INVESTIGATION OF THE EFFECT OF MELTING TEMPERATURE ON THE WEAR-RESISTANCE PROPERTIES OF AUSTENITE STRUCTURED MANGANESE STEEL

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Abstract
The process of making most manganese steels involves raising the melting and casting temperatures to 1500 oC and above to increase the fluidity of the metal and facilitate slag removal. It helps to separate alloy elements with micro and macro carbide at high temperature and to form brittle transformation products. The presence of segregation at the grain boundaries serves as an obstacle for the movement of dislocations. This can result in uneven, inconsistent corrosion rates of the steel and the quality of the alloy.
This article investigates the effect of casting/melting temperature on the carbide segregation tendency of austenitic microstructure manganese steel and its effect on the corrosion resistance properties of jaw crushers.

Keywords: Austenite, microstructure, steel, casting, induction furnace, solid materials, carbide.

Introduction

Iron and its alloys, considered the main machine-building material in the world until now, are of special importance among metals. Iron and its alloys make up 90% of metals produced worldwide. This is explained by the fact that ferrous metals have important physical and mechanical properties, as well as the fact that iron ores are widely distributed in nature, and the production of steel and cast iron is cheap and easy to produce. Metals used in technology are mainly divided into two groups - ferrous and non-ferrous metals. Ferrous metals include iron and its compounds (cast iron, steel, ferroalloys). The rest of the metals and their alloys make up the group of non-ferrous metals.
In addition to the quality indicators, it is important to increase the economic efficiency of the production of steel parts produced in our country. In this regard, one of the important tasks is to carry out targeted scientific research, including scientific research in the following directions: for example, calculation of solid materials for liquefaction of steel alloy; selection

and modification of the optimal modifier to the steel alloy; expanding the scope of industrial use, taking into account the mechanical, physical and operational properties of the steel alloy to increase its ductility; development of technology that eliminates factors that negatively affect quality indicators during the liquefaction of steel alloy; it is important to create a technology that provides energy and resource saving in the process of liquefaction of steel alloys [1, 2].

Due to the alloy's good impact toughness, it is widely used in railways, jaw crusher parts by casting them and heat treating them without any modification due to its high impact and corrosion resistance properties.

There are many variations of fully austenitic microstructured manganese steel [3-7], and only a few of the research studies conducted have been considered as significant improvements. They usually involve varying the proportion of carbon and manganese with or without additional elements such as chromium, nickel, molybdenum, vanadium, titanium, and bismuth [8].

The mechanical properties of the alloy change depending on the content of carbon and manganese. As carbon increases, it becomes increasingly difficult to retain all of the carbon in the solid solution, which can lead to reduced tensile strength and ductility. However, as carbon increases above 1.2%, corrosion resistance increases and ductility decreases. The carbon content is usually lower than 1.4% and 13% manganese, because it is difficult to obtain an austenite microstructured cast with insufficient grain boundary carbides that impair strength and ductility [9].

In the as-cast state, 110Г13Л contains carbides and structural changes in the as-cast product [10]. The heat treatment of the casting in the complete state is carried out at a temperature from 1000 ^oC to 1100 ^oC, depending on the thickness of the casting walls. High heat treatment temperatures of the casting should not be allowed, as carbon separation can cause initial melting and lead to decarburization (decarburization). In addition, the cooling rate limits the carbon concentration in the casting [11]. Although some in-cast grain growth may occur, final austenite grain size can be strongly influenced by casting temperature and solidification rate [12, 13].

Castings in molds are slowly cooled carbides. Also, regardless of the mold cooling rate, if the cast contains more than 1.0% C, carbides are formed [14-16]. During heat treatment, they form in thick castings, and carbides can form at temperatures above about 275 ^oC if etching is ineffective in producing rapid cooling throughout the thickness of the part.

MATERIALS AND METHODS

Using 450 kg of scrap steel, 15 kg of ferrochrome, 110 kg of ferromanganese and 3 kg of ferrosilicon, 380 kg of manganese was melted in a 1 ton capacity induction furnace to obtain ingots. Table 1 shows the quantity and chemical composition of the powder. The resulting spectrometric analysis of 110Г13Л steel is shown in Table 2 [17-19].

Three batches of materials weighing 330 kg each were melted to three different heats/melting temperatures as shown in Table 3.

Liquid metal is poured into preheated sand-clay moulds. The mold is made of a sand-clay mixture bound with sodium silicate based on the standard [18]. Cast surface temperature was measured at different points using a digital probe pyrometer. When extracting the ingot from the sand-clay mold, the liquid metal was extracted 32 hours after pouring into the mold.

Table 1 Charge materials

Charge materials	Weight of charge materials, kg	Element composition, (%)					
		C	Si	Mn	P	S	Cr
Returned metal	380	1.31	0.66	12.10	0.03	0.03	1.82
Steel scraps	450	0.43	0.32	0.32	0.21	0.21	-
Ferrochrome	15	0.64	-	-	-	-	61.95
Ferromanganese	110	4.33	-	55.48	-	-	
Ferrosilicon	3	-	70.25	-	-	-	-
Total	**958**	**1.23**	**0.63**	**13.57**	**0.02**	**0.02**	**1.69**

Table 2 Chemical composition of manganese steel, %

Alloy	Element composition, (%)							
	C	Si	Mn	Ni	P	S	Cr	Al
Sample 1	1.0-1.3	0.5-0.8	12-14	-	0.005 >	0.005 >	-	-
Sample 2	1.23	0.60	12.8	-	0.005	0.006	2.40	-
Sample 3	1.27	0.90	12.6	0.40	0.06	0.05	2.10	0.08

Heating of slag materials and corresponding casting temperature

Heating	Sample 1	Sample 2	Sample 3
Temperature, °C	1550	1450	1380

Heat treatment of the alloy

Cast products were austenitized in laboratory conditions in a muffle furnace at a temperature of 1050 °C for 4 hours.

Different samples were immersed in water for 5 minutes, which is necessary to ensure that no steam is formed during cooling.

The entire surface of the sample was tested using a magnetic piece after curing to determine the degree of transition to a full austenite microstructure [21].

Samples with dimensions of 25 mm x 25 mm x 12.5 mm were obtained after heat treatment from the edge (a), the middle, i.e. the thickest part (b) and the mounting part (c) of the grinder casting is obtained. After preliminary grinding and cleaning, the surface of the sample was prepared for metallographic examination using ethyl alcohol. An optical metallurgical

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microscope was used to obtain x250 magnification microstructures of the processed samples [22]. Microstructures are shown in Figures 1, 2 and 3.

RESULTS AND DISCUSSIONS

The microstructures of three selected sections of sample 1 showed a non-uniform distribution of carbides in the austenite matrix (see Fig. 1). A high concentration of carbide particles was found at the grain boundaries at high temperature.

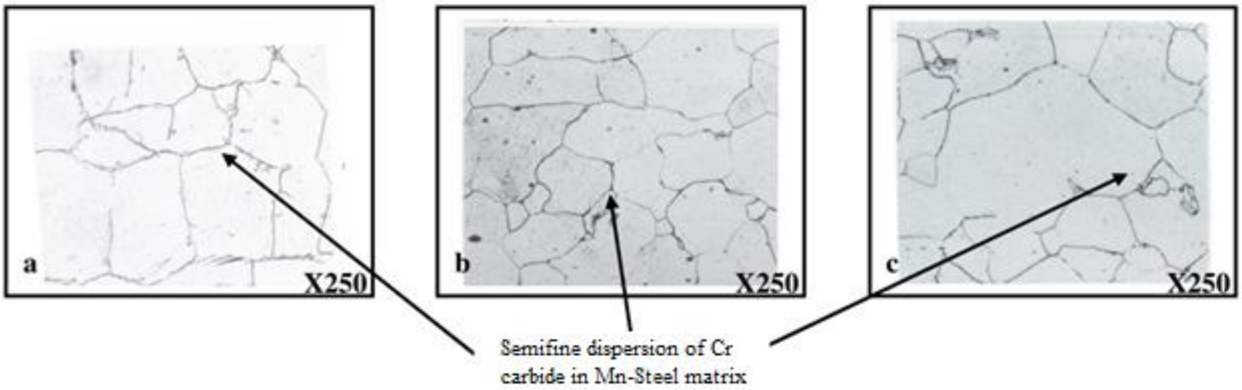

Fig. 1. Microstructures of the edge (a), middle (b) and mounting (c) parts of the grinder detail from sample 1. These microstructures are characterized by the presence of irregular, segregated chromium carbides around grain boundaries

In sample 2, several carbide particles are visible scattered in the austenite matrix (Fig. 2).

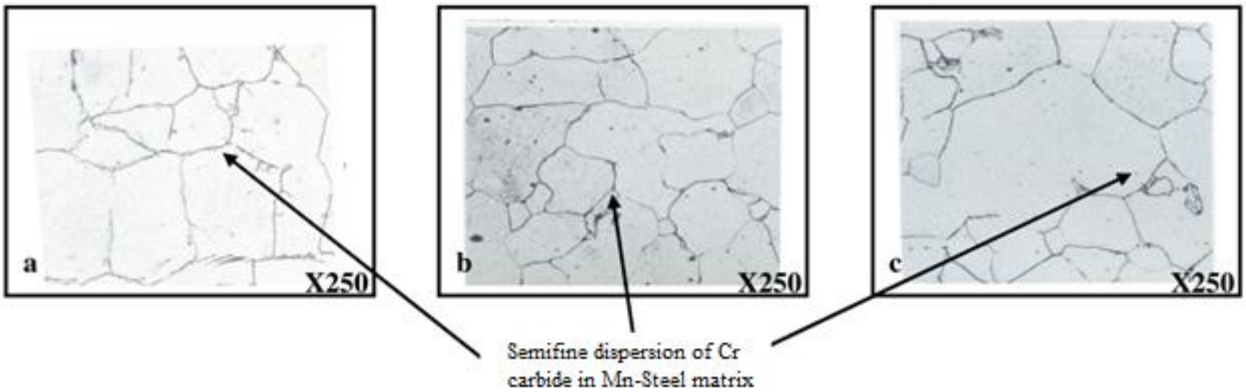

Fig. 2. Microstructures of the edge (a), middle (b) and mounting (c) parts of sample 2 grinder detail

As shown in Figure 3, the microstructure of sample 3 does not show the concentration of carbides in the grain boundaries of the austenite matrix. It was observed that the dark colored carbide particles were uniformly distributed in the matrix.

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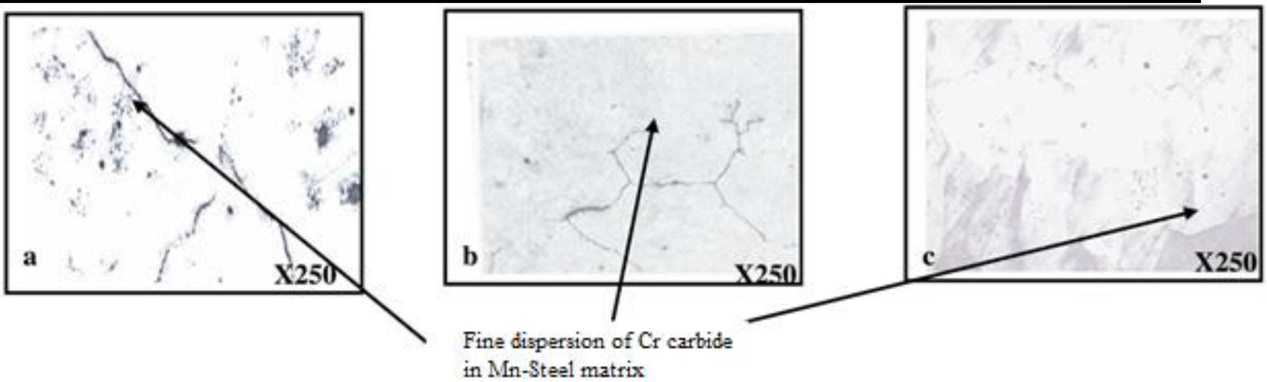

Fig. 3. Microstructures of the edge (a), middle (b) and mounting (c) parts of sample 3 grinder detail

As shown in Figure 4 below, the silicon element remains uniformly distributed in the austenite matrix regardless of casting temperature, meaning that there is little or no silicon segregation in the structure. However, as the casting temperature is higher than 1450 °C, there is a sharp increase in chromium separation. Manganese steel contains more chromium, 2.4% (see Table 2), which leads to the formation of a large amount of coarse carbide, the distribution of which is not uniform at the grain boundaries and separated at the grain boundary. Due to the wide differential cooling of the casting in the mold, which is a direct function of casting temperature. (See Figure 4). The most important factor is the highest melting temperature, because high melting temperatures guarantee segregation, once formed, cannot be reversed by changing the casting temperature [23-25].

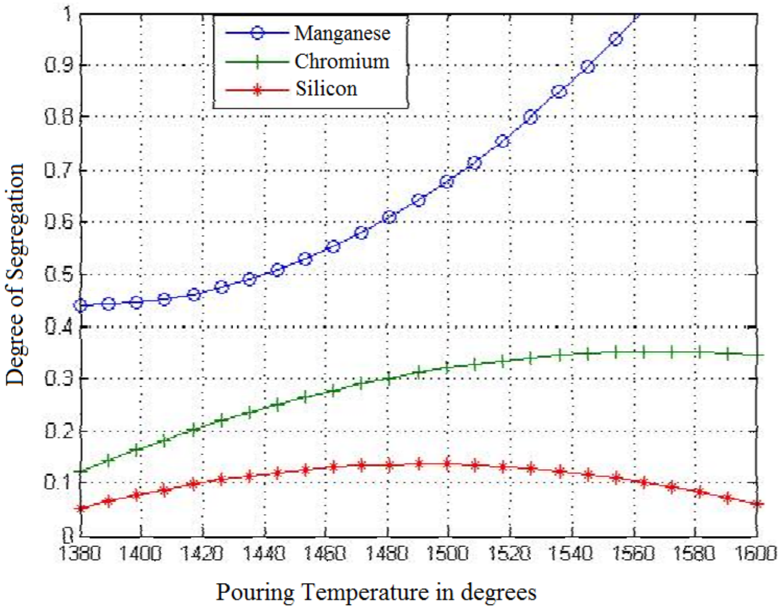

Fig 4. Degree of Segregation versus Pouring Temperature

Many domestic foundries have a practice of melting and pouring the liquid metal at very high temperatures (≥ 1500 °C) to increase the fluidity of the liquid metal and facilitate the removal of slag, especially in induction furnace melting, but this practice has been found to be ineffective because above 1500 °C during high temperature melting, the reaction between the manganese and the refractory lining ensures the formation of excess slag. This process accelerates the erosion of the furnace lining and increases overheating. This eventually leads to erosion of the inner layer of the furnace. This practice, used in a local foundry, shortens the life of the furnace. As a result, repairing or completely replacing the inner layer of the oven takes a lot of time, and as a result, it is more expensive from the economic side.

CONCLUSION

The results of the analysis showed that casting temperatures higher than 1450 ^{o}C should be avoided because it promotes segregation at the micro and macro levels. In particular, the presence of segregation in high-manganese steel causes rapid corrosion due to the unevenness of the microstructure. Segregation around grain boundaries acts as a barrier and prevents dislocation movement around grain boundaries where Cr-C segregation is very pronounced.

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