Features of microscopic and macroscopic analysis of 35HGSL steel

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Abstract. Foundry steels are widely used in modern engineering today. But it is foundry steels that have the greatest number of defects, which can be detected by macro-and microanalysis. In addition, with the help of these studies, you can get an idea about the General structure of the metal and the presence of certain specific defects in it – stone-like and naphthalene fractures. Using microanalysis methods, it is also possible to evaluate the properties of multiphase alloys and cast iron, for which there are special scales that classify graphite and phosphide eutectic by shape and quantity. The article describes the features of conducting these studies using optical microscopy.

1. Introduction

35HGSL steel is widely used in modern engineering production due to its high mechanical properties and relatively low cost. In foundry production, there are defects that can only be detected by macro-and microanalysis.

Macroanalysis of steel 35HGSL consists in determining the structure of the metal by viewing its fracture or specially prepared surface with the naked eye or through a magnifying glass at small magnifications of up to 30 times. This allows you to simultaneously observe a large surface and get an idea of the General structure of the metal and the presence of certain defects in it.

In contrast to macroanalysis, the microstructure of cast metals and alloys (in shaped castings) is checked in various casting sections - from the largest to the smallest, since such sections are usually cooled at different speeds, and the structure of many cast alloys, such as cast iron or bronze, depends on the cooling rate. In addition, in these cases, it is important to determine the direction in which to make the microchip. Often, the plane on which the microstructure is studied is chosen perpendicular to the heat removal surface, so that it is possible to determine the structure in the peripheral and middle layers of the metal.

Features of macro-and microanalysis should be taken into account in modern engineering to control possible defects formed during complex technological processes for obtaining castings.

2. Features of macro-and microanalysis of steel 35HGSL

Unlike microscopic examination, macroscopic analysis does not determine the details of the structure and is often a preliminary, but not the final type of study. Describing many features of the structure, macroanalysis allows you to select those areas that require further microscopic examination. Using macro analysis, you can determine [1, 2]:

• violation of metal continuity: shrinkage looseness, gas bubbles and sinks, voids formed in cast metal, cracks that occurred during hot mechanical or heat treatment, floccenes, welding defects (in the form of non-steam, gas bubbles, voids);
• dendritic structure and transcrystallization zone in cast metal;
• chemical heterogeneity of the alloy (liquation);
• heterogeneity of the alloy structure caused by pressure treatment: banding, as well as sliding lines (shifts) in the riveted metal;
• heterogeneity created by thermal or chemical heat treatment.

The surface is subject to macro analysis, studying directly (by type of fracture), or polished and etched with a specially prepared reagents. On the ground surface should not be dirt, traces of oil, etc., so it should be wiped with cotton wool soaked in alcohol before etching. The prepared sample is called a macrochip.

The correct choice of the most characteristic section or fracture for the studied part is of great importance for the successful implementation of macroanalysis. Methods of macroanalysis differ depending on the composition of the alloy and the tasks set in the study.

To detect defects that violate the continuity of the metal, the structure of cast steel, rolled steel fibers, reagents are used for both deep and surface etching. After etching, the macroshliff acquires a relief surface with clearly visible dendrite axes (cast steel), a liquation zone and cracks. For these purposes, often used transverse macrosections.

For surface etching, Gein reagent is most often used, containing (per 1000 ml of water) 53 grams of ammonium chloride NH₄Cl and 85 grams of copper chloride CuCl₂.

When the macrochief is immersed in the reagent (for 30...60 s), an exchange reaction occurs: iron displaces copper from the aqueous solution, and it settles on the surface of the slot; in areas that are not sufficiently protected by copper (pores, cracks, non-metallic inclusions), etching occurs. Then microslip removed, a layer of deposited copper is removed with a cotton wool under running water and wipe dry microslip to protect it from rapid oxidation in air.

Microslip removed, a layer of deposited copper is removed with a cotton wool under running water and wipe dry microslip to protect it from rapid oxidation in air. This reagent more clearly reveals the character of liquation and microstrips on deformed steel, but less sharply reveals the structure of cast metal and cracks, especially caused by flockens. For the latter purposes, the above-mentioned deep etching reagents are more suitable [3, 4].

When determining chemical heterogeneity using macroanalysis, in contrast to chemical analysis, it is impossible to determine the quantitative content of impurities, but it is possible to establish the heterogeneity of their distribution in the metal. For this purpose, the macroscape should be cut from rolled or forged steel in the longitudinal direction. The distribution of sulfur is determined by the Bauman method.

The method for determining the liquor of phosphorus and carbon is based on different etching of sites with different content of these elements. Areas enriched with carbon and phosphorus, are painted in a darker color. The best results are achieved for steel containing less than 0.6% C. In steel with a higher carbon content, the copper precipitate released during etching is poorly washed off the surface of the strip.

The direction of the fibers created by the pressure treatment is also clearly visible on the macroscope, since the metal fibers and especially their border sections, which differ in structure and content of impurities, have different etchability.

When determining the thickness of the hardened layer, the sample is broken. The layer that has been quenched differs in the type of fracture (finer-grained, and when quenched without overheating - porcelain-like fracture). More precisely, the thickness of the hardened layer is determined after grinding the sample along the fracture (perpendicular to the axis) and etching for 3 minutes in 50 % hydrochloric acid solution at 80°C. The hardened layer gets a darker color.
Microscopic analysis of metals consists of examining their structure using an optical microscope (using conventional white or ultraviolet radiation) and an electron microscope. When using an optical microscope, the metal structure can be studied at a total magnification of several tens to 2000...3000 times. Microanalysis allows us to characterize the size and location of various phases present in alloys, if the particle size of these phases is not less than 0.2 microns. Many phases in metal alloys have dimensions of $10^{-4}...10^{-2}$ mm and therefore can be distinguished in a microscope.

When microanalysis of single-phase alloys (usually solid solutions) and pure metals, it is possible to determine the grain size and note the existence of a dendritic structure. Grain sizes are determined either by quantitative metallography methods or by comparing the structure with pre-determined scales.

3. Ways to solve the problem

For a more complete study of the structure of the microshliff, it is necessary to etch various reagents. Grains of alloys and metals that fall into the plane of the slot have a different ability to etch, depending on the crystallographic orientation. The electrochemical potential of various phases, the stress state of the grain boundaries, and the presence of impurities along the grain boundaries are also important. Therefore, the etched surface turns out to be uneven and the rays reflected from it go in different directions (figure 1), revealing the structure well.

![Figure 1. The reflection of rays at the optical investigation of microsection.](image)

The dendritic structure is associated with a certain chemical heterogeneity, which is detected when etching the sample to be microanalyzed. If single-phase alloys consist of grains that are completely homogeneous in composition, this indicates that an equilibrium state has been reached.

In multiphase alloys via trace analysis is possible to determine not only the quantity, shape and size of the inclusions of individual phases, but also their relative distribution.

Different phases can form stable forms of mutual distribution that are characteristic not for a single alloy, but for entire groups of alloys that have common types of transformations described by the state diagram (for example, eutectic and eutectoid transformations).

The amount of eutectic or eutectoid structure, as well as the structure and distribution of these structures have a great influence on the properties of alloys. In particular, the properties of steel depend very much on the amount of eutectoid (perlite) and its structure [7, 8]. The form of perlite depending on the nature of heat treatment can be different - from coarse to fine-grained. The microstructure of 35HGSL steel is shown in figure 2.
Other combinations of phases may depend on the conditions of thermal and hot machining; the phases may be in the form of individual inclusions of rounded, plate or needle shape, as well as in the form of rows and a grid. For example, it is well known that the uniform distribution of carbides in the structure of a non-eutectoid steel provides high mechanical properties of the tool, while the presence of a mesh distribution of cementite along the grain boundaries (cementite mesh) causes brittleness [9].

4. Conclusion
Using microanalysis methods, it is also possible to evaluate the properties of a number of multiphase alloys and, in particular, cast iron, for which there are special scales that classify graphite and phosphide eutectic by shape and quantity.

By the area occupied by each phase or structural component in the field of view of the microscope, it is possible in some cases to determine the number of phases present, if their density is known. In addition, if the composition of each phase is known, the composition of the studied alloy can be approximately determined. Such calculations will only be accurate enough if the present phases are not too dispersed and are in a significant amount.

Using microanalysis, it is possible to determine the structure of the alloy not only in equilibrium, but also in a non-equilibrium state, which in some cases allows you to establish the previous processing of the alloy.

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