Effective Cooling Method for Spin Casting Process

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Abstract

Spin casting has been widely used in prototyping industry as a secondary process to convert a master model into a functional metal or plastic part. The main problem of the spin casting process consists in the poor thermal conductivity of silicone rubber as mold material which leads to a long cooling time between each casting processes and also to a short life time of mold. To solve this problem, different cooling methods have been developed and compared to each other experimentally. First, air cooling channel has been integrated into the spin casting mold to enhance the heat removal. Secondly, the silicone rubber has been mixed with different metal and ceramic powders to increase its thermal conductivity. The results so far prove an applicability of the developed cooling methods.

1. Introduction

Spin casting is a secondary process to produce metal and plastic parts quickly from an existing master model. It is especially suitable for the manufacture of die casting parts since the manufacture of dies is normally very time-consuming and expensive. In spin casting, a silicone rubber material is used. Since the silicone rubber is a flexible material before vulcanizing, it can be easily formed around the master model, thus making the mold manufacture fast and easy to learn.

Although the silicone rubber material can withstand a temperature of 420 °C and thus allowing the use of low-melting alloys such as tin and zinc for casting, it has a low thermal conductivity. A typical value for the thermal conductivity of rubber is _=0.2 W/Km [1]. This low thermal conductivity leads to an increasing mold temperature in the course of casting process. The constant heating-up of the mold has a damaging effect on the mold surface since it can be worn off due to the thermal stress or even burned off. To avoid such a damage, it is necessary to cool down the mold surface between each shots with compressed air or just with natural convection. This, however, increases the total cycle time. Also, according to [2], the deviation increases with higher mold temperature. For this reason, it is necessary to cool down the mold during spin casting, thereby keeping the mold temperature constant.

2. Development of cooling methods

In the experiment, a spin casting equipment of Tekcast is used. Since the mold rotates during the casting process, it is rather difficult to supply a constant flow of coolant from the outside into the mold as it is mostly done in conventional injection molding. A closed loop of coolant flow also imposes a serious problem regarding the proper sealing of the mold. Under the circumstances, air seems preferable to water. Also in view of easier integration into the existing spin casting equipment, air cooling seems a better choice than water cooling. To realize an air cooling system, the center of the shaft coaxial to the pneumatic cylinder is modified to let the air flow into the inside of the mold, as shown in **Fig. 1**. To connect the lower and the upper mold, a plastic tube is used. By this means, the air flows from the lower part of the mold to the upper part.

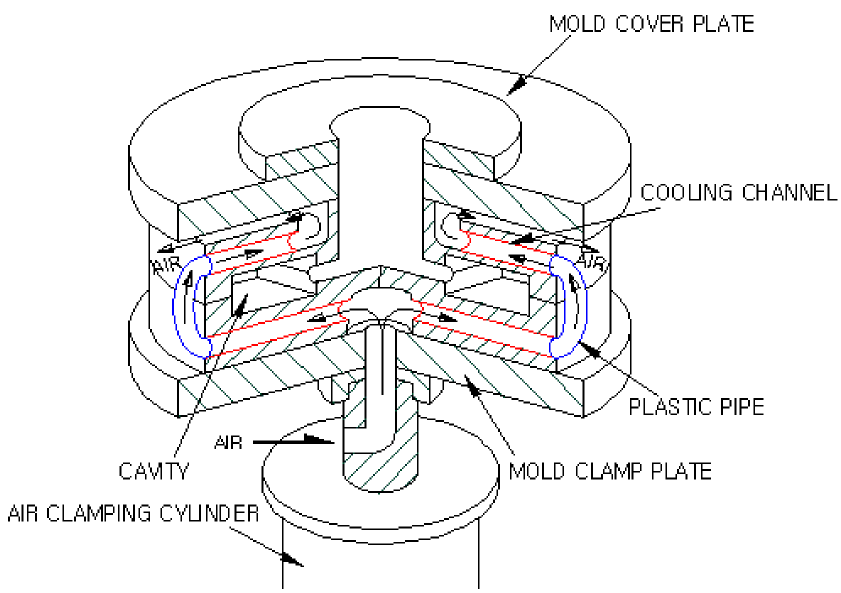
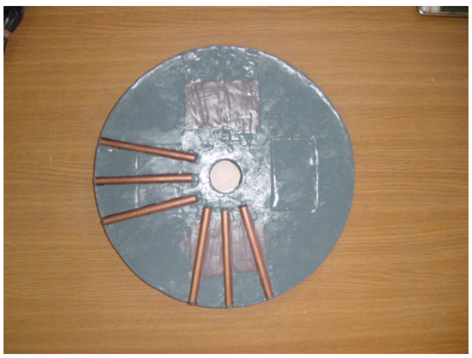


Fig. 1: Flow of cooling air through the mold

The way how the mold is fabricated offers a great flexibility to design the cooling channel into the inside of the mold. According to the thickness of a master model used, an appropriate number of silicone rubber discs are stacked on each other. To implement an internal cooling channel in the mold, the copper pipes are then inserted between those silicone rubber discs, preferably directly beneath the cavity surface**, Fig. 2**. The copper pipes can be bended prior to the insertion and in this way different shapes of the cooling channel can be realized. After vulcanizing of the silicone rubber discs, the pipes are then firmly included in the mold. With regard to a high thermal conductivity around the cooling channel, it is recommendable to let the copper pipes in the inside of the mold.

In order to enhance the cooling effect in the mold during air cooling, it is tried to increase the thermal conductivity of the mold locally around the cavity. A commonly used method for this purpose is to add a high thermal conductivity material to the mold material. For example, a high thermal conductivity metal powder such as aluminum is added to the UV-curable resin which is then used in SLA process to make a mold for low temperature molding process [3, 4]. Two metal powders, copper (_=350 W/Km) and aluminum(_=221 W/Km), as well as two ceramic powders, alumina (_=27.6 W/Km) and silicon nitride (16-33 W/km), are used in the experiment. Although ceramics have lower thermal conductivities compared to those of metals, ceramics offer a higher heat resistance, thus protecting the mold surface better than metals at higher casting temperature. The powder size of used powder materials is between 15-40 _m.



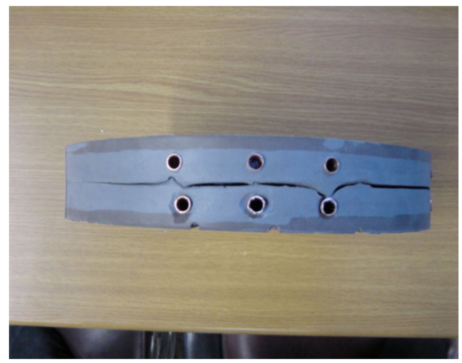


Fig. 2: Copper-mixed cavity and cooling pipes in the spin casting mold

3. Comparison of different cooling methods

To measure how effective each cooling methods are, molds with and without internal cooling channel are compared to each other regarding their surface temperatures. The experimental parameters are as follows:

Clamping pressure:	4000 PSI
Rotating speed:	500 rpm
Melting temperature of zinc:	410 ºC
Pouring time:	1 min.
Flow rate of cooling air:	140-150 l/min

In case of in-process cooled molds, the cooling effect of the combination of air cooling with the copper-mixed cavity is compared to that of the solely air cooled mold as well as to that of the copper-mixed cavity without air cooling. The weight mix ratio of silicone rubber to copper is 3:2. After each shot, the surface temperature of the molds is measured. As shown in **Fig. 3**, the surface temperature of a mold without any cooling reaches 140 °C after 20 shots and then remains almost constant at that temperature. If air is supplied to the mold, the surface temperature is reduced to 110 °C. This result means that even a simple air supply into the mold is an effective cooling method.

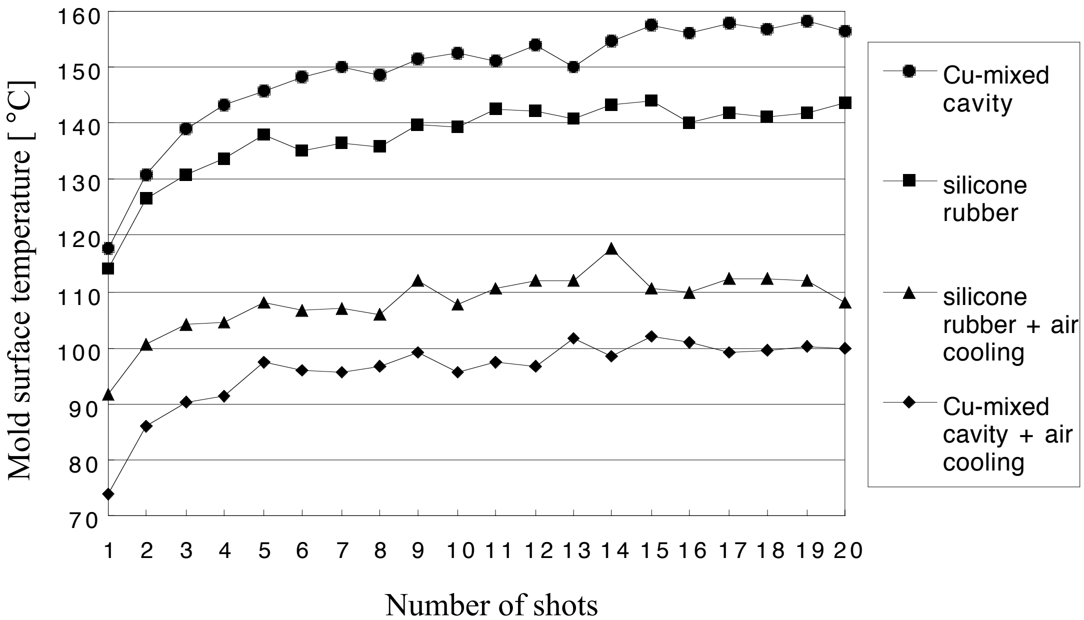


Fig.3: Surface temperatures of molds cooled with different cooling methods

The high surface temperature of the copper-mixed mold around 160 °C proves that the addition of copper to silicone rubber increases the thermal conductivity of the cavity and thus making it a heat sink. When cooled with air, the surface temperature drops to 100 °C, which is around 10 °C lower than that of the pure silicone rubber mold cooled with air. This result implies that the combination of copper-mixed mold with air cooling can be used if air cooling of silicone rubber mold alone is not sufficient enough.

In case of aluminum-mixed molds, the surface temperature also increases to around 160 °C if no air cooling is additionally used, **Fig. 4**. When air is supplied, the surface temperature decreases to around 120 °C. Compared to that of the pure silicone rubber mold, however, this is no distinct temperature difference, the reason being that the mix ratio of silicone rubber and aluminum is not optimal yet. The ceramic-mixed molds also show no distinct cooling effect compared to that of the pure silicone rubber mold. However, the ceramic-added molds show less surface burn after several shots. Therefore, in terms of the surface protection, the addition of ceramic powder gives a distinct advantage over the use of pure silicone rubber mold.

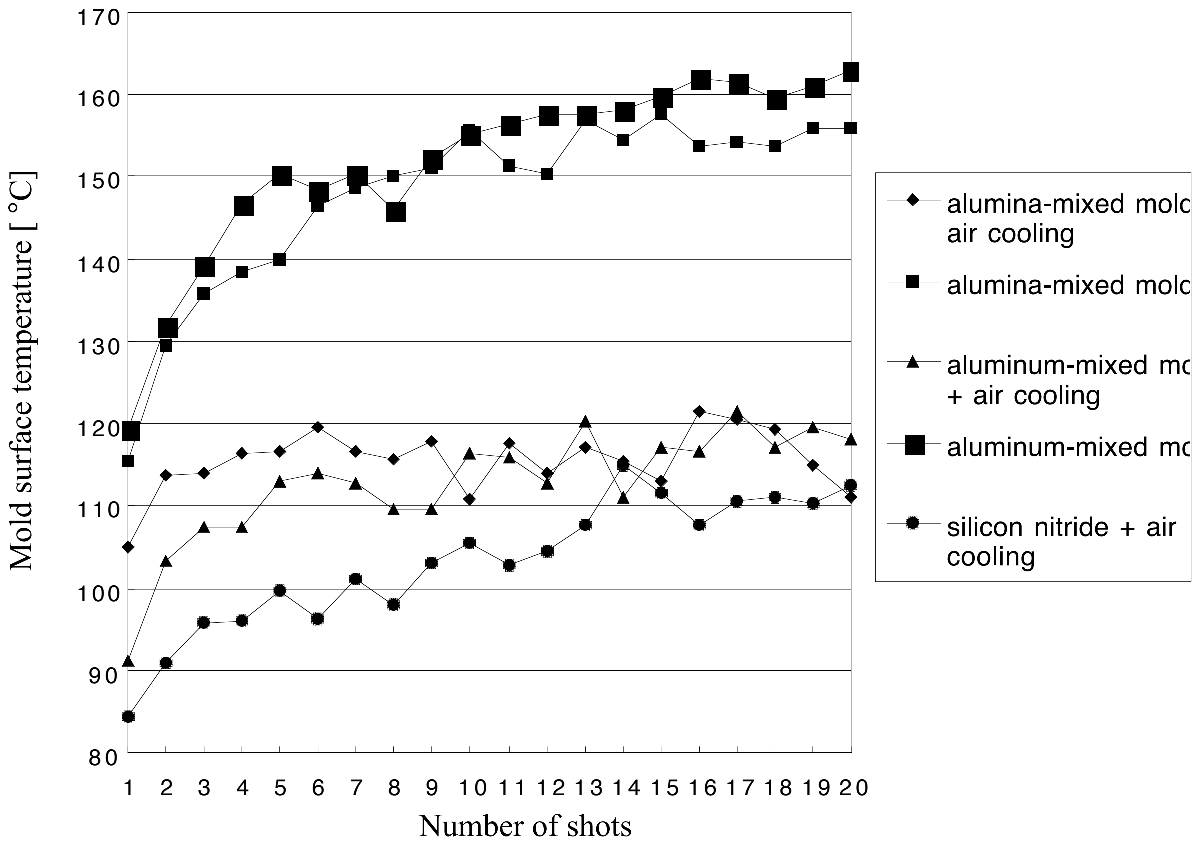


Fig. 4: Surface temperatures of molds mixed with different materials

4. Conclusion

It was aimed to develop an in-process cooling method for spin casting process. Two cooling methods are proposed: First, an insertion of internal cooling channel with copper pipe for air cooling and second, an increase of thermal conductivity of mold by mixing the silicone rubber with a high thermal conductivity material. The result of the investigation shows that a cooling effect can be already achieved when compressed air is supplied into the mold through the copper cooling pipes. By this means, the surface temperature can be decreased by around 30 °C. The cooling effect can be enhanced if materials of higher thermal conductivity such as copper are added to the silicone rubber in the cavity area. Among the tested materials, copper shows the best cooling effect. In case of the copper-mixed mold with air cooling, the surface temperature is even reduced by around 40 °C. This result clearly indicates the effectiveness of the developed cooling methods. Regarding the surface protection during spin casting, ceramic materials offer a distinctive advantage over metals and pure silicone rubber mold. In future work, the influence of mold cooling temperature on the part accuracy has to be investigated in detail.

5. References

[1] http://www.mininglife.com/Miner/general/thermalconductivity.htm

[2] Barnard, L.J., “Spin casting as a tool in rapid prototyping”, Solid Freeform Fabrication 1999, The University of Texas at Austin, 9-11 August 1999, pp. 719-725

[3] Girouard, D., “Molds for low temperature molding processes using rapid prototyping”, The Fourth International Conference in Rapid Prototyping, 14-17 June 1993, Dayton, Ohio, p. 61-66

[4] Nakagawa, T., “Rapid Prototyping in Japan”, The Eighth International Conference on Rapid Prototyping, 12-13 June 2000, Tokyo, pp. 1-16