Simulation of Counter Blow Process of PBL Quartz Bottle Fabrication

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Abstract :

Several kinds of defects that occur in bottle industry will reduce efficiency of bottle production. The defective bottle products are caused by several factors, such as human error, compositions, faults in temperature and machinery setting. From such those errors, faults in temperature and machinery setting often occur during bottle fabrication. This research aims to simulate bottle fabrication by using Computational Fluid Dynamic (CFD) and being used to predict loading mark bottle defect. The results indicate that the temperature range in counter blow process should be 600-800°C and in order to reduce the inhomogeneous parison temperature distribution the proper air velocity should be 0.1 m/s. The inhomogeneous parison temperature distribution at the contact area between parison and blank mold may lead to the presence of loading mark. Based on the simulation results, the loading mark is likely to take place at the shoulder and neckring of the bottle.

Keywords: counter blow , CFD, parison temperature distribution, loading mark

1. Introduction

Bottles fabrication technology has been improving to minimize defective bottle products and increase bottles production efficiency. The defective bottle products are generally caused by several factors, such as human error, compositions, faults in temperature and machinery setting. From such those errors, faults in temperature and machinery setting is able to decrease production efficiency to be less than 80% **[1]**. The process of bottles fabrication commonly consists of 4 steps such as melting, pressing, blowing and annealing **[2]**. The focus of this research is the second step, i.e. pressing. According to the survey undertaken **[1]**, pressing is a step in which temperature setting error frequently takes place. Especially for PBL Quartz bottles, from 39 kinds of bottles defect ± 22 kinds of the defect are caused by error in temperature setting in both pressing and blowing processes **[1]**.

The process of blow and blow has 2 main processes inside blank mold, i.e. settle blow and counter blow. In the settle blow, outward air blow vastly affects the shape of bottle mouth; while in counter blow, the velocity of air blowed into parison (bottle liquid in blank mold) considerably influences parison temperature distribution. The inhomogeneity of parison temperature distribution will consequently result in defective bottle. Therefore air velocity blowed in this phase must be considered so that the temperature distribution in bottle spreads homogeneously and hence good quality of bottle can be obtained. There are 5 sorts of bottle defects which often occurs in PBL Quartz, namely loading mark, crack shoulder, crack body, and blow pipe mark **[1]**. Loading mark defect is caused by error of temperature setting which particularly caused by inhomogeneity parison temperature distribution, such that the parison temperature may exceed the blank mold temperature. Under such conditions, this research is expected to provide solution to overcome loading mark bottle defect in PBL Quartz.

2. Material and Methods

Time settings of each part given in bottles fabrication machine (IS machine) must be precise to avoid defect. Time used in bottles fabrication machine has an angle unit. Table 1. shows time conversion in angle to second from gob interceptor process to blanks open. Two seconds of counter blow process is used in this simulation. Five designs of bottles drawing according to the process time is used based on time discretezations t= 0 second; 0.5 second; 1 second; 1.5 seconds and 2 seconds. The calculation of air height blowed to the parison and parison height in blank mold are based on the data from the company **[1]** and literature **[3]**. Emhart standar is used in both air and parison height determination to obtain valid data.

Table 1. Time of each process from bottle fabrication to counter blow process

Process of bottle fabrication	ON	OFF	Time (s)
Gob Interceptor	355	55	1.7142
Plunger Up	9	70	1.7428
Funnel Down	346	82	2.7428
1st Baffle Down	25	65	1.1428
Settle Blow	10	65	1.5714
Plunger Down	197	7	4.8571
2nd Baffle Down	97	198	2.8857
Counter Blow	120	190	2.0001
Blanks Open	200	338	3.9431

Table 2. indicates height change in counter blow in interval of 0.5 second. The results of the height calculation are used to design height at those particular time intervals. The parison shape change as being pressed by the air process is represented in Figure 1.

Table 2. Parison and air height blowed calculation results

Time (s)	Air height blowed (mm)	Parison height (mm)
0	11.6	94.72
0.5	97.2	112.08
1	149.9	170.67
1.5	188.3	214.42
2	220.1	229.6

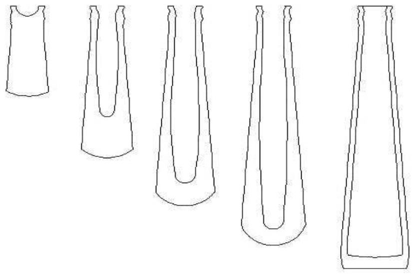

Figure 1. Parison shape change in counter blow

The simulation used in this research is Computational Fluid Dynamics (CFD). The mesh kind and width greatly influence the simulation results. The meshes used in this simulation are submap and pave. Submap is used for the first and fifth figure designs while pave is for the second, third and fourth figure designs. The use of the two meshes is aimed to keep meshing condition in figure design boundary. If the mesh exists outside the boundary, it can no longer be used for simulation.

Table 3. Mesh kind and widht determination

Figure designs	Mesh kind	Mesh widht	Value Interval	Element numbers
1	Submap	Amount interval	100	290.216
2	Pave	Distance interval	0.025	876.797
3	Pave	Distance interval	0.025	331.921
4	Pave	Distance interval	0.025	71.410
5	Submap	Amount interval	100	161.160

The determination of the mesh width will affect simulation result validity. The mesh width used in the simulation is amount and distance interval. Amount interval width mesh is used for the first and fifth figure designs while distance interval is used for second, third and four figure designs. The greater the amount interval, the more valid simulation result obtained. On the contrary, for distance interval value decision the smaller the distance interval value, the more valid simulation results. From Table 3. it appears that the result of mesh determination determines element numbers. The bigger elements obtained, the more valid simulation attained. The boundary condition of the simulation is determined according to PBL Quartz bottles fabrication in counter blow. The boundary condition consists of 4 kinds such as wall, air inlet, air outlet and wall between air and parison. The fluid used in the simulation is glass.

Table 4. Parison temperature and molds of each figure design

t (s)	Parison temperature (°C)	Mold temperature (°C)
0	788.8247	314.5645
0.5	756.5776	332.6628
1	727.8613	345.381
1.5	706.2572	354.5125
2	695.2795	358

After determination of the boundary condition with a good mesh quality, the simulation can be done. The simulation uses solution initialization from whole boundary condition along with addition initialization (patch) on glass. Parison temperature is used as glass initialization. Table 4. represents parison temperature and molds of each figure design.

Table 5. Residual error value in the simulation

Residual Error	Value
Continuity	10^{-6}
X-velocity	10^{-6}
Y-velocity	10^{-6}
Energy	10^{-6}

Transient time is applied in the simulation so the result of each shape change in selected time can be saved. Residual error is an optimum error value boundary in the calculation of each mesh element. The smaller the residual error value, the more valid simulation result is achieved. Residual error standard of the simulation is continum, velocity in both x and y axes are 10^{-4} while the energy is 10^{-6}. Table 5. shows 10^{-6} residual error values set in the simulation.

3. Result and Discussion.

3.1. Air Pressing into Parison Discretization Simulation

Figures 2. (a), (b), and (c) show the parison temperature distribution which uniformly spreads while Figures 2. (d) and (e) show variation of colors between blank mold and parison boundaries. This phenomenon is caused by a temperature difference between blank mold and parison which is approximately 350°C. The same result from different simulation method has been accomplished **[2,4]**. Figures 2. (d) and (e) indicate inhomogeneity temperature distribution particularly in the neck and lower body of parison. These simulation results agree well with analytical calculation using semi infinite solid method **[5]**.

As mentioned earlier, loading mark bottle defect takes place due to the inhomogeneous temperature distribution between parison and blank mold **[6]**. At this point the parison located close to the blank mold will solidify quickly resulting in folds at the bottle surface. The defect physically appears on the surface of the bottle in which wrinkles exist and make the bottle does not seem to be flat. Loading mark defect may appear in both neck and lower part of bottle according to the simulation result.

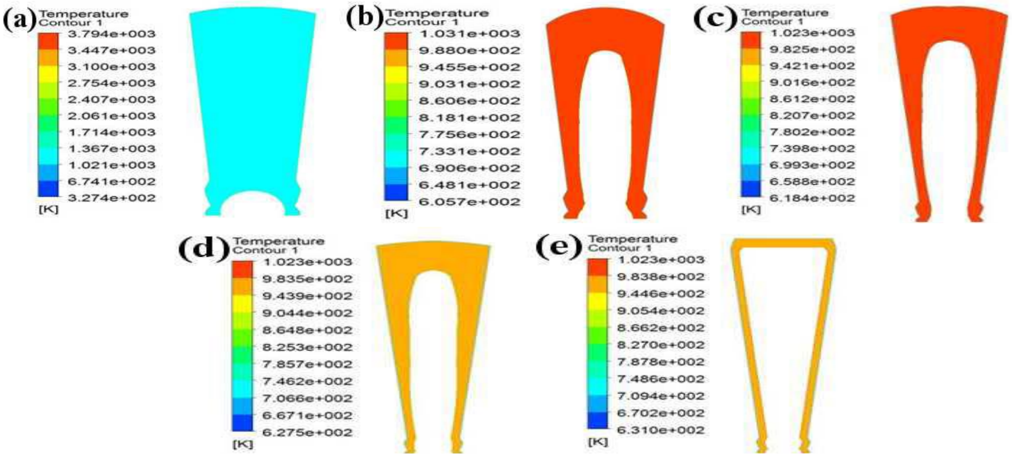

Figure 2. Parison temperature contour in : (a) 0.01 s, (b) 0.51 s, (c) 1.01 s, (d) 1.51 s, (e) 2.01 s

According to the simulation, loading mark defect possibility on PBL Quartz in counter blow process is considerably small. This is indicated by a short distance having temperature gradient between parison and mold. Therefore, temperature range for counter blow process should be between 600-800 °C in PBL Quartz fabrication. This findings agree with **[2,7]** which suggest that the temperature during blank mold process should be in the range of 600-1050 °C.

3.2. Simulation of Air Velocity Variations into Parison

Air velocity blowed into parison in counter blow process will affect parison shape change. Figures 3 (a), (b), and (c) show the temperature distribution after certain air velocity was given. At this point, the parison becomes gob (liquid bottle out of burning chamber). As the high temperature of air blowed through the parison, the parison experiences re-heating and becomes liquid.

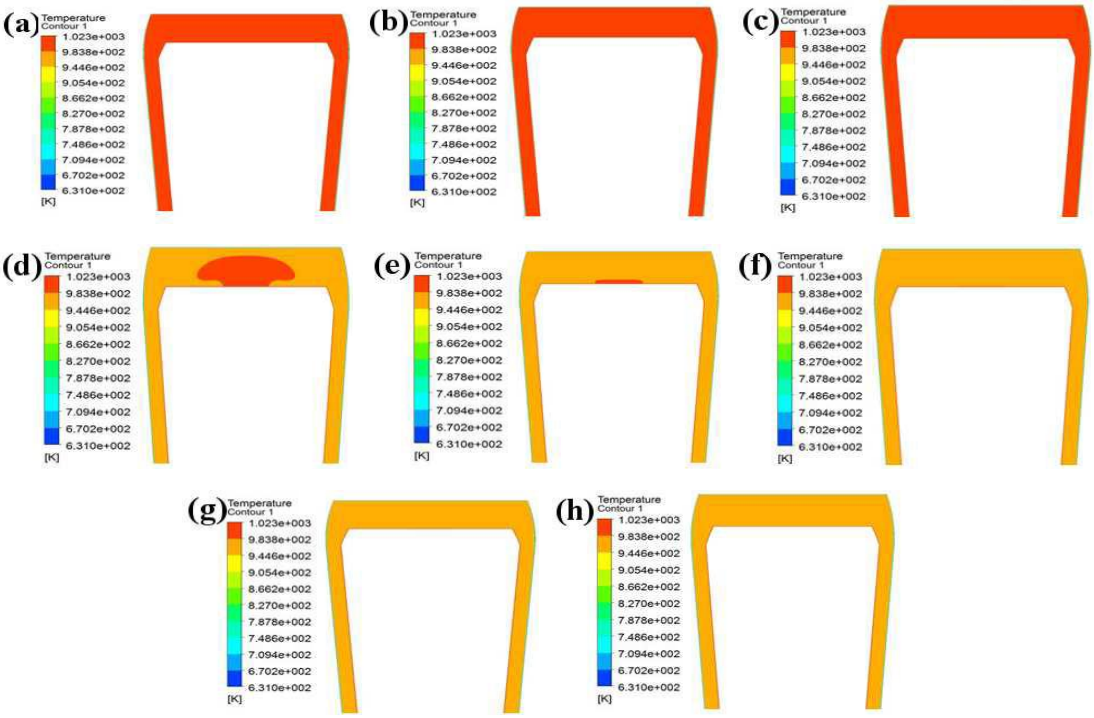

Figure 3. Temperature contour in t = 2.01 second with air velocity pressing parison at (a) 10^6 m/s, (b) 10^5 m/s, (c) 10^4 m/s, (d) 10^3 m/s, (e) 10^2 m/s, (f) 10 m/s, (g) 1 m/s, (h) 10^{-1} m/s.

Figures 3. (d), (e), and (f) show inhomogeneous temperature distribution due to air velocity in counter blow process. In contrast, Figures 3. (g) and (h) show the results of appropriate air velocity blowed into parison. It appears that parison temperature distribution around air blowing area spreads equally.

Quantitatively, it appears in Figure 3. that air velocities of 1 m/s and 0,1 m/s result in similar average parison temperature of 968,28 K. At those particular velocities, the parison still has capability of changing in volume and phase from liquid to solid. Air velocity of 0,1 -1 m/s can be applied as reference in PBL Quartz production process. In agreement with other findings **[2,8]** which state that 0,1 m/s air velocity is often used in both simulation and real implementation.

4. Conclusion

The temperature range in counter blow process should be 600-800°C and in order to reduce the inhomogeneous parison temperature distribution the proper air velocity should be 0.1 m/s. The inhomogeneous parison temperature distribution at the contact area between parison and blank mold may lead to the presence of loading mark. Based on the simulation results, the loading mark is likely to take place at the shoulder and neckring of the bottle.

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References

[1] PT.IGLAS. 2011. Recording mutu produksi PT Iglas: 525/PBL QUARTZ 65CL IG-FMPMP-01-36. Technical report, PT. IGLAS.
[2] Laevsky K. 2003. Pressing of Glass in Bottle and Jar Manufacturing : Numerical Analysis and Computation. PhD thesis, Dept. of Mathematics and Computer Science, Eindhoven University of Technology, The Netherlands.
[3] Deidewig F., Müller T. –. Temperature distribution in blank dan blow moulds. Technical report, Emhart Glass SA, Zurich.
[4] Giannopapa C.G, Groot J.A.W.M. 2011. Modelling the blow-blow forming process in glass container manufacturing : A comparison between computations and experiments. Eindhoven Univesity of Technology, The Netherlands.
[5] Warude A. 2004. Analysis of glass mold to enhance rate of heat transfer. PhD thesis, University of South Florida.
[6] Matousek I. –. Computer modelling and optimisation of glass forming cycle. Technical report, Departements of Glass Producing Machines and Robotics, Technical University of Liberec, the Czech Republic.
[7] Kent R. 1976. Mold temperature and heat flux measurements and the control of heat transfer during the production of glass containers. IEEE Transactions on Industry Applications, IA-12(4):432 – 439.
[8] Groot J.A.W.M, Mattheij R.M.M, Laevsky K. 2009. Mathematical modelling of glass forming processes. Technical report, Dept. of Mathematics and Computer Science, Eindhoven Univesity of Technology, The Netherlands.