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Performance Parameter Based Design of Cooling Channel For Plastic Injection Moulding Process

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***Abstract*: The work illustrated in this paper is on the possible material selection for the injection molding process-based product. The present work is carried out considering a hand torch outer body as a product to be manufactured using two different materials: Polycarbonate and Acrylonitrile Butadiene styrene (ABS), which are widely used materials for plastic products. The analysis process for the selection of material for considered product has been carried out using simulation software packages to analyze the quality of product before real production. A conventional cooling channel without having any curvature is initially considered and analyzed for material selection. The parameters like cooling time, sink marks and volumetric shrinkage decide the final quality of the product. The analysis has been performed for these parameters for the selected materials. The obtained results depict that ABS can be a preferred material as compared to Polycarbonate. The process parameters, sink marks and volumetric shrinkage are having almost comparatively about 15.55 % and 20% reduction respectively. Although the cooling time required to be higher for ABS compared to Polycarbonate, but the overall achievable quality of the product has been greatly affected by other two performance parameters. Further product material as ABS is analyzed for the possible different conventional cooling channel having curvature at the corner. The obtained results for the performance parameters for considered two different configurations of cooling channel depict that the effect of curvature in the conventional cooling channel is not much significant. As the cooling channel is grooved/drilled through the mould material, the channel without curvature is more economical to manufacture. The considered simulation approach is more useful for the design of conventional cooling channel for the injection moulding process, based on parameters, which control the final quality of the product made up of plastic material.**

Keyword— cooling channel, injection moulding process

I. INTRODUCTION

In this work, comparative analysis of two different cooling channel is done to analyze the cooling time, sink marks and total deformation. The conventional cooling channel is used in injection moulding machine to cool the product. Various design variables are set to analyze different performance parameters of injection moulding process. Two cooling channels are prepared for the same product. Cooling channel 1 is having sharp bends while cooling channel 2 is given curvature of 10 mm. This modification was done to analyze the effect of cooling channel on cooling time, sink marks and total deformation of the part. Omar A. Mohamed designed and analyzed different types of cooling channel for the plastic product. There are four types of cooling channels designed to provide the optimum cooling to the product namely (i) normal, (ii) conformal combination with baffle, (iii) conventional combination with conformal and (iv) conformal. The volumetric shrinkage for (i) normal, (ii) conformal combination with baffle, (iii) conventional combination with conformal and, (iv) conformal channel is 17.1%, 16.72%, 16.7%and 15.72% respectively. Likewise, sink mark is 3.905mm, 3.721mm, 3.6735mm and 3.588mm respectively. The warpage is 1.481 mm, 1.595 mm, 1.627 mm, 1.587 mm respectively. He recorded ejection part temperature and maximum temperature in the part for different cooling circuit. The maximum temperatures in the part for (i) normal, (ii) conformal combination with baffle,(iii) conventional combination with conformal and (iv) conformal channel are 220˙C, 218.4˙C, 218.3˙C, 141.5˙C respectively [1]. Wanga introduced an approach to generate spiral channels for conformal cooling. The cooling channels designed by this algorithm has very simple connectivity and can achieve effective conformal cooling for the models with complex shapes. Cooling channel has been produced by voronoi diagram based algorithm. In addition, comparison has been carried out between cooling channel produced by voronoi algorithm and spiral cooling channel. The time to freeze the part of voronoi diagram (VD) based channel is 42.73 seconds and for conformal channel it is 37.91 seconds [2]. Agazzi developed a new technique of cooling channel design, which is somewhat similar to combination of conventional and conformal cooling channel for a particular part. The result obtained by this case study is not much effective then conformal cooling channel [3]. Saifullah developed square cross sectional conformal cooling channel (SCSCCC) using direct metal deposition (DMD). It has better temperature distribution in the mould, which reduces cycle time of the injection moulding process, compared to conventional cooling channel [4]. Wu developed mould design using conformal cooling channel. The analysis and simulation was done in Ansys. It was noted that after 50 seconds, part comes to ejection temperature (87˙C).Plastic part takes 14.6 seconds to cool down after ejection of part. It is more efficient compared to conventional cooling channel [5]. Filiposki proposed different conventional cooling channel designs for the particular plastic part and reduced ejection temperature of the part [6]. Masood proposed some conventional and conformal cooling channels for this plastic part as shown in Fig.1 and he found that conformal cooling channel is the best for reducing the cooling time [7].

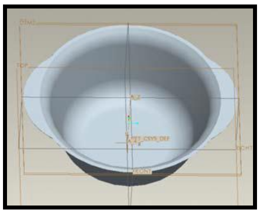

Fig.1. Plastic part [7]

Nooraizedfiza evaluated the performance of cooling channels compared to straight drilled cooling channels to minimize warpage of parts. Taguchi method and analysis of variance are used for the result and analysis [8]. Emanuel Sachs compared the mould surface temperature during injection cycle of a 3D printed mould with conformal cooling channels and mould machined with conventional straight channels. They concluded that inserts with conformal cooling channels exhibit more uniform surface temperature than straight channels [9]. D. E. Dimla generated a virtual model using Model Master in I-DEAS and mould flow software to find the best location for the runner channels [10].We have to prepare conventional cooling channel for the hand torch as shown in Fig.2.

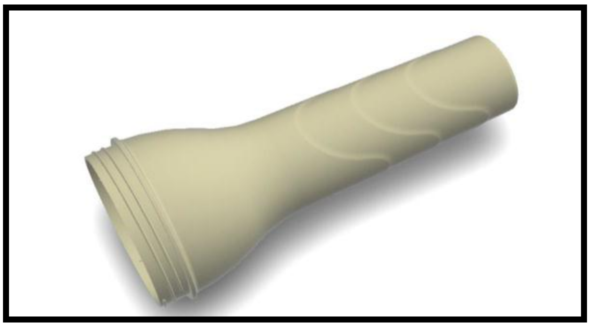

Fig.2. Plastic product (Hand torch, O.D=75 mm, L=180 mm)

II. DESIGN VARIBLES AND PERFORMANCE PARAMETRS

Table I. shows the design variables required for the analysis. Cooling time, sink marks and volumetric shrinkage are the performance parameters of the injection moulding process.
Cooling time is the time taken by the product to cool down. Sink marks is the local depression on the surface of the product due to non-uniform cooling. Volumetric shrinkage is the amount of product volume shrinkage during moulding process. For better results, these performance parameters should be minimum. In this work, performance of two types of cooling channel is compared with objective of minimizing above-mentioned parameters.

III. SIMULATION OF CONVENTIONAL COOLING CHANNEL

To analyse performance of cooling channels, simulations are performed using solid works. Water is considered as coolant. Meshing of product is done using hexahedrons with triangle size 1.7965 mm. Mould has been meshed by tetrahedrons using triangle size 15 mm. Product thickness is 2 mm. Cooling channel dimensions are considered as per table 2.

Table I. Design Variables

Sr.no	Design Variables	Channel 1 & 2
1	Product material	ABS
2	Mould Material	420SS
3	Coolant type	Water
5	Melt Temperature	230°C
6	Mould temperature	50°C
7	Injection pressure limit	100 MPa
8	Coolant temperature	25°C
9	Ambient temperature	30°C
10	Mould open time	5 Seconds
11	Average coolant flow rate	150 CC/S
12	Mesh of product	Hexahedrons(1.7965mm)
13	Mesh of mould	Tetrahedrons(15mm)
14	Cooling channel diameter	10mm

Table Ii. Design Criteria for Cooling Channel

Product Thickness, (mm)	Hole diameter of channel (a),	Centreline Distance between holes, (mm)	Distance between centre of hole and cavity, (mm)
0-2	4-8	2-3×a	1.5-2×a
2-4	8-12	2-3×a	1.5-2×a
4-6	12-16	2-3×a	1.5-2×a

VI. RESULT & DISCUSSION

Table III and Table IV show the results of the analysis performed.

TABLE III. RESULTS OF ANALYSIS FOR CHANNEL 1

Sr. no	Name of analysis	ABS	PC
1	Cooling time (sec.)	13.8730	10.4193
2	Sink marks (mm)	0.0744	0.0881
3	Volumetric shrinkage (%)	9.1999	11.4991

TABLE IV. RESULTS OF ANALYSIS FOR CHANNEL 1&2

Sr. no	Name of analysis	Channel 1 (Straight)	Channel 2 (Curvature)
1	Cooling time(sec.)	12.6650	12.6657
2	Sink marks(mm)	0.0661	0.0676
3	Total displacement(mm)	1.1154	1.1230

Simulation results show that the cooling time of channel 1 is 12.6650 seconds whereas, cooling time of channel 2 is 12.6657. Fig.3 shows the cooling time taken by the channel 1. Fig.4 shows the cooling time taken by the channel 2. Sink mark of channel 1 is 0.0661 mm and channel 2 is 0.0676 mm as shown in Fig.5 and Fig.6. The total deformation of body for channel 1 is 1.1154 mm and for channel 2 is 1.1230 mm respectively as shown in Fig.7 and Fig.8. Better results in case of straight path channel may be associated with flow of coolant inside the channels, flow analysis and heat transfer analysis can give exact information about it.

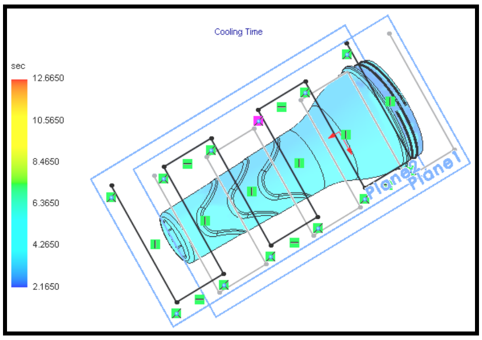

Fig.3. Cooling time of torch body for channel 1

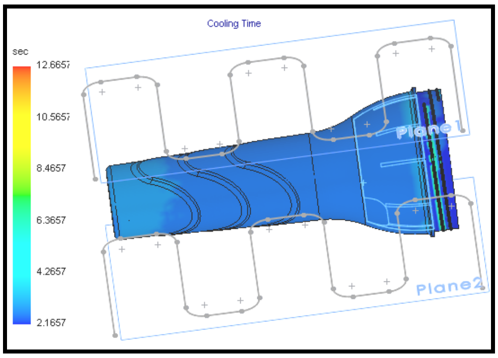

Fig.4. Cooling time of torch body for channel 2

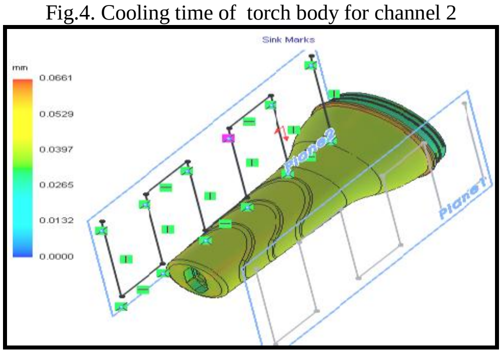

Fig.5. Sink marks of torch body for channel 1

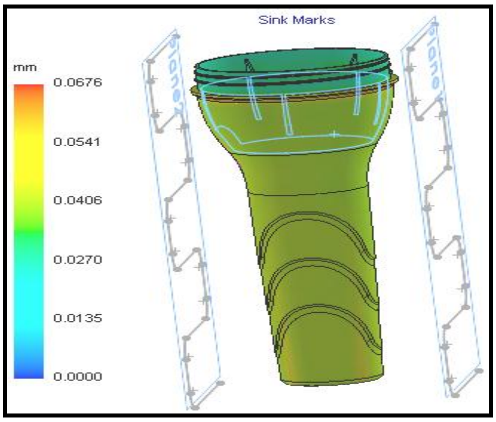

Fig.6. Sink marks of torch body for channel 2

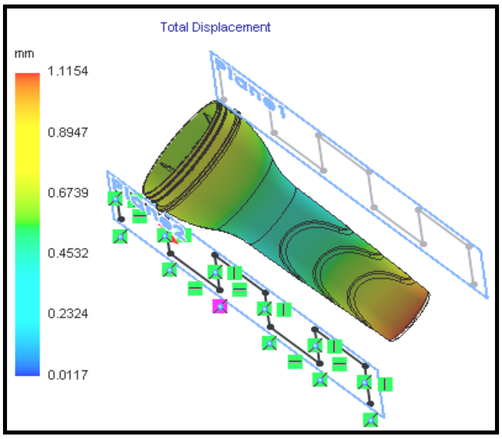

Fig.7. Total displacement of torch body for channel 1

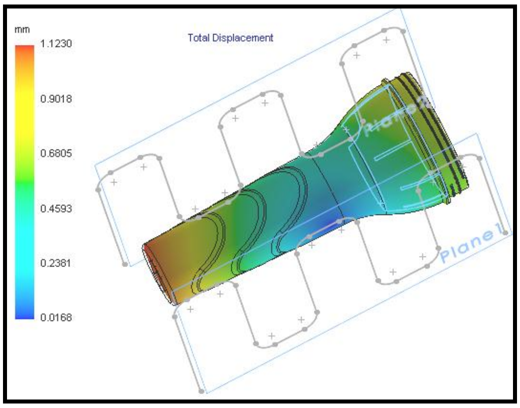

Fig.8. Total displacement of torch body for channel 2

V. CONCLUSION

Study on effects of modifications in cooling channel is important to achieve optimum performance. The cooling channel without curvature gives best result as compared to channel with curvature. It is also concluded that change in flow affects heat transfer rate, which can increase or decrease cooling time of product inside mould.

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