Analysis of gate location and its effect on warpage in plastic injection molding

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ABSTRACT

This project emphasizes conveying a crucial message to mold designers, makers, and organizations. Moldex3D, with its powerful pre-processing tools like automatic mesh generator and intelligent modeling wizards, significantly enhances designer efficiency. Moldex3D Design's information, including material flow rate, filling rate, cooling rate, shrinkage graphs, and virtual mold, helps verify the permanent bending (warpage) in components due to non-uniform cooling rates. The analysis focused on gate location and points for an automotive tailgate lower trim plastic component. Three cases (A, B, and C) were studied, with estimated total warpage ranging from 0.15 to 15.77 mm. The minimum warpage is preferred during mold manufacturing for this component.

Keywords— Injection molding; Gate location; total warpage; Moldex-3D

I. INTRODUCTION

The injection molding technique was first designed in the 1930s and was originally based on metal die casting designs. Injection molding is manufacturing method for forming components by injected molten plastic at high pressure into a mold, to produce the product's shape in manufacturing field, molding by injection method extensively utilized to produce a variety type of parts, from the tiny component to biggest component. The typical application of this process involves thermoplastic materials that undergo consecutive steps of melting, reshaping, and cooling. Sink marks are depressions positioned at the surface of injection-cast plastic parts caused during the plastic cooling process. Thicker sections of plastic will cool at a slower rate than others, and will yield a higher percentage of shrink in that local area [11]. The extra shrinkage in that local area is what causes the depressions. After the on the outside has cooled and solidified the core material start to cool. Its shrinkage pulls the exterior portion of the main wall inward, causing a sink mark, this defect is called as warpage defect.to overcome from this defect we need select a proper gate location and size of the gate during mould design.in this research we considered three types gate and they are located at different location we made comparison between these three gates by their warp / displacement by using moldex-3d simulation software.by this study we comes to know that which type of gate location produces minimum warpage product.

II. LITERATURE SURVAY

Header Haddad, Syed H. Masood, Abul B.M. Saifullah [1] he determined the Gate Location and its effect on Product Quality in Injection Molding by using simulation software, Xiaomin Cheng, Shuzhen Liu, Xudong Zheng, Naiyu Seng, [2] they determined Effect of Gate Number on the Warpage in Injection Molding Through the utilization of MOLDFLOE software, the effect of gate number on warpage in the injection molding technique was examined, NikMizamzulMehat, Shahrul Kamaruddin, and Abdul Rahim Othman G. A. Britton,

Y. C. Lam and Y.-M. Deng they made [3] An extensive simulation study was conducted on plastic gears used in diverse applications involving power transmission and motion. By employing a systematic grey-based Taguchi optimization method, the effects of gating system types, gate locations, and processing parameters on gear performance were analysed, Huang-Ya Lin, Wen-Bin Young they made aresearch on [4] Analysis of the filling capability to the microstructures in micro-injection molding, this research introduces an analytical model specifically tailored for micro-injection molding. The analytical model developed in this study estimates the temperature of the plastic melt near the entrance of the microstructure once mold filling is complete. Using thistemperature data, the injection distance into the microstructures of the mold insert during the packing stage can be calculated, this study emphasizes the value of the analytical model presented herein as a reliable alternative for such predictions, Jakub Kalus , Jens Kjær Jørgensen they made a research on [5] By utilizing digital image correlation they measured mechanical properties and deformation in weld lines of short fiber reinforced thermoplastics, from Shiang-Yu Teng , Sheng-Jye Hwang [6] The study of explores the relationship between package geometry and paddle shift by examining six models of Thin Quad Flat Packages (TQFP) with varying geometrical parameters. By comparing the simulation results with investigational data, the paper demonstrates the accuracy of the active numerical approach, Mladen Šercer, Damir Godec, Božo Bujan they made a research on [7] Application Of Moldex3D For Thin-wall Injection Moulding Simulation,Moldex3D software was employed to simulate injection molding processes, enabling the prevention of potential molding issues. The simulation results were then utilized to optimize existing product designs facilitate mold development, and refine processing parameters such as injection pressure and mold cavity temperature, from Cebeli Ozek and Yahya Hıs¸man C¸ elık [8] This research study aimed to address this challenge by developing an innovative software program named NPP-Software. The software utilizes an artificial neural network (ANN) model to calculate various injection molding parameters for polymer products,from S.Selvaraj, P.Venkataramaiah [9] There research focuses on the development of an automated injection molding tool for efficient 18 manufacturing of CAM BUSH connectors used in electrical engines, from G. A. Britton, Y. C. Lam and Y.-M. Deng [10] this paper proposes a 39 novel approach using a specification model that integrates analysis and evaluation data with the CAD model of a plastic part. This enables designers to directly specify their verification and evaluation criteria within the CAD design model, facilitating seamless activation of Moldflow for relevant analyses and automated taking of data from the results to verify and evaluate the designs.

III. PROBLEM STATEMENT

The selection of an improper gating system and gate location can have a substantial impact on the quality of an output molded part. Design departments should, therefore, not to underestimate the importance of the gate location. Apart from carrying out design calculations for plastics parts, designers must pay the particular attention to mould gating. They have to choose the correct gating system and the number and location of gating points. The type of gate and gating locations can have a considerable effect on part quality.

IV. FINITE ELEMENT MODELING AND GATE LOCATION

The automotive tailgate lower trim is chosen as the molding part for Analysis of gate location and its effect on warpage in plastic injection molding, CAD model of the automotive tailgate lower trim (Dimensions of Part Width: 1183mm Length: 631mm Height: 160mm) is showed in Fig.1, 'stl' file format CAD model is imported into moldex-3D and meshing operation is performed on it Higher solid mesh gives the higher quality of result, mesh file is saved as a 'MDE' file format, different size and types of gate with different height and length of the runner and sprue is selected in this studies,

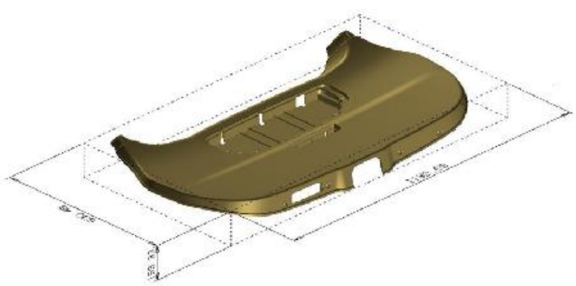

FIG.1 CAD model of Tailgate lower trim

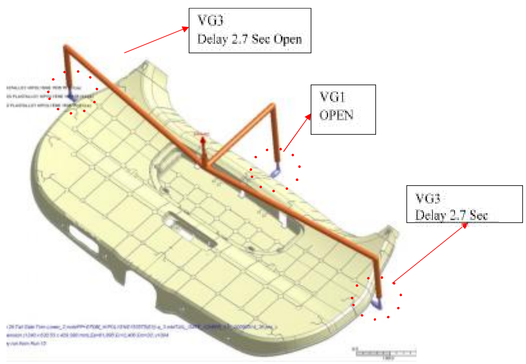

FIG.2 model after mesh division and runner layout (case A)

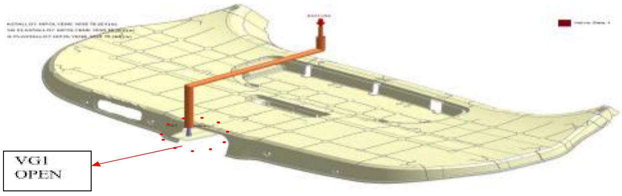

FIG.3model after mesh division and runner layout (case B)

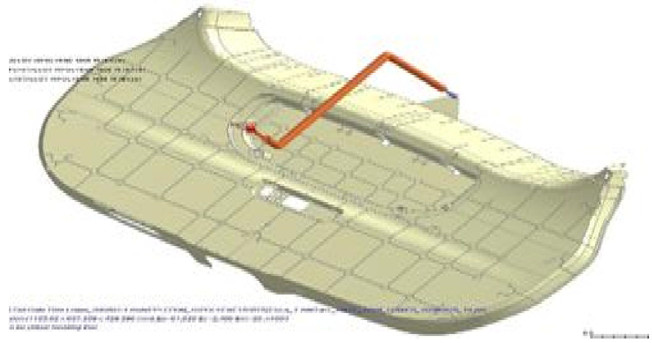

FIG.4 model after mesh division and runner Layout (case A)

Fig 2 shows the flow of molten plastic into the part through three Fan gate(Dimension of Fan gate width=60, height=1.5, depth=16, distance between the centre of the gate and the edge of the mold =16) located at different location, the VG1 gate opens first, and the plastic flows into the part quickly. The VG3 gate opens after a delay of 2.7 seconds, and plastic flows into the part, Fig 3 shows the flow of the molten plastic into the part through tab gate (Dimension of Tab gate=)Fig.4 shows the use fan gate(dimension of the fan gate that is located at the one point (width=100, height=1.0, depth=12, distance between the center of the gate and the edge of the mold =12).

V. RESULT AND DISCUSSIONS

A. MATERIAL INFORMATION

Material used PP+EPDM HIPOLYENE 1535 T5(EX), in this material the melt temperature, mold temperature and eject temperature is 220°, 35° and 120° in each below table.1 shows the material and parameter and also shown in fig. 5..

Description	
Polymer	PP+EPDM
Grade Name	HIPOLYENE 1535 T5 (EX)
Producer	ZYLOG PLASTALLOY
Comment	22% Talc Filled
Last modified date (yy/mm/	2009/04/24
Process condition	
Melt temperature (minimum)	200 oC
Melt temperature (normal)	220 oC
Melt temperature (maximum	240 oC
Mold temperature (minimum	30 oC
Mold temperature (normal)	35 oC
Mold temperature (maximun	40 oC
Ejection temperature	120 oC
Freeze temperature	127 oC

Table 1: Materials and Parameters

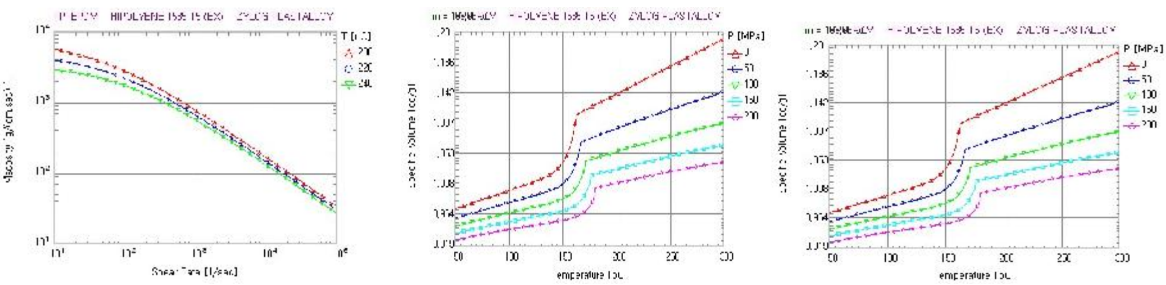

FIG.5 Viscosity, PVT Relationship, Heat Capacity, Thermal Conductivity of PP+EPDM HIPOLYENE 1535 T5(EX)

B. EFFECT OF GATE LOCATION ON THE VOLUMETRIC SHRINKAGE AND DENSITY

Process Control adequate to the material the adequate basic process conditions are provide in Moldex3D, in this material the melt temperature, mold temperature and eject temperature is 220°, 35° and 120° in each.

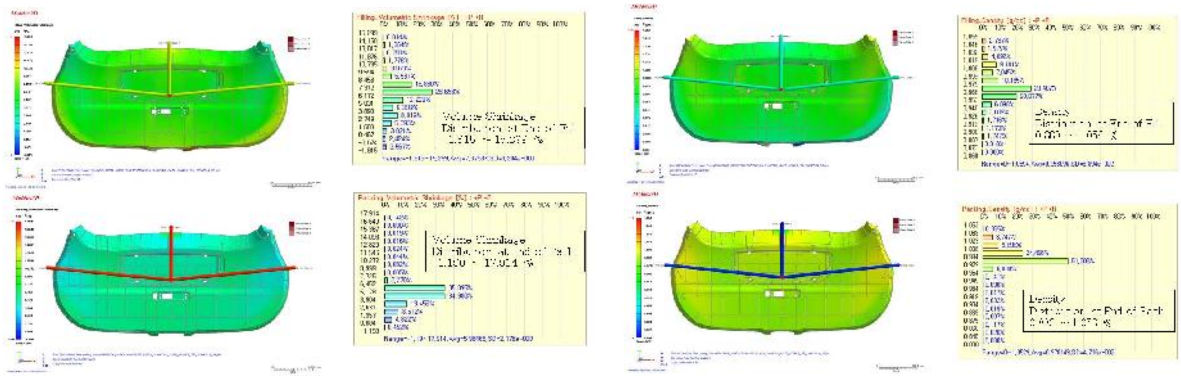

FIG.6 CASE-A Flow Pack / Volumetric Shrinkage and Flow Pack / Density

The simulation is showing the distribution of volumetric shrinkage and density of material at the end of the filling and packing stages. The color scale indicates the amount of shrinkage and density of material, Fig.6 shows the case A here we used fan gate at three locations in this case percentage of volumetric shrinkage distribution at end of fill is -1.815 – 15.299%, volumetric shrinkage distribution at end of pack is -1.190-17.914% and Density Distribution at the end of fill is 0.860-1.059%, Density Distribution at the end of pack 0.830-1.053%.

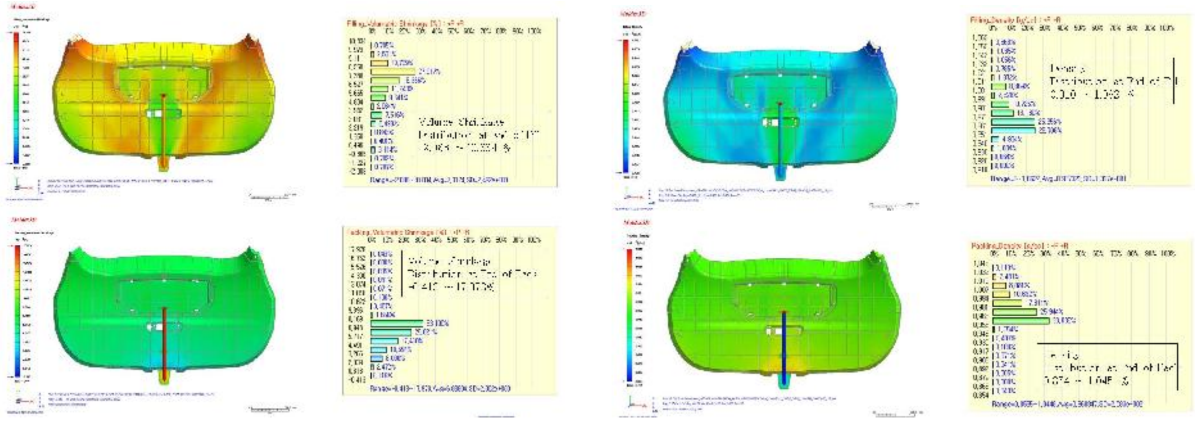

FIG.7 CASE-B Flow Pack / Volumetric Shrinkage and Flow Pack / Density

Fig.7 shows the case B here we used tab gate located at the one location in this case percentage of volumetric shrinkage distribution at end of fill is -2.088 –10.834 %, volumetric shrinkage distribution at end of pack is -0.413-17.978% and Density Distribution at the end of fill is 0.910-1.062%, Density Distribution at the end of pack 0.854-1.045%.

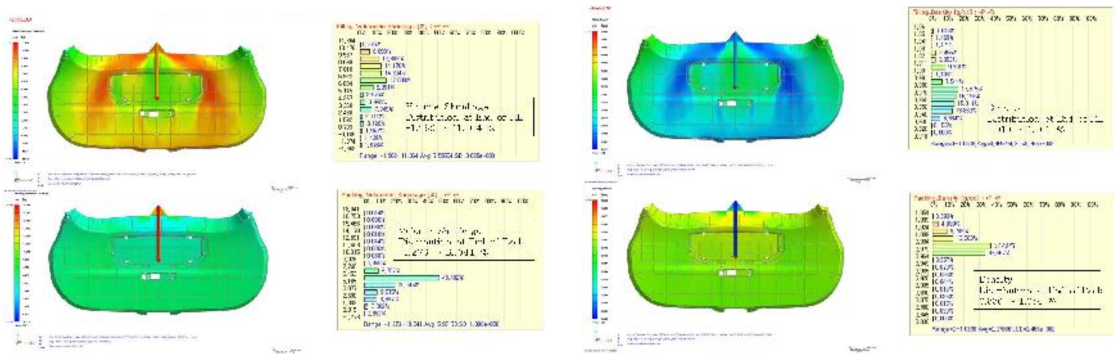

FIG.8 CASE-C Flow Pack / Volumetric Shrinkage and Flow Pack / Density

Fig.8 shows the case C here we used fan gate located at the one location in this case percentage of volumetric shrinkage distribution at end of fill is -1.962–11.364%, volumetric shrinkage distribution at end of pack is -1.273-18.041% and Density Distribution at the end of fill is 0.910-1.061%, Density Distribution at the end of pack 0.830-1.054%.

C. EFFECT OF GATE LOCATION ON THE WARPAGE

Warpage is a distortion that can occur in injection molded parts due to uneven cooling and shrinkage. The gate location is one the factors that can affect warpage.in study we considered three cases for an analysis how gate location affects the warpage defects by using moldex-3D software to analysis the total warpage and warpage at X,Y,Z axial directions. we made comparison between three cases to know the which gate location case will provide minimum warpage defect.

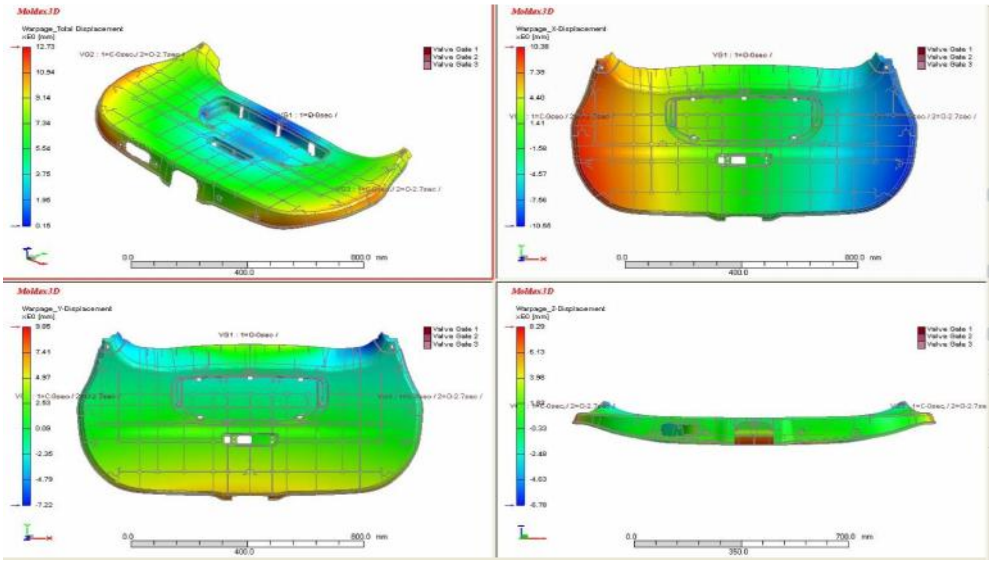

FIG.9 CASE-A Warpage / Displacement

Warpage/displacement analysis of case A is as shown in Fig.9
Total-Displacement-0.15~12.73mm
Displacement in X-direction-10.55~10.38mm
Displacement in Y-direction-7.22~9.85mm
Displacement in Z-direction-6.78~8.29mm

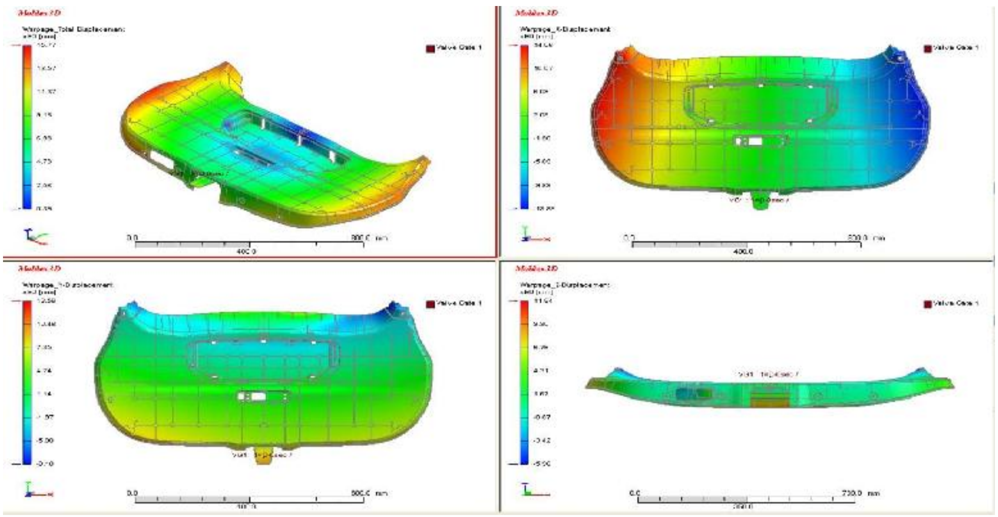

FIG.10 CASE-B Warpage / Displacement

Warpage/displacement analysis of case B is as shown in Fig.10
Total-Displacement-0.39~15.77mm
Displacement in X-direction-13.88~14.06mm
Displacement in Y-direction-8.18~13.56mm
Displacement in Z-direction-5.96~11.84mm

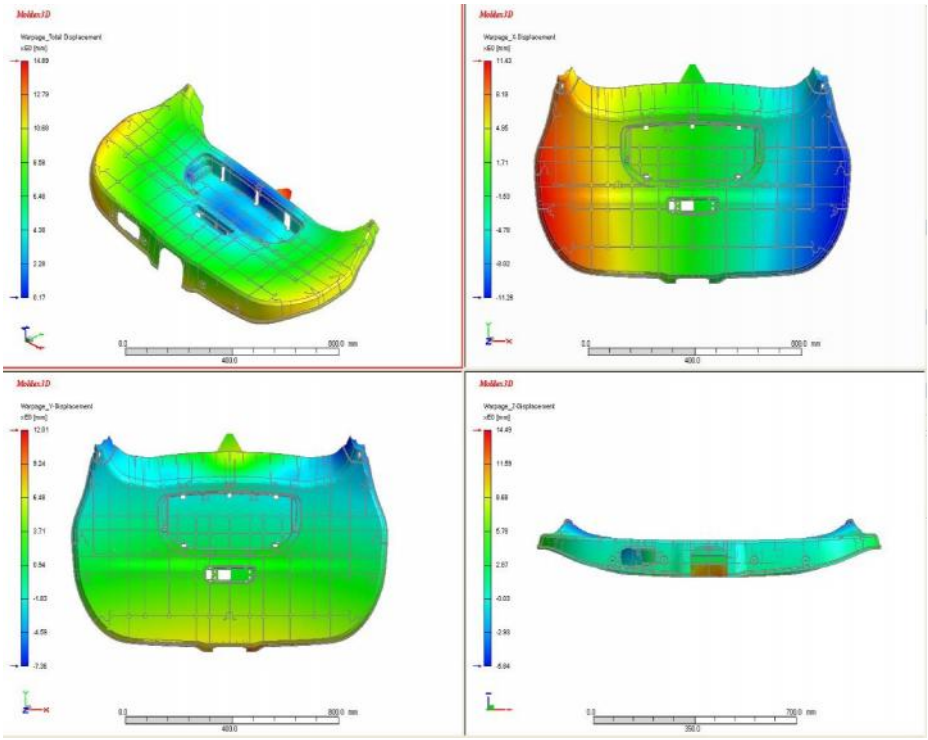

FIG.11 CASE-C Warpage / Displacement

Warpage/displacement analysis of case C is as shown in Fig.11
Total-Displacement-0.17~14.89mm
Displacement in X-direction-11.26~11.43mm
Displacement in Y-direction-7.36~12.01mm
Displacement in Z-direction-5.84~14.49mm

D. FLOW PACK / SPRUE PRESSURE

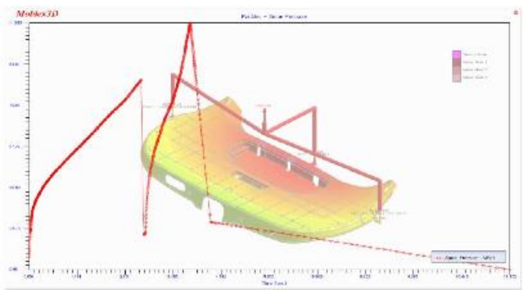

FIG. 12: CASE A. Flow pack / sprue pressure vs time

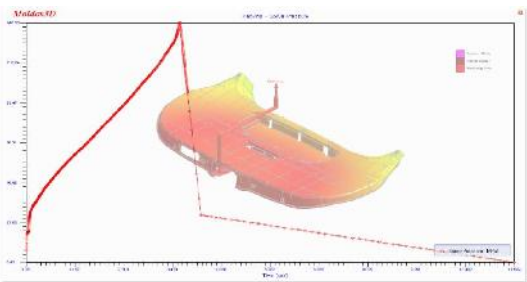

FIG. 13: CASE B. Flow pack / sprue pressure vs time

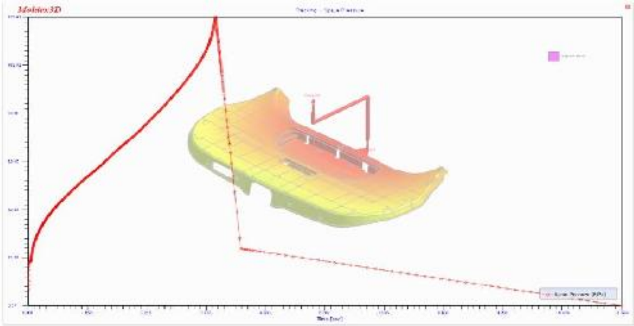

FIG. 14 CASE C. Flow pack / sprue pressure vs time

The red circle represents the last filling area – end of filling – and the melt front advancements are biased shape. It can be easily checked the weld locations from the melt-front advancements and the void locations. From Fig. 12 Sprue pressure: 113.58 MPa of case A, Fig. 13 shows the Sprue pressure: 140 MPa of case B, Fig. 14 shows the Sprue pressure: 126.43 MPa of case C.

VI. CONCLUSION

Warpage is a notable flaw that can occur in the plastic injection molding process, primarily attributed to non-uniform cooling. Temperature variations within the mold can cause different layers to solidify and contract at varying rates, resulting in the formation of internal stresses. The analysis demonstrates that the placement of the gate and the quantity of gate points significantly influence the quality of the plastic injection molded part. Effective optimization of the gate location and number of gate points is crucial in mitigating warpage concerns and improving the overall quality of the molded component.

1. Case A: 0.15-12.73 mm warp displacement, Sprue pressure: 113.58 MPa
2. Case B: 0.53-15.77 mm warp displacement, Sprue pressure: 140 MPa
3. Case C: 0.17-14.89 mm warp displacement, Sprue pressure: 126.43 MPa

By the observation, case A (three gate points) has got minimum total warpage and also reduced sprue pressure.

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