10.10.2022

Mgr inż. Sabina PUZIO

"Selection of the type and technology of hardening sand molds for the ablation casting of aluminum alloys"

Abstract

The aim of the doctoral dissertation is to select the composition of molding sands and the best hardening technology for molds for ablation casting of aluminum alloys.

The technology of ablation casting with sand molds has a number of advantages, such as the possibility of making castings of various wall thicknesses and complex shapes without the need to core them, a high temperature gradient is ensuring and a short solidification time of the casting, which contributes to the fragmentation of its structure. The ablation casting process allows for very rigid castings that can be located in the crush zones and function as large aluminum structural nodes. Aluminum profiles are inserted into the sockets in the nodes cast by ablation method, which nodes act as holders to hold the elements of the spatial frame in position. The American patent describing the ablation casting technology assumes the possibility of using various watersoluble binders in the process, but in practice only water glass is used. The literature lacks data on the properties of castings made in the ablation casting technology with the use of sand molds with other binders and with the use of various sand hardening technologies. Hence the subject of the doctoral dissertation.

The molding sand used to produce the ablation casting molds should have got the strength necessary to transfer the metallostatic pressure of the liquid alloy, while being susceptible to destruction by the ablating agent (water). So it should be in the range of 1.5 ÷ 1.7 MPa. The most suitable binders for this process are water-soluble inorganic binders, which are eroded by the action of the ablating agent. A technology commonly used in the foundry industry for making molds and cores with the use of inorganic binders is the Floster S process, in which the binder is water glass chemically hardened with esters. A more expensive process, which allows the elimination of the organic ester hardener, is the physical hardening of water glass at elevated temperature or using microwaves. These processes are also advantageous in terms of significantly reducing the amount of binder used therein. The inorganic binders for the production of molds and cores also include binders based on mineral polymers, the geopolymers. Similar to water glass and adhesives based on modified water glass, they are physically and chemically hardened with an ester hardener. As part of the dissertation, the possibility of using an inorganic phosphate binder for ablation casting molds was also analyzed. This binder is not currently used in foundry practice, but the analysis of literature data and own research have shown that its use allows to achieve appropriate mass strength while maintaining the ecological nature of the process. This binder can be cured both physically and chemically with the aid of magnesium oxide.

As part of the dissertation, the sands with 6 different commercial binders were tested, and the molds were hardened in various technologies. Molding sand strength tests were carried out along with an analysis of bonding bridges, gas release tests from molding sand, derivatographic tests of molding sand, mold erosion tests and mold wettability tests. For selected molding sands, computer simulations of the casting process were carried out and trial castings were made. Due to the widespread use in the foundry industry, the AK7 aluminum-silicon alloy was

selected for the execution of trial castings. In order to compare the differences in the crystallization path of the casting solidifying traditionally in the sand and metal form at ambient temperature and the casting made in the ablation casting technology, measurements of temperature changes over time were carried out simultaneously for each of the above-mentioned technologies. During non-equilibrium crystallization of Al-Si alloys, a change in the position of points characteristic for the equilibrium system is observed. At a higher crystallization rate, the range of maximum solubility of silicon in aluminum increases. Studies have shown that the eutectic point has shifted towards higher silicon contents, and the liquidus and eutectic transition temperatures have decreased. At the same time, dendritic microsegregation was observed. The α solid solution is in the form of elongated dendrites, primary silicon crystals are fragmented and the eutectic silicon dispersion increases. Superfast crystallization creates a cell structure free from dendritic heterogeneity. The eutectic grain has the structure of one highly branched dendritic silicon crystal. The cross-sections of the arms are bent plates that are visible on the surface in the form of needles of different thickness. Under certain supercooling conditions, fibrous branches of dendrites may form, visible on the specimen as a configuration of fine grains.

The last stage of the research was testing the materials left over from the process. Ablation casting is a technology that allows the sand matrix to be recovered without having to undergo mechanical regeneration. During the destruction of the mold, the matrix grains are washed from the binding material, which is dissolved in water. The tests showed that the matrix after drying is of high quality and has properties similar to those of fresh sand. The research also showed that the water remaining after the process, containing small amounts of inorganic binder, is characterized by low harmfulness and, without the need for additional treatment, can be discharged into municipal wastewater.