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Design and Analysis of Plastic Injection Parts by Using Moldflow

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ABSTRACT

The injection molding is one method used to produce plastics products. The method depends on a series of stages. To design the mould for specific product, require experience and trial and error method. In this research used the analytical methods to calculate the different parameters of the design. The selected products are a disc and bucket. The results of analytical methods were compared with the computer program results. The parameters considered are: cooling time, injection pressure, the clamping force, the volume of the product and its Wight. The analytical results for the disc are almost the same as the computer program results for the case of the bucket there is a difference between the analytical results and the computer program results. This due to the difference in the used density. The analytical calculation used the solid material density while the program depends on the melt density, also in analytical calculation the bucket rim volume was not included. This study shows that the Autodesk Moldflow program is good in the design of the complicated shapes present in toys and automobile parts were the analytical calculations is a tedious job. The program provides the design parameters needed to make the mould using CNC machine.

Key words: Moldflow, injection Molding, Fill time, injection pressure

INTRODUCTION

Injection Molding is one of the common methods to do the mass-production of plastic product. With 32% of the plastic in the world are processed by injection molding, IMR [1]. the mould design for injection molding has become a very critical aspect to achieve the optimum use of a mould plate. In this time and situation, Injection Molding simulation software is the right tool to be incorporated in the mould design process. It is what helps the mould designer and mould maker to get the maximum output of a mould plate for a particular product design [2]. Autodesk Moldflow Plastic Insight is an in-depth process simulation tools to predict and eliminate potential manufacturing problems and optimize part design, mould design and the molding process itself. There are over nineteen distinct modules that can be used to simulate nine unique molding processes, by which thermoplastic injection molding is one of them. Moldflow [3].

Fei NC in (2013) reduced the fill time variation depends on injection molding process parameters. Injection molding is one of the most Exploited industrial processes in the production of plastic parts. Fill Time behavior of molded plastic part plays an important role in determining the final dimensions of part. Input parameters play an important role of quality of plastic parts. In this work input parameter melt temperature, mold temperature, injection speed and packing pressure to control fill time as response of injection molded parts to improve the quality of plastic part. In this study Mould Flow Advisor (MFA) is used to study & verify the effect to process parameters and optimize the fill time. Optimization of process parameters done using design of experiments (DOE) and analysis of variance (ANOVA) optimum combination of process parameter is governed by signals to noise (S/N) ratio and analysis of variance (ANOVA) and using the fuzzy logic approach [4].

Kitayama S in (2017) studied of different types of cooling channels in an injection molded plastic part and compares the performance in terms of time to ejection temperature, shrinkage, temperature profile, and part warpage to determine which configuration is more appropriate to provide uniform cooling with minimum cycle time. Autodesk Moldflow Insight (AMI) simulation software is used to examine the results of the cooling channels performance [5].

Finkeldey Fk.in (2020) used a Moldflow software and the determination of optimum gate locations for it. The analysis is complete look into the various quality features important for the mould, it considers identification and improvement of parameters such as fill time, quality, extent of packing and reduced defects and warpage. Utilization of the optimized gate locations for the mould lead to reduced production costs, higher quality and enhanced competitive power of mould enterprises [6].

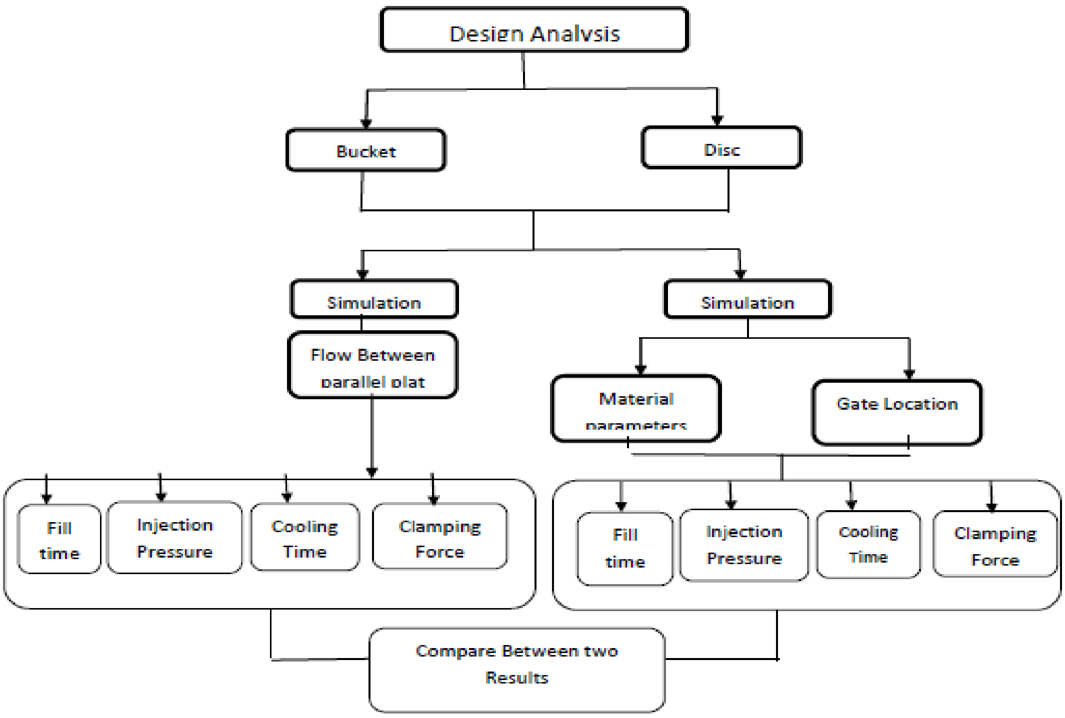
Li D in (2021) found the most appropriate parameter in injection molding process for honeycomb floor panel by simulation using Moldflow software and optimize the quality of injection molding process parameter by using Response Surface Methodology (RSM) as to obtain an optimal response and meets the requirement specification in the aviation scope [7].

Radhwan H in (2019) determined the best set combination of molding parameters that could reduce the warpage defect. There are six parameters that have been selected in this study which are mold temperature, melt temperature, packing time, cooling time, injection time and packing pressure. Taguchi orthogonal array is used to simplify the experimental runs. The analysis is done by applying S/N ratio approach and ANOVA method. Based on the results obtained from the analysis, it is found that the best set combination parameters give out the smallest warpage value [8].

MATERIALS AND METHODS

Materials

In this study the design parameters of two product the disc and the bucket were calculated analytically and compared with results obtained from simulation analysis. The same material was used on both parts. The design parameters of the fill time, injection pressure, cooling time and clamping force were obtained. The following flow diagram shows the overall step used in the theses flow chart as shows below:



Polypropylene is used in injection material in numerical simulations has viscosity cross viscosity model used to characterize the shear rate depend once of viscosity, in this study it was assumed that temperature distribution of polymer is uniform and equal and for this temperature related parameters for cross viscosity model blew for other properties [9].

$\mu_0 = D_1 \exp^{\left[\frac{-A_1 (T-T^*)}{A_2+(T-T^*)}\right]}$ (1)

$T^* = D_2 + D_3 P$ (2)

where :

μ_0 = zero share rate viscosity

D_1, D_3, A_1 , D_2 and A_2 Are Data fitted Coefficient

T^* = The glass transtion Temerture

p = is the pressure (pa)

Method:

Analytical Calculations methods

Analytical Calculations For single cavity disc and bucket Model With centre location (gate) To analysis the design parameters fill time , injection pressure clamping force and cooling time by using analytical calculations methods [10].

Fill time:

using equation (3) to calculate Filling Time:

$(t) = \frac{V}{Q}$ (3)

Where t is fill time, (v) is product volume and (Q) is the volumetric flow rate

cooling time :

To calculate the cooling time firstly using equation (4) to calculate temperature gradient.

$t = \frac{4x^2}{\pi^2 \alpha} \ln\left(\frac{4}{\pi . \Delta T}\right)$ (4)

where (t) is cooling time (x) is product thickness, (α) thermal diffusely (ΔT) temperature gradient

The injection pressure:

using equation (5) to calculate injection pressure for the disc and equation (6) to calculate injection pressure for the bucket:

$P = Q^n \left(\frac{2n+1}{2\pi n}\right)^n \left[\frac{\mu_0 (2)^{2n+1}}{(1-n)H^{2n+1}}\right] R^{1-n}$ (5)

$P = \left[L^{(n+1)}\right] \left[\frac{2}{H}\right]^{(n+1)} \mu_0 \left[6t_f \left(\frac{n}{4n+1}\right)\left(\frac{n}{3n+1}\right)\left(\frac{n(n+1)}{(2n+1)^2}\right)\right]^{-n}$ (6)

Where (P) injection) pressure (n) power constant, (Q) is the volumetric flow rate, (H) product high (l) flow length and (μ_0) share viscosity.

Clamping Force:

using equation (7) to calculate Clamping Force:

$F = P \times \pi R^2 \left(\frac{1+n}{3+n}\right)$ (7)

Where (F) is clamping force, (p) injection pressure, (n) power constant and (R) is product radius

Analytical Simulation methods

Software assistance

Many software's can be used in designing the required product with accurate calculations and minimized time spam. 2D and 3D modelling, assembly and part designing such as Solid Work. Analysis and simulation of the phases of injection under varying temperature and pressure such as Moldflow Location of injection point for the required product which in turn gives adequate filling of cavity.

Part Design:

The parts that is designed in this project for tow model such as the Disc and the Bucket, the two model parts dimensions are:

–**the first model the Disc:**

The diameter is 120mm and the thickness 3mm the Fig (1) shows the sketch of the disc.

the second model the Bucket:

The bucket used in this analysis was a hollow cone shape as shown in figure (.2) with top diameter of 220mm. The bottom diameter is 100 mm, the height is 150 mm and the thickness is 1.5mm.

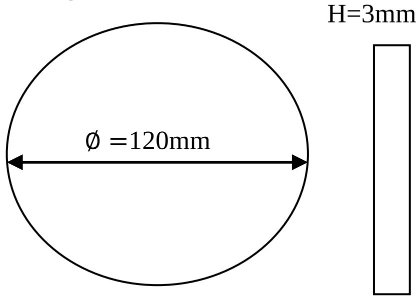


Fig. 1 Sketch of the Disc product

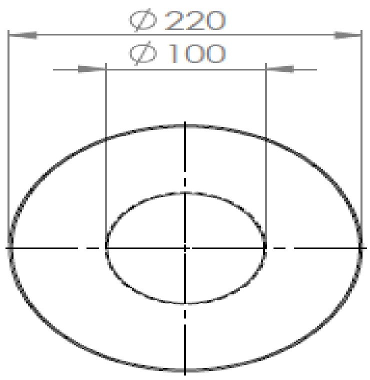


Fig. 2 Top and side view of a bucket product

Moldflow Analysis

Analysis of the product using Autodesk Mould flow (Simulation tool) software helps us validate and optimize plastic parts, injection moulds, and the injection molding process. This software is essential for designing and mould making through simulation setup and results interpretation to show how changes to wall thickness, gate location, material, and geometry affect manufacturability. And also experiments with "what-if" scenarios before finalizing a design. The first step in analysing is importing the design into the Moldflow software using IGES Format. After importing the design after that selected material from materials list.

RESULTS AND DISCUSSIONS

Results

Simulation Analysis

Fill Analysis

The main benefit of doing fill analysis are predicting Fill pattern this will help us understand some of the flaws if any in the product. Some other benefits include Reduce scrap, Balance filling and pressure distribution, polypropylene Material selection the material has include all properties and the condition in mould flow the same material was used in analytical calculations such as melt temperature, mould temperature and ejection temperature and other conditions as shown in appendix to Determining the fill time ,injection pressure ,cooling time and clamping force,. This analysis can help predict short shots. Short shots are a legitimate concern for those involved in creating plastic parts.

Analytical Simulation of singe cavity disc and bucket for center location gate

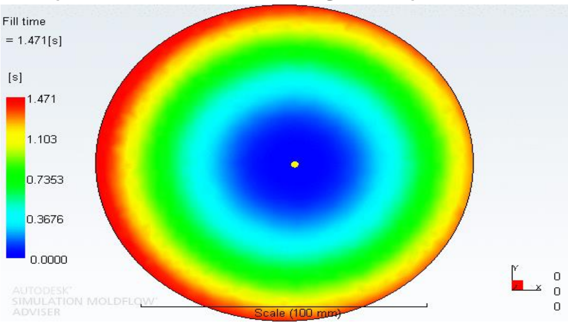


Fig. 3 Fill Time of the Disc

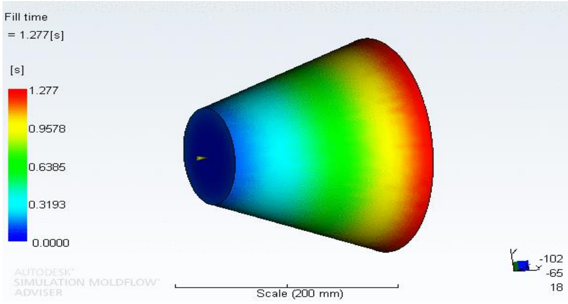


Fig. 4 Fill Time of the Disc

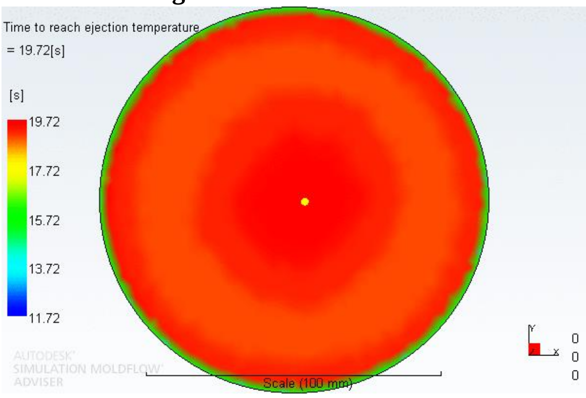


Fig. 5 Cooling Time of Disc

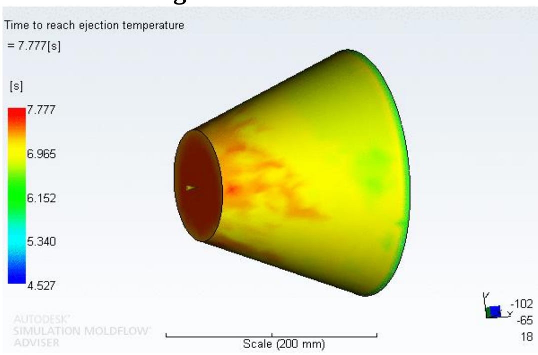


Fig. 6 Cooling Time of Bucket

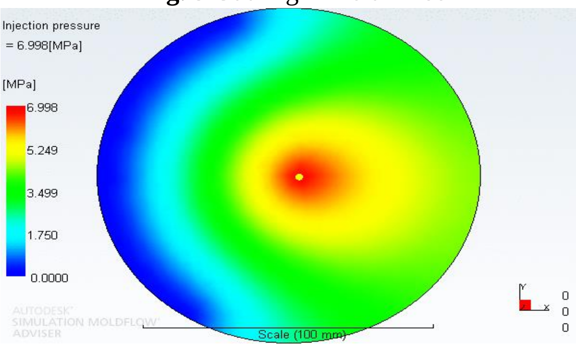


Fig. 7 Injection Pressure of Disc

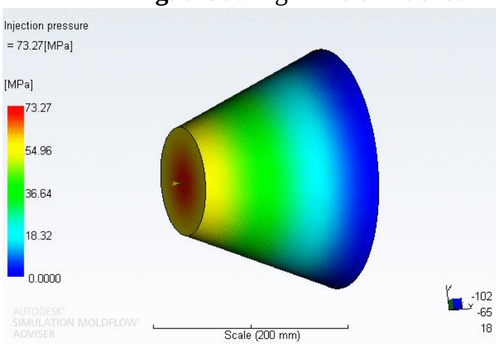


Fig. 8 Injection Pressure of Bucket

Analytical calculations and Simulation results for Disc:

Table -1 Analytical calculations and Simulation results for Disc

Parameters	Fill time (sec)	Cooling time (sec)	Injection Pressure (MP)	Clamping force area (cm^2)	Max Clamping force (Ton)	Volume (cm^3)
Calculation	1.401	13.49	5.720	113.0970	2.5	33.91000
Simulation	1.470	19.72	6.998	113.0380	3.924	33.91114

Table -2 The Analytical calculations and Simulation results for Bucket

Parameters	Fill time (sec)	Cooling time (sec	Injection pressure(MP)	Clamping force area (cm^2)	Max Clamping force (Ton)	Volume (cm^3)
Calculation	1.13	4	71	380	105	124.8
Simulation	1.28	7.777	73.275	473.58	114.710	131.6066

Discussions

The calculated fill time is less than the time computed by the program. The difference is due to the time elapsed in the sprue. the calculated cooling time is less than that of the program since the heat resistance in the program is less than the value used in calculation. The calculated injection pressure is less by 22% from the program value. The pressure drop at the gate was not included. The area of the clamps is almost the same, it's the noticed that is mould clamping force in the computer program is higher than analytical calculated volume provided the effective area is the same. This due to the clamping pressure in the program is higher.

Fill time of the program is the higher by 1.28 sec than the calculated one. The difference is due to the volume difference and the time elapsed in the sprue. The calculated cooling time is less than that of the program. This is due to the heat resistance in the program is higher. the calculated injection pressure is less by 3.2 % from the program the reason is the pressure drop at the gate was not included in the calculations. The mathematically calculated volume of the bucket is $124.8cm^3$ which is less than that of the program $131.6cm^3$. This is due to the rim of the bucket was not included.

CONCLUSIONS

The important parameters (injection time, cooling time, injection pressure, clamping force, volume of product) to design a disc and a bucket these parameters are computed using two schemes the analytical and computer program (Moldflow) for the disc the volume of the product was the same but for the bucket the calculated volume is lower due to the rim volume was not included .for injection time and pressure the calculated values are lower due to the sprue effect was not covered the calculated clamping force is lower this is due to the program used a complicated equations while the analytical used approximate equations .the Moldflow program is a suitable To calculate these parameters for the complicated shapes where the analytical method is a tedious job.

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