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Cooling of Plastic Injection Moulds Using Conformal Cooling Canals

Mustafa GÖKTAŞ[1], Abdulmecit GÜLDAŞ[1], Ömer BAYRAKTAR[2]

Abstract

This study has been done to increase the effect of the cooling stage which is one of the most critic stages during plastic injection moulding. A practical way for conformal cooling canal has been presented to increase the production quality and reduce the production time. Firstly, a conformal cooling canal surface to the cavity surface has been created to produce this system. The roots which have been created by offsetting the edge of surface have been converted to cooling canals. An algorithm has been developed to preserve the distance between the canals and the distance between mold canals for the plastic parts which have a complicated geometry. The cooling performance of these cooling canals has been examined by conducting numerical analysis. It has been noticed that the cycle time has decreased by increasing the cooling effect with conformal cooling canals.

Keywords: Injection molding, conformal cooling, canal design, high speed molding

1. INTRODUCTION

Plastic injection moulding is one of the most common plastic processing methods. This method consists of stages such as melting of the plastic material, filling the mould, cooling and de-moulding. One of the most time consuming stage of the moulding cycle is the cooling process. Besides reducing the cooling time, an effective cooling process also reduces the possibility of injection errors of sinking and warpage which depends on the thickness. Moreover, it also effects the rate of crystallization of particularly the semi-crystalline plastics during the solidification stage of the molten plastic.

An effective cooling system is required to reduce the cycle time and production of high quality plastic part. Traditionally, cooling process is provided by cooling canals which are obtained by drilling the mould plate which is close to the mould cavity. Although this method is compatible with plastic parts, it does not provide regular and homogeneous cooling to parts with complex surface [1]. This results in problems such as warpage, sink and irregular withdrawal on the plastic part [2, 3]. Lack of uniform results to non-homogenous pressure and temperature distribution in the mould cavity. This causes undesired results on production of quality product and moulding errors. Also, channels which are obtained by conventional drilling becomes insufficient for uniform cooling if the thickness of the plastic part is not same everywhere.

Various studies in literature have been conducted to create cooling canals in regards to plastic part geometry and thickness as well as providing cooling compatible to mould cavity geometry [1-3, 7-12]. Cooling holes following the outline of part geometry to provide effective cooling have been used in literature. But, these drilled holes which have linear line do not provide effective cooling to complex parts with concave and convex surfaces [4-7]. Instead of these classic holes, curtain and fountain methods have been used to cooling mould cores but homogenous temperature distribution was not fully obtained [8, 9].

[1] *Corresponding author: Gazi University, Technical Sciences Vocational School, 06374, Yenimahalle/Ankara, Turkey.*
mustafagoktas@gazi.edu.tr

It is known that cooling canals obtained by linearly drilling are insufficient for plastic part production of complex parts and variable thicknesses. Due to developing manufacturing technologies, it is possible to create cooling canals with different ways depending on the manufacturing technology instead of the conventional drill holes. One of the possibility is production with metal laser sintering technology. with the development of metal laser sintering technology, it is possible to create cooling canals which are conformal cooling (shape adaptive), have desired geometry, desired frequency and the most effective cooling ducts. Although the high cost of metal sintering method creates a limitation, cooling canals with desired geometry can be produced. Besides, one of the advantages of metal sintering technology is using metal powder with desired ratio which provides creating an effective heat transfer within the mould. Different geometries to the cooling canals are being tested due the possibility of creating mould cores with metal sintering. In this regard, various methods have been proposed in literature for conformal cooling canals to create effective cooling [1, 10-13]. Voronoi curve and contour lines have been used in several proposed methods. However, the distance between the canals regarding to the surface curve are ever-changing and the flow in the canals cannot be fully controlled. Furthermore, topologic optimisation studies have been conducted to reduce to mould cores produced by incremental production method [12, 13].

Regular and effective cooling to mould cores and mould cavity with complex geometry is intended in this performed study. Conformal cooling canal design method is proposed to provide effective cooling. Firstly, in CAD, part surface has been offset to the outside and an offset algorithm has been used for removal of errors [14, 15]. Then, the edges of the newly formed faces were offset onto itself. The path which the cooling canal will follow was determined by combining the obtained offset lines. By using Moldflow software, the analysis reports of the designed canals have comparatively examined [16].

2. MATERIAL AND METHOD

2.1. Plastic Part and Canal Dimensions

Plastic parts with curve surface geometries were addressed and studied to analyse in the scope of this study (Figure 1). The reason for choosing plastic parts with curved surface geometry is to select a geometry which cooling cannot be done effectively with the conventional drilling method. The thickness of the part is 2mm and the outer dimensions are 188 x 120 x 116 mm. The mould cavity needs to be filled to conduct cooling analysis. Polypropylene (PP) is selected as the plastic material for this procedure.

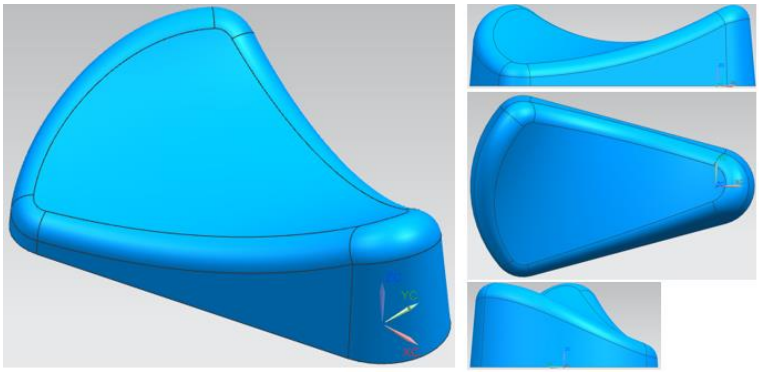


Figure 1. Plastic part

Circular cross section cooling canal has been chosen as cooling canals and the most widely used hole diameter and spacing in literature and industry were chosen (Figure 2).

As shown in Figure 2; canal diameter is d=8mm, distance between canal axis b=20mm, distance between canal axis and mould surface a=14mm and plastic part thickness t=2mm.

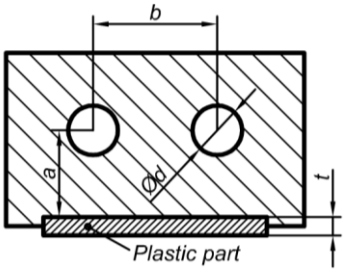


Figure 2. Dimensions of cooling canal

2.2. Creation of Cooling Canals

Firstly, during creation of cooling canals, internal and external surfaces of the plastic part have been offset in regards to the distance between the canal axis and mould surface being (a) as shown in Figure 3. The distance of the canal to the mould surface have been identified due to canal axis being created on this surface.

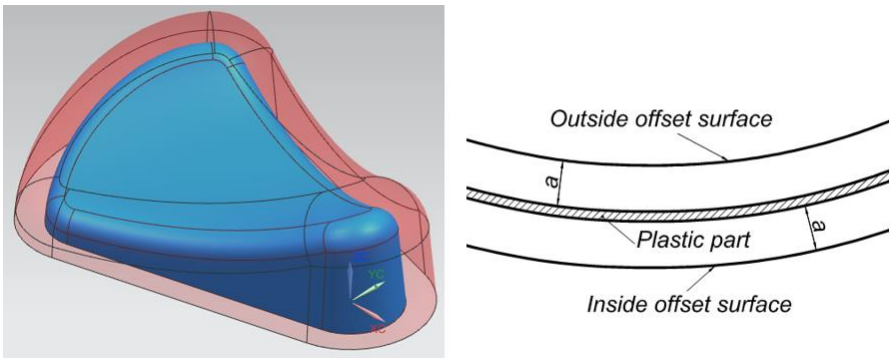


Figure 3. Offsetting of plastic part surface

After surface offset, the slopes of the boundary edge are offset to surface for identifying the canal paths. During this offset process, offset distance "b" has been defined as the distance between the cooling canal paths. During conducting the offset procedure, a plane surface which is perpendicular to a point within the boundary curve has been identified. A circle with a radius of "b" has been created with the centre being on the boundary curve. This circle can be seen in Figure 4.

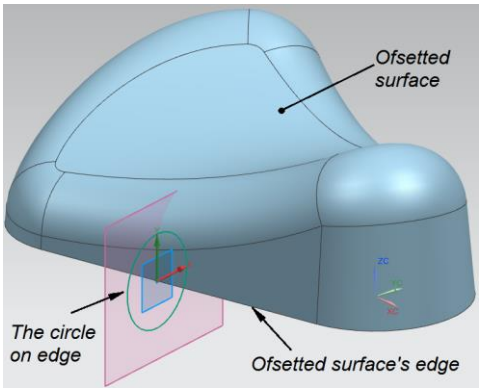


Figure 4. Circle created on the boundary curve

A tube with a radius of "b" has been created by sweeping the circle throughout the boundary curve as shown in Figure 5. The curve inter section between the generated tube and offset surface has been identified. This curved offset is the offset of the boundary curve on the surface. The self-intersections occurred during inter section procedure have been removed by creating an offset algorithm [15, 16]. The results of offsetting of boundary curve can be seen in Figure 6.

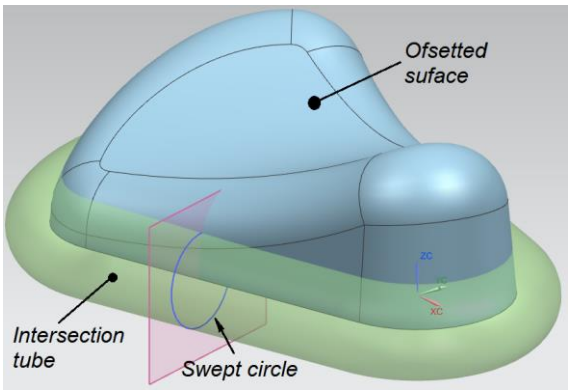


Figure 5. Obtaining the inter-section tube

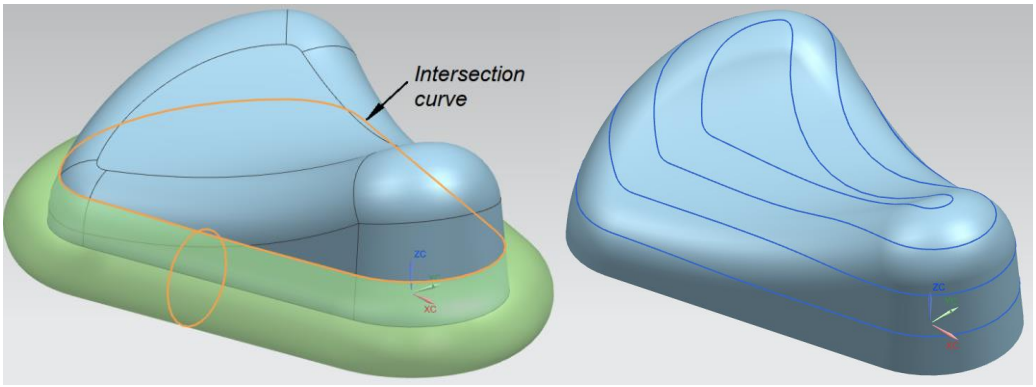


Figure 6. Obtained offset curves

Other canal paths were obtained by repeating the sweeping and taking cross-section using offset curves. The canal curves which are obtained during this procedure were combined to create a spiral. The spiral-formed canal paths are shown in Figure 7. sharp turns which might hamper the flow of the coolant have been softened by rounding.

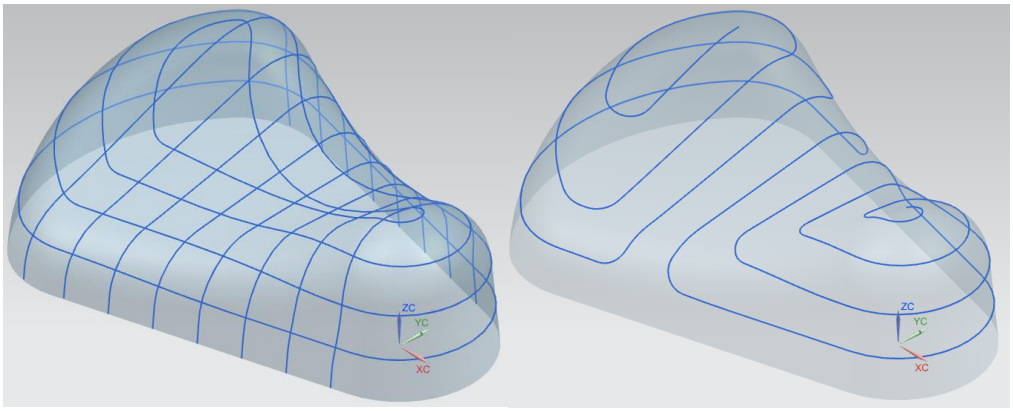


Figure 7. Spiral-formed canal paths

In order to prevent growth differences between inlet and outlet temperature of cooling water, flow line has been converted parallel line by line dividing. Distance from each other and cavity wall of canal are maintained at fix. Cavity and conformal cooling canal are shown in Figure 9.

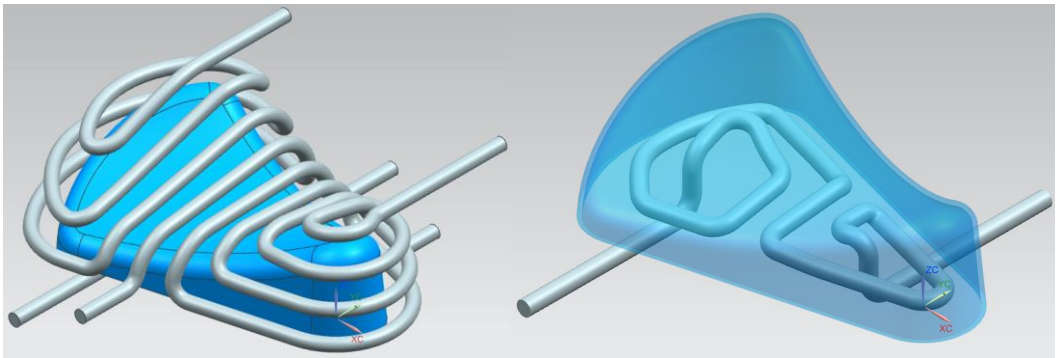


Figure 8. Conformal cooling canals in both sides

3. RESULTS

Both typical cooling canal and conformal cooling canal are designed and modelled with CAD software and then cooling analysis of these canals have been performed. Polypropylene (PP) Hostacom G2 U02 are used as a plastic material to filling of cavity and cooling analyses. Mesh generation is produced before cooling and filling analysis. In context, 685000 mesh element are generated for conformal cooling canal and 292000 mesh elements are generated for typical canal. As recommended processing parameters, melt temperature 230˚C, injection temperature 160˚C, and mould temperature 40˚C are used. 5 lt/min is determined for flow rate of cooling water. Three inlet and three outlet are determined in conformal cooling canal, and also two inlet and outlet are used in typical canal. Cooling analysis results of conformal cooling canal and typical cooling canal (straight line) have been presented in Figure 9. In Figure 9, average temperatures distribution of plastic part at 7^{th} second have been shown to conformal cooling and typical cooling canal. According to cooling analysis, it is determined that average temperature value of plastic part having conformal cooling canal is less than typical cooling canal. While average temperature using conformal cooling canal is 106.9 ˚C, average temperature was measured as 115.9 ˚C using typical canal.

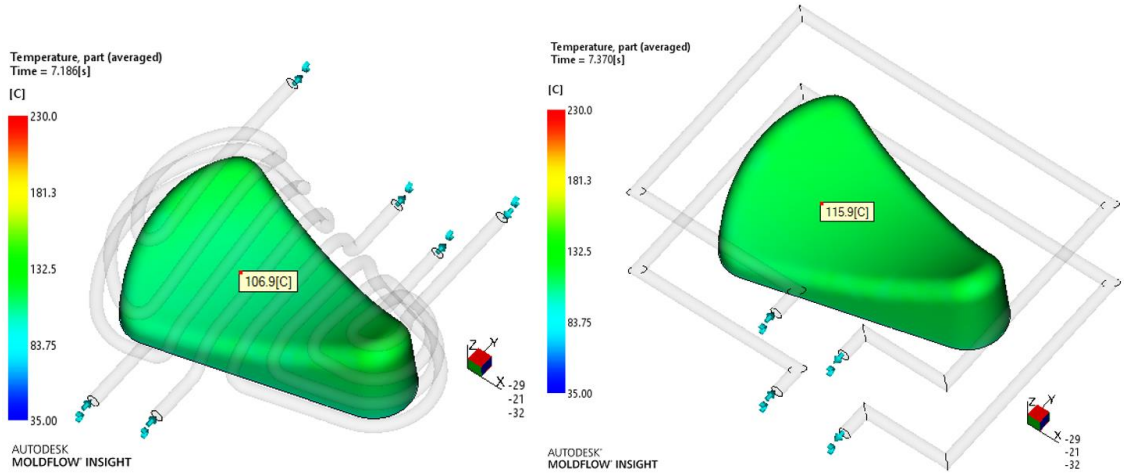


Figure 9. Temperature distribution on plastic part in the same time steps

As shown in Figure 10, temperature distribution of mould surface was determined. Accordingly, conformal cooling system is more effective than classic/typical cooling canal.

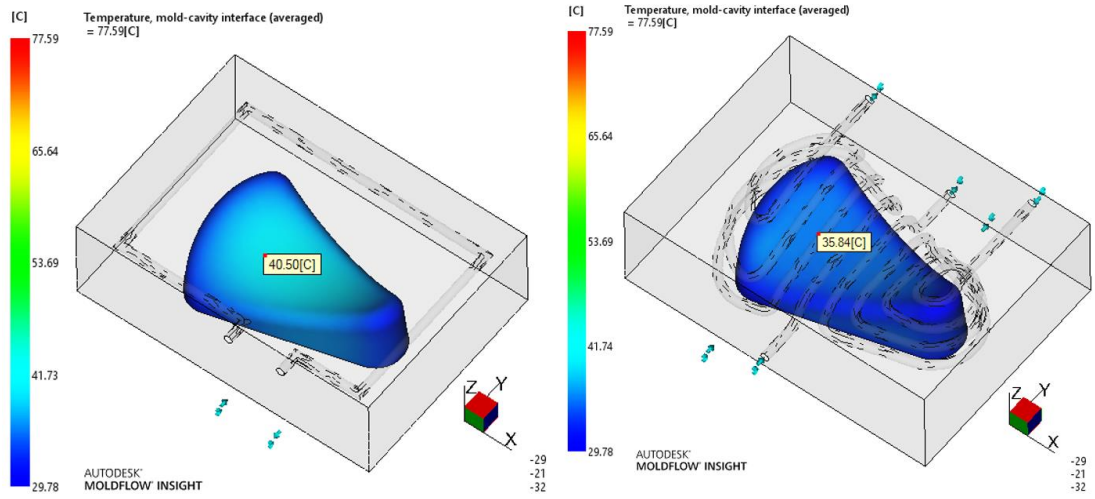


Figure 10. Comparison of the mould surface temperature distribution for both cooling canal type

Ejection time of plastic part from mould for both conformal cooling and typical cooling type were determined as shown in Figure 11. According to this, conformal cooling system has less ejection time then typical cooling canal. Thus, mold having conformal cooling canal has shorter time for one cycle which can affect the cost of plastic part.

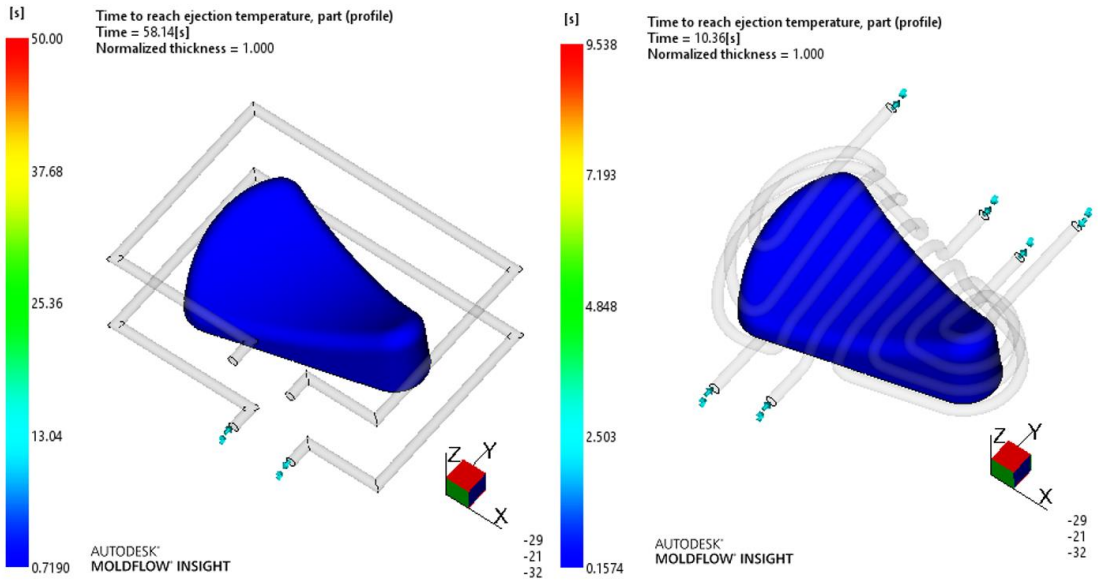


Figure 11. Comparison of the time to reach ejection temperature

4. CONCLUSIONS

A method for conformal cooling canals of plastic injection moulds has been presented in this study. Offset surface of the plastic part has been used in the proposed method. Thus, the distance of the cooling canals from the mould surface is maintained neatly. The boundary curves of the offset surface has been offset to the offset surface to regulate the distance of the cooling canals from each other. The resulting offset curves were combined to create a spiral and the parts with high curve were softened. Cooling canals were obtained extending along the resulting curves. Conformal cooling canals for complex geometries can be created with the proposed method. Moldflow software was used to analysed the effect of cooling canals designed for plastic parts with curved surface. Typical linear cooling canal created for the same part was compared. According to the analysis reports, conformal cooling canals are more effective than linear hole method.

Manufacturing of plastic injection moulds using laser metal powder sintering method is planned to be studied experimentally for the later stages in the study. Development of a software to make the designing of conformal cooling canals more practical is intended.

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