Process simulation and morphology evolution of micromouldings

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ABSTRACT: Micro injection moulding is an advanced method of injection moulding techniques. It provides us with the opportunity to develop micro parts in mass production. For producing these micro parts, several heating systems have been designed. One of these systems is the infrared heating system, known as variotherm system. Other micro injection parts were produced without a variotherm system, by means of heating rods. They were produced under different process conditions and have been subdued to a morphology and skin-ratio research. The different process conditions were created by changing the mould and injection temperature. Results were concluded on the influences of these changes on morphology, skin-ratio and injection pressure. Pressure curves were obtained by the use of sensors inside the mould during the injection of the micro parts. All of this data will support to understand the influences of changing process parameters on the injected micro part.

1 INTRODUCTION

Micro injection moulding is an upcoming industry for the last 10 years. A lot of research has been done to improve the quality of the part and the process conditions. The great advantage of the small dimensions, mass production and the variety of compositions with a high level of detail, motivates further research in that area.

2 THE MOULD WITH HEATING AND COOLING

2.1 *The mould*

The research mould consists two inserts. The cavity insert is flat and is integrated with two P/T sensors and one P sensor for data retrieval on three different positions on the part's surface. The core insert has the shape of the part with micro details. Both parts are a little different, as illustrated in Figure 1, since one of the inserts has been provided with minerature cones. The mould is designed on a way that the left and right micro part can be produced separately. The choice of producing one or two parts at the same time can easily be achieved by rotating the turnable lock for 90°. It is centered in between the two cavity inserts,

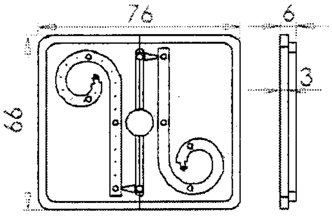


Figure 1. Core inserts [1]

2.2 *Heating and cooling system*

The heating system consists of four heating rods. Two heating rods on each side of core and cavity, with each a power of 250W. They will heat up the mould until the preferred temperature.

The cooling will be done by a water flow trough the cooling channels.

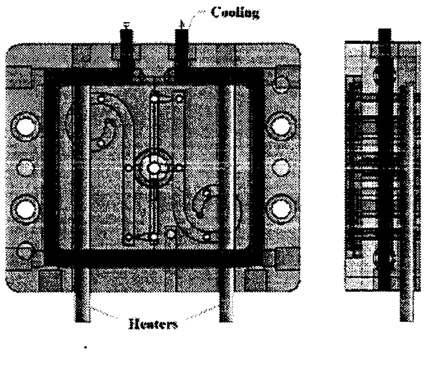


Figure 2. Cooling and heating channels [1]

3 VARIOTHERM SYSTEM

3.1 Infrared system

The infrared system as illustrated in Figure 3 has been designed to improve the melt flow inside the mould and the quality of the part. Before every new cycle, the infrared system will move between the mould and heat up the surface. Once the required temperature has been reached, the system will retract and the injection cycle can continue.

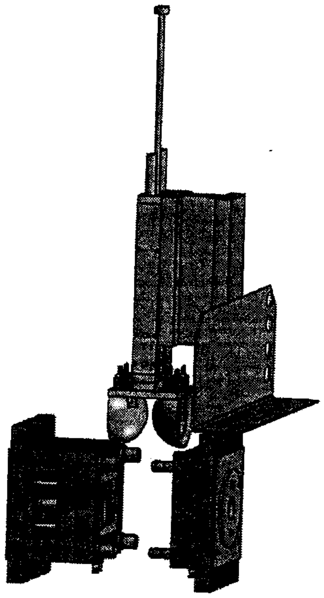


Figure 3. The infrared system

The infrared system has three main components.

The first one is the **pneumatic cylinder**. A pneumatic cylinder was chosen because of the comfort of pressured air. It is easy to produce and it was immediately available at the research facility. The cylinder will be controlled by a 5/2-way single-pilot pneumatic valve, pneumatically actuated in one direction with spring return.

It has a displacement of 200 mm, but has an adjustable end position to insure the precise distance the cylinder should extract.

Two guiding bars will prevent the extractable part of the cylinder of turning around, providing a controlled movement of the infrared system in between the mould.

The second component are the **lamp caps**. Two lampcaps have been designed for the purpose of concentrating the infrared light onto the surface of the mould and to prevent any radiation to escape.

A good heat dissipation after the system has retracted is important to prevent any malfunctions in the electrical circuit. For this reason there was chosen for a shell formed lamp cap. A solid structure would absorb too much heat and would be less practical at cooling down. For the same reason, aluminum was chosen as material because of the low absorption factor. Iron for example has an absorption factor of 40%, whereas aluminum has 10%. Figure 4 illustrates the different absorption factors according to the IR light (Red line). The inside of the lamp caps will be coated with a reflective paint to improve the reflection of the infrared light.

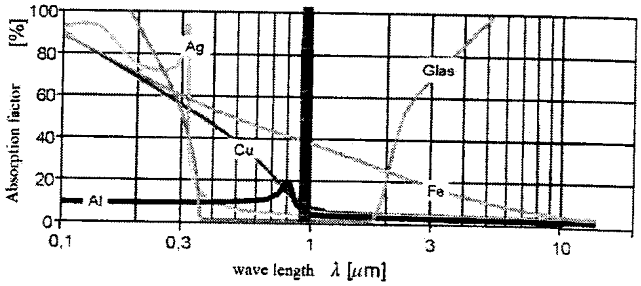


Figure 4. Absorption factor according to wave length [1]

The last main component are the **infrared lamps**. For this system, halogen infrared lamps have been selected. Six lamps will heat the surface of the mould. The lamps are Phillips 6990P with a power of 1000W and working on 120V. Each of the two lamp caps consists of three infrared lamps. The lamps and lamp caps will then be mounted to the plate, which will be mounted to the pneumatic cylinder.

4 THE MICRO INJECTION PART

The micro injection part is produced in PP and has an overall thickness of 0,5 mm. It consists out of 3 main sections. The first section is a long rectangular part with a length of 43mm and a width of 4mm. The next section follows two half sized circles with a different diameter and the last section is a mineraturе arrow. The arrow's maximal dimensions are 3mm to 3,5mm. Also, 18 minerature cones have been placed on the micro part. The dimensions are shown in Figure 5.

Considering the overall length and width to the height of the part, it is possible to conclude that this micro part has a high surface to volume ratio.

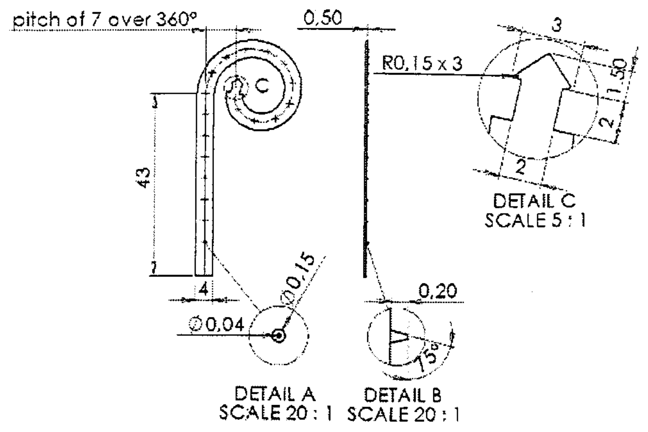


Figure 5. Micro part dimensions [1]

5 PRESSURE CURVES RESEARCH

5.1 Location sensors

A pressure curve research was made to compare the pressure in two different locations of the part. To retrieve the needed information, two sensors are integrated. One sensor is located at the beginning of the micro part and another at the end of the straight section of the micro part. Figure 6 illustrates the locations of the sensors.

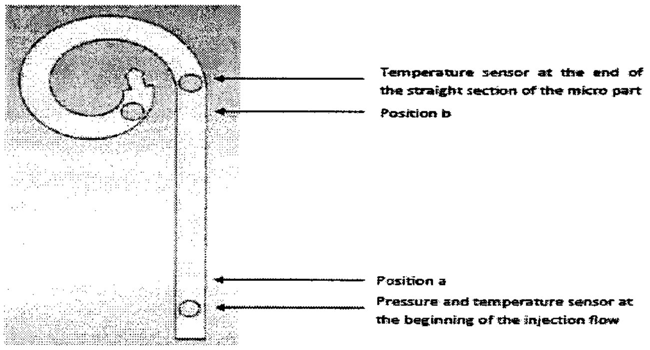


Figure 6. Localization of sensors and section for morphology research

5.2 Pressure curves

The data from the sensors is collected into the graphics of Figure 7. They represent the injection pressure data while using different injection and mould temperatures. The left column represents the data from the part at an injection temperature of 200°C and the right column the data at injection temperature of 240°C. Every row represents a different mould temperature. The first row illustrates the data at a mould temperature of 70°C, the second row at 90°C and finally the third row at 110°C mould temperature.

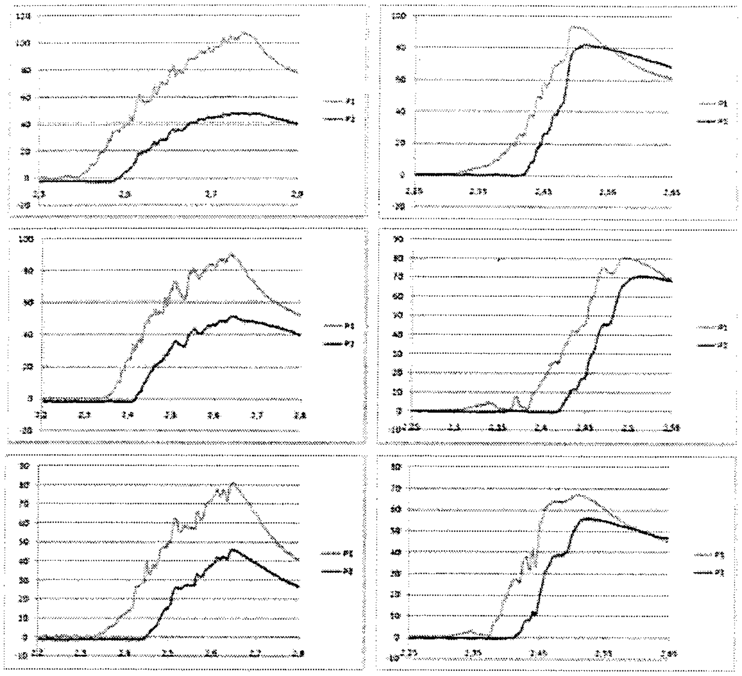


Figure 7. Injection pressure curves

5.3 Conclusions

Following results were obtained:

- An increasing mould temperature results in a pressure drop at the beginning of the part. The higher the temperature of the mould, less pressure is needed for the filling of the micro part
- At the second location, the pressure is constant for lower injection temperatures. On the other hand, higher injection temperatures lower the needed pressure for the filling process.
- A shorter injection time is needed when using higher injection temperatures.

6 MORPHOLOGY RESEARCH AND SKIN RATIO

6.1 Morphology

The morphology of the micro part has been analyzed close to the sensors in positions a and b, as shown on Figure 6. The samples have a thickness of 15 µm. For every process condition, as mentioned above, samples are produced at both locations. The area at the sensor location is avoided due to turbulence of the melt flow at the small widening when passing the sensor. Figures 8 and 9 illustrate the morphology analysis results.

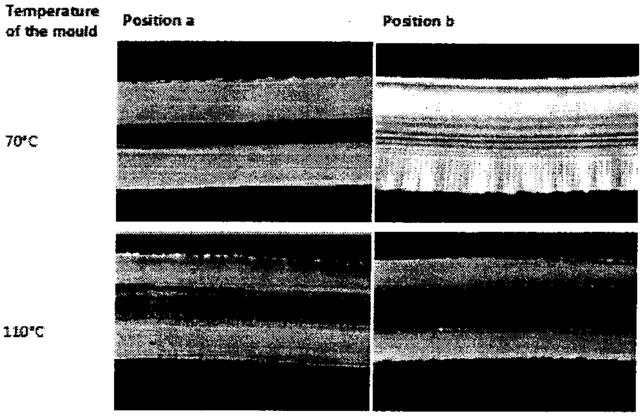


Figure 8. Morphology at 200°C injection temperature

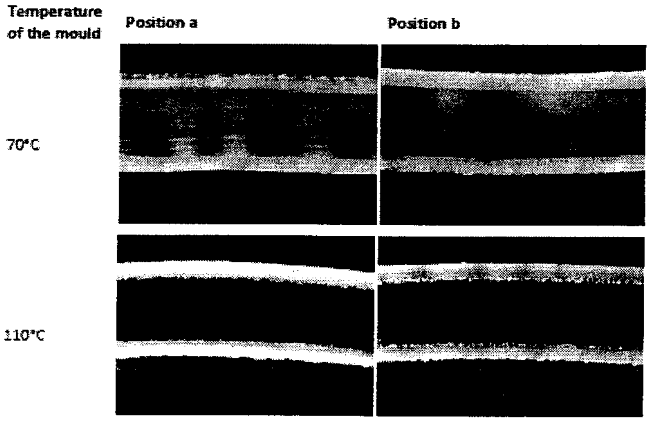


Figure 9. Morphology at 240°C injection temperature

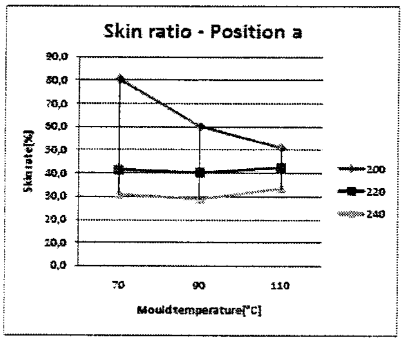
As illustrated, the biggest core thickness between position a and b can be noticed at lower temperatures. The combination of high shear rate in the beginning of the part and lower injection temperature produce more skin [2].

It has also been analyzed that the increasing mould temperature influences the core thickness. It diminishes with a higher injection temperature. The higher the injection temperature will be, the smaller the differences in core thickness.

Both the increase of injection and mould temperature provide a better crystallization of the part. The higher the injection temperature, the slower the cooling process and the more crystallization occurs. Based on the results, the increasing mould temperature has most effect on the morphology.

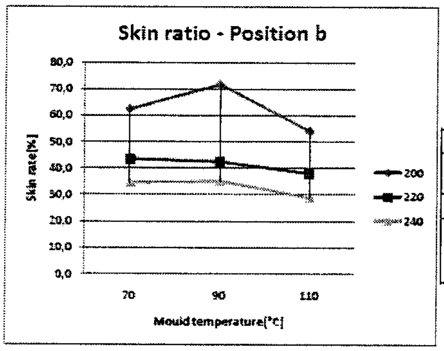
6.2 Skin ratio

For every sample that was analyzed, measurements were made to calculate the skin ratio. The results are illustrated in Figures 10 and 11.



Skin ratio - position a			
Injection temperatures	Mould temperatures		
	70	90	110
200	80,4	60,2	51,0
220	41,6	40,2	42,4
240	31,0	28,9	33,5

Figure 10. Skin ratio – position a



Skin ratio - position b			
Injection temperatures	Mould temperatures		
	70	90	110
200	62,4	71,7	53,9
220	43,6	42,4	38,0
240	34,7	35,3	28,8

Figure 11. Skin ratio – position b

Increasing the mould temperature has a great effect on lowering the skin ratio, when injecting at low injection temperatures. The effect diminishes when using higher injection temperatures. However, depending on the position on the part, a high mould temperature can also increase the skin ratio. A compromise should be made.

Higher injection temperatures also provide us with a decrease of skin ratio. For every increase of injection pressure, the lowering of skin ratio decreases.

7 CONCLUSION

Micro injection moulding is a new and growing industry. It offers opportunities in several industries such as the mechanical and medical sector. Its short cycle time together with the use of a wide range of polymer materials and an easy automatisation of the process are some of the advantages.

To improve the filling of micro features, several variotherm systems have been designed. Their purpose is to heat up the surface of the mould before every cycle to improve the melt flow during injection.

Different places in the part result in different pressure curves, as expected. The data retrieved from the sensors, both at different location, shows that pressure curves can vary with increasing injection or mould temperature. At the beginning of the part, a higher mould temperature will result in a lower pressure. At the second sensor, the pressure remains the same for lower injection temperature. For a higher injection temperature, in most cases the pressure reduces when the mould temperature is increased.

When combining a low injection temperature and a high shear rate, it produces more skin. For this reason, there will be more skin in the beginning of the part at low injection temperatures.

An increase of the injection or mould temperature results in more crystallization inside the part, due to the slower cooling process.

Higher injection temperatures also provide us with a decrease of skin ratio. Increasing the mould temperature also has an effect on lowering the skin ratio, when injecting at low injection temperatures. The effect diminishes when using higher injection temperatures.

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