Modelling of Parison Formation and Process Optimization for Blow Moulded Parts

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Modeling of Parison Formation and Process Optimization for Blow Molded Parts

F. Thibault (a), A.M. Yousefi (a), R. Di Raddo(a) and H. Atsbha (b)

(a) Industrial Materials Institute, National Research Council of Canada, Canada
(b) Kautex-Textron, Inc., Canada

Abstract

In extrusion blow molding, the parison thickness has a highly non-linear relationship with die gap opening, in particular at lower die gaps when the gradient can completely reverse direction. This causes the optimization problem to be extremely challenging to solve from a mathematical and consequently a numerical perspective. The work aims to optimize the die gap programming profile, for a given final fuel-tank thickness distribution. The finite element software developed at IMI is used to predict the parison formation and part formation accounting for swell, sag, and non-isothermal effects.

1 Introduction

Parison dimensions in extrusion blow molding are affected by two phenomena, swell due to stress relaxation and sag drawdown due to gravity. The availability of a modeling technique ensures a more accurate prediction of the entire blow molding process, as the proper prediction of the parison formation is the input for the remaining process phases. The finite element software developed at IMI, couples a fluid mechanics approach to represent die flow, with a solid mechanics approach to represent parison behavior outside the die. To our knowledge, this approach is the first that is able to yield stable predictions based on first principles, at high Weissenberg numbers. Further computational details can be found elsewhere [1,2]. This work deals with the integration of parison formation and part inflation prediction into the optimization iteration. This is done in an effort to optimize die gap programming profile, for a given final part thickness distribution. The process optimization employs a gradient-based algorithm that manipulates the design variables to minimize the part weight subject to a constraint of a minimum thickness. The die gap programming profile is defined as the design variable in the formulation of the optimization problem.

2 Materials and Methods

2.1 Experimental

The experiments were conducted on an industrial scale machine at Kautex-Textron, Inc. using HDPE-4261 resin from Basell. To eliminate the trial and error approach, the die gap programming profile from simulation was used as a starting point for machine profile settings. The fuel tank was subsequently formed into the mould cavity.

2.2 Numerical Modeling

IMI's finite element software was used to predict the consecutive phases of the fuel-tank production, e.g. parison formation, part blowing, and clamping. For these simulations, a 3-node membrane element was used to create the finite element mesh of the parison (16992 elements).

2.3 Optimization Model

The commercial software (BlowDesign) manipulates the design variables or processing parameters such as die gap opening profiles and flowrate subject to process constraints such as extrusion time and parison length. For each optimization iteration, BlowDesign modifies the design variables to minimize the objective function, which is defined as the PFT weight subject to a minimum target thickness value by keeping the parison length constant [3]. This step is very challenging since the swell phenomenon is strongly non-linear in term of gap opening and flowrate in particular at lower die gaps when the gradient can completely reverse direction. The optimization methodology uses a sequential linear gradient-based algorithm to target the optimal design. In the plastic fuel tank industry, it is well accepted that the PFT minimum target thickness value should be around 3.0 mm.

3 Results and Discussion

Figure 1 (a) compares the die gap programming profile (pin traveling) recommended by the numerical optimization with the final machine profile. It can be seen that the simulation provides an accurate starting point for die gap programming. Figure 1(b) compares the predicted thickness distribution with the actual part thickness distribution. A summary of predicted and physical values are compared in Table 1, showing statistically evident correlations.

Figure 3 illustrate the optimization thickness and part weight history, starting from the previous initial design and iterating over the die gap openings. BlowDesign has decreased the part weight from 13.1 kg down to 10.2 kg after only 2 optimization iterations respecting the minimum thickness constraint of 3 mm.

4 Conclusions

As a result of process modeling and optimization tools for complex blow molded parts, programming points from simulation can be readily used as a starting point for machine profile settings reducing the required time to make good parts from days to few hours.

5 References

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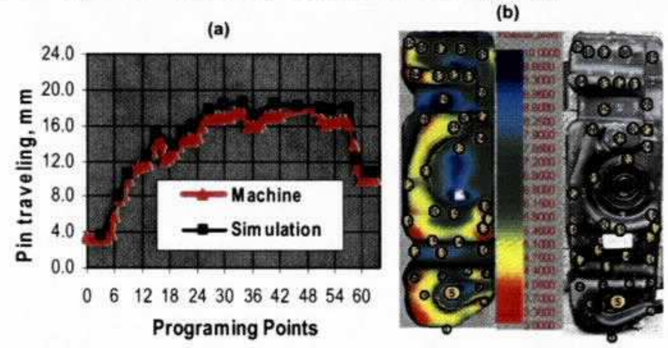

Figure 1. Comparison between machine settings and simulation results.

Variable	Physical Data	Simulation Data	%Error
Flow Rate (kg/s)	888.6	872.5	1.8
Cycle Time (s)	57.1	56.1	1.7
Shot Weight (kg)	13.81	13.91	0.7
Part Weight (kg)	9.995	9.91	0.8
Minimum Thickness (mm)	3.04	3.06	0.6

Table 1. Summary of predicted and physical values for a fuel tank.

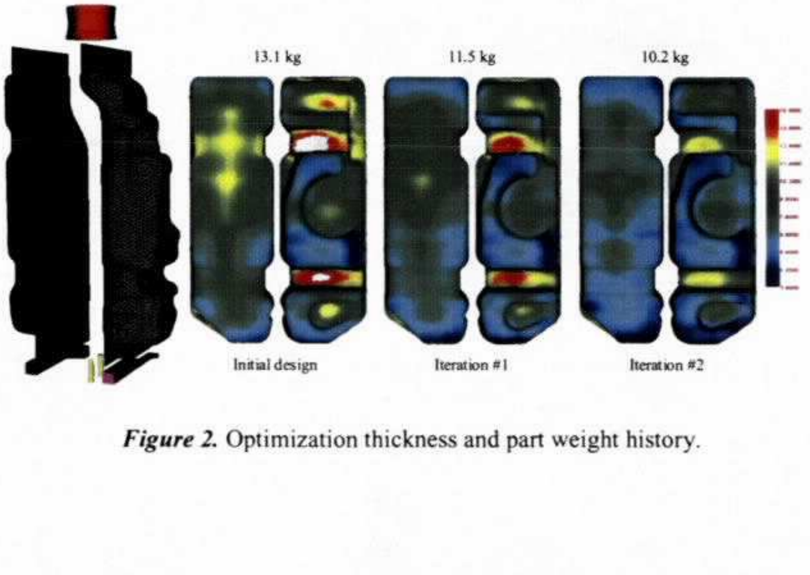

Figure 2. Optimization thickness and part weight history.