Investigation of the Properties of Carbon Product Prototypes in Real Conditions Conducted in the Process of Melting and Continuous Casting of Non-Ferrous Metals Simulating Real Conditions

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Abstract: The continuous casting process in the non-ferrous metals industry is a very widespread and constantly developing process for producing both finished and semi-finished products for further plastic working. This trend affects the constantly growing demand and, consequently, the development of graphite materials used, among others, for crystallizers, crucibles or heaters.

The manufacturing technology for new varieties of graphite products developed in the work conducted is based on new varieties of carbon materials impregnated with resins and antioxidants, thanks to which they obtain above-standard functional properties, namely an extended service life compared to commonly used products made of commercial grades of graphite.

Keywords: Melting and casting, Continuous casting, static casting, Carbon materials, Crystallizers, Heaters, Crucibles

1 Introduction

Annually Poland produces 1,062 thousand tons of castings, of which 353 thousand tons concern non-ferrous metal casting processes [1]. In 2020, the foundry industry, like most industries, had to face a crisis resulting from the outbreak of the COVID-19 pandemic. In the analyzed period, the global production of castings amounted to 105.5 million tons and was lower than the year before (109.1 million tons) by approximately 3.3% [2].

Graphite materials used for products for the metallurgical industry should be characterized by an appropriate set of functional properties, mainly high hardness, bending and compressive strength, resistance to abrasive wear, erosion of liquid metal and oxidation [3]. As part of the work, a range of new composite materials was produced, both based on pressure impregnation technologies of commercial graphite materials currently used, as well as the production of completely new graphite-based composite materials, selected variants of which were also subjected to impregnation treatments.As part of the technological tests carried out, a wide range of material variants was produced and subjected to basic tests aimed at determining their functional and operational properties.

2 Experimental procedure

A graphite crystallizer impregnated with phenol-formaldehyde resin with the addition of boron nitride and graphite heaters impregnated with a boron nitride suspension were used for testing. At individual stages of operation, samples of products obtained using newly developed prototypes were taken in order to assess the quality of the surface, structure and test their mechanical properties. In order to finally assess the quality, durability and functionality, the newly developed graphite products were also tested after operation.

3 Result and discussion

Crystallizers tests

Tests using prototypes in the form of crystallizers were carried out during the casting process of a copper-based alloy - CuNi2Si. No excessive surface degradation was observed on the external and internal surfaces of the crystallizers after the casting process. It was assessed that the surface quality of the crystallizers would be acceptable for further operation. Metallic traces which appeared in places where the crystallizers were worn as a result of the casting process did not lead to deterioration of the quality or change in the dimensions of the cast rods. For a ø21 mm crystallizer made of graphite material impregnated with phenol-formaldehyde resin with the addition of boron nitride, it was possible to increase the casting speed by 12% compared to the standard speed for this diameter. Increasing the speed did not negatively affect the casting process or the surface quality of the cast bars.

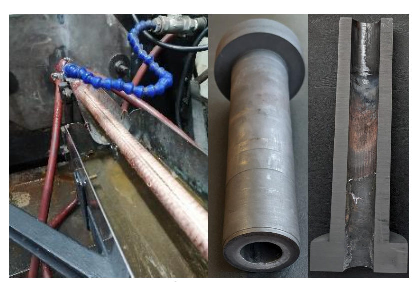

Figure 1. Crystallizers tests

Metallic materials obtained during casting campaign were also tested. No internal casting defects were observed for any of the tested samples. Depending on the point where the test sample was taken from (the beginning, middle or end of the casting campaign), no significant differences were noted in the properties of the cast bars, which confirms the stability of the continuous casting processes. The macro-microstructure is typical for a given material group.

Heaters TESTS

In the case of heaters, a heater made of the material previously used and an isostatically pressed graphite material impregnated with a boron nitride suspension were selected for testing. In both cases, the heaters were used until they lost the ability to heat the tundish lining to the assumed temperature of 1100°C.

The currently used graphite heater gradually, from melt to melt, lost its heating properties. Effective heating of the tundish lining took place over 11 melts (approximately 33 hours of operation). Then, on the 12th melt, this heater completely lost its ability to heat the lining to a temperature of 1100°C, which resulted in the need to replace it with a new one. The heater made of the newly developed material is characterized by a longer operating time, over 43 hours, and maintaining virtually unchanged heating parameters for 14 melts. Only at the 15th melting it began to lose its heating capabilities. Its service life significantly exceeded the results of graphite heaters previously used in the VSG100S vacuum furnace - an increase in the heater operating time by 31%.

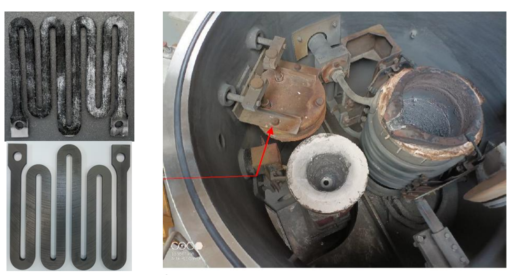

Figure 2. View of the tested heaters and the location of the graphite heater in the vacuum furnace

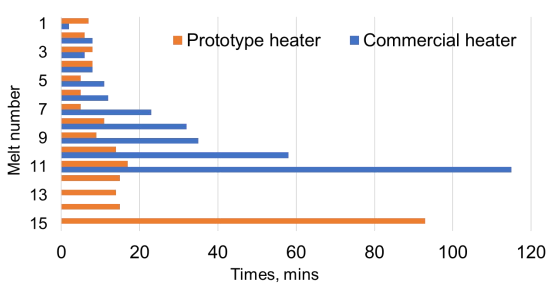

Figure 3. Time to reach a temperature of 1100°C by lining the tundish during heating with a prototype and commercial heater

4 Conclusion

As a result of the research work, a new generation of graphite and composite products was created, which are characterized by increased resistance to wear, erosion of liquid metal and oxidation.

The technological processes developed as part of the work enabled the production of new materials for finished products dedicated to the metallurgical industry with significantly higher functional characteristics than commonly used graphite products. When the crystallizer prototype was used, the casting speed was increased by 12% without deterioration of the surface quality of the cast bars. However, thanks to the use of newly developed material for the heaters, its operating time was increased by 31%.

Acknowledgments

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