01H02

Cavity Filling Analyses of Injection Molding Simulation - Bubble and weld line formation in Polystyrene Flask -

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1. Introduction

Cavity filling analyses of injection molded part for Polystyrene flask was performed. These analyses were done to reproduce the manufacturing problem thru. simulation to help determine and eliminate the cause of a bubble and a long visible weld line in the part, often occurring during manufacturing process.

During the last decade, the injection molding is required more accurate and high dimensional products. Precision in injection molding requires dimensional accuracy and stability in time, which are related to the distribution of a number of thermo-mechanical properties across the material. This study focuses to identify and visualize the problems to help understand the cause of the problem and thus find the solution thru. simulation technique. The video animation, which shows the flow pattern of the polymer as it fills the cavity, highlights the details of the weld line and subsequent bubble formation which could not be captured with static graphics.

2. Analyses

2.1 Molding Conditions

Per the product specification, the material used in all analyses was Mobil 1500 Polystyrene. All of the analyses were performed at a mold temperature of 50 ℃ (122 ° F), and a melt temperature of 260℃ (500 ℉), as provided by product specification. The injection time selected to fill the cavity (1.5 sec) was based on minimizing the flow stresses in the part. The terminology used throughout this paper, the original gate location (Gate 1), and a proposed gate location (Gate 2) are defined in Figure 1.

2.2 Analyses Overview

The analyses indicate that with the original wall thickness, a weld line form on the SIDE WALL opposite the gate, just below the LIP. This weld line is formed when separate flow fronts meet at this location. The complex filling pattern also leads to gas entrapment resulting in the formation of a bubble near the sonic-weld area. This correlates well with samples of the part with problems above. Measurements taken from the samples indicate that the core was shifted leading to a wall thickness difference of 0.005 inches between the two sides. The analyses with core shift indicated that this core shift does not significantly effect the weld line formation and/or gas entrapment in the part.

Based on the analyses, the best solution is to change the gate location to the rear of the part. However, since this is not possible with the existing four cavity mold, alternate wall thickness designs are investigated. The analyses therefore, focussed on investigating the flow pattern as the cavity fills under various wall thickness designs, in order to try and eliminate the gas entrapment and weld line. Six different wall thickness design alternatives were investigated and these are listed below:

Design 1 : Original wall thicknesses per drawing.

Design 2 : All wall thicknesses are the same as in Design 1, except for the FLOOR thickness which is increased by 0.008 inches.

Design 3 : Same as Design 2, except wall thickness in the SIDE WALL increased by 0.015 inches.

Design 4 : Same as Design 3, except wall thickness in the SIDE WALL further increased by 0.010 inches.

Design 5 : Same as Design 4, except wall thickness in the FLOOR reduced to the same as in the original wall thickness design.

Design 6 : Original wall thickness design, except wall thicknesses in the LIP and SIDE WALL modified to be uniformly thick.

Table 1 shows the wall thicknesses in the different areas of the part for each design. The part volumes and the relative increase in material utilization for each design are presented in Table 2.

Table 1. Nominal Wall Thicknesses (in.)

Area	Design 1	Design 2	Design 3	Design 4	Design 5	Design 6
FLOOR	0.062	**0.070**	0.070	0.070	**0.062**	0.062
SIDE WALL	0.055	0.055	**0.070**	**0.080**	0.080	**0.080**
LIP	0.110	0.110	0.110	0.110	0.110	**0.080**

Note : 1. Numbers in bold indicate changes in wall thicknesses from the previous design except Design 6 (see No. 2 below).
2. For Design 6, numbers in bold indicate changes in wall thicknesses from Design 1.

Table 2. Part Volume (㎤)

Design	Volume	% Change
1	67.8	---
2	71.5	+ 5%
3	79.3	+ 17%
4	84.5	+ 25%
5	80.8	+ 19%
6	79.4	+ 17%

3. Results

Figure 2a shows the flow pattern of the polymer for Design 1 (original wall thickness design) as the cavity fills. All figures showing flow fronts have a time scale such that dark blue indicate areas that fill early in the injection cycle and the light pink indicates areas that are the last to fill.

In the current design, the thick LIP acts as a flow leader. When the polymer goes past the NECK, a weld line forms, and due to the distorted flow front caused by the thick LIP, the filling pattern never recovers to an acceptable state (notice the pink U-shaped area in Figure 2a). There is strong evidence that the complex filling pattern leads to gas entrapment resulting in the formation of a bubble near the sonic-weld area. this phenomenon is better illustrated in the video animation.

Figure 2b shows the flow pattern with the gate located in the rear of the flask (Gate 2 in Figure 1). Although changing to this gate location might not be feasible at this point in time, the part was analyzed with this gate location to demonstrate how this gating scheme might solve the weld line and gas entrapment problem. As the figure shows, the polymer fills the cavity evenly and the fill pattern tends to be free from weld line formation. The air should vent naturally through the neck insert.

Figure 3 shows the temperature of the polymer at the end of a 1.5 sec. fill time for the original design. The figure indicates the temperature throughout the part is reasonably hot at the end of fill. Flow stresses shown in Figure 4 indicate that the stresses are well within the degradation level of polystyrene (250,000 Pa) throughout the part. Although temperatures and flow stresses are not a problem in general, they are shown for Design 1 as a representative example.

Figure 5 through 7 show the flow patterns for Designs 2 through 6. Figures 5a and 5b are for Designs 2 and 3, Figures 6a and 6b for Designs 4 and 5, and Figure 7 for Design 6.

Figure 5a indicates that increasing the wall thickness in FLOOR (Design 2) leads to a slightly more even fill pattern. the flow pattern is still likely to cause a weld line in the area below the LIP and there is a reasonable indication that gas will be entrapped.

Figure 5b shows the flow pattern obtained by increasing the SIDE WALL thickness

(Design 3). As the figure shows, the U-shaped flow front becomes less pronounced, thus decreasing the possibility of weld line formation and gas entrapment.

Flow fronts shown in Figure 6a are obtained by further increasing the SIDE WALL thickness (Design 4). By reducing the thickness difference between the LIP and the other main areas of the part, a much more even filling pattern is achieved (see Figure 6a). Although a weld still occurs on the side of the NECK away from the gate, the filling pattern quickly recovers, and there is no sign of a long weld line formation or gas entrapment. The video animation shows a better illustration of this phenomenon. There may be some concern regarding material usage with this design, and the wall thicknesses should be increased incrementally.

Figure 6b shows the flow pattern for Design 5 (FLOOR thickness is the same as the original wall thickness design). We analyzed the design to assess the effect of increasing the SIDE WALL thickness and leaving the FLOOR thickness alone. The flow fronts in Figure 6b indicate that there is a greater likelihood of gas entrapment near the sonic-weld area compared to Design 4.

Figure 7 shows the flow fronts obtained with Design 6 (SIDE WALL and LIP areas modified to be uniformly thick). This design was chosen because our analyses indicated that the thicker LIP area acts as a flow leader, thus, allowing the polymer to fill the LIP area before it fills the SIDE WALL. As Figure 7 shows, the flow fronts are now even (LIP relative to SIDE WALL) and a weld line is not likely to form. Furthermore, the uniform fill pattern indicates that the air would naturally vent at the parting line.

4. Summary and Conclusions

- The current part and mold design results in a long visible weld line in the part and a bubble formation near the sonic-weld area.
- Increasing the wall thickness in the FLOOR leads to a more even fill pattern, reducing the possibility of a weld line formation in the SIDE WALL.
- Increasing the wall thicknesses in the SIDE WALL and FLOOR helps the polymer flow more uniformly in the LIP and SIDE WALL, further reducing the possibility of weld line formation.
- Increasing the SIDE WALL and leaving the FLOOR thickness along does not improve the flow pattern sufficiently and is likely to result in bubble formation in the sonic-weld area.
- Equal wall thicknesses in the LIP and SIDE WALL leads to simultaneous filling of these areas, almost eliminating the possibility of weld line formation.
- Change the gate location in the part to Gate 2 (Figure 1) for future molds in order to fill the cavity uniformly.
- Increase the wall thickness in the FLOOR and the SIDE WALL to ease the flow of polymer in the SIDE WALL relative to the LIP area and allow the air to naturally

vent at the top.

- In order to eliminate the weld line and bubble formation, Design 4 is recommended. Since material usage for this design may be excessive, the wall thicknesses should be increased incrementally.

5. References

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2. J.F. Stevenson, Polym. Eng. Sci. 26, 746, 1986
3. J.M. Castro, C.C. Lee, Polym. Eng. Sci. 27, 218, 1987
4. CIMP Progress Report No. 14, 1988
5. MOLDFLOW Design Philosophy

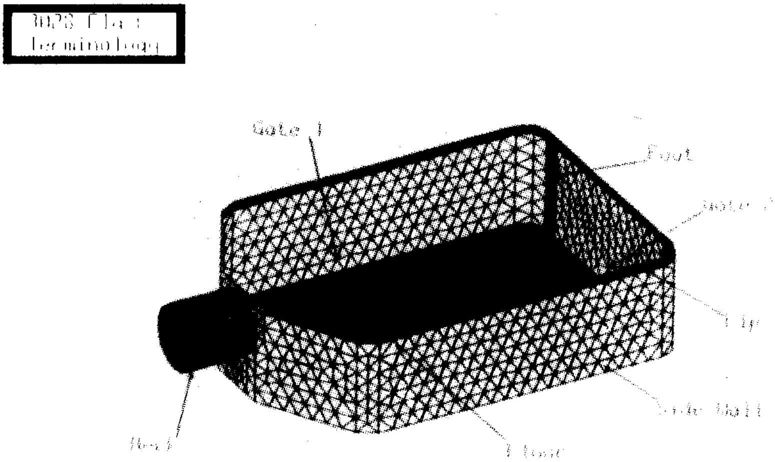

Figure 1

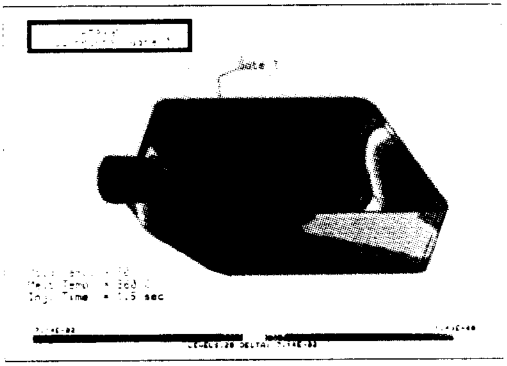

Figure 2a

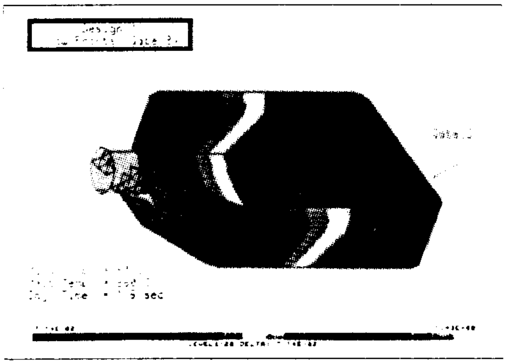

Figure 2b

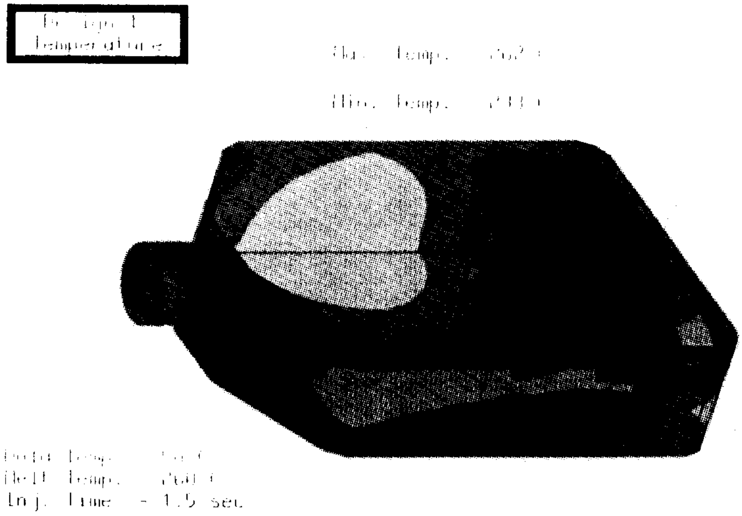

Figure 3

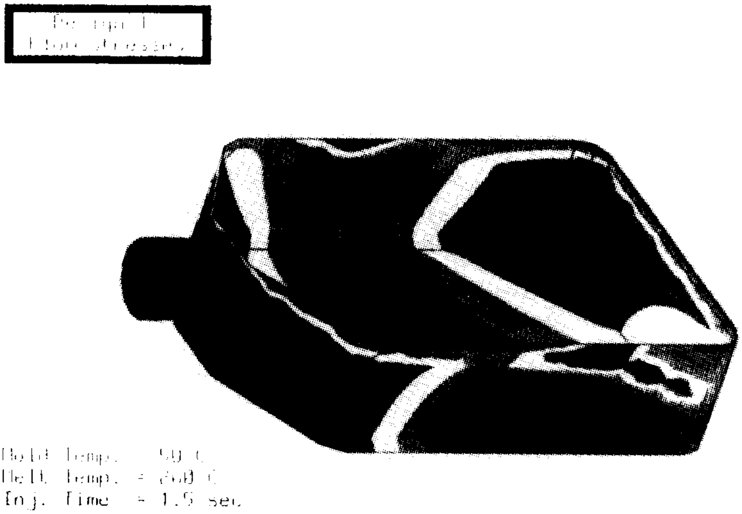

Figure 4

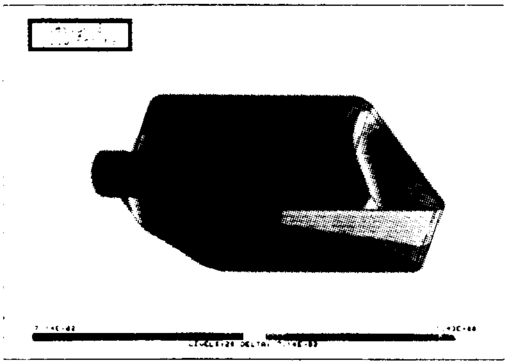

Figure 5a

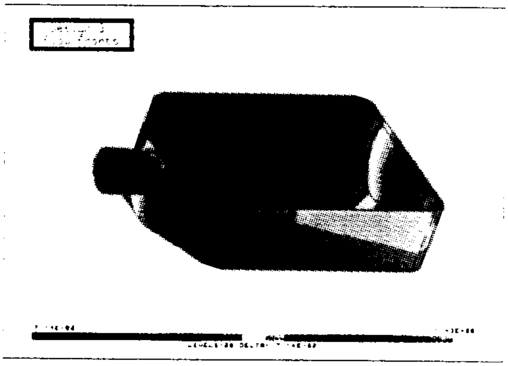

Figure 5b

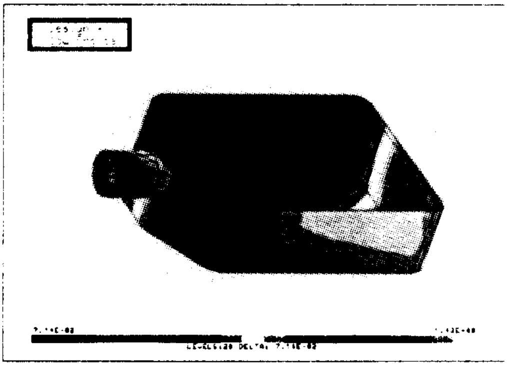

Figure 6a

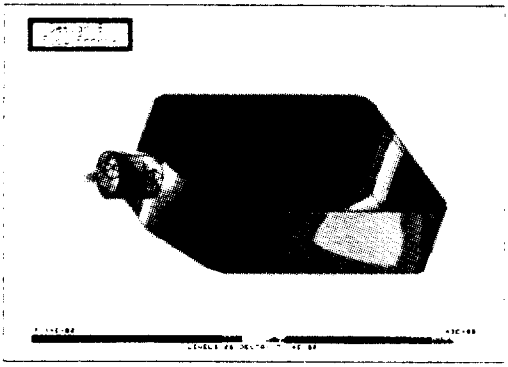

Figure 6b

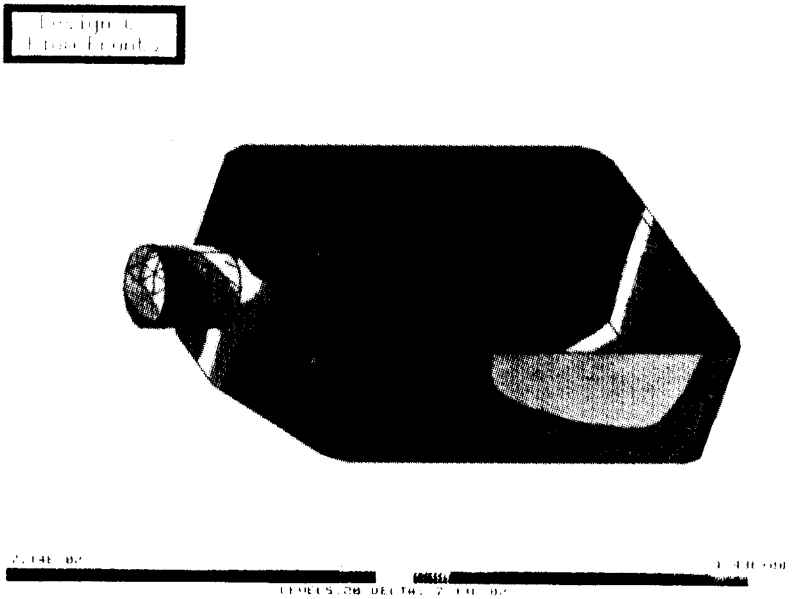

Figure 7