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EXPERIMENTAL INVESTIGATIONS OF TEMPERATURE EVOLUTION IN STEEL DIE DURING DIE CASTING

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ABSTRACT: At liquid steel casting in a die the heat stored by the melt during heating and melting is transferred to the die walls and then to the environment. In this study, a die casting experiment using 200-400 steel was conducted. In order to measure the temperature profiles inside the die made from 55MoCrNi16 steel, K thermocouples were installed at different heights and depths.
KEYWORDS: steel die, temperature measurement, liquid steel, die casting

INTRODUCTION

During cooling of the melt in a metallic die the heat is transferred from the interior to the surface of the piece and into the interior surface of the die. The next stage consists in forming of a temperature gradient from the interface liquid steel-die to the outer wall in contact with the atmosphere. Further the heat is transmitted to the environment. So, in this process the heat transfer is done through the three known means: conduction, convection and radiation [1,2].

In the studied process first the liquid steel is cast in the die and then, when the melt becomes semisolid, the punch closes the die in order to obtain a piece of glass shape (figure 1). Given this, for die design and choice of the die material must be considered both the recommendations given for the execution of the metallic forms for casting and for the execution of dies for hot forging.

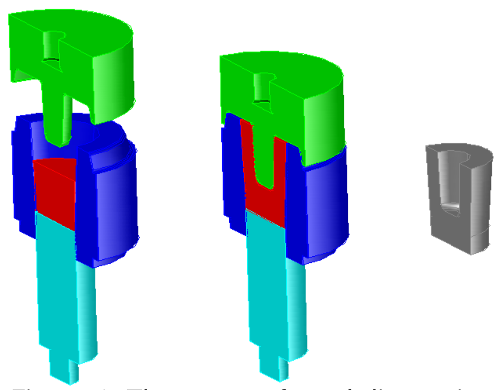

Figure 1. The stages of steel die casting

At liquid steel casting, die design has a very important role because it must ensure the desired solidification speed for the piece. Also, it is necessary that the die do not heat up above a certain temperature imposed by the technology or by the die material. Knowing this, the die wall thickness was calculated after Dubinin [2] relation.

Generally, during work the metallic forms used for hot die forging are subject to alternative heating and cooling which can lead to the occurrence of small cracks. If the heating temperature of the die exceeds the tempering temperature of the die tool steel the mechanical characteristics modify and the wear resistance sharply decreases [3]. The tempering temperature for hot work die steels is between 450°C and 560°C [4].

According to the literature [5] the temperature reached in the metallic form during liquid die casting process has influence both on the quality of the piece surface and on to the durability of the die. If the temperature in the die during processing is lower then 100°C the liquid alloy in contact with the cold walls quickly cools forming a hard crust on the outside surface of the piece, which represents a surface defect, which also favors the formation of surface cracks. If the temperature in the die walls during processing is higher then 350°C the liquid alloy can adhere to the die surface, which leads to the degradation of the piece surface and of the die.

So, the aim of this article is to study the temperature evolution in the die wall during casting and processing of steel, considering that overcoming certain limits of temperature affects both the piece and the die quality.

EXPERIMENTAL PROCEDURE

Working conditions of dies and punches used for die casting of steel processed in semi-solid state are difficult, because the working temperature is high (the steel is cast in the die in liquid state) and the deformation force applied during steel solidification acts both on the die and punch that comes in contact with the processed alloy.

In this study the cast steel was 200-400, and the tool steel chosen for die and punch manufacturing was 55MoCrNi16. The chemical composition for the two steel grades is given in table 1.

Table 1. The chemical compositions of die tool steel and casting

	C[%]	Mn[%]	Si[%]	S[%]	P[%]	Cr[%]	Ni [%]	Mo[%]	Cu[%]
55MoCrNi16	0,50-0,60	0,50-0,80	0,10-0,40	-	-	0,50-0,80	1,40-1,80	0,15-0,30	0,30
200-400	0,18-0,20	0,40-0,45	0,26	0,011	0,016	0,07	0,12	0,03	0,23

In order to measure the temperature reached during test in the die wall at different heights and depths were used K thermocouples. The measuring range for this type of thermocouple is from -200°C to 1250°C. Also, the variation of Seebeck coefficient with the temperature (the sensitivity of the thermocouple) is roughly constant at about 41µV/°C from 0°C to 1000°C [6]

To study the temperature profiles in the die wall during casting, processing and early solidification of steel were used five thermocouples noted TH1, TH2, TH3, TH4 and TH5. They were placed radial in die wall at different depths (figure 2) and heights (figure 3).

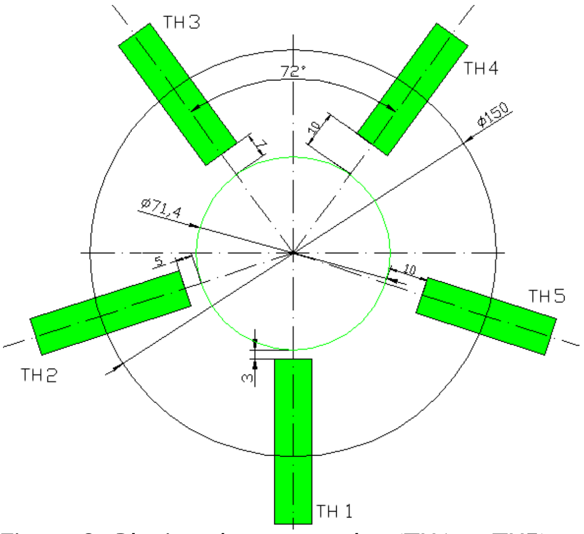

Figure 2. Placing thermocouples (TH1 to TH5) at different depths from the inner wall of the die

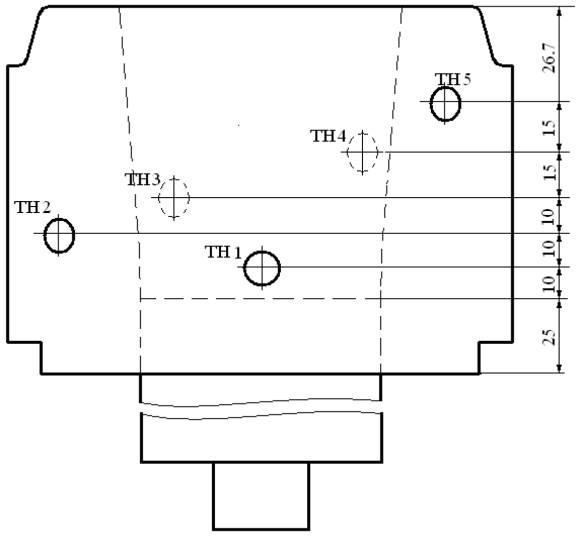

Figure 3. Placing thermocouples (TH1 to TH5) at different heights in the die wall

The experimental installation is shown in figure 4.

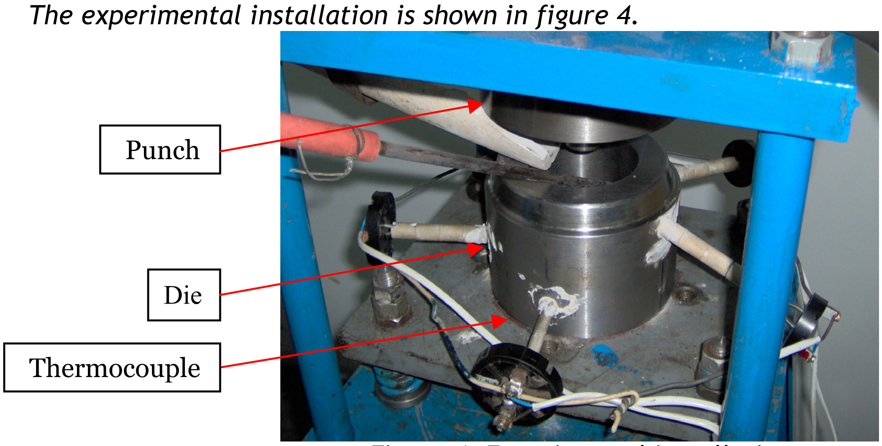

Figure 4. Experimental installation

To record the temperature values simultaneously with all five thermocouples is used a data acquisition board, model NI PCI-6221 to which they are linked. Recording data every second, to the computer system connected to the acquisition board is made with a special program that provides directly the temperature values.

RESULTS AND DISCUSSION

The graphs illustrated in Figure 5 shows the evolution of the temperature in the die wall for each thermocouple, during the process.

Because the temperature difference between the liquid steel at casting (1541°C) and the steel die at ambient temperature is very high it is necessary to heat up the die and the punch until reaches a minimum temperature of 100°C, so the liquid alloy in contact with the die walls don't form a surface defect in the piece. Die heating is also done in order to reduce the thermal shock.

Given this, an oxy-fuel burner was used to heat up the die until a temperature between ~120°C and ~152°C as we observe in figure 5.

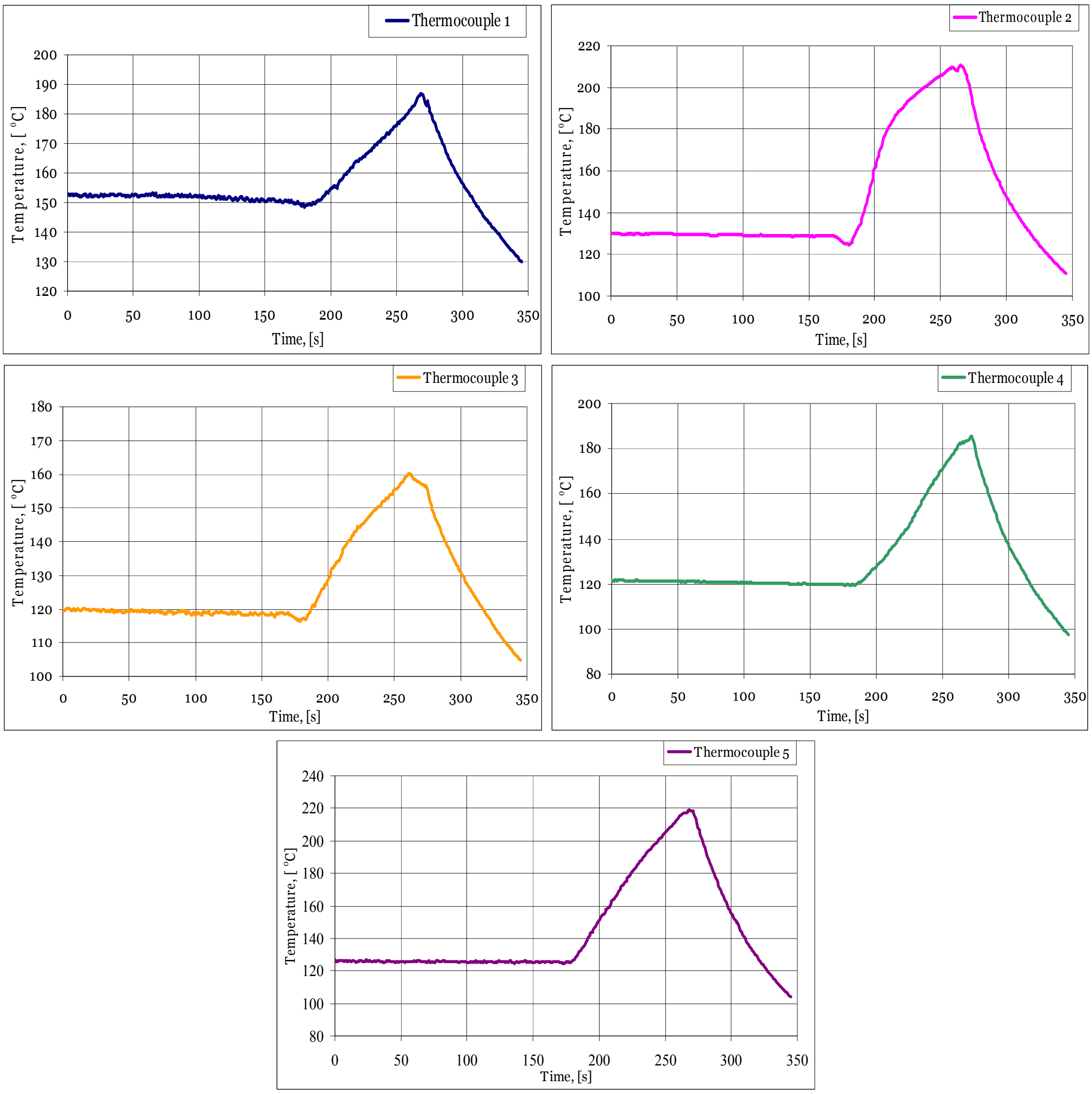

Figure 5. Temperature profile in die wall for the five thermocouples

By overlaying the 5 curves (figure 6) we obtained an overview on the temperature evolution in the steel die walls for the glass shaped piece processing.

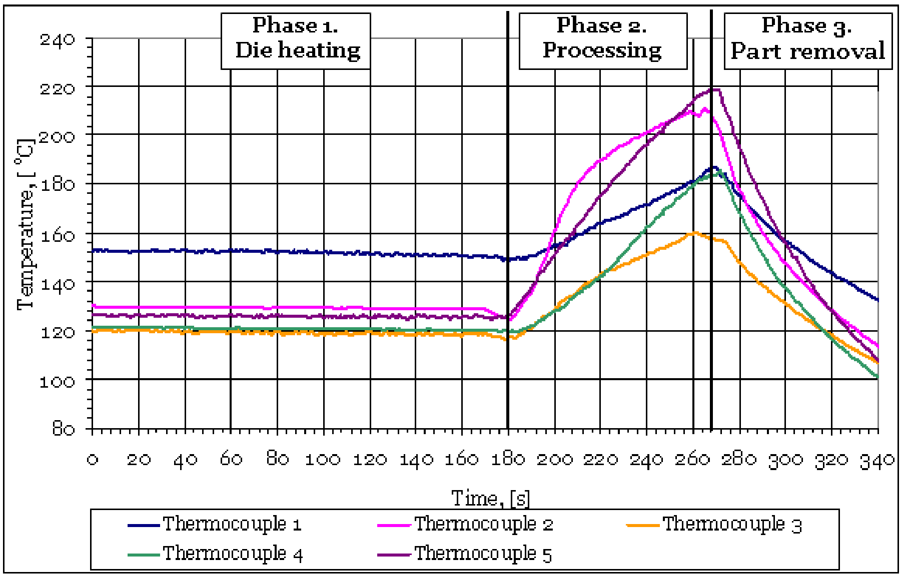

Figure 6. Die wall temperature variation in time during the process

Figure 6 shows in phase 1 a maximum temperature difference of 32°C between TH3 and TH1, while between TH2, TH3, TH4 and TH5 the registered temperature difference was of ~10°C. These differences are caused because the heating was realized with the oxy-fuel burner. But, even if the die wall heating is not uniform the temperature in the die during process was not less then 100°C, which is requested.

The beginning of the second phase coincides with the liquid steel casting in the die and then continues with punch closing the die. Because at casting the melt has a very high temperature we observe an abrupt increased of die wall temperature. As shown in figure 6 the maximum temperature value reached in the die wall during processing is 218.33°C for thermocouple 5. This is probably because the melt, at die casting, flows on the inner wall of the die, in the action zone of TH5. Also must be mentioned that at die closing, the punch take part of the heat from the melt. In the last phase the temperature begins to decrease because the piece is removed from the die.

CONCLUSIONS

Giving that overcoming the tempering temperature (450 - 560ºC) for tool steel 55MoCrNi16 during work would lead to structural changes that alter the tools and finally appears degradation, were measured the temperature values reached in the die during the process. Because the maximum temperature value attained was 218.33°C we find that there are no structural changes in the die. Also was not exceeded the temperature of 350°C at which there is a high probability of sticking the piece on the die wall. Therefore the temperature achieved in the steel die wall during processing does not affect the die quality.

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