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Modeling and Analysis of Micro Cooling Channel for Plastics Injection Mould by using Moldflow Adviser

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Abstract:
Injection molding is the most widely used method for the production of complex shape with good dimensional accuracy. The overall injection molding process involves basically of injection of plastics melt into the injection mold, cooling of the part and then ejection of part from the mold. The domain of project is to improve cooling circuit design, for that purpose various conventional and conformal designs are created to reduce the cycle time and to improve the product quality. The cooling time possesses direct impact on overall production cycle time, hence better cooling circuit design will increase the production quantity and quality as well. A different approach is adopted to design "Micro cooling channels". A comparison is done among the effects of cooling circuit on the PIM process and the quality of the product. The work comprises of several analysis performed for different types of cooling circuits. The best cooling channel is selected on the basis of minimum time to reach ejection temperature, uniform temperature distribution, and minimum warpage of part. It is observed that the cooling channel design which conforms to shape of the part is giving better results. Moreover, efforts are put to create conformal micro channel design, so that to take the benefit of both i.e. conformal shape and the grid of micro channels which will provide uniformity in cooling due to minimum pitch gap. The 3D model of food container was created in "CREO parametric 2.0", whereas the analysis is performed by using "AutoDESK Mold Flow Advisor".

Keywords: AutoDESK Mold Flow Advisor, Micro cooling channels, Plastic injection molding

I. INTRODUCTION

Thermoplastic injection molding is a well known process for manufacturing effortless and complex shaped products in short time and at low cost. Nowadays there is need for optimizing the processing parameters to increase productivity [1]. The injection molding process consists of melting of polymer and then its injection into the cavity in the molds.

This molten material is ejected from the molds after reaching the cooling temperature. Thus, the main phases of the injection molding process are injection, packing, cooling, and part ejection. Among these, part cooling takes up 50 to 80 percent of the cycle time [2].Cutting down the cycle time for each part is a major concern in injection molding machine. Design of the cooling system in the thermoplastic injection molding process is one of the most important steps during mould design.

It has a direct influence on the quality of the parts produced, and thereby impinges on the cycle time. Cooling channel design was traditionally limited to relatively simple configurations due to the main process for manufacturing being limited to drilling of straight holes. Nowadays, helped by 3D printers, complex shapes are able to be produced with intricate details and more complex geometries [3]. The manufacturing of conformal cooling with 3D printing presents several challenges.

The loose powder within the channels must be removed. This presents a constraint on the length and diameter of the channels as well as a challenge in determining the point of completion of the powder removal operation. Porosity can also present challenges. There are also some issues associated with the material's properties, such as hardness and toughness [4].

In the sense of cooling circuit design micro channel is the word used for cooling circuit having very small diameter of about 1mm -2mm. It have been proven with the analysis that micro-channel cooling effects are more closely conform to the theoretical minimum cooling time while the standard cooling channel results are closer to the adjusted theoretical value. The effectiveness of micro channel cooling is high because of minimal pitch gap of cooling circuit.

Through these channels the flow of coolant is possible throughout the area near to the part surface. Moreover, due to less diameter of channels it is not effecting the strength of the mold therefore we can provide micro channels near as possible to the surface of the core and cavity.

II. MATERIAL AND METHODOLOGY

To initiate our project we have chosen "Cycle Time Reduction in Injection Molding Process by Selection of Robust Cooling Channel Design" as our base paper. This paper is published in "Hindawi Publishing Corporation" with Article ID 968484 [2]. First of all we have created the same part with the given dimensions shown in the reference paper. This model is created on CREO Parametric 2.0 (Educational version). The basic drawing with the dimension of the product is shown in figure 1.

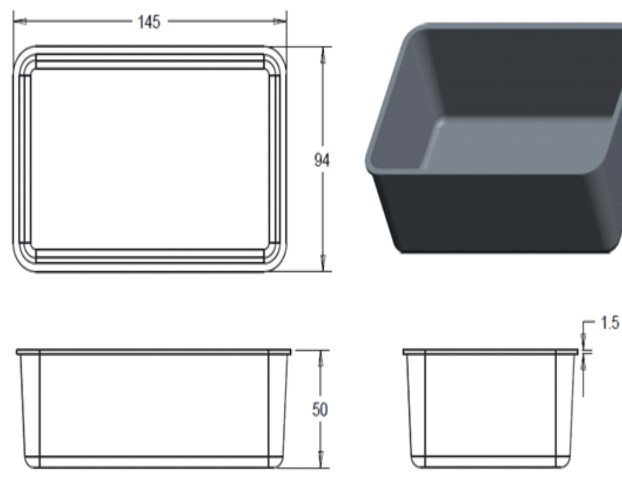


Figure.1. Orthographic Drawing of Food Container

According to the base paper, the plastic food container is having dimensions of 145mm in length, 94 mm in width, 50 mm in height and 1.5 mm uniform wall thickness. This model is then saved in to IGES format (integrated graphics exchange system), so that to import it in to Auto-DESK Mold Flow Advisor for simulation the simulation of plastics injection molding process. Material for mold tool "steel P-20" is selected. First of all, we create the same cooling circuits as given in the base paper to validate the approach of the project.

Table.1. List of cooling channels

Prior Cooling Circuits (Base paper)	**Micro-channel Cooling Circuits(** Our Contribution**)**
Conventional Cooling Channels (CCC) Fig 2(a)	Straight micro cooling channel of 2mm dia. (Fig-3-a)
Series Cooling Channels(SCC) Fig 2(b)	Spiral micro cooling channel design of 2mm dia.(Fig-3-b)
Parallel Conformal Cooling Channels (PCC) Fig-2(c)	
Conformal Cooling Channels With Additive Cooling Lines" (CCAL) Fig- 2(d)	

In conventional cooling channel (CCC) straight drilled cooling lines are used). In the second design, series conformal cooling channels (SCC), cooling channels conform to the shape of the part and they are connected in series with each other whereas, in the third design ,parallel conformal cooling channels(PCC), the same conformal cooling channels are connected in parallel(Figure4(c)). In the last channel design, conformal cooling channel with additive cooling lines (CCAL), along with conformal cooling lines, two straight cooling channels are also placed on both sides of the part.

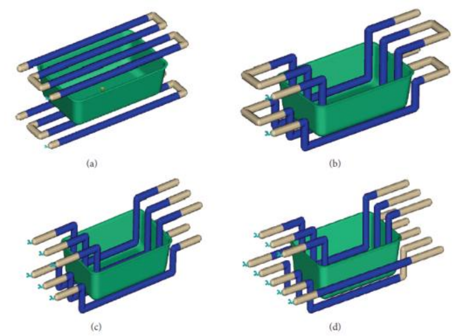
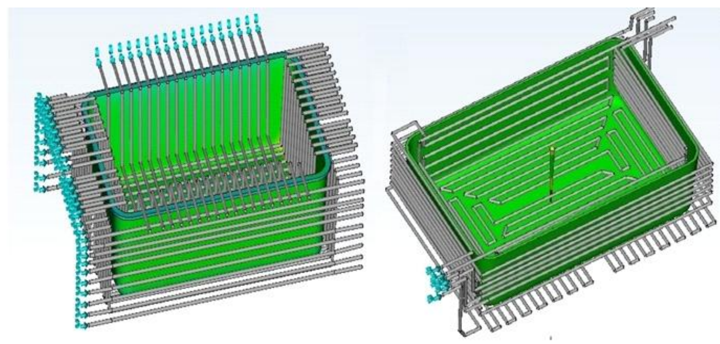


Figure.2. (a) Conventional cooling channel design. (b) Series conformal cooling design. (c) Parallel conformal cooling channel. (d) Conformal cooling channel with additive cooling lines.



(a) (b)

Figure.3. Micro Cooling Channel (A) Straight Micro Cooling Channel (B) Spiral Micro Cooling Channel

In this project two types of micro cooling channels were designed, straight micro cooling channel was designed on the basis of numbers of inlet or outlet i.e. to provide more numbers of inlet or outlet to improve the uniformity of cooling effect and spiral micro cooling channel designed to conforms the shape of the product, so that the coolant can flow throughout the regions of the part as the cooling circuits are near as possible to the wall.

- **Material Assigned:-** Polypropylene (PP) Purell HM671T (density 0.9 g/cm^3, melt temperature 168^oC, thermal conductivity 2.8 $x10^{-4}$ cal/sec cm ^oC and heat capacity 0.9 cal/g ^oC) [2].
- **Parameters Selected**: - Mold temperature (38.89 ^oC), Melt temperature (225 ^oC), Injection time .6912and proper gate location is at the center of the base.
- **Mold Flow Analysis: -** The mold flow analysis is performed after assigning material to plastic part .Using these input parameter Fill + Pack + Warp + Cool analysis is performed.
- The simulation result in the term of reach ejection temperature (time to reach the ejection , which is measured from the start of fill),time to reach part ejection temperature (time required by the part to freeze), volumetric shrinkage at ejection(This parameter gives information about the percentage reduction in volume of the part with respect to the original part at the time of ejection), and the temperature variance(is the temp difference between different regions of the part with respect to the average ejection temperature of the part) of the part are discussed .

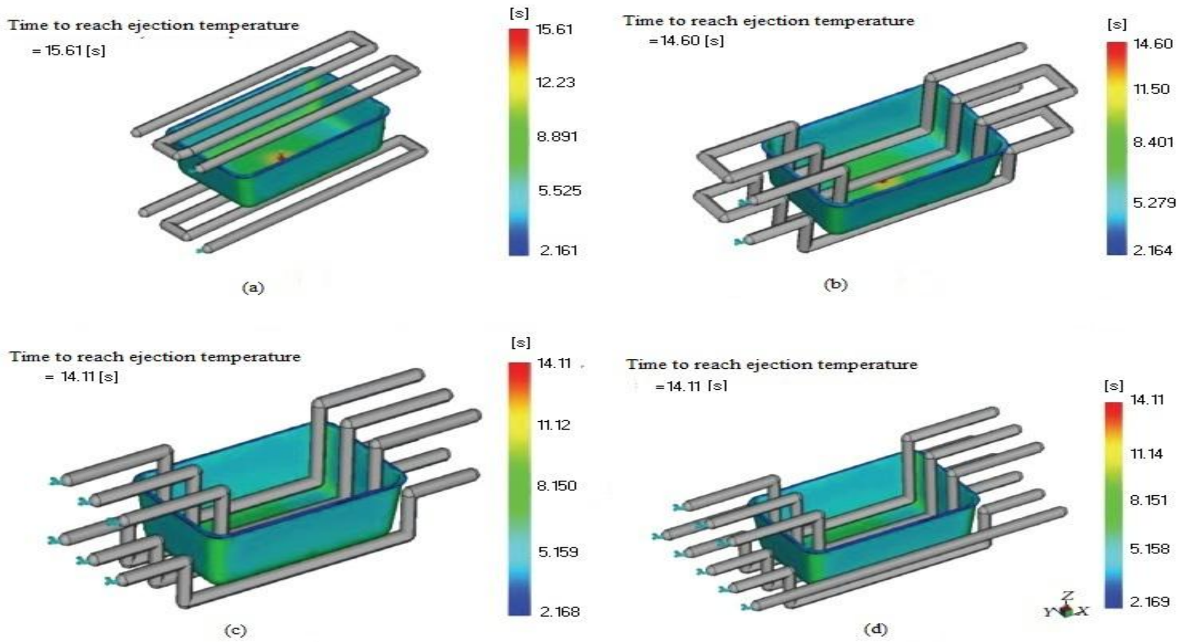
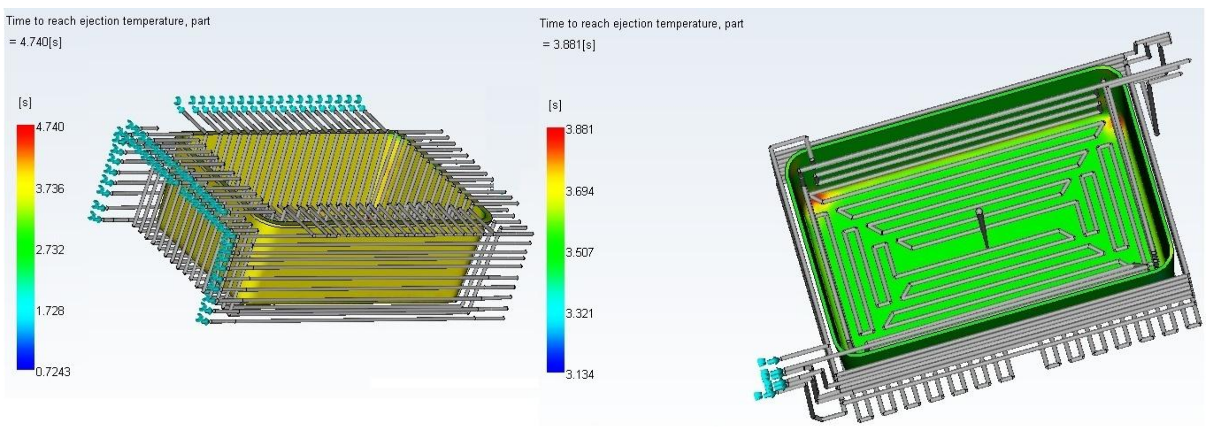


Figure.4. Time to Reach Ejection Temp (a) CCC (b) SCC (c) PCC (d) CCAL



(a) (b)

Figure.5. Time To Reach Ejection Temperature (a) Straight MCC (b) Spiral MCC

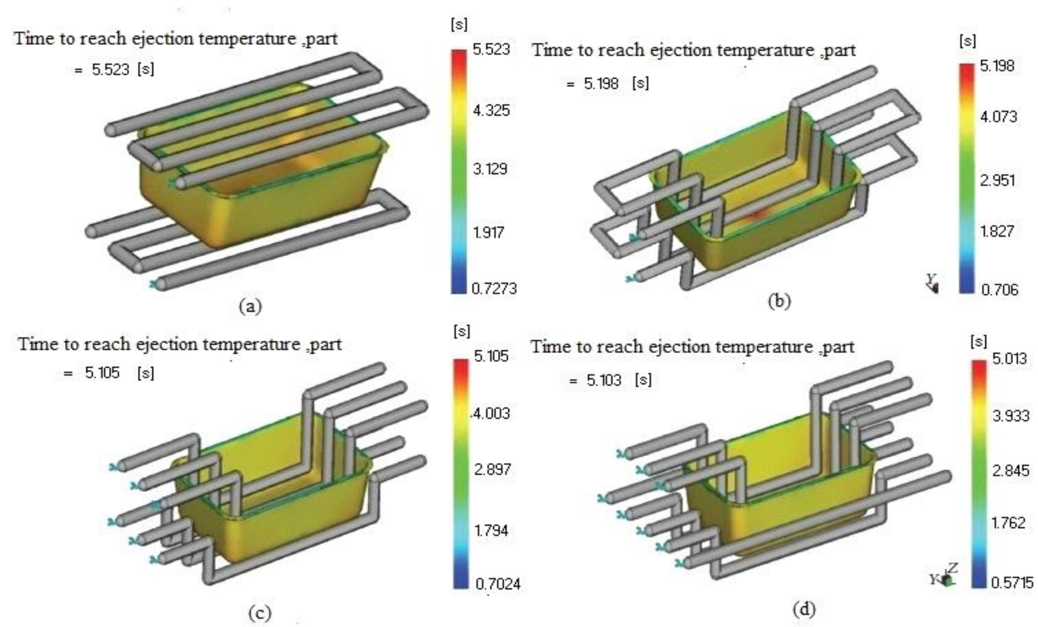
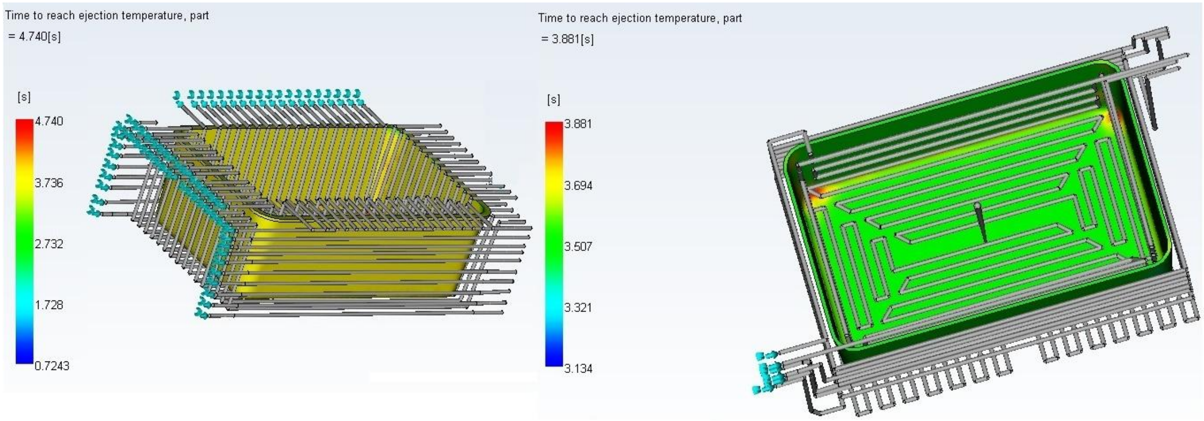


Figure.6. Time to reach part ejection temp (a) CCC (b) SCC (c) PCC (d) CCAL



(a) (b)

Figure.7. Time to Reach Part Ejection Temperature (a) Straight MCC (b) Spiral MCC

III. RESULTS AND DISCUSSION

The simulation results show that both the micro cooling channels are most efficient and suitable cooling channel among other cooling channel. Micro Cooling Channels have lower time to reach ejection temperature (figure 5), lower time to reach part ejection temperature (figure7), lower volumetric shrinkage (figure 9), and lower temperature variance (figure 11) is; thus it will lead to better part quality with minimum cycle time. As the temperature variation is minimum in Micro Cooling Channel , there will be minimum warpage of the part that translate to better part quality as compared to CCC, SCC ,PCC and CCAL because of more uniform cooling in micro cooling channels.

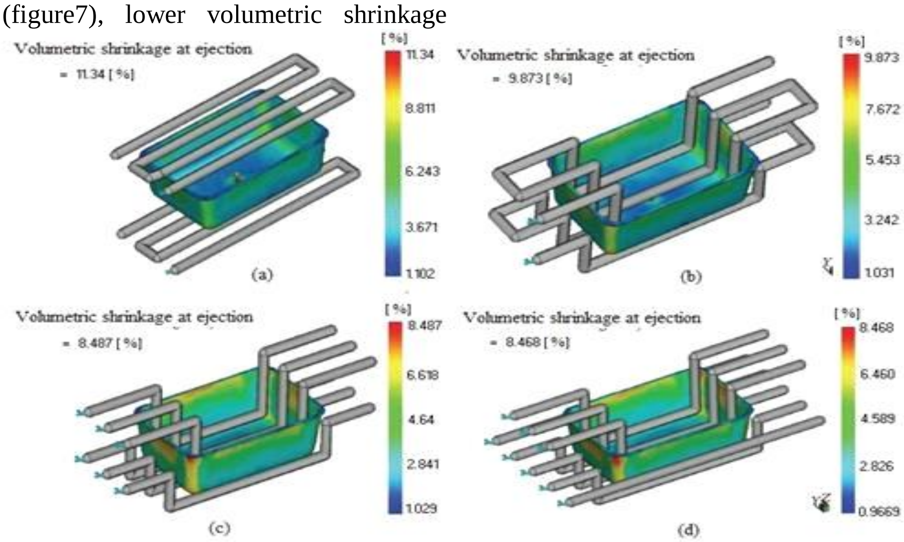
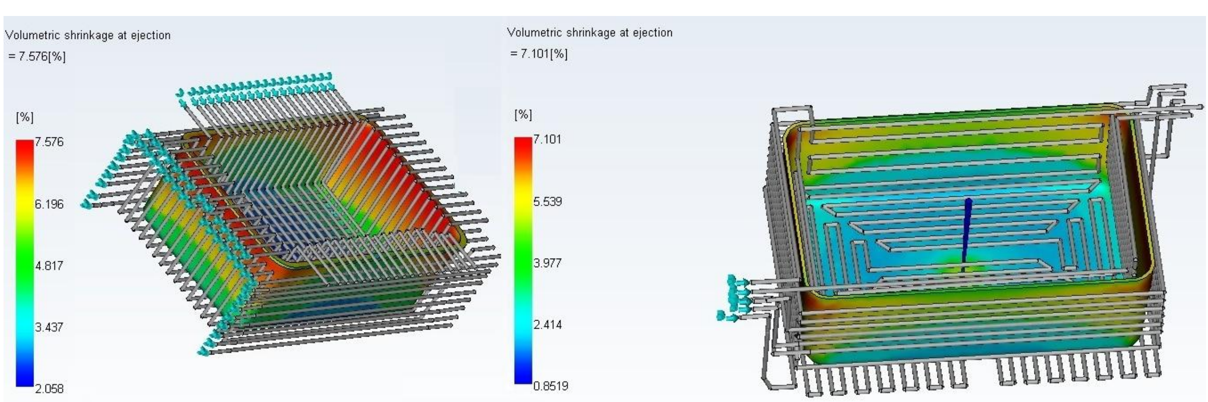


Figure.8. Volumetric Shrinkage (a) CCC (b) SCC (c) PCC (d) CCAL



(a) (b)

Figure.9. Volumetric Shrinkage At Ejection (a) straight micro cooling channel (b) Spiral micro cooling channel

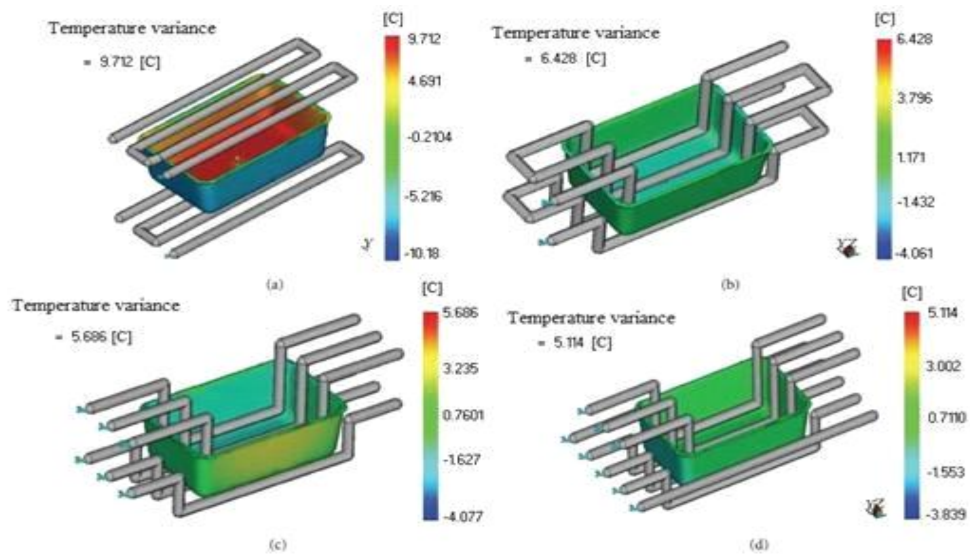
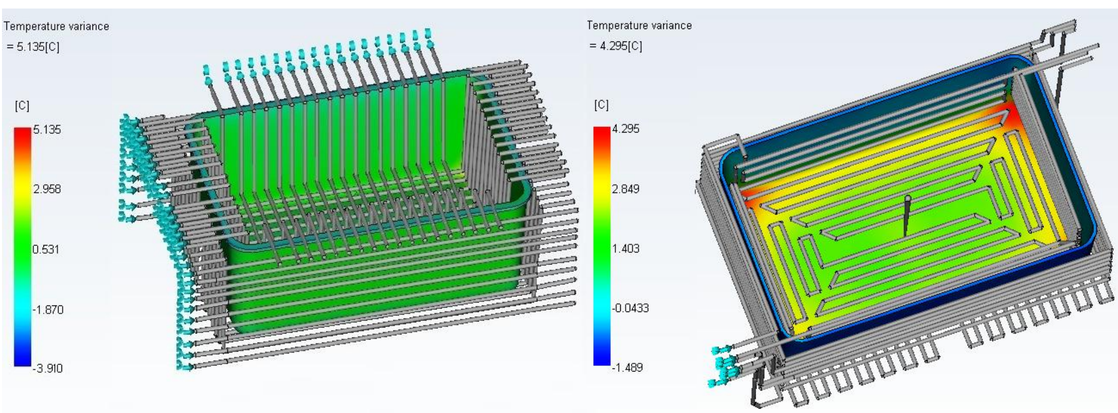


Figure.10. Temperature Variance (a) CCC (b) SCC (c) PCC (d) CCAL



(a) **(b)**

Figure.11. Temperature Variance (a) Straight Micro Cooling Channel (b) Spiral Micro Cooling Channel

Table.2. Results of FILL + PACK + COOL ANALYSIS

OUTPUT RESULTS	PROJECT RESULTS					
	CCC	SSC	PCC	CCAL	Straight Micro CC	Spiral Micro CC
Time to reach ejection temperature [seconds]	14.11	14.11	14.60	15.61	13.01	11.11
Time to reach part ejection temperature [seconds]	5.103	5.105	5.198	5.523	4.740	3.881
Volumetric shrinkage at ejection [%]	8.468	8.487	9.873	11.34	7.576	7.101
Temperature variance [^{o}C]	5.114	5.686	6.428	9.712	5.135	4.295

IV. CONCLUSION

In this project, six different types of cooling channel layouts are studied named as “conventional cooling channels”(CCC), “series conformal cooling channels” (SCC), “parallel conformal cooling channels” (PCC), “conformal cooling channels with additive cooling lines” (CCAL) and micro cooling channel (MCC) for cooling of a food container. Effect on the product and hence increasing the quality of the product. In our design the pitch gap between the cooling circuits are reduced to great extent which results in uniform cooling throughout the part surface. So the designer must think about reducing the pitch gap while designing cooling circuits. The shape of micro cooling circuit conforms to the shape of the object which brings the cooling circuit near to the impression, by this we can say the circuit must be designed in such a way so that it will keep closer as possible to the cavity reason. Smaller the diameter of cooling circuit place more number of circuits, which will cover more surface area. Hence result in uniform cooling effect .Uniform cooling effect will results in uniform shrinkage and minimum warpage. Hence, we can get better quality product by improving the cooling circuit design. Moreover, the better cooling system will reduce the volumetric shrinkage of the part.

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