IMPROVING THE CHEMICAL COMPOSITION OF HIGH-STRENGTH SPECIAL-PURPOSE STEELS WITH THE FORMATION OF A BAINITE STRUCTURE

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The work considers the improvement of the chemical composition of high-strength special-purpose steels in order to reduce the mass of products, the content of expensive alloying elements while increasing the level of mechanical properties. The main attention is paid to the alloying of steels of the Cr–Ni–Mo system using microalloying elements (V, Ti, Nb, B), which contributes to the formation of a homogeneous bainite structure after heat treatment. Four variants of experimental steels were manufactured in laboratory conditions, for which the chemical composition, microstructure and microhardness were studied. Metallographic analysis was carried out, the nature of the liquation, the morphology of bainite, the presence of retained austenite and other structural components were determined. It is shown that by changing the content of alloying elements, it is possible to controllably influence the structure and properties of steels. The results obtained can be used to develop new materials with improved performance characteristics for special-purpose products.

Key words: chemical composition, bainite, steel, chromium, nickel, microstructure

One of the important tasks in the manufacture of special-purpose products is to reduce mass while maintaining/increasing the level of operational indicators by improving the complex of mechanical properties.

In serial production, high-strength and ultra-high-strength special steels with a temporary tensile strength of 1500–2350 MPa are most often used for the manufacture of special-purpose products, with an alloying system, in the absolute majority of cases, Cr–Ni–Mo, etc. and a limitation of the upper permissible carbon content (no more than 0.30% for thicknesses up to 100 mm) [1–3].

The increase in the complex of mechanical properties is possible due to effective microalloying with elements V, Ti, Nb, Ca, Cu, Al. Alloying with carbonitride-forming elements ensures grinding and achieving a uniform grain size of austenite due to inhibition of its growth during high-temperature heating, and also improves the uniformity of properties in the seam and in the heat-affected zone of welding [4].

One of the main characteristics of special purpose steels is hardness, which provides the necessary resistance. Along with high hardness, steels must have sufficiently high ductility and toughness (relative shrinkage from 25 to 40%) [4–5] to ensure energy absorption, which leads to deformation of the metal, but not to its rupture or splitting [5–7].

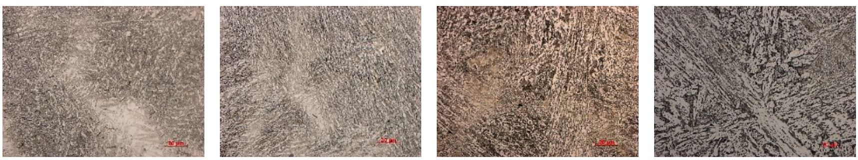
Purpose of the work: development, manufacture and analysis of the microstructure and microhardness of ingots of economically alloyed research steels for special purposes.

According to the results of analytical studies of the influence of chemical elements on the formation of the structure and mechanical properties of structural steels, in order to ensure the formation of the final structure of carbide-free bainite after appropriate heat treatment, four variants of the chemical composition of the experimental steels were manufactured in the work. Steel 1 is a prototype. The developed steels have a lower content of expensive elements and are economically alloyed, contain microalloying with vanadium.

Table 1. The actual chemical composition of the experimental melts, % mass.

Steel	Chemical element							
	C	Si	Mn	Cr	Mo	Ni	V	B
1	0,31	0,38	0,35	2,86	0,45	2,54	0,0057	0,002
2	0,32	1,68	0,74	2,26	0,45	1,92	0,15	0,001
3	0,32	0,36	0,54	0,81	0,35	2,26	0,14	0,002
4	0,25	0,28	0,65	0,98	0,31	1,84	0,13	0,002

The microstructure was evaluated using optical microscopy on a light microscope "AxioVert 200 M MAT" from "Carl Zeiss" on mechanically polished sections. The microstructure was detected using the Nital reagent. The microstructure of the test steels is shown in Fig. 1. The microhardness was determined in accordance with the requirements of DSTU ISO 6507-1:2007 on the LHVZ-1000 device with a load of 200 grams, on microsections after their metallographic studies. The indenter is a tetrahedral diamond pyramid with a square base and an angle at the apex of 136º.



a b c d

Fig. 1. Microstructure of experimental steels:
a – steel 1, b – steel 2, c – steel 3, d – steel 4.

From the results of the microstructure analysis and hardness measurement data, it was established that steel 1 is characterized by pronounced dendritic liquation. In the interdendritic areas, a structure of martensite (martensite microhardness 4481.6–5001.3 MPa) and residual austenite is formed, in the axial zones of the dendrites – products of intermediate decomposition of austenite (bainite). From the ingot surface zone to the center, the shape of bainite changes from needle-like to more spherical (3451.9–4628.7 MPa).

Experimental steel 2, like steel 1, is characterized by pronounced dendritic liquation, at the same time, in the interdendritic areas of steel of composition 1, a decrease in the amount of retained austenite is observed compared to the prototype. The structure of steel 2 consists of bainite of various morphological forms with microhardness (3599.0…4569.9 MPa) and retained austenite along the grain boundaries.

In steel 3, a decrease in the degree of dendritic liquation is observed compared to steel 1 and steel 2. The experimental steel has a predominantly bainite structure (2961.6–3599.0 MPa). In the liquation areas, a pearlite structure (1853.4–2814.5 MPa) is formed, which is located in small single areas in the grain body. Retained austenite is present along the grain boundaries.

Experimental steel 4 has a structure of bainite, acicular ferrite (3226.3–3373.4 MPa), pearlite (2343.7–2696.8 MPa) and residual austenite.

As a result of the work, four experimental steels were manufactured in laboratory conditions, which are characterized by pronounced dendritic liquation. The formation of the structure in the cast state occurs mainly by an intermediate mechanism with the formation of bainite structures.

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