

**Drilling, Countersinking and Counterboring – Course: Technique for
Manual Working of Materials. Methodical Guide for Instructors**

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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:

Objectives

- 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:

Contents

- 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 must. 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”.

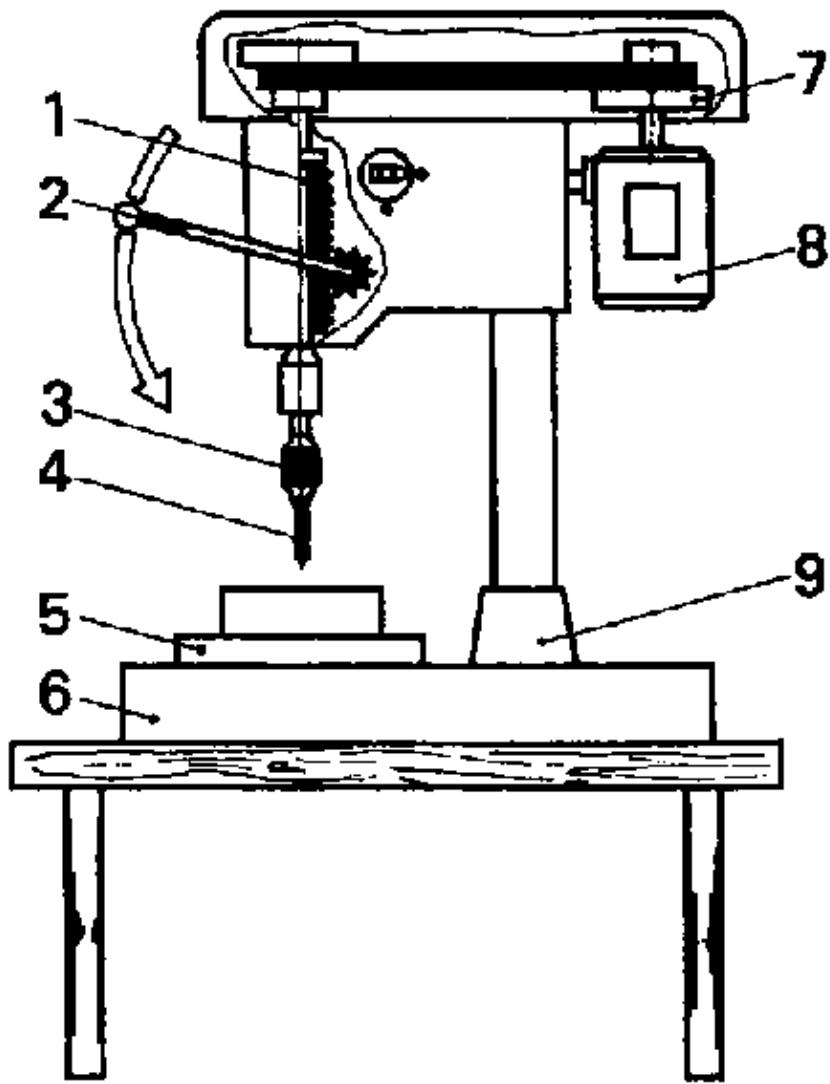
Instruction can be carried out on the basis of the main points contained in the “Trainees’ Handbook of Lessons”.

Purpose of drilling, countersinking and counterboring/countersinking

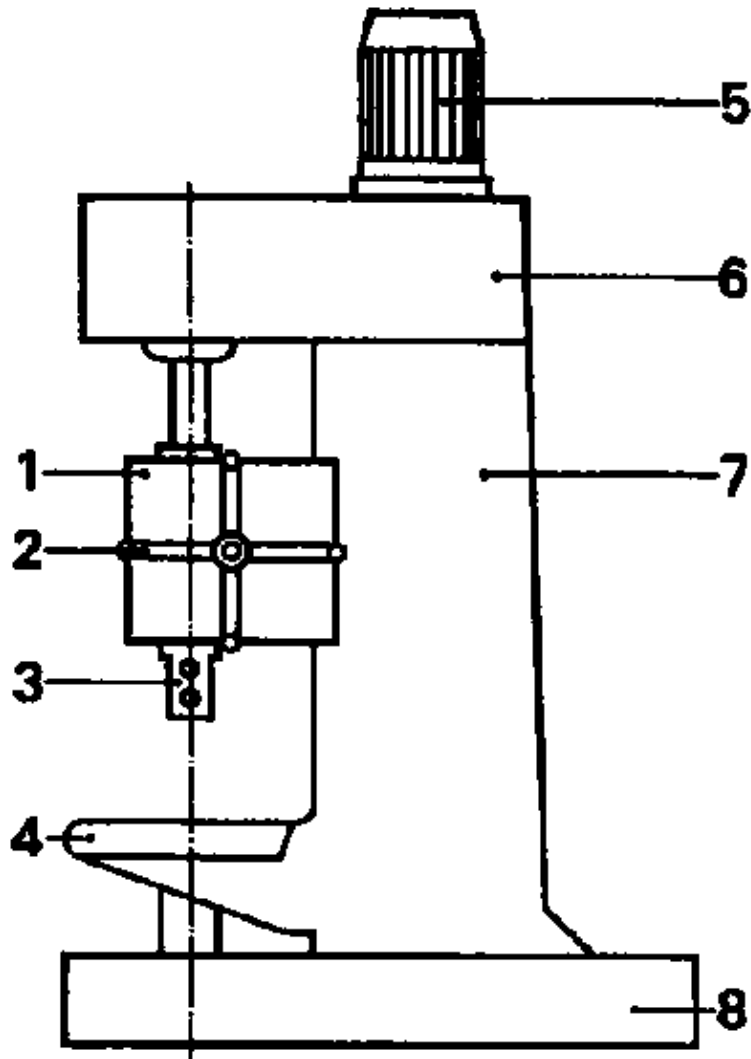
To illustrate the purpose of these working techniques, it is recommended to show workpieces with blind and through holes. It has to be pointed out that these techniques create the prerequisites for bolted, pin-type and rivet-type connections.

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:

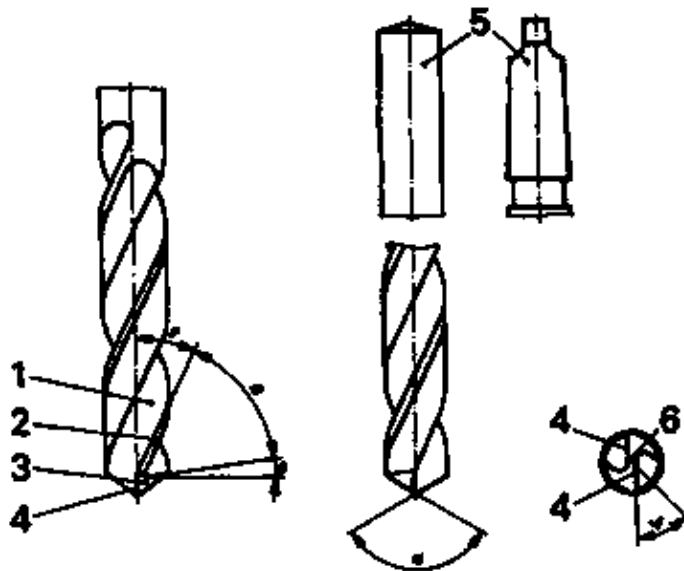
- 'hard'-type drills
- 'normal'-type drills
- 'soft'-type drills
- drills with carbide tips
- drills with double-taper drill point
- drills with flat drill point and centre point.

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.

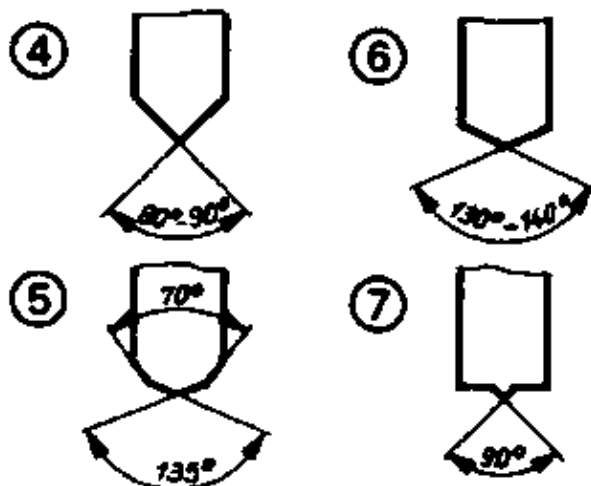
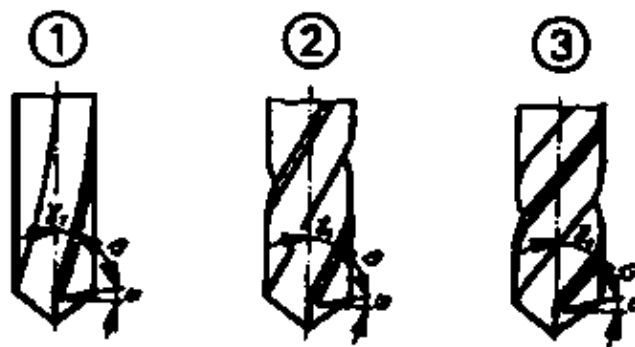
Transparencies nos. 7.3. and 7.4. can also serve to give an illustrative description of "design and angles at the drill" and of types of drills as well as special kinds of drill point grinding.

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

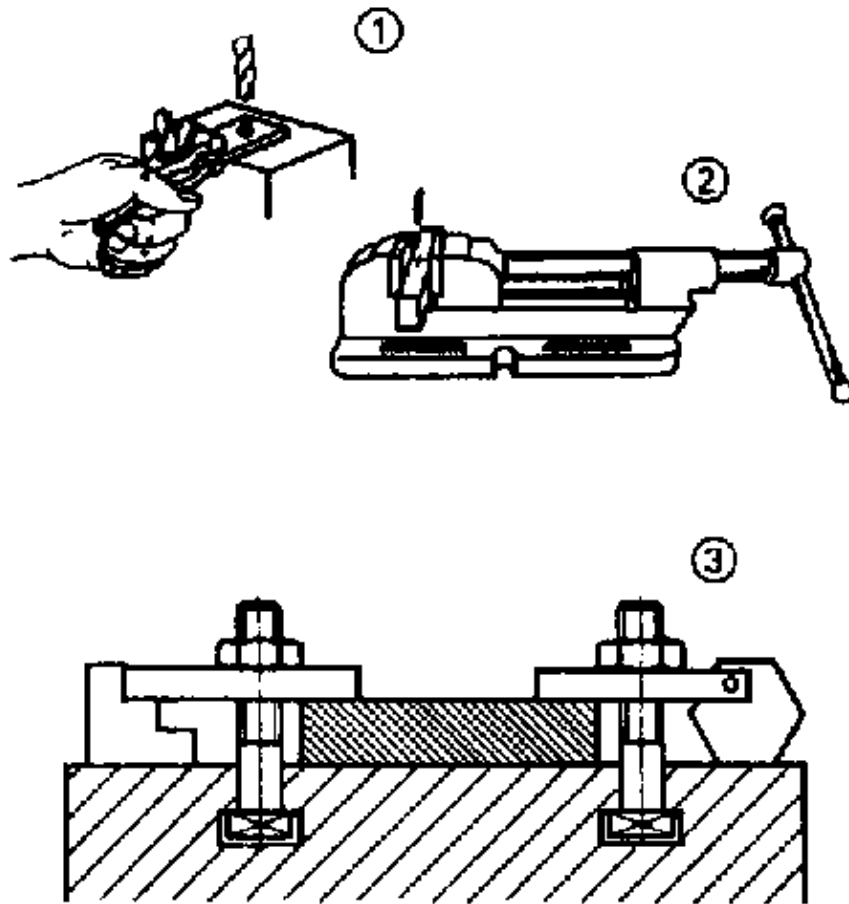
After having imparted this knowledge to the trainees exemplary calculations can support this instruction. It is recommended to ask the trainees to determine various rotational speeds. They must learn how to read the table values and how to set the machines accordingly.

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

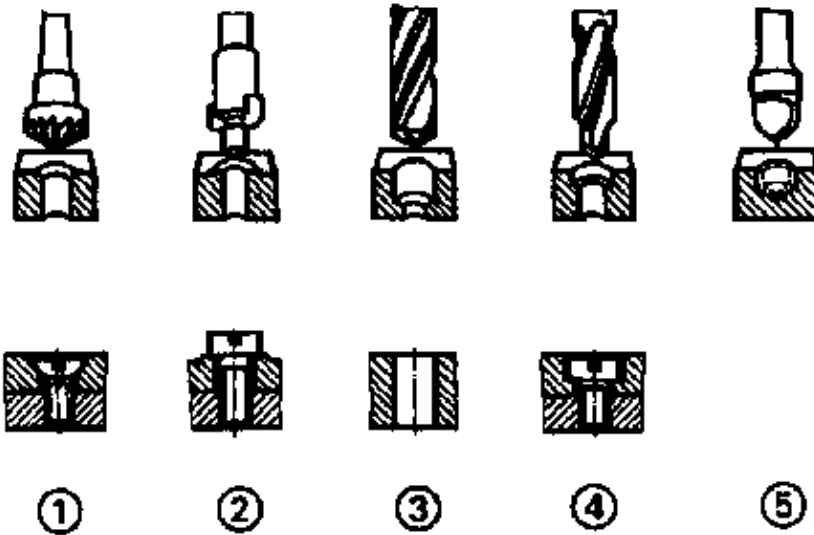
9 steps of work are described in the “Trainees’ Handbook of Lessons” in order to produce a blind hole. These steps need comprehensive explanation. Such a instruction includes hints about possible errors and their effect on the hole.

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 must 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 carbide 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.

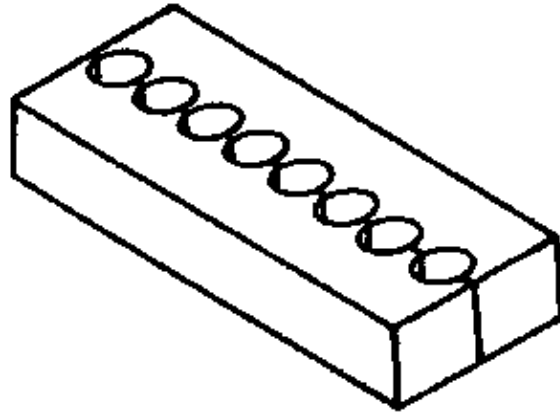
This is the only way to guarantee a just evaluation of the achievements.

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:

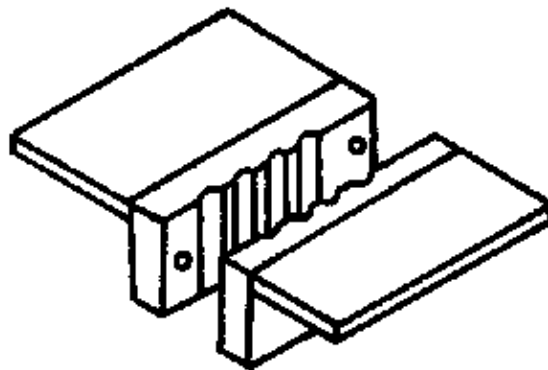
Instruction example no. 7.1. Drilling, countersinking and counterboring training workpiece



This is a component consisting of two clamped square steel bars.

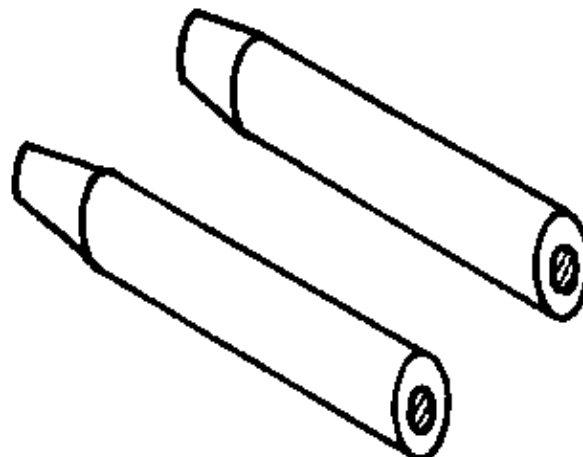
Along the dividing line the trainee has to drill and counterbore/countersink several holes. After this process, the two pieces can be separated again and the trainees can optically check the produced bore-hole walls.

Instruction example no. 7.2. Clamping jaws for round material



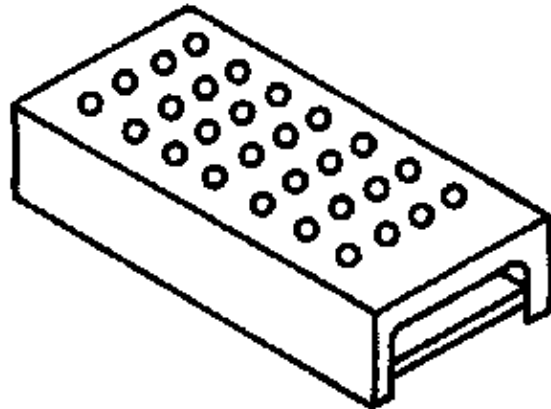
Two pieces of flat steel with a spacer of thin steel sheet will be provided with simple through holes of small diameters. After their completion these clamping jaws can be used as accessories for clamping round materials (similar to vee jaws)

Instruction example no. 7.3. Rivet set and rivet header



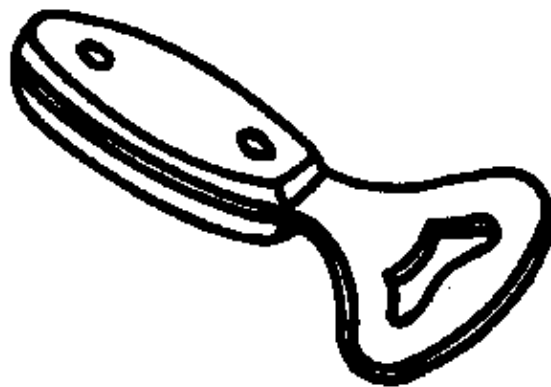
Silver steel round materials are provided with a hole and a counter-bore each in their centre. After their completion and hardening these parts can be used as tools for the working technique of riveting.

Instruction example no. 7.4. Drill stand



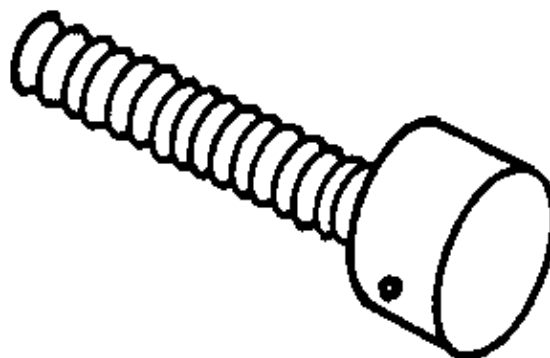
Channel steel will be provided with small-size blind and through holes (increments of 1/10 mm). The parts produced as instruction examples 2.3. or 4.2, will be employed now. After completion, the drill stand can serve as an easy to survey and practical support for drills in the workshop.

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 holes?
- 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 carefully 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 $1 = 10^\circ$
- (2) "normal" type $1 = 25^\circ$
- (3) "soft" type $1 = 35^\circ$
- (4) Point angle $80^\circ - 90^\circ$
(small)
- (5) double-taper drill point
- (6) point angle $130^\circ - 140^\circ$
(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. Types and use of counterbores/countersinks

(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