Volume 6 Issue 7, 14-20, July 2019

Numerical Study of the Mould Contours Effect onThe Plate Cooling Process Heated From The Side

Muttaqin Rahmat Pangaribawa[#1], Fauzun[#2]

[#]Department of Mechanical and Industrial Engineering, Gadjah Mada University, Yogyakarta, Indonesia
Bulaksumur, Yogyakarta, Indonesia 55281

Abstract

Cooling reconstruction of the plate heated from the side on the mould contour can be optimized. This research was performed by observing, documenting, document studying, simulating, and simulating based on optimization.The research aims of finding out the cooling effect, the cooling distance compared with the flat plate, and the cooling effectiveness.Based on the simulation result, the reconstruction cancool effectively.The minimum distance to cool the packaging mould contour is equal to 15 mm with the cell size 2 x 1.6 mm (Lr =2, H =1.6) with the type of 1 l packaging mould. Cooling depth of the contour plate optimum is 4.57 times that of the flat plate. The packaging cooling effectiveness of 1 l grip packaging simulation based on optimization is 70.85%: 70.77% and for 1 l non-grip is 71.09%: 71.04% compared with simulation so that the production rate of 1 l grip packaging increased 0.11% and 1 l non-grip packaging increased 0.07%.This method has the potential to resolve the main problem in the blowing mould cooling process.

Keywords *- mould contour, flat plate optimization, side heating, cooling effectiveness, cell*

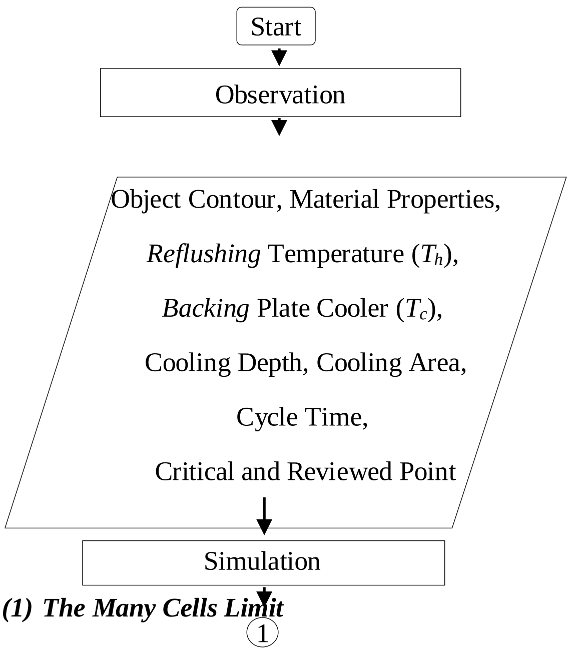
I. INTRODUCTION

Refrigeration system to speed up the time of plastic production using blow moulding is still being debated. Chemical Industry used refrigeration system and heat transfer in pesticide packaging production process. But, on the starting production, after machine heating, the spotting of condensation appears. It needs pretty much-shot product rejected to obtain appropriate mould temperature. As a consequence, it needs longer setting up production time and brings down the production product. Because of that, analysis of refrigeration is needed as a way to eliminate condensate from condensation that happened in the mould, or another side by reheatingthemould.

In the depth study, the observation result ofa packaging production process in Chemical Industry obtains some actual findings, theyare:
unstable production time cycle, rejection of products due to overheating and condensation, the mould breaking is caused by repetitive load, some pesticide packaging production new machine proposal. Based on research were done and applied before like: the application of theinner part mould cooling, cooledwater or other cooling that circulated through the part of the mould so that the mould and product becomes cool, cooling system with cooling device outside the mould section caused ineffectiveness, the need to be careful of using cooling parameter 5-20 ^oC because of lower temperature create condensate on the part of the mould and surface product defect for the next, as in [1]. This research will be an important alternative to reconstruct the cooling process of the blow mould in factory scale.

II. MATERIAL AND METHODS

The research design flow chart is shown in Fig.1.



(1) The Many Cells Limit

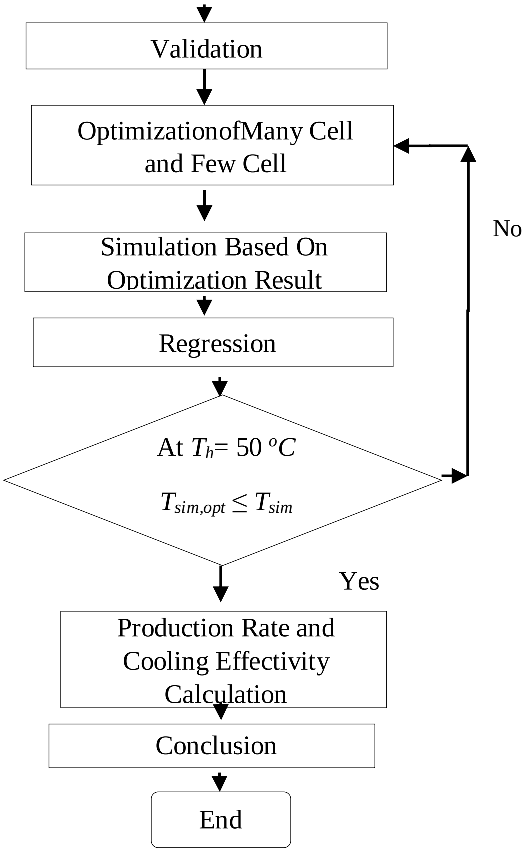


Fig. 1: Flow chart of the simulation process

Material that are simulated consists of: HDPE 5401, Steel cast DIN 2311, and water liquid.

A. Simulation

The equation of two dimension heat transfer system energy between T_h (hot temperature) and T_c (cold temperature) as a simulation based oncooling optimization which is reviewed can be determined by using Equation 1 as follows:

$$\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)-\frac{\dot{m}\,C_{pf}}{A\,\bar{k}}\left(\frac{\partial T}{\partial x}+\frac{\partial T}{\partial y}\right)=\frac{1}{\alpha}\frac{\partial T}{\partial t} \quad (1)$$

When the side or bottom part of the surface plate is cooled by convection of the fluid at $T_f$temperature having heat transfer coefficient h_f,heat transfer the boundary of the surface hot plate and cool liquid could be expressed by using Equation 2, as in [2]:

$$-k\frac{\partial T}{\partial y}(x,0)=h_f[T(x,0)-T_f] \quad (2)$$

And, system energy can be analyzed through Equation 3 as follows:

$$\Delta Q=U_m\rho\, V c\,\frac{\Delta T}{\Delta x}\Delta t \quad (3)$$

B. Optimization

An average heat flux that can beremoved by the alternating flow from below the wall is presented in Equation 4 and 5, as in [3]:

The optimization is done by plotting asymptote the Equation 4:

$$q''=\frac{2kg\beta L_r^{2}}{27\alpha v}(\Delta T)^2\left[1-\frac{9}{2Ra_H}\left(\frac{H}{L_r}\right)^4\right]^2 \quad (4)$$

(2) The Few Cells Limit

The optimization is done by plotting asymptote the Equation 5:

$$q''=0.161\frac{k\Delta T}{H}\left(\frac{H}{L_r}\right)^{1/2}Ra_H^{1/4} \quad (5)$$

The optimization on intersecting the equation 4 and 5.

III. PREPARATION OF SIMULATION

A. Simulation Setup

Simulation setup is done by using steps as follows:

1. Choosing solver
2. Determining dimension
3. Importing IGES type formatfilemodel
4. Meshing the plane model
5. Determining boundary conditions
6. Determining volume conditions
7. Exporting filesin CAE file
8. Opening a CAE file Simulation process is executed with some criteria as follows:

1. Mesh Check and Quality Check
2. Scale, Converts unit, Mesh was created in : *mm*
3. Solver type : Pressure based, transient, and gravity direction –Y
4. Interface : Coupled Wall
5. Reference value : Produk
6. Solution methods, Pressure-velocity coupling scheme : SIMPLE
7. Spatial *discretization*
   - Gradient : Least Squares Cell Based
   - Pressure, Momentum, and Energy : Second Order Upwind
8. Transient formulation : First Order Implicit

B.Schematic Diagram and Boundary Condition

The following is the sample of the schematic diagram and boundary condition of 1 *l* grip packaging mould simulation. The blue one was the cooling interface and the red one was the hot interface, as shown in Fig. 2.

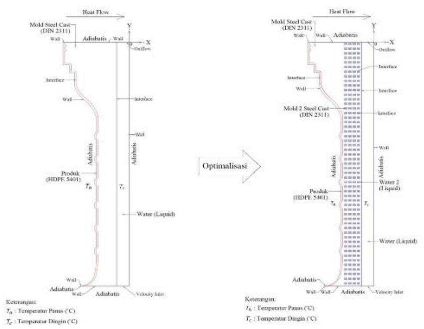


Fig. 2: The sample of the schematic diagram and boundary condition of 1 *l* grip packaging mould simulation

C. Reviewed Point

This critical point is the last standard that has to be reached by the system before mould opened. In critical point, *reflushing* temperature, 50 *°C* had to be reached. Asample of the review point of the 1 *l* grip packaging mould is shown in red colour in Fig. 3.

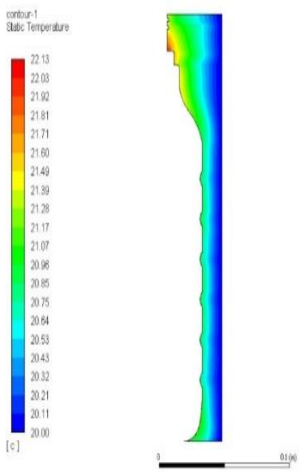


Fig. 3: Sample of the reviews point of the 1 *l* grip packaging mould

IV. RESULT AND DISCUSSION

A. Simulation

Simulation result is more valid to represent the *validator*whenthe simulation error is as small as possible, so that, the validity can represent the real optimization result. It could be seen in Table I, II, and III as follows:

TABLE II
Cycle Time of 1 *l* Non Grip Mould Packaging Simulation

Parameter	*Validator*	Simulatio n	Error
Unit	(*s*)	(*s*)	(*%*)
Cycle Time	25	26.35	5.4

TABLE III
Cycle Time of 250 *ml* Metaprima Mould Packaging Simulation

Parameter	*Validator*	Simulatio n	Error
Unit	(*s*)	(*s*)	(*%*)
Cycle Time	25	26.15	4.6

TABLE IV
The Optimum Cycle Time of 1 *l* Grip Packaging Mould

Parameter	Simulatio n	Simulation Based on Optimization
Unit	(*s*)	(*s*)
Cycle Time	26.45	26.4206

TABLE V
The Optimum Cycle Time of 1 *l Non* Grip Packaging Mould

Parameter	Simulatio n	Simulation Based on Optimization
Unit	(*s*)	(*s*)
Cycle Time	26.35	26.332

TABLE VI
The Optimum Cycle Time of 250 *ml* Metaprima Packaging Mould

Parameter	Simulatio n	Simulation Based on Optimization
Unit	(*s*)	(*s*)
Cycle Time	26.15	26.491

TABLE I
Cycle Time of 1 *l* Grip Mould Packaging Simulation

Parameter	*Validator*	Simulation	Error
Unit	(*s*)	(*s*)	(*%*)
Cycle Time	26	26.45	1.73

B. Optimization Methods

The optimization, asymptote intersection result of convection optimization geometry flow at thecooling depth 15 *mm*is shown in Fig.4.

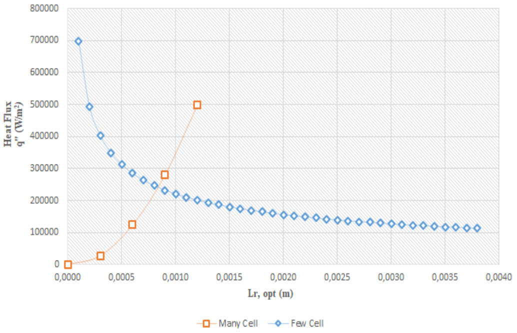


Fig. 4: The asymptote intersection result of convection optimization, geometry flow at the cooling depth 15 *mm*

While, the optimization, asymptote intersection at the cooling depth 10 *mm*is shown in Fig. 5.

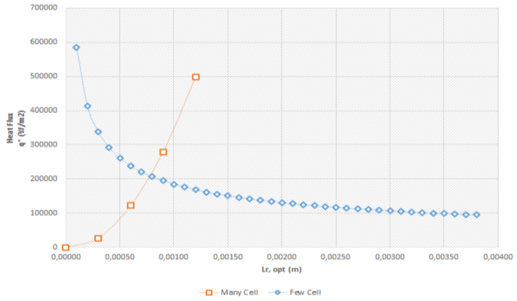


Fig. 5: The asymptote intersection result of convection optimization, geometry flow at the cooling depth 10*mm*

C. Simulation Based on Optimization

The followingTable IV, V, and VI show the effect of simulation based on optimization,geometry convection flow in the Chemical Industryis convertedto the shot each a time. At the same product production,time of the simulation based on the optimization result is shorter than simulation:

D. Temperature Distribution

The temperature distribution of 1 *l*grippackagingmouldsimulation which isthen optimized is captured in the 15.6thsecond of cooling. That time is the time before the 1 *l*

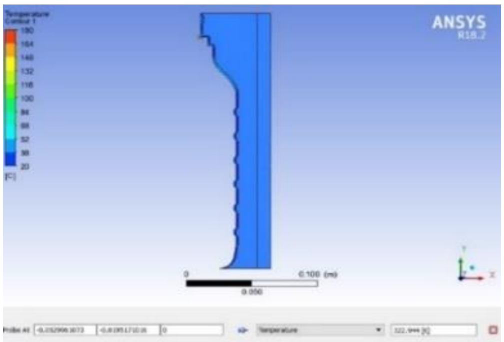


Fig. 6:Temperature distribution of simulation of 1 *l* grip packaging mould 15.6ththe seconds of cooling

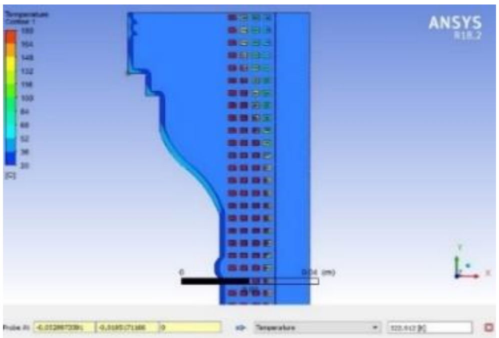


Fig. 7:Temperature distribution of simulation based on optimization of 1 *l* grip packaging mould 15.6ththe seconds of cooling

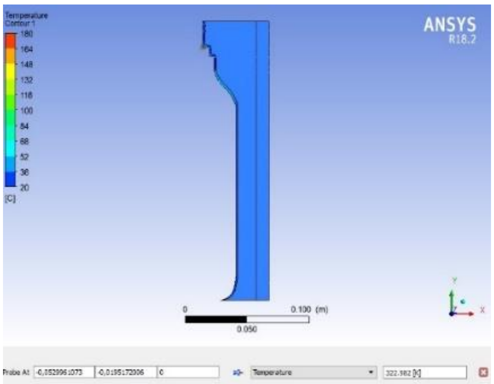


Fig. 8:Temperature distribution of simulation of 1 *l*non grip packaging mould 15.5ththe seconds of cooling

The temperature distribution of 1 *l*nongrippackagingmouldsimulation which isthen optimized is captured inthe 15.5th second of cooling.The temperature of 1 *l* non grip packaging mould simulation before the mould is opened is 322.982 and simulation based on optimization is 322.945*K*as shown in Fig. 8 and Fig. 9.

grip mould packaging is opened. In the picture,the temperature of the simulation based on optimization before the mould is opened is smaller than simulation.The temperature of 1 *l* grip packaging mould simulation before the mould is opened is 322.944 *K*and simulation based on optimization is 322.912 *K*as shown in Fig. 6 and Fig. 7.

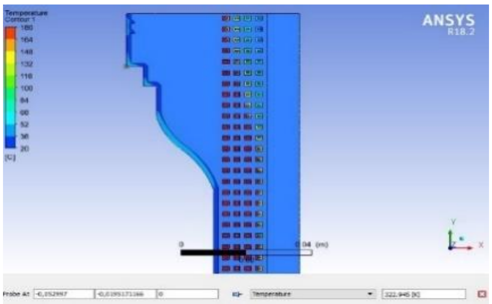


Fig. 9:Temperature distribution of simulation based on optimization of 1 *l* non grip packaging mould 15.5th the seconds of cooling

The temperature distribution of 250*ml*Metaprima packagingmouldsimulation which isthen optimized is shown in Fig. 10 and Fig. 11.

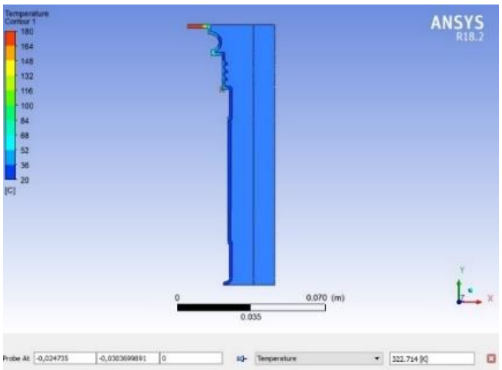


Fig. 10:Temperature distribution of simulation of 250*ml*Metaprima packaging mould 15.3rd the secondsof cooling

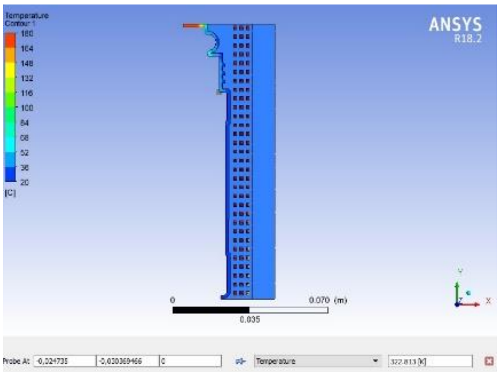


Fig. 11:Temperature distribution of simulation of 250*ml*Metaprima packaging mould 15.7th the secondsof cooling

E. Production Rate and Cooling Effectiveness

In the Table VII, VIII, IX, production rate after the optimization of pesticide packaging mould is converted to production result presentation from target:

TABLE VII
Production Rate of 1 *l* Grip Packaging Mould

Parameter	*Cavity*	Cycle Time	PCs/Shift
Unit	*(PCs)*	*(s)*	*(PCs)*
Validator	6	26	6646
Simulation	6	26.45	6533.081
Simulation Based on Optimization	6	26.4206	6540.351
Simulation Result Difference (Optimization – Validated)			7.269804
***(%)* Target Enhancement**			0.11

TABLE VIII
Production Rate of 1 *l* Non Grip Packaging Mould

Parameter	*Cavity*	Cycle Time	PCs/Shift
Unit	*(PCs)*	*(s)*	*(PCs)*
Validator	6	25	6912
Simulation	6	26.35	6557.87
Simulation Based onOptimization	6	26.332	6562.36
Simulation Result Difference (Optimization – Validated)			4.48282
***(%)* Target Enhancement**			0.07

TABLE IX
Production Rate of 250 *ml* Metaprima Packaging Mould

Parameter	*Cavity*	Cycle Time	PCs/Shift
Unit	*(PCs)*	*(s)*	*(PCs)*
Validator	6	25	6912
Simulation	6	26.15	6608.031
Simulation Based on Optimization	6	26.491	6522.97
Simulation Result Difference (Optimization – Validated)			85.06
***(%)* Target Reduction**			1.28

The picture is captured in the15.3rdand the15.7thsecond of cooling.The temperature of 250*ml* Metaprima packaging mould simulation before the mould is opened is 322.714*K* and simulation based on optimization is 322.813*K*. The cooling time of the simulation based on optimization is higher than a simulation at a cooling distance of 10 *mm*.

The effectiveness of cooling is obtained by comparing net and grossproduction input. The following is the cooling effectiveness of packaging mould as shown in table X, XI, and XII:

TABLE X
The Cooling Effectiveness of 1 *l* Grip Packaging Mould

Parameter	Product *PCs*	Weight	Cooling Effectiv e-ness
Unit	(*PCs*)	(*kg*)	(*%*)
Simulation	6533.081	0.065	70.77
Simulation Based onOptimization	6540.351	0.065	70.85

TABLE XI
The Cooling Effectiveness of 1 *l* Non Grip Packaging Mould

Parameter	Product *PCs*	Weight	Cooling Effectiv e-ness
Unit	(*PCs*)	(*kg*)	(*%*)
Simulation	6557.87	0.065	71.04
Simulation Based on Optimization	6562.36	0.065	71.09

TABLE XII
The Cooling Effectiveness of *250 ml* Metaprima Packaging Mould

Parameter	Product *PCs*	Weight	Cooling Effectiv e-ness
Unit	(*PCs*)	(*kg*)	(*%*)
Simulation	6608.031	0.032	42.29
Simulation Based on Optimization	6522.97	0.032	41.75

F. Optimum Cooling Distance

The cooling depth of the plate optimum is obtained by comparing the optimal distance of

TABLE XIII
The Comparison of Optimize Distance Between Flat Plate and Contour Plate

1 *l* Grip	1 *l* Non Grip	250 *ml* Metaprima	Flat Plate
Rayleigh Number			
>163314	>163314	>48389	>1708
(*mm*)	(*mm*)	(*mm*)	(*mm*)
Horizontal Distance (*L*)			
15	15	10	3.28
Optimal	Optimal	UnOptimal	Optimal

G. Discussion

At the cooling distance of 10 *mm*, the parameterof the optimization effect cannot be found. The followingwill discuss the minimal requirements of optimization: Nusselt Number, Rayleigh Number, *H*, and *L*, water characteristic at hydrodynamic boundary layer, and characteristic of operating condition.

Rayleigh Number influences the asymptote intersection of many cells and few cells.From the asymptote intersection of many cells and few cells, the value of *H* and *L* is obtained. The value of *H*, *L*, and the Rayleigh Number is combined so that Nusselt Number is obtained as shown in Fig. 12.

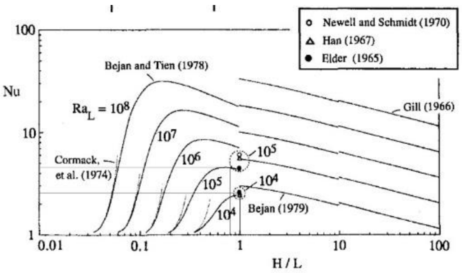


Fig. 12:The relationship of Nusselt Number, Rayleigh Number, *H*, and *L*

The thermal conductivity effect of porous media is increased as high as theNusselt Number, as in [4].

Nusselt number is influenced by the convection coefficient.The height of convection coefficient is indicated by the natural velocity of the fluid in small cell is shown in table XIV.

flat plate and the optimal distance of the sample plate which is obtained from 1 *l*grip, 1 *l* non grip, and 250 *ml* Metaprima packaging mould as shown in Table XIII.

TABLE XIV
Average Natural Fluid Velocity

Parameter	Packaging Mould		
	1 *l* Grip	1 *l* Non Grip	250 *ml* Metaprima
Unit	(*m/s*)	(*m/s*)	(*m/s*)
Average Velocity	0.0013	0.0012	0.0005

Another behaviour of heat transfer inside the porous is obtained as in [5].

Mould temperature difference during the cooling process is shown in Fig. 13, Fig. 14, and Fig. 15.The Figure below is validated as in [6].

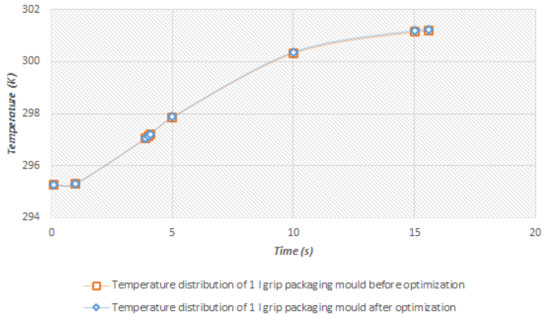


Fig. 13:Temperature distribution of 1 *l* grip packaging mould

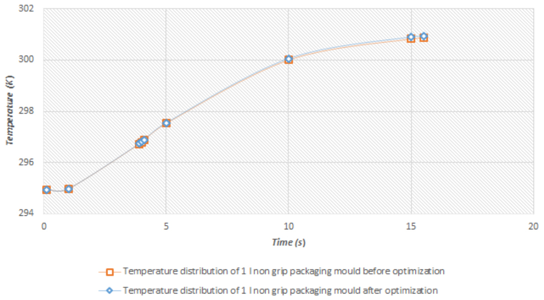


Fig. 14:Temperature distribution of 1 *l*non grip packaging mould

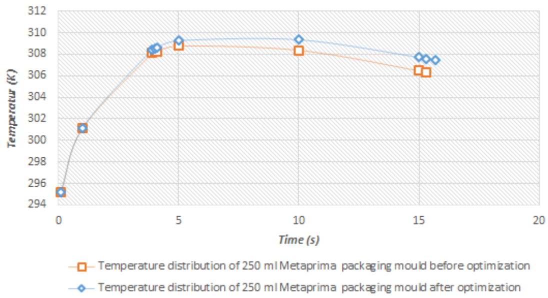


Fig. 15:Temperature distribution of 250 *ml* Metaprima packaging mould

V. CONCLUSION

Based on the simulation result, the potential to increase the cooling effectiveness is obtained by reconstructing mould contour at the distance 15 mm or equal to 4.57 times the flat plate interface. By using porous media, the cooling effectiveness could be optimized for packaging mould of 1 *l* grip and 1 *l* non grip.

ACKNOWLEDGMENT

Thank PT CBA Chemical Industry for giving the permission to use the company name, take properties during the research.

REFERENCES

[1] Brdlĭk, P., 2017, "*The Influence of Cooling Blow Moulding Process on Mechanical Behavior*", AD ALTA, Vol. 461, pp. 1-2.
[2] Aziz, A., 2009, *"A Similarity Solution for Laminar Thermal Boundary Layer Over a Flat Plate with A Convective Surface Boundary Condition"*,Elsevier, Vol. 14, pp. 1064-1068.
[3] Nelson, R. A., 1998, *"Constructal Optimization of Internal Flow Geometry in Convection"*,ASME Journal of Heat Transfer, Vol.120, pp. 357-364.
[4] Ould-Amer, 1998, "*Forced Convection Cooling Enhancement by Use of Porous"* Materials, Elsevier, Vol. 19, pp. 251-258.
[5] Al-Rashed, 2016, *"Double Diffusive Flow in a Porous Medium Embedded with Vertical Annulus with Power Law Heating"*,SSRG – IJME, Vol. 3, pp. 1-4.
[6] Agrawal, Kevin., 2016, *"An Analytical Approach for Inverse Heat Conduction Problem"*,SSRG – IJME, Vol. 3, pp. 5-8.
[7] Phuong Chi Nguyen, DucQuan Tran, *"Research on a PID Controller using PLC for a Heating System"* SSRG International Journal of Electrical and Electronics Engineering 5.1 (2018): 1-5.
[8] RakeshPrajapati ,AvadhootRajurkar , Vijay kumarChaudhary. *"Tool Path Optimization of Contouring Operation and Machining Strategies for Turbo Machinery Blades"*. International Journal of Engineering Trends and Technology (IJETT).
[9] Sandeep Kumar Sharma, Dr.S.K.Nagpure, *"Parametric Analysis of Heat Sink using Finite Element Volume"* SSRG International Journal of Thermal Engineering 3.1 (2017): 8-11.