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Study on the Effects of Size-Shape Parameter Variation of Exothermic Riser Sleeves and Its Influence on Temperature Dependent Parameters

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ABSTRACT

Using exothermic sleeves allows to reduce the volume of the risers required in the casting of ferrous alloys, as well as the amount of metal used, and the costs involved. In this work, flat plates of nodular iron were casted and the effects of the shape and size of the risers were analyzed. For this purpose, risers with two configurations (with and without exothermic sleeves), three shapes (cylindrical, spherical, oval), and two relative sizes (100% volume and 60% volume) were considered. The mixture that would experience a thermite reaction with the highest temperature was defined. Experimental tests and computational simulations were performed, indicating that the spherical sleeves result in the lowest porosity in the risers and the pieces. It was also found that the risers with exothermic sleeves and 60% of the base volume used satisfy the feeding requirements and reduce the defects in the piece.

KEYWORDS

Metal Casting Simulation, Casting, Risers, Exothermic, Sleeve

Risers are important in a casting feeding system, since they provide additional material during solidification and absorb any contraction or porosity of the part being manufactured. The volume-to-surface ratio of the risers must be greater than that for other sections of the feeding system to ensure that they solidify after the rest of the mold (AFS Molding Methods and Materials Division & Thomas, 2020). However, not all riser volume is available for use in casting. In fact, for conventional feeders, i.e., feeders not covered with sleeves, only 10% to 15% is available for the mold. Most of the material remains trapped in the riser itself or is used to compensate for contractions of the riser itself (Brown, 1999, 2000). As the complexity of the parts increases, more sophisticated riser designs are required, including insulating risers or risers that release energy in contact with the melted alloy (Purwadi et al., 2016). Using exothermic riser sleeves can increase the solidification time by 44%, compared to moldings without risers. From an economical point of view, exothermic riser sleeves offer several advantages over traditional risers in the context of iron casting. These advantages can

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lead to cost savings and improved overall efficiency in the casting process, such as reduced material usage, minimized waste, reusability, improved yield, reduced defects, improved casting quality and productivity, and time savings (Chougule & Ravi, 2006; Coatanéa et al., 2006; Hardin, Williams, & Beckermann, 2013). Exothermic mixtures can be used to produce heat inside the riser, which is frequently described by the Goldschmidt reaction. These mixtures commonly include aluminum particles smaller than 50 µm, and other oxides, such as aluminum oxide (Al_2O_3), commonly called alumina, iron(III) oxide or ferric oxide (Fe_2O_3), and silicon dioxide (SiO_2). Mixtures with adequate proportions of the components would increase the reaction temperature (Junghare et al., 2022; Miki, 2002; Neu & Gough, 1993; Yücel, Turan, & Can Candeger, 2018).

Experimental analyses on the ideal reaction mixture have been presented by Hardin et al. (2013) and Yücel et al. (2018). Thus, if the temperature of the reaction, the amount of aluminum can be increased. In Hardin et al. (2013), simulations are presented to determine the properties that depend on the temperature of the riser, finding an agreement between the measured temperatures and simulation estimations of the solidification process. Among the main conclusions derived from the study is that the use of exothermic sleeves on risers increased the solidification time by 44% compared to moldings that did not use risers. Other authors have studied the phenomenon of solidification in risers using numerical approaches. The use of numerical techniques allows for an analysis of this type of phenomena, which is an economic approach without the use of materials, energy, and labor. However, the control of the errors intrinsic to numerical analysis must be kept at an acceptable level so that the conclusions are extrapolatable to reality. Adequate validation and professionals trained in numerical simulations can help in this regard. For example, Ciobanu et al. (2014) in their three-part publication, use numerical techniques to establish testing criteria during riser analyses. The results suggest that riser analysis operations should be based on solidification time maps and not on temperature maps at the end of solidification. A direct relationship between the solidification time and the square of the modulus has been determined for metals commonly used in engineering. The proportionality constant depends on factors such as the type of sand, alloy used, alloy temperature, among others.

However, not all riser volume is available for use in casting. In fact, for conventional feeders, that is, feeders that are not covered with sleeves, only 10% to 15% are available for the mold. Most of the material remains trapped in the riser itself or is used to compensate for contractions of the riser itself (Butterworth-Heinemann, 1999). This is when the use of insulating risers with better performance than the mold, or even risers that generate their own internal heat, are appropriately justified. In these places, the appearance of microporosities is influenced by the temperature gradient and the local cooling rate during the solidification of the alloy. This can be estimated using the Niyama criterion (Carlson et al., 2001; Chvorinov, 1940; Imafuku & Chijiiwa, 1983; Niyama, 1982;). The Niyama criterion is commonly used in foundry processes to detect microporosity-type defects. It is defined as the relationship between the local temperature gradient and the square root of the cooling rate at the analysis site. Low temperature gradients cause the material to have less pressure to fill interdendritic spaces. This, combined with high cooling rates, makes the material solidify more quickly, further complicating the ability to fill interdendritic spaces. The lower the value of the Niyama parameter, the higher the probability of shrinkage and microporosities. With these tools, detailed studies of the location and size of risers that can be used in moldings have been previously presented by Ou, Carlson, and Beckermann, (2005) and Wlodawer, (2013).

Casting numerical simulation techniques, such as finite element analysis (FEA) and computational fluid dynamics (CFD), are commonly employed to model and analyze the casting process, predict defects, and optimize the final product. By reducing the need for physical tests, these techniques offer valuable insight into the filling and solidification stages, ultimately enhancing the quality of the casting by minimizing surface and internal defects (Das, 2021).

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