SimPGM – A Commercial Simulation Tool for Precision Glass Molding Industry

F. Klocke[1], F. Wang[1], G. Liu[1], Kyriakos Georgiadis[1], O. Dambon[1], A. Y. Yi[2]
[1]*Fraunhofer Institute for Production Technology (IPT), Aachen, Germany*
[2]*The Ohio State University, Columbus, Ohio, USA*
fei.wang@ipt.fraunhofer.de

Abstract

The precision glass molding is an efficient manufacturing process for the replicate production of non-spherical glass lenses. In industrial applications, due to lack of understanding of the molding process, there are still several challenges for mold and process design, e.g. thermal shrinkage and index-drop. Based on both ANSYS and ABAQUS platform, an integrated numerical simulation tool – SimPGM – was developed to provide scientific understanding of the molding process for solving of the above mentioned problems and thus providing an optimized layout of the process as well as the tool insert geometry for the industrial applications.

1 Precision glass molding process

In precision glass molding process, glass gob or raw material is firstly heated to a temperature above its transition temperature (e.g., P-SK57, T_g = 493 °C, forming temperature 550 °C) and subsequently pressed into a lens shape (Figure 1).

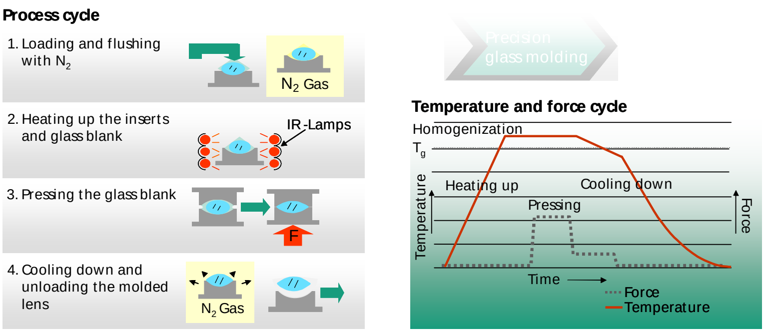

Figure1: Schematic illustration of a molding cycle

Although the molded lens is carefully cooled together with the mold inserts, in most cases also with a moderate holding force, the form and volume deviation generated by uneven temperature distribution and quick cooling lead to thermal shrinkage and refractive index variation in the glass material, which normally cannot be completely eliminated without trial molding and error compensation on the mold inserts.

2 Development of SimPGM for process simulation

In order to achieve prescient understanding of the molding process to solve the problems, an integrated numerical simulation tool – SimPGM - was developed at Fraunhofer IPT based on the commercial Finite Element Method (FEM) software packages ANSYS™ and ABAQUS™ to predict the form deviation error and index drop on the molded glass lenses even before the initial mold manufacturing. To reduce the complexity for simulation users to operate the simulation, a user-friendly interface was developed in C# developing language (Figure 2).

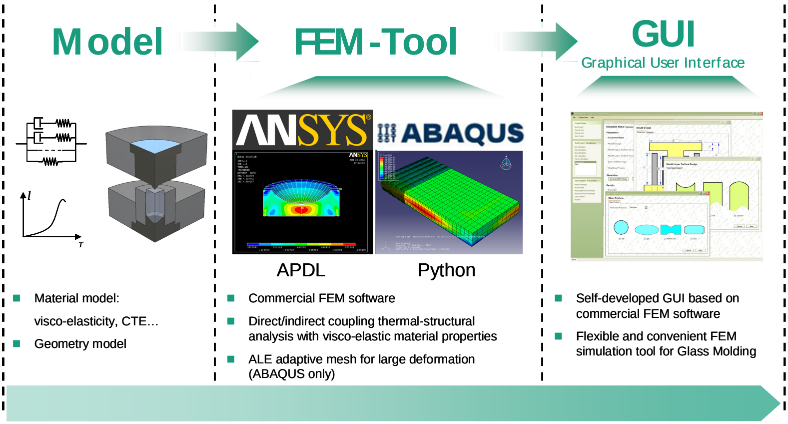

Figure 2: Design of glass molding software - SimPGM

The developed process simulation tool consists of a thermal model predicting the actual temperature distribution and a mechanical model to predict the viscoelastic deformation and thermal shrinkage of the molded glass lens. To describe the viscoelastic behavior, a generalized Maxwell model was used to model the stress relaxation of glass at transition temperature. Various results based on industrial molding tasks proved a form error prediction accuracy of less than 1 µm[1].

Due to structural relaxation in glass material during quick cooling, an average refractive index drop of about 0.3% is expected after molding. In the simulation tool, this phenomenon is successfully modeled using the Tool-Narayanaswamy-Moynihan (TNM) model for different heat treatment and cooling rates. [2]

3 Functions of the SimPGM software tool

In the SimPGM software, two types of commercial precision glass molding machines are integrated: Die-molding fix system and die-molding transfer system according to the way how the molding units move. An example of the die-molding fix system can be found in Figure 1, where the mold dies are in the middle of heating elements and have only vertical movement. In Figure 3, the working principle of a die molding transfer system is illustrated. Here several molding units consisting mold inserts and guiding parts are transferred with defined tact through multiple stations heated up to different temperatures. This system layout is especially suitable and widely used for mass production.

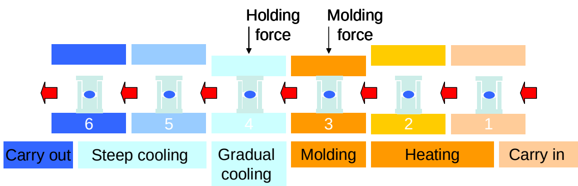

Figure 3: Schematic illustration of a die molding transfer system

The SimPGM also provides full flexibility by glass pre-form selection and mold geometry description. Through a user-friendly entry mask, different glass pre-form geometries can be selected for the process simulation by specifying the dimensions according to trade standard defined by glass pre-form manufactures (Figure 4).

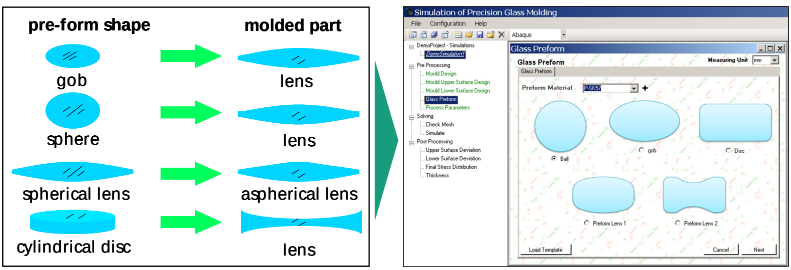

Figure 4: Pre-form shape selection and the SimPGM user interface

After the mold shape is entered in the form of standard non-spherical equation or any other customer specified format, simulation can be first carried out in the SimPGM software for the glass pre-form selection and process suitability test, where the glass deformation inside the mold cavity can be predicted under the molding temperature. The amount of deformation, effective contact surface diameter, critical stress (Figure

5) and the extent of the mold filling are the main criterion for the optimized pre-form selection. Using this tool, innovative mold assembly design can also be validated for its suitably on the challenging molding tasks.

Another highlight of the SimPGM software tool is its capability to provide an optimized process design for the precision glass molding, i.e. the best combination of molding force, molding temperature, molding time and cooling speed, which can be found currently only by time consuming molding trials. As an effective substitution of try-out molding, SimPGM simulation tool can be applied for different molding system concepts for systematic analysis with different process parameter matrix. An integrated evaluation algorithm is under development now to enable a full automatic process window optimization before the real molding process is carried out.

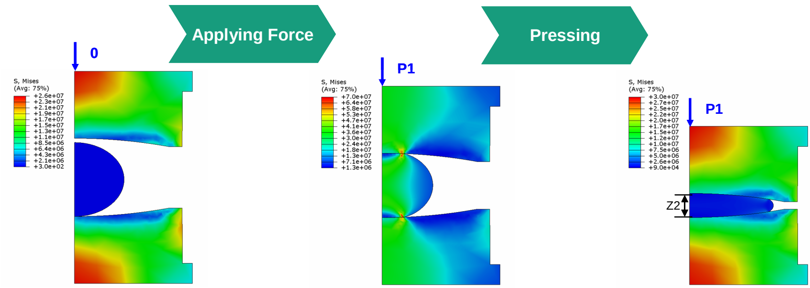

Figure 5: Simulation details – Stress distribution during pressing process

3 Conclusion

As conclusion, the SimPGM software presents an effective and reliable functionality including shrinkage error prediction, index drop prediction, pre-form evaluation, mold filling prediction and process parameter optimization. With a user-friendly entry interface it is now ready to be implemented to diverse industrial applications.

References:

[1] O. Dambon, F. Wang, Y. Chen, A. Y. Yi, F. Klocke, G. Pongs, “Efficient Mould Manufacturing for Precision Glass Moulding,” J. Vac. Sci Technol. B, 27 (3), 1445-1449 (2009).

[2] A. Jain, A. Y. Yi, X. Xie, R. Sooryakumar, “Finite Element Modeling of Stress Relaxation in Glass Lens Moulding Using Measured, Temperature-Dependent Elastic Modulus and Viscosity Data of Glass,” Model Simul Mater SC, 14 (3), 465-477, Mar (2006).