# A COMPARISON STUDY OF FLOW ANALYSIS IN 2-PLATE MOULD AND 3-PLATE MOULD USING COMPUTER SOFTWARE ANALYSIS


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# A Comparison Study of Flow Analysis in 2-Plate Mould and 3-Plate Mould Using Computer Software Analysis

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*Abstract* - **This paper studies the comparison of flow analysis in 2-plate mould and 3-plate mould on an Electronic Cash Register (ECR) plastic product using computer software analysis. There are three parts in ECR plastic product which including top casing, bottom casing and paper holder. Improvements on design of gate, runner, sprue, water holes and plastic parts were made to ensure optimum result analysis. This project started from design all the three parts of 3D modeling in the Unigraphic software and then transfer to Rhinoceros software for post processing and finally used Moldex software as a final stage for flow analysis in 2-plate and 3-plate mould. In the Moldex software the filling melt front time, packing melt front time, cooling and warpage analysis were done to determine and to solve the part defects which including short shot, unequal filling, over filling, welding line, cooling time and measured the value of warpage. Some calculations were done to determine the size of gate, runner and sprue to ensure the smooth flow of plastic material into the cavities area. In addition, calculations had been used for water holes design, which based from the distance of plastic parts surface to the distance of external diameters of water holes. This project showed encouraging on analysis results for all the three parts of ECR product. It solved various problems including short shot, unequal filling, overfilling, welding line, cooling time and measured the warpage value on the all three parts.**

*Keywords* – Computer Software Analysis, Simulation Software, Plastic Flow Analysis, 2-Plate Mould, 3-Plate Mould

## I. INTRODUCTION

The plastic injection moulding process involves the injection of a plastic melt into a mould, plastic cools and solidifies to form a plastic product. It is generally a three phase process comprising filling, packing and cooling phases. Its popularity is typified by the numerous products produced in this way at the present time. The introduction of simulation software has made a significant impact in the industry where in the past, much was unknown about the injection process itself. Indeed, it was known by only a handful of experts. However, with the increasing use of computers in design engineering, the amount of commercially available software on the market has also increased [1]. To the versatile user, simulations can produce a variety of results on all aspects of the injection process. Traditional trial runs on the factory floor can be replaced by less costly computer simulations. Recently, research on plastic injection molding has included a growing number of papers on optimization algorithms, the focus being in generating routines to assist the designer in the work of mold and part design.

## II. METHODOLOGY

Both of these moulds apply family type of mould which is the most difficult task for mould designer to design the mould rather than single or multi cavities mould. This because of family mould involves multi cavities with different weight and shape. Many mould makers are still using conventional approach in mould making [1]. Sapuan [2] noted that the conventional method which the moulds design is based on allowances for post mould shrinkage of the part. Conventional practice involves an interaction of modification of finished mould until the moulded part is within the specification as shown in Fig. 1. Such procedure results in long and expensive product development time.

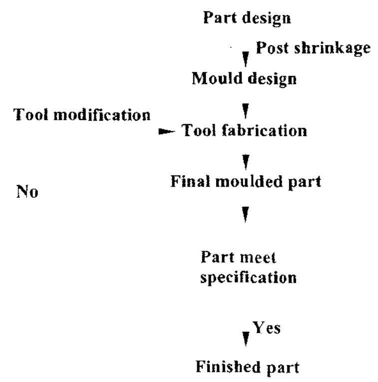


Fig. 1. Conventional method of mould making

This project started from design 3D modeling of ECR product using Unigraphic software and then transferred into Rhinoceros software for post processing. In Rhinoceros software the feeding system including gate, runner, sprue, waterholes and mould base were designed. Finally, Moldex software is used by importing post processing file and then processing conditions had decided before run filling, packing, cooling and warpage analysis. If results did not satisfy, the modification will be done again.

## III. DESIGN OF 2-PLATE MOULD

ECR product consist of top casing, bottom casing and paper holder were exported from Unigraphic software to the Rhinoceros software. The files were saved under DXF extension, which it can be read by Rhinoceros software. The example of top casing was converted from solid modeling into mesh modeling as shown in Fig. 2.

Fig. 2. Meshing surface of top casing

The locations of three parts were decided where each part is located 50mm from centre of mould. Top and bottom casing thickness are 2mm and paper holder is 3mm. Rectangular edge gate is used which consideration on depth and width. The formula of depth is h = nt, where h is depth of gate (mm), t is wall section thickness (mm) and n is material constant [3]. Calculation from formula the depth of top and bottom casing is 1.2mm and the paper holder is 1.8mm. The width of edge gate is derived from equation 1.

$$W = \frac{n \times A^{1/2}}{30} \qquad (1)$$

Where, W is width (mm); A is surface area of cavity (mm$^2$) and n is material constant. From calculation which taken surface area of top casing is 84648mm$^2$, so the width is 5.8mm, the surface area of bottom casing is 85873mm$^2$ so the width is 5.9mm and the surface area of paper holder is 4041mm$^2$, so the width is 1.27mm. Circular runner was calculated from equation 2.

$$D = \frac{W^{1/2} \times L^{1/4}}{3.7} \qquad (2)$$

Where, D is runner diameter, W is part weight and L is distance part to centre mould. Volume of top casing was taken from Rhinoceros software is 78202mm$^3$ and the weight is 80.5gram so the diameter of runner is 6.5mm. The volume of bottom casing is 83432mm$^3$ and the weight is 85.9gram, so the diameter size is 6.7mm. The volume of paper holder is 4048mm$^3$ and the weight is 4.2gram, so the diameter of runner is 1.5mm. Sprue was decided by taking the thickness cavity plate mouldbase and given angle one degree from diameter 7mm. Initial cold slug well is 7mm and base cold slug well is 10mm. Size of mould base, length is 550mm, width is 330mm and cavity thickness is 90mm and core thickness is 40mm. Diameter of water holes is 8mm and distance water holes from product are 20mm. The distance between the edges of water holes to the edge of product is 16mm. This distance 16mm was decided based on suggestion by Pye [3]-[4]. Distance between water hole is 50mm. There are 10 units of water hole at core side and another 10 units at cavity side as shown in Fig. 3. After completed all the information of 2-plate mould this file was saved to Moldex 3D Shell Mesh file where it can be read by Moldex software for analysis.

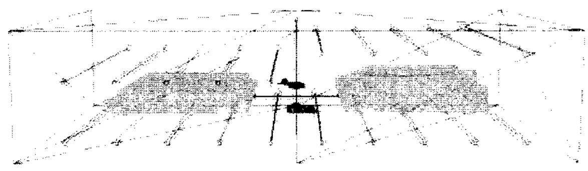

Fig. 3. Mouldbase structure of 2-plate mould

## IV. ANALYSIS OF 2-PLATE MOULD

Filling analysis in Fig. 4 shows that the total filling period of melt front time is 1.041 seconds. There were two results after filling analysis where the top casing is short shot and the paper holder totally did not complete filling at all. After increasing pressure welding line found at side face top casing. Welding line is the result of a flow front, which easily breaks up into two separate parts. When the two fronts meet, they try to welding back together again so as result form a single front line where it can be easily broken down [5].

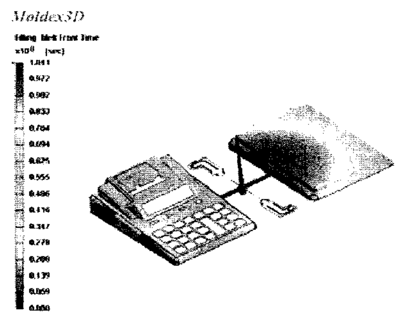


Fig. 4. Filling analysis in 2-plate mould

## V. MODIFICATION OF 2-PLATE MOULD

Due to bottom casing earlier filling than top casing, the modification was done on gate width of bottom casing by decreasing 25% from 5.9mm to 4.3mm and the runner size of bottom was decreased by 25% from diameter 6.7mm to diameter 5mm Paper holder runner was changed by relocating the paper holder from 50mm to 25mm near to centre of mould and runner size has changed by increasing 25% from diameter 1.5mm to the diameter 1.9mm. The top casing will be redesigned adding grooves to ensure the plastic flow towards at the corner of top casing. The groove was made which it was made from entrance of gate to left, middle and right side of top casing and the groove thickness was 2.5mm as shown in Fig. 5.

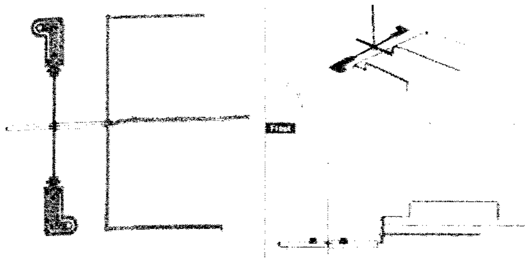

Fig. 5. Modification on 2-plate mould

VI. FLOW ANALYSIS AFTER MODIFIED OF 2-PLATE MOULD

Result filling analysis shows the flow filling of three components were balance each part. The total filling melt front time is 0.7814 seconds. The welding line was eliminated on the side body of top casing and flow pattern was balance where it flows towards on the corner of part as shown in Fig. 6.

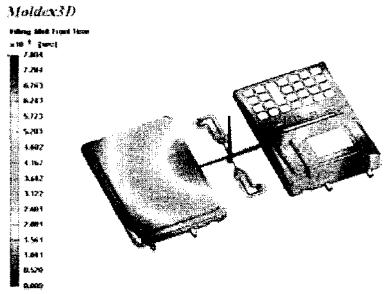

Fig. 6. Result after modified

Result from packing analysis was 0.8183 seconds and cooling analysis was 42.206 seconds as shown in Fig. 7.

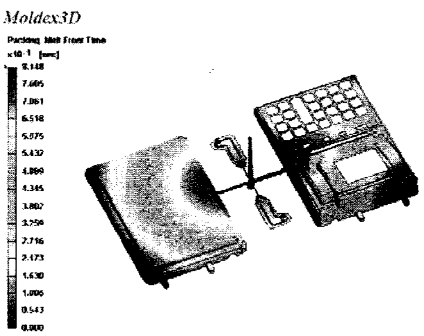

Fig. 7. Packing and cooling analysis

VII. DESIGN OF 3-PLATE MOULD

Size of pin point gate was calculated using formula $D = nC * 4\sqrt{A}$ where, D is diameter of pin point gate, n is material constant, C is function of wall thickness and A is surface area [3]. The value of n is 0.6, C = 0.294 and A = 84648mm$^2$ and the diameter of pinpoint gate for top casing is 3mm. Distance front gate to the secondary sprue is 0.75mm with angle 20°. So size between front gate to secondary sprue become, x = 0.75 x tan 20°, x = 027 per side. The total size of both distance are 0.54mm. Finally, the diameter of front gate is 2.46mm where 3mm minus 0.54mm. Diameter of the secondary sprue is starting from 6mm to 9.33mm at the end. The runner size is 9.33mm with 5° angle with maximum size is 10.14mm. Diameter pinpoint gate for bottom casing which n = 0.6, C = 0.294 and A = 85873mm$^2$, so D = 3.02mm. All calculations for secondary sprue same as top casing and all size of gate and secondary sprue. Diameter pin point gate for paper holder which n = 0.6, C = 0.355 and A = 85873mm$^2$, so from the calculation D is 1.7mm. Calculation of secondary sprue same as primary sprue. Secondary sprue size is 6mm at the front sprue with touching to the nozzle of injection machine and the end of primary sprue is 10.2mm. The completed layout of 3-plate mould, which including water hole, feeding system and ECR parts as shown in Fig. 8.

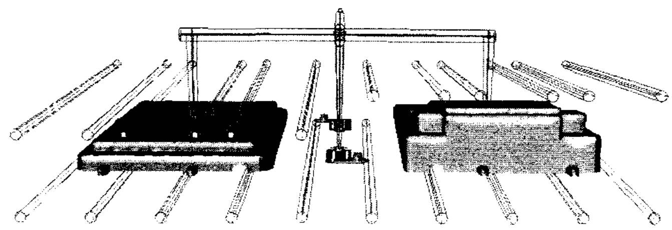

Fig. 8. Completed design of 3-plate mould

VIII. FLOW ANALYSIS OF 3-PLATE MOULD

The flow of material at top casing, bottom casing and paper holder enter at cavity area equally. The filling analysis was taken around 0.7965 seconds as shown in Fig. 9.

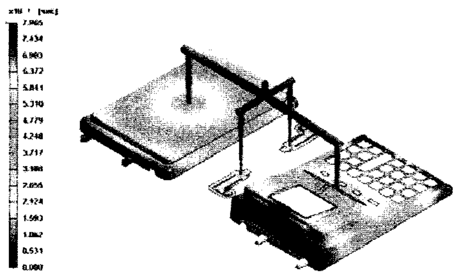

Fig. 9. Filling analysis on 3-plate mould

It was found that flows of material on the three parts were balance. However, it was found the centre area of top casing will develop some welding lines which front flow of plastic material is met together. The results from Moldex software has shown that the packing time was 0.8086 seconds and cooling analysis was 46.603 seconds as shown in Fig. 10.

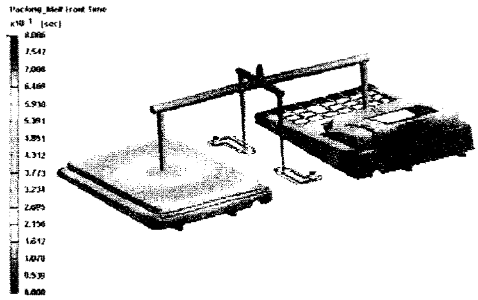

Fig. 10. Packing and cooling analysis

IX. DISCUSSION

Simulation result in 2-plate mould showed that the size of runner of paper holder was increased by 25% and location was shifted to eliminate the unfilling process. The gate and runner of bottom casing were decreased by 25% due to the over filling. To eliminate the welding line on this area the top casing was redesign by adding groove along the top surface of top casing. As the result, the welding line on side body of top casing was eliminated. The filling process on 2-plate mould was 0.7814 seconds and 3-plate mould was 0.7965 seconds, which the difference was 0.0151 seconds. Packing time of 2-plate mould was 0.8183 seconds and 3-plate mould was 0.8086 seconds. Cooling time on 3-plate mould was 46.603 seconds and 2-plate mould was 42.206 seconds. The cooling time of 3-plate mould is higher 4.397 seconds than 2-plate mould. The addition square area of plastic was added at the entrance of pinpoint gate, which it called a tab gate. This was done because the outer surface of top casing is appearance area, which no gate mark is allowed.

X. CONCLUSION

As mentioned earlier, objective of this project was to compare of flow in 2-plate and 3-plate mould. From analysis results generated by Moldex software, it was found that the size of gate and runner for paper holder and bottom casing in 2-plate mould should be changed. In addition, due to the welding line was found at top casing, a groove was added and as result, the welding line was eliminated. However, no modification was done on 3-plate mould because only found some small welding lines at top casing. Hence, it can be concluded that by using analysis software this ECR product can be designed in both 2-plate and 3-plate mould. This because of the defects which including short shot and over filling can been eliminated before the actual mould is fabricated.

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