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THE STUDY OF SILICON MOULD'S THERMAL LOADING DURING SPIN CASTING OF ZINC ALLOYS

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Abstract

The aim of this paper is to verify through experiment, the thermal loading of silicon moulds used for Tekcast spin casting technology. Heating of the moulds was studied from 1 through 50 casting cycles, as well as their cooling time after 5, 10 and 15 casting cycles. Subsequently, it has been determined that higher number of casting cycles and casting of thick-walled castings expose moulds to high thermal loading due to insufficient thermal conductivity of silicon rubber.

Key words

temperature, mould, silicon, casting, zinc

Introduction

Spin casting into silicon moulds is the process of the mould's cavities filling by increased forces. The material of the mould is Teksil – silicon rubber, which enables low cast melting point alloys like zinc and tin alloys, and even thin-walled castings from aluminum alloys. Teksil silicon material is soft during the mould's preparation and can be processed like plasticine. The final toughness and flexibility of mould is achieved by vulcanization (i.e. by pressure and heat application).

The process of mould making and casting is relatively short and simple. This technology has both advantages [1] and disadvantages. One of these disadvantages is the mould's lifetime, which is affected by thermal loading that causes them to crack. The next serious problem is the casting's quality (i.e. porosity, shrinkage cavities). These problems are caused by poor thermal conductivity of the mould. Although silicon moulds resist to temperatures up to 450^{o}C during zinc alloys casting, they have low thermal conductivity, which causes the

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mould's overheating and delays the production process due to necessary cooling times. The cyclic heating of the mould during a larger number of casting cycles can cause defects on the mould's cavity surface and possible burnout of the mould's parts on the casting. Thus, it is necessary to find solutions for eliminating this disadvantage of silicon moulds during the casting process [2]. It is also very difficult to eliminate the non-uniform heat conduction in mould, which creates the risk of cracking in corners of complex shape castings with varying wall thickness.

Teksil Silicon Material

Teksil is material developed especially for Tekcast spin casting technology by TEKCAST Industries from the USA. It is used for production of silicon rubber moulds with high heat resistance for zinc, tin alloys, and even thin-walled aluminum parts casting. These very precise, chemically heat-resistant moulds are finished by vulcanization at 170°C with applied pressure, dependent on the mould's size. After vulcanization the mould is able to produce highly precise castings [3]. It also has high reproducibility of surface details and a relatively long lifespan (up to tens of thousands of castings from zinc and tin alloys). The advantages of this technology enable it to be used not only for decorative parts, but also for precise complex shape construction parts. One of its major disadvantages is low thermal conductivity. Tables 1 and 2 show basic properties of silicon compared with other materials. The typical thermal conductivity of rubber is λ = 0,2 W/mK. This poor thermal conductivity leads to gradual heating of the mould during the casting process. Subsequent casting cycles cause increased thermal loading, which can lead to mould destruction and lower quality casting.

THERMAL PROPERTIES: COMPARISON BETWEEN DIFFERENT METALS AND SILICONE [2]

Table 1

Material	Silicone	Pure aluminum	Pure copper	Plain carbon steel
Specific heat [J/kg K]	~1250	903	385	434
Density [kg/m^3]	1535	2702	8933	7854
Thermal conductivity [W/m K]	0,71–1,0	237	401	60,5

THERMAL PROPERTIES OF DIFFERENT MATERIALS [2]

Table 2

Material	Average specific Heat [J/kg. °C]	Latent heat [kJ/kg]	Average density [kg/m^3]	Melting point [°C]	Thermal conductivity [W/m.°C]
Beeswax	*	174.6	2255.44	62.2	0.0744
Paraffin	905.4	146.7–200	2062.1	56.1	0.0713 (0.18)
Plain steel	434	N/A	7854	N/A	60.5
Silicone	1250	N/A	1535	N/A	0.71–1.0

x*Value not available.

The small thermal conductivity of mould causes mould cracking for thick walls castings with more subsequent casting cycles, as well as influencing the casting's quality (Fig. 1).

Fig. 1. *The crack in the mould's cavity caused by thermal loading*

Experiment

For the mould's production, silicon material TEKSIL Silicone - GP-S, with a diameter of 305 mm, was used. The mould was vulcanized at 170 °C with 25 MPa. The patterns for mould making were polished by electrolytic – plasma technology [4]. Figure 2 shows the mould before casting with marked places of temperature measurements. Each measurement was made in the place of runner connection, due to the assumption that if molten metal solidifies here as last, the thermal loading of this part will be the greatest.

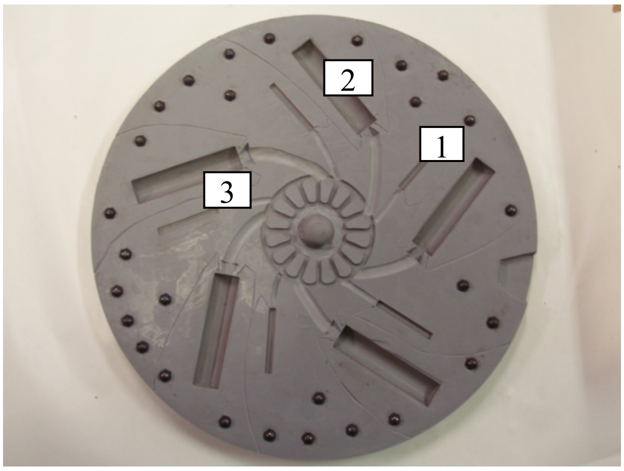

Fig. 2. *The bottom part of the mould (temperature was measured in marked cavities)*

Fig. 3. *Tekcaster Series 100-D spin casting machine*

The experiments were made on spin casting machine Tekcaster Series 100-D (Fig. 3). The casting cycle lasted 40 s and the interval between measurements was 60 s. Table 3 shows parameters of the casting process during experiments. The temperature was measured by CEM DT-8810 digital thermometer. Cast metal was zinc alloy Zamak 2 with a melting point of 420 °C. Its chemical composition is shown in Table 4.

THE PARAMETERS OF CASTING PROCESS DURING EXPERIMENTS Table 3

Parameter	Value
Mould's rotational speed	475 rpm
Casting cycle	40 s
Holding pressure	241,5 KPa

THE CHEMICAL COMPOSITION OF ZAMAK 2 ALLOY Table 4

Chemical element	**Al**	**Cu**	**Mg**	**Fe**	**Pb +Cd**	**Zn**
[wt.%]	**4,0**	**2,8**	**0,04**	**0,075**	**0,004**	**balance**

Figure 4 shows heating curves of the mould's cavities during the casting process up to 50 casting cycles. The difference between measured values in various mould's cavities is less than 2,5 %, thus the heating curve can be drawn from an average value (Fig. 5). Figure 6 shows details of the mould's cavities' heating curve from 5 to 50 casting cycles. Figure 7 shows the heating curve of the mould in central gate.

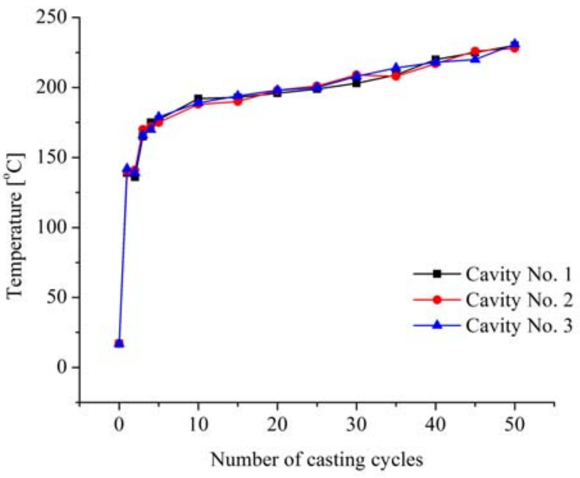

***Fig. 4.** The dependence of temperature of selected mould's cavities from the number of casting cycles*

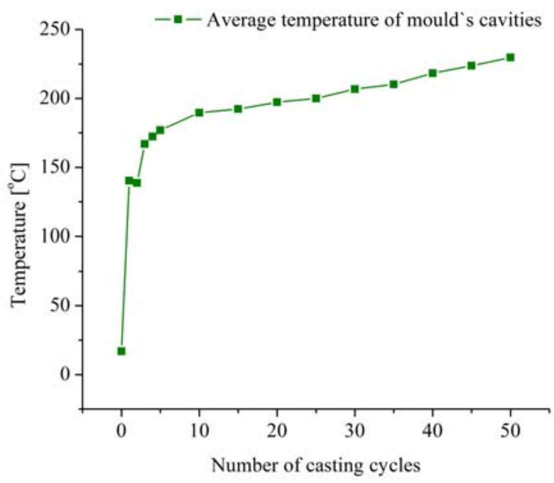

***Fig. 5.** The dependence of average temperature mould's cavities from the number of casting cycles*

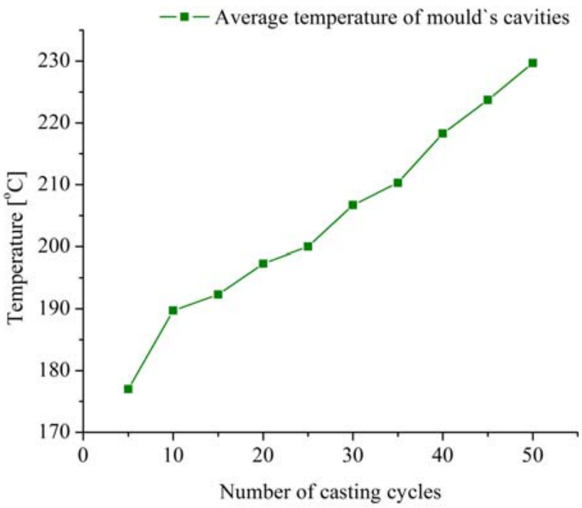

__Fig. 6.__ Detail of curve from Fig. 5 in range from 5 and 20 casting cycles

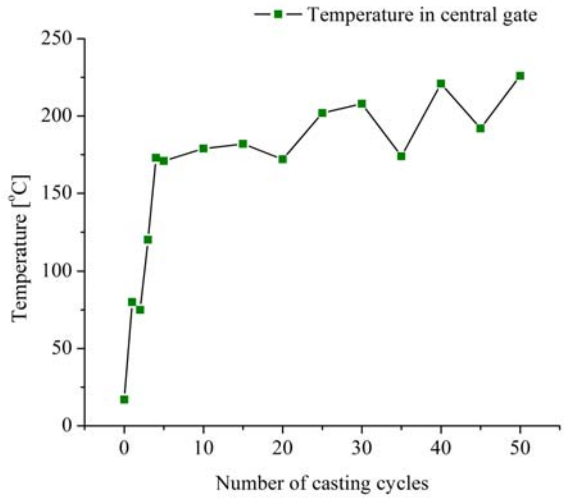

__Fig. 7.__ The mould's heating in central gate

Figure 8 shows cooling rates of mould's cavities measured after 5, 10 and 15 casting cycles. The cooling rates were monitored in period from 10 to 300 s.

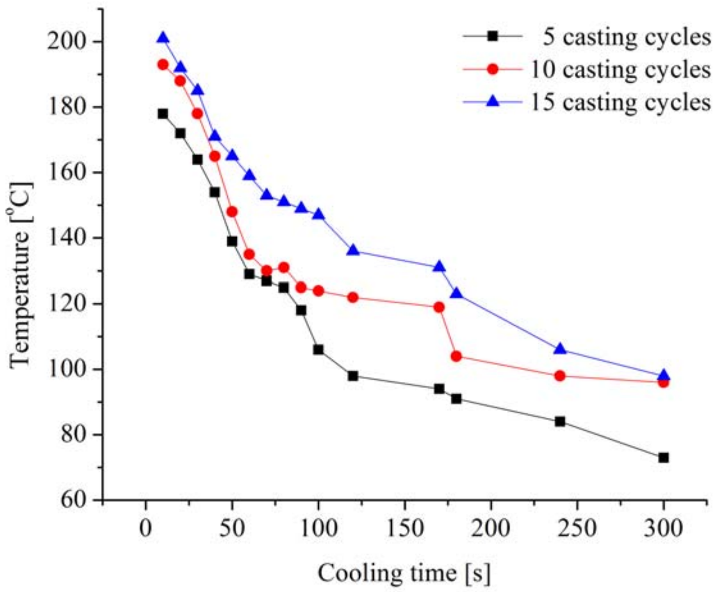

__Fig. 8.__ The cooling of mould's cavities

Discussion

From the heating curves in Figure 4, it is obvious that the heating is nearly similar for all three of the mould's cavities where the temperature was measured. The differences between temperatures in each mould's cavity are no greater than 2,5 %. This allows us to draw a curve of the mould's cavities' average temperature (Fig. 5). The rapid heating during the first casting cycle can be explained by the pouring of molten metal with a temperature of 420 ^{o}C into the mould with a temperature of 17 ^{o}C and low thermal conductivity of the mould. This rapid heating can be avoided by preheating of the mould. The small decreasing of the mould's temperature after the 2nd casting is caused by low thermal conductivity of the mould, which is great enough at this point because the mould is not cyclically heated by casting cycles every 60 s.

Figure 6 shows the temperature of the mould's cavities in intervals from 5 to 50 casting cycles. The heating of the mould is not as intensive as during the first 10 casting cycles, but the mould's temperature reaches more than 230 °C after 50 subsequent casting cycles. This has a negative effect on the mould's lifetime (Fig. 1). Figure 7 shows the heating curve of the mould in the central gate. The differences in temperature compared with the mould's cavities are caused by different amounts of metal poured into the mould, which leads to partial or complete filling of the central gate. This causes cyclic thermal loading of the central gate. In Figure 8 the cooling curves reveal that larger number of cycles leads to longer cooling of the mould, even if they start to cool at the same temperature.

Conclusions

The cyclic thermal loading of mould has significant influence on its lifetime [2]. The cyclic thermal loading can be eliminated by the heating of the mould before the first casting cycle and at minimum intervals of 120 s between two cycles. One casting cycle lasts about 40 s, depending on the mould's size. Therefore, it would be better to use more moulds, subsequently changing them in order to avoid the prolongation of the production cycle due to necessary cooling times. This can be accomplished by implementing a carousel mould changer. Such a solution can accelerate the production rate to meet mass production. It is also necessary to pour the same amount of molten metal into mould cavities to guarantee adequate filling of the central gate (maximum to half of the upper mould height).

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References:

[1] BEZNÁK, M. Technologický postup výroby presných odliatkov z nízkotaviteľných zliatin metódou Tekcast. In *Archiwum odlewnictwa (Archives of Foundry)*, 2006, Vol. 6, Nr 18 (2/2), p. 283-288. ISSN 1642-5308, ISBN 83-922029-9-6

[2] HUAN, Z., JORDAAN, G.D. Investigation of the cooling of spin-casting moulds. In *Applied Thermal Engineering*, 2003, Volume 23, Number 1, pp. 17-27.
[3] VEZZETTI, E. Spin casting characterization: An experimental approach for the definition of runners design guidelines. In *Journal of Materials Processing Technology*, 2008, vol. 196, no.1-3.
[5] PODHORSKÝ, Š. Leštenie odliatkov elektrolyticko-plazmovým procesom - vplyv základných parametrov procesu na úroveň dosahovaného lesku. In *Archives of Foundry*, 2006, No. 18, pp. 511-516. ISSN 1642-5308

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