Simulation on the Effect of Bottle Wall Thickness Distribution using Blow Moulding Technique

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Simulation on the Effect of Bottle Wall Thickness Distribution using Blow Moulding Technique

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Abstract. The aims of this study are to assess the deformation behavior of a polymeric material during a blow moulding process. Transient computations of two dimensional model of a PP bottle were performed using ANSYS Polyflow computer code to predict the wall thickness distribution at four different parison's diameter; 8mm, 10mm, 18mm, and 20mm. Effects on the final wall thickness diameter and time step are studied. The simulated data shows that the inflation performance degrades with increasing parison diameter. It is concluded that the blow moulding process using 10mm parison successfully meet the product processing requirements. Factors that contribute to the variation in deformation behaviour of the plastic during the manufacturing process are discussed.

1. Introduction

In today's competitive foundry industry, manufacturers are aiming for reliable products with characteristics such as light weight, high-quality parts, defect-free output and minimal lead time, all at the lower level of investment. One of the obstacles of its emergence as a major product on the market is the added cost of fabrication and a large uniform thickness distribution [1]. Blow molding technologies will be used in these study for the improving the quality of plastic products for the replacement of conventional blow molding techniques. Blow techniques have many advantages over that conventional blow molding such as higher part quality in more uniform wall thickness distribution, maintained the mechanical properties, lower regrind content and lower flash weight. The temperature control, blow pressure, time control, thermal properties and die design is a importance variable that need to be consider in production to has a better final products [2,3]

The design of blow molds, parison and the specification of process parameters are important and it combined of science, art and skill. A small change in die and mold design, die temperature and blow pressure can greatly effect on the molding results, plastic forming behaviour, materials parameters, the fluid viscosity and quality of the products [4,5]. To validate these parameters and accelerate the design approval, prototype tooling is needed and it very costly and takes time. To reduce lead time and expenses, Finite Element Modelling (FEM) analysis is needed [1]. It will predict and virtually assist the blow molding process design and very useful to support the foundry industry especially in designing a new products, redesign of existing products and detect the defects. By inputting blow pressure and temperature characteristic data, this analysis is able to simulate and visualize the blow molding process for achieving a uniform wall thickness in the final product [6,7]. In blow moulding simulations, numerical models have to take into account large deformations of the material, the evolving contact between tools (mould and stretch rod) and polymer, and temperature gradients [8]. The aims by using this information, the manufacturer can improved the quality of its product, reduce lead time and reduce unnecessary costs, which eventually make them more competitive and gain more profit [9]. The analysis will focused to simulate the wall thickness distribution and stress counter [10].

2. Simulation Work

In this study, ANSYS Polyflow software was used to predict the blow molding behavior on the effect of four different diameter's parison; 8mm, 10mm, 18mm, and 20mm on the final wall thickness distribution and stress contour occurred. Polypropylene (PP) ASTM D4101 was used as the parison materials and aluminium as mould material. PP has excellent moisture resistance, low density, good fatigue resistance, high flexural strength and good impact strength [11, 12]. The PP property is shown in Table 1.

The simulation task is divided into five stages. First, the 2-D models of the mould and parison shape circular cross section was developed at geometry stage. The visual of model is formed in one half of the mould. The graphical of bottle is sketch referred the design according by Pepliński and Bielinski, 2009 [13]. The design cavity should meet the equation 1 and 2 requirements. The diameter of the bottle is 100mm, depth, D is 0.05 to 0.08mm, blowing pressure, p is 2.0 MPa and density is 2.7g/cc. The simulation starts with the generation of mesh and the value of element size was set to 0.001m. The mesh is done to divide the geometry into cells or control volumes. Next, the simulation parameter and specific materials for the mould and parison was set up. Table 2 shows the assumption parameters were considered in this simulation. Next step was set up the condition of analysis for operating at setup stage. Lastly, the behavior of plastic during the process and the wall thickness distribution and stress contour results can be viewed in 2-D graphic at result stage.

Blow ratio equation for one cavity mould halves [13]

$$\text{Cavity–Cavity Blow Ratio} = W > D \quad (1)$$

Blow ratio equation for 2 cavity mould halves

$$\text{Cavity – Core Blow Ratio} = W > 2D \quad (2)$$

w=diameter and a depth, d=radius (2:1)

Table 1. Properties of Polypropylene [14]

Properties	Value
Temperature, T	190° C
Viscosity, μ	100000 Pa.s
Density, ρ	0.906 g/cm^3
Gravity, g	-9.81g/cm^2
Pressure, p	0.9Mpa
Yield stress	25 MPa
Thermal coefficient of expansion	100 - 150 x 10^{-6}
Melting point (recommended)	210 C-240 C
Elastic modulus	840 MPa
Tensile strength	32MPa

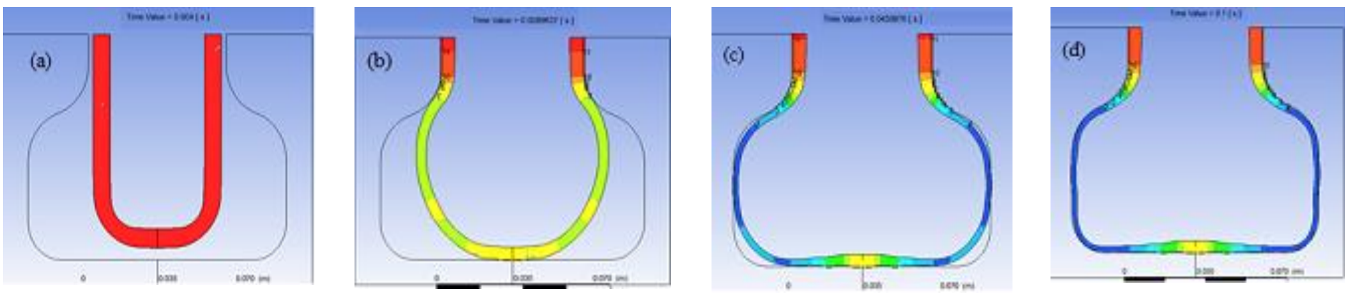
Table 2. The parameter input for simulation

Input	Data
Element size	0.001m
Viscosity	100000 Pa.s
Density	0.906 g/cm^3
Gravity	-981g/ cm^2
Slipping coefficient	1e+09
Penalty coefficient	1e+09
Inner free surface	-2e06
Initial time value	0.0000000e00
Upper time value	1.0000000e-01
Initial value of time step	1.0000000e-03
Max value of time step	1.0000000-e07
Tolerance	1.0000000e-02
Max number of successful step	200
Number of step	4

3. Results and Discussion

Figure 1 shows the results of wall distribution thickness at the surface contour on the bottle obtained from parison diameter from initial time step (TS) from 4 until the blowing process finished at time step 33. Dark blue depicted the region is too thin and can be acceptable for safety reasons and yellow and red colour depicted the region can be economically attractive. The wall thinning influenced to the mechanical properties of the product. The wall thickness on red region was more thick compare to blue region was more thin because the forces on the upper of the bottle is too high to maintain the bottle strength. It is decrease the thickness slowly until the uniformly surface along the bottle. At the bottom of bottle the thickness become high because it want to support the density of the bottle when the water was insert into the bottle. The total steps are also effect on the blowing process where the 8mm of parison diameter will take more steps between 20mm of parison diameter. It is happen because the parison will contact at the mould cavity based on the parison size.

Table 3 shows the minimum and maximum thickness value. The agreement is fair. Figure 1 (d) shows the distribution of wall thickness in the final bottle and 10mm diameter parison shows the uniform wall distribution and has full contact with mould cavity's wall. The parison is not fully inflated for parison diameter 18 and 20mm because the blow up pressure is too low and blow time is too short. To solve this problem the blow up pressure and blowing time must be increased. Figure 2 shows the graph of comparison thickness between different parison diameters. The distributions graph moving high thickness and then decrease the thickness because it is currently at the middle of the bottle and the wall thickness is uniformly. Then the thickness increase when the parison contact at the bottom of the mould because the bottom of bottle is much strength from the middle of the bottle.



8mm parison thickness (a) TS 4, t=0.004s (b) TS 12, t=0.003s (c) TS 20, t=0.046s and (d) TS 35, t=0.1s

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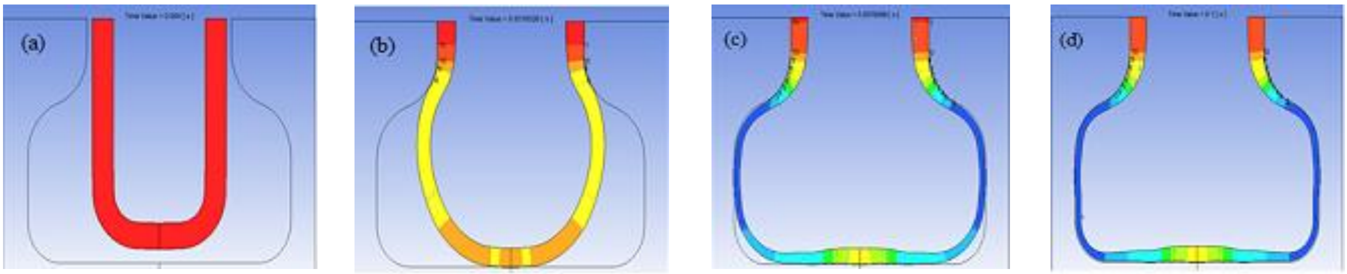
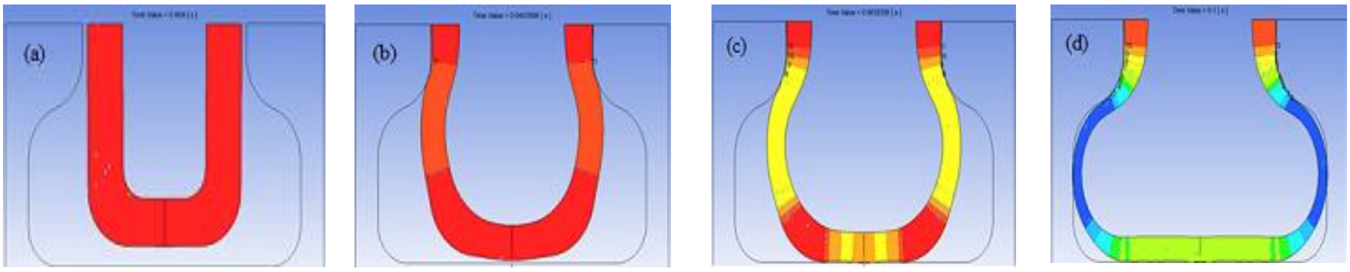
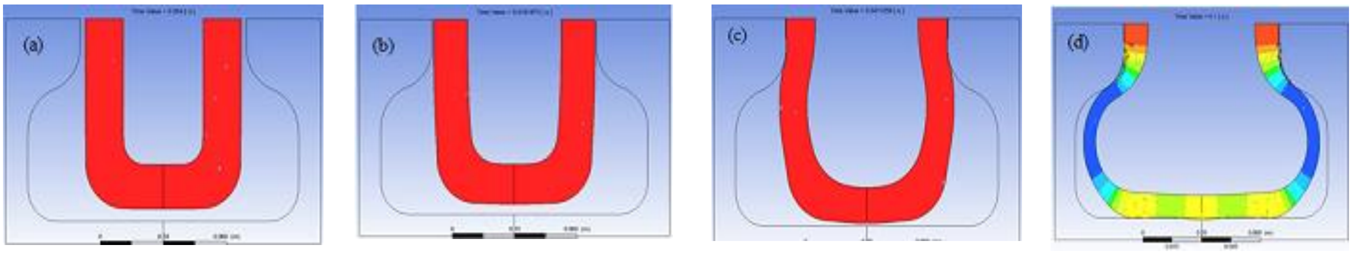


10 mm parison thickness (a) TS 4, t=0.004s, (b) TS 12, t=0.032s, (c) TS 20, t=0.058s, and (d) TS 33, t=0.1s



18 mm parison thickness (a) TS 4, t=0.004s (b) TS 12, t=0.044s (c) TS 16, t=0.063s and (d) TS 21, t=0.1s



20 mm parison thickness (a) TS 4, t=0.004s (b) TS 8, t=0.162s (c) TS 12, t=0.041s and (d) TS 19, t=0.1s

Figure 1. The effect of parison thickness visualization change of counter of thickness on time step, TS and time, t

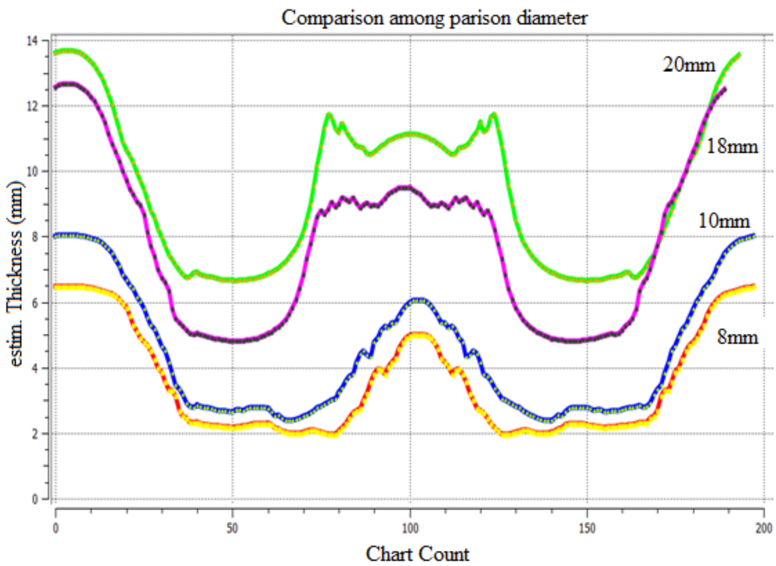


Figure 2. Comparison part thickness distribution againts chart count on 8mm, 10mm, 18mm and 20mm parison diameter

Table 3. Summary of the results obtained for the simulation

	Blowing consideration			
Dimension of parison(mm)	**Minimum thickness(mm)**	**Maximum thickness(mm)**	**Mean of thickness(mm)**	**Area (m^2)**
8	1.9463	6.4880	3.5315	0.0005
10	2.3896	8.0483	4.4087	0.0006
18	4.8097	12.6564	7.7858	0.0012
20	6.6555	13.6885	9.3849	0.0014

4. Conclusion

A 2-D model has been developed for the simulation of blow molding using ANSYS Polyflow software and optimization of the perform shape to minimize the weight of the bottle. The simulation works allows for minimizing the consumption of plastic on the product while retaining some structural assumption and the higher dimension of parison effected the parison thickness at the bottom of bottle because the pressure push the parison to the following shape of bottle. The 10mm diameter shows the best results compare to others diameter because the parison is fully contact on the mould cavities and the shape and cavity of mould appropriate with the material used. Based on the results it can see the bottle wall thickness depends primarily on the shape and dimensions of the cavity mould and varying degrees of individual areas stretching of parison and at different times of contact parison with the mould. At the end it can exception may arise from the relationship between the parison diameter and the material waste obtained in the upper and lower zone of the bottle and also minimization the product thickness in these simulation process.

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