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Investigation of the thermal treatment effect on the structure and properties of high-quality cast iron

Specialization: 3312.01-"Materials technology"

Field of science: Technique

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ABSTRACT

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Dissertation work was performed at the Department of "Materials Science and Processing Technologies" of Azerbaijan State Oil and Industry University.

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GENERAL CHARACTERISTICS OF THE WORK

Relevance of the topic and degree of development. There is a great need for high-quality castings for piston rings, pistons, cylinder and cylinder liners, and water-cooled cylinder covers of gas-motor compressors used in the country's oil and gas complex. These parts are bought abroad paying foreign currency at a high price and brought to the republic. In addition, submersible pump parts (guide apparatus) used in oil production are made of high-alloy austenite cast iron. These parts work in an aggressive environment during operation. The most important of these requirements is resistance to wear and corrosion, but the cost of such cast iron is high. Besides these, many parts of oil and drilling equipment are made of cast iron and work in marine conditions. They corrode by being exposed to the marine atmosphere and non-aggressive water. These equipment include air and gas compressors, water and oil pumps, etc. Their parts are usually made of gray cast iron, alloyed with nickel and chromium. Here, in addition to the chemical composition, the corrosion resistance of cast iron is affected by its density. Therefore, the development of new innovative technological processes and the intensification of the production of these parts, as well as the creation, adoption and industrial application of the technology for obtaining high-quality synthetic cast iron from local cheap raw materials - metal scraps and waste is an urgent issue.

Research results show that as the density of cast iron increases, so does its corrosion resistance. Therefore, the development of the technology of obtaining high-density synthetic cast iron and the production of the above-mentioned details from such cast iron is an issue on the agenda.

Research goals and objectives. To obtain parts with high mechanical, physical and operational properties by designing a rational composition of high-quality synthetic cast iron and conducting a controlled melting process. In order to achieve the set goal, the following issues have been resolved:

- obtaining of high-quality synthetic cast iron by the method of controlled melting and study of its technological parameters;
- study of the effect of technological parameters on the crystallization process;
- change of the physical-mechanical and operational properties and structure of synthetic cast iron depending on the melting parameter;
- obtaining of synthetic cast iron in production conditions
- study of the structure and properties of molten cast iron under production conditions.

Research methods. The issues raised in the dissertation work were solved on the basis of theoretical and experimental studies conducted in laboratory and industrial conditions. Modern equipment and devices, including optical and electron microscope, X-ray structure and spectral analysis, were used in the research. The integrity of the obtained results is ensured by the experimental studies conducted with the use of modern devices, measuring devices and accessories.

Main clauses defended:

The following issues were considered in the dissertation:

- development of a rational charge composition;
- obtaining of high-quality synthetic cast iron by the method of controlled melting and study of its technological parameters;
- study of the influence of technological parameters of synthetic cast iron on the crystallization process;
- control of the physical-mechanical and operational properties of synthetic cast iron, as well as its structure, depending on the melting parameter;
- obtaining of synthetic cast iron in production conditions;
- study of the structure and properties of molten cast iron under production conditions.

Scientific novelty of the research. Si/C ratio, (Sev) eutectic degree, controlled melting and ¬thermal treatment regimes and the structure and properties of high-quality cast iron were correlated, new cast iron was developed.

- Based on the idea of Hadfield steel, a new structural cast iron consisting of austenite + small graphite elements was obtained after casting and high temperature hardening.
- Reinforcement of cast iron is ensured on the basis of the obstacle in the movement of dislocations of mechanical bifurcation twinning of austenite as a result of the deformation of cast iron in the work process during rolling. Bifurcations have prevented the localization of plastic deformation and the formation of cracks by relaxing the internal stresses. The new scientific postulate has confirmed itself in cast iron. For the first time, the current considerations about the mechanism of austenite-bainite transformation in cast irons have been clarified and expanded. The assumption that upper bainite is formed from austenite and lower bainite from martensite is confirmed.

Theoretical and practical significance of research. The theoretical basis of the research is the classic theoretical and technological provisions of the science and technology field of materials science, metallurgy and materials technology. In addition, the provisions of monographs and articles published in periodical scientific and technical publications on the problem of using high-quality synthetic cast iron in the near and far abroad were also used in the research work. The practical significance of the research - it was applied in the obtaining of castings for submersible pump parts in the foundry of the experimental production facility for repair and rental of submersible equipment of Azneft Production Union.

Application of the results of the research. For "Baku Steel Company", cast iron components for responsible parts such as rolling shafts, punching machine splash, rings of belt shafts, piston rings for internal combustion engines, mill spheres, their casting and thermal processing technologies were developed and applied in production. The composition of processed high-quality cast iron is protected by a patent of the Republic of Azerbaijan.

Approval and application. The main provisions of the dissertation were discussed and approved in the following conferences and seminars:

International scientific-technical and scientific-practical conferences:

1.Science and Enlightenment" Collection of articles X International scientific-practical conference Penza, June 20, 2020.

Republican scientific and technical conferences:

2. Azerbaijan Technical University materials of the national scientific and technical conference of students and young researchers on "Youth and scientific innovations" dedicated to the 94th anniversary of the National Leader of the Azerbaijani people, Baku 2017.
3. Materials of the 2nd International scientific-technical conference on "Problems of metallurgy and materials science", Azerbaijan Technical University, Baku 2017.
4. Scientific seminars of the Department of "Materials Science and Processing Technologies" of ASOIU, 2017-2021.

The name of the organization where the dissertation work was carried out. The dissertation work was carried out at the "Materials Science and Processing Technologies" department of Azerbaijan State Oil and Industry University.

Personal contribution to the conducted research: the relevance of the research, the purpose of the work and the issues set to achieve the goal were determined by the applicant, and the direction of the research was indicated. Mechanisms of casting and plastic deformation of cast iron in the process of controlled melting of synthetic cast iron are systematized and discussed. Thus, the presented dissertation is a completed scientific research work, which includes the set of scientific-practical propositions and conclusions put forward for defense, written by the applicant.

The total volume of the dissertation with a sign indicating the volume of the structural sections of the dissertation separately. The dissertation consists of an introduction, 4 chapters, 155 pages of computer text, 37 images, 30 tables, a bibliography of 140 titles and an appendix. Cover and table of contents (3198 characters), introduction (10476 characters), Chapter I (34226 characters), Chapter II (35139 characters), chapter III (46584 characters), chapter IV (37899 characters), conclusion (3588 characters) and bibliography (22726 characters). The volume of the dissertation consists of 171110 characters, excluding pictures, tables, and the bibliography.

Degree of publication: The main content of the dissertation was published in 12 scientific works, including 1 invention, 8 articles (4 of them abroad, 1 included in the SCOPUS database), 3 conference materials (1 of them abroad).

MAIN CONTENTS OF THE WORK

At introduction of the dissertation the relevance of the topic and the main propositions defended have been formulated.

In the first chapter, provisions on the technology of melting synthetic cast in an induction furnace were reviewed, and a review of local and foreign literature was conducted.

It has been noted that steel and cast iron sawdust, scrap and waste are promising material for smelting high-quality synthetic pig iron. Here use blast furnace cast iron can’t be used, as these cast irons have "hereditary" properties, they lower the quality of cast iron.

It has been determined that in order to eliminate the "inheritance" effect of the charge material, the cast iron must be superheated and then modified. When applying different charge material, graphite findings are obtained differently; when melting with steel sawdust, graphite is obtained in an isolated form, and when melting with cast iron sawdust, graphite is obtained between dendrites [1][1] .

It is shown that the mechanical properties of cast iron melted in an induction furnace are high. In synthetic cast iron, pearlite is homogeneous. Thermo-time processing makes the alloy homogeneous. After superheating, the length of graphite in cast iron melted from cast iron and steel shavings decreases, it becomes compact, isolated, the dispersion of pearlite increases and it becomes homogenous. However, as graphite is crushed, the amount of graphite between dendrites increases. Therefore, the strength limit first increases and then decreases. This situation does not affect the impact viscosity, monotonically increasing the hardness of cast iron.

It is noted that by creating a controlled melting regime, cast iron with stable properties and an isotropic structure can be obtained. For this purpose, it is necessary to superheat the alloy, keep it at that temperature, purify, alloy and modify it.

It is shown that after carburizing high-quality cast iron, it is necessary to add silicon to the alloy. It has been proven that 50% of the silicon required in the cast iron grade should be given to the charge, and 50% during modification at 1400^0C.

In the second chapter, to determine the density of cast iron in liquid and solid state, the device constructed by the research institute "НРО ЦНИИТмаш" was used (figure 1). In this device, the properties of metals and alloys are studied by the gamma radiation method, and the device is called "Paraboloid-3". Here, the absolute and relative density of metal in liquid and solid state is determined in automatic mode.

The device consists of three main parts:

- high-temperature electric furnace with graphite heater;
- container with gamma radiation source;
- temperature and radiation recording system.

[1] Babanli, M.B., Huseynov, B.H., Jabbarov, T.G., Shahmarova, R.S., Aliyev E.A. Density and volume settlement of high-quality synthetic cast iron.

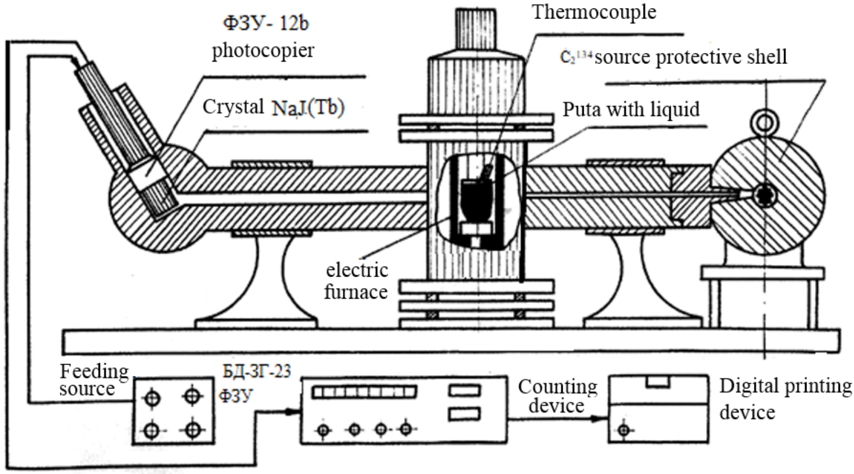

Fig. 1. Investigation of the properties of metals and alloys by gamma radiation ("Paraboloid-3" device)

The working volume of the furnace is 300 cm^3. A tungsten-rhenium thermocouple was placed in the furnace to measure the temperature of the studied metal. A vacuum of 0.15 Pa can be obtained in the working volume, but all experiments are carried out in an inert gas environment (argon).

The activity of the radiation source is obtained through the Cesium-37 isotope and is 5.4 Ku. This method has many advantages: it creates a high temperature field, the alloy has no contact with measuring devices, the process is fast and highly accurate.

The density is determined by the change in the intensity of gamma rays passing through the melt-filled pot:

$$\Delta\rho = \rho_1 \cdot \frac{\ell n J_2}{\ell n J_1} \Big/ \frac{J_1}{J_0},$$

where ρ_1 is the density of the metal at the initial temperature, g/cm^3; J_1 – intensity of rays passing through the initial temperature, pulse/second; J_2 – radiation intensity at the final temperature; J_0 – the intensity of the radiation flux falling on the metal, pulse/sec.

The density is measured every 30 seconds after a stable temperature is established (within 8-10 minutes) using a quartz counter.

In this study, the density of eutectic and pre-eutectic cast irons was studied. The cast iron was melted from low-silicon charge and the casting temperature was 1590°C.

A sample with a mass of 300 g was used to conduct the experimental alloy, the sample was cut from a cast iron melted in an ИСТ-0.16 furnace (1360°C) with a diameter of 30 mm and a length of 600 mm. The aggregate material was calculated so that the amount of carbon in the composition was 3.5%, and the amount of silicon was variable, that is, 0.75÷2.5%. After the sample was melted in the "Paraboloid-3" device, thermo-time processing was carried out [2][2].

The metal was superheated to a temperature of 1590°C at a rate of 7 k/min: after holding at this temperature for 5 minutes, it was cooled to 1400°C at the same rate. After that, ferrosilicon ФС75 was added to the alloy. The amount of this additive was such that the amount of silicon was 1.5%, after keeping for 5-10 minutes, it was cooled to room temperature at that rate.

In order to detect the effect of thermo-time processing, melting was performed a second time by the same method (1440°C), the storage time at this temperature was 15 minutes.

The concentration of chemical elements in cast iron was studied in "Leko", AN-7529, "Kvantovak-31000" devices, and the amount of oxygen was studied in "Leko" boiler analyzer and "Balvers" device.

Tensile strength limit, hardness, tendency to whiten and microstructure of cast iron were studied by standard methods. Mathematical reports were made in ECM. The solid density of cast iron was determined by the hydrostatic weighing method.

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[2] Babanli, M.B., Huseynov, B.H., Habibov, I.A., Jabbarov, T.G., Shahmarova, R.S., Non-magnetic cast iron and its production method

The issues raised in conducting the research include the use of low-silicon charge when melting high-quality cast iron, complex modification and ensuring high properties of cast iron in devices used in industry.

The following materials were used for smelting from silicon charge steel and cast iron scraps, production waste, ferroalloys (ФС45, ФС75, ФMn75). To carbonize the alloy, graphited electrode scraps (ЕГ-О brand), complex modifiers КМ-1, КМ-2 and ligatures (containing NTM) were used in the modification.

Cast iron was made both in an induction furnace (ИЧТ-2.5) and in an electric arc furnace (ДСП-3 sour masonry). The concentration of chemical elements was determined in "Leko", FY-7529, "Kvantovak-31000" devices.

Micro- and macro-sections were prepared from the test samples. The microstructure of the cast in the inoculated and uninoculated state was studied under a NEOFOT-21 microscope.

Samples of 5×25×500 mm size were cut from the cast to determine the main indicator of operational properties – corrosion resistance. The measurements were carried out in the SL-06 type device of "Nippon Electric Industry" used in high-speed wear.

A 20×50×110 mm test sample was cast to determine the tendency of cast iron to turn white. The effect of different wall thicknesses of the cast on bleaching was studied in a stepwise test pattern.

In the third chapter, the selection of the charge material for the obtaining of high-quality cast iron was made. It has been established that additives affect the physical-chemical state of the alloy and cause its structure and properties to change. Therefore, it is necessary to buy high-quality synthetic cast iron using scrap steel, which is cleaner than additives. One of the most important processes in the melting of synthetic cast iron is carbonization of liquid metal.

It has been determined that the dissolution of carbon in liquid iron goes through certain stages: first, the packages of its base planes are separated from the surface of solid carbon particles and dissolve in the liquid, and then the carbon atoms diffuse in the solution. It is assumed that the dissolution of carbon in iron, between the base planes of iron atoms takes place including Further dissolution of carbon depends on temperature and time [3][3] .

The results of the research show that the higher the temperature of the metal, the greater the dispersity of the carburizing agent, the faster the carbonization will be.

The temperature of the metal must be above 1400°C for the carbonization process to take place. In the melting of synthetic cast iron, there should be a certain dependence between the chemical composition, high temperature and the time of storage at this temperature (thermo-time treatment). Experiments show that each percentage of silicon in a synthetic cast iron alloy reduces the solubility of carbon by 4-5%. Therefore, after carbonizing synthetic cast iron, it is necessary to add silicon to the alloy.

The results of the research show that one of the important factors in obtaining high-quality synthetic cast iron is when and how much silicon is added to the alloy [4][4].

It has been proven that 50% of the silicon required in the cast iron grade should be provided by charge, and 50% by modification at 1400°C. As a result, it turns out that there are quite a lot of factors affecting the carbonization process, and to get quality cast iron, the process must be controlled.

The purpose of conducting controlled melting is to design a technological regime for the preparation of the necessary parts. Experimental smelting was carried out in IKT-1.0 induction and DSP-0.5 electric arc furnaces in ship repair plants and other foundries. Steel scrap and industrial waste, ferroalloys (FS75, FMn75) were included in the charge material.

To carburize the alloy, a GQ-O brand graphitized electrode crushed to the size of (50÷10) mm was used. The chemical

[3] Kahramanov, V.F., Aliyev, E.A., Mashayev, Sh.M., Shahmarova, R.S., Whitened surface mill balls made of high-quality cast iron

[4] Kahramanov, V.F., Aliyev, E.A., Mashayev, Sh.M., Shahmarova, R.S., Thermal processing of rings of belt rolling shaft

composition was determined in "AH-7529" and "Kvantovax-31000" devices, and the temperature of liquid cast iron was determined by an optical pyrometer.

When the smelting process was carried out in an induction furnace, 50% of the charge material was liquid cast iron (bolota), and when it was melted in an arc furnace, the amount of silicon in the charge material was 50% of the required amount. In the furnace, the liquid alloy was thermally processed at 1450 – 1460°C for 10 minutes.

Silicon is added to the chemical composition during the modification time at 1400°C. Controlled melting parameters include eutectic degree (Sevt), silicon to carbon ratio (Si/C), silicon in the charge material, as well as the amount of silicon added during chemical composition.

Standard specimens (d=30 mm and l=600 mm) were cast from each alloy to study the mechanical properties and structure of the synthetic cast iron. The strength properties were determined by standard methods, and the structure of cast iron before and after inoculation was studied under the МИМ-7 microscope. The results of chemical analysis, properties of cast iron and controlled parameters are given in table 1.

It can be seen from the table that the properties of cast irons with the same degree of eutectic have different values. The reason for this is the variety of controlled parameters. The value of density and strength properties increased depending on when and at what temperature and how much silicon was added, the value of the Si/C ratio, and the excess of manganese by 0.1-0.2%.

Controlled melting also has a positive effect on the structure of cast iron. The main core of the metal consists of dispersed pearlite and isolated compact graphite. Pearlite dispersity increased from 0.8 μm to 0.1-0.2 μm. The size of graphite additives decreased to 20-30 μm (picture 2). Based on the results of the research, the technological regime was designed and applied in production.

Table 1.
Chemical composition, properties and controlled parameters of synthetic cast iron alloys

Alloy No	Chemical composition			Parameters				Density ρ, q/sm³	Firmness, HB	Durability σ_d, MPa	Volume sittingα %
	C	Mn	Si	S_{evt}	Si/C	Si (on the charge)	Si (in delivery)				
The original ordinary cast iron	3,01	0,72	2,10	0,80	0,63	1,95	0,15	7,0	150	200	0,7
Primary synthetic cast iron	3,00	0,70	2,05	0,80	0,63	1,80	0,25	7,10	180	250	0,8
1	2,88	0,95	2,20	0,80	0,70	1,10	1,10	7,30	240	300	–
2	2,85	0,92	2,00	0,80	0,70	1,00	1,00	7,32	240	300	–
3	2,88	0,90	1,80	0,81	0,61	0,90	0,90	7,31	240	300	–
4	2,92	0,91	2,05	0,80	0,70	1,00	1,00	7,30	240	300	–
5	3,02	0,85	1,79	0,80	0,60	1,04	0,90	7,32	240	300	–
6	2,40	0,95	2,08	0,69	0,81	1,01	1,04	7,35	250	350	0,2
7	2,69	0,85	2,03	0,75	0,78	1,10	1,02	7,35	245	320	–
8	2,70	0,74	2,20	0,74	0,80	1,05	1,10	7,35	245	320	–
9	2,44	0,78	2,10	0,69	0,85	1,95	1,05	7,34	250	350	–

Thus, it was possible to improve the properties and structure of cast iron with the same eutectic grade by the method of controlled melting.

As liquid cast iron crystallizes in the mold and cools to room temperature, the volume and linear dimensions of the casting change. Depending on the stages of cooling, these dimensions either decrease (settling) or increase (expansion).

a)

b)

c)

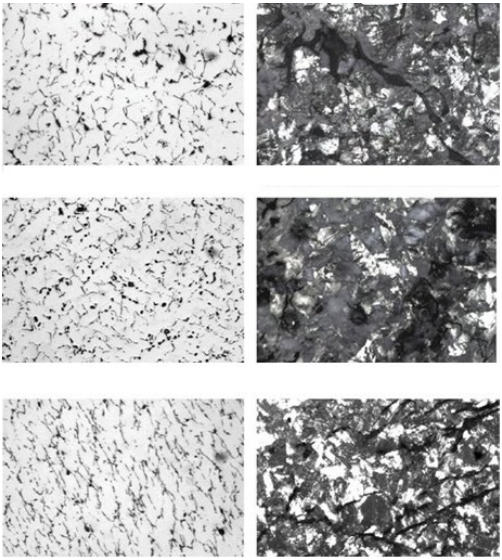

Fig. 2. Microstructures of cast iron with the same degree of eutheticity, ×100:
a – primary ordinary cast iron (СЧ20);
b – primary synthetic cast iron (СЧ25);
c – controlled melting synthetic cast iron (СЧ35)

Depending on the state of the aggregate, settling consists of settling of the liquid alloy during solidification and after solidification. The most complicated of these is the settling of cast iron in a solid-liquid state.

Thermal factors, phase transformations, outgassing, graphitization, etc. processes are affected. The most important factors affecting the settling of liquid cast iron are the release of gases during solidification and the separation of carbon in the form of graphite. These factors can either reduce or increase the volume of cast iron.

The value of settling coefficients varies depending on the type of cast iron. So, the value of the coefficient of linear settling for gray cast iron is (0.9 - 1.0) %, for white cast iron (1.6 - 2.3) %, etc. is within limits. It was found that as the amount of chemical combination of carbon and iron in the structure increases, the value of the settling coefficient also increases and approaches the settling coefficient of steel [5][5]. The use of a casting additive to prevent settling in the casting results in 10–15% waste of liquid metal. From this point of view, investigating the measures to avoid the settling space in cast iron castings is one of the urgent issues.

It is known that the settling space in the castings is formed during the crystallization of the liquid alloy (in the solid-liquid phase). If the graphitization process is regulated at this stage, the settling due to expansion can be reduced to zero. In liquid metal, as the volume expansion increases, the volume of the settling space decreases. Volume settlement is also influenced by parameters such as metal composition, temperature, eutectic degree, carbon equivalent, silicon to carbon ratio, when and how much silicon is added to the metal. As a result of this, the settling space in the casting can either increase or decrease to zero [2, p263-266].

It should be noted that the effect of metal fluidity, temperature, and when and how much silicon is added on settling space volume is generally poorly studied. It is only known that as the grade of cast iron increases and the carbon equivalent decreases, the volume of the settling space increases. The research results show that brands of synthetic cast iron with the same degree of eutectic, obtained by the controlled melting method, differ by several levels [6, p.5]. These cast irons obtained by controlled smelting reduced their volume settling from (0.7–0.8)% to 0.2%, and even became zero-valued. Their density was 7.3-7.35 g/cm^3. From the essence of the controlled melting method, it can be seen that in order to obtain high-quality synthetic cast iron, it is necessary to monitor and influence all the processes, starting from the melting of the charge material and finally pouring into the mold. These areas of influence are as follows:

[5] Babanli, M.B., Huseynov, B.H., Jabbarov, T.G., Shahmarova, R.S., Aliyev, E.A., Thermomechanical processing of austenitic cast iron

1. The composition of the charge material;
2. Melting of material, thermo-time processing of liquid alloy, modification;
3. The effect of the physical state of the alloy on the crystallization process, the structure and properties of cast iron, etc.

The density of synthetic cast iron alloy at the temperature range of 1020-1590°C was studied using gamma radiation in the "Paraboloid-3" device at NPO UNIITMASH and the following results were obtained:

1. To obtain cast iron with high density, it is necessary to limit the amount of silicon in the charge and to add it to the alloy during modification.

2. In order to obtain a homogeneous composition, it is necessary to heat-treat the alloy at 1430 - 1450°C for 15 minutes.

In order to save metal, in the melting of synthetic cast iron, it is heat-treated in order to obtain a homogeneous alloy. As a result, the liquid state of the alloy changes, the sizes of graphite additives are reduced and the dispersion of pearlite increases [6][6].

Thus, it is necessary to reduce the amount of silicon in the charge, and then add the missing silicon to the alloy during modification. The study of the effect of the amount of silicon in the charge and its ratio to carbon on the structure and properties of cast iron, depending on the amount of silicon added later, remains relevant. The degree of eutectic as an object of study (Fig. 3). 0.7÷1 has been gray cast iron.

In order to obtain high-quality synthetic cast iron, it is necessary to maintain the value of the "K" coefficient within (0.8 - 1.2), the degree of eutecticity within (0.74 - 0.8) and the ratio of silicon to carbon within (0.6 - 0.7).

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[6] Babanli, M.B., Huseynov, B.H., Jabbarov, T.G., Shahmarova, R.S., Aliyev, E.A., Thermal processing of rolling shafts made of high-quality cast iron

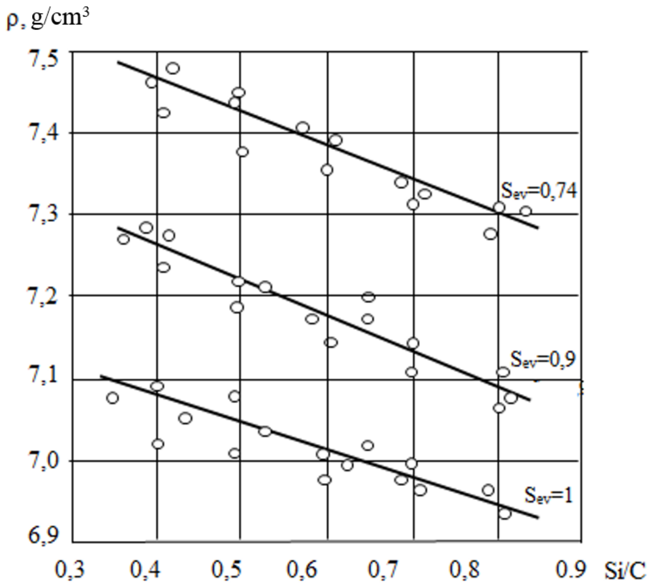


Fig. 3. Eutectic degree of the density of synthetic cast iron and graph of dependence on the ratio of silicon to carbon

When investigating the effect of the ratio of silicon to carbon on the density of cast iron, it is necessary to take into account the addition of silicon to the composition at the same time:

$$K = Si_{den.} / Si_{comp.}$$

In cast irons superheated up to 1440°C, eutectic crystallization temperatures are higher than in cast irons heated up to 1410°C (Figure 4). This indicates that superheating affects the crystallization temperature.

In addition to the chemical composition, the corrosion resistance is also affected by the density of cast iron. It has been determined that as the density of cast iron increases, its corrosion resistance increases.

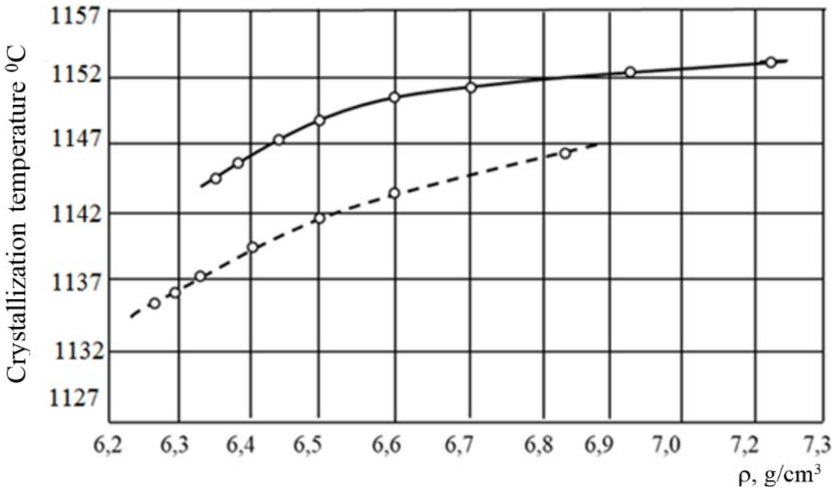


Fig. 4. Different superheated depending on the density of the alloy change of starting temperatures of cast iron crystallization:
—— – superheating temperature 1440°C;
------- – superheat temperature 1410°C

Here, the pearlite structure is considered more favorable, compared to the ferrite structure, in the absence of spaces and non-metallic additives in the pearlite, it becomes difficult for oxygen to pass into the depth of the metal. The main goal in solving this problem is to achieve the necessary mechanical properties of the synthetic cast iron produced by the new technology, to completely cancel the use of valuable alloying elements contained in the currently used "non-resistant" cast iron, to reduce the cost of the product without any changes in the existing production process. 3-5 times [7][7].

[7] Babanli, M.B., Huseynov, B.H., Jabbarov, T.G., Shahmarova, R.S. Temperature regimes of austenite - bainite transformation

In order to optimize technological parameters in production, 6 experimental alloys with different composition and technological sequence were made. Alloys were made in the IST-0.16 induction furnace, which is currently used in the foundry of the Baku "Submersible pumps" production and tenant experimental production enterprise, following special technological regimes, modified with complex modifiers. Molds are made of sand-clay materials and cast in molds with 8 "directing devices" each. At the main stage of the smelting process, after the processing of synthetic cast iron at a temperature of 1450ºC, fully cooked cast iron is poured into a mold at a temperature of 1400ºC. During casting process, ferrosilicon (ФС 75) with dimensions of 3-5 mm is supplied to the mold. As it is mentioned, the methodology of the research work includes the modification by keeping the melting and casting processes under control with the application of new technology. The obtained results are given in tables 2 and 3.

Table 2

Composition and density of non-resistive and synthetic cast iron

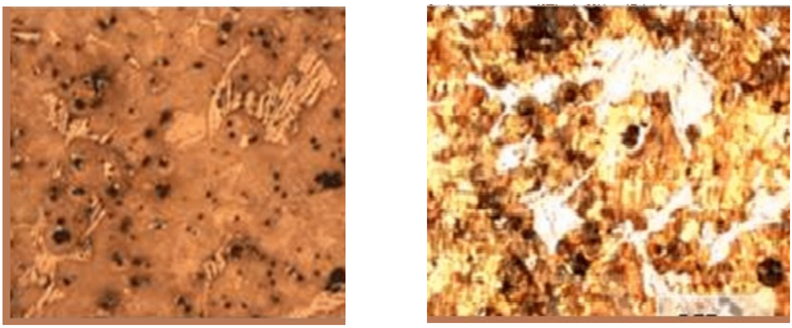
Alloy No	Chemical composition of cast iron								Density, g/cm^3
	C	Si	Mn	P	S	Cr	Ni	Cu	
Cast iron	3,7	1,6	0,94	0,04	0,03	0,8	11,1	5,0	7,3
1	3,01	2,53	0,24	0,02	0,02	0,1	0,5	0,25	7,37
2	3,43	2,66	0,32	0,03	0,02	0,11	0,15	0,25	7,22
3	3,21	2,48	0,54	0,01	0,02	0,16	0,77	0,18	7,31
4	3,03	2,17	0,15	0,025	0,045	0,008	0,47	0,15	7,15
5	3,47	2,35	0,21	0,007	0,005	0,05	0,43	0,2	7,11
6	3,4	2,36	0,252	0,019	0,077	0,125	0,775	0,21	7,32

Table 3

Some characteristics of non-resistive and synthetic cast iron

Alloy No	σ_m, MPa	Firmness, HB	Relative wear, gr	Structure
Cast iron	300	120	0,016	F + P + A + granular graphite
1	400	260	0,004	Dispersed perlite + graphite
2	250	180	0,014	Perlite + plate graphite
3	300	210	0,011	Ferrite + plate graphite
4	220	150	0,017	Ferrite + pearlite + graphite
5	220	150	0,018	Ferrite + pearlite + graphite
6	300	210	0,012	Ferrite + pearlite + graphite

The structural arrangement of the "directing device" made of HQC is given in figure 5.



a **b**

Fig. 5. Microstructure of the "Directing apparatus".

a) Graphite distribution (ungrafted grind) x100

b) Matrix (grafted grind) x200

In the fourth chapter, the influence of thermal processing processes on the structure and properties of high-quality cast iron was considered. The industrial application of high-quality synthetic cast iron produced by the controlled melting method, the effect of thermal processing processes on the structure and properties of high-quality cast iron are shown.

Rolling shafts made of high-quality cast iron are subjected to normalization operation (after controlled melting) [8][8]. The microstructure of cast iron consists of dispersed pearlite and small-plate graphite (graphite plate length 30-50 µm). The dispersion of pearlite is 0.1/0.2 mm, and its density is 7.4 g/cm^3. Normalization mode: heating up to 920ºC, holding for 15 minutes, cooling in air up to 750º, cooling in a gas atmosphere in the furnace up to 100ºC+ cooling in air. After thermal treatment, pearlite was dispersed to the level of sorbite. As a result, the hardness was 290 HB according to Brinell. Since there is no cementite in the structure, mechanical processing was preserved.

The piercing tool is thermomechanically processed. The mode of heat treatment is as follows: the hardening is heated at 1050º-1100ºC, then cooled in water (hardening). The properties of austenite at room temperature were as follows: σb=700 MPa; δ=35.4%; KCV=100 coul/cm^2. To increase corrosion resistance, after mechanical processing, it is riveted by cold deformation in the stamp. After riveting, the hardness increases to 500/550 HB; the strength limit is σb=1500-1800 MPa [9][9] .

The shaft rings are thermally treated. The casting of the belt shaft is austemitized by hardening method (Mn-containing austenite cast iron). The mode is as follows: heating up to 1050º – 1100ºC + (5/10) min holding in water (cooled). The castings are then subjected to a wear operation (where dispersed carbides are separated from the austenite). For this purpose, the rings are heated to 300º - 350ºC

[8] Babanli, M.B., Huseynov, B.H., Jabbarov, T.G., Shahmarova, R.S. Thermal treatment of piston rings made of high-quality synthetic cast iron
[9] Shahmarova, R.S., High-quality mills from synthetic cast iron

(kept in the furnace for 5 hours). During this process, the permanent austenite separates into upper bainite and troostite phases. As a result of this transformation, surface hardness according to Brinell is HB450, σb=1000 – 1200 MPa, impact viscosity KCV=80 coul/cm^2 [10][10].

Piston rings are thermally processed. After casting, they are subjected to normalization operation. The mode is as follows: heating up to 920^{0}C (2 hours) + storage at this temperature (4 hours) + cooling at 720^{0}C (2 hours) + storage at 720^{0}C (4 hours) + cooling in air [11][11]. After normalization, the microstructure of granular pearlite (approaching sorbite and plate-shaped pearlite graphite dispersion) is thermofixed to maintain the elastic force of the rings (Pd=16-22 kgs). This operation is carried out at a temperature of 600º-620ºC: it is kept at this temperature for 25-30 minutes and cooled in air. The preparation of the material of the rings with the new optimal technology led to an increase in density, i.e. 7.3 g/cm^3, so it increased in elasticity. If in ordinary cast irons, as the temperature increases, the elastic force decreases after 500ºC, in this cast iron, the elasticity begins to decrease after 600º - 620ºC. The reason for this is that pearlite breaks down into its components after 600ºC.

Surface whitened mill balls are thermally treated. In surface bleached castings, there is an intermediate zone with a cast iron structure between the fully bleached surface layer and the core. Both graphite and cementite eutectics crystallize in this zone. The structure of fully bleached surface consists of austenite dendrites and eutectic transformation structure. The structure of the transition zone consists of an austenite-graphite group. Surface hardness in the bleached zone is 50-60 HRC, impact viscosity KCV=10-80 coul/cm^2.

[10] Shahmarova, R.S., Effect of density on eutectic crystallization temperature in superheated cast iron

[11] Jabbarov, T.G., Aslanov, C.N., Shahmarova, R.S., Saturation of glass particles with metal permanent sintering of a composite material of the iron-cast iron-glass system

The hardness in the transition zone is 40-45 HRC, and in the core zone 15-20 HRC. The macrostructure of the fully bleached zone is the structure of the cementite + ledeburide transition zone: austenite-graphite eutectic. The casting is then hardened and reversed. After tempering, high-carbon martensite is obtained on the surface of the casting. In the core part, it is heated (150 - 200^0)C to remove internal stresses. After this operation, hardness HRC=56-60 is obtained on the surface, and HRC=25-15 in the core [12][12].

After heat treatment, large needle-like martensite is formed on the bleached surface, and a coarse coarse-grained structure is formed in the core part. During hardening (for 2 hours), dispersed carbides are separated from martensite.

GENERAL CONCLUSIONS

1. Metal waste is preferred for smelting high-quality cast iron. The main reason for not using blast-furnace cast iron is that these cast irons have inherent properties and reduce the quality of the cast iron. It was found that the chemical composition plays a key role in the formation of the structure in cast iron smelting. The correct selection of slag material is considered as one of the main conditions for obtaining high-quality cast iron. The different nature of the structures and properties is explained by the presence of different micro-additives in the composition

2. In order to increase the degree of carbon assimilation in the content of the obtained cast iron, it is determined to add the silicon to the liquid cast iron after the carbonization process. It has been found that each percentage of silicon in a synthetic cast iron alloy leads to a 4-5% reduction in carbon solubility.

3. It has been determined that liquid cast iron must be superheated and then modified to eliminate the inherent influence of the charge material. In order to eliminate the unpleasant "inherited"

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properties of the charge material during melting, it is necessary to subject liquid cast iron to a high-temperature processing process. High-temperature superheating and homogenization of the alloy are the main indicators for obtaining a high-quality casting. Thus, when the temperature increases, the dissolution and uniform distribution of carbon in the metal is accelerated. In such a processing, the alloy is cleaned of non-metallic additives and gases.

4. After melting cast iron scraps in the melting furnace, adding steel scraps is considered the most optimal option. Selection of the casting material and its preparation for melting, its homogenization, purification, modification, alloying, selection of the optimal casting temperature and determination of the appropriate casting speed, etc. were considered the main conditions for the obtaining of high-quality cast iron.

5. It was determined that in synthetic cast iron with a homogeneous pearlite structure, when the superheating temperature is increased, the dispersion of pearlite increases compared to ordinary cast iron. Dispersity of pearlite is higher after 1400□C, pearlite is homogeneously distributed along the cross-section of the sample. In order to increase the homogeneity of cast iron, thermo-time processing and high-quality charge material were used. As homogeneity increased, so did the tendency to overcool. At this time, as the degree of supercooling increases, the initial and final temperatures of eutectic crystallization decrease, the interval narrows, and as a result, graphite crystals are dispersed.

6. It is determined that the superheating temperature should be high, and the modification temperature should be low. During superheating, the number of crystal centers decreases, the degree of supercooling increases, the tendency of cast iron to whiten increases, the shape and distribution of graphite become passive, and the mechanical properties decrease. Therefore, one of the main conditions for obtaining a high-quality alloy is the modification of cast iron.

7. Cast iron with stable properties and isotopic structure can be obtained by creating a controlled melting regime. For this purpose, it is necessary to superheat the alloy, keep it at that temperature, purify, alloy and modify it.

8. It is indicated that the liquid metal must be carburized. The rate of carbonization is highly dependent on the temperature of the metal and the dispersion of the carburizer. The higher the temperature of the metal, the greater the dispersion of the carburizer, the faster the carburization. For this process to proceed smoothly, the temperature of the metal should be above 1400^0C.

9. In high-quality synthetic cast iron, the absorption of carbon from the carburizer depends on the melting time, the method and location of the carburizer. In order to increase carbon absorption from the carburizer, ferrosilicon metal is introduced after the carburizing process

10. One of the important factors in obtaining high-quality synthetic cast iron is when and how much silicon is added to the alloy. It has been proven that 50% of the silicon required in the cast iron grade should be provided by slag, and 50% by modification at 1400^0C. Thus, it turns out that there are quite a lot of factors affecting the carbonization process, and in order to get quality cast iron, it is necessary to conduct the process under absolute control.

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1. Babanli, M.B., Huseynov, B.H., Jabbarov, T.G., Shahmarova, R.S., Aliyev E.A. Density and volume settlement of high-quality synthetic cast iron. ASOIU//News of Azerbaijan Higher Technical Schools, Vol. 19 No. 1(105) 2017, pp. 61-68.

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In the case No. [8], the applicant performed the problem statement, theoretical research and the composition of the article.

In case No. [11], the applicant conducted theoretical and experimental studies.

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