Impact of HPDC's Core Temperature on Internal Homogeneity of the EC Electromotor Housing Casting

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Abstract: High pressure die casting (HPDC) is one of the most productive casting methods to produce a wide range of aluminum components with high dimensional accuracy and complex geometry. The process parameters of high-pressure casting generally directly affect the resulting quality of the castings, such as the presence of pores in the casting or the microstructure. These defects can lead to a significant reduction in mechanical properties. The aim of the presented article is to describe the effect of the temperature the high-pressure mold on the presence and distribution of porosity and the microstructure of the aluminum casting in two geometric variants. The temperature of the core was changed due to the use of two flowing media in the thermoregulation circuit, i.e. demineralized water and heat transfer oil. The change in core temperature fundamentally influenced the presence of gas porosity, microporosity and microstructure changes in the evaluated area of the high-pressure die casting.

Keywords: HPDC; Al-Si-Cu alloy; Porosity; Microstructure

1 Introduction

High-pressure die casting is a complex process that considers a number of factors that significantly affect the final quality of the cast part. The basic parameters of the high-pressure die casting process are mainly the maintenance temperature, casting and molds temperature, hydrostatic pressure, pressing pressure, and alloy flow rate in the inlet channel. The mechanical properties of a HPDC product are primarily related to the temperature of the mold, the speed of the metal at the inlet and the applied casting pressure [1].

The combination of mold temperature, the fluidity of the molten metal, the complexity of the part geometry, and the cooling rate during high-pressure die casting all affect the integrity of the cast component. If these factors are not properly controlled, we can expect the appearance of various defects in the final casting. The thermal profile of the tool during operation is another important aspect of producing high quality components. Mold temperature is a key factor affecting heat removal from the molten metal, as well as for filling the mold and for correct setting of the casting properties [2,3].

The key factors for effective temperature control of the die are the temperature control unit, suitable heat transfer medium and tempering circuits in the mold die. The heat-transfer medium plays an important role in ensuring optimal temperature regulation. The better the heat transfer properties of the used medium, the more efficiently it is possible to transfer a large amount of heat [5].

2 Experimental procedure

In the experimental part, an aluminum alloy AlSi12Cu1(Fe) was used, the chemical composition of which is shown in Table 1. For experimental purposes, a casting marked Statorbuchse EC75 and EC55 was used in two height variants of the tube part (Figure 1). EC 75 and EC 55 castings are part of the EC electromotor.

Table 1. Chemical composition of the AlSi12Cu1(Fe) alloy

	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn
wt.%	11.4	0.69	0.89	0.32	0.07	0.01	0.07	0.34

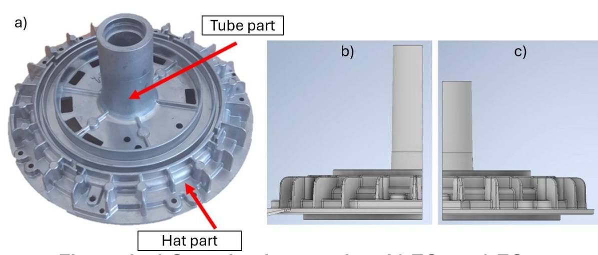

Figure 1. a) Statorbuchse casting; b) EC75; c) EC55

Both variants of castings were cast with a change of the medium flowing in the thermoregulating circuit of the mold in the core part, namely water and heat transfer oil - ITERM 6MB. Other machine parameters did not change during the casting process.

3 Result and discussion

Simulation ProCast software

From the images of mold cycling, it can be observed that oil-tempered cores reach higher temperatures than water-cooled cores (Figure 2). The use of oil also caused a higher temperature of the subsurface layers to a temperature of approximately 380°C at the time of opening the mold, which reduced the cooling rate of the solidification melt.

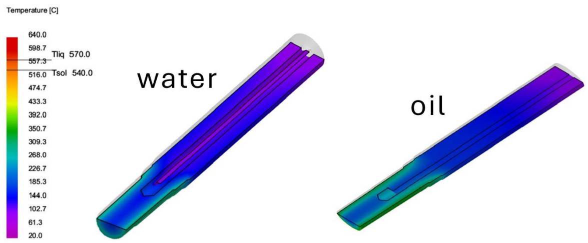

Figure 2. Temperature distribution in the core during the mold opening phase within the tenth cycle for EC 55

Porosity evaluation

The presence of pores in the castings was evaluated by X-ray and computed tomography (CT). The tube part of the casting, which represents the critical area for the formation of pores, was evaluated. When comparing EC 55 castings, we see that the number of pores when using tempering oil is smaller compared to water-cooled castings. By observing castings with a larger tube (EC 75) that have been tempered with oil, we see that the porosity presents in the volume of the tube. In castings that were cooled by water, the number and size of pores increased significantly. The range of pores found in EC 75 castings is significantly larger than in EC 55 castings. In EC 75 castings that were water tempered, the pore size also increased (Figure 3).

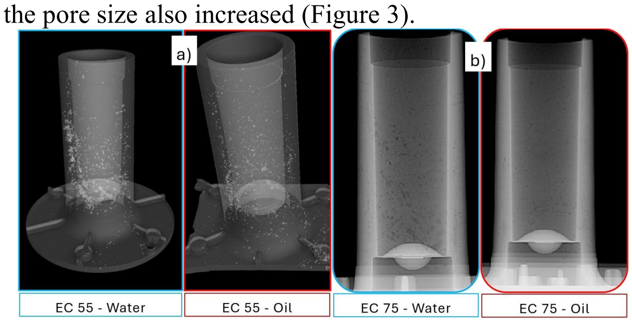

Figure 3. Porosity evaluation: a) CT; b) X-ray

Microstructure analysis

The microstructure is formed by the eutectic (dark gray color) distributed in the α-Al phase (pale gray color) and intermetallic phases based on Fe and Cu. When taking a closer look at the morphology of eutectic Si, a clearly visible change is the effect of the used medium in the thermoregulation system of the core (Figure 4). The morphology of the eutectic in the water-cooled casting is observed in the cutting plane as various round grains and lamellae, which in the 3D morphology are observed as rods. The morphology of the eutectic in the tempered casting is in the form of sharp-edged lamellae (needles) with an uneven surface (protruding steps), which are related to the twinning of the basic Si crystalin 3D morphologies observed as hexagonal plates.

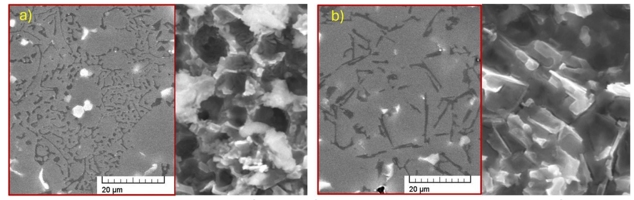

Figure 4. Eutectic Si in EC 55 casting; a) Water, b) Oil

4 Conclusion

The use of heat transfer oil caused an increase in the temperature of the core during the work cycle and a decrease in the cooling rate of the aluminum melt. This caused the presence of pores in a smaller number and dimensions in the volume of the EC 55 and EC75 cast tube. By applying water to the thermoregulation circuit, the initial temperature of the core during the work cycle was reduced, which resulted in the appearance of a larger number of pores in the form of closed air in the entire volume of the tube. The effect of tube growth confirmed the trend of increasing the presence of pores in the evaluated area of the EC 75 casting.

A better microstructure was achieved by the influence of water flow in the core. The microstructure of the water-cooled castings was characterized by finer grains of the α phase (Al) and eutectic silicon in the form of round grains and lamellae. Coarse grains of the α phase (Al) and Si lamellae in the form of sharp-edged lamellae (needles) with an uneven surface were characteristic of the oil-tempered castings.

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References

[1] Sadeghi M and Mahmoudi J. Experimental and Theoretical Studies on the Effect of Die Temperature on the Quality of the Products in High-Pressure Die-Casting Process. Advances in Materials Science and Engineering, 2012, 9.

[2] Jarfors A, Sevastopol R, Karamchedu S, Zhang Q, Steggo J and Stolt R. On the Use of Conformal Cooling in High-Pressure Die-Casting and Semisolid Casting. Technologies, 2021, 9(2):39.

[3] Shin S S. Lee S K, Kim D, Lee B. Enhanced cooling channel efficiency of high-pressure die-casting molds with pure copper linings in cooling channels via explosive bonding. Journal of Materials Processing Technology. 2021, 297.

[4] Hu H, Chen F, Chen X, Chu Y and Cheng P. Effect of cooling water flow rates on local temperatures and heat transfer of casting dies. Journal of Materials Processing Technology, 2004, 148(1): 57-67.