The study of casting defects in steel 35HGSL

M L Skryabin and V A Likhanov
Vyatka State Agricultural Academy, Kirov, Russia

E-mail: max.dvs@mail.ru

Abstract. In this research work the classification of defects of castings obtained by electric arc smelting is considered. Of particular interest to researchers is the rock-like and naphthalene fractures. A stone-like fracture is characterized by a clearly defined uniform surface over which the fracture occurs. Grain boundaries are partially soluble in the austenite phase, consisting of fine individual particles or films formed from molten eutectics. It is also worth noting that most often the stone-like fracture is observed at the grain boundaries.

1. Defects in metal smelting
To improve the quality of parts produced by modern industry, one of the main operations is the timely detection of individual defects that can lead to irreversible consequences during operation.

Manufacturing defect of metal materials is a deviation from the quality of the composition or technical parameters provided. These include deviations from the chemical and phase composition, the state of the surface layer, etc.

In General, absolutely any metal material or alloy present certain defects, but some of them are minor, which practically does not affect the quality of the finished product. It is for the regulation of defects that there are standards that determine the presence of certain deviations.

According to the current regulations, defects are called individual product non-compliance with the established requirements. Defects obtained during casting can be divided into five groups [1]:

- inconsistency in a geometric form;
- surface layer defects;
- discontinuities formed in the casting body;
- the discrepancy between the structure of the metal;
- presence of non-metallic inclusions.

In addition to casting defects, cast parts may also have defects in fractures [2]:

- intergranular layer (chips, layered fractures);
- obesplozhenny and the carbonized layer;
- lithoidal and naphtalansky fracture.

Of particular interest is the stone-like fracture, as there is still no clear mechanism explaining its origin [3].
A stone-like fracture is characterized by a clearly defined uniform surface over which the fracture occurs. Usually the destruction takes place on grain boundary objects, which are formed at sufficiently high temperatures. At the grain boundaries, the austenite-soluble phases are present, consisting of small particles or individual films formed from fused eutectics. Lithoidal fracture is formed by high-temperature heating, typically at a temperature of about 1200...1250°C [4].

On the surface of the stone-like fracture there is always a matte light gray shade, with a characteristic metallic luster. Separate, distinct stone-like grains can be identified during heat treatment.

Lithoidal fracture formed in the cast steel can be divided into two groups: primary and secondary [5].

The primary stone-like fracture is observed in the process of overheating. It is formed due to the appearance of a special granulation structure $\sigma$-Fe, which is formed during crystallization at a low cooling rate at sufficiently high temperatures. At the same time, carbon carbides, alloying elements, sulfides and nitrides, which are limited soluble in the $\gamma$-phase, begin to stand out at the grain boundaries.

Secondary stone-like fracture is formed in the process of high-temperature machining after overheating of the metal, such as free or machine forging, hot forging, rolling, etc.

Consider the mechanism by which a secondary stone-like fracture is formed: when heated to a temperature of 1280...1360°C, individual grains of austenite begin to grow and take the form of a polyhedron. Then carbides of alloying elements, cementite, sulfides and nitrides begin to dissolve in these grains.

2. Ways to solve the problem

Harmful impurities, such as nitrogen and sulfur, at the near-phase and interphase boundary form particularly thin films of sulfides that can persist after cooling. It is also worth noting that in most cases, the stone-like fracture is observed along the grain boundaries with thin sulfide films. These factors affect the reduction of toughness and reduce individual mechanical characteristics.

Stone-like fracture is observed in parts obtained by electric arc smelting, as well as in parts after electric arc smelting with further electroslag remelting.

There are stable and unstable stony fracture. A stable stone-like fracture is divided into a fracture of the first and second kind.

Considering the stone-like fracture of the first kind, it should be noted that it can be corrected at lower temperatures of phase transformations. But with heat treatment it is almost impossible. Stone-like fracture of the second kind can be corrected by homogenizing annealing or by high-temperature normalization. But all these operations are quite energy-intensive and time-consuming, which affects the cost of the final product.

Studies have suggested that some mechanisms of formation of a stone-like fracture is influenced by the presence of rare earth metals introduced in the smelting of steel. They are introduced as a deoxidizer in the melting of structural alloy steel 35HGSL. This steel is most often used in aircraft components, engines and other highly loaded units with increased reliability [6].

To confirm the effect of rare earth elements on the stone-like fracture, it was decided to add silicocalcium SC30 to the part of the melting.

Silicocalcium is an active complex deoxidizer, which is a degasser of cast steels and cast iron, as well as an effective desulfurizer. The process consists in the reduction of calcium oxide lime silicon ferrosilicon. The chemical composition of silicocalcium SC30 by mass fraction of the components is as follows: Ca-30%, Si-50%, Al-2%, C-0.5%, P-0.02%.

In this study, we examined 36 heats: heats 26, where a reducing agent was aluminium Al99, added at 160 g in each melting, and 10 trunks, which used the silico-calcium SK30 added to each melt also at 160 g. [7].

When using the deoxidizer Al99, the stone-like fracture is not detected in the following melting of metal samples: 19, 22, 23, 24, 40, 41, 47, 49, 51, 52, 53. In the melting of metal samples 20, 21, 34,
35, 36, 37, 38, 39, 42, 43, 44, 45, 46, 48, 50 when using this deoxidizer, a stone-like fracture is detected. When using deoxidizer SC 30 in melting of metal samples 25, 26, 27, 28, 29, 30, 31, 32, 33, 54 no stone-like fracture was found.

To study the effect of microalloying on the presence of lithoidal fracture were selected 5 heats: 27, 33, 34, 35, 44, as with solid break, and without it. Figure 1 and figure 2 show the fractures of the samples of these heats.

![Figure 1. Kink bottoms No. 27 (a) and 33 (b) steel 35HGSL (reducing agent SK30).](image1)

![Figure 2. Kink bottoms No. 34 (a) and 35 (b) steel 35HGSL (reducing agent Al99).](image2)

The elemental chemical composition of steels of various 35hgsl steel melts was determined using the energy dispersive x-ray fluorescence spectrometer EDX-720P/800P and no deviations in the chemical composition of the samples were detected.

Microstructures after final heat treatment (figure 3) practically did not differ between satisfactory and rejected samples, but needle sorbitol was observed on smelters No. 27 and No. 33 (figure 4).
Figure 3. Microstructure of steel 35HGSL (a - melting No. 25), (b - melting No. 26) after final heat treatment.

Considering as a modifier of silicocalcium SC30 with a high content of calcium and silicon, we can note the complete absence of a stone-like fracture in the melting with its addition. SC30 refers to ferroalloys, although it contains iron only as an impurity, which is not more than 5% of the total weight. The main application is as a deoxidizer.

Figure 4. Microstructure of steel 35HGSL (a - melting No. 27), (b - melting No. 33) after final heat treatment with distinct grains of sorbate.

In General, silicocalcium SC30 increases the hardness of steel and its resistance to corrosion. Ferroalloy contains with its composition up to 30% calcium, but up to 10...15% calcium can be presented in the form of complex and simple oxides, which leads to unstable assimilation of the element [8]. It is also established that silicocalcium SC30 helps to prevent the appearance of a stone-like fracture in the electric arc smelting of cast steels.

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