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DEVELOPMENT OF QUALITY STEEL ALLOY LIQUIDATION TECHNOLOGY

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Abstract

In this article, the mode of liquefaction of 35XGCL steel alloy was used. The obtained liquid metal is cleaned from non – metallic inclusions and gas pores by non – furnace processing, and casting technology was developed on the basis of energy and resource efficient innovative technologies. The composition of the sand – clay mold was worked out to obtain a high – quality cast product, and a high – quality cast product was obtained by liquefaction. Also, thermal treatment regimes were developed to increase the mechanical properties of the cast alloy, and as a result, a high – quality and resource – efficient cast product was obtained.

Keywords: chrome, manganese, alloyed, shaft, sand – clay mold, hardness, viscosity, gas pores, nonmetallic inclusions, fluxes, alloy, cast iron, mechanical properties, semi finished productб steel, carbon, microstructure, electric arc furnace, ferromanganese, calcium carbonate.

Introduction

The origin of the production of ferrous metal alloys can be traced back to 2000 BC, when manuscripts found in ancient China and India refer to artificial ferrous metals. Competitive forces and market globalization in the metallurgical and mechanical engineering industries continue to develop and implement new technologies for steel and cast iron production in the 21st century. The attitude of the industry to its own local and global technologies leads to the step – by – step improvement of existing technologies, as well as major changes in several important areas, such as the production of steel and its alloys [1 – 4].

Ferrous metal alloys have satisfactory physical – chemical, technological and mechanical properties, they are characterized by the change of properties due to the change of chemical composition, as well as the direction of the properties in the necessary direction due to the change in structure due to thermal treatment, the cost of the alloy is cheaper [5 – 8].

Foundries are one of the important branches of the mechanical engineering industry, in which castings of different shapes and sizes are obtained by pouring various metals or their alloys into a pre-prepared mold. The mass of castings (parts or their semi – finished product) can be from a few grams to 250 tons and more. As for the cast semi – finished product, their shape and size are slightly larger than the investment value, designed for mechanical processing, depending on the shape and size of the details. Statistics show that about 70% by mass of cast irons produced today are gray and modified high – strength cast irons, about 20% are steels, and the rest are malleable cast irons and non – ferrous metal alloys [9, 10].

Steel is one of the most widely used metals in industrial production. As the global economy expands, the demand for steel and its alloys is increasing rapidly, leading to increased supply needs. For reference, in the last 15 years, the production of high – quality steel in the world has doubled [11 – 13], from 24 million tons in 2005 to 51 million tons in 2020. According to the data of the World Steel Association published at the end of January 25, in 2021, the volume of steel production worldwide will grow by 3.6% per year, and the total production volume in 2021 will reach 1.95 billion tons, and the volume of pig iron production will be 1.6 billion tons, which in turn indicates a high demand for steel [14 – 16].

MATERIAL AND METHODS

Shafts made of 35XGCL and 35XGCA steels are used for ball rolling machines in the "1st grade rolling" workshop of "UzMetkombinat" JSC, one of the leading enterprises of our republic. This steel alloy of the 35XGCL brand is cast in the "Casting Mechanics" workshop of the combine.

Alloy steels are of great importance in reducing their mass, while improving the quality of machines and structures, ensuring long – term accurate operation. Alloying elements increase the fineness, viscosity, corrosion resistance and other mechanical properties of steel, as well as the malleability property, the depth of corrosion and other technological properties, change the physical (magnetic and electrical) properties, corrosion resistance properties at high temperatures and under normal conditions. improves [17 – 22].

Today, in the "Casting – Mechanics" shop of "UzMetkombinat" JSC, shafts made of 35XGCL brand steel, which are cast for ball rolling machines, are cast into sand – clay molds.

Iron ore, low – manganese steel, secondary metal, ferroalloys, ferrosilicon (FeSi 65), ferromanganese (FeMn 95), calcium carbonate ($CaCO_3$) and others were prepared as raw materials for slag. A basic 2.0 ton electric arc furnace was initially selected to liquefy the alloy. After checking that the inner lining of the furnace was in good condition, first small and then large solid materials were loaded into the furnace. As soon as the alloy began to liquefy, 3 percent limestone ($CaCO_3$) by weight of the alloy was added to the furnace as a flux. According to the established norms, the temperature of liquefaction of the chemical composition reached 1550°C. After that, ferroalloys with high melting point were put into the furnace at 1565°C. To reduce the carbon content of the alloy, oxygen was pumped from the side of the furnace with a pressure of 0.8 – 1 MPa through a specially installed furnace. As a result, carbon and harmful gases in the alloy were reduced. After the alloy was completely liquefied, samples were taken from three places by mixing the liquid alloy, and the chemical composition of the alloy was checked on the "SPECTROLAB – 10 L" equipment. When the temperature of the liquid alloy reached 1610 – 1620°C, it was poured into a special ladle preheated to 800 – 850°C (Pic. 1).

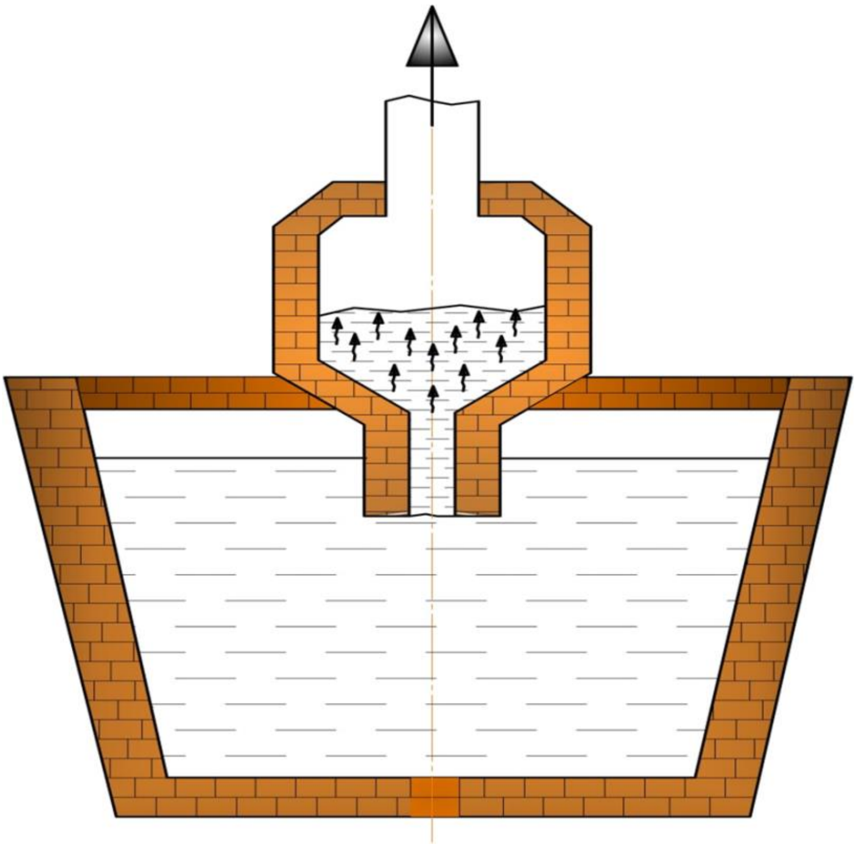
a) b)

1 – picture. a) The process of loading ferroalloys into the furnace, b) The process of heating the furnace using a gas burner

Several methods were used in order to reduce gas pores and mirror inclusions in the alloy, to obtain high – quality cast products.

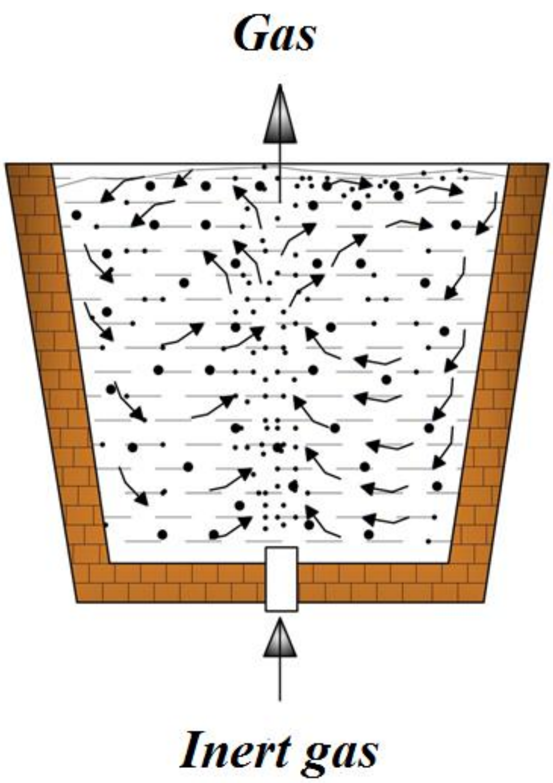
The first method: This method is considered a chemical method and cleans the alloy from non – metallic inclusions by 50 – 70%. For this purpose, synthetic slag (55% CaO, 40% Al_2O_3 and a small amount of SiO_2, MnO, FeO) liquefied in an electric furnace was introduced into the furnace at 3 – 5 % based on the weight of the liquid alloy. In this method, the liquid alloy quickly reacts with the synthetic slag, cleaning the mirrors from impurities and gases. Then it became possible to obtain high – quality cast products.

The second method: This method is to process the steel alloy in a vacuum chamber, and this method is shown in Picture 2. It is known that the dissolution of O_2, H_2, N_2 and other gases in it decreased as the metal pressure in the furnace decreased. As a result, the gases released from it also followed the mirror inclusions with it. Therefore, in order to clean the metal in the cavity from gases and non – metallic materials, first the air in the chamber was pushed to a pressure of 0.267 – 0.667 kPa, then the molten metal was introduced into it and kept there for 10 – 15 minutes. Non – metallic inclusions followed along with the gases separated from the metal in the form of bubbles, and as a result, the amount of gases in it decreased by 3 – 5 times, and the amount of non – metallic inclusions decreased by 2 – 3 times.



2 – picture. The process of refining the alloy in a vacuum chamber

The third method: In this method, one of the inert gases (helium, neon, argon, krypton, xenon, radon, oganesson) was transferred from the liquid alloy in the cavity under a low pressure (Pic. 3). In this, the metal was thoroughly mixed and cleaned of gas and non-metallic inclusions. Casting in a stream of inert gases through a special device to prevent metal from oxidizing when pouring into the mold gave good results, especially for alloy steel ingots.



3 – picture. The process of cleaning by inert gas to the alloy

The fourth method: It is considered to purify the alloy from sulphur, which is a harmful element, and for this purpose, the liquid alloy was removed from the furnace in another electric furnace. For this, the temperature of the liquid alloy is raised to 1630 – 1650° C in the second electric furnace, slaked limestone ($CaCO_3$) and CaF_2 are introduced into the furnace, and after holding for 10 – 15 minutes, the slag separated from the liquid alloy is taken out of the furnace.

$$CaCO_3 = CaO + CO_2$$

$$FeS + CaO \rightarrow CaS + FeO$$

$$CaF_2 + H_2SO_4 \text{(конц.)} \rightarrow CaSO_4 + 2HF$$

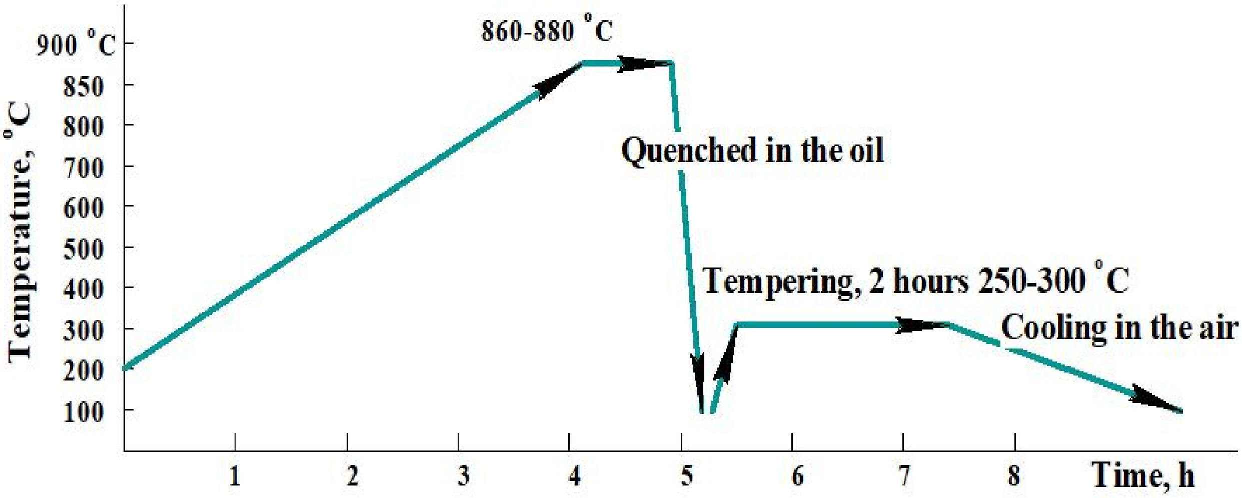
The fifth method: In this case, the harmful element in the alloy was removed from phosphorus, and for this purpose, the liquid alloy was removed from the furnace in another electric furnace. For this, the temperature of the liquid alloy is raised to 1440 – 1450° C in the second electric furnace, slaked limestone ($CaCO_3$) is introduced into the furnace, and after 8 – 10 minutes, the slag separated from the liquid alloy is thrown out.

$$CaCO_3 = CaO + CO_2$$

$$2[P] + 5\,(FeO) + 4CaO \rightarrow 4(CaO \bullet P_2O_5) + 5Fe$$

After using the out – of – furnace liquid alloy in five ways, the liquid alloy was cast into prepared sand – clay molds after removing pores and mirror inclusions.

In order to improve the physical – mechanical and technological properties of the shaft parts cast in sand – clay molds by casting method, they were subjected to heat treatment in order to increase their operational performance.



4 – picture. Mode of heat treatment of the alloy

The main purpose of such heat treatment is to change the properties of the alloy due to structural changes without changing the chemical composition of cast products. Figure 4 shows the thermal treatment of the alloy.

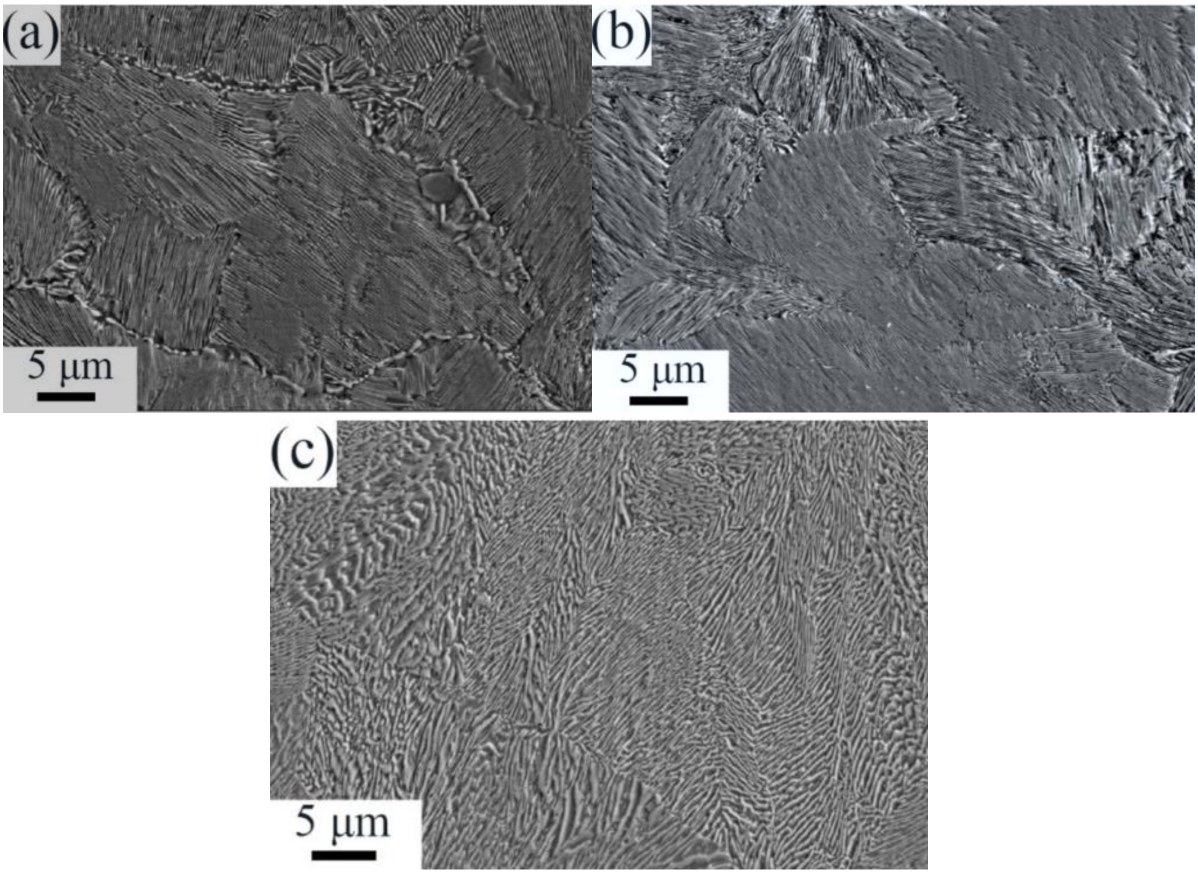
RESULT

Production of high – quality cast products from 35XGCL steel alloys and reduction of gas pores and mirror inclusions in its content, liquefaction mode of alloys and their processing technology were developed, and high – quality cast products were cast. After removing the alloy from the casting mold, a special sample was prepared, and the chemical composition of the alloy was determined using the "SPEKTROLAB – 10M" device (Table 1).

Table 1 Chemical composition of the samples obtained based on the results of the research

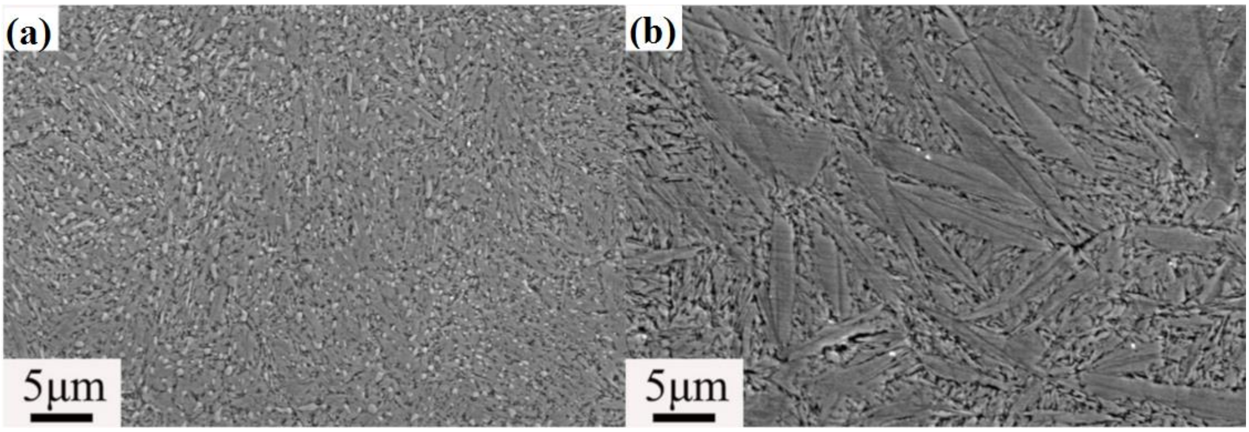
№	Elements, %								
	C	Si	Mn	Ni	P	S	Cr	Cu	Ti
N-1	0.21	0.71	0.70	0.10	0.021	0.026	0.79	0.16	0.039
N-2	0.28	0.70	0.71	0.10	0.023	0.026	0.75	0.15	0.041
N-3	0.21	0.70	0.62	0.11	0.023	0.033	0.67	0.17	0.030

Samples were metallographically examined at the "Center of Advanced Technologies under the Ministry of Innovative Development" at a magnification of x500 to 2000 times on a SEM Zeiss EVO MA 10 scanning electron microscope, and the obtained results are shown in Pictures 5 – a, b, c.



5 – picture. Microstructure of cast steel alloy

5 – a, b, c – the microstructures obtained in pictures can be observed with the help of an electron microscope scanning from x500 to x2000.



6 – picture. The microstructure of the alloy after it was quenched in the oil

6 – a, b – the alloy was heated to a temperature of 860 – 880^{0}C for 4 hours and kept at this temperature for 1 hour. Then it was fired at 250 – 300^{0}C for 2 hours and cooled in the open air. Pearlite and more austenite can be seen in heat treated microstructures.

CONSLUCION

Based on the liquefaction regimes of 35XGCL alloy at different temperatures in electric arc furnaces, the technology of obtaining cast products with surface cleanliness and high mechanical properties has been improved, and the technology of liquefaction of the alloy in an optimal way and pouring into casting molds has been developed. The alloy was treated with inert gases outside the furnace. Processing mode and casting technology were developed based on the dynamics of gas and mirror inclusions in the resulting alloy.

Based on the results of the research, the following conclusions were made, which were taken as the main reasons for the flux, furnace lining, quality of refractory materials, preheating process of the charge and other similar factors. Based on the stated reasons, the quality of the furnace lining and lining material were considered to be the most important factors that led to a decrease in the quality of the final casting.

The approach used in this work made it possible to achieve a complex and reliable result. In addition, as a remedial process, the oven lining, oven top, and cavity lining were replaced with high – quality refractory material. The results of the re – survey were discussed and the rate of substandard castings was reduced as only 1 in 10 shafts were found to be substandard in the current study. In addition, it has been proven that by controlling the percentage of additives at each step, the level of poor quality cast product can also be reduced.

Also, in order to smooth the structure of the cast part and improve its mechanical properties, a thermal treatment regime was developed.

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