SIMULATED VS. MEASURED PART WARPAGE WITH AND WITHOUT STAMP

Drew Tracy and Payton McKee
Advisor: Mr. Bradley Johnson
Sponsors: Steve Brenno, Hunter Beaumont, Erik Foltz
Penn State Behrend, Erie, PA

INTRODUCTION

This project aimed to understand the fidelity of Moldflow's STAMP warpage model, compared to the original uncorrected residual stress (URS) model.

To better understand the impact of process parameters, part geometry and fill patterns on the simulation's prediction various mold inserts were used to adjust the Lutron lid part's thickness, fill pattern by moving the gate location, and hold pressure during molding.

Six dimensions were compared in simulation and with measurements taken on the Keyence and FARO arm metrology systems.

A digital twin of the mold was created in Moldflow based on steel dimensions. Fully characterized materials were used in molding and simulation.

[Steel Dimensions]
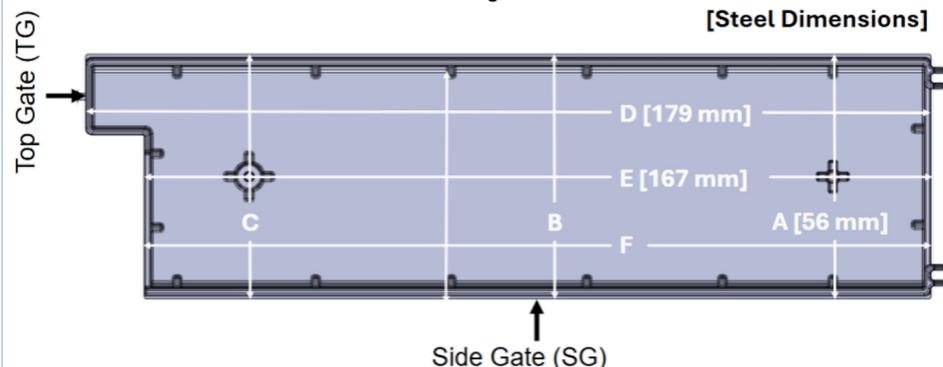
1.) Dimensions of interest (A through F) for the shrinkage measurements of the "Lutron Lid".

MOLDING PROCESS

During molding process data including melt temperature, cavity pressure and cooling line temperature were measured and recorded to improve simulation parameters and validate results.

Further machine process data was recorded for every sample including injection time, cycle time, barrel temperatures, maximum injection pressure, etc.

Various mold inserts were used to adjust the part thickness (1mm or 3mm) and the flow direction via different gate locations. Top gate (TG) and side gate (SG) locations were used.
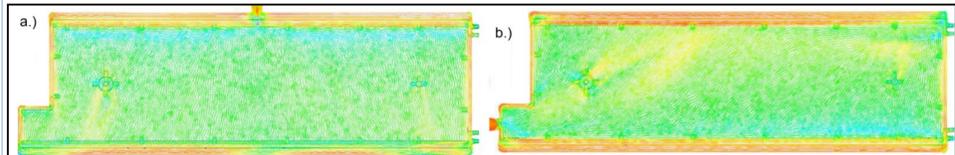
2a.) Side gated, nonuniform flow front with fiber orientation tensors.
2b.) Top gated, uniform flow front with fiber orientation tensors.

EQUIPMENT

Krauss Maffei IM Machine, Lutron Lid Mold, CavityEye Pressure Transducers, Futaba IR Temp. Sensors, RJG eDART System, Temp. Control Unit, Keyence LM, FARO Arm 3D Scanner.

RTP MATERIALS & PROJECT NAMING

| ID	Description	Date Tested
TPV	PP + EPDM (vulcanized) (87 Shr. A)	8 / 2024
PE	HDPE Blend	9 / 2024
PP+FRM	PP + flame retardant (particulate) + mineral	4 / 2024
PP+GF	PP + short glass fiber (30 weight %)	2 / 2024

ABSTRACT

This project aimed to determine the model fidelity of the new shrinkage test adjusted mechanical properties (STAMP) shrinkage model in Autodesk's Moldflow compared to the previous legacy model, known as the uncorrected residual stress model. Four polyolefins were simulated to compare shrinkage and warpage predictions to injection molded parts. The hypothesis stated that the STAMP model could improve simulated predictions of warpage and shrinkage across the tested materials, sample thicknesses, gate locations, and process conditions. The STAMP model was expected to accurately predict warpage within 8% of measured values and have a minimum 10% improvement in shrinkage prediction compared to the uncorrected residual stress model. The hypothesis was supported by a validation study from Autodesk and a paper by Costa and Bakharev [1]. Both reports showed a significant improvement in prediction accuracy using STAMP.

KEYENCE LM INSPECTION

- Parts were conditioned for 48 hours before measuring to allow internal residual stresses to relax
- Excess flash was removed from some parts to improve measurement alignment
- Deviation from steel dimensions for flow and transverse directions were analyzed (Figure 1)

FARO ARM INSPECTION

- 3D laser scanning allowed for complex measurements and simulation comparisons
- The out-of-plane deflection magnitude was compared via flatness of the core face (surface area = 74.2 cm^2)
- The warpage shape was compared via 5 points along the core face and exported part overlays, shown in Figure 3b below
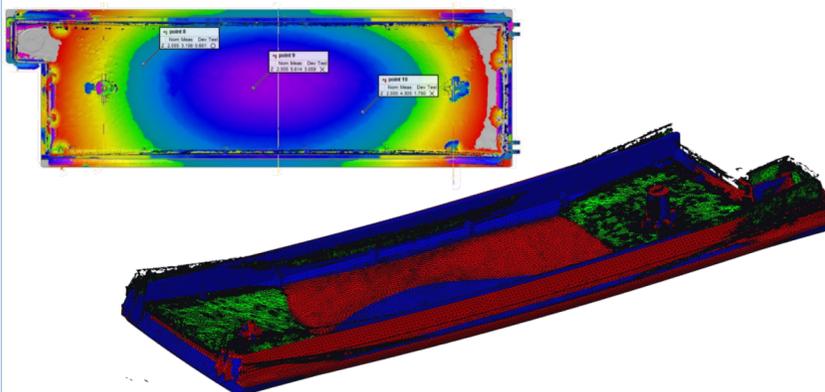
3a.) FARO scan heat map of PE material deformation.
3b.) Part overlay: FARO Scan – Green | STAMP – Blue | URS - Red

STAMP VS. UNCORRECTED RESIDUAL STRESS

- Uncorrected residual stress (URS) calculates internal stresses using PvT models and anisotropic (fiber-driven) shrinkage
- STAMP uses empirical data to calibrate mechanical properties (CTE, Young's Modulus) based on part thickness and flow orientation to adjust part deformation
- The STAMP model relies on the correlation between pack pressure and shrinkage to create a compressibility coefficient

4.) STAMP Calibration Diagram

5.) PE+GF Deflection Result 5x Scale

6.) Combined shrinkage for all materials
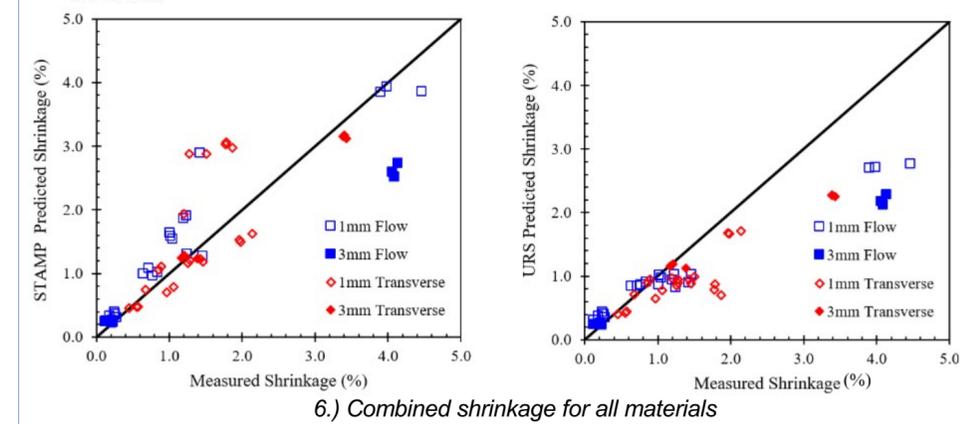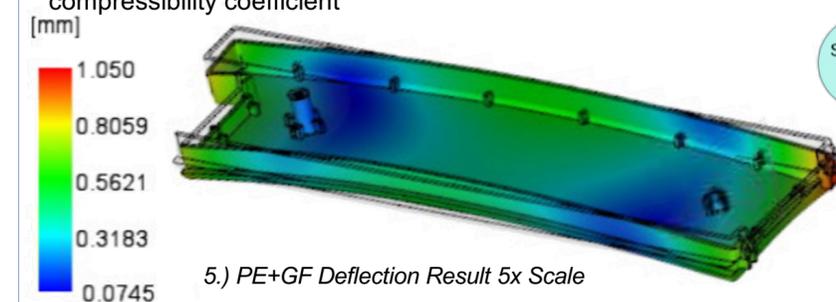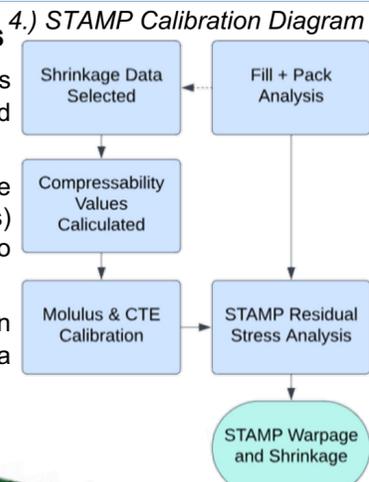
CONCLUSIONS

- PE saw the greatest improvement in shrink. prediction (+88% accuracy) with STAMP; the TPV saw increased prediction error with STAMP (-56%); and the remaining two materials had negligible differences between shrink. models.
- The TPV exhibited the greatest improvement in warp. prediction (+74% improvement) with STAMP; PE also had notable improvement (+13%); and the two remaining materials had negligible differences.
- The validity of the STAMP shrinkage model depends on the material matrix and part geometry compared to characterized data. The model does not improve prediction in all molding cases.

REFERENCES

1. F. S. Costa, A. Bakharev, Z. Yuan, and J. Wang, "Improved Injection Molding Warp Predictions by Characterization of Material Properties Using Measured Shrinkage Molding Data", SPE ANTEC Tech. Papers (2023).

ACKNOWLEDGEMENTS