SPIN CASTING AS A TOOL IN RAPID PROTOTYPING

(CENTRIFUGAL RUBBER MOULD CASTING)

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Abstract

The one thing that comes to mind when parts are manufactured by means of spin casting is the dimensions of the parts, the reason being that it is very difficult to produce castings with high tolerances.

There are numerous factors in the spin casting process that influence the final product. Some of these factors are the temperature of the mould, the temperature of the material used for casting, the spin speed of the mould and the clamping pressure on the mould. The type of material used for casting will also influence the accuracy of the final product.

In our research we control these factors to see what influence a certain factor has on the process. We are working towards being able to predict what the shrinkage of a part cast will be in a certain material, to incorporate a shrinkage factor in the prototype, to ensure that the final product will be on size.

1. INTRODUCTION

It is very important to be able to reproduce parts that have been developed by Rapid Prototyping to be able to evaluate the product and to manufacture them after the development stage. Spin Casting or Centrifugal Rubber Mould Casting is the cheapest means of achieving this. There is only one problem and that is the accuracy with which this can be done. Shrinkage of the material with which you cast is the main reason for the difficulty to cast parts with a high dimensional tolerance. The other process factors can be changed to get the required results. These factors are the temperature of the casting material, the spin speed of the mould, the clamping pressure applied on the mould and the temperature of the mould when you cast. This research is aimed to be able to get the best parameters at which to cast and to get the smallest shrinkage of your part. If you can predict the shrinkage of your part at certain casting parameters you are able to alter your master so that you will get the wanted final product.

2. TYPICAL SPIN CASTING SET-UP

Figure 1 shows the typical spin casting set-up, which consist of a spin caster, an LP-gas or electric furnace, and a vulcaniser with applicable vulcanizing frames. This normally can be purchased for less than the cost of a moderately complex mould.

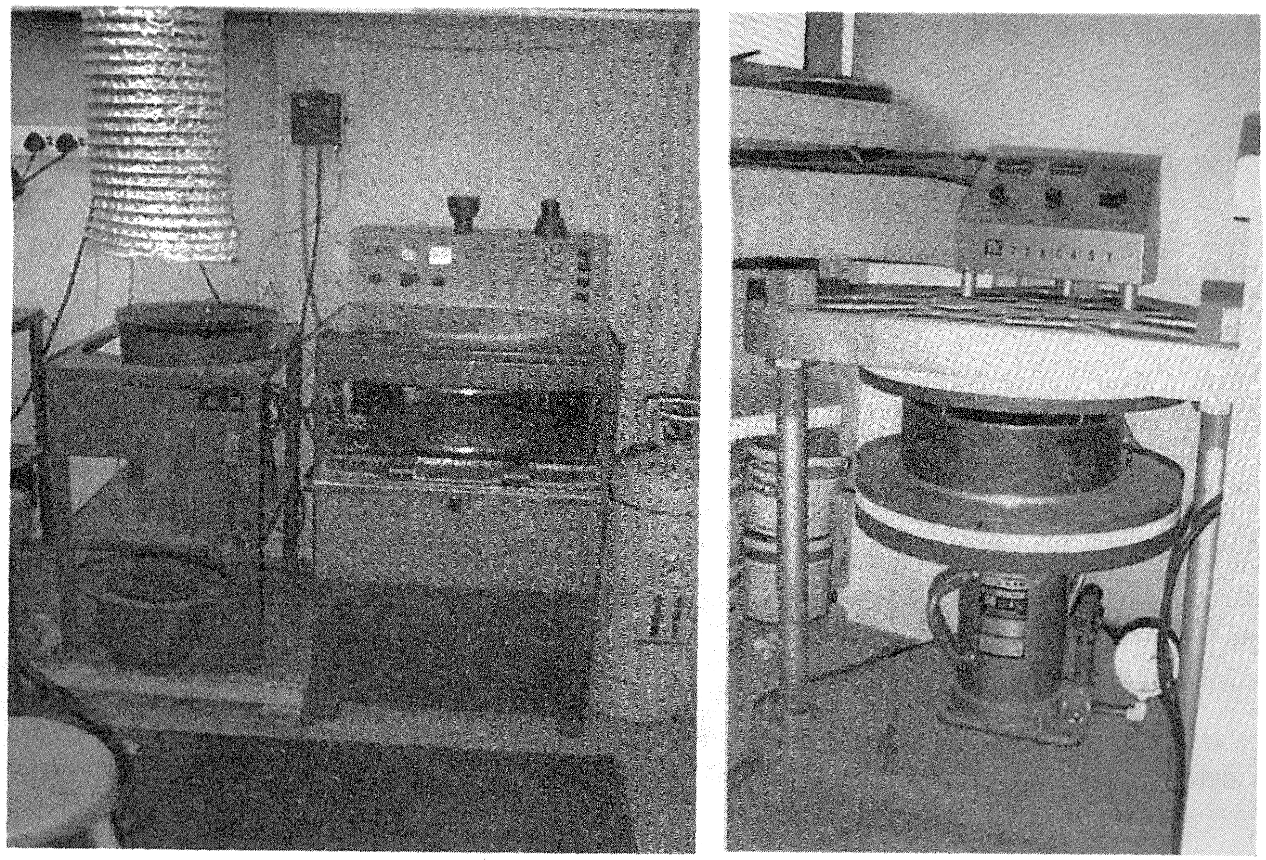


Figure 1 – A complete Spin Casting set-up.

3. PROCESS OVERVIEW

3.1 PROCESS CONTROL

The front loading system as shown in figure 1, provides three key functions for the production of functional, highly engineered or detailed parts. [1]

3.1.1. Mould stabilization without distortion:

The special mould clamping system centers and supports the mould in a horizontal plane, while a pneumatic cylinder applies an even, closely controlled clamp pressure which holds the mould halves firmly together during pouring without distorting the mould cavity by over-squeezing.

3.1.2. Mould pouring under pressure:

Rapid, speed-controlled rotation provides the adjustable centrifugal force that distributes the liquid metal or plastic throughout the mould, filling all cavities and intricate details under pressure before the material can solidify or set up.

3.1.3. Complete control of centrifugal force and pressure:

The system is fully controlled and automated to provide a complete range of spin speeds and clamp pressures. This optimizes the part's quality, tolerances, precision and detail, while improving productivity of the spin casting cycle.

3.2 SPIN CASTING PROCEDURE FOR HEAT-CURED (VULCANISED) MOULDS

3.2.1. Mould making

Parts are laid out on a disc of uncured silicone rubber. [2] Depending upon model/pattern thickness and shape, cavities may be cut or moulded by hand to accommodate the part. The uncured silicone material is soft and hand-mouldable like clay. (Figure 2) The mould parting line is formed at this stage and can be built up or lowered around any section of the model/pattern, to accommodate critical edges, surfaces, etc. Parts of any complexity can be handled.

At this time, cores and pullout sections can also be incorporated, if required. When special features like holes or bosses need to be incorporated, virgin grade Teflon inserts can be used. Through the use of a CNC lathe, an interchangeable core system has been developed, which speeds up the process for mass production, and contribute to accuracy. A special jacket-approach, as shown in figure 3, has been developed to get rid of the parting line on critical surfaces. Release agent is sprayed on the mould and "Acorn" nuts are arranged around the edge where-like pins of a die- they precisely position the mould halves to each other.

3.2.2. Vulcanization

The uncured mould is placed in a ring-shaped vulcanising frame. This frame is placed in the electrically heated vulcanising press for curing. Hydraulic force (15 MPa for WACKER™ silicones, and 14 MPa - 21 MPa for TEKSIL™ silicones) clamps the mould frame shut between the heated platens, forcing the silicone into all details of the model/patterns.

The heat cross-links the uncured silicone. The resulting mould is tough, resilient, dimensionally accurate, and heat and chemically resistant. After vulcanisation the mould is easily flexed to released the patterns (and later, parts) from the cavities. This is true even for patterns with a wide variety of undercuts.

3.2.3. Gating and venting

The gates, runner system and air vents are easily cut into the rubber with a sharp knife or scalpel. (Figure 4) If the initial spin-casting tests show a need for faster flow or more air venting, the in-gates can be cut thicker and the air vents may also be drilled into the cavity to aid in the removal of entrapped air or gases. Similar gating and venting systems is used for both metals and plastics, so both materials can be cast in the exact same mould for evaluation, if desired.

3.2.4. Spin-casting set-up

The mould is placed into the front loading unit; automatically centred and closing the door actuates a pneumatic mould clamp. Spin speed, clamping pressure and cycle time can be fully adjusted.

3.2.5. Pouring

After the spin cycle starts, the liquid metal or plastic is poured into the caster. Pressure caused by centrifugal force pushes the liquid through the mould's runner system, completely filling every section; corner, detail and surface finish in each mould cavity. (Figure 5)

3.2.6. Parts removal and mould recycling

After metals solidify and plastics set up, the parts are quickly removed from the mould.

Figure 2 - Mould lay-out and design

Figure 3 – Development of a "Jacket"

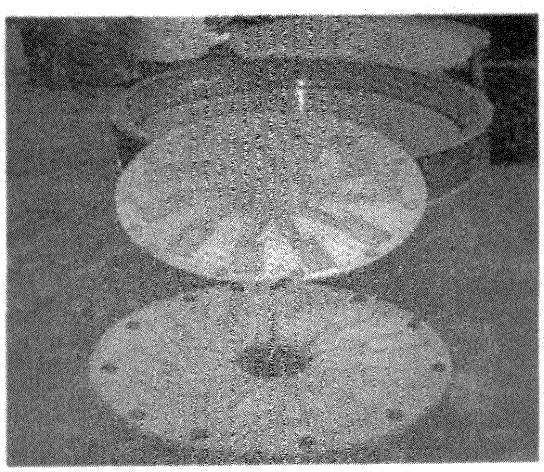


Figure 4 – Gating and Venting

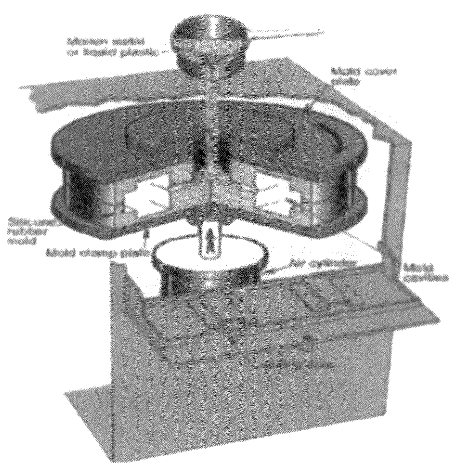


Figure 5 – Pouring by hand

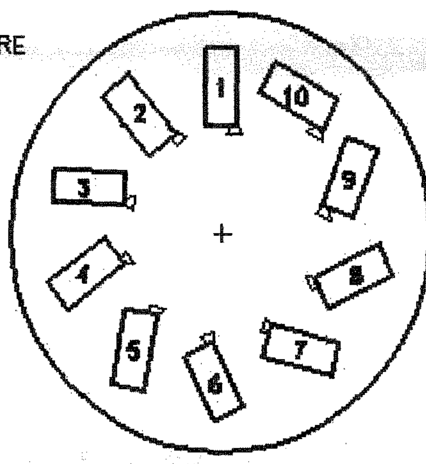
4. THE WAY RESEARCH WAS DONE

To obtain the shrinkage factor of the parts numerous experiments were done to control some of the factors that influence the casting process and change one factor after a set of results were obtained. The experiments were done with the Wacker Silicones using the same vulcanizing parameters. The temperature of the melted metal was kept constant by the automatic temperature control of the Tekcast furnace. The mould temperature was checked by drilling a hole in the side of the mould and inserting a temperature probe in the hole and reading the mould temperature at the inside of the mould. The mould was only cast after it reached the required temperature.

The parts that were machined were rectangular prisms with dimensions of 40.17-mm length, 19.38-mm width and 9.79-mm thickness. These masters were machined out of mild steel to the required size. Experiments are being done on cylindrical parts to see what the effect is on round objects. The cylinder's dimensions were 40.65 mm outside diameter, 9,36 mm thickness and a hole drilled through with a diameter of 13.17 mm. It was machined from mild steel, copper and vesconite.

The mould layout was done in such a way that the ingates were the same distance from the centre so that the centrifugal force did not influence the outcome of the experiments. Ten prisms were placed at certain angles to the centerline. The first prism was placed with its longitudinal side on the centerline. The tenth prism was placed 90^0 with the centerline. The ingates were cut to the same size so that the melted metal would flow into the cavity at the same speed. All the experiments were done with AZM 6 Zinc and JM 90 Pewter as the casting material. The measurements were done with a digital vernier with accuracy of 10^{-2} mm.

DISTANCE FROM CENTRE
TO OUTER EDGE :
1. 94.98 mm
2. 96.00 mm
3. 95.74 mm
4. 95.86 mm
5. 97.73 mm
6. 96.77 mm
7. 94.16 mm
8. 94.88 mm
9. 94.11 mm
10. 91.98 mm



DISTANCE FROM CENTRE
TO INGATE :
1. 55.14 mm
2. 56.64 mm
3. 54.67 mm
4. 55.40 mm
5. 55.53 mm
6. 56.32 mm
7. 56.08 mm
8. 57.01 mm
9. 57.14 mm
10. 74.57 mm

Figure 6 –Placing of masters in mould

5. RESULTS OBTAINED

5.1. Results from the rectangular prisms with AZM 6 zinc

From all the experiments done the best position of the master in the mould was position 10 which was 90^0 with the center of the mould. Looking at the different speeds at which the mould was spun the best results were obtained from 650 rpm. At this speed the percentage fill of the cavity was 98% which was also the best of all the experiments. All results shown are the percentage deviation from the original master model.

PRESSURE PSI	MATERIAL TEMP.	MOULD TEMP.	SPIN DIRECTION	MEDIANS	RESULT
20	388	50	CLOCKWISE	LENGTH	0.66
				WIDTH	-0.18
				THICKNESS	0.41
				AVERAGE MED.	0.3
				% FILL	98

Table 1: Results at 650 rpm

When the speed was kept constant at 450 rpm and the clamping pressure was changed ,it was found that the higher the pressure the bigger the thickness deviation from the original thickness. The other dimension did not change that much. But with the lower pressure, the parting line was more visible and in some cases there were signs of shifting of the two mould halves. This is unacceptable in the production of parts with high tolerances.

PRES-SURE	MAT. TEMP	MOULD TEMP	LENGTH	WIDTH	THICK.	AVE-RAGE	% FILL
[illegible]	388	35	1.72	1.08	3.32	1.85	100
[illegible]	388	35	1.83	1.06	4.81	2.56	100
30	388	35	1.62	1.24	4.29	2.38	90
35	388	35	1.68	1.34	5.42	2.81	100

Table 2: Results at 450 rpm

The change in mould temperature had the effect that with higher temperature the deviation increased.

PRES-SURE	MAT. TEMP	MOULD TEMP	LENGTH	WIDTH	THICK.	AVE-RAGE	% FILL
25	388	35	1.83	1.06	4.81	2.56	100
25	388	50	1.20	1.7	5.62	2.84	90

Table 3: Results at 450 rpm with different mould temperature

By changing the spin direction, the deviation decreased due to the fact that the speed with which the melted metal flowed into the cavity was reduced by the change in direction. This also had a negative effect because it was more difficult to fill the cavity.

5.2 Results from the rectangular prisms with JM 90 Pewter

The same results as for the zinc were obtained. The best results were at the higher speeds due to the centrifugal forces and the moment of inertia of the material. As a result of the fluidity of the pewter, the highest speed at which the experiments were done was 550 rpm. With the higher speeds, the pewter flashed through the mould split line.

PRESSURE PSI	MATERIAL TEMP.	MOULD TEMP.	SPIN DIRECTION	MEDIANS	RESULT
30	280	50	CLOCKWISE	LENGTH	0.29
				WIDTH	-0.08
				THICNESS	2.5
				AVERAGE MED.	0.94
				% FILL	100

Table 4: Results at 550 rpm

By increasing the clamping pressure, the other dimensions stayed almost constant but the thickness deviation increased due to the fact that the cavity became smaller with the higher pressure. With the lower pressure, the parting line was unacceptable. The best results were obtained at 30 psi.

5.3 Preliminary results from the cylindrical parts

From the results obtained so far it was found that the shape of the parts became elliptical to a lesser degree. The outside diameter decreased and the inside diameter of the hole increased. More experiments should be done on the cylindrical parts to be able to make a prediction on what the shrinkage in the different axes will be.

6. CONCLUSION

With these results it is possible to predict what the dimensional deviation of a certain material will be when used in the spin casting process under certain conditions. By making use of these shrinkage factors the master can be upscaled and then from that produce the parts required. The next step in this research is to produce a master which has been scaled up with the SLA machine and then cast a few parts. This is in order to test the results and see if the predictions are correct and to see if it works in practice as indicated by the experiments.

7. References

[1] Schaer, L.S & De Santis, E (1994) Moldmaking & Spin-casting Instruction Manual, Tekcast Industries.

[2] de Beer, D.J. (1998) From CAD Models to Multiple Parts Using SLA and Spin Casting. Proceedings of the Time-compression Technologies Conference 1998, Nottingham, UK.