MOLD FLOW SIMULATION OF BELLY PAN FOR FEEDING AND WARPAGE ANALYSIS

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ABSTRACT

Belly Pan discovers their applications in Automobile and in aerospace. Vehicles Quarter and Half fairings are combined with the Belly dish. Paunch container redirects the wind current far from under the engine.it is utilized to diminished streamlined lift, cools the motor and gives corrective look to the vehicle. Old stream reproduction programming is utilized to investigate Filling, Wrapping and to get the entryway area of mold. The Analysis can be done with the beginning of the stream channels, for example, Barrel, spout, sprue, runners, and entryways until the cavity is totally filled. Change has been made to the part outline and sustains frameworks in the mold taking into account the examination. The investigation incorporates the area of the entryway at the part outline, size of sprue, runners and doors. Autodesk Moldflow Insight (AMI) programming is utilized to examine the procedure parameters taking into account 4 level and 5 component Orthogonal Array. The five parameters of programming are Mold Temperature, Melt Temperature, Injection Time, Packing Pressure and Packing Time. The principle point of this anticipates is to Analyze Feeding and War page of Belly dish by utilizing Mold stream reproduction programming. Pressing Pressure is the most powerful Parameter on the war page. IR traps, Welding lines. These imperfections can be dictated by utilizing programming. Programming helps in limited essential examination utilized as a part of the configuration of plastic item, shape outline and generation of plastic components. Finally, the ideal parameters setting are chosen with a specific end goal to get a quality plastic.

Keywords - *Belly Pan, Autodesk Mold flow Insight, Orthogonal Array, Packing Pressure*

1. INTRODUCTION

Plastics are the materials which are ordinarily utilized as a part of each region of industry. Plastics can created in numerous shapes which are usually utilized as a part of routine life. In this day and age client requires more tasteful appearance of parts .For this present day age plastic is perfect.it can be shaped into the different structures and solidified for the business use. Items are delivered from the plastics relying upon the plastic material required. This anticipates will clarify mold stream reenactment of Belly container. Paunch Pan is a plastic part which is matched with the motor. Stomach container Manufactured from the few procedures like infusion embellishment, blow forming, pressure shaping, film embed shaping, gas help forming, rotational trim, auxiliary froth trim, expulsion and Thermoforming. Gut container is made by infusion forming process. In Injection shaping procedure the plastic material is infused into a mold framing a plastic item. It is an assembling method for making parts from thermoplastic material. Plastic material is sustained into an infusion shaping machine, after which warmed and after that squeezed into the mold. Plastic pellets or granules are encouraged from a container into a warming Chamber in infusion forming. A plunger or screw pushes the plastic through the warming chamber, where the material is diminished into a liquid state. The pitch is constrained into a cooled, shut mold toward the end of this chamber. The mold opens and the completed part is launched out when the plastic cools to the strong state. Most critical issue in plastic part is Warpage. The Part delivered by the infusion forming process doesn't have coveted shape because of warpage issue. Warpage is only the bending where the surface does not take after the planned shape. Warpage can be maintained a strategic distance from by taking right infusion parameters and plastic material. Pressing weight influences warpage. Gut Pan can be delivered by utilizing mold .Feeding, cooling and injector framework are the components of the mold. The mind boggling nature of the infusion forming process required the improvement of modern, numerical procedure reproductions to gauge the advancing melt fronts, weight conveyance, and temperature elements of the procedure. Plan choices that are bolstered may incorporate number of entryways, area of doors, weight drop through doors, divider thickness; process info parameters, shrinkage remuneration, and others. These procedure reproductions have been generally received, and have empowered the improvement of to a great degree propelled forming applications. This base is essential since the embellishment procedure is not prepared to do altogether adjusting the formed part quality characteristics once a mold is produced. In this manner, critical exertion must be used amid item advancement to guarantee the mold tooling conveys the sought item before the tooling enters creation. The recreation of the procedure completed to acquire the weight, temperature and shear rate appropriation in a shut mold and examination of melt stream front development in cavity and also deciding the stream length in various infusion shaping conditions. There are a few modules of MOLDFLOW programming which for the most part comprise of Flow Analysis, Cooling Analysis, Warpage Analysis and Shrinkage Analysis.

Fig.1 Isometric View of Belly Pan.

Fig.2 Front View of Belly pan

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Desired products can be produced by using mould. Feeding, cooling and injector system are the elements of the mould.To design mould CAD Software is used. The simulation is done by Autodesk moldflow software for injection moulding.The simulation of the process is carried out to obtain the pressure, temperature and shear rate distribution in a closed mould and investigation of melt flow front movement in cavity as well as determining the flow length in different injection moulding conditions.There are some modules of MOLDFLOW software which mainly consist of Flow Analysis, Cooling Analysis, Warpage Analysis and Shrinkage Analysis.

2. LITERATURE REVIEW

Following literature review is carried out for the basic study regarding the effect of injection molding parameters and the types of thermoplastics composites (amorphous or crystalline based polymer matrix) on the shrinkage and warpage properties through simulation using Autodesk mold flow simulation software.

Wanli Jiang, Dehui Xu (2015) proposed an iterative finite element simulation method based on Von Mises yield criterion to determine the plastic deformation of silicon microstructure. Single crystal silicon MEMS microstructures could be plastically deformed during high-temperature manufacturing process. In the proposed method, the critical condition for plastic deformation is that the maximum Von Mises stress of the microstructure equals to the yield stress. Sculptured diaphragm microstructures with different dimensions are designed to verify the method. Plastic deformation of the structure is measured after the annealing process of 1100 °C. The simulation value fits the experiment well and the average deviation between the simulation data and experimental data is 2.2%. [1]

Babur Ozcelik , Ibrahim Sonat (2008) worked on the warpage and structural analysis of thin shell plastic in the plastic injection molding. While the warpage analyses were done, four injection parameters were used. These parameters are melt temperature, mold temperature, packing pressure and packing time. After getting the warpage values, the effect of each injection parameter on each material was examined. ANOVA analysis was used for this examination. As a result of analysis, the most influential parameter for PC/ABS material is packing pressure. The warpage analyses results can be seen in Appendix A. when we look at the structural analysis, the strongest materials are 15% carbon fiber reinforced PC/ABS, 15% carbon fiber reinforced ABS, PC, PC/ABS and ABS, respectively. The strongest points over the top surface of the cell phone cover are Points 4, 3, 2, 1 in order. This result is the same for every material. When we look at the points A, B, C and D, it is seen that the strongest point is point B, if the force is applied towards Y-axis. But if the force is applied perpendicular to the surface, point B would be the weakest point. The most critical point on the top surface of the cell phone is point.The failure of the cell phone cover starts at this point. [2]

Eghbal Hakimian(2012) successfully investigated the effect of injection molding parameters and the types of thermoplastics composites (amorphous or crystalline based polymer matrix) on the shrinkage and warpage properties through numerical simulation using design of experiment method (Taguchi method). Lacking of direct validation of numerical simulation result is the main limitation of this study. Based on appropriate material data selection, especially for composite materials, resulted in physical behavior of injection molded composite is in parallel with theoretical behavior. Fiber glass loading (percentage) in both type of polymer matrix gives the most significant influence on the warpage and shrinkage properties compare to mold temperature and melt temperature. This phenomenon is due to the orientation effect fibers along the direction of injection flow during molding process. Numerical simulation results also reveal that amorphous polymer composites (PC/ABS and PPE/PS) have better resistance against shrinkage and warpage than crystalline polymer composite (POM). This phenomenon due to molecular structure of amorphous in randomly oriented not allows shrinkage and warpage progressive forms follow its order. [3]

Rong Zheng (2010) perform experiments and numerical simulations to investigate the effects of two colorants on flow-induced crystallization and anisotropic properties of injection molded parts.it is carried out on flow-induced crystallization of an injection-molded isotactic polypropylene (iPP) mixed with colorant additives. Two types of blue colorants were used.one is the ultramarine Blue composed of Sodium Alumino Sulpho Silicate (UB) and the other is the PV Fast Blue composed of Cu-Phthalocyanine(CuPc). The CuPc colorant exhibits increased nucleation of both quiescent and flow induced crystallization, and results in more oriented microstructures, causing a high degree of anisotropy in material properties and shrinkage of the injection molded parts. The two colorants have different particle geometries and surface patterns. The CuPc colorant with flat surfaces has shown to be a very effective nucleating agent in both quiescent and flow conditions. Moreover, it results in a higher degree of anisotropy in shrinkage. The UB colorant with spherical surface is not effective in the quiescent conditions but increases the sensitivity to pre-shear effects. It does not lead to anisotropic shrinkage. A basic FIC model with the parameters determined separately for different samples gave a good prediction of the colorant effects observed in experiments.[4]

Jagannatha Rao (2013) designed Motor rare housing component with multi cavity as the plastic part in the two plate injection mold which is used in domestic motor and analyses plastic flow in two plate injection mold. Mold flow analysis was carried out on the component and feed system of injection molding tool. This gave satisfactory results and the same was confirmed from analysis such as injection pressure, fill time, flow front temperature, quality of fill, weld line, air traps etc. The results indicated that the injection molded components could be manufactured with minimum molding defects. The tool was manufactured using the CNC and NC machining process according to DME standard and manufactured elements were assembled. The trial out of the injection mold tool revealed the components produced without defective. Further work can be carried out by him by performing the stress analysis to core and cavity inserts using ANSYS software for more effective design. Fatigue analysis can also carried out for the tool which results in improving the life of the tool. The mold flow analysis can be used to carry out for design of experiments for fill analysis, Wrap analysis, the best gate location and the result can be utilized for further optimization of the tool design. [5]

Ilangovan,S. and Nayak (2012) Optimized Injection Molding Cycle Time Using MOLDFLOW ANALYSIS. The simulation for optimization of plastic injection molding processing parameters based on the optimization of cycle time has been performed by Moldflow software. In finding optimum values, the use of Moldflow, Orthogonal process is exploited. Mold temperature, melt temperature, packing time and cooling time are the important process parameters. When using the process parameter recommended by Moldflow the cycle time reduced from 35 seconds to 24 seconds. All other parameters are under the limit only. By using these parameters given by Moldflow, it has been verified in Injection molding machine and the obtained final quality of the product gave the good results. Thus the Moldflow software is a Preventive and Corrective tool used by him to analyze the process, to decrease the cycle time. [6]

Kunal H.Kate (2015) Performed Simulations and injection molding experiments for aluminum nitride feedstock. Toper form PIM simulations, measurements for feedstock properties such as physical, thermal and rheological are required as input parameters. The availability of data for such feedstock properties is limited and fresh measurements are often required in order to perform PIM simulations for variations in feedstock composition. A recent study by our group presented a procedure to estimate feedstock properties and use them in mold-filling simulations. The present work compares the predictions of PIM mold-filling simulations using experimental and estimated feedstock properties with injection-molding experiments. Aluminumnitride(AlN) feedstock of 80.5wt% was compounded using a win-screw extruder and injection-molded as tensile bars. Injection-molding experiments performed using the AlN feedstock at various melt temperatures and injection pressures to obtain complete and partially filled parts. Simulations were performed using measured and estimated AlN feedstock properties on the tensile-bar geometry used during injection molding experiments. Melt temperature was varied while performing simulations to obtain a process window for complete and partially filled parts. A comparison between injection molding experiments and simulations was made to understand the dependence of the estimated and experimental feedstock properties in predicting mold filling behavior. [7]

Chao fang Wang (2015) Suggested special algorithm to predict the deformation of the injection-molded plastic strip-like part. The Hele-Shaw model is not suitable to predict the warpage of this kind of parts due to its limitation. On the other hand, the general 3D model is too time consuming and not acceptable for users. In fact, there is no commercial CAE software available to handle this kind of parts up to date. The present work solved the problem to a certain degree. The 3D FEA was replaced by the several 2D FEA and one 1D FEA, which enormously reduced the computing time. This two-step FEM was proved very simple and efficient, and the predicted warpage was reasonable. Although most strip-like parts may not be straight and the mold temperature might not be uniform either, the present job provides a new thought to solve the problem. Cases that are more complicated could be handled as well. For any non-straight strip-like part, the section curvature obtained as this work demonstrates, and then the part deformation easily calculated by FEM used in the structural analysis. This algorithm believed to be a promising tool for the mold design of strip-like plastic parts [8].

Hwa Jin Oh, Doo Jin Lee (2013) Researched on micro-molded parts prepared with liquid crystalline polymer based composites. A new definition of microstructure, i.e., ‘‘skin–shear–core’’ layer, was proposed in the thickness direction with respect to the orientation of LCP molecules and fillers. Understanding of such a microstructure in a micro-molded part is the first step to design a new polymeric composite material and to develop proper polymer processing conditions. WAXD, CT, and SEM experiments were conducted to observe the orientation of LCP molecules and fillers.The anisotropic elastic modulus and CTE of micro-injection molded parts were investigated and a new model for prediction of the elastic modulus was introduced. An effective experimental and numerical tool was investigated in this study for characterization of LCP composites particularly in an effort to offer a bridge between anisotropic properties and microstructure of micro-injection molded parts. Furthermore, they have investigated injection molding with micro- connectors experimentally and numerically. The orientation of glass fibers in a micro-injection molded part was observed by CT scanning and then quantified by the orientation tensor to compare with numerical prediction. The method of measuring the CTE of an anisotropic material was established so that the warpage of a micro-connector could be predicted precisely. The shear layer specimen of an injection molded part was needed to measure CTEs of anisotropic materials exactly. In addition, the CI factor for glass fiber reinforced anisotropic matrix composites was evaluated to investigate the effect of flow induced orientation of glass fibers. Finally, They carried out numerical simulations to control the orientation of glass fibers and warpage with several geometries of pangates. This study is expected to help understand micro-injection molding for glass fiber reinforced LCP composites. [9]

Literature study helps in designing the proper gating system.

3.PROBLEM DESCRIPTION

The plastic part on which Simulation and Experimentation carried out is a Belly Pan.Its dimensions are approximately 364.9x130.9x16 mm^3.The mold is a hot runner mold with two cavities and a short cold runner with two submarine gates for each cavity in the middle of the part.

Fig.3 Belly Pan

During the first test of the mold an uneven flow pattern was observed. It was found that the right half of the cavity was filling quicker and showed a strong tendency to Warpage and flashing. The molded parts from cavity one and two where the injection process aborted before the cavity was completely filled (also called “short shot”). A fine-tuning of the process parameters did not lead to parts with acceptable quality and even the introduction of flow leaders on the left side of the cavity could not solve the problem. Therefore, analysis and Experimentation of the mold filling process performed to investigate and improve the filling behavior of the part.

I. COMPONENT DETAILS

Belly pan is made of nylon66 (PA6) polyamide materials have high mechanical strength and superior resistance to wear and organic chemicals.The important properties of PA6 are high tensile and flexural strength, stiffness, excellent heat deflection temperature, and superior abrasion and wear resistance.

Component material: Polyamide (Nylon 66) PA6

Shrinkage: 1.5 %

Moulding type: Multi Cavity injection mold tool

Family name	POLYAMIDES (NYLONS, PPA, ...)
Trade name	Akulon K222-D Natl
Manufacturer	DSM EP (Americas)
Link	
Family abbreviation	PA6
Material structure	Crystalline
Data source	Moldflow (Formerly C-Mold) : pvT-
Date last modified	22-MAR-05
Date tested	10-OCT-97
Data status	Non-Confidential
Material ID	5940
Grade code	CM5940
Supplier code	DSMEPA
Fibers/fillers	Unfilled

Mold surface temperature	80	C
Melt temperature	255	C
Mold temperature range (recommended)		
Minimum	60	C
Maximum	100	C
Melt temperature range (recommended)		
Minimum	240	C
Maximum	270	C
Absolute maximum melt temperature	311	C
Ejection temperature	176	C
Maximum shear stress	0.31	MPa
Maximum shear rate	100000	1/s

Fig.4 Properties of Belly Pan

II. Mold Flow software

Mold flow International Pvt. Ltd., Australia has developed Mold Flow Software. It helps in finite elemental analysis used in the design of plastic product, mould design and production of plastic components. Following are the modules of MOLDFLOW software.

1. Flow Analysis: The Flow analysis is used to determine the gate position and filling pattern. It analyses polymer flow within the mould, optimizes mould cavity layout, balances runners and obtains mould processing conditions for filling & packing phases of the Moulding cycle.
2. Cooling Analysis: It analyses the effect of cooling on flow, optimizes cooling line geometry & processing conditions.
3. Process Optimization Analysis: It gives optimized-processing parameters for a component considering injection-moulding conditions.
4. Warpage Analysis: This analysis simulates the effect of Moulding on product geometry, isolates the dominant cause of warpage so that the correct remedy can be applied.
5. Shrinkage Analysis: This analysis gives dimensions of mould cavities, using shrinkage determined from specific grade material shrinkage data & flow analysis results.

Benefits of MOLDFLOW Software:
1. Avoid high costs and Time Delays,
2. As analysis is productive so there is no need of fillers and Fibre reinforcement to simulate filling, packing and cooling phases.
3. MPI is the world's largest material database of more Than 7800 thermoplastic materials.

Fig.5 Initial Belly Pan with warpage and other defects

Fig.6 Modified Belly Pan without defects

In Injection molding process the plastic material is injected into a mold forming a plastic product. It is a manufacturing technique for making parts from thermoplastic material. Plastic material is fed into an injection molding machine, after which heated and then pressed into the mold. Plastic pellets or granules are fed from a hopper into a heating Chamber in injection molding.

4. SIMULATION ANALYSIS

1. CREATING FINITE ELEMENT MODEL

Modelling is done by the Catia Software. Then it is imported to MOLDFLOW by IGES format. The modeling and meshed product in Mold flow is shown in the figures 1 and 2.The plastic material used for Belly Pan is PA6.In MOLDFLOW Software there are 3 types of the mesh. Which includes Midplane, 3D And Fusion.Due to the thickness of the plastic product, we adopt the surface meshes (Fusion) and used grid mesh tool to modify mesh defects.

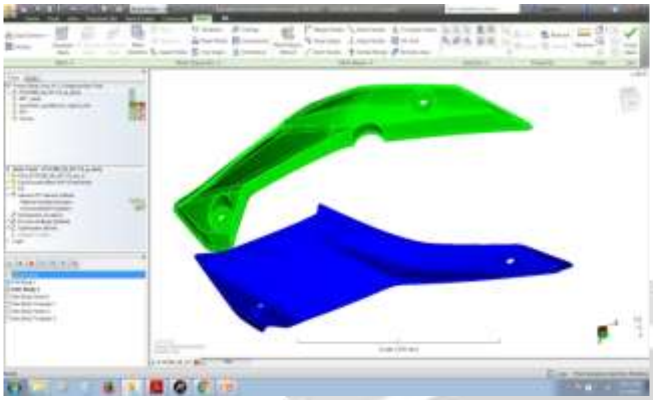

Fig.7 Modelling Product

Fig.8 Meshed Model

2. INJECTION MOLDING PROCESS ANALYSIS

The Best gate location result is generated by the Gate Location analysis. This result rates each place on the model for its suitability as an injection location. The most suitable areas are rated as best and are colored blue. The least suitable areas of the model are rated as worst and colored red. A best location rating does not necessarily mean that the part can be filled from this location. This must be checked by running a full analysis. Designers can quickly and accurately work out the best gate location by Moldflow software, thereby improving the efficiency of the mold design, the quality of products and reducing the cost [8]

I. Flow analysis of modified belly pan

The filling simulation is carried out with a melt temperature of 255°C, a mold wall temperature of 80°C and a target injection time of 2s. The injection flow rate for the simulation and defined analogous to the molding machine settings used for the experiments.

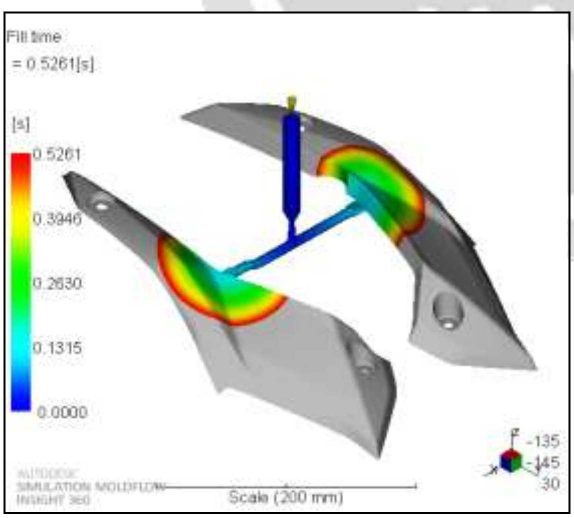

Fig.9 25% Filling of Belly Pan

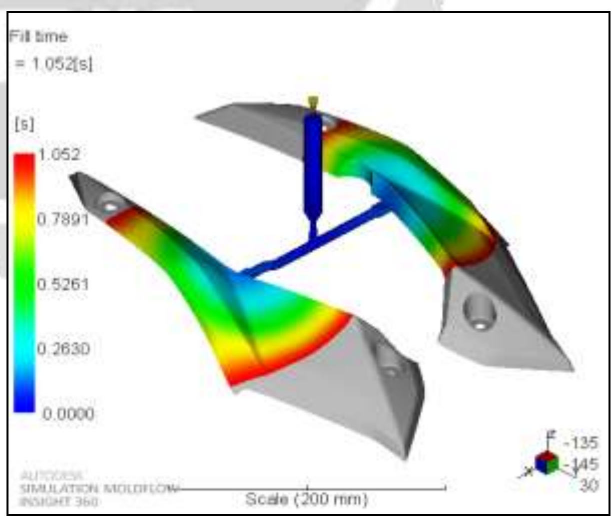

Fig.10 50% Filling of Belly Pan

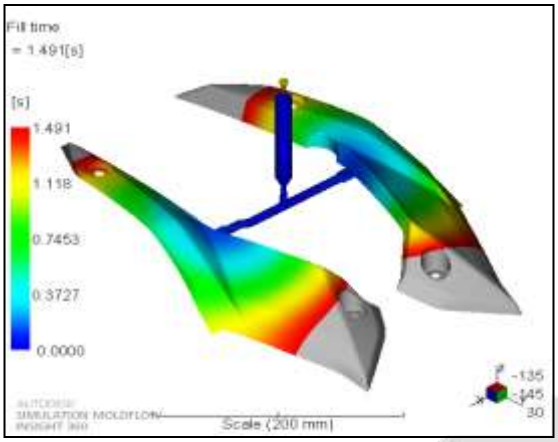

Fig.11 75% Filling of Belly Pan

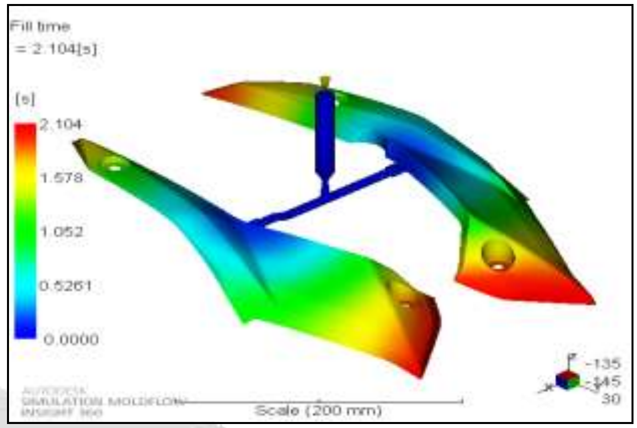

Fig.12 100% Filling of Belly Pan

Optimization done by using simulation software Autodesk Moldflow Insight Software flow plus by implanting modified packing pressure.

Part is filling completely fill without any flow related problems in 2.104s & With flow rate 92.77 cm3/s. Red areas highlighted in the plot indicates the EOF areas in the part.

Time (s)	Volume (%)	Pressure (Mpa)	Clamp Force (Tonn)	Flow Rate
0.101	3.88	8.46	0.12	89.08
0.199	8.58	11.43	0.15	91.96
0.499	23.32	12.65	0.91	92.54
0.597	28.15	12.91	1.06	92.55
0.697	33.03	13.20	1.31	92.56
2.104	100	17.44	35.11	47.43

Table No. 1

This result shows the flow path of the plastic through the part by plotting contours which join regions filling at the same time. These contours are displayed in a range of colours from red, to indicate the first region to fill, through to blue to indicate the last region to fill.

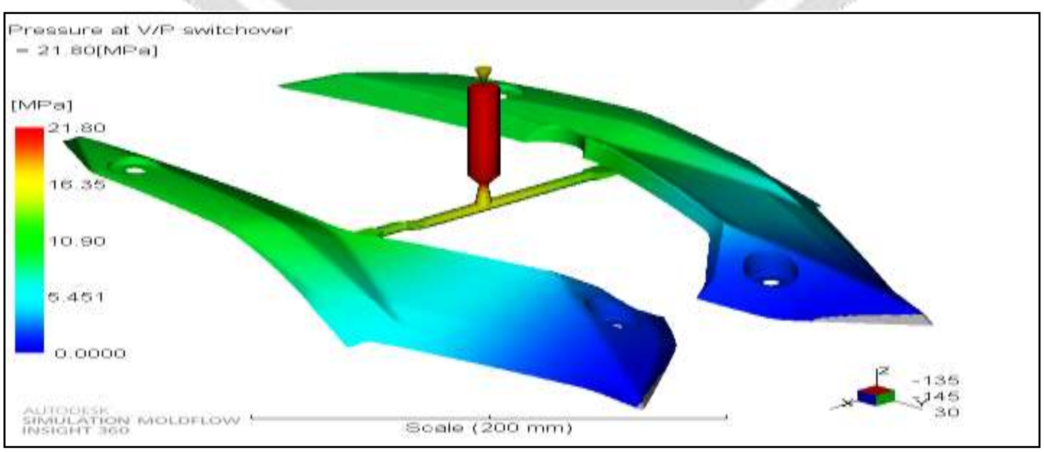

Fig.13 Pressure At V/P Switch Over

Pressure Drop in the part is 11.98Mpa.Pressure Drop in Runner System is 9.82 Mpa.Total Pressure in the part & runner system 21.80 Mpa.

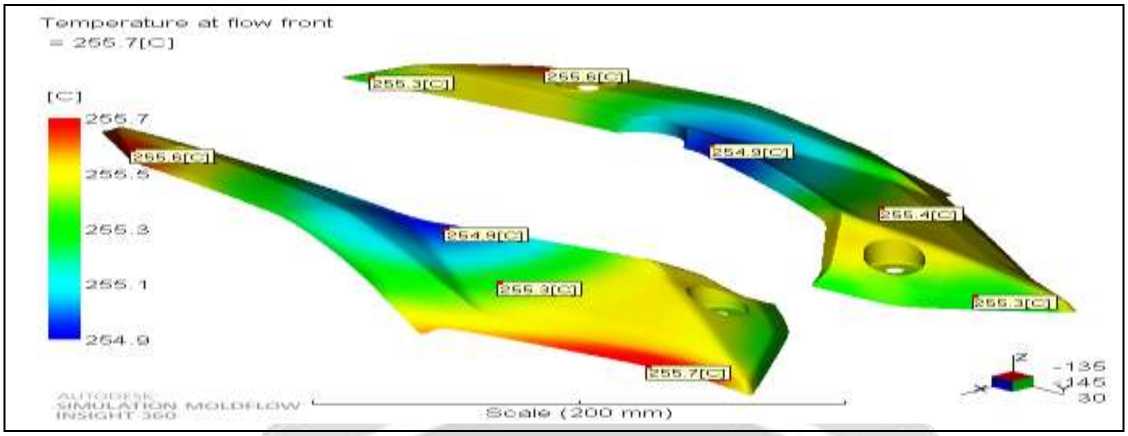

Fig.14 Temperatures at flow front

Plot shows variation in the temperature flow front in the component during the fill time. Due to shear heating there is temperature rise of 0.7°C and the drop in the temperature is up to 0.1°C (Melt temperature is 255°C). The temperature rise and drop is within the acceptable limit.

II. Warpage Analysis

Main Objective of project is to reduce warpage of Belly Pan, which is beyond its tolerance.In plastic injection molding, the production of the thin walled part is very difficult. It is hard, because melted plastic cannot easily fill the mold cavity. Because of this, the most important problem in belly pan component is warpage.Belly Pan which is produced by using injection molding method does not have the desired shape and dimensions, because of the warpage problem.The best way to prevent warpage problem is to choose the plastic material and injection parameters right. The decrease in the thickness of the Belly Pan also weakens the strength of the part. This problem can be solved by choosing the appropriate material for the durability. However, a material may be appropriate for the strength of the Belly Pan. As a result, packing pressure was found as the most important factor that affects warpage. It has seen that gate location and filling time have little effect over warpage.At packing pressure 28 Mpa warpage of belly pan observed to be beyond specification.

Warpage Analysis of Belly Pan have been done for three packing pressure values.They are as follows.

From the Warpage Analysis it was found that 17.44 Mpa is the optimum Packing pressure at which warpage is within limit.

Following are the Analysis Results for different pressure values get from Warpage Analysis

Sr. No.	Maximum Packing Pressure(Mpa)	Maximum Deflection occurred(mm)
1	26.51	3.86
2	22.14	3.5
3	17.44	2

Table No.2 Warpage Analysis Result

From the Warpage Analysis it was found that 17.44 Mpa is the optimum Packing pressure at which warpage is within limit.

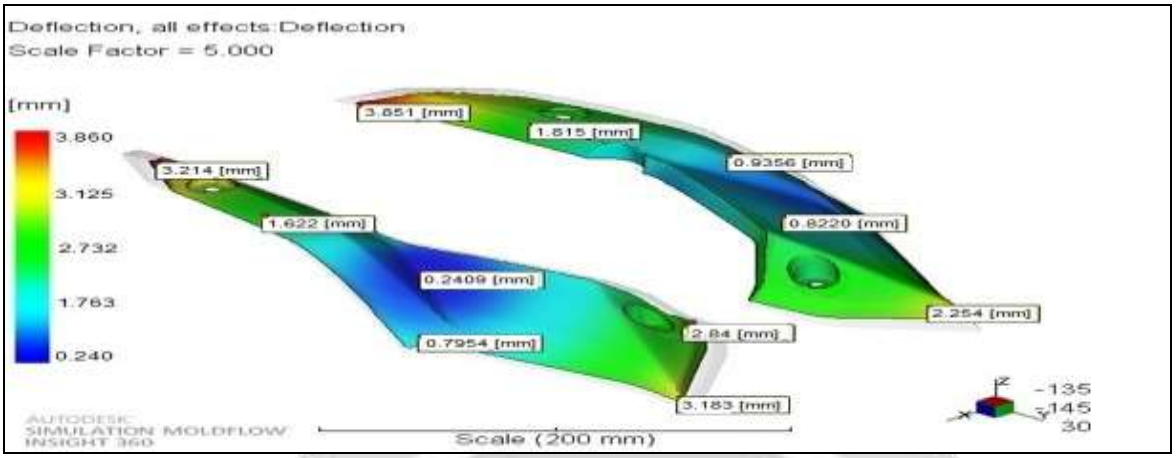

Fig. 15 Warpage At Pressure 26.51 Mpa

Fig. 16 Final Accepted Defect Free Belly Pan

5. CONCLUSIONS

Mold flow analysis was carried out on the Belly Pan. Mold Flow analysis gives accurate solution by determining exact defects.This solution consist of less number of molding defects. Feeding and Warpage Analysis can be done properly with minimum number of defects

I. From the Feeding Analysis by Autodesk Moldflow software we get Optimum Injection or Packing time as 2.104 sec at which we get Optimum packing Pressure as 17.44Mpa.
II. Packing Pressure plays important role in Analysis and Manufacturing of belly pan.
III. Initially large amount of warpage has been observed in belly pan.After Performing analysis we got the optimum packing pressure.warpage analysis performed for three different packing pressures.at optimum packing pressure 17.44 Mpa warpage value comes within tolerance which is

2mm..

IV. During Actual Experimentation packing pressure changes from 28 Mpa to the 17.44 Mpa which came from the analysis.the value of warpage obtained is 2.1mm which is much lesser than the initial value of 3.86 mm.

V. During Experimentation Injection time reduces from 8 seconds to the 2.55 seconds.

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