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The Features of Using Recycled Material Scrap in Manufacture of High-Strength Cast-Iron Castings

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Abstract

The quantitative analysis of distribution of MgS inclusions on sulphur prints of 2200 kg roll revealed a minimum quantity of inclusions in the surface layer of casting up to a depth of 6-7 mm, high concentration in the hot top and at a depth of ~25 mm. The pouring gate system corresponds to data of smelting chemical analysis, and casting scrap contains less amount of sulphur. These features of MgS distribution in recycled material scrap are necessary to be considered when burdening and smelting high-strength cast-iron.

Keywords: *casting, high-strength cast-iron, recycled material scrap, "black spots"*

Statement of the problem and analysis of scientific literature

At present, in Ukraine the main output of high-strength cast-iron casting production falls at such roll-casting works as JSC "Dnepropetrovsk Forming Rolls Works" and JSC "Lutugino State Research & Production Roll Company". Their annual output is 21 thousand tons. Owing to expansion of rolling production in Ukraine, restoration in export abilities of the plants, the prospects of application of castings with globular graphite will increase significantly. However, it is necessary to stress that there is such a type of defect in roll manufacture as "black spots" – the clusters of nonmetallic inclusions MgS [1.] As a rule, the "black spots" are detected after machining or when roll remachining for a smaller diameter in the rolling mill. Since mass of the rolls is substantial, a manufacturer bears significant expenses.

Such existing methods of "black spots" removal as addition of calcinated soda (Na_2CO_3) or cryolite (Na_3AlF_6) into inoculated cast-iron at the temperature not lower than 1390 °C, neutral gases or air blowing of cast iron, "overpoling" or any other methods only reduce, but do not eliminate completely the possibility of this defect formation in the castings [2]. Furthermore, each method discussed has the negative drawbacks, which can lead to unsatisfactory results in relation to graphite shape and mechanical properties of the cast iron [3].

The purpose of research is to work out the recommendations on decrease of such defect formation as "black spots" in the castings made of high-strength cast-iron.

The results of investigation

According to the known theories of globular graphite formation in the process of inoculation of cast iron by magnesium, the cast iron, first of all, interacts with sulfur, which results in formation of magnesium sulfide inclusions. Some of these inclusions are removed with the slag. The other inclusions get into the casting pattern during melt pouring. The elevated concentration of MgS leads to formation of "black spots" that determines tear and decrease in service durability of the rolls.

The features of distribution of magnesium sulfides were studied on sulfur prints [4] and using macrostructure of 2200 kg roll made of high-strength cast-iron. Earlier, MgS inclusions were analyzed only visually and there was no quantitative estimation of their distribution along the radius and height of the rolls. In present work, the quantity of MgS was determined by sulfur prints applying Image Expert Pro 2 program that is a graphic analyzer of new generation and is intended for analysis of both 2-dimensional and 3-dimensional images. This made it possible to study the features of distribution of MgS inclusions and to work out the recommendations on decrease of such defect as “black spots”.

The 2200 kg roll was cast from high-strength cast-iron at JSC “Dnepropetrovsk Forming Rolls Works”. The metal was melted in 25-ton furnace with acid lining. Inoculation was carried out by metallic magnesium at the temperature of metal 1370 °C using a "bell", which was immersed into a ladle bottom. After the slag has been removed, die casting was carried out at ~1320 °C. The chemical composition of the cast-iron was as follows, wt. %: C 3.10; Si 1.41; Mn 0.58; P 0.214; S 0.010; Cr 0.34; Ni 0.91; Mg 0.03. The hot top was warmed by charcoal and filled with the cast-iron twice, wt. %: C 3.04; Si 1.90; Mn 0.63; P 0.23; S 0.019; Cr 0.43; Ni 1.76. The melt was poured through the bottom gate with a tangential admission of metal into the bottom neck. The roll barrel was formed in the metal mould with 450 mm in diameter and wall thickness of 180 mm. The bottom roll neck ∅320 mm, the top roll neck and top hot ∅330 mm were made of sand-clay mixture. 8 disks and 3 lengthwise templates were cut from the casting of 2.9 m high. The sulfur prints were taken by method [2].

Calculation of the volume occupied by MgS inclusions in the hot top, top neck, barrel and bottom neck (V_{inc}, %) was carried out with the use of results of quantitative estimation of magnesium sulfides distribution on sulphur prints according to the following formula:

$$V_{inc} = (S_{c1} \cdot P_1 + S_{c2} \cdot P_2 + \ldots + S_{cn} \cdot P_n)/S_d,$$

where S_{c1}, S_{c2}, … S_{cn} – the area of round specimen under investigation across the cross-section of sulphur print from the disk or roll template, cm^2; P_1, P_2, … P_n – MgS inclusion per cent in calculated round specimens 1, 2 …n, %; S_d – the area of the disk or roll template, cm^2.

The calculations have shown that MgS inclusions in the casting bulk are distributed nonuniformly, and their quantity increases throughout the height of the roll (Figure 1):

- in the bottom roll neck – 0.02 %;
- in the barrel – 0.7 %,
- in the top roll neck – 1.7 %;
- in the hot top – 48 %.

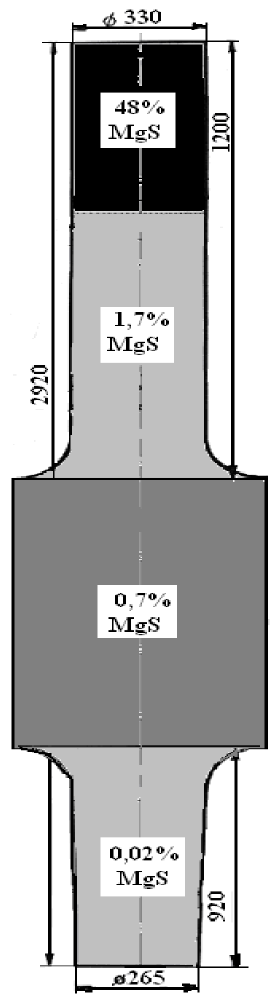

Figure 1. Pattern of distribution of MgS inclusions in the volume of lower neck, upper neck and hot top of 2200 kg roll made of high-strength cast-iron

Thus, the most part of MgS inclusions emerge in the hot top from the bottom roll neck, barrel and top roll neck. MgS inclusions in least amount are located in the bottom roll neck as, except for floating of nonmetallic inclusions, there are turbulent mixing of the melt during pouring and its slow solidification. The latter is determined by the fact that in the bottom gate with a tangential admission of a choke the overall mass of cast-iron passes through the pattern of the bottom roll neck and heats it. The area of insclusions is minimal and is 0.12-0.13 mm^2 in the roll barrel ∅450 mm in a surface layer up to 6-7 mm deep. The inclusions are coarsened owing to coagulation and form the “black spots” at a depth of ~25 mm.

The tendency related to change in the

average area of MgS inclusions through-the-thickness is identical both in the barrel and top roll neck. Having reached the maximum at a depth of ~25 mm, there is observed their sharp decrease and increase of the average area of inclusions in the casting center: in the top roll neck up to ~0.11mm^2, in the barrel 0.33-0.23 mm^2. Besides, on approaching near the hot top, there is easily observed the increase in quantity and size of inclusions on sulphur prints obtained from disks and template from the top roll neck.

The major cluster of MgS inclusions is in the roll hot top, which is ∅330 mm and 500 mm high (Figure 2). Light V-shaped zones with low content of sulphur are formed as a result of double hot- topping to control the shrinkage. The depth of its penetration through a sulphur print is 400-410 mm at the hot top height of 500 mm, which specifies the low efficiency of shrinkage control method applied. The large clusters of inclusions on the interface with the metal being hot topped did not float in the upper part of the hot top since MgS was in the solidified biphasic solid-liquid area of the metal.

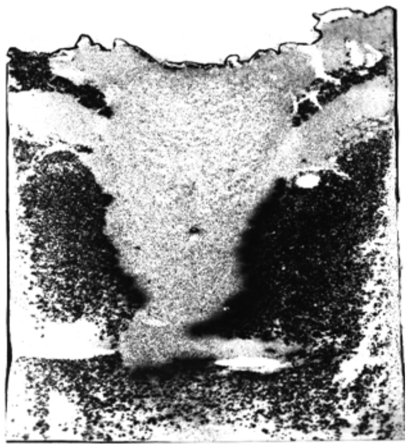

Figure 2. Sulphur print of lengthwise hot top template ∅ 330 and 500 mm high with traces of double hot topping for shrinkage control

There is a concentrated shrinkage cavity, which is not precisely observed on the sulphur print, in the top part of the hot top template in the zone of metal being hot topped (with smaller content of sulphur). In the bottom part of the hot top template, the structure of metal is dense and has no visible shrinkage defects. However, there are a cavity and shrinkage porosity, which finishes in the distance of ~340 mm from the top end of the roll barrel.

According to operating technological process, sampling for chemical analysis is made from the ladle before cast-iron pouring. The results of this average chemical analysis are indicated in the roll certificate, and also they are used when burdening production wastes and salvage of the rolls received after operation on the rolling mills. According to the sulphur prints presented, it is possible to conclude that when machining the roll, the chip contains a minimum quantity of MgS inclusions. The roll scrap contains more sulphur but its quantity is also lower than it is specified in the certificate. In the hot top, the content of MgS inclusions is several times more and only the chemical composition of the bottom gate meets the certificate.

These features of sulfur distribution should be considered when melting the castings of high-strength cast-iron. If to burden the hot tops, then transfer of MgS inclusions in new castings is possible. It is necessary to correct these melts due to change of slag modes, quantity of inoculant or addition alloys.

Conclusions

1. The features of magnesium sulfides distribution along the radius and height of 2.2 ton roll made of high-strength cast-iron are established.

2. In the hot top, the quantity of MgS inclusions is several times more as compared to data of chemical analysis of metal. When burdening the melts on the basis of hot tops, the transfer of MgS inclusions in new casting is possible. Only the subsequent change of thermal and time modes of melting and innoculation will ensure obtaining of spherical graphite.

3. The surface layer of casting up to a depth of 6-7 mm contains a minimum quantity of MgS. Therefore, the chip obtained after machining of the castings made of high-strength cast-iron is reasonable to apply in the induction furnaces for charge-adjustment.

4. The scrap of castings with globular graphite contains less sulphur as compared to data of the average chemical analysis and only the chemical composition of pouring gate system corresponds the certificate. The results of non-uniform distribution of sulfur in recycled material scrap should be considered in making castings of high-strength cast-iron.

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Особенности использования лома возврата при производстве отливок из высокопрочного чугуна

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Количественный анализ распределения включений MgS по серным отпечаткам валка массой 2200 кг выявил минимальное количество включений в поверхностном слое отливки до глубины 6-7 мм, повышенное содержание в прибыли и на глубине ~25 мм. Соответствует данным химического анализа плавки литниковая система, а лом отливок содержит меньше серы. Эти особенности распределения MgS в ломе возврата необходимо учитывать при шихтовке и плавке высокопрочного чугуна.