DEVELOPMENT AND RESEARCH OF BAINETIC STEELS FOR RAILWAY RAILS

OLEXANDER BABACHENKO, GANNA KONONENKO,
OLEKSII MERKULOV, ROSTISLAV PODOLSKYI, ELENA SAFRONOVA

Iron and Steel Institute of Z.I. Nekrasov of NAS of Ukraine

The strength of pearlite rail steels has reached its limit. An increase in the carbon content will affect the impact strength and weldability of rail materials. Thus, there is a need for other alternative materials. The use of bainite steel, which provides both high strength and excellent plasticity, is considered one of the most promising areas. As a result, recommendations were presented regarding the chemical composition for further production of experimental ingots. From the results of the microstructure analysis, it was established that test steel No. 1 has a pearlite structure with areas of coarse-plate pearlite and austenite along the grain boundaries, test steel No. 2-4 mainly has a structure of granular bainite and residual austenite.

Keywords: 316L, CoCrMo, Ti6Al4V, chemical composition, mechanical properties

Based on the researches of recent years [1–2], it is known that the strength of pearlite rail steels has reached the limit [3]. In addition, an increase in carbon content will affect the impact toughness and weldability of rail materials [4]. For example, according to the requirements of DSTU EN 13674-1:2018 Railway transport. Track. Railway. Part 1: Railway rails weighing 46 kg/m and above (EN 13674-1:2011, IDT) the relative elongation in metal tensile tests of R200 rail made of pre-eutectoid steel shall be 6% greater than that of R400HT rail steel, made of pre-eutectoid steel. Therefore, there is an urgent need for other alternative materials. Bainite steel, which provides both high strength and excellent plasticity, is considered one of the most promising directions. As is well known, during the bainite transformation, the formation of a packet of bainite rails occurs from the austenite grain boundary, and further growth of the packet occurs deep into the grain. The bainite package consists of ferrite rails, separated mainly by low-angle boundaries [5], while acicular ferrite is heterogeneously nucleated on non-metallic inclusions inside the austenite grain and grows in different directions without forming pronounced packages, otherwise remaining similar to bainite [6].

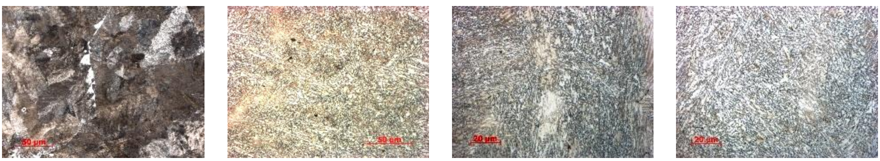
Based on the literature analysis, the steels used in world practice for the production of railway rails with a bainite structure were determined and a comparative analysis was carried out according to the content of chemical elements in steels used in various fields in Ukraine. As a result of this analysis and mathematical modeling [7], the influence of the chemical composition was determined in the ranges of carbon 0.28...0.58%, manganese 0.81...1.41%, silicon 0.89...1.57%, molybdenum 0, 1...0.5%, nickel 0.1...0.17% per structural state relative to cooling rates. It has been established that the formation of a bainite structure is possible in basic steels during isothermal aging. Based on the obtained results, recommendations were developed regarding the chemical composition for further production of experimental ingots.

In order to fulfill the task and achieve the specified limits for the chemical composition of the newly developed steel compositions, the most appropriate variant of the charge material was chosen for the possibility of bringing the content of alloying elements to the required limits. Melting was carried out by the method of remelting without forced oxidation of impurities with a fixed cooling rate. As a result of the smelting, 4 experimental ingots were obtained with the actual chemical composition of the steel presented in the Table. 1.

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

Steel	Chemical element						
	C	Si	Mn	Cr	Mo	Ni	V
1	0.47	0.59	0.90	1.01	0.15	0.03	0.07
2	0.37	1.02	1.38	0.77	0.19	0.03	0.09
3	0.37	1.42	1.56	1.17	0.21	0.04	0.23
4	0.37	1.11	1.35	0.74	0.17	0.03	0.15

According to the results of the analysis of non-metallic inclusions, it was established that the contamination of steel does not exceed the permissible level for railway rails. The different content of chemical elements led to the formation of different structural states. Photographs of microstructures in the as-cast state after etching with a 3-4% alcoholic solution of nitric acid are shown in Figure 1.



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, it was established that test steel No. 1 near the surface of the ingot has a pearlite structure with areas of coarse-plate pearlite and ferrite along the grain boundaries, at a distance of ½ radius of the ingot, the steel has a pearlite-bainite structure with ferrite along the grain boundaries (microhardness of pearlite 266...274 kg/mm^2 and bainite 363...376 kg/mm^2). The center of the ingot consists mainly of a pearlite-bainite structure with ferrite areas along the grain boundaries. Test steel No. 2 in the area of the surface, 1/2 radius and the central part of the ingot consists of a structure with microhardness (376...415 kg/mm^2), which according to literature data [7] was identified as granular bainite with areas of ferrite. Test steel No. 3 near the surface and 1/2 radius of the ingot has a structure of granular bainite with differently oriented bainite lamellae (458...495 kg/mm^2). The center of experimental ingot No. 3 has a structure of bainite (average microhardness – 495 kg/mm^2), acicular ferrite (microhardness 331…344 kg/mm^2) and residual austenite. It should be noted that from the zone of the surface of the ingot to the center, the shape of bainite changes from elongated to more spherical. Test steel No. 4 has a homogeneous structure of granular bainite (482...484 kg/mm^2) with regions of ferrite (312...318 kg/mm^2).

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