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Material Science and Technology of Structural Materials

Laboratory Works

ZNTU, Dike Pole

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The study guide includes 17 laboratory works, which cover main sections of the “Material Science and Technology of Structural Materials” course of study. Each laboratory work contains brief theory from course of lectures, equipment list and instructions on its carrying out.

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CONTENTS

PREFACE

The present study quide is intended for students of a specialty 7.030507 “Translation”, and also for students of other specialties studying technical disciplines in English. The laboratory works, submitted in the textbook, cover the basic sections of the discipline “Material Science and Technology of Structural Materials”: material science of steels and cast irons, ferrous and nonferrous metallurgy, foundry practice, metal forming, welding, machining of workpieces. The English – Russian – Ukrainian Dictionary is presented in the study quide.

The description of laboratory works can be divided into two parts. In the first part the brief theoretical data necessary for preparation for independent performance of a laboratory work are given; in the second one methodical instructions on performance of works and drawing up of written reports are presented.

With the purpose of more complete mastering of the discipline and acquisition of practical skills, elements of primitive research are incorporated in the majority of laboratory works. Thus an academic group is divided into 5…6 subgroups, and each of them receives an individual task. Results of calculations and the tests, obtained by each subgroup, are generalized as a graph or a table being analyzed by the whole group and recorder down in wriiten reports.

Students have to be instructed on the safety precautions at the beginning of each laboratory work. With the aim of time savings the monitoring of students’ knowledge is carried out by means of tickets with special tests or by automated facilities.

1 INVESTIGATION OF STRUCTURE AND MECHANICAL PROPERTIES OF METALS AND ALLOYS

1.1. *INVESTIGATION OF MACRO- AND MICROSTRUCTURE OF ALLOYS*

Purpose of the work*:* to acquire skills at macrostructural analysis of ferrous and non-ferrous alloys, both on fractures and special macroetched sections; to study the microstructure of hypoeutectoid, eutectoid and hypereutectoid carbon steels, grey, malleable and nodular cast irons; to investigate the influence of graphite inclusions' shape on mechanical properties of cast iron.

Theory. Crystal is formed during the solidification process in castings and ingots may be of various shapes, arrangement and orientation primarily because of cooling nonuniformity. Due to the selective crystallization detrimental impurities (sulphur, phosphorus, etc) are displaced to the grain boundaries. This process is usually called the dendrite liquation. In case of protracted crystallization impurities with low density migrate into the upper part of the ingot. Thus, so-called zone liquation is developed. Liquid metal has a higher unit volume than a solid one and does not solidify simultaneously throughout the ingot. Therefore, a cavity, called a pipe, is formed in the part of the ingot that freezes last. Shrinkage porosity is also the result of the nonuniform volume decrease. Besides, blowholes and gas porosity are formed in consequence of the decreasing gas abilities to be dissolved in solid metal in comparison with the molten one. Further treatment of metal products: hot and cold working, welding, heat-treatment or chemical heat-treatment, — also influences greatly upon metal structure and, correspondently, its mechanical and service properties. Thus, macro- and microstructural analysis is considered to be among the main quality control methods in metallurgy and machine-industry. Macrostructure is the constitution of a metal or an alloy investigated by the naked eyes (visually) or by low-power magnification (not more than 50x). Macrostructural analysis is employed to disclose surface defects (cracks, porosity, inclusions). It also enables a general picture of the crystalline structure of a metal to be obtained for the large volumes. It may be performed either by external examination and control or on special macroetched sections (specimens, cut of large billets or parts, ground on one surface and then etched with special reagents), called templets. The visual inspection can disclose surface cracks, gas and shrinkage porosity, slag inclusions and other defects. Fracture examination gives an idea of fracture pattern. Brittle materials are characterized by crystalline fracture. In this case fragments of cleavage plains with specific luster occur on fracture surfaces. Brittle fracture, in turn, is divided into intercrystalline (crack passes trough the grain body) and interfacial (crack travels along the grain boundaries) fracture. Investigating brittle fracture it's possible to make a general conclusion concerning the grain size and shape. Another type of fracture is the tough one (the result of a tough failure). It is usually characterized by fiber (fibrous) fracture surface. Because of the significant strain it is almost impossible to assess the grain size and shape on such fracture.

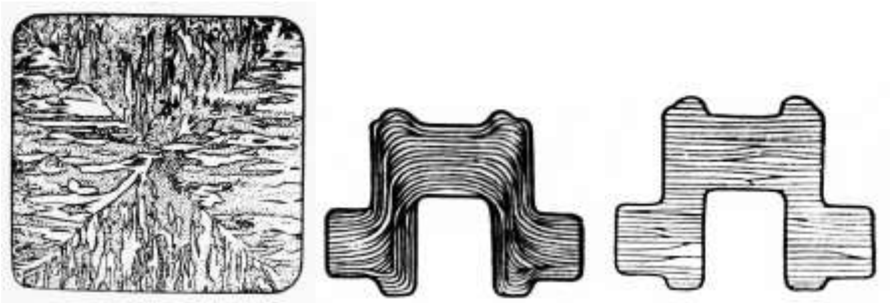
One can frequently come across intermediate fracture when brittle and tough regions are mixed up on the same fracture.

Fatigue fracture is typical to the parts and components exposed to alternate repeated load (shafts, axles, gears, etc). It consists of the crack initiation zone, the slow fracture propagation zone and the ruptured zone.

Special macroetched sections are prepared for the internal structural analysis and disclosing internal defects. They are etched with special reagents (etchants). The action of these etchants is based on their ability to dissolve and colour differently various structural components of an alloy. Examination of a macroetched section enables to assess the shape, size and arrangement of crystals in "as cast" structure; the direction of grain flow lines (deformed crystallites in, for instance, smith of closed-die forgings (Fig. 1.1), chi1led zone in cast iron and hardened layer in steel; chemical nonhomogeneity of an alloy caused by solidification process or resulting from heat-treatment or chemical heat-treatment; shrinkage porosity, blowholes, cracks etc.

Carbon, phosphorus and sulphur are the most nonhomogeneously distributed elements in steels. To reveal the distribution of sulphur in steel the Baumann's method is commonly used. A sheet of glossy bromide photographic paper, wetted in a 5% aqueous solution of sulphuric acid, is applied to the section. As a result of the reaction between sulphurous compounds on the steel surface and sulphuric acid the hydrogen sulphide is obtained:

$$\mathbf{FeS(MnS) + H_2SO_4 = Fe(Mn)SO_4 + H_2S}$$



a b c

Fig. 1.1. Macrostructure of a steel: a – “as cast”; b – forged; c – rolled

The hydrogen sulphide reacts with the silver bromide of the photographic emultions:

$$H_2S + 2AgBr = Ag_2 S + 2HBr$$

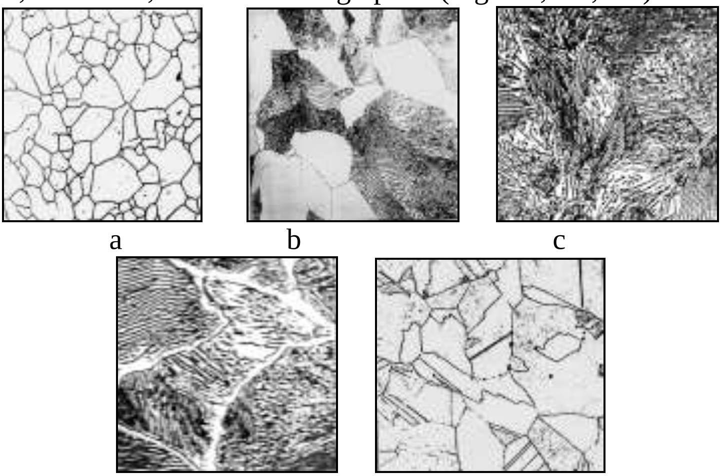
After being fixed with hyposulphite, the paper will darken in sulphur-rich areas owing to the formation of silver sulphide (Fig. 1.2).

Fig. 1.2. Chemical nonhomogeneity (liquation) of sulphur in steel

Microstructural analysis (micrography) is the investigation of metal structure with an optical metallurgical microscope in which a specimen is observed in reflected light and magnification ranges from 50X to 2000X. The electron microscope with magnification up to 1000000X and over is also extensively used to study the structure of metals. Microscopic structural analysis enables the number, size, shape of the grains to be determined, as well as the arrangement and mutual ratio of phases that make up the alloy. It also makes possible to detect very fine defects (flows) in the metal (nonmetallic inclusions, microcracks, etc).

To conduct a microscopic investigations a microsection of the metal to be analyzed is prepared. At first the microsection is investigated without preliminary etching to reveal porosity, microcracks, nonmetallic and graphite inclusions.

Microstructure of a metal is revealed by etching the specimen (microsection). The most commonly used etchant is an alcoholic solution of nitric acid (5 ml HNO_3 per 100 ml of alcohol). The etchant causes selective dissolution of grains and their boundary regions in homogeneous alloys, as well as metallic or other phases in heterogeneous alloys. The main structural components of the iron-carbon alloys are following: ferrite, austenite, cementite, ledeburite and graphite (Fig. 1.3, 1.4, 1.5).



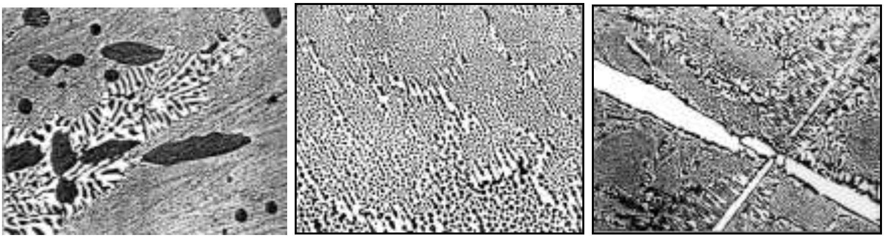
a b c

d e

Fig.1.3. Microstructure of a steel: a – ferrite, 100x; b – ferrite + pearlite, 1000x; c – pearlite, 500×; d – pearlite + cementite (white), 1000×; e – austenite, 100×

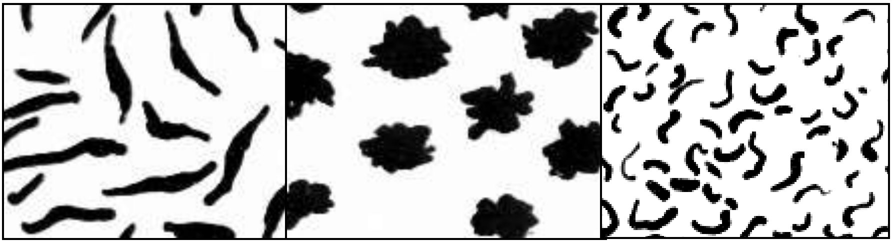
The solid solution of carbon in alpha-iron is called ferrite. Depending upon the temperature the carbon content in ferrite ranges from 0.006% at room temperature to 0.02% at 727°C. It possesses high plasticity and rather low hardness (HB 800…1000 MPa).

Austenite is the carbon solid solution in gamma-iron. It contains 0.8% of carbon at 727°C and 2.14% at 1147°C. Austenite has rather high plasticity and hardness (HB 1700…2200 MPa).



a b c

Fig. 1.4. Microstructure of chilled cast irons: a – hypoeutectic: pearlite (dark) + ledeburite; b – eutectic: ledeburite; c – hypereutectic: ledeburite + cementite (white). 100×



a b c

d e f

Fig. 1.5. Graphite in cast irons: a – lamellar, b – flaky, c – vermicular, d – speroidal (globular); structure of grey (e) and high strength (f) cast irons. 100×

Iron and carbon also form a chemical compound, iron carbide Fe_3C, which has been named cementite. It is characterized by low plasticity and high hardness (HB 7000…8000 MPa).

Pearlite is a mechanical (phase) mixture (euctectoid). It is obtained by simultaneous precipitation of ferrite and cementite particles from the austenite. Perlite contains 0.8% of carbon and possesses hardness number of HB 1600…2000 MPa.

Ledeburite (eutectic) is a mechanical (phase) mixture formed in either austenite and cementite simultaneous precipitation from the liquid metal at the temperature range from 727 to 1147°C, or pearlite and cementite simultaneous precipitation at the temperature below 727°C. It contains 4.3% of carbon and is known to be the main structural component of white (chilled) cast iron. The hardness of this mixture is approximately HB 6000 MPa at room temperature.

Graphite is a free carbon possessed low plasticity and tensile strength. The typical feature of grey cast iron is that in its structure the graphite is in the form of lammelas. Grey cast iron has been named so because its fracture appearance is dark grey or almost black. In malleable cast iron the graphite separates out in form of flakes (called temper graphite). The graphite in microstructure of high-strength (nodular) cast iron is of globular (spheroidal, nodular) shape. In the recent time vermicular graphite cast iron (intermediate form between lamellar and globular graphite) has been widely applied in industry (Fig. 1.5). The graphite inclusions may be regarded as internal notches which violate the continuity of the metal. Thus, they reduce the resistance to fracture, the tensile strength and, especially, the plasticity of the cast iron. Average mechanical properties of the steel 45Л with ferrite-pearlite structure and cast iron with the same structure but different types of graphite inclusions are represented in the table 1.1. From the table it's possible to make the inference that globular graphite provides the highest cast iron mechanical properties to be obtained.

1.1. Comparative properties of steel grade 45Л and cast irons

Alloy	Shape of graphite inclusions	Tensile strength, MPa	Percent elongation, %
Steel, grade 45Л	–	620	15
Nodular (high strength) cast iron	Globular	550	12
Malleable cast iron	Flaky	400	10
Vermicular graphite cast iron	Vermicular	250	1.5
Grey cast iron	Lamellar	150	0.2

Equipment, materials and pictorial means

Optical metallurgical microscope	5...6
Templets with pipe, porosity, cracks and other defects	1...2 (with the each defect)
Specimens with fatigue, tough and brittle fractures	2 (of the each type)
Macrosections after cold or hot working	3...4
Macroetched sections of steels (grades 10, 25, 45, У7, У10, У13), chilled, malleable and grey cast irons	1...2 (of the each alloy)
Macro- and microstructures of steels and cast irons (photographs)	1...2 (of the each alloy)

The work must be executed as follows. Investigate surface defects on parts and specimens, external appearance of various fractures and become skilful at their classification. Examine templets of cast steel and steel after cold or hot working; defects in metals, disclosed by means of microanalysis.

Develop skills in distinguishing the components that constitute steel and cast iron structure. Analyse the influence of carbon on quantity and mutual ratio of structural components in steel. Estimate the graphite shape parameter (index) – ratio of the maximal dimension of graphite inclusions to the minimal one, – in grey, malleable and nodular cast irons. Plot the graph of the tensile strength and the relative elongation as a function of the graphite shape parameter (apply the data from the table 1.1). Make a conclusion how the shape of graphite inclusions influences the cast iron strength and plasticity.

Contents of the report. Characterize briefly fatigue, intermediate, tough and brittle fractures, as well as steels' microstructure; exhibit microstructures of hypoeutectoid, eutectoid and hypereutectoid steels, grey, malleable and nodular cast irons (scketches). Make brief inference about carbon effect on the mutual ratio of structural components in steel and the influence of graphite shape on strength and plasticity of cast iron.

1.2 DETERMINATION OF STRENGTH AND PLASTICITY OF ALLOYS

***Purpose of the work*:** to develop practical skills at tensile strength test technique; to study the determination of strength and plasticity indices by means of stress-strain diagrams and by measurement of specimens; to plot graphic dependences of tensile strength and plasticity upon carbon content in steel and analyze them.

Theory. Strength is the resistance of a material to deformation and failure. Plasticity is its ability to withstand a permanent deformation (remaining after the removal of the deforming load) without failure.

Tension tests determine the strength properties; proportional limit, yield point (physical or conventional), ultimate or tensile strength and true strength, as well as the plasticity (ductility) indices: percent or relative elongation and reduction in area.

Tension tests are conducted on standard specimens mainly of round or square cross section with the initial gage length l_0 of 50 mm and 10 mm in diameter (Fig. 1.6a). It is possible to use specimens of other dimensions. Shape and dimentions of the specimens are determined by GOST 1497-84.

Testing machines have an instrument that records the stress-strain diagram, i.e. the change in length of a specimen versus the applied load (Fig. 1.6b). Characteristic points are obtained from the stress-strain diagram, that enable to determine indices of mechanical properties. At the beginning of the test the elongation is proportional to the applied load (the portion from the point 0 to the point A). The law of proportionality is valid up to a certain load that corresponds to the point A. The stress calculated for this load is called the proportional limit:

$$\boldsymbol{\sigma_p = P_p/F_0}\text{, MPa}$$

where P_p is ultimate load the law of proportionality is valid up to;

F_0 is initial cross-sectional area of the specimen.

When the load exceeds the proportional limit the law of proportionality is violated. But the strain still remains elastic, i.e. strain that disappears when the load is removed. The elastic limit is frequently defined as the stress at which the residual strain reaches a certain value, such as 0.005% of the initial length of the specimen. This limit is obtained at the point B of the diagram that corresponds to the load P_e. The elastic limit is calculated for this load on the basis of the initial cross-sectional area of the specimen:

$$\boldsymbol{\sigma_e = P_e/F_0}\text{, MPa}$$

At an increase in load above P_e, the relationship between the load and the elongation deviates and will no longer be linear. The straight line of the diagram becomes a curve and, at a certain load, a horizontal step is sometimes observed. This step (portion CD) indicates that the metal is elongated (yields) without any increase in the load. The stress corresponding to the load P_y (point C) is called the yield point (physical):

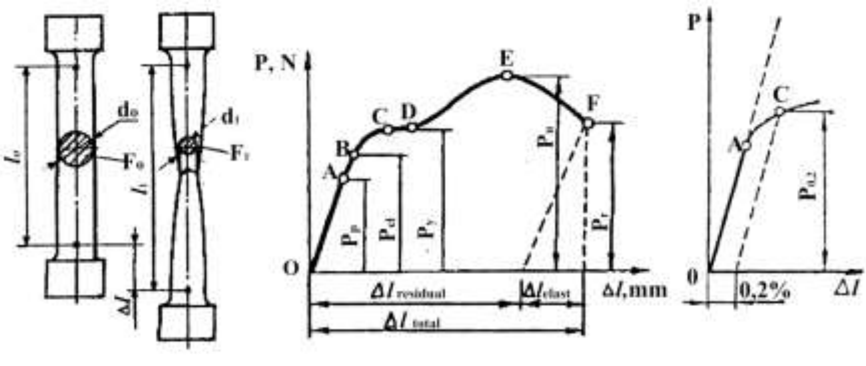
$$\boldsymbol{\sigma_y = P_y/F_0}\text{, MPa}$$

The most materials (especially brittle) do not have a clear-cut yield step. For such diagrams the conventional yield point is defined as the stress at which the specimen acquires a permanent elongation equal to 0.2% of the initial gage length (Fig. 1.6c). It is denoted by $\sigma_{0.2}$:

$$\boldsymbol{\sigma_{0.2} = P_{0.2}/F_0}\text{, MPa}$$

The stress corresponding to the maximal load preceding failure of the specimen (point E) is called the ultimate strength or tensile strength:

$$\boldsymbol{\sigma_u = P_u/F_0}\text{, MPa}$$



a b c

Fig. 1.6. Specimen for tests (a); stress-strain diagram obtained after tension test on a ductile metal (b); principle of a conventional yield point determination (c)

Load decrease after the point D relates to localized reduction of the cross-sectional area, called necking, appeared on specimens of ductile materials. The load drops (portion EF), but the stress increases. The true or instantaneous stress $\mathbf{S_f}$ is found by division the load at the failure instant $\mathbf{P_f}$ by the cross-sectional area of the specimen at the same instant $\mathbf{F_1}$:

$$\boldsymbol{S_f = P_f/F_1}\text{, MPa}$$

According to the measurements of the specimens before and after tests plasticity (ductility) indices are determined. The percent elongation is defined as the following ratio:

$$\boldsymbol{\delta = (l_1 - 1_0) \cdot 100 / l_0}, \%,$$

where l_0 is initial gage length, mm;
l_1 is gage length of the speciment after fracture, mm.

The reduction in area φ is determined by the formula:

$$\boldsymbol{\varphi = (F_0 - F_1)\ 100\ /\ F_0}, \%,$$

where F_0 and F_f are the initial cross-sectional area and the cross sectional area of the specimen after fracture, correspondently.

Equipment, instrument and materials

Testing machine with the capacity exceeding 100000 N	1
Jig (device) for marking out the specimens	6
Dimension gauge with the least division of 0.05 mm and the upper limit of the range run to 125 mm	6
Micrometer with the limits of the range 0…25 mm	6
Specimens for tensile strength tests of normalized steels, grades 10, 25, 45, У7, У10, У13	2…3 (of the each grade)

The work must be executed as follows. Study the design of testing machine and the principle it works by. Make acquaintance with safety precautions. Mark-out and measure the specimens. Test the specimens, conduct measurements both on the specimens and on the diagram and fill the results in the form (Table 1.2). Calculate the indices of the mechanical properties and average them for the each steel grade. Plot the graph of a relationship between carbon content in steel and its mechanical properties. Make a conclusion about the influence of carbon on strength and plasticity indices.

Contents of the report. Plot the stress-strain diagram; sketch the specimens before and after tests showing their dimensions; present the calculating formulas and calculation procedure of the mechanical properties, table with the results of calculations and plot the graph of mechanical properties as a function of carbon content in steel.

1.2. The testing form

Dimensions of the specimen, mm							Load, N				Mechanical properties						
before test				after test							σ_p	σ_e	σ_y	σ_u	S_f	δ	φ
l_0	d_0	F_0	l_1	d_1	F_1	P_p	P_e	P_y	P_u	P_f	MPa			%			

1.3 DETERMINATION OF HARDNESS OF METALS AND ALLOYS

Purpose of the work: to develop practical skills at Brinell, Vickers and Rockwell hardness determination; to analyze the relationship between normalized steel hardness and its tensile strength; to investigate the carbon content influence on steel hardness.

Theory. Hardness is the property of external layers of a material to resist plastic deformation (less frequently, brittle fracture) upon penetration from side of harder body called an "indentor". Indentor, however, has to remain without residual strain. In many cases a definite relationship exists between the hardness of a metal and its mechanical, service and technological properties (yield point or tensile strength, wear resistance, machinability, workability, etc). Therefore hardness determination tests have found exceptionally wide application in the quality control of metals and metal components. The main standard hardness determination methods are following: Brinell, Vickers (diamond pyramid) and Rockwell hardness tests. The testing conditions for these methods are regulated by GOST 9012-59, GOST 2999-75, GOST 9013-59 correspondently.

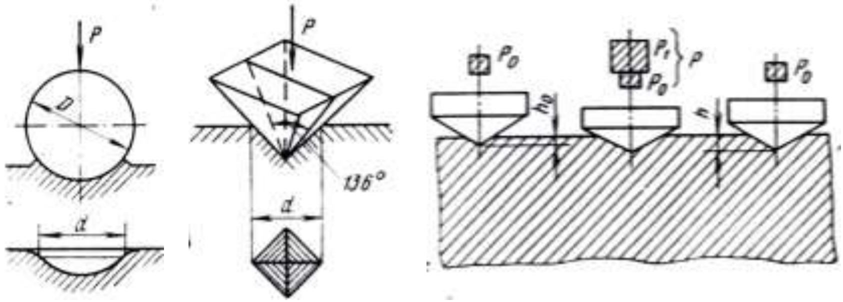
The principle of **the Brinell hardness test** is shown in Fig. 1.7 a. This method consists in forcing the hardened steel ball 2.5, 5 or 10 mm in diameter D at a constant load P into a flat surface of a metal. When the load is removed, an impression (indentation) remains on the surface of the metal. Its diameter d is measured by optical magnifying device with a scale marked every 0.05 mm. The Brinell hardness number (HB) is the ratio of the load, applied to the ball in the test P (N), to the surface area of the impression obtained, F (m^2):

$$\mathbf{HB = P/F = 2P[\pi D(D - \sqrt{D^2 - d^2})]}.$$

Special standard table is used in practice to avoid the prolonged calculations. The diameter of the impression is measured and is used to find the HB number directly from the table. The ball diameter (2.5, 5 or 10 mm), the load P (from 156 to 30000 N) and the pressure holding (10, 30 or 60 sec) are selected to suit the expected hardness and the thickness of the test specimen (Table 1.3).

The simplicity of the test and the accuracy of measurements are among the advantages of the method. Besides, the definite relationships in the form of σ_u = kHB are known for several ductile alloys. The k is the coefficient equal to 0.35 for steel and duralumin; 0.55 – for copper and its alloys after annealing; 0.4 – for copper and its alloys after strain-hardening.

Nevertheless, it is not recommended to employ the Brinell tests for metals of a hardness exceeding HB 4500 MPa as the ball may be deformed, thereby introducing errors into the test results. It is also impossible to testify thin components (with the thickness less than 2…3 mm) and thin surface layers (less than 1 mm). Sometimes the impression of 2…6 mm in diameter may be regarded as a demerit of the method.



a b c

Fig. 1.7. Principle of hardness tests: a – Brinell test; b – diamond pyramid (Vickers) test; c – Rockwell test

Vickers (diamond pyramid) method enables to avoid the drawbacks mentioned above. It consists in forcing a square-based diamond pyramid (with an angle of 136 degrees between opposite faces) into ground, or even polished, surface being tested (Fig. 1.7b). The Vickers hardness number (HV) is the ratio of the load P (N) applied to the diamond pyramid to the area of the permanent indentation F:

$$\mathbf{HV = 2P\sin(\alpha/2)/d^2 = 1.8544P/d^2},$$

where d – arithmetic average of the two diagonals of the indentation after removing of the load. The average diagonal d is usually converted to the Vickers hardness number by the use of tables supplied with a testing machine.

The applied load changes to suit the thickness of a specimen or surface layers and their hardness. The load may be equal to 10, 20, 50, 100, 200, 300, 500, 1000 N. Such variety of loads as well as the extreme hardness of the diamond pyramid enables to determine a hardness of almost any material. It is possible to measure the Vickers hardness on specimens with the minimal total thickness of 0.03…0.05 mm.

1.3. Table for selection of the Brinell hardness test parameters

Alloy	Brinell hardness number range, MPa	Minimal thickness of the specimen, mm	Diameter of the ball, mm	Ratio between the load P, kgf, and the ball diameter, mm	Load		Time pressure holding, sec
					kgf	N	
Ferrous alloys	1400...1500	From 6 to 3	10.0	$P=30D^2$	3000	29430	10
		From 4 to 2	5.0		750	7357	
		< 2	2.5		187.5	1839	
	<1400	> 6	10.0	$P=10D^2$	1000	9810	10
		From 6 to 3	5.0		250	2452	
		< 3	2.5		62.5	613	
Non ferrous alloys	>1300	From 6 to 3	10.0	$P=30D^2$	3000	29430	30
		From 4 to 2	5.0		750	7357	
		< 2	2.5		187.5	1839	
	350...1300	From 9 to 6	10.0	$P=10D^2$	1000	9810	30
		From 6 to 3	5.0		250	2452	
		< 3	2.5		62.5	613	
	80...350	> 6	10.0	$P=2.5D^2$	250	2452	60
		From 6 to 3	5.0		62.5	613	
		< 3	2.5		15.6	153	

According to the GOST 9012-59 and GOST 2999-75 hardness obtained by Brinell and Vickers methods have the same dimensions and coincide (approximately) for materials with hardness up to about 4500 MPa. They are denoted as follows: HB 230, HV 200 if the measurements are conducted in kgf/mm^2, and HB 2300 MPa, HV 2000 MPa if the measurements are conducted in MPa.

In **Rockwell test** the hardness is determined by the depth of an indentation remained after the removal of a load. The indentor or penetrator is a diamond cone (called a brale) with an apex angle of 120 degrees and radius of 0.2 mm, or a hardened steel ball 1.588 mm in diameter. The brale or ball are indented by two consecutive loads: the minor (preliminary load P_0 equal to 100 N and the main (additional) load P_1 (Fig. 1.7c). The sum of the mentioned loads represents the total load P, which is chosen in accordance with the type of indentor and expected hardness (Table 1.4).

1.4. The Rockwel1 test conditions

Expected Vickers hardness, MPa	Scale	Indentor type	Load, N	Permissible Rockwell hardness number ranges
6000...2400	B	Hardened steel ball	1000	25…100
2400...9000	C	Diamond cone	1500	20…67
3900...9000	A	The same	600	70…85

The hardness number is read directly on the dial of an instrument. Rockwell hardness is determined in conventional units. If the brale is employed, with the total loads of 1500,or 600 N, the hardness number is read on the black scale of the instrument and is denoted by HRC and HRA correspondently. The Rockwell hardness number is conventionally calculated by the formula:

$$\mathbf{HRC(HRA) = 100 - e}$$

where e is found by the formula:

$$\mathbf{e = (h_1 - h_0) / 0.002}$$

h_0 is depth of penetration of the indentor when preliminary P_0 is applied, mm;

h_1 is depth of penetration of the indentor due to the total load P, mm.

When the hardened steel ball is employed, the hardness number is depicted on the red scale shifted (displaced) from the initial point of the black one by 30 units. The formula, therefore modifies:

$$\mathbf{HRB = 130 - e}$$

Thus, in a Rockwell test the hardness is determined by the depth of the indentation (after application of the two consecutive loads P_0 and P_1), but not by its diameter or diagonals. The indicator's pointer marks not the depth, but the value of (100-e) on the black scale and (130-e) on the red one. It is necessary to take into account that Rockwell hardness numbers determined by different scales do not coincide. Scales A and C are used for testing rather hard materials and scale B for softer ones. The specimen thickness for Rockwell tests has to exceed 0.5…1 mm (8 depths of an indentation).

The correspondence between hardness numbers determined by different methods is shown in Fig. 1.8. The Vickers hardness scale is recognized to be the basic standard for comparison in this case.

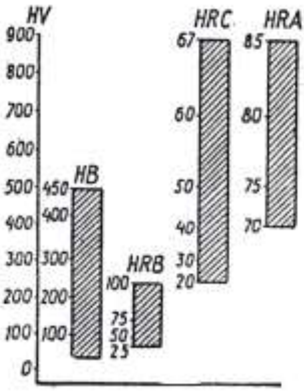


Fig.1.8. Relationship between hardness numbers determined by different methods.

Equipment, instrument, materials

Brinell, Vickers and Rockwell hardness testing machines;
Specimens - 15x50x100 mm of steels, grades 10, 25, 45, У7, У10, У13 after normalizing, grades У10 and У13 after hardening and low-temperature tempering;
srecimens of copper, aluminium, brass and bronze.

The work must be executed as follows. Study the design and working principle of Brinell, Vickers and Rockwell hardness testing machines. Make acquaintance with safety precautions. Master the test technique.

Determine the hardness number of the materials (each subgroup investigates 1…2 alloys according to the task). Compare the hardness numbers determined by Brinell and Vickers methods for the steels after normalizing. Calculate the tensile strength for carbon steels from the dependences between hardness and strength. Compare the calculated data with the experimental one, obtained during the 1.2 work execution.

Plot the graphical dependences of normalized steel hardness upon carbon content using the tables.

Establish a relationship between the tensile strength and the hardness for carbon steel. Compare the coefficient value known from literature and obtained experimentally.

Contents of the report. The report must contain the following: the calculating formulas for hardness number determination by 3 methods; the hardness numbers of investigated alloys; the calculating procedure for tensile strength determination as a function of Brinell hardness number; graph of the dependence between hardness and carbon content in steel.

1.4 DETERMINATION OF IMPACT STRENGTH OF METALS

Purpose of the work: to study the design and operation of a pendulum-type impact testing machine; to master the impact strength determination technique; to investigate the influence of carbon content on strain (reduction in area) of impact specimens and impact strength of carbon steel.

Theory. Many parts and structures in normal operational conditions undergo impact loading that promotes brittle fracture. Susceptibility to brittle fracture is enhanced by increase in loading rate and grain size, decrease in temperature, and presence of notches. Chemical content also influences the impact strength: it is reduced with the increase in content of carbon and detrimental impurities, such as sulphur, phosphorus, hydrogen, nitrogen and oxygen. Static tests do not reveal the resistance of materials to brittle fracture. Therefore the dynamic tests are used.

The dynamic impact bending tests (GOST 9454-78) are the most wide spread. They are of the most severe type and promote brittle fracture. Notched-bar test specimens are commonly used in these tests. The impact strength KC is determined as a ratio of the work required to fracture the specimen to its cross-sectional area and, hence, represents the specific work required to fracture. The area is gauged (at the notched section before fracture (specimens of brittle materials do not require notches). The impact strength is normally denoted (signed) in accordance with the form of the notch (U-notched specimen with the notch radius of 1 mm; V-notched, with the radius of 0.25 mm (Charpy) and crack-notched): KCU, KCV and KCT correspondently. The work required to fracture decreases with the decrease in notch radius.

The initial angle through which the pendulum of mass P (Fig. 1.9) is raised corresponds to the potential energy level of PH. After the test (impact) and fracturing of the specimen the pendulum raises up to the height of h and possesses the energy level Ph. The work required to fracture is equal to the loss of potential energy:

$$\mathbf{K = PH - Ph}, \quad \textbf{or}$$

$$\mathbf{K = Pt\,(\cos\alpha_2 - \cos\alpha_1)} \quad ,$$

where t is length of the pendulum, m;

α_1 is angle to which the pendulum is raised before the impact**;**

α_2 is angle to which the pendulum raises after fracturing the specimen.

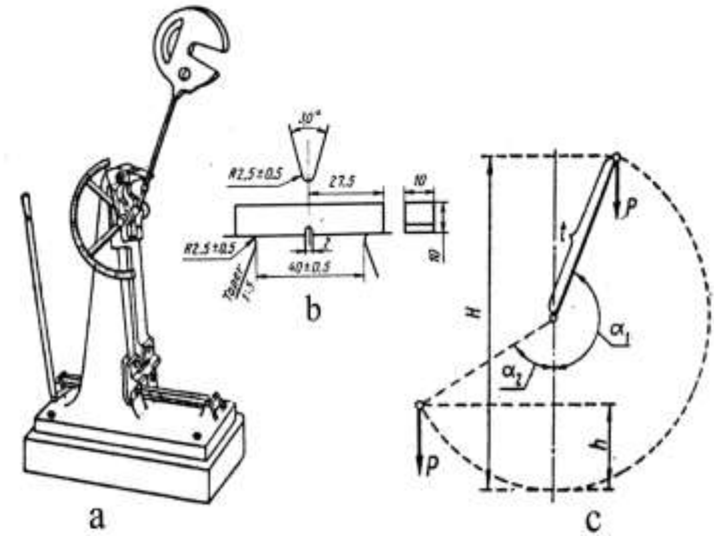


Fig. 1.9. Pendulum-type impact testing machine (a); notched-bar test specimen (b); principle of the impact test (c)

The initial angle α_1 is a constant value and the angle α_2 is measured on a dial gage of the machine. Special tables are available for determining the work K, J. These tables list the work of impact for each value of the angle α_2 . Next, the impact strength may be found by the formulas

$$\mathbf{KC = K/F},$$

where F is the cross-sectional area of the specimen at the notch before fracture (normally 80 mm^2).

The impact strength mainly depends on work consumed in deforming the specimen before rupture, i.e. on plasticity of a material. Reduction in width of the specimen after fracture may be regarded as one of the plasticity characteristics. According to this index the reduction in area of the specimen may be determined as follows:

$$\psi = (b_0 - b_1) \cdot 100\% / b_0 ,$$

where b_o and b_1, is width of the specimen before and after the test correspondently, mm.

Equipment, instrument and materials

Pendulum-type testing machine	1
Dimension gauge	6
Specimen set device	1
U-notched specimens of steels, grades 10, 25, 45, У7, У10, У13 after normalizing	3 (of the each grade)

The work must be executed as follows. Make acquaintance with safety precautions for the impact tests. Study design and operation of the pendulum-type impact-testing machine. Gauge the specimens, test them, determine the impact strength and reduction in area for each steel grade, and fill the results in the form (Table 1.5). Plot the graphical of dependences between impact strength and carbon content in steel and also between impact strength and reduction in the area.

Make a conclusion about the influence of carbon content and plasticity on impact fracture resistance of steel.

Contents of the report. Depict the sketch of the impact specimen; the principal testing scheme; testing form; graphical dependences between the impact strength and such characteristics of a material as carbon content and reduction in area of specimens. Make inference about carbon content influence on impact strength and plasticity and characterize the dependence between impact strength (toughness) and plasticity in accordance with the data obtained.

1.5. The form for impact strength tests

Steel grade	Number of the specimen	Dimensions of the specimen , mm				α_1, deg	α_2, deg	K, J	KCU, J/m^2	ψ, %
		b_0	b_1	h	F, mm^2					

2 METALLURGY

2.1 *MANUFACTURE OF PRODUCTS BY POWDER METALLURGY PROCESS*

Purpose of the work. To make acquaintance with powder metallurgy process; to get experience in burden calculation procedure and in assessing the molding pressure required.

Theory. Powder metallurgy is known to be a field of engineering that covers such processes as powder (of metals, chemical compounds or ceramics) production and molding the articles of the mentioned powders without melting those. A powder metallurgy process comprises the following stages: powder production and sorting, a necessary mixture of the powders (burden) preparation, molding of a powder article, sintering that renders an article proper strength and finishing (impregnation, machining, sizing, etc).

The main advantage of a powder metallurgy process is considered to be the manufacture of materials that are impossible to produce by any other method: porous articles (filters); self – lubricating bearings (porous metal base impregnated with mineral oil, sulphur, sulphides and other substances); metal-ceramic composites (bronze-graphite, for instance); wear- and heat-resistant materials of high-melting carbides, nitrides, borides, silicides, phosphides; materials with specified electrical, magnetic and other properties.

Conventional manufacture processes in industry are inseparately linked with the significant losses of metal: 15…25% during riser and bottom ingot parts removal (2…5% in case of continuous pouring); 2…5% while rolling and forging as a result of oxidation, cutting, dimension defects; 20…50% during machining. Powder metallurgy process provides the total loss value not exceeding 3…5%. Therefore, it is available to employ powder metallurgy methods, besides mentioned cases, also in mass production of simple articles such as washers, spacers, levers, gears, bushings etc. Flash absence and machining exception gives the main contribution to substantial saving in starting materials and expenses. It has been estimated that 1000 tons of iron powder articles facilitate saving in rolled products or castings of 2000…2500 tons, enables up to 80 units of machining equipment and approximately 200 skilled workers to be available for another occupation.

The most commonly used process is the cold molding (Fig. 2.1) with one-sided or double-sided pressing. One can also enumerate other powder molding methods: extrusion, rolling and hydraulic press molding.

Properties of powder articles are primarily determined by their porosity PR (percentage of pors in total article volume) and density γ_a. Certain relationship exists between the mentioned values:

$$\mathbf{PR = (1 - \gamma_a / \gamma_S)\cdot 100\%,}$$

where γ_a is density of an article after sintering, g/cm^3 ;

γ_S is density of an article without pors, g/cm^3.

Density of mixtures is usually determined by the additive rule:

$$\boldsymbol{\gamma_k = (a_1\gamma_1 + a_2\gamma_2 + a_3\gamma_3 + ... a_n\gamma_n)/100\%}$$

where γ_1, γ_2, $\gamma_{3,...}\gamma_n$ is density of separate mixture components, g/cm^3;

a_1, a_2, a_3,….a_n is mass content of separate components in mixture, %.

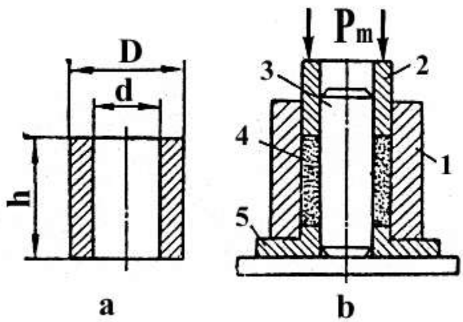


Fig.2.1. Draught of the bushing (a) and its manufacture scheme (b): 1 – bed mould; 2 – top mould; 3 – core; 4 – article (bushing); 5 – base

Porosity and density of sintered materials are determined by molding pressure. Hence, assuming the porosity or density of a finished article, molding pressure, $\mathbf{P_m}$ (Fig. 2.2) and, next, manometer pressure P are determined:

$$\mathbf{P = P_m S_{CS}/S_{Pl}\ ,\ MPa}$$

where P is monometer pressure in the hydraulic press, MPa.

P_m is molding pressure (pressure per cross-sectional unit of an article), MPa;

S_{CS} is cross-sectional area of an article, m^2;

S_{Pl} is cross-sectional area of a press plunger, m^2.

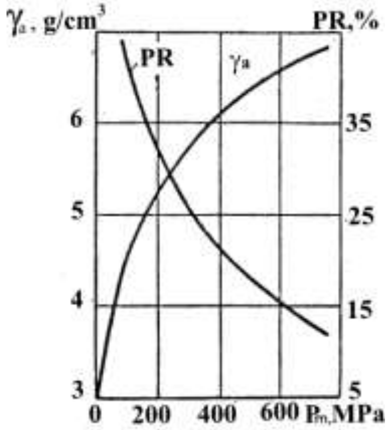


Fig.2.2. Dependence of porosity PR and density γ_a of iron powder article upon molding pressure P_m

The necessary powder quantity Q, g, for manufacture of an article is calculated by the formula:

$$Q = \gamma_S V(1 - PR/100)\ K,$$

where V is volume of a sintered article, cm^3;

K is coefficient, that corrects for mass losses while molding and sintering, equal to 1.01…1.03.

Equipment, instrument, materials.

Hydraulic press	1
Mould	5...6
Mixer	1
Sintering furnace with argon atmosphere	1
Technical balance (scales)	5...6
Dimension gauge	5...6
Iron powder, kg	3
Copper powder, kg	0.3
Graphite powder, kg	0.3
Oil for mould lubrication, kg	0.5

The work must be executed as follows. Study the drawings of the articles and the mould design. Weigh the mixture components according to the given mass percentage: iron powder – 95.5, copper powder – 2.5, graphite – 2. Mix the components by the mixer. Calculate and weigh the necessary amount of the powder mixture Q.

According to the article's density, given by an instructor, determine the molding pressure (Fig. 2.2). Calculate the manometer pressure in correspondence with the dimensions of article. Mould the article by the hydraulic press.

Sinter the powder article. Gauge its dimensions and estimate volume. Determine its real density and porosity. Compare the given and real data.

Contents of the report. Describe briefly the essence of powder metallurgy. Present the sketches of the article, calculations for the sample amount, manometer pressure, density and porosity after sintering.

2.2 CALCULATION OF HARMFUL EMISSIONS FROM A BLAST FURNACE

Purpose of the work: to become acquainted with influence of blast-furnace process on ecological conditions of the environment; to practice making calculations of harmful gases emissions at selection of blast-furnace technology.

Theory. A blast furnace is intended to manufacture cast iron (steelmaking, foundry and mirror cast iron) and ferroalloys (ferromanganese and ferrosilicon). Coke is used both as a fuel and as a reducer of iron, manganese, silicon, etc. elements in the blast furnace. Coke has the following composition: 80...88% of carbon, 0.5...1.8% of sulphur, 0.02...0.2% of phosphorus, 8...12% of ashes, 2...5% of a moisture. The coke consumption for production of the basic blast furnace product – steelmaking cast iron – varies from 400 up to 550 kg/ton of cast iron depending on temperature of blasting, quantity of additional kinds of fuel (coal dust, natural gas) and other factors.

Blast furnace gas is a result of coke combustion and oxidation-reduction reactions occurring in the furnace. It has the following composition (mass%): 12...20 $C0_2$, 20...30 CO, 1...8 H_2, to 0.5 CH_4, to 0.8 NO_2, 50...58 N_2. Physical and chemical heat of blast furnace gas is used in air preheaters (stoves) where it is reburned together with natural or coke gas and then exhausted out to atmosphere. In general, practically all carbon of coke is released in atmosphere as carbonic gas CO_2, as well as 10...20% of sulphur entered the furnace with coke and ore is exhausted as sulphur dioxide (the rest of sulphur is distributed between metal and slag). Moreover, about 10 kg of nitrogen dioxide is formed while burning 1 ton of coke.

On the difference to sulphur and nitrogen oxides, carbonic gas CO_2 is not referred to toxic chemical compounds. Its content in atmosphere normally makes 0.03%. Carbonic gas lets in visible sunlight from the Sun to the Earth and detains a part of the infra-red radiation reflected from the Earth. Due to so-called "hotbed effect" created by this gas, the stable climate on the Earth is maintained. During the last 25 years (as a result of operation of heat power stations, automobile transport, metallurgical plants, etc.) CO_2 content in an atmosphere has been increased by 10%. As calculations showed, further increase in CO_2 concentration will lead to rise in average annual temperatures (i.e. to warming of climate), melting of glaciers in Antarctica and Greenland, rise in world ocean level by 6...8 m and flooding of a significant part of the land.

Nitrogen and sulphur oxides emitted out in atmosphere react with water and form nitric and sulphuric acids, which in form of "acid rains" drop out on the Earth. Nitrogen and sulphur oxides are toxic gases, their maximum permissible concentration (MPC) in air should not exceed 0.085 and 0.05 mg/m^3 correspondently. "Acid rains" result in souring of soils and appropriate decrease in their productivity, in death of plants and animals in water basins, in the accelerated destruction of buildings, architectural monuments, technical constructions, etc.

In recent years especially high attention is paid to environmental problems while designing and putting into operation of modern manufactures, and, in particular, metallurgical plants. There are two ways for reduction of highly toxic emissions from blast-furnace process: (1) development and installation of clearing facilities and (2) transition to direct production of iron (to eliminate blast-furnace process). Clearing facilities in turn demand the significant power expenses. Therefore, direct production (reduction) of iron is preferable among modern trends in development of metallurgy.

The order of performance of the work

1. Every group of students has to receive the individual task from the table 2.1 and fulfill them under the instruction of their teacher.

2. Determine quantity (mass) of carbonic gas, sulphur and nitrogen dioxides, formed within a day, m_i, ton/day:

$$\mathbf{m_{CO2}=0.0312QPC;}$$
$$\mathbf{m_{SO2}=0.02QPS\eta_s;}$$
$$\mathbf{m_{NO2}=QPN,}$$

where Q is daily productivity of the blast furnace, ton/day; P is the consumption of coke on 1 ton of melted cast iron , ton/ton (in the given laboratory work P=0.5 ton/ton is accepted); C is carbon content in coke, % (C=85% is accepted); S is sulphur content in coke, %; η_s is the share of sulphur which is burning down in the blast furnace (η_s=0.15 is accepted); N is the quantity of nitrogen dioxide produced at combustion of 1 ton of coke (N=0.01 is accepted).

Table 2.1. Individual tasks

No of the Task	Blast furnace Productivity, Q, ton/day	Sulphur Content in Coke, S,%	No of the Task	Blast Furnace Productivity, Q, ton/day	Sulphur Content in Coke, S,%
1	2000	0.4	16	2000	1.6
2	4000	0.4	17	4000	1.6
3	6000	0.4	18	6000	1.6
4	8000	0.4	19	8000	1.6
5	10000	0.4	20	10000	1.6
6	2000	0.8	21	2000	2.0
7	4000	0.8	22	4000	2.0
8	6000	0.8	23	6000	2.0
9	8000	0.8	23	8000	2.0
10	10000	0.8	25	10000	2.0
11	2000	1.2			
12	4000	1.2			
13	6000	1.2			
14	8000	1.2			
15	10000	1.2			

In formulas for determination of carbonic gas and sulphur dioxide quantities nuclear weights of corresponding elements and their ratio have been already taken into account.

3. Determine volume of the carbonic gas formed within a day:

$$\mathbf{V_{CO2}=10^3 m_{CO2}/\rho_{CO2},\ m^3/day,}$$

where $\boldsymbol{\rho_{CO2}}$ – density of carbonic gas, kg/m^3 (ρ_{CO2}=1.98 kg/m^3).

4. Calculate the daily volume of air polluted by sulphur and nitrogen acids up to maximum permissible concentration (MPC):

$$\mathbf{V=10^9 m_i/П,\ m^3/day,}$$

where $\mathbf{m_i}$ – weight of dioxides (sulphur or nitrogen), produced within a day, ton/day; Π – maximum permissible concentration of corresponding gas, mg/m^3 ($\mathbf{\Pi_{SO2}}$=0.05 mg/m^3 and $\mathbf{\Pi_{NO2}}$=0.85 mg/m^3 are accepted).

5. Compare results by emission of the harmful gases, received by various subgroups, and propose corresponding conclusions.

The contents of the report

1. Specify the harmful gases which are included in emissions of a blast furnace, and the reasons of their formation.
2. Write down the initial data of the individual task.
3. Perform calculations on definition of weight of emissions and the volumes of air, polluted by them.
4. According to the data obtained by several groups of students plot the graphs of influence of harmful gases emissions on productivity of the blast furnace and content of sulphur in coke.
5. Make conclusions based on analysis of the graphs featured the influence of productivity of blast furnaces upon amount of harmful emissions and propose recommendations on their decrease.

2.3 ANALYSIS OF ENERGY CONSUMPTION OF DIFFERENT STEEL PRODUCTION TECHNOLOGICAL PROCESSES

Purpose of the work: to analyze energy consumption of steel production methods, depending on type of technological process and composition of initial charging materials.

Theory. Metallurgy is one of the most energy-intensive processes. Therefore total expenses of energy and a degree of its consumption for a unit of production may be used as an index of the basic economic expenses for manufacturing cast iron, steel and other metals.

Total expenses of energy are the integrated parameter displaying energy expenses both in technological process of metal obtaining, and at all stages of manufacture previous to this technological process, including extraction (mining), processing and transportation of power resources (natural gas, coal, etc.) and raw materials (ore, fluxes, liquid cast iron , refractory materials, etc.).

The basic methods of steel production: in oxygen converters, in open-hearth and electric arc furnaces, - differ both in power consumption (i.e. on production expenses) and in quality of finished goods. At the same time even within the limits of one steel production method, change in structure of initial charge allows changing essentially both expenses for finished goods, and quality of produced steel. The opportunity to reveal the most modern and economically effective process to produce steel of necessary quality is offered in this laboratory work.

Oxygen - converter process is a method of steel melting from liquid steelmaking iron in a converter with the basic lining by blowing through the liquid of pure oxygen. Oxygen is submitted from above through water-cooled lance. This method has a number of advantages:

- High productivity (up to 400…500 ton per hour);
- Low capital expenses for construction of converter departments;
- Process is convenient for automation of melting.

It is possible to process liquid steelmaking-iron of any content in oxygen converters. Due to use of pure oxygen, heat of oxidation of carbon, silicon, manganese and phosphorus contained in cast iron is more than sufficient for heating of steel to the temperature necessary for passing of the basic physical and chemical melting processes. Surplus of heat allows to convert a significant amount of metal scrap (up to 25…30 % of weight of cast iron).

Low-carbon structural quality steels are normally produced in oxygen converters. Introduction of alloying elements during converter melting is hindered by an oxidizing atmosphere and, therefore, by rather fast oxidation of alloying elements in volume of liquid metal. Thus, the content of alloying elements in steels does not exceed 2…3%.

Increase up to 100 % of scrap share in converter charge has proved to be a perspective technological solution. Oxygen-converter process with the increased share of scrap in charge (so-called oxygen - fuel process) is carried out in converters with combined blasting. Intensive heating (and fusion if necessary) of solid metal charge is carried out due to natural gas being submitted into the unit through lateral torches. Gas combustion and partial reburning of carbon oxide in the converter also produce necessary additional amount of heat.

Open-hearth process is carried out on a hearth of a flame reverberatory furnace with regenerators. Charging materials (liquid iron, scrap, ore, ferroalloys, etc.) are loaded into the furnace and are melted gradually under the effect of flame created by burning fuel. Various additives are given into the furnace bath after fusion to receive metal of the necessary chemical composition and temperature.

The process is carried out during 5…8 hours. This time is sufficient to modify the chemical composition of melted steel. Therefore it is possible to produce steel of any chemical composition (including alloyed steels) in open-hearth furnaces. But productivity of furnaces attains 70…80 ton per hour that is lower (in 6…10 times) than productivity of oxygen converters. Their construction and operation require significant capital expenses. Therefore new open-hearth furnaces are not under construction now.

Pig-and-ore as well as scrap-and-ore processes are distinguished depending on a ratio of initial components in charge of the open-hearth furnace.

Pig-and-ore process is used when blast furnace, open-hearth and rolling shops are included into structure of a production plant. It allows delivering pig-iron (steelmaking-iron) to open-hearth shop in liquid state. Charging materials in cast-and-ore process consist of liquid iron (50…70 %) and waste products of own metallurgical manufacture as well as purchased scrap (the rest). Carbon content in metal is adjusted by variation of iron ore quantity in the charge. Normally iron ore consumption constitutes 12…16 % of metal charge weight. With increase in ore content in the charge the carbon content in melt decreases. Open-hearth cast-and-ore process is carried out in big furnaces (up to 300 tons) with application of oxygen for intensification of physical and chemical processes of melting.

Scrap prevails in structure of charge for scrap-and-ore process. The small amount of cast iron is given into charge in solid state. The ratio between scrap and cast iron quantities charged into the furnace is determined by scrap and cast iron composition, oxidizing ability of the furnace and grade of steel to be melted. Carbon content in steel depends on quantity of cast iron in charge. If there is no cast iron in charge, or charge contains insufficient amount of cast iron, the deficiency of carbon is filled up by carburizers (coal, coke, electrode breakage, etc.). Scrap-and-ore process is realized in furnaces of the middle tonnage (150…200 ton) without application of oxygen.

In electric-arc furnaces a source of heat is the arc burning between electrodes and metal charge or between electrodes. By adjusting electric parameters of an arc, it is possible to influence carrying out of steel-smelting process essentially. Metal scrap, including alloyed waste products, is used as charging materials. If it is necessary to oxidize excessive carbon and other impurities, iron ore or oxygen are submitted into a furnace. At the same time it is possible to create an inert or reduction atmosphere in the furnace for melting of high-alloy steels. Productivity of electric arc furnaces ranges from 80 to 120 ton per hour.

In electric furnaces it is possible to produce steel and alloys of any composition with the minimum content of harmful impurities, nonmetallic inclusions. Therefore high-alloy, tool, corrosion-resistant, heat-resistant and high-temperature steels as well as alloys of crucial assignment are smelted only in electric furnaces.

Now in steel manufacturing in connection with wide use of insufficiently well-sorted scrap there is a problem of contamination of metal by undesirable alloying elements (in particular copper). Up to 80 % of metallized pellets, obtained by direct reduction of iron ore, are included in charging materials of electric arc furnaces for high purity steel production.

Seven technological processes are analyzed within the framework of the present laboratory work:

1. Oxygen-converter process with 100% of liquid steelmaking iron as charging materials;
2. Oxygen-fuel process, in which charging materials consist of 50% of liquid iron and 50% of solid steel and cast iron scrap;
3. Oxygen-fuel process, in which all charging materials consist of solid scrap;
4. Open-hearth cast-and-ore process with metal scrap share of 45%;
5. Open-hearth scrap-and-ore process, in which 100% of scrap is used;
6. Electric-arc process in which 100% of scrap is used;
7. Electric-arc process with 25% of scrap and 75% of metallized pellets in charge.

Charge composition, consumption of electric energy and other auxiliary materials for each technological process, as well as specific energy consumption for production of each charging component are given in the table 2.2.

2.2. Charge composition for production of 1 ton of carbon steel and specific energy consumption for charge components

Components of charge and materials to be consumed	Specific energy consumption E_i, MJ per unit	Consumption of materials, m_i, units, depending on variant of technological process						
		1	2	3	4	5	6	7
Cast iron, kg	23.8	1280	605	–	597	–	–	–
Metal scrap, kg	0.2	–	495	1093	489	1080	1064	300
Metallized pellets, kg	14.0	–	–	–	–	–	–	900
Ferroalloys, kg	62.7	15	15	15	15	15	15	15
Coke, kg	40.4	–	–	–	–	30	6	–
Anthracite (hard coal), kg	31.0	–	14	85	–	–	–	–
Black mineral (furnace) oil, kg	41.0	–	–	–	20	50	–	–
Natural gas, m^3	37.6	–	11	37	50	130	–	–
Electrodes, kg	186.0	–	–	–	–	–	4.7	7.0
Oxygen, m^3	5.8	52	82	115	40	–	25	12
Refractory materials, kg	16.5	5	6	10	11	15	12.3	16.5
Lime, kg	5.4	80	70	70	10	10	70	70
Electric energy, kW·h	11.25	–	–	–	–	–	540	665

The order of performance of the work

1. An academic group should be divided into subgroups of 3…4 students. Each subgroup should analyze (under the instruction of the teacher) one of the technological processes of steel production described above.

2. After reception of the task on the technological process, the following data should be written out of the table 2.2: (1) quantity m_i of charge components and other consumable materials, necessary for 1 ton of carbon steel production; (2) specific energy consumption, necessary for production of each component of charging materials E_i.

3. Amount of primary energy consumed in production of 1 ton of carbon steel for the selected technology should be calculated summarizing power expenses on each component:

$$\mathbf{E = \Sigma(E_i \cdot m_i).}$$

4. Consumption of primary energy for production of 1 ton of carbon steel by various technological processes should be compared on the basis of data obtained by various subgroups.

The contents of the report

1. Describe briefly the basic methods of steel production: oxygen-converter, open-hearth and electric-arc; their peculiarities, merits and demerits, fields of application.

2. Describe in details technological features of the analyzed (according to instruction of a teacher) technological process of steel production.

3. For investigated technological process write down in tabular form quantity of each component consumed in melting m_i and specific energy consumption necessary for production of each component E_i. Write down calculations of power consumption for manufacture of 1 ton of steel for selected technological process.

4. According to the data obtained by various subgroups compare energy consumption for manufacture of 1 ton of steel in all surveyed technological processes of steel production.

5. Make conclusions on the work performed, having defined the best and the worse among the considered methods of steel production by the following parameters: energy consumption (manufacture expenses); productivity; quality of obtained steel.

6. Note merits and demerits of the technologies in which significant amount of steel scrap is provided to be utilized.

3 FOUNDRY PRACTICE

3.1 SAND MOULD CASTING

Purpose of the work: to study the sand mould -foundry practice; to assess the metal utilization coefficient and quality of castings.

Theory. Foundry is one of the main preparatory bases of modern industry. Intricate castings (blanks or finished products) are the usual foundry products manufactured by pouring molten metal into moulds.

Foundry accounts for almost 66.7% of total blank production in machinery-building, 49% – in tractor and agricultural machine-building, 40% – in chemical and oil machine-building, 33.7% – in automobile-producing, 32.6% – in instrument-producing, 32.5% – in civil and road engineering machine-building industries (for 1987). Such extent may be attributed to possibility of castings 0.5...500 mm and over in width, from a few grams to hundreds of tons in mass, of intricate shape and wide alloy range to be manufactured. Casting frequently occurs the only (unique) process to obtain a proper shape.

The world overall foundry production nowadays exceeds 80 mln tons annually. Approximately 70% of them are manufactured in sand moulds, because of simplicity and universality of the process.

For expendable mould manufacturing, besides molding materials, the following set is needed (Fig. 3.1): pattern of a future casting; core boxes in case if there are openings or cavity in the casting; gating system patterns; pattern board (hand molding) or pattern plate (machine molding), etc.

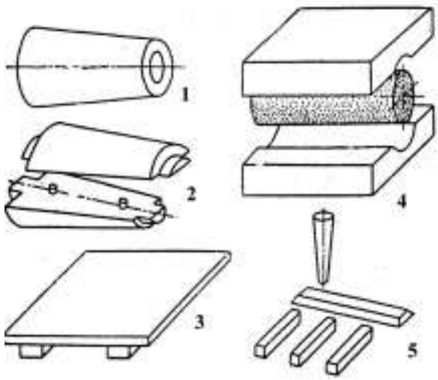


Fig. 3.1. Casting and set of patterns and molding accessories: l – casting; 2 – pattern; 3 – molding board; 4 – core box with core; 5 – gating system pattern

Pattern's dimensions are in excess of casting's ones by shrinkage value. Split structure of a pattern and tapers promote its easy withdrawal from a mould. Wooden patterns are usually employed in hand (manual) molding. Aluminium or steel half-patterns and gating system patterns are disposed on a metal pattern plate in machine molding. Core boxes of wood or metal are intended to manufacture cores used for cavity (openings) formation.

Metal frames (flasks) promote sand containment in molding, transportation and pouring.

Molding materials include molding and core sands. Molding sand consists of used sand and fresh materials: sand (fireproof base), fireproof clay (binder) and water (service ingredients). Three kinds of molding sands are distinguished: facing, backing (hand molding) and unified (machine molding) sands.

So far as cores (except core prints) are surrounded while pouring by molten metal, core sand should exhibit higher strength, gas permeability and compliance in comparison with molding one. It contains, besides clay bond, or instead of it, other binders (pitch, oil), sawdust and peat (for proper compliance during crystallization).

Hand molding in two mould sections over split pattern has found the wid est use. Pattern drag (bottom half) is disposed on a pattern board with its joint face abut on the board (Fig. 3.2) and a drag flask is mounted next. The flask is filled at first with facing and then with backing sand and rammed. The flask has to be turned over. The upper (cope) half-pattern is joined to the drag one and, next, the upper flask has to be set up. After setting up of the gating system pattern, filling the flask with sand, the last must be rammed in much the same way. Then the upper half-mould is removed and the patterns are withdrawn.

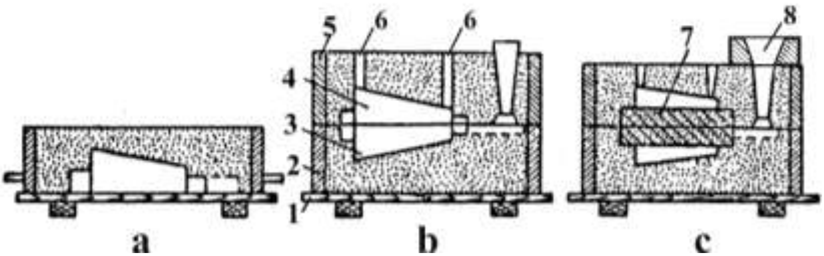


Fig. 3.2. Hand two-part molding: bottom half-mould (a) and top half-mould (b) molding; c – assembled mould: 1 – molding board; 2 – bottom flask; 3 – bottom half-pattern; 4 – top half-pattern; 5 – top flask; 6 – gas relief sprue pattern; 7 – core; 8 – gating system

Hand molding is employed in individual and batch-production. Nevertheless, low productivity and high manual labour consumption are the demerits peculiar to this process. The main drawbacks of castings produced in hand-manufactured moulds are following: rough surface and inaccuracy of dimensions.

Equipment and materials

Crucible furnace	1
Pouring ladle	1
Pattern	5...6
Core box	5...6
Flasks, as a set	5...6
Gating system pattern, as a set	5...6
Molding accessories, kit	5...6
Zinc alloy ЦАМ 10-4, kg	12
Molding sand, kg	180
Article manufactured of the casting	5...6
Set of surface roughness basic standards	1
Dimension gage	5...6

The work must be executed as follows. Make acquaintance with molding equipment, accessories and materials.

Manufacture drag and cope half-moulds, as well as cores for 5...6 types of castings. Assemble the moulds. Pour the molten metal into the moulds. After crystallization and cooling shake out the castings. Give them a close visual inspection to make sure that no defects occured. Assess the surface roughness by means of the basic standards. Gage the main casting dimensions. Compare them with the dimensions of finished article and determine stocks allowed for machining. Calculate the coefficient of metal utilization after weighing the casting and the finished article:

$$\mathbf{K = (Q_1 / Q_2)\ 100\%,}$$

where Q_1 is mass of the finished article, kg;

Q_2 is mass of the casting with gating system, kg.

Content of the report. Outline the stages of molding process. Draw the assembled mould and specify its components. Present the surface roughness data, stacks allowed for machining and metal utilization coefficient value.

3.2 CASTING IN METAL MOULDS

Purpose of the work: to study the metal mould casting technology; to assess casting's quality and metal utilization coefficient; to compare the obtained data with the same indices for castings manufactured in sand moulds; to study the temperature effect on quality of castings.

Theory. Metal mould casting process has several obvious merits over sand mould casting practice: repeated many times utilization of a mould (up to a few of tens thousands); fine-grained, dense metal structure and high mechanical properties of castings; accuracy and stability of dimensions; small stocks allowed for machining; comparatively high productivity and low manufacturing cost.

The technology distinctions are attributed to high cooling rate, the lack of gas permeability and compliance of metal moulds. To reduce chill (cooling) rate metal moulds are coated with a fireproof cladding and paste and heated up to 100…450°C before pouring (Fig.3.3).

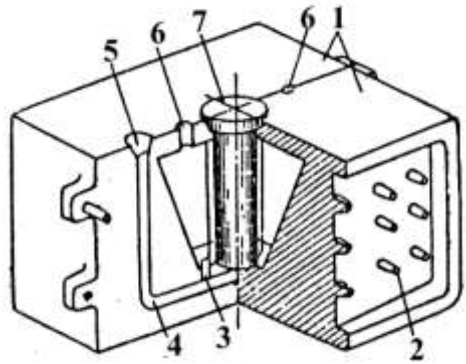


Fig. 3.3. Metal (chill) mould:

1 – half-moulds; 2 – dowels for high-rate heat removal; 3 – runner (ingate); 4 – sprue (downgate); 5 – pouring basin; 6 – gas relief sprue; 7 – metallic core.

The drawbacks of metal mould casting are the following: significant cost of metal mould; difficulties with intricate shape castings manufacture (especially in case of thin-walled castings); possibility to chill cast iron products.

Equipment and materials

Crucible furnace	1
Pouring ladle	1
Metal mould	5…6
Thermocouple (group XA)	1
Article manufactured of casting	5…6
Set of surface roughness basic standards	1
Technical scales	1
Dimension gage	5…6
Zinc alloy ЦАМ 10-4, kg	20

The work must be executed as follows. Heat the moulds up to 150…200°C and coat their internal surface with the refractory paste.

Melt the alloy ЦАМ 10-4. Pour the alloy into metal moulds with surface temperature of 20, 100, 150, 200, 250, 300°C (the pouring temperature must be equal to 420°C).

Withdraw the castings from the moulds. Make their close visual inspection to reveal surface cast defects. Assess the surface roughness by means of the basic standards. Determine stocks allowed for machining and metal utilization coefficient. Make a conclusion about metal mould temperature effect on surface quality of castings and filling up of moulds.

Contents of the report.. Describe the essence of metal mould casting process, its merits and demerits. Characterize the manufactured casting's quality, record stocks allowed for machining and metal utilization coefficient.

Present data about metal mould temperature effect on quality of castings.

3.3 CENTRIFUGAL CASTING

The purpose of the work: to become acquainted with the technology of centrifugal casting; to study influence of frequency of rotation of a mould on quality of casting.

Brief theoretical data. Centrifugal casting holds the lead among the special casting processes by the volume of production of cast items. The method involves pouring of liquid metal into a revolving mould, which continues to rotate at a definite speed during the entire period of metal crystallization. The metal is held against the wall of the metal mould by centrifugal force, so the casting acquires a dense structure of increased strength because segregated gases and slag move to the center of the casting under pressure applied to the metal. Impurities on the inner surface of the casting may be removed afterwards by boring operations.

Any symmetrical object may be cast by rotating the mould around its horizontal or vertical axis. In both cases the axis of rotation coincides with the axis of the casting, the wall thickness being determined by the amount of the metal poured. In casting of small shaped pieces the axis of rotation may not coincide with the axis of the piece. This method is known as centrifuge casting.

Centrifugal casting is used for individual, batch and mass production of items of various alloys in metal and shell moulds. The range of cast products includes pipes, bushings, sleeves, liners, piston rings, wheels, pulleys, barrels and two-layer (bimetallic) objects. Centrifugal casting is the most widely used for production of iron pipes.

The frequency of rotation affects significantly the quality of castings. Too low frequency prevents from obtaining the exact cylindrical shape. Too high frequency results in formation of hot cracks. The optimum frequency for devices with horizontal axis may be calculated by Konstantinov's formula:

$$\mathbf{n = 17456 / \sqrt{\gamma\, r}}\ ,$$

where n is frequency of rotation, rpm; γ is density of cast alloy, kg/m^3; *r* is radius of the inner surface of a casting, m.

Design of the laboratory unit. The laboratory unit with a horizontal axis of rotation (Fig. 3.4) consists of a direct current electric motor 1, a laboratory autotransformer 7 for regulation of frequency of rotation of cast iron mould 4, an AC rectifier (it is not shown in the scheme), a voltmeter 8, a scale and a pointer of which show frequency of mould rotation. With the help of the autotransformer, frequency of rotation of the electric motor is changed from 200 up to 3000 rpm.

Equipment and materials, pcs

Crucible furnace	1
Pouring ladle	1
Laboratory unit for centrifugal casting	1
Technical scales	1
Zink alloy ЦАМ 10-4, kg	10
Dimension gage	5…6

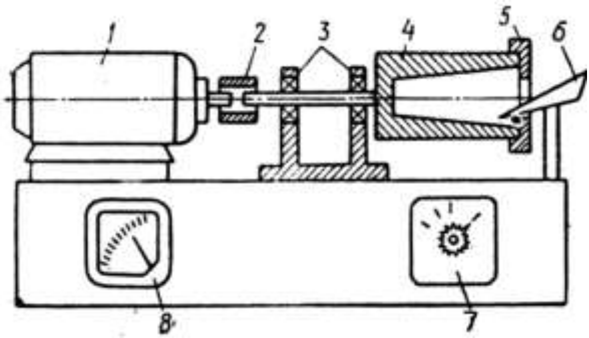


Fig. 3.4. Design of the laboratory unit for centrifugal casting:

1 – electric motor; 2 – coupling; 3 – bearing parts; 4 – mould; 5 – cover; 6 – pouring spout; 7 – rotation frequency regulator; 8 – rotation frequency indicator

The order of performance of the work. Become acquainted with the device and working principle of the laboratory unit for centrifugal casting.

According to a drawing of a workpiece, determine optimum frequency of rotation of the mould by Konstantinov’s formula.

Heat the mould up to 100…150 ^{o}C and paint it as well as a pouring ladle.

Switch the unit on, with the help of the regulator establish frequency of rotation equal to 15; 20; 40; 70; 100 and 150% of design (calculated) value.

Pour liquid metal in the rotating mould.

Weigh the casting after cooling, weigh the workpiece and determine the coefficient of metal utilization. Compare the coefficient with the similar indices for casting in sand and metal moulds.

Estimate quality; make a conclusion on influence of frequency of rotation of the mould on this parameter.

The contents of the report. Describe briefly the essence and depict schemes of centrifugal casting. Give calculation of frequency of rotation of the mould and the data on the coefficient of metal utilization for the method. Describe influence of frequency of mould’s rotation on quality of casting.

4 METAL FORMING

4.1 DETERMINATION OF DEFORMING FORCES AND DEFORMATION DEGREE DURING METAL FORMING

Purpose of the work: to study the methods of deforming force and deformation degree determination for several kinds of metal forming; to understand the essence of drawing and pressing processes; to become acquainted with the equipment and tools employed; to establish a relationship between deforming force and deformation degree.

Theory. The necessary condition for metal forming process is the proper plasticity possessed by a material, i.e. the ability to be deformed under an external load without failure. Plasticity of any material is limited and primarily depends upon the deforming scheme (scheme of stress condition, at first), chemical content and structure of a deformed metal, temperature and deforming rate.

The term "deformation degree" has been introduced into metal forming practice; it represents relative change in cross-sectional area or linear dimensions of a billet. Before deformation degree determination one must proceed from the volume constancy law. The condition of volume constancy applied to a prism with 90-degree angles and dimensions before deforming H, B, L and after it, correspondently, – h, b, 1 may be expressed as follows:

$$\mathbf{HBL = hbl.}$$

Hence, the deformation degree (coefficient of decrease in height):

$$\boldsymbol{\gamma = H/h = bl/BL.}$$

Each forming method is characterized by the peculiar loading scheme and billet deforming scheme. Therefore the calculating dependences for deformation degree and deforming force determination are quite different.

Pressing. During pressing (Fig 4.1), metal is extruded from a container through a die orifice which is so shaped as to impart the required form to the product. Essentially the process is one by which a block of solid metal is converted into a continuous length of uniform cross-section by forcing it to flow under high pressure. Metal undergoes uniform squeezing and, therefore, acquires high plasticity. Hence, pressing is available for alloys of low plasticity. Deformation degree in pressing is measured by reduction and extension coefficients (percentage), based on the cross-sectional areas of the container (F_C) and the die aperture (F_d):

$$\varepsilon = (F_c - F_d)100\%/F_c, \quad \lambda = F_c/F_d.$$

Direct pressing-force is determined by the Unksovs formula:

$$P = F_c\sigma_y(2L/D + \ln(F_a/F_d)/\alpha + 4fl/d),$$

where L is length of a billet at the instant of its egress from die orifice, m;

D is container diameter, m;
d is diameter of cylindric part of die orifice, m;
α is apex angle of die cone, rad;
1 is length of cylindric part of die orifice, m;
f is friction coefficient;
σ_y is yield point of a material, MPa.

Drawing (Fig. 4.2) is the process in which a billet is pulled through a reducing die to be decreased in cross-sectional area. Procedure is usually executed without heating, providing, therefore, high surface quality and dimensional accuracy to be obtained. Drawing is the unique process to produce thin (capillary) pipes and a wire of at least 0.002 mm in diameter. Deformation degree after drawing is also measured by extension and reduction coefficients:

$$\lambda = 1/L = F_b/F_p; \qquad \varepsilon = (F_b - F_p)100\%/F_b$$

where L, l is length of a billet and a product correspondent;
F_b, F_p is cross-sectional area of a billet and a product correspondently.

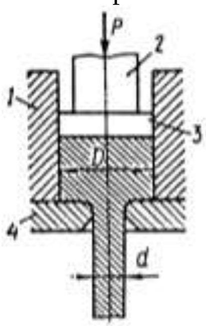


Fig. 4.1. Principle of direct pressing:
1 – container; 2 – ram; 3 – press-spacer;
4 – die

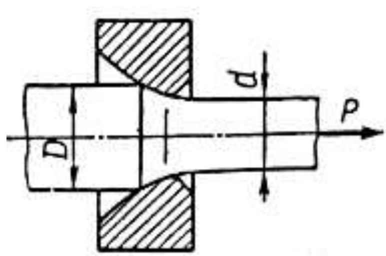


Fig. 4.2. Principle of drawing

Drawing force for continuous rod may be determined by Perlin's formula:

$$\mathbf{P = F_p \ln(F_b / F_p)(\sigma_y + f(\sigma_y - \sigma_q)(ctg\alpha_1 + \sigma_q)),}$$

where σ_y is yield point average value in nucleation site of deformation, MPa;

σ_q is inverted-stretch stress, MPa;

f is friction coefficient;

α_1 is transformed angle of deformation cone,

α_1 is $arctg((D-d)/2l_S)=arctg\ ((D-d)tg\alpha/(2l_2tg\alpha+D+d))$,

$l_S=l_1+l_2$; l_1, l_2 – length of deformation zone in cone part of reducing die and length of calibrative belt respectively, m (Fig. 4.3);

α is angle between the axis of a rod and formative line of reducing die cone deforming zone, rad (Fig. 4.3).

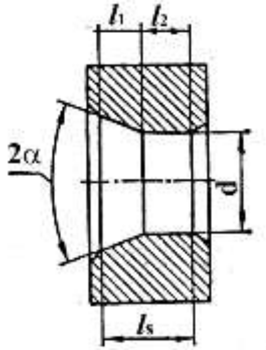


Fig. 4.3. Dimensions of reducing die

Forging. During forging, a billet is deformed by block heads (or other tools) impacting its different parts. The method is characterized by low productivity and rather low dimensional accuracy of products. Nevertheless, it offers shaped -forgings of various mass (from hundreds of grams to 250 tons) to be manufactured. Flow of metal has some peculiarities in each forging operation, so the dependences for deformation degree determination is different in each case. Deformation in upsetting is determined by the formula:

$$\mathbf{U=F_p/F_b}$$

where F_p, F_b – cross-sectional area of a billet before and after deformation correspondently.

Equipment, instrument, materials

Hydraulic press with the nominal force of 0.62 MN	1
Laboratory drawing mill with the pulling force of 4000 N	1
Pneumatic hammer with the mass of falling parts of 50 kg	1
Technological equipment for direct pressing of lead cylindric rods 5 mm in diameter (container's diameter is 26 mm)	1
Set of reducing dies with the calibrative orifice diameter of 3.1; 3.2; 3.3 mm	1
Dimension gage	5...6
Aluminium wire 3.5 mm in diameter, 10 m in length	5...6
Specimens of lead 25 mm in diameter 50 mm in length	5...6
Specimens of lead 30 mm in diameter 50 mm in length	5...6

The work must be executed as follows: Make acquaintance with the design and operational principle of equipment employed in pressing, drawing and forging.

Determine technological pressing force and deformation degree as a function of container, die and product (rod) diameter.

Press the round product of a given diameter.

Draw the aluminium wire through orifice (3.1…3.3 mm in diameter). Drawing force must be measured according to disposed on the mill indicator's readings and calibrative graph. Gage wire dimensions before and after deformation.

Determine deformation degree for each test and compare the values obtained with the permissible values for correspondent kind of metal forming. Plot the graphical dependences of drawing force upon deformation degree.

Fill the results in the form (table 4.1).

4.1 Results of the tests

Metal forming kind	Material of a billet	Dimensions of a billet, mm		Extension coefficient, upsetting,%	Redu-ction coef-ficient, %	Force of deformation, kN	
		before defor-mation	after defor-mation			Calcu-lated	Deter-mined by test
Pressing							
Drawing							
Forging							

Contents of the report. Describe briefly the essence of pressing, drawing and forging processes (accompany the descriptions with required skethes), equipment employed. Characterize external appearance and quality of finished products. Present the formulas for deformation degree and technological forces determination in pressing, drawing and forging.

Present the filled testing form (table 4.1). Depict the effect of deformation degree on drawing forces and give necessary explanations.

4.2 DIE FORGING OF METALS

Purpose of the work. To study a die forging process, a procedure of forging's draught development; make acquaintance with design and operation of crank press.

Theory. Die forging process has found a wide use in custom-made production of half-finished articles and provides forgings of high quality, favorable microstructure and minimal stocks allowed for machining to be manufactured. Die forging is a technological process of metal working, in which deforming and flow of a metal is carried out in special tools cal1ed dies.

Working surfaces of a die form close cavity which conforms in shape and sizes to the desired forging. The cavity is called an impression. Open and close impressions are distinguished in accordance with the character of metal flow during forging. In open impressions a clearance between die parts (top and drag) allows a metal to flow through it, facilitating, therefore, filling up of the impression and withdrawal of surplus metal (fin). In close impression, on the contrary, small clearance doesn't permit metal outflow from a die and, consequently, fin formation.

Forgings of a simple shape are usually stamped in dies with a single impression. Manufacture of intricate forgings in such dies is considered to be injudicious, because a lot of metal is wasted for fins and impression wears out rapidly. Intricate forgings are manufactured by sequential deforming of a billet in several impressions, thus, gradually approaching the required shape. Preliminary forming is carried out in preparatory impressions (upsetting, extending, bending etc). Finishing forming, correspondently, – in blacking and finishing impressions.

All the impressions are usually disposed in one die (Fig. 4.5). Application of preparatory impressions and sequence of their employment is determined during the design of forging technological process and based on forging's shape and sizes. Draught of a forging is developed in accordance with draught of an article (finished product), accounting stocks allowed for machining, technological biases, curvature radiuses, imprints of openings etc. It is for a designer to pick out a joint plane (face) of a die; to set up the stocks allowed for machining, technological biases, curvature radiuses and, if necessary, to provide imprints of orifices for subsequent piercing; to introduce corrections for machining convenience. The draught development procedure is presented in Fig. 4.6.

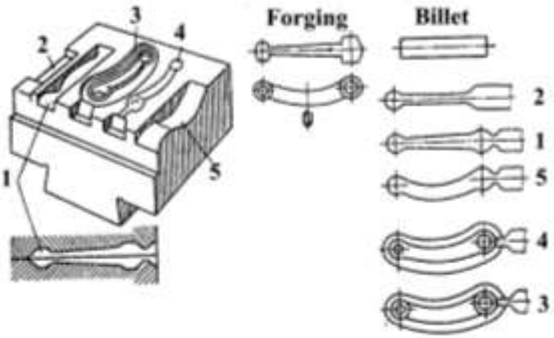


Fig. 4.5. Draught of a forging, die, multiple-impression die and sequence of operations, carried out in the die (2-1-5-4-3). Impressions: 1 – rolling; 2 – extending (fuller); 3 – finishing; 4 – blacking; 5 – bending

Volume of a billet is determined by dimensions of a forging:

$$\mathbf{V_b = V_f + V_{fin} + V_l + V_w}$$

where V_f is volume of a forging;

V_{fin} is volume of fins, equals $(0.05\ldots0.25)\cdot V_f$;

V_l is metal losses while heating, equals $(0.5\ldots0.8)\%\ V_f$ for electric heating; $(1.6\ldots2.0)\%\ V_f$ for flame heating;

V_w is wastes of metal.

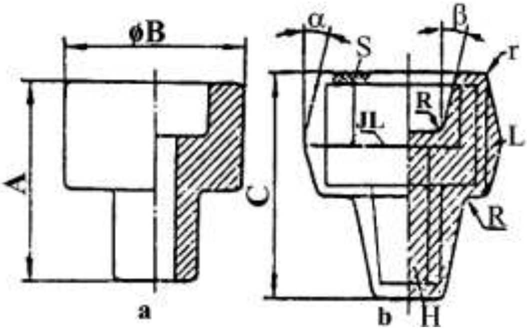


Fig. 4.6. Draught of the article (a) and the forging (b); S – stock, allowed for machining; L – overlap; α and β – stamping biases; JL-joint line; R; r – curvature radiuses; A, B- dimensions of the article; C – dimension of the forging

There are several types of equipment used for die forging, distinguished by the design and operational principle. Option is determined by sizes and shape of forgings, total output, technological and mechanical properties of working metal, automation requirements, convenience of operation, quality of finished products etc.

Steam-air hammers with the mass of fallen parts of 630…25000 kg are used for stamping of rather shaped forgings (0.5…200 kg).

Crank hot-forging press with the nominal force of 6.3…160 MN is the most advanced forging machine, differed favorably with high productivity, quality of forgings, small stocks allowed for machining and other advantages. The main units of this machine are following (Fig. 4.7): drive, principal executive mechanism and control system. Principal executive mechanism (crank mechanism) consists of crankshaft 9, coupler 10 and slider 1. Drive consists of electric motor 4, belt transmission 3, idler shaft 5 and gears 6, 7. The electric motor is turned on and shut down by means of clutch 8 and brake 2. Wedge 12 enables table 11 of the press to move vertically, providing adjustment of a clearance between top and bottom (drag) dies.

Dimensions of die forging equipment are selected to meet the deforming force (presses) or the work required for deformation (hammers).

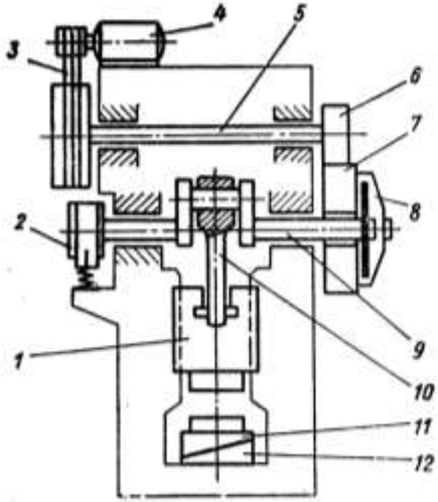


Fig. 4.7. Kinematics scheme of a crank hot-forging press: 1- plunger; 2 – brake; 3 – belt transmission; 4 – electric motor; 5 – shaft; 6 – gear; 7 – gear; 8 – mufticoupling; 9 – crank-shaft; 10 – lever; 11 – table of variable height; 12 – bas of the table

Equipment, tools, materials

Crank press with the nominal force of 630 kN	1
Die for die forging of gear billet	1
Dimension gage	5...6
Lead billets (11 mm in diameter and 15; 16.5; 17 mm in height	5...6 (of the each type)

The work must be executed as follows: Make acquaintance with design and operation of crank press and die. Study the safety precautions.

Develop draughts of the forgings. The articles to be manufactured of them are represented in Fig. 4.8. Stocks allowed for machining, biases and curvature radiuses would be given by an instructor.

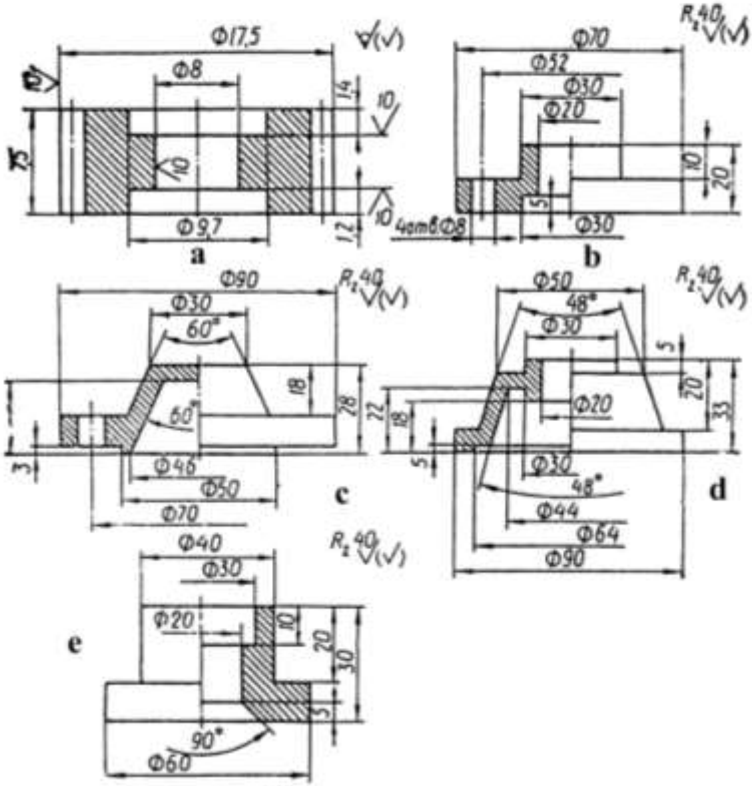


Fig. 4.8. Draughts of the articles: a – gear; b – half-clench: c – lid; d – neck support; e – bushing

Determine volumes of the forgings and billets. Stamp 2…3 billets of calculated, lesser and greater volume.

Assess the character of filling up the finishing impression, surface quality of the forging and fin size. Make inferences.

Contents of the report. Describe briefly the essence of die forging process and forging's draught development procedure. Present the draught of finished product (article) and forging with all the necessary calculations.

Depict the kinematic scheme of crank press and explain its design.

Outline quality of the forging, degree of impression's filling up, fin size.

Make inferences.

5 WELDING OF METALS

5.1 MANUAL ELECTRIC ARC WELDING

Purpose of the work: to become acquainted with electric arc welding processes, welding arc properties, design and operation of welding equipment, to become skilful at welding regimes determination and adjustment.

Theory. Welding is a process of permanent joints manufacture by setting up atomic bonds between working pieces while heating, deforming or heating and simultaneous deforming them. Local or general heating may be employed. Electric arc welding has found the most wide use due to its advantages over other welding processes: both high heat concentration and productivity, relative universality, various weld position in space, simple and inexpensive equipment, possibility to obtain stable and relatively high properties of weld metal.

The following kinds of electric arc welding are distinguished: alternating-current (a-c) and direct-current (d-c) welding; manual and automatic (machine) welding; unshielded arc, submerged arc and gas-shielded arc welding.

Electric arc with the temperature of 6000…8000 °C in its core is the heating source in arc welding. Electric arc is a powerful stable arc discharge in ionized atmosphere of gases and metallic vapors. Arc distance ionization occurs at the instant of arc initiation and is sustained while arcing as a result of collisions between moving electrons (towards a cathode) and either gas molecules or metal vapor atoms. Electric properties of the arc are described by the static voltage-current characteristic, representing the dependence between voltage and current intensity (strength) at stable arcing instant. The main power source characteristic is considered to be its external characteristic – the relationship between output terminal voltage and current intensity in welding circuit. The intersection point of these two characteristics is supposed to accommodate the stable arcing (welding) (Fig. 5.1).

In arc welding transformers of ТД, ТС, СТШ, ТСК types may be employed as a power source; in d-c welding – welding generators of ПСО, АСБ, АСД, САМ types and also rectifiers of ВД, ВКС, ВСС, ВДУ etc types. Welding current is adjusted by means of supply chokes (a-c welding) or variable resistances (d-c welding).

Manual arc welding is performed by an arc arcing between an electrode and working pieces. It is possible to use either non-consumable (of tungsten or graphite) or consumable electrodes – metallic rods (1.6…12 mm in diameter) coated with luting. Luting serves for stabilization of arcing, protecting of molten metal, deoxidizing an alloying it. Chemical content of electrode material has to match the content of a metal, which undergoes welding.

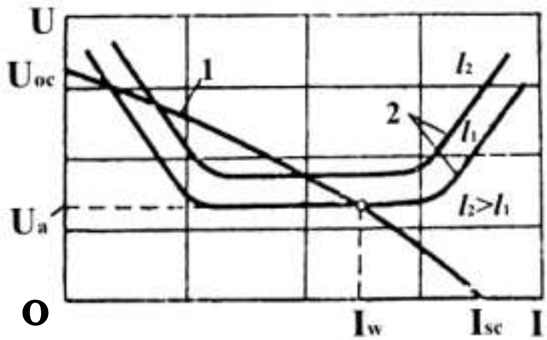


Fig. 5.1. Static voltage-current characteristic of a power source (1) and an arc (2) with different arc length l

Electrodes of 3…6 mm in diameter are mainly used in manual arc welding. Voltage is sustained within the range from 16 to 30 V, welding current intensity – 120…350 A.

Welding regime is completely characterized by welding current intensity I_W and electrode diameter d_e. The thickness of welding pieces determines the electrode diameter, the last determines the welding current intensity (approximately $I_W = (40…60)\ d_e$). Quantity of surfacing metal in welding is independent upon arc voltage. Therefore, voltage is not considered as welding characteristic.

Useful power N_u, W, released while arcing is determined by the formula:

$$\mathbf{N_u = I_w U_a}$$

where I_w is welding current intensity, A;

U_a, is arc voltage, V.

Efficiency of welding transformer η is usually equal to 0.84…0.87. Hence, consumed power should be determined as follows:

$$\mathbf{N_c = N_u/\eta}$$

Equipment and materials

Power source for a-c (d-c) welding 1

Ammeter for welding current intensity determination	1
Voltmeters for tapping off voltage at the power source output terminals and on the arc	2
Welding electrodes of 338, 340 types	2…4
Welding pieces – plates of various (4; 5; 6; 8 and 10 mm) thickness	2...4 (of the each dimension).

The work must be executed as follows. The electrode diameter, welding current intensity and welding rate should be determined as the function of the thickness of plates which undergo welding. Tap off the arc voltage U_a, welding current intensity I_w voltage during open-circuit test and, finally, current intensity in short circuit test. Refer presented above formulas to calculate useful power N_u, and consumed power N_C.

Plot the external voltage-current characteristic of the power source according to the available data.

Contents of the report. Characterize the arc welding process, its peculiarities and fields of application. Characterize the welding arc as a heating source.

Quote technical characteristic of the welding power source, plot its external voltage-current characteristic.

Calculate the consumed power and fill the following table 5.1.

5.1. Power calculations in welding

N° of the test	Voltage at input terminals of power source U_1, V	Input current of power source I_1, A	Consumed power N_C, W	Power source coef-ficient, η	Voltage in open circuit test U_{0C}, V	Current density in short circuit test I_{SC}, A	Voltage on the arc U_a, V	Welding current intensity, U_a, A	Useful power N_U, W

In accordance with the data obtained in different tests plot the dependence between consumed power and thickness of welding plates.

5.2 *GAS WELDING*

Purpose of the work*:* to study the design and action principle of gas welding equipments, to master the adjustment of welding flame and welding regimes selection.

Theory. Gas welding is one of the chemical welding processes in which the necessary heat energy is produced as a result of oxidation (combustion) of a gas. The main substances available for gas welding are known to be the acetylene or another gas (hydrogen, natural gas) and oxygen used as an oxidizer.

Acetylene, possessing the high heat-producing ability, provides the highest flame temperature to be achieved (3100…3200°C) in combustion. The gas is usually produced in special installations – acetylene generators or taken from cylinders charged at special stations. Acetylene is explosive and requires careful treatment.

Oxygen is obtained from the air using selective evaporation at special shops and conveyed in cylinders.

Equipment necessary for gas welding is as follows: acetylene generators, water protective seals, oxygen cylinders, pressure regulators, welding torches.

Calcium carbide CaC_2 interacts with water to produce acetylene C_2H_2 in acetylene generators with a given productivity. Three types of generators are distinguished: contact-type (water recession), water-to-carbide and carbide-to-water.

In contact-type generators at the beginning the whole carbide amount interacts with water. As far as the gas is produced, water has to be removed from the work chamber. Thus, the interaction surface reduces and generator's productivity decreases. These generators provide the lowest acetylene yield to be obtained. Their productivity ranges from 0.8 to 1.25 m^3/h.

In water-to-carbide generators water periodically drops on calcium carbide pieces. Such generators possess a simply design, relatively high acetylene yield (80…90%) and productivity (1.25…3 m^3/h). They have obtained the most widespread.

Carbide-to-water generators (carbide in portions is fed into water) provide the highest acetylene yield (almost 95%) and productivity (10…35 m^3/h) to be obtained. Simultaneously they are of the most complicated design.

Protective seal is used to prevent an explosion in case of so-called "reverse impact of the flame" occurred when the oxygen-acetylene mixture inflames within the torch and the flame spreads towards the generator. Such phenomenon happens if the torch is heated over the temperature of 500°C.

Oxygen and acetylene cylinders have spherical bottoms and necks at the top. Special pad at the bottom permits to set the cylinder upright. Normal capacity of the cylinder is 40 litres(liters). Oxygen is kept under the pressure of 15 MPa (6 m^3 of the gas within the cylinder).

Acetylene is transported in the cylinders under the pressure no more than 1.6 MPa, because explosion may happen if the pressure exeeds this value. The gas should be dissolved in acetone and the cylinder's cavity should be filled with porous carbon mass (sizes of carbon grains range from 1 to 3.5 mm).

Pressure regulators are employed to reduce the gas pressure to the working value and to maintain the value at a constant level automatically. The thread of oxygen and acetylene regulators nuts differs that excludes the possibility to mount the regulators vice versa.

Welding torches are used to produce acetylene-oxygen mixture in subsequent combustion of which the welding -flame is obtained. Welding torches of injector type (Fig. 5.2) are normally employed nowadays. The oxygen pressure before the injector is about 0.3…0.4 MPa. Running out with the high speed into the mixture chamber it produces significant vacuum. Hence, acetylene is also sucked into the chamber (its pressure within the pipeline may be rather low – up to 0.001 MPa).

The flame power is determined by gas flow adjusted by replacement of tips. The torches of injector type are delivered as a set of a trunk and several tips. Technical data of the welding torches is given in the table 5.2.

The welding flame has three peculiar zones: core, welding zone and tongue (Fig. 5.3). The highest temperature is achieved in the welding (middle) zone. Hence, it is used in welding process.

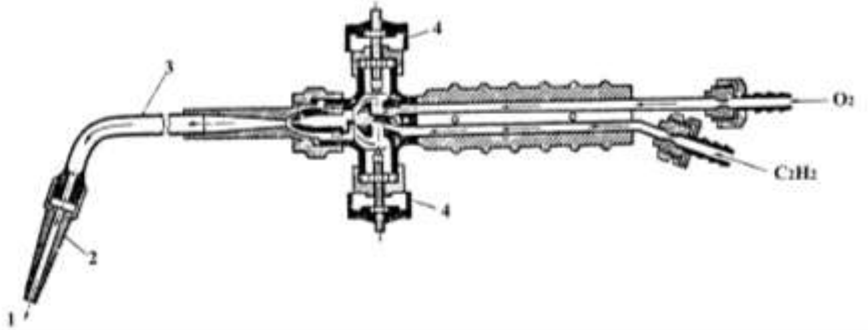


Fig. 5.2. Gas welding torch: 1 –fuel mixture; 2 tip -; 3 – injector; 4 – valves

5.2. Technical data of the welding torchs

Type of the torch	N° of the tip	Thickness of work piece, mm	Gas consumption, 1/h		Oxygen working pressure MPa
			Acetylene under the pressure of 0.001 MPa	Oxygen	
ГС-2	0	0.3…0.6	25…60	28…70	0.8…0.4
	1	0.5…1.5	50…125	55…135	0.1…0.4
	2	1.0…2.5	120…240	130…260	0.15…0.4
	3	2.5…4.0	230…400	260…440	0.2…0.4
ГС-3	1	0.5…1.5	50…125	55…135	0.1…0.4
	2	1.0…2.5	120…240	130…260	0.15…0.4
	3	2.5…4.0	230…400	260…440	0.15…0.4
	4	4.0…7.0	400…700	430…750	0.2…0.4
	5	7.0…11.0	660…1100	740…1200	0.2…0.4
	6	10…18	1050…1750	1150…1950	0.2…0.4
	7	17…30	1700…2800	1900…3100	0.2…0.4

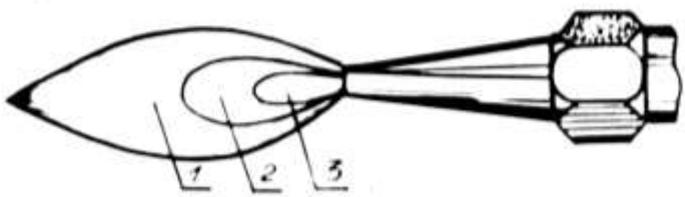


Fig. 5.3. Welding flame: 1 – tongue; 2 – welding (middle) zone; 3 – core

Three types of the flame are distinguished according to the ratio between oxygen and acetylene in the mixture: balanced (normal), oxidizing and reducing (carbonizing) flame. Different flame types are employed in welding various alloys. In welding, for instance, of high-carbon steels the reducing flame is needed, in welding of brasses – the oxidizing one. In the majority of cases the balanced flame is employed. The ratio between acetylene and oxygen is adjusted by respective valves on the torch.

Gas welding provides fluent (smooth) and slow heating to be achieved. It is the main peculiarity of the process. That is why gas welding is used for thin steel parts (0.2…0.5 mm in thickness), non-ferrous metals, cast iron and a number of alloy steels inclined to crackness. If the thickness of welding parts rises, the heating time increases, but productivity falls abruptly. More than that slow heating causes deformation and strain that reduces the field of gas welding application.

Equipment and materials

Acetylene generator AGM-1-66	1
Water seal ЗСП-7-67	1
Oxygen pressure regulator	1
ГС-type welding torch with the set of tips	1
Calcium carbide, kg	10
Specimens: steel plates of 1; 2; 3; 4 and 5 mm in thickness	2 (of the each dimension)
Timer	5

The work must be executed as follows. Study the design and operation of acetylene generator, water protective seal, injector type welding torch.

Prepare the equipment; make the necessary setups following the safety precautions.

Referring the table 5.2 opt the required tip and assemble the torch.

Inflame the torch and adjust different types of flame. Master to differentiate the flame type by its appearance.

Weld the specimens. Accounting the welding time determine the consumption of acetylene and oxygen (table 5.2).

Contents of the report. Characterize the gas welding process and materials used.

Name the equipment employed in gas welding; present scheme of the welding torch. Specify the application field of gas welding.

Record the data which characterize the welding process: the material, thickness of the specimens, number of the tip, working gas pressure and gas consumption.

According to the data obtained by different subgroups plot the dependence between thickness of the welding specimens and gas consumption (per 1 m of the seam).

5.3 ELECTRIC RESISTANCE WELDING

Purpose of the work: to study design and operation of resistance welding machines, to become acquainted with resistance welding procedure, to become skilful at welding current intensity determination and adjustment while welding specimens of various materials.

Theory. Resistance welding comprises a group of welding processes wherein coalescence is produced by the heat obtained by resistance of the work parts to the flow of electric current in welding circuit and by the application of pressure. The heating may be accompanied by local melting of the metal. Three main groups are distinguished in accordance with the size and shape of formed welds: spot, seam an upset welding.

Spot welding coalescence is used, as a rule, while welding overlapped sheet pieces (Fig. 5.4). The size and shape of individually formed welds are limited primarily by the size and contour of electrodes (spots of 3…12 mm in diameter). The resulting weld in seam welding is a series of overlapping spot welds made progressively along a joint by rotating circular electrodes (welding wheels) (Fig. 5.5). Flash welding is a process wherein coalescence is produced simultaneously over the entire area of abutting surfaces (Fig. 5.6). Pressure is applied before welding is started and maintained throughout the heating period.

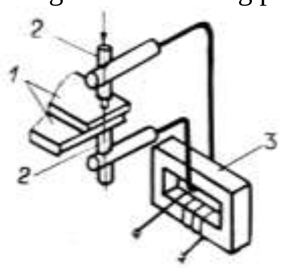


Fig. 5.4- Scheme of spot welding:
1-workpieces;
2-electrodes;
3-transforrner

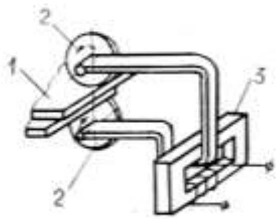


Fig. 5.5. Scheme of seam welding: 1-workpieces:
2-welding wheels;
3-transformer

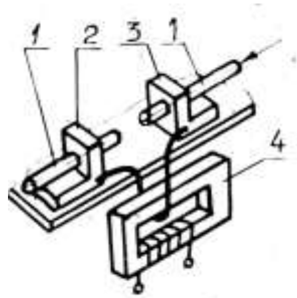


Fig. 5.6. Scheme of flash welding:
1-workpieces,
2-movable clamp,
3-stationary clamp,
4-transformer

The welding regime is determined by welding current intensity, squeeze force, time that welding current flows and hold (upset) time, as wel1 as by mutual ratio between heat and upset time. To decrease the work temperature and wear of electrodes they are manufactured of cadmium (БрКд1) or chromium (БрХ) bronzes and cooled by passing water.

Electric equipment of resistance welding machines consists of transformer, contactor and heat (or current) control circuits. The power of welding transformers ranges from 1 to 600 kVA. The secondary winding usually has only one turn. The output voltage does not exceed 12 V. The current intensity is from 100 to 100000 A and should be adjusted either by switching into or out of the primary circuit a given number of turns. Thus, 4…16 sets of adjustment are available for current control. The secondary circuit composed of various elements (up to the electrodes) is sometimes called the welding loop. Total resistance of the welding loop, if it has been designed correctly, should not axed 60…100 μΩ.

The contactor is a device for repeatedly establishing and interrupting the electric power circuit. It works in step with squeezing (upsetting) mechanism. There are three basic types of welding contactors: mechanical, magnetic and electronic.

Drive mechanism provides transport of electrodes or welding pieces with simultaneous squeeze of the last ones.

Powerful welding machines are air or hydraulically operated (squeeze force up to 200 kN). In other types, cam or lever-spring drives are employed.

Spot welding is available for sheets of the same or different thickness, intersected rods or shaped sheets coalescence. The sheet thickness may be up to 30 mm.

By means of seam machines the pieces of steel or non-ferrous alloys (4…5 mm in thickness) may be joined with rate of 12…18 m/min.

Flash welding provides coalescence of various articles: from the wire 0.4 mm in diameter to the rods, pipes etc with face area up to 2500 mm^2.

Determination of welding current intensity. A current transformer is hooked up to the primary winding of the machine transformer. An ammeter incorporated by the mentioned circuit provides the current impulse measurements. As the voltage at input U_1 and output U_2 transformer terminals is known, the welding current intensity I_2 may be determined as follows:

$$\mathbf{I_2 = I_1U_1/U_2},$$

where I_1 is current intensity in primary circuit, A.

Equipment and materials

Machines for spot and upset welding	2
Current transformer	2
Ammeter for current impulse in primary circuit measurements	2
Specimens: steel sheets of 1; 1.5; 2 mm in thickness; steel rods of 8; 10; 12 mm in diameter	2 (of the each type)
Timer	2
Dimension gage	6

The work must be executed as follow:. Study the construction of the welding machine (electric circuits, drive mechanism, cooling and heat control systems) and their assignment. Make setups for welding of given articles and carry out the welding procedure. Determine the welding current intensity and welding time. Calculate the welding current density (current intensity per weld area).

Fill in the following table 5.3.

Plot the dependences of welding current intensity and density upon thickness (diameter) of welding specimens.

Contents of the report. Characterize the electric resistance welding, its variants and fields of application.

5.3. Resistance welding regimes

N° of the test	Material of the specimen	Thickness of the specimen S, mm	Current strength I, A	Current density j, A/mm^2	Time that welding current flows τ, sec	Welding regime

Characterize the welding machine employed; present the schematic diagram of its electrical circuits.

Present the current intensity value measured while welding and current density calculations for specimens different in thickness or diameter.

Analyze the relationship between welding current intensity and density on the one hand and thickness of specimen on another hand.

6 MACHINING OF STRUCTURAL MATERIALS

6.1 LATHE OPERATIONS

Purpose of the work. To study the basic principles of lathe operations, design and working principles of a screw-cutting lathe and a single-spindle semi-automatic lathe, to make acquaintance with lathe cutting tools and basic operations involved, to study the effect of cutting regime upon quality of finished products, to determine the automation level influence on machining productivity.

Theory. Lathe cutting is the most widespread among metal machining operations. The lathe is an important machine shop tool. Its share in the total machine-tool stock runs into 30…40%.

Lathe machining is characterized by rotational movement (the main movement) and feed movement: longitudinal and transverse (cross). Operations performed on a piece of work in the lathe fall into two general classifications: external (turning, facing, knurling, external thread cutting, etc) and internal operations (drilling, reaming, boring, internal threading, etc). A work surface should form a rot table body shape while, for instance, turning, or plane while facing.

Engine lathes are classified as the first group according to ЭНИМС's classification. The group is subdivided into turning, screw-cutting, turning and boring, multiple-tool, turret, automatic and semi-automatic, special and specialized lathes, etc.

Cutting regime in lathe machining is primarily defined by the following values: cutting speed V, feed S_L, S_c and cutting depth. Cutting speed is determined as a speed of a work surface dot removed to the utmost from the rotation axis. The distance a cutting edge will advance along a work piece (into it) per unit time or in one complete revolution is called the feed and labeled by S, mm/min or mm/r. The feed may be either longitudinal S_L or cross (transverse) S_c. The cutting depth t, mm, is the distance between a work surface and already machined surface measured in perpendicular to the last. In lathe machining the cutting depth is determined by the formula:

$$\mathbf{t = 0.5(D - d),}$$

where D is work piece diameter;

d is machined diameter.

The parameters of cutting regime influence significantly on cutting performance and finished product's quality. Cutting speeds, for instance, determine the heat quantity, released in machining, chip built-up intensity, strain hardening of a work surface, chip formation character, wear of cutting tools and other phenomena. Feed and cutting depth affect on force system, work, consumed in machining, heat phenomena, etc.

The quality of finished products is primarily determined by cutting regime (especially by cutting speed and feed) and cutting tool geometry. Two consequent positions of a tool, which is advanced past a workpiece in one complete revolution, are depicted in Fig. 6.1. Turning is afforded by the combination of several movements (V and S_L). Hence, the true value of a cut layer f is smaller than the nominal one (f_t = ab) by f_0 – factor of fins cross-sectional area. Fins' height mainly determines finished roughness and accuracy rating. The height may be decreased by reducing the side cutting-edge and the end cutting-edge angles φ_1 (Fig. 6.1), increasing the nose radius, reducing the longitudinal feed, application of additional cutting edges, as well as special finish-machining tools (Fig. 6.2).

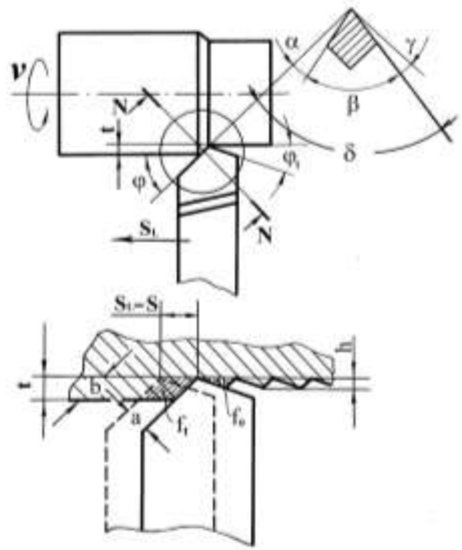


Fig. 6.1. The cutting edge angles and cross-section of cutting layers: α- clearance angle; β - wedge angle; γ - top rake angle; δ - cutting angle; φ - main angle; φ_1^+ – auxiliary angle

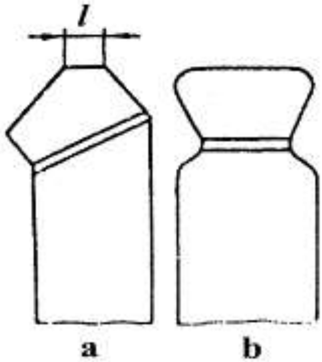


Fig.6.2. Cutting tools: a – with additional cutting edge; b – finishing

The chip built-up formation (especially in cutting of plastic materials) and its periodical spalling (spelling) also deteriorate the surface quality. The intensity of the process rises as the cutting speed increases up to 18…30 m/min (depending upon other conditions). In further cutting speed increase (above 40…50 m/min) the built-up formation is interrupted and surface quality improves.

Besides mentioned factors the surface quality is also affected by physical and mechanical properties of a work material, wear of a tool, cutting fluid type, stiffness of a technological circuit.

Automatic and semi-automatic lathes are usually employed in mass-production for reducing the manual share in labor input. A lathe, which provides all operations, except mounting of a workpiece and removal of a finished article, to be carried out automatically, is called semi-automatic lathe. An automatic lathe performs all the operations exclusively without human intervention.

The most wide spread single-spindle semi-automatic lathe has predominantly horizontal spindle axis and at least two carriages – longitudinal and transverse (Fig 6.3, a). The lathes facilitate working of, for instance, step shafts. The semi-automatic lathes are divided into multiple-tool and profile-turning machines. In the first machines every work surface is machined by a special tool. In the second case, machining is carried out by a single cutting tool, advancing along a given trajectory (Fig. 6.3, b).

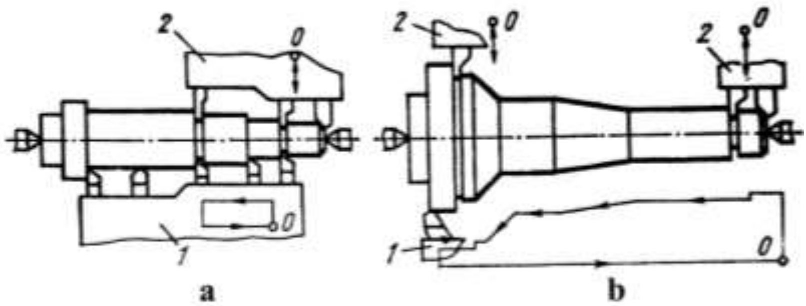


Fig. 6.3. Machining of step shafts in multiple-tool (a) and profile-turning (b) semi-automatic lathes

Horizontal single-spindle bar machines are the most widely used automatic lathes (bar is the workpiece). They may be as follows cutting off, longitudinal turning and turret lathes.

In the cutting off automatic lathes cutting operations are performed while tools are involved in transverse movement (Fig. 6.4, a). The absence of longitudinal feed limits the field of their application.

In case of the longitudinal-turning, automatic machines the main movement (rotation) and longitudinal feed of the workpiece 5 are provided by the spindle 7. The tool carriages 4, supported by the pillar 3 with the bushing 6, move as a unit along the bedways (Fig. 6.4, b). More intricate and long parts may be produced in such lathes.

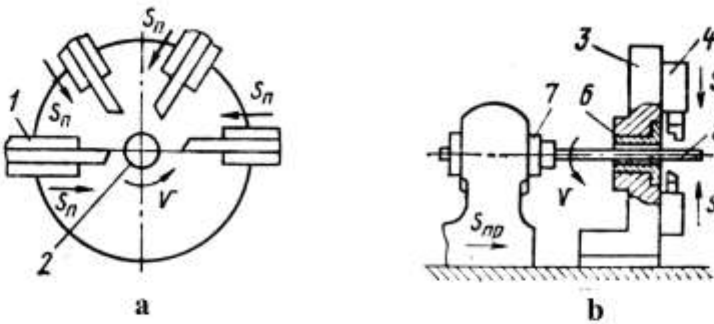


Fig. 6.4. Machining in single-spindle automatic lathes: a – cutting off, b – longitudinal turning

The most intricate parts are machined in the turret automatic lathes with a hexagon turret, mounted on longitudinal carriage. The hexagon turret has several built-in transverse carriages and, different cutting tools.

Automatic and semi-automatic lathes of other designs, for example, multiple-spindle, are also employed in mass production.

Equipment, tools, materials

Screw-cutting lathe	1
Single-spindle automatic lathe	1
Set of cutting tools	2
Dimension gage	6
Timer	6
Bar of low-carbon steel 20 mm in diameter, 500 mm in length	4

The work should be executed as follow:. Study the design and action principle of the screw-cutting laths; make acquaintance with tools, lathe accessories and main technological operations employed.

Study the design, action principle and setups of the semi-automatic lathe. Study the draught of the part (Fig. 6.5) and determine the sequence in which machining operations should be performed to manufacture the part in screw-cutting lathe and semi-automatic machine. Gage the workpiece diameter D_w and determine machining allowance (stock):

$$Z_0 = 0.5(D_W - D),$$

where D is external diameter of the finished part.

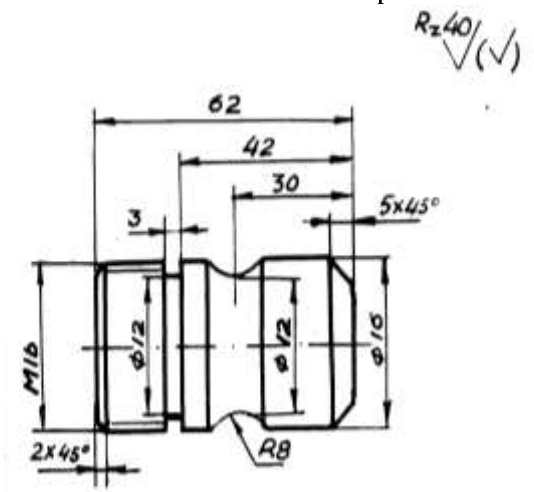


Fig. 6.5. Draught of the part

It is for an instructor to specify the cutting regime giving the V, S_L, S_C values for all the operations performed in screw-cutting lathe. The depth of cut should be adopted as (0.7…0.8) Z_0 in rough and (0.2…0.3) Z_0 in finish machining while turning, 0.2…0.3 mm while facing or tapering.

The formula for spindle revolutions per minute in determination is following:

$$\mathbf{n = \frac{1000V}{\pi D}}.$$

Enter the cutting regime parameters in the setup table (table 6.1).

6.1. Screw-cutting lathe setup table

Operation	Tool	Cutting speed m/min	Spindle revolutions per minute	Feed mm/r	Depth of cut, mm

Mount and lock the workplace and proper tools for machining in screw-cutting lathe. Make setups according to the table 6.1 and machine the workpiece in a given sequence. Manufacture 5…6 parts. The same parts should be manufactured in semi-automatic lathe. Note machining time in these two cases.

Turn the workpiece with roughing tool, then with finishing one. Investigate the influence of cutting tool geometry on surface quality, comparing the surface roughness R_Z, obtained in mentioned cases (use surface roughness standards).

Study the cutting speed effect on surface quality after turning with speeds slower (by 30…50%) and higher (by 60…70%) than the recommended one. Determine the R_Z value of finished surface and plot the dependence between cutting speed and R_Z.

Turn the workipece with feeds slower (by 30…40%) and higher (by 30…50%,) than the recommended one and determine R_Z value. Plot the dependence between feeds S and roughness R_Z

Gage the parts manufactured on screw-cutting and semi-automatic lathes and determine accuracy in the two cases.

Determine the average time for manufacture in the two types of lathes.

Make inferences.

Contents of the report. Present the draught of the part. Depict the machining operations in screw-cutting and semi-automatic lathes.

Present the setup table with necessary explanations and calculations. Plot and explain the dependences between surface roughness R_Z on the one hand and cutting speeds as well as feeds on the other hand (2 graphs).

Present the turning productivity data (for two lathe types employed).

Explain the tool geometry effect on surface roughness.

Present the inferences.

6.2 MILLING OPERATIONS

Purpose of the work. To study the construction of milling machine-tools with horizontal and vertical spindles; to make acquaintance with the types of milling cutters; to master the necessary setups according to a given milling conditions; to determine the main (machine) time in milling.

Theory. Milling is the process of producing machined surfaces by progressively removing a predetermined amount of material from a workpiece which is fed to a rotating milling cutter. Milling cutters are often referred to as multitooth tool. The main movement in this case is the rotation of the milling cutter. Feed (longitudinal, transverse (cross) and vertical) is imparted to the workpiece, mounted on the table. Milling is a high-productive process to machine flat (horizontal, vertical and inclined), shaped surfaces, grooves, shoulders etc.

There is a number of different milling cutters, each one designed for a certain purpose (Fig. 6.6): plain or slab cutters (a), face mills (b), side milling cutters (c), end mills (d), angle (e), keyway (f) and form mills (g, h) are some of the more common ones. By the teeth contour and girding method the milled (sharp-cut) and form-relieved milling cutters are distinguished (Fig. 6.6 i, j). Teeth of a form-relieved cutter retain their cutting edge contour in radial section while sharpening along the front plane.

The milling cutters may be either solid (single-piece) mainly of high-speed steel or with inserted teeth. The last cutters are often made of carbon steel. Inserted teeth of high-speed steel, tungsten or titanium carbides and ceramic may be fastened in special holders, brazed or screwed down to the cutter.

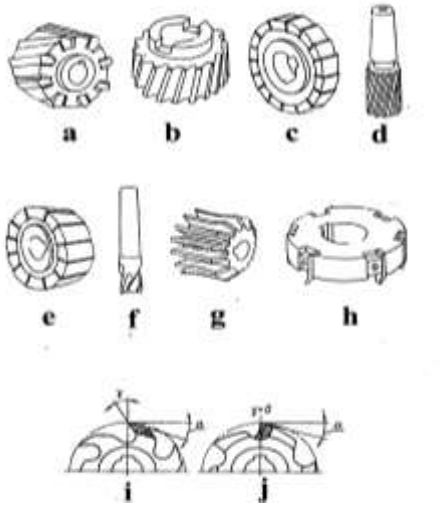


Fig. 6.6. Milling cutters

Horizontal and vertical knee-and-column milling machines are depicted in Fig. 6.7. They have a base 1, a column 2, an electric motor, equipped with a belt transmission 3, a spindle speed gear box 4, a horizontal or vertical spindle 5, an overarm 6, an outer arbor support 7, a table for the workpiece mounting 8, a slide 9, a knee 10 and a feed gear box 11.

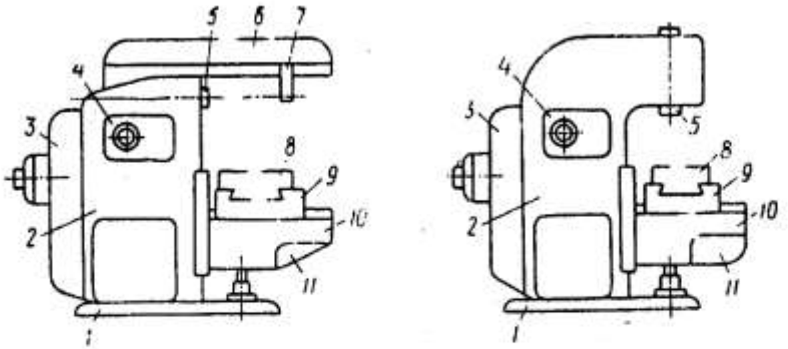


Fig. 6.7. Horizontal (a) and vertical (b) knee and column milling machines

A cutting regime is determined by cutting speed V, m/min, feed and depth of cut t, mm. The feed may be determined as: feed per minute S_m – surface mm per minute, traveled by the cutting edge of a cutter; feed per revolution S_r – travel of a workpiece per one revolution of a spindle, mm, and feed per tooth S_Z, mm. The feeds are mutually related to each other:

$$\mathbf{S_m = S_r \cdot n = S_Z \cdot Z_n}$$

where n is revolutions per minute of a spindle;

Z is teeth number of a cutter.

Feed per minute determines the machining productivity, while feed per tooth characterizes tooth loading and, thus, durability of a milling cutter.

The milling productivity is estimated by a number of articles Q, machined per certain period of time T (month, shift, hour);

$$\mathbf{Q = T/T_k}$$

where T_k is time, required to machine one article, min.

The machine (technological) time T_m, mm, (the direct manufacturing time, spent in the process of machining) is the main component of the total time, required to manufacture an article:

$$\mathbf{T_m = L \cdot I / S_m}$$

where L is calculated length of a workpiece, mm

i is number of passes.

The calculated length (Fig. 6.8)

$$\mathbf{L = l_1 + l + l_2}$$

where 1_1 is cutting-in distance of a milling cutter, mm;

1 is true length of the workpiece, mm;

1_2 is overtravel of the milling cutter, mm (is taken as 2...5 mm).

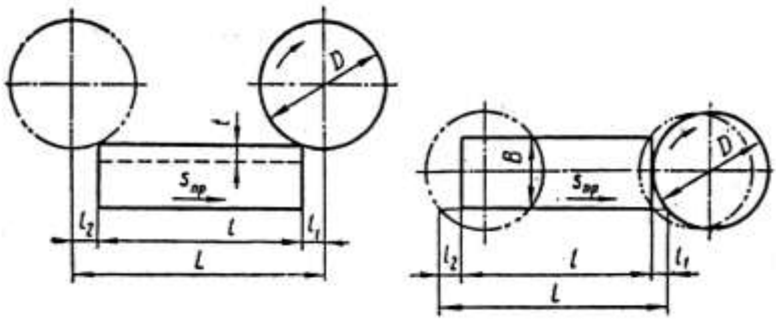


Fig. 6.8. Determination of calculated length of a workpiece in plane (a) and face (b) milling

The cutting-in distance 1_1, mm, is determined in plain milling as follows:

$$\mathbf{l_1 = \sqrt{t(D-t)},}$$

in symmetric face milling respectively:

$$\mathbf{l_1 = 0{,}5(D - \sqrt{(D^2 - B^2}),}$$

where D is diameter of the milling cutter, mm;
t is depth of cut, mm;
B is width of work surface, mm.

Equipment, tools, materials

Steel plates, less than 60 mm wide	6
Horizontal knee-and-column milling machine	1
Milling cutters of various types	4...6
Face cutter more than 60 mm in diameter	1
Machine vise	2
Dimension gage	6

The work must be executed as follows: Study the design of the milling machine, its main units and their operation. Make acquaintance with the basic types of milling cutters, setups and operations for a variety of milling jobs.

Make proper setups and adjustments in accordance with the individual tasks. It is necessary to determine the spindle rotational speed n, min^{-1} (rpm) by a given cutting speed V, m/min, and cutter's diameter D, mm:

$$\mathbf{n = \frac{1000V}{\pi D}},$$

select the speed (closely spaced to the calculated value) on the face of the dial and turn the crank until the indicator points to the chosen speed.

Machine the workpiece in chosen milling conditions.

Gage the milling cutter and the work surface (D and B, mm, respectively). Determine the machine time T_m. Assuming that the time, required to machine one article T_k is (conventionally) equal to machine time T_m, determine the productivity per hour Q in the given milling conditions.

Compare the data, obtained by different subgroups and determine the effect of speed, feed and depth of cut on productivity and surface roughness.

Contents of the report. Characterize briefly milling as a machining method.

Present scheme of the universal knee-and-column milling machine (vertical or horizontal), name its main units, describe their function and basic milling operations.

Record the given milling regime. Depict the work scheme in accordance with Fig. 6.8, specify the necessary dimensions. Present the calculations in respect to spindle revolutions per minute, machine time and productivity in the given milling conditions.

Make inference about speeds, feeds and depths of cut effect on machining productivity and quality of machined surface.

7.ENGLISH – RUSSION –UKRAINIAN DICTIONARY

abrasive	абразивный материал	абразивний матеріал
absorb	поглощать	поглинати
absorber	амортизатор	амортизатор
abut	примыкать	примикати
acetone	ацетон	ацетон
acetylene (C_2H_2)	ацетилен	ацетилен
acetylene generator	ацетиленовый генератор	ацетиленовий генератор
acid	кислота	кислота
acid refractory materiall	кислый огнеупор	кислий вогнетрив
acid slag	кислый шлак	кислий шлак
actual grain	действительное зерно	дійсне зерно
actual size	действительный размер	дійсний розмір
actuator	привод	привод
adjust	регулировать	регулювати
admixture	добавка, примесь	добавка, домішка
aerator	аэратор	аератор
affinity	сродство	спорідненість
ageing	старение	старіння
agglomerate	агломерат	агломерат
alignment	соосность	співвісність
alkali	щелочь	луг
allotropy	аллотропия	алотропія
alloy steel	легированная сталь	легована сталь
alloyed cementite	легированный цементит	легований цементит
alloying element	легирующий элемент	легуючий елемент
alpha iron	альфа железо	альфа залізо
alpha-stabilizing agent (element)	альфа-стабилизатор	альфа-стабілізатор
alternate motion	возвратно-поступательное движение	зворотно-поступальний рух
alternating current	переменный ток	змінний струм
alternating tests	циклические испытания	циклічні випробування

alumina (Al_2O_3)	глинозем	глинозем
aluminium	алюминий	алюміній
aluminium hydroxide	гидрат окиси алюминия	гідрат окису алюмінію
amenable	поддающийся	що піддається
ammonia	аммиак	аміак
amorphous body	аморфное тело	аморфне тіло
angle cutter	гловая фреза	кутова фреза
Angstrom unit	ангстрем (10^{-10} м)	ангстрем (10^{-10} м)
anion	анион	аніон
anisotropic	неоднородный	неоднорідний
anisotropy	анизотропия	анізотропія
annealing	отжиг	відпал
annihilation	аннигиляция	анігіляція
anode	анод	анод
anthracite	антрацит	антрацит
antimony	сурьма	сурьма
anvil	наковальня	ковадло
anvil block	шабот	шабот
apex	вершина	вершина
apron	фартук	фартух
arc discharge	дуговой разряд	дуговий розряд
arc rays	излучение дуги	випромінювання дуги
arc torch	сварочная головка (при газоэлектрической сварке)	зварювальна головка (при газоелектрич-ному зварюванні)
arc-erosion machining	электроимпульсная обработка	електроімпульсна обробка
arsenic	мышьяк	миш'як
artificial ageing	искусственное старение	штучне старіння
ash	зола	зола
atomic half plane	атомная полуплоскость	атомна полуплоскость
austenite	аустенит	аустеніт
austenite transformation diagram, C-curves	диаграмма распада аустенита, С-образная кривая	діаграма розпаду аустеніту С-образна крива

austenitic steel	аустенитная сталь	аустенітна сталь
austenitic-carbide steel	аустенитная сталь с карбидным упрочнением	аустенітна сталь з карбідним зміцненням
austenitic-intermetallic steel	аустенитная сталь с интерметаллидным упрочнением	аустенітна сталь з інтерметалідним зміцненням
autoclave	автоклав	автоклав
automatic arc welding	автоматическая дуговая сварка	автоматичне дугове зварювання
automatic bare-wire submerged arc welding	автоматическая дуговая сварка под флюсом	автоматичне дугове зварювання під флюсом
auxiliary	вспомогательный	допоміжний
axe	топор	сокира
axial tension	осевое растяжение	осьове розтягування
babbitt	баббит	бабіт
back rake	передняя поверхность (резца)	передня поверхня (різця)
back rake angle	передний угол	передній кут
backing sand	оборотная (наполнительная) формовочная смесь	оборотна (наповнювальна) формувальна суміш
bainite	бейнит	бейніт
bakelite	бакелит	бакеліт
balanced flame	нормальное пламя	нормальне полум’я
balanced pressure torch	горелка безынжекторного типа	пальник безінжекторного типу
bank of condensers	батарея конденсаторов	Батарея конденсаторів
bar	пруток	пруток
barb	заусенец, облой	задирка, облой
bare-electrode welding	сварка электродом без покрытия	зварювання електродом без покриття
basic refractory material	основной огнеупор	основний вогнетрив.
basic slag	основной шлак	основний шлак

bauxites	бокситы	боксити
beam	луч, пучок	промінь, пучок
bearing steel	подшипниковая сталь	підшипникова сталь
bed die	матрица	матриця
belbor	белбор	белбор
bell	колокол	дзвін
belt transmission	ременная передача	пасова передача
bench-type drilling machine	настольный сверлильный станок	настільний свердлильний верстат
bending	изгиб, гибка	згинання, гнуття
bentonite (Al_2O_3*$4SiO_2$*H_2O)	бентонит	бентоніт
beryllium	бериллий	берилій
beta iron	бета железо	бета залізо
beta-stabilizing agent (element)	бета-стабилизатор	бета-стабілізатор
beveling	получение фасок	отримання фасок
billet	заготовка	заготівка
bimetallic	двухслойный, биметаллический	двошаровий, біметалічний
binder	связующее, крепитель	зв’язуюче
black oil	мазут	мазут
black smithing	ковка	кування
blacksmith welding	кузнечная сварка	зварювання куванням
blade	режущая часть (вершина резца)	ріжуча частина (вершина різця)
blanking	вырубка	вирубування
blast purnace	доменная печь	доменна піч
blast furnace shop	доменный цех	доменний цех
blind hole	глухое отверстие	глухий отвір
block head	боек	бойок
bloom	блюм	блюм
blooming	блюминг	блюмінг
blowing	дутье	дуття
blunt	тупой	тупий
Body of drill	рабочая часть сверла	робоча частина свердла

body-centered crystal lattice (bcc)	объемно-центрированная кубическая решетка (оцк)	об'ємно-центрована кубічна решітка (оцк)
boiler steel	котельная сталь	котельна сталь
boiling	кипение	кипіння
bolting	соединение болтами	з'єднання болтами
bonding	сварка (кузнечная)	зварювання (ковальське)
bore	зенкер	зенкер
boring	растачивание	розточування
boring	зенкерование, растачивание	зенкерування, розточування
boring mill	расточной станок	розточувальний верстат
boron	бор	бор
bott	пробка (летки)	пробка (льотки)
bottom hole	глухое отверстие	глухий отвір
brass	латунь	латунь
break-blowing gauge	черновой калибр	чорновий калібр
briquette	брикет	брикет
brittleness	хрупкость	крихкість
broaching mill	протяжной станок	протяжний в.
bronze	бронза	бронза
buffer	амортизатор	амортизатор
bumper	амортизатор	амортизатор
Burgers' vector	вектор Бюргерса	вектор Бюргерса
burning	пережог	перепал
bushing	втулка, гильза	втулка, гільза
butt weld	Сварное соединение встык	стикове зварне з'єднання
butt welding	стыковая сварка оплавлением	стикове зварювання оплавленням
cable sheating	оболочка кабеля	оболонка кабелю
calcium	кальций	кальцій
calcium carbide (CaC_2)	карбид кальция	карбід кальцію
calibration	калибровка	калібрування
cam drive	кулачковый привод	кулачковий привод

caolinite (Al_2O_3*2SiO_2*2H_2O)	огнеупорная глина	вогнетривка глина
cap	крышка	кришка
capacitor-stored energy welding	конденсаторная сварка	конденсаторне зварювання
Carbide-forming elements	карбидообразующие элементы	карбідоутворюючі елементи
carbide-to-water	карбид на воду	карбід на воду
carbon	углерод	вуглець
carbon steel	углеродистая сталь	вуглецева сталь
carbonate	карбонат	карбонат
carbonitriding	нитроцементация	нітроцементація
carbonizing flame	восстановительное пламя	полум'я, що відновлює
carburizer	карбюризатор	карбюризатор
carburizing	цементация	цементація
carnallite ($MgCl_2$*KCl*6H_2O)	карналлит	карналіт
carriage	каретка	каретка
casehardening	химико-термическая обработка	хіміко-термічна обробка
casehardening steel	цементуемая сталь	сталь, що цементується
case-reducing	обжим	обтиск
cast alloy	литейный сплав	ливарний сплав
cast iron	чугун	чавун
casting	литье, отливка	литво, виливок
cathode	катод	катод
cation	катион	катіон
cavity	полость	порожнина
CCT-diagram (continuous cooling transformation diagram)	термокинетическая диаграмма	термокінетична діаграма
C-curves, austenite transformation diagram	С-образная кривая, диаграмма распада аустенита	С-образна крива, діаграма розпаду аустеніту
cemented carbides	твердые сплавы	тверді сплави
cemented oxides	керметы	кермети
cementite	цементит	цементит

cementite carcass (shell)	цементитная сетка	цементітна сітка
center of gravity	центр тяжести	центр ваги
centerless grinding machine	бесцентрово-шлифовальный станок	безцентрово-шліфувальний верстат
centrifugal casting	центробежное литье	відцентрове лиття
ceramic	керамика	кераміка
ceramics	керметы	кермети
cerium	церий	церій
cermets	керметы	кермети
chain mill	цепной стан	ланцюговий стан
chalk	мел	крейда
chamber furnace	камерная печь	камерна п.
Chamotte	шамот	шамот
charcoal	древесный уголь	деревне вугілля
charge	завалка, шихта	завалка, шихта
charge, burden	колоша, шихта	колоша, шихта
checkerwork of brick	клетчатая кладка из кирпича	клітчата кладка з цегли
chemical compound	химическое соединение	хімічне сполучення
chemical heat-treatment	химико-термическая обработка	хіміко-термічна обробка
chilled cast iron	отбеленный чугун	відбілений чавун
chilling	отбел (чугуна)	відбілювання (чавуну)
chip	стружка	стружка
chisel	резец; зубило; долото	різець; зубило; долото
chloride	хлорид	хлорид
chlorine	хлор	хлор
choke	дроссель	дросель
chopping	рубка, отрезка	рубка, відрізка
chrome- magnesite	хромомагнезит	хромомагнезит
chromite (Cr_2O_3)	хромит	хроміт
chromium	хром	хром
chuck	патрон	патрон
chute	желоб	жолоб
circular shears	дисковые ножницы	дискові ножиці

circumference	окружность	окружність
cladding	плакирование	плакування
clamp	зажим	затискач
clamp	скоба, зажим	скоба, затискач
clay	глина	глина
cleaning	очистка (от пригара)	очищення (від пригару)
climb milling	попутное фрезерование	попутне фрезерування
closed die	закрытый штамп	закритий штамп
closed gauge (pass)	закрытый калибр	закритий калібр
cluster mill	многоклетьевой стан	багатоклітковий стан
clutch	муфта	муфта
coalescence	коалесценция, соединение	коалесценція, з’эднання
coated electrode	электрод с покрытием	електрод з покриттям
cobalt	кобальт	кобальт
coherence	когерентность	когерентність
coil spring	пружина	пружина
coining	калибровка	калібрування
coke	кокс	кокс
coke-chemical plant	коксохимический завод	коксохімічний завод
coking coal	коксующийся уголь	коксівне вугілля
cold deformation	холодная деформация	холодна деформація
cold die forging	холодная объемная штамповка	холодне об’ємне штампування
cold extrusion	выдавливание	видавлювання
cold heading	холодная высадка (операция ОМД)	холодне висаджування (операція ОМТ)
cold pressing chamber	холодная камера прессования	холодна камера пресування
cold resistance	хладостойкость	холодостійкість
cold treatment	обработка холодом	обробка холодом
cold upset forging	высадка (холодная)	висадка (холодна)

cold welding	холодная сварка	холодне зварювання
cold work hardening	наклеп, деформационное упрочнение	наклеп, деформаційне зміцнення
collective recrystallization	собирательная рекристализация	збиральна рекристалізація
column	колонка	колонка
combustion	горение	горіння
common steel, ordinary quality steel	сталь обыкновенного качества	сталь звичайної якості
compliance	податливость (смеси)	піддатливість (суміші)
component	компонент	компонент
composite material	композиционный материал	композиційний матеріал
compound die	совмещенный штамп	сполучений штамп
compression	сжатие	стиснення
condensate	конденсат	конденсат
coned cutter	коническая фреза	конічна фреза
conform	соответствовать	відповідати
congregation	сосредоточение	зосередження
connecting rod	шатун	шатун
conoda	конода	конода
Constitutional diagram	диаграмма состояния, фазовая диаграмма	діаграма стану фазова діаграма
consumable electrode	расходуемый электрод	електрод, що витрачається
contact type	контактного типа	контактного типу
contact-initiated discharge machining	электроконтактная обработка	електроконтактна обробка
contactor	прерыватель тока	переривач струму
container	контейнер	контейнер
contamination	загрязнение	забруднення
continuous casting	непрерывное литье	безперервне лиття
continuous chip	сливная стружка	зливна стружка
continuous furnace	методическая печь	методична піч.
continuous hardening	непрерывная закалка	безперервне гартування

continuous teeming	непрерывная разливка	безперервне розливання
contour	контур	контур
contour of Burgers	контур Бюргерса	контур Бюргерса
contraction	уменьшение размеров, усадка	зменшення розмірів, усадка
controlled (protective) atmosphere	контролируемая (защитная) атмосфера	контрольована (захисна) атмосфера
convection	конвекция	конвекція
conventional milling	встречное фрезерование	зустрічне фрезерування
conversion iron	передельный чугун	переробний чавун
convex	выпуклый	опуклий
coolant	Смазочно-охлаждающая жидкость (СОЖ)	мастильно-охолоджувальна рідина (МОР)
coordination number	координационное число	координаційне число
cope	верхняя часть (модели, формы)	верхня частина (моделі, форми)
cope and drag pattern	разъемная модель	рознімна модель
copper	медь	мідь
copper glance	медный блеск	мідний блиск
copper pyrite	медный колчедан	мідний колчедан
core box	стержневой ящик	стрижневий ящик
core of flame	ядро пламени	ядро полум’я
core print	знак (знаковая часть стержня)	знак (знакова частина стрижня)
corner cutter	угловая фреза	кутова фреза
corner weld	угловое соединение	кутове з’єднання
corrodent	вещество, способствующее коррозии	речовина, що сприяє корозії
corrosion-resistant steel	нержавеющая сталь	нержавіюча сталь
counterbore	зенковка, цековка	зенківка, цековка
counterboring	зенкование	зенкування

countersink	зенковка	зенківка
countersinking	зенкование	зенкування
coupler	хамут, сцепка	хомут, зчіпка
coupling	муфта	муфта
crack	трещина	тріщина
crank press	кривошипный пресс	кривошипний прес
crank shaft	кривошип	кривошип
crater	кратер	кратер
creep	ползучесть	повзучість
creep limit	предел ползучести	границя повзучості
critical castings	ответственные отливки	відповідальні виливки
critical cooling rate	критическая скорость охлаждения	критична швидкість охолодження
critical diameter	критический диаметр	критичний діаметр
critical radius	критический радиус	критичний радіус
cross rolling	поперечная прокатка	поперечна прокатка
cross section	поперечное сечение	поперечний переріз
crossgate	шлакоуловитель	шлаковловлювач
crucible	тигель	тигель
crucible (coreless) induction furnace	тигельная индукционная печь без сердечника	тигельна індукційна піч без сердечника
cryolite (Na_3AlF_6)	криолит	кріоліт
crystal lattice	кристаллическая решетка	кристалічна решітка
crystal structure	кристаллическая структура	кристалічна структура
crystalline body	кристаллическое тело	кристалічне тіло
crystallite	кристаллит, мелкий кристалл	кристаліт, дрібний кристал
crystallization	затвердевание, кристаллизация	затвердіння, кристалізація
cupola	вагранка	вагранка
curing	отверждение	отвердіння
current cut-off switch	прерыватель тока	переривач струму
current lead	токоподвод	стумопідведення
current strength	сила тока	сила струму
cut-off valve	отсечной клапан	відсічний клапан
cutter	фреза	фреза

cutting angle	угол резания	кут різання
cutting face	передняя поверхность (резца)	передня поверхня (різця)
cutting fluid	смазочно-охлаждающая жидкость (СОЖ)	мастильно-охолоджувальна рідина (МОР)
cutting of	обрубка (отделение литниковой системы и прибылей)	обрубка (відділення ливникової системи та додатків)
cutting stroke	рабочий ход	робочий хід
cutting tool	резец	різець
cutting, machining	обработка резанием	обробка різанням
cutting-off	рубка, отрезка	рубка, відрізка
cutting-off mill	отрезной станок	відрізний верстат
cutting-out	вырубка	вирубування
cut-up milling	встречное фрезерование	зустрічне фрезерування
cyaniding	цианирование	ціанування
cyclic tests	циклические испытания	циклічні випробування
cylinder	цилиндр	циліндр
cylindrical grinding mill	круглошлифовальный станок	круглошліфувальний верстат
damage	повреждение	пошкодження
dead center	неподвижный центр	нерухомий центр
decarburization	обезуглероживание	зневуглецьовування
deep vacuum	глибокий вакуум	глибокий вакуум
defect	дефект	дефект
deficit solid solution	твердый раствор вычитания	твердий розчин вирахування
deformability	податливость (смеси)	піддатливість (суміші)
deformation	деформация	деформація
degassing	дегазация	дегазація
degree of supercooling	степень переохлаждения	ступінь переохолодження
degree of tetragonality	степень тетрагональности	ступінь тетрагональності
degrees of freedom	степени свободы	степені свободи
delta iron	дельта железо	дельта залізо

dendrite	дендрит	дендрит
dendrite segregation	дендритная сегрегация	дендритна сегрегація
deoxidation	раскисление	розкислення
deoxidize	раскислять	розкислювати
deoxidizer	раскислитель	розкислювач
dephosphorization	дефосфорация	дефосфорація
depth of cut	толщина срезаемого слоя, глубина резания	товщина шару, що зрізується, глибина різання
design engineer	конструктор	конструктор
design size	номинальный размер	номінальний розмір
designation	обозначение	позначення
desulphurization	десульфурация	десульфурация
desulphurize	удалять серу	видаляти сірку
detaching	удаление	видалення
deviation	отклонение	відхилення
device	прибор, устройство	прилад, пристрій
dew point	точка росы	точка роси
dextrin	декстрин	декстрин
dial	шкала (прибора)	шкала (приладу)
diamond	алмаз	алмаз
die	матрица, штамп	матриця, штамп
Die	штамп	штамп
die forging	объемная штамповка	об'ємне штампування
die steel	штамповая сталь	штампова сталь
diffusion	диффузия	дифузія
diffusion annealing	гомогенизация, диффузионный отжиг	гомогенізація, дифузійний відпал
diffusion coating	диффузионная металлизация	дифузійна металізація
diffusion welding	диффузионная сварка	дифузійне зварювання
diffusionless transformation	бездиффузионное превращение	бездифузійне перетворення
dilution	растворение	розчинення
dimension	размерность	розмірність
dimension accuracy	размерная точность	розмірна точність
dinas brick	динасовый кирпич	динасова цегла

dipping	погружение	занурення
direct (forward) pressing	прямое прессование	пряме пресування
direct current	постоянный ток	постійний струм
direct polarity	прямая полярность	пряма полярність
direct pouring	разливка сверху	розливання зверху
direct reduction	прямое восстановление	пряме відновлення
directional solidification	направленная кристаллизация	спрямована кристалізація
dirt (slag) trap	шлакоуловитель	шлаковловлювач
discontinuous chip	стружка скалывания	стружка сколювання
disk cutter	дисковая фреза	дискова фреза
dislocation	дислокация	дислокація
dislocation density	плотность дислокаций	щільність дислокацій
dispersity	дисперсность	дисперсність
displacement	перемещение	переміщення
dissipate	рассеивать	розсіювати
distillation	дистилляция	дистиляція
distilling	дистилляция	дистиляція
distortion	деформация, искажение	деформація, викривлення
divider	циркуль	циркуль
dolomite	доломит	доломіт
double tee	двутавр	двотавр
double-housing planer	двухстоечный продольно-строгальный станок	поздовжньо-стругальний верстат з двома стійками
down weld	нижний (напольный) шов	нижній шов
down-cut milling	попутное фрезерование	попутне фрезерування
downgate (sprue)	стояк	стояк
downhand (flat) weld	нижний (напольный) шов	нижній шов
drag	нижняя часть (модели, формы)	нижня частина (моделі, форми)

draw	тянуть, волочить	тягнути, волочити
drawhole	волока	волока
drawing	чертеж	креслення
drawing	волочение, протяжка, вытяжка	волочіння, витягування, протягування
drawing capacity	способность к вытяжке (технологическая пластичность)	здібність до глибокого витягування (технологічна пластичність)
drawing coefficient	коэффициент вытяжки	коефіцієнт витягування
dressing	обогащение (руды)	збагачування (руди)
drill	сверло	свердло
drilling mill	сверлильный станок	свердлильний верстат
drop	капля	крапля
drop-bottom bucket	корзина с раскрывающимся дном	кошик із дном, що розкривається
droplet segregation	дендритная сегрегация	дендритна сегрегація
dropping	падающая	що падає
drum mill	барабанный стан	барабанний стан
dry sand	сухая формовочная смесь	суха формувальна суміш
duct	канал	канал
duo mill	дуо-стан	дуо-стан
duplex process	дуплекс-процесс	дуплекс-процес
durability	долговечность	довговічність
duralumin	дюралюминий	дюралюміній
duration	длительность	тривалість
dynamic tests	динамические испытания	динамічні випробування
eddy currents	вихревые токи	вихрові токи
edge	кромка, острие	кромка, вістря
edge dislocations	краевая дислокация	крайова дислокація
edge weld	торцевое соединение	торцеве з’єднання
edge-runner mills	бегуны	бігуни

elastic limit	предел упругости	границя пружності
elastic strain	упругая деформация	пружна деформація
elasticity	упругость	пружність
elbor (cubic borous nitride)	эльбор	ельбор
electric arc welding	электродуговая сварка	електродугове зварювання
electric resistance arc machining	электроконтактная обработка	електроконтактна обробка
electric resistance welding	контактная сварка	контактне зварювання
electrical conductivity	электропроводность	електропровідність
electrical discharge machining	электроискровая обработка	електроіскрова обробка
electrical sheet steel	листовая электротехническая сталь	листова електротехнічна сталь
electrical steel	электротехническая сталь	електротехнічна сталь
electrical-pulse discharge machining	электроимпульсная обработка	електроімпульсна обробка
electric-arc furnace	электродуговая печь	електродугова піч
electro slag remelting	электрошлаковый переплав (ЭШП)	електрошлакове переплав
electrochemical grinding	электрохимическое шлифование	електрохімічне шліфування
electrochemical machining	электролитическая размерная обработка	електролітична розмірна обробка
electrode	электрод	електрод
electrolysis	электролиз	електроліз
electrolyte	электролит	електроліт
electrolytic etching	электролитическое травление	електролітичне травлення
electrolytic grinding	электрохимическое шлифование	електрохімічне шліфування
electrolytic polishing	электролитическое (электрохимическое) полирование	електролітичне (електрохімічне) полірування

electrolytic refining	электролитическое рафинирование	електролітичне рафінування
electrolytically assisted cutting-off machine	анодно-механический отрезной станок	анодно-механічний відрізний верстат
electrolytically assisted discharge machining	анодно-механическая обработка	анодно-механічна обробка
electromachining	обработка с использованием электрического тока	обробка з використанням електричного струму
electromagnetic work-holding fixture (table)	электромагнитный стол	електромагнітний стіл
electron gun	электронная пушка	електронна пушка
electron microscope	электронный микроскоп	електронний мікроскоп
electron-beam machining	электронно-лучевая обработка	електронно-променева обробка
electron-beam welding	электронно-лучевая сварка	електронно-променеве зварювання
electrophysical and electrochemical machining	обработка с использованием электрического тока	обробка з використанням електричного струму
electroslag welding	электрошлаковая сварка	електрошлакове зварювання
electrospark machining	электроискровая обработка	електроіскрова обробка
elevated temperature	повышенная температура	підвищена температура
elongation	удлинение	здовження
embrittle	делать хрупким	робити крихким
emit	испускать, излучать	випромінювати
end cutter, shank cutter	концевая фреза	кінцева фреза
end quench test	торцевая проба	торцева проба
end, face	торец	торець

endothermic atmosphere	эндотермическая атмосфера	ендотермічна атмосфера
engineering material	конструкционный материал	конструкційний матеріал
engineering steel	машиностроительная сталь	машинобудівна сталь
engineering strength	реальная прочность	реальна міцність
enlarging	рассверливание	розсвердлювання
enthalpy	энтальпия	ентальпія
entropy	энтропия	ентропія
equiaxed grain	равноосное зерно	рівноосне зерно
equilibrium diagram	диаграмма состояния, фазовая диаграмма	діаграма стану фазова діаграма
etchant	травитель	травник
etching	травление	травлення
ethyl silicate	этил-силикат	етіл-силікат
eutectic	эвтектика, эвтектический	евтектика, евтектичний
eutectoid	эвтектоид, эвтектоидный	евтектоїд, евтектоїдний
evolve	выделять	виділяти
exhaust pipe	дымоход	димохід
expendable	расходуемый	що витрачається
explosion welding	сварка взрывом	зварювання вибухом
explosive gas	взрывоопасный газ	вибухонебезпечний газ
extension coefficient	коэффициент вытяжки	коефіцієнт витягування
external terminals	выходные клеммы	вихідні клеми
extra plane	экстраплоскость	екстра площина
extrusion	экструзия, прессование	екструзія, пресування
extrusion ram	плунжер	плунжер
eye shield	защитное стекло для глаз	захисне скло для очей
face	грань	грань
face cutter	торцевая фреза	торцева фреза

face-centered cubic lattice (fcc)	гранецентрированная кубическая решетка (гцк)	гранецентрована кубічна решітка (гцк)
facing	торцевание	торцювання
facing sand	облицовочная формовочная смесь	лицювальна формувальна суміш
facing tool	торцевой резец	торцевий резець
failure	поломка	поломка
fasten	крепить	кріпити
fatigue strength	усталостная прочность	втомна міцність
feed gear	коробка подач	коробка подач
feed motion	движение подачи	рух подачі
feed value	толщина срезаемого слоя, глубина резания	товщина шару, що зрізується, глибина різання
ferrite	феррит	ферит
ferrite-cementite aggregate	феррито-цементитная смесь	ферито-цементитна суміш
ferritic steel	ферритная сталь	феритна сталь
ferroalloys plant	ферросплавный завод	феросплавний завод
ferromanganese	ферромарганец	феромарганець
ferrosilicon	ферросилиций	феросиліцій
ferrous alloy	сплав на основе железа	сплав на основі заліза
fettling	очистка (от пригара)	очищення (від пригару)
fettling	заправка (печи)	заправка (печі)
fibrous	волокнистый	волокнистий
fibrous structure	волокнистая структура	волокниста структура
filament-like crystal	нитевидный кристалл	нитковидний кристал
filler rod	присадочный пруток	присаджувальний пруток
filler wire	сварочная проволока	зварювальний дріт
fillister-head screw	винт с потайной головкой	гвинт зі схованою голівкою
film boiling	пленочное кипение	плівкове кипіння
fin	заусенец, облой	задирка, облой

fine boring mill	координатно-расточной станок	координатно-розточувальний верстат
fine grain	мелкое зерно	дрібне зерно
fine structure	мелкозернистая структура	дрібнозерниста структура
finish cutting	чистовая обработка резанием	чистова обробка різанням
finish grinding	чистовое шлифование	чистове шліфування
finished article	деталь (готовая)	деталь (готова)
finishing	чистовая обработка	чистова обробка
finishing gauge	чистовой калибр	чистовий калібр
finishing mechanical treatment	окончательная обработка резанием	остаточна обробка різанням
fire refining	огневое рафинирование	вогневе рафінування
fireproof clay, fireclay, caolinite (Al_2O_3*$2SiO_2$*$2H_2O$)	огнеупорная глина	вогнетривка глина
fireproof material	огнеупорный материал (огнеупор)	вогнетривкий матеріал (вогнетрив)
first-type annealing	отжиг первого рода	відпал першого роду
fit	пригонка	припасовування
fitting	пригонка	припасовування
flake	флокен	флокен
flaked graphite, flaky	хлопьевидный графит	пластівчастий графіт
flanging	отбортовка	відбортування
flank	торец, боковая сторона	торець, бік
flash	заусенец, облой	задирка, облой
flash welding	стыковая сварка оплавлением	стикове зварювання оплавленням
flask, moulding box	опока	опока
flexible cable	гибкий кабель	гнучкий кабель

floor sand	оборотная (наполнительная) формовочная смесь	оборотна (наповнювальна) формувальна суміш
flotation	флотация	флотація
flow off	выпор	випор
flowing chip	сливная стружка	зливна стружка
fluctuation	флуктуация	флуктуація
flue	газовый канал	газовий канал
fluidity	жидкотекучесть	рідкотекучість
fluidized bed furnace	печь кипящего слоя	піч киплячого шару
fluidized sand	«кипящий» песок	«киплячий» пісок
fluoride (CaF_2), fluorspar (CaF2)	плавиковый шпат, фторид	плавиковий шпат, фторид
flute	паз, выемка, канавка	паз, виїмка, канавка
flux	флюс	флюс
fly wheel	маховик	маховик
follow die	штамп последовательного действия	штамп послідовної дії
foreign impurities	посторонние примеси	сторонні домішки
forge (fire) welding	кузнечная сварка	зварювання куванням
forge hammer	кузнечный молот	ковальський молот
forge pitch	кузнечный уклон	ковальський ухил
forging	поковка, ковка	поковка, кування
form cutter	фасонная фреза	фасонна фреза
form-cutting method	метод копирования	метод копіювання
forming	получение фасонных поверхностей	отримання фасонних поверхонь
forming (cold)	объемная формовка (холодная)	об’ємне формування (холодне)
forming (shaping) operation	формоизменяющая операция	формозмінна операція
forming tool	фасонный резец	фасонний резець
foundry	литейное производство	ливарне виробництво
foundry alloy	лигатура, сплав для легирования	лігатура, сплав для легування

foundry iron	литейный чугун	ливарний чавун
foundry practice	литейное производство	ливарне виробництво
foundry properties	литейные свойства	ливарні властивості
foundry slope	литейный уклон	ливарний ухил
four-high mill	кварто-стан	кварто-стан
fracture	излом (сплава)	злам
free cutting steel	автоматная сталь	автоматна сталь
free energy	свободная энергия	вільна енергія
free-cutting brass	автоматная латунь	автоматна латунь
Frenkel defect	атом внедрения, дефект Френкеля	атом проникнення, дефект Френкеля
friction	трение	тертя
friction welding	сварка трением	зварювання тертям
fringe crystal	вытянутый кристалл	витягнутий кристал
front clearance angle	задний угол	задній кут
fuel	топливо	паливо
full annealing	полный отжиг	повний відпал
full heating	полная закалка	повне гартування
fumigating chamber	распар	розпар
fundament	фундамент	фундамент
furnace	нагревательная печь	нагрівальна піч
fusion	плавление, плавка	плавлення, плавка
fusion welding	сварка плавлением	зварювання плавленням
gang cutter	наборная фреза	фреза, що набирається
gap	зазор	зазор
gas carburizing	газовая цементация	газова цементація
gas permeability	газопроницаемость	газопроникність
gas welding	газовая сварка	газове зварювання
gating system	литниковая система	ливникова система
gauge, gage	калібр, измерительный прибор	калібр, вимірювальний прилад
gear (tooth) cutter	модульная фреза	Модульна фреза
gear- and thread-cutting machines	зубо- и резьбонарезные станки	зубо- і різенарізні верстати

gear box	коробка скоростей	коробка швидкостей
gear cutting	изготовление зубчатых колес	виготовлення зубчастих коліс
gear rack	зубчатая рейка	зубчаста рейка
gearcase	корпус редуктора	корпус редуктора
gelatin	желатин	желатин
generating process	метод обкатки (огибания)	метод обкатки (огинання)
generator	генератор	генератор
germanium	германий	германій
glass	стекло	скло
globular graphite	шаровидный, глобулярный графит	кулястий, глобулярний графіт
globular structure	равноосная структура	ровноосна структура
glue	клей	клей
grade	марка (стали)	марка (сталі)
grade steel, good quality s.	качественная сталь	якісна сталь
gradual, smooth	постепенный, равномерный	поступовий, рівномірний
gradually dropping	полого падающая	що плавно падає
grain	зерно (кристаллит)	зерно (кристаліт)
grain boundary	граница зерна	границя зерна
granular pearlite	зернистый перлит	зернистий перліт
graphite	графит	графіт
graphite-chamotte	графито-шамот (огнеупор)	графіто-шамот (вогнетрив)
graphitized cast iron	графитизированный чугун	графітизований чавун
graphitizing elements	графитизирующие элементы	елементи, що сприяють графітизації
grate	решетка	грати
gravel	гравий	гравій
gravity segregation	ликвация	ліквація
green sand	сырая формовочная смесь	вогка формувальна суміш
grey cast iron	серый чугун	сірий чавун

grind	шлифовать	шліфувати
grinding	шлифование	шліфування
grinding mill	шлифовальный станок	шліфувальний верстат
grip	захватывать	захоплювати
groove	паз	паз
guide cylinder	направляющий цилиндр	направляючий циліндр
guillotine shears	гильотинные ножницы	гільйотинні ножиці
Guinier-Preston zone	зона Гинье-Престона	зона Гіньє-Престона
half-finished article	заготовка	заготовка
hammer	молот	молот
hammer welding	кузнечная сварка	зварювання куванням
hammering	ковка	кування
hand (machine) forging	ручная (машинная) ковка	ручне (машинне) кування
hard alloys, cemented carbides	твердые сплавы	тверді сплави
hard drawn wire	холоднотянутая проволока	холоднопротянота проволока
hardenability	прокаливаемость	прогартовуваність
hardened steel	закаленная сталь	загартована сталь
hardening	упрочнение, закалка	зміцнення, гартування
hardening capacity	закаливаемость	загартовуваність
hard-facing alloy	твердый сплав	твердий сплав
hardness	твердость	твердість
harmful	вредный	шкідливий
heading	высадка	висадження
headstock	передняя бабка	передня бабка
hearth	горн	горн
hearth bottom	днище печи	днище печі
heat conductivity	теплопроводность	теплопровідність
heat erosion	высокотемпературная эрозия	високотемпературна ерозія
heat treatment	термическая обработка	термічна обробка
heater	нагревательная печь	нагрівальна піч

heat-insulting coat	теплоизоляционное покрытие	теплоізоляційне покриття
heat-producing ability	теплотворная способность	теплотворна спроможність
heat-resistant steel	теплостойкая сталь	теплостійка сталь
helical rolling	поперечно-винтовая прокатка	поперечно-гвинтова прокатка
helmet shield	шлем с прозрачным экраном	шолом із прозорим екраном
hematite (Fe_2O_3)	гематит, красный железняк	гематит, червоний залізняк
heterogeneous	гетерогенный, неоднородный	гетерогенний, неоднорідний
hexagonal close packed lattice (hcp)	гексагональная плотноупакованная решетка (гпу)	гексагональна щільно упакована решітка
high-frequency induction quenehing	закалка токами высокой частоты	гартування токами високої частоти
high-precision mill	прецизионный станок	прецизійний верстат
High-speed steel	быстрорежущая сталь	швидкорізальна сталь
high-strength cast iron	высокопрочный чугун	високоміцний чавун
high-strength steel	высокопрочная сталь	високоміцна сталь
high-temperature tempering	высокий отпуск	високий відпуск
hob cutter	червячная фреза	черв'ячна фреза
holding furnace	миксер	міксер
holding time	время выдержки (при заданной температуре)	час витримки (при заданій температурі)
hollow casting	пустотелая отливка	пустотілий виливок
homogeneous	гомогенный, однородный	гомогенний
homogenization	гомогенизация, диффузионный отжиг	гомогенізація, дифузійний відпал
honing	хонингование	хонінгування
hopper	бункер	бункер
horizontal forging	горизонтально-	горизонтально-

machine	ковочная машина (ГКМ)	кувальна машина (ГКМ)
horizontal weld	горизонтальный шов	горизонтальний шов
hot deformation	горячая деформация	гаряча деформація
hot die forging	горячая объемная штамповка	гаряче об’ємне штампування
hot pressing chamber	горячая камера прессования	гаряча камера пресування
hot resistance	жаростойкость	жаростійкість
hot spot	термический узел	термічний вузол
hot strength	жаропрочность	жароміцність
hot top	верх (надставка) изложницы	верх (надставка) виливниці
hot-shortness	красноломкость	червоноламкість
housing	корпус	корпус
hydraulic press	гидравлический пресс	гідравлічний прес
hydroblasting	гидравлическая очистка	гідравлічне очищення
hydrocarbon	углеводород	вуглеводень
hydrogen	водород	водень
hydrostatic pressure pipe	напорная труба	напірна труба
hypereutectic	заэвтектический	заевтектичний
hypereutectoid	заэвтектоидный	заевтектоїдний
hypoeutectic	доэвтектический	доевтектичний
hypoeutectoid	доэвтектоидный	доевтектоїдний
ilmenite	ильменит	ільменіт
immerse	погружать	заглиблювати, занурювати
impact force	ударная нагрузка	ударне навантаження
impact strength	ударная вязкость	ударна в’язкість
impact tests	динамические испытания	динамічні випробування
impact toughness	ударная вязкость	ударна в’язкість
impede	препятствовать, замедлять	перешкоджати, сповільнювати
impracticable	невыполнимый	нездійсненний
impregnation	насыщение	насичення

impression	отпечаток	відбиток
impression, gauge	ручей	рівчак
inclination	склонность	схильність
inclined	склонный	схильний
incubation period	инкубационный период	інкубаційний період
indentation	отпечаток	відбиток
indentor	индентор	індентор
index	показатель	показник
indices of atomic planes	индексы атомных плоскостей	індекси атомних площин
indices of directions	индексы направлений	індекси напрямків
indirect (reverse) pressing	обратное прессование	зворотне пресування
indirect reduction	косвенное восстановление	непряме відновлення
induction furnace with core	индукционная печь с сердечником	індукційна піч із сердечником
induction heating	индукционный нагрев	індукційне нагрівання
inductor	индуктор	індуктор
inert refractory material	инертный огнеупор	Інертний вогнетрив
inflection	отклонение	відхилення
ingate	питатель	живильник
ingot	слиток	злиток
ingot mould	изложница	виливниця
ingredient	ингредиент, компонент	інгредієнт, компонент
inherently coarse-grained steel	наследственно крупнозернистая сталь	спадково крупнозерниста сталь
inherently fine-grained steel	наследственно мелкозернистая сталь	спадково дрібнозерниста сталь
initiate discharge	инициировать разряд (зажигать дугу)	ініціювати розряд (запалювати дугу)
injector	инжектор	інжектор
inoculant	модификатор	модифікатор
inoculation	модифицирование	модифікування

input terminals	входные клеммы	вхідні клеми
insert	вставка	вставка
integrally cast hole	отверстие, полученное в отливке	отвір, отриманий у виливку
interaction	взаимодействие	взаємодія
intercryslalline corrosion	межкристаллитная коррозия (МКК)	т. феритна корозія (МКК)
intercrystallyne	внутризеренный	інтеркристалітний
interface	граница, поверхность раздела	границя, поверхня розділу
intergranular	внутризеренный	інтеркристалітний
intermediate (bainite) transformation	промежуточное (бейнитное) превращение	проміжне (бейнітне) перетворення
intermittent welding	шовная сварка	шовне зварювання
internal grinding mill	внутришлифовальный станок	внутрішньо-шліфувальний верстат
intersect	пересекаться	перетинатися
interstitial atom	атом внедрения, дефект Френкеля	атом проникнення, дефект Френкеля
interstitial compound	фаза внедрения	фаза проникнення
interstitial solid solution	твердый раствор внедрения	твердий розчин проникнення
inverted weld	потолочный шов	стельовий шов
investment	огнеупорная оболочка (в литье по выплавляемым моделям)	вогнетривка оболонка (при литті за витоплюваними моделями)
investment casting	литье по выплавляемым моделям	лиття за моделями, які виплавляються
iron	железо	залізо
irremediable	неисправимый	непоправний
irremediable	неисправимый	невиправний
irreversible temper brittleness	необратимая отпускная хрупкость (первого рода)	незворотна відпускна хрупкість (першого роду)
isomorphic impurity	изоморфная примесь	ізоморфна домішка
isothermal annealing	изотермический отжиг	ізотермічний відпал

isothermal austenite transformation diagram, TTT-diagram	диаграмма изотермического превращения аустенита	діаграма ізотермічного перетворення аустеніту
isothermal quenching	изотермическая закалка	ізотермічне гартування
isotropic	однородный	однорідній
item	изделие, деталь	виріб, деталь
jet	горелка, форсунка, струя	пальник, форсунка, струмінь
jet	факел	факел
joint line	линия разъема	лінія рознімання
jolting knock-out grid	вибрационная выбивная решетка	вібраційна вибивна решітка
Joule	Джоуль	Джоуль
kerosene	керосин	гас
knee	консоль (станка)	консоль (верстата)
knocking out	выбивка (отливок, стержней)	вибивання (виливків, стрижнів)
knurling	накатка	накатка
lamellar graphite	пластинчатый графит	пластинчастий графіт
lamellar pearlite	пластинчатый перлит	пластинчастий перліт
lance	фурма	фурма
lanthanum	лантан	лантан
lap	напуск	напуск
lapping	притирка	притирка
laser material processing	лазерная обработка	лазерна обробка
laser welding	лазерная сварка	лазерне зварювання
latent heat of solidification	скрытая теплота кристаллизации	прихована теплота кристалізації
lathe	токарный станок	токарний верстат
lattice constant	постоянная решетки	постійна решітки
lattice points (sites)	узлы решетки	вузли решітки
Laves phase	фаза Лавеса	фаза Лавеса

leaching, lixiviation	выщелачивание	вилуження
lead	свинец	свинець
leather	кожа	шкіра
ledeburite	ледебурит	ледебурит
ledeburitic steel	ледебуритная сталь	ледебуритна сталь
left-hand tool	левый резец	лівий різець
lengthwise rolling	продольная прокатка	поздовжня прокатка
lever-spring drive	рычажно-пружинный привод	важільно-пружинний привод
lime (CaO)	известь	вапно
limestone ($CaCO_3$)	известняк	вапняк
limit	предел	границя
limit of proportionality	предел пропорциональности	границя пропорційності
limited solid solution	ограниченный твердый раствор	обмежений твердий раствор
limonite ($2Fe_2O_3*3H_2O$)	бурый железняк	бурий залізняк
linear defect	линейный дефект	лінійний дефект
linear motion	прямолинейное движение	прямолінійний рух
linear shrinkage	линейная усадка	лінійна усадка
liner	вкладыш	вкладиш
lining	футеровка	футеровка
linkage	шарнир	шарнір
lip	режущая кромка (сверла)	різальна кромка (свердла)
liquation	ликвация	ліквація
liquid solution	жидкий раствор	рідкий розчин
liquidus line	линия ликвидуса	лінія ліквідусу
lithium	литий	літій
longitudinal motion	продольное движение	поздовжній рух
long-range order	дальний порядок	дальній порядок
long-term strength	длительная прочность	тривала міцність
loop	петля	петля
loose abrasive	незакрепленный абразивный порошок	незакріплений абразивный порошок
lower bainite	нижний бейнит	нижній бейніт

low-temperature tempering	низкий отпуск	низький выдпуск
lubricant	смазка	мастило
luting	покрытие электрода	покриття електрода
machinability	обрабатываемость резанием	обробка різанням
machine arc welding	автоматическая дуговая сварка	автоматичне дугове зварювання
machine steel	машиностроительная сталь	машинобудівна сталь
machine surface	обработанная поверхность	оброблена поверхня
machine tool	станок	верстат
machine tool operations	обработка металлов резанием	обробка металів різанням
machine-building plant	машиностроительный завод	машинобудівний завод
machinery allowance	припуск	припуск
machine-tool, machine	станок	верстат
machining	обработка металлов резанием	обробка металів різанням
machining allowance	припуск на механическую обработку	припуск на механічну обробку
macrostructure	макроструктура	макроструктура
magnesite	магнезит	магнезит
magnesium	магний	магній
magnetic flux	магнитный поток	магнітний потік
magnetic permeability	магнитная проницаемость	магнітна проникність
magnetic saturation	магнитное насыщение	магнітне насичення
magnetic steel	сталь с особыми магнитными свойствами	сталь з особливими магнітними властивостями
magnetically hard materials	магнитотвердые материалы	магнітотверді матеріали
magnetically soft materials	магнитомягкие материалы	магнітом’які матеріали

magnetite (Fe_3O_4)	магнитный железняк	магнітний залізняк
magnetostriction	магнитострикция	магнітострикція
magnification	увеличение	збільшення
major cutting edge	главное режущее лезвие	головне різальне лезо
malleability	ковкость	ковкість
malleable cast iron	ковкий чугун	ковкий чавун
mandrel	прошивень, оправка	оправка
manganese	марганец	марганець
manual (hand) arc welding	ручная дуговая сварка	ручне дугове зварювання
marageing steel	сталь мартенситно-стареющая	сталь мартенситно-старіюча
marble	мрамор	мармур
martensite	мартенсит	мартенсит
martensite decomposition	распад мартенсита	розпад мартенситу
martensite transformation	мартенситное превращение	мартенситне перетворення
mass density	плотность	щільність
mass of falling parts	масса падающих частей	маса частин, що падають
master die	пресс-форма	прес-форма
mating	сопряжение	сполучення
matte	штейн	штейн
medium-temperature tempering	средний отпуск	Середній відпуск
мelting	плавление	плавлення
melting	плавление, плавка	плавлення, плавка
melting point temperature	температура плавления	температура плавлення
meshing	зацепление	зачіп
metal cutting	обработка металлов резанием	обробка металів різанням
metal forming	обработка металлов давлением (ОМД)	обробка металів тиском (ОМТ)
metal forming	обработка металлов давлением	обробка металів тиском

metal mould	кокиль, металлическая форма, постоянная форма	кокіль, металева форма, постійна форма
metal mould casting	литье в металлические формы, кокильное литье	лиття в металеві форми, кокільне лиття
metallic compound	металлическое соединение	металічне з'єднання
metallurgy	металлургия	металургія
microfinishing mill	lоводочный станок	доводочний верстат
Microirregularity	микронеровность	мікронерівність
microstructure	микроструктура	мікроструктура
microstructure	микроструктура	мікроструктура
mill	завод, прокатный стан, станок, мельница	завод, прокатний стан, верстат, млин
milling	фрезерование	фрезерування
milling cutter	фреза	фреза
milling mill, machine	фрезерный станок	фрезерний верстат
мine	шахта	шахта
mine-dressing plant	горно-обогатительный комбинат	гірничо-збагачувальний комбінат
minor cutting edge	вспомогательное режущее лезвие	допоміжне різальне лезо
mixer	миксер	міксер
modification	модифицирование	модифікування
modifying mix	смесь для модифицирования	суміш для модифікування
modulus of elasticity	модуль упругости	модуль пружності
monocrystal	монокристалл	монокристал
monovariant	моновариантный	моноваріантний
mosaic structure	мозаичная структура	мозаїчна структура
mottled cast iron	половинчатый чугун	половинчатий чавун
mould	форма	форма
moulding	формовка	формування
multiroll mill	многовалковый стан	багатовалковий стан
multi-spindle machine	многошпиндельный станок	багатошпиндельни й верстат

Multiturn coil	многовитковая катушка	багатовиткова котушка
natural ageing	естественное старение	природне старіння
natural gas (C_mH_n)	природный газ	природний газ
necking	сужение	звуження
necking	прорезка кольцевой канавки	прорізання кільцевої канавки
neutral strengthening agent (element)	нейтральный, не упрочняющий элемент	Нейтральний не зміцнюючий елемент
nickel	никель	нікель
niobium	ниобий	ніобій
nitride	нитрид	нітрид
nitriding	азотирование	азотування
nitrogen	азот	азот
nodular cast iron	высокопрочный чугун	високоміцний чавун
nodular graphite	шаровидный, глобулярный графит	кулястий, глобулярний графіт
nominal size	номинальный размер	номінальний розмір
non- ferrous alloy	цветной сплав	кольоровий сплав
non heat-treatable alloy	сплав, не упрочняемый термообработкой	сплав, що не зміцнюється термообробкою
nonconsumable electrode	постоянный электрод	постійний електрод
nonequilibrium phase	неравновесная фаза	нерівноважна фаза
non-metallic inclusion	неметаллическое включение	неметалеве включення
nonoxidation heating	безокислительный нагрев	безокисне нагрівання
nonvariant	нонвариантный	нонваріантний
normal flame	нормальное пламя	нормальне полум’я
normal stress	нормальное напряжение	нормальне напруження
normalizing	нормализация	нормалізація
notation	обозначение	позначення
notch	надрез	надріз

notched bar	призматический образец с надрезом	призматичний зразок з надрізом
notching	надрезка	надрізання
nozzle	выпускное отверстие	випускний отвір
nozzle	сопло	сопло
nucleus	ядро, зародыш	ядро, зародок
numeral control mill	станок с числовым программным управлением	Верстат з числовим програмним керуванням
nut	гайка	гайка
odorless	без запаха	без запаху
Ohm	Ом	Ом
oil coke	нефтекокс	нафтококс
open die	открытый штамп	відкритий штамп
Open-circuit run	холостой ход	холостий рух
open-hearth furnace	мартеновская печь	мартенівська піч
optical microscope	оптический микроскоп	оптичний мікроскоп
ordered solid solution	упорядоченный твердый раствор	упорядкований твердий розчин
ore deposit	месторождение руды	родовище руди
ore process	рудный процесс	рудний процес
orifice	отверстие	отвір
origin of coordinates	начало координат	початок координат
oscillator	осциллятор	осцилятор
output	выпуск, производительность	випуск, продуктивність
output terminals	выходные клеммы	вихідні клеми
overall length	полная длина	повна довжина
overarm	хобот (станка)	хобот (верстата)
overflow	выпор	випор
overflow pipe	сливная труба	зливальна труба
overheating	перегрев	перегрів
overlap	напуск	напуск
overlaying metal	наплавляемый металл	метал, що наплавляється
oxidation resistance	сопротивление окислению	опір окисленню
oxide	оксид	оксид

oxidizing flame	окислительное пламя	полум’я, що окислює
oxidizing melting	плавка с окислением	плавка з окисленням
oxidizing roasting	окислительный обжиг	окисний випал
oxygen	кислород	кисень
pack carburizing	цементация в твердом карбюризаторе	цементація у твердому карбюризаторі
paraffin	парафин	парафін
part	деталь (готовая)	деталь (готова)
partial annealing	неполный отжиг	неповний відпал
partial quenehing	неполная закалка	неповне гартування
parting	отрезка	відрізання
parting line	линия разъема	лінія рознімання
parting tool	отрезной резец	відрізний ріцець
pattern	модель	модель
pattern making	модельное производство	виробництво моделей
fireproof base	огнеупорная основа	вогнетривка основа
pattern taper	литейный уклон (на модели)	ливарний ухил (на моделі)
paying out mill	пилигримовый стан, раскатной стан	пілігримів стан, розкатний стан
paying-out	раскатка	розкочування
peak	выступ	виступ
pear-like tank	сосуд грушевидной форм	посудина грушевидної форми
pearlite	перлит	перліт
pearlite transformation	перлитное превращение	перлітне перетворення
peat coke	торфяной кокс	торф’яний кокс
peening	наклеп, деформационное упрочнение	наклеп, деформаційне зміцнення
pendulum testing machine	маятниковый копер	маятниковий копер
penetration	проникновение, внедрение	проникнення

penetrator	индентор	індентор
percent elongation	относительное удлинение	відносне здовження
percent reduction in area	относительное сужение	відносне звуження
periods of lattice	периоды решетки	періоди решітки
peritectic	перитектика	перитектика
permalloy	пермаллой сплав	пермалой сплав
permanent deformation	остаточная деформация	залишкова деформація
permanent joint	неразъемное соединение	нероз’ємне з’єднання
permanent load	статическая нагрузка	статичне навантаження
permanent magnet	постоянный магнит	постійний магніт
permanent mould	кокиль, металлическая форма, постоянная форма	кокіль, металева форма, постійна форма
permissible variations	допустимые отклонения	припустимі відхилення
persistent	постоянный	постійний
phase	фаза	фаза
phase diagram	диаграмма состояния, фазовая диаграмма	діаграма стану фазова діаграма
phase mixture	фазовая смесь	фазова суміш
phase rule	правило фаз	правило фаз
phase transformation	фазовое превращение	фазове перетворення
phenol-formaldehyde resin	фенол-формальде-гидная смола	фенол-формальде-гідна смола
phosphorus	фосфор	фосфор
physical metallurgy	металловедение	металознавство
piercing	прошивка	прошивання
piercing mill	прошивной стан	прошивний стан
pig iron	передельный чугун	переробний чавун
pig-and-ore process	скрап-рудный процесс	скрап-рудний процес
pig-and-scrap process	скрап-процесс	скрап-процес

pilger mill	пилигримовый стан, раскатной стан	пілігримів стан, розкатний стан
pine	сосна	сосна
pinning	соединение шпильками	з’єднання шпильками
pipe	труба	труба
piston	поршень	поршень
piston ring	поршневое кольцо	поршневе кільце
piston rod	шток поршня	шток поршня
piston stroke travel	ход поршня	хід поршня
pit furnace	колодец (нагревательный)	колодязь (нагрівальний)
pitch (fossil) resin	каменноугольная смола	кам’яновугільна смола
plain milling cutter	цилиндрическая фреза	циліндрична фреза
plain roll	гладкий валок	гладкий валок
plane	рубанок	рубанок
plane defect	плоский дефект	плоский дефект
planer, planing machine	продольно-строгальный станок	поздовжньо-стругальний верстат
planning	строгание на продольно-строгальном станке	стругання на поздовжньо-стругальних верстатах
plasma arc remelting	плазменно-дуговой переплав	плазмово-дугове переплавлення
plasma furnace	плазменная печь	плазмова піч
plasma jet	плазменная струя	плазмовий струмінь
plasma-arc welding	плазменная сварка	плазмове зварювання
plastic	пластмасса	пластмаса
plastic metal working	обработка металлов давлением	обробка металів тиском
plastic strain	пластическая деформация	пластична деформація
plastic metal working	обработка металлов давлением (ОМД)	обробка металів тиском (ОМТ)
plasticity	пластичность	пластичність
plot	строить (диаграмму)	будувати (діаграму)

plunger machine	плунжерная машина	плунжерна машина
pneumatic	пневматический	пневматичний
point	вершина (резца)	вершина (різця)
polish	полировать	полірувати
polished	полированный	полірований
polycrystal	поликристалл	полікристал
polyhedral	полиэдрический, многогранный	багатогранний
polymorphic	полиморфный	поліморфний
porosity	пористость	пористість
portable	переносной	що переноситься
pouring basin (cup)	литниковая чаша	ливникова чаша
pouring weight	литейный груз	ливарний вантаж
precipitate	выделяться	виділятися
precipitation	выделение	виділення
precipitation hardening	дисперсионное твердение	дисперсійне твердіння
precise	точный	точний
precision	точность	точність
predominantly	преимущественно	переважно
press mould	пресс-форма	прес-форма
pressing	экструзия, прессование	екструзія, пресування
pressing rest	пресс-остаток	прес-залишок
pressing stress	сжимающее напряжение	стискаюче напруження
pressing washer	пресс-шайба	прес-шайба
pressure casting die	пресс-форма	прес-форма
pressure diecasting	литье под давлением	лиття під тиском
pressure reducing regulator	редуктор (для газа)	редуктор (для газу)
pressure welding	сварка давлением	зварювання тиском
pressure-gas welding	газопрессовая сварка	газопресове зварювання
primary (cutting) motion	главное движение	головний рух
primary aluminum	первичный алюминий	первинний алюміній
primary recrystallization	первичная рекристаллизация	первинна рекристалізація

principial stress	главное напряжение	головне напруження
process engineer	технолог	технолог
profile cutter	фасонная фреза	фасонна фреза
protective water seal	защитный водяной затвор	захисний водяний затвор
pulley	шкив, ролик	шків, ролик
pulse welding	шовная сварка	шовне зварювання
pulver-bakelite	пульвербакелит	пульвербакеліт
punching	пробивка	пробивання
pusher	толкатель	штовхач
quartz	кварц	кварц
quartzite	кварцит	кварцит
quenching	быстрое охлаждение	швидке охолодження
radial drilling mill	радиально-сверлильный станок	радіально-свердлильний верстат
radius forming	закругление	заокруглення
ram	трамбовать, уплотнять	трамбувати
ramming-up board	подмодельный щиток	підмодельний щиток
rapid tool steel	быстрорежущая сталь	швидкорізальна сталь
rare earths	редкие земли	рідкісні землі
rate of growth of nuclei	скорость роста зародышей	швидкість росту зародків
rate of nucleation	скорость зарождения центров кристаллизации	швидкість зародження центрів кристалізації
rate of production	производительность	продуктивність
ratio of excess air	коэффициент избытка воздуха	коефіцієнт надлишку повітря
reamer	развертка	розвертка
reaming	развертывание	розвертання
rearrange	перестраиваться	перешиковуватися
receiver	копильник	копильник
reciprocating motion	возвратно-поступательное движение	Зворотно-поступальний рух

recovery	возврат	зворот
recrystallization	рекристаллизация	рекристалізація
rectification	ректификация (перегонка)	ректифікація
rectifier	выпрямитель	випрямляч
red-hard steel	быстрорежущая сталь	швидкорізальна сталь
red-hardness	красностойкость, теплостойкость	червоностійкість, теплостійкість
reducing die	волока	волока
reducing flame	восстановительное пламя	полум'я, що відновлює
reduction gear	редуктор	редуктор
reel	бобина (проволоки)	бобина (дроту)
refining process	процесс обогащения	процес збагачення
refractory material	огнеупорный материал (огнеупор)	вогнетривкий матеріал (вогнетрив)
regenerator	регенератор	регенератор
reinforcing	армирование	армування
relative elongation	относительное удлинение	відносне здовження
relative reduction in area	относительное сужение	відносне звуження
reliability	надежность	надійність
relief	снятие, устранение	зняття, усунення
relief-slotting machine	долбежно-затыловочный станок	довбально-затиловувальний верстат
relieve	освобождать	звільняти
remelting	переплав	переплавлення
residual deformation	остаточная деформация	залишкова деформація
residual stresses	остаточные напряжения	залишкові напруження
resistance furnace	печь сопротивления	піч опору
resistance welding	сварка сопротивлением	зварювання опором
responsible castings	ответственные отливки	відповідальні виливки

retained austenite	остаточный аустенит	остаточний аустеніт
retort	реторта	реторта
return stroke	холостой ход	неробочий хід
reveal	выявлять	виявляти
revealing	выявление	виявлення
reverberatory furnace	отражательная печь	відбивна піч
reverse (inverted) impact	обратный удар	зворотний удар
reverse polarity	обратная полярность	зворотна полярність
reversible temper	обратимая отпускная хрупкость (второго рода)	зворотна відпускна крихкість (другого роду)
ridge	гребень, выступ	гребінь, виступ
right-hand tool	правый резец	правий різець
rigid	жесткий	жорсткий
rimming steel	кипящая сталь	кипляча сталь
ring rolling	раскатка	розкочування
riser	прибыль	додаток
rivet	заклепка	заклепка
riveting	клепка	клепання, клепка
roll formed section	гнутый профиль	гнутий профіль
roll formed shape	гнутый профиль	гнутий профіль
roll pass	калибр	калібр
roll spot welding	шовная сварка	шовне зварювання
rolled steel sections	стальной прокат	сталевий прокат
rolled stock	прокат	прокат
roller	ролик	ролик
rolling	прокатка	прокатка
rolling mill	прокатный стан	прокатний стан
rolling shop	прокатный цех	прокатний цех
root gap	зазор (при сварке)	зазор (при зварюванні)
rosin	канифоль	каніфоль
rotary gear cutter	долбяк	довбальній інструмент

rotary motion	вращательное движение	обертальний рух
rough aluminum	черновой алюминий	чорновий алюміній
roughing	черновая обработка	чорнова обробка
roughing	обдирка, грубая обработка	обдирка, грубе оброблення
roughness	шероховатость	шорсткість
rubber	резина, каучук	гума, каучук
rule of segments	правило отрезков	правило відрізків
ruler	линейка	лінійка
rumbling	очистка в галтовочных барабанах	очищення в галтувальних барабанах
runner	питатель	живильник
rustless steel	нержавеющая сталь	нержавіюча сталь
rutile	рутил	рутил
sample	образец	зразок
sand	песок	пісок
sawdust	древесные опилки	тирса
scale	окалина	окалина
scheme of deformation	схема деформации	схема деформації
scrap	скрап, лом	скрап, брухт
screw dislocation	винтовая дислокация	гвинтова дислокація
screw press	винтовой пресс	гвинтовий прес
seal	затвор	затвор
seam welding	шовная сварка	шовне зварювання
seamed tube	шовная труба	шовна труба
seamless tube	бесшовная труба	безшовна труба
secondary (proeutectoid) cementite	вторичный цементит	вторинний цементит
secondary hardness	вторичная твердость	вторинна твердість
second-type annealing	отжиг второго рода	відпал другого роду
section mill	сортовой стан	сортовий стан
segregation	сегрегация	сегрегація
selenium	селен	селен

self-tempering	самоотпуск	самовідпуск
semiautomatic gas arc welding	полуавтоматическая газоэлектрическая сварка	напівавтоматичне газоелектричне зварювання
semiferritic steel	полуферритная сталь	напівферитна сталь
semikilled steel	полуспокойная сталь	напівспокійна сталь
semimartensite zone	полумартенситная зона	напівмартенситна зона
separating operation	разделительная операция	розділювальна операція
service life	срок эксплуатации	термін експлуатації
setup motion	установочное движение	установчий рух
shaft	шахта	шахта
shaking out	выбивка (отливок, стержней)	вибивання (виливків, стрижнів)
shank	стержень (хвостовик) резца	стрижень (хвостовик) різця
shape rolled stock	сортовой прокат, сорт	сортовий прокат, сорт
shaper	долбяк	довбальній інструмент
shaper	поперечно-строгальный станок	поперечно-стругальний верстат
shaping	придание формы, строгание на поперечно-строгальном станке	додання форми, стругання на поперечно-стругальних верстатах
shaping machine	поперечно-строгальный станок	поперечно-стругальний верстат
sharpened tool	заточенный инструмент	заточений інструмент
shear deformation	деформация на срез	деформація на зріз
shear modulus	модуль сдвига	модуль зрушення
shear stress	касательное напряжение	дотичне напруження
shearing chip	стружка надлома	стружка надлому

sheet rolled stock	листовой прокат	листовий прокат
sheet stamping	листовая штамповка	листове штампування
shell	корпус, оболочка	корпус, оболонка
shell-and-mill cutter	цилиндрическаяфреза	циліндрична фреза
shell-mould casting	литье в оболочковые формы	лиття в оболонкові форми
shielding-gas arc welding, welding in shielding gases	дуговая сварка в среде защитных газов, газоэлектри-ческая сварка	дугове зварювання в середовищі захисних газів, газоелектричне зварювання
shipment	отгрузка	відвантаження
shock absorber	амортизатор	амортизатор
short circuit	короткое замыкание	коротке замикання
short-range order	ближний порядок	ближній порядок
shot	дробь	дріб
shot blasting	дробеструйная очистка	дробоструминне очищення
shot peening	дробеструйная обработка	дробострумінна обробка
Shottky defect, vacancy	вакансия, дефект Шоттки	вакансія, дефект Шотткі
shoulders	заплечики	заплічки
shrinkage	усадка	усадка
shrinkage cavity, pipe	усадочная раковина	усадочна раковина
siderite ($FeCO_2$)	шпатовый железняк	шпатовий залізняк
silchrome	сильхром	сильхром
silica carbide (SiC)	карбид кремния	карбід кремнію
silica floor	маршалит	маршаліт
silica sand (SiO_2)	кварцевый песок	кварцовий пісок
silicate	силикат	силікат
silicon	кремний	кремній
silumin	силумин	силумін
simple multiple	простое кратное	просте кратне
single-spindle machine.	одношпиндельный станок	одношпиндельний верстат
singular point	сингулярная точка	сингулярна точка
sintered alloy	спеченный сплав	спечений сплав

sintered aluminium powder	спеченная алюминиевая пудра	спечена алюмінієва пудра
sintering	спекание	спікання
size roll	ручьевой валок	рівчаковий валок
size tolerance	размерный допуск	розмірний допуск
sizing	калибровка	калібрування
skelp	штрипс	штрипс
skim off	скачивать (шлак)	скачувати (шлак)
skin effect	поверхностный эффект	поверхневий ефект
skin on castings	корка на отливках	кірка на виливках
slab	сляб	сляб
slabing	слябинг	слябінг
slag	шлак	шлак
slag basicity	основность шлака	основність шлаку
slag hole	шлаковая летка	шлакова льотка
sleeve	втулка	втулка
slider	ползун	повзун
slime	шлам	шлам
slip	скольжение	ковзання
slip plane	плоскость скольжения	площина ковзання
slope	наклон	нахил
slotted pattern key	шип для соединения верхней и нижней частей модели	шип для з’єднання верхньої та нижньої частин моделі
slotter	долбежный станок	довбальний верстат
slotting	долбление	довбання
slotting machine	долбежный станок	довбальний верстат
sludge	шлам	шлам
slurry	суспензия, шлам	суспензія, шлам
smelting	плавление, плавка	плавлення, плавка
smith	ковка	кування
soda (Na_2CO_3)	сода, карбонат натрия	сода, карбонат натрію
sodium aluminate (Na_2AlO_3)	алюминат натрия	алюмінат натрію
soldering	пайка	паяння
solid solution	твердый раствор	твердий розчин
solidification	затвердевание, кристаллизация	затвердіння, кристалізація

solidus line	линия солидуса	лінія солідусу
solute	растворенный компонент	розчинений компонент
solvent	растворитель	розчинник
solvus line	сольвус	сольвус
sorbite	сорбит	сорбіт
sound casting	плотная отливка	щільний виливок
source of welding current	источник сварочного тока	джерело зварювального струму
space factor	коэффициент компактности	коефіцієнт компактності
space lattice	кристаллическая решетка	кристалічна решітка
spark	искра	іскра
spark erosion	электроискровая обработка	електроіскрова обробка
spark gap	искровой промежуток	іскровий проміжок
spear	копье	спис
special electric metallurgy	специальная электрометаллургия	спеціальна електрометалургія
specific strength	удельная прочность	питома міцність
specimen	образец	зразок
spherical graphite	шаровидный, глобулярный графит	кулястий, глобулярний графіт
spike	шип	шип
spindle	шпиндель	шпиндель
spinning	центробежное литье	відцентрове лиття
spiral flute	спиральная канавка	спіральна канавка
splashing	разбрызгивание	розбризкування
split pattern	разъемная модель	рознімна модель
sponge	губка	губка
spot welding	точечная сварка	точкове зварювання
spot-facing	цекование	цекування
spout	желоб	жолоб
spring	пружина	пружина
spring-loaded ejector pin	подпружиненный выталкиватель	підпружинений виштовхувач
square-based	четырехгранная	чотиригранна

pyramid	пирамида	піраміда
squeezing	сжатие	стиснення
squeezing pressure	сжимающее усилие	стискаюче зусилля
stable (rigid)	стабильная (жесткая)	стабільна (жорстка)
stable arcing	стабильное горение дуги	стабільне горіння дуги
stainless steel	нержавеющая сталь	нержавіюча сталь
stamp	штамп	штамп
stamping	листовая штамповка	листове штампування
stampings	высечка (отходы)	висічка (відходи)
standard of surface finish	стандарт качества поверхности	стандарт якості поверхні
starch	крахмал	крохмаль
static tests	статические испытания	статичні випробування
static voltage current characteristic	(статическая) вольт-амперная характеристика	(статична) вольт-амперна характеристика
stearin	стеарин	стеарин
steel	сталь	сталь
steel cylinder	стальной баллон	сталевий балон
steel for structural improvement	улучшаемая сталь	сталь, яку покращують
steel tapping	выпуск стали (из печи)	випуск сталі (з печі)
steel-making shop	сталеплавильный цех	сталеплавильний цех
step-down transformer	понижающий трансформатор	понижуючий трансформатор
stepped quenching	ступенчатая закалка	ступінчасте гартування
stock,stock removal	припуск на механи-ческую обработку	припуск на механічну обробку
stony fracture	камневидный излом	каменеподібний злом
stool	подставка	підставка
stopper	стопор	стопор
stove	сушильная камера	сушильна камера
straight flute	прямая канавка	пряма канавка

straight shank	цилиндрический хвостовик	циліндричний хвостовик
strain hardening	наклеп, деформационное упрочнение	наклеп, деформаційне зміцнення
stream	струя	струмінь
strength	прочность	міцність
stress	напряжение	напруження
stress-relief annealing	отжиг для снятия напряжений	відпал для зняття напружень
stretched crystal	вытянутый кристалл	витягнутий кристал
striker	нож (копра)	ніж (копра)
strip	снимать	знімати
strip	полоса	смуга
structural material	конструкционный материал	конструкційний матеріал
structural steel	конструкционная сталь	конструкційна сталь
stud bolt	штифт, цапфа, ось качания	штифт, цапфа, вісь хитання
subgrain	субзерно	субзерно
sublimation	возгонка	сублімація
substitution solid solution	твердый раствор замещения	твердий розчин заміщення
sub-zero treatment	обработка холодом	обробка холодом
sulfide	сульфид	сульфід
sulphur	сера	сірка
superalloys	жаропрочные сплавы (суперсплавы)	жароміцні сплави (суперсплави)
superconductivity	сверхпроводимость	надпровідність
supercooling	переохлаждение	переохолодження
superfinishing	суперфиниширование	суперфінішування
superfluous	излишний	надлишковий
super-grade steel	высококачественная сталь	високоякісна сталь
super-quality steel	высококачественная сталь	високоякісна сталь
supersaturated	пересыщенный	пересичений
superstructure	сверхструктура	надструктура
support	опора	опора

support	суппорт	супорт
suppress	подавлять	пригнічувати
surface energy	поверхностная энергия	поверхнева енергія
surface grinding mill	плоскошлифовальный станок	плоскошліфувальний верстат
surface hardening	поверхностное упрочнение	поверхневе зміцнення
surface strain hardening	поверхностное упрочнение	поверхневе зміцнення
surface tension	поверхностное натяжение	поверхневий натяг
surface-active	поверхностно-активный	поверхнево-активний
susceptibility	чувствительность	чутливість
suspension	суспензия	суспензія
sustain arcing	поддерживать горение дуги	підтримувати горіння дуги
synthetic slag	синтетический шлак	синтетичний шлак
tailstock	задняя бабка	задня бабка
tang	лапка (сверла)	лапка (свердла)
tap	кран, вентиль, метчик	кран, вентиль, мітчик
tap hole	летка для чугуна	льотка для чавуна
tape	лента	стрічка
taper	конус	конус
taper shank	конический хвостовик	конічний хвостовик
tapering	обработка конической поверхности	обробка конічної поверхні
tapping throat	горловина для выпуска металла	горловина для випуску метала
tap-to-tap time	время плавки	час плавки
tearing chip	стружка скалывания	стружка сколювання
technical diamond	технический алмаз	технічний алмаз
technological plasticity	технологическая пластичность	технологічна пластичність
tee butt weld	тавровое соединение	таврове з’єднання
teeming ladle	разливочный ковш	розливний ківш

teeming, pouring	разливка (металла)	розливання (метала)
tellurium	теллур	телур
temper	отпуск	відпуск
temper brittleness	отпускная хрупкость	відпускна крихкість
temper brittleness of the second type	обратимая отпускная хрупкость (второго рода)	зворотна відпускна крихкість (другого роду)
temper brittleness of the first type	необратимая отпускная хрупкость (первого рода)	незворотна відпускна хрупкість (першого роду)
temperature coefficient of electrical resistance	температурный коэффициент электрического сопротивления	температурний коефіцієнт електричного опору
tempered carbon	углерод отжига	вуглець відпалу
tempered martensite	мартенсит отпуска	мартенсит відпуску
tempered troostite	троостит отпуска	тростит відпуску
tempering	отпуск	відпуск
tensile modulus	модуль упругости	модуль пружності
tensile strength	предел прочности	границя міцності
tensile stress	растягивающее напряжение	розтягувальне напруження
tertiary cementite	третичный цементит	третинний цементит
tests	испытания	випробування
tetrahedral pyramid	четырехгранная пирамида	чотиригранна піраміда
texture	текстура	текстура
theoretical strength	теоретическая прочность	теоретична міцність
thermal conductivity	теплопроводность	теплопровідність
thermal expansion	тепловое расширение	теплове розширення
thermal fatigue strength	термостойкость	термостійкість
thermit (aluminothermit) welding	термитная (алюмотермитная) сварка	термітне (алюмотермітне) зварювання
thermo-couple	термопара	термопара

thermokinetic diagram, CCT-diagram (continuous cooling transformation diagram)	термокинетическая диаграмма	термокінетична діаграма
thermomechanical treatment	термомеханическая обработка	термомеханічна обробка
thickness of removal metal	толщина срезаемого слоя, глубина резания	товщина шару, що зрізується, глибина різання
threading die	плашка	плашка
threading tool	резьбовой резец	різенарізний різець
three-high mill	трио-стан	тріо-стан
threshold	порог	поріг
through hole	сквозное отверстие	наскрізний отвір
tilting mechanism	поворотный механизм	поворотный механізм
tin	олово	олово
tip	наконечник, мундштук	наконечник, мундштук
tolerance	допуск	допуск
tongue	факел	факел
tool point	режущая часть (вершина резца)	ріжуча частина (вершина різця)
tool steel	инструментальная сталь	інструментальна сталь
top	колошник	колошник
top pouring	разливка сверху	розливання зверху
top rake angle,	передний угол резца	передній кут різца
torsion	кручение	скручування
trailing cutting edge	вспомогательное режущее лезвие	допоміжне різальне лезо
transcrystalline segregation	транскристаллитная сегрегация	транскристалітна сегрегація
transcrystallyne	межкристаллитный	міжкристалітний
transference	перемещение	переміщення
transformer	трансформатор	трансформатор
transient surface	поверхность резания	поверхня різання
transverse motion	поперечное движение	поперечний рух

traverse	траверса	траверса
troostite	троостит	тростит
true rake	передняя поверхность (резца)	передня поверхня (різця)
true stress	действительное напряжение	дійсне напруження
trunnion	штифт, цапфа, ось качания	штифт, цапфа, вісь хитання
TTT-diagram	диаграмма изотермического превращения аустенита	діаграма ізотермічного перетворення аустеніту
tube furnace	трубчатая печь	трубчаста піч
tumbling	очистка в галтовочных барабанах	очищення в галтувальних барабанах
tungsten	вольфрам	вольфрам
turn	виток (обмотки)	виток обмотки
turning	точение	точіння
turning tool	проходной резец	прохідний різець
turret lathe	токарно-револьверный станок	токарно-револьверний верстат
tuyere	фурма	фурма
T-weld	тавровое соединение	таврове з’єднання
twist drill	двухперовое сверло	двохперове свердло
twisting	скручивание	скручування
two-layer	двухслойный, биметаллический	двошаровий, біметалічний
ultimate strength	предел прочности	границя міцності
ultrasonic machining	ультразвуковая обработка	ультразвукова обробка
ultrasonic welding	ультразвуковая сварка	ультразвукове зварювання
numeral control mill	станок с числовым программным управлением	верстат з числовим програмним керуванням
undergo	подвергаться	піддаватися
unit sand	единая формовочная смесь	єдина формувальна суміш

universal mill	универсальный стан	універсальний стан
unlimited solid solution	неограниченный твердый раствор	необмежений твердий раствор
unsplit (solid) pattern	неразъемная модель	нерознімна модель
uphill teeming	разливка снизу (сифонная)	розливання знизу (сифонне)
upper bainite	верхний бейнит	верхній бейніт
upper die	пуансон	пуансон
upright drilling mill	вертикально-сверлильный станок	вертикально - свердлильний верстат
upset welding	стыковая сварка сопротивлением	стикове зварювання опором
upsetting	осадка	осадження
utilization factor	коэффициент использования (металла)	коефіцієнт використання (металу)
vacancy, Shottky defect	вакансия, дефект Шоттки	вакансія, дефект Шотткі
vacuum arc remelting	вакуумно-дуговой переплав (ВДП)	вакуумно-дугове переплавлення (ВДП)
valency	валентность	валентність
valley	впадина	заглиблення
valve	клапан	клапан
vanadium	ванадий	ванадій
vapour blanket	паровая рубашка	парова оболонка
variable resistance	переменное сопротивление (реостат)	перемінний опір (реостат)
V-belts	клиноременная передача	клинчасто-пасова передача
versus (vs)	в зависимости от, против	в залежності від, проти
vertical weld	вертикальный шов	вертикальний шов
violate	нарушать	порушувати
viscosity	вязкость (жидк.), внутреннее трение	в’язкість (рідн.), внутрішнє тертя
voltage	напряжение (электр.)	напруга (електр.)
volume energy	объемная энергия	об’ємна енергія

volumetric shrinkage	объемная усадка	об'ємна усадка
warping	коробление	жолоблення
waste gas	отходящий газ	газ, що відходить
water glass ($Na_2O*mSiO_2$)	жидкое стекло, гидросиликат натрия	рідке скло, гідросилікат натрію
water recession generator	генератор контактного типа	генератор контактного типу
water-to-carbideg	вода на карбид	вода на карбід
wax	воск	віск
wear	износ	зношування
wear resistance	износостойкость	зносостійкість
wear-resistant steel	износостойкая сталь	зносостійка сталь
wedge	клин	клин
wedge angle, lip angle	угол заострения	кут загострення
weld	сварной шов, сварное соединение	зварний шов, зварне з'єднання
weldability	свариваемость	зварюваність
weldable steel	свариваемая сталь	зварювальна сталь
welded-cast	сварно-литой	зварно-литий
welded-forged	сварно-кованый	зварно-кований
welder	сварщик, источник тока	зварювальник, джерело струму
welding	сварка	зварювання
welding flame	сварочное пламя	зварювальне полум'я
welding head	сварочная головка	зварювальна головка
welding loop	сварочная цепь	зварювальний ланцюг
welding rod holder	держатель электрода	тримач електрода
welding torch	сварочная горелка	зварювальний пальник
welding tractor	сварочный трактор	зварювальний трактор
welding zone	сварочная зона	зварювальна зона
weldment	сварное соединение	зварне з'єднання
wetability	смачиваемость	змочувальність
whiskers	«усы»	„вуса"
white cast iron	белый чугун	білий чавун

Widmanstatten structure	Видманштетова структура	Відманштетова структура
winding	обмотка (электр.)	обмотка (електр.)
wire	проволока	проволока
work surface	обрабатываемая поверхность	поверхня, що обробляється
working motion	рабочее движение	робочий рух
workpiece	заготовка	заготовка
worm	червяк	черв'як
worm gear hob	червячная фреза	черв'ячна фреза
wrought alloy	деформируемый сплав	сплав, що деформується
yield limit, yield point	предел текучести	границя текучості
yoke	коромысло	коромисло
yttrium	иттрий	ітрій
zinc	цинк	цинк
zirconium	цирконий	цирконій
zirconium sand	цирконовый песок	цирконовий пісок
zone segregation	зональная сегрегация	зональна сегрегація

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