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Design Optimization for Assemblies Using CAE Tools to Simplify Tolerance

[1]Saikumar Amda, [2]N.V. Srinivasulu, [3]L. Sivarama Krishna
[1]Research scholar, [2]Professor, [3]Professor
[1]Department of Mechanical Engineering,
[1]University College of Engineering Osmania University, Hyderabad, India

Abstract: The need of tolerance analysis is required for any mechanical product as this influences the accuracy and functional performance during the assembly of mechanical system. The tolerance of inserts play a crucial role in the success of mould filling. If the tolerances are too tight, it can lead to restricted flow and incomplete filling, while loose tolerances can result in excessive flash and overfilling. It is essential to carefully consider and optimize the tolerances to ensure proper mould filling. The tolerance of inserts can greatly affect the flow of molten material into the mould, as any deviations in the dimensions of the inserts can lead to uneven filling and potential defects in the final product. A study is conducted on the effects of the injection pressure, melting temperature and cooling time on the defects of Injection Moulding die, accordingly adjusting the tolerances in the mould inserts during the design phase of multi-cavity cap mold filling are crucial for ensuring consistent and precise production. CAE tools play a crucial role in optimizing the multi cavity threaded cap injection mould filling process. By simulating and analyzing the flow of molten plastic in each cavity, these tools help identify potential filling imbalances, optimize gate locations, and ensure consistent quality throughout the production cycle the resulting mould filling simulations generated by CAE tools can provide more reliable predictions of the actual manufacturing process. This allows for better optimization of the mould design and reduces the risk of defects or inconsistencies in the final molded products.

***keywords* – Tolerance, Moulding ,Die ,Multicavity, CAE.**

I. INTRODUCTION

The integration of tolerance in CAD supports the tolerance activities during the product design development. Traditional tolerancing methods often fall short when dealing with flexible components, which can deform under various conditions, leading to assembly inaccuracies. A model that integrates the mechanical behavior of parts into the tolerancing analysis to predict and accommodate the deformation of parts during the assembly process. By incorporating finite element analysis (FEA) into the CAD environment, the model provides a more realistic simulation of part behavior under assembly forces. This integration allows for the identification and correction of potential misalignments and tolerance issues before physical prototypes are created [1]. By using CAE, a powerful simulation tool, the method accurately predicts potential defects and evaluates the performance of dies under different conditions. This predictive capability allows for preemptive adjustments, thus preventing defects before they occur in actual production. Cost reductions are achieved by minimizing material waste and enhancing process efficiency. Product quality is improved through precise control over forging parameters, ensuring consistent and defect-free outcomes. Cycle times are shortened due to the streamlined process and reduced need for iterative shop floor trials. Additionally, the comprehensive analysis of die performance and forging loads helps in designing more robust and durable tooling. The application of CAE softwares in the study underscores the critical role of modern simulation tools in revolutionizing the die industry, making processes more efficient, cost-effective, and reliable [2]. The aim of this research is to study the tolerance interpretation with Moulding Die assemblies. So, the need for more comprehensive studies on the effects of different process parameters on part quality could be investigated.

II. TOLERANCE ANALYSIS AND OPTIMIZATION FOR MECHANICAL ASSEMBLIES

The survey examines recent advancements and methodologies in dimensional tolerance analysis and optimization for mechanical assemblies. R. Mordia and colleagues explored tolerance analysis for both symmetric and asymmetric tolerances in mechanical assemblies. A. Corrado and W. Polini focused on integrating Finite Element Analysis (FEA) with tolerance analysis using Skin Model Shapes. R. Chavanne and B. ecent advancements and methodologies in dimensional tolerance analysis and optimization for mechanical assemblies. R. Mordia and colleagues explored tolerance analysis for both symmetric and asymmetric tolerances in mechanical assemblies. A. Corrado and W. Polini focused on integrating Finite Element Analysis (FEA) with tolerance analysis using Skin Model Shapes. R. Chavanne and B. Anselmetti discussed functional tolerancing for complex junctions using virtual material conditions. E. Bassoli et al. investigated the effects of surface roughness, dimensional tolerance, and tool-chip interaction in deep drilling of aluminum die-cast parts. B. Barbero, J. Azcona, and J. Pérez presented a meth odology combining 3D CAT with a dimensional hierarchization matrix and optimization algorithms. M. Walter and co-authors surveyed the use and awareness of statistical tolerance analysis in German industry. M. Mazur, M. Leary, and A. Subic developed a Computer Aided Tolerancing (CAT) platform for assemblies subjected to various forces. A. Rezaei Aderiani et al. integrated tolerance and fixture layout design for compliant sheet metal assemblies. A. Huotari studied simultaneous optimization of design and manufacturing tolerances with alternative processes. A. Ballu and colleagues represented mechanical assemblies and specifications using graphs, while P.G. Bernardos and others predicted elastic deflections of workpieces under cutting forces.E. Bassoli et al. investigated the effects of surface roughness, dimensional tolerance, and tool-chip interaction in deep drilling of aluminum die-cast parts. B. Barbero, J. Azcona, and J. Pérez presented a methodology combining 3D CAT with a dimensional hierarchization matrix and optimization algorithms. M. Walter and co-authors surveyed the use and awareness of statistical tolerance analysis in German industry. M. Mazur, M. Leary, and A. Subic developed a Computer Aided Tolerancing (CAT) platform for assemblies subjected to various forces. A. Rezaei Aderiani et al. integrated tolerance and fixture layout design for compliant sheet metal assemblies. A. Huotari studied simultaneous optimization of design and manufacturing tolerances with alternative processes. A. Ballu and colleagues represented mechanical assemblies and specifications using graphs, while P.G. Bernardos and others predicted elastic deflections of workpieces under cutting forces.

There are various methods and techniques for tolerance analysis and optimization in mechanical assemblies of plastic injection molding. Magesh and Mani Kandan focused on the design, fabrication, and tolerance analysis of progressive tools. Haghighi et al. automated tolerance analysis from CAD models with PMI. Umaras and colleagues applied a cost-based optimization approach for dimensional tolerances in mechanical assemblies. Govindarajalu and Sivakumar utilized FEA and neural networks for parametric tolerance analysis and cost-competent synthesis. Chang et al. analyzed and experimentally verified mechanical errors in clamping mechanisms. Jasurda emphasized dimensional engineering and tolerance analysis for precision. Sahani et al. conducted tolerance stack-up analysis for mechanical assemblies. Sharma et al. assessed process-based tolerances in connecting rod machining. Judic proposed a new approach to integrate process truths in tolerance analysis. Tsai and colleagues improved assembly precision in injection molds through tolerance allocation and stack-up analysis. Bharti et al. reviewed optimization methods for plastic injection molding processes. Lemes compared injection-molded parts using coordinate measuring machines. Alkaabneh et al. presented a statistical analysis for residual stress in injection molding. Gasparin et al. assessed quality control and process capability in micro-molding. Baruffi et al. compared micro and conventional molding processes. Lin and Chen used Taguchi optimization for roundness and concentricity in molded plastic barrels. Kale and Hambire optimized HDPE molding processes to reduce shrinkage. Liu et al. focused on multi-objective optimization for plastic optical lenses. Prabu and Sathishkumar enhanced and optimized plastic injection molding design. Rajalingam and Vasant optimized molding parameters for cell phone housing components, while Darekar and Venkatesh reviewed optimization aspects for the molding process. Sowrabh used CAE simulation software to optimize plastic injection molding by analyzing parameters like fill time, pressure, and temperature. Optimal conditions were identified as a fill time of 2.5 seconds and an injection pressure of 85 MPa. The uniform temperature distribution minimized defects such as warping and sink marks. Strategic gate and runner placement reduced potential issues and led to a 15% reduction in material usage and a 20% improvement in cycle time. Overall, mold flow analysis software proved effective in enhancing product quality and manufacturing efficiency. The techniques employed include automation, cost-based optimization, FEA, neural networks, Taguchi methods, and statistical analysis.

III. MOULD FLOW ANALYSIS

The present work is to study the effects of different process parameters on threaded cap quality by adopting CAE tools and find out optimum values through this analysis.The following is the step-by-step procedure for the "Hot runner mould design and plastic flow analysis for cap" problem using the PRO-E & MOULD FLOW ANALYSIS

Overview of Steps Involved in Solving the Problem.
Step 1: Data preparation
Step 2: Preparing drawing as per industrial standards
Step 3: Preparing pro-e models
Step 4: Mold flow analysis and comparison between normal and hot runner mold.
Step 5: Calculating mould parameters
Step 6: Preparing 3D models of general and hot runner molds

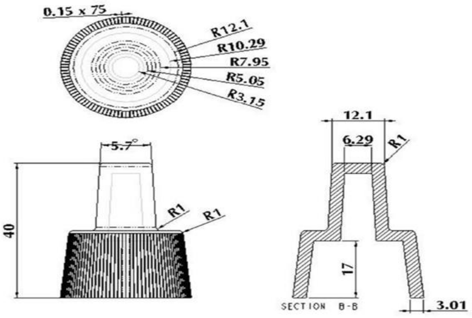
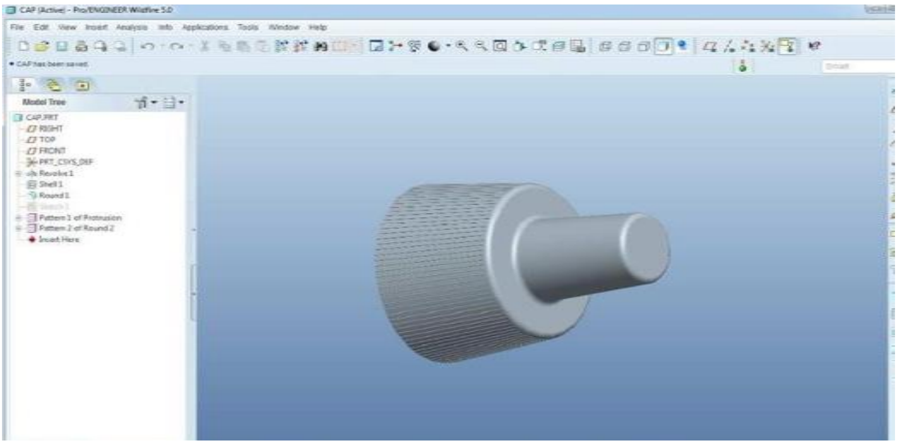
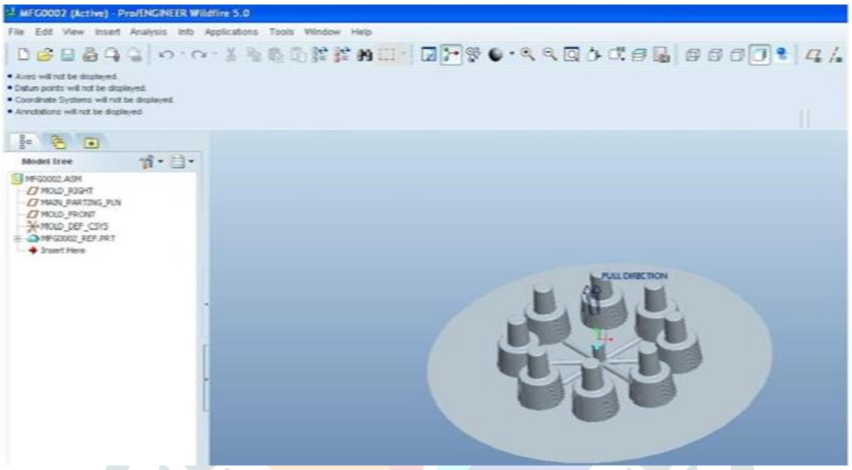


Fig.1 :Drafting of Cap



• CAP has been saved.

Fig .2 :Cap



• Axes will not be displayed.
• Datum points will not be displayed.
• Coordinate Systems will not be displayed.
• Annotations will not be displayed.

Fig. 3: Cap solid model

3.1 Plastic Flow Analysis

The Flow Analysis summary page gives an overview of the model's analysis, provides information about pressure, actual injection time and whether weld lines and air traps are present. In order to assess the mold ability of the part, the dialog uses the Confidence of Fill.

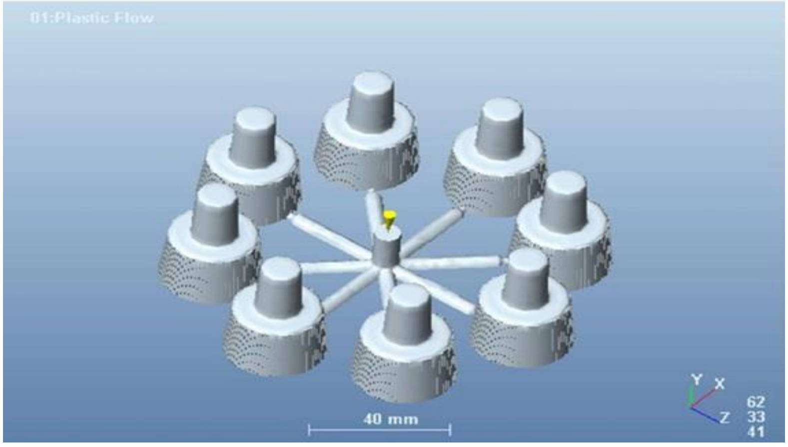


Fig.4: Plastic Flow in model.

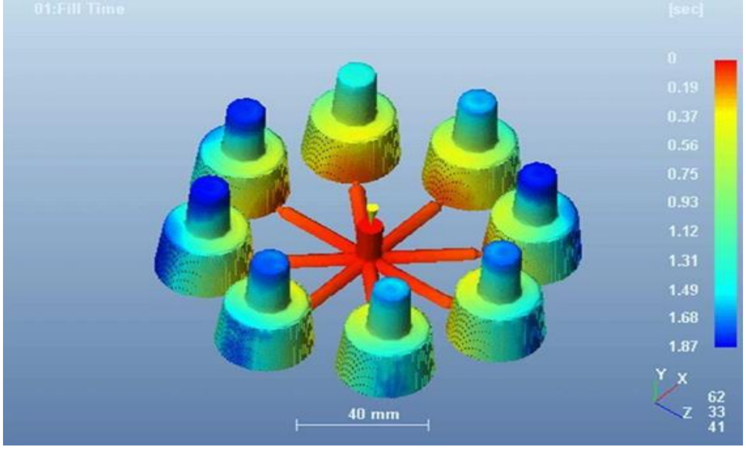


Fig.5: Plastic flow in fill time.

Fill Time: Pressure Result Derivation This result shown by plotting contour of the part which joins regions of filling plastic at same time through the flow path of the plastic. These contours are displayed in a range of red color, to indicate the first region to fill, through to blue to indicate the last region to fill. A part of the model that did not fill is known as short shot, and will be displayed as translucent. The impression of plastic flowing into the mould is given by plotting these contours in time sequence.

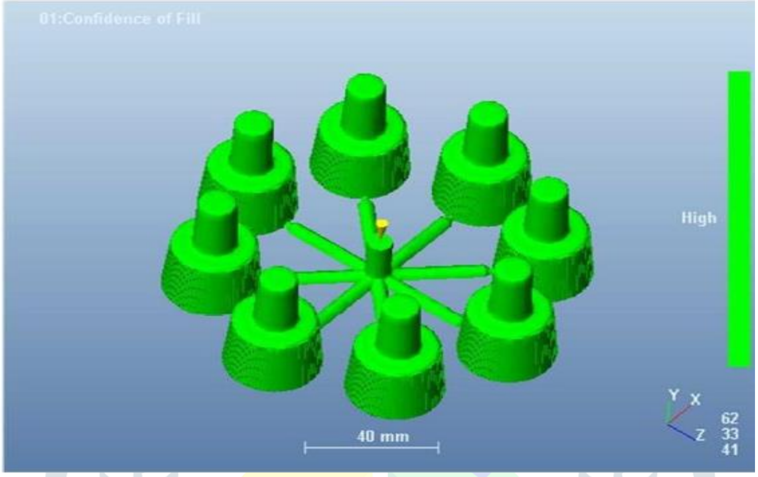


Fig.6: Plastic flow in confidence of fill.

Confidence of Fill: The probability of a region within the cavity filling with plastic at conventional injection molding conditions is displayed as a result of confidence of fill. This result is derived from the pressure and temperature results.

Pressure Result Derivation

There is always a pressure gradient from a maximum value at the injection location down to atmospheric pressure at the flow front at any point during Filling. The pressure distribution is measured continuously throughout the cavity filling by the adviser and presents you with 2 pressure results considered as a reference to the following simple part having single polymer injection location at one end.

The graph below shows how pressure varies over time at both the polymer injection location and at the point marked X

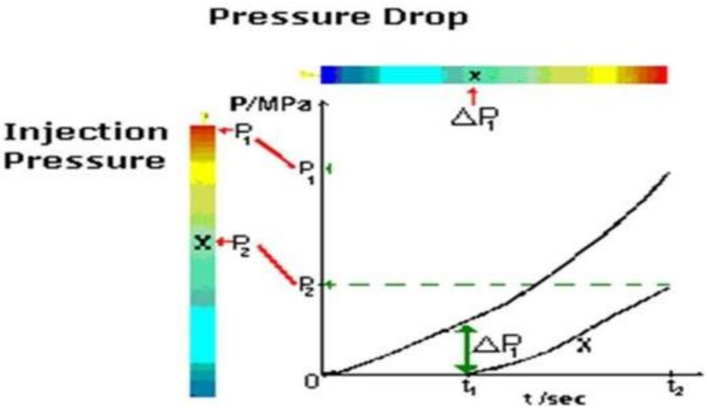


Fig.7: Pressure Drop plot

- The Advisor calculates both of its pressure results in the above graph.
- The contour plot showing the pressure required to flow material to each point in the cavity is the result of Pressure Drop. The pressure at the injection location is a calculated value as a point (X in our example) fills and this value is plotted at the point with respect to X on the model. The drop in pressure is not displayed for any moment but the Injection Pressure result is displayed.
- The displayed value is related to the location in question (X) actually filled at that time.

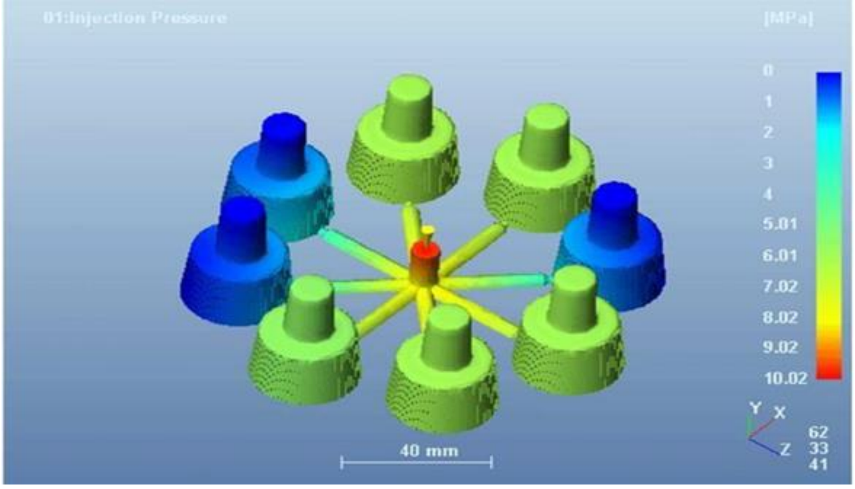


Fig.8: Injection pressure in model.

A contour plot of the pressure distribution throughout the cavity at the end of filling is the result of Injection Pressure. This effective image is taken at a instant of time. The above image shows that at the injection location value is maximum and minimum at the last point of the cavity to fill.

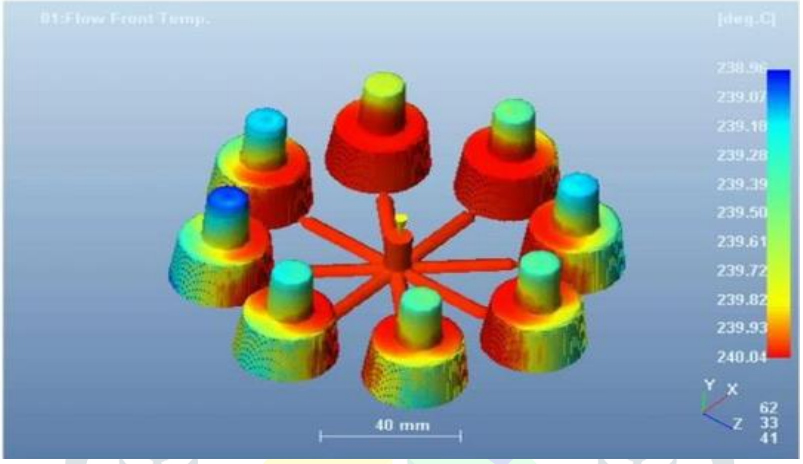


Fig.9: Flow Front temperature in model

Flow Front Temperature:

A range of colors is used to indicate the region of lowest temperature (colored blue) through to the region of highest temperature (colored red) shown in the result of flow front temperature. The color shows the material temperature at each point as that point was filled,Changes in temperature of the flow front during filling are shown as a result.

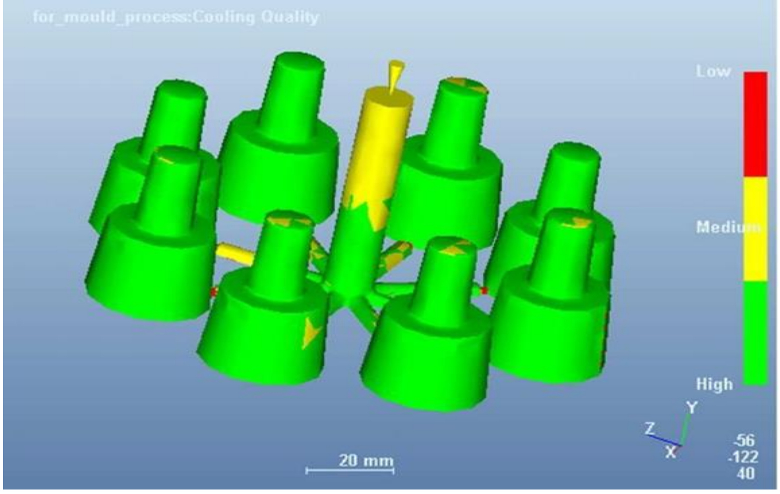


Fig.10 :Cooling Quality in model.

Cooling Quality

The entire time that is required to freeze all areas of the part completely and plots variations from that time value is calculated in the Cooling Quality analysis. The area need more cooling which has a greater freeze time than normal as indicated in a result to compensate for the heat that is concentrated in that area.

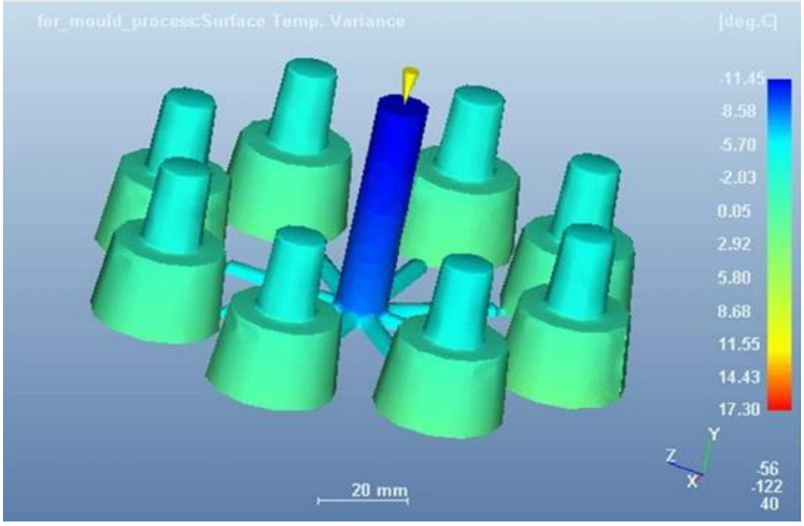


Fig.11:Surface Temperature Variance in model

The Mould Flow Analysis is done on cap set which is made for the cavity preparation. We are using mould flow analysis for finding the material filling, pressure distribution, air traps, and weld lines formed during injection molding process. the plastic-filling process for injection molded parts, Pro/ENGINEER Plastic Advisor enables engineers to design for manufacturability, uncover problems, and propose remedies, reducing development time and expense. Hot runner mould is used for minimizing expenditure and cost estimation. By using hot runner mould we can increase the production rate of caps 10 times than general mould. Using hot runner mould, reduction of time in production so that we can increase the production rate.

IV. RESULTS AND DISCUSSION

The results from the mould analysis are studied for Cavity fill time up to 1.87seconds, Injection pressure for 10.02 MPa, 70% flow front temperature is observed at 230ºC to 240ºC.

Table 1 CAE results of mould cavity

S.no	Parameters	Values
1	Melting Temperature [°C]	230-240
2	Injection Pressure (MPa)	0-10
3	Cooling Time [seconds]	0-120

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V. CONCLUSIONS

CAE tools play a crucial role in optimizing the design of flip cap moulds for injection moulding. These tools allow for simulation and analysis of various factors such as flow, cooling, and warpage, ensuring the production of high-quality caps. The use of CAE tools in these 8 caps regular and flip cap moulds of injection moulding enables engineers to simulate and optimize the filling process, ensuring uniform and consistent filling of the mould cavities.

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