Study of the nature of destruction of castings made of 35HGSL steel after a long service life

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Abstract. Today, castings of their alloy steels are an integral part of modern foundry production. In the process of obtaining castings, any defects inevitably appear. This paper deals with the issues of stone-like destruction of castings made of 35HGSL steel after a long service life. The paper compares the macro- and microstructures of the rock-like fracture and based on the analysis revealed that its causes are large grain and the presence of impurities in steel in the form of sulfides or nitrides, which are located on the grain boundaries and weaken them. The influence of ferrite layers around bainite grains on the presence of the studied defect was also revealed.

1. Introduction
One of the most important methods of studying metals and alloys is the analysis of the structure of fractures. Studies of metal fractures are used to study and determine the causes of destruction of structures and machine parts. The study of sample fractures makes it possible to determine the reasons for the deviation of mechanical properties of steel from the regulated values.

Knowledge of the nature of sample fractures during tensile tests, impact strength at different temperatures, in different structural States specified by different heat treatments, can be used to determine the cause of failure of a part made of a given alloy in a known state.

The viscous fracture is caused by the presence of macroplastic deformation. The destruction of the part material during a viscous fracture is the result of a sharp increase in the applied static load. A viscous fracture occurs as a result of exceeding the yield strength of the part material. There are traces of plastic deformation on the surface of the viscous fracture [1-3].

A brittle fracture is characterized by a complete absence or very small amount of plastic deformations. The reasons are the presence of stress concentrators in the dangerous section and the instantaneous application of the load. With a brittle fracture in the fracture zone, the crystal structure of the material is well observed with the naked eye, especially at the location of the stress concentrator.

2. Reasons for the appearance of a rock-like fracture
The appearance of a brittle rock-like fracture is associated with the internal adsorption of individual elements in the surface layers of austenite grains. Some impurities that can lower the surface energy of austenite grains accumulate at the surface of these grains to the limit of solubility.

As the temperature increases, the solubility of impurities increases, at the temperature of overheating, their concentration in the surface layers of austenite grains significantly exceeds their solubility at low temperatures. With sufficiently rapid cooling, the impurities do not have time to move into the depth of
the grains, so that the surface layers of austenitic grains are supersaturated with these impurities, which leads to their separation from the solution in the form of fine crystals of intermetallic substance [4-6].

Thus, a thin layer of increased brittleness is formed along the borders of the original austenitic grains. This layer is very stable and does not break down when heated for normal heat treatment operations, although the structure may change inside these fragile shells. Only when heated to high temperatures close to superheat temperatures, these fragile shells can resolve and the stone-like fracture is eliminated [7, 8].

There are two types of rock-like fracture: a stable rock-like fracture of the first type, associated with the release of impurities along the boundaries of austenite grains during overheating, and a rock-like fracture of the second type, associated with the texture of overheating inside the grain and the release of impurities during tempering in the range of development of release fragility [9-11].

3. Methods of rock-like fracture research

To study the fracture after a long service life, a sample was selected from a cast coupling made of 35HGSL steel. The sample fracture is shown in figure 1.

![Figure 1. 35HGSL steel sample break.](image)

The resulting intercrystalline fracture of steel indicates the weakening of grain boundaries as a result of improper heat treatment and unacceptable liquation of elements such as phosphorus and sulfur [12-15].

After quenching and low tempering, the heating temperature for quenching is estimated by the grain size of the crystal fracture. The stone-like fracture is caused by the formation of films of iron and manganese sulfides (with a predominance of iron sulfides) and aluminum nitrides at the borders of large austenite grains, which remain after cooling and subsequent heat treatment. The fracture has a matte hue.

The primary rock-like fracture is observed immediately after overheating and cooling. If during the crystallization of metal along the boundaries of crystallites, non-metallic inclusions were deposited, then intercrystalline layers (chips) will be visible in the fracture. Chips have the appearance of light areas of various shapes and sizes, their surface has a crystalline fine-grained structure. This same defect can have the form of a layered fracture, in which there is an alternation of bands with a fine-grained and ordinary metal structure [16]. The microstructure of the test sample is shown in figure 2.
Macroanalysis of the steel fracture allows us to determine the depth of the hardened layer with sufficient accuracy for practical purposes. The hardened layer is Matt and has a finer crystal structure, which significantly differs from the type of core fracture [17]. It also differs from the core metal in color. When evaluating the types of fracture, it is necessary to take into account the conditions of destruction of samples, since the type of fracture depends on the test temperature and the load conditions [18-20].

When casting into a metal mold, a continuous transcrystallization zone can be formed with small casting sizes. At the same time, due to the weak strength bond between dendrites, transcrystallization leads to high brittleness of cast steel. The crater structure is a sign of a rock-like fracture. A crater on the destruction surface (figure 3) is formed by merging micropores [21-23].
Often at the base of the crater is the inclusion that led to its formation. The size of the craters depends on the size and number of particles that initiate destruction in a given sample. With a large number of foci, the growth of pores is limited due to their intersection and the length of the pits is small.

The shape of the crater is determined by the stress state and direction of the destructive forces. Under conditions of volumetric stretching, equiaxed craters appear, and elongated parabolic craters are formed due to the action of tangential stresses.

4. Conclusion
Comparison of macro - and microstructure with breaks suggests that one of the reasons lithoidal fracture is a major grain. Another reason for the appearance of a rock-like fault is the presence of impurities in the steel in the form of sulfides or nitrides, which are located at the grain boundaries and weaken them.

The nature of the destruction is influenced by the ferritic layers around the bainite grains, which participate in the destruction, forming a pattern in the form of a stream.

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