

Design and Analysis on Disposable Mouth Mirror

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Abstract

This paper presents on a conceptual design approach for developing design and simulation analysis on dental toolkit for disposable mouth mirror. Disposable mouth mirror designs contain with a very small and precise features for it handles and fix angle between shank and working area (mirror). To develop a 3D cad data, a conceptual design method in establishing disposable mouth mirror is carried out by using morphological chart and the best concept has been selected. A 3D cad model of disposable mouth mirror has been construct by using CATIA V5 based on the best criteria. The simulation and analysis by moulding software package is used in order to determine its suitable gate location, runner system, sprue, and fill time for single and double cavity. Material used for this product has been selected from plastic material polypropylene (PP) for its durability, light weight and low cost. At the end, a new innovative design of disposable mouth mirror including all ergonomics aspects and criteria has been designed and simulates to study its product behaviour.

Keywords: *Conceptual Design, Plastic Injection Moulding, Moldflow Simulation, Runner Geometry, Disposable Mouth Mirror*

1. Introduction

Fabricating new improvement product to obtain a good quality and innovative design require a several steps and methods. The beginning phase of designing process is normally a conceptualization process after identifying every aspects and functions in a product features. Product design features can be hundreds or thousands of different kind of designs to solve any problems relates to the product and comes with alternatives solutions. It depends on the creativity of the designer itself. Creativity is related to conceptualization process by generating alternatives solutions [1]. In the past studies, a conceptualization process designing a fascia bumper system has been applied to select the best ranked design within other several design by comparing its utility values [1].

Morphological chart is one of an alternatives method in design solutions in determining the most reliable and essential features in a product made up of the combinations of sub functions. Also known as a general method for structuring and investigating the total set of relationships contained in multidimensional, usually non quantifiable problem complexes [2]. By listing every aspect that is dominant in developing product design including a brief detail and its technical future characteristics and specifications, it then will be selected based on the best features to be used by weighting objectives.

In developing a new product, a collaboration of idea between professional is a must and mainly there are three types of designers which are industrial designers, experts in ergonomics and aesthetics to develop a product quality [3]. A product for this study has been carefully designed to ensure there is no upcoming geometry error during injection process. The appearance of the moulded part has been the important criterion in injection process[4] follows by desired final shapes, features, material and the capacity of the moulding machine [5].

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. Recently, injection moulding process has been selected as a fabricating method for over 30% for plastic parts [3].

This paper discusses the application of a conceptual design in developing a disposable mouth mirror by using morphological chart. The process of designing starts from identifying an existing market of the product and listing their functions and sub functions in developing a new design. A selected design has been selected to construct its 3D CAD model by using CATIA software package before move in next step. In the following section, a Moldflow Plastics Insight (MPI) software package will be used to study part behaviour and to determine the best injection location and fill time for single cavity. This is followed by double cavity simulation to determine suitable runner system, sprue and fill time. Fill time then will be compared with single cavity to identify any differences occur. Polypropylene (PP) has been selected as a thermoplastics material used for this study.

2. Experimental in Conceptual Design

Conceptual design method frequently used during brainstorming of an idea in developing and innovating a new product. An existing product will be used as a benchmark in developing an innovative design by optimizing every aspects and features in a product during designing process. Disposable mouth mirror is a dental instrument that was used by a dentist to inspect patient's teeth, gums and various areas in a mouth. Differ from sterilized stainless steel mouth mirror that commonly used in commercial clinics and hospitals, stainless steel mouth mirror usually was made for multiple used after sterilized. Disposable mouth mirror commonly used by dentist during community program or in rural area where there is no water resources and tools sterilizer machine. Generally, disposable mouth mirror was made by thermoplastics material for its lightweight, low

cost, and durability. As for price range of the product in Malaysia, this product happen to be around as low as RM 0.30 to RM12 per piece based on the shipment country and quantity of the product per order. This product was famous to be manufactured in China.

2.1 Morphological Chart

There are several existing design for this product in a manufacturing market. Morphological charts help designer to choose the best product from maximum score in resulting a final product. Table 1 shows a morphological chart method to come out with the most efficient design in designing disposable mouth mirror. Morphological chart consists of a table layout which couples together with the desired product functions with the possible solutions for each of them [2].

Table 1 shows a morphological chart for disposable mouth mirror and conceptual models resulting from combining functions from chart are shown in Figure 1. The combination of functions in red labelled cells is assembled in the 3D model shown in Figure 1. Morphological chart shows in Table 1 provides more solutions for further combination of the functions listed in the table. Functions in Table 1 shows a major aspect in disposable mouth mirror that consists of five major concerns which are working area (mirror), shank, handle, ergonomics design and has been determined based on the product features and design properties. The solution 1-4 has been developed based on the best four criteria of the product from existing design in manufacturing.

Table 1: Morphological chart for disposable mouth mirror

Solutions Functions	Solution 1	Solution 2	Solution 3	Solution 4
Working area (mirror)	Flat Surface Size 5 (24 mm)	Front Surface Size 3(20 mm)	Front Surface Size 5 (24mm)	Double Sided
Shank	Straight	Bulky	With Grip	U-type bended
Handle	With Grip	Without Grip	Mobility end-point with Grip	-
Ergonomics	U-shape ergo-handle	-	-	-
Material	Acrylic	Polypropylene (PP)	ABS	PVC

Disposable mouth mirror functions concern in Table 1 shows a few aspects that should be taken as a consideration in developing new product. Four solutions for each sub functions have been studies. As for type of mirror used for this part, front surface would be a better choice since the reflecting surface is on the front of the lens rather than on the back like flat/plane surface or magnifying surface mirror. Flat surface mirror mostly used in disposable mouth mirror, and it may produce a double images. Front surface have an advantage of eliminating *ghost images*.

Figure 1 shows the combination of applying grip in both shank and handle. The application of grip on shank helps users to grip lips during mouth opening. As for grip on handles, it helps user to grip on the product during usage and prevents it from slipping. U-shape ergonomics handle at the end point of handle promotes comfortability for users during usage, mobility types for disposable mouth mirror is not necessary since it mostly was designed for sterilized stainless steel mouth mirror.

Polypropylene (PP) was selected as molten material for this part since it provides lightweight, high in durability and low cost. It is typically available in a form of pallets, its low melt viscosity makes the plastics flow very well in the cavities[4] part such as at grip area. General melt temperature for polypropylene is from 130°C to 250°C and typical injection mold temperature is from 20-60°C.

Table 2 shows a mechanical properties of polypropylene (PP) used during simulation phase.

2.2 Final concepts

Final concepts of a disposable mouth mirror based on combination from morphological chart has been developed in 3D CAD model by using CATIA V5 shown in Figure 1. All dimension was based on majority existing product details and based on background of product research. This selected part have a 5 gram in weight, 24mm in diameter for mirror, 160mm length, 1004 kg/m³ density and 5.03x10⁻⁶ m³ volume. Figure 2 shows part angle dimension from side view and Figure 3 shows mirror diameter and other dimension from top view.



Figure 1: 3D model of disposable mouth mirror

2.3 CAD Model

Figure 2 shows a full dimension in side view for disposable mouth mirror, it shows that there is an angle of 45° between shank and working area (mirror). This part has been developed with 40 mm long gripping area on a handle and 7 mm thickness for its handle. Next, Figure 3 presents the dimension of a product in a top view with 160 mm length. Disposable mouth mirror has no standard length for its handle. However, based on market survey most of the handle length for disposable mouth mirror is between 150mm to 170mm. Same goes with clinical mouth mirror, they comes in various type of handle some of it can be remove and replace with different size of mirror based on the condition of patients. Figure 3 shows the size for mirror shares 12 mm radius which conclude to 24 mm in diameter. Later, the meshing process takes places on the selected 3D part by using simulation software package.

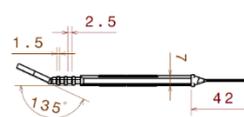


Figure 2: Side view

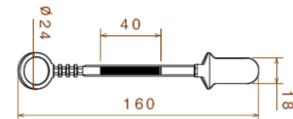


Figure 3: Top view

2.4 Process parameter

The geometry CAD model then imported into simulation software package to analyse the model. As for material, Table 2 shows a properties of the molten material that will be used for product in simulation process by Autodesk Moldflow Plastic Insight (MPI). All the parameters in Table 2 was based on technical data sheet of the material. The parameter input for this simulation shown in Table 3 for both single and double cavity was based on the best criteria for injection moulding.

Table 2: 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
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Table 3: Parameter input for Moldflow software

Parameter	Value
Mold surface temp. (°C)	49
Melt temp. (°C)	246
Injection pressure (MPa)	237
Machine clamp force (Tonne)	165
Runner size (mm)	6
Sprue length (mm)	60

3. Simulation Results

The development of the numerical simulation started with the developing 3D model of disposable mouth mirror with the dimensions that has been discussed earlier. Selected 3D part model then undergo the meshing process that has been set as triangle types of element having three nodes on one element and gives a result of 32584 number of elements with total number of nodes of 16293 for single part. Figure 4 shows a 3D model after meshing process takes place.

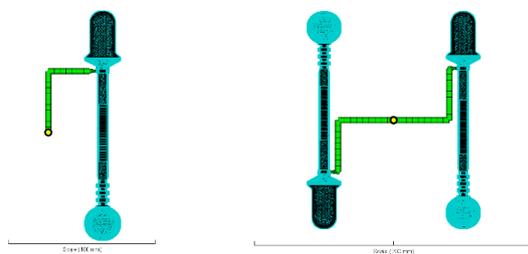


Figure 4: Mesh statistics for disposable mouth mirror

3.1 Single Cavity

Upon clearing the meshing process for a single cavity, the gating system or injection location of a selected part takes place. This process has been set manually at the handle of a part, to protect the appearance of the product. The injection location is one of the crucial part in manufactured a plastic product through injection moulding process. Hence, it is a must to select the best location for a product. From the simulation results it shows that there are no possible error in an analysis regarding the location of injection. Figure 5 (a.) and (b.) shows simulations results of fill time for single cavity and its pressure. The selection of gate position may affect the fill time of a product and temperature distribution of a moulded parts [6].

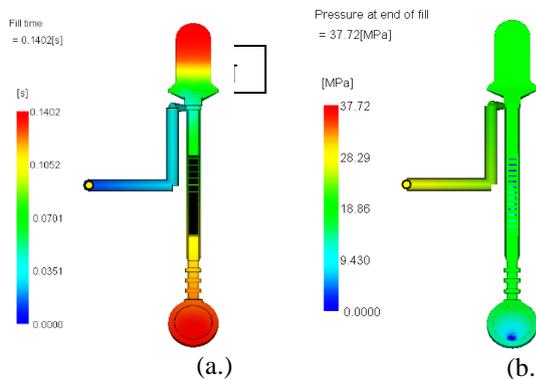


Figure 5: (a.) Fill time and (b.) Pressure analysis for single cavity

One injection location has been set at the nodes label 13093 on a selected part, the selection of injection location depends on the product features and its material flow. Fill time for this single cavity is 0.1402 second (s) and the pressure at end of fill is 37.72 MPa.

The pressure difference from one location to another is the force that pushes the material during filling.

3.2 Double Cavity

Differ with single cavity, double cavity consists with two parts in a mold connected with runner. Meshing data shows double cavity subsist 209169 elements and 104608 nodes. Runner system is a connection line between sprue and gates and its main purpose is to transfer the molten plastic from sprue to gates [7]. Runner size has been set to 6mm with 7.5° tapered angle circular cross section. Figure 6 shows a results of analysis for (a.) fill time and (b.) Pressure at the end of fill for double cavity.

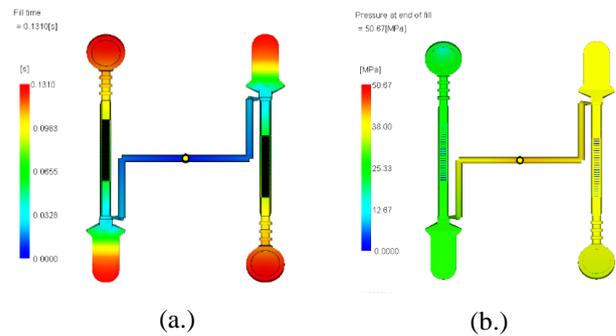


Figure 6: (a.) Fill time and (b.) Pressure for double cavity

As shown in Figure 6 double cavity consists of two parts connect with runner and the fill time analysis shows double cavity have 0.1310 second (s) to complete its filling and the pressure at the end of fill is 50.67 MPa, results in 0.0092 second shorter in time between single cavity.

Fill Time

Two different types of cavities were analysed to study its variation of fill time. Fill time results has been obtain from simulation analysis Moldflow Plastic Insight (MPI) software. Previous studies shows that the number of cavities affect the fill time and injection pressure [8]. Parameter analysis based on number cavity shown in Table 4 and Figure 7 shows a correlation of fill time and number of cavities.

Table 3: Parameter analysis based on number of cavity

No. of cavities	Fill Time (s)	Pressure at end of fill (MPa)
1	0.1402	37.72
2	0.1310	50.67

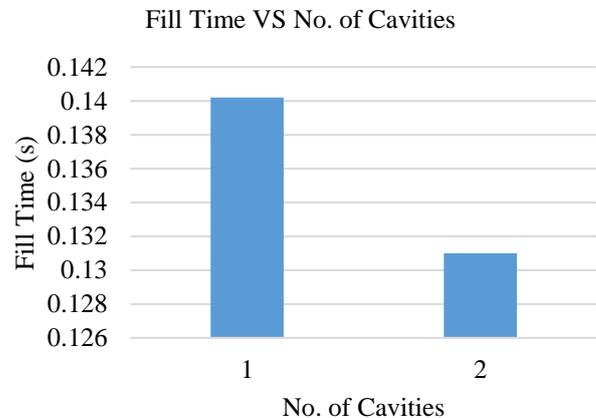


Figure 7: Correlation of fill time against number of cavities

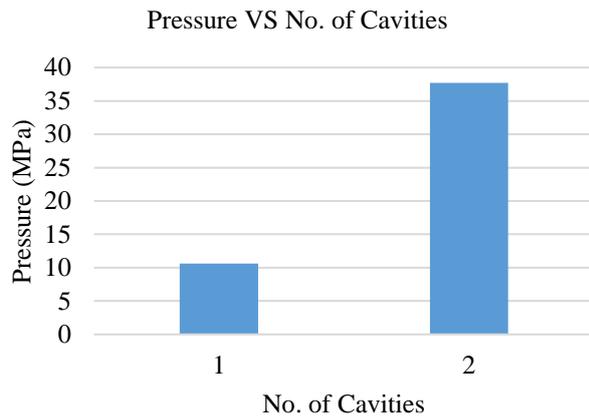


Figure 8: Correlation of Pressure against number of cavities

Interrelationship between times taken for molten material to fully fill the cavities and number of cavities shown in Figure 7, it shows that double cavity fills faster than single cavity in consequence of high pressure taken to fills in double cavity. The results and relation between pressure and number of cavities can be seen in Figure 8.

4. Conclusion

The application of conceptual design method in developing new product has been applied in this paper. The development of disposable mouth mirror has been study by looking into the best criteria using morphological chart depends on several factor. An analysis has been carried out to analyse the best injection location, sprue, runner system and variation of fill time between single and double cavity via Moldflow Plastic Insight (MPI). As a result, the best injection location has been set at the node 13093 to attain its good appearance and fill time for double cavity gives shorter time (0.1310 s) than single cavity (0.1402).

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