REDUCING MATERIAL COSTS

R&D reduced material costs for a water container by 10 percent while maintaining product integrity.

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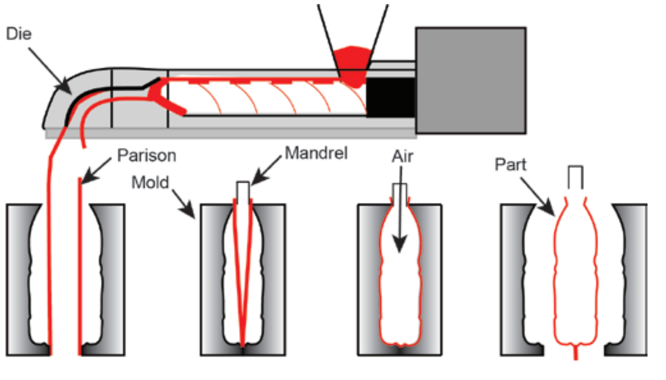
Extrusion blow molding (EBM) is a common manufacturing process for containers, bottles and gas tanks with complex shapes that require precision in manufacturing. Using engineering simulation to design these products can help to reduce weight and materials yet achieve acceptable performance. This can, in turn, avoid expensive prototyping and prevent failure while the product is in use.

Reducing materials can deliver significant cost savings for the manufacturer, who can then make the product more competitive in the marketplace by passing some of these savings to the consumer. In addition, weight reduction provides sustainability benefits with regard to decreased material disposal at the end of the product lifecycle. Gamma Point, a services company that assists customers in the plastics industry via numerical simulation, employs ANSYS software as a regular part of its engineering process to meet specific structural performance criteria while minimizing the usage of raw materials.

EBM consists of four main phases: parison extrusion (preforming the plastic to be molded in the form of a tube), inflation, part cooling/solidification and mold release. Simulation is used during both parison extrusion and inflation phases to reduce materials.



Extrusion blow-molding process

In general, any blow-molded part varies in material thickness. Engineers must take this variation into account when performing simulation to obtain accurate results, which can reduce materials, avoid expensive prototyping and prevent failure.

As an example, simulation during the design process for a blow-molded 1,000 liter water container involved three main steps:

- Model verification and comparison with existing experimental data
- Weight reduction/optimization through parison programming
- Coupling with ANSYS Mechanical for top-load analysis and ANSYS Explicit STR for drop analysis

BASELINE MODEL VERIFICATION

Gamma Point's first step was to verify that the blow-molding simulation using ANSYS Polyflow yielded results that correlate with experimental data. The Polyflow simulation used viscosity obtained from simple capillary testing, in which the viscosity of the high-density polyethylene (HDPE) material was measured at various shear rates.

To perform blow-molding simulation with Polyflow, Gamma Point engineers imported the mold for the water container from CAD software into ANSYS DesignModeler. A shell representation of the parison was used because the thickness of the materials is much less than the overall part dimensions. After performing standard repairs of the mold geometry within DesignModeler, the team meshed it in preparation for Polyflow simulation.

The engineer then fed baseline (original design) settings that included initial parison thickness variation, inflation pressure variation over time, and blow-molding machine settings (mold motion) into Polyflow. Zero shear rate viscosity used in the simulation was obtained by simple extrapolation of the viscosity model.

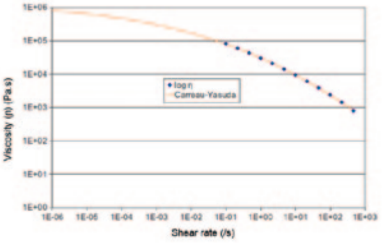
Engineers compared the Polyflow results of the blow-molded part to measurements from a real part that they sliced along two different planes to measure thickness variation. The average error was below 12 percent and considered acceptable.

PARISON PROGRAMMING

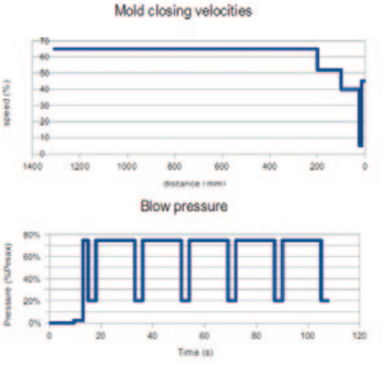
ANSYS Polyflow contains a very efficient algorithm to adjust the initial parison thickness variation to meet a predefined final thickness variation for the blow-molded part. This helps design engineers to answer the question, What should the minimum initial thickness be at selected points on the parison so that the final thickness variation meets specific target value(s)? The iterative algorithm suggests a new initial parison thickness variation that, under the exact same blow-molding conditions, will result in meeting the required final thickness variation.

Using the parison programming algorithm, Polyflow calculated the initial thickness variation of the parison in about four to six simulation iterations. The corresponding final thickness variation showed that the flash weight has been reduced. Flash is the excess plastic surrounding the actual useful part; this scrap material is trimmed and recycled. This optimization process allowed reduction of an unnecessarily thick area in the middle of the container that was evident in the baseline design. After material reduction, the final container weight was reduced by 10 percent.

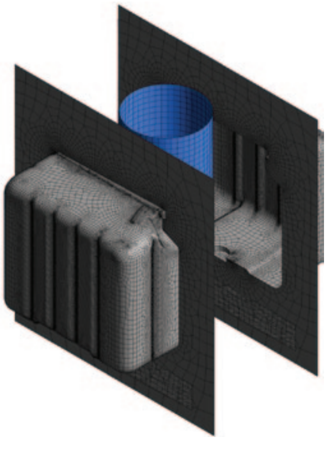
Gamma Point optimized a 1,000 liter water container to reduce material and save manufacturing costs.



Experimental data for viscosity vs. shear rate variation. This data was extrapolated and used as input for simulation.



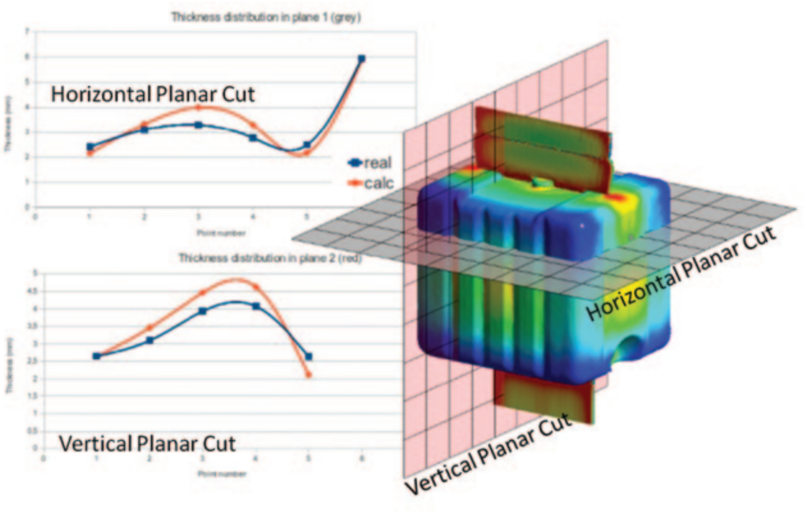
Variation of mold closing and inflation pressure over time



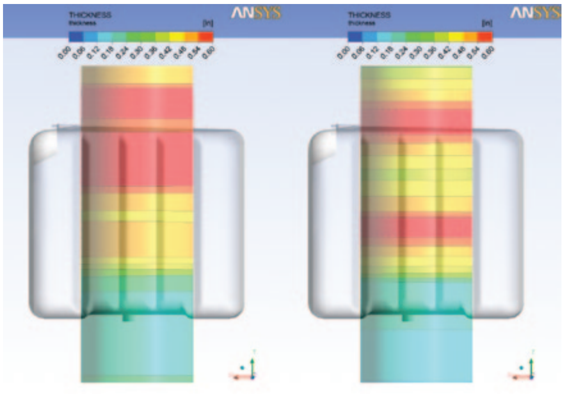
Mold for water container showing parison geometry and mesh

Initial material distribution for parison

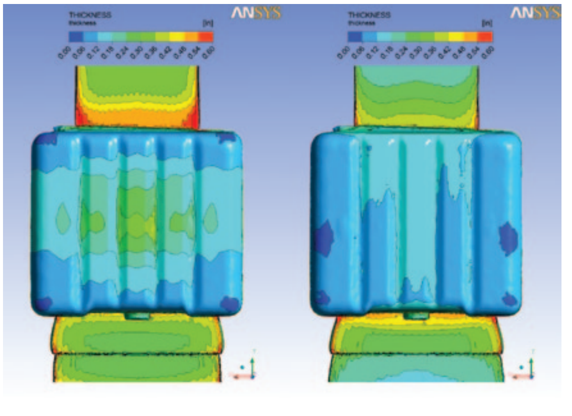
Final material distribution for container



Comparison of material thickness distribution between simulation and experiment showed good agreement.



Initial parison thickness comparison: baseline (left), optimized (right)



Final thickness variation indicated that the weight of the container could be reduced by 10 percent: baseline (left), optimized (right).

TOP LOAD AND DROP TEST

As the next step in the design process, the team performed top load and drop test analyses using ANSYS Mechanical and ANSYS explicit software. This ensured that the container will withstand the rigors of normal use, such as stacking while filled or dropping. The engineering team mapped the material distribution obtained from Polyflow onto a structural model. Mapping the thickness variation improves the accuracy of the structural model when compared with the assumption of standard thickness that is often used, since any weak or strong spots in the container due to material distribution will be represented. A static top load test provided maximum von Mises stress variation for the loaded and filled part. The structural simulation was performed for the baseline and the optimized container. The final deformation as a result of drop testing was provided by ANSYS Explicit STR software.

The results for top load performance indicated that even though the parison optimization resulted in a 10 percent weight reduction, the maximum deflection that the container experiences under hydrostatic loading (filled with 1,000 liters of water) is also reduced from the previous design. This suggests that the materials could be used even more efficiently, as also confirmed by a comparison of the maximum total (von Mises) stresses. The optimized design shows a maximum stress reduction of 17 percent, enabling even further material reduction and optimization of the container.

Finally, the optimized design was drop tested in an unfilled state by simulating a drop from a height of 1 meter. No failure mechanism was added to the simulation for the sake of simplicity, although this could have been done. The purpose was to obtain the maximum equivalent stresses and corresponding deformation under drop test conditions. In this case, both were acceptable.

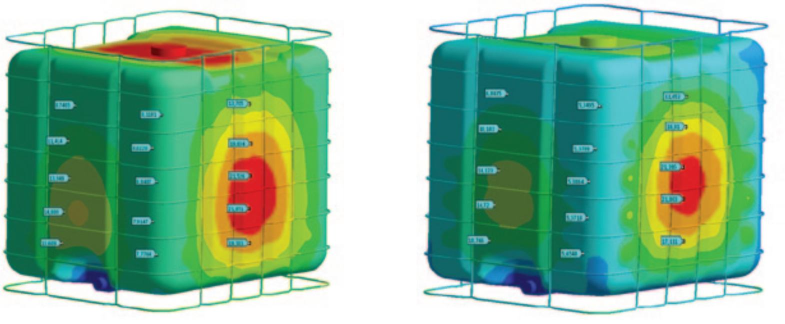
CONCLUSIONS

In this example, employing engineering simulation allowed material reduction of 1.75 kilograms for each container. During production of 22 parts each hour, this translates to 38 kg/h. With current material costs of about €1.80 per kg, the savings would be €69 per hour (approximately $100 U.S. per hour). Such savings can contribute to a company's bottom line in cost reduction, improved marketability and increased sustainability. Furthermore, the results of the stress simulation provide the company with an option for further material reduction by conducting additional virtual prototyping through engineering simulation.

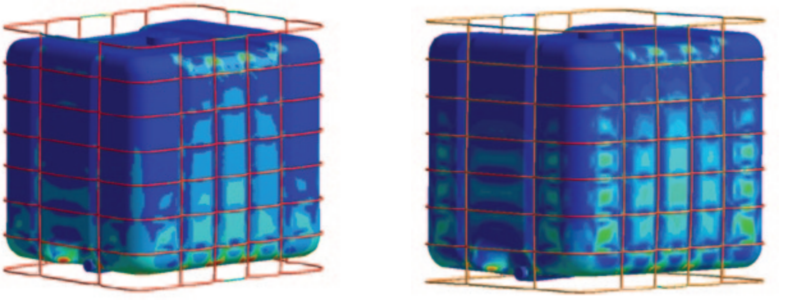
Optimization using virtual prototyping can not only result in substantial cost savings, but also in accelerated product design by allowing designers and engineers to perform many what-if scenarios quickly without the cost of creating real prototypes. Performing blow-molding simulation as well as structural analysis provides a method for companies to ensure reliability. Changes made to the manufacturing process can be directly related to final part performance through top load and/or drop test simulation. Using engineering simulation as part of the design process allows companies to impact the bottom line while designing reliable products.

Reference

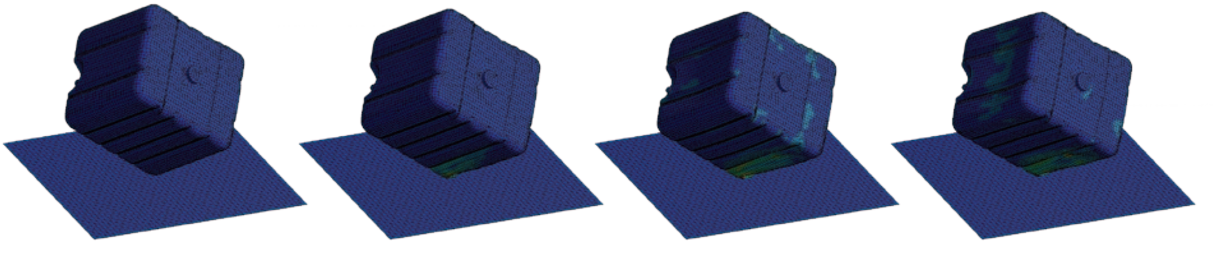
Klein, P.; Fradet, F.; Metwally, H.; Marchal, T. *Virtual Prototyping Applied to a Blow-Molded Container*, Proceedings of SPE ANTEC, Orlando, Florida, U.S.A., 2012.



Total deformation under hydrostatic loading (filled with 1,000 liters of water) simulation shows that materials could be further reduced: (left) baseline, (right) optimized.



Total (von Mises) stress variation under hydrostatic loading (filled with 1,000 liters of water) shows that maximum value was reduced by 17 percent: (left) baseline, (right) optimized.



Equivalent stress buildup during drop testing from height of 1 meter

Employing engineering simulation allowed material reduction of 1.75 kilograms for each container, which could mean production savings of $100 U.S. per hour — a significant impact on a company's bottom line.