Міністерство освіти і науки України

ОДЕСЬКА ДЕРЖАВНА АКАДЕМІЯ БУДІВНИЦТВА ТА АРХІТЕКТУРИ

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Technology of Materials and Ships Equipment Repair

НАВЧАЛЬНИЙ ПОСІБНИК

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як навчальний посібник для здобувачів вищої освіти, які навчаються за технічними спеціальностями

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В навчальному посібнику викладено матеріал для засвоєння таких тем, як визначення основних механічних властивостей матеріалу, виконання операцій термічної обробки сталі, вибір марки матеріалу, або його замінника для виготовлення деталі з урахуванням умов її роботи, вибір оптимальної геометрії різця і елементів режиму різання при обробці матеріалів на токарному верстаті, вибір оптимального режиму ручного електродугового зварювання матеріалів з урахуванням його особливостей, залежно від того, які зварюються матеріали і інше, можуть які можуть бути придбані тільки при вивченні дисципліни ТМіРСО.

Навчальний посібник призначений для широкого кола фахівців, діяльність яких орієнтована транспортну, будівельну, електро- та радіотехнічну та іншу технічну діяльність.

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TABLE OF CONTENTS

Division 1. Features of study of discipline

Table of contents division. Table of contents, task and value of discipline, basic pre-conditions and methodology of her study, form of independent work and recommended educational-methodical materials.

Table of contents of discipline "Technology of materials and ship repair equipment" consist of two parts: material science and treatments (technologies) of materials.

Name science, that studies intercommunication between connection, structure and properties of materials, **material science.**

Name science, that studies the methods of treatment of materials and the technical equipment necessary for making (to repair) details, **treatment (by technology) of materials.** It is based on the substantive provisions of material science and other disciplines.

The basic divisions of the considered discipline are:

1. Structure and properties of materials.
2. Materials applied in shipbuilding and ship repair.
3. Heat and thermal treatment of materials.
4. Methods of receipt of purveyances and unspectional connections.
5. Treatment of materials cutting and other methods.
6. Renewal and strengthening of working surfaces of details of STE (ship technical equipment).

After the study of discipline there is examination.

The basic tasks of discipline are:

1. A study of intercommunications is between connection, structure and properties of the materials applied for making (to repair) details of ship technical equipment (STE) and tools of automation (TA).
2. Study of methods of treatment materials.
3. A receipt of some skills is for practical activity. The value of discipline consists in that mastering of her divisions will assist understanding and successful

mastering of such disciplines as "Diagnostics and technology of repair of STE and control system" and other except it, without knowledge of substantive provisions of material science and technology of materials, successful professional activity of officer of fleet is impossible. As such necessary practical skills as determination of basic mechanical properties of material, implementation of operations of heat treatment of steel, choice of brand of material or its substitute for making of detail taking into account the terms of her work, choice of optimal geometry of chisel and elements of the cutting mode at lathing of materials, choice of the optimal mode of the manual arc welding of materials taking into account its features can be purchased only at the study of discipline.

Basic pre-condition for the study of discipline is the successful mastering of corresponding divisions of next disciplines.

"Sketch geometry, engineering and computer graphic arts" (ability to read the draft of detail is used). "Chemistry" (knowledge of laws of flowing of chemical reactions of oxidation and proceeding in metals is used), "Physics" (knowledge of laws are used on the aggregate state of substances and phase transformations, about a warmth and heat transfer, solutions, basic physical properties of metals in the hard and liquid states).

Methodology of study of discipline consists in the following.

Laboratory works are made, as a rule, after reading of corresponding division and elaboration of substantive theoretical provisions, stated in a train aid for laboratory works.

Deep mastering of programmatic material and successful handing over to examination on discipline largely depends on correct organization of independent work.

The forms of independent work of students above discipline are recommended following:

1. Elaboration of compendium lectures, recommended educational - methodological materials for mastering of substantive theoretical provisions of discipline. This form is most responsible and that is why regulated by the specially

worked out methodical manual. In a manual, on every division there are the disciplines, resulting in short methodical pointing, theoretical positions and control questions. A robot with a compendium and this train aid must present no more than 50 % from time of the pre-arranged independent work.

2. Elaboration is on the literary sources of questions that carry descriptive character not examined in the divisions of manual. Such questions include: description of machines and machine-tools, description of instruments and adaptations, area of application of non-metallic materials and so on. On this form of independent work spared, as a rule, to 15 % time.

3. Elaboration of methodical materials of manual for preparation to implementation of laboratory works, is spared to 25% time of independent work.

4. Preparation to current control and examination presents no more to 20 % time of independent work.

Control questions after division of 1:

1. What is understood under material science and treatment (by technology) of materials. What is the connection between these sciences?

2. What does the basic value of discipline consist in when preparing a ship mechanic?

3. What basic practical skills must students have after the study of discipline of «Technology of Materials and Ships Equipment Repair»?

Division 2. Mechanical properties of materials

Table of contents of division. A test of standard is on a stretch and determination of durability, plasticity and resiliency. Determination of shock viscidity and hardness. Methods of determination of hardness. Deformation and recrystallization of metal.

Name descriptions that determine behavior of material under the action of the added external mechanical forces mechanical properties of materials. To mechanical properties of metal, certainly, take durability under that understanding resistance of metal of deformation and to destruction and plasticity, that is capacity of metal for remaining deformation non-destructive.

As a result of mechanical tests, get the numerical values of mechanical properties, id east, value of stresses or deformations there are physical and mechanical state of material transitions at that.

Deformation is named the change of sizes and form of body under the action of the added forces. These forces can be both external, added to the body and internal, that arise up in a body under the action of change of volume of separate crystallex at phase transformations, temperature gradient and other Arising up here tensions, in case of uniaxial stretch, look like (2.1)

$$\sigma = P / F \tag{2.1}$$

Force P , added to some area of F, certainly, not perpendicular to it, but directed under some corner, that is why there are normal and tangent tensions in a body. Normal tensions subdivide into stretching (positive) and squeezing (negative).

Internal tensions most often arise in the process of the rapid heating or cooling of metal as a result of heterogeneous expansion (compression) of superficial and internal layers. These tensions name thermal. In addition, phase or structural tensions that arise during crystallization, heat treatment, so-called,, as a result of the heterogeneous flowing of structural transformations on a volume and other.

At small tensions, deformation is accompanied by the insignificant changes of atoms from the places of equilibrium. At the removal of tension, these changes disappear, because atoms go back into the positions of equilibrium. In this case deformation is named resilient.

At tensions that exceed the limit of resiliency of metal, next to resilient deformation there is (remaining) a flowage that is the consequence of considerable changes of atoms. These changes are analogical to the skidding-change mostly. Atoms find new positions of equilibrium and at the removal of tensions in initial position does not return.

Skidding of atoms during a flowage takes place under the action of tangent tensions and for the fully certain planes of crystalline grate, that have the name slickenside. Such planes are planes that are most densely manned by atoms.

The mechanism of skidding during a flowage is fully explained by the theory of distribution. This theory assumes that the change of atoms takes place not by the simultaneous moving of all atoms that are inplan skidding, but by moving of row of the preliminary displaced atoms, id east linear bug of crystalline grate - distribution.

Distribution, moving in plane skidding, causes the successive, relay change of all atoms that are in plane skidding.

Structural state of the plastic deformed metal thermodynamics is not permanent, although at a room temperature most metals can be kept long enough.

At heating the plastic deformed metal gradually proceeds in his structure and passes again to the proof state. This transition can be broken up on a few stages; return, recrystallization of treatment and collective recrystallization.

A return takes place at the not high heating and removes resilient tensions. A crystalline grate and properties of metal recommence partly.

Recrystallization of treatment, or primary recrystallization takes place at heating of metal higher temperatures of recrystallization conditioned after (2.2)

$$Tr = Tm \qquad (2.2)$$

where Tm and Tr is a temperature according to recrystallization and melting.

In the process of recrystallization, analogical to the process of crystallization, there are centers of crystallization, on that atomic layers accumulate with the undistorted crystalline grate, a microstructure substituted for by new grains, in most cases, different in a size from grains of the initial undeformed metal.

Collapsible recrystallization shows by itself the process of further increase of grains. Large grains grow, taking in shallow, that results in diminishing of free energy and thermodynamics does a structure more proof.

Secondary recrystallization shows by itself the process of increase of separate new grains from more than in others by speed. Grains that grow with greater speed it is possible to examine as embryonic centers. The enormous amount of shallow grains and small amounts of very large ones appear in the total. Such different graininess reduces plasticity.

The size of grain of recrystallization metal depends on the temperature of heating the degrees of deformation, with the increase of temperature diffusive processes that cause increase of grain are accelerated.

At very small degrees of deformation, heating does not cause recrystallization. At *3-15 %* deformation, the size of grain then sharply grows annealing and can in many times exceed the size of initial grain. Such a degree of deformation is called critical. Heating after the critical degree of deformation causes only hasty growth on weekends of not recrystallization grains due to absorption of others (like secondary recrystallization). At the degree of deformation higher critical the process of primary recrystallization flows.

With the further increase of degree of deformation, the size of grain of recrystallization metal diminishes. It is explained that at the small degree of deformation not all grains are deformed plastic. The not deformed grains carry out the role of centers of crystallization at heating, growing due to the plastic deformed grains. At the greater degrees of deformation all grains are plastic deformed and strongly crushed. There are plenty of centers of crystallization at heating, that and results in the receipt of shallow grain. For determination the degrees of flowage on a structure and properties are permanent the foreseen implementation of corresponding laboratory work.

Fig. 2.1

The basic type of tests for determination of durability and plasticity of materials is a test on a uniaxial stretch. On these types of tests, also, implementation of laboratory work is foreseen.

For a test on a stretch apply a standard sample (fig. 2.1), that before a test is marked, measure and mark out. Initial calculation length of standard within the limits of working length is limited to the shallow stipples.

At a test, the marked standard is fastened by ends in fascination of bursting machines and stretches with small speed to destruction. B it is written down the step of the test, so-called, curve of stretch (fig. 2.2) dependence between loading that is put to the standard, *P* and him absolute lengthening. From this figure evidently, that the curve of stretch has four characteristic areas of the physical phenomena, that show flowing in material of difficult processes. Line on an area 1 testifies to continuation of the proportional loading, id east, on this area the law of proportion (law of Gunk) keeps force. After the removal of loading deformation of stretch will disappear, atoms in a grate will occupy the primitive position. Tension at that a proportion is violated between effort and lengthening is named **the limit of proportion**, conditioned by a formula:

$$\sigma_{PR} = P_{pr} / F_0 \tag{2.2}$$

Where *Fo* is an area of transversal cut of sample.

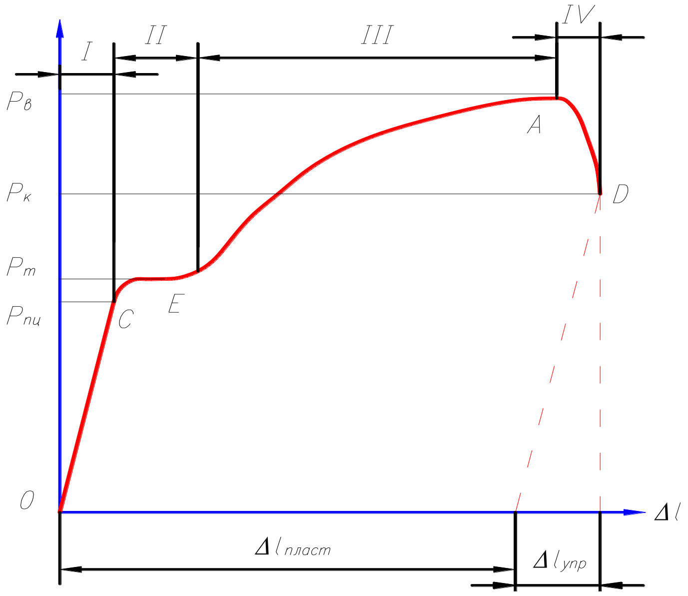


Fig. 2.2

The details of machines expect that working tensions that arose during exploitation (p) did not exceed the limit of proportion (to the resiliency). Certainly, $p < 0,6\ \%\ C$

The further increase of loading results in the appearance of the remaining lengthening (area of II) that does not disappear after the removal of loading. In this moment length of standard increases without the increase of loading as a result of flowage, moving of one part of grain in relation to other on crystallography slickensides. Material stretches, and loading *of Tr* answers **the limit of fluidity** - minimum tension at that a standard gets the remaining lengthening without the noticeable increase of loading (2.3):

$$\sigma_m = \frac{P_m}{F_0} \quad . \tag{2.3}$$

Most metals do not have the obviously expressed area of fluidity, then for the limit of fluidity accept conditional tension, at that a standard gets remaining deformation *0.2 %* primitive length of standard (2.5) :

$$\sigma_{0.2} = \frac{P_{0.2}}{F_0} \quad , \tag{2.4}$$

At the further increase of loading, a metal plastic becomes deformed and becomes (area of III) stronger.

Temporal resistance or **border of durability** in is tension, that answers the most loading that is preceded to destruction of standard, id east

$$\sigma_{в} = \frac{P_{в}}{F_0} \quad , \tag{2.5}$$

For soft materials of achievement of loading Pв accompanied by destruction. In plastic - to this moment, lengthening of standard and narrowing of him primitive cut it takes place evenly on all calculation length. Then in the place of the least resistance narrowing of transversal cut (necks) appears: here loading diminishes to Pk standard collapses.

Border of durability for plastic metals after a formula (4) less actual resistance of break because actually area of cut to the end of stretch of standard less than *Fo.*

For determination of descriptions of plasticity, fold for surface destruction of half of the torn standard and will measure a trammel head distance between on tracks the stippler of lk and diameter of neck close surfaces of destruction of dк. Thus, under **the relative lengthening δ** and **relative narrowing** Ψ understand the corresponding relations of the absolute lengthening and narrowing of standard after a break to their initial calculation values shown in %, so that:

$$\delta = \frac{l_k - l_0}{l_0} \cdot 100\% \quad (5) \qquad \psi = \frac{F_0 - F_k}{F_0} \cdot 100\% , \qquad (2.6)$$

where lo and lк is initial and eventual, calculation length of standard, mm

Fк is an area of cut of neck, mm^2,

Fo is an initial area of cut of standard, мм^2. Relative lengthening(5) it is possible to define also on the diagram of stretch (fig.1.2). With this aim from the place of D conducted to crossing with the abscise axis line, parallel to the segment OS. The got segment answers (plastic, equal to the absolute lengthening of calculation part of standard after destruction in a mm^2.

The considered descriptions of durability and plasticity are exceptionally important for all materials, because on the basis of these indexes the areas of the use of stills are set, irons, brass and other materials for making or proceeding in the details of ship machines and mechanisms that perceive and pass the power loading. However, in many cases, these properties do not characterize durability of materials in the conditions of exploitation of details of . They can be used only for the limited amount of simple on a form wares that work in the conditions of the static loading at temperatures near to the room. For most wares and constructions, especially from high strength materials apt to fragile destruction it is necessary to use other criteria of estimation, structural durability so-called. Aught, it is compensated by the account of metal inclination to the fragile destruction, conditioned at run-time tests on a shock bend and by the receipt of corresponding description of material that has the name shock viscidity.

Shock viscidity, КС, as durability at the shock loading is determined by destruction of standard sample by the blow of massive pendulum and shows by itself the relation of the work A (J) expended in the fracture of standard to the area of transversal cut of standard of F. м^2, places of fracture, that is

$$KC_{н} = \frac{A_{н}}{F} \, . \qquad (2.7)$$

Except the considered mechanical properties, a large value for the capacity of details of STE hardness of their working surfaces.

Hardness is property of material to counteract too much penetration for him other, more solid of certain form and sizes.

Methodology of determination of hardness simple enough and can come true directly on the prepared detail without her destruction. In most cases, at determination of hardness do pressing in the tested material the indenter made from considerably more hard material. At hardness indentation there is a flowage of the tested material under an indenter. Then anymore resistance of material of flowage, themes on a less depth penetrates indenter themes higher hardness. Thus, hardness at tests characterizes resistance of metal pressing methods to the flowages, id east the same mechanical properties of material, that is determined at tests on a stretch, are essentially determined, but in the new terms of the tense state.

The next methods of determination of hardness are widely used in Brinell. Rockwell and Poldi for determination of hardness, also, foreseen implementation of laboratory work.

Hardness in Brinell *HB* *(Pa)* is expected as an attitude of size of loading of P (H) toward the area F (m^2) of surface got on the standard of imprint, that is a bullet segment. Determinations of area of bullet segment determine after a formula:

$$F = \frac{1}{2} \cdot \pi \cdot D \cdot \left(D - \sqrt{D^2 - d^2}\right) \qquad (2.8)$$

where D is a diameter of indenter, m; d is a diameter of imprint.

Then a final formula for the calculations of hardness after the method of Brunell will have such kind

$$HB = \frac{2 \cdot P}{\pi \cdot D \cdot \left(D - \sqrt{D^2 - d^2}\right)} . \qquad (2.9)$$

The considered method is most exact, however, using as an indenter of steel hard-tempered marble it is impossible for materials with hardness, anymore *HB= of 4500 mPa* through deformation of indenter. Except it, an imprint on a detail will nurse enough greater sizes, that can drive a working surface to uselessness.

Choice of diameter of marble and loading, depending on hardness and thickness of the tested standard regulated and conducted for corresponding to its tables.

After the method Rocwell's hardness is determined after the depth of penetration of steel marble that presses (in d= a 1,588 mm at loading 1000 H (scale of B) or diamond cone with a corner in tops 1200, at loading 600 and 1500 H (scale of A and C). At a test at first put the previous loading of Realtor, even 100 H, and then marked loading, depending on a select scale. The difference of depths of penetration of marble or diamond under loading of Realtor and P characterizes hardness. Than less than this difference, the harder tested material and vice versa, than anymore this difference, the more soft material. The value of hardness (HB) is determined after next formulas

At measuring on scales But also *C* (2.11)

$$HR - 100 - e, \qquad (2.10)$$

and at measuring on a scale *In (2.12)*

$$HR - 130 - e. \qquad (2.11)$$

where *e* is the size conditioned for by a formula (2.12)

$$e = (h - ho) / 0.002 \qquad (2.12)$$

where h, h_o is a depth of hardness indentation in the tested material under the action of loading of P and P_0 accordingly;

0,002 - size taken for unit of hardness and answers distance to the axial moving of indenter to *a 0.002 mm*

Hardness after Rocwell's is designated *HRA, HRB, or HRC accordingly on scales A, U and C.*

The method Rocwell's is less exact in comparison to the method of Brinell. However, next to the more wide range of hardness of the tested materials, he allows to avoid calculations, get small imprints on working surfaces, to measure hardness of superficial layers of details after chemical-thermal treatment, and also hardness of shallow details.

For the choice of indenter and loading, depending on description of the tested material, it is recommended to use tabular data.

After method Poldi the same chart of determination of hardness is used, that and on the method Brinell is pressing steel hard - tempered marble. Therefore practically the same peculiar limitations put him after hardness. A fundamental difference is a loading simultaneously to the detail and standard, that allows to exclude it from consideration and compare the value of hardness to the account only of diameters of the got imprints.

A standard shows by itself rectangular, certainly, steel oilstone at that in good time in the laboratory of dockyard certain and inflicted on its side of value of hardness after the method of Brinell. He is pasted in a corps by adaptations so that above a marble an imprint did not appear from earlier the conducted tests. Then, setting adaptation on cleaned out a file, or sandpaper place of detail, inflict for a fight a slog by a hammer weighing *5-10 H.* After it, take out a standard and measure on a standard and on a detailed diameters of imprints. The values of hardness of detail calculate on a formula (2.15):

$$H\text{в}_{det} = HB_{et} (\mathrm{d}_{et} / \mathrm{d}_{det})^2, \qquad (2.13)$$

where HB_{det} is hardness in Brinell of material of standard;

d_{et}- is a diameter of imprint on a etalon, mm;

d_{det} - is a diameter of imprint on a detail, mm

Important advantage of method Poldy is the possibility of application of him for determination of hardness of large details directly on a ship or in the workshop of a plant. It largely compensates for the small exactness of the results obtained at tests comparatively.

Except for the considered methods there is a method of determination of hardness after Wickers on a microhardness . The first is used for determination of hardness of details of small thickness and superficial skims, and second - for determination of microhardness of shallow details and separate structural component alloys. In both cases hardness (H) is determined after a formula

$$H = 1.8544\, P / d^2. \tag{2.14}$$

where *P is loading, H; d* is a diagonal of imprint, mkm .

Mechanical properties of not metallic materials have the features, that depend on their structure, bodily condition, temperatures and other As a result of high molecular mass, they not able to pass to the gassiest , at heating form viscid liquids low, but some, that own a term stable spatial structure, even grow soft.

Polymers can be in three bodily conditions: in glassy, highly elastic and viscid fluid.

Glassy state - hard, amorphous (atoms do fluctuating motion close of position of equilibrium, motion of links and moving of macromolts does not take place).

Highly the elastic state is peculiar only highly to the polymers, characterized by the capacity of material for the greater circulating changes of form at the small loading (links and macromoles hesitate to obtain the ability to convolve).

Viscidly the fluid state reminds the liquid state, but differs from him with very large viscidity (all macromoles are movable). With the change of temperature a linear or ramified polymer can go across from one bodily condition to another.

To polymeric materials the peculiar aging is an involuntary not circulating change of major technical descriptions, that takes place as a result of difficult chemical and physical processes that develop in material, in the process of exploitation and storage. Aging reasons are light, warmth, oxygen, ozone and other unmechanical factors.

Control questions after 2-nd division :

1.What are types of tensions and in what their essence?

2.What formulas are descriptions of durability, plasticity and shock viscidity of materials determined after at corresponding tests?

3.What conditional denotations do answer the relative lengthening and narrowing, borders of durability and shock viscidity?

4.How does a crystalline grate behave at resilient deformations on the corresponding area of the diagram of stretch?

5.What is understood under the hardness of metal?

6.What formulas is hardness determined after the method Poldy?

7.What advantages of method of determination of hardness after a method did Divorce?

8.Where is the determination of hardness after the method Poldy?

9.What form does an indenter have at the different methods of determination of hardness?

10.What from the methods of determination of hardness is more precise?

11.What features of mechanical properties of polymers and what are they explained?

Division 3 Structure of materials. Diagram of the state of iron-carbon alloys

Table of contents of division the Crystalline structure and grate of metals, polymorphism of iron, anisotropy of metals, bugs of crystalline structure, crystallization of metals. General information about the structure of alloys and diagrams of the state «carbon-iron». Transformations that take place in an alloy depending on the concentration of its components and temperature. Phases and structural constituents of stills and irons: ferity, austenite, cementite, pearlite,ledeburite . Structure not-ferrum materials.

Crystalline structure of metals. Swinging majority of metals have such structure, as cube grates (by volume of centered and face-centered), and hexagonal densely packed, that is accordingly body centered cubic lattice (Cr, Mo. W), face-centered cubic lattice (Ni, Al. Cu) and hexagonal lattice (Zn, Mg).

Some metals and, first of all, iron, at a different temperature have a different crystalline form (modification), that is designated in Greek letters α ,β,γ,δ ,etc.

Existence of metal in different crystalline forms is named **polymorphism,** and transition from one modification in another by polymorphic transformation. This position matters very much for understanding of bases of physical metallurgy and in the first turn heat treatment.

Set those properties of separate crystals (single-crystals) in different directions, as the number of atoms and distance between them are different. Such phenomenon, as dependence of properties of metals on direction, was named **an anisotropy** that matters very much in a technique. It follows to pay attention and explain why the real metals (**polycrystals**) are isotropic, so that their properties do not depend on direction, if they are not subject to the special treatment, for example, to rolling.

Crystalline grates of metals are not ideal, but have many bugs: **l**ocal are vacancies, displaced atoms, atoms of admixtures and linear are distributions (to the edge and screw). These bugs, largely, change properties of crystals. For polycrystal, that consists of grains that, in turn, consist of blocks of the single-crystals oriented under different corners, takes place, a superficial bug that appears on the limits of grains and free-form so-called.

The process of crystallization of metal is begun with formation of centers (embryos) of crystallization. The primary (main) to the landmark of future crystals grow from them, then athwart to them - to the landmark of higher orders. Such primary crystals, that remind the original appearance of a tree, got the name of dendrites. Their further height and forming of crystals take place due to a liquid metal that fills interaxle space. In a final result crystal, running into each other, obtain a casual external form. Such a crystal is named grains. The size and amount of grains are characterized by two factors: by the number of centers of crystallization(NC) and speed of their height, and by speed of crystalline (SC). From these factors the size of grains depends mainly, and thus, and properties of metal. With the rev-up of cooling of NC increases to a greater degree, why SC, that is why the size of grains diminishes in a metal. Schematically the structure of the metallic bar is presented on rice. 3.1. It is necessary to explain why grains in different zones strongly differ one from another.

General information is about the structure of alloys. Alloys consist of two or more metals or metals and non-metals. Their alloys threw in a technique, certainly, attribute to one group of materials - metals. Alloys, or their parts can be one or diphasic (phase - homogeneous after connection and structure the part of alloy, dissociated from other parts by an interphase in transition through that properties change saltatory). Alloys appear as a solid solution, when components dissolve in each other in the hard state, mechanical mixture and compound. A solid solution and compound are monophase and have one type of crystalline grate, and mechanical mixture of two components of diphasic and other Here, there are atoms of soluble component in a solid solution, or replace the atoms of solvent in its crystalline grate, or included for it.

The diagram of the state shows by itself the graphic image of all transformations that take place in an alloy, depending on the concentration of its components and temperature. The construction of it is conducted experimentally, on the critical values of transformations to the alloys at their heating and cooling. Studying the diagram of the state of alloy, it is possible to get a clear imagination about close intercommunication of structure and properties of material, it's crystalline structure and phase connection.

Diagram of the state *of Fe - C gives* an opportunity to know about the structure of iron-carbon alloys : stills and irons. The first idea about this diagram was given by D. K. Chernov that specified on existence in steel of critical values. He discovered that at a temperature approximately 700 °C exists critical value of A1, below that steel does not get tempering, as though it was not cooled quickly. The second critical value is Element - variable and depends on maintenance of carbon in steel.

Diagram of Fe - C, as evidently from the name, must spread from Fe to C. Taking into account that iron with a carbon forms the row of compounds : Fe3C, Fe2C and others, the marked diagram can be examined for two parts.

The article of our study will be the first part of the diagram of Fe -C, diagram of Fe - Fe3C. It is explained that metallic alloys are used in practice with maintenance of carbon not more than 5%, but the nearest on maintenance a carbon a compound there is cementite or Fe of 3C, that contains to the carbon of 6,67%. Thus, at the analysis of the diagram of the state of Fe - C as one of iron is examined, and the other is a compound of Fe of 3C.

To understand the diagram of Fe - C, it is necessary, first of all, to become familiar with a structure and properties of initial components of this system : by iron and cementite.

Iron is a 26th element in a Mendeleev's table. In practice clean iron is used technically on maintenance the admixtures of 0.1...0,2% and by the temperature of melting 1535 0 C. Depending on a temperature iron, as we examined already, exists in different crystalline forms, or, as they are named, in different polymorphic modifications: α,β,γ,δ (fig. 3.1). Typical indexes of mechanical properties of iron,, $\delta_в$ = 250 Н/мм, $\delta_т$ = 120 Н/мм^2, δ = 50%,. НВ = 800 Н/мм, КС = 300 Нм/см^2.

With many elements iron forms solid solutions. Most interest presents creation of solutions of carbon in iron. Solubility of C in Fe substantially depends on that, what crystalline form Fe is in. Yes, solubility of carbon in α-iron and presents close 0.02%. and in y-iron - to 2.14%, id est in 100 times anymore.

Solid solutions of introduction of carbon in α and γ - iron named accordingly **ferrite and austenite.**

Ferrite is designated by the letter of F, or Fe2. It’s basic mechanical properties: HB = 600, δ = 330 H/of mm, δ = 40%.

An austenite is designated by a letter A, т, or Fe2. It’s basic mechanical properties: HB = 1600, δ = 700 H/of мм2, δ= 60%.

Cementite is designated by the letter of C or Fe3C, has a difficult crystalline grate, character of connection between the atoms of Fe and C exactly is not set. Temperature of melting of cementite is about 1600°C, hardness of HB = 8000. zero plasticity, at 21700 Fe3C loses the magnetic properties. Cementite connection is unsteady and in certain terms can be laid out on iron and carbon as a graphite that matters very much in the process of gelation of cast-iron. Simplified diagram of the state of Fe - Fe3C is brought around on fig. 3.1.

For the abscise axis on a diagram maintenance of carbon and cementite is shown. Obviously, the amount of cementite in an alloy equals 15-multiple maintenance of carbon.

The line of ACD of diagram is named a line liquidus, that answers the temperatures of beginning of crystallization of alloys of Fe - C. Higher this line alloys are in the liquid state.

A line of AECF is a line solidus and answers the temperatures at the end of crystallization. Below this line all alloys are in the hard state. Between lines liquidus and solidus an alloy is in the diphasic state: fluid and solid.

The line of GS belongs to steel with maintenance of carbon to 0.8% and answers the temperatures of selection of ferrite from an austenite, id est below values 3 on pic. 3.1 steel will consist of austenite and ferrite, thus a selection to the ferrite results in the increase of maintenance of carbon in an austenite to 0.8%.

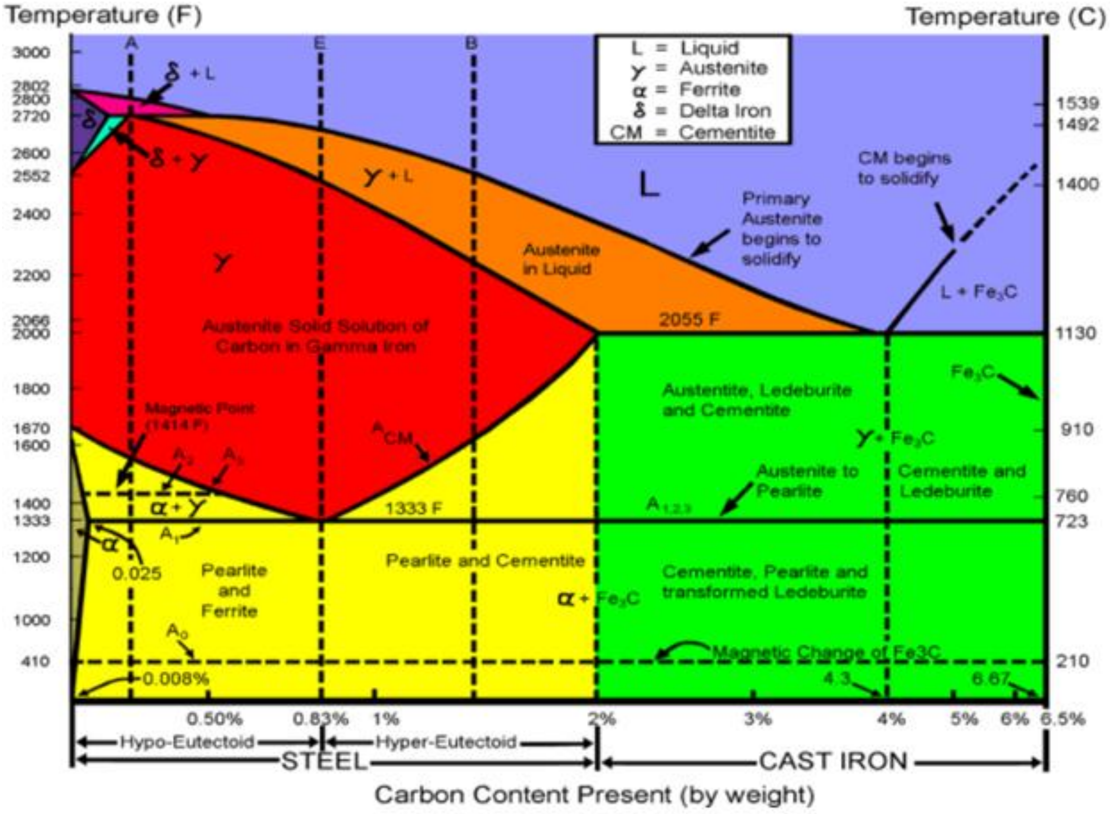


Fig.3.1Simplified state diagram of Fe-Fe3C

The line of SE belongs to steel with maintenance of carbon more 0,8% and answers the temperatures of selection of cementite secondary from an austenite, id est below values 4 on rice. 3.1 steel will consist of austenite and secondary cementite, the selection of that reduces maintenance of carbon in an austenite to 0,8%.

A horizontal line on a diagram, line PSK, answers flowing of next eutectoid reaction (3.1) :

$$A_s \xrightarrow{727\,^{\circ}C} \Phi_p + Ц_к \tag{3.1}$$

So that austenite concentration of S at a temperature 7270 ○C is laid out on the ferrite of concentration of P and cementite concentrations TO, that answers 6,67 % C

As a result of this reaction eutectoid mixture of ferrite appears and cementite is adopted by a perlite (type of mother of pearl). This reaction takes place at all alloys of the system, that contain C > 0,02 %, that is practically at all industrial iron-carbon alloys. This reaction is named eutectoid or by perlite transformation. Basic mechanical properties of perlite plate- HB = 2000, σ = 800 H/ мм2 δ = 10%; grainy perlite - HB ~ 1800, σ= 650 H/of мм2, δ = 20%.

According to the structure carbon steel is classified as hypoeutectoid, eutectoid and hypereutectoid.

Hypoeutectoid steel contains more than *0,02%, but less than 0,8%* carbon. Their structure consists of light grains of ferrite and dark grains of perlite, that are ferrite grains pierced by the plates of cementite .

With the increase of maintenance of carbon the amount of ferrite diminishes in hypoeutectoid steel but perlite increases . Because practically all carbon is in a pearlite, then maintenance of carbon in hypoeutectoid steel can be defined on a formula (3.2), in %:

$$C\,\% = 0{,}8\ Fn\,/\,100\,, \tag{3.2}$$

where Fn is the area touched by a pearlite. %.

Eutectoid steel contains 0,8 % C and has a pearlite structure. In microscope sight, eutectoid steel with a lamellar pearlite is expressive enough and shows by itself the form of cementite as a dark vein on a light field of ferrite. At megascopic, the diphasic structure of pearlite can not appear. In these cases a pearlite is under a microscope, at digestion of steel of 4% by the solution of HNO_3 in an alcohol, has the continuous dark field.

Hyper Eutectoid Steel consists of pearlite and secondary cementite, that was situated as a net or grains . In these steel maintenance of carbon can be approximately obtain with a next formula (3.3), %

$$C\% = (0.8\ Fn + 6{,}67\ F\text{ц}) / 100 \qquad (3.3)$$

where: Fц is the area touched secondary cementite , in %.

After digestion of 4% - by solution of HNO3 them in an alcohol, cementite under a microscope looks as well as ferrite, and a pearlite is a type of dark constituent.

To distinguish after the microstructure of cementite from a ferrite, microsection bitten-into 4% - in an alcohol repeatedly polished solution of HNO_3 them and then processed by an alkaline solution of natrium picrate, that dyes cementite in a dark color.

The analysis diagram of the state iron-carbon shows that maintenance of carbon in steel determines it’s set and structure. In connection with it, it is interesting to trace the influence of carbon on basic mechanical properties of steel (fig. 3.2).

From this picture evidently that with an increase in steel of carbon grows hardness of HB and border of durability σ, decrease the relative lengthening δ , narrowing φ and shock viscidity K . As further increase in steel of carbon (0,9 %) hardness grows more, and the border of durability diminishes. It is explained by an allocation of secondary cementite beyond the grains, that forms a continuous framework around perlite grains. At a test on the stretch of loading perceived, first of all, by this framework. Cementite, being fragile, collapses, that results in premature destruction of standard to the decline of the border of durability.

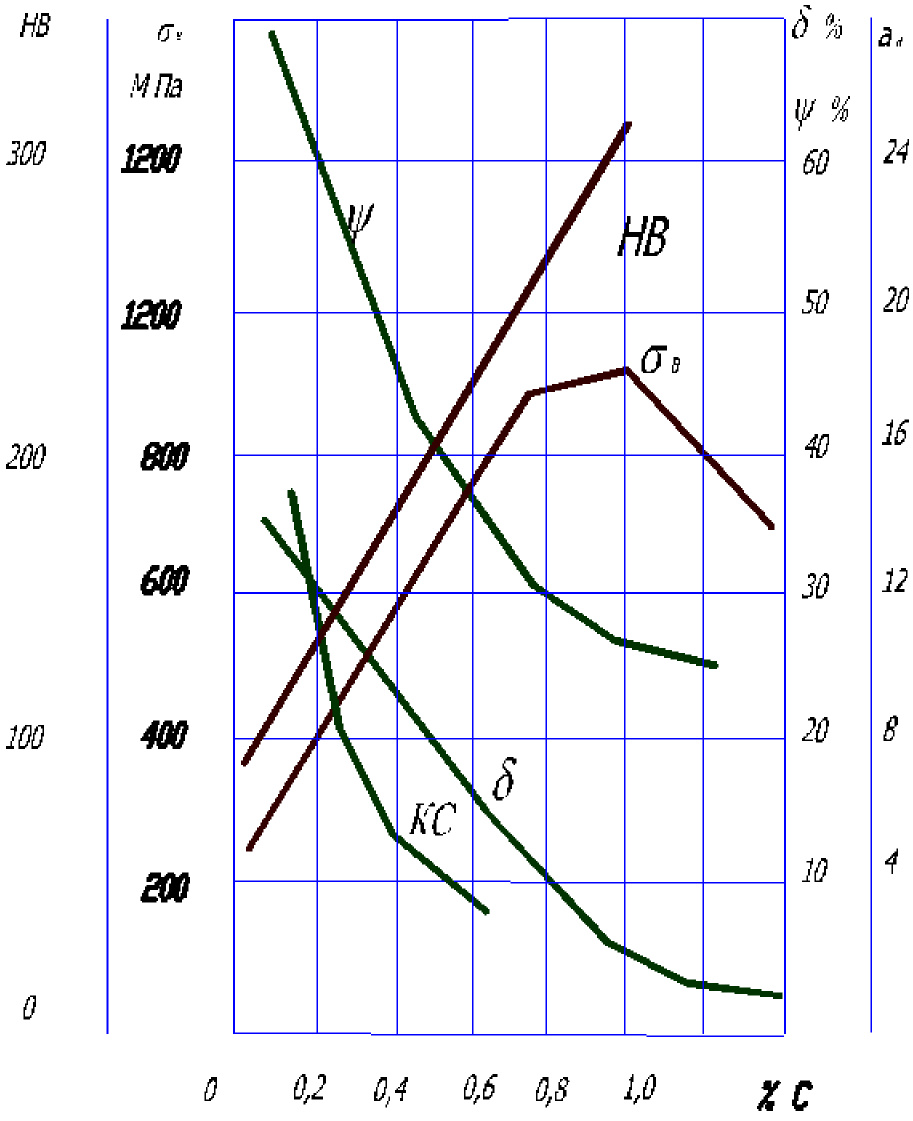


Fig. 3.2 Influence of carbon is on basic mechanical properties of steel

From this picture evidently that with an increase in steel of carbon grows hardness of HB and border of durability σ, decrease the relative lengthening δ , narrowing φ and shock viscidity K . As further increase in steel of carbon (0,9 %) hardness grows more, and the border of durability diminishes. It is explained by an allocation of secondary cementite beyond the grains, that forms a continuous framework around perlite grains. At a test on the stretch of loading perceived, first of all, by this framework. Cementite, being fragile, collapses, that results in premature destruction of standard to the decline of the border of durability.

Thus, knowing the microstructure of steel, we can obtain corresponding dependencies defining content in steel of carbon and her mark, and using dependencies of lines.. 3.3 is a value of it’s basic mechanical properties.

Crystallization of cast-iron (an alloy of III is on fig. 3.1) is begun with formation of austenite in a place 5. In a place 6, as well as in any other place of line of ECF, a reaction flows after a formula:

$$Ж_c \xrightarrow{1147^0 C} A_c + Ц_F \tag{3.4}$$

That is liquid of concentration of place From at a temperature 1147°C is laid out on the austenite of concentration of place of E and cementite concentrations of place of F. This eutectoid mixture (from a word eutecticum - that melts easily) got the name ledeburite. Thus, after complete consolidation (an alloy is more subzero value 6) the microstructure of cast-iron will consist of austenite, cementite secondary and to the ledeburite.

At the further cooling of alloy, to the line of PSK, the structure of cast-iron does not change. Below lines of PSK, through flowing of the known eutectoid reaction, the structure of cast-iron will consist of P + Zn+to L (P + Zn). Thus the austenite of ledeburite also passed to the pearlite. The analogical reasoning can be conducted and for cast-iron with maintenance of carbon more 4,3%, for example, for the alloy of IV.

Control questions are after the division of 3:

1.W ith what elements iron forms solid solutions of introduction and substitution?

2. How does the volume of iron change at transformation *of* $Fe\gamma \rightarrow$ Feα?

3. What is named the phase of alloy (systems)?

4. In what difference and between the hard phase of alloy and him by a structural constituent?

5. What determinations do have basic phases of iron-carbon alloys : ferrite, austenite and cementite?

6. How are the structural constituents of alloy named with maintenance of carbon 0,8 %, *4,3 % and 6,67 %?*

7. What maximum solubility of carbon at a ferrite and austenite?

8. How are named and microstructures of iron-carbon alloys with maintenance of carbon 0,8 *and 4,3 %?*

9. What formulas is maintenance of carbon determined after in hypoeutectoid and after eutectoid steel?

10. What microstructure do the hypoeutectoid have, eutectoid and hypereutectoid to steel ?

11. What elements does iron form solid with solutions of introduction and substitution?

12. How does the volume of iron change at transformation *of* $Fe\gamma \rightarrow Fe\alpha$?

13. What is named the phase of alloy (systems)?

14. In what difference and that general, between the hard phase of alloy and its structural constituent?

15. What determinations do have basic phases of iron-carbon alloys : ferrite, austenite and cementite?

16. What maximum solubility of carbon at a ferrite and austenite?

17. How named and, that show by itself the microstructures of iron-carbon alloys with maintenance of carbon 0,8 *and 4,3 %?*

18. What formulas is maintenance of carbon determined after in hypoeutectoid and hypereutectoid steel?

Division 4. Carbon steels and cast-irons

Table of contents of division : Steels of ordinary quality, medium-quality, high-quality; cast-irons are grey, malleable and high-strength. Classification and marking of steels and cast-irons.

Alloys of iron with a carbon with content last to *2,14 %* steel are named, and more *2.14 %* - by cast-irons.

Carbon steels, applied in practice, contain except a carbon,0,4% of Si, 0,5-0.8% of Mn and for 0,02-0,05% of S and Silicon and manganese are useful admixtures; dissolving at a ferrite, they strengthen steel. Sulphur forms the connection of FeS and causes hot shortness, and phosphorus is a cold brittleness of steel.

Carbon construction steels are of ordinary quality and high-quality.

It is subdivided steel of ordinary quality into groups A, B and V. Permanent groups A characterized by mechanical properties, group B - by chemical composition, and groups V - by mechanical properties and compounds. After the degree of desoxydation they are boiling (bl), semiquiet (sq) or quiet (q), and depending on the rationed indexes of mechanical properties they are subdivided into the row of categories.

Construction to steel of ordinary quality designated in a letter of Century and number - by the number of steel. A group is specified by a corresponding letter at the beginning of the brand (for a group A a letter does not belong). At the end of the brand the degree of desoxydation and number of categories (the first category is not specified) are specified. For example, Ст1кп, ВСт1пс, ВСт1кп3, ВСт6 etc. It has been used steel of ordinary quality for making small or responsible small loaded details: rollers, screw-bolts, lids of bearing and other.Their σ is from 300 to 450 MPa, and δ - from 15 to 25%.

Quality construction to steel differs in less content of harmful admixtures (sulphur and phosphorus <0,04%). They are subdivided into steel with normal content of manganese, about 0,62 (I group) and increased, close 1,2% (II group), and on maintenance a carbon: on small carbon (to 0,25% of C), middling to the carbon (0,25 - 0,6 % C) and highly carbon (more 0.6% of C).

Quality construction to steel marked by such method : to steel of a 1 group - by numbers 08, 10, 25...60, that specify maintenance of carbon in hundredth parts of percent, and for steel of II of group - additionally the letter of G that specifies on enhanceable maintenance of manganese belongs at the end of numbers. It has used steel of I and II of groups for making a wide circle of responsible details. Thus medium and highly carbon to steel inflict, as a rule, to heat treatment. Their σ is from 350 to 750 MPa hesitates, and δ - from 30 to 10%.

Carbon instrumental to steel subdivide into quality: B7 ... B12, B13 and high-quality: B7A ... B12A, B13A. Numbers in a brand specify on maintenance of carbon in tenth parts of percent, and letter A at the end of brand marks high-quality steel, that has a less percent of harmful admixtures (S and P).

After a structure **cast-irons** classify on to hypoeutectic, eutectic and hypereutectic.

Hypereutectic cast-irons contain more than 2,14%. but less than 4% of carbon. Their structure consists of dark grains of pearlite, light cementite secondary and to the ledeburite that is, in turn, dark places of pearlite on light to the background of cementite. With the increase of maintenance of carbon, the amount of ledeburite increases, and to the pearlite and cementite secondary diminishes, passing to the ledeburite with maintenance of carbon 4,3 %.

Eutectic cast-iron contains a structure of ledeburite, light background of cementite, sown by dark grains of pearlite.

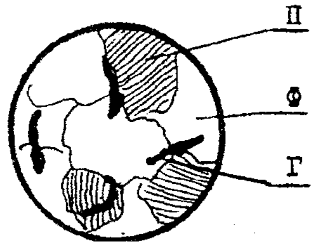
Eutecticum cast-iron consists of ledeburite and primary cementite. Grains of ledeburite as the grey areas sown by the shallow dark including pearlite, as though, pierced by the light large plates of primary cementite.

The considered cast-irons on a fracture have a white tint, that is why they got the name of white; for them all carbon is in the constrained state, as Fe_3C (cementite). Such cast-irons differ in high hardness and are used, mainly, for processing in steel.

Protracted to annealing of white cast-iron, cementite disintegrates on iron and carbon, there is graphitization, when a carbon is distinguished in a free kind, in the type of graphite. Depending on technology of treatment, a graphite can be extracted as plastins, flakes and bullets. Such cast-irons are named accordingly grey, malleable and high-strength.

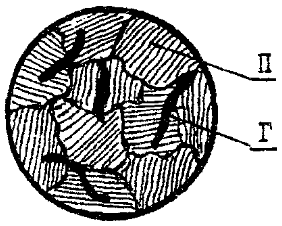
Cast-irons are subdivided into **white and grey**. In white cast-irons a carbon is in the constrained state, in cementite, and in grey in the free state - to the graphite.

Thus, a graphite in cast-iron is distinguished as plates, or bullets, and metallic bases can be ferrite,ferrite-pearlite structure, or perlite. Grey cast-irons that are used in practice contain: 3-3,5% of C, 1,5-3% Si, to 0.5% of Mn, to 0,12% of S and 0,3-0,8% of P). Cast-irons with a lamellar graphite are named grey.



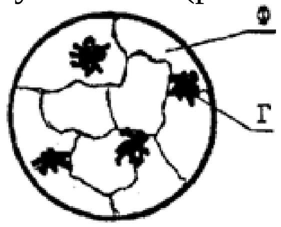
Grey cast-iron (ferrite-pearlite)

Grey cast-iron, that has the lamellar includings of graphite, that are to emptiness with sharp incisions, that in turn stipulates him subzero mechanical properties: σ = 100-450MPa, δ = 0.2÷0.8%, KC < 0.1 MJ$^{/}$м2.



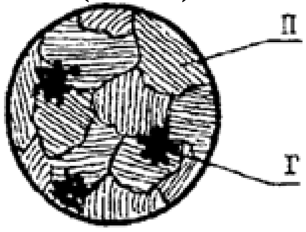
Grey cast-iron (perlite)

Malleable cast-iron is obtained by protracted annealing. As a result, cementite disintegrates with a selection to the graphite as plates. Such including, in a less measure, weaken basis, that is why malleable cast-iron more firmly and more plastic grey: σ=300-630МПа, δ=2-12%.



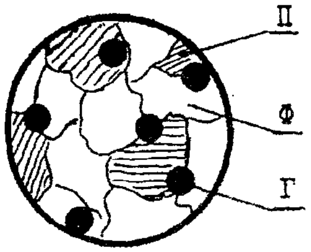
Malleable cast-iron (ferrite)

It allows to apply malleable cast-iron for making details that work at moderate shock loading.



Malleable cast-iron (perlite)

High-strength cast-iron is got at retrofitting of grey cast-iron magnesium or cerium. The graphite of spherical form that eliminates sharp incisions in metallic basis appears thus. Therefore mechanical properties of this cast-iron considerably rise: (to 1200 MPa, δ = 2-17 %, KC = 0,2-0,6 MJ$^{/}$of м2. Such cast-iron in a number of cases is the substitute of steel.



High-strength cast-iron

Mechanical properties of cast-irons are determined by their structure, that depends not only on chemical composition but also from the condition of consolidation. Therefore standards regulate chemical not composition of cast-irons, but their properties. These properties are specified in brands. For example;

SC 15 is grey cast-iron with σ = 150 MPa;

KC 32-8 is malleable cast-iron with σ=320 MPa and δ = 8%;

HF 60-10 is high-strength cast-iron with σ= 600 MPa. and δ = 5-10%.

Carbon steel and cast-irons find wide application for making details of CT3 and CA. Basic from them is:

Steel 15 - insert of frame support and persistent bearing of ship middling circulating engines (MDE), frame bearing with the inundation of B83; spindle, axis of roller of regulator with cementation 0,8-1,2 mm; a puck is a fist, hob of fuel puck and fuel puck with next cementation 1,2-2,0 mm of ship small circulating engines (MAUDE).

Steel of 25L - bottom connecting rod, frame fundamental, slide-block of crosshead with the inundation of B83 or BH and corps of pushrod of drive unit distributive, billow genicular, piston-rod of working cylinder, screw-bolt a piston-rod, crosshead, billow distributive, corps of main starting valve.

Steel 45 - billow distributive, gear and other details, screw-bolt, nut and check-nut of the frame bearing; asterisks after casting and axis of driving unit of camshaft, corps of sprayer, gears, billow of drive muff of regulator with an occasion.

SC 21 - frame fundamental, lid of the scope bearing, crankcase, and also corps, overhead and bottom lid of regulator of number of turns of ship engines, bearing lid, crankcase, fly-wheel, piston rod compression , corps of stuffing-box,fuel pump housing, bearing of regulator with an occasion, servo motor regulator.

SC 24 - corps of drive unit of petrolift, lid of working cylinder, ring making more compact and oil survey, insertion of head piston.

SC 28 - lid-hob of working cylinder , medium speed engine piston parallel and trunk piston.

Control questions are after the division of 4:

1. What is named steel, cast-iron?
2. How do the carbon to steel subdivide?
3. How does subdivide to steel of ordinary quality?

4. What permanent ordinary qualities are: on mechanical properties, after chemical composition, on mechanical properties and after chemical composition?

5. How designated to steel of ordinary quality?

6. What indexes is supplied on steel *of Всm3* ?

7. How to decipher steel *of Всm1кn2*?

8. What purpose is permanent groups *A, B and V?*

9. How are quality carbon to steel designated?

10. How do the quality carbon to steel subdivide?

11. How to decipher steel *of 45G, 08*?

12. What alloys are named cast-irons?

13. What cast-irons are named grey, white, malleable, high-strength?

14. How are grey, malleable and high-strength cast-irons designated?

15. Why is not chemical composition included in denotation of brand of cast-iron, how for steel, and mechanical properties?

16. How to decipher the basic brands of steel and cast-iron, applied in shipbuilding and shiprepair for the details *of STE and OA*?

Division 5. Alloyed steel.

Table of contents of division : Influence of alloying elements on properties permanent, classification and marking of alloyed steels.

Alloy steel - steel in that specially enter (alloying) elements, the Basic alloying elements of construction steel are Cr., Ni, Si, Mn, and such elements as *W, Mo, V, Ti* etc enter in steel in combination with basic for the additional improvement of properties.

Influence of alloying components on properties permanent depends on the amount of elements that is entered, and their co-operating, with iron and carbon. With iron they usually are as solids of substitution (alloyed ferrit and alloyed austenite) or compound (Fe_3W_2, Fe_3Mo_2). an at co-operating with a carbon - in constrained (TIC, WC) or in the free state.

The alloyed ferrite is in all construction steel, that tests an improvement, and the alloyed austenite is the basis for the structural constituent of heatproof and non-rusting steel. Intermetallic compounds are a strengthening phase in heat treatment.

All alloying components, except for a manganese, at heating detain the increase of grain of austenite, that allows alloy steel to add treatment pressure in more wide intervals of temperatures or to add chemical heat treatment treatment, being not rather afraid of an overheat.

It should be remembered that in most measures, advantages of alloy steel show up after her heat treatment.Especially strongly rise σ,δ and α . It is explained by that alloyed steel has less stalling speed of tempering, and thus, better piercing. It allows tempering of details in less sharp coolers (oil, air) that diminishes deformation of wares and danger of formation of cracks. In addition, after heat treatment they have more shallow grain and more dispersible structures.

Dissolving in iron, elements that alloy very influence the position of critical values in steel. One alloying element (NT, Mn) extends γ-area, reducing $_{A3}$ and $_{A1,}$ $_{other}$ (W, Y, Cr, Mo) narrow γ and extend α-area, promoting A3 and A1. Almost all alloying elements move the value of E and S of diagram of Fe - C to the left, that is aside less concentrations of carbon. Exception - V, Ti, Nb, that promote the concentration of carbon in an eutectoid.

Will consider the influence of separate alloying elements and their combination on some basic properties of steel.

Chrome (C) promotes hardness and durability of steel, but reduces viscosity and obstructs malleability, largely increases stain-resistance.

Nickel (N) promotes durability and shock viscidity, improves her malleability and diminishes inclination to oxidation , formation of fine-grained structure of steel promotes and makes it less sensible to overheat.

Tungsten (T) promotes red-hardness, removes fragility at assoiling of steel, promotes hardness, assists the receipt of shallow grain.

Vanadium (V) promotes heat resistance. At the high temperatures of property, vanadium.

steel does not almost change.

Molybdenum (M) promotes an acid resistance. hardness, borders of durability and fluidity, but reduces viscidity, assists maintenance, mechanical properties at high temperatures, results in the origin of fragility at assoiling.

Manganese (MG) promotes hardness, firmness against elimination, tempering in oil, but promotes fragility of steel.

Silicon(S) promotes resilient properties at enhanceable maintenance (to 15-20 %) steel has acid resistant characteristics.

The analysis of influence of the marked alloying elements shows on properties permanent, that by their combination it is possible to obtain the receipt of necessary properties of steel. For example, good results are given by common influence to the chrome and nickel; practically provides piercing wares of any sizes, and characteristic lack of chromium-nickel steel is increased fragility at assoiling is removed by the additional alloying by a tungsten and other.

Other alloying elements in steel mark with next letters: A is nitrogen, B is niobium, D is a copper, S is selenium, D is a cobalt, P is phosphorus, R is the coniferous forest, Z is zirconium, C are rare-earth metals, U is an aluminium.

A number at the beginning of the brand of construction steel specifies maintenance of carbon in hundredth parts of percent, number after letters, maintenance of this element in percent. For example; the brand of 18X2H4B means, steel with middle maintenance 0,18% - C, 2% - Cr, 4% - Ni, and close 1% of W.

At the marking of instrumental and some special steel walk away from this rule. For them maintenance of carbon is specified in tenth parts of percent. For example, the brand of 9XC means that steel is with maintenance of a 0.9 % carbon, about 1 % chrome and to 1% silicon, and in default of number is maintenance of carbon from 1% to 1.5 %.

Some alloy steel extracted in separate, groups: C - to the ball-bearing, P - high-speed, E - magnetic and other.

Alloy steel is classified after a structure in the normalized state, on connection and maintenance of alloying elements, on a purpose.

In the annealed state alloy steels are divided on hypoeutectoid, eutectoid, hyper eutectoid and ledeburite steels, and in normal state on three classes - perlite (to 5 % alloying elements), martensite (to 13%), austenite (to 20÷30 %, mainly Ni and Mn). On connection of presence in steel of certain elements, and also for their amounts - lightly alloyed (to 2,5%), middle-alloyed (2,5÷10 %) and highly alloyed (over 10 %).

By destination alloyed steels are subdivided into: construction, instrumental with the special physical properties.

To construction alloyed steels belong steels that are used for making the cemented details that get better heat treatment, STE (ship technical equipment). These permanent alloy such elements - Mn, Ni, Si, Cr, Mo, Ti, Al and others.

To instrumental steels belong steels for cutting and measuring instruments. These are permanent, for the receipt of high hardness alloy mainly carbide resistant elements**:** Cr, W, V, Mo and others.

To steels with the special physical properties magnetic materials belong to alloys, with high electro-resistance, with the set coefficient of linear expansion, with the special resilient properties and other majority from them differ in high maintenance of Ni, Cu, Co and others.

Alloyed steels are widely applied for making details of STE. Main steels are:

Steel of 15X, 18X. 20X, 18XГ with cementation and heat treatment are pushers of petrolift and valves of gas distribution, roller, roller of starting slide-valve, axis of roller of drive unit of petrolift, fuel and starting with fists pucks, corps of valve.

Steel of 38XMUA with nitriding and heat treatment is a corps and plunger of petrolift of СОД (middling circulating engines).

Steel of CX15 - a valve forcing petrolift of ship СОД, plunger and saddle of valve of petrolift of SOD, nozzle of sprayer of petrolift of MAUDE (small circulating engines)

Steel of 18X2H4BA with cementation on a depth a 0.5 - 0,9 mm and by heat treatment of HRC 60 is a directing needle of sprayer of SOD.

Steel 4X9C2 - valves inlet and final SOD and valves starting to MAUDE.

Steel of P18 - needle of sprayer of SOD.

Steel of 3X13 - valves preventive and air diffuser valve of SOD

Steel of 35XM - a head of piston of MAUDE.

Steel of XBG - a valve and hob of petrolift of MAUDE.

Steel 40X with tempering of СВЧ on 1,5 - 2, 5 mm of HRC 54 is a corps of sprayer of MAUDE.

Steel of 3X13 - a hob and corps of piston, overhead and bottom piston rod and slide-valve of servo motor regulator, saddle of main starting valve of MAUDE.
Х12ВНМФ steel and 2X18H9M - external and internal rings, shoulder-blades of turbocharge MAUDE.

Steel 3Х19Н9МВБТ - shoulder-blade of rotor of turbo charge MAUDE.

Control questions are after the division of 5:

1. What is named alloy steel?

2. To lead, following a brand, chemical composition of marked steel, from that make the details of STE, and also brands of steels : 37Х12Н8ГМФБ, 10ХСНД, EB6, 09G2, 65C2BA. B13A, 09Х15Н8Ю, 60C.,

3. What characteristic bugs do take place in alloyed steels?

4. Why alloyed steel at the same amount of carbon higher mechanical characteristics, what to the carbon?

5. What basic principle is stopped up in the basis of marking of alloyed steels?

6. What elements do assist the increase of shock viscidity in alloyed steels?

7. How do alloying elements influence on position of critical values at steel and value *of E of u of S of diagram of Fe* - *C*?

8. How does a chrome, nickel and tungsten influence on properties permanent and why this combination is optimal for the terms of work of details of STE?

9. What do basic phases in alloys and as they are determined in alloyed steels?

10. What phases are the basis of non-rusting, instrumental and construction steels?

Division 6. Coloured metals and alloys

Table of contents of division : Copper, aluminium, titan and their alloys, anti-friction materials. Classification and marking of the coloured alloys.

The coloured metals and, mainly, their alloys have, comparatively, large application in shipbuilding and shiprepair. In some constructions of ship, mechanism and devices they while are irreplaceable.

All coloured metals in comparison to black have a general defect: high cost. In practice mostly come running to the use of the coloured metals in the cases when necessary material, that has a high heat-conducting and conductivity, corrosive firmness, anti-friction properties, and also, for the decline of mass of constructions, machines and others.

Copper and her alloys, due to their proof conductivity and heat-conducting, plasticity, chemical and corrosive firmness, polishing ability, widely used for making of pipes of the ship systems, explorers of current, slideways and other .Mostly copper is used for making major construction alloys : brass and bronzes.

Composition-metal are alloys of copper with zinc - used for making of the ship systems and screw-propellers. In simple (double) brass maintenance of zinc does not exceed *38 %.* In special brasses, except zinc *Al* is entered*, Fe, Sn, Pb, Si* and other alloying elements. Alloying additions influence on properties of brasses. Additions of lead improve workability, to the manganese - the mechanical promote and corrosive, and in combination with lead, anti-friction properties, iron - improves plasticity in the cold and hot state, to the aluminium (to 6 %) - promotes durability and corrosive firmness. Silicon is entered with the aim of improvement of casting properties. In the hard state a composition-metal, at to content of zinc to 39%, forms the solenoid of substituting for zinc in a copper. Such composition-metal well yields for treatment pressure in the hot and cold state, welding, to soldering and tinning.

Brand of composition-metal is marked with the letter *L*, then the initial letter of alloying component, numbers that specify AV maintenance at *%* a copper and alloying elements follow after that. For example, alloy *of LMc 58-2,* from that make the corps of valve management of engines starting, the corps of indicatory faucets *of* ship *FASHIONS,* contains 58 *%* copper and *2 %* manganeses. *LAmCG 67-5-2-2*, used for making screw-propellers, contains 67 *%* copper, to a *5 %* aluminium and 2 *%* manganeses and iron.

On the technological sign of composition-metal subdivided into deforming and casting.

Deforming to the composition-metal process pressing, rolling and punching. Use them for making of details of armature, pipelines, details of portholes and other

Casting of composition-metal use for making of the shaped founding of armature, business things and screw-propellers. All casting of composition-metal can be welded and soldered by soft and hard solders.

Bronzes are lettered Бр and first letters of basic alloying components, after that the indicated numbers about their percent content. For example, alloy of Br.Dmc10-2, is used for making of turning hob of petrolift, contains to the 10% aluminium and 2 % manganeses, Br.OCs5-5-5 are hobs of regulator of number of turns, contain for a 5 % tin, zinc and lead, Br.AMc 10-3-1,5 - slide-valve of valve of management starting of SOD, contains to the 10% aluminium. 3 % irons and 1,5 % manganese.

Tin bronze on a technological sign divide on casting and deformed. Tin casthouse bronzes have the high casting and anti-friction properties, easily processed by cutting, well tinned and have a good color in the finished goods. Their corrosive firmness in salt water is conditioned by education on the surface of proof dense tape oxide of tin. From the tin bronze Br.OF 10-1 the job of small-end of SOD is made, from BrOZ-7-5-1 and BrOSC8-4-3 - thin-walled armature of revetment of billows, corps of pumps, that work in salt and freshwater, fuel, pair and others.

The deformed bronzes apply for making different types of rent, forging and punching of details.

Except the marked brands of bronze, for the details of SOD and MAUDE found application also BrDVD 9-2 -2 for the bar of valve of BrOCH5-23-1 directing pass, Br.AG of 8-4L, Br.OF10-1 are hobs of roller and other time to be wormed.

Division 7. Non-metal materials

Table of contents of division : Non-metal materials. Plastics, rubber, paints and varnishes translation materials, earth-flax. General information and applications.

Basis **of non-metal materials** are synthetic and natural polymers. The first are foods of the chemical processing of oil, natural gases, anthracite coal, pyrosales, those that meet in the wild is natural rubber, cellulose, mica, earth-flax, natural graphite.

Polymers are substances the macromols of that consist of numerous elementary links (monomers) of identical structure. Molecular mass presents them from *5000* to *1000000*. At such largenesses of macromoles, property of substances determined by not only chemical compositions of these molecules but also them by a mutual location and structure. The macromoles of polymer show by itself chainlets that consist of separate links. A transversal cut of chain is about *1* angstrom unit, and length is a few thousands angstrom units. Therefore to the macromols of polymer peculiar flexibility that is one of the properties of polymers. Flexibility of polymers is limited to the size of segments - hard areas that consist of a few areas. Atoms that are included in a basic chain are bound by strong chemical connection, and forces of intermolecular co-operation, that have physical nature usually, far fewer. Thus, the molecules of polymers are characterized by strong connections in macromoles and relatively weak between them.

Polymers are found in the wild as natural rubber, cellulose, mica, earth-flax, natural graphite. However, a leading group are the synthetic polymers obtained in the process of chemical synthesis from low-molecular connections. Possibilities of creation of new polymers and change of properties already of existing are very large. It is possible to get polymers a synthesis with various properties and even to create materials with the descriptions set in good time. All polymers in relation to heating subdivide into thermoplastic and thermosetting. Thermoplastic polymers at heating grow soft, melt even, at cooling - harden. This process circulating, id est, no further chemical transformations material has. The structure of macromoles of such polymers is linear or ramified. The representatives of thermoplastic are polyethylene, polystyrene, polyamides and others. Thermosetting Polymers on the first stage of formation have a linear structure and at heating grow soft, then, as a result of flowing of chemical reactions, harden (a spatial structure appears) in future remains hard. Thermosets can exemplify the phenol of formaldehyde, glyphthalic and other resins. From synthetic or natural polymers together with other components: get different artificial materials fillers, dyes, plasticizers and other. Basic from them are plastics, paints and varnishes translation materials, glues, rubber, earth-flax, and found application in shipbuilding and shiprepair.

Plastics are widely used as construction materials, their properties are determined by physico mechanical descriptions of basis are resins. Depending on her behavior at heating, plastics subdivide into thermoplastic and thermosets.

Thermoplastic plastics (thermoplastic) at every heating grow soft, pass to the thick-flowing state, and at cooling - harden. To such materials belong: plexiglass, polyethylene, rigid-vinyl plastic and others. Thermosets plastics (**thermosetting polymer**) at heating at first grow soft, and then, at a certain temperature, pass to hard, infusible and insoluble connections, they can not be repeatedly redone that is why. It is the plastic arts on basis phenol of formaldehyde, polyester and other resins.

For expansion of properties of plastics, fillers (powders, fibres and others), plasticizers (glycerin, paraffin oil and others) and other additions (stabilizators, dyes), enter in her composition. Plastics have a greater variety of properties : small closeness, high corrosive firmness, high electrical insulating descriptions, good anti-friction properties, high coefficient of friction, large range of hardness and elasticity, possibility of treatment in number of different ways and other it is necessary to take into account. Together with this it’s necessary to consider that for them peculiar have small durability and hardness,greater creep, especially at thermoplastic; a subzero thermostability (*60-200□C)*, subzero heat-conducting, aging, is a loss of properties under the action of heat, light, water and other factors.

Rubber is valuable enough characteristics: elasticity, resiliency and others. It is got by the special treatment (to vulcanization) by mixtures of rubber and sulphur with different additions. It is used in shipbuilding for making more compact elements (stuffing-boxes, gaskets, cuffs), bearing, electrical insulating elements, water swimming tools etc.

Paints and varnishes translation materials belong to the group of film-formers materials. Except film-formers substances (synthetic resins, oils) by components them there are solvents, plasticizers and others

Paints and varnishes translation materials are widely used for the corrosion protection of a ship's frame and her equipment, becoming overgrown with decorative aims. Classification of paints and varnishes translation materials is conducted on connection and purpose, to compatibility them with the ground paints.

Name colloid solutions of film-formers polymers, capable of consolidation to form strong tapes that better stick to different materials, **glues.**

Name the group of minerals of fibred structure, that show by itself the accumulation of the thinnest fibres as the crystals prolonged on one of the axes, **an earth-flax.** On the special technology, asbestine minerals slit on elastic and strong fibres. These fibres are a feedstock for the production of rows of asbestine materials : filaments, cords, sheet and friction materials, cap stuffing and others. So, the cords interlaced from an asbestine filament and saturated with anti-friction oil-resistant connection or glue on the basis of rubber and graphite or rubbered and saturated with a graphite, are used as a cap stuffing that work in different environments (water, pairs, fuel, ammonia and other) at temperatures to 500 °C. Non-metal materials are widely enough used in shipbuilding and shiprepair.

Control questions are after the division of 7:

1. What basic non-metal materials are used in shipbuilding and shiprepair?
2. What are the plastics?

Division 8. Technology of heat and chemical heat treatment of materials

Table of contents of division : the Basic kinds and elements of the mode of heat and chemical heat treatment. Tempering, assoiling, annealing and normalization; cementation, nitriding and cyaniding, diffusive metallization.

Heat treatment is named heating of metallic alloys in the hard state to a certain temperature, self-control set time and next rapid, or their slow cooling, with the aim of receipt of desirable physico mechanical properties, by the corresponding change of their microstructure. Thus, the mode of heat treatment can be described by four basic parameters: by speed of heating *of Vн*, maximal temperature of heating *of tmax.* sometimes self-controls of ty at this temperature and by speed of cooling of V(охол). On the basis of it, any process (mode) of heat treatment can be presented by a chart (fig. 8.1.)

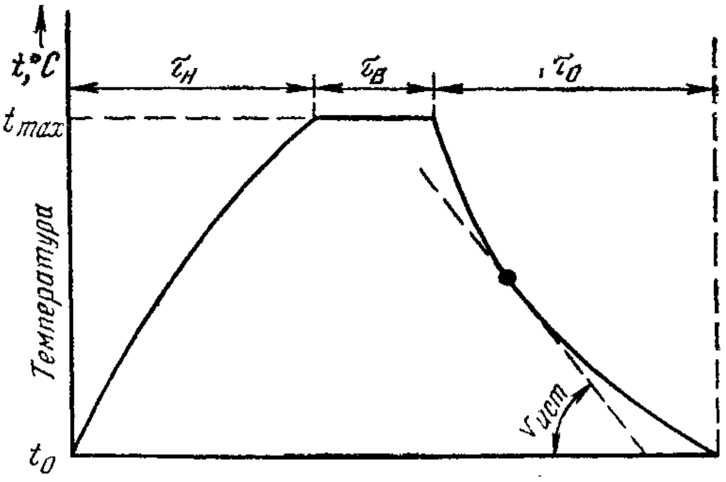


Fig. 8.1 Process (mode) of heat treatment of materials

Determine speeds of heating and cooling the tangent of angle of slope of curves. Speed of heating of metal must provide the burst performance of heater equipment and protect a detail from high internal tensions, and also to provide flowing of necessary transformations. It depends on many factors: sizes and material of detail, presence of concentrators of tensions and other. The maximum temperature of heating is determined by the type of heat treatment.

Time of self-control at the achievement of maximal (set) temperature is determined, mainly, by two factors:

1) by the necessity of achievement of the exemplary smoothing of temperature on a cut or volume of detail;

2) providing the complete flow of transformation to steel.

Cooling (degree of supercooling) speed determines the flow of those or other transformations to steel, and thus its eventual structure and properties.

Depending on tmax and V(cooling), distinguish the next basic types of heat treatment : tempering, assoiling, annealing and normalization.

Tempering is permanent. Tempering of steel is named heating of its higher temperatures of transition of structural constituents in a solenoid (austenite) and next snap-chilling. It is used for the increase of durability and hardness of steel. At the same time fragility of steel increases and goes down her plasticity.

Temperature of heating permanent under tempering it is determined it by chemical composition and, mainly, maintenance in it to the carbon: for hypoeutectoid steels it must be on 30 - 50 ⁰C higher critical values of Ac3 (line of GS on the diagram (of Fe - Fe of 3C), and for eutectoid and hypereutectoid steels - at 30-50 ⁰C higher critical values of Ac1 (a line of SK is diagrams). At these temperatures the structure of hypoeutectoid and eutectoid steels consists of austenite, and structure hypereutectoid steel - from an austenite and second-rate cementite.

If steel slowly freezes at these temperatures, then complete disintegration of austenite will take place and the equilibrium, proof structures of alloys, marked on the diagram of Fe, turn out - Fe of 3C. At rapid cooling, for example, submersing steel, or oil, an austenite grows into an unsteady (not equilibrium) structure - **martensite**.

Next to martensite in hard-tempered steel there always being a remaining austenite that is, also, by an unsteady structure. Hereupon, the protracted self-control at a room temperature results in partial transformation of remaining austenite in martensite. As a result, there is a decline of hardness, durability and also, some change of detail sizes . Last especially impermissible for measuring instruments, precision details of fuel apparatus (needle of nebulizer) and others. For stabilizing of structure, right after tempering, it follows that to treat a cold, differently, stabilization of austenite will take place and he will not fully transform into martensite.

A troostite is following, then martensite, by the transitional structure of disintegration of austenite and can be obtained by tempering of steel at more moderate speed of cooling (for example, for the construction steel in water, heated to 400○C). In comparison with martensite , a troostite has less hardness (3000 - 5000 HB) and not such fragile, has a high limit of resiliency, but subzero viscidity. The structure of troostite is desirable for details since high durability and resilience are needed, for example, for springs.

Sorbitium is the further structure of disintegration of austenite that turns out at the yet less speeds of cooling, applied at tempering (for example, cooling of shallow details in the stream of air, and massive - in oil). He has high mechanical internals: by greater temporal resistance of break and high viscidity at the increased hardness (2500 - 3000 HB). Sorbitium is considered on that ground the best structure for construction steels.

The most wide application got the continuous tempering, in one cooler. In many cases, especially for the wares of difficult form, and, if necessary, diminishing to deformation, apply other ways of tempering : irregular (in two environments), from self-assuming, step and isothermal.

At implementation continuous, and another ways, tempering can arise up different bugs: insufficient hardness - through the subzero temperature of heating under tempering; formation of soft areas - through the local accumulation of ferrite ; increased fragility - through the high temperatures of tempering; oxidation and decarburization surfaces - through heating on flaming stoves without the controlled atmosphere; deformation, warping, cracks - through the wrong choice of cooling (considerable internal tensions) speed and other. These bugs can be removed, or warned, by some methods. Insufficient hardness, presence of soft areas and fragility, is removed by the repeated tempering; окиснення and decarburization surfaces must be carried out heating material in salts and in a neutral atmosphere; cracks and deformations are a remaining shortage. It is necessary reasonably to choose speeds of heating and cooling of wares.

Many marked bugs can be removed **by a hard-facing** that provides high hardness of a superficial layer of detail and keeps viscidity of its internal layers, that assists the increase of general durability due to the increase of limit of tiredness of material. The most common method of such tempering is a heating of high-purity (tempering of SVC) current.

Essence **of tempering of SVC** consists of a detail which is located in the special inductor (spool) through that the alternating current of weak force (to 5000 - 8000 A) is skipped by frequency 50 Hertzs, or by the increased frequency - 104 Hertzs, or by high-frequency - 106 Hertzs. A current creates a magnetic thread, what induces in that part of detail, that is in an inductor, vortical currents that cause in the surface of detail a most closeness and carry out heating of superficial layers of detail during a few seconds to 850 - 950 ^{o}C. After heating on the surface of good water, as a result of what, a superficial layer is tempered. The depth of the hard-tempered layer, constituent from parts to a few ten of mm, is regulated by frequency of current and sometimes holding detail in an inductor. The surface of detail remains almost not oxidation , that is a large advantage of this method of tempering.

To tempering of SVC, on a depth of 1,5 - 2.5 mm and by hardness of HRC > 54. often the scenery add teeth, that made from steel of 40X.

Tempering is permanent. Assoiling is named heating of hard-tempered steel to the temperatures that lie below to the line of PSK of diagram of the state of Fe - Fe of 3C, with the following ambulances, or slow cooling. The purpose of tempering consists of that, to remove internal tensions that arise at tempering up , and add good desirable mechanical and physical properties. Tempering is not the independent variety of heat treatment and is used always after tempering and treating a cold.

Martensite of hard-tempered steel is an unsteady structure that is kept at a normal temperature only due to small mobility of atoms. With the increase of temperature, mobility of atoms increases and martensite passes to more proof structural form. The higher temperature of tempering, the quicker and complete the process of transformation of martensite goes to other structural forms (at first in troostite, and then in Sorbitium). Structure of troostite and Sorbitum, got as a result of tempering of hard-tempered on martensite of steel, named the troostite assoiling and by Sorbitum of tempering. These structures are free of internal tensions and are the best mechanical characteristics than troostite and Sorbitum of tempering. Depending on the temperature of heating, distinguish the subzero, AV and high assoiling.

Heating of to 180 - 200 ºC does not cause noticeable disintegration of martensite and is executed only for the removal of internal tensions.

Subzero tempering. A microstructure of steel after the sub zero tempering is the martensite tempering, or martensite + troostite. The instrumental test such tempering steel. At heating of hard-tempered steel to 300 - 400ºC, get the troostite tempering . **Such tempering is named middle**. From such steels instruments that work with shots, and also, springs, gears and others are made.

Most details of machines that are made from construction steels are added after tempering **to the high tempering** - at a temperature from 500-600 ºC . In this case, aim is to get the sorbite structure of steel that has, next to the increased hardness and durability, high . Treatment that consists in tempering and high assoiling usually, is named making better treatment, as, in this case, the best combination of durability and plasticity of steel is provided.

Except the temperature of heating, on the results of tempering time of self-control has a large influence permanent at a temperature assoiling: then anymore self-control, the complete passing of hard-tempered steel flows to more proof state and internal tensions are in a greater degree removed. Cooling speed at assoiling does not have an influence on mechanical properties of steel.

Annealing of steel. Named annealing of steel, heating is permanent on 40 - 50 ○C higher temperatures of phase transformations (line of GSK of diagram of the state) with the following, her very slow cooling carried out together with a stove.

Annealing of steel is conducted with the aim of improvement of her structure and removal of internal tensions that arise as a result of the hot or cold tooling. Annealing diminishes hardness and proceeds in viscidity, and thus, facilitates it further tooling.

Structures of steels, got then falling off, exactly tense (such that over is brought on the diagram of Fe - Fe of 3C alloys).

Distinguish the next types of annealing : complete, incomplete,recrystallization, diffusive and annealing for the removal of remaining tensions.

Normalization of steel. Normalization is name the process of heating permanent to the temperature that exceeds on 50-60 ^{0}C line of GSE of diagram of the state with the next cooling on air. Normalization is named one with the variety of annealing or intermediate operation between annealing and tempering. The primary purpose of normalization is a removal of the striped structure as a result of the cold tooling (rolling, dragging and other) and creation of normal fine-grained structure.

As a result of normalization, the thin-walled wares get, mainly, from orbital structure, because cooling of them in air takes place with speed sufficient for stabilizing the Sorbitium. Normalization of massive wares finds out the same action, as well as annealing with the slow cooling, but as compared to annealing, is a more simple and less protracted process. Normalization is often used. Therefore instead of forging, after forging in the hot state of purveyances for large details (crankshafts, cog-wheels and other). In this case, normalization is conducted as a preparatory operation before tempering and has for an object making small grains and removal of internal tensions.

Among the methods of chemical heat treatment most application in shipbuilding and shiprepair was found by cementation and nitriding.

Name the process of superficial carbonization cementation details, low-carbon and low-alloyed steels at 850 - 950°C in an environment with a carbon (carburization). A depth of cementation is a 0.5 - 2,0 mm with maintenance of carbon in a superficial layer 0,75 - 1,2 mm. After heat treatment of details, nationals of cementation, the structure of superficial layer consists of martensite and surplus cementite. Hardness of the superficial layer is 6000 - 7000 HB, durability rises .

Cementation can be conducted in hard, liquid and gaseous carburizations.

The charcoal and carbonate salts of BaCO3 and Na2CO3 are used in the quality of hard carburization. An active carbonized element is an oxide of carbon; carbonate salts accelerate the process of formation of oxide of carbon.

An environment that contains molten salts of Na2CO3 is used in the quality of liquid carburization, NaCl and SIC. An active carbonized element is a carbide of silicon.

An environment that contains methane (CH4), oxide of carbon, hydrogen and other elements, is used in the quality of gas carburization.

Active carbonized elements are methane and oxide of carbon.

The cemented layer has a variable concentration of carbon on a depth that diminishes from a surface to the core of detail. For the effective thickness of the cemented layer accept the sum of hypereutectoid, eutectoid and half transitional hypoeutectoid of zones. As a rule, it presents at 0,5 - 1,8 mm during the concentration of carbon in a superficial layer at 0,8 - 1,0 mm. For the increase of pin tiredness, the amount of carbon can be megascopic to 1,2 mm over higher maintenance of carbon brings to the decline of mechanical properties. For the details of CTZ cementation is used most often :

- for a fuel and starting with fists puck (steel is a 15X depth at 1,5 - 2 mm of HRC 56-62)
- for the directing needle of sprayer of SOD (steel of 18X2H4BA, h = 0,5 - 0,9, HRC = 60),
- for the pushrods of petrolift and valves of газорозподілу, roller and axis of roller of engine of TBH - 40 (steel of 15X, h = 0,8 -1.2 mm, HRC = 56 - 62) and others.

Name the process of superficial satiation of details **nitriding** by nitrogen at 480 -650ºC in the atmosphere of ammonia (NH3). For the increase of hardness, waterproofness and corrosive firmness. Details are added nitriding from middling carbon and alloyed steels, that add to tempering, assoiling and tooling, including polishing. After nitriding the final polishing or leading to is conducted only. The nitrided surface is got in thick by 0,2-0,4 mm Most applications get the gas nitriding.

For the acceleration of process nitriding is used a smouldering digit. In practice a corps and plunger of petrolift of SOD (steel of 38XMOA, h = 0,3 - 0,5 mm, hardness by Wickers HV > 820) are added nitriding.

Except the marked methods of chemical heat treatment are used : **cyanidation** is a process of simultaneous satiation of steel by a carbon and nitrogen, **diffusive metallization** is a process of superficial satiation of steel by an aluminium (aluminizing), chrome (chrome-plating), by silicon (siliconizing) and others.

Control questions are after the division of 8:

1. What parameters do characterize the mode of heat treatment?

2. What transformations do take place in steel at cooling with different speed from the austenitic state?

3. How are structures determined: to Sorbitium, troostite, martensite? What is the difference between them?

4. How are the basic types of heat treatment determined: annealing, normalization, tempering and assoiling?

5. In what essence and purpose of tempering *of SVC*?

6. In what essence and purpose of treatment for a cold?

7. What basic bugs do arise up at tempering?

8. What are types of tempering, what their purpose?

10. What methods of chemical heat treatment did find application for the details of CTZ?

Division 9. General information about the production of metals.

Table of contents of division. General information and physical essence of production of materials. Essence of casting production and receipt of founding, treatment of metals by pressure and forging.

Before iron was directly from ore renewal in furnaces. With the increase of height of furnaces iron was saturated by a carbon, got an alloy fragile, but with good casting properties. This alloy was adopted by cast-iron. From XIII in. cast-iron was begun to redo in steel - alloy with less, what in cast-iron, by maintenance of carbon, silicon, manganese and some other elements that have high plasticity and durability. Such two phasic charts of production permanent smelting of cast-iron in a high furnace and processing of him in steel - is in our time basic.

Cast-iron is melted from iron-stones by a pyrometallurgical method (a receipt of heat is due to incineration of fuel) in high furnaces, using a hard fuel - coke and gumboils for this purpose.

A coke carries out yet and the role of repairer of iron from ore, and gumboil - allows to transfer a gob in slags, to link and delete, that is in a fuel and ore, sulfur. A limestone serves in the quality of gumboil, $CaCO3$ .Physical and chemical essence of ironmaking consists in the following. A charge (enriched ore raw material) in a high furnace is heated, moisture evaporating from it, volatiles that at a temperature 750 - 900 ^{0}C enter into a reaction with proceeding in iron are secreted.

$$3Fe2O3 + 3 = 2Fe3O4 + \text{of } CO2$$

$$Fe \text{ of } 3O4 + 3 = 3FeO + CO2$$

$$FeO + 3 = Fe + CO2$$

Part of protoxide of iron recommences the carbon of coke, forming, porous iron that at a temperature 1000 - 1100 ^{0}C of carbonization are so-called

$$3Fe + 23 = Fe(3)C + 3(2)$$

$$3Fe + 3 = Fe(3)C.$$

A carbon, reducing the temperature of melting of alloy, assists its melting and additional satiation of carbon and other elements refurbishable from ore : by a manganese, silicon, phosphorus, sulphur. As far as formation of their piling up, cast-iron and slags produce.

Steel is made in a number of different ways: in oxygen converters, martin and electric stoves. Physical and chemical essence is production permanent consists in processing of cast-iron, diminishing in him the maintenance of carbon and other elements and transferring them in slags or gases.

An Oxygen-converter process is receipts permanent consists in продувці of liquid cast-iron oxygen. There is oxidation of carbon and other admixtures at purge, both directly by oxygen and by the oxide of iron of FeO. For diminishing to maintenance of oxygen, steel at a release from a converter is desoxydation. Id est, enter for its elements with more than at iron, by a cognation to oxygen (Si, Mn, Al). Co-operating from FeO, they form the insoluble oxides of MnO, SiO2, Al2O3. transitional in slags.

A martin process is receipts permanent consists in oxidation the admixtures of cast-iron due to the oxides of iron, ore and scraps.

$$3Si + 2Fe203 - 3Si02 + 4Fe$$

$$3Mn + Fe203 = MnO + 2Fe$$

$$6P + 5Fe2\,O3 = 3P2O3 + FeO$$

$$3C + Fe2\,O3 - SCO + 2Fe.$$

Sulphur becomes separated from as a result of cooperating of sulphureous iron with a lime:

$$Fes + Ca0 = Feo + CaS.$$

Oxides of SiO2, MnO, P2O5. CaO, an also sulfide of CaS, form slags. Finally, deoxidize steel. an aluminium and ferrosilicon at the release of it from a stove. Steelmaking in electric furnaces has a row of advantages : ability of the rapid heating and support of the set temperature scope to 20000 °C, by possibility of creation of oxidizing, restoration or neutral atmosphere, and also, to the vacuum. It allows steel with the least of admixtures and optimal maintenance of components that is characterized by high quality and is special characteristics. The period of rehabilitation includes desoxydation permanent, moving away from sulphur and leading to maintenance of all of the tools to set. Physical essence of chemical reactions is analogical to the previous, with some features. Melting without oxidation is used for the receipt of alloy steel from scrap and wastes of corresponding connection.

The structure of the bar at pouring of steel is determined by not only cooling (by a crystalline structure) speed but also degree of desoxydation. On this sign of steel divided by boiling, quiet and semi quiet.

Name **boiling** steel not fully deoxidization in a stove. It’s desoxydation lasts in the mold. Also in a bar appears a non-shrinkage shell, but a large amount of gas marbles that are removed following the hot rolling. Such steel is most cheap, practically does not contain admixtures, and has high plasticity.

Quiet steel is obtained at the complete desoxydation of metal in a stove and scoop. Such steel has a dense structure, and a усадкова shell is concentrated in the overhead part that diminishes a return to the metal considerably.

Semi Quiet steel goes out at desoxydation a ferromanganese and sufficient amount of ferrosilicon or aluminium. In the underbody of the bar such steel has a structure of quiet, and in overhead - boiling.

The production of the coloured metals differs in the greater variety of technological processes of pyrogenating and determined by the features of connections of their ores.

A copper is got from sulfide ores in that it is as sulphureous connections of CuS, Cu2S, CuFeS2 and other Process of smelting of copper includes enriching and burning-out of ore, smelting of intermediate product to the matte from that then get a draft copper with the next cleaning - affinage.

An aluminium is made from bauxite, apatites and other ores. An aluminium is included in them as an alumina of Al2O3. The production of aluminium consists of two processes: selection to the alumina from ore and its electrolysis.

Titan is got from ilmenite ore of Ti02*FeO. After enriching ore using an electromagnetic or gravitational method, a concentrate is added to the restoration melting in an electric arc stove for moving away from oxides of iron.

The production **of non-metal materials** is based on the use, mainly, of synthetic polymers, that are foods of the chemical processing of oil, natural gases, anthracite coal, and pyrosales. Except for it, polymers meet and in the wild: natural rubber, cellulose, mica, earth-flax, natural graphite. It may be to get polymers a synthesis with various properties and even to create materials with the descriptions set in good time.

In shipbuilding and shiprepair next non-metal materials found application: plastics, rubber, earth-flax, glues, paints and varnishes materials and others.

Plastics get from synthetic, or natural polymers together with other components: by fillers, dyes, plasticizers and others. They are able, at certain terms, to be formed and keep the form added to them. Synthetic resins are used in the quality of binding substance.

Rubber is got by the special treatment (to vulcanization) by mixtures of rubber and sulphur with different additions. As technical material, it is characterized by high elastic properties.

Name the group of minerals of fibred structure, that are an accumulation of the thinnest fibres as the crystals prolonged on one of the axes, **an earth-flax.** On the special technology asbestine minerals slit on elastic and strong fibres. These fibres are a feedstock for the production of rows of asbestine materials : filaments, cords, sheet and friction materials, cap stuffing and others.

For making of details of STE the purveyances got in a number of different ways. Basic from these methods are **a casting production and treatment of metals by pressure.** By casting they get different kind founding, and by treatment of metals by pressure is forging of different kind products of rental production. Get the finished goods that do not require the next treatment.

Essence of technology **of casting production** consists in that the shaped details (purveyances) are obtained in the inundation of liquid metal in the specially prepared casting form the cavity that answers their sizes and forms. After crystallization metal, the poured detail (purveyance) adopted by founding is deleted from a casting form, add it to heat treatment and control of quality and, if necessary, sent to mechanical, or other workshops to eliminate defects and subsequent processing.

A technological process of obtaining a casting is quite complex. In addition to these elements of the technological process, it includes the manufacture of a model of the cored box, the preparation of the molding cored mixtures, the manufacture of appropriate molds and bars, their drying. And only after that the mold is assembled and filled with liquid metal.

Cast irons, carbon and alloy steels, alloys of non-ferrous metals based on aluminium, copper and titanium are widely used to obtain castings in ship engineering.

Casting alloys, along with certain mechanical features must have technological properties: rarely fluidity, low shrinkage.

Rare **fluidity** is the ability of liquid metal to completely fill the mold depending on the chemical composition temperature of the alloy being poured. Phosphorus, silicon and carbon, improve it, and sulphur determines. The increase of temperature of liquid metal rarely improves fluidity .

Shrinkage is a decrease in the volume of metal and linear sizes of casting during its crystallization and cooling in the solid state, leads to the formation of porosity (by volume shrinkage) and the emergence of internal stresses leading to gouging (linear shrinkage).

A liquid is heterogeneity of the chemical composition of alloy in the cross section of the casting. It leads to heterogeneity of mechanical properties of casting .

The final stage of casting is to control its quality. Thus attention is paid to the following types of shortage : to gas, sandy, slag and shrinkage shells, various cracks. The lack of casting is corrected by surface and welding , as well as sealing with putty or mastic.

The essence of the technology **of processing metals** consists of pressure in the use of one of basic properties of metals - plasticity, i.e. irreversible change of form and sizes of body under the action of external forces and change, in this regard, the structure and mechanical properties of metal. Thus, obtaining the workpieces , and in some cases, the parts themselves, the required size and shape in such processing is achieved by the plastic redistribution (shift) of metal particles. This is the main difference and advantage of pressure treatment compared to cutting,in which the shape of the product is to remove part of the workpiece.

The main types of metals pressure treatment used in shipbuilding are forging, bulk, sheet metal stamping, ets. The structural state of the plastically deformed metal is not thermodynamically stable, but at room temperature, for most metals, can be kept long enough.

When heated, the plastically deformed metal gradually proceeds his structure and becomes stable again. The essence of the processes taking place in this case , we considered earlier. At low heating elastic stresses are eliminated. The crystal lattice and properties of metal are partially restored. Recrystallization treatment occurs when the metal is heated above the recrystallization temperature. Harvest recrystallization is a process of further grain growth. Large grains grow, absorbing small ones , which reduces the free energy and makes the structure thermodynamically more stable.

The grain size of the recrystallized metal depends on the temperature of heating and the degrees of deformation. With increasing temperature, diffusion processes accelerate, which causes grain growth. Small degrees of deformation sometimes cause grain enlargement. The degree of deformation, at which, after annealing, the maximal grain size is obtained, is called the critical degree of deformation. With a further increase in the degree of deformation, the grain size of the recrystallized metal decreases.

Determinations of hot and cold pressure treatment are connected with recrystallization temperature .

Hot pressure treatment is plastic deformation at temperatures higher than the recrystallization temperature. In this case, the recrystallization process partially or completely proseeds during processing.

Cold pressure treatment is called plastic deformation at temperatures below the recrystallization temperature.

In this process of cold deformation, the metal is riveted. If it is needed to reduce the strength and restore plasticity, the metal is subjected to recrystallized annealing - heating above the recrystallization temperature , which can be determined by the formula, :

$$Tp = a * \text{Тпл}, \qquad (9.1)$$

where Tp and $T_{пл}$ is a temperature, accordingly, recrystallization and melting $a = 0.4$ - for technically pure metals and $0{,}5 \div 0{,}6$ - for alloys, solid solutions. To increase ductility, reduce resistance to deformation, metals and alloys before pressure treatment. Thus, heating of metal is accompanied by a number of the phenomena that must be taken into account. Thus, when steel is heated above *700C°*, there is an intensive oxidation of the surface layer with formation of scale, and at *1330 ÷ 1350°C* scale melts and iron burns with the formation of a beam of bright blue sparks. The loss of metal on scale (burnout) with a single heating is up to *2,5 %*. Along with oxidation, there is also decarburization of the surface layer of steel due to carbon burnout. The thickness of the decarbonized layer is, certainly, *0,2 ÷ 0,5* mm, sometimes reaching up to *2,0* mm. At high heating temperatures, the grain size increases intensively, which leads to overheating of the steel. The overheated steel has lower mechanical properties. The structure of overheated steel can be corrected by annealing. The further increase in temperature, close to the melting point, leads to the final lack of steel.

Control questions under division 9:

1. What alloys are called cast iron and steel?
2. What are the physico-chemical essence and features of cast iron, steel ?
3. What characterizes the structure of a steel casting ?
4. What steels are called calm, semi-calm and boiling?
5. Which one is the cheapest ?
6. How to get copper, aluminum, titanium ?
7. What is the basis for obtaining non-metallic materials?
8. What are plastics, adhesives, asbestos ?

Division 10. Methods of obtaining one-piece connections

Contents of division : Classification of methods. Welding, soldering and gluing of materials.

The basic methods of obtaining integral joins **welding, soldering** and **gluing** of materials. Using them to obtain blanks and parts significantly reduces the complexity of manufacture and reduces material consumption.

Welding of metals is called the process of reception of inseparable connections of products due to the use of intermolecular and interatomic forces of coupling. Therefore, to weld the workpieces it is necessary to bring them closer to the interatomic distance.

Welding of metals and their alloys has the most important value in comparison with other methods of receiving inseparable connections. This is due to its widespread use and high technical and economic efficiency. Thus, replacement of casting welding saves *40 ÷ 50* % of the weight of the part. These methods give a great economic effect in the repair of *STZ* and restoration of parts. Welding is widely used for connection of homogeneous and heterogeneous materials.

Physical essence of welding metal products is to bring them closer to a distance approximately equal to the parameter of the crystalline lattice. This convergence is hindered by uneven machining and presence of oxide films, which are several orders of magnitude greater than the specified distance. To overcome this obstacle it is necessary, or to compress these preparations, or to melt a place of their connection. In connection with it, welding is divided into two basic methods: **pressure welding and fusion welding**.

The methods of fusion and pressure welding have a number of varieties: electric arc, plasma, electroslag, gas, thermite, casting, linear beam, electrocontact, induction, furnace, press, friction, ultrasonic, diffusion,ets.

The most important is a group of electrical methods in which an electric current is used for heating.

The weldability of metals and alloys depends on their physicochemical properties and the chosen method of welding. High thermal conductivity, low coefficient of linear and volumetric expansion, low shrinkage lead to good weldability of metals and alloys by melting. Metals that form a number of solid solutions have the best weldability, worse - with limited solubility in the solid state. Metals that are not soluble in the solid state can not be welded. In this case, either pressure welding is used, or an intermediate metal soluble in both materials is selected.

At pressure welding the welded connection appears, or at the expense of only pressure in the cold condition (lead, aluminum, copper and other plastic metals); or heating and pressure (methods of the electrocontact welding of iron-carbon alloys).

When fusion welding, the edges of the connecting parts, the base metal and, if necessary, additional (additive), are heated to a molten state, forming a common welding bath. After removing away the heat source, the metal of the bath is cooled and solidified, forming a weld metal, or weld, thus connecting the parts into one..

By its nature, fusion welding is a complex and diverse form of metallurgical process. The properties of metal in the weld zone are determined by the conditions of melting process, metallurgical treatment of the main and additive materials and crystallization of the obtained weld during cooling. Properties of the welded connections, as the whole, are defined by character of thermal influence on metal in near seam zones.

Behind the seam zone is the zone of the base metal, where it does not change its original chemical composition. However, its structure, due to heating to high temperatures and subsequent cooling, changes greatly. This zone is called the thermal affected (TAZ) zone. It's dimensions depend on the method and mode of welding and range from *2* to *25 mm*.

The structure of the weld , as well as the essence of structural changes and properties in *TAZ* will be consider when comparing the curve of maximum heating temperatures, *TAZ* values with the diagram of *Гe - Fe3C,* presented for low-carbon steels in Fig. 10.1.

From this figure it can be seen that *TAZ* can be represented in the form of six sections: I-section, which is a mixture of base metal with molten,having a coarse-grained structure and a small linear size.

II-a site of an overheat *(1100 ÷ 1500°C)* having the coarse-grained and ferritoholchaty structure with the lower mechanical properties, that is the weakest place of the weld-fabricated connection;

III- area of normalization *(900 ÷ 1100°C)* ,which has a fine-grained structure and increased mechanical properties;

IV- area of incomplete recrystallization *(727 ÷ 9110°C),* characterized by the fact that along with large ferrite grains that have not test undergone recrystallization, new , smaller grains are formed;

V- recrystallization area *(450 ÷ 7270°C),* which helps to restore the former shape and sizes of grains destroyed by machining (plastic deformation) before welding, and it is absence ,which does not undergo structural changes;

VI- area of blue fragility *(200 ÷ 4500°C)*, which does not undergo visible structural changes, but reduces ductility and toughness.

During welding and subsequent annealing of low carbon steel, the structural changes of the base metal in the *TAZ* slightly affect its mechanical properties. However, at welding of average carbon and low-alloyed steels in *TAZ* formations of hardening structures, which sharply reduce plastic properties of welded connections and often is the reason for formation of cracks can occur. When welding such steels, the metal structure in the *TAZ* will consist of sections of complete and incomplete hardening and tempering sections.

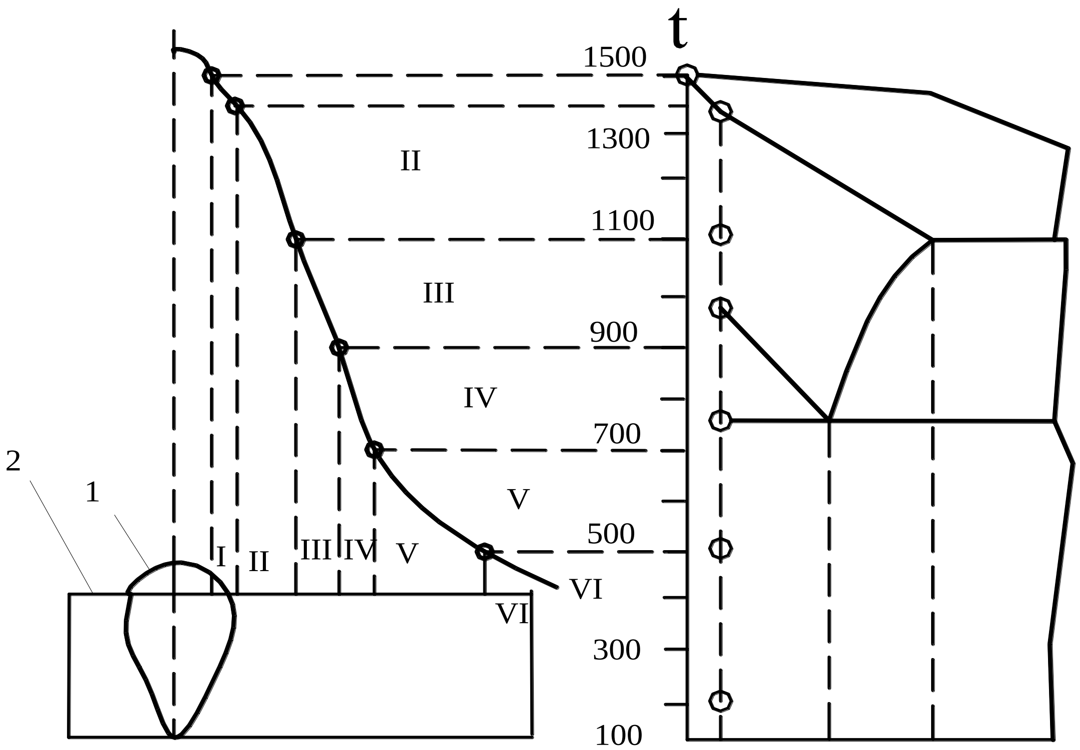


Fig.10.1

A qualitative characteristic of the propensity of steel to form hardening structures and cracks is the equivalent content of carbon of *Seq*., calculated with a known chemical composition by the formula:

$$C_{экв} = C + \frac{1}{2}P + \frac{1}{4}Mo + \frac{1}{5}\left(Cr + V\right) + \frac{1}{6}Mn + \frac{1}{15}Ni,\% \quad , \qquad (10.1)$$

Depending on the value of *Seq.,* steels are divided into the following three groups.

1. *Seq.* < 0,5 - 0,6 % - that is non-hardening or low-hardening (steel of 10HSND, 09G2 and etc.).

2.0.7 < *Seq.* < 1.3 % - hardened. In *TAZ* of such steels there can be not equilibrium structures: sorbitium, cane, cane-martensite and even martensite (steels 30HGSA, 40X, 20OHMFA, etc.).

3. *Seq.* > 1.3 - 1,5 - highly hardening. Martensite is present in *TAZ* of such steels (steels 3X12, 4X13, 18X2H4BA, 40XHM, etc.).

Based on the above, it is clear that to obtain a high-quality quality welded joint when welding steels with a content of Seq. > 0,7 %, it is necessary to apply special measures to prevent the formation of martensite and hardening cracks. Most often for these purposes use the preheating of metal before welding, or in the course of welding. Thus approximate heating temperature *t* can be determine by the formula:

$$t = 350\sqrt{C_{екв}\left(1 + 0,005\sigma\right) - 0,25} \quad . \qquad (10.2)$$

where σ is the thickness of thickness of the welding site, mm

Certainly, the heating temperature of low-alloy steels is in the range of *100 ÷ 200 C,* and for high-alloy can reach *400 ÷ 500°C.* In addition to heating, before welding, to improve the quality of the welded joint, it is also recommended, thermal insulation of the welded part (asbestos coating, sand, etc.). This is especially important when welding in a ship's environment.

Welding of plastics is carried out by means of the heat carrier (the heated gas or tool), or heating by microwave oven, ultrasound, and friction. Welding using gas heated to *180 ÷ 2200°C* gas (air, nitrogen, carbon dioxide) and heated tools (plate, soldering iron, etc.). After removal of the tool, or heating of the welded surfaces , details compress, then provide welding.

Soldering is the process of obtaining integral joints of parts due to the diffusion of molten solder, which penetrates into the heated surface layers of workpieces. Solder is a metal alloy that has a melting point below the melting point of materials to be joined. The soldering temperature is usually *100 ÷ 300°C* higher than the solder liquidus temperatures.

Soldering is characterized by wide possibilities in relation to combinations of dissimilar materials : metals with ceramics, glass, graphite , etc. The quality of soldered joints (strength, density, corrosion resistance, etc.) largely depends on the following side processes occurring in the soldering zone.

1. Dissolution of the joining materials in the solder and, as a result, a change in its chemical composition and melting point, as well as the structure and mechanical properties of the brazed seam.

2. Diffusion of solder elements into the base metal.This lead to a change in the chemical composition and mechanical properties near the suture zones.

3. Formation of chemical compounds from the elements that are part of the solder and the base metal - intermetallics. Their high brightness reduces the ductility and strength of the soldered joints.

4. Possibility of hardening in near seam areas.

During soldering, as well as during welding, the formation of interatomic bonds over the entire contact surface of the parts is preceded by the convergence of the solder particles and the base metal- the formation of physical contact. The faster and more reliably this process proceeds, the better the solder moistens a metal surface and spreads on it. Moistening determines such an important property as capillary penetration into narrow gaps between connecting parts.

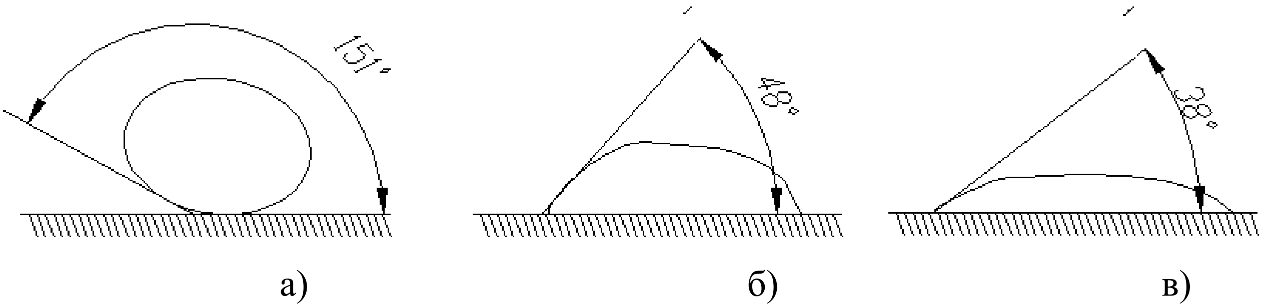


Fig. 10.2. The position of drop of solder on the material surface;
a - solder does not wet the surface (metal covered with a thick oxide film)
b - solder poorly wets the surface , *c* - solder wets the surface well

It is estimated by the angle σ (Fig . 10.2). The smaller the angle *d*, the higher the moistening. The presence of oxide, grease and other foreign films on the surface increases σ and sharply impairs moisening. Therefore, the parts must be mechanically or chemically cleaned before soldering, and soldering done either with the use of fluxes, or in chambers with a protective neutral or active atmosphere.

It is customary to distinguish between soldering, with soft and hard solders. Melting point of soft solders, and accordingly, soldering, below *450°C* , hard solders - above *450°C* (even higher 800 ÷ 900°*C*).

Depending on physical or chemical processes used to obtain high-quality soldered joints, there are the following types of soldering: capillary, cermet, diffusion and soldering with self-fluxing solders.

Solders for capillary soldering are located outside the gap between the connecteen surfaces. It gets into the gap due to moistening of the walls.

Metal-ceramic soldering is carried out by solders with fillers - powders or fibres of more refractory metals than solders. The formation of the seam occurs as a result of interaction of the liquid part of the solder with a base metal and filler.

When soldering self-fluxing solders, solders doped with elements that are active with oxide films are used. Soldering with such solders is performed without the use of flux by all the above methods.

In the diffusive film, the phenomenon of dissolution of the base metal in the solder and mutual diffusion of elements that make up the braze weld and braze metal are used to increase the melting point of the solder and aline the chemical composition of the weld and the base metal. As a result, the strength and ductility of the soldered joints can be increased.

All these types of soldering can be performed by diffusion mode, if the solder is properly selected, the minimum gap, and the soldering time is increased.

Bonding of materials is the process of obtaining a one-piece connection of the product due to **adhesion, cohesion and mechanical adhesion** of the adhesive film with the surfaces of the glued workpieces. The adhesion (stickiness) is the ability of the adhesive film to hold firmly on the surface of the bonded materials, and cohesion is the intrinsic strength of the film.

Bonding materials, in comparison with other methods of obtaining integral joints, has a number of advantages : the possibility of combining different materials (metals and alloys, plastics, glass, ceramics, etc.) both among themselves and in various combinations; atmospheric resistance and corrosion resistance of the adhesive seam; possibility of combination of thin materials, considerable simplification of technology of manufacturing of products, etc. The disadvantages of adhesive compounds are the relatively low long-term heat resistance (up to *3500°C),* the tendency to age, and others.

The bond strength of adhesive joints depends mainly on adhesion and cohesion.

To explain the physicochemical nature of digesic phenomena, there are three theories: adsorption, electrical and diffusion. Adsorption theory considers adhesion as a purely surface process similar to adsorption; the film is retained on the surface of material as a result of intermolecular forces. Electric theory considers adhesion as a result of electrostatic and van der Waals forces. The diffusion theory of the assumption that for the formed links by non-polar polymers the electric mechanism of an adhesion is impossible and adhesion is caused by interweaving of surface layers of results of their mutual.

The strength of the adhesive can be increased by mechanical adhesion of the adhesive film to the rough surface of material; for this purpose before gluing of a surface process an emery paper or other way.

The following complements are a part of gluing materials: film-forming substance (resin, rubber) - the basis of glue, which determines the adhesion, cohesive properties of adhesive and the basic physical and mechanical characteristics of adhesive joints; solvents (alcohol, acetone, gasoline, etc.) that create a certain viscidity of glue; plasticizer, to eliminate shrinkage in the film and increase its elasticity; hardeners and catalysts for converting the film-forming substance into a thermostable state; fillers (powders, fibers, fabrics) to reduce the shrinkage of the adhesive film, increase the strength of bonding and save materials that are glued.

Control questions under division 10:

1. What are the basic methods to obtain one-piece connections? What are their advantages and disadvantages?

2. What is called welding, soldering and moisening materials? What is their physical essence?

3. What are the characteristic areas of the welded joint?

4. What structures of the welded connection reduce its mechanical properties?

5. What measures must be taken to restore the mechanical properties of the welded joint?

6. How does the appearance of hardening structures affect the mechanical properties of welded joints?

7. What is the equivalent carbon content and what does it characterize?

8. How are steels divided, depending on the equivalent carbon content?

9. What is called *TAZ* weld?

10. By what formula can you determine the heating temperature during welding?

Division 11. Electric arc welding

Contents of division. General information and properties electric arc, welding materials and equipment, basic methods of electric arc welding and selection of elements of manual electric arc welding mode.

When choosing a method of obtaining a one-piece connection, to eliminate cracks and other purposes, it is necessary to pay attention to the operating condition of the part (load, temperature, environment, etc.), and its efficiency.

Electric arc welding of metals and their alloys can provide durability of welded connection at the level of the main material if features of its technological process will be considered.

First of all, it concerns the correct choice of a mode of welding and welding materials, and also the subsequent heat treatment of a welded connection.

Electric arc welding is the most common way to obtain integral joints. This method of welding ranks first in the number of welding machines, employees, volume and cost of production. The source of heat there is a voltaic (welding) arc that burns between the electrodes and workpiece.

Uneven heating of the base metal, casting shrinkage of the weld and structural transformations in *TAZ*, lead to stresses and strains during welding. Consisting of stresses arising from the application of external forces, they can reach values exceeding the allowable. Then, in the welds or in the *TAZ* cracks may occur, leading to the destruction of the welded part.

The basic methods to reduce these stresses and deformations are: preheating of the part, and after welding - annealing or normalization.

Preheating reduces the temperature difference between unheated and heated to the high temperatures, the main and molten and reduces internal stresses. The heating temperature is determined by properties of the metal. Thus, when welding different steels, it is 100 ÷ *600°C*, when welding cast-iron - *500 ÷ 800°C*, aluminium - *250 ÷ 270°C*, bronze - *300 ÷ 400°C.* Heating can be general, or local.

The heating temperature can also be determined by the approximate formula discussed in the previous division.

Annealing after welding relieves internal stresses and increases the ductility of welds.

In practice, two methods of electric arc welding are used: non-fusible welding electrodes (Fig. 11.1, a) and fusible electrode welding. Welding is performed on direct current. The electrode, certainly, is connected to the negative pole of the generator, and the material - to the positive. When welding material with reverse polarity, the arc is less stable.

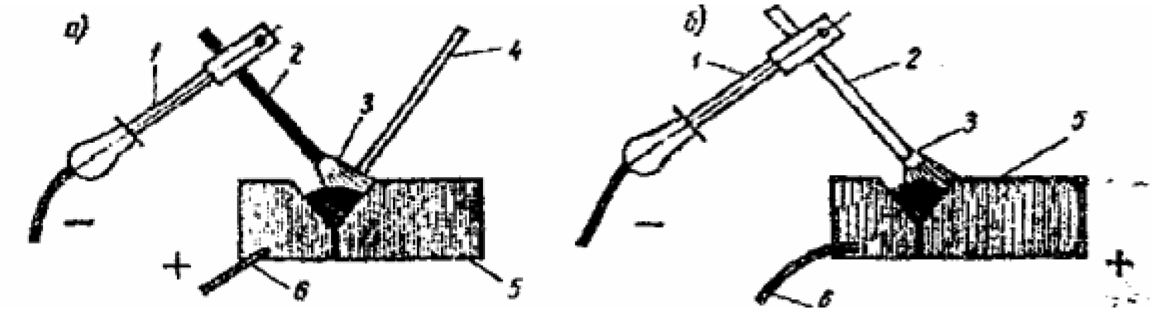


Fig.11.1 Charts of electric arc welding :

1- holder; 2 - electrode; 3 - electric arc; 4- additive solder; 5 - welded partl; 6 - flexible wire.

When moving the arc, a welding bath is formed. Liquid metallic is protected by a gaseous medium and a layer of molten slag. Slag is formed by solidification of high-quality coated electrodes with a special coating. Sometimes active or inert gases are supplied to the welding zone, which isolate the arc from the external environment. Irresponsible products, certainly, are welded with an open arc without protection from the effects of air, in which case the arc burns only at a constant current.

Wide jamming on alternating current, that is installation for welding on alternating current is much cheaper, smaller weight and dimensions, easier in operation. In addition, the efficiency of AC welding transformers is *0,8% ÷ 0,85%,* and DC units - *0,3% ÷ 0,6%*; the consumption of electric power at welding on an alternating current is almost *3* times less : than on direct. The disadvantage of AC welding is less resistance to arc combustion.

A Electric (welding) arc is a continuous flow of electrons and ions, which is formed between two electrodes in a medium, with the release of a significant amount of heat and light. Ionising of the gas gap during arc welding is mainly due to electron emission from the hot cathode.

To heat the cathode between it and the anode connected to the welding current source, make a short circuit. After the separation of the electrode from the part of the heated cathode, which in DC welding can be both the electrode (direct polarity) and the part (reverse polarity), under the influence of the electric field begins electronic emission (alternating current polarity is constantly changing). Electrons emitted from the surface of the cathode are sent to the anode and, meeting on their way with molecules and atoms of air, ionize them. Formed in the air gap minus - ions and electrons move to the anode, and plus - ions to the cathode. On the surface of the cathode and anode is the neutralization of charged particles and the conversion of electrical energy into heat.

The release of thermal energy in the welding arc is uneven. An amount of heat released at the anode is about 43 % due to the bombardment of its electrons, which have a kinetic energy greater than the ions that bombard the cathode. The cathode emits about 36 % of the total heat of the welding arc. The rest of the heat is released in the arc. This fact should be taken into account, for example, when welding thin materials, where polarity plays a major role.

In electric arc welding, $60 \div 70$ % of heat is used to heat and melt the metal. The rest of the heat is dissipated in the surrounding space.

To main parameters, that characterize the properties of the arc are : voltage, current and arc length. The voltage of the arc V depends on its length L, the current in it I, the material and size of the electrode, the connection and pressure of the gases, and others. The greater L, the greater V. Stable arc combination with stable welding quality is provided at $L = 3.\div.5$ *mm*. The dependence between V *and* I, at a steady state, the arc ($L = const$), is expressed by its static current voltage characteristic, it can be falling *I*, and a solid, increasing *III*. The most widely used is an arc with a solid characteristic, in which the arc voltage does not depend on the strength of the welding current. For stable combustion of the arc on alternating current it is necessary to increase the voltage and frequency of the current, use a special gas or coating (for ionization of the medium).

The main welding material in electric arc welding will be: welding wire, diameter of *0,3mm, 2 mm,* melting or non-melting electrode, flux (coarse-grained, glassy powder, the composition of the electrode) and gas (helium, argon).

The most widely used melting electrodes are a metal rod with a length of *350 - 450 mm*, diameter *d = 2.÷.6 mm*, with a thick (quality) or thin (stabilizing) coating. The thickness of the coating varies from *1 to 3 mm.* It includes the following components: stabilizing (elements *of Na, Ca, Ba*, ets.), oxycellulose, slag forming (feldspar, marble), deoxidizing (*FeMn, FeSi),* alloying *(FeCг, FeMo* and other) and liquid glass. In the marking of the electrode (*E145A)*, the number indicates the lower value of *Fc* and A is the increased value of plastic properties.

Welding machines and devices are used to supply a welding electric arc in DC welding, power supply of a welding electric arc comes from welding generators, or rectifiers, and in AC welding - from welding transformers. Welding generators differ in equipment and characteristics from conventional generators used for power plants and lighting. This is clearly illustrated by the external characteristics of conventional and welding power sources. More detailed equipment and operation of welding machines and devices will be considered during the technological practice.

Depending on the type of electrode, the method of protection of the welding bath, the degree of mechanization of the process of supply and movement of the electric arc welding: manual, semi-automatic (automatic wire feed and manual movement along the seam) and automatic (under the flux layer and in the environment of protective gases).

The manual electric arc welding is most common in the repair of STZ and their parts in ship conditions (without decommissioning). It is performed with artificial electrodes. To obtain a quality weld, the elements of the welding mode must be correctly selected: diameter of the electrode *d,* the magnitude of the welding current *I* and the length of the arc *L*.

The diameter of the electrode is chosen depending on the thickness of the metal *h* and the type of welded joint. You can be guided by the following data:

h / d, in a mm: 0,5/1,5; 1÷2/2÷2.5; 2÷5/2,5÷4,0; 5÷10/4÷6; over 10/4÷8.

The magnitude of the welding current is determined mainly by the selected electrode diameter.

$$I = of\ k * d, And. \qquad (11.2)$$

where *k* is a coefficient equal to *40÷60* for electrodes with a rod of low-carbon steel and 35÷*40* - for electrodes with a rod of high-alloy steel. It affects not only the depth of boiling, but also the shape of the seam. With a seam width equal to (3 ÷ *4 mm)* , we obtain the most favorable shape. The greatest depth of boiling is obtained by welding at a constant current of reverse polarity. When welding on direct polarity, the depth of penetration is less by 40 ÷ *50%, and* when welding on alternating current - less by 15÷*20* % then when welding on direct current of reverse polarity.

Length of arc affects the quality of the seam; the shorter it is, the higher the quality of the weld metal. The length of arc is determined by the formula:

$$L = 0.5\ (d1+2),\ mm \qquad (11.2)$$

Violation (lighting) of arc during manual electric arc welding can be done in two ways:

1) touching the end of the electrode to the welded part and removing the electrode from the part at a distance of *3÷4 mm.*

2) rapid lateral movement of the electrode to the part to be welded, and the removal of the electrode from the part (similar to lighting a match).

Division 12. Technological features of obtaining integral connections

Table of contents of division. Welding of carbon and alloy steels, cast-irons, non-ferrous metals and alloys.

Welding of carbon steels is determined mainly by their carbon content. When placed in them up to *0,25% C* , they are well welded in all ways. With a large content *of C* - it is necessary to perform preheating of the welding site.

Welding low - and high - alloy steels is carried out, as a rule, with preliminary heating which temperature is determined by the known formula. After welding, they are subjected to heat treatment - normalization or high tempering.

Welding of cast iron is carried out, generally, at correction of lack of cast-iron castings, welding of cracks in the block of cylinders and a base frame of engines, etc. The main difficulties in performing these works are associated with the formation in the welded joint of the bleaching zone (cementite structure), which occurs during the rapid cooling of molten iron and the appearance in the *TAZ* hardening structures. Cast-iron with such structures has a high hardness and is very brittle, it is difficult to process with ordinary tools. Therefore the main task at welding of cast-iron is reception of the welded connection with identical hardness of metal, or transition zones, without cracks. In practice several methods of welding cast-iron are used, which can be divided into three groups: hot, semi-hot and cold welding.

The hot welding of cast-iron is carried out with pre- and concomitant heating of all material to $600 \div 7000°C$, followed by slow cooling. Cast metal rods with a diameter of $5 \div 15 mm$ containing $3 \div 3{,}5\%$ of carbon and $3 \div 4{,}6\ \%$ of silicon serve as filler material. After welding, the part is slowly cooled together with the furnace, or covered with dry sands and slag. Such method provides complete graphitization of the weld metal and the absence of bleaching in the *TAZ*, eliminates the possibility of welding stresses. It is used for welding (repair) of the most responsible parts that have a complex shape (cylinder blocks, frames,etc.).

Semi-hot welding of cast-iron is carried out when part is heated to $250 \div 4500°C$ (mainly in welding places). Such method is used for the parts of small thickness and with a small volume of weld metal. After welding, the part is covered with dry sand or slag for slow cooling.

The cold welding of cast-iron is carried out without preheating the part. Steel electrodes, non-ferrous metal electrodes, , flux-cored wire are used for this purpose. The surface of the edges is welded with short rollers, electrodes of small diameter at low current, so that the metal does not have time to heat up.

Welding of aluminium and its alloys can be performed by all methods. In the form of filler material used wire or rods of the same chemical composition as the base material. The main complications in their welding is the presence on the metal surface of refractory $(Tmelt = 2050^{\circ}C$) and dense (γ = 3,9 g/cm3) oxide film Al2O3, the thickness of which increases with time and with increasing of temperature (for Al: Tmelt = 6580°*C*, γ = 2,7 g/ cm3). It must be removed mechanically and prevent formation during welding. For this purpose, fluxes are used, which include fluorine and chlorous compounds of lithium, potassium, sodium and others. Under the action of these fluxes Al203 turns into volatile AlCl3, which has a low density (2,7 g/cm3) and selfignation, at 1830°*C*. Larger values of coefficients of linear expansion and thermal conductivity often lead to deformations, and sometimes to cracks in welded joints. Therefore, during welding, preheating to 250 ÷ 2600°*C* is performed. and sometimes annealing at 300 ÷3500°*C*.

Welding of copper and its alloys carried out with the number of features that complicate this process. The high heat thermal conductivity of copper causes the necessity of concentrated heat sources and, often, heating. Slide oxidation and greater solubility of hydrogen is molten copper, in combination with *Cu2O3* can cause the formation of pores and small cracks in the seam and *TAZ*. The high coefficient of linear expansion leads to significant residual deformations of the part. There are different ways of welding copper and its alloys. The manual electric arc welding of copper is carried out by carbon and metal electrodes.

Welding of copper with carbon electrodes is carried out using fluxes, the most common of which is boron. The current is *250 ÷ 350 A*, and diameters of electrode and the filler wire are *12÷14 and 3÷7 mm*, respectively.

Welding of copper with metal electrodes is carried out on a direct current of reverse polarity, short arc, electrodes with a diameter of *3÷6 mm*, without oscillations. The current is selected by the diameter of the electrode.

$$I = 50 * d. \qquad (12.1)$$

Welding of bronze is carried out mainly to correct the lack of casting, welding cracks and other defects in the part. Bars or electrodes of the same chemical composition as the base metal are used as the seizure metal. Electrode coatings and fluxes are the same as for copper welding. When bronze is heated above *5000°C,* it loses viscosity and becomes soft. Therefore, to prevent welding cracks, it is necessary to use preheating up to *300 ÷ 4500°C.*

Welding of brass with graphite electrodes is carried out on a current of direct polarity using fluxes made of cryolite, potassium chloride, sodium and charcoal. The flux is applied to the rod with a diameter of *6÷8 mm* from additive material brand *LK80-3*. Welding of brass by a metal electrode is carried out, also, on a direct current by electrodes from brass *LK80-3,* or *VRK MTSZ-1* brones with corresponding covering.

Welding of titanium and its alloys is associated with certain difficulties, the main of which is the high chemical activity of *Ti* at high temperatures relative to *N2, O2* and *H2.* Therefore for reception of qualitative welded connection careful protection against gases of air not only of a welding bath, but also the cooled sites, metal of a seam in *TAZ* up to *5000°C.* It is necessary to protect the reverse side of the seam even if it does not melt, but only heats about *5000°C.* The quality of gas protection during titanium welding can be judged by the color of the weld metal and near the seam area. The shiny silvery surface of the seam indicates good protection against *O2* and satisfactory properties of the seam. The blue color of the seam and grey plaque shows poor quality protection. Argon arc welding with direct current tungsten electrodes at direct polarity is widely used for combinations of parts with *Ti* and its alloys.

Control questions under division 12:

1. What are the main types of electric arc welding?
2. What is the volt ampere characteristic of the welding arc?
3. What are called welding materials?
4. What is called welding, soldering and gluing materials?
5. What are the main components of a quality electrode coating?

6. What is the physical essence of the welding arc? What are its main properties?

7. How to choose the amount of welding current depending on the material and diameter of the electrode?

8. What are the main ways to obtain one-piece connections? What are their advantages and disadvantages?

9. What measures must be taken to restore the mechanical properties of the welded joint?

Division 13. General information on processing materials by cutting

Table of contents of division : Methods of treatment cutting, main and auxiliary motions, types of chips, heat balance equations, outgrowth, geometry of the cutting part of the tool and elements of the cutting mode, instrumental materials.

Treatment cutting is the process of separating a layer of material from a workpiece with a cutting tool to obtain parts of the desired shape, size and surface roughness. Nowadays, most machine parts get their final shape and dimensions by cutting on metal-cutting machines. Only this treatment satisfies growing requirements for the quality of the treated surface and dimensional accuracy.

The complexity of processing is up to *40 %* of the complexity of manufacturing machines in general. It increases even more due to increasing requirements for accuracy and quality of work surfaces due to the increase in the volume of finishing. This situation will continue and in the near time, despite the tendency to replace previous cutting operations with pressure, die casting , etc.

On metal-cutting machines, from blanks (forgings, castings, rolled products, stampings, etc.) the final is prepared by removing a layer of metal called allowance. Thus, the workpiece and the cutting tool must make certain movements. They are divided into main (for chip removal) and auxiliary, or preparatory (supply and removal of the tool, gear shifting,ets.). The main movements in turn are divided into main and feed movement. With the help of the main movement, the chips are removed, and the fed movement allows it to be carried out from the entire surface of the workpiece. In metal-cutting machines, main movement is often rotational or rectilinear and can relate to both the tool and the workpiece.

Depending on the type of work performed and the type of toolt, there are the following main methods of cutting are schematically   presented in:
Fig. 13.1: a - turning, b - drilling, c - milling, d - planing, e - drawing, f and j - round and flat grinding. It is necessary to determine, using this figure, what movements are the main and which - the feed movements.

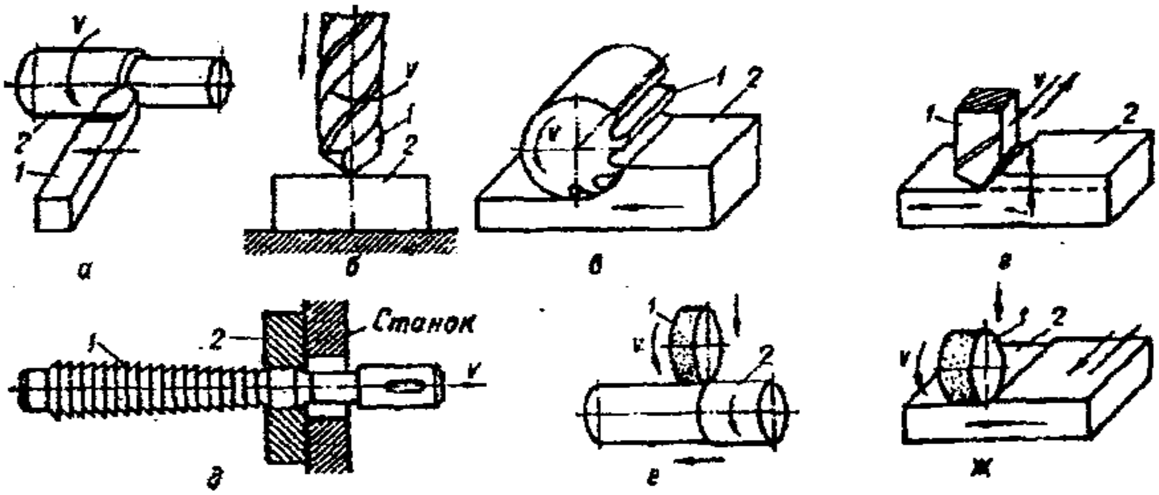


Fig. 13.1. Schemes of the main methods of cutting.

Physical essence of cutting is the mechanical destruction of the surface layer of the workpiece material, which is based on the deformation of this layer under the influence of external forces - cutting forces. The cutting process is accompanied by heat release and other phenomena that affect the quality of the treated surface and the layers of material adjacent to it. The quality of the treated surface, in addition to roughness, is also characterized by hardness, microstructure, residual stresses, etc.

Forming of details by cutting is carried out on metal-cutting machines by the cutting tool, which hardness and durability is much more, then the processed material. The kinematics of the cutting process is a combination of the optimal relative speed of movement of the contact surfaces and the workpiece.

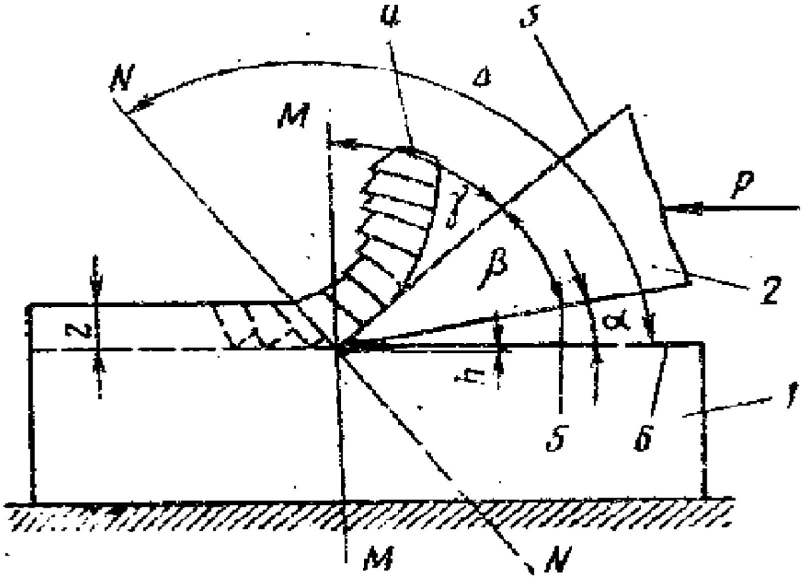


Fig.13.2

To overcome the internal forces of adhesion of the separated layer of metal in the cutting process (Fig. 13.2) to the cutting tool *2*. presented in the form of a wedge, an external force is applied - the cutting force R. Under the action of this force tool *2*, its front surface *3* part *1* and subjects it to elastic and plastic deformation. The stress moments that occur exceed the strength of the workpiece, there is a shift (chippin) of the chip element in the plane of the shift *N* - *N* at an angle equal to *180°* - (called the shear angle). This shear angle does not depend on the geometric parameters of the tool or on the properties of the workpiece and is usually about 30°. The shear process is continuous and the treated surface is removed a layer of metal thickness z in the form of shavings 4. These shavings, depending on properties of the workpiece, geometry tool, elements of the cutting mode and other processing conditions, can be formed of three types: drain, chipping and breakage.

The drain chip, that is a continuous tape that curls, is formed when processing plastic metals with significant cutting speeds, small cut thicknesses and large front corners of the tool. The treated surface has minimal roughness.

Chip chips, which are separate, interconnected elements, appear during the processing of medium hardness with low cutting speeds, significant cut thicknesses and small front corners of the tool.

Fracture chips, which are separate, unbounded, or weakly bound to each other, pieces of metal of irregular shape, are formed during the processing of brittle metals. The treated surface has significant irregularities.

In the process of cutting, due to elastic-plastic deformation and friction, a significant amount of heat is released. The equalization of heat balance in this case can be represented as:

$$Q1 + Q2 + Q3 = q1 + q2 + q3 + q4$$

where $Q1$, $Q2$ and $Q3$ - heat, released respectively due to deformation and friction of the workpiece on the front and rear surfaces of the tool, a $q1$, $q2$, q3 and q4 - heat that goes to the chips, toll, part and environment, respectively.

Values of $Q1$, $Q2$, $Q3$ and $q1$, $q2$, q3, q4 depend on the physical and mechanical properties of the workpiece, cutting mode, geometric parameters and material of the tool, and other processing conditions. As the cutting speed increases, the amount of heat generated as a result of elastic-plastic deformations increases: the chip increases, and the tool and part decrease. Under normal operating conditions, the cutting temperature is $800 \div 10000\,^{\circ}C$ when machining with metal-ceramic alloys, and $1000 \div 12000\,^{\circ}C$ when working with ceramics.

Thermal processes during cutting greatly affect the quality of the treated surface and tool wear. They can cause the decrease in accuracy and violation of the correct geometrical shape and sizes of the treated surface, intense wear of the cutting tool. Under stress cutting conditions, the heating of the surface layer of the treated surface can reach the temperatures of phase transformations, significantly changing its properties.

Physical processes that take place during tool wear are similar to the friction and wear of friction pairs, but they do occur, certainly. at high pressures and temperatures, high coefficient of friction, constant, restoration of surfaces. Depending on the cutting speed and other processing conditions, the following types of wear occur: abrasive, adhesion, diffusion and oxidation. The form of tool wear can be different. The maximum allowable wears, at which the tool loses normal performance is called the blunting criterion. When roughing, as a criterion for blunting, wear on the rear or front surfaces is taken, and when finishing - technological, ie, such wear, in which the accuracy and roughness of the treated surface cease to meet the technical conditions.

Metal that goes into the chips and the layer of metal adjacent to the treated surface is strengthened, it changes the macro and microstructure, increases the hardness and internal stresses. At the same time, in the surface layer, macro and microcracks are formed, which deteriorate its physical and mechanical properties. The thickness of this defective layer, depending on the cutting conditions, can vary from tenths of a millimetre to tenths of a micrometre.

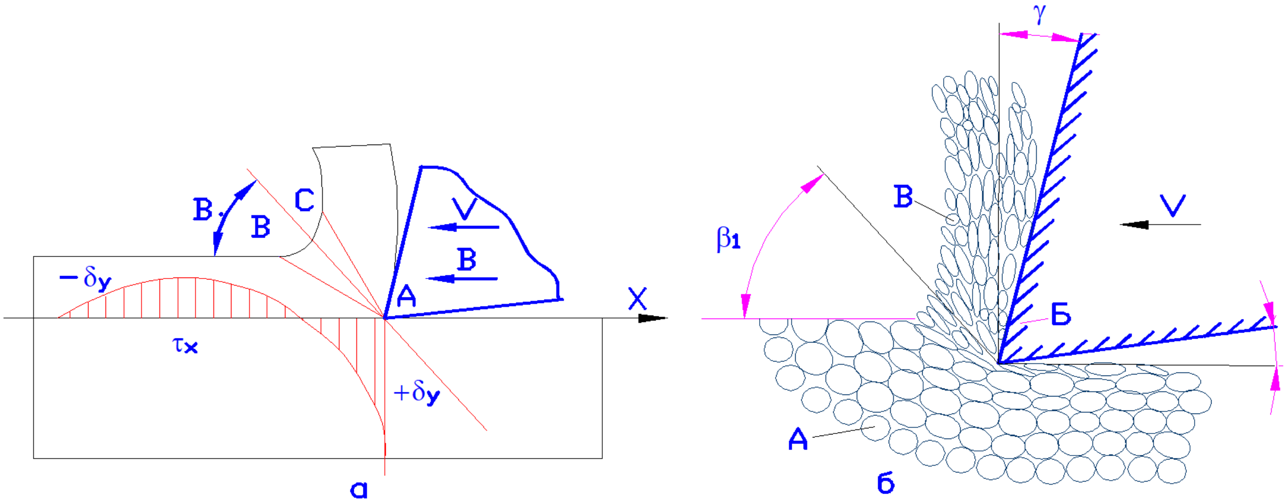


Fig 13.3

Schemes of the stress state (a) and deformation (б) of the metal in the cutting zone of cutting are shown in Fig. 13.3: circles (A) show undeformed grains, *fy* and *fv* are normal compressive and tensile stresses, respectively.

It is experimentally established that the chips are plastically deformed throughout the cross section, and the distribution of plastic deformation deep into the machined surface of the part depends on the properties of the workpiece, tool geometry, cutting elements and other processing conditions. The maximum plastic deformation occurs in the area of chip formation *ABC* and the consequence is deformation in the cut layer.

In the process of cutting there is a so-called phenomenon of growth, which occurs due to inhibition of the lower layers of chips when it slides on the front surface of the tool, high pressure and high temperature at the contact of chips with the tool. Indeed, the high coefficient of friction (up to $0,8 \div 0,9$), removal of oxide films, molecular (interatomic) interaction between the surfaces of the chips and the tool, as well as other phenomena, contribute to the setting, inhibition of the lower layer of chips. As you remove from the surface of the tool, the adhesion strength of the layers of chips will decrease due to a decrease in the degree of plastic deformation (hardening) and other phenomena. When the tool is immediately removed from the cutting zone, on its front surface, at the cutting edge, a dense accumulation of metal particles is detected (under certain cutting conditions), which is called the growth. This growth is strongly deformed, its hardness is $2 \div 3$ times higher than the hardness of the base metal. On the basis of research of a condition of shaving and the processed surface, it is possible to assume that it is periodically destroyed and carried by shaving and a detail, then is again formed. At the same time accuracy and quality of the processed surface get worse, there are vibrations of the tool and details. It is established that the growth appears in a certain range of cutting speeds for different materials. Thus, for carbon structural steel, at a cutting speed of up to *10 m/min,* the growth is quite small, at *15 - 40 m/min* it reaches a maximum. A further increase in the cutting speed leads to a decrease in growth and its disappearance and, as a result, a decrease in roughness and reduced vibrations. The use of lubricating and cooling fluids and increasing the front angle reduces the growth.

The efficiency of the cutting process depends on many factors and, above all, on the geometry of the cutting part of the tool and the elements of the cutting mode.

Control questions under division 13:

1. What is called treatment cutting?
2. What are the main methods of treatment cutting?
3. What is the physical essence of treatment cutting?
4. What is the equation of heat balance when cutting metals?
5. What types of chips are formed when cutting different materials? What are their features?

6. How to explain the formation of growths when cutting metals and what determines its value?

7. What are the main parameters of the efficiency of the cutting process and how they are determined?

8. What are the requirements for tool materials for the cutting part of the tool?

Division 14. Turning and other methods of treatment cutting

Table of contents of division : Cutter and its geometry, material of cutting part, wear, blunting criteria and stability; elements of the cutting mode : speed, feed and cutting depth; forces and cutting power; selection of the optimal cutting mode.

Turning is the most common method of tooling, as most machine parts have the shape of rotating bodies. The main movement in this case is the rotation of the workpiece 2, and the feed movement is the translational movement of the tool 1 relative to the workpiece.

The tool for turning is a cutter, the main parts and elements of which are shown in Fig. 14.1. It consists of a working (cutting) part or head *A* and a rod or holder *B*. Its main elements are: front 4 and rear (main 6 and auxiliary 1) surfaces, main 5 and auxiliary 3 cutting blades (edges) and tip of the cutter 2. The geometry of the working part of the cutter, as well as other cutting tools is a set of all structural elements (angles, the size and shape of cutting edges, the shape of the front and rear surfaces, radius of the cutting blades, etc.) which allow to ensure the process of metal cutting It is based on a cutting wedge, the interaction of which with the workpiece is discussed in the previous divisions. It follows that all the basic provisions (definitions) given for the cutterm, in fact, will be true for other tools, because for them, in a section perpendicular to the cutting blade, there will be a cutting wedge, with the difference that the shape of its surfaces can be different (concave, convex, etc.)

Geometry of the cutter greatly affects the process of cutting. Thus, increasing the front angles reduces the cutting forces and power spent on processing the material. Too much increase in the front angle leads to breakage of the cutting tool.

Without a rear corner, the cutting process is impossible, and its excessive increase leads to a decrease in the stability of the toolt. When studying the geometry of the cutter, it is necessary to pay attention to the purpose of each structural element, the role it plays in cutting. The main geometrical parameters of the cutter are shown in Fig. 14.1.

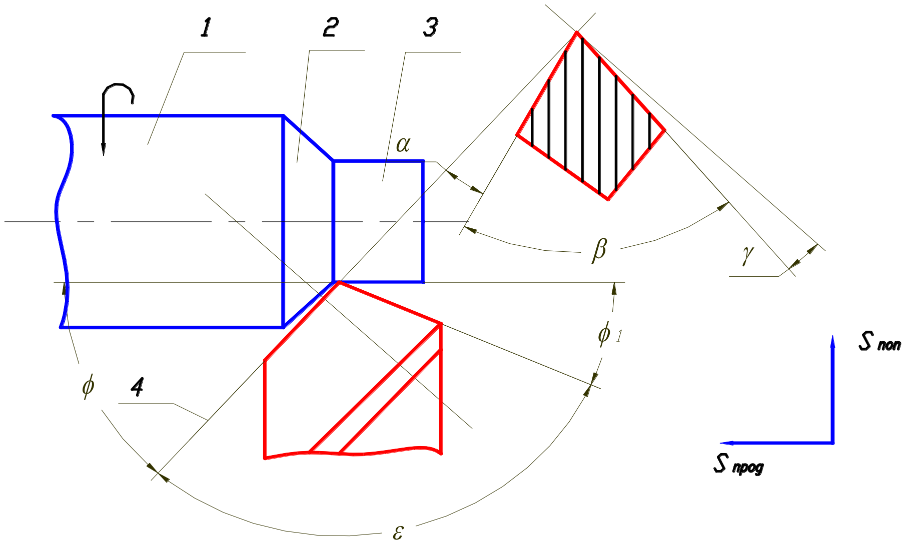


Fig. 14.1.

To determine the geometry of single-blade and multiple-blade tools, it is necessary to study, first of all, the original coordinate planes (Fig. 14.2)

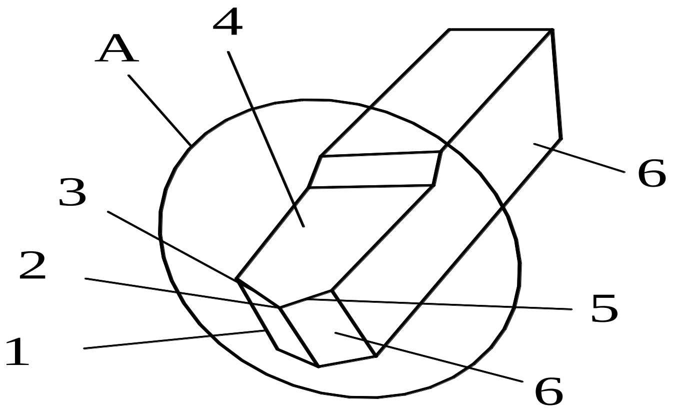


Fig. 14.2

Cutting plane 4 is a plane that passes through the main blade, the velocity vector and tangent to the cutting surface 2; the main plane 5 is a plane parallel to the longitudinal and transverse feedes and normal to the cutting speed vector, and normal to the cutting speed vector; hence to the cutting plane; the main cutting surface 6 is a plane normal to the projection of the main blade on the main plane. There are also auxiliary cutting planes - a plane normal to the projection of the auxiliary blade on the main plane.

The angles of the cutter are denoted by the following letters of the Greek alphabet : ***α** , **γ, β, σ, φ, φ_1 , ε, and λ***, defined as follows (Fig. 14.1):

α **- rear angle** between the main rear surface and the cutting plane;

γ **- front angle** between the front surface and the plane perpendicular to the cutting plane and passing through the cutting edge;

β **- sharpening angle,** located between the front and main rare surfaces;

σ **- cutting angle** between the front surface and the cutting plane;

φ **- the main angle** in the plan, located between the projection of the main blade on the main plane and the direction of longitudinal feed;

$\boldsymbol{\varphi_1}$ **- auxiliary angle** in the plan, located between the projection of the auxiliary blade on the main plane and the direction of longitudinal feed;

ε **- angle at the vertex**, located between the projections of the main and auxiliary blades on the main plane.

λ **- angle of inclination** of the main blade, which is located between the main blade and the normal to the velocity vector.

Angles *α, γ, β* and *σ* are principal because they characterize the working wedge of the tool; they are measured in the main cutting plane and are interconnected by the following dependencies:

$$\alpha + \beta + \gamma = 90° \tag{14.1}$$

If $\sigma > 90°$, then the angle γ is conditionally called negative.

Angles in the plan φ, φ_1 and ε are measured in the main plane and are independent:

$$\varphi + \varphi_1 + \varepsilon = 180 \tag{14.2}$$

Angle λ , is measured in the cutting and is selected depending on the treatment conditions: the need to ensure a given direction of chip growth, the pressure on the surface of the workpiece of foundry growth, etc. It is accepted to distinguish the angle λ positive, negative and equal to zero.

Cutter and its geometrical parameters are thoroughly considered in the basic theoretical positions of laboratory work.

As the material of the cutting part of the cutter is used mainly tool steels, metal and mineral-ceramic hard allows.

Carbon and alloy tool steels (*B10, B12A, HVG, 9HS* , etc.) are used for cutters only at treatment of non-metallic materials, as their heat resistance is low.

High-speed steels (P9K5, P18, P6M8 etc.) are used for cutters working in difficult conditions, when processing on hard-to-process materials (heat-resistant, non-rusting, etc.).

Metal-ceramic hard alloys are divided into three groups: tungsten (*ВК*), titanium tungsten (*ТК*) and titanium tantalum-tungsten (*ТТК*).

Alloys of group *ВК* consist of tungsten carbide grains cemented with cobalt (*ВК2, ВК6. ВК6В, ВК6М*, etc.). The number indicates the percentage of cobalt, the rest - tungsten carbide, and letters *В* and *М* at the end of mark - the value of carbide grains respectively coarse and fine-grained. These alloys are used for processing cast iron, non-ferrous alloys, plastics.

Alloys of the *ТК* group consist tungsten and titanium carbide grains cemented with cobalt(*Т5ДО10, T15R12B*, etc.). The number after the letter *T* indicates the percentage of titanium carbide, and after *ДО* - cobalt, the rest - tungsten carbide. These alloys are used for treatment of steels and other materials.

The alloys of group *ТТК* consist of titanium, tantalum and tungsten carbides. The number after the second letter *T* indicates the percentage of tungsten and tantalum carbides in the sum. The stability of the cutters of this alloy is *3,5* times higher than that of *P18*. They are especially high quality for treatment of hard-to-heat-resistant alloys.

Mineralo-ceramic hard allows high heat resistance (*1200°C*), and low bending strength. They allow to process materials with much higher speeds of cutting at small sections and absence of vibration. The best example of domestic mineral ceramics is the alloy of ЦМ-*332.* To increase the strength of the alloy add refractory metals. Such alloys are called ceramite, they are used for treatment of difficult to process materials. The wear of the cutter depends on the treatment conditions and, by its physical nature, can be abrasive, adhesion and diffusive. Abrasive wear is conditioned by presence in the processed material of fairly solid components (carbides, oxides, etc.), which retain significant hardness when heated. They act as abrasives, scratching the friction surface. Adhesive wear is manifested at higher cutting speeds and higher pressures and is accompanied by setting of the tool material with the workpiece material under the action of atomic forces. Thus, the particles of tool material continuously pulled out and removed with the workpiece, descending chips. Diffusion wear is manifested at high cutting speeds, when high temperatures develop, the tool material intensively wears out under the action of diffusion. There is mutual penetration and dissolution of structural components of tools and processed materials. Intensive diffusion is facilitated by the fact that all new areas of the processed material and shaving continuously come into contact with the tool. Under certain processing conditions, there is so-called oxidizing wear of the oxide film, this is when the film is constantly formed on the surfaces of the tool, periodically detached and transferred by chips and workpiece.

Criteria for blunting of the cutter : during roughing wear on the rear surface of cutter, equal to *0,8÷1,0 mm* - for steel and *1,4÷1,7 mm* - for cast-iron; at finishing we receive the technological moment, when excess of wear leads to that accuracy and roughness of the processed surface cease to satisfy technical conditions for the manufacturing of detail.

Stability of the cutter is called the time of its operation between re-sharpening at a certain cutting mode. Values of stability are brought in reference books. Thus, for cutters from high-speed parts, it is 30÷*60 min, and* from hard alloys - 45÷*90 min.*

The elements **of the cutting mode** at turning are **a depth** and cutting **speed**, and **serve**. Sometimes they include elements of sections of cut: width, thickness and area. The depth of cut, serve and speed of the workpiece are called technological elements of the cutting mode when turning (they are directly set on the machine), and cutting speed, width, thickness and area of cut - physical, as they serve for the ground of choice of technological elements, based on physical essence of cutting process at turning: speed, serve and cutting depth; forces and cutting power, choice of the optimal mode of cutting. Between the technological and physical elements of the cutting mode there are corresponding dependences.

The cutting depth *t* is the thickness of metal layer, which is removed in one pass:

$$t = (D - d) / 2, \text{ mm} \qquad (14.3)$$

where D and *d* are diameters of workpiece and treated surface, *mm.*

Cutting speed *V,* simply called the speed of the main movement, which is the path of the marked place on the surface of workpiece, relative to the cutting edge of the cutter per unit time:

$$V = pi * Dn / l000, m/min \qquad (14.4)$$

where *n* is the speed of rotation of the workpiece, at *a m / min.*

Serve *s* - the path of cutter passed for one revolution of the part, *mm /rev.*

The width of the cut layer, *b,* is the distance between the processed and treated surfaces, measured on the cutting surface:

$$b = t / \sin\varphi \text{ , mm .} \qquad (14.5)$$

The thickness of the cut layer is called the distance between two positions of cutting surface or main cutting edge per revolution of the part:

$$\delta = S \text{ of } \sin\varphi \text{ , mm} \qquad (14.6)$$

Cutting force when turning *R* is equal to all forces acting on the cutter and can be determined from the expression:

$$R = \sqrt{P_z^2 + P_y^2 + P_x^2} \quad H \qquad (14.7)$$

where *Pz, Py, Px* - accordingly - tangential, radial and axial component of cutting force.

The cutting force is determined by the component force of the cutter. Therefore, it is called the main component of the cutting force, or simply force. Constituents of *Pz. Py and Px* relate to each other as *1:0, 4:0.2.* The force *Pz* during turning is determined by the following empirical formula:

$$Pz = Cp_z \cdot t^{X_p} \cdot S^{Y_p} \cdot Kp_z \text{ H} \qquad (14.8)$$

where *Cpz* is a coefficient that depends on the properties of the processed material; Kpz - generalized correction factor for the changed treatment conditions in comparison with those for which the value is given.

Value of *Cpz, Kpz, Xp, Yp, Zp* for different materials and concrete terms of treatment are given in reference books. Then cutting power is determined by the formula:

$$Ne = Pz * V / 60 * l03 \text{ kW}., \qquad (14.9)$$

Power of electric motor must be less than *Ne*, due to the formula:

$$Ne = Ne / \eta , \qquad (14.10)$$

η - efficiency machine, equal to $0{,}7 \div 0{,}8$.

The choice of the optimal cutting mode is made in the following sequence. At first choose the depth of the cut *t*, trying to remove the entire allowance in one pass. Then choose the serve *S,* based on the requirements for accuracy and roughness of the treated surface. Here, it is necessary to take into account cutting properties of material, machine power, hardness of the part and the whole system *ВПІД* (machine - device - tool - part). Then determine the cutting speed allowed by the given stability of the cutter, according to the formula:

$$V = \frac{Cv}{T^m \cdot t^{X_p} \cdot S^{Y_p}} \cdot K \text{ ,} \qquad (14.11)$$

where *K* is the total correction factor that takes into account the changed cutting conditions in comparison with those for which the values of *Cv*, XV, УV resulted in reference books.

Defining cutting speed, find frequency of rotation of spindle of machine corresponding to this cutting speed, m/min :

$$n = 1000 * V / \, n * \, D. \qquad (14.12)$$

If the machine does not have such frequency, then take the next smaller.

This procedure for determining the optimal cutting mode is explained by the fact that the depth of cut does not affect the cutting process, and the cutting speed, on the contrary, affects. Therefore, if cutting power is greater than the power of a machine, then reduction of the cutting mode begins with the element that exhibits the greatest value, i.e. the cutting speed.

Drilling is one of the most common methods of formation of openings in a solid material using drills on drilling and lathes. In the first case, main movement and serve movement is fed to drill, in the second - main movement is the rotation of the workpiece, and serve movement - the movement of the drill along the axis. To obtain more accurate opening, they must be countersunk, drilled or deployed after drilling. All these operations can be performed on both drillings and lathes. Basic schemes of treatment of apertures are brought in Fig. *14.3*. where *a* - is drilling, *b* - is reaming, g - countersinking, d - boring , e - reaming, w - cutting, c - threading.

Geometry of drill, as well as the main elements of the cutting mode when drilling can be defined by analogy with turning.

Milling - the process of treatment cutting, in which cutting tool is a cutter that performs the main rotational movements, and the workpiece - translational or rotational serve movements. Milling is one of the most productive and common methods of treatment cutting.

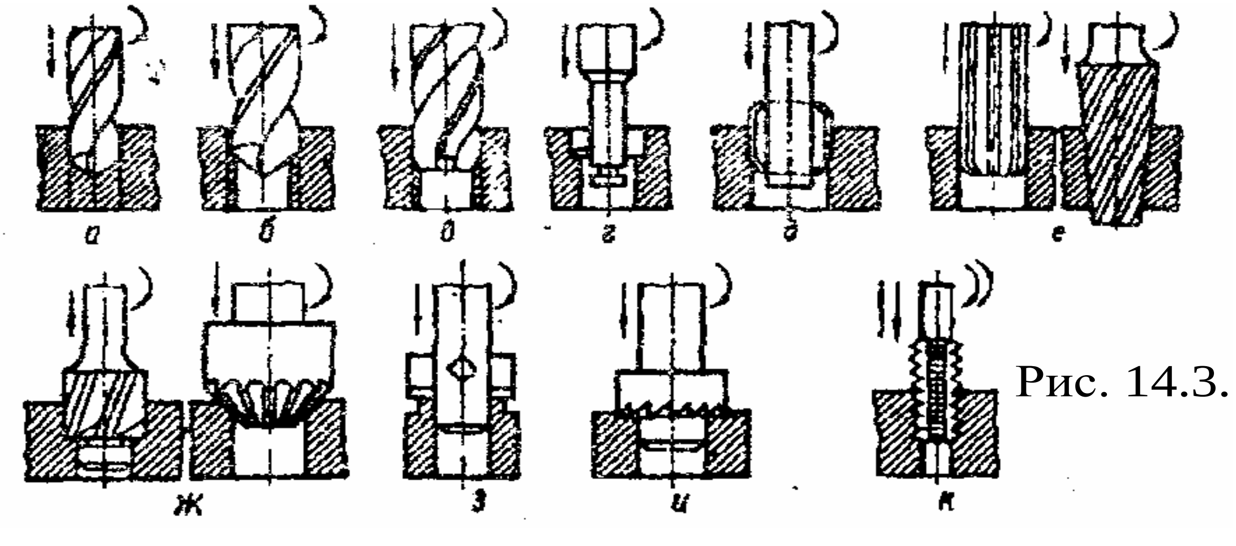


Fig. 14.3

Grinding is a process of surface treatment with abrasive tools, often grinding wheels. The abrasive tool consists of the grains of abrasive material, connected among themselves by spesial binding. Grinding is used, in most cases, for final finishing and is the main method of obtaining high accuracy and low surface roughness. You can grind both very soft and extremely hard materials of various shapes. The main characteristics of an abrasive tool is its granularity, hardness, cohesiveness and structure.

The granularity is determined by the grain size due to the size of two adjacent control sieves used for analysis. The number of granules indicates the size in hundredths of millimetre of sieve socket, on which the main fraction is delayed.

Grinding provides connection of abrasive grains in one unit. In practice most widely used ceramic (inorganic), and also becelite and _t_ volcanic (organic) bonds. The hardness of the abrasive circle is called the resistance of the blinding to the pulling of abrasive grains by external force. They are divided into soft (M), medium (C) and extremely hard (HT). In the circle of increased hardness, the brunt grains continue to be held, which disrupts its normal operation and leads to the appearance of burns on the ground surface. In the circle of reduced hardness, grains , which have not lost their sharpness, are pulled out prematurely, which leads to excessive wear and loss of form of circle. At treatment of hard materials abrasive grains wear more intensively and to avoid defects in the circle, it should be chosen softer. At treatment of soft materials - vice versa. Thus, the softer the processed material, the harder the circle is chosen, and vice versa, that is, the circle should be self-sharpening.

The structure of the abrasive tool is called the volume ratio of grains, binding and pores.

Marking of the grinding circle includes its main characteristics. For example, marking _E40CM2 K5;ПП250*16*35; a 35 m/s_ means that the circle is made of the electro-corundum, has a grain size _(N40)_, hardness_(CM2)_, ceramic bonding (K), structure _(N5)_, flat shape of a straight profile with size _250*16*35 mm_ rotation speed allowed _35 m/s_ .

Control questions under division 14:

1. What are the main elements of a lathe cutter ? How are they determined?

2. What are the main geometrical parameters of the lathe ? How are they determined?

3. What are the main brands of tool materials used for cutters? How are they deciphered ?

4. What is the essence of the main types of wear of the incisors? Which of them predominates in hard alloy machining and why?

5. What are the criteria for overlapping incisors?

6. What is the concept of firmness of chisel entered for and what is its maintenance?

7. What is meant by technological and physical elements of the cutting mode during turning?

8. What is the order of choosing the optimal cutting mode and why?

9. What is the essence of such methods as drilling, milling, grinding?

Division 15. Technological equipment of marine ships

Table of contents of division : the Technological equipment of marine ships, Ship mechanical workshop. Welding post. Metalwork equipment and instruments.

A marine vessel is an autonomous closed system, within the framework of the function of which it is often carried out to repair parts and institutions of STZ. In this case, the technological standards that installed on the ship are partly too hard in nomenclature and foldable in possession in order to complete the bigger part of the crew’s important tasks of the ship’s repair.

A large part of the technological installation of the sea vessel is concentrated in the ship's mechanical mains and at the primacy of the ship's post.

The main equipment of SMM, as a rule, are metal-cutting machines: turning-screw-cutting, drilling, milling and sharpening. In a complex they allow to carry out practically all works connected with processing by cutting. The suitability of the machine for solving certain tasks is judged by its technical characteristics.

The lathe and screw-cutting machine is intended for processing of external and internal surfaces of rotation, drilling, cutting of carvings, cutting of preparations, receiving flat surfaces, etc. - up to 80% of all works are performed on it.

The drilling machine provides obtaining material of openings and their reaming, cutting of carvings by taps, countersinking and development of openings.

The milling machine allows to process flat surfaces, to cut teeth of gear wheels, to mill keyways, to receive other surfaces with a difficult profile.

The sharpening machine is used mainly for sharpening (re-sharpening) cutting tools: cutters, drills, chisels, scrapers, etc. Its most important characteristics are the power of the electric motor and the maximum diameter of the abrasive wheel that can be installed on it.

Welding post - a specially designated place on the ship for welding, which houses the necessary equipment, tools, fixtures and equipment to ensure compliance with safety rules. Depending on the type and dimensions of the vessel, it can only have a manual arc welding post, or, in addition, a post for gas welding.

Welding on ships is given, exceptionally, an important place. It is used for welding pipelines, welding cracks, surfacing worn surfaces, connecting individual elements in the manufacture of new structures. The gas flame allows not only welding of thin-walled designs, but also soldering, to carry out technological heating of details.

Due to the great variety of machines and mechanisms on ships there are numerous locksmith equipment and tools. However, as a rule, it is scattered in the immediate vicinity of the facilities being served.

The obligatory attribute is the metalwork vices which are used for fastening of the processed details and knots. Among the most important are pipe benders, which allow the pattern to bend the pipes and then replace the defective, failed areas. They are divided into manual and hydraulic. Jacks are designed to create significant effort in disassembling the mechanisms.

The ships have a mechanized tool: pneumatic drills, chisels, wrenches. Recently, electric cutting machines are becoming more common.

There are a large number of sets of keys: horn, cap, torque, etc.

Also widely represented are tools: cutting (drills, countersinks, hacksaw blades, chisels, crossmasters, scrapers, etc.) and measuring (calipers of various types and sizes, micrometers, indicator tools, etc.).

Thus, the locksmith equipment, together with the machine and welding, allow the ship's crew to solve various tasks for the repair of STZ.

Control questions under division 15:

1. Define the technological operation.
2. Give a consolidated classification of technological operations.
3. What work can be performed in the ship's workshop?
4. What is a lathe for?
5. What measuring instrument do ship mechanics use during repairs?
6. What machines are installed in the ship's workshop?
7. What is a welding station?

Division 16. Billows and axes

Contents of the section: Purpose of shafts. Design and shape of shafts. The main structural elements of the shafts. Material for the manufacture of shafts., Calculations of shafts for strength. Calculations of shafts for elasticity.

Shafts and axes are used to attach parts to them and provide a geometric axis of rotation of these parts. In this case, the shafts perceive the forces acting on the parts and transmit them to the supports.

Unlike shafts, axles do not transmit useful torque and undergo only bending deformations, and shafts undergo both bending and torsional deformation. Axles are a special case of shafts and can be movable and immovable, shafts - only movable.

Shafts are divided by design and shape into:

1. Direct (studied in the course of machine parts);
2. Cranked (for example, for reciprocating engines);

Shafts are divided by the shape of the cross section into:

1. Smooth solid cross section;
2. Hollow (cardan shafts, spindles of lathes);
3. Slotted.

Straight shafts are divided into:

1. Smooth cylindrical (stable section);
2. Step;
3. Gear shafts;
4. Shafts-worms;
5. Flange.

For connection of knots and units among themselves (for example, in rolling equipment, textile cars) torsion shafts which transfer the moments and do not carry any fixed details are used.

In a number of machines (road construction, spinning) long folded shafts are used to transmit torque from one engine to several actuators, they are called **transmission**.

Shafts of reducers and other mechanisms, as a rule, are stepped that allows:

- bring the shape of the shaft closer to the beam of the same resistance;
- easy to assemble and disassemble parts that are on the shaft;
- perform axial fixation of parts;
- to divide and implement the technical requirements for the manufacture of the shaft on the surface in terms of accuracy and roughness.

The constructive form of any shaft is caused by:

- the size and type of parts worn on it;
- magnitude and direction of loads;
- ways of fastening of details on shafts;
- conditions of assembly and manufacture.

Shaft diameters are determined based on strength, stiffness, vibration resistance, or for design reasons, then rounded to standard values.

The main structural elements of the shafts (Fig. 16.1):

- **filler** - smooth transition with radius r (r> 0,1d) between two cylindrical surfaces with different diameters (d <D);

- keyway into which the key is inserted;

- annular groove - groove (according to DSTU) for the output of the cutting tool, grinding wheel, etc .;

- conical landing surface and threads (standard);

- **pin** - the bearing surface of the shaft;

- **heel** - the bearing surface of the shaft, which perceives only the axial force and interacts with the support - the **thrust bearing**;

- center holes, cots, slotted grooves, chamfers and others.

All these elements are places of sharp change of the form and a zone of the maximum pressure in a section of a shaft therefore they are called **stress concentrators**.

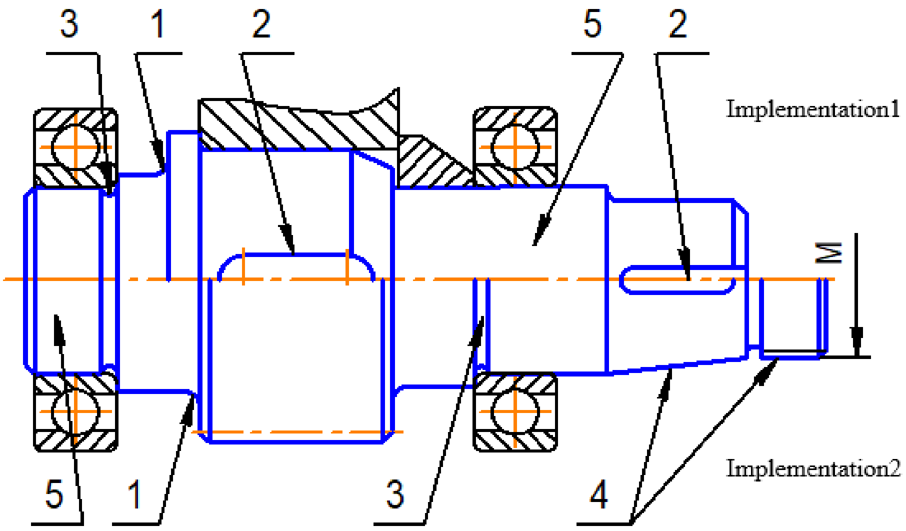


Fig. 16.1 Straight stepped shaft and its structural elements

The shafts absorb forces from the gears and undergo complex deformation: bending, torsion, tension, compression. In the course of work static and other breakdowns, and also deformations of inadmissible sizes are possible.

In this regard, the main criteria for performance are strength, rigidity and vibration resistance. For shafts paired with plain bearings, it is important to ensure the wear resistance of the pins.

Practice has shown that the destruction of the shafts and axles of high-speed vehicles in most cases is fatigue, so the main thing for the shafts is to calculate the fatigue resistance. In addition, they rely on rigidity and vibration resistance.

For the manufacture of shafts (axles) use carbon steel (preferably 30, 40, 45 and 50) and alloy (40H, 40HN, 40HNMA, etc.) in the form of rolled metal or forgings. Type of heat treatment - improvement. Shafts that work in conjunction with plain bearings, as well as splined shafts are made of steel grades 20H, 20HN with cementation and subsequent hardening.

Calculations of shafts for strength are performed in several stages.

In the first stage (approximate calculation), when only the torque **T** on the shaft is known, but the length of the shaft is unknown, and hence the bending moments in the sections, approximately determine the minimum shaft diameter $d_{\min}$ from the conditions of its torsional strength at low allowable stresses $[\tau] = 15 - 25\ mPa$:

$$d_{\min} \geq \sqrt[3]{16\, T / (\pi\, [\tau])} \qquad (16.1)$$

The minimum diameter of the shaft is required for further execution of its sketch and determination of the diameters of all sections of the shaft, taking into account design and technological factors.

The second stage is a design calculation with such an algorithm.

1. According to the results of the approximate calculation compose the designed node.

2. Make the design scheme of the shaft, taking into account the type of supports and forces acting on the shaft.

3. Plot diagrams of internal force factors - moments M_x, $M_{y\ \text{bending}}$ and torsional M_t.

4. After analyzing the plots, set the characteristic (dangerous) cross sections of the shaft, for which determine the equivalent moments of M_E, and then from the conditions of flexural strength and diameters d_s:

$$d_s \geq \sqrt[3]{M_E / (0,1\,[\sigma_b])} \qquad (16.2)$$

where $[\sigma_b]$ it is allowable bending stress for shaft material.

5. The obtained values of dv are rounded to the nearest standard number. Finally, the diameters of dangerous and other sections, the length of the shaft sections is set during the layout, taking into account the design and technological features of the node.

The third stage - the specified (basic, checked) calculation of dangerous sections of a shaft. This calculation is called the calculation of endurance and takes into account the nature of stress changes, fatigue resistance characteristics of materials, stress concentration, the effect of absolute size, surface roughness and surface hardening.

The refined calculation of shafts for endurance is reduced to definition of a stock of the tired durability **S** which still name the safety factor on fatigue resistance, and its comparison with admissible [*S*]*:*

$$S = S_\sigma S_\tau / \sqrt{S_\sigma^2 + S_\tau^2} \geq [S], \qquad (16.3)$$

where $\boldsymbol{S_\sigma}$ - fatigue strength margin under normal stresses, ie under the action of only bending under the assumption that $\tau = 0$;

$\mathbf{S_\tau}$ - the margin of fatigue strength at tangential stresses, ie under the action of only torsion under the assumption that $\sigma = 0$;

$$S_\sigma = \sigma_{-1} / (K_{\sigma D}\, \sigma_a + \psi_\sigma\, \sigma_m); \qquad S_\tau = \tau_{-1} / (K_{\tau D}\, \tau_a + \psi_\tau\, \tau_m) \qquad (16.4)$$

Where σ_{-1}, τ_{-1} - the limits of endurance of the shaft material, respectively, in a symmetrical cycle of changes in bending and torsional stresses;

$K_{\sigma D}, K_{\tau D}$ - total coefficients that take into account the influence of all design and technological factors on the fatigue resistance of the shaft in a particular cross section, respectively, in bending and torsion (selected by reference tables);

ψ_σ , ψ_τ - coefficients that characterize the sensitivity of the shaft material to the asymmetry of the stress cycle during bending and torsion (calculated by formulas or selected according to recommendations);

σ_a , τ_a - amplitudes of cycles of stress changes during bending and torsion;

σ_m , τ_m - average stresses per cycle.

Due to the fact that the bending stress in the shaft and the rotating axis varies according to the sinusoidal law (alternating cycle), and the torsional stress according to the pulsating cycle, the amplitude and average values of stresses are determined as follows:

$$\sigma_a = M_b / (0{,}1\ d^3), \quad \sigma_m = 0\ , \quad \tau_a = \tau_m = 0{,}5\ T / (0{,}2\ d^3) \qquad (16.5)$$

where d - the diameter of the dangerous cross section of the shaft;

M_b, T - bending and torque in this section.

The allowable margin of safety [S] depends on the accuracy of the calculation scheme, the degree of conformity of the shaft and the homogeneity of the material. As a rule, [S] = 1.5 ÷ 2.5.

The purpose of the calculation of elasticity - to determine the elastic displacements that correspond to the type of deformation, and compare them with the allowable values, ie, to check the conditions of rigidity of the shaft:

$$f \leq [f], \quad \theta \leq [\theta], \quad \varphi \leq [\varphi], \qquad (16.6)$$

Shafts are deformed by bending and torsion. Displacement (linear and angular) with these deformations affect the operation of bearings and gears (more often in gears and worms, less often - in chain and belt).

Displacement: deflections f; angles of rotation of sections θ (at bending); torsion angles φ (torsion) - must be determined by conventional methods of resistance of materials.

Permissible elastic displacements depend on the specific requirements for the structure and are determined in each case.

Shaft oscillations are associated with periodic changes in the stiffness of supports and transmission parts, as well as the transmitted load; not the balance of rotating masses; not uniform distribution of forces in the area of connection of shafts with other details. The most characteristic oscillations of the shafts are transverse bends, torsional and bending-torsional.

The task of calculating the vibration resistance is to determine the range of working angular velocities of the shafts, at which the amplitudes of oscillations And will not exceed the allowable [A]:

$$A \leq [A], \tag{16.7}$$

In other words, the task of calculating the vibration resistance is to determine the critical, resonant speeds of the shaft at which its operation is prohibited.

Control questions for section 16:

1. Calculations of shafts and axles for strength.
2. Structural and technological ways to increase fatigue resistance and shaft stiffness.

Division 17. Rolling bearings

Section content: Purpose of rolling bearings, Classification of bearings, Requirements for bearings, Design features of rolling bearings.

The supports of the shafts and axles are bearings, which:

- determine the position of shafts and axes in space;
- perform radial and axial fixation of shafts and axes;
- provide free rotation of these parts;
- perceive the load from the shafts and axles and transfer it to the body.

By type of friction bearings are divided into:

- rolling bearings;
- plain bearings.

The following requirements are put forward to supports:

- reliability of radial and axial fixation;
- rigidity;
- minimum resistance to rotation (especially during start-up);
- accuracy of movement due to the accuracy of centering (**centering** - the coincidence of the axes of the wheels, shafts and supports);
- low sensitivity to temperature changes;
- stability during work in the conditions of shaking, vibrations, blows;
- high wear resistance of conjugate surfaces;
- high durability;

- small dimensions;
- low cost of production, assembly, operation.

The design of the rolling support unit and the forces (radial Fr and axial Fa) acting on the shaft are shown in Fig. 17.1, where marked:

- pin; case (not demountable or demountable); rolling bearing;
- bearing cover (flange, or mortgage, deaf, or with a hole);
- gasket (adjusting or protective);
- a stopper that closes the hole for the supply of thick oil;
- seals.

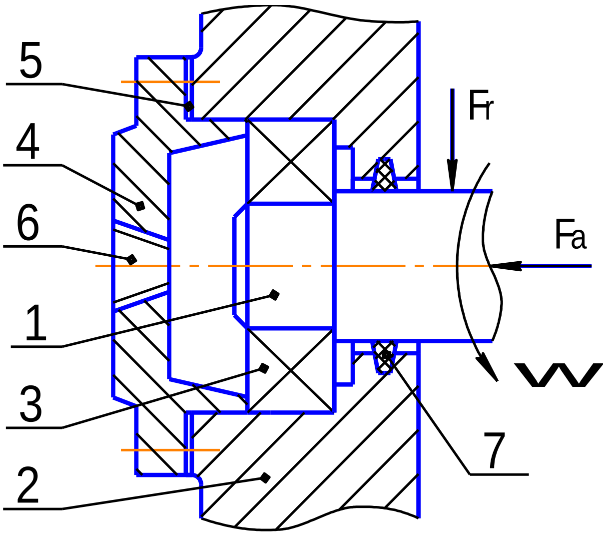


Fig. 17.1 Design of the rolling support unit

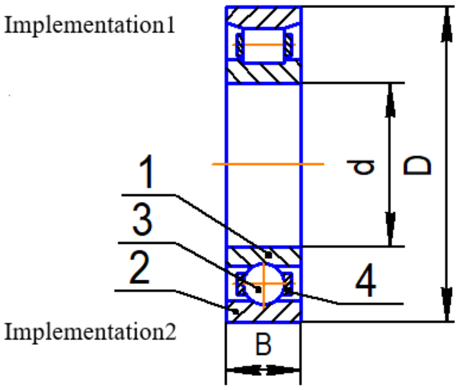


Fig. 17.2 Rolling bearing

The rolling bearing (Fig. 17.2) consists of inner 1 and outer 2 rings with rolling tracks, rolling elements (balls or rollers) 3 and a separator 4, which separates and directs the rolling elements. In addition to these, there may be other structural elements.

The bearings may be missing all of these elements, except for the rolling elements, because it is important to separate the surfaces of the movable shaft and the stationary housing.

Main sizes:

d, D - nominal diameters of rings: respectively - inner and outer;

B - width.

All designs of rolling bearings are classified according to the signs which are the basis of GOST 3395-89.

According to the direction of action of the perceived load:

- radial, receiving mainly radial load F_r;
- stubborn, receiving only the axial load F_a;
- radial-persistent, receiving both radial F_r and axial F_a load;
- persistent-radial, perceiving mainly the axial load F_a and much less radial F_r.

By shape of rolling elements:

- ball;
- roller (Fig. 17.3): a) with cylindrical rollers; b) with conical rollers; c) with needle rollers; d) with tubular rollers; e) with twisted rollers.

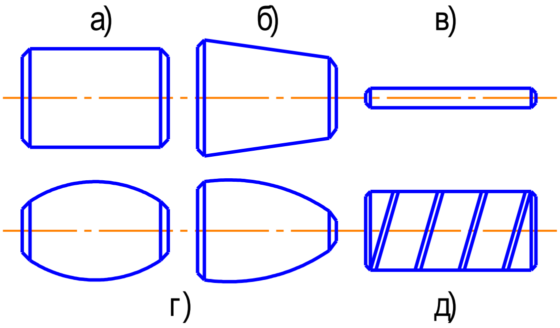


Fig.17.3 Forms of rollers

By the number of rows of rolling elements:

1) single-row;

2) two-row;

3) four-row.

By size (with the same inner diameter d):

- radial: ultralight; especially light; medium; heavy;
- width: especially narrow; narrow; normal; wide; especially wide.

By ability to self-install:

- not only installation;

- self-installing (spherical); in which the inner surface of the outer ring is spherical (Fig. 17.4), which allows the rotation of the inner ring together with the rolling elements relative to the outer, without violating the performance of the bearing, at an angle θ = 2 ÷ 4 ° (for bearings of other types θ≤0.5 °) .

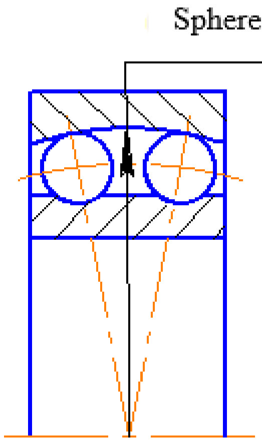


Fig. 17.4 the Ball-shaped spherical bearing

By accuracy class:

- normal accuracy (class 0);
- high accuracy (classes 6, 5, 4, 2).

Accuracy classes of bearings characterize the accuracy of the main dimensions (values of limiting deviations in size, shape, location of surfaces) and accuracy of rotation (radial and lateral beats of tracks, beating of end faces of rings). Accuracy increases as the class number decreases. With increasing accuracy, the cost of the bearing increases.

The main advantages of rolling bearings compared to plain bearings:

- low coefficient of friction f = 0,0015 ÷ 0,006, and hence smaller moments of friction forces and, accordingly, heat generation in the bearing;
- small dimensions in width;
- high degree of standardization;
- low requirements for material and heat treatment of shafts;
- insignificant consumption of non-ferrous metals and lubricants;
- ease of maintenance of bearings.

Disadvantages:

- low durability at high speeds and vibration and shock loads;
- low damping capacity;
- significant dimensions in diameter.

Ball bearings are faster and cheaper than roller bearings, which have a higher load capacity, require rigid shafts and are more rigid than ball bearings.

Needle roller bearings are used for:

- very compressed radial dimensions;
- circular shaft speeds up to 5 m / s;
- oscillating movements (couplings of cardan shafts, piston fingers).

The kinematics of rolling bearings must be known to: study the force on the rolling elements; determination of the number of load cycles and calculation of bearings for durability; study of the separator.

The rolling bearing is kinematically similar to the planetary mechanism (Fig. 17.5). Where the circular velocity of the separator $V_C = 0,5 \cdot V_1$, where $V_1 = \omega\, D_1 / 2$ - circular velocity of the inner ring.

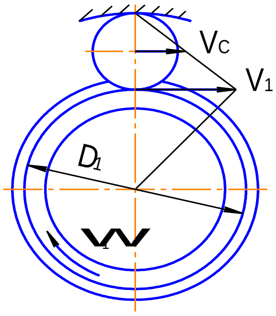


Fig. 17.5 Plan of speeds for the details of bearing.

The axial force Fa in the rolling bearing is distributed between all Z rolling elements, and we can assume that the axial force per body $F_{a1} = F_a / Z$.

The radial force F_r on the bearing is perceived only by the rolling elements placed on an arc not exceeding 180 °, i.e. not more than half of the rolling elements

(Fig. 17.6). The body on the force vector F_r will be the most loaded. The maximum radial load on this body can be approximately determined by the formula F_{r1} max = $F_0 \approx 5\ F_r / Z$.

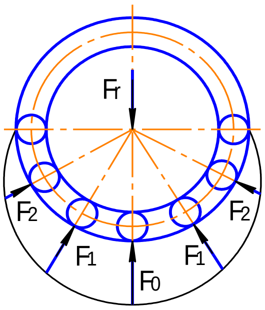


Fig. 17.6 Scheme of distribution of radial load between rolling elements

Deformations and stresses in rolling elements and rings are variable. In this case, the working condition is significantly affected by contact voltages, which vary from zero (pulsating) cycle.

High-level alternating contact stresses and the presence of the effect of rolling on rings with elastic deformation in the surface layer after a certain number of load cycles, leads to the formation on the raceways and balls of tired microcracks, which wedge oil penetrating them. This leads to progressive chipping of surfaces.

Tired chipping is the main cause of bearing failure. In addition, the destruction (splitting) of rings, rolling elements and separators is possible. At dynamic and big static loadings dents (holes) on working surfaces can be formed. In the course of work in the abrasive environment operation (wear) of rings and rolling bodies is observed.

External signs that indicate some damage to the bearing and the need to replace it are:

- loss of rotation accuracy;
- increased noise;
- increased resistance to rotation;

The main criteria for the performance of rolling bearings:

- cyclic strength or contact endurance;
- static strength when the bearing rotates with a frequency of n <1 rpm;

- wear resistance, which is provided by the appropriate material and hardness of the surfaces, as well as improving the design of seals and lubricants.

When designing bearings with rolling bearings, it is necessary to select the standard size (type and size) of the bearing from the standard range in accordance with the recommendations of DSTU. Bearings are selected:

- dynamic load capacity C to ensure cyclic strength;
- on static loading capacity C_0 for maintenance of static durability and prevention of residual deformations.

Dynamic load capacity C (given in the catalog) is a constant radial or axial (for thrust bearings) load at which 90% of the bearings of the test batch will not be tired during 10^6 revolutions of the inner ring.

Static load capacity C_0 (given in the catalog) - static load, which corresponds to the total residual deformation of the rolling elements and rings at the most loaded point of contact, which is equal to 0.0001 of the diameter of the rolling element.

The type of bearing is selected depending on:

- design features of the support (the purpose of the bearing);
- speed;
- magnitude and direction of loading;
- rigidity requirements;
- conditions of assembly and disassembly and the cost of the bearing.

Bearings that operate under variable load modes, which corresponds to the vast majority of cases, are selected by the **equivalent load**. Under the equivalent understand the conditional constant load, under the action of which provides the same durability of the bearing, as under the actual load conditions.

When the type of bearing is known and the specified diameter of the shaft, from the catalog choose the size (series) of the bearing, taking into account the condition

$$C_p \leq [\, C \,] = C_{table}, \tag{17.1}$$

where Cp, [C] - dynamic load capacity, respectively: estimated (required) and passport (from the table in the catalog).

When the bearing size is selected and the bearing life [L] assigned in hours is known, the durability is calculated - the bearing life L is calculated and the fulfillment of condition L ≥ [L] is checked. If this condition is not met, move to a heavier series, change the type of bearing, or increase the diameter of the shaft.

In the process of designing the supports it is necessary to correctly choose the methods of bearing installation, fitting and fixing (fixing) them on the shaft and in the housing, the method of their lubrication and the design of sealing devices.

Possible schemes of installation of bearings are given in textbooks. For example, when using deep groove ball bearings, a scheme with one fixed support and the other with a "floating" one is most often chosen. In a fixed support, the inner ring is fixed on the shaft, and the outer - in the housing. For the "floating" support - the inner ring is fixed on the shaft, and the outer has the ability to perform axial movement in the housing.

Guaranteed gap between the outer ring of the bearing and the bearing cover (Fig. 17.1) $\Delta = 0.2 \div 1.0$ mm and is provided with steel gaskets. Such a gap is required to compensate for manufacturing inaccuracies, installation and thermal deformations.

Lubrication of rolling bearings is performed to remove heat and reduce friction, damping load fluctuations, and preventing corrosion of contact surfaces. In addition, lubrication is important to increase bearing sealing as well as to reduce noise.

Liquid, plastic and solid lubricants are used to lubricate rolling bearings. When choosing a lubricant, it is necessary to take into account the size of the bearing and its speed, load, operating temperature, state of the environment.

Ways to lubricate bearings with liquid oils:

- immersion of the bearing in an oil bath (oil level should not exceed the center of the lower body of rolling);
- spraying one of the high-speed wheels or rings from the common oil bath of the unit;
- drip lubrication.

Seal bearing assemblies prevent them from contaminating and leaking oil.

There are contact and non-contact sealing methods.

The contacts include seals with felt or felt rings at V = 5 m / s and cuffs at V <10 m / s.

Non-contact seals include slotted, labyrinthine, centrifugal and combined.

The bearings are mounted in a heated state (heated in an oil bath to a temperature of 80 ÷ 100 ºC), or with the help of presses (hydraulic, screw), or light blows through a copper (aluminum) knocker.

The bearings are dismantled with the help of special pullers.

The general rule for mounting and dismounting bearings is that no force can be transmitted through the rolling elements.

Control questions under section 17:

1. Types, designs and purpose of rolling bearings.
2. Semantic module of symbols of rolling bearings.
3. Calculations of rolling bearings.
4. Materials of details of rolling bearings.
5. Ways of installation of bearings, landing of rings on a shaft and in the case.
6. Stages of designing bearing assemblies.
7. Ways to increase the reliability, durability and speed of bearings.

Division 18. Plain bearings

Contents: Purpose of plain bearings, Classification of bearings, Requirements for bearings, Design features of plain bearings.

Sliding bearings are the supports of rotating parts that work in the conditions of sliding of the pin surface on the bearing surface. The simplest plain bearing can be considered a sleeve (Fig. 18.1), mounted on a shaft with a guaranteed gap, which should be lubricated. The main dimensions of the bearing are the diameter of the pin d and the length of the liner l.

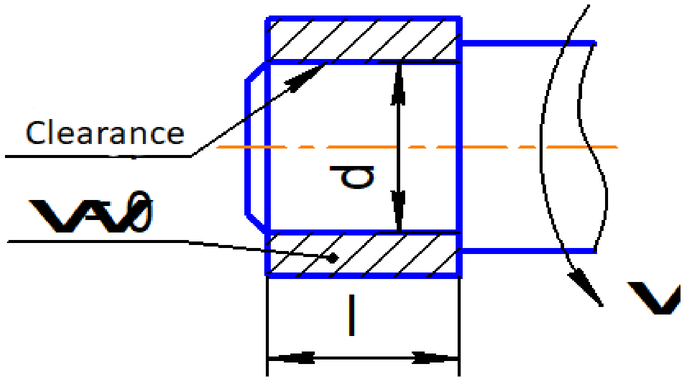


Fig. 18.1 Pin in the sliding support

The designs of heavy-duty and high-speed sliding bearings consist of a housing, liners, lubricating, protective and cooling devices. **Bearing inserts** - are working elements that interact directly with the supporting part of the shaft.

Sliding bearings use:

- at high loads and especially high speeds (more than 10000 rpm);
- at the compressed dimensions on diameter;
- in **precision machines**, which require a particularly precise direction of the shaft and the ability to adjust the gap;
- at shock and vibration loadings;
- in demountable supports (supports, crankshafts);
- in particularly polluted conditions and in supports that are constantly in water or in other aggressive environments, where rolling bearings are unsuitable due to corrosion;
- in irresponsible units of cheap low-speed mechanisms.

Sliding bearings are divided into two main groups according to the direction of perceived loads:

- radial, also called **support**, designed to absorb loads perpendicular to the axis of the shaft;
- stubborn, designed for the perception of axial loads.

Thrust bearings, which are used to fix the horizontal shafts in the axial direction and have a small load, are called **end**.

Thrust bearings mounted on vertical shafts are called **thrust bearings**.

For plain bearings, the pins can be cylindrical, tapered or spherical.

Depending on the type of oil bearings are divided into:

- **hydraulic**:

- **hydrodynamic**, in which the pressure of liquid oil in the gap between the pin and the liner is created by the rotation of the pin;

- **hydrostatic**, in which the pressure of liquid oil in the gap is created by the pump;

- **gas**:

- **gas-dynamic,** in which the pressure of gas oil in the gap is created by the rotation of the pin;

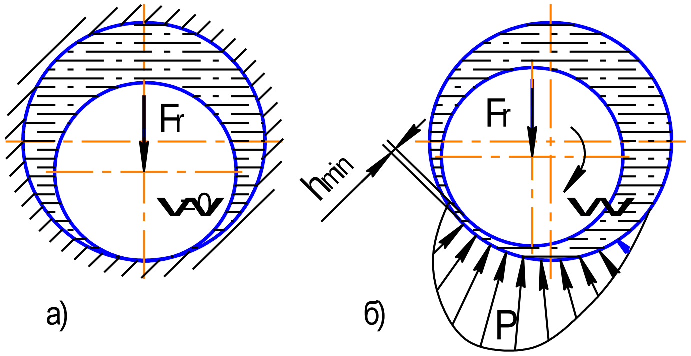
- **gas-static** (gas pressure in the slit is provided by a pump).

Hydrodynamic friction plain bearings have become widely used in engineering. The principle of operation of these bearings is explained by the hydrodynamic theory of lubrication, according to which liquid lubricants - oils due to their properties (oiliness and dynamic viscosity) are able to form thin films on the connected surfaces of pins and liners, resist displacement of one layer of fluid relative to another. forces in the liquid.

Consider the operation of a radial hydrodynamic plain bearing (Fig. 18.2).

In the plain bearing, the shaft is always installed with a certain gap, which is filled with oil. If the shaft does not rotate ($\omega = 0$), then under the action of radial load F_r it occupies an eccentric position in the bearing and the gap acquires a crescent shape (Fig. 18.2 a).

In the process of rotation of the pin, the oil, due to its oiliness and viscosity, is trapped in the wedge slot, i.e. the pin acts like a pump, injecting oil into the slot. Due to this, a hydrodynamic pressure P is created in the bearing, which is able to balance the load F_r. In this case, the pin emerges and occupies an eccentric position (Fig. 18.2 b), and between its surface and the bearing, an oil layer is formed, the thickness h of which depends on the properties of the oil, the circular velocity ω and the load F_r.



Rice. 18.2 The position of the shaft in the bearing and the scheme of the bearing lubricating layer

The main types of failures of plain bearings:

- wear (including abrasive), which is observed during frequent starts and stops, as well as in case of insufficient protection against abrasives;
- setting due to the lack of the required thermal regime and with small cracks;
- breakage of liners, tired chipping and peeling of filling of liners at variable loading.

The main criterion for the performance of plain bearings - wear resistance. Therefore, the pin and liners must form an antifriction pair. Inserts are made of antifriction cast iron, cermets, bronze, brass, kapron, rubber, graphite, etc. In most cases, the inserts are bimetallic: the base (steel, bronze, aluminum alloys, etc.) is filled with a thin layer of babbitt (alloy of tin and lead), etc.

The ability of the bearing to work also depends on the ratio of the length of the bearing to the diameter of the pin l / d. Reducing the length l with a constant diameter d leads to an increase in oil leakage through the ends and a decrease in the working capacity of the bearing. However, bearings with a low l / d ratio are less sensitive to skew that occurs during installation or shaft deformation. The optimal ratio is
l / d = 0.8 - 0.9.

When the pin rotates, the work of friction forces heats the bearing and the pin to a temperature that should not exceed some limit value that is permissible for a particular bearing material and type of oil. With increasing temperature, the viscosity of the oil decreases, the probability of jamming of the pin in the bearing increases, the melting of the liners is possible. To prevent the bearing from overheating, measures are taken to cool the oil or the support structure.

First, perform conditional calculations of bearings, and then - refined hydrodynamic and thermal.

Let's limit ourselves to the consideration of conditional calculations.

1. For low-speed mechanisms and machines with frequent starts and stops, at oscillating movement (bushings of levers, bearings of springs, etc.) when the condition of not squeezing out of lubricant has to be carried out, carry out calculation on admissible pressure in the bearing. The strength of the liner under such static load depends on the specific conditional pressure p on the liner, which should not exceed the allowable pressure [p], depending on the type of machine

$$p = F_r / (l\ d) \leq [\ p\ ], \qquad (18.1)$$

2. Due to the fact that the lubricity of the bearing oil depends on the heat dissipation in the contact zone, and it, in turn, depends on the specific pressure p on the pin and the circular velocity v, for medium speed bearings it is necessary to comply with the condition $p\ v \leq [p\ v]$.

Calculation of the parameter $p \cdot v$ in the approximate form prevents intense wear, overheating and jamming. Permissible values [p v] are set from the experience of machines.

For high-speed machines, the calculations of plain bearings are based on the equations of hydrodynamics.

Control questions under section 18:

1. Types and designs of supports with sliding bearings.
2. Calculations of plain bearings.
3. Designs and materials of "dry" friction plain bearings that work without oil.
4. Design and use of sliding bearings.
5. Thermal calculation of high-speed plain bearings.
6. Methods of supplying oil to bearings and plain bearings.

Division 19. Couplings of drives

Contents of the section: Designs of couplings, Calculations of couplings.

Couplings - devices (assemblies and mechanisms) that are used to connect the shafts of the shafts when transmitting torque, for example, the shafts of the engine and gearbox, gearbox and actuator (Fig. 19.1). The motion parameters do not change, because the gear ratio of the clutch u = 1.

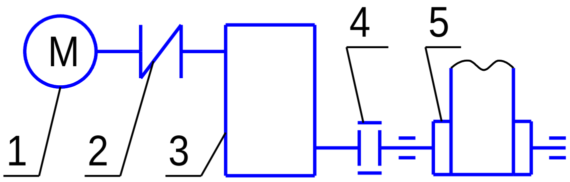


Fig. 19.1 The scheme of the drive of the belt conveyor

In the shown drive two couplings are used: the high-speed coupling 2 connects shafts of the electric motor 1 and a reducer 3; low-speed clutch 4 connects the output shaft of the gearbox with the shaft of the drum 5.

Couplings can also perform other functions:

- compensate for non-alignment of shafts;
- reduce the level of dynamic load in the drive;
- connect and disconnect shafts during operation without stopping the engine;
- to protect cars from breakdowns at overloads and change of an operating mode.

Virtually any coupling consists of a master and slave half-couplings mounted on the master and slave shafts, and the connection of the half-couplings with the shafts is usually deaf. The couplings are interconnected by means of additional parts or structural elements made as a whole with the couplings.

Basic requirements for couplings:

- simplicity of a design and the minimum dimensions;
- high reliability and accuracy of motion transmission;
- the minimum possible cost;

- high efficiency.

According to the principle of operation of the coupling is divided into classes: mechanical; hydraulic; electric, etc. Only mechanical couplings are studied in the course of machine parts.

On the basis of controllability distinguish the following groups of mechanical couplings:

- uncontrolled (not detachable), designed for permanent connection of shafts;
- controlled (coupling), which are used to connect and disconnect the shafts during operation;
- self-controlled (automatic), which automatically connects or disconnects the shafts in the event of a change in the specified operating mode.

Classification of mechanical couplings on the basis of controllability in the form of a scheme of division into groups and subgroups is performed in Fig. 19.2.

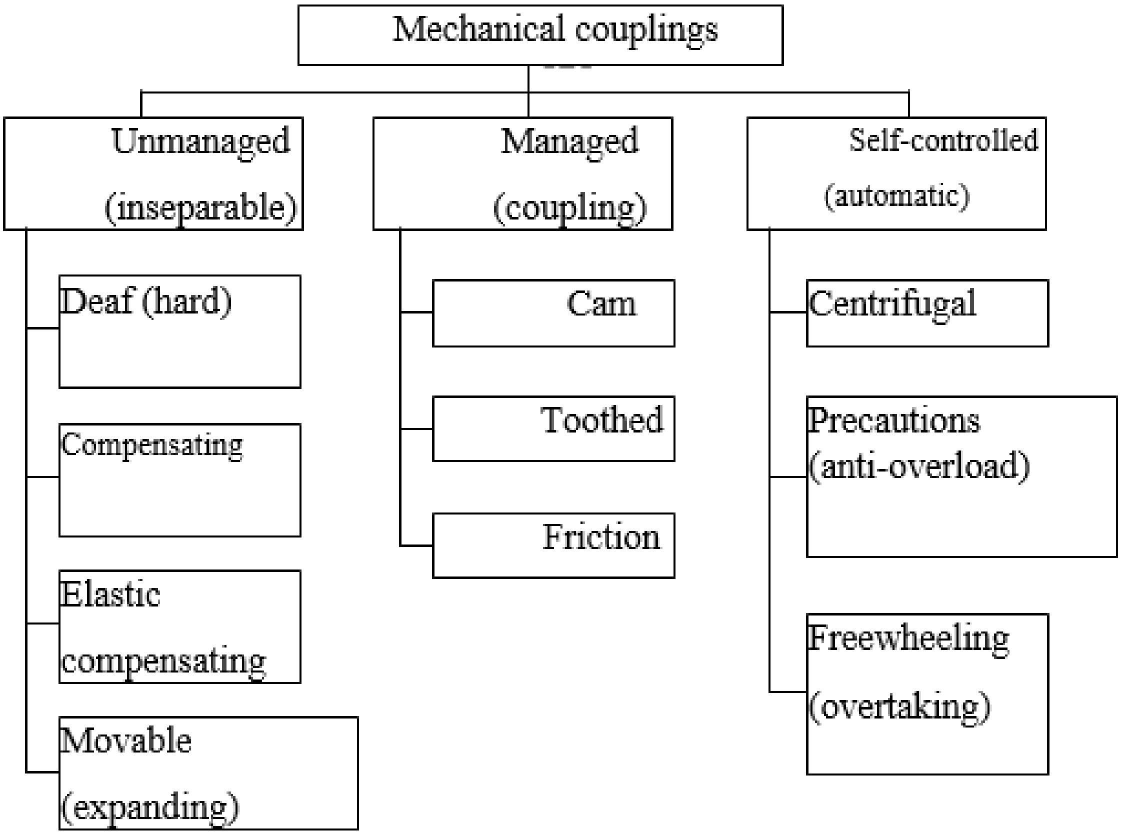


Fig. 19.2 Classification of mechanical couplings

Drive clutches are characterized by the following parameters:

- torque T (N m), or power transmitted at a certain speed (for example, n = 100 rpm, P100);

- diameters of the connected shafts d1 and d2, which vary in a certain range $d_{imin} \leq d_i \leq d_{imax}$, i = 1, 2. In a particular drive, it is advisable that $d_1 = d_2$, at least $d_1 = (0.8 - 1.2)\, d_2$;

- overall dimensions;

- mass and moment of inertia (these values are required in the process of dynamic study of the drive);

- the maximum speed $\mathbf{n_{lim}}$, which is determined by the strength of the rotating parts, wear resistance, heating of the working elements or other criteria.

Most couplings are standardized. In this regard, the task of selection is reduced to the selection of the standard size of the coupling among those available in the standards. The type of coupling must meet the operating conditions of the unit, installation and other requirements for couplings in a particular drive. The size of the coupling is selected by the larger diameter of the connected shafts in accordance with the following conditions:

$$T_P = T_H\, k_1\, k_2 \leq [\, T\,], \quad \mathrm{n} \leq \mathrm{n_{lim}} \qquad (19.1)$$

where T_P, T_H - torque, respectively: design and nominal;

k_1 - the coupling coefficient of the coupling, which depends on the severity of the consequences caused by the failure of the coupling (k1 = 1.0 ÷ 1.8);

k_2 - coefficient that depends on operating conditions, type of engine and actuator (with uniform load and quiet work take k2 = 0, when working with shocks and load fluctuations k2 = 1.5);

$[T]$ - allowable torque for a certain size of the coupling;

n, n_{lim} - clutch speed, respectively: nominal and maximum allowable.

After selection of the coupling it is necessary to check its weak element which defines reliability of the coupling, on the corresponding criterion of operability.

The design of couplings is discussed in detail in textbooks.

Deaf couplings are intended for connection of coaxial shafts whose axes lie on one straight line. They include:

- bushings;
- flanged;
- longitudinally screwing.

The disadvantage of bushings and flanged couplings is the inconvenience of their installation and dismantling, which requires axial displacement of the shafts.

Compensating couplings are used to connect non-coaxial shafts (axes do not lie on one line, they have certain offsets). Non-alignment is due to inaccuracy of manufacture, installation and elastic deformations.

There are the following types of deviations from the correct relative position of the axes of the shafts (Fig. 19.3):

- transverse or radial displacement Δr;
- longitudinal or axial Δa;
- angles Δδ;
- combined.

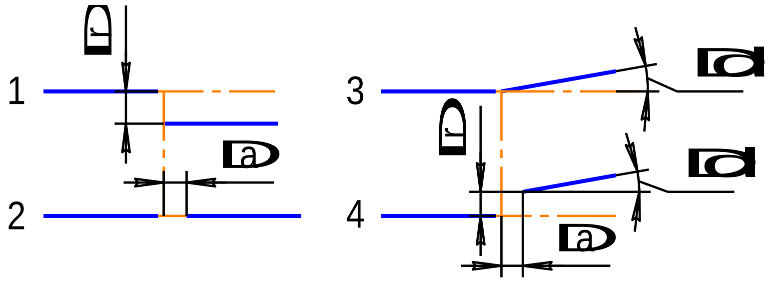


Fig.19.3Types of non-coexistence.

Such displacements cause additional loading of shafts and their supports. Compensating couplings make it possible to reduce the harmful effects of non-alignment on the operation of parts. Compensation is carried out due to the mutual movement of coupling parts (rigid compensating and movable couplings), or deformation of elastic elements (elastic compensating couplings).

Compensating rigid couplings include: toothed and chain.

Gear couplings are widely used in mechanical engineering due to their advantages: small size and weight; high load capacity, which is determined by the large number of teeth that engage simultaneously; admissibility of high circular speeds (up to 25 m / s and more); manufacturability.

Elastic compensating couplings are mainly used to reduce dynamic (including shock) loads and protect the drive from resonant oscillations. In addition, they involve some compensation for non-alignment of the shafts due to the deformation of the elastic elements, which may be metallic or non-metallic.

Metal elastic elements include: serpentine springs, radial plates of plates, twisted cylindrical springs, sleeve springs, rods. These elements work on bending and torsion. They provide greater load capacity and durability of the coupling than non-metallic elements.

The main material of non-metallic elastic elements is rubber, because it has high ductility and damping ability, as well as electrical insulating properties.

Couplings with non-metallic elastic elements:

- the coupling elastic plug-finger (MPVP);
- coupling with a rubber sprocket;
- coupling with a conical disk;
- coupling with rubber crackers;
- coupling with a toro-like shell;

Widespread use in mechanical engineering of the MPVP coupling, especially in drives from electric motors, is explained by such advantages as ease of production, simplicity of elastic elements, convenience of its replacement and reliability. The outer surface of these couplings can be used as a brake pulley.

Movable couplings are designed to connect shafts that have significant relative displacements due to the layout of the machine drive. Such couplings include:

- cam-disc (cross);
- hinged.

Such couplings make it possible to connect or disconnect the shafts (as well as the shafts and the parts mounted on them) at rest, or when rotating them with the help of a mandatory device - the control mechanism.

According to the principle of operation, such couplings are divided into two subgroups - synchronous, based on adhesion, and asynchronous using friction forces.

Synchronous couplings are used under heavy loads, compressed dimensions, infrequent switching and coaxial shafts. They provide a rigid kinematic connection of the couplings. They are switched on in a strictly defined position and only at low speed, and switching on occurs with shocks and noise. If synchronous clutches are engaged frequently, then to reduce shocks and noise use synchronizers - friction clutches, which are pre-engaged in order to equalize the speed of the driven and master half-clutches synchronous clutch.

Controlled synchronous couplings include:

- cam;
- toothed couplings.

Asynchronous couplings provide smooth connection and disconnection of rotating shafts in a wide range of angular speeds and loads. Thanks to smooth switching it is possible to prevent the big acceleration and noise. However, when switched on, there is slipping and, consequently, the operation of machine parts. Slippage can also occur in the event of overloads, while the coupling acts as a safety device.

Controlled asynchronous couplings include:

- friction disk;
- friction conical.

Self-operated (self-acting, or automatic) couplings automatically disconnect and connect shafts:

- with increasing speed (centrifugal couplings, or maximum speed);
- at overloads (safety couplings);
- when changing the direction of movement (overtaking clutches that transmit motion in only one direction).

Centrifugal couplings are used to increase the smoothness of the start; overclocking

Safety couplings include: mechanisms and machines that have significant moments of inertia, engines with low starting torques.

- couplings with a collapsing element;
- friction automatic normally closed;
- spring-cam;
- spring-ball.

Bypass couplings include:

- toothed and snoring;
- cam-snoring;
- roller overtaking.

Control questions under section 19:

1. Designs of couplings.
2. Calculations of couplings.

List of literature

Recommended educational - methodical materials.

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