Autodesk® Moldflow Insight 2021.2

MOLDFLOW SOLVER ACCURACY IMPROVEMENTS

Executive Summary

The Autodesk Moldflow Insight 2021.2 and Autodesk Moldflow Adviser 2021.2 software releases include a significant improvement in the 3D Flow and 3D Warp solvers for more accurate prediction of shrinkage and deflection of polymers. In this report, the impact of this change is demonstrated on a large set of molding data.

In addition, other improvements for solution accuracy and mechanical property predictions impacting all solvers are also outlined in this report.

Contents

Flow and Warp Simulation for Polymers using 3D Meshes

Background

The residual stress calculation during a 3D Fill+Pack analysis has been changed. The 3D warp calculation uses these residual stresses as an input to predict final part deformation. Two major areas of change are:

1. Improved sensitivity to PVT model data for some semi-crystalline polymers. (Typically, this change impacts semi-crystalline polymers other than polypropylene).
2. Improved packing pressure sensitivity for low modulus materials.

For some cases, the accuracy of 3D Warp predictions is improved significantly. 3D Warp calculations utilizing the older Generic Shrinkage model are not affected by these changes.

Improved sensitivity to PVT model data

It has been observed that the 3D Residual Stress model in Moldflow 2021.1 and earlier releases was very sensitive to small differences in the PVT model fit in the solid phase. Sometimes these differences in fitting the PVT model arose due to experimental variation and uncertainty. A particularly strong example of this sensitivity is shown below for two Polyamide 66 with 35% glass fiber filler coming from the same manufacturer. Having such similar compositions, these two compounds also have similar Specific Volume magnitudes (Figure 1), although subtle differences exist in the model curve fit below 200℃.

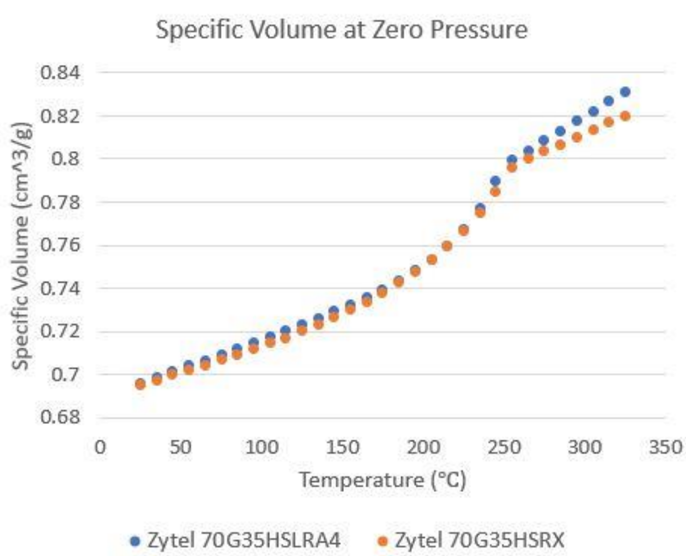

Figure 1: Specific Volume at zero pressure from the PVT model of two similar PA66 compounds with 35% glass fiber filler.

Both of these PA66 compounds have been characterized for shrinkage in the Autodesk Moldflow laboratory. Shrinkage characterization is performed by molding end-gated rectangular plaque samples for at least 25 different processing conditions by varying packing pressures, melt temperatures, plaque thickness and injection speeds. Averaging over all these shrinkage characterization moldings, the measured shrinkage in the direction transverse to flow is shown in Figure 2. Also shown are the average transverse shrinkage predictions for these molding conditions from Moldflow 2021.2 and two prior software releases. Due to the similarity of these two PA66 compounds, the measured shrinkage is found to be quite similar. The small difference in measured shrinkage which does exist between the two materials is due to differences in the range of molding conditions used. The prediction of transverse shrinkage from Moldflow 2021.2 for the two PA66 compounds are quite similar, matching the measured similarity, whereas the predictions from the prior software versions show a large difference, demonstrating the over-sensitivity to PVT model data which existed prior to the Moldflow 2021.2 release. Simulation trials confirmed that these prediction differences were coming solely from the PVT model fit differences.

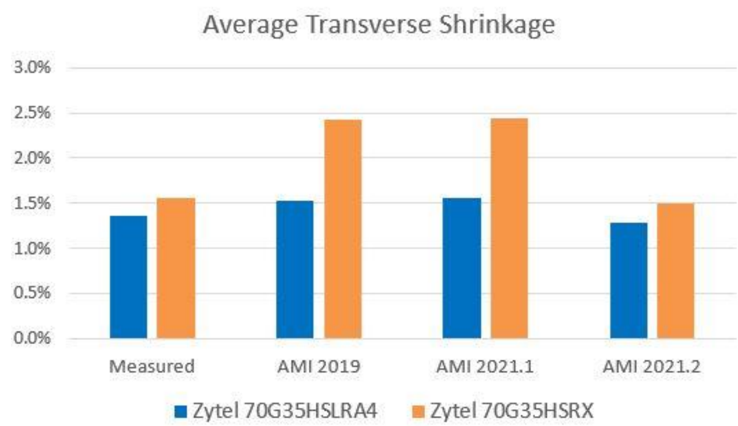

Figure 2: Average transverse shrinkage (measured and predicted) for two similar PA66 compounds with 35% glass fiber filler.

Improved Packing Pressure Sensitivity

The influence of packing pressure in compensating the thermal shrinkage effect of molded parts depends on the volumetric compressibility characteristics of the molded polymer. An improvement in the 3D Residual Stress model has been introduced in Moldflow 2021.2 to guard against inconsistencies between the volumetric compressibility and the linear elastic modulus data. The impact of this change is strongest for low stiffness materials and can be seen as a change in the shrinkage prediction sensitivity to packing pressure. For affected polymers, the sensitivity of shrinkage to packing pressure is reduced in Moldflow 2021.2.

This change in 3D Residual Stress model sensitivity to packing pressure can be validated using the shrinkage molding data measured in the Autodesk Moldflow Laboratory. Among the 25 or more molding conditions used for each polymer grade, the packing pressure is varied between three packing pressure levels for each melt temperature and plaque thickness condition.

Figure 3 shows the comparison between the molded and predicted shrinkages for a Polypropylene material with 31% by weight talc filler calculated with Moldflow 2021.1 and Moldflow 2021.2. It shows the shrinkage magnitudes in the flow direction and in-plane transverse direction for each of the 25 molding conditions. The 3D shrinkage prediction values from Moldflow 2021.2 are in much closer agreement with the measured molding data than the 3D shrinkage predictions from the Moldflow 2021.1 analysis. This improvement is seen not only in the shrinkage magnitudes, but also in the sensitivity to changes in the process conditions (primarily the packing pressure setting). The sensitivity to packing pressure change is lower in the Moldflow 2021.2 predictions, which is in better agreement with the measured shrinkage sensitivity to packing pressure.

(a) (b)

Figure 3: Shrinkage comparison for a 31% talc filled PP material in (a) flow direction and (b) transverse to flow direction.

Confirmation of 3D Shrinkage Prediction Changes on a Large Validation Dataset

Average Difference of Shrinkage Between Experiment and Simulation

It is possible to calculate an average relative shrinkage prediction error by calculating the relative difference between measured and predicted shrinkage values for each processing condition and then averaging these differences to establish an overall shrinkage prediction quality measure for each polymer. This average relative shrinkage prediction error was calculated for both the flow direction and in-plane transverse direction for 201 polymer grades (of which, 94 contained a fiber filler and 107 did not contain fiber fillers). The comparison of the Moldflow 2021.1 and Moldflow 2021.2 predictions on 3D meshes is shown in Figures 4 - 6. The X-axis is for Moldflow 2021.1 and the Y-axis is for Moldflow 2021.2. Each data point presents the relative shrinkage prediction error of a polymer material averaged over three processing conditions, with the three processing conditions varying by set packing pressure. Data points on the diagonal line are those materials for which the average relative shrinkage prediction error from Moldflow 2021.2 is the same as it had been in Moldflow 2021.1. Data points below the diagonal line are polymers for which the average relative shrinkage prediction error is lower in Moldflow 2021.2 than it had been in Moldflow 2021.1.

(1) Non-Fiber Filled Semi-Crystalline Polymer Materials

Figure 4 shows the change in average relative shrinkage prediction error for the non-fiber filled semi-crystalline polymer materials of the large validation dataset. Overall, Moldflow 2021.2 shows better accuracy than Moldflow 2021.1 for this group of polymers, with the shrinkage prediction error reduced significantly for some polymers in both the flow and transverse directions.

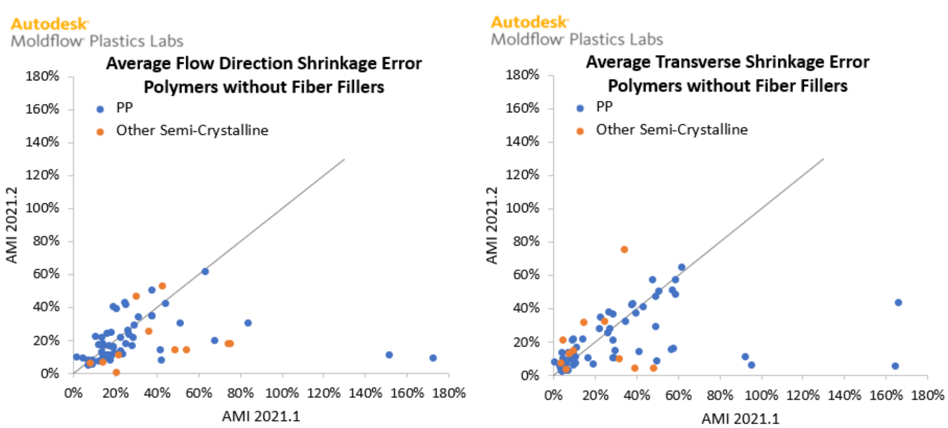

Figure 4: Average Relative Shrinkage Prediction Error for non-fiber filled semi-crystalline polymer materials.

(2) Fiber Filled Semi-Crystalline Polymer Composites

Figure 5 shows the change in average relative shrinkage prediction error for fiber filled semi-crystalline polymer composites in the large validation dataset. Overall, Moldflow 2021.2 shows better results than Moldflow 2021.1 for this group of polymers. Non-PP semi-crystalline polymers show the strongest improvement. Note that the absolute shrinkage prediction error (not shown) is much lower in the flow direction than in the transverse direction because the flow direction is also the dominant direction of fiber alignment, which restricts the amount of shrinkage in that direction.

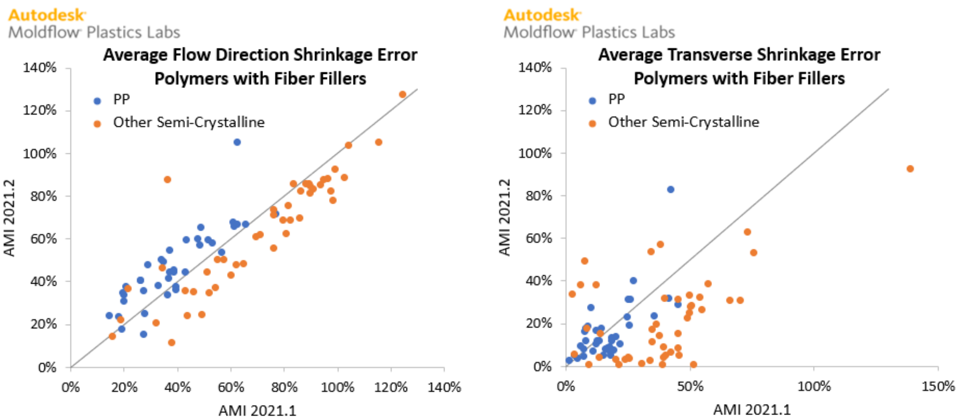

Figure 5: Average Relative Shrinkage Prediction Error for fiber filled semi-crystalline polymer composites.

(3) Amorphous Polymer Materials

Figure 6 shows the change in average relative shrinkage prediction error for amorphous polymer materials in the large validation dataset. Overall, Moldflow 2021.2 shows better accuracy than Moldflow 2021.1 for this group of polymers. A few polymer grades show a strong improvement, while most other amorphous polymers tested have only minor changes in the shrinkage error in both the flow direction and transverse direction.

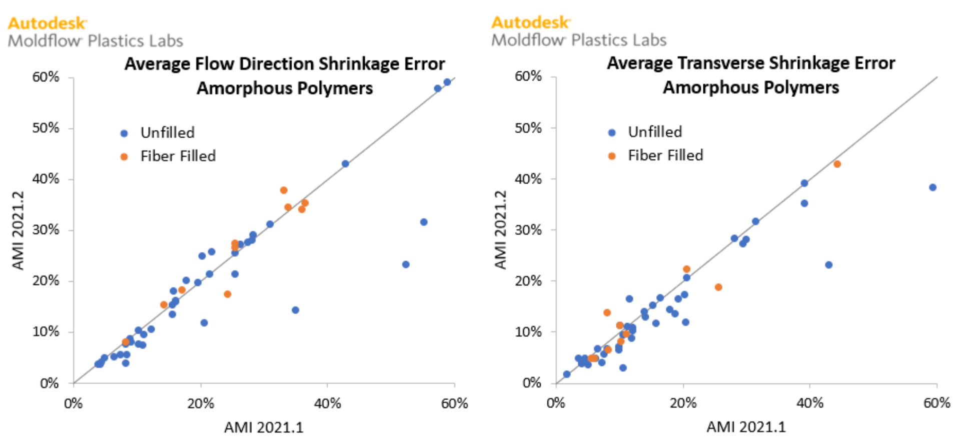

Figure 6: Average Relative Shrinkage Prediction Error for amorphous polymer materials.

Process Sensitivity of Shrinkage Between Experiment and Simulation

The sensitivity of the calculated shrinkage values to packing pressure can be measured by an F-Test value. This value represents the ratio of variances of shrinkage on the process conditions (packing pressures) obtained from simulation and experiment. The F-Test value will be between 0 and 1. If the value is closer to 1, it means that the measured and predicted shrinkage values have a similar sensitivity to changes in packing pressure. The F-Test value was calculated for both the flow direction and transverse direction 3D shrinkage predictions for 201 polymer grades (of which, 94 contained a fiber filler and 107 did not contain fiber fillers). The comparison of the Moldflow 2021.1 and Moldflow 2021.2 predictions is shown in Figure 7. The X-axis is for Moldflow 2021.1 and the Y-axis is for Moldflow 2021.2. Each data point represents one of the polymer grades. If the data point is above the diagonal line, it signifies an improved match between the measured and predicted sensitivity of shrinkage to changes in packing pressure. As can be seen from Figure 7, the F-Test values for the flow direction are better with Moldflow 2021.2 than Moldflow 2021.1 for most materials. The F-Test values for the transverse direction are better with Moldflow 2021.2 than Moldflow 2021.1 for a majority of materials.

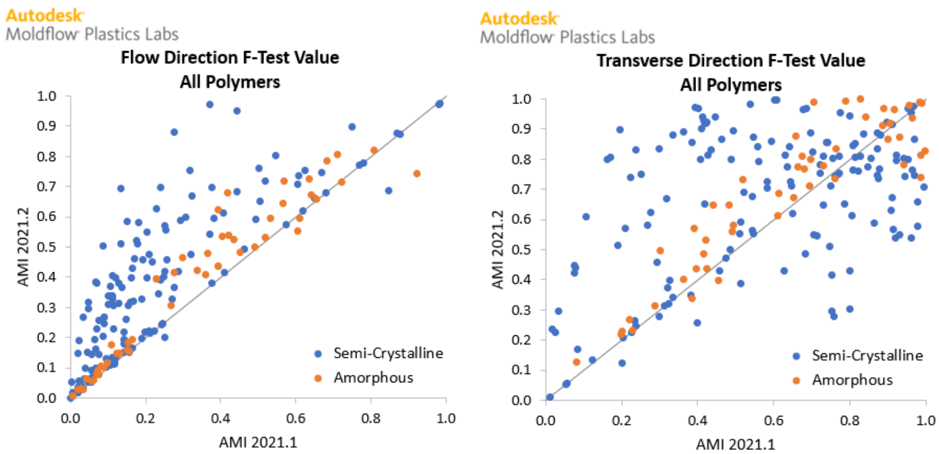

Figure 7: F-Test values showing correlation between predicted and measured shrinkage sensitivity to changes in packing pressure for all polymers.

Other Solver Accuracy Improvements

In addition to the improved accuracy of the 3D Flow and Warp solvers, other accuracy improvements are also included in the Moldflow 2021.2 release version. These include:

- Mold temperature solution accuracy close to cooling circuits and baffles has been improved for the Cool solver. This reduces the incidence of false hot-spots on the mold cavity surface close to the cooling circuits or baffles.
- Display of the actual polymer temperature on the part surface of the Temperature result for 3D meshed models. Previous software releases had displayed the set mold temperature boundary condition on the surface.
- The calculation of corner effects during a Midplane or Dual-Domain Warp analysis has been significantly improved for materials with anisotropic mechanical properties, including fiber filled materials. Previous software versions could show an asymmetric twisting in the corner effects deflection due to a misalignment of the anisotropy.
- The convergence stability of 3D Large Deflection analyses in 3D Warp has been improved. This stability improvement also allows the introduction of the mesh aggregation option for 3D Large Deflection analyses which can greatly reduce the computation time required.
- The selection of Automatic Rigid Body Motion constraints for a 3D Warp analysis has been improved to reduce the risk of poorly converged results. This improvement reduces the occurrence of asymmetric deflection results on symmetric parts.
- Flow front temperature predictions have been improved for 3D analyses with valve gates where previously excessively high flow front temperatures might be found near a valve gate.
- The switchover of injection from velocity control to pressure control can now occur after cavity filling is complete for 3D analyses, matching more closely the behavior which can occur during actual injection molding.
- The accuracy of venting analysis for 3D cases has been improved. This may show more short shot cases for 3D venting analyses.
- The effect of shear stress calculated by the flow analysis is now included in the core shift analysis for 3D cases.