

THE ESSENCE OF THE RESEARCH OF THE MICROSTRUCTURE OF CAST IRONS ON THE INVENTOR METALLOGRAPHIC MICROSCOPE OXION INVERSION OX.2653 PLMI

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Abstract

This article investigates the microstructure of cast irons using a metallographic microscope. Various types including white, gray, malleable, and modified cast irons were analyzed. The analysis revealed differences in graphite shape and the structure of the metal matrix. In gray iron, graphite appears in flake form; in malleable iron — as nodular particles. These results are significant for enhancing mechanical properties and selecting suitable applications for cast iron materials.

Keywords

cast iron, microstructure, graphite, gray iron, malleable iron, modification, cementite, pearlite, ledeburite, microsample, mechanical properties, metal matrix, microscope, heat treatment, carbon.

Introduction

Cast iron is an iron-carbon alloy, and its microstructure directly affects its mechanical properties, processing capabilities, and applications. In this study, types of cast iron (white, gray, malleable, and modified cast irons) were studied at the microstructural level. Iron-carbon alloys containing from 2,14% to 6,67% carbon are called cast iron. Cast irons have a ternary Fe-C-Si system and have relatively low melting points (approximately 1200-1350°C). The high silicon content, as well as the slow cooling rate during the crystallization process, contribute to the release of carbon in a free form - graphite. This process is called graphitization. The structure of cast iron and its main properties depend on the chemical composition, production process, and heat treatment regime.

Depending on the state of carbon in the casting, cast irons are divided into two groups:

- 1) Cast irons in which all carbon is bound in the form of cementite or other carbides.
- 2) Cast irons in which all or part of the carbon is in a free state in the form of graphite.

The first group includes white cast irons. The second group includes gray, high-strength and malleable cast irons.

White cast iron. The alloy received this name because of its bright white color when fractured. In white cast irons, all carbon is in the form of cementite (free or in the form of ledeburite), therefore they are characterized by high hardness and brittleness, and it is almost impossible to process them with cutting tools. White cast iron is not used for the production of machine parts and mechanisms, most of it is used for turning into steel, and only a part is used in the form of castings for subsequent conversion into malleable cast iron.

In practice, three groups of white cast iron are used (Fig. 1):

- 1) Cast irons with a carbon content of up to 2,5-3,5% eutectic, which are mainly used for converting into steel and malleable cast iron (therefore, they are also called malleable cast iron), as well as wear-resistant parts ($HB \approx 4000 \dots 4500$ MPa, $\delta = 0\%$) and parts (balls and bushings for mills), as well as containers and boilers.

- 2) Eutectic cast iron with a carbon content of 4,3%, intended for use in the production of steel, since eutectic cast iron is very hard ($HB = 5500$ MPa) and brittle ($\delta = 0\%$), it is practically not used for other purposes.

3) Post-eutectic cast iron with a carbon content of more than 4,3% (carbon 5-6%) used for stationary radiation protection. The mechanical properties of these cast irons ($HB \approx 6000 \dots 6500 \text{ MPa}$, $\delta = 0\%$) do not allow their use for loaded parts.

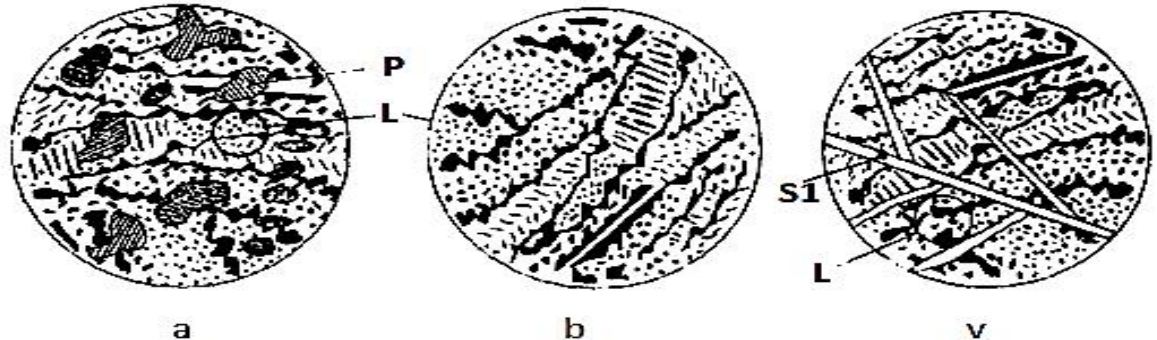


Figure 1. Structure of white cast irons

(a- pre-eutectic cast irons, b- eutectic cast iron, c- post-eutectic cast iron (P-perlite, L-ledeburite, S1 primary cementite).

Graphitized cast irons. According to the shape of the graphite inclusions in the cast iron, gray, high-strength, malleable cast iron and vermicular graphite cast irons are distinguished.

Gray cast iron is produced at a lower cooling rate than white cast iron. They contain 1-3% Si, which has a strong graphitizing effect. Gray cast irons are widely used in mechanical engineering and are well processed by cutting tools. Cylinder blocks, cylinder liners, pistons, fundamental frames, etc. are made of them. Gray cast iron has a gray color due to the fact that carbon is in a free state. In the structure of gray cast iron, graphite has a plate-like shape and exists in three types (Fig.



2).

Figure 2. Microstructures of cast gray cast irons: a - ferrite-graphite; b - ferrite-pearlite; c - pearlite

Gray cast irons are designated by the letters CЧ and then the value of the ultimate tensile strength (kgk/mm^2) is given, for example CЧ15, CЧ20, CЧ35 (State standard 1412-85). Gray cast iron is observed in the form of dark inclusions on a light background of an unaffected section. The mechanical properties of unaffected gray cast iron in the section are largely determined by the shape and dispersion of the undetermined part of the graphite. The degree or completeness of graphitization is assessed by the amount of freely separable (unbound) carbon.

Modified gray cast iron. In order to crush graphite inclusions and increase the mechanical properties of gray cast iron, it is modified by adding silicon and calcium to molten cast iron. Silicon and calcium react with oxygen dissolved in the cast iron to form small solid particles of SiO_2 and CaO , which serve as centers for the forced crystallization of graphite. Due to their abundance, the graphite becomes more finely grained, which has a positive effect on increasing the strength of the cast iron. (Fig. 3). Modified cast iron is used for casting parts of furnaces and internal combustion engines. Gray cast iron is designated by the letters CЧ (gray

cast iron) and two numbers indicating the minimum value of the tensile strength limit of the cast iron.

For example, for gray cast iron CЧ25, $\sigma_B = 245$ MPa (25 kgf/mm²). Gray cast iron grades CЧ15, CЧ18, CЧ21, CЧ24, CЧ25 are widely used in railway transport for the manufacture of moving parts. Gray cast iron is also used for the manufacture of cylinder parts of diesel locomotive engines.

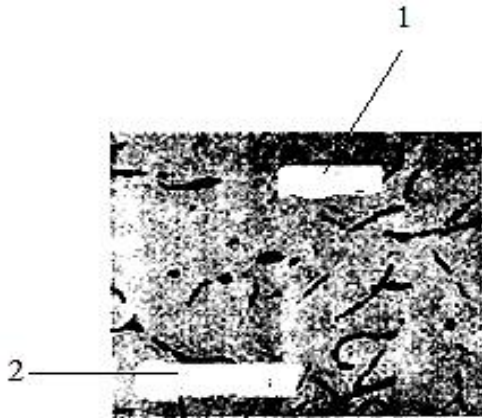
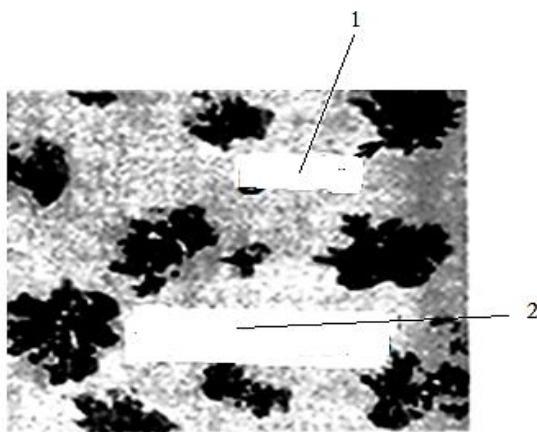


Figure 3. Modified gray cast iron structure. 1. Graphite, 2. Metal base.

Malleable cast iron. Malleable cast iron differs from gray cast iron in the appearance of graphite: in gray cast iron, graphite is in the form of thin flakes, while in malleable cast iron, the metal base is in the form of less sharp fragments (Fig. 4). Therefore, the strength of malleable cast iron is 2,5-3 times higher than that of gray cast iron, and its plasticity can reach 12%.

Cheap malleable cast iron is used as a substitute for steel in railway transport: it is used to manufacture couplings, air brake line couplings, and parts operating under high dynamic and static loads from malleable cast iron of grades KЧ37-12, KЧ35-



10.

Figure 4. Unaffected malleable iron with graphite flakes.

1. Graphite, 2. Metal base.

Cast iron of grades KЧ50-5, KЧ55-4 is used to manufacture parts with high strength, medium ductility and good anti-friction properties. Malleable cast iron is designated as follows: KЧ means malleable cast iron, followed by a number indicating the tensile strength in kgf/mm² and a number indicating the relative elongation in %. For example: KЧ 30-6, KЧ 37-12.

High-strength cast iron. The letter BЧ is denoted by numbers. For example: BЧ 38-17 - the first two-digit number indicates the temporary resistance to elongation, the next number indicates the relative elongation in %. They are obtained by adding alloying elements to the composition of gray cast iron. To increase their mechanical properties, they are heat treated. Parts operating under extreme loads are made from these cast irons. In many cases, they can be used instead of steel, for example, crankshafts, press traverses, and thrust shafts.

Methods

The study used an Oxion Inversion OX.2653 PLMI inverter metallographic microscope. Micro sections of cast iron samples in an unaffected and affected state were examined. Their graphite forms and metal base structure are different, and each microstructure is schematically depicted. Adjusting the Oxion Inversion OX.2653PLMi inverter metallographic microscope to the required magnification (from 100 to 300 times), installing the appropriate lens and eyepiece. Micro sections of cast iron with various graphite and metal base structures are examined under a microscope. This is done in the following sequence:

1. Micro sections of unaffected cast iron samples are examined to determine the shape, size and distribution of graphite inclusions.
2. Then these microsections are treated with reagents and re-examined to determine the type of structure of the metal base.
3. Each examined microstructure should be schematically drawn, indicating the name of the cast iron.
4. Formulation of a work report based on the results obtained.

Results

In gray cast iron, graphite was found to be plastic, and in malleable cast iron, graphite was found to be in the form of flakes. In white cast iron, a ledeburite structure was observed on a background of pearlite and cementite. In modified cast iron, graphite was more finely and evenly distributed, and the strength of the material was increased.

Discussion

The microstructure of different types of cast iron is closely related to their mechanical properties. Ductile iron has high ductility due to the graphite form. Improving the mechanics of cast iron through modification is an important factor in production. Cast irons are iron-coal-based alloys with a carbon content of more than 2.14%. They are widely used in industry due to their various mechanical and physical properties, ease of processing and cost-effectiveness.

Studies show that:

1. Cast irons have excellent weld ability and formability, which makes them ideal materials for casting.
2. Depending on the graphite structure, cast irons are divided into types: ductile (with fine graphite), porous, spheroidal and tetragonal graphite cast irons. These types have different mechanical and technological properties.
3. Additives (e.g. silicon, manganese, phosphorus) have a strong influence on the mechanical properties of cast iron. For example, silicon enhances graphitization in cast iron.
4. Advanced research shows that it is possible to modify cast irons, strengthen them with nanoalloys, and improve their properties by coating them with protective layers.
5. The hardness, corrosion resistance, and vibration damping properties of cast irons make them important materials in mechanical engineering, the automotive industry, and construction.

General conclusion: Cast irons, due to their low cost, ease of processing, and balanced mechanical properties, continue to be of constant importance in technical fields. Scientific research is opening up opportunities for their further improvement and expansion into new areas of application.

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