Simulation of twin-sheet blow molding technology for automotive fuel tank industry

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SIMULATION OF TWIN-SHEET BLOW MOLDING TECHNOLOGY FOR AUTOMOTIVE FUEL TANK INDUSTRY

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Abstract

Extrusion blow molding using cylindrical-shaped parisons has been the process of choice for the production of plastic fuel tanks (PFT) for the automotive industry. A revolutionary process called twin-sheet blow molding is now recognized as an innovative technology for manufacturing PFT. BlowView©, a commercial finite element software developed by the National Research Council Canada's Industrial Materials Institute, has now been adapted to simulate this new process type. It supports engineers to sketch and visualize PFT designs resulting from the twin-sheet process, before committing to expensive tooling in manufacturing. Optimization to improve quality, decrease cost, etc., is also under investigation.

Introduction

Extrusion blow molding technology has traditionally been used to manufacture plastic fuel tanks (PFT) for the automotive industry, typically from a parison having a cylindrical shape. A new system for producing PFT, twin-sheet blow molding, is recognized to take production processes to a new level [1]. This technology can produce plastic fuel systems having more complex designs, as it meets the high performance and emissions standards, thus replacing the current co-extrusion blow molding process (which requires boring and welding of externally mounted components).

The BMW 7 series 2009 fuel tank is the first commercial application of twin-sheet blow molding. Twin-sheet blow molding reduced the design complexity from two shells to one [2]. Sheets are extruded between a central core and a mold. Core actions attach the components during initial sheet forming. The empty core is then withdrawn and the mold is closed to join the formed sheets in a second blowing step. Components that can be attached to the core include baffles, gauges, valves, jet pumps, lines, fuel modules and canisters. Weight savings could go up by 10% compared to conventional blow molding due to improved wall thickness control in twin-sheet blow molding. There is also an additional 10% savings through component simplification and reduction in finishing costs [3].

Developed at the Industrial Materials Institute of the National Research Council of Canada, the BlowView© software simulates and optimizes blow molding processes. The virtual prototype of the manufacturing process allows engineers to determine how part designs will perform before committing to expensive tooling. Recently, in response to requests from research engineers working in the twin-sheet blow molding field, simulation of this advanced technology has successfully been implemented in the new version of BlowView©. The software allows engineers to assess the part design and the twin-sheet extrusion processing conditions prior to manufacturing.

Twin-Sheet Extrusion Process

The traditional extrusion blow molding process primarily consists of three phases: parison formation, parison inflation, and part cooling and solidification. The most critical phase is the parison formation since it affects the final thickness distribution and mechanical performance of the part. The BlowParison© software (in BlowView©) is used to predict the parison formation for a combined virtual wall distribution system (VWDS) and die slide motion (DSM). It considers the swell, sag, and non isothermal effects, as well as, other mechanical approaches [4]. New challenges arise when applying the BlowParison© software to simulate twin-sheet extrusion.

It is well known that the die geometry, resin characteristics and operating conditions affect the swell and sag of the sheet during extrusion. Furthermore, the swell and sag significantly influence the sheet dimensions [7], [8]. The contribution made to deal with twin-sheet extrusion is to consider the sheet as a cut and open parison [5]. The diameter swell and the thickness swell, which are used to describe an extruded cylindrical parison [6], are redefined by sheet parameters. Other simulation algorithm changes are also considered for the twin-sheet extrusion process.

Therefore, the BlowParison© software has successfully been adapted to simulate the twin-sheet extrusion process phenomena in order to predict the sheet thickness.

Software Simulation of Twin-Sheet Blow Molding Process in BlowView©

Recently, the implementation of the overall simulation of the twin-sheet blow molding process has been undertaken by the commercial software BlowView©. As BlowView© is a popular simulation tool in the plastic industry, requests from clients motivated this implementation. Hence, twin-sheet blow molding was added as a new process type in BlowView©, apart from extrusion blow molding, even though similarities exist between the two. A new Twin-Sheet Die Editor has also been developed for the twin-sheet die design allowing the user to sketch the design of the double flat die instead of the traditional cylindrical die.

The twin-sheet die editor is shown in Figure 1 (a). , The user is asked to input the vertical measurement of the die, the length of the die slits, and the mandrel dimensions along the axial position. Parameters such as the die gap, as well as the distance between the left and right mandrels at the die exit tip are also required.

The mandrel and bushing interface of the twin-sheet die editor allow the user to sketch the die using a pop up drawing of the design results. The die shape, die gap opening, and other characteristics can all be activated via the visualization interface, see Figure 1 (b).

Similarly to extrusion blow moulding, the sheet thickness in twin sheet extrusion is controlled using VWDS (i.e., vertical wall distribution system), which allows the double flat die gap openings to be manipulated. In addition to this, a new type of sheet thickness control using the die slits' movements is addressed. The new die is actually combined by the die slits that can move individually. It allows the user to manipulate the distance between the die slit to its neutral position, in order to vary the die gap opening in a particular zone. This concept is similar to the advanced die shaping technology, die slide motion (DSM), which is used to manufacture complex part shapes in extrusion blow moulding [6]. Although BlowView© supports the DSM thickness control, it will have to be improved to fulfill this new requirement for twin-sheet blow molding.

A new interface has been developed to input the positions of the die slits. From the processing condition window in BlowView©, the user can access this option when the TSExtrusion (twin-sheet extrusion) process is selected. Both sides of the die slit positions must be defined since they work independently. There are two types of machines which contain 64 or 128 extrusion points. The user can choose the one which corresponding to their setup. At each extrusion point, every die slit can be assigned a position. It is not necessary to define all 64 or 128 extrusion points. Only master points must be assigned, and the remaining die slit positions will be calculated by a linear interpolation algorithm. The user can then verify the results via the interface. With the aim of mimicking the real machines, a graphic view of the die slit positions profile is plotted according to the interpolated data, as shown in Figure 3. This profile is available for all extrusion points. Individual die slit graphs with details are also available.

In summary, BlowView© provides a user friendly interface to create and run a twin-sheet blow molding simulation, assuming all die slits stay in the neutral position, and only VWDS is used. With the twin-sheet editor, the user can design and/or select an existing double flat die. Additional information is also necessary to define a complete project, such as the material information, the mould geometries, the twin-sheet extrusion processing conditions, etc [9].

The simulation will run according to the project definition using the twin-sheet blow molding solvers. Once the simulation calculations are completed, all results can be accessed and viewed from the interface either as text files or visualization images, see Figures 2 (a-e). An animation of the entire process can be created, and modifications to the process can be made if needed.

Gas Tank Case Study

In order to validate the new BlowView© software, a twin-sheet blow molded gas tank was used as a case study. The material used in the simulation is HDPE Lupolen 4261A+EVOH Recycled, manufactured by BASF. The Carreau and K-BKZ models are used to simulate the flow in the die and part forming, respectively.

The double flat die is designed by means of the Twin-sheet Die Editor as shown in Figure 1 (a).

Other processing conditions defined in the simulation include:

- twin-sheet extrusion,
- insert components,
- mould displacement,
- pressure variation and,
- part cooling.

The visualization window allows the user to view the simulation results for the entire process. For instance, the user can see the sheets' thickness data and shape during all stages of the extrusion, as well as, the mould displacements and inflation evolution. Figures 2 (a-e) give a brief overview of the simulation results. Figure 2 (a) illustrates the initial state of the twin sheet extrusion process. The mould component inserted inside the tank is shown in grey. Figure 2 (b) shows the coiled twin-sheets after extrusion; and 2 (c) displays the mould clamping prior to inflation. Once the moulds are clamped, the pressure is increased in order to inflate the part. The inflated part along with the predicted final thickness distribution is shown in Figures 2 (d) and 2 (e).

Conclusions

In response to requests from engineers working in twin-sheet blow molding, simulation of this advanced technology has successfully been implemented in the new BlowView© software. Further developments to the software will include the simulation of the die slits thickness control during sheet extrusion, the optimization of the process design, as well as any other new achievements in twin-sheet blow molding.

Acknowledgement

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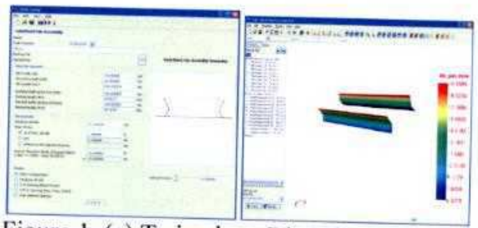

Figure 1 (a) Twin-sheet Die Editor
(b) Visualization

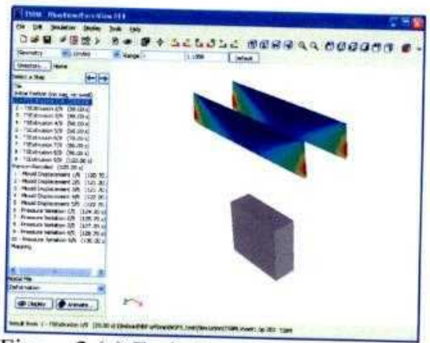

Figure 2 (a) Early Stage of Extrusion

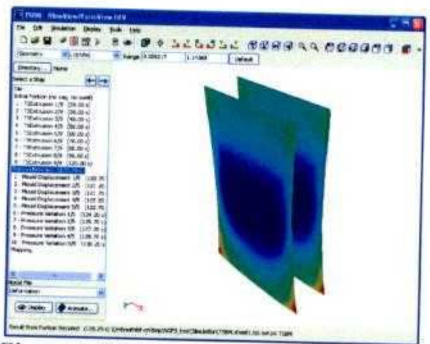

Figure 2 (b) End of Extrusion

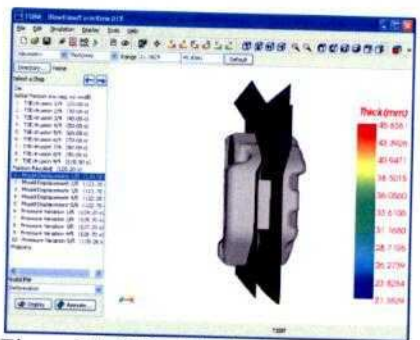

Figure 2 (c) Mould Displacement

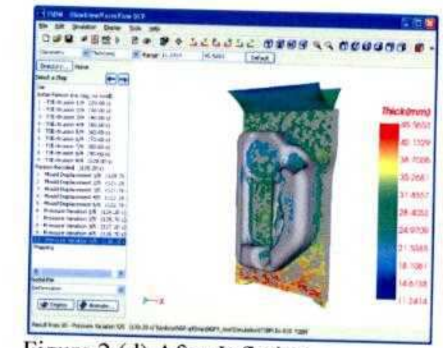

Figure 2 (d) After Inflation

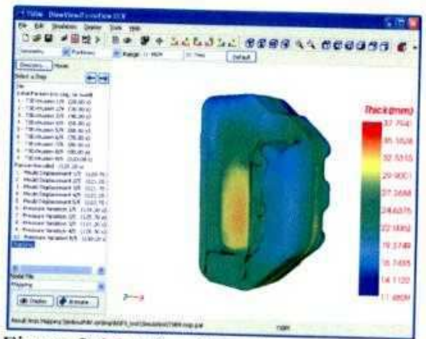

Figure 2 (e) After Mapping

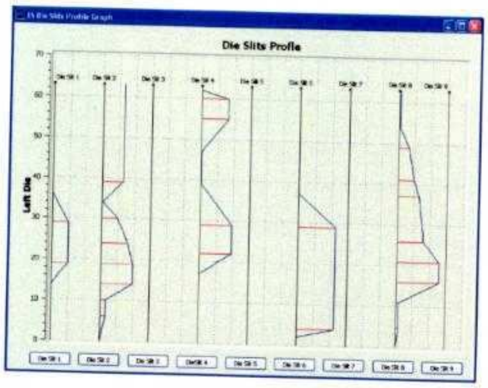

Figure 3 Graphic of all die slits on Left side