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Advanced Technologies of Cast Iron Complex Alloying and Inoculation for Mining and Smelting Equipment Parts Casting

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The results of experimental and industrial investigation of efficiency of ultra- and nanodispersed inoculants obtained by plasma-chemical synthesis method are stated. We have developed new compositions of complex-alloyed cast irons for two-layer plate rolls. Operational durability of mining and smelting equipment parts made of complex-alloyed and inoculated cast irons is raised by 15-45 %.

Keywords: CAST IRON, MELT, INOCULATION, PLASMA-CHEMICAL SYNTHESIS, NANOPARTICLES, ROLLS, MOULDS, ALLOYING, CRYSTALLIZATION, DURABILITY

Introduction

Quality and, consequently, operation durability of mining and smelting equipment parts (rolls, press tools, moulds, grinding bodies, dredging pumps) are determined by macro- and microstructure of cast iron. Application of alloyed and inoculated cast irons enables to increase qualitative and operation performances of castings. The paper covers development and adoption of technologies related to ultra- and nanodispersed inoculation and complex alloying of cast iron at plants of Ukraine and Russia.

The task of this investigation is to create and apply highly effective complex ultra- and nanodispersed inoculants, determine regularities of structure formation processes and properties of cast iron when inoculating and complex alloying, as well as develop new processes of mining and smelting equipment parts casting with increased mechanical and operating performances.

Results and Discussion

Breakdown of large parts of metallurgical equipment (rolls, moulds, dredging pumps) is caused by casting defects and, first of all, by unsatisfactory macrostructure of cast iron. Inoculation by ultradispersed (fraction size up to 1000 nanometers) and nanodispersed (up to 100 nanometers) materials in the form of briquettes or powder is one of the perspective ways to improve quality of large castings. This method enables to change inoculation technique qualitatively: reduce the required amount of inoculants and raise the efficiency and completeness of processes course in the melt. The primary reason inhibiting wide implementation of inoculation is instability of achieved effect caused by not only melting conditions and pouring susceptibility, but also by susceptibility to processes of coagulation, dissolution, inoculant distribution in the melt. Removal of these disadvantages by means of complex ultradispersed inoculants creation will ensure changes in the liquid melt structure, which increases casting properties. Theory and technique of cast iron inoculation by ultra- and nanodispersed heat-proof compounds (TiCN, SiC, TiN, AlN, VC) is developed by authors of the paper for large castings and has been under industrial inspection currently.

Roll manufacture as the supplier of the most critical parts of metallurgical equipment has considerable achievements in the area of pouring technique advancement, improvement of quality and adoption of new types of Cr-Ni cast iron rolls. However, in conjunction with intensification of processes in sheet rolling, durability of two-layer mass-produced rolls does not meet the requirements concerning high production operation of continuous sheet mills. It has predetermined the expediency of investigations upon further increase of operation properties of two-layer rolls by means of cast iron complex alloying.

The results of investigations carried out by Foundry Department of National Metallurgical Academy of Ukraine and related to the development of theoretical and practical fundamentals of advanced technologies of cast iron inoculation by nanomaterials and complex alloying to decrease metal consumption and improve cast product quality are presented in the paper.

It follows from analysis of theories of various cast iron inoculation methods that inoculation is a universal method to control crystalline structure of castings. However, there is no common view on the impact of inoculants on the formation of cast metal characteristics at various stages of crystallization, which complicates their selection and prevents application of intensive methods to affect cast iron structure. Ultradispersed and especially nanodispersed powder effect data are not enough. Problems of thermodynamics, adsorption and heterogenization are studied only for steel deoxidation, and principles of inoculation selection are contradictory. Conventional cast iron inoculation becomes ineffective, therefore increase of inoculation efficiency is a scientific and economic problem. A set of operations related to application of better charge materials on the basis of refined cast irons with no nonmetallic inclusions and sulfur, which ensures purer metal melts for postprocessing in ladles and moulds, was performed to increase efficiency of inoculation and alloying of roll cast iron melts [1].

As a result of investigations, complex ultra- and nanodispersed inoculants (UDI and NDI) on the basis of heat-proof compounds (TiCN, SiC, TiN, AlN, WC) synthesized from the wastes of ferroalloy, titanium-magnesium, silicon-polymeric etc. industries by using special high-frequency plants by plasma-chemical synthesis method (TSU 24.6-24242050-00-12008) were developed at the plants of Ukraine and Russia.

Criterion estimation of the known inoculants efficiency taking into account their activity at all stages of cast iron crystallization is suggested: nucleation and growth of primary austenite, eutectic crystallization, matrix formation in solid. It is shown that inoculating activity of heat-proof compounds depends on melting temperature, enthalpy of formation, solubility and electron affinity of inoculant to the melt. Application of heat-proof ultradispersed powders as inoculants is the most perspective way of cast iron treatment [2].

The role of oxidizing processes in adsorption activity of ultra- and nanoparticles obtained by plasma-chemical synthesis method was considered. Developed mechanism of particles oxidation protection by means of their coating provided high adsorption activity to creation of artificial solidification centers in the melt for particles of 10-250 nanometers size. Oxygen concentration in the clad inoculant is 8.0-8.5 times lower than in not clad one [3].

Computational and experimental data showed that nanoinoculants had rather high kinetic stability due to uniform distribution in the melt. At TiCN consumption 0.20-0.25 wt. %, Ti concentration deviation throughout the height of inoculated melt in 10-ton teeming ladle does not exceed 0.02%.

Experiments reveal that ultradispersed SiC sharply reduces chill in the casting only in the case of particle cladding: consumption of clad SiC for 1 mm chill decrease reduced by 30-60 times (from 0.060-0.065 to 0.001-0.002 wt. %). Retention of inoculating effect was as long as 25 minutes at the chill depth 1-2 mm in sample, while 75 % FeSi processed cast iron already after 10 minutes had the chill depth 10 mm. The mechanism of SiC particles graphitizing effect related to their decomposition in the melt is following: SiC+Fe=FeSi+C. Carbonaceous compounds are thermodynamically active crisallization centres, and microcompounds of Si raise carbon activity. As compared to conventional inoculants FeSi and SiBa, SiC inoculation efficiency raised in 50-70 times. TiCN inoculating treatment enabled to raise microhardness of cementite in white cast iron by 8-12%, austenite by 18-26%, perlite by 28-37% [4, 5].

On the basis of experimental data array analysis it is determined that when casting 7-10 t steel-pouring moulds, ultradispersed inoculation of pig iron and cupola iron eliminates clusters of graphitic inclusions throughout the height and cross-section of walls, diminishes branching of graphite, disperses perlite and improves strength properties of cast iron by 30-35%. Comparative investigations of structure and properties of grinding balls made of traditional electric-furnace cast iron and cast iron processed by ultradispersed inoculants showed that inoculated balls had higher hardness and impact strength (by 30-45%). The process of casting of high-chromium cast iron parts of dredging pumps with part substitution of Ni by Mn and TiCN ultradispersed inoculation was developed. Hardness of inoculated cast iron parts increased from 46-49 up to 55-60 HRC [6,7].

The processes of structure formation were investigated, and isothermal-transformation diagrams in roll-foundry irons alloyed with W, Nb, Co, In, Cu, B, Mo, V, Cu+Mo, Cu+Mo+V were plotted. Bainite structures in cast irons were described, and temperature intervals of bainite structure formation were defined. It was determined that alloying elements, except for Co, enhanced stability of austenite in bainite area, which increased amount of more wear resistant martensite. Cast iron complex alloying is an effective way to improve quality of roll faces due to increase of amount of austenite transformation fine-needled products and, accordingly, enhancement of strength and wear resistance of cast iron. Concentration of Cu+Mo and Cu+Mo+V in two-layer roll face was optimized at reduced content of Ni (3.0-3.2%). Hardness of experimental roll face, strength and wear resistance exceed the corresponding indexes of mass-produced rolls by 20-25%, 15-20% and 25-35%, respectively.

There are theoretical justifications of Mn high concentration in two-layer roll face: 1.3-1.5% Mn at 3.0-3.1% Ni. 680 rolls of 5740 t weight were cast with developed chemical composition. We statistically analyzed data and established the effect of chemical composition on technological parameters of two-layer roll casting. Two-layer roll casting technique with Mn high concentration 1.7-2.0% and Cu 1.0-2.0% at Ni content 2.0-2.2% was developed. It was determined that developed cast iron rolls had high chill depth (30-35 mm), high degree of dispersion of primary austenite, carbides and austenite transformation products. Two-layer roll casting technique with the use of Ni+Mo+W-containing waste was developed and adopted. Strength and wear-resistance of LPHNVd-74 roll face are higher by 10-12% and 12-15% respectively than parameters of Cu+Mo alloyed roll face.

Practical studies upon inoculation of two-layer roll face cast iron by ultra- and nanodispersed TiCN in amount of 0.010-0.025 wt.% were performed. In the inoculated cast iron rolls, area of columnar crystals reduced by 30-45%, eutectic grain size decreased by 2-2.5 times, anisotropy of strength properties reduced in the radial and tangental directions of casting. Increase of thermal and wear resistance of the inoculated cast iron by 26-35% was achieved [8].

Extremely hard two-layer roll casting technique by means of SiC application as ultradispersed graphitizing addition at the charge of 0.005-0.010% from roll weight was developed and adopted. And amount of cast iron was reduced from 40-50% down to 20-25%. Industrial batch of two-layer rolls of total weight 3120 t was cast under the technique offered. Actual tests of rolls on sheet-rolling mills 1450, 1700 and 2000 of integrated iron & steel works of Ukraine and Russia showed that their durability was by 15-40% higher than durability of mass-produced rolls.

Actual tests of steel-pouring moulds made of ultradispersed inoculated cast iron showed that their durability was by 30-45% higher than that of mass-produced moulds. The reasons for mould breakdown were defined, crack propagation mechanism while moulds were in service was determined.

Conclusions

1. New types of ultra- and nanodispersed inoculants on the basis of heat-proof compounds obtained by plasma-chemical synthesis method were developed and tested.
2. Nanodispersed inoculant cladding method that ensures deoxidation protection of particles and keeps their high efficiency in the melt was developed.
3. Ultra- and nanodispersed inoculation of cast iron enables to considerably reduce its charge, refine the structural components, remove chill, increase mechanical properties and by that to produce high-quality cast irons without additional consumption of scarce alloying and inoculating elements.
4. Application of the developed cast iron inoculation technique when manufacturing mining and metallurgical equipment parts (rolls, moulds, dredging pumps, grinding bodies) raises their operational durability by 30-45%.
5. New compositions of alloyed cast irons for two-layer rolls of sheet hot rolling mills were developed. Operational durability of these rolls is higher by 15-40% than that of mass-produced rolls.

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Прогрессивные технологии комплексного легирования и модифицирования чугунов для литья деталей горно-металлургического оборудования

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Изложены результаты опытно-промышленного исследования эффективности ультра- и нанодисперсных модификаторов, получаемых методом плазмохимического синтеза. Разработаны новые составы комплексно-легированных чугунов для двухслойных листопрокатных валков. Повышена эксплуатационная стойкость деталей горно-металлургического оборудования из комплексно-легированных и модифицированных чугунов на 15-45%.