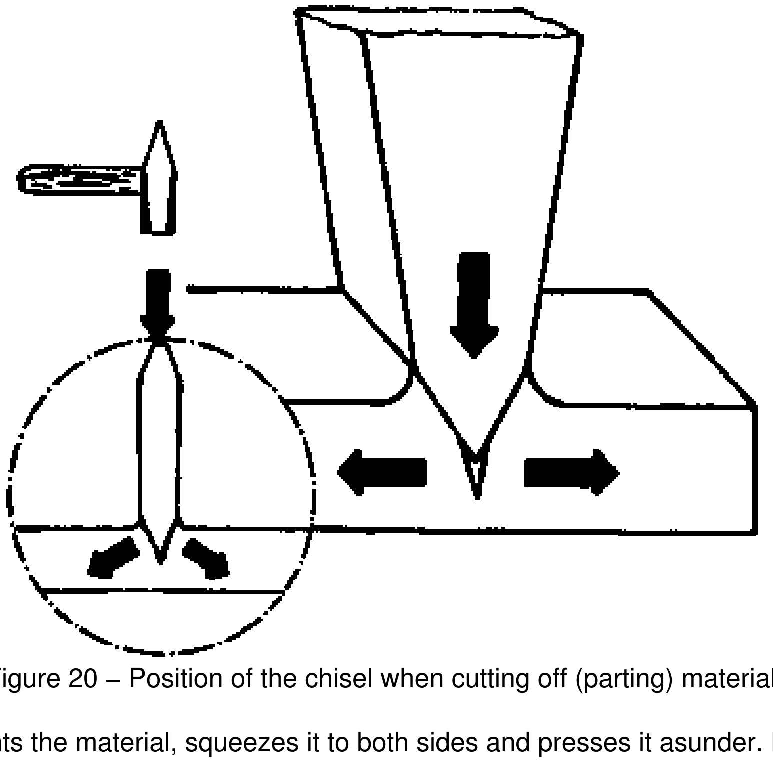

Figure 20 – Position of the chisel when cutting off (parting) material

The cutting edge indents the material, squeezes it to both sides and presses it asunder. By this, the material tears in front of the cutting edge the cutting edge is clear. With further penetration, the workpiece tears asunder.

Working recommendations

– Thin, flat materials or sheet metal have to be cut off from one side and on a hardened support. The limitting points have to be drilled first.

– Thicker parts have to be indented on all sides and then broken.

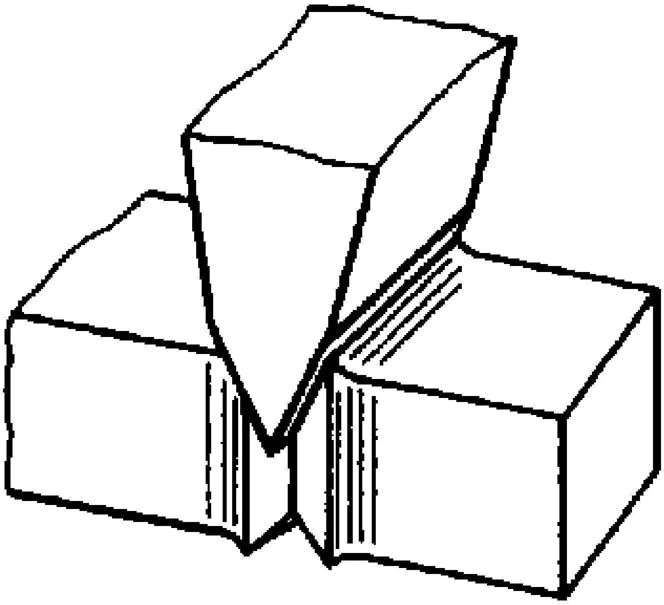

Figure 21 – Indenting of a square bar on all sides for parting it

– Long cutting lines have to be prepared by chiselling a guiding slot.

– Curved contours at thicker workpieces (from 4 mm on) have to be prepared by a bore line the scribing is made with the help of a double–point punch.

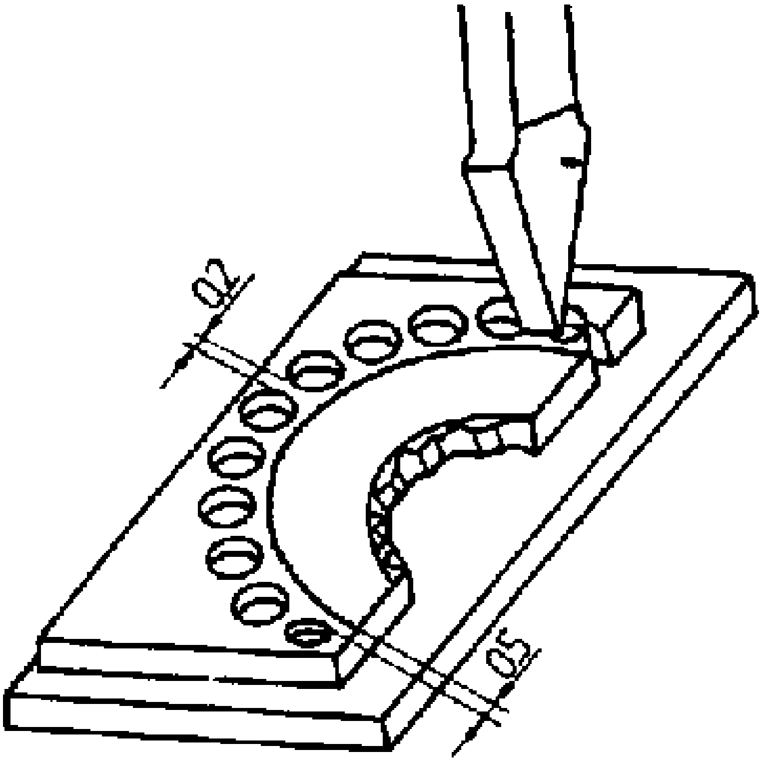

Figure 22 – Drilling and chiselling out of curved contours

The following conditions apply to this:

D = diameter of the drill
y = width of the double−point punch
x = distance of the bore line to the scribed line

D = y − 0.2 mm

$$x = \frac{D}{2} + 0.5 \text{ mm}$$

The webs between the bore holes are cut by a flat chisel or cross−cut chisel. With thicker workpieces (from 8 mm on), a cut−out tool is to be used.

How is the chisel applied for the parting operation?

____

____

How can curved contours be cut out of thicker workpieces?

____

____

5. Labour safety recommendations

− When chiselling, put up safety lattices or safety guards
− Wear safety goggles to protect the eyes.
− Do only use chisels that are free from burrs.

Drilling, Countersinking and Counterboring – Course: Technique for Manual Working of Materials. Methodical Guide for Instructors

Table of Contents

Drilling, Countersinking and Counterboring – Course: Technique for Manual Working of Materials. Methodical Guide for Instructors

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1. Objectives and contents of practical vocational training in the working techniques of "Drilling, Countersinking and Counterboring"

By concluding their training, the trainees shall have a good command of the working techniques of "Drilling, Countersinking and Counterboring". Therefore, the following objectives are to be achieved:

<u>Objectives</u>

– Knowledge of purpose and application of the drilling, countersinking and counterboring techniques.

– Appropriate command of portable electric drills, bench–type drilling machines and upright drilling machines in compliance with the regulations on labour safety, they are in a position to determine tool values and to set up the machines appropriately.

– Capability of selecting and properly using the appropriate working tools and clamping tools.

– Precise command of the working processes involved in boring and counterboring of blind and through holes as well as capability of making independent decisions on quality.

The following contents have to be imparted to the trainees:

<u>Contents</u>

– Purpose of drilling, countersinking and counterboring
– Drilling machines and tools
– Action of drilling
– Setting of the tool values
– Clamping of tools and workpieces
– Technological sequence of drilling
– Purpose and application of counterboring/countersinking

2. Organizational preparations

In order to guarantee a trouble–free development of the instructions, exercises and practical work it is necessary to prepare this training appropriately.

The following steps have to be taken:

2.1. Preparation of instructions on labour safety

Prior to the exercises a brief instruction in the proper use of tools and equipment (the machines in particular) has to be given. This comprises also hints for accident–free work.

Any operation at the machines with freely movable (rotating) components involves dangers to health. Therefore, a strict compliance with the labour safety regulations is a roust. In addition to the operating instructions of the respective machines, the following hints must be given:

– Use tight–fitting clothes and protective headgear! (Long hair must be covered under the headgear)

– If there is no anti–glare device mounted on the machine, you must wear goggles!

– In order not to distract somebody from working with the machine, only one person has to work with the machine at a time.

– Setting up and cleaning work must not be done with the machine running!

– Workpieces must be secured against twisting and pulling up in relation to their sizes.

– Drilling needs adequate lubricating and cooling agents.

– Do not remove the chips by hand, use proper means (metal hooks, short metal bars)!

– Do not leave the machines until they have come to a standstill!

Familiarity with these hints has to be confirmed by the trainees' signatures in a control book.

2.2. Provision of teaching aids

The "Trainees' Handbook of Lessons" – Drilling, Countersinking and Counterboring" is to be handed out to the trainees in sufficient numbers.

When using the transparencies series of "Drilling, Countersinking and Counterboring", check whether they are complete (transparencies nos. 7.1. – 7.6.) and whether the overhead projector is functioning (Check the operating conditions at the place of use and make sure of the proper mains supply!)

Surveys etc. which are to be written on the blackboard have to be completed prior to the instruction.

All the tools and accessories mentioned in section 3 should be kept ready for illustration purposes.

2.3. Provision of working tools and materials

The "Instruction Examples for Practical Vocational Training – Drilling, Countersinking and Counterboring" have to be handed out to the trainees to provide them with the theoretical foundations for the exercises to be carried out.

The initial materials required for the exercises have to be prepared and laid out in sufficient numbers according to the materials mentioned in the "Instruction Examples...".

Two trainees should share a workbench with vice and – if possible – a drilling machine.

The trainees' workbenches have to be fully equipped with tools and accessories according to the planned exercises.

Recommended basic equipment:

– steel rule, vernier caliper with depth gauge, centre square
– steel scriber, marking gauge, centre punch

– locksmith’s hammer, hand hacksaw
– bastard and smooth files 350 mm (flat), (half–round)
– standard–type drills from 1.1 to 12 mm diameter soft–type drills 6.75; 8.0; 8.4; 9 mm diameter
– countersinks 60°; 75°; 90°

• Bench–type and upright drilling machines as well as (in individual cases of application) portable electric drills can be employed as drilling machines.

• Prior to the exercises you have to check the functionality of the drilling machines according to the labour safety regulations.

2.4. Time schedule

Time planning is recommended for the following training stages:

– introduction to the working techniques in the form of instructions
– necessary demonstrations
– job–related instructions to prepare the exercises
– carrying–out the exercises
– recapitulations and tests.

The necessary time–shares depend on the respective training conditions. The schedule has to take into account that waiting times may occur at the machines during the stage of practical work, unless there is a sufficient number of drilling machines available.

Such waiting times should be bridged by minor and subject–related jobs.

3. Recommendations for practical training in the working techniques of “Drilling, Countersinking and Counterboring”

The following paragraphs comprise proposals on conducting trainee instruction, the demonstration of working techniques as well as the exercises and tests.

We recommend two course variants:

Variant no. 1

This variant should be chosen for trainees with generally good achievements and receptiveness:

1.1. Introductory instruction with demonstrations according to the “Trainees’ Handbook of Lessons”

1.2. Drilling, Countersinking and Counterboring exercises according to the “Instruction Examples 7.1. – 7.6.” and subsequent evaluation.

1.3. Final test of theory knowledge based on the contents of the “Examples for recapitulation and tests”.

Variant no. 2

This variant should be chosen for trainees with little previous knowledge or poor achievements.

2.1. Introductory instruction with demonstrations according to the “Trainees’ Handbook of Lessons”.

2.2. Exercises in drilling, countersinking and counterboring according to the “Instruction example 7.1.” and subsequent evaluation.

2.3. Supplementary instruction and recapitulation of the subjects of “Setting of tool values” and “Technological sequence of drilling, countersinking and counterboring according to the “Trainees’ Handbook of Lessons”.

2.4. Exercises in drilling, countersinking and counterboring according to the “Instruction Examples 7.2. – 7.6.” and subsequent evaluation.

2.5. Final test of theory knowledge based on the contents of the “Examples for recapitulation and tests”.

Practical skills should be evaluated immediately after handing in the finished training workpieces. Knowledge of theory should be constantly checked. However, it is recommended to have a final test written (item 1.3. or, resp., 2.5.) after concluding the exercises.

3.1. Introductory instruction

If possible, this instruction should be given in a classroom. Make sure that the trainees put down necessary supplementary notes or answers to questions in their “Trainees’ Handbook of Lessons”.

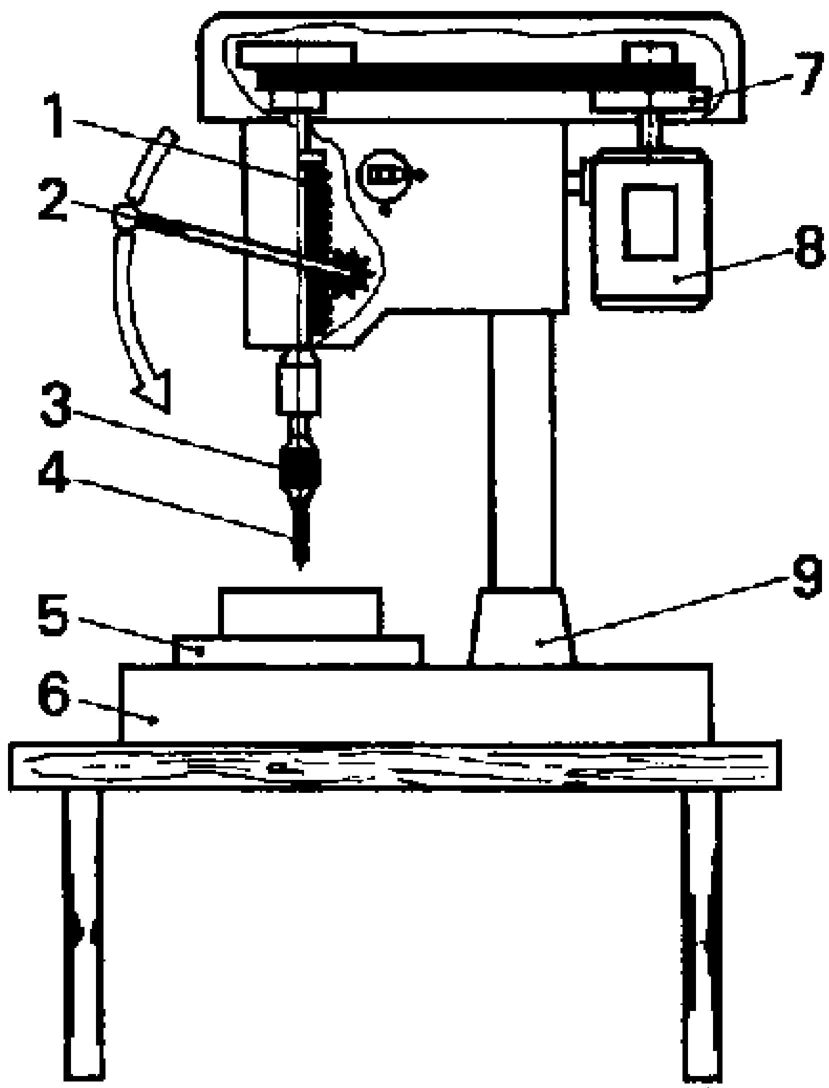
Instruction can be carried out on the basis of the main points contained in the “Trainees’ Handbook of Lessons”.

Purpose of drilling, countersinking and counterboring/countersinking

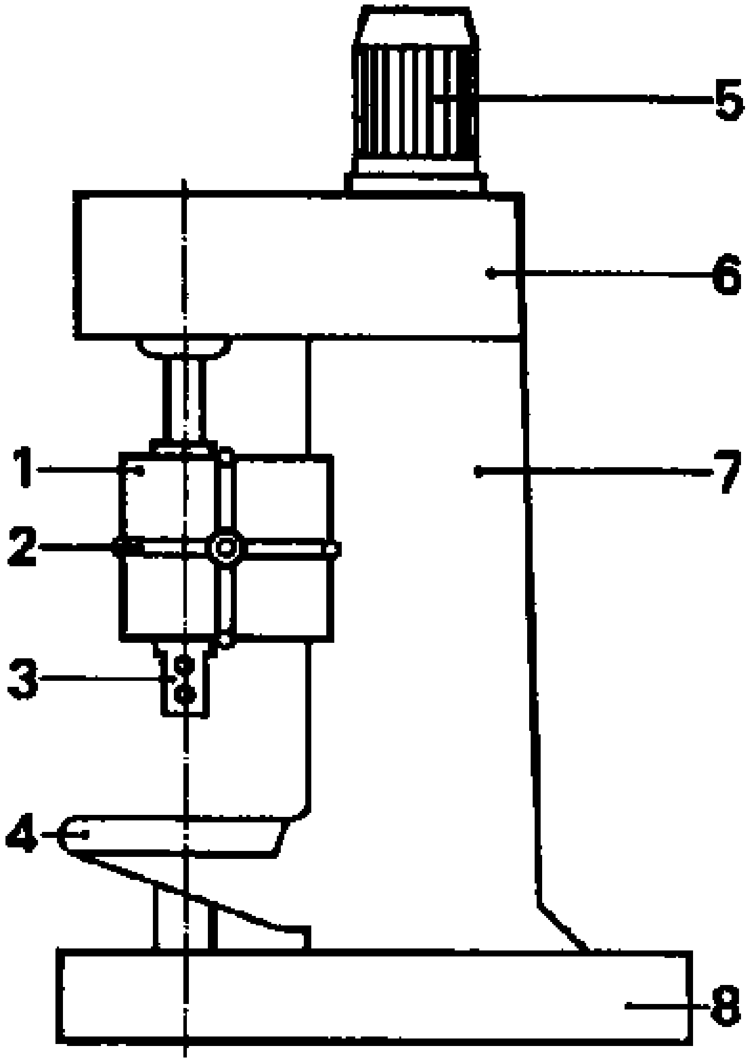
To illustrate the purpose of these working techniques, it is recommended to show workpieces with blind and through holes. It has to be pointed out that these techniques create the prerequisites for bolted, pin–type and rivet–type connections.

Machines and tools for drilling

Transparencies nos. 7.1. and 7.2. can serve to show the basic design of drilling machines. Do not forget to include the instructions contained in the operating manuals of the machines in the workshop. Thus, the trainees are in a position to apply the general knowledge described on the transparency to the machines they are working with.



Transparency 7.1



Transparency 7.2

The instructor must not forget to mention the regulations on labour safety. It is also recommended to show protective devices of the machine (if available).

After having described the design and operation of the machines, the following drills have to be described:

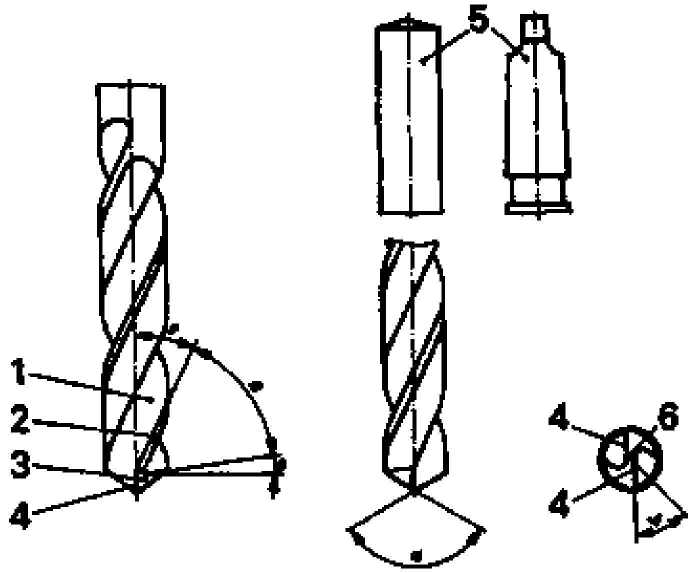
- 'hard'–type drills
- 'normal'–type drills
- 'soft'–type drills
- drills with carbide tips
- drills with double–taper drill point
- drills with flat drill point and centre point.

If the original tools cannot be shown, the illustrations contained in the "Trainees' Handbook of Lessons" will be sufficient to impart the necessary knowledge to the trainees.

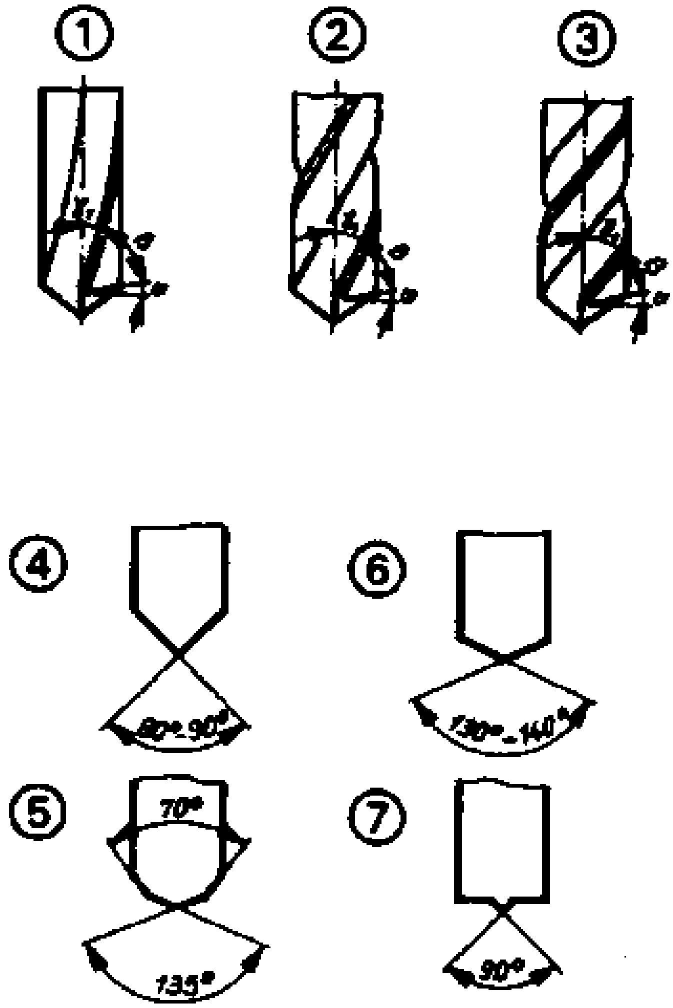
<u>Transparencies nos. 7.3. and 7.4.</u> can also serve to give an illustrative description of "design and angles at the drill" and of types of drills as well as special kinds of drill point grinding.

The distinctions between the types of drills and their different fields of use have to be explained in detail.

The comprehensive hints contained in the "Trainees' Handbook of Lessons" can support this instruction.



Transparency 7.3



Transparency 7.4

Subsequently, the trainees should answer the questions contained in the "Trainees' Handbook of Lessons".

Action of drilling

The instructor describes the main movements of a drill and describes the interaction of feed and rotary movement during chip removal. He has also to comment on the reduction of friction. The trainees have to understand that permanent cooling extends the life of drills.

In this connection it is advisable to speak about the trends of development in the field of drill materials mentioned in the “Trainees’ Handbook of Lessons”.

Setting of tool values

The instructor has to describe in detail how to determine the correct values for adjusting the rotational speed, cutting speed and feed.

The rules and tables contained in the “Trainees’ Handbook of Lessons” need comprehensive explanation. This can be supported by transparencies or by illustrations on the blackboard.

The rules for automatic feeds are:

> Low feed – with high rotational speeds and hard materials high feed – with low rotational speeds and soft materials.

The rules for rotational speeds are:

> Low speed – with hard materials and large drill diameters high speed – with soft materials and small drill diameters.

Table of rotational speeds (Gross Survey) at a cutting speed for drilling without automatic feed:

Material	**diameters of drills in mm (ranges)**					
	1 – 3	**3 – 5**	**5 – 8**	**8 – 10**	**10 – 12**	**12 – 16**
soft materials	7100	5600	3500	2800	2200	1800
Al, Cu	4500	3500	2200	1800	1400	1100
medium–hard steel	2800	2200	1900	1100	900	710
cast steel hard materials	1800	1400	900	700	560	450
Cr, Ni–alloys	350	350	350	350	280	220

Rotational speed calculation

$$n = \frac{v \cdot 100}{d \cdot \pi}$$

> n = rotational speed in r.p.m.
> v = cutting speed in m/min
> d = diameter of drill in mm
> ? = 3.14

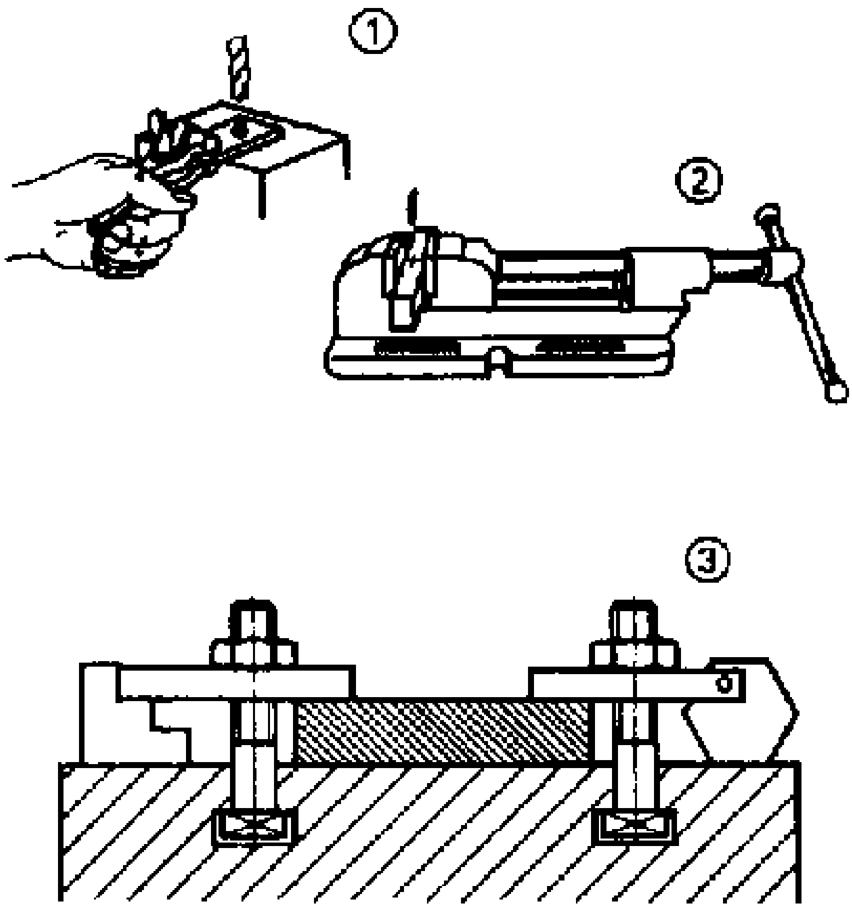
After having imparted this knowledge to the trainees exemplary calculations can support this instruction. It is recommended to ask the trainees to determine various rotational speeds. They must learn how to read the table values and how to set the machines accordingly.

Clamping of tools and workpieces

The instructor demonstrates the use of such tool clamping devices as e.g. “three–jaw chuck” and “taper–sleeve”.

The instruction comprises the description of the interactions of drill shank and tool clamping device.

Transparency no. 7.5. can illustrate the process of clamping a workpiece. Subsequently, all the clamping devices available in the workshop (machine vices, clamp dogs, clamps) should be described and their use explained.



Transparency 7.5

Technological sequence of drilling

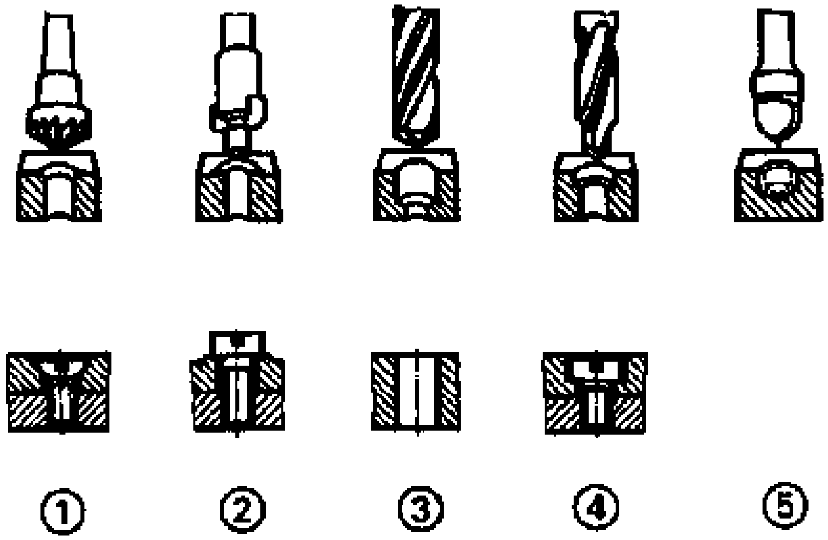
9 steps of work are described in the “Trainees’ Handbook of Lessons” in order to produce a blind hole. These steps need comprehensive explanation. Such a instruction includes hints about possible errors and their effect on the hole.

Purpose and application of counterboring/countersinking

Available workpieces should be used to explain the purpose of counterboring/countersinking operations. Subsequently, the counterbores/countersinks and their different uses should be described:

- (pointed) countersink 60°, 75°, 90°
- flat countersink
- three–lipped twist drill (spiral countersink)
- head counterbore or counterboring tool with pilot
- form counterbore or rotary files.

If these tools are not available, the illustrations contained in the “Trainees’ Handbook of Lessons” or transparency no. 7.6. can serve as a model.



Transparency 7.6

3.2. Exercises

If it has not been possible to include the necessary demonstrations of drilling actions into the instructions, this shall be done immediately before the start of the practical exercises. After a short practice in setting the machines, the exercises of the "Instruction Examples for Practical Vocational Training" can be carried out.

However, it is necessary to prepare every individual exercise by a job–related instruction during which the trainees are shown a completed workpiece so as to demonstrate aim and object of the exercises.

> The instructor roust have made such a workpiece by himself in order to be familiar with all the problems which might arise in producing such a workpiece.

The instructor can mention the criteria for evaluation as well as the problems involved. During these lessons of special instruction the sequences of operations and the working drawings of the training examples must be placed on the desks so that the trainees can make notes therein.

> The trainees must not operate these drilling machines unless they had an instruction in the functions of the controls.

It must be checked, whether the trainees have had such an instruction in labour safety regulations for drilling machines. (Check, whether there is an entry on labour safety instructions in the control book.) If this is not the case, the trainees must have such instructions right now!

When the trainees carry out these exercises, the instructor must always monitor their work. Special attention must be drawn to the drilling of holes, and you must not forget to check the clamping tightness.

It is advisable for the instructor to demonstrate again to all trainees the operation of the machine, the clamping of the workpiece and of the drill. Special attention must be drawn to the process of centring (alignment of holes and work–spindle), if the workpiece had been unclamped after the drilling and before the counterboring/countersinking stages.

As it will not be possible to provide each trainee with a drilling machine, the instructor has to determine the proper succession in which the trainees will operate the machines. This is to be included into the instruction in the actual task (taken from the training examples).

> During the exercise the instructor has to make sure that only one trainee operates the machine! Several trainees at one machine could distract each other from working and increase the risk of accidents.

If waiting times occur, caused by using the machines during the exercises, these times should be bridged by performing some other subject–related work.

3.3. Examples for recapitulation and tests

This section comprises questions which are to consolidate and test the acquired skills and knowledge. Each question is accompanied by the respective answers to questions. Questions which are also contained in the "Trainees' Handbook of Lessons" are marked with the letter "A".

1. What is the purpose of drilling

   (Production of straight openings and holes.)

2. Name the types of drilling machines!

   (Bench−type and upright drilling machines and portable electric drills.)

3. Which types of drill designs do you know?

"A" (The drill types are "hard" – "normal" – "soft" drills with caribide tips.)

4. When do we use a "normal" type drill?

"A" (When drilling in general structural steel, low−alloy steel and cast iron.)

5. Name the main parts of a drill!

"A" (Chisel edge, principal cutting edge, flanks, land, helical flute, shank.)

6. What are the disadvantages of chisel edges and how can we overcome them?

"A" (They exert pressure and squeezing actions in the hole and consume about 1/3 of the feed force – therefore, pre−drilling or a lateral grinding of the chisel edge is recommended.)

7. What is the task of the helical flute?

   (Removal of chips.)

8. Which forms of shanks do you know?

   (Up to about 10 mm they are straight, above 10 mm they are tapered.)

9. What is the point angle of "normal" type drilling?

(116° − 118°).

10. Name appropriate kinds of drill points for drilling hard materials!

"A" (Point angles from 80° to 90° or double−taper drill points)

11. Name appropriate kinds of drill points for drilling soft materials!

"A" (Point angles from 130° to 140° or flat drill point with centre point.)

12. Where can we use drills with "flat drill point and centre point"?

"A" (We use them for soft materials, thin sheet metal and cylindrical counterborings.)

13. What is the correct rotational speed to be selected for drilling a hole of 5 mm diameter in a workpiece of steel by means of a bench−type drilling machine and hand feed (manual feed)?

"A" (

$$n = \frac{22 \cdot 1000}{5 \cdot 3.14} = 1400 \text{r.p.m.}$$

tabular value = 1400 or 2240 r.p.m.)

14. What rules do we apply for selecting the rotational speed?

(High rotational speed with small drill diameters and soft materials.)

15. Name clamping devices for

1. tools with straight shank
2. tools with tapered shank.

"A" (1. three−jaw chuck; 2. taper sleeve.)

16. Which kinds of clamping workpieces do we know?

(Clamp dog, machine vice, drilling vee, clamping device for machine table.)

17. What is the sequence of operations of drilling a blind hole?

    (Scribing, prick–punching, spot–drilling, setting of depth, drilling up to the stop, cleaning, checking.)

18. What do we have to take into account for counterboring/countersinking?

“A” (Before counterboring/countersinking operations can begin you must align the hole with the work spindle. In order to avoid unclean surfaces you must employ low rotational speeds.)

19. When do we use a 90° countersink?

“A” (Spot–facing of holes which will be reamed or into which countersunk screws will be fitted.)

20. When do we use form counterbores?

    “A” (We need them for deburring work and for completing irregular and curved openings.)

4. Application of the working techniques of “Drilling, Countersinking and Counterboring”

The sequence of exercises can follow the variants mentioned in section 3. The subject can be dealt with comprehensively or subdivided into several stages.

The “Instruction Examples for Practical Vocational Training –Drilling, Countersinking and Counterboring” provide 6 exercises. These “Instruction Examples...” also comprise a list of required materials (initial material, working tools, measuring and testing tools, accessories) as well as the sequence of operations for the exercise and an illustrative working drawing, Thus, the trainees avail of all the information necessary for carrying out their exercises in a task–related way.

If the quality of the produced workpieces is considered substandard, the trainee has to carry out comprehensive preliminary exercises. For this purpose, any waste parts may be used. If the respective skill has been practised sufficiently, the envisaged training workpiece can be produced. The following hint should be taken into consideration:

> The trainee has to do all the work involved alone – from cutting the initial material to completing the workpiece.

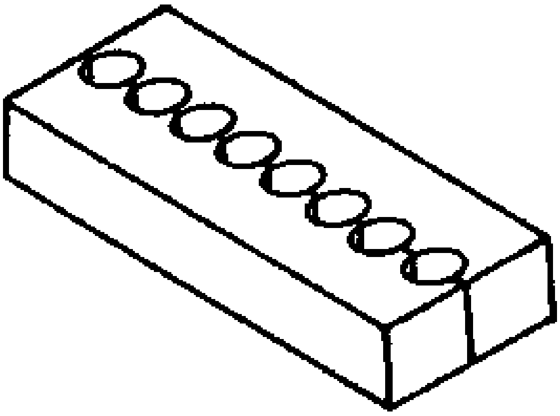
This is the only way to guarantee a just evaluation of the achievements.

If the proposed “Instruction Examples” are not used for practical training, it will be possible to select other parts for practising. In this case, all the working techniques discussed earlier should be also practised on those parts.

4.1. Instruction Examples

What follows is a brief description of the individual training examples in order to give a survey of the parts to be produced for practising the knowledge acquired:

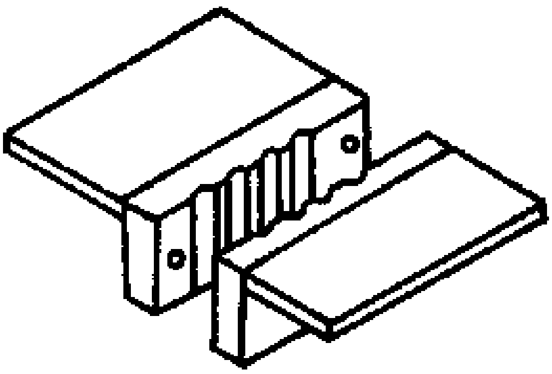
Instruction example no. 7.1. Drilling, countersinking and counterboring training workpiece



This is a component consisting of two clamped square steel bars.

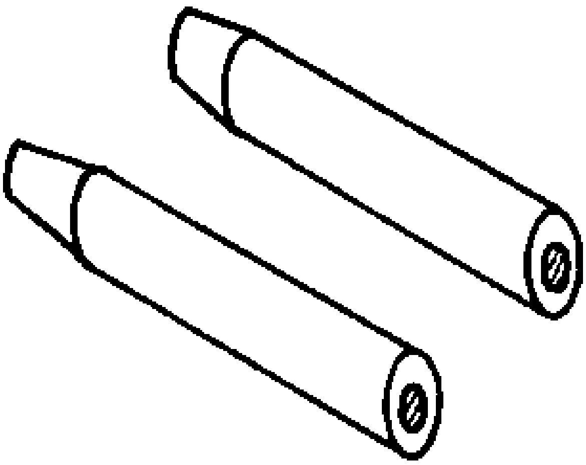
Along the dividing line the trainee has to drill and counterbore/countersink several holes. After this process, the two pieces can be separated again and the trainees can optically check the produced bore−hole walls.

Instruction example no. 7.2. Clamping jaws for round material



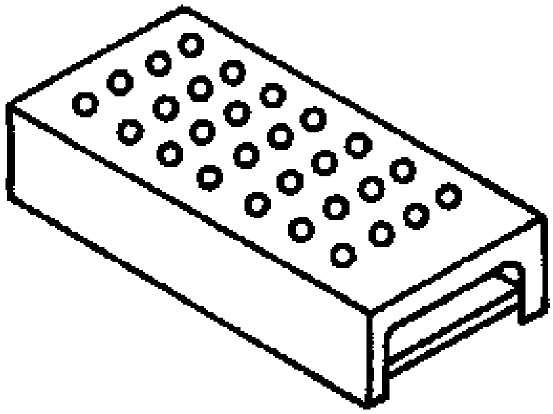
Two pieces of flat steel with a spacer of thin steel sheet will be provided with simple through holes of small diameters. After their completion these clamping jaws can be used as accessories for clamping round materials (similar to vee jaws)

Instruction example no. 7.3. Rivet set and rivet header



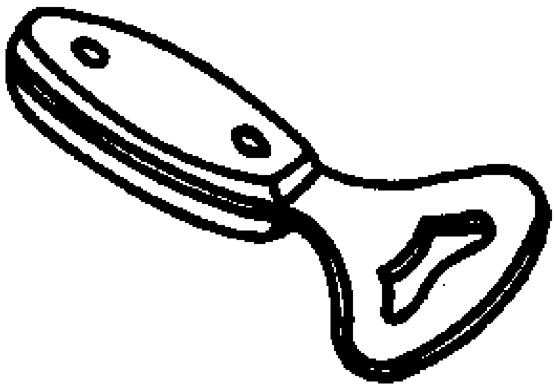
Silver steel round materials are provided with a hole and a counter–bore each in their centre. After their completion and hardening these parts can be used as tools for the working technique of riveting.

Instruction example no. 7.4. Drill stand



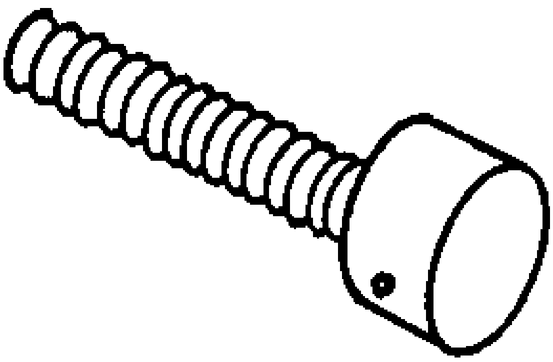
Channel steel will be provided with small–size blind and through holes (increments of 1/10 mm). The parts produced as instruction examples 2.3. or 4.2, will be employed now. After completion, the drill stand can serve as an easy to survey and practical support for drills in the workshop.

Instruction example no. 7.5. Bottl–opener



Stainless steel plates serve to practise drilling of curved contours and drilling of several parts at a time. After completion the trainees can use this bottle opener.

Instruction example 7.6. Rotary head for threaded spindle



The trainees practise drilling on inclined surfaces of round steel provided with an inserted threaded spindle. As the drilling must be carried out on the lateral area of the cylindrical surface, the workpiece must be turned step by step during this process. This component can be combined with the components of the instruction examples nos. 2.5., 8.2. and 9.5. to a C clamp.

4.2. Criteria for practical training

It is recommended to determine some major points of observation and evaluation. The following criteria can serve as a guideline:

– Is the hole properly scribed and pre−punched?

– Is the drill properly clamped?

– Did the trainee check whether there are grinding flaws on the drill?

– Does the trainee align the workpiece exactly and does he clamp it appropriately?

– Did the trainee protect the workpiece from being pulled up or distorted?

– Does the trainee select the proper rotational speed?

– Did the trainee think of protecting his head and eyes?

– Did the trainee find the correct drilling depth of planned blind hob s?

– Does the trainee use lubricants and coolants during drilling operations?

– Does the trainee properly check hole diameter and hole depth?

– Does the trainee centre the hole exactly below the counterbore/countersink?

– Does the trainee select the exact rotational speed for the counterbore/countersink?

– Does the trainee pay attention to the fact that the counterbore/countersink must be pressed into the hole care−fully and sensitively?

– Does the trainee clean the hole properly?

5. Captions and legends of the “Drilling, Countersinking and Counterboring” transparencies series

Transparency no. 7.1. Bench−type drilling machine

1 drill spindle

2 hand lever for feed

3 drill chuck

4 drill

5 workpiece

6 machine table

7 cone−pulley transmission

8 motor

9 column

Transparency no. 7.2. Upright drilling machine

1 spindle head

2 hand lever for feed

3 drill spindle

4 machine table

5 motor

6 drive head

7 machine column

8 column base

Transparency no. 7.3. Design and angles at drills

1 helical flute

2 land

3 flank

4 principal cutting edge

5 shank

6 chisel edge

? clearance angle

? wedge angle

? rake angle

? point angle

? complementary angle of the chisel edge angle

Transparency no. 7.4. Types of drills and special drill points

(1) "hard" type 1 = 10 °

(2) "normal" type 1 = 25°

(3) "soft" type 1 = 35°

(4) Point angle 80° – 90° (small)

(5) double–taper drill point

(6) point angle 130° – 140° (large)

(7) flat drill point with centre point

Transparency no. 7.4. Clamping of workpieces

(1) holding of flat, small workpieces in a hand vice

(2) securing of small parts in a machine vice

(3) securing of large workpieces on a machine table with holding clamps.

Transparency no. 7.6. <u>Types and use of counterbores/countersinks</u>

(1) (pointed) countersink – for fitting of countersunk screws

(2) flat countersink – for screws on uneven surfaces

(3) three–lipped twist drill – for enlarging holes by minor dimensions

(4) head counterbore or counterboring tool with pilot – for fitting of cylindrical cap screws

(5) form counterbore – for different forms

Drilling, Countersinking and Counterboring – Course: Technique for Manual Working of Materials. Trainees' Handbook of Lessons

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Drilling, Countersinking and Counterboring – Course: Technique for Manual Working of Materials. Trainees' Handbook of Lessons

Institut für berufliche Entwicklung e.V.
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1. Purpose of drilling

By drilling, cylindrical recesses or break–throughs are cut out of workpieces.

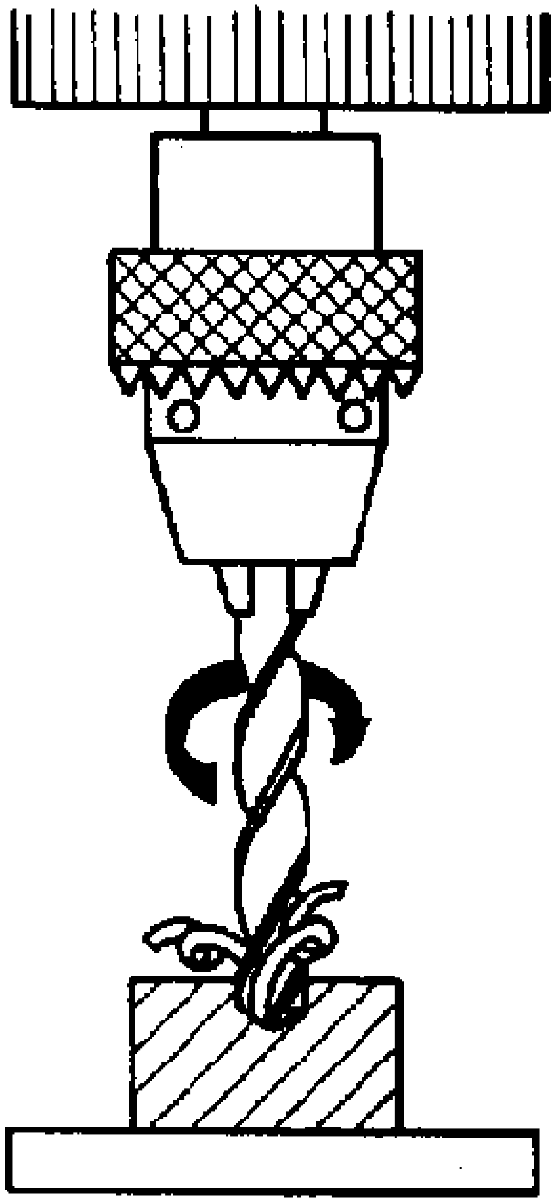

Figure 1 – Drilling

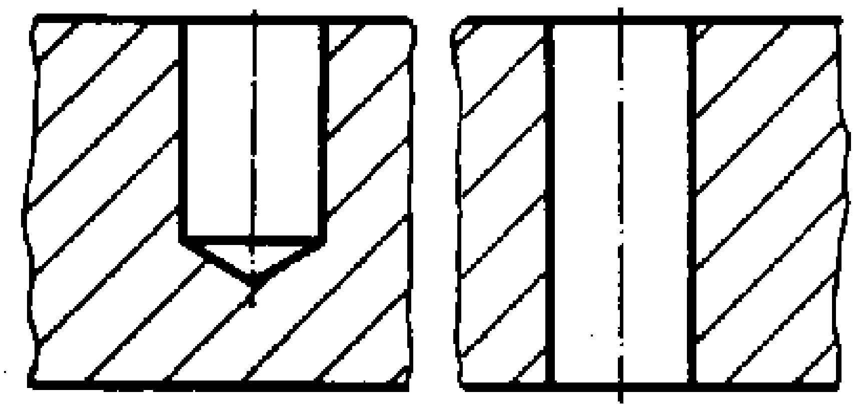

Figure 2 – Blind hole and through hole

It is necessary if

– screw joints
– pin joints
– riveted joints
– passages for fluids and gas

shall be made and if cylindrical machine parts shall be guided or carried.

2. Machines for drilling

In the field of maintenance and repair, simple bench−type drilling machines, upright drilling machines and portable electrodrills are used. In modern production plants, multi−spindle drilling machines, boring mills as well as numerically controlled machines are used, also turning machines and automatics.

3. Tools for metal drilling

There are various kinds of drills:

Drills type “hard”

They are used for materials harder than steel, for instance chromium−nickel alloys, cast steel and alloyed steels of a tensile strength of more than 500 MPa

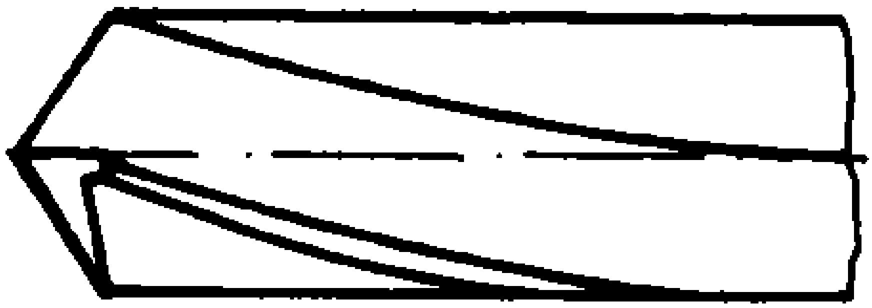

Figure 3 − Drill type “hard”

Drills type “normal”

Application with general−purpose constructional steel, low−alloy steels, cast iron

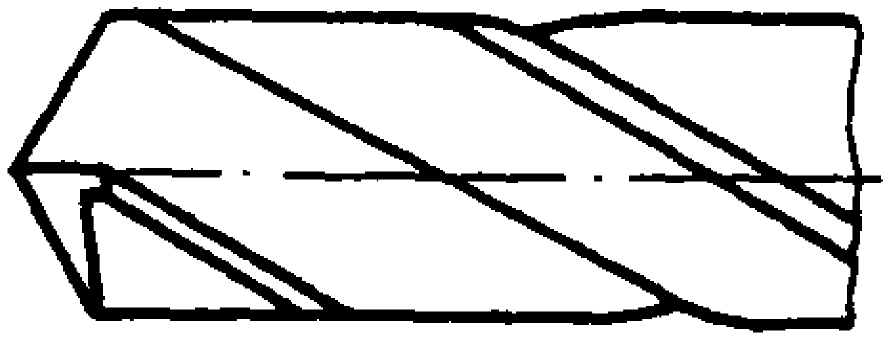

Figure 4 − Drill type “normal”

Drills type “soft”

Used for materials softer than steel such as long−chip aluminium alloys, copper, zinc, plastics, a number of compression moulding materials

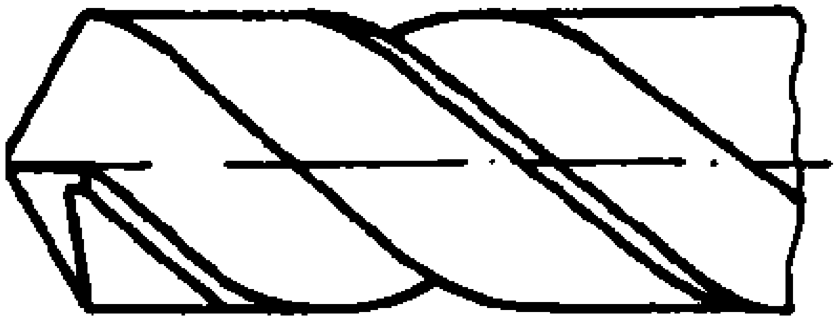

Figure 5 – Drill type “soft”

Drills with cemented carbide tips

Used with very hard and resistant materials as well as natural materials (such as stone, concrete, ceramics, glass)

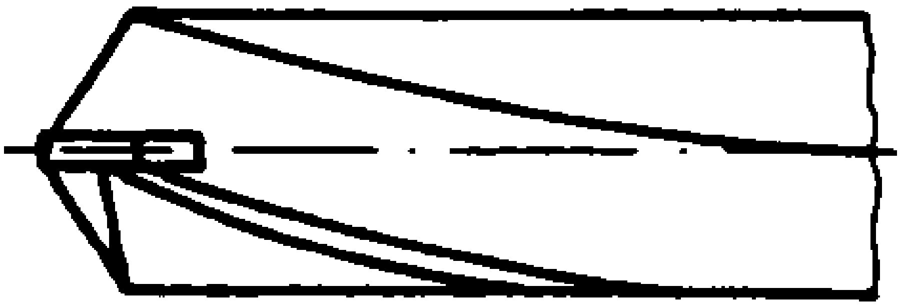

Figure 6 – Drill with cemented carbide tips

3.1. Construction and drill point of a drill type “normal”

This type of drill is the most common tool for drilling of steel:

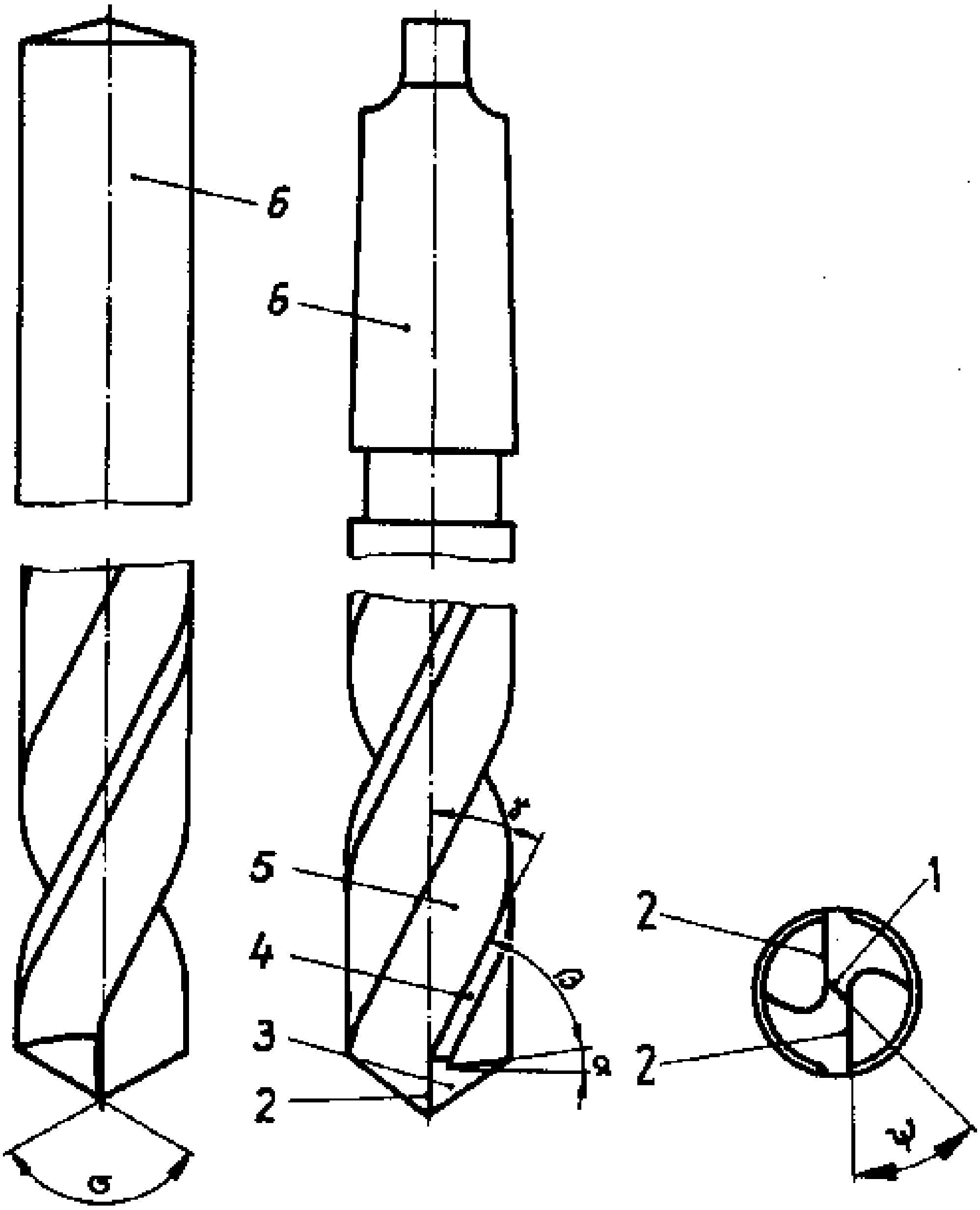

Figure 7 – Construction of the drill type “normal”

1	chisel edge	?	– lip relief angle (4° – 6°)
2	principal cutting edges	?	– lig angle
3	flanks	?	– rake angle (25°)
4	land	?	– point angle (116° – 118°)
5	helical flute	?	– complementary angle of the chisel edge angle (55°)
6	shank		

The chisel edge is an edge at the point of the drill. It presses and squeezes the material in the bore hole and, in doing so, consumes approximately one third of the thrust.

Therefore, larger bore holes are predrilled with smaller drills (according to the length of the chisel edge of the big drill) or the drill is equipped with a laterally sharpened chisel edge. The principal cutting edges do the actual chipping work; they must always be sharp and provided with a flank (behind the cutting edges), so that these cutting edges have the effect of a wedge.

The land is in contact with the bore hole wall; due to its narrowness, there is only a little friction during the boring process and a good guidance of the drill (no walking off centre) is achieved.

The helical flute transports the chips out of the bore hole and, at the same time, enables the lubricating and cooling agent to reach the point of the drill.

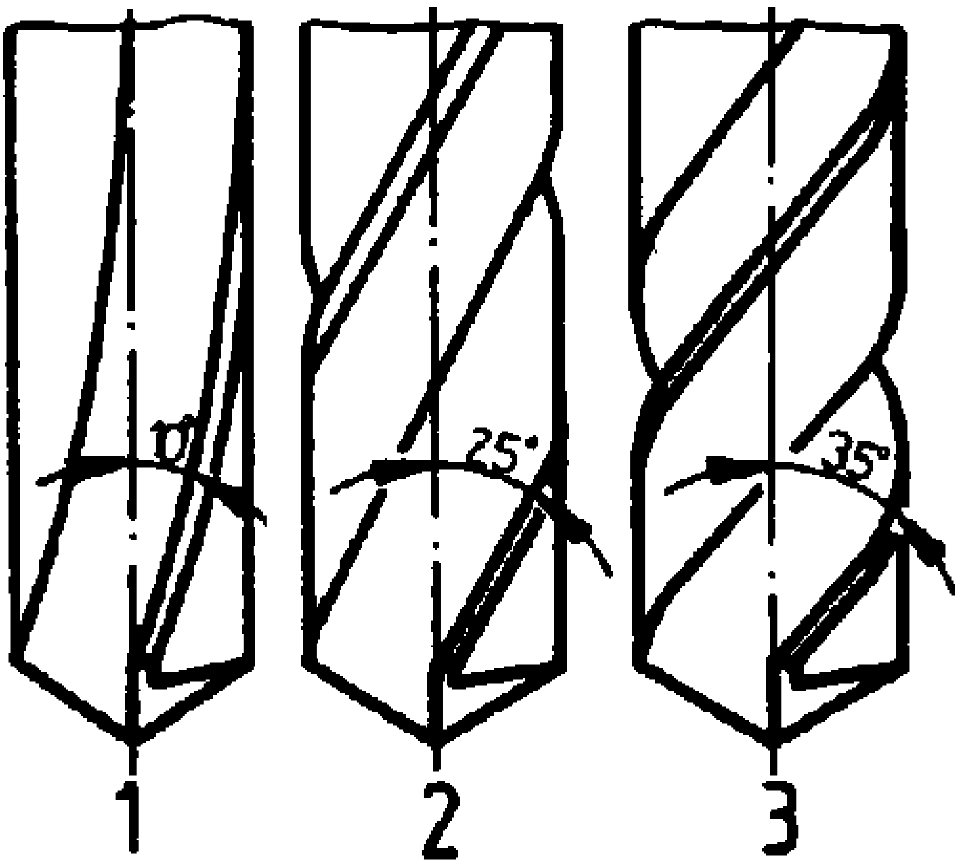

Figure 8 – Comparison of the rake angles

1 Drill type “hard”,

2 Drill type “normal”,

3 Drill type “soft”

The three types of drills are distinguished by the rake angle, which determines the slope of the helical flute (type “hard” –15°; type “soft” – 35°).

The shank – with drills of diameters up to 10 mm – is normally cylindrical, with diameters of more than 10 mm it is conical, because with these drills, the very strong power transmission is effected through the favourable reception of the taper sleeve in the machine.

3.2. Special drill point

In addition to the type of drill, the drill point can be different with hard or soft materials in order to achieve a good chip removal:

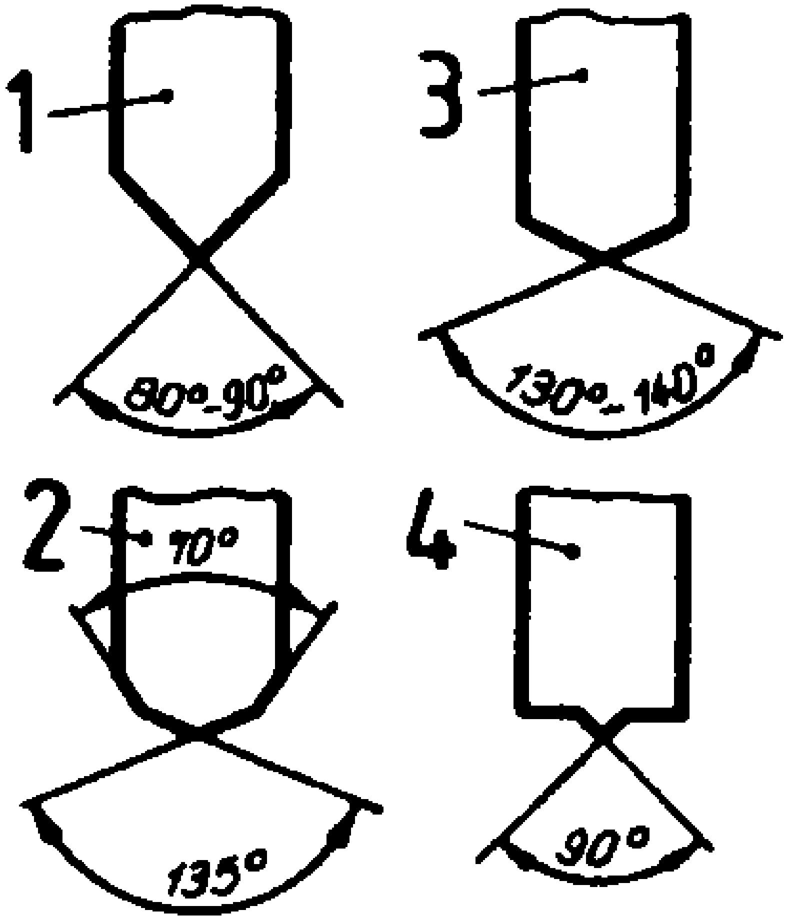

Figure 9 – Special drill points

With hard materials

– Point angle 80° – 90° (1) or double–cone drill point (2)

With soft materials

– Point angle 130° – 140° (3) or flat drill point with centre point (4)

For drilling of thin sheet metal, too, the drill with “flat drill point and centre point” is used in order to prevent the bore hole from tearing out. This drill may also be used for cylindrical counterboring instead of a counterboring tool with pilot.

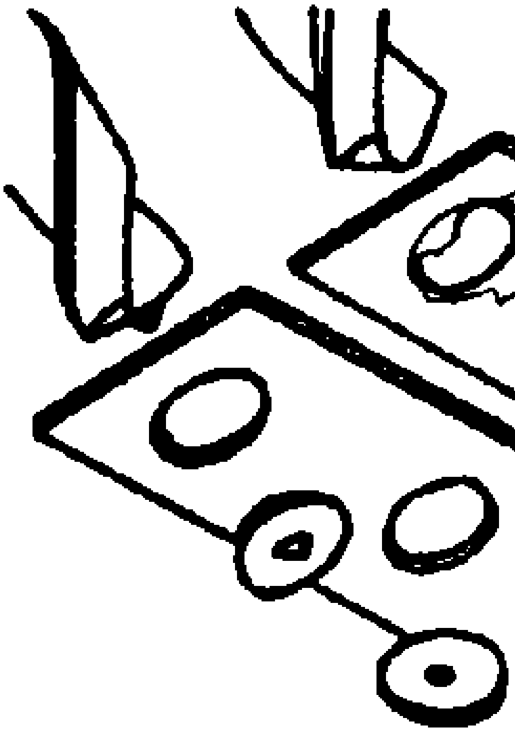

Figure 10 – Use of the drill with “flat drill point and centre point” for thin sheet metal

What kinds of drills are there?

____

When do you use the “normal” type of drill?

What main parts does the drill consist of?

What is the disadvantage of the chisel edge and how can it be compensated for?

Which kinds of drill points are recommendable for drilling hard materials?

Which kinds of drill points are recommendable for drilling soft materials?

What fields of application are there for the use of the drill with “flat drill point and centre point”?

4. The operation of drilling

The removal of chips is effected by the combination of the feed and the rotary motion. The rotary motion can be made by the tool or by the workpiece (the latter being the case when drilling by turning machines). The chips are removed by the principal cutting edges only. This is done at the bottom of the drilled hole. For this purpose, the material of the drill roust be harder than that of the workpiece to be drilled.

By the friction in the bore hole, tool and workpiece are heated up. Too strong heating up leads to a loss of hardness Of the drill. Therefore, a suitable lubricating and cooling agent must be used. The best suitable agents are hydrated fluids with soap or oil constitutents.

When the water evaporates, it absorbs great quantities of heat, the rest of the constituents enables a reduction of the friction and smooth bore hole walls.

Figure 11 – Operation of drilling

By drilling, only roughing quality of the wall of the bore hole and a dimensional accuracy of 0.05 to 0.1 mm is achieved, more accurate bore holes must be reamed afterwards.

4.1. Materials of the drills

In general, drills consist of tool steel, high–speed steel and super high–speed steel. In addition, the cutting edges can be tipped with cemented carbide tips.

Development trends

Modern drills, as to their hardness, are influenced further by techniques such as nitrogen freezing hardening and various coating techniques (evaporation coating with titanium nit ride).

Also, drills of a combination of metallic and ceramic materials are being developed.

All these changes result in a considerably wider field of application and longer service life of the drills under the special conditions of modern production.

Even after resharpening of the cutting edges (due to abrasion), these tools are still more efficient than traditional drills.

5. Setting of the tools

At bench–type and upright drilling machines, the ‘rotational speed’ and – with modern types – the ‘cutting speed’ and ‘feed’ must be set.

The rates of ‘rotational speed’, ‘cutting speed’ and ‘feed’ depend on the material to be drilled and the diameter of the drill.

To automatic feeds the following rules apply:

Low feed rate – with high rotational speed and hard material
High feed rate – with low rotational speed and soft material

The automatic feed is not required for making smaller bore holes (up to 12 mm dia.)

The cutting speed for drilling without automatic feed can be fixed at 22 m/min. Thus, the following rotational speeds apply:

Materials	Diameter of the drill in mm (Range)					
	1 – 3	3 – 5	5 – 8	8 – 10	10 – 12	12 – 16
Soft materials (aluminium, copper)	7100 to 4500	5600 to 3500	3500 to 2200	2800 to 1800	2200 to 1400	1800 to 1100
Medium hard steels cast steel	2800 to 1800	2200 to 1400	1400 to 900	1100 to 700	900 to 560	710 to 450
hard materials (chromium–nickel alloys)	350	350	350	350	280	220

The following rule applies to the setting of the rotational speed:

Low rotational speed – with hard materials and great drill diameters
High rotational speed – with soft materials and small drill diameters

The rotational speed can be calculated with the help of the following formula:

$$n = \frac{v \cdot 1000}{d \cdot \pi}$$

n = rotational speed (in r.p.m.)
v = cutting speed (in m/min)
d = diameter of the rotating piece (in mm)
? = 3.14

Calculating example

What rotational speed has to be set if a bore hole of 10 mm shall be drilled into a workplace of steel on a bench–type drilling machine with feed by hand?

$$n = \frac{22 \cdot 1000}{10 \cdot 3.14} = \frac{2200}{3.14} = 700 \text{r.p.m.}$$

Exercise

What rotational speed has to be set if a bore hole of 5 mm dia. shall be drilled into a workpiece of steel by a bench–type drilling machine with hand feed?

Compare the result with the value of the table:

Calculated value	Value indicated in the table

6. Clamping of the tools

According to the size of the drills (type of the shank), the drills are clamped in a three−jaw chuck or in taper sleeve collets. In mass production, quick−change chucks are often used for the drilling machines, which enables the drill to be changed with the machine running.

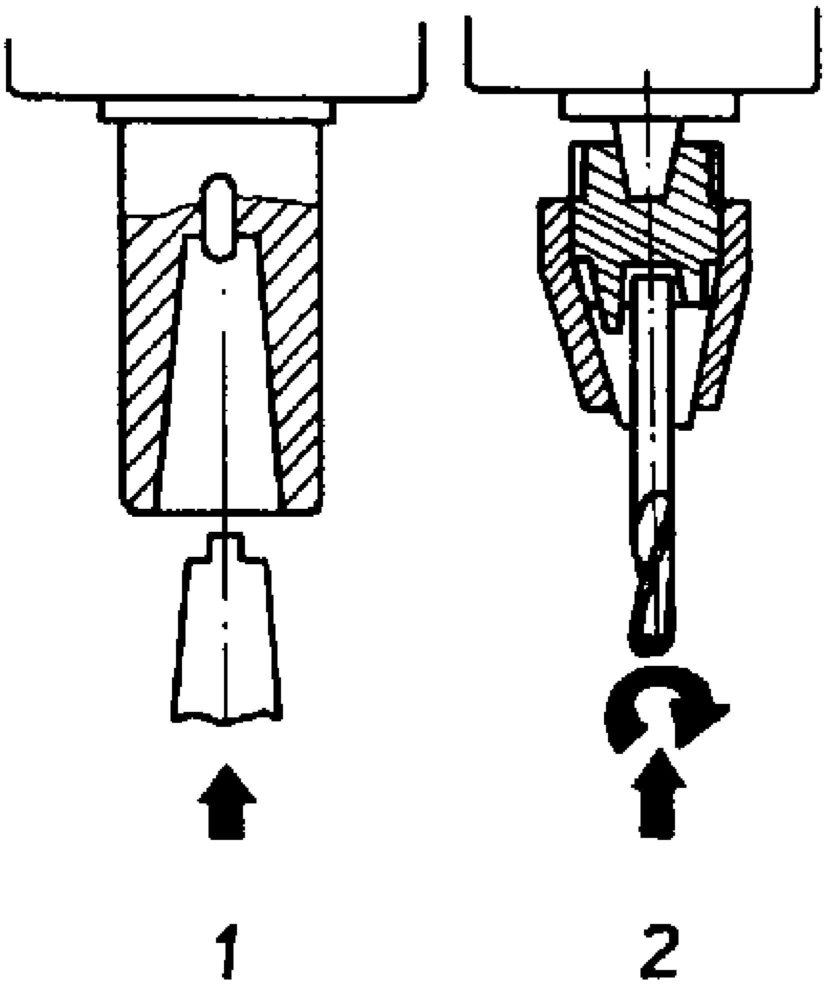

Figure 12 − Tool holding fixtures

1 − taper sleeve
2 − Three−jaw drill chuck

What clamping possibilities are there for:

1. Tools with cylindrical shank
2. Tools with taper shank?

1. ________________________________
2. ________________________________

7. Clamping of the workpieces

Workpieces roust be clamped in such a way that they cannot fling around or be drawn up.

Small workpieces can be held by clamp dogs or hand vices on a support if only a small rotary power is to be expected (small bore holes).

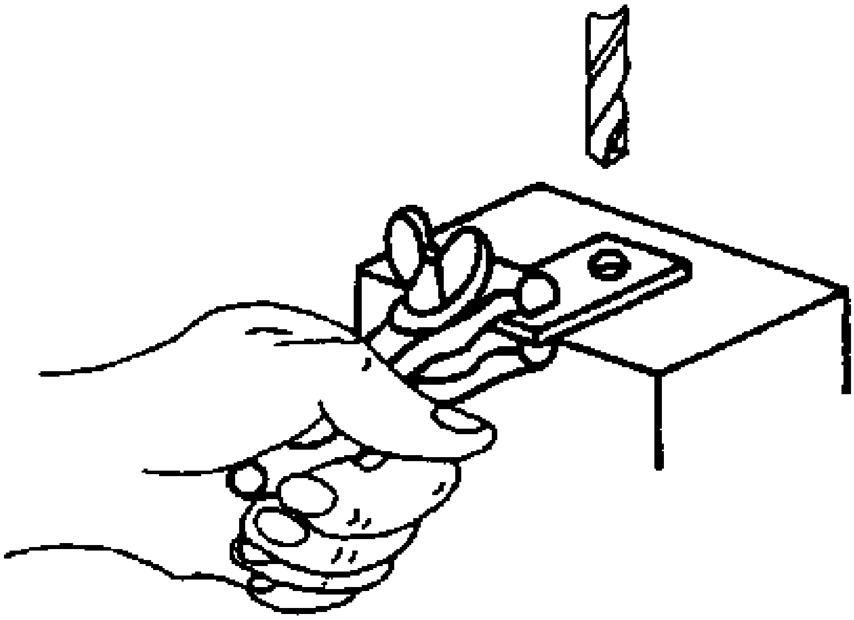

Figure 13 – Holding of flat, small workpieces in the hand vice

Larger workpieces are safely clamped in the machine vice that can be equipped with straight or prismatic jaws.

Cylindrical parts may also be clamped in the drilling v–block

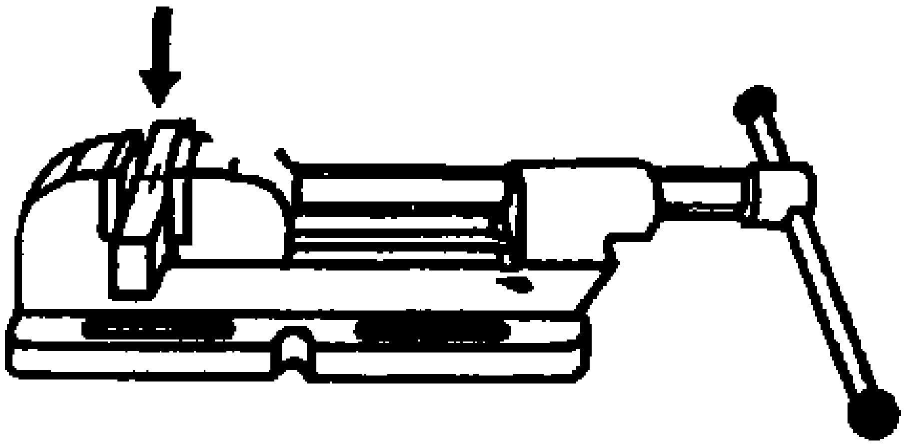

Figure 14 – Clamping of small workpieces in the machine vice

Very big parts must be clamped on the machine table directly.

For this purpose, clamps and locking screws as well as other auxiliary means are required.

For series and mass production, drill jigs are used.

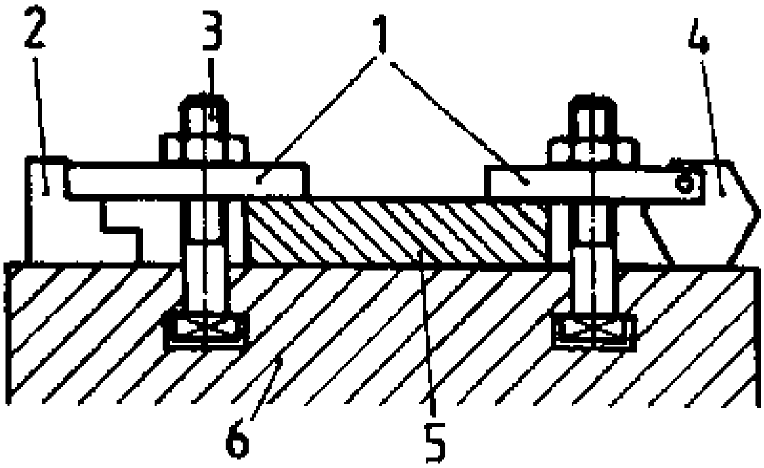

Figure 15 – Clamping of big workpieces on the machine table by clamps

1 – Clamps
2 – Step block
3 – Locking screw
4 – Supporting hexagon (fixed at the clamp)
5 – Workpiece
6 – Machine table

8. Technological process of drilling

Drilling of a blind hole:

1. Scribing and prick–punching

2. Clamping of the drill

3. Clamping of the workpiece in the machine vice and placing the point of the drill right above the punch mark;

Clamping the machine vice on the machine table

4. Setting the rotational speed at the machine

5. Spot–drilling of the workpiece (the point of the drill completely penetrates into the workpiece)

6. Setting the drilling depth at the machine which is switched off during this operation

7. Drilling up to the dog of the feed handle and/or depth indicator (feeding of cooling agent and permanent control of the flow of chips)

8. Cleaning and deburring

9. Checking of the diameter and of the depth of the bore hole with the help of a vernier caliper and depth gauge

If the bore hole is not true to size, i.e. if it is too large, this can have the following reasons:

Cause of the fault	Correction of the fault
Wrong drill point	Regrinding of the drill
The drill runs out when the spindle is running	Cleaning of the cylindrical shank of the drill as well as of the sleeve and reclamping of the drill. If the shank is severely damaged by ridges it can no longer

	be used and has to be replaced
The workpiece is not fixed	Clamp the workpiece on the table more firmly or secure it against displacement at least.

9. Purpose and application of counterboring/countersinking

By counterboring/countersinking, bore holes are deburred, precast or predrilled holes are enlarged or their rims worked in such way a that screwed or riveted joints can be made.

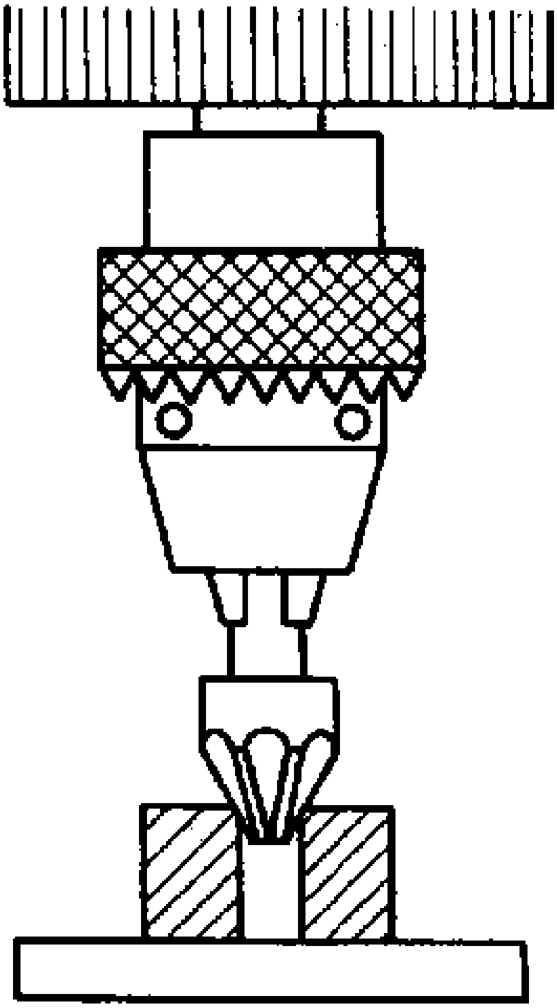

Figure 16 – Counterboring/countersinking

For this purpose, attention has to be paid to the following:

– Before counterboring/countersinking, the bore hole must be brought in line with the working spindle.

– Work at a low rotational speed (approximately 350 r.p.m.), otherwise there will be uneven surfaces.

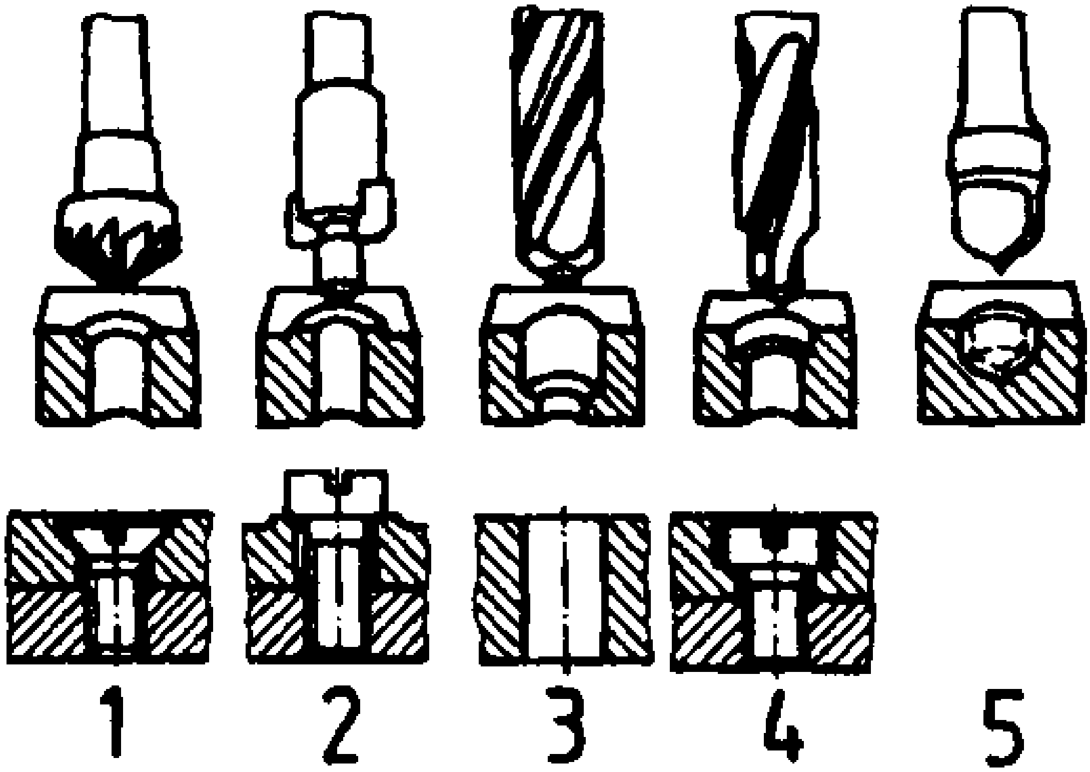

Figure 17 – Types of counterbores/countersinks

1 – Countersinking cutter (60°; 75°; 90°)
2 – Flat countersink
3 – Counterbore with spiral flutes
4 – Counterboring tool with pilot or spot facer
5 – Form counterbore (special forms)

9.1. Use of the counterbores/countersinks

– Countersinking cutter 60°:

Spot–facing of bore holes in which threads shall be cut (Nominal measurement: D_s = N)

– Countersinking cutter 75°:

Spot–facing of bore holes for countersunk–head rivets

– Countersinking cutter 90°:

Spot–facing of bore holes that shall be reamed (Nominal measurement: D_s = N + 0.2 mm) as well as spot–facing of bore holes in which countersunk screws shall be fitted

– Flat countersink

Spot–facing of flat seating faces for screws on uneven surfaces

– Counterbore with spiral flutes:

Boring of predrilled holes by a small measure (Example: from 8 mm to 10 mm)

– Counterboring tool with pilot or spot facer:

Spot–facing of cylindrical screw head location. Pay attention to the guiding clearance of the pilot of 0.05 mm – 0.1 mm. (Also possible by a drill with flat drill point and centre point),

– Form counterbore:

Deburring and forming of irregular or curved pockets; for this purpose, also rotary files or small form cutters are used.

What has to be taken into consideration when counterboring/countersinking?

____

____

When do you use a 90° countersinking cutter?

____

____

What are the fields of application of form counterbores?

____

____

10. Labour safety recommendations

– Wear close–fitting clothes and head shield, if necessary, safety glasses, too.

– Only one person must work at a machine – otherwise there is the danger of being distracted.

– Always do the cleaning and setting work with the machine switched off.

– Secure the workpieces safely against twisting and being pulled up.

– Do not remove any chips with bare hands, but with the help of suitable auxiliary means (such as short hooks or metal rods).

– Leave the machine only when it is at rest.

Drilling, Countersinking and Counterboring – Course: Technique for Manual Working of Materials. Instruction Examples for Practical Vocational Training

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Drilling, Countersinking and Counterboring – Course: Technique for Manual Working of Materials. Instruction Examples for Practical Vocational Training

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Introduction

The present material includes 6 selected instruction examples by means of which the essential operations of drilling, countersinking and counterboring can be practised.

For that purpose, through–hole and bottom–hole bores, holes on flat and inclined surfaces as well as counterbores and countersinks will be made.

Apart from the mere exercise of drilling, countersinking and counterboring on a special workpiece, the jaws for round material, the drill stand as well as the rivet set and the rivet header can be used in the workshop. The rotary head for a threaded spindle is a single part of a C clamp; the bottle–opener can be used by the trainees themselves.

In order to facilitate the preparation and execution of works, the required materials, working tools, measuring and testing tools as well as accessories are given for each of the practical examples. Furthermore, the previous knowledge is mentioned that is necessary for executing the exercises.

In addition to the working drawing attached, a favourable sequence of operations is described.

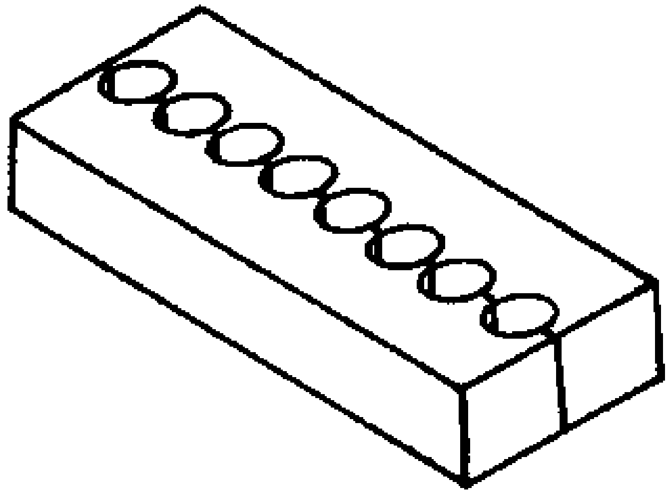
Explanation to material data:

Steel grading is as to the value of tensile strength given in the unit "Megapascal" (MPa).

Instruction example 7.1. Drilling, countersinking and counterboring training workpiece

Practise drilling and counterboring/countersinking in medium–hard and soft materials to given dimensions.

Material



2 x squares made of steel (380 MPa) and of aluminium or copper

Thickness: approx.	24 mm
Length:	130 mm

Working tools

Steel scriber or marking gauge, centre punch, locksmith's hammer, three−square scraper, drills ("Normal" type) of 6.75, 8. 8.4. 9 mm dia., drills ("Soft" type) of 6.75, 8, 8.4. 9 mm dia., three−groove twist drill of 10 mm dia., counterboring tool of 15 mm dia. with pilot of 8.9 mm dia., drill with flat drill point and centre point of 15 mm dia., countersink 60, 75°, 90°

Measuring and testing tools

Steel rule, vernier caliper with depth gauge

Accessories

2 C clamps, machine vice, diluted soluble oil, spirit

Required previous knowledge

Reading of drawings, scribing, prick−punching, measuring, testing, sawing, filing

Sequence of operations	**Comments**
1. Arrange workplace Prepare working material	− Check for completeness
2. Check initial length of workpieces; if necessary, saw and deburr to 130 mm	− Begin with workpieces made of steel!
3. Clamp workpieces together by means of C clamp; scribe and punch hole centres onto the centre line visible through edges	− Condition: distance between finished upper edges of holes shall be 4 mm each!
4. Fix workpieces clamped together into a machine vice, set up the drilling machine	

5. Produce holes and counterbores/countersinks

5.1. Through hole of 8 mm dia. – (1)

– Chuck drill of 8 mm dia.	
– Adjust drill point onto punch mark and fix machine vice	
– Select speed of machine	– n = 1100 r.p.m.
– Put into operation and take the drill into workpiece by slowly applying a pressure onto feed lever	– Add diluted soluble oil
– Reduce pressure before drill point is through	
– Clean and deburr hole	– (Three–square scraper)

5.2. Bottom hole Ø 8 x 20 – (2)

– Adjust drill point above punch mark	– Fix machine vice!
– Put machine into operation and spot–drill workpiece	– To nominal dimension of 8 mm (take drill point completely into the workpiece)
– Stop machine and adjust depth gauge on machine	– To 20 mm depth
– Put machine into operation and push drill down to stop by means of feed lever	– Add diluted soluble oil
– Clean and deburr after drilling	

5.3. Counterbore a through hole of 8 mm dia. to 10 mm dia. up to 15 mm depth – (3)

– Produce through hole of 8 mm dia.	
– Chuck three–groove twist drill of 10 mm dia., centre	– Clamp workpiece!
– Select speed of the machine	– n = 350 r.p.m.
– Put three–groove twist drill on hole and adjust depth gauge	– To 15 mm depth
– Put into operation and counterbore to stop	– Cool
– Clean and deburr hole	

5.4. Drilling and counterboring for socket head cap screw M 8 – (4)

– Produce through hole of 9 mm. dia.	– n = 1100 r.p.m.
	– To 8 mm depth

– Centre counterboring tool of 15 mm dia. Above hole with machine stopped, press pilot into hole and adjust depth	
– Select speed	– n = 350 r.p.m.
– Put into operation and counterbore to stop	– Add coolant
– Clean hole	

5.5. Drilling and counterboring for fillister head screw with slot M 8 – (5)

– Centre drill with flat drill point and centre point of Ø 15 above the hole	– Clamp workpiece!
– Select speed	– n = 710 r.p.m.
– Put drill on workpiece and adjust depth gauge	– To 6 mm depth
– Put into operation and drill to stop	– Cool
– Adjust drill of 9 mm dia. above hole centre and drill through	– n = 1100 r.p.m.
– Clean and deburr hole	

5.6. Drilling and countersinking for countersunk screw M 8 – (6)

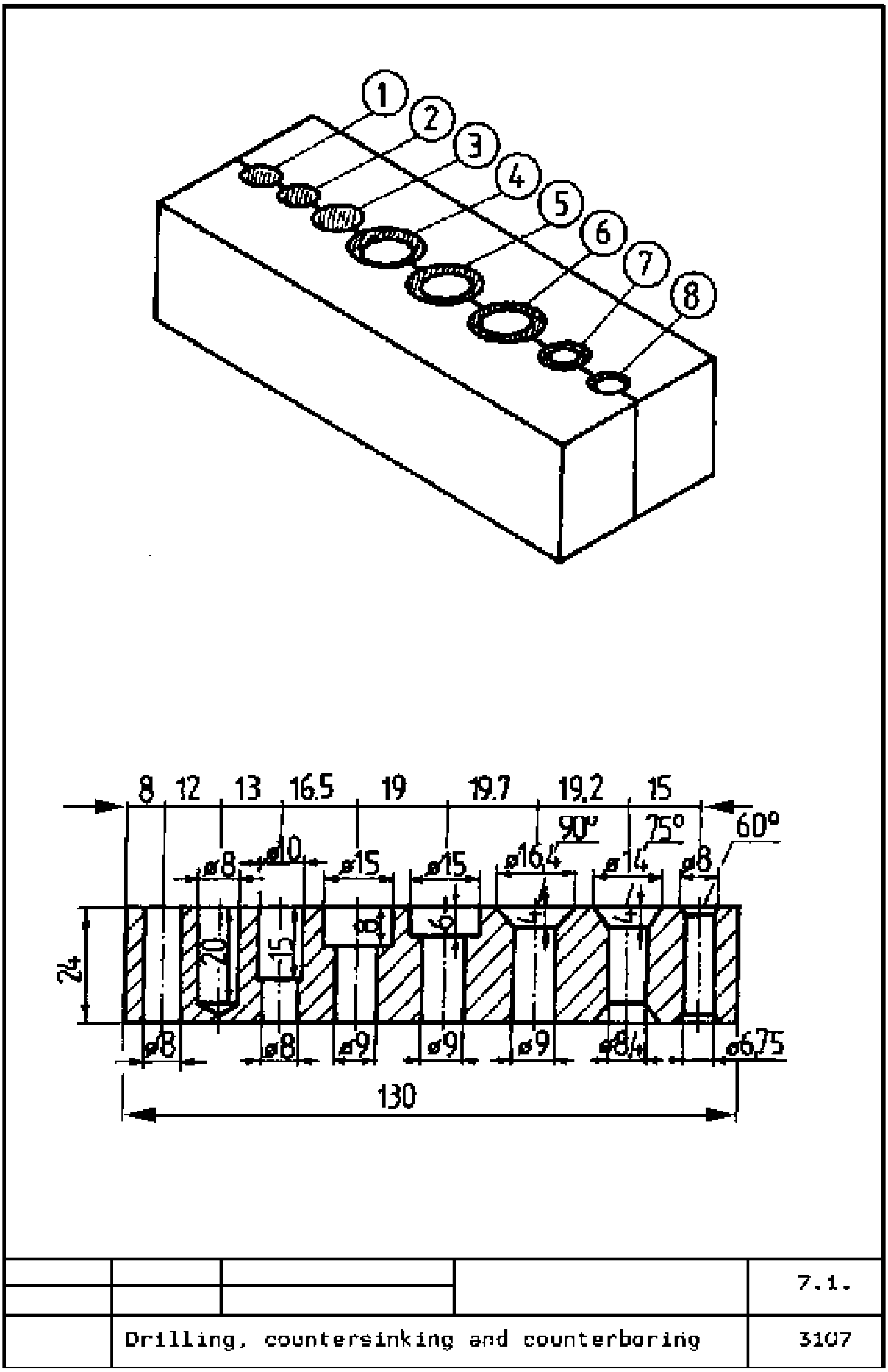
– Produce through hole of 9 mm dia.	– n = 1100 r.p.m.
– Centre 90° countersink above hole, put it on hole and adjust depth gauge	– To 4 mm depth – Clamp workpiece!
– Select speed	– n = 350 r.p.m.
– Put into operation and countersink to stop	– D_s = 16,4 mm
– Clean hole	

5.7. Drilling and countersinking for countersunk rivet Ø 8 – (7)

– Produce through hole of 8.4 mm dia.	– n = 1100 r.p.m.
– Centre 75° countersink above hole and countersink step by step until countersinking dia. of 14 mm is reached	– n = 350 rpm. – Check intermediately by means of vernier caliper
– Unclamp workpiece, reverse and adjust, clamp again	– Press countersink into hole with machine stopped – hole draws to centre!
– Repeat countersinking	
– Clean hole	

5.8. Drilling and countersinking for tapped hole M 8 (8)

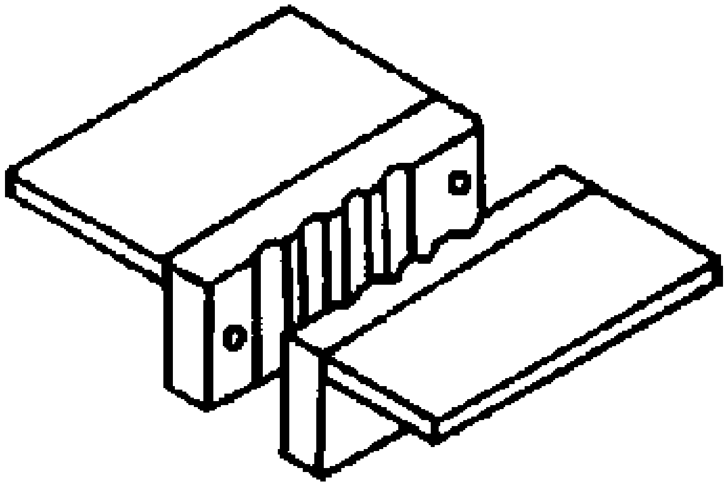
– Produce through hole of 6.75 mm dia.	– n = 1400 r.p.m.
– Centre 60° countersink above hole and countersink to 8 mm countersinking dia.	– Check by means of vernier caliper
– Unclamp workpiece, reverse and adjust	
– Repeat countersinking	
– Clean hole	
6. Unclamp workpiece, loosen C clamps	
7. Repeat operations No. 2 to 6 on workpieces made of aluminium or copper, determine new speeds for drilling operations	– Use drill of “Soft” type. Use spirit as coolant
8. Final check on halves of workpieces	– Holes and counterbores can be checked on sections!



Instruction example 7.2. Clamping jaws for round material

Practise the production of simple through holes by drilling with spacer

<u>Material</u>



– 2 x steel sheet (380 MPa)

thickness:	3 mm
width:	80 mm
length:	120 mm

– 2 x flat steel (380 MPa)

thickness:	10 mm
width:	25 to 30 mm
length:	120 mm

– 4 x countersunk rivet Ø 4

Working tools

Centre punch, locksmith's hammer, steel scriber or marking gauge, drills ("Normal" type) of 3, 4. 4.1., 5, 6, 8. 10. 12 mm dia., countersink 75°, portable electric drill

Measuring and testing tools

Steel rule, vernier caliper

Accessories

2 C clamps, machine vice, diluted soluble oil, steel sheet of 2 mm x (30) x 120 as spacer

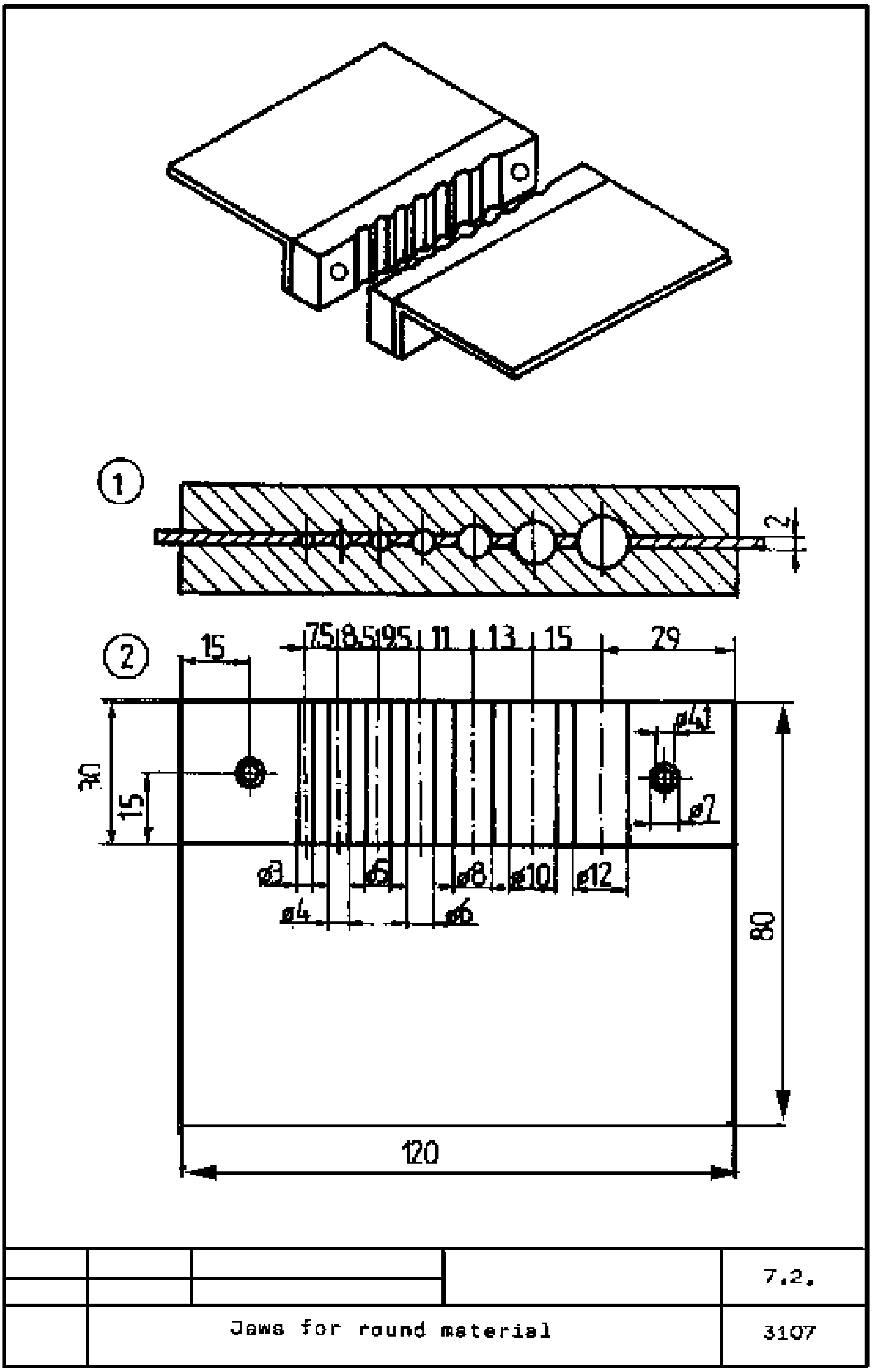
Required previous knowledge

Reading of drawings, scribing, prick–punching, measuring, testing, sawing, filing

Sequence of operations	**Comments**
1. Arrange workplace Prepare working material	– Check for completeness
2. Check initial dimensions of workpieces; if necessary, finish as to given dimensions, deburr	– (shearing, sawing, filing)

3. Clamp flat material together with spacer into C clamps	– Top faces in the same level! Stage (1)
4. Scribe bore centres on top face	– Punch marks on the spacer
5. Clamp clamped workpieces into machine vice	
6. Produce holes as to drawing dimensions	
– Select speed	– determine by formula $n = \frac{V \cdot 1000}{d \cdot \pi}$
– Chuck drill	
– Adjust punch mark below drill point	
– Fix machine vice	
– Drill	
– Clean and deburr bore	– Cool
7. Unclamp workpieces, scribe bores for riveted joints	
8. Clamp together one flat steel with steel sheet, drill together and countersink (on both sides) by electrical/hand drill	– drill Ø 4.1 mm countersink 75° to 7.0 mm dia. Stage (2)
9. Check holes	

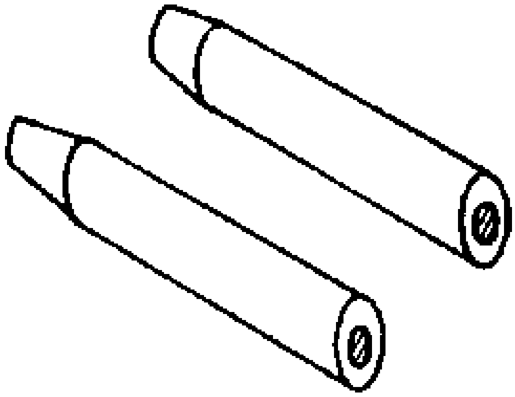
Finishing: Joint flat steel and steel sheet by means of countersunk rivets, bend steel sheet behind the flat steel (90°).



Instruction example 7.3. Rivet set and rivet header

Practise the production of concentric holes and counterbores/countersinks in round material

<u>Material</u>



2 x round material made of silver steel (1.1 to 1.25 % of carbon)

diameter: 12 mm

length: 100 mm

Working tools

Steel scriber, centre punch, locksmith's hammer, drill of 4.3 mm dia., form counterbore (rotary file – ball dia.: 8 mm)

Measuring and testing tools

Steel rule, vernier caliper

Accessories

Centre square, machine vice with vee jaws, diluted soluble oil

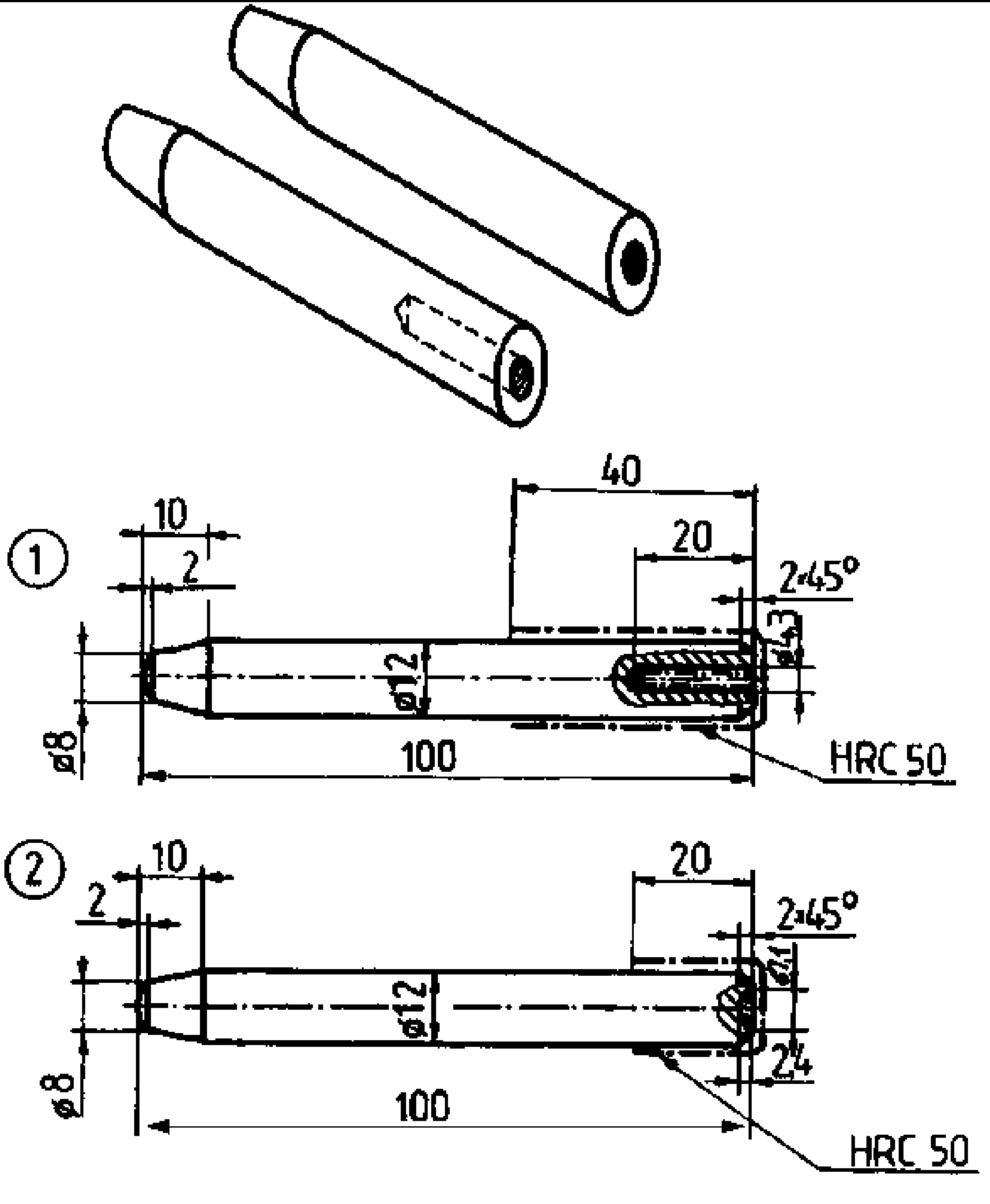
Required previous knowledge

Reading of drawings, scribing, prick–punching, measuring, testing, sawing, filing

Sequence of operations	Comments
1. Arrange workplace Prepare working material	– Check for completeness
2. Check workpieces for initial length; if necessary, finish	– Sawing, Filing
3. Scribe and punch hole on end face by means of centre square	
4. Drill hole for rivet set (1) of 4.3 mm dia. to 20 mm depth	– Clamp round material vertically into vice – n = 2240 r.p.m.
5. Drill hole for rivet header (2) of 4.3 mm dia. to 2 mm depth, subsequently counterbore to 2.4 mm depth by means of form counterbore (rotary file)	– n = 2240 r.p.m.

6. Check hole and counterbore – Concentricity, accuracy to size

Finishing: Grind tool heads true–to–size as to drawing by means of grinding machine, the same goes for chamfer 2 x 45°, harden rivet set 40 mm on hole end, harden rivet header 20 mm on counterbore end to HRC 50

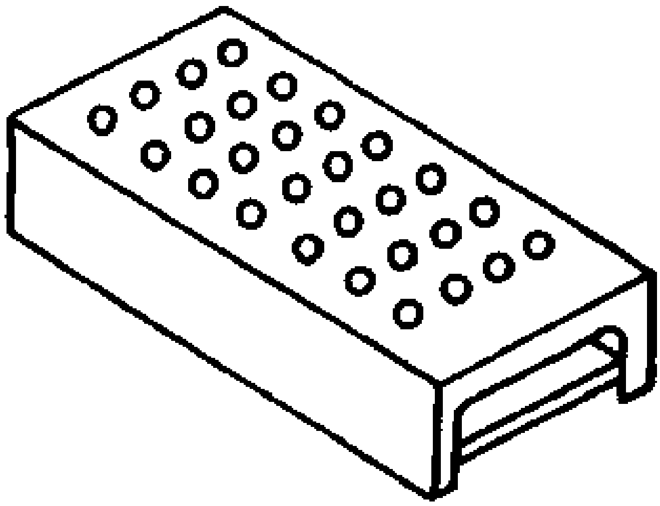


			7.3.
	Rivet set and rivet header for rivets of 4 mm dia		3107

Instruction example 7.4. Drill stand

Practise drilling of small bottom holes and through holes

Material



– channel–section steel (380 MPa) 80 x 45 x 6 x 8 length: 120 mm (or from training examples 2.3 or 4.2)

– plate made of steel or plastic material

thickness: approx.	10 mm
width: approx.	80 mm
length:	120 mm

– 4 x slotted nail Ø 4 x 10

Working tools

Hand hacksaw, bastard file of 300 mm (flat), surface gauge, centre punch, locksmith's hammer, drills of 1.1 to 5.0 mm dia., countersink 90°

Measuring and testing tools

Steel rule, vernier caliper

Accessories

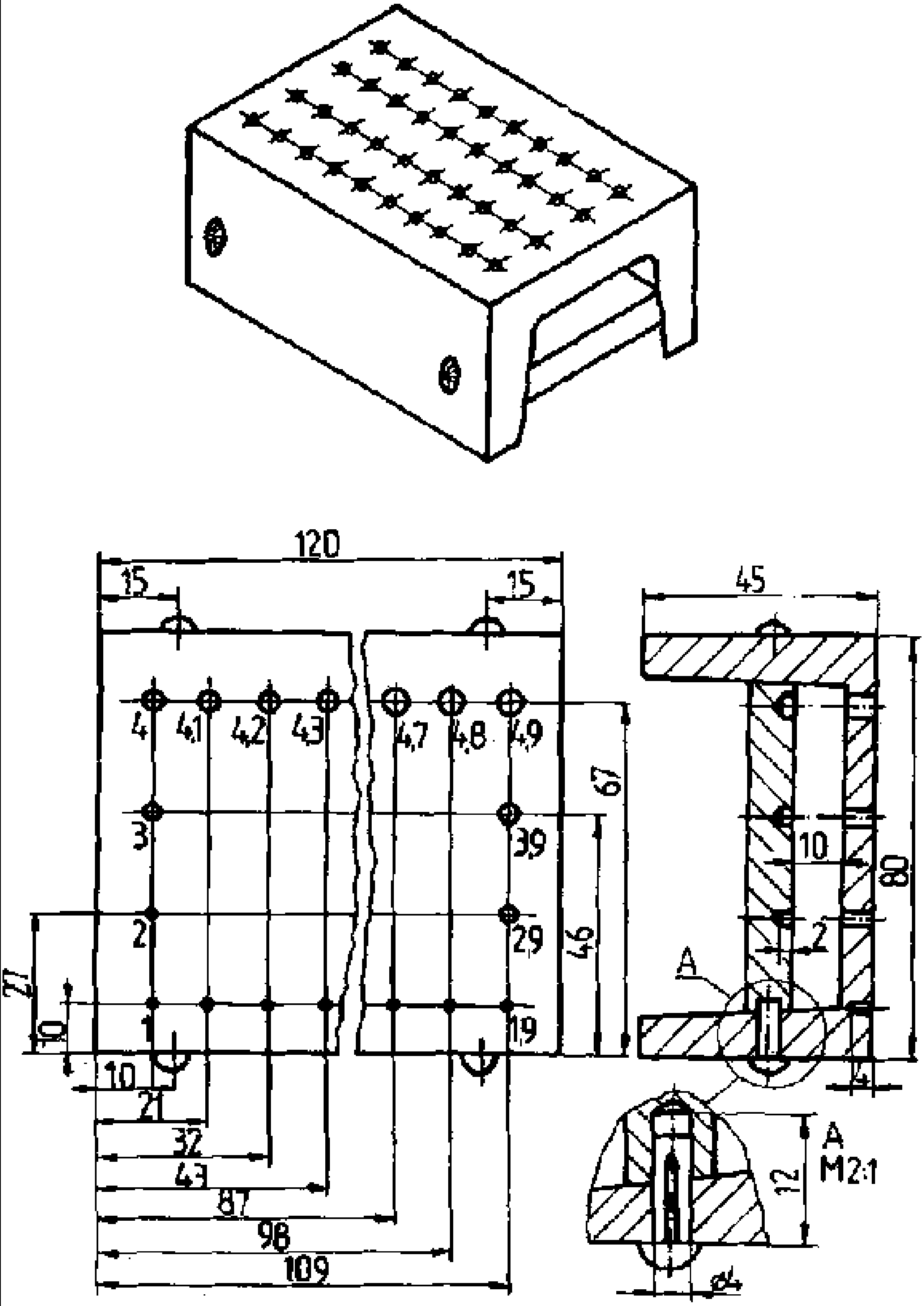
Machine vice, diluted soluble oil, 2 x C clamps, spacer

Required previous knowledge

Reading of drawings, scribing, prick–punching, measuring, testing, sawing, filing

Sequence of operations	**Comments**
1. Arrange workplace Prepare working material	– Check for completeness

2. Take workpiece from training examples 2.3 or 4.2 or pre−finish as to drawing and scribe holes	
3. Fit plate into channel section, subsequently clamp together	– Sawing, filing
4. Scribe lateral holes of 4 mm dia. for slotted nails, punch, drill together and deburr	– n = 2240 r.p.m.
5. Drive in slotted nails	
6. Produce holes as to drawing:	
– drill holes of 1.1 to 2.0 mm dia. as bottom holes to 4 mm depth into the channel section	– Drill holes specified in drawing by 0.1 mm greater, e.g. for (1) hole of 1.1 mm dia.
– Drill holes of 2.1 to 5.0 mm dia. as through holes into channel section and as bottom holes to 2 mm depth into the plate	– Drill in one pass – Insert spacers as gap fillers
7. Deburr holes (by means of countersink)	
8. Mark holes by number punch as to drawing	
9. Check the holes	– Accuracy to size

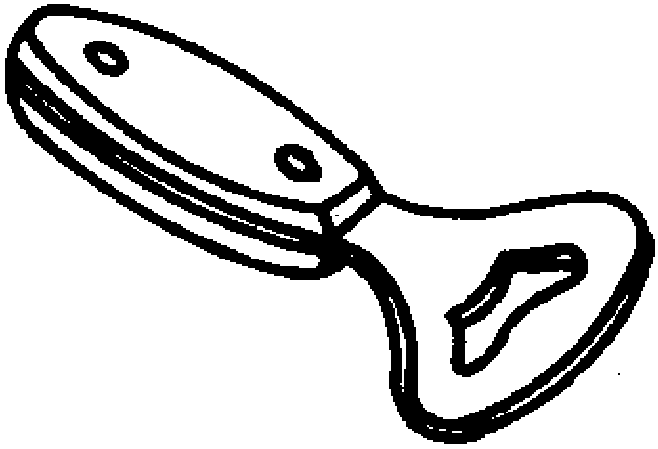


				7.4.
	Drill stand			3107

Instruction example 7.5. Bottle–opener

Practise drilling of curved contours in steel sheet

Material



– sheet made of stainless steel (chromium–nickel alloy)

thickness:	approx. 2.5 mm
width:	90 mm
length:	approx. 150 mm

– 2 x flat material made of plastic material or wood (timber)

thickness:	4 mm
width:	25 mm
length:	90 mm

Working tools

Hand lever shear, hand hacksaw, steel scriber, centre punch, double–point punch (y = 3.2 mm), locksmith's hammer, drill with flat drill point and centre point (type hard) of 3 mm dia., cross–cut chisel, flat chisel, smooth files of 250 mm (half round, round), drill of 4.1 mm dia., countersink 75°

Measuring and testing tools

Steel rule, vernier caliper

Accessories

Scribing stencil as to drawing, C clamps, clamp dogs, rape–oil, drilling support, surface plate

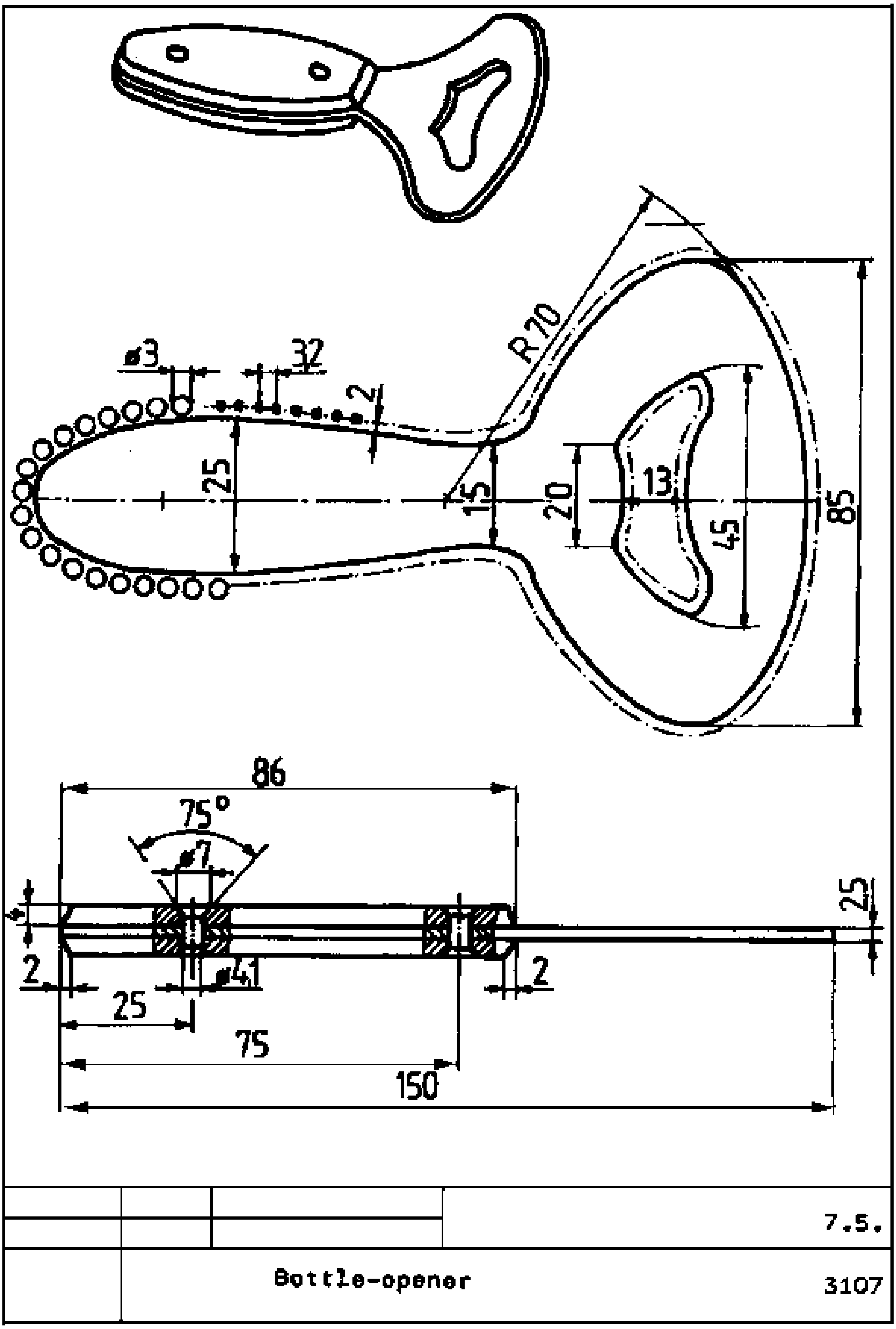
Required previous knowledge

Reading of drawings, scribing, prick–punching, measuring, testing, chiselling, filing

Sequence of operations	**Comments**
1. Arrange workplace Prepare working material	– Check for completeness

2. Scribe contour by means of scribing stencil applied	– subsequently punch check marks
3. Scribe hole line and punch by double–point punch, re–punch by means of centre punch	
4. Drill the hole line:	
– Chuck drill of 3 mm dia.	
– Clamp sheet into clamp dog	
– Select speed	– n = 350 r.p.m.
– Adjust punch mark	
– Drill every second hole	– Cool (rape–oil)
– Check distances between holes	– When the distance is smaller than 3.4 mm, intermediate holes have to be made with a suitable drill of smaller size.
– Drill intermediate holes	
– Deburr	
5. Check holes	– No hole must overlap another hole

<u>Finishing</u>: Chisel, file contour on scribed line, scribe flat material (as grip halves) and work true–to–size, clamp together with steel sheet, drill, countersink, rivet, smooth or pattern–scrape the outer contour



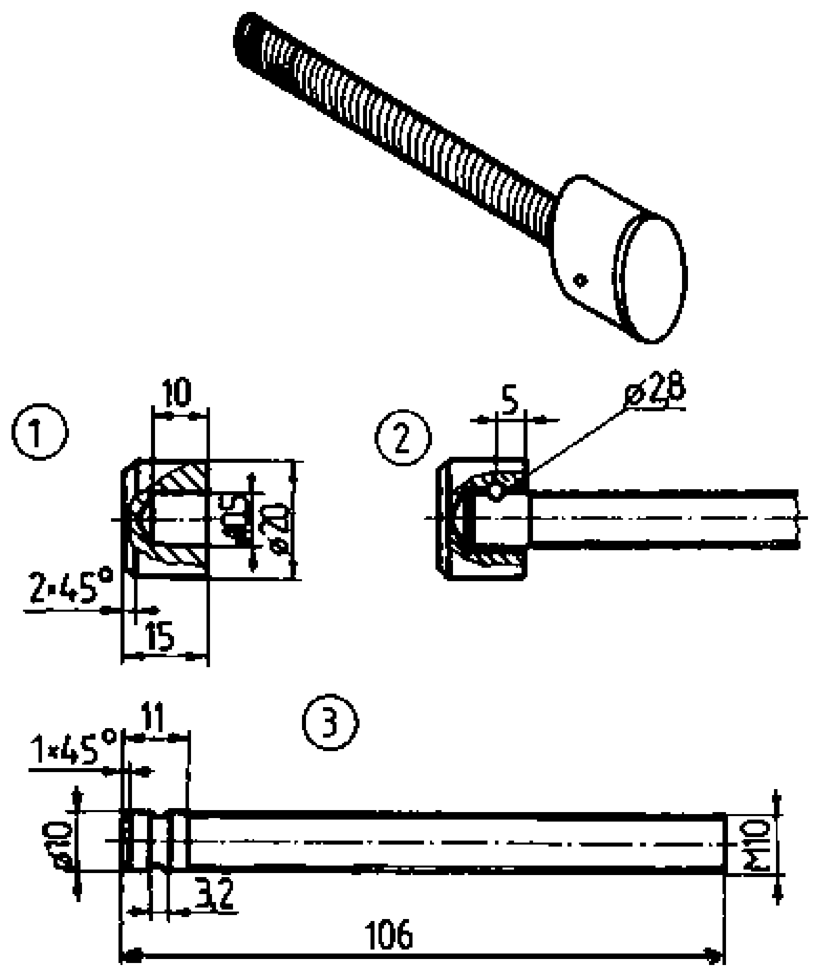
Instruction example 7.6. Rotary head for threaded spindle

[...]

Sequence of operations	**Comments**

1. Arrange workplace Prepare working material	– Check for completeness
2. Check initial dimensions as to drawing	
3. Scribe hole in head by centre square and punch, drill bottom hole of 10.5 mm dia. to 10 mm depth	– Stage (1) – n = 900 r.p.m.
4. Scribe and punch hole of 2.8 mm dia. as to drawing, clamp head in machine vice and spot–drill	– Stage (2) – Let drill point penetrate only
5. Loosen machine vice, turn head together with hole 1 mm outwards, spot–drill again until drill point does not walk off centre any more	– Apply only slight pressure onto drill
6. Repeat operation No. 5 until hole centre is 5 mm off centre	
7. Insert threaded bolt's thread–free part into head, drill hole through head and threaded bolt with threaded bolt held in position	
8. Disassemble the parts, deburr the hole	
9. Check the hole	

Finishing: Ream hole in the head by means of reamer Ø 3 K 7, file groove in the threaded bolt in height of hole mark as to drawing stage (3); assemble parts and secure by means of straight pin Ø 3 m 6, check for rotatory movement of the head on the bolt.



				7.6.
	Rotary head for threaded spindle			3107