iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** III **Month of publication:** March 2015

DOI:

Volume 3 Issue III, March 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Influence of Cooling Channel Position and Form on Polymer Solidification and Temperature in Injection Molding Die

S.Karthikeyan[1] S.Jayabal[2] S.kalyanasundaram[3] C Boopathi[4]
[1]PG Scholar, [2]Assistant Professor, [3]Research scholar, [4]PG Scholar A.C.College of Engineering and Technology, Karaikudi

Abstract*-This investigation focuses on the temperature distribution in injection molding component and die, which plays a major role in cooling time and quality of the part. When the molten plastic enters the mold, it cools down and solidifies by dispatching its heat through cooling channels. To study the influence of cooling channel position and forms, a full two dimensional transient type of analysis carried out using ANSYS. For higher productivity and product quality, mold cycle time should be minimized and at the same time, uniform cooling of component should be necessary to avoid thermal residual stresses. An optimized position and form of cooling channel is determined, leads to uniform distribution of temperature with minimized mold cycle time. This study also, shows the comparison between results of positional cooling channels and conformal cooling for die. The results obtained from conformal cooling system design highly minimize the cooling time and it fails to achieve homogeneous cooling throughout the mold.
***Keywords*- Polymer, solidification, Injection molding die, cooling channel, Ansys**

I. INTRODUCTION

Every product in our day to day life involves the use of polymer and plastic products. Polymer injection molding method is the most preferred method of producing these plastic components and is the most efficient method too. It is a cyclic process of three stages includes filling, cooling and ejection. The process cycle of plastic injection molding is shown in Figure1. From the figure, time consumption for Plasticizing and cooling is more than that of all other stages in injection molding. Increased cooling time reduces the productivity of the component. At the same time the quality and strength of the component depends on uniform cooling of plastic inside the mold. Hence an efficient cooling is of great importance for components produced by injection molding technique. Non uniform cooling causes undesired effects such as thermal residual stresses, warpage, and differential shrinkage. Widespread researches and various methods have been conducted in the analysis of efficient cooling cannel design to achieve the objective. H.Hassan et al studied the effect of cooling system on the shrinkage and temperature on a T-shaped plastic part with four cooling channels. They showed that the position of cooling channel highly effect the final product temperature and shrinkage rate [1,3 4]. D.E Dimla et al presented a work on an optimum and efficient design for conformal cooling/heating channels in the configuration of mold. They focused mainly on reducing the mold cycle time, which ultimately increases the productivity of the part [2]. X.P.dang presented a work in U-shaped milled grove with conformal cooling channels. Their focus is to obtain optimal cooling channels configuration and solidification temperature. The relation between cycle time temperature distribution on mold cavity and the cooling channel was illustrated [5]. S.H Tang et al studied the effect of thermal residual stress developed in the mold. These stresses are due to uneven cooling of the specimen, and a model was developed and solved by finite element software called LUSAS. They studied the occurrence of shrinkage near the cooling channels as compared to other parts of mold [6,10].

In this study, the temperature distribution on an injection molding die has been analyses and their discrepancy in distribution by the influence of cooling channel positions and form has also been studied and it also includes the investigation on

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

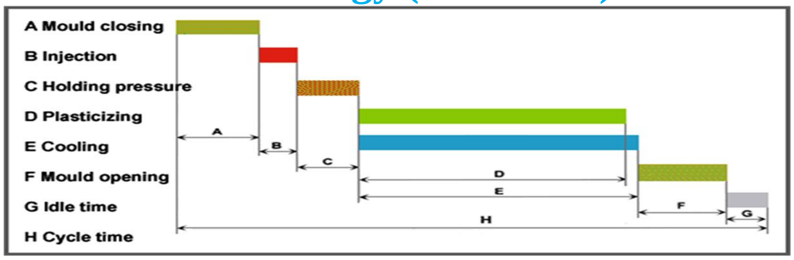


Figure.1 Stages in plastic injection molding

reducing the mold cycle time. Reduction in mold cycle time increase the productivity and uniform cooling eliminate residual stress, shrinkage and warpage problems. It is achieved by selection of proper cooling channel position, form and the outcome is compared with conformal cooling channel design. An optimized cooling channel is identified and the results are validated.

II. METHODOLOGY

A. Selection Of Component

This section illustrates the selection of component which is used for analysis, shown in Figure 2. A cup shaped component is selected of material ABS plastic. The plastic components of simple and complex shapes are manufactured using injection molding machine. The dimensions of the selected component for analysis are shown in Table.1

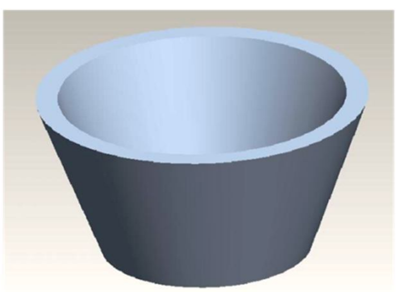


Figure.2 Component for Analysis

Table.1 Dimensions of Component

Component	Size
Base diameter of the cup	50 mm
Thickness of the cup	5 mm
Height of the cup	40 mm
Angle of Inclination of the cup	110^{o}

B. Design Of Injection Molding Die For Analysis

During cooling, mold near the cooling channel experiences more cooling than location far away from the cooling channel. This difference in temperature causes the material to experience differential shrinkage causing thermal stresses. By the way, cooling channels are placed for the selected component shown in Figure 3.

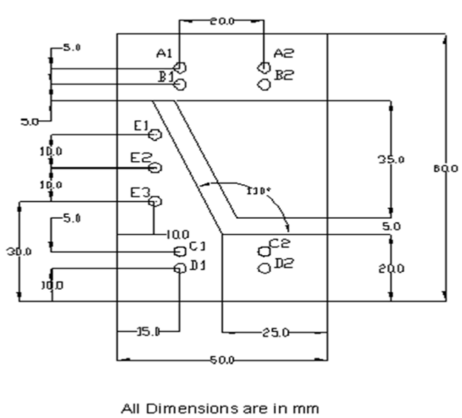


Figure 3.Die for analysis

C. Solving In Ansys

The model for solidification and temperature distribution analysis is developed and solved by using finite element analysis software called Ansys, version 14.5. This software, contour plots of polymer solidification temperature of different mold cycle times. The process flow chat for analysis is shown in Figure 4.

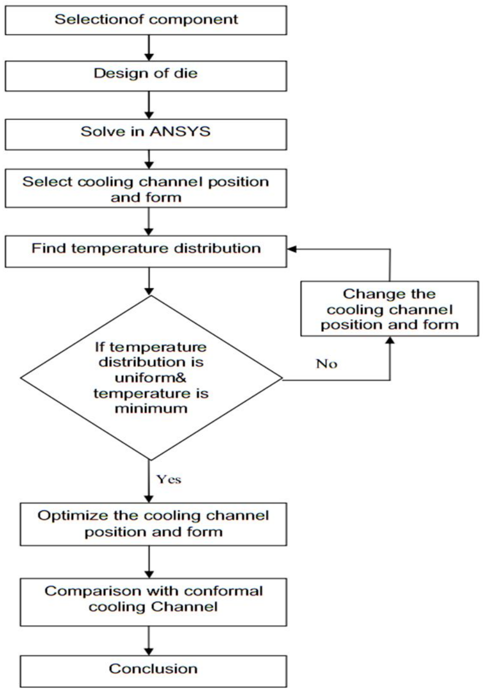


Figure 4.Process Flow Diagram

D. Selection Of Cooling Channel Position

To simplify the analysis, symmetry of the component is selected. Totally eleven cooling channel are selected for the analysis. Four cooling channels are in top, four cooling channels are in bottom and three cooling channels are in side of the component. Six cooling channels are used to cool the component. Two channels are selected from each side of the component. Four rows and one column are analyzed. A, B, C and D represents the rows and E represents the column. A, B, C and D contains the two cooling channel in each row and column E contains three cooling channels. Two cooling channels are selected from the top position, so that six positions are available from the top. For every fixed top position there is a change in bottom and side position of cooling channels. Totally 108 positions are found for the analysis. The cooling condition parameters are shown the Table 2.

Table 2.Cooling Parameters

Cooling Parameters	
Polymer injection temperature	943 K
Temperature of fusion o ABS plastic	393 K
Temperature of coolant fluid	301 K
Ambient air convection temperature	303 K
Heat transfer co efficient of ambient air	77 W/m^2K
Heat transfer of cooling channel fluid(Water)	3650 W/m^2K

E. Selection Of Cooling Channel Form

Once the best cooling channel has identified, the different cooling channel forms of circular, square and rectangle are taken for the analysis to study the effect of cooling with different cooling channels by considering are of the cooling channels are to be same. For analysis, diameter of circular cooling channel is 3 mm. By the way, Sides of the square cooling channel is 1.5 mm and length, breadth of rectangular cooling channel is 2.1, 1.05 mm.

www.ijraset.com
IC Value: 13.98

Volume 3 Issue III, March 2015
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

F. Finding Uniform Temperature Distribution

For every different cooling channel position and form, analysis has been made to find uniformity in cooling. If temperature distribution is not uniform, change the cooling channel forms and positions and redo the analyses. An optimized position is one which expels maximum temperature and uniform cooling of polymer at the end of 20^{th} cycle.

III. RESULTS AND DISCUSSION

A. Influence Of Cooling Channel Position

To investigate the influence of cooling channel position, a full two dimensional transient thermal analysis has been carried out on a cup shaped component of 108 different cooling channels positions. The material for die and cup component is stainless steel and ABS plastic. The cooling configurations and the properties of die and component are shown in the Table 3. The analysis is repeated by changing all the positions for every two fixed positions at the top (A and B). Initially, the analysis was made for circular cooling channels. The diameter of all the channels is same as 3mm. By the way, the position (A2B2C1C2E2E3) giving uniform cooling and expels more heat than any other position. This position is selected in such a way that there is linearity in polymer solidification for every time step and expels more heat from the die. Some other positions expel more heat than position (A2B2C1C2E2E3), but their uniformity in polymer solidification was not up to the earlier. It is found that there is a slight difference between numerical and theoretical values of temperature. The contour plots of Temperature Vs Solidification Time for circular cooling form after 20Sec are shown in Figure 4.

Table 3 Material Properties

Properties	Stainless Steel	ABS Plastic
Thermal conductivity (W/m-k)	36	0.25
Specific heat (J/kg-k)	510	1250
Density (Kg/m^3)	7850	1080
Young's modulus (Kg/m^2)	20×10^9	0.23×10^9
Thermal expansion(m/K)	17.3×10^{-6}	99×10^{-6}

An efficient cooling system design is one providing uniformity in cooling considerably reducing mold cycle time which will enhance quality of the component and productivity. To illustrate the uniformity in cooling and reduction in mold cycle time, the result of best cooling channel position has been selected (A2B2C1C2E2E3). It is fount from the plot that there is evenness in solidification of ABS polymer. Here water is taken as coolant which flow through the holes of the die. It dissipates the heat from the molten polymer, enhance consistency in cooling and reduce the cooling time. The reduction in temperature (K) due to the proper positioning of cooling channels and time steps (Sec) is shown in Figure 5.

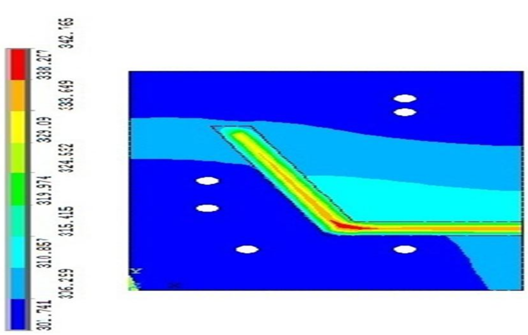


Figure 4. Temperature distribution for circular cooling channel position A2B2C1C2E2E3 after 20s

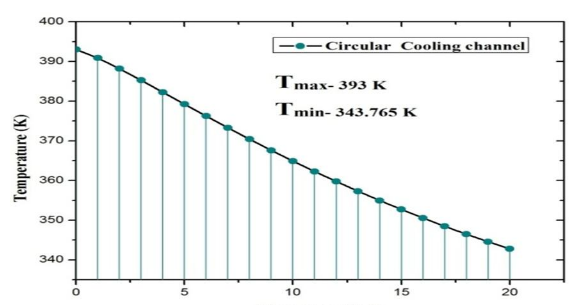


Figure 5. Time steps Vs Temperature for position A2B2C1C2E2E3

B. Influence Of Cooling Channel Form

To demonstrate the influence of cooling channel form on die, there are three different cross sectional forms were taken for analysis as Circular, Square and Rectangle. A consideration is taken that the area of all three forms are same and their influence on polymer solidification, mold cycle time were studied. It is found that there is a non uniformity in polymer solidification which is shown in Figure 6. The variation in temperature distribution with respect to time step for square and rectangular cooling channels were shown in Figure 7. The contour plot result shown in Figure 8-9, indicates that square cooling channel expels more heat than that of rectangular cooling channels. It is noticed that, circular cooling channel positions give better uniformity in cooling, dissipates more heat from die than that of square and rectangular cooling channels. It also reduces the mold cycle time and it will enhance the productivity of the component.

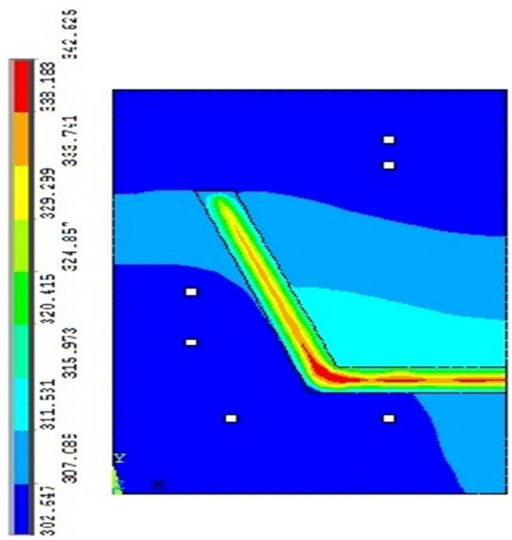


Figure.6 Temperature distribution for square cooling channel position A2B2C1C2E2E3 after 20s

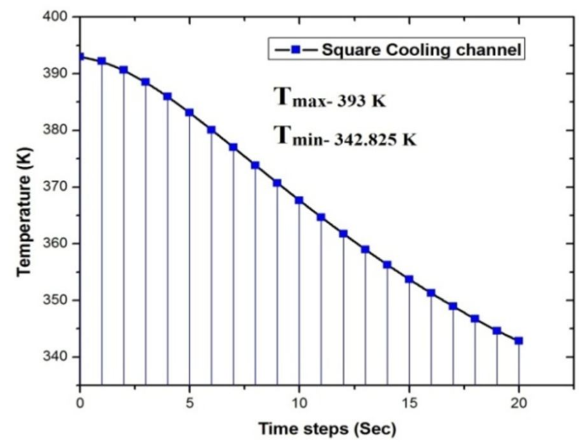


Figure 7 Time steps Vs Temperature for square cooling channel position A2B2C1C2E2E3

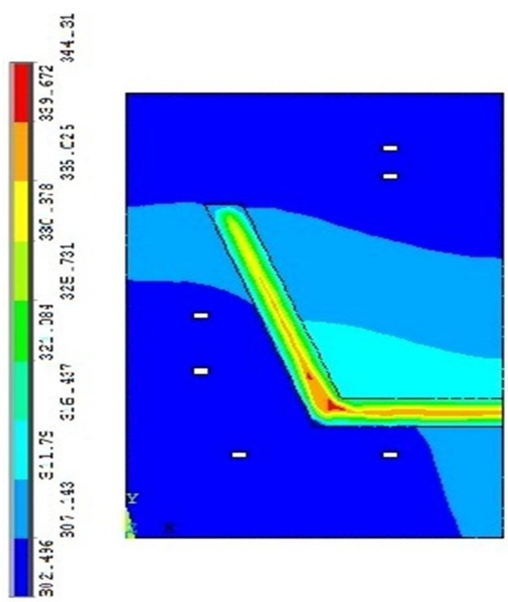


Figure.8 Temperature distribution for rectangular cooling channel position A2B2C1C2E2E3 after 20s

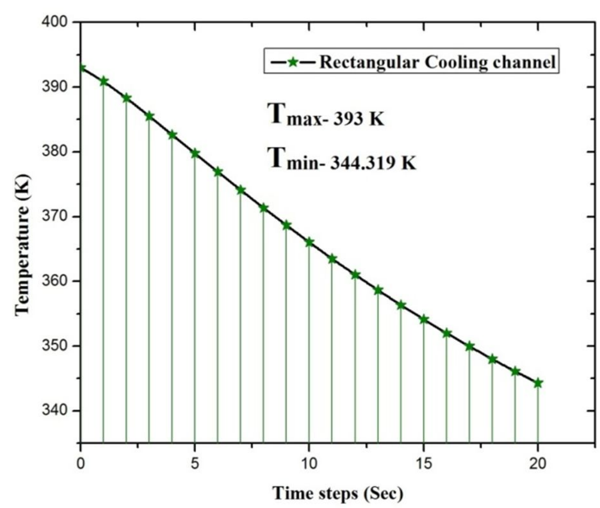


Figure 9. Time steps Vs Temperature for rectangular cooling channel position A2B2C1C2E2E3

Volume 3 Issue III, March 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

C. Positional Cooling Vs Conformal Cooling

It is important to investigate the effect of cup component with conformal cooling design. The effect of polymer solidification temperature on conformal cooling has been studied by placing cooling channel form of shape same that of mold[8,9]. It is observed from the contour plots and graph shown in Figure 10-11, that conformal cooling channel highly enhance the solidification of ABS plastic and expels more heat than positional cooling channels. But there is a non uniformity in cooling of plastic, which causes thermal residual stresses, warpage, results in poor product quality.

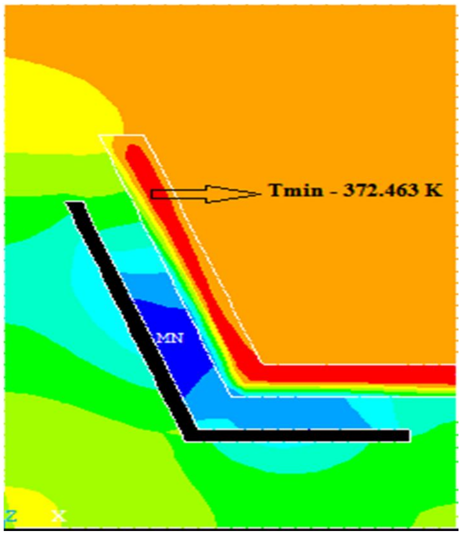


Figure 10. Temperature distribution for conformal cooling channel position

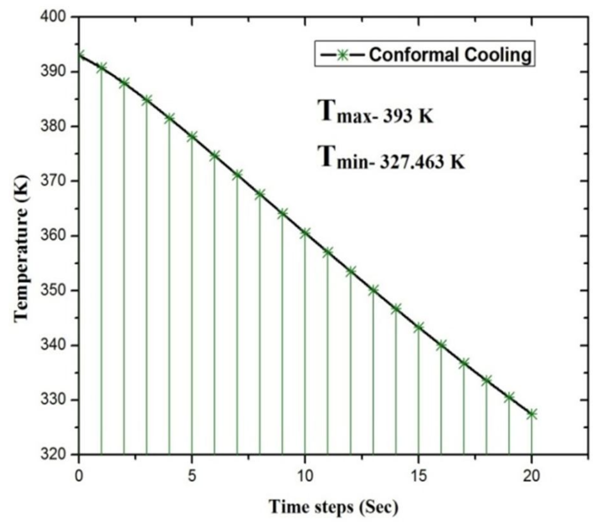


Figure 11.Time steps Vs Temperature for conformal cooling channel position

D. Validation

The results obtained from numerical simulation are validated in accordance with theoretically values. Here a mode, shown in Fig12, of 17 nodes taken for theoretical validation. Out of 17 nodes, the temperature at nodes 1,2,3,4,5,6 were evaluated with the aid of remaining nodes with their initial conditions find the temperatures at nodes 1, 2, 3, 4, 5, 6 with the help of other nodes by applying their initial conditions using Finite Difference Method.

The developed transient finite difference equations are

$$T_1^{i+1} = 0.1T_1^i + \left(T_2^i + 378.5\right) \times 0.4$$
$$T_2^{i+1} = 0.26T_2^i + \left(4T_3^i + 2110.14\right) \times 0.067$$
$$T_3^{i+1} = 0.2T_3^i + \left(T_2^i + T_4^i\right) \times 0.2$$
$$T_4^{i+1} = 0.6T_4^i + \left(T_3^i + T_5^i\right) \times 0.2$$
$$T_5^{i+1} = 0.6T_5^i + \left(T_4^i + T_6^i\right) \times 0.2$$
$$T_6^{i+1} = 0.96T_6^i + 0.0112T_5^i$$

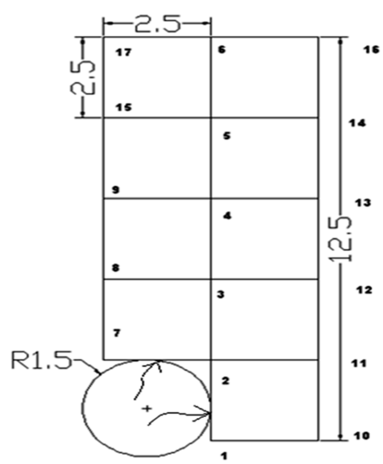


Figure 12. Model for Validation

By applying $i = 0,1,2,3..$ in above equations, the values of temperature at nodes 1, 2, 3,4,5,6 were obtained for time 5,10,15,20 sec. The comparison between analytical and theoretical values for nodes 1, 2, 3,4,5,6 are shown in Table 4. The percentage error of validation is 1.8% which is less than 5%.

Table 4. Analytical Vs Theoretical validation

Nodes	1	2	3	4	5	6
Analytical At t=15 sec in k	301	301.6	307.3	324.33	347.047	352.7
Theoretical At t=15 sec in k	301.6	302.2	308.67	330.98	358.98	359.5

IV. CONCLUSIONS

Temperature distribution is more important in injection molding die because, it affects the quality of the part and cooling time of the product. Placing of cooling channel position affects the cooling time of the product. More heat is transferred from the particular surface of the component, so that more cooling channels are in need for those surfaces. By the way, conformal cooling channel design expels more heat when compared with positional cooling. On the contrary, non-uniformity in conformal cooling highly influences the part quality which will enhance thermal residual stresses. From the positional analysis it is found that A2B2C1C2E2E3 is more effective when compared with all other positions of the cooling channels. In form of cooling channels, circular cooling channel is more effective when compared to rectangular and square cooling channel. Correctly placing the cooling channel reduces the uneven cooling of the part, thermal residual stresses and warpage problem of the component.

REFERENCES

[1] Hassan, Hamdy, Nicolas Regnier, Cedric Lebot, Cyril Pujos, and Guy Defaye. "Effect of cooling system on the polymer temperature and solidification during injection molding." *Applied Thermal Engineering* vol.29, no. 8, pp.1786-1791, 2009.

[2] Dimla, D. E., M. Camilotto, and F. Miani. "Design and optimization of conformal cooling channels in injection moulding tools." *Journal of Materials Processing Technology* vol.164, pp.1294-1300, 2005.

[3] Hassan, Hamdy, Nicolas Regnier, Cyril Pujos, Eric Arquis, and Guy Defaye. "Modeling the effect of cooling system on the shrinkage and temperature of the polymer by injection molding." *Applied Thermal Engineering* vol.30, no. 13 pp.1547-1557, 2010.

[4] Hassan, Hamdy, Nicolas Regnier, Cédric Le Bot, and Guy Defaye. "3D study of cooling system effect on the heat transfer during polymer injection molding."*International Journal of Thermal Sciences* vol.49, no. 1, pp.161-169, 2010.

[5] Dang, Xuan-Phuong, and Hong-Seok Park. "Design of U-shape milled groove conformal cooling channels for plastic injection mold." *International Journal of Precision Engineering and Manufacturing* vol.12, no. 1 (2011): pp.73-84, 2011.

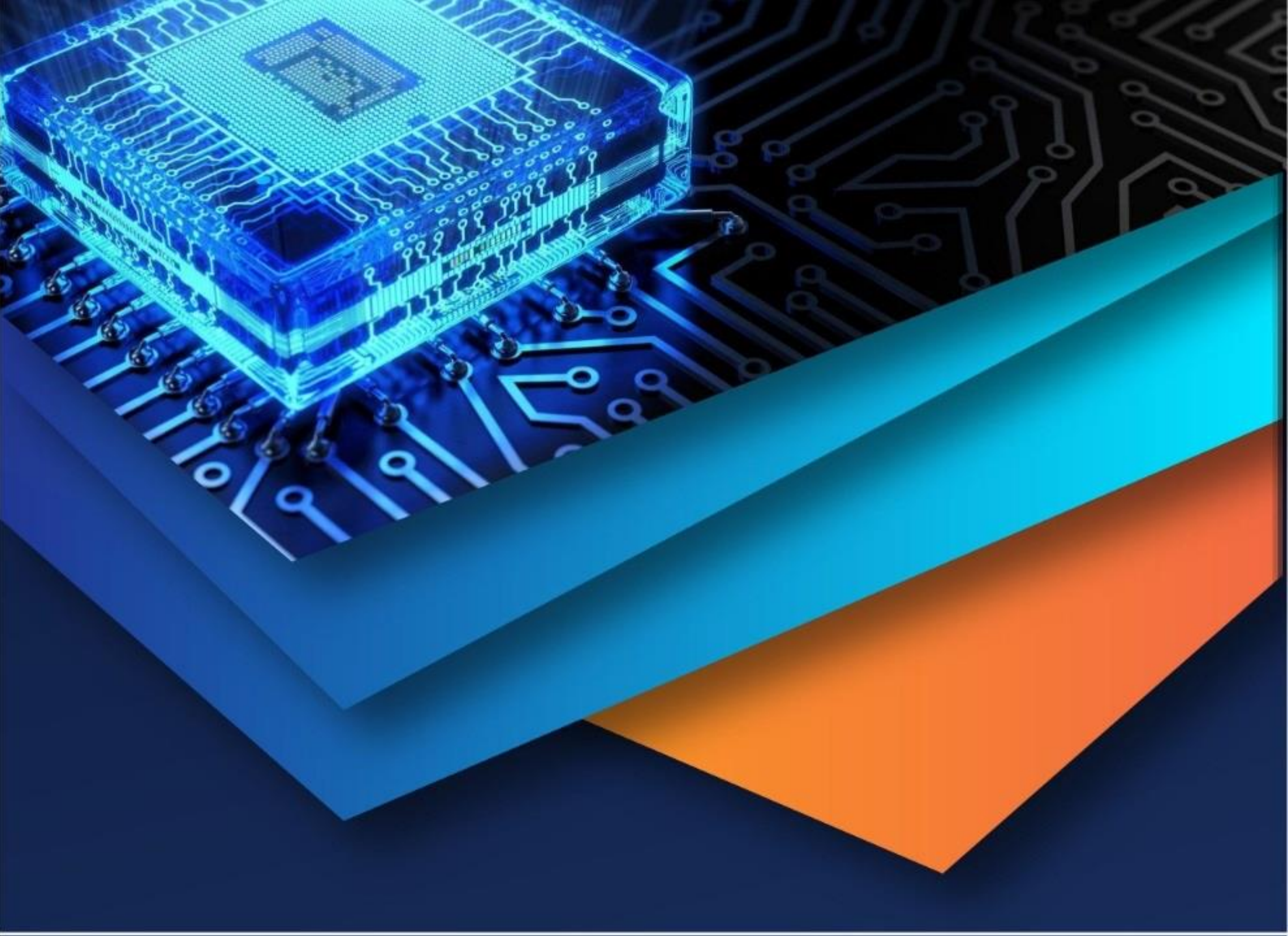
[6] Tang, S. H., Y. M. Kong, S. M. Sapuan, R. Samin, and S. Sulaiman. "Design and thermal analysis of plastic injection mould." *Journal of materials processing technology* vol.171, no. 2 , pp.259-267,2006

[7] Tang, Li Q., Constantin Chassapis, and Souran Manoochehri. "Optimal cooling system design for multi-cavity injection molding." *Finite Elements in Analysis and Design* vol.26, no. 3, pp.229-251, 1997.

[8] Hsu, F. H., K. Wang, C. T. Huang, and R. Y. Chang. "Investigation on conformal cooling system design in injection molding." *Advances in Production Engineering & Management* vol.8, no. 2 , pp.107-115, 2013

[9] Au, K. M., and K. M. Yu. "Conformal cooling channel design and CAE simulation for rapid blow mould." *The International Journal of Advanced Manufacturing Technology* vol.66, no. 1-4 , pp.311-324, 2013.

[10] Tang, Li Q., Constantin Chassapis, and Souran Manoochehri. "Optimal cooling system design for multi-cavity injection molding." *Finite Elements in Analysis and Design* vol.26, no. 3, pp.229-251, 1997.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY