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Wydział Mechaniczny Technologiczny
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ROZPRAWA DOKTORSKA

Technologia obróbki cieplnej stali X46Cr13 zintegrowana z procesem odlewania żeliwa szarego w układzie bimetalowym

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Abstract

X46Cr13 steel heat treatment technology integrated with the casting process of gray iron in a bimetallic system

The paper presents issues related to the technology of layered castings manufactured in the system: the working part made of high-chromium steel X46Cr13 – the base part made of gray cast iron with flake graphite, basing on mould cavity preparation method. Taking into account the high hardenability of the above-mentioned steel grade, the aim of the research was to optimize the casting parameters of gray cast iron in such way that it was possible to execute heat treatment of the steel directly in the casting mold. For this reason, a series of layered castings were made, for which the variable factors of the manufacturing process were the thickness of the cast-iron base part g, the pouring temperature T_{zal} and the cooling rate of the system resulting directly from the thermal conductivity coefficient λ of the molding sand used.

As part of the preliminary tests, the material was selected for the base and working part of the layered castings, the geometry of the model castings, and guidelines for the mold technology from the point of view of the molding sand were developed. In the first stage of the main tests, model layered castings were made in accordance with the developed assumptions, and then the thermal parameters and cooling kinetics of the working parts of these castings were determined. In order to determine the quality of the connection between the base and the working part, ultrasonic defectoscopy tests were performed. Microstructure studies were also carried out, with particular emphasis on the working parts of castings in the field of phase composition forecasting using ThermoCalc and JMatPro programs, qualitative and quantitative analysis of chemical composition using a light microscope and ImageJ image analysis software, X-ray phase analysis, scanning electron microscopy with point, linear and surface EDS analysis and transmission electron microscopy. The metallographic tests were supplemented by determining the functional properties of the working parts of castings by testing the hardness and abrasion resistance on the surface of the working part, as well as microhardness on its cross-section.

On the basis of the conducted research, it was found that there is a possibility of integrating heat treatment, such as hardening of X46Cr13 steel, with the process of manufacturing a layered casting in a system with gray cast iron with flake graphite. The choice of casting parameters was aimed at a compromise between the possibility of heating the insert to the austenitizing temperature, and at the same time creating thermo-kinetic conditions conducive to cooling the system at a speed that guarantees the occurrence of martensitic transformation. It was noticed that the application of the molding sand on the SiC matrix, showing the highest heat conduction coefficient among the selected ones, did not allow the achievement of the assumed research objective. The heat from the system was

dissipated too intensively, so that the surface of the steel insert was not able to heat up to the required temperature and in the microstructure of the surface of the working part, apart from martensite, there was a significant amount of perlite as well as ferrite, so that the obtained hardness was lower than expected.

On the basis of the obtained test results, it was found that in the case of castings made with the use of molding sand on a matrix of chromite sand, the desired increase in hardness on the surface of the working part up to 516 HV (50 HRC) was noticed. In the microstructure of the castings, the presence of perlite, apart from martensite, was noticed, but its amount was relatively low (on average approx. 4%). Additionally, tests of abrasion resistance of working surfaces made of X46Cr13 steel of the above-mentioned of castings showed that in most cases the resistance increased more than twice as compared to the X46Cr13 steel in the annealed condition. At the same time, it was found that the developed technology of integrating the heat treatment of X46Cr13 steel with the gray cast iron casting process in a bimetallic system does not allow for obtaining hardness and wear resistance at the level achieved in the traditional hardening of this steel grade from the austenitizing temperature in the open air.