CAE Analysis for Disposable Mouth Mirror Based on Autodesk Moldflow Plastic Insight

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Abstract. This study is carried out to focus on computer aided engineering analysis on dental toolkit for disposable mouth mirror by using Autodesk Moldflow Insight (AMI) software. Disposable mouth mirror designs contain with a very small and precise features for it handles and fix angle between shank and working area (mirror). A 3D cad model of disposable mouth mirror has been constructed and imported to the simulation software. The part has been analysed with thermoplastic material of Polypropylene (PP) as a part material for its lightweight and durability. The simulation and analysis by moulding software package is used in order to determine the best range of operating parameter for injection moulding process in furtherance to get the low manufacturing defect. The process parameters that has been selected includes mould surface temperature, melt temperature, flow rate and cooling time during the injection moulding process. At the end, the best range of operating parameters has been proposed and simulates to study the product behaviour.

1. Introduction

Computer aided engineering has been chosen as a one of the tools that is very common in plastic injection moulding process in performing the analysis by submitting the process input to obtain the expected result. Many researchers and manufacturers has been using this approach in order to analyse their product before the actual process take place. CAE analysis has been proven to be the best way in order to analyse finite element behaviour for the product with low time consuming and low cost. In 2011, W. Kuang et al. [1] implementing CAE technology to analysed out shell for digital camera. As mention by Satoshi Kitayama et al. computer aided engineering in the plastic injection moulding is an alternative approach to determine the optimal process parameters. [2] Recently, computer aided design (CAE) is widely used in industries such as automotive, aeronautics, medical device and plastic manufacturing.

Autodesk Moldflow Insight (AMI) is one of the famous software in injection moulding process to determine product behaviour based on its thermoplastic properties. G. Singh et al. [3] find that most researchers believe that Moldflow Plastic Insight software generated simulation analysis report gave good results in comparison to any other software, AMI essentially can predict the part cycle time, fill time, pressure at end of fill, and give desired results to the researchers. Najiy et al.[4] used Moldflow software in order to analyse the flow of 20 g parison with different cavity numbers. R. Ramakrishnan et al. [5] simulates Acetal Polymer gear by using Moldflow to identify the main effect of volumetric shrinkage. The author obtain the results by controlling factors of melt temperature, mold temperature, packing time, packing pressure and cooling time in the process settings.
Injection moulding process generally known as a forming process that involves in high pressure hydraulics injection system that melts down a plastic pallets and solidifies in mold under packing pressure. It is has been preferred in plastic manufacturing industry for its short cycle times and can produce a complex shape design in a large quantity. [6] In 2017, study shows that injection moulding is major net shape processes for thermoplastic polymers with over 30% of all plastic part has been using this method in processing plastic part. [3]

This paper discusses the application of computer aided engineering in simulating disposable mouth mirror by using Autodesk Moldflow Insight software package to obtain the sprue size, runner size, type of gating system, sequence analysis and material selection. Polypropylene (PP) has been selected as a thermoplastic material for this study. This is followed by determining the best range of operating parameter without the existence of any error such as short shot. A full method in achieving this study will be discussed in the next section. Results are discussed and finally the paper concludes with the findings of the study.

2. Experimental and Test Details

Based on objectives, the purpose of this study is to identify the best range of processing parameter for disposable mouth mirror by using simulation software package Autodesk Moldflow Insight. The process setting has been simulated by trial and error process. The best range of processing parameter has been obtained after several running simulation without the existence of any error. In order to get the best practise of parameters, there are several factor that has to be emphasized such as runner system, gating system, the position of sprue and many other criteria. The selection of thermoplastic material also is one of a major factor in developing good quality of the product. As said by previous researchers, the quality of the plastic part depend on its process parameter, material features and mould design [7].

2.1. Mould Design

In this study, Autodesk Moldflow Insight software is utilized to design a two plate mould with two samples of disposable mouth mirror. Single gating system has been used in this study as shown in Figure 1. 3D mesh is applied on the moulded part with 127288 of triangle elements, 63673 nodes and number of sprue, runner and gate elements are 52. The sprue diameter is 3 mm with the length of 60 mm while the diameter of runners are 6 mm.

![Figure 1. Mould design of disposable mouth mirror.](image)

2.2. Mould and Thermoplastic material

The 3D solid part injection moulded thermoplastic model is made of Polypropylene (PP) and its material properties are given in Table 1. Tool steel P-20 was used as its moulded insert material. Previous researchers prove that this material is generally used for plastics that have lower viscosity [8]. Table 2 shows the properties of moulded insert material.
Table 1. Mechanical properties of polypropylene (PP).

| Parameter                        | Value |
|----------------------------------|-------|
| Melt temperature (°C)            | 240   |
| Injection mould temp. (°C)       | 20-60 |
| Tensile strength (MPa)           | 55.2  |
| Shrink rate (%)                  | 0.1-0.3|
| Density (kg/m³)                  | 728.28|
| Young modulus, E (MPa)           | 1340  |
| Melt flow index (g/min)          | 0.2   |

All the parameters in Table 1 were based on technical data sheet of the material. P-20 steel has been selected as its mould material, it is chosen for its steel properties that is pre-hardened, machines well, high carbon and its general purpose steel. Table 2 shows the properties of the material.

Table 2. Properties of P20 mould steel [9].

| Properties                                    | Value |
|-----------------------------------------------|-------|
| Mould density (g/cm³)                        | 7.8   |
| Mould specific heat (J/kgs)                   | 460   |
| Thermal conductivity, K (w/m⁰C)               | 29    |
| Elastic modulus, E (MPa)                      | 2.0 x 10⁵|
| Poisson’s ratio                               | 0.33  |
| Mould coefficient of thermal expansion (1/C)  | 1.2 x 10⁻⁵|

2.3. Injection Moulding Machine Setup

The specification of injection moulding machine has been set as a default in the Moldflow software package to perform the simulation. Table 3 shows the specification of the machine during running the simulation.

Table 3. Injection moulding machine specification.

| Description                             | Value |
|-----------------------------------------|-------|
| Maximum pressure limit (MPa)            | 180   |
| Screw intensification ratio              | 10    |
| Machine response time (s)               | 0.01  |
| Maximum machine clamp force (tonne)     | 7000  |

2.4. Process Parameter

The selection of process parameter in this study was developed by defining the independent parameters and its range. A few test run has been carried in order to get the best range of operating parameter. The controlling process parameter in this study were mould surface temperature, melt temperature, flow rate and cooling time. Where, the hydraulics pressure was kept constant as 9 MPa. Table 4 shows the best range of operating parameter for disposable mouth mirror without the existence of any error. From this range, it can be proved that this range has the best operating parameter for this study.

Table 4. Range of process parameter.

| Parameter                        | Minimum | Maximum |
|----------------------------------|---------|---------|
| Mold temperature (°C)            | 30      | 70      |
| Melt temperature (°C)            | 180     | 220     |
| Flow rate (cm³/s)                | 162.4   | 243.6   |
| Cooling time (s)                 | 8       | 12      |
3. Simulation Results
After running simulation, the results can be obtained on result summary and analysis log. The results in terms of bulk temperature, fill time, pressure, volumetric shrinkage and warpage has been tested on double cavity polypropylene disposable mouth mirror based on the best range of process parameter input as mention in Table 4. Test has been done for part that shown in Figure 1 with the analysis sequence of Fill+Pack+Warp.

3.1. Bulk Temperature
Bulk temperature is a weighted average temperature across the part. It also indicate an average temperature when the flow stops. Bulk temperature are an alternative way to examine the flow distribution [10]. As for this study, bulk temperature recorded for two samples are from 50°C to 226°C as shown in Figure 2. It starts with higher temperature and takes 10.09 s to cool down to 50°C. Through this result, the bulk temperature has to be higher that degradation temperature to ensure that there is no non uniform shrinkage.

3.2. Fill Time
Fill time results has been obtain from simulation study and gives results with 0.0950 s for both samples. It shows that the cavity fills in a regular intervals with the help of contour colours. From Figure 3 we can see that the last areas to fill are red, while if there is any occurrence of short shot, the cavity that did not fill has no colour. A good fill time result can be seen when the flow pattern is balanced for both part. This can be achieved by arranging the mould cavities in a balanced pattern [11].
3.3. Volumetric Shrinkage

Volumetric shrinkage is the percentage increase in local density from the end of the packing phase to when the part has cooled to its reference temperature. Figure 4 shows the simulation results of volumetric shrinkage for two samples disposable mouth mirror with the values of 10.99%. Higher volumetric shrinkage indicates that the material of the plastic part has a greater transition of specific volume [12].

![Figure 4. Volumetric shrinkage.](image)

3.4. Warpage

As shown in Figure 5 below, the deflection for this plastic part is from 0.0742 mm to 1.233 mm. Higher deflection occurs at the end of the handle may cause by the lower thickness at the area compare to the other part. And it’s depend on the phenomenon of the polymer shrinkage.

![Figure 5. Deflection on all effects.](image)

4. Conclusion

The use of computer aided engineering to obtain the best range of processing parameter has been reported in this paper. Using Moldflow simulation software package, four main parameters subsist of mold temperature, melt temperature, flow rate and cooling time has been set in order to achieve this study objectives. As the results, the operating parameter range of 30 - 70°C for mold temperature, 180 - 220°C for melt temperature, 162.4 - 243.6 cm³/s for flow rate and 8 - 12 s for cooling time shows the best operating parameter for this samples without the occurrence of any error.
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