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OBTAINING OF HIGH QUALITY SYNTHETIC CAST IRON

Rafiga Sakhavat Shahmarova

Department of Mechanical and Materials Science Engineering, Azerbaijan State Oil and Industry University, Baku, Azerbaijan

Email: rafiga.shahmarova@asoiu.edu.az

ABSTRACT

The article is devoted to the technology of obtaining quality cast iron. Based on the results of the research, a technological regime has been developed and applied in production. It was possible to improve the properties and structure of the same eutectic cast iron by the obtained controlled melting method. In order to obtain high-density cast iron, it is also necessary to limit the amount of silicon in the shit and add it to the alloy during modification. For obtaining homogeneous composition it is necessary to process alloy at 1703-1723K within 15 minutes. One of the main factors in obtaining of qualitative cast iron is the purity of the shit material from various additives. These additives change the structure and properties of the alloy by changing its physical and chemical state. It turns out that in order to get qualitative cast iron, it is necessary to obtain synthetic cast iron using steel scrap, which is purer than additives. One of the most important processes in the melting of synthetic cast iron is the carbonation of the liquid metal. For the carbonation process to take place, the temperature of the metal must be higher than 1673K. In the melting of synthetic cast iron, there must be a certain relationship between the chemical composition, high temperature and the storage time at this temperature (thermal processing). Experimental results show that each percent of silicon in a synthetic cast iron alloy reduces the solubility of carbon by 4-5%. Therefore, after carbonization of synthetic cast iron, it is necessary to add silicon to the alloy.

Keywords: Cast iron, Alloy, High density, Production technology, Thermal.

INTRODUCTION

One of the main factors in obtaining of qualitative cast iron is the purity of the shit material from various additives. These additives change the structure and properties of the alloy by changing its physical and chemical state. It turns out that in order to get qualitative cast iron, it is necessary to obtain synthetic cast iron using steel scrap, which is purer than additives. One of the most important processes in the melting of synthetic cast iron is the carbonation of the liquid metal. It has been studied that dissolving of carbon in liquid iron passes through certain stages: first, base plane packages are separated from the surface of solid carbon particles and then liquid solution and then, carbon atoms diffuse in the solution (Zhilkin, 1969; Elansky and Kidrin, 1984). It is believed that the dissolution of carbon in iron takes place by passing of iron atoms into the base planes. Subsequent dissolution of carbon depends on temperature and time. The results of the study show that the higher the temperature of the metal, the higher the dispersion of the carbonizer, the faster the carbonation. For the carbonation process to take place, the temperature of the metal must be higher than 1673K. In the melting of synthetic cast iron, there must be a certain relationship between the chemical composition, high temperature and the storage time at this temperature (thermal processing). Experimental results show that each percent of silicon in a synthetic cast iron alloy reduces the solubility of carbon by 4-5%. Therefore, after carbonization of synthetic cast iron, it is necessary to add silicon to the alloy. The results of our research display that one of the important factors in obtaining high quality synthetic cast iron is when and how much silicon is added to the alloy (Elansky and Kidrin, 1984; Zhukov and Snezhnoy, 1978; Girshovich, 1949; Huseynov, 2010; Das, 2014). It has been proved that 50% of the silicon required in the cast iron grade should be given by the shit and 50%-during its modification at 1673K. As a result, it turns out that there are many factors that affect the process of carbonization, and in order to obtain qualitative cast iron, the process must be controlled.

MATERIALS AND METHODS

Purpose of the study

The purpose of carrying out of controlled melting is to develop a technological regime for the preparation of these parts. Experimental melting was carried out in ship repair plants and other foundry shops in electric furnaces with ICT-1.0 induction and DSP-0.5 arc. Steel scrap and industrial waste, ferroalloys (FS75, FMn75) have been included into shit material. Solving the problem: GQ-O (50 ÷ 10) mm fine graphite electrode was used to carbonize the alloy. The chemical composition was determined in “An-7529 and Kvantovax-31000” devices, and the temperature of liquid cast iron was determined with an optical pyrometer.

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When the melting process was carried out in an induction furnace, 50% of the shit material was liquid cast iron, and when melted in an arc furnace, the amount of silicon in the charge material was 50% of the required amount. The liquid alloy in the furnace was thermally processed at 1723-1733K within 10 minutes. The time of modification of silicon to the chemical composition was carried out at 1673K. The controlled parameters of the melting consist of the eutectic degree (S_{eut}), the ratio of silicon to carbon (S_i/c), the amount of silicon in the shit material and silicon added during chemical composition obtaining. To study the mechanical properties and structure of synthetic cast iron, standard samples (d=30 mm and l=600 mm) have been casted from each alloy. The strength properties have been determined by standard methods, and the structure of the cast iron has been studied under a microscope MIM-7 before and after casting, the results of chemical analysis, the properties of the cast iron and the control parameters have been presented in Table 1.

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

Alloy №	**Chemical composition**			**Parameters**				**(Density ρ, g/sm^3**	**Solidit--y HB**	**Strength ϭ. Mpa**	**Volume fitting α %**
	C	M_n	S_i	S_{evt}	S_i/C	S_i (in shit)	S_i (obtaining)				
Initial ordinary cast iron	3.01	0.72	2.10	0.80	0.63	1.95	0.15	7.0	150	200	0.7
Initial syantherik 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	-

The table shows that the properties of cast irons of the same eutectic grade are of different value. This is due to the variety of controlled parameters. The value of density and strength properties increased depending on when and at what temperature silicon has been applied, the value of the Si/C ratio, manganese has been taken more than 0.1-0.2%. Controlled melting also had a positive effect on the structure of the cast iron. The core of the metal consists of dispersed perlite and insulated compact graphite. The dispersion of perlite increased from 0.8 μm to 0.1-0.2 μm. The size of graphite additives are decreased by 20-30 microns (Fig 1).

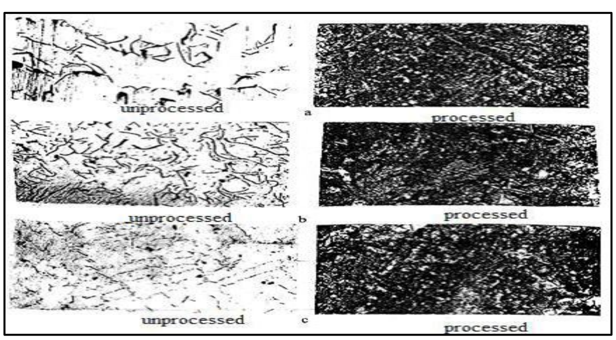

Fig 1. The microstructure of same eutectic cast iron × 100: a-ordinary cast iron (СЧ20); b-synthetic cast iron (СЧ25); c-controlled molten synthetic cast iron (СЧ35).

RESULTS

Based on the results of the research, a technological regime has been developed and applied in production. Thus, it was possible to improve the properties and structure of the same eutectic cast iron by controlled melting method (Ehrhardt, 2020). As the liquid cast iron crystallizes in the mold and cools to room temperature, the volume and linear dimensions of the casting change. Depending on the cooling stages, these dimensions may either decrease (settling) or increase (expanding). Depending on the condition of the aggregate, the settling consists of settlings of the liquid alloy during and after solidification. The most complicated of them is settling of cast iron in the solid liquid state. This is due to the effect of thermal factors, phase transitions, gas emissions, graphitization, etc. processes.

The settling of the alloy in the liquid state is considered as a change in its density. A lot of work has been devoted to the study of this issue (Girshovich, 1949, Ho, 1978). However, depending on the chemical composition and nature of the cast iron, there is no exact information on how it settles in the liquid state. It is assumed that the liquid volume for conventional synthetic cast iron is in the range of (190-230) ·10-6 I/degree (Elansky and Kidrin).

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 cost of settling ratios varies depending on the type of cast iron. Thus, the value of the linear settling ratio for gray cast iron is (0.9–1.0) %, for white cast iron (1.6–2.3) %, and so on limits.

Thus, it turns out that as the amount of chemical compounds of carbon and iron in the structure increases, the value of the settling ratio also increases and approaches the settling coefficient of steel. As a rule, the increase in the ratio of settling forces the foundry men to build an additional structure for the casting when it is designed. This prevents the settling space in the cast iron mold. However, the application of the additive causes 10-15% useless consumption of liquid metal. In this regard, the study of measures to prevent the settling gap in cast iron mold is one of the urgent issues.

It is known that the settling gap in the molds is formed during the crystallization of the liquid alloy (solid-liquid phase). If the graphitization process is regulated at this stage, the settling can be reduced to zero due to expansion.

The (total) settling coefficient in cast iron is equal to the sum of the settling coefficients in the individual stages:

$$E_{tot} = \left(E_{s.b.p} - E_x\right) + (E_{s.a.p} - E_{\Upsilon\to\alpha})$$

Where, E_{ex} -pre-settling expansion;
$E_{.s.b.p}$ – settling before perlite;
$E_{\gamma\to\sigma-}$eutectoid expansion during the conversion;
$E_{s.a.p}$ –settling after eutectoid transformation

Experimental results show that for synthetic cast iron these parameters are within the following limits:

E_{ex} = (0.14–0.15) %; $E_{s.b.p}$ = (0.5–0.81)%;
$E_{\gamma\to\sigma} = (00310033)\%$; E_{tot} = (1, 33–1, 35)%.
Total linear settling coefficient E_{Linear} = 1.18 →1.2.

It turns out that as the volume expands in the liquid metal, the volume of the settling space decreases. Volume settling is also affected by parameters such as metal composition, temperature, eutectic rate, carbon equivalent, ratio of silicon to carbon, when and how much silicon is added to the metal.

As a result, the settling space in the mold may either increase or decrease to zero ((Elansky and Kidrin, 1984; Zhukov and Snezhnoy, 1978). It should be noted that the effect of the liquid state of the metal, temperature, and when and how much silicon is applied to the volume of the settling space has been 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 results of the study show that the grades of synthetic cast iron obtained by the method of controlled melting, which have the same eutectic degree, differ by several steps (Huseynov, 2010). The volume of these cast irons obtained by controlled melting decreased from 0.7-0.8% to 0.2% and was even zero. Their density was 7,3-7,35 g/cm^3 (Tables 1 and 2).

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Table 2. Indicators of high quality cast irons.

Melt s/s		1	2	3						
Cast-iron type		**Initial ordinary cast iron**	**Primary synthetic cast iron**	**Experimental cast iron 3.1**	3.2	3.3	3.4	3.5	3.6	3.7
Chemical composition	C	3.01	3	2.88	2.85	2.8	2.92	3.02	2.4	2.69
	Mu	0.72	0.7	0.95	0.92	0.9	0.01	0.85	0.95	0.85
	Si	2	2.05	2.2	2	1.8	2.05	1.79	2.08	2.03
Control Parameters	S	0.5	0.8	0.8	0.8	0.81	0.8	0.8	0.69	0.75
	Si/c	0.63	0.63	0.7	0.7	0.61	0.7	0.6	0.81	0.78
	Si In the shit	1.95	1.8	1.1	1	0.9	1	1.04	1.01	1.1
	Si delivery	0.15	0.25	1.1	1	0.9	1	0.9	1.04	1.02
Graphitization coefficient,%		5.65	5.04	4.6	4.5	4.6	4.2	4.3	4.4	4.4
Density, $\rho^3 g/sm^3$		7	7.1	7.3	7.32	7.31	7.3	7.32	7.35	7.35
Strength limit in tension, M_{pa}		200	250	300	300	300	300	300	300	320
Linear settling stages,96	Expansion before settling, $E_{e.b.s}$	0.25	0.12	0.35	0.32	0.31	0.32	0.31	0.3	0.34
	Seating before perllite, $E_{s.b.p}$	0.43	0.35	0.36	0.32	0.3	0.33	0.34	0.35	0.36
	Linear seating, l.s.	1.09	1.13	0.86	0.8	0.87	0.85	0.86	0.92	0.82
	Expansion during Evtectoid transformation, $E_{e.d.e.t.}$	0.07	0.03	0.01	0.02	0.009	0.008	0.005	0.003	0.007
	Seating after eutectoid, $E_{s.ae}$	0.54	0.9	0.85	0.82	0.87	0.85	0.81	0.9	0.9

As a result of reducing the settling volume to zero, there was no need for additional design when casting for mass parts of internal combustion engines (weight 300–800 kg, wall thickness up to 20-60 mm). This means liquid metal consumption is zero useless. In addition, the cost of general linear settling also decreased (from 1.33% to 0.65%). This reduced the cost of linear settling and reduced the consumption of liquid metal. The performance of synthetic cast iron is given in Tables 1 and 2.

It is seen from the essence of the method of controlled melting that for obtaining of high-quality synthetic cast iron the melting of shit has been started. Finally, it's necessary to control all the processes before molding and affect them. These areas of influence are:

- The composition of shit material;
- Melting of material, thermal processing of liquid alloy, modification;
- Influence of physical condition of alloy on crystallization process, structure and properties of cast iron, etc.

Thus, the physical condition of the alloy is more important in obtaining of high-quality cast iron. Academician A.A. Baykov showed that the problem of liquid metal is the first problem of metallurgy. From the processing point of view to metal crystallic structure, it is seen that the close location of atoms and their coordination number, interatomic distance form physical properties of metal and its assignment begins with electrons of the outer layer. It has been confirmed that the melting of the metal does not change its electronic state, but here the density of vacancies changes. That is, the distant order between atoms is broken, while the close order remains. It has been shown that during the melting of many metals, such a change occurs in the electronic structure of ions.

DISCUSSION

The study of structure- sensitivity and other properties shows that iron-carbon alloys always contain micro particles of graphite, it is impossible to break the bonds of atoms in the hexagonal base planes of carbon (in conventional metallurgical processes), the temperature must be too high to break these bonds and get a free carbon atom. However, such temperatures are never obtained during the melting process (i.e. above 1650ºC). Therefore, iron-carbon alloys will always have separate blocks of graphite packages.

In the process of real crystallization, the most decisive influence on the structure and properties of cast iron is caused by graphite additives in the liquid. The liquid, dispersing the graphite additives in the alloy, is absorbed by the growing crystals during the crystallization process resulting in increased inter-crystalline bonding, which in its turn increases the strength and other properties of cast iron. The parameter that mostly affects the structure and properties of iron-carbon alloys is the high temperature and storage at that temperature.

In the melting of synthetic cast iron obtained as a result of the application of metal-saving technologies, the alloy is processed thermally to achieve a homogeneous alloy. As a result, the liquid state of the alloy changes, the size of graphite additives decreases and the dispersion of perlite increases.

To obtain these results, it is proposed to reduce the amount of silicon in the shit and then add the missing silicon to the alloy during modification. This is due to the fact that the carbon is soluble and the exposure time of silicon is preserved. Here the thermal treatment is carried out in 1773–1753K within 15 minutes. However, it is necessary to study the effect of silicon on the density of the alloy. The density of synthetic cast iron alloy in the temperature range of 293–1863K has been studied at NPO UNIITAM using gamma radiation on the "Paraboloid-3" device and the following results have been obtained.

CONCLUSIONS

1. In order to obtain high-density cast iron, it is necessary to limit the amount of silicon in the shit and add to the alloy it during the modification to achieve the composition.
2. To obtain a homogeneous composition, the alloy must be thermally processed at 1703–1723K within 15 minutes.

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