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SIMULATION BASED RESEARCH ON THE UTILIZATION OF COPPER AND CAST IRON EXTERNAL COOLERS FOR THE CASTING OF CAST IRON PARTS

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Abstract: *The paper discusses the possibility of replacing cast iron by copper coolers in casting moulds. The concrete case of a 12 mm thick cast plate with a 12 mm thickening is analyzed. The cooling rate of the cast part surfaces in contact with copper coolers is significantly higher than in the case of cast iron or steel coolers, allowing the obtaining of castings with special properties of their superficial layers*
Key words: *cooler, casting, solidification, cast iron, simulation*

1. INTRODUCTION

In foundry practice external coolers are used in casting moulds in order to ensure local acceleration of cast part cooling and solidification for one of the following purposes:

- uniform (even) solidification of castings;
- oriented solidification of castings;
- obtaining a local structure gradient.[1]

Ensuring uniform solidification is pursued in the case of mechanically less stressed parts with small hot spots. By uniform solidification the concentrated shrinkheads in the hot spots disperse in form of axial porosity.

The complete elimination of shrinkheads from parts require the utilization of feeders as well as ensuring solidification of the liquid alloy oriented towards these. In this case the coolers are located in areas opposite to the feeders.

2. PROBLEM STATEMENT

Using cooler in the form of hardware is demanding and not investigated sufficiently. The proof is very little literature, almost nonexistent. Research whit real solidification moduls help was made for influence of the number of casting fed by the same feeder.[2]

Previous studies based on the method of the real solidification modulus have revealed that external coolers with superior thermo-physical characteristics, high specific heat, density and particularly high thermal conductivity (generally having very high values of the heat accumulation coefficient) cause a considerable decrease of the casting solidification modulus in the area of the hot spot.[3] This means that such coolers (made from Cu, Al, Ti, Ag, Ni) induce a significantly more rapid cooling of the hot spot and the part in the location area of the cooler, respectively.

Consequently special effects can be obtained particularly when targeting fine structures with special properties favoured by high local cooling rates. The only problem in the deployment of such coolers is their melting temperature being smaller than the casting temperature of the alloy. In the case of casting parts from cast iron, coolers made from Cu or Al may melt.

3. THE OBJECT OF STUDY

The objective of the paper is to present a study on the solidification of a part cast from cast iron in the presence of copper coolers. A main focus was placed on the maximum heating temperature of the cooler in the vicinity of the part, in relation to cooler dimensions, cooling temperature of the part layers in contact with the cooler, etc

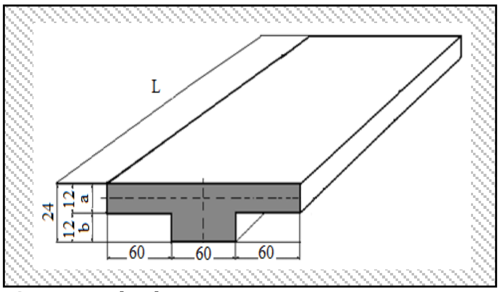


Fig. 1. Casting with a hotspot

The solidification of the part shown in figure 1 was simulated, under the circumstances of using coolers of various thicknesses and length.[4]

4. WORKING METHOD

The research method was based on computer based simulation of the solidification of the cast part.. The software is based on a mathematical model with finite differences. Whole mold is divided into cubic volume elements (in 3D simulation) or square (in 2D simulation). As initial moment of simulation it is considered the moment when the form is full filled with liquid alloy.[5]

The part was cast from grey cast iron, while using copper coolers. The cooler thickness varied between $x_r = 4 \div 20$ mm, its length being of $L_r = 60$. Figure 2 shows the dimensions of the mould used for the simulation of solidification, as well as the positioning of the cooler in the mould.

In each case position of the hot spot and solidification time were determined. Further, the cooling rate was determined at the surface of the casting, prior to solidification.

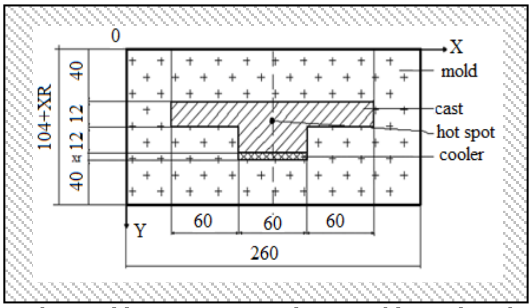


Fig. 2. The mould – cast part – cooler assembly used in the simulation of solidification

5. RESULTS

Figure 3 shows the distribution of the isotherms in the casting moulds in the case of parts cast in the absence of coolers. The results concerning solidification of castings in the absence of a cooler as well as the cases using a cooler are given in table 1.

No.	Cooler Thickness	Results concerning the hot spot			
		The hot spot coordinates in an xOy frame of reference		Time of solidification	
		Cooper	Iron	Coope	Iron
Symbol	Xr	(x,y)	(x,y)	t sol	
u.m.	mm	mm x mm	mm x mm	S	S
1	0	(130;60)	(130;60)	542,3	542,3
2	4	(130,61)	(129,61)	318,2	333,5
3	8	(81,61) (179,61)	(79,61) (181,61)	216,5	210,9
4	12	(77,61) (183,61)	(69,61) (191,61)	201,1	179,9
5	16	(69,61) (191,61)	(65,61) (195,61)	179,5	165,9
6	20	(67,61) (193,61)	(63,61) (197,61)	166,5	158,7

Tab. 1. Results concerning the influence of cooler thickness on hot spot position and solidification time in the case of the part

A better evaluation of the possibility of using copper coolers for the casting of cast iron parts called for the study of the solidification of the same cast iron part in the presence of cast iron coolers.

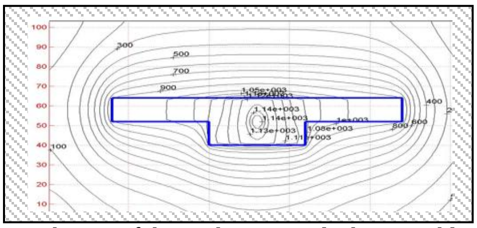
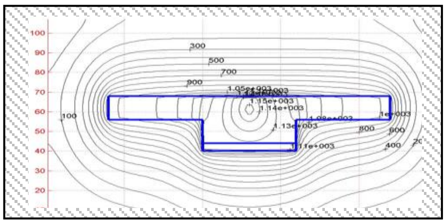


Fig. 3. Distribution of the isotherms inside the assembly of the mould at the end of solidification (in the absence of cooler)

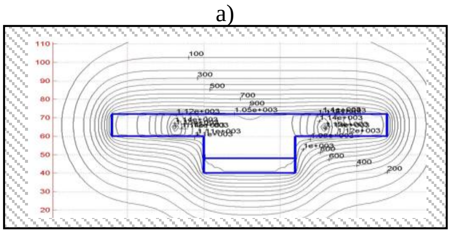
Figures 4a, 4b show the distribution of the isotherms in the casting mould at the end of solidification of a part cast in the presence of cast iron coolers.

Thus a comparison is possible between the two types of coolers as to their effects of uniformizing part solidification and enhancing the cooling rate of the part surface in contact with the cooler, respectively. The curves plotted in figure 5 illustrate the difference between cast iron and copper coolers. The curves plotted in figure 5 illustrate the difference between cast iron and copper coolers.

The solidification time of the hot spot in the case of the copper cooler is smaller than in that of the cast iron one. The utilization of materials with high values of the heat accumulation coefficients allows decreasing the surfaces to that coolers are applied, in the cast of cast iron parts.



a)



b)

Fig..4. Distribution of the isotherms inside the assemblyof the mould at the end of solidification: a) for cooler thickness xr = 4mm; b) racitor din fonta xr = 8mm

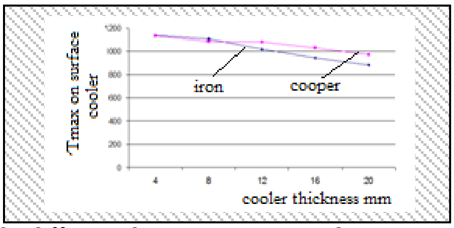


Fig. 5. The difference between cast iron and copper coolers

6. CONCLUSION

The conducted research has revealed that for smaller thicknesses of the cooler (smaller than the thickness of the hot spot) the copper cooler melts. The solidification time of the part decreases for an increasing thickness of the cooler.

Maximum temperature is cooler surface heat decreases with increasing cooler thickness.

Maximum temperature during cooler surface heating also decreases with increasing thickness cooler.

In case of iron cooler, surface cooling rate in casting at solidified momonet is around 1224 ^{0}C against 2182 ^{0}C at the cooper cooler. This shows that using copper cooler structure can lead to much different structurs from those obtained in case of iron cooler.

Speed variation in the surface layer of parts does not change even cooler thickness is varied between 4-20 mm.

When iron coolers are used, the surface of the cast in contact with the cooler, cools and solidify very fast, almost instantaneiy

When iron coolers are used, the surface of the cast in contact with the cooler, cools and solidify very fast, almost instantaneiy.

The further envisaged research based on these results will study the possibility of applying the results in the concrete case of a part cast from cast iron, targeting the obtaining, locally, of hard white cast iron layers, particularly wear resistant (for example for engine pegs.

Research will focus on the optimization of technologies and the possibility of protecting copper cooler surfaces such as to prevent their partial melting and extend their durability.

7. ACKNOWLEDGEMENT

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