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GEOMETRY AND SURFACE QUALITY OF THE CRYSTALLIZATION SYSTEM AND THEIR INFLUENCE ON THE TEMPERATURES THROUGHOUT THE CONTINUOUS CASTING PROCESSES OF COPPER-MAGNESIUM ALLOYS

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Copper-based materials for electrical purposes usually find their origin in continuous casting lines where the effectiveness of the process and the quality of the final product depends among others on the crystallization system. The paper investigates the influence of the surface quality of the crystallizer and the geometry of the cooling system on the temperature distribution throughout the copper-magnesium alloys casting process. The obtained results prove that as the contact between the crystallizer and the cooling system is worsening the temperature of the crystallizer and the cast rod increase significantly, therefore affecting the efficiency of the process.

Keywords: copper-magnesium alloys, continuous casting, crystallization, temperature distribution, surface

INTRODUCTION

The rapid development of today's technology creates an incredibly high demand for electrical energy and therefore makes it necessary to improve the existing conductive materials. Copper being only second to silver in terms of electrical conductivity with a much lower price per kilogram is the reason why it is the crucial material used for electrical wires [1]. However, more often than it used to, the electrical conductivity needs to coexist with a high level of mechanical properties, thus making it impossible to obtain using pure materials and proves the importance of copper alloys such as copper-magnesium alloys [2 – 4]. The input material for the wire drawing process is usually obtained in the continuous casting line in the form of cast rods or wire rods, where the process parameters are an important factor influencing not only the casting process but also shaping the properties of the final product after the metal forming process. The essence of the continuous casting process itself lies in the constant supply of liquid metal to the primary cooling system where it crystallizes into the form of a cast rod. The most significant part of the casting furnace is the crystallization system made of a crystallizer responsible for the heat transfer to the cooling system [5, 6]. The effectiveness of the process should depend solely on the characteristics of the material used for the cooling system, its geometry and quality of contact between the cooling system and the crystallizer [7 - 9].

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EXPERIMENTAL PROCEDURE

The conducted study took into consideration the laboratory continuous casting furnace presented schematically at Figure 1, where all the vital parts of the furnace have been marked. However, the study focuses on the crystallization system, which consists of the crystallizer and the cooling system which were presented up close at Figure 2. Research conducted with the FLUENT module of the ANSYS software determined the cast rod temperature and cooling medium temperature after exiting the crystallization system. Additionally the temperature distribution of the crystallizer was determined in the form of temperature mapping. The set constant conditions were as follows, the temperature of the liquid metal 1200 °C, the cast rod diameter 14 mm, the casting feed 0,1 m/min. The variables were centred around the crystallization system i.e. surface roughness of the crystallizer, material used for the manufacturing of the cooling system and the shape of the cooling system's internal canals.

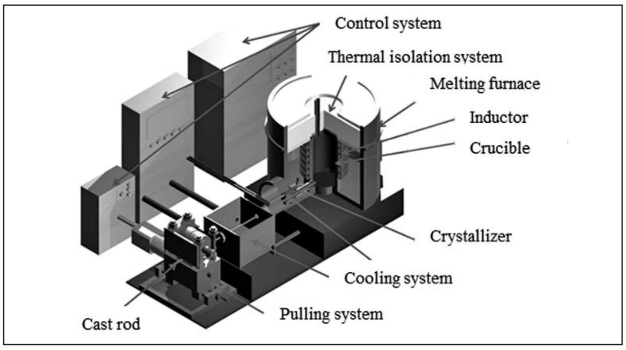

Figure 1 The schematics of the laboratory continuous casting furnace

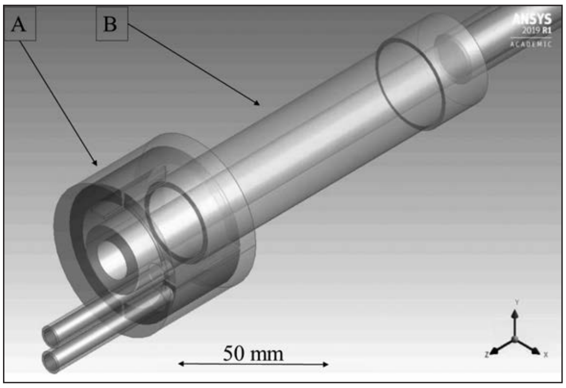

Figure 2 The model used for the continuous casting process finite element method simulations; A – primary cooling system; B – crystallizer

RESULTS AND DISCUSSION

The variables applied for the simulations of the continuous casting process were carefully selected in order to determine the influence of the surface roughness of the crystallizer (Ra 0,63 μm and 1,25 μm) at the place of contact with the cooling system, the geometry of the internal canals of the cooling system (empty cooling system, cooling system with two division walls and spiral cooling system) and finally the material used for the manufacturing of the cooling system (copper and steel).

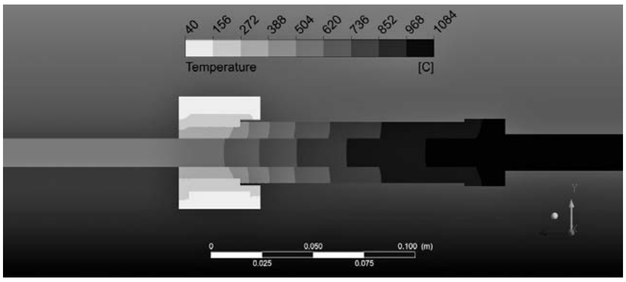

Figure 3 Empty cooling system made of Cu and graphite crystallizer with Ra 1,25 / °C

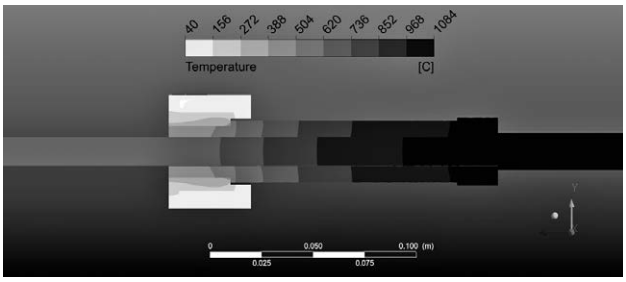

Figure 4 Empty cooling system made of steel and graphite crystallizer with Ra 1,25 / °C

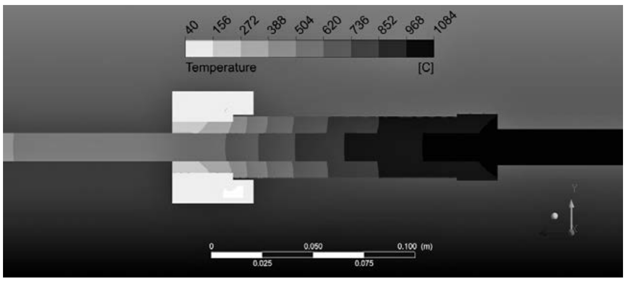

Figure 5 Two divisions cooling system made of Cu and graphite crystallizer with Ra 1,25 / °C

The obtained results were presented at Figures 3 – 10 and collective data regarding the registered temperatures were put together in Table 1. The data represent the temperature of the cast rod and the cooling medium

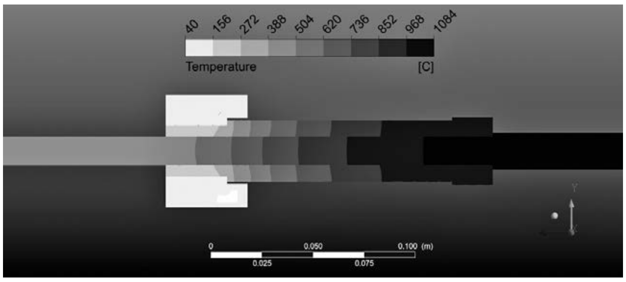

Figure 6 Two divisions cooling system made of Cu and graphite crystallizer with Ra 0,63 / °C

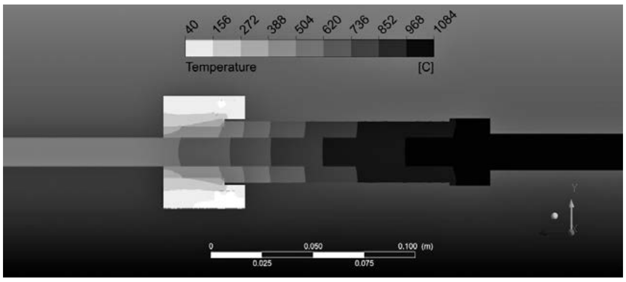

Figure 7 Two divisions cooling system made of steel and graphite crystallizer with Ra 1,25 / °C

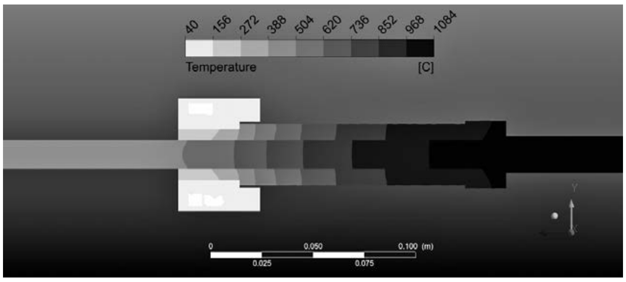

Figure 8 Spiral cooling system made of Cu and graphite crystallizer with Ra 1,25 / °C

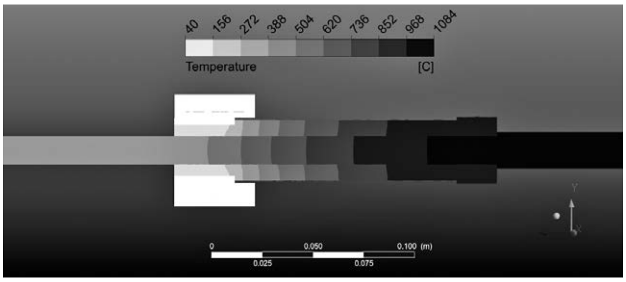

Figure 9 Spiral cooling system made of Cu and graphite crystallizer with Ra 0,63 / °C

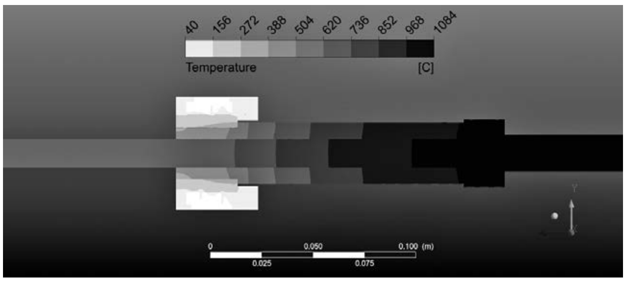

Figure 10 Spiral cooling system made of steel and graphite crystallizer with Ra 1,25 / °C

Table 1 **Collective data of the registered temperatures of the cast rod and water after exiting the cooling system / °C**

	Empty cooling system		Two division walls cooling system			Spiral cooling system		
	Copper - graphite (Ra 1,25)	Steel - graphite (Ra 1,25)	Copper - graphite (Ra 1,25)	Copper - graphite (Ra 0,63)	Steel - graphite (Ra 1,25)	Copper - graphite (Ra 1,25)	Copper - graphite (Ra 0,63)	Steel - graphite (Ra 1,25)
Cooling medium temperature at measuring point	56,12	45,76	59,84	63,60	49,66	61,40	64,96	49,35
Cast rod temperature at measuring point	541,36	654,13	507,97	461,29	606,45	501,02	452,06	628,77

temperature after exiting the cooling system. The important factor that needs to be understood is that the registered cooling medium temperatures are closely related to the heat transfer between the crystallizing material through the crystallizer to the cooling system, therefore the higher the cooling medium temperature the better the heat transfer. On the other hand the better the heat transfer the lower the temperature of the obtained cast rods and this is what the continuous casting industry is looking for in a nutshell, as by lowering the prospective temperatures of the crystallizer and the cast rod the feed may be increased, thus increasing the production rate.

The proposed temperatures were quantified as with constant values of the other parameters of the process they remain a solid measure of the heat transfer at the continuous casting crystallization system. As presented at the collective Table 1 it is clearly visible that regardless of the geometry of the cooling system copper based material corresponds with a much better heat transfer than steel cooling system. The differences in the obtained temperatures for the tested parameters reach over a 100 °C in favour of copper cooling system. When considering the geometry the differences are not that vital, however, the application of two division walls or a spiral division inside of the cooling system instead of the no division at all shows that it has an impact on the process temperatures. What is of much importance for the industrial processes is that by lowering the surface roughness of the crystallizer at the place of contact with the cooling system the registered temperatures of the cast rod were drastically lower. Bearing that in mind it may be stated that by simply polishing the contact surface of the graphite crystallizer the process may by conducted at higher feed velocity, therefore increasing the production rate. Based on the tested parameters, constants and variables it has been proven that the copper cooling system with a spiral internal canal system and a graphite crystallizer with surface roughness Ra 0,63 at the place of contact with the cooling system provides the best heat transfer and therefore the lowest temperature of the cast rod.

CONCLUSIONS

On the basis of the conducted research it may be stated that:

Even though the price of copper is higher than steel the registered temperatures of the process decrease significantly when copper cooling system is being applied, therefore making it a much desirable choice.

Construction of the cooling system should account for using kind of a division wall instead of an internally empty system as by directing the cooling medium flow the obtained temperatures of the cast rod are visibly lower.

Improving the surface quality of the graphite crystallizer at the place of contact with the cooling system significantly increases the heat transfer therefore lowering the registered temperatures of the obtained cast rod.

The conducted research discusses the copper-magnesium alloys, however, it may be easily adapted to other copper alloys or pure copper obtained in the continuous casting lines.

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Note: The translator responsible for English language: Andrzej Mamala, AGH University of Science and Technology, Kraków, Poland