New Design Method for Conformal Cooling Simulation for Increasing Part Quality

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Abstract - *Injection Molding is a popular method that is used to make plastics product with high efficiency and process ability. Mould designers and researchers have been trying to improve performance of cooling channel due to propositional relation between cooling time and product cost, cooling time becomes inherent part as the rate of production and quality of part produced is totally dependent on it .In order to reduce the cycle time and control the uniform distribution of temperature, it is necessary to create conformal cooling channels which take the shape of the mold cavity and core .This research work present new set of design mythology and rules for developing local conformal cooling channel for various complex shapes and geometry, We proposed variable cooling channel diameters, baffle system free from channel for both core and cavity as per wall thickness and injection design limitations ,CAE simulation (NX11.0 & Auto Desk Mould Flow, Moldex 3d) is done on proposed defense TSU shell (HDPE) Molded Part using DMLS Techniques. Cooling channel are manufactured of product topology, in that best cooling design is selected based on minimum cycle time, uniform temperature distribution and defect free. The results show that local conformal cooling channel reduces cycle time (Up to 32%) part defect (98%) ,uniform temperature distribution (+-5 Degree) and mould cost. It increases productivity, part quality, tooling life and free from mould part after analysis, experimental tests are performed on JIT (80 tonne), injection moulding machine for results validation, In addition design for best thermo mechanical and hydrodynamics performance are identified.*

Keywords; Injection moulding. *conformal cooling, hydrodynamics, mold cavity*

1. Introduction

In today's manufacturing world, time is money. This is especially true in the injection molding industry, where a reduction in the cooling time can help achieve significant savings [1]. In the present world, a wide variety of plastic products are used in everyday life. Injection molding is a major part of the plastic industry, consuming a large percentage of the total amount of plastics [2]. Plastic injection molding is a multipurpose process to obtain different complex sizes and shapes of high quality products from thermoplastic and thermosetting materials with the application of heat and pressure [3]. To obtain a better-quality plastic part the design of the injection molding tooling, specifically the design of die core and cavity is very critical. It also plays an important role in the economic aspects of the business. The cooling of injection molding tooling plays very important role in the total production cycle time of the injection molding process. Time is significant in the entire molding process, as it constitutes about half of the time in the overall production cycle [4]. Figure 1 shows a generic distribution of time in the total injection molding process.

2. Brief overview of the injection moulding process

The injection moulding industry, like all industries, at present needs to reduce costs to remain competitive. This need has been addressed using various technologies ranging from design software to computer numerical control machinery. After these technologies are in place and moulding begins the cost is usually based on cycle time. Adjustments can be made to the moulding machine to help reduce the time to mould but in the final analysis the time is dictated by the ability of the mould to carry the heat away

Fig. 2: Pressure history during injection moulding

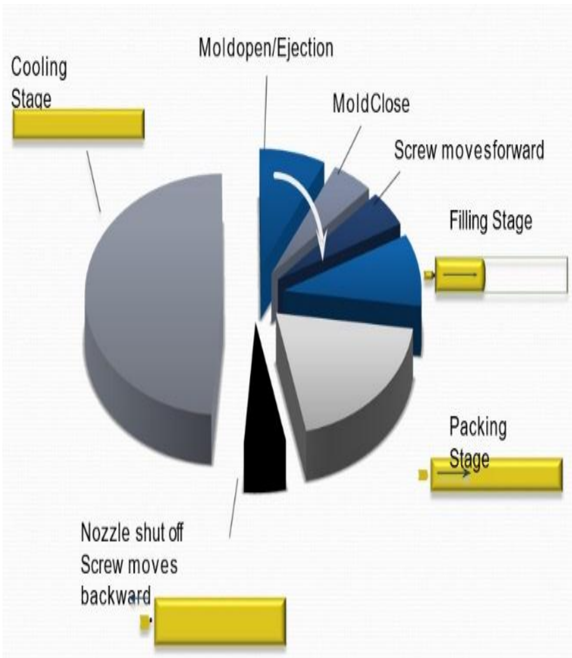

Fig. 3: Cycle time in injection moulding

2.1. Cooling channels

Cooling channels should be properly design to release the heat of the product during casting time. As with most manufacturing fields, production time and costs (lead and lag) are strongly correlated. The longer it takes to produce parts the more are the costs, and with injection moulding production industries cooling time is often taken as the indicator of cycle time. Improving cooling systems will reduce production costs. A simple way to control temperature and heat interchange is to create several channels inside the mould where a cooler liquid is forced to circulate. Conventional machining like CNC drilling can be used to make straight channels. Herein, the main problem is the impossibility of producing complicated channels in three-dimension, especially close to the wall of the mould. This produces an inefficient cooling system because the heat cannot be taken away uniformly from the mould and the different shrinkage causes warpage and cooling time increase (Fig. 4). On the other hand, if the cooling channels can be made to conform to the shape of the part as much as possible (Fig. 5), then the cooling system the cycle time can be significantly reduced with cooling taking place uniformly in all zones.

3. Problem definitions

From last 9 year we are producing TSU by plastic by using conformal cooling system which decrease 20% to 30% of cooling then convection cooling system due to which the production cost of TSU will decrease and productive of the system get increase. In process of casting most of the time is consumed by cooling process which can be eliminated by conformal cooling system. Shown in fig 6

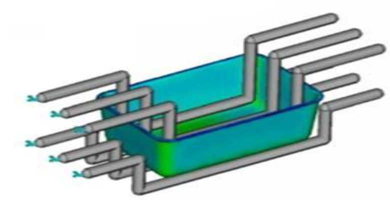

Fig 6: conformal cooling system

4. TSU Model detail

Table 1: TSU Model detail

Diameter	**90mm**
Height	**120mm**
Thickness	**2mm**

Fig. 7: TSU Model detail

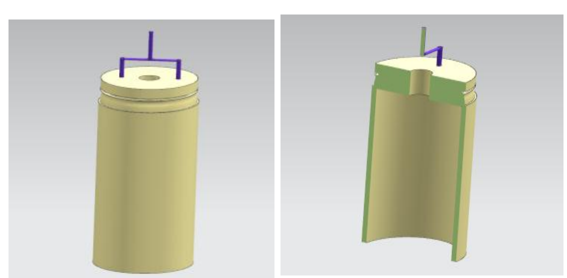

Fig 8: TSU Model detail

Table 2: Cooling time of conformal cooling channel

Case no.	Centre line distance(mm)	Diameter (mm)	Pitch distance(mm)	Cooling time(sec)
I	8mm	4mm	6mm	18.005sec
II	9mm	5mm	7mm	19.425sec
III	10mm	6mm	8mm	22.625sec

Case 1

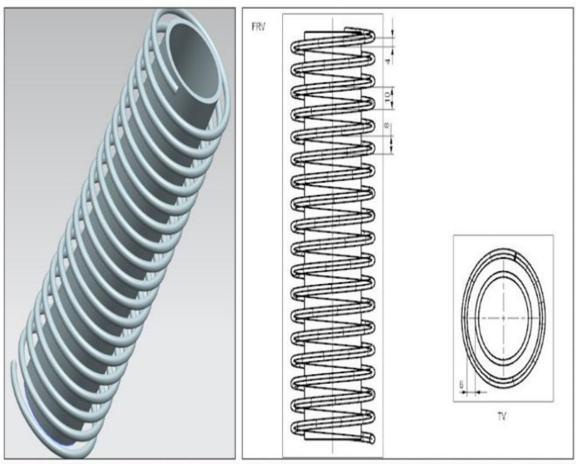

Fig. 9: Model detail

Case 2

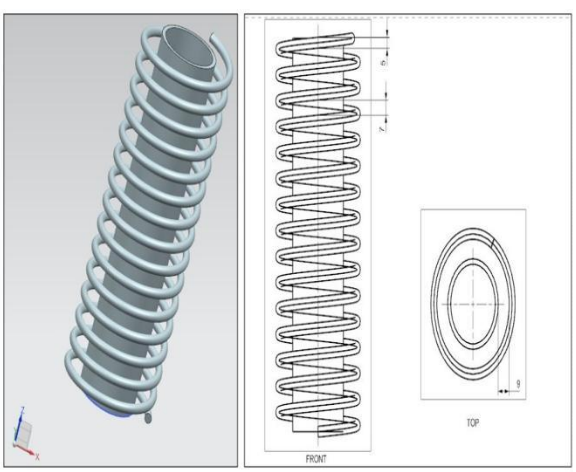

Fig. 10: Model detail

Case 3

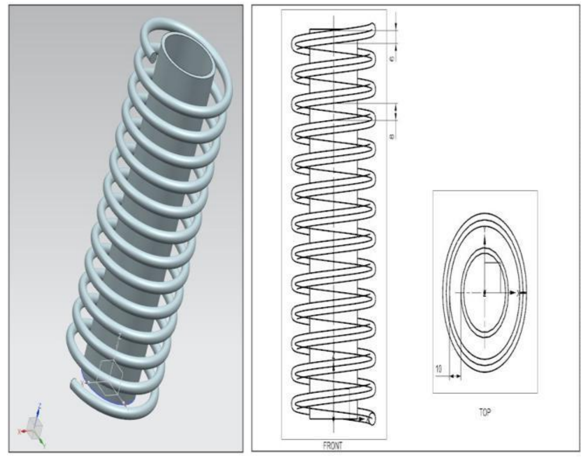

Fig. 11: Model detai

Table 3: Cooling time to reach DE molding temperature comparison

Case no.	Cooling Channel Arrangements	Cooling time(sec)
I	Without cooling Channel	33.2518sec
II	With Convectional cooling Channel	30.605sec
III	With Conformal cooling Channel	18.005sec

4. Result

Table 4: Table Cooling time to reach DE molding temperature comparison

Case no.	Cooling Channel Arrangements	Cooling time(sec)
I	Without cooling Channel	33.2518sec
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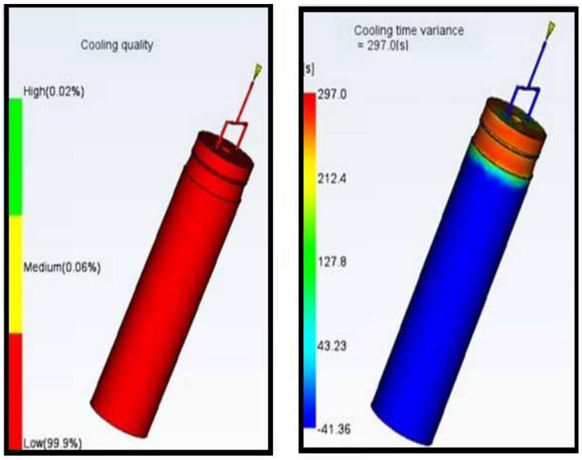

Fig. 12: Cooling time to reach DE molding temperature comparison

Table 5: Part temperature difference inside the TSU (a) without cooling channels, (b) with conventional cooling channels, and (c) with conformal cooling channels

Cases	Max.part temp.- Min. Part temp.(Degree Celsius)	Temp. Difference with in part(Degree Celsius)
Without cooling channel	29.0 ~ 58.9 c	29.9 c
With conventional cooling channel	29.0 ~ 37.4 c	8.4 c
With conformal cooling channel	29.0 ~ 29.67 c	0.67 c

Table 6: Mold temperature difference (a) without cooling channels, (b) with conventional cooling channels, and (c) with conformal cooling channels

Cases	Max. Mold temp. – min. Mold temp. (Degree Celsius)	Temp. difference (Degree Celsius)
Without cooling channel	0.81 ~ 21.765 c	20.95 c
With conventional cooling channel	0.09 ~ 9.340 c	9.25 c
With conformal cooling channel	0.00 ~ 0.187 c	0.197 c

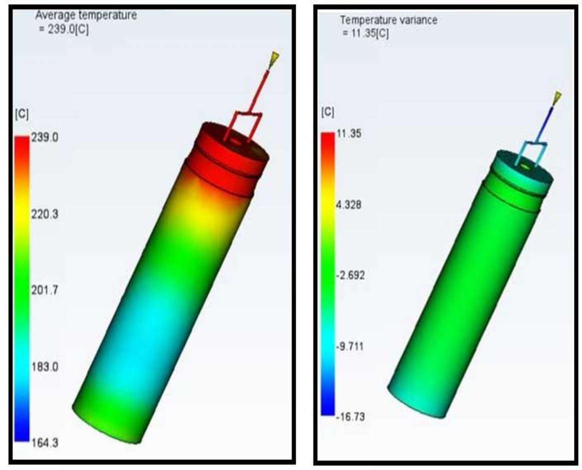

Fig. 13: Mold temperature difference (a) without cooling channels, (b) with conventional cooling channels, and (c) with conformal cooling channels

Table 7: Product displacement comparison on (a) X-displacement, (b) Y-displacement, (c) Z-displacement, and (d) total displacement

Cases	Displacement Direction	Warpage displacement
Without cooling channel	In X axis	-0.140 ~ 0.141mm
	In Y axis	-0.161 ~ 0.310mm
	In Z axis	-0.130 ~ 0.130mm
With conventional cooling channel	In X axis	-0.110 ~ 0.120mm
	In Y axis	-0.131 ~ 0.162mm
	In Z axis	-0.116 ~ 0.116mm
With conformal cooling channel	In X axis	-0.903 ~ 0.102mm
	In Y axis	-0.100 ~ 0.110mm
	In Z axis	-0.106 ~ 0.105mm

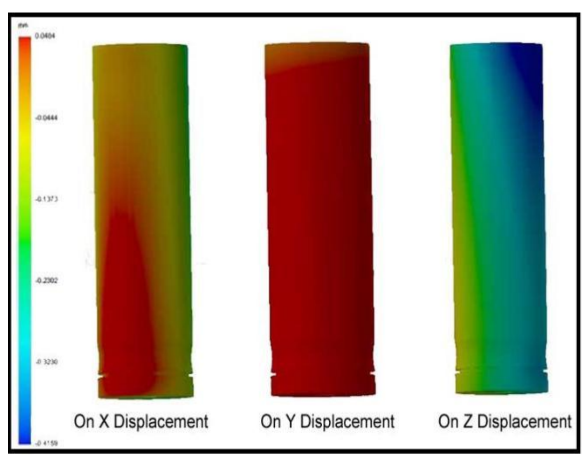

Fig. 14: Product displacement comparison

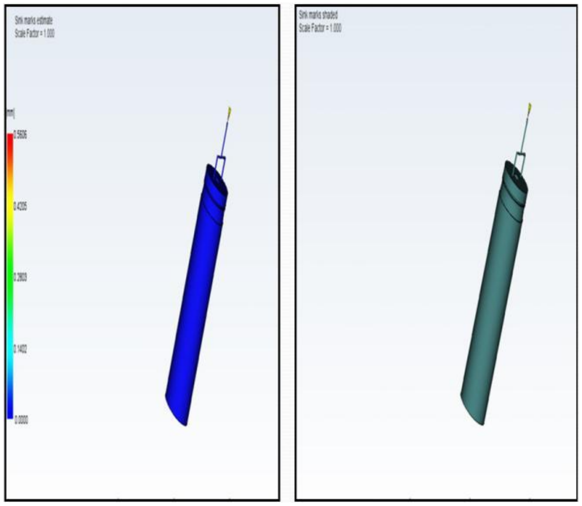

Fig. 15: Defect Analysis-Mold Flow

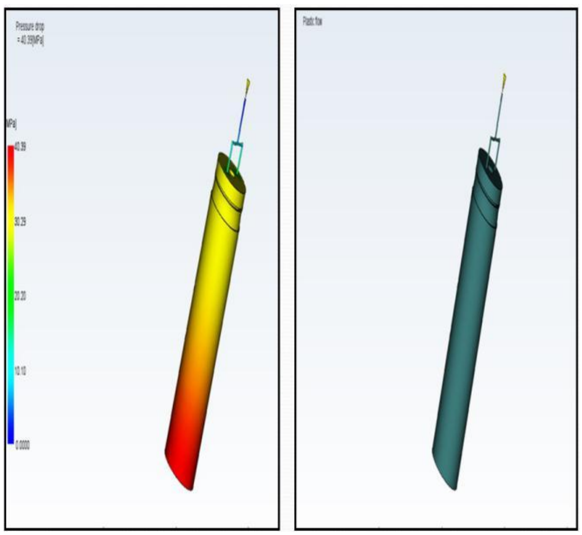

Fig. 16: Defect Analysis-Mold Flow

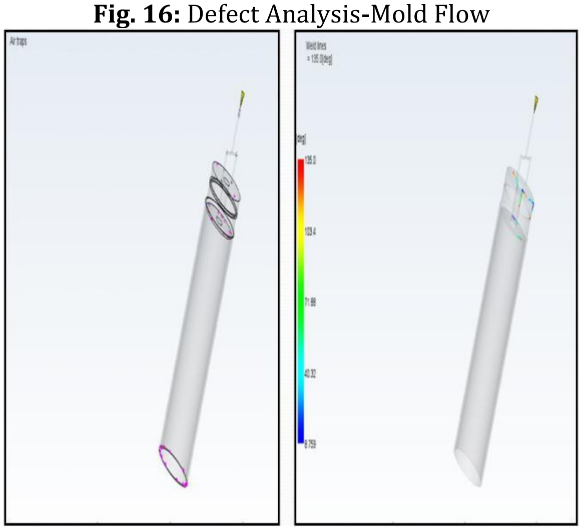

Fig. 17: Defect Analysis-Mold Flow

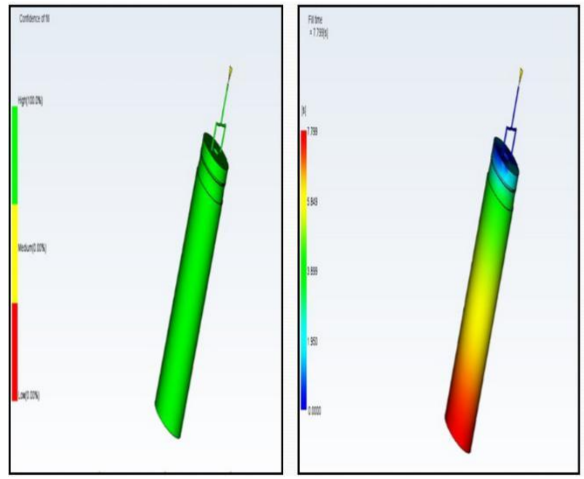

Fig 18: Quality Analysis-Mold Flow

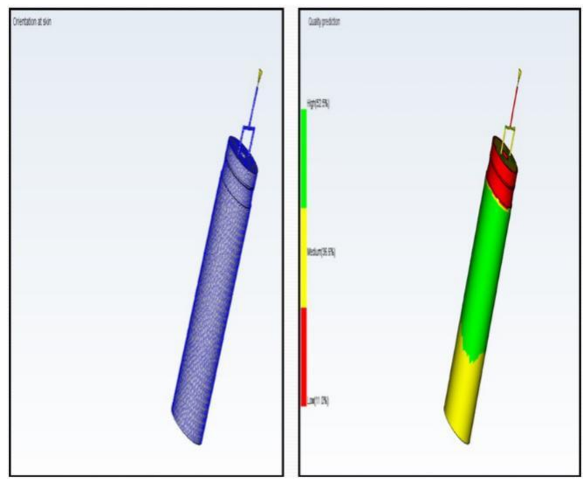

Fig. 19: Quality Analysis-Mold Flow

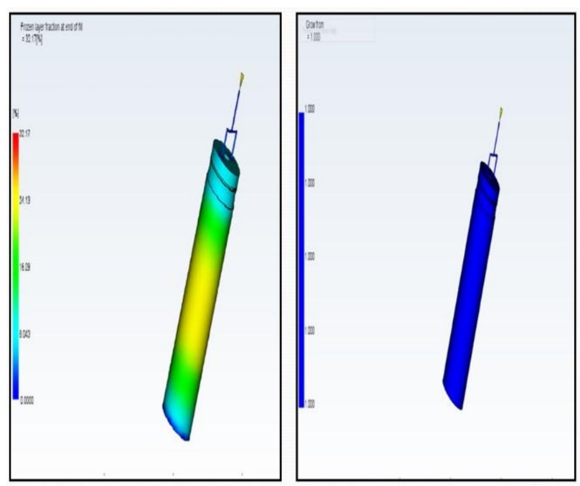

Fig. 20: Quality Analysis-Mold Flow

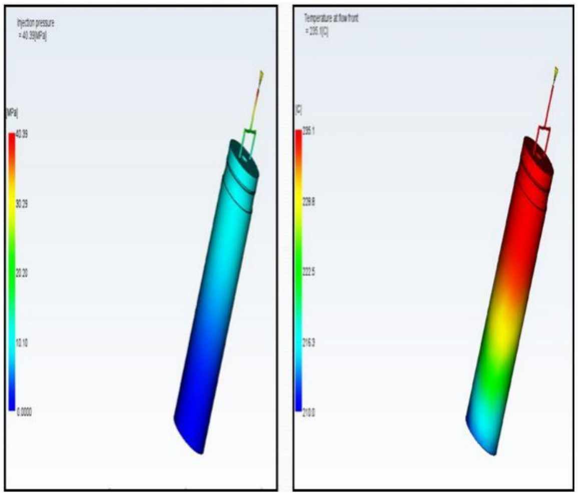

Fig 21: Quality Analysis-Mold Flow

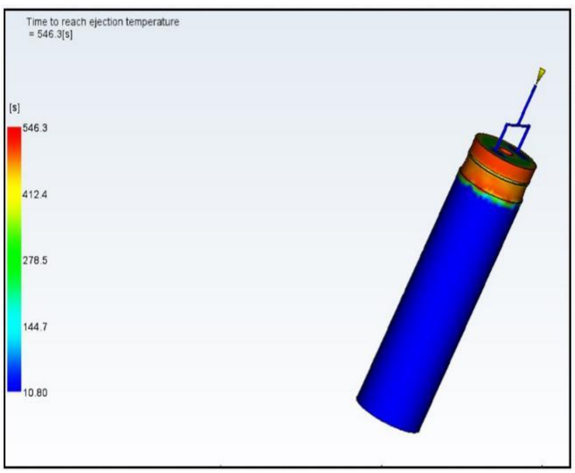

Fig. 22: Quality Analysis-Mold Flow

5. Conclusion

1. ***Shorten Cooling time***
   In the second evaluation, the result showed that the conformal cooling channel provided much greater thermal control compared with the conventional cooling channel and the one without cooling channel and decreased the cooling time by 70.03% and 90.26% respectively

2. ***Quality Prediction***
   The mold and part temperature difference between the upper and the lower cavity walls was also reduced up by 99.5% compared with the design without cooling channels.

3. ***Defect Analysis***
   Conformal cooling design has the smallest displacement values among all and reduced the total displacements of the conventional cooling and no cooling channel system by 24.05% and 56.01%, respectively

6. Future Aspects

1. Introducing a Befell System in cooling channels.
2. Cleaning of Conformal cooling channels.
3. Optimization of various cooling channel design on the basis of machine limitations, material, geometry and working environment.

7. References

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