TOMSK POLYTECHNIC UNIVERSITY

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CONSTRUCTION MATERIALS ENGINEERING

PRACTICE

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The study aid contains methodical instructions for laboratory works on discipline "Construction Materials Engineering" and is intended for training students majoring in the direction 150700 "Mechanical engineering" in English. The laboratory practice is directed to intensification of theoretical knowledge in discipline and allows students to get practical skills in processing of materials.

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LABORATORY WORK № 1

MANUFACTURING OF EXPENDABLE CASTING MOULD

Laboratory work objective

1. Study properties and mixing ratio of sand mix and core sand mixture.
2. Study equipment, tools and devices applied for molding.
3. Study technological process of a casting mould manufacturing.
4. Make a casting mould under the supervision of the instructor.

The equipment and materials

1. Molding plate.
2. Bin with sand mix.
3. Casting pattern.
4. Flasks (molding boxes).
5. Core box.
6. Molding tools and devices.

Basic principles

Foundry manufacture is mechanical engineering branch related to making cast products from various metals and alloys. Foundry manufacture produces *castings* by pouring the fused metal into a casting mould which cavity has a work piece configuration.

Approximately 50 % of all machine parts are made by casting. For example, the share of cast parts in a forge hammer makes 90 %, in metal-cutting machine tools – 80 %, in cars and tractors – 55 %.

All the methods of casting are subdivided into two groups:

- Sand casting (sandy-and-clay moulds are used).
- Special methods of casting which include chill casting, investment casting, shell casting, pressure casting, centrifugal casting and other methods.

Not less than 80 % of all castings are manufactured by sand casting.

Properties of sand mixtures

Sand mixes should possess certain properties that high-quality castings could be produced.

Strength is an ability of a mix to provide safety of the mould without destruction while manufacturing and metal pouring.

Compliance is an ability of a mix not prevent crystallizing metal shrinkage upon cooling.

Plasticity is an ability of a mix to reproduce a casting pattern outline.

Gas permeability is an ability to pass gases through mould walls. Gases are superseded from a mould cavity in the process of liquid metal pouring. If gas permeability is insufficient, gaseous pores can be formed in a casting.

Thermochemical stability means that a mix does not interact with liquid metal. Films of gritty scale worsen casting surface quality and complicate the subsequent processing by metal-cutting machine tools.

The sand mix consists of following components:

- Clay (binding) 8–10 %,
- Quartz sand (filler) 84–88 %,
- A coal dust (parting dust) 0.5–1 %,
- Water – the rest.

Properties of core mixtures

Cores serve for holes formation in castings. They work in heavier conditions than moulds under the influence of the fused metal and consequently should possess the raised strength.

Mixing ratio of a core mix: 4–6 % of clay, 90–92 % of quartz sand, 2–3 % of the substances providing additional strength (sulfite draft, liquid glass or synthetic resin), 3–4 % of water.

After manufacturing cores are exposed to drying at 150–280 °C. Thus resin hardens, and the core gets the required strength.

Technological process of casting mold manufacturing

1. In foundry shop of a plant sand and core mixes are made.

2. Engineers of processing department develop *the casting* drawing (Fig. 2) according to *the part* drawing (Fig. 1).

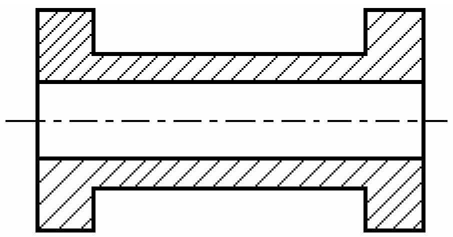


Fig. 1 Part drawing

While drawing is working out *the allowance for machining* of casting and *an allowance for shrinkage upon crystallization and cooling* are added. The plane of mould splitting is chosen, and pattern tapers are assigned for convenience of pattern removal from the mould. Than *fillets* which round off sharp corners of pattern are assigned. They prevent cracks formation at shrinkage.

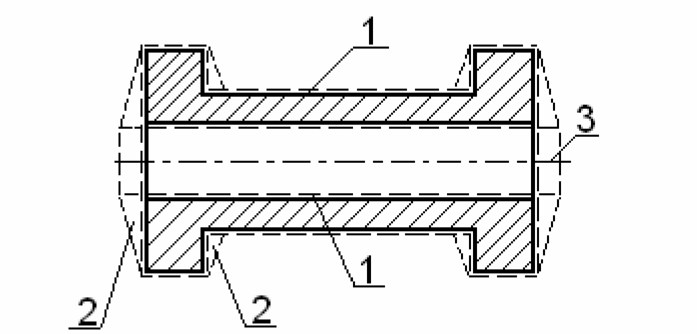


Fig. 2 Drawing of casting:
1 – machining and shrinkage allowance; 2 – pattern tapers;
3 – mould opening area

3. According to the casting drawing in a pattern shop *casting pattern* and a *core box* are made (Fig. 3). They usually are manufactured of metal, textolite or wood.

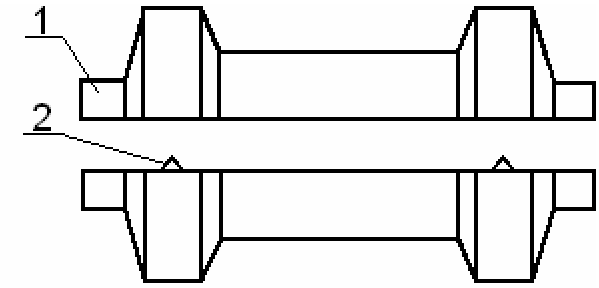


Fig. 3 Drawing of casting pattern:
1 – core marks; 2 – fixers

The pattern has a splitting; its halves are fastened by conic pins called fixers. In places of a hole output pattern has projections – *core marks* – for making prints in a sand mix in which the core will be laid.

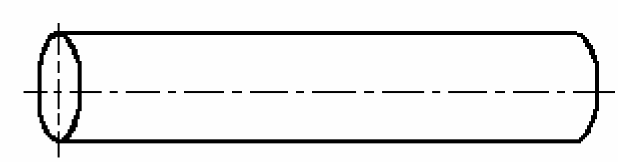


Fig. 4 Core

4. In a core box the core (Fig. 4) is mould from the core mixture. The length of a core is more than one of a hole on size of core marks.

Molding technique

5. A half of pattern (without fixers) 3 is placed onto molding plate 4 (Fig. 5). Then bottom flask 2 is put. The pattern surface is covered by a thin layer of parting dust (graphite) in order the sand mix did not stick while molding. For powder sticking to a surface the pattern is moisten with kerosene or solar oil. The sand mix 1 is filled in the flask and compacted with the help of rammer.

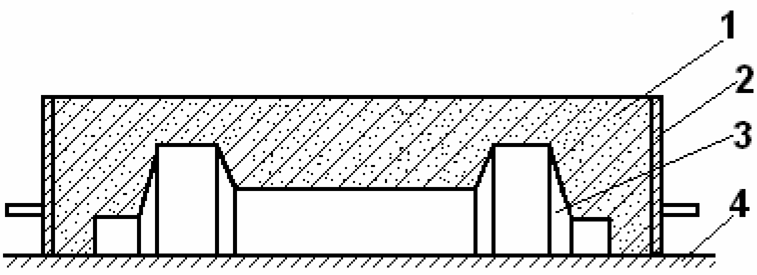


Fig. 5 Manufacturing of mould bottom half:
1 – sand mix; 2 – flask; 3 – casting pattern; 4 – pattern plate

6. When the mould bottom half is ready it turns on 180°. Top half of pattern is mounted on fixes. Top flask is established, and mutual position of flasks is rigidly fixed.

Split of casting mould is powdered with parting sand. The model of pouring gate is mounted, than sand mixture is filled up and compacted (Fig. 6).

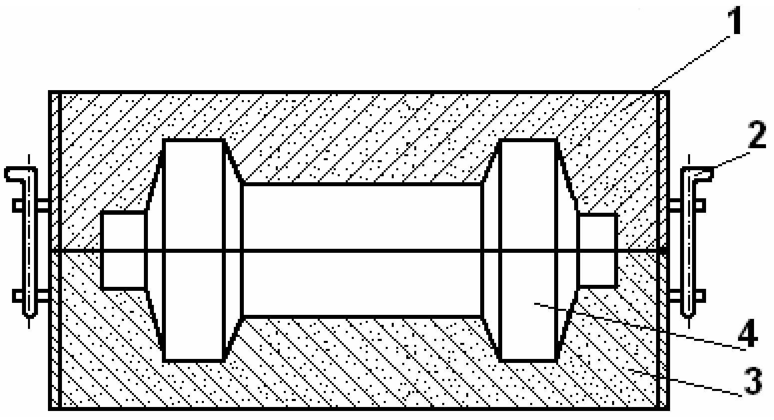


Fig. 6 Manufacturing of mould top half:
1 – top flask; 2 – flask centering device;
3 – bottom flask; 4 – pattern

7. The model of pouring gate is deleted and *gating system* is made up (Fig. 7): the pouring basin is cut, and ventilating channels are pinned.

8. The top flask with the dense sand mix is taken off from the bottom flask. The pattern is taken out. A feeder and slag catcher are cut.

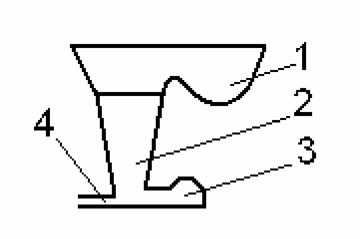


Fig. 7 Gating system:
1 – pouring basin; 2 – pouring gate; 3 – slag catcher; 4 – feeder

Assembly of a mould

9. Before assemblage the casting mould is inspected, local destructions are closed up, from a cavity of the mould and gating system particles of a sand mix are deleted. After placement of cores the top half of mould is mounted onto the bottom part, and now the mould is ready for metal pouring (Fig. 8).

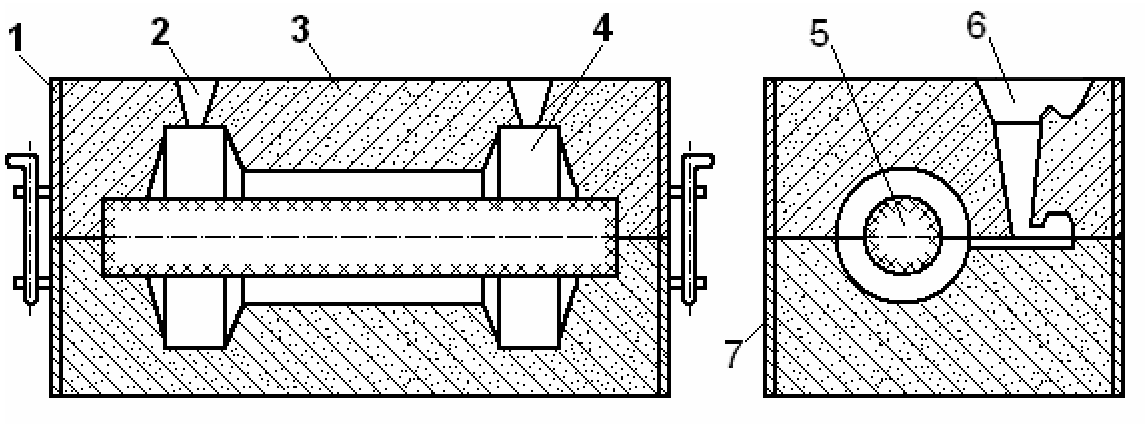


Fig. 8 Casting mould:
1 – top flask; 2 – vent pipe (discharge gate); 3 – sand mix;
4 – mould cavity; 5 – core; 6 – gating system; 7 – bottom flask

Report contents

The report should contain main data concerning sand and core mixtures and equipment for molding. The particular attention should be given to the description of technological process of a casting mould manufacturing and sketches of operations.

Test questions

1. List the basic ways of molding.
2. The role of foundry manufacture in mechanical engineering (examples).
3. List properties of a sand mixture.
4. What is the strength and plasticity of a sand mixture?
5. What are gas permeability and plasticity of a sand mix necessary for?
6. Mixing ratio of a sand mix.
7. Service conditions of a core and structure of a core mix.
8. What is the difference between drawing of casting and the part drawing?
9. What is the pattern, a core, flasks? What are they necessary for?
10. The structure of gating system.
11. List operations of a casting mould manufacturing.
12. What parts does the casting mould consist of?

LABORATORY WORK №2

SPECIAL METHODS OF CASTING (CHILL CASTING AND CAVITYLESS CASTING)

Laboratory work objective

1. Get acquainted with casting methods: chill casting and cavityless casting.
2. Make cast samples for mechanical tests.
3. Study a macrostructure and define impact strength of samples, made by chill casting and cavityless casting.

The equipment and materials

1. Cast alloy – silumin (aluminium-based alloy with silicon).
2. Moulding mix – dry quartz sand.
3. Crucible for metal melting.
4. Chill mould – a metal casting mould.
5. Consumable pattern made of polystyrene foam.
6. Muffle furnace for metal fusing.
7. Pendulum hammer for impact test.

The order of performance

1. Familiarize with the basic principles of chill casting and cavityless casting.
2. Execute an experimental part.
3. Analyse the received data and draw your conclusions.

Basic principles

1. Chill casting

Chill mould is metal mould for casting, which provides high speed of metal crystallisation and casting formation. Chill mould is made of pig-iron, steel, or other alloys.

Chill casting has advantages in comparison to sand casting. Chill moulds maintain a great number of pourings (from several hundred to ten thousand) depending on an alloy filled in: the lower temperature of an alloy is, the more durability of a mould. This method excludes application of a sand mix, hence, technical and economic indexes of production raise, sanitary-and-hygienic working conditions improve.

High heat conductivity of chill mould accelerates process of alloy crystallization and promotes manufacturing of castings with high mechanical properties. High durability of metal moulds allows receive multiply castings of the identical sizes with small machining allowances. The minimum physical and chemical interaction between a liquid metal and the mould raises a surface quality of casting.

High labour input to manufacturing and cost of chill moulds concern lacks of this casting method.

There is a danger of internal stresses origination in a casting, because the metal mould does not possess pliability. In the surface layer of cast-iron pieces cementite may form that complicates their machining, therefore thermal treatment (annealing) of castings is required.

45 % of all aluminium and magnesium castings, 6 % of steel castings and 11 % of cast iron ones are manufactured by chill casting. This way of moulding is economically expedient for serial and mass production.

Depending on a shape and size of casting metal moulds are subdivided into single-piece and split moulds.

In ***single-piece metal moulds*** a casting entirely turns out in one mould (look-alike a cup). In Fig. 1 the single-piece shaken-out mould is represented. It is applied for making simple castings, having sufficient taper of lateral walls (plates, boxes, etc.).

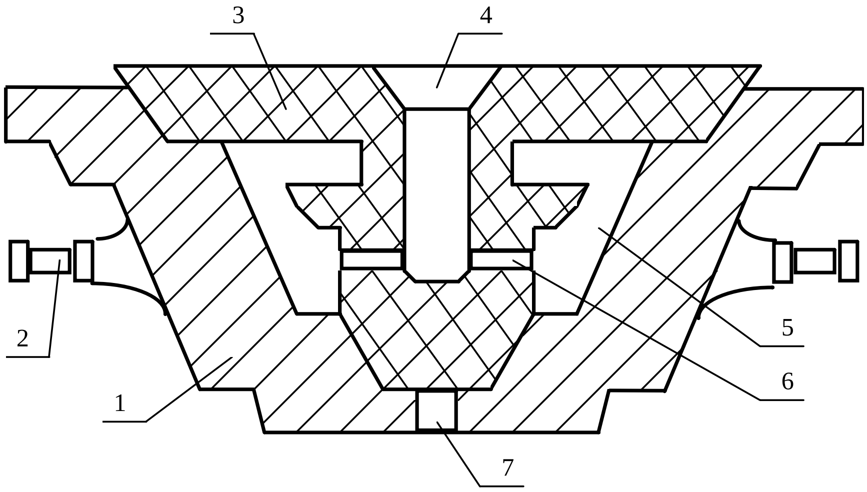


Fig. 1 Single-piece metal mould:
1 – mould body; 2 – neck for turning of a mould at casting knock-out;
3 – sand core; 4 – pouring basin and gate; 5 – mould cavity;
6 – feeder; 7 – vent pipe

Internal and external surfaces of mould piece in the single-piece metal mould are shaped by means of cores. The gating system is performed in a core. Such metal moulds are usually fixed by necks in special framework. After pouring a mould is turned around and mould piece is deleted (shaken out) together with a core.

Split moulds consist of two or more parts and, in turn, are subdivided into moulds with the horizontal, vertical and combined splitting.

The metal mould with a horizontal split (Fig. 2) is applied for the same mould pieces, as well as the single-piece mould. But the upper face is more complicate, and is formed by a working surface of the mould top half.

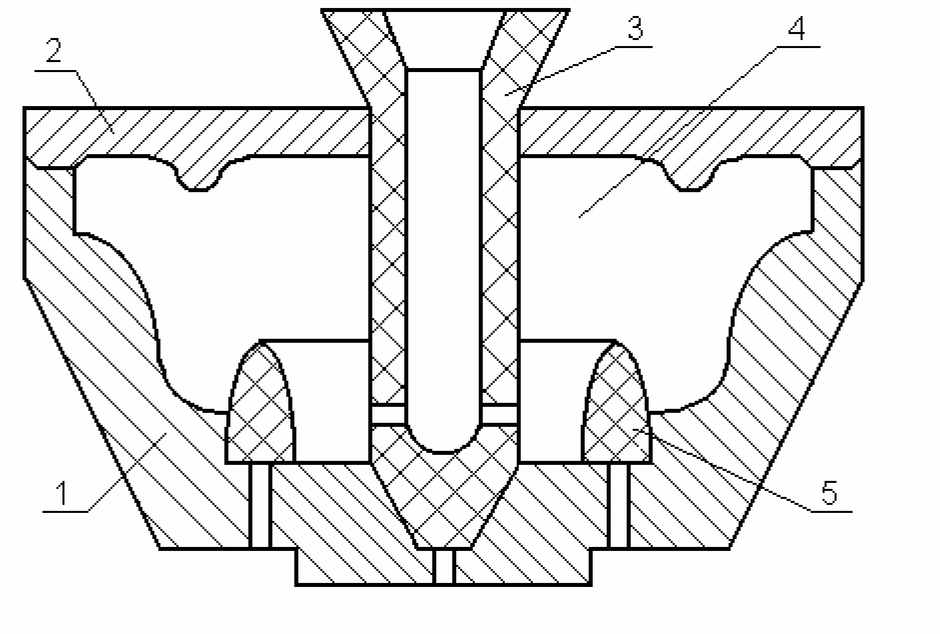


Fig. 2 Metal mould with horizontal split:
1 – mould bottom half; 2 – mould top half; 3 – central sand core;
4 – mould cavity; 5 – bottom ring core

Metal moulds with a vertical split (see Fig. 3) are applied to manufacture more manifold and difficult mould pieces (case details, molten cylinder blocks of automobile engines, large pistons, caps with large flanges etc.).

Metal moulds with the combined split are applied to casting mould piece of the irregular configuration. An internal configuration and holes in mould pieces are carried out by means of sand or metal cores.

Sand cores are used to mould steel and cast iron pieces. They possess a heightened compliance, gas permeability and refractoriness. However, smoothness of internal surface of mould pieces is worse, than if metal cores are applied.

Iron cores are applied for low-melting temperature alloys: aluminum, magnesium, etc. Iron cores do not ensure the free shrinkage of casting upon cooling; therefore they are deleted from the mould piece in a setting time, before knock-out of the mould piece from the mould. For venting of the metal mould gas-escape holes and whistlers are made in a splitting plane. Gas-escape holes are routinely 0.2–0.5 mm depth. Through such channels the liquid alloy does not outflow, but gases are deleted easily.

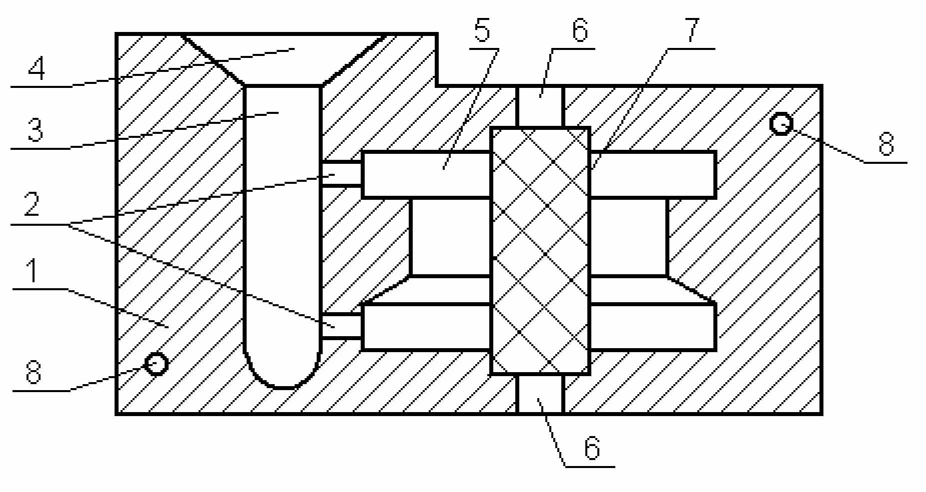


Fig. 3 Metal mould with vertical split and sand core:
1 – mould left half; 2 – feeders; 3 – pouring gate;
4 – pouring basin; 5 – mould cavity; 6 – venting channel;
7 – sand core; 8 – centering holes

In order to reduce cooling rate, to avoid formation of the strengthened layer on their surface and to increase life time of metal mould, the working surface is covered with low-conductivity coat. The coat is prepared from one or several fire-resistant materials (quartz dust, ground fireclay, graphite, chalk, talc, etc.) and a binding material (liquid glass, sulfide alkali liquor, etc.).

It is easier to mechanize and automate the process of chill casting, than process of sand casting. For mechanization chill casting machines are applied, single-station or rotary ones. These machines automate following technological operations: opening and closing of chill moulds, placing and removal of metal cores, pushing out of casting from a mould.

In metal moulds iron castings from 10 g to 15 t weight, steel castings from 0.5 g to 5 t weight and castings of non-ferrous alloys (copper, aluminum, magnesium) from 4 g to 400 kg are manufactured.

2. Cavityless casting

Very often there is a necessity to have single mould piece of any machine part. In these cases according to traditional engineering practice it is necessary to do previously wood or metal pattern for printing of external surface in a mould and core box for formation of internal surfaces of mould piece. Complexity of pattern sets manufacture three–five times exceeds complexity of the mould piece itself manufacture. For lowering the cost price of single mould pieces it is possible to make patterns not of wood, but of polystyrene foam which is gasified by molten metal. Last years usage of expanded polystyrene as a modelling material is widely extending. Use of expanded polystyrene (polyfoam) ensures possibility of manufacturing various mould pieces in single-piece moulds without pattern sets draw from moulds, without tapers and with minimum machining allowances (Fig. 4).

Expanded polystyrene is an easily formed material therefore it is possible to make patterns of irregular configuration.

Beaded expanded polystyrene is applied to patterns manufacturing for cavityless casting. It consists of granules, the closed cells containing powdery filler (a fusible component).

The requirement for gasifiable patterns expanded polystyrene is volume weight 0.015–0.025 g/cm^3. Polystyrene foam with the bigger specific weight does not contain air enough for its burning; such polystyrene only melts, without burning down, thereby fills a part of the mould and leads to reject at casting. Expanded polystyrene with smaller specific weight is deformed at moulding that leads to distortion of the shape and the sizes of casting.

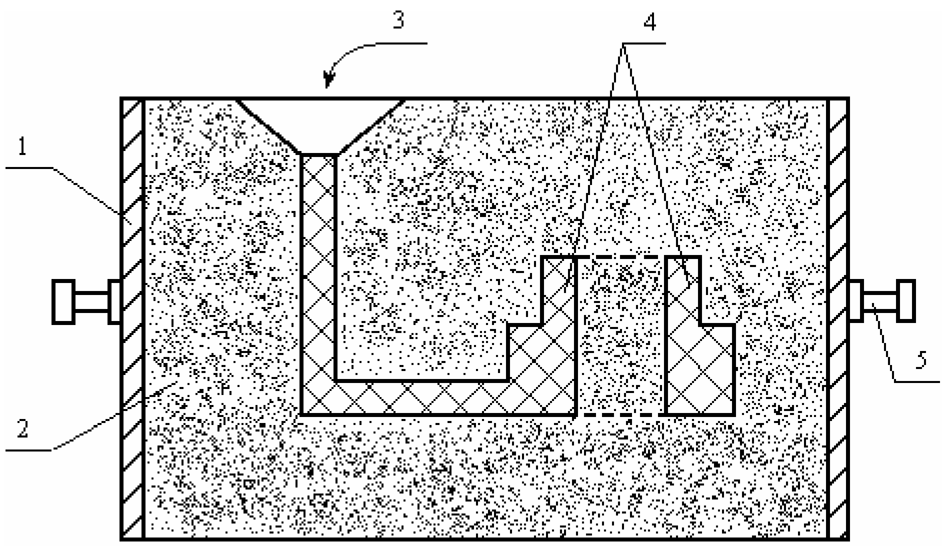


Fig. 4 Single-piece mould with expanded polystyrene pattern:
1 – flask; 2 – sand mix; 3 – molten metal;
4 – pattern of expanded polystyrene (polyfoam); 5 – necks

Application of polystyrene patterns makes labour input to moulding 80 % less, volume of fettling and cleaning – 70 % less. Advantage of polystyrene patterns is their ability not to dry out and not to bulk up from moisture. It excludes distorting during transportation and storage. Upon casting of pieces with a difficult configuration of external and internal outlines the pattern can be made in parts which are mounted at the time of moulding.

Disadvantage of cavityless casting is, first of all, the big gas liberation while pattern combustion. Under wrong pouring conditions (pouring should be carried on with certain speed) and pour gas permeability of a sand mix it may lead to formation of a gas porosity in castings, reducing their strength.

Other essential lack of polystyrene patterns is loss of accuracy at compacting of a sand mix because of an expanded polystyrene compliance. It is possible to solve this problem by means of an electromagnetic field and replacement of a sand mix with iron sawdust. On a bottom of a flask, inserted in the solenoid attached to a network of an alternating current, a layer of an iron powder is filled, polystyrene pattern with a gating system is put on it and filled up to the top with the same iron powder (sawdust). Then a current is switched transforming the iron powder to a monolith, and pouring of a fused metal instantly burns polyfoam. As soon as casting hardly will solidify, a current is switched off, and the mould becomes again a powder.

By means of such method magnesium blocks for automobile engines are successfully cast, and quality does not concede chill casting. Absence of expensive metal moulds, simplicity and universality of magnetic forms with use of gasifiable patterns have allowed to lower production cost price exactly twice.

Tasks and methodological instructions

1. Prepare metal mould (Fig. 5) for pouring. For this purpose smooth out an internal cavity of a mould from scale and then grease a cavity surface with fire-resistant lubricant. Join halves of the chill mould and warm up to 100–300 °C.

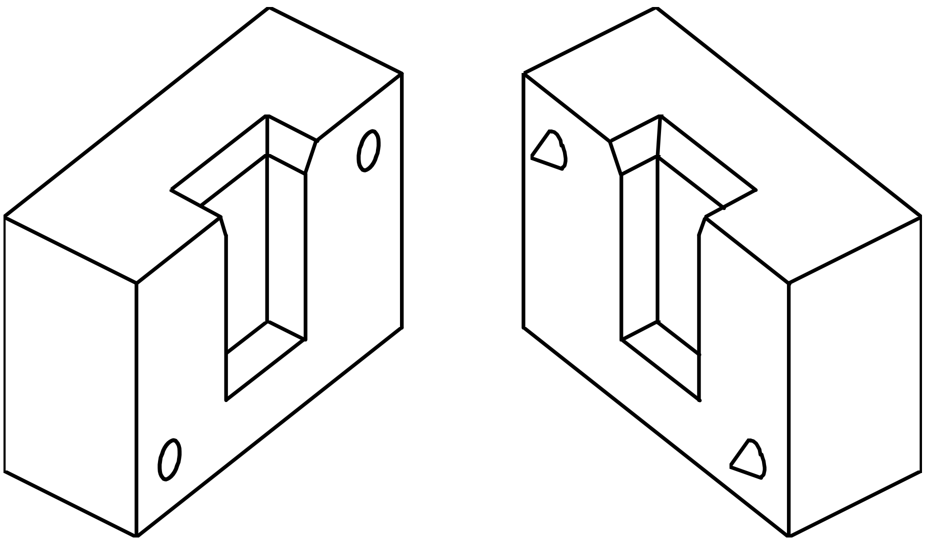


Fig. 5 Metal mould for manufacture of testing sample

2. Prepare a sand mix for moulding. For this purpose it is necessary to loosen mix, remove metal inclusions in the form of drops. The mix should be absolutely dry.

3. Mould expanded polystyrene patterns into a sand mix (Fig. 6).

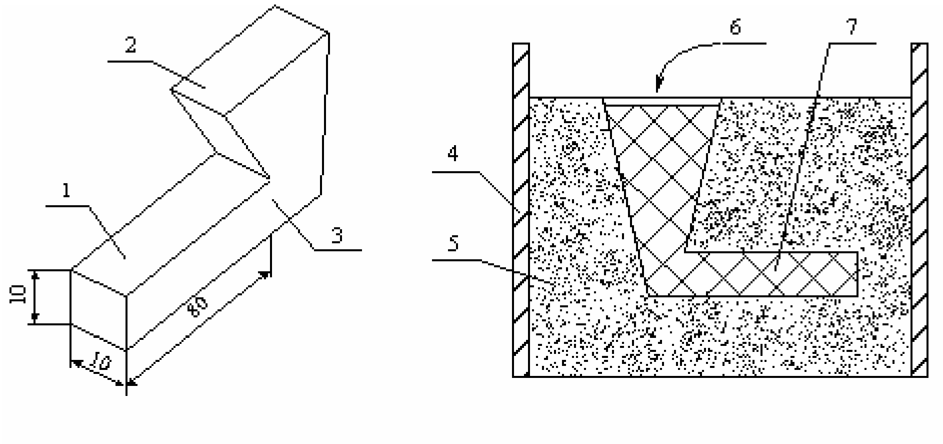


Fig. 6 Expanded polystyrene pattern for manufacture
of testing sample and its location in a flask:
1, 7 – pattern of expanded polystyrene; 2 – gating system; 3 – line of cutting out of gating system; 4 – flask; 5 – sand mix; 6 – pouring of molten metal

4. Watch the pouring of metal carried out by the master, and cooling of castings. Note time it takes.

5. Separate gating systems from samples.

6. Test the samples in impact strength by means of pendulum hammer and put results to a table. Explain the test results.

Report contents

1. The work purpose.
2. Materials and equipment.
3. Describe (briefly) methods of chill casting and cavityless casting (include Fig. 5, 6 into your report).
4. Determine impact strength of the cast samples using the formula

$$KC = \frac{A}{S}; \text{ where}$$

   A – an energy spent for the sample fracture [J];
   S – a cross-section of the sample [m^2].
5. Describe an experiment and its results; give your explanations. Explain why castings have a different macrostructure, impact strength and quality of a surface.
6. Make a short conclusion based on the results of the lab.

Test questions

1. What is chill mould and for what is it intended?
2. Name advantages of chill casting in comparison with casting in sandy moulds.
3. What lacks chill casting has?
4. Name an area of performance of chill casting.
5. What design may metal moulds have depending on a configuration and the sizes of casting?
6. What type of castings can be received in single-piece moulds?
7. For what purpose are necks necessary?
8. What kinds of split moulds do you know?
9. For what castings are metal moulds with a horizontal split applied?
10. For what castings are metal moulds with a vertical split applied?
11. For what purpose are sandy cores applied at chill casting?
12. What are the gas-escape holes and whistlers and for what purpose are they necessary?
13. What is low-conductivity coats, what do they consist of and for what they serve?
14. What is gasifiable (consumable) pattern?
15. What are advantages of cavityless casting in comparison with casting in sandy moulds?
16. What are disadvantages of cavityless casting in comparison with casting in sandy moulds?
17. What is a density of expanded polystyrene applied for gasifiable moulds manufacturing?
18. What will occur, if the expanded polystyrene density is more or less, than it is necessary for normal process of molding?
19. List ways of increasing labor productivity while using methods of chill casting and cavityless casting.

LABORATORY WORK №3

CASTING DESIGN

Laboratory work objective

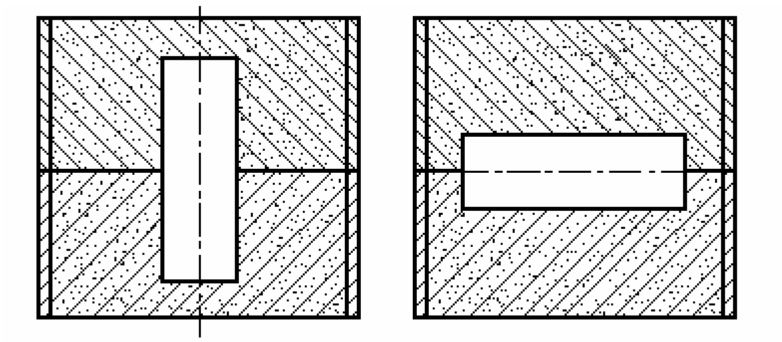
1. Get acquainted with the basic methods of casting designing.
2. Develop design of casting on the basis of the part drawing and necessary industrial equipment for manufacturing of the sand mould.

Basic principles

One of the basic technological processes for making work-pieces of metals and alloys is casting. The ***sand casting*** method is most often applied. The casting mould is made usually in two flasks. Upon mould designing it is necessary to observe **key rules**:

1) the rule of a casting location in the mould with the least height;
2) the rule of parallel rays;
3) the rule of the inscribed circles;
4) the rule of assignment of fillets;
5) the rule of minimum of cores;
6) the rule of bevels necessity;
7) recommendations for splitting planes choice.

When casting has considerable length and small cross-section, it is expedient to place it ***with the least height of a cavity of the mould*** (Fig. 1). The small height of the mould (Fig. 1*b*) saves a moulding material. A liquation influence on gravity segregation decreases, mechanical properties along casting section therefore are levelled.

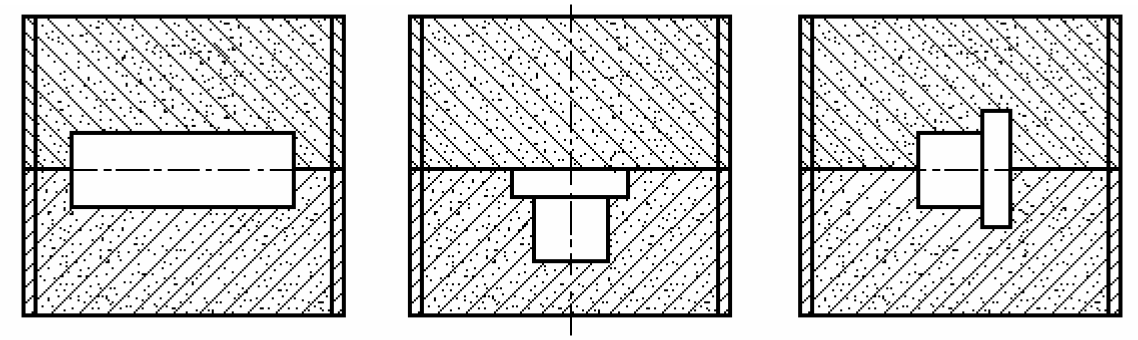


a *b*

Fig. 1 Types of casting mould:
a – with vertical casting axis, *b* – with horizontal casting axis

Liquation is gravitational segregation of alloy components having various relative densities upon cooling of melt. Easy fractions aspire upwards, whereas heavy ones go downwards; therefore there is a difference of mechanical properties in the top and bottom parts of casting at arrangement shown in Fig. 1*a*.

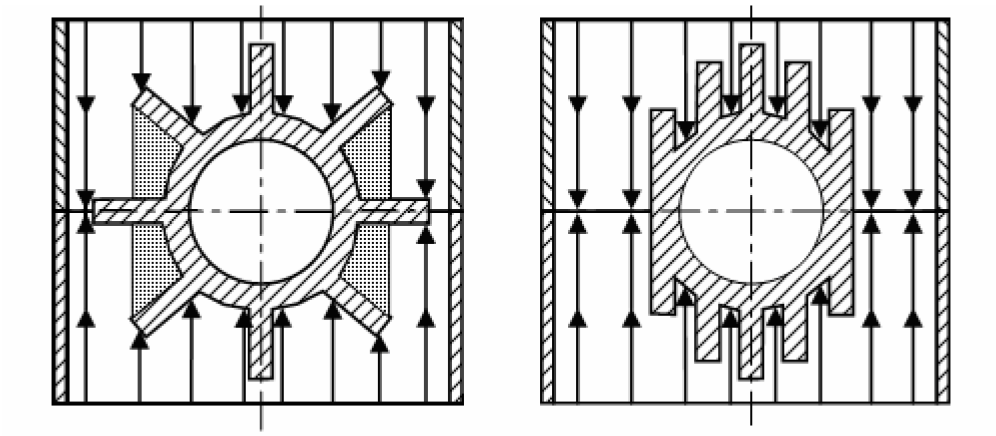
Therefore if the parts have one overall dimension much more than others, it is favourable to place them so that the maximum size lays in a horizontal plane, as it is shown in Fig. 2*a*. The part with approximately identical overall dimensions can be arranged both vertically (Fig. 2*b*), and horizontally (Fig. 2*c*).



a *b* *c*

Fig. 2 Variants of casting arrangement in a casting mould

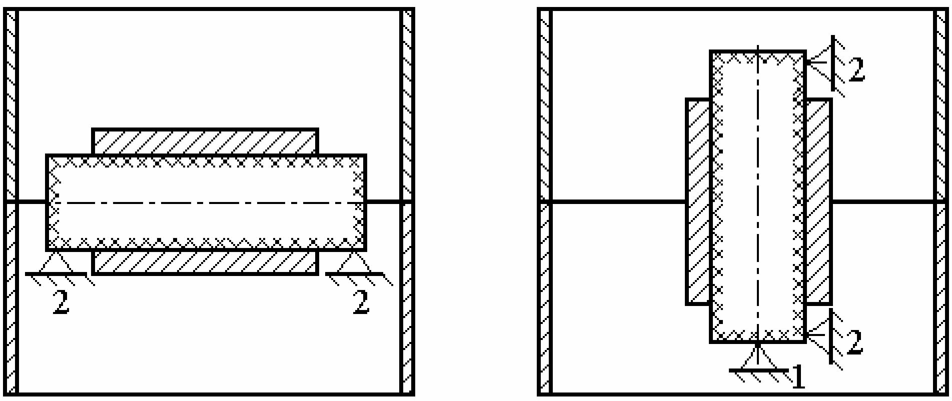
The configuration of external contours depends on a casting arrangement. For example, it is necessary to cast the long case of the electric motor having edges of cooling (Fig. 3). For easy pattern deleting from the mould parts of casting should not give the shaded sites at a direction of parallel beams to the mould from below and from above. This rule is named a ***rule of parallel beams***, or a method of a shadow relief. In Fig. 3*a* this rule is not observed, means, it is necessary to change a configuration of edges: to make them parallel to beams (Fig. 3*b*). The alternative way is changing a casting arrangement to the vertical one.



a *b*

Fig. 3 Use of a rule of parallel beams

The vertical arrangement of a hollow casting axis in a mould is favourable also that the core forming a cavity or an aperture in a casting, can have two and more supports (Fig. 4*b*). It means that the core occupies steadier position in the mould, than at a horizontal arrangement of an axis (Fig. 4*a*).

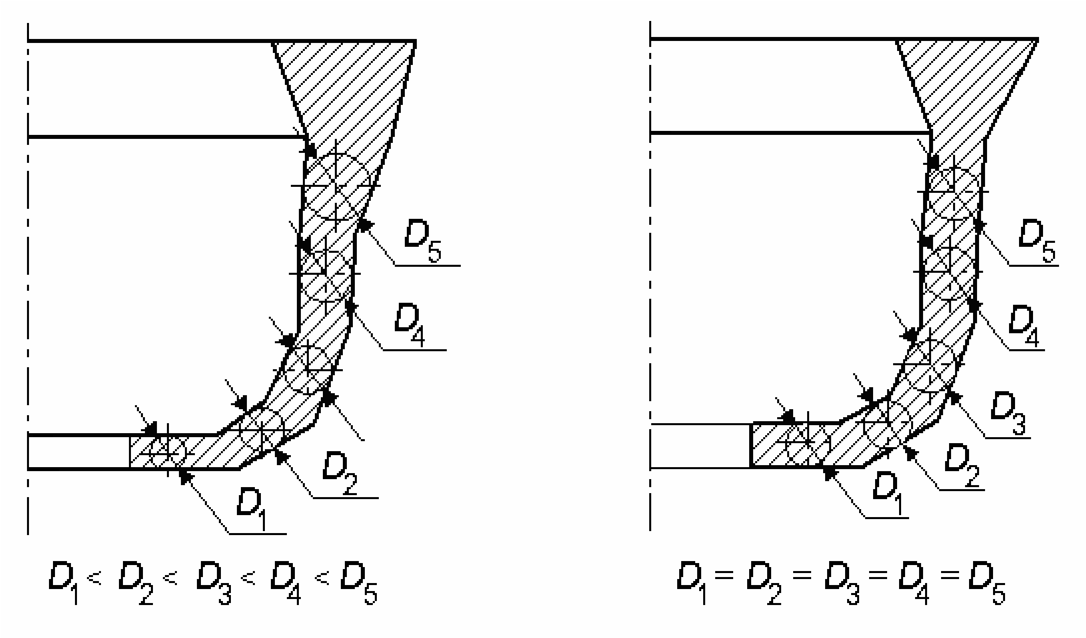


a *b*

Fig. 4 Variants of hollow casting arrangement

Principles of the directional or simultaneous solidification upon cooling should be put in a basis of a cast part design depending on requirements. The directional solidification provides reception the dense casting, without shrinkage cavity and porosity. However it leads to complication of moulding. At the ***directional solidification*** metal crystallizes, beginning from thin sections of casting in the most distant parts of the mould to the most massive sections in places of feeders input to the mould. Each larger casting section feeds with liquid metal its thin parts, being for them as though lost head. In this case proper design is checked by a **method of the inscribed circles**. Thus the circle inscribed in any section of casting, should pass freely across any overlying sections in a crystallisation direction (in a direction to feeders, see Fig. 5*a*).

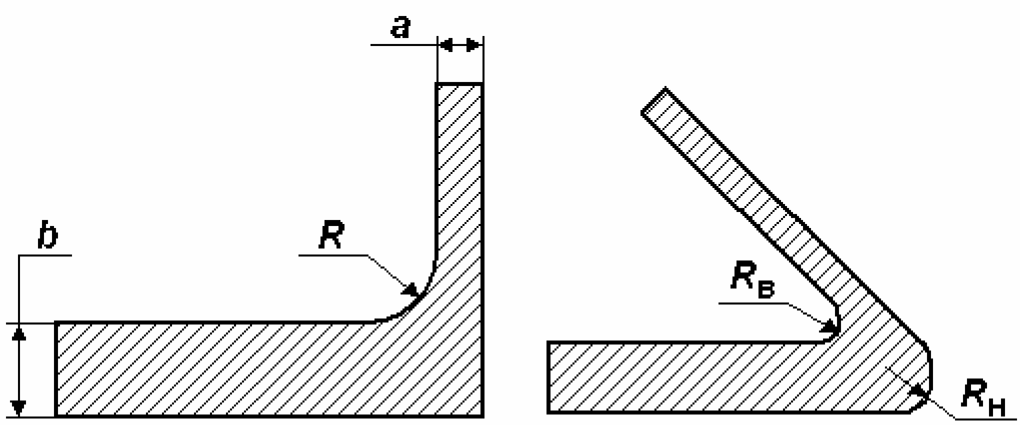
Design according to a principle of ***simultaneous solidification*** upon cooling is applied for small and average thin-walled castings when the high density of a casting is not demanded. Presence of the central porosity is supposed. The casting designed with the account of the simultaneous solidification principle has approximately an identical thickness in all parts of a workpiece (Fig. 5*b*).



a *b*

Fig. 5 Application of a method of the inscribed circles

The thickness of casting walls depends on strength required with allowance for metal fluidity. For conjugation of walls *fillets* are applied (fillet is a radius of internal rounds, Fig. 6).



a *b*

Fig. 6 Fillets for conjugation walls of different thickness

Fillets are necessary for the prevention of cracks formation in corners of conjugated walls. The fillet's radius (Fig. 6*a*) is calculated by the formula

$$R = (a + b)/2. \quad (1)$$

The thickness of conjugated casting walls should not differ more than twice:

$$b/a \leq 2. \quad (2)$$

In order to get a gradient junction upon angle conjugation of walls a rounding is made with external radius (fig. 6*b*) calculated by the formula

$$R_{н} = a + b. \quad (3)$$

Internal cavities and holes are made by means of cores and "blockheads". The external configuration of cores copies internal contours of a casting cavity. Cores are made in core boxes.

To mould cavities of a difficult configuration the multiple cores consisting of several parts are applied (Fig. 7*a*). However in a mould it should be **as less cores as possible**. If instead of two cores 1 and 2 (Fig. 7*a*) one core 3 (Fig. 7*b*) is used than it will have three fixed points of support while in the first variant the cores have two and one point of support. Besides, the increase in quantity of cores complicates the technological process and raises casting mould manufacturing in price; accuracy of casting drops.

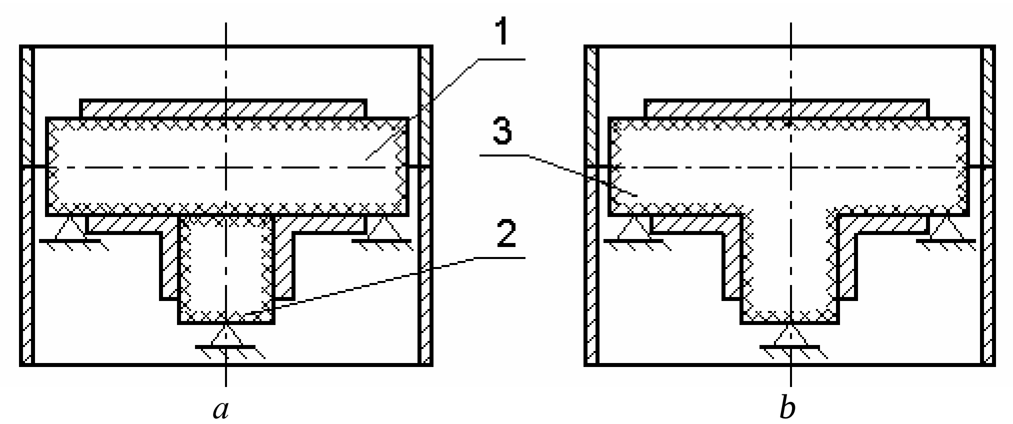


Fig. 7 Rule of a minimum of cores application

The cores applied for blind cavities manufacturing have only one support and consequently can lose stability. At assemblage they can fall into a mould cavity that leads to a melt contamination and to failure of the mould configuration. For stability of single-supported cores the artificial support 2 (gagger) is made. It is established between a core 1 and mould walls (see Fig. 8).

A gagger is the metal core having a chemical compound close to an alloy from which the part is cast. Application of gaggers is extremely undesirable, as they are sources of defects formation in castings (blow-holes, unweldability).

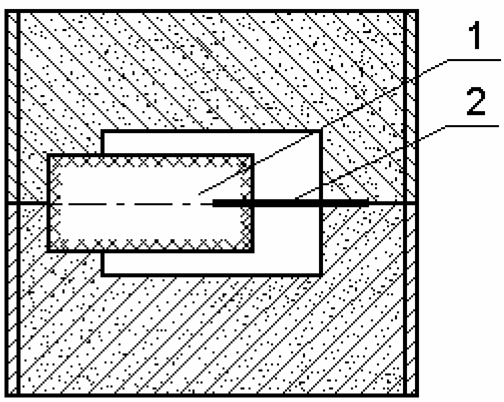


Fig. 8 Placement of gagger in casting mould

Sometimes "blockheads" are applied instead of cores in order to make blind (not through) holes. They give the chance to make the mould without cores, carrying out their functions. The *blockhead* is the part of the mould which is not come out of splitting plane. The height of the internal cavity which is carried out by "blockhead" in the bottom part of the mould should not exceed width or diameter of its section $H \le B$ (Fig. 9). If the internal cavity is carried out by "blockhead" in the top part of the mould, $h \le 0.3 \cdot b$.

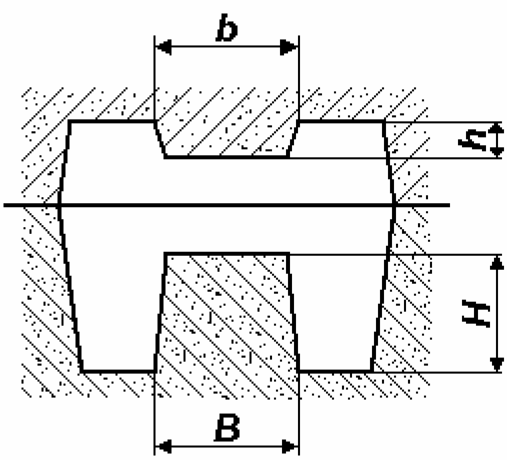
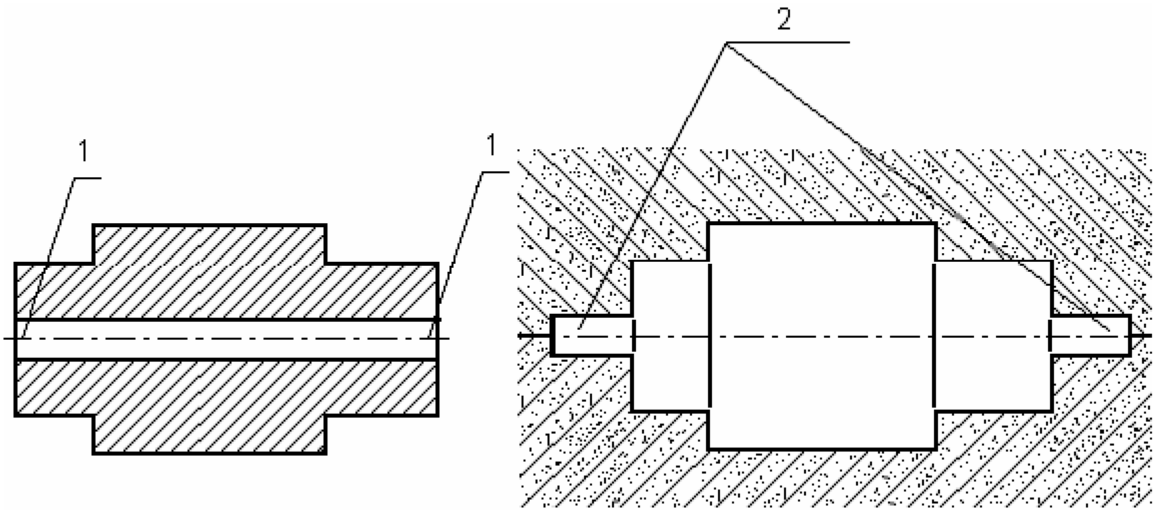


Fig. 9 "Blockheads" application for casting cavities fulfillment

Core position should be strictly fixed in a mould cavity. Core (foundry) marks, as continuations of holes, are provided for this purpose. In places where a part has holes (see Fig. 10, 1) the pattern has projections for printing of so-called foundry marks in the mould (Fig. 10, 2).

For the best removal of patterns from the mould, their vertical surfaces have *pattern tapers* (Fig. 11 and 12, 1). The value of tapers can make up to 3° depending on pattern height. Pattern tapers are set also to patterns of "blockheads" and mark parts of cores (up to 15°).



a *b*

Fig. 10 A part *(a)* and a casting mould for it *(b)*

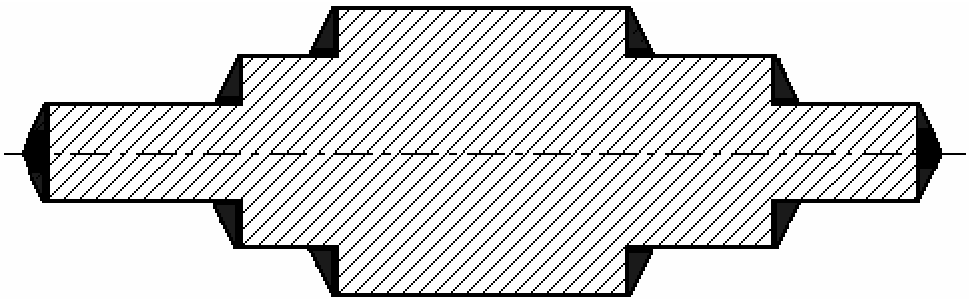


Fig. 11 Application of pattern tapers

The casting pattern is carried out according to all these rules; besides, allowances for machining and shrinkage are considered (Fig. 12, 2).

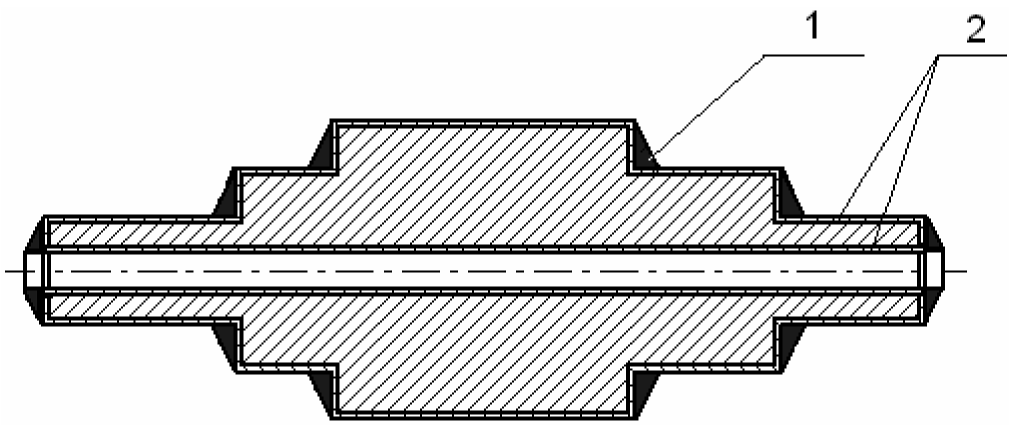


Fig. 12 Allowances for machining and shrinkage

Allowance for machining is the layer of metal provided for removal upon the machining that the necessary size accuracy and surface roughness be reached. Its value depends on a material of casting, a way of casting, a volume of output, position of a processed surface in a mould.

Allowance for shrinkage is the layer of metal compensating reduction in casting volume during crystallisation and cooling. It depends on amount of alloy shrinkage.

For simplification of internal cavity moulding the pattern is parted by splitting planes, more often onto two parts. **The splitting plane usually coincides with one of the axes of symmetry of casting.** By this realization of the rule of parallel beams and economy of foundry materials for the account of smaller metal expenses for tapers manufacturing is reached.

The gating system is brought to casting in a splitting plane of the mould. The sizes of gating system elements for castings made of various alloys are calculated by means of special diagrams and empirical formulas. With the account of weight of the fused metal and speed of pouring the cross-sections of feeders, slag catcher and a pouring gate is defined.

To prevent shrinkage cavities formation upon crystallisation of difficult castings, the additional reservoir for a liquid metal is carried out in the mould. This reservoir is called *lost head* (Fig. 13, 1). It is connected with a mould cavity and feeds a casting with liquid metal as shrinkage of metal in the mould goes. The lost head is established in that place of the mould where the greatest volume of liquid metal is located. The size of lost heads (length and width of its basis, and also its height) is calculated by empirical formulas, depending on the sizes of the fed volume.

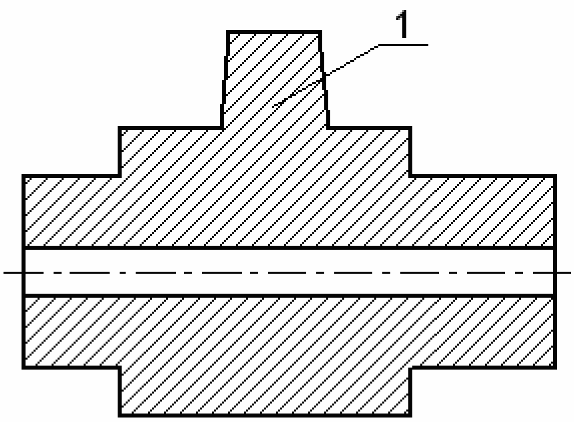


Fig. 13 A lost head placement in a mould

The order of performance

1. Familiarise with key rules of casting design.

2. According to the task received represent the sketch of a finished part (see Fig. 14*a*).

3. Choose casting position in a mould upon pouring, define a pattern and core configuration, and set a splitting plane of the pattern and the mould using a rule of parallel beams.

4. Draw the sketch of casting with the consideration of allowance for machining, pattern tapers and fillets (Fig. 14*b*). The allowance is required only for the surfaces connected by the sizes.

5. Draw the pattern sketch, specify a splitting surface (SPM), and outline the core marks (Fig. 14*c*).

6. Draw the core sketch, with the account of core marks tapers (Fig. 14*d*). Design a core box.

7. Draw a vertical section of a casting mould with a mould cavity and gating systems (Fig. 14*e*).

The example of the task performance is given in Fig. 14.

Notes:

1. The moulding should be carried out in two flasks.
2. Application of напусков is not allowed, i.e. destination of additional metal volumes for simplification of a work-piece shape.

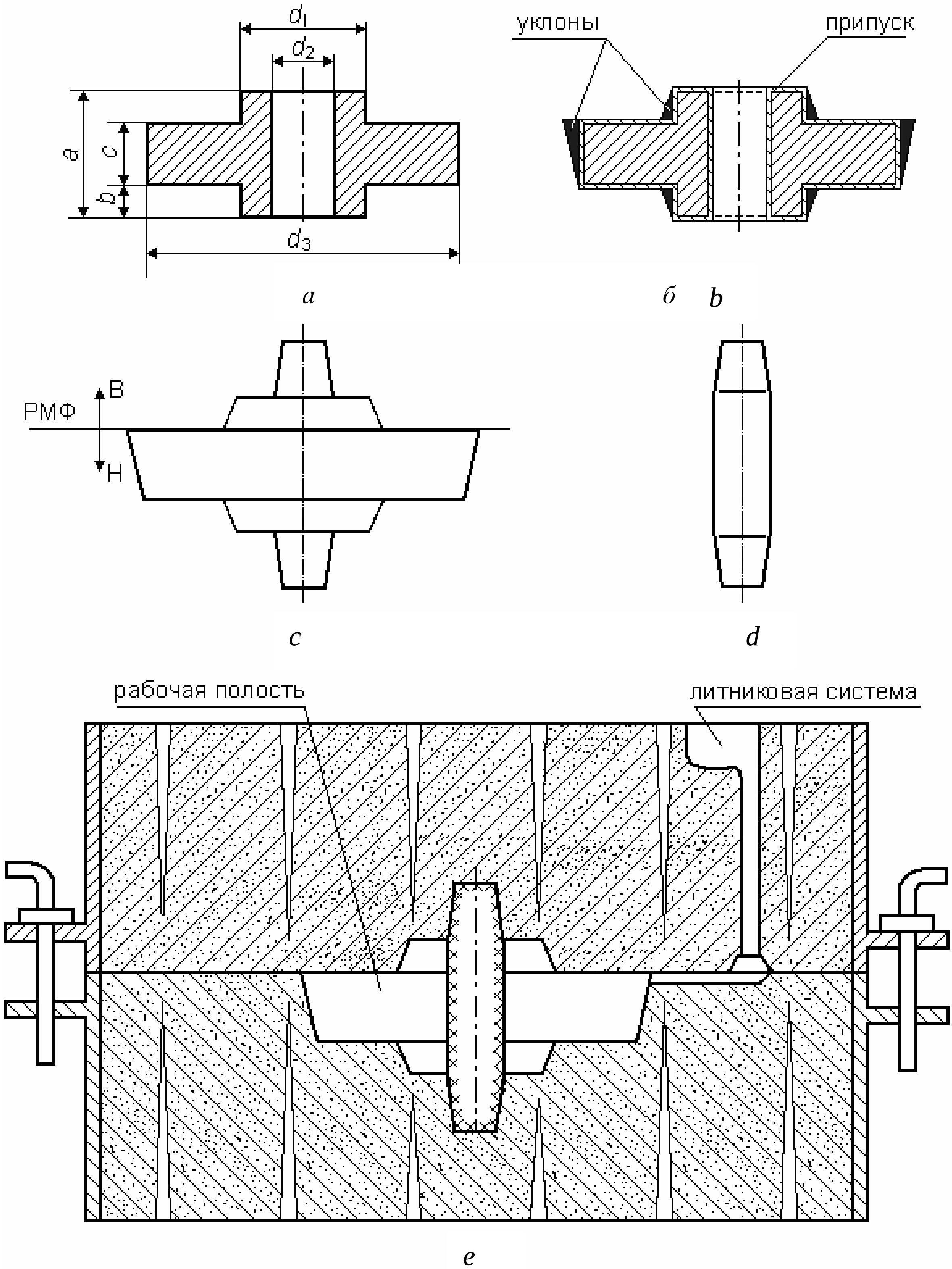


Рис. 14. Example of task completion:
a) drawing of a part; *b)* drawing of a casting; *c)* drawing of a pattern;
d) drawing of a core; *e)* vertical section of casting mould

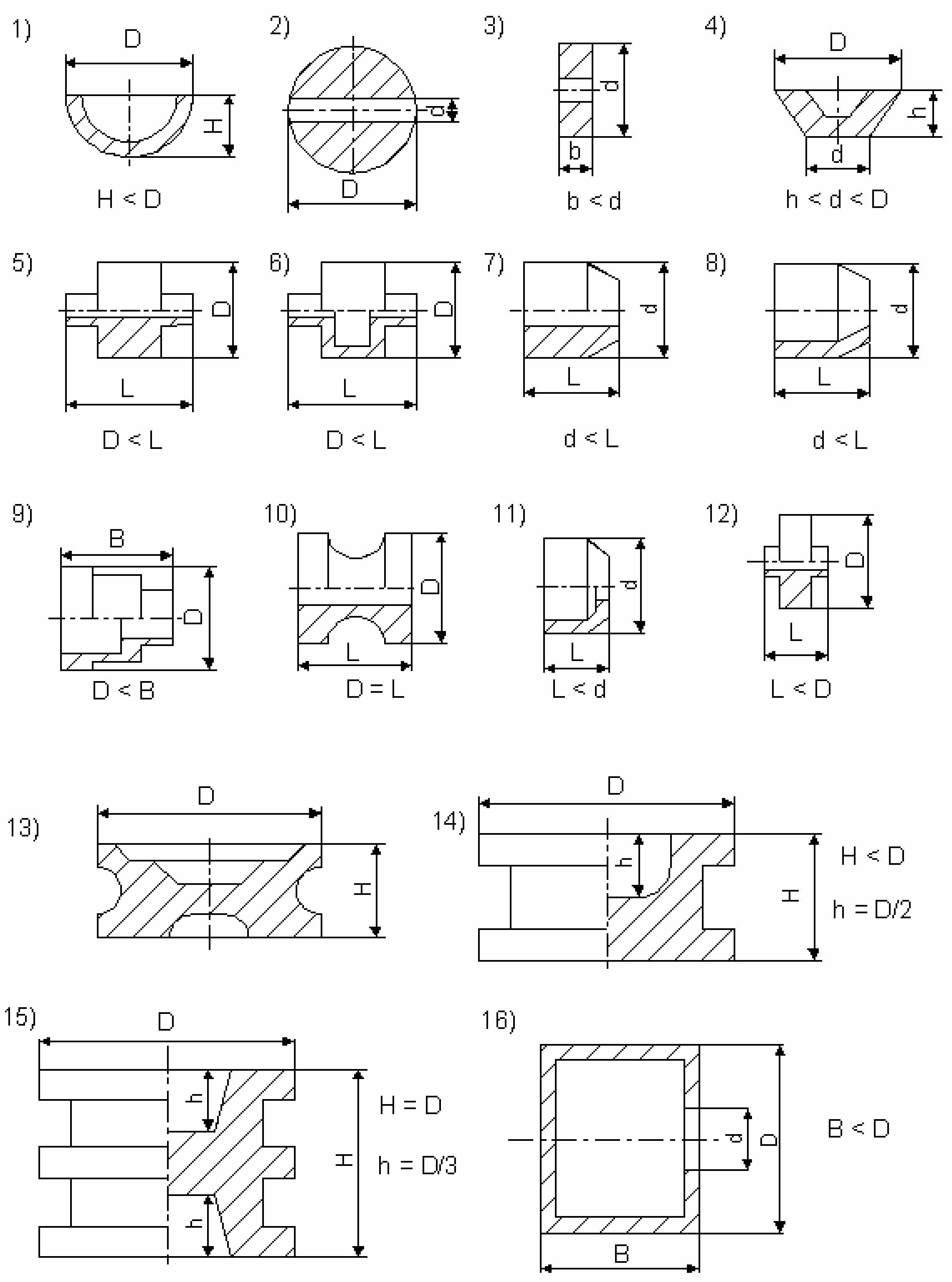
Contents of report

1. The work purpose.
2. Key rules of casting design.
3. Stages of design of the expendable sand mould according to the individual task.
4. Longitudinal and cross sections of the mould with attached gating system.

Test questions

1. Name advantages of a casting placement in a mould with the least height of the mould cavity.
2. What is liquation?
3. What is a rule of parallel beams applied for?
4. Name advantages and lacks of a design of the cast part made according to a principle of directional solidification.
5. What cast details are carried out according to a principle of directional solidification upon cooling and why?
6. What is the essence of a method of the inscribed circles?
7. What is a fillet and what are fillets applied for?
8. Why should it be as less as possible cores in a mould?
9. What is a "blockhead" and what is it applied for?
10. What is a gagger and what is it applied for?
11. For what purpose are pattern tapers set?
12. What is the allowance for machining?
13. What is shrinkage?
14. What are foundry marks applied for?
15. What purpose is the lost head applied for? Where is it established?

Individual tasks



LABORATORY WORK № 4

VAKUUM-FILM MOULDING (V-PROCESS)

Laboratory work objective

1. Study vacuum-film moulding process.
2. Make a casting mould by vacuum-film moulding method.

The equipment and materials

1. Moulding table.
2. Heater of a film.
3. Casting patterns.
4. Gating system.
5. Vacuum chamber with a receiver.
6. Forvacuum pump.
7. Ethyl-vinyl acetate film 75–100 ?m in thickness.
8. Dry sand.

The order of performance

1. Read attentively basic principles of a work theme.
2. Make a casting mould by the vacuum-film moulding method.
3. Write the report using necessary drawings and explains.

Basic principles

Vacuum-film moulding has been developed in 1971 in Japan. The method was applied for producing various art castings of aluminium and copper alloys. By this way it is possible to make decorative lattices and openwork surfaces without caring of hollows, deepenings, negative corners and other. This method permits to reproduce even a branch of coniferous trees, using a branch as a pattern, and to receive the exact copy executed in metal.

Technological process consists of the following (see Fig. 1). Patterns of the future casting and gating system 1 are fasten to a metal modelling plate 2.

Patterns and modelling plate have through holes of small diameter. A plate with patterns is established on the vacuum box-shaped chamber 3 (Fig. 1, *a*) which is joined the vacuum pump by means of a branch pipe. For smoothing spasmodic air leak-in to the vacuum chamber the additional capacity with preliminary pumped away air is used (a receiver). The modelling plate is covered with a polyvinyl-acetate film 5 (100 ?m in thickness), heated to a plastic state by radiating or convective way. For the first method gas or electric heating is applied, for the second – blowing with hot air. When rarefying in the vacuum chamber is created, the film fits densely the pattern and the plate. Then top box-shaped flask 4 is established on the plate (Fig. 1, *b*). The internal walls of a flask have apertures. The flask itself is connected to the vacuum pump by means of a branch pipe. The modelling plate is supplied by the vibrating device.

The flask is filled with a mix of dry sand (grains 0.2 mm in size) and compacted by its vibration. Then the top surface of the flask is levelled, deleting a surplus of sand by a ruler, until a plain counter surface is obtained. The top counter surface is covered with a non-heated film and vacuum is created. The sand in box-shaped flask appears densely compressed by a film from below and from above. Then, without switching off the pump creating vacuum in top flask, vacuum in the vacuum chamber is flashed down. The top flask is removed from the pattern set (Fig. 1, *c*), and then a bottom flask is moulded similarly. Further the mould is assembled from two halves (Fig. 1, *d*); a surface of the half-mould making out a casting is painted with a refractory paint. In exceptional cases a surface of the bottom half-mould is painted, too. While painting the paint and the sand should be divided by the film.

Then the assembled mould (Fig. 1, *d*) is poured with metal (while pouring both halves of a mould is under vacuum). Metal is poured to pouring basin established in the top half of a mould. The top half-mould is loaded for the purpose of prevention it's shifting at metal pouring. After metal hardening the vacuum pump is switched off, and casting with sand in which it was moulded falls out from the flask. Further sand is used for moulding again.

Unfortunately, vacuum moulding has low productivity: 5–6 castings per hour. However, this process has huge advantages in comparison with other foundry processes when metal is filled into expendable moulds. First, there is no moulding mix as dry sand is applied. Secondly, the difficult moulding equipment and along with it mix preparation is excluded. Thirdly, application of binding materials is excluded, and casting knock-out and scrubbing becomes simpler. Fourthly, working conditions and ecological characteristics improve. At last, it is possible to use the art product as a pattern, because the film used for forming copies almost any profile of an art product.

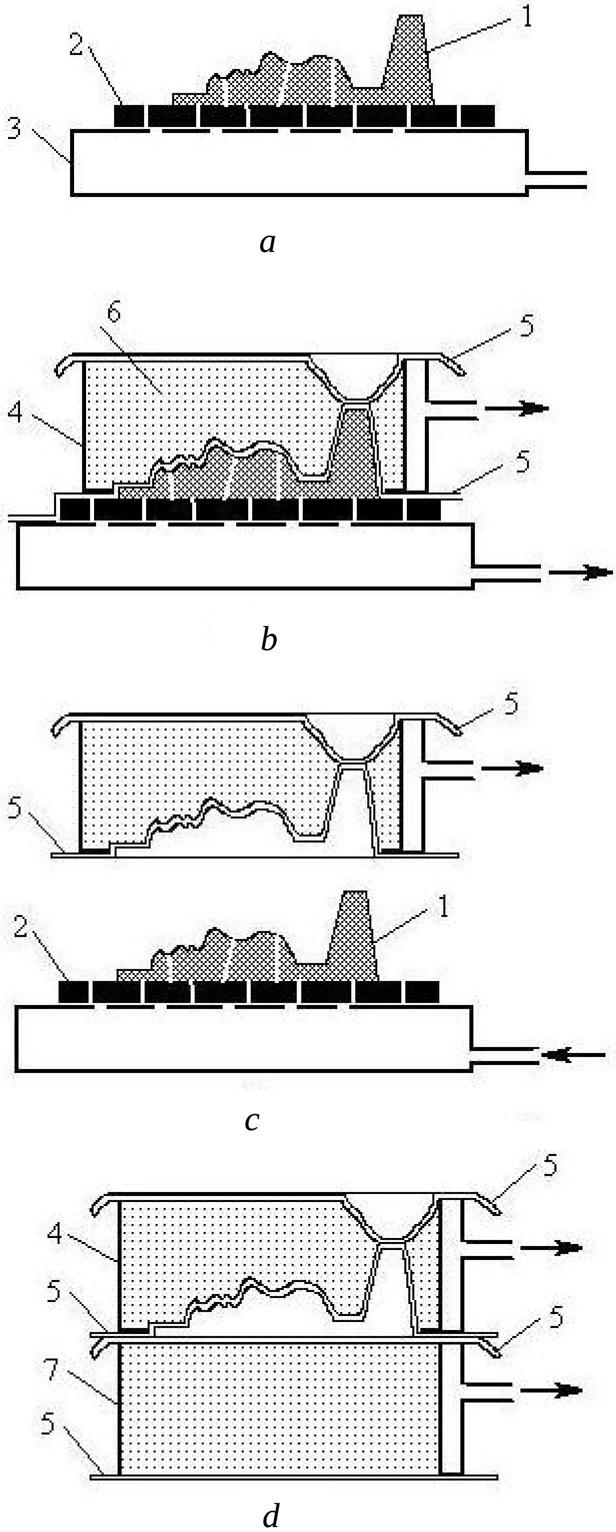


Fig. 1 The scheme of vacuum-film moulding process:
a – pattern installation onto modelling plate with through apertures above the vacuum chamber; *b* – stretching of patterns by a heated synthetic film and the top flask moulding

with a pouring gate and a feeder under vacuum; *c* – removal of the top flask from the modelling plate under vacuum; *d* – assemblage of a casting mould under vacuum. *Positions*: 1 – the pattern with a pouring gate and a feeder; 2 – modelling plate with through apertures; 3 – the vacuum chamber with apertures; 4 – a top flask; 5 – a synthetic film; 6 – dry sand; 7 – a bottom flask

Besides the listed advantages, vacuum-film moulding process has also lacks. They are low productivity of process, as it has been already specified, and also the high technological discipline required for casting manufacture. This method is suitable for manufacturing rather simple configuration of casting, flat mainly. Application of the vacuum equipment demands qualified professionals. At last, film heating to 100 °C puts forward a number of requirements to the film materials destruction, leading to gritty scale formation and ingress of sand inclusions into casting. As fire-resistant coatings graphite, talc, zircon, kaolin (china-clay) and the aluminium powder are used. All these substances are dissolved in methanol or ethanol – i.e., in the solvents which does not react with a film. Water is not used as solvent, because it does not moisten a film.

Report contents

1. Work purpose.
2. Equipment and materials required.
3. Description of experiment with drawings and schemes.
4. Advantages and disadvantages of vacuum-film moulding in comparison with sand casting.

Test questions

1. For what purpose is the synthetic film used?
2. For what purpose is the receiver necessary?
3. What is the thickness of a synthetic film used for vacuum-film moulding?
4. For what purpose the film is heated up?
5. What material is used for moulding?
6. What is the main requirement for moulding sand?
7. For what air is the vacuum chamber filled while top flask moulding?
8. Which shape of castings is preferable for vacuum-film moulding?
9. Is air exhaust disconnected while alloy pouring?

LABORATORY WORK № 5

EQUIPMENT AND TECHNOLOGY OF FORGING

Laboratory work objective

1. Get acquainted with equipment and technological process of forging.
2. Study basic forging operations.
3. Learn to choose equipment and forging technology for work-pieces.

The equipment and materials

1. Pneumatic hammer with weight of falling parts 75 kg.
2. Heating furnace with the thermocouple and a potentiometer.
3. Measuring tool (a calliper, a ruler).
4. Samples of carbon steel.

The order of performance

1. Read attentively basic principles on a work theme.
2. Get acquainted with the equipment, the tool, the appliances used for free forging. Study the structure and a principle of a pneumatic hammer work operation.
3. Get acquainted with the basic operations of free forging (upsetting, bolt heading, draw), sketch billets and forged pieces. Performance of forging operations is made by the master.
4. Carry out calculations according to trainer's instructions. Explain your decisions.
5. Observe safety precautions. Do not touch forged pieces before full cooling and be on safe distance from a working hammer.
6. Write a qualitative report on the laboratory work.

Basic principles

Forging is technological process of metal deformation by means of forge hammer blows or press pushing.

Forging is still named ***free forging*** because metal broadens freely in a horizontal direction under the influence of vertical hammer blows. It is well visible, for example, in draw operation. Hand forging is applied for manufacturing of small forged pieces, mainly, in repair shops (Fig. 1). At hand forging blows are struck by a sledge hammer (a heavy hammer about 10 kg in weight).

Among advantages of forging it is necessary to note: possibility of manufacturing forged parts of various weight, shape and sizes; absence of expensive equipment; usage of the simple and universal tool.

Limitations of the method are: rather low labour productivity, low accuracy of forged pieces, the big allowances for the subsequent machining leading to metal losses for chips.

Before forging billets are exposed to heating in order to increase plasticity of metal and simplify the process.

Change of strength and plasticity upon heating of some metals and alloys are given in Table 1.

The temperature range of forging is defined by data given in Table 2.

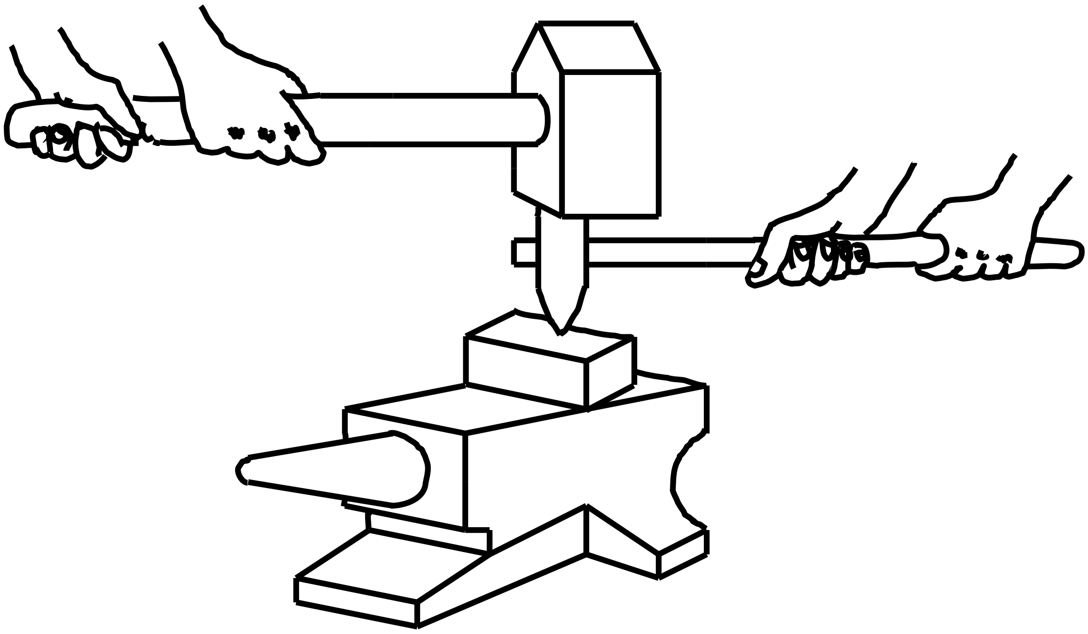


Fig. 1 Hand forging

Table 1

Grade of steel or alloy *(Russian classification)*	**Treatment temperature, °C**				
	200	600	800	1000	1200
Steel Ст3	42/25	21/–	8/70	5/80	3/88
Steel 45	64/16	32/25	12/48	5/53	3/64
Steel У12	68/5	18/1	11/52	4/65	2/92
Steel 30ХГСА	64/12	18/–	6/–	3/30	1/60
Steel 40Х9С2	75/15	29/–	5/68	4/29	2/72
Copper МЧ	27/40	4/56	1/70	–/77	–
Brass Л68	33/56	5/34	2/72	–	–
Titanium alloy ВТ3	80/16	60/20	8/100	4/100	–

The note: numerator is a tensile strength in kg/mm^2, denominator – percentage elongation in %.

Excess of metal heating temperature upon forging conducts to formation of defects named overheat and overburning. The *overheat* is a metal grain growth over allowable size that leads to decrease in mechanical properties. *Overburning* means oxidation of grain boundaries, such metal fractures under forging. Forging at temperature below the bottom limit of a temperature range leads to destruction of metal because of insufficient plasticity.

Table 2

Groups of metal and alloy	**Temperature, °C**	
	Beginning of forging	**End of forging**
Structural carbon steel	1200–1300	800
Tool carbon steels	1050–1100	820
Alloyed steels:		
low-alloyed	1100	820–850
medium-alloyed	1100–1150	850–875
high-alloyed	1150–1200	875–900
Aluminium	500	310
Aluminium alloys	470–490	350–400
Copper	900	650
Copper alloys: bronze	850	700
brass	750	600
Magnesium alloys	370–430	300–350

Technological process of forging represents set of operations, basic of which are:

1. ***Upsetting*** is increase in the area of work-piece cross-section at the expense of height reduction (see Fig. 2).

2. ***Bolt heading*** is an upsetting of a part of billet (see Fig. 3).

3. ***Draw*** is increase in length of billet at the expense of thickness reduction (see Fig. 4).

4. ***Chipping*** is division of metal piece into parts (see Fig. 5).

5. ***Hollow forging***, or ***piercing*** is making a hole in a billet (see Fig. 6). A blind piercing and through one are distinguished (in fig. 6 the through piercing is shown).

6. ***Expansion*** means increase in diameter of ring work-piece at the expense of reduction in thickness of a ring (see Fig. 7).

7. ***Cranking*** is displacement of one part of billet concerning another (see Fig. 8).

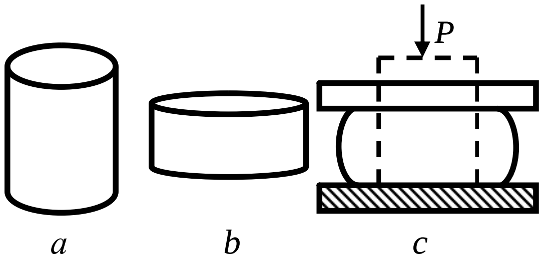


Fig. 2 Upsetting

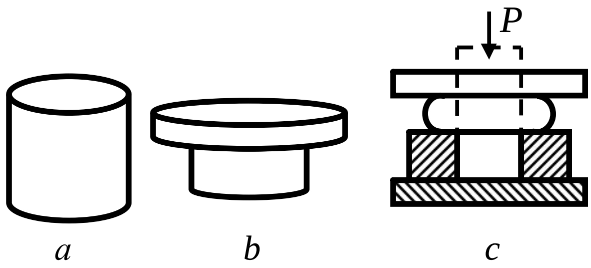


Fig. 3 Bolt heading

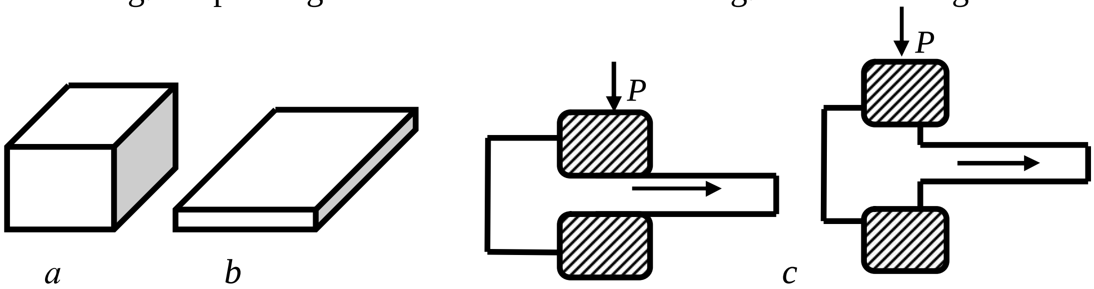


Fig. 4 Draw

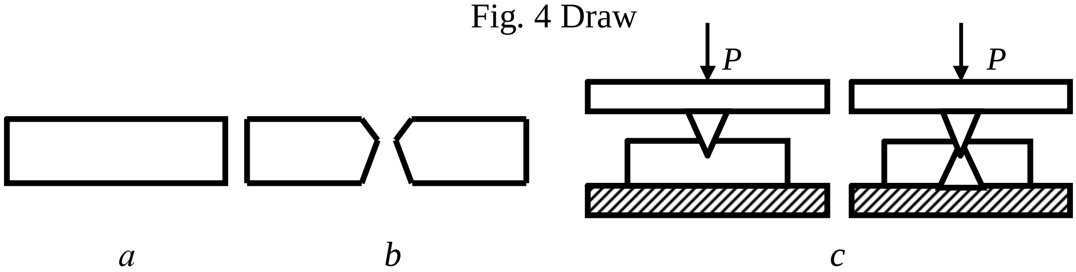


Fig. 5 Chipping

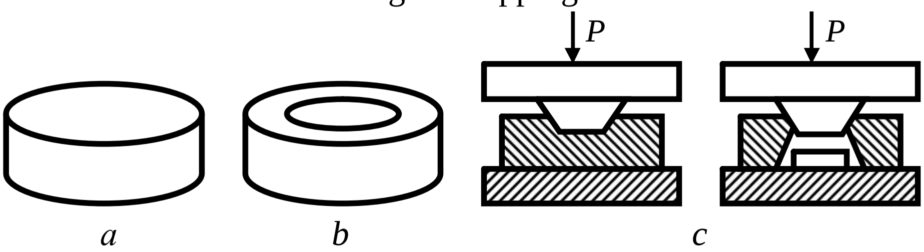


Fig. 6 Hollow forging

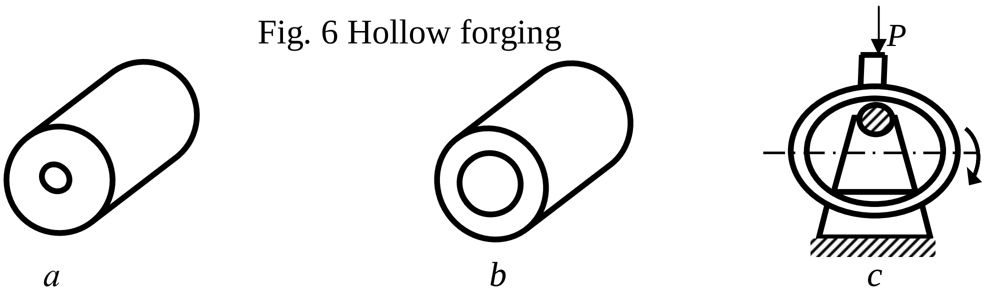


Fig. 7 Expansion on a mandrel

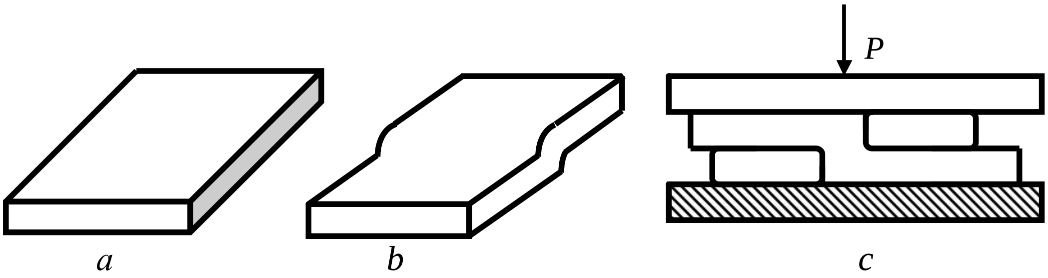


Fig. 8 Cranking

In figures 2–8 letters designate: *a* – a billet; *b* – forged piece; *c* – scheme of operation. There are also other forging operations.

The deformation value for forging is characterised by forging reduction *FR*:

$$FR = F_{max}/F_{min},$$

where F_{max} and F_{min} are the greatest and the least area of cross-section before and after forging.

Forging of rolled billets more often gives the forging reduction equal to 1.3–1.5, and for forging of ingots *FR* = 3–10. The more forging reduction of ingots is, the better metal structure and higher its mechanical properties are.

The equipment for forging is compressed-air hammers and presses. ***Hammers*** are machines of impact action, and ***presses*** are machines with slow load application.

Small pieces are usually forged on pneumatic hammers, large ones – on steam-air hammers, and very large and heavy ingots – on hydraulic presses.

The scheme of a pneumatic hammer is presented in Fig. 9.

The pneumatic hammer has two cylinders: compressor cylinder 1 and working cylinder 2. The piston 3 of compressor cylinders forces air into the working cylinder 2 and drives the working piston 4 which is made as a single whole with a massive stock 5. These two parts together are called a hammer head. Up-and-down motion of the piston in the compressor cylinder is carried out by the connecting rod gear 6 which gets movement from the electromotor 7 through V-belt transmission 8 or by means of gear wheels.

Both cylinders of a hammer are connected by air channels so that compressed air arrived to the working cylinder alternately from below and above, forcing the hammer head to move upwards and downwards.

Hammer control is carried out by air cranes, or throttles 9. Cranes open and closed by means of a foot pedal 10. Air distribution ensures functioning of a hammer with the individual or several blows automatically following one after another, or allows pressing a piece to bottom block. Also it is possible to keep the head in the top position at the working compressor.

The top block is attached to the hammer head by the shaft 11 of dovetail shape and a wedge. The bottom block 12 is attached to a chuck 13 established on the massive metal basis 14. The basis is not connected with a hammer frame. The weight of basis should be 15–20 times more than *weight of falling parts* of a hammer which is the characteristic of hammer capacity. It is weight of all parts of the hammer moving in its top part (the working piston, the stock and top block). The more weight of falling parts is the higher energy of top block blows on a billet. Pneumatic hammers are made with weight of falling parts from 50 kg to 1000 kg, and steam-air ones – from 1000 kg to 8000 kg. Therefore steam-air hammers are applied to forge large, massive pieces.

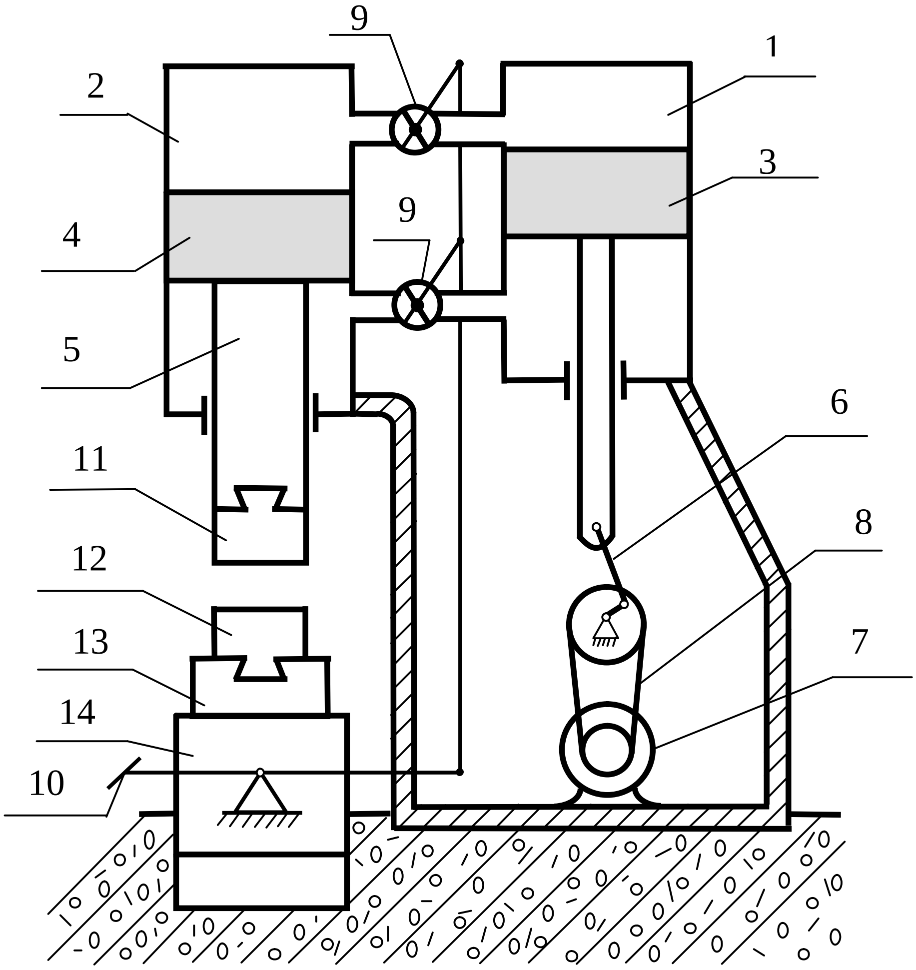


Fig. 9 Pneumatic hammer

Hydraulic presses are used to forge very large, heavy products. In these machines top block, connected to other mobile parts of a press, is set in motion by pressure of a liquid in the main working cylinder. As such liquid mineral oil under the pressure of 20–50 MPa is usually applied. Metal deformation on a hydraulic press occurs slowly enough (some seconds, sometimes tens of seconds). Deformation goes without blows. The press capacity characteristic is the effort developed and transferred to billet. For forging hydraulic presses with effort from 300 t to 15000 t are used.

To compare hammer and press capacity it is possible to accept that 1 t weight of falling parts of a hammer is approximately equivalent to 100 t efforts of a press. Presses are able to forge massive, large ingots. So, for example, on a press with effort 1000 t it is possible to forge ingots under 8 t in weight; a press with effort 15000 t forges ingots under 350 t in weight.

In practice while choosing equipment capacity for forging special directories, tables, formulas are used. So, necessary capacity of a hammer can be defined by the formula:

$$G = K \cdot F,$$

where G – weight of falling parts of a hammer, kg,

F –cross-section of a piece, cm^2,

K – factor equal 5 for carbon steel, 7 – for alloyed steel, 3.5 – for non-ferrous metals.

The necessary effort of a press can be found by the formula:

$$P = F \cdot \sigma_T, \text{ kg},$$

where σ_T is tensile strength of metal under forging temperature, kg/cm^2,

F is the block contact area with forged piece in cm^2.

At free forging the sizes of forged work-piece are made more than sizes of a completed part on value of allowances.

Allowance Z is an increase in the sizes of a part for the subsequent machining by metal-cutting machine tools in order to get the necessary accuracy of the sizes and quality of a part surface.

Tolerance Δ is a maximum deviation from the forged piece size, i. e. an accuracy with which forged piece should be made.

Explanations concerning location of allowance and tolerance zones are given in Fig. 10:

A is the size of a part according to the drawing;

B is the least admitted size of forged piece: $B = C - \Delta/2$;

C is the nominal (design) size of forged piece: $C = A + Z$;

D is the greatest admitted size of forged piece: $D = C + \Delta/2$.

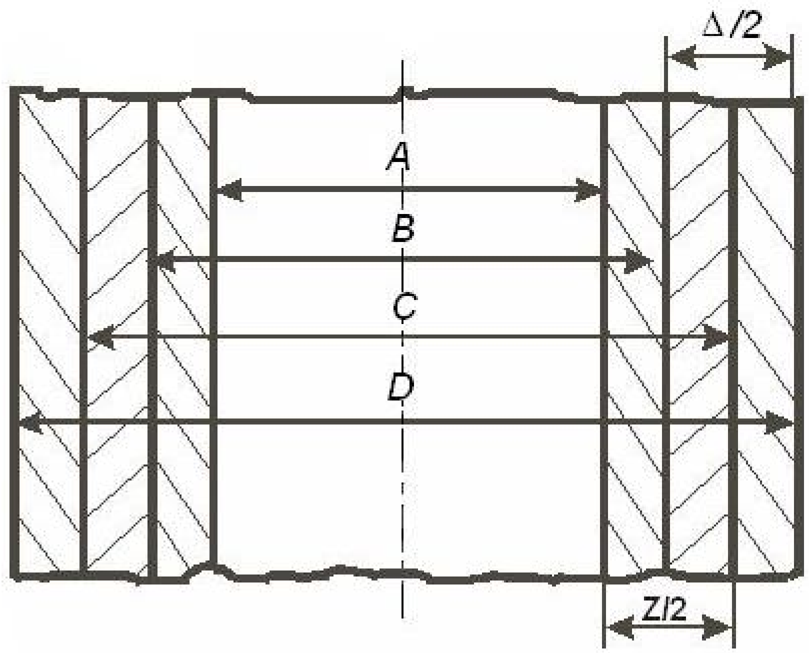


Fig. 10 Allowance and tolerance zones for forged work-piece

The size of allowance and tolerance depends on many factors. Approximately allowances for machining (mm) can be calculated by following formulas.

1. For forging by hammers:

a) allowance for diameter or thickness of forged piece *D*

$$Z_1 = 0.06 \cdot D + 0.0017 \cdot L + 2.8;$$

b) allowance for length of forged piece *L*

$$Z_2 = 0.08 \cdot D + 0.002 \cdot L + 10.$$

For forging by hydraulic presses:

a) allowance for diameter or thickness of forged piece *D*

$$Z_1 = 0.06 \cdot D + 0.002 \cdot L + 2.3;$$

b) allowance for length of forged piece *L*

$$Z_2 = 0.05 \cdot D + 0.05 \cdot L + 26.$$

2. Tolerances (mm) for forged pieces sizes can be calculated approximately by following expressions:

a) for diameter or thickness of forged piece *D*

$$\Delta_1 = 0{,}028 \cdot D + 0.0004 \cdot L + 0.5;$$

б) for length of forged piece *L*

$$\Delta_2 = 0.03 \cdot D + 0.003 \cdot L + 1{,}2.$$

Then nominal diameter or thickness of forged piece (D_F) is defined as

$$D_F = D + Z_1,$$

and the least and the greatest admitted diameters are expressed as

$$D_{F\,max} = D_F + \Delta_1/2;$$

$$D_{F\,min} = D_F - \Delta_1/2.$$

Nominal length of forged part makes up: $L_F = L + Z_2$, and the least and the greatest admitted length are expressed as

$$L_{F\,max} = L_F + \Delta_2/2;$$

$$L_{F\,min} = L_F - \Delta_2/2.$$

Tolerances are set for all sizes of forged piece, including those, which are not machined subsequently.

Individual tasks

1. Define what operations of forging were carried out by the master. Make necessary measurements and calculate forging reduction for each of them.

2. Calculate necessary capacity of a hammer or a press and kinds of forging operations for following products.

a) Make a forged piece of square section (60?60 mm) from copper billet 100 mm in diameter and 120 mm length.

b) Forge ingot from steel with 1.2 wt% C 100?100 mm in cross-section and 1300 mm length onto a shaft 80 mm in diameter.

c) Make a ring 200 mm in external diameter and 80 mm in internal diameter from a steel billet 150 mm in diameter and 120 mm height (steel grade Cт 3).

d) Brass work-piece 30 mm in diameter it is necessary to forge onto hexahedron.

e) Forge work-piece made of steel with 0.45 wt% C, 800?800 mm in section and 1100 mm length and receive a shaft 600 mm in diameter.

f) Ingot from steel 30ХГСА 1200?1200 mm in section and 2600 mm length it is necessary to forge and to manufacture a three-stage shaft with steps diameters 1000, 850 and 680 mm.

g) Make a disk 82 mm in diameter and 36 mm in thickness from steel 40Х9С2.

3. Define allowances and tolerances for forging following products: Fig. 11, *a*, *b*, *c*, *d*.

4. There is an order for manufacturing of forged products 100 mm in diameter, 100 mm height. In a stock bank there are no bars of such diameter; bars 80 mm in diameter are available.

Calculate what length is to be cut off from a bar to receive a forged piece of required sizes.

It is known that the metal volume remains constant during forging:

$$V_{\text{billet}} = V_{\text{forged piece}}.$$

Volume of cilinder $V = \pi R^2 \cdot h$.

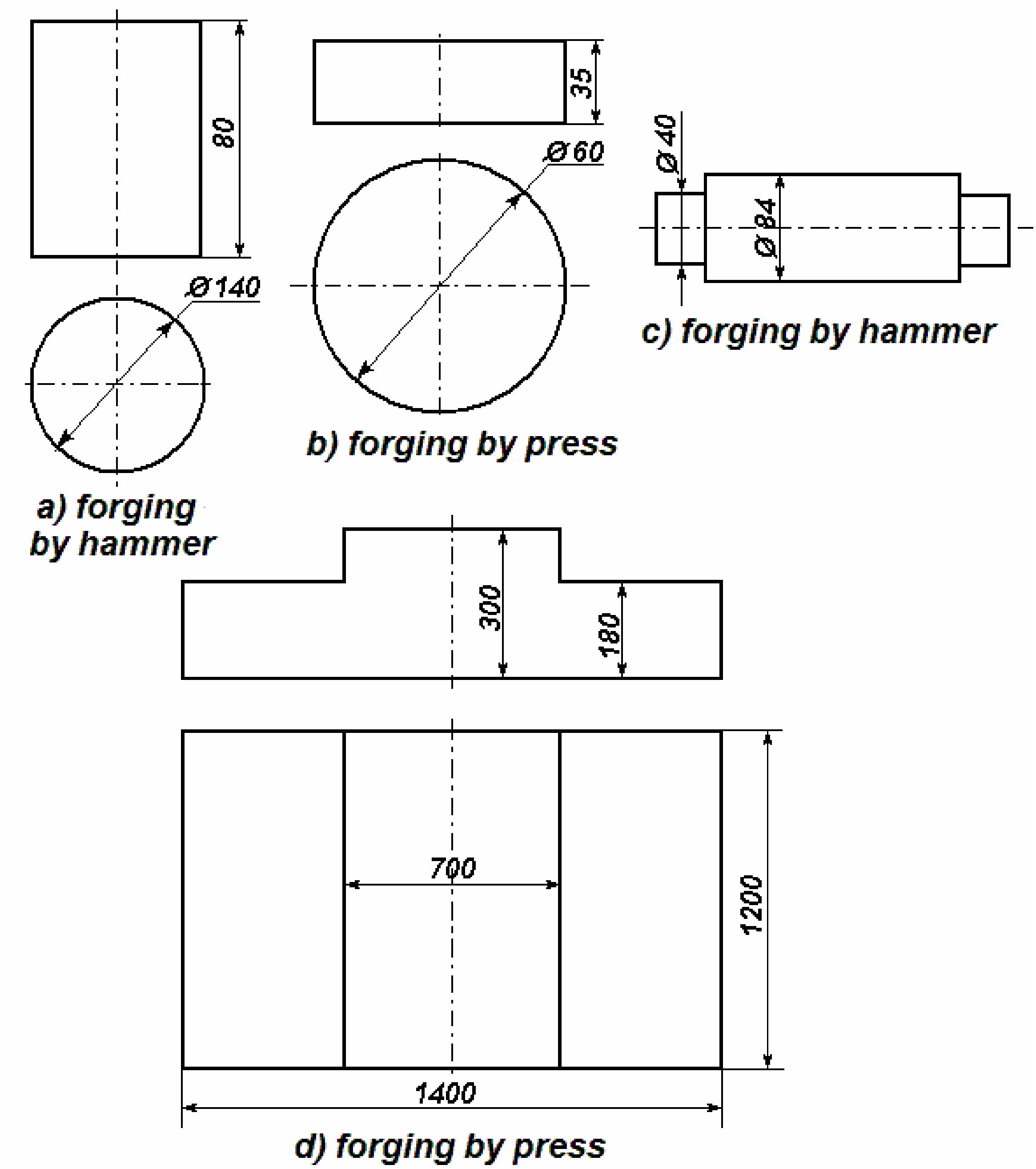


Fig. 11 Sketches of forged pieces for allowance and tolerance calculation

Report contents

1. Report purpose.
2. Equipment and materials used.
3. Basic principles of technology and equipment for forging, definition of allowances and tolerances for forged pieces.
4. Design tasks with necessary sketches and explanations.
5. Analysis of work results.

Test questions

1. What technological process is called forging?
2. What are advantages and limitations of forging?
3. For what purpose is metal heated up before forging?
4. What is overheating and overburning of metal?
5. Describe the basic forging operations.
6. What is the forging reduction?
7. What is a difference between deformation on a hammer and on a press?
8. List the main parts of pneumatic forging hammer.
9. How capacity of a hammer and a press is defined?
10. What are the allowance and the tolerance?

LABORATORY WORK №6

EQUIPMENT AND TECHNOLOGY OF ARC MANUAL WELDING AND RESISTANCE WELDING

Laboratory work objective

1. Study equipment and parameters of manual arc welding mode.
2. Study kinds and equipment of resistance welding.
3. Master elements of practical skills in welding.

Equipment and materials

1. Welding post for manual arc welding.
2. Welding machines for resistance welding.
3. Devices for voltage and current strength measurement.
4. Samples of welding and welding materials.

The order of performance

1. Familiarize with the basic data on a work theme.
2. Execute an experimental part according to methodical instructions.
3. Analyse the received results and draw conclusions on results of work.

Basic principles

1. Manual arc welding with a coated consumable electrode

Welding is a process of permanent joints producing by an arising of interatomic bonds between surfaces of welded pieces at the expense of their fusion and plastic deformation.

In manufacture of welded metal structures manual arc welding is used more often than other ways. It is caused by its following advantages: high strength of welded joints, possibility of application in hard-to-reach spots, simplicity and reliability of the equipment, a wide choice of welding electrodes types and, hence, the big range of technological possibilities.

At manual welding the arc strikes between work-piece and an electrode fixed in electrode holder, which the welder holds in a hand. All operations on arc striking, moving of an arc along a product and electrode feeding into an arc zone are carried out manually.

Welding is based on use of thermal energy of an electric arc in which column the temperature 6,000–8,000 °C develops. The ***welding arc*** represents the powerful stable discharge of electricity in the ionised atmosphere of gases and metal steams. Ionisation of an arc gap begins at the moment of an arc striking and is continuously supported in the process of welding. Striking of an arc usually includes three stages:

1) electrode short circuit on work-piece, thus in contact points a metal warming up occurs;

2) electrode removal on a distance 3–6 mm. At this stage under the influence of electric field electron emission begins from the surfaces of heated spots. Collision of quickly moving electrons with molecules of gases and metal steams leads to ionisation of an air gap; the arc space becomes electroconductive;

3) occurrence of the steady arc discharge.

2. Equipment for manual arc welding

The power supply of a welding arc is a device which allows obtain necessary type and strength of a current. Sources of a welding current should have the special *external characteristic*, i. e. dependence of voltage on its output pins on a current in an electric circuit. External characteristic can be high-angle falling, low-angle falling, flat and increasing.

Work of any source is characterised by three basic states: an *open-circuit conditions* (the welding circuit is opened, the arc does not strike), a *short circuit conditions* (in a welding circuit the short circuit current flows) and a *load conditions* (the arc strikes steadily at the set working current). The certain points of external characteristic correspond to these three states.

For manual arc welding sources with high-angle falling characteristic are used. For obtaining such characteristic transformers with heightened inductive resistance X_t are applied (for usual power transformer $X_t \approx 0$). Then voltage on a transformer output (voltage of welding arc U_a) will be defined by the formula

$$U_a = \sqrt{U_{oc}^{\,2} - Y_a^{\,2} \times X_t^{\,2}}\,,$$

where U_{oc} – open-circuit voltage of transformer, V,

Y_a – arc current (welding current strength), A,

X_t – inductive resistance of the welding transformer, O.

The increase in a welding current (at reduction of arc length) causes an arc voltage reduction and vice versa, i. e. electric capacity of an arc does not change almost, and it provides stable welding arc striking. The maximum current strength corresponding to a short circuit conditions at the first stage of arc striking also is limited, that prevents overheat of wires and current sources. It is defined by value of transformer inductive resistance X_t:

$$Y_{sc} = \frac{U_{oc}}{X_t}\,.$$

Thus, regulation of a short circuit current and a welding current in welding transformer is carried out due to change of its inductive resistance value X_t.

The current source should be electrical safety for the welder (secondary voltage of a source under open-circuit conditions is limited by value 60–80 V). It is necessary to remember that voltage 36 V for dry rooms and 12 V for wet rooms is absolutely safe. However at voltage lower 60 V there are difficulties at arc striking, thus, welding voltage is not absolutely safe and under certain conditions (a disease state, alcoholic intoxication, a wet premise etc.) can lead to a deadly case.

For manual arc welding depending on a current type in a welding circuit alternating current sources – *welding transformers* and direct current sources – *welding rectifiers* and *generators* are used.

Alternating current sources are more extended, as they possess a number of technical and economic advantages: welding transformers is more easy-to-work, is much more durable and have higher efficiency than rectifiers and generators.

There are welding transformers of two groups:

1. Transformers with normal magnetic leakage. These transformers can be of two types. In the first case the choke can be carried out separately from the transformer. In the second case transformer represents one-case modification.

2. Transformers with the heightened magnetic leakage also are divided into two types: with the mobile shunt or with a mobile winding.

Transformers with the heightened magnetic leakage and a mobile primary winding are most widely used. The transformer (see Fig. 1) consists of closed magnetic conductor 1 which is assembled from plates of an armco iron, and two windings. The secondary winding 3 is fastened to magnetic conductor motionlessly. The primary winding 4 connected to an industrial mains can freely move along magnetic conductor cores by means of the screw mechanism 2. Primary and secondary windings are carried from each other, that causes the raised inductive resistance of the transformer owing to occurrence of magnetic fluxes of leakage. At work of the transformer the basic magnetic flux Φ_o, created by primary and secondary windings, closes through magnetic conductor. The part of a magnetic flux closes round windings through air space, forming leakage fluxes Φs_1 and Φs_2. With increase in distance between windings leakage fluxes increase, too, and, hence, inductive resistance of the transformer increases.

For welding current regulation a distance between transformer windings is changed. The minimum welding current corresponds to the greatest distance between windings and to the maximum leakage fluxes.

Except traditional arc power supplies for manual arc welding are more and more widely applied *inverter alternating current sources*. At enough big capacity they have small dimensions and weight.

Workplace of the welder (*welding post*) at small dimensions of products is organised in welding cabins 2.0?2.5?2.0 m in the sizes. Exhaust ventilation is obligatory. In a cabin the welding transformer is established; presence of knife switches, cables, electrode holder, grounding of the power supply, cases of knife switches and welding tables should be provided. On a post there should be a complete set of appliances: a chisel, a hammer and a metal brush for slag removal, an electric cabinet for calcinations of electrodes, the measuring tool, guards and masks for the welder protection from splashes of metal, particles of slag, sparks and radiation.

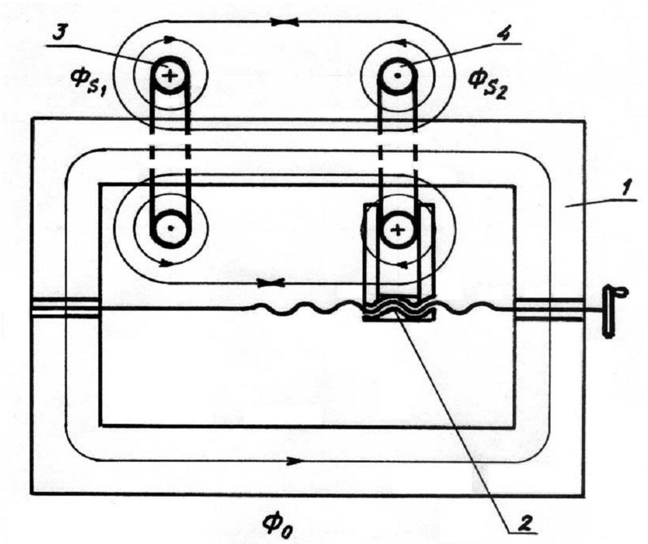


Fig. 1 Scheme of welding transformer

The guard is kept in a hand, and the mask is put on a head and releases welder's hand. The guard and the mask have a sight glass with an optical filter which absorbs dangerous radiation of an arc. Optical filters are divided into weakening optical filters of constant density (black glasses), which have optical density (the number showing, in how many time decreases brightness of an arc luminescence of) from 3 to 13 depending on mark, and also optical filters with the changing optical density. The last without an arc are transparent, and while an arc striking in time less than 0.01 s optical density of a filter automatically increases to the nominal. Action of such optical filters is based on ability of liquid crystals to change the optical density under the influence of external actions.

Overalls for the welder is made of a dense canvas or cloth, it should not have open pockets. The footwear should have deaf top, trousers must be over boots. Mittens are made of a dense canvas, a skin or an asbestos fabric.

3. Welding electrodes

The electrode for manual arc welding (see Fig. 2) represents a metal core 1 300-450 mm length on which surface the coating 2 is put. In the course of welding the arc 6 strikes between a core of an electrode and the basic metal. The electrode core melts off and together with metal of the fused edges of welded parts forms a metal bath 4. An electrode coating melts also, forming a protective slag bath on a surface of the fused metal that protects it from harmful influence of atmosphere. Set of metal and slag baths is called a *welding bath*. In process of arc movement the metal bath hardens, and the welded seam 5 is formed. Liquid slag after cooling forms a solid slag crust 3.

Cores of electrodes are made of a welding wire. The Russian standard provides 77 grades of a steel wire 0.2–12 mm in diameter which is classified as three groups: low-carbon, alloyed and high-alloyed. In Russia grades of a wire "Св" means "welding", first two figures designate the carbon content in the 100-th shares of the percent, the subsequent letters and figures show the content of alloying elements according to the alloyed steels grades; last letter "A" means the lowered maintenance of sulphur and phosphorus.

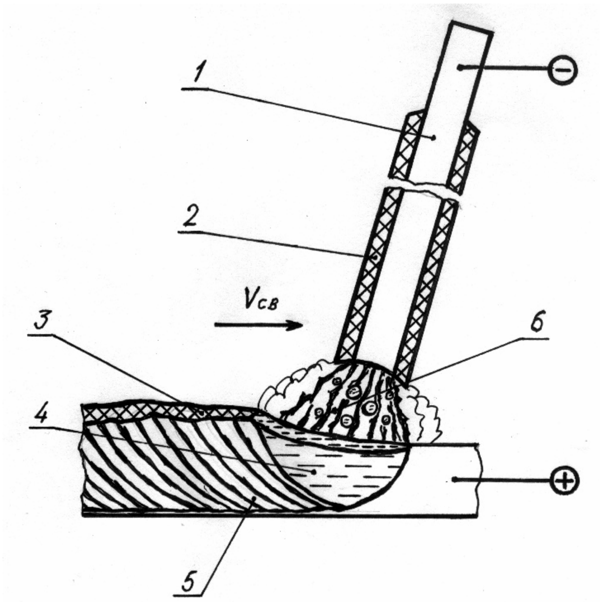


Fig. 2 Scheme of welding process

Electrode coatings are intended for maintenance of stable arcing, protection of the fused metal against influence of atmosphere and formation of seam metal with the necessary structure and properties. Uniform arcing is reached at the expense of stabilising components in a coating. They are easy ionizing substances (compounds of sodium, potassium, calcium in the form of a chalk, marble, etc.). Gas protection of a welding bath is carried out by introduction into coatings gas-forming substances: cellulose, starch, etc. For maintenance of slag protection into coatings slag producing elements are included, for example, rutile concentrate, feldspar, and manganese ore. For removal of oxygen from a welding bath deoxidizing components enter into coatings: alloys of iron with active metals, for example, ferromanganese. Manganese entering into its structure reacts with the oxygen dissolved in a bath, and also with oxygen in oxides and reduces pure iron, manganese thus is oxidized and transfers into slag. After hardening slag forms on a seam surface a hard glassy crust. At removal of a slag crust by hammer blows it is necessary to protect eyes from scattering of glassy slag parts, being closed by a guard or a mask. Into coatings also alloying elements enter for alloying weld metal. Besides, softeners and binding are added into coatings; they give to it strength and good cohesion with a core.

The following kinds of coatings are distinguished:

1) ***acid*** (the main components are MnO and SiO_2), possess good technological properties, but at welding allocate toxic manganese compounds, therefore their application is reduced;

2) ***rutile*** (the main component is TiO_2), possess high welding properties;

3) ***basic*** (contain $CaCO_3$ and $MgCO_3$), technological properties are limited;

4) ***cellulose*** (the main components are cellulose and other organic substances), create good gas protection and form small quantity of slag.

The standard symbol of electrodes contains the basic information on welding electrodes.

4. Welding conditions

Key parameters of welding conditions for manual arc welding are an electrode diameter and a welding current strength.

Electrode diameter *d* is chosen depending on a thickness *S* of welded metal sheets by means of Table 1.

Table 1

S, mm	1–2	3–5	6–10	11–15	16–20	21 and more
d, mm	2–3	3–4	4–5	5	5–6	6–8

Strength of a welding current *I* is defined by the formula:

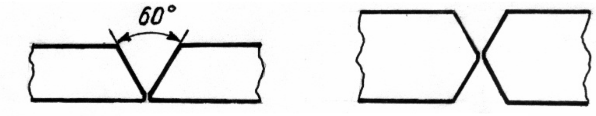
$$I = (20 + 6d)\cdot d,\ \text{A}.$$

At welding of high-alloyed steels for reduction of metal overheat the design value of a current strength is reduced by 20-30 %.

Under workshop conditions a welding current strength is defined by nameplate data of electrodes.

Sheets up to 6 mm in thickness are welded end-to-end from the one side, and up to 12 mm – from both sides without welding grooves. At welding of sheets more than 6 mm in thickness from the one side usually V-shaped cutting of edges with an angle 60° (Fig. 3, *a*) is carried out. If the seam can be welded from two sides, then for thickness over 12 mm X-shaped welding grooves (Fig. 3, *b*) are made. There are also other kinds of edges cutting.

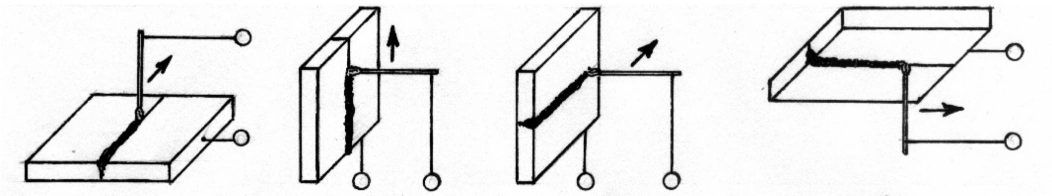
If a thickness of welded sheets is more than 6 mm multilayered welding is made: so, at butt welding of sheets 20 mm in thickness 6–7 passes are carried out.



a *b*

Fig. 3 *V*-shaped *(a)* and *X*-shaped *(b)* welding grooves

Manual welding is convenient at performance of short and curvilinear seams in any spatial positions – flat, vertical, horizontal and overhead (Fig. 4). It is suitable for welding in hard-to-reach spots, and also for installation works and assemblage of designs of the complicated shape.



a *b* *c* *d*

Fig. 4 Possible spatial positions for welding:
a – flat; *b* – vertical; *c* – horizontal; *d* – overhead

Warmth brought to a welded product is characterised by thermal capacity of an arc. *Full thermal capacity* of a welding arc

$$Q = K \cdot I \cdot U, \text{ W},$$

where I is a welding current strength, A,

U is an arc voltage, V,

K is a factor characterising voltage and current deviations from sinusoidal shape (for alternating current $K \approx 0.84$).

The part of capacity of an arc dissipates, and that quantity of warmth which is entered into a welded product, is called *an effective thermal capacity* of a welding arc:

$$G = r \cdot Q, \text{ W},$$

where r is arch efficiency (for manual arc welding $r \approx 0.81$).

The basic *defects* of welded joints are lack of penetration and lack of fusion, cracks, cavities and pores.

Quality of the welding joints is defined by various means of the technical control: the external inspection, non-destructive and destructive methods.

5. Resistance welding

Resistance welding is a process of permanent joint formation at the expense of metal heating by passing through a spot of contact an electric current and plastic deformation of a welded seam by compressing force. Maximum quantity of heat is evolved in a place of welding contact as this site has the raised electric resistance because of the insignificant area of tops of adjoining micro asperities and presence of pollution films and oxides on welded surfaces.

The quantity of heat evolved in a zone of welding, is defined by the Joule's law:

$$Q = K{\cdot}I^{2}{\cdot}R{\cdot}t, \text{ J},$$

where I is a welding current strength, A,

R is electric resistance of a circuit in a place of welding contact, Ohm,

t – time of a current passage, s,

K – proportionality factor (for alternating current $K \approx 0.24$).

At continuous squeezing of welded parts heated metal in contact places is deformed, surface oxide films are destroyed and leave from a contact zone. Heating proceeds to a necessary plastic condition or melting a material of pieces.

Parameters of welding conditions for resistance welding are value of compressing force P (N), current density j (A/mm^2) and time of current passage t (s).

The basic ways of resistance welding are butt, spot and seam welding.

5.1. Butt welding

At ***butt welding*** pieces are welded around the whole surface of contact. The way is applied, basically, for joining of billets from sectional iron and pipes. Welded billets are fixed in clamps of the welding machine, squeezed by a force P and then a current is switched (Fig. 5). Upon termination of heating a current is switched off and simultaneously compressing force P increases: it is called upsetting.

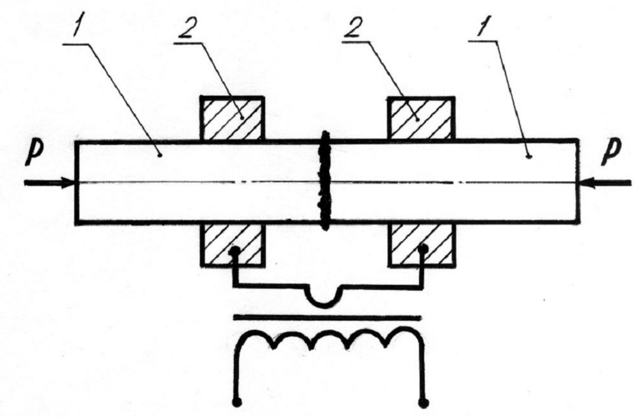


Fig. 5 Scheme of resistance butt welding:
1 – work-piece; 2 – clamp

Butt welding with a warming up of a joint to a plastic condition is called *upset welding*, and at a warming up to melting – *flash welding*.

A cyclogram of welding is a combined graphic representation of a current strength and pressure value in the process of welding. Cyclograms of various welding methods are similar; time of a welding current passage is usually essentially less than time of the application of compressing force P (Fig. 6).

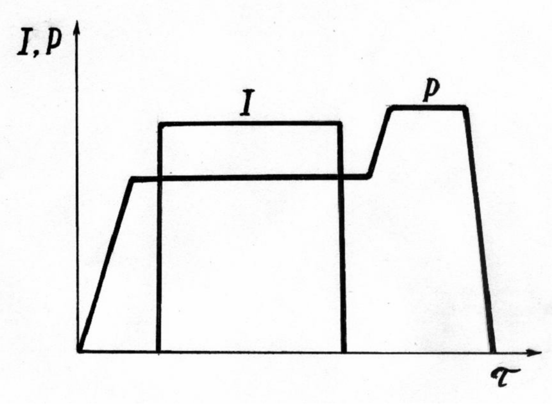


Fig. 6 Cyclogram of resistance upset butt welding

Before upset butt welding billets are cleared by various methods, and their end faces are adjusted densely to each other. Flash welding does not demand special preparation of a joint place as in process of melting all roughness of a joint are levelled, and pollution are removed. Butt welding is applied for billets of steels, copper, aluminium and other alloys. It is used for manufacture of the end cutting tool, reinforcement, lengthy tubular products, and rails.

5.2. Spot welding

A spot welding is the way of resistance welding at which metal sheets are joined in the separate limited sites of contact – spots. Sheets 0.2–6 mm in thickness are compressed between electrodes of the welding machine (Fig. 7) and a current is switched. Heating is continued until internal contacting layers are fused. After that a current is switch off, pressure is increased a little, and then removed. As a result the cast welded spot is formed. Spot's crystallization proceeds under pressure, it allows avoid formation of shrinkage cavities. Before welding a place of contact should be cleared of pollution and oxide films. Parameters of welding conditions (a current strength, time and pressure) are chosen by means of reference tables, and then corrected by practical experience. Spot welding is applied for manufacture of products from steels, aluminium alloys in various industries. Spot welding in motor industry is irreplaceable at manufacture of bodies, cabins, doors.

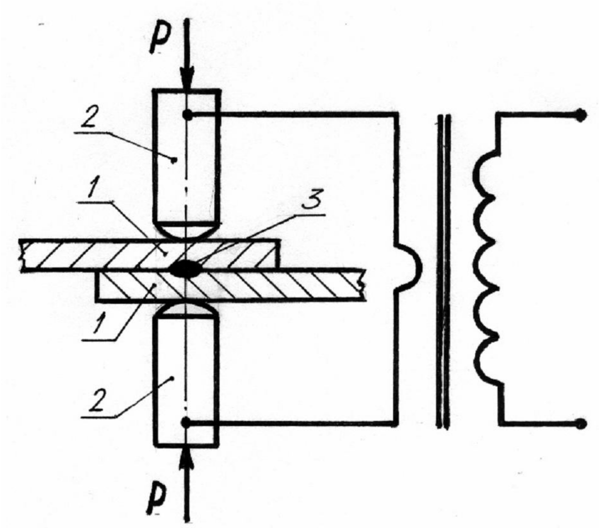


Fig. 7 Scheme of resistance spot welding:
1 – work-piece; 2 – electrode; 3 – welded spot

5.3. Seam welding

A seam welding is the version of resistance welding at which the current supply from the power source to welded parts is carried out by means of two rotating disk electrodes-rollers (Fig. 8).

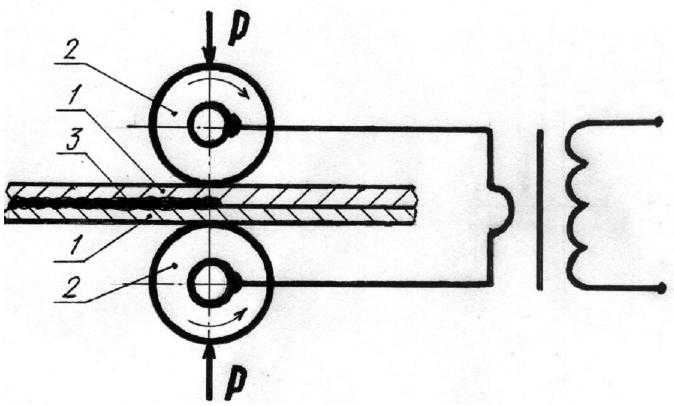


Fig. 8 Scheme of resistance seam welding:
1 – work-piece; 2 – electrode-roller; 3 – welded seam

Metal sheet are lapped assembled, clamped between electrodes and a current is passed through. At movement of rollers along billets welded spots overlapping each other are formed; therefore the continuous tight seam turns out. Resistance seam welding is a high-efficiency process, its speed can reach 10 m/min; it is widely applied for joining of steels, aluminium, magnesian and titanic alloys; a thickness of sheets is from 0.3 to 4.0 mm. Application of seam welding in mass production at manufacture of vessels for liquids and gases is especially effective. Seam-butt welding of pipes with a direct longitudinal welded seam is widely applied.

5.4. Accumulated energy welding

Lack of resistance welding is short-term pulse consumption of considerable capacity at the moment of welding that creates essential loading for a feeding electric network. Welding by preliminary cumulative energy allows create more favorable loading conditions for a network.

There are four modifications ***of welding by the accumulated energy***:

1) *condenser*: energy is stored in the battery of condensers;

2) *electromagnetic*: energy is reserved in a magnetic field of the special welding transformer;

3) *inertial*: energy is reserved in rotating parts of the generator;

4) *accumulator*: energy is stored in the accumulator battery.

Condenser welding is most widely applied; it is used in manufacture of electrical measuring and aviation instruments, clockworks, cameras, elements of semiconductors and electronic schemes.

The basic *defects* of joints at butt welding are lack of penetration, and also excessive grain growth and steels decarbonisation because of overheat.

The basic indicator of quality for spot and seam welding are the sizes of a spot weld nugget and a cast zone of a seam.

Quality of resistance welding is inspected by external examination, by methods of non-destructive testing, and lack of penetration is tested by destruction of samples in a jaw with a hammer and a chisel.

Tasks and methodological instructions

1. Under the supervision of the master strike an arc and carry out manual arc welding of samples.
2. Define values of voltage and current strength in welding circuit under an open circuit conditions, under a load conditions and under a short circuit conditions. Put results in Table 2.

Table 2

Transformer work conditions	*U*, V	*I*, A
1. Open circuit conditions		
2. Load conditions		
3. Short circuit conditions		

3. According to data of Table 2 draw the external volt-ampere characteristic of the welding transformer.
4. Define full thermal capacity and effective thermal capacity of welding arc.
5. Under the supervision of the master make spot welding of plates and butt welding of rods. Define quality of welding by external examination.
6. Draw conclusions on results of the work.

Report contents

1. The work purpose.
2. Short data concerning manual arc welding and resistance welding.
3. External characteristic of power source.
4. Conclusions on results of the work.

Test questions

1. What is wide application of manual arc welding caused by?
2. What arc is called welding arc?
3. How to strike a welding arc?
4. Is it possible to strike a welding arc, without touching a billet with an electrode?
5. Why does the source of a welding current with high-angle falling characteristic provide steady arcing?
6. How is the high-angle falling characteristic of the welding transformer provided?

7. How is smooth regulation of welding current carried out?
8. How is a welding post for manual arc welding arranged?
9. What is the optical density of an optical filter?
10. What groups steel welding wire is divided into and how are they marked?
11. What electrode coatings are intended for, and what components are included into their structure?
12. What are parameters of manual arc welding conditions?
13. How are welding electrodes designated?
14. In what spatial positions is manual arc welding carried out?
15. In what sequence is resistance butt welding carried out?
16. What is a cyclogram of resistance welding?
17. What products are made with spot welding usage?
18. What products are made by seam welding?
19. Name modifications of welding by the accumulated energy.
20. What products are made by resistance butt welding?
21. What are the basic defects of resistance welding?

LABORATORY WORK №7

METAL WORKING BY CUTTING

Laboratory work objective

1. Study parameters of a cutting mode, geometry of cutting tools, design of metal-cutting machine tools.
2. Study technological processes of machining by turning, milling, shaping.
3. Train in turning, milling and shaping.

Equipment and Materials

1. Lathes, milling and shaping machine tools.
2. Metal-cutting and measuring tools.
3. Metal billets.

Basic Principles

Working of metals by cutting is a process of cutting off a layer of metal from a surface of a work-piece in the form of chips by a cutting tool to obtain the necessary geometry, sizes accuracy, interposition and surfaces finish of a part.

1. Cutting Mode

Motions which are imparted to the tool and work-piece for removing a layer of metal are called *primary motions*. They are divided into the *principal*, or *cutting*, *movement* D_r, which determines speed of deformation and removal of chips, and *feed movement* D_s, which provides a continuity of cutting process. The cutting movement is single for each machine tool; but there are several feed movements usually.

Speed of the cutting movement v (m/min) is a speed of moving of a cutting tool edge point concerning a processed surface in a direction of the principal movement. For rotary cutting movement speed of cutting is:

$$v = \pi \cdot D_{wp} \cdot n \cdot 10^{-3}, \text{ m/min.}$$

Speed of feed movement (feed rate) v_s is a speed of a cutting edge point in a direction of feed movement. The ***feed s*** (mm/rev; mm/double stroke) is a moving of the tool in a direction of feed movement per one revolution, or a double stroke of a work-piece or the tool.

Depth of cut t (mm) is a distance between the processed and finished surfaces, measured perpendicularly to the last, passed for one stroke of the tool.

For making cylindrical surface:

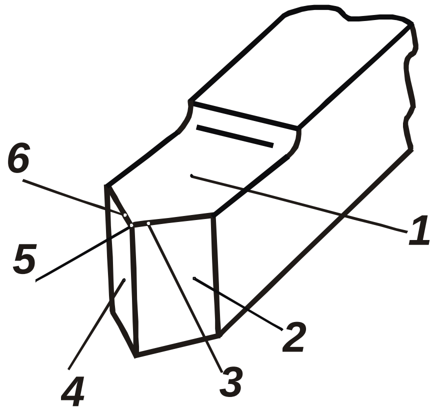
$$t = 0{,}5 \cdot (D_{wp} - d), \text{ mm.}$$

Speed of the principal cutting movement ***v***, feed ***s*** and depth of cut ***t*** characterise intensity of processing and are called ***parameters of a cutting mode***.

2. Tool Geometry

In spite of variety of cutting tools designs they have much in common, therefore detailed studying of a turning cutter allows to limit with consideration of only specific design features of other tools.

The *turning tool*, or *cutter*, consists of a tool shank by which it is fixed on the machine tool, and a cutting part. Elements of a cutting part of turning tool are shown in Fig. 1:



face, or *rake surface* 1, along which the chips come off;

flanks, or *clearance surfaces*, which are turned to: *major flank* 2 – to cutting surface, *minor flank* 4 – to finished surface;

major 3 and *minor* 6 *cutting edge*;

cutter tip (point, corner) 5.

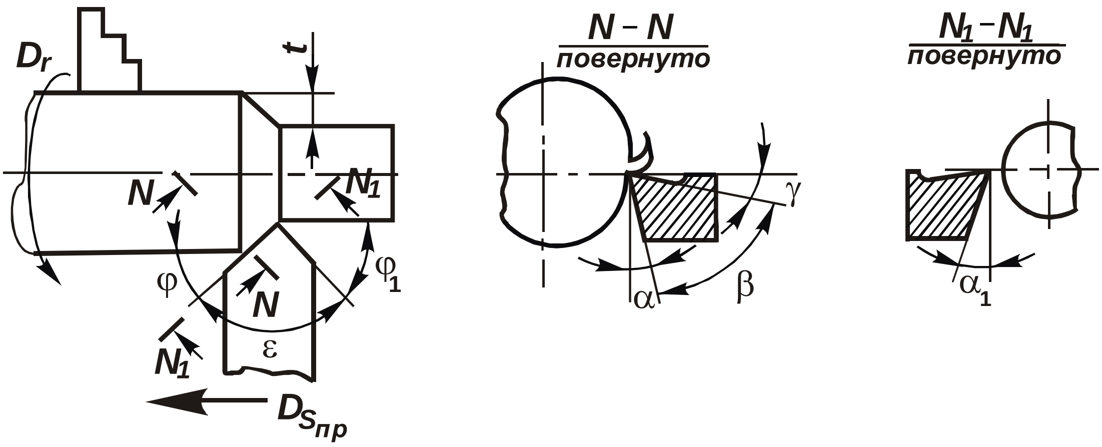
Fig. 1

The interposition of surfaces of the tool cutting part is regulated by angles for which definition co-ordinate planes are brought in. The plane which is parallel to directions of longitudinal and cross feeds and passing through a cutter tip is called *the reference plane*.

The cutting edge plane passes through the major cutting edge perpendicularly to the reference plane.

The major angles of a cutter are placed in *the major secant plane N–N* (see Fig. 2, *a*, *b*) which passes perpendicularly to a projection of the major cutting edge onto the reference plane. *The rake angle* γ is formed by a rake surface and a normal to the cutting edge plane, and *the major clearance* α – by the major flank and cutting edge plane. *The wedge angle* β is situated between face and major flank.

The minor clearance α_1 is measured in *the minor secant plane* N_1–N_1 (Fig. 2, *a*, *c*), which is perpendicular to projection of minor cutting edge to the reference plane. *The major cutting edge angle* φ is formed by a projection of the major cutting edge to the reference plane and a direction of feed movement; *the minor cutting edge angle* φ_1 is formed by a projection of the minor cutting edge to this plane and a direction opposite to feed movement (Fig. 2, *a*). *Point angle* or *corner angle* ε is measured between projections of cutting edges to the reference plane.



a *b* *c*

Fig. 2

Tool angles determine a sharpness of a cutting wedge, the shape of a cut off layer section and influence essentially process of cutting and chip formation.

3. Machining by Lathes

On turning machine tools, or lathes, the revolving work-pieces are processed. The tool continuously moves in parallel to the axis of work-piece rotation (longitudinal feed) or perpendicular to it (cross feed).

Before attempting to operate a lathe, one should become familiar with its main parts, control, and accessories.

The general view of a ***lathe*** is shown in Fig. 3.

A bed 1 with bed ways is fixed onto *cabinet bases*, *head* 12 and *tail* 10. In a *headstock* 4 *gear box* and *spindle* are mounted. Spindle has a fixing device – *three-jaw chuck* 5. *Gear box* 2 is fixed in front surface of the bed. On the left end of the bed *the quick-change gear box* 3 is fastened. *Carriage* 6 moves along bed ways; *cross slide* 8 with *tool post* 7 is mounted on it. *An apron* 11 is fastened to carriage; mechanism of longitudinal and cross feed is placed in apron and connected by feed rod with *gear box* 2. The feeding mechanism transforms lead screw rotation into translation feed movement, transmitting to carriage 6 or *cross slide* 8. The tapered hole of *the tailstock* 9 accepts tailstock centre or tool for holes machining (drills, core drills, reamers).

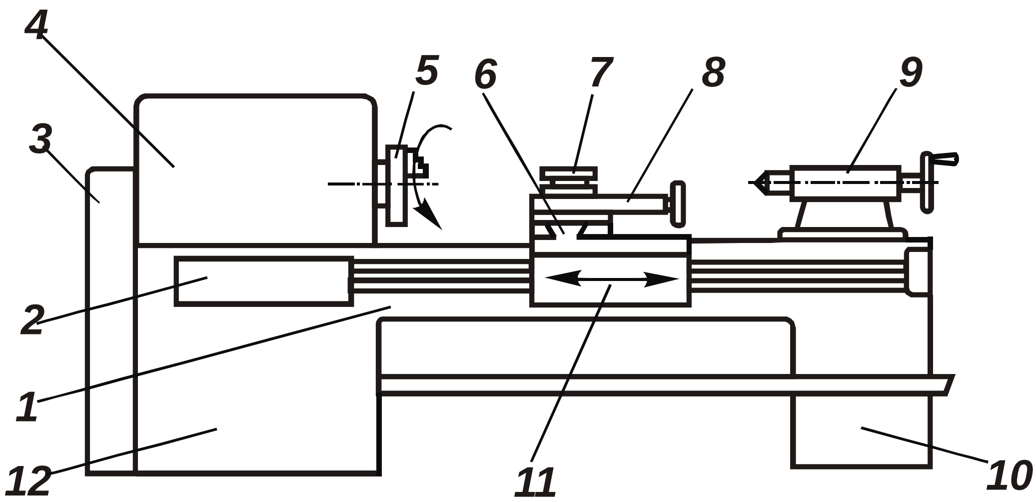


Fig. 3

As it has been told above, for work-piece fastening on a lathe three-jaw chuck is used more often. Long work-pieces are established on the centres, and for transferring a twisting moment from a spindle to a piece driver chucks and clips are applied. For fastening parts as plugs, rings and barrels conic or collet swages are used.

Lathes are intended for the following main operations (see Fig. 4). *Straight turning* is carried out with *turning cutters* 5. *Facing* of the work-piece end is performed by *facing cutters* 3. *Cutting-off*, or *parting*, is made by *parting cutters* 7. *Drilling*, *core drilling* and *reaming* of holes are performed with suitable tools (for example, *drill* 1). *Boring* of internal cylindrical surfaces is fulfilled with *boring cutters* 2. Shaped surfaces are process with *shaped cutters* 6. Turning of external conical surfaces can be carried out: *a)* with wide turning cutters, *b)* by the turn of the compound rest, *c)* by displacement of the tailstock in a cross direction and *d)* with the help of conical rulers. *Thread cutting* is performed with *threaded cutters* 4, *threading dies* and *taps*.

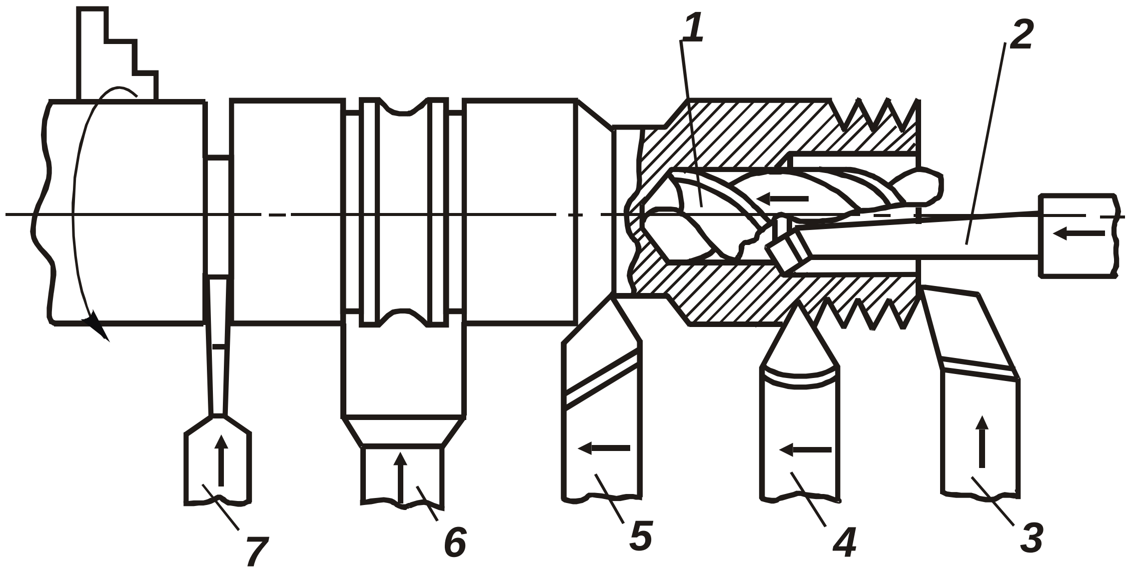


Fig. 4

4. Machining by Milling Machines

Milling is a way of parts machining with multiple-point cutting tool, called *a mill*, or *a milling cutter*. The method is characterised by rotary principle movement of the tool and translation feed movement of work-piece.

Horizontal milling machines and vertical milling machines which are subdivided depending on spindle rotation axis position are most extended.

Horizontal milling machine consists of following main parts (see Fig. 5): in a *column* 1 *a gear box* 2 is placed. Along vertical guide ways of the column *a knee* 6 travels. A work-piece set in a vise on *a table* 4, has feed movement in three directions: longitudinal, cross and vertical. *Feeding mechanism* 7 is disposed in the knee. *A peel* 3 serves for fastening *a hanger* 5, supporting the end of *milling swage* 8 with fixed on it tool – *milling cutter* 9.

Vertically-milling machine tools have a rotary spindle head which can turn in a vertical plane for machining of inclined planes with a cross feed.

For fastening a work-piece on milling machines machine vice, straps, triangles, prisms are applied. The important accessory of milling machine are dividing heads, which serve for periodic turn of a work-piece on a set angle or for its continuous rotation at milling of helical grooves.

Horizontal-milling machines perform following operations (see Fig. 6). Horizontal planes are milled with *cylindrical mills* 2. Vertical planes are processed with *face mills* 1. Inclined planes and bevels are milled with *angle* *mills* 3. Angular and shaped grooves are carried out with *double-angle mills* 4 and *shaped* disk mills 5. Ledges and rectangular grooves are milled with *disk mills* 6 and 7. Shaped surfaces with the curve generating line and straight directional line are processed by *shaped mills* 8.

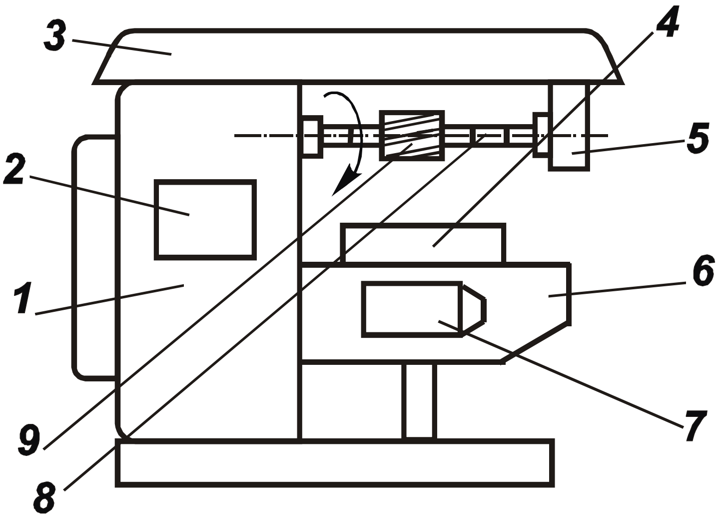


Fig. 5

Similar works may be carried out on ***vertical milling machines*** by *face mills* 9 and *end mills* 10 of various designs.

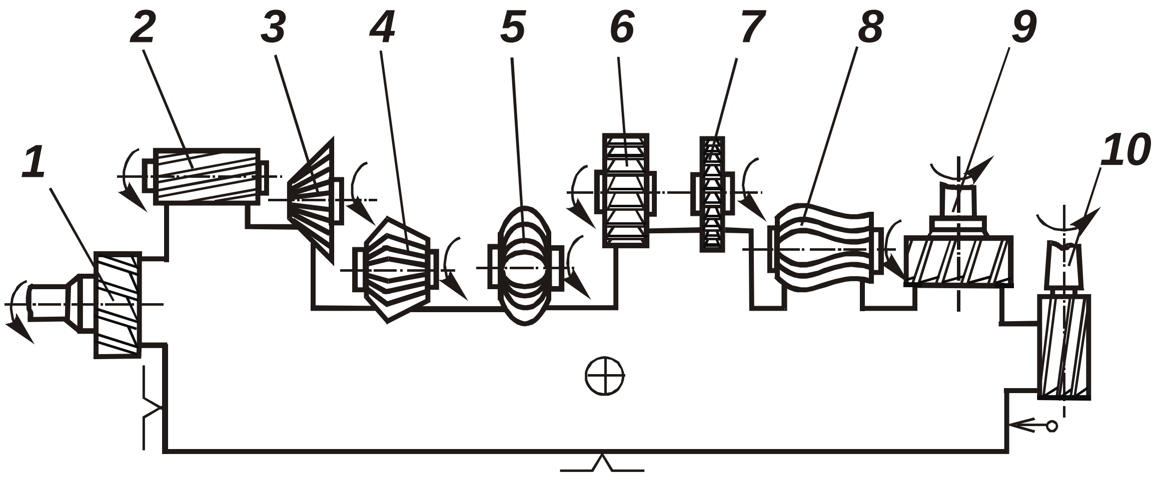


Fig. 6

For fastening mill cutters and transferring of a twisting moment from a machine spindle to a mill milling swages are applied. Cylindrical and disk mills are fitted on a long swage and fixed with locating rings. A conic shank of swage is inserted into a spindle hole; another end of swage is supported by a hanger. Face arbour-type milling cutters are fixed in short end swages. Mills with a shank are fixed in a conic hole of a spindle directly or through adapter.

5. Machining by Shaping and Planing

Planing is a method of machining by straight-line back and forth motion of the tool or a work-piece. A table with a work-piece or a cutter has discontinuous feed movement in the end of each double stroke.

Planing machine tools are divided into shaping and planing machines. In ***shaping machines*** (Fig. 7) *a slider* 3 makes the principal back and forth motion; it moves along guide ways of *a bed* 4.

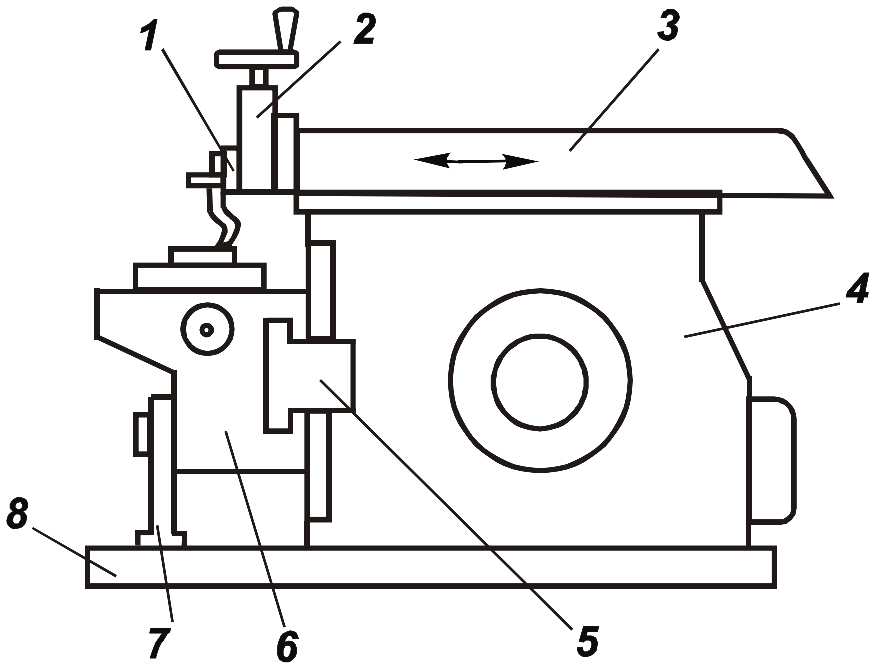


Fig. 7

At the left end face of slider *the support* 2 is established; it can move manually in a vertical plane. Tool holder is fastened to *a hinged bar* 1 which allows a cutter to deviate at return idle pass that reduces its flank wearing. On vertical guide ways of the bed *traverse* 5 is established, along which *the table* 6 moves in a horizontal plane, carrying out feed movement. Feeding is carried out periodically in the end of each idle pass, when the cutter leaves contact with a work-piece. The table has T-shaped grooves in which rotary vice or other devices for work-piece fastening are mounted. For more rigidity a table is additionally strengthened with *a rack* 7 leaning against *a base plate* 8.

For ***planing machines*** the principal reciprocating straight-line movement of a table is characteristic. As a rule, machine tools have some supports (or carriages) which make discontinuous cross feed motion. These machine tools are intended for processing of large-sized parts.

The cutting tool for planing and shaping is a planing cutter. To reduce cutter jamming at cutting, it is recommended to make a shank of planing cutters bended.

Planing and shaping machins perform following basic operations (Fig. 8). Horizontal planes are processed with *planing cutters* 2. Vertical planes are made with *facing planing cutters* 1.

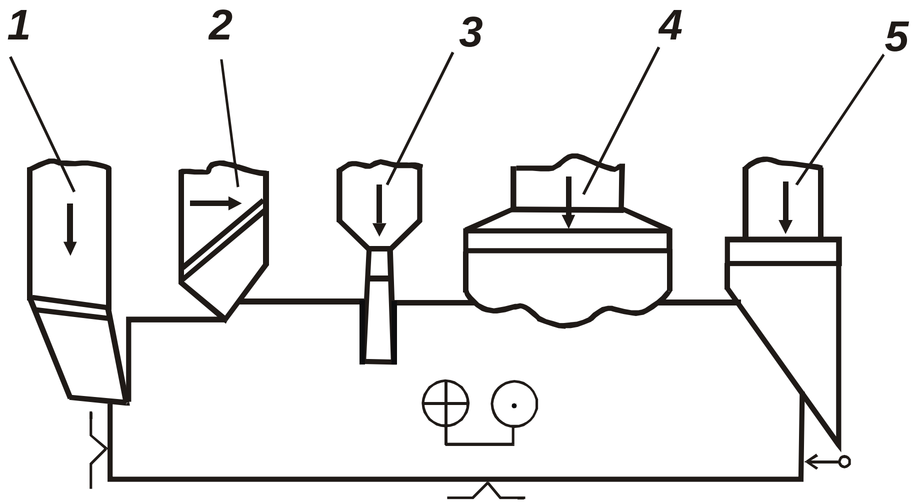


Fig. 8

Grooves slotting or cutting off are carried out with *grooving (parting) cutters* 3. Shaped grooves and surfaces are planed with *wide shaped cutters* 4, or using multiple-tool holder in which at once some planing cutters are fixed. Bevels and inclined planes are processed by wide cutters 5 or by facing planing cutters with turn of support on a plane slope angle.

6. Technical Control

Technical control is intended to test parts machining accuracy and quality of the processed surfaces.

Machining accuracy means an accuracy of sizes, shapes and interposition of surfaces performance. The sizes are controlled by universal measuring tools – callipers and depth gauge – and by special tools – clearance gauges, templates, etc.

Indicator of ***surface quality*** is the surface roughness, i. e. set of the irregularities forming a relief of a certain profile on a surface. A widespread method of roughness determination is the method of checking with the standards having the set roughness.

Technical control of machined parts usually consists of their external inspection and control of the sizes.

Order of Performance

1. Familiarize with basic data on a work theme.
2. Make a part following the trainer's recommendations on the turning, milling, or shaping machine tool.
3. Describe sequence of part manufacturing operations on turning, milling or shaping machine tools.
4. Note: performing point 3 use educational technological cards for processing on the metal-cutting machine tools, presented in laboratories of metals processing by cutting.
5. Perform one of tasks for individual work (under trainer's instructions).
6. Write a report on work you have done.

Report contents

1. Work purpose.
2. Basic data on a work theme.
3. Technological process of part manufacturing.
4. Task for individual work.

Test Questions

1. What primary motions of the machine tool are necessary at turning processing, planing, drilling, milling and grinding?
2. What are parameters of a cutting mode? What units they are measured in?
3. What is the speed of cutting?
4. What is the feed?
5. Name elements of a turning cutter working part.
6. What surfaces of a cutter working part are called face and flank?
7. What edges of a cutter are called major and minor cutting edge?
8. Name main units of a lathe.
9. What movement is the principal upon turning?
10. What movements of feed are possible on a lathe?
11. In what parts of a lathe are a work-piece and the tool fixed?
12. What kinds of tools are used on a lathe, and what operations are carried out with them?
13. Name main units of the horizontal milling machine.
14. What movement is principal for milling?
15. What movements of feed are possible on the horizontal milling machine?
16. Where is a work-piece fixed upon milling?
17. Name kinds of mills and the operations which are carried out with them.
18. Describe a design of the shaping machine.

19. What movement is principal for shaping? How feed is carried out on the shaping machine?
20. What kinds of operations can be executed on the shaping machine?
21. Prove the recommendation to use bent cutters at planning and shaping.
22. What is the machining accuracy? How is it controlled?
23. What is an indicator of surface quality?

CONTENTS

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Сборник методических указаний

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по курсу «Технология конструкционных материалов»

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