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TMG News

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Opening Up Injection Molding Simulation with Virtual Design of Experiments

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Injection molding is the most commonly used process to manufacture plastics parts. However, this dynamic and complex manufacturing process requires the control of numerous variables in order to produce quality parts. Both designers and engineers commonly use injection molding simulation to validate their plastic part design prior to shooting any plastic. In some cases injection molding simulation is extended to help determine the size of the processing window. However, the use of simulation has often been limited to the conventional "guess-and-check" approach. While this approach can be effective, it is often limited to the previous experience of the engineer or analyst. Additionally, this approach limits the ability of the engineer or analyst to identify the sensitivity of an input variable on the overall process.

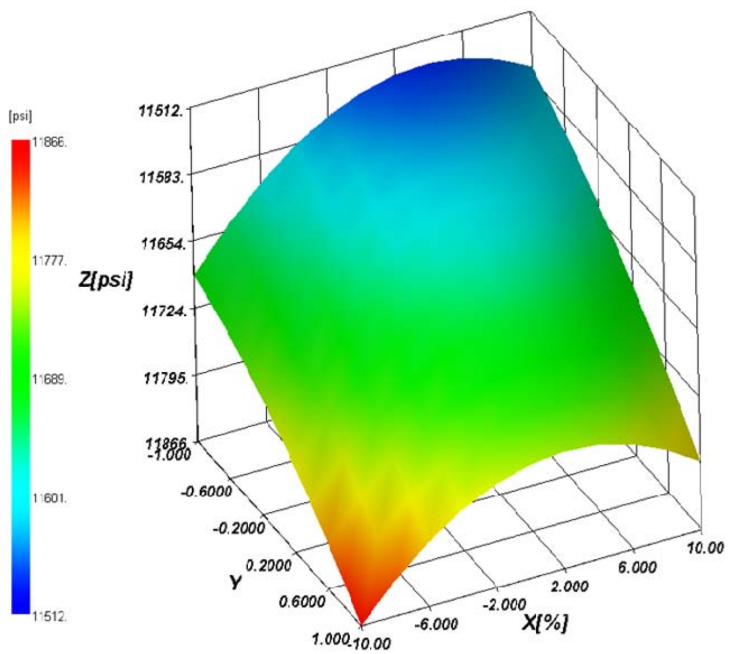

Figure 1: Performing a virtual DOE can provide a response surface plot that helps illustrate the effect different input variables have on a desired result.

Utilizing design of experiments (DOE's) with simulation, can help expand the findings available and allow the end customer to better understand their process. The goal of both injection molding simulation and design of experiments is to obtain information quickly and efficiently. However, the two methods are often decoupled from one another with simulation implemented during the design phase, and DOE reserved for hands-on testing after the mold is constructed. By coupling the two techniques, often referred to as a virtual DOE, significant insight can be gained regarding the sensitivity of part design and process parameters on the desired result. This allows for more informed decisions to be made regarding minimum part wall thickness, critical rib thickness and dimensional stability of the part.

Virtual DOE creates an ordered structure for the design evaluation in simulation. Instead of running fifteen different simulations independently, an analyst can use a DOE to select multiple different variables and systematically change the variables to determine the relationship to a desired response. By running the DOE, the analyst can look at a response surface, Figure 1, rather than a series of independent results. The non-planar response surface conveys information regarding how a desired response changes with alterations to the input

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variables. A virtual DOE can also be an efficient use of time. While parameters such as mold and melt temperature can take a significant amount of time to change in a physical DOE, in a virtual DOE, it is simply a value change of a parameter. It also allows for variables that cannot be changed in a physical DOE, like wall thickness and gate size, to be easily evaluated with a virtual DOE. Finally, the virtual DOE can supplement the set-up of a physical DOE by helping select the desired variables to test at the press.

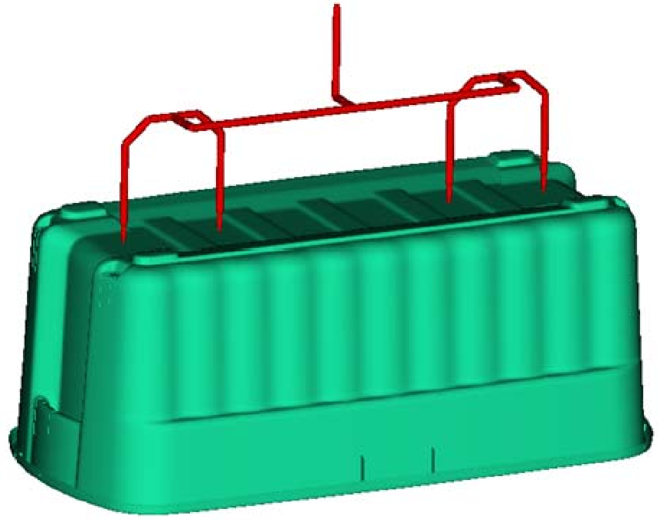


Figure 2: Container geometry used for virtual DOE.

Virtual DOE is not limited to only mold filling issues. The DOE technique can extend into cooling and warpage analysis as well. Therefore, the virtual DOE can assist in determining how coolant inlet temperature and flow rate will alter the mold temperature and overall cycle time. It can also help evaluate how a change in geometry might influence the predicted warpage of the part.

An example of how virtual DOE can be utilized, is to minimize material use while maintaining a reasonable processing window. The primary objective of the analysis was to minimize the wall thickness of the polyethylene container, while maintaining a clamp force requirement below 6,000 US tons. The container mold was filled through a four-drop manifold system, Figure 2.

Injection molding simulation was used to evaluate the moldability of the container over a range of nominal wall thicknesses. A virtual DOE was created to determine the effects of melt temperature, mold temperature, injection time, pack time, and pack pressure on the manufacturing process, Table 1.

Table 1: Parameters for DOE analysis	
Mold surface temperature	75 – 100 °F
Melt temperature	450 – 500 °F
Injection time	1.5 – 2.5 seconds
Pack time	4 – 8 seconds
Pack pressure	4,000 – 8,000 psi
Nominal wall thickness	0.090” – 0.110”

The virtual DOE revealed that long injection times and high melt temperatures can significantly reduce pressure requirements, Figure 3A, and allow for a thinner walled container, Figure 3B. The DOE also showed that long injection times and high melt temperatures can reduce clamp force requirements, Figure 4A. The DOE analysis revealed that the container’s wall thickness can be reduced by as much as 10% from the current nominal wall, and still be manufactured in the 6,000 US ton press, Figure 4B.

The DOE analysis demonstrated that, as part thickness decreases, melt temperatures should be increased to minimize injection pressure and clamp force. This showed no significant effects on the predicted cycle time for the part. However, as melt temperatures increase, the probability of thermal degradation also increases. With the wealth of information provided by the DOE analysis, an informed decision can be made to balance the size of the molding window with the cost savings of reducing the part thickness.

In conclusion, injection molding simulation coupled with virtual DOE analysis, can identify and quantify the importance of key variables for optimizing the injection molding process. This allows for significant time and cost savings over the traditional de-coupled approach. Additionally, the data generated through a virtual DOE analysis can reveal complex variable responses that may not be identified through traditional injection molding simulation. The ability to incorporate geometric variables into the virtual DOE significantly extends the information that can be gathered beyond a typical physical DOE.

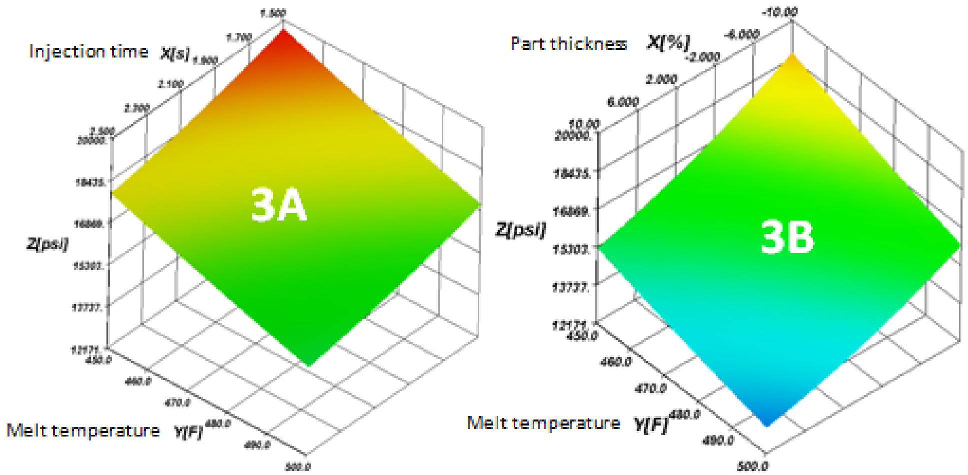


Figure 3: Injection pressure surface response plots.

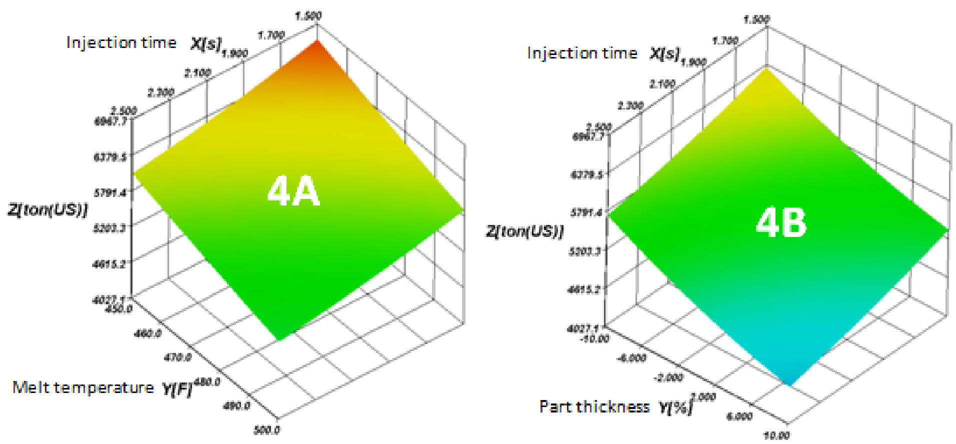


Figure 4: Clamp force surface response plots.

If you would like more information regarding design of experiments and injection molding simulation please contact The Madison Group for more information at 608-231-1907 or send an email to ross.jones@madisongroup.com or erik@madisongroup.com.

For further information regarding processing simulation, see papers authored by the staff at The Madison Group.
"Simulate Your Way to a Better Mold"
http://madisongroup.com/publications/Simulate-Your-Way-To-A-Better-Mold.pdf

"Using Computer Simulation to Solve Warpage Problems"
http://madisongroup.com/publications/TMG-News-January-2012.pdf

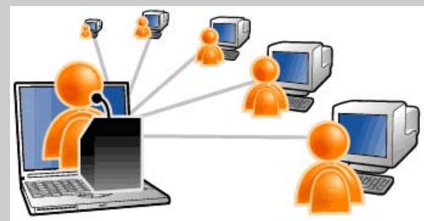
Upcoming Society of Plastics Engineers Webinars

Educational Opportunities - SPE Webinars

Webinars provide a cost-effective way to expand your knowledge of plastics. The Society of Plastics Engineers (SPE) offers a wide selection of high quality webinars, many of which are taught by Jeffrey A. Jansen from The Madison Group. Below is a list of the upcoming webinars:

Plastic Failure Prevention
Thursday, March 12, 2015 10:00 a.m. Central Time

The Effects of Impact and Other Rapid Loading Mechanisms on Plastics
Wednesday, April 15, 2015 10:00 a.m. Central Time



Ductile to Brittle Transitions in Plastic Materials
Thursday, May 21, 2015 10:00 a.m. Central Time

Understanding Wear of Plastics
Wednesday, September 16, 2015 10:00 a.m. Central Time

Fourier Transform Infrared Spectroscopy in Failure and Compositional Analysis
Wednesday, October 7, 2015 10:00 a.m. Central Time

Dynamic Mechanical Analysis of Plastics
Thursday, November 12, 2015 10:00 a.m. Central Time

For more information on the webinars or to register, contact SPE's Scott Marko at 203-740-5442 or smarko@4spe.org.

Webinars that have been previously given are also available as a recorded DVD. Some that may be of interest are:

Non-Destructive Analysis of Plastics Parts using CT Imaging

Opening up Injection Molding with Virtual Design of Experiments

Failure Analysis of Plastics — 3 Parts

Introduction to Plastics

Degradation Failure of Plastics

Creep Rupture Failure of Plastics

For more information contact SPE's Scott Marko at 203-740-5442 or smarko@4spe.org.

SPE
SOCIETY OF PLASTICS ENGINEERS

From the TMG Solutions Archives:

Creep Lifetime Prediction

Keywords - Creep, Lifetime prediction, Dynamic mechanical analysis

What Was Needed?

A plastic retention clip was required in a commercial appliance. Based upon the application requirements, including impact resistance, polycarbonate appeared to be a good material choice. However, the clip also needed to withstand a continuous loading of 6,400 psi, thus creep failure was a concern. The useful life requirement for the product was stated to be 2 years.

Evaluation

Dynamic mechanical analysis (DMA) was used to evaluate the polycarbonate resin being considered. Initially, a temperature sweep was conducted to characterize the response of the material to temperature (Figure 1). The modulus of the material was relatively stable near 23 °C, the nominal use temperature of the clip.

A series of isothermal DMA scans were performed and the results were combined using time-temperature superposition (TTS) to create a master curve of modulus over time. The response of the material showed an apparent loss in modulus over time with an inflection point (Figure 2).

Tensile testing was conducted on the polycarbonate material to characterize the mechanical properties, and determine the modulus, yield point, and the proportional limit (Figure 3). The tensile data and the apparent modulus master curve were then combined to create a master curve of strain over time (Figure 4). Based upon the obtained results, the material was expected to undergo creep, with cracking projected to initiate after approximately 3.9 years in service.

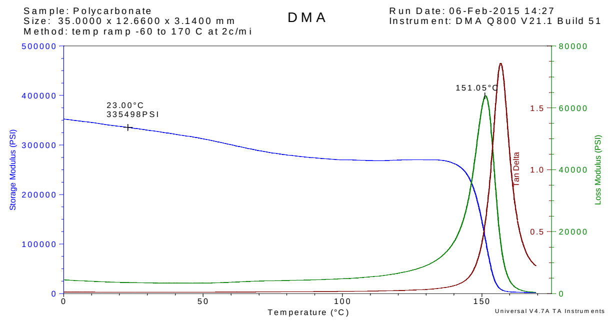


Figure 1: DMA temperature sweep showing the response of modulus to temperature.

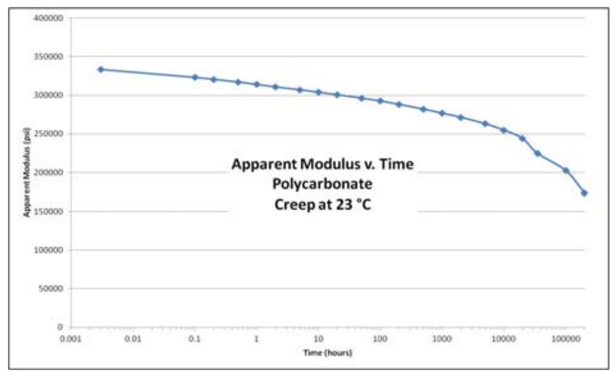


Figure 2: Plot of apparent modulus over time.

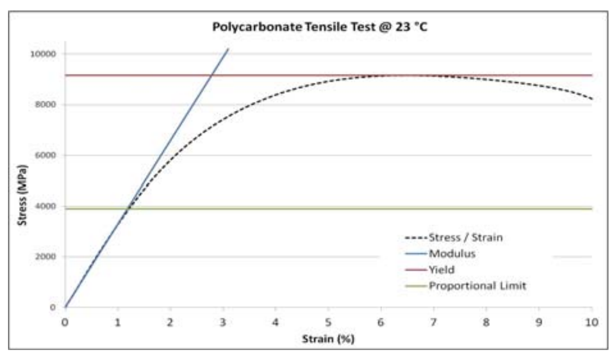


Figure 3: Stress-strain obtained on the polycarbonate resin..

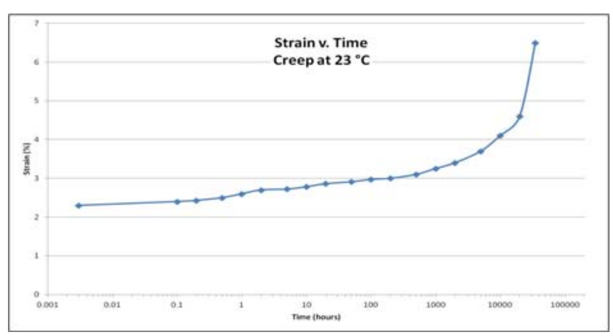


Figure 4: Plot of projected strain versus time.

Conclusion

The creep prediction study showed that the polycarbonate resin had a projected lifetime of 3.9 years under the indicated application conditions, including use at 23 °C under continuous loading at 6,400 psi. This was almost double the 2 year requirement, and so the polycarbonate resin appeared to be a good selection.

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Understanding and Preventing Plastic Failures

Do you have parts that are cracking, do not look good, are not molding correctly?

Are you looking for input on what material to use, how to fix a design, or how to modify a process?

Then take part in an open panel to be Held at ANTEC/NPE to
Solve Your Plastic Failures and Molding Issues……

"Understanding and Preventing Failures of Injection Molded Plastics"

If you are attending the Society of Plastics Engineers' ANTEC conference during NPE week in Orlando, Florida this is the one event that you must attend. A panel of the top experts in design, material behavior, injection molding and failure analysis has been assembled to answer your questions. These experts will give you advice that may solve an issue that you have been struggling with for years – and it is free! Participants are encouraged to ask as many questions as they would like and bring parts for the panel to examine – whatever is needed to solve your issue.

Given by: Injection Molding Division and Failure Analysis/Prevention SIG
When: Tuesday, March 24th, ANTEC Session: T25 Time: 3:00 – 4:30pm

Experts on the Panel include:

Mike Sepe, The Material Analyst from Mike Sepe Consulting
Jeff Jansen, Partner from The Madison Group
Vikram Bhargava, Retired Director of Engineering at Motorola
Suhas Kulkarni, President from FIMMTEC

Mike Sepe

Jeff Jansen

Vikram Bhargava

Suhas Kulkarni

The Madison Group Adds Engineering Staff

Matt Dachel joined The Madison Group in June of 2014 after receiving his B.S. in Plastics Engineering from the University of Wisconsin—Stout. Matt gained work experience from internships with Phillips-Medisize and Callaway Golf. At Phillips-Medisize, he gained experience as a project engineer. At Callaway, Matt worked in the golf ball research and development department and used Moldflow simulation software to improve their injection molding and simulation processes. As a teacher's assistant for the Process Simulation class, Matt helped the students learn how to use Moldflow and assisted with the development of new projects for the class. Matt has passed the Moldflow exam to become a certified Moldflow consultant.