

CUSTOMIZATION OF META POST FOR DISPLAY OF RESULTS FROM A MOLDING SIMULATION

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ABSTRACT – MetaPost [1] is a versatile post processor for viewing results from different types of analyses. One of the key strengths of MetaPost is its ability to be customized to suit one's needs. The introduction of embedded Python compiler in MetaPost has further enhanced the ease of customization of complex numerical calculations. We have used this feature of MetaPost to develop a Molding Post-Processing Toolbar with specialized functions to calculate user – defined results from a molding simulation.

The Molding Post-Processing Toolbar uses a Python script to provide a standardized post-processing method for molding simulation. Some of the features of the toolbar are:

- a. Automatic calculation of shrinkage and warpage based on the decomposition
- b. Creation contour plot for shrinkage and warpage components of results.
- c. Ability to analyze shrinkage and warpage results across user – defined sections.
- d. Ability to create PPTX reports.

Numerical examples showing shrinkage and warpage contour plots are given. Procedure describing creation and analysis of sections through various examples are shown. In summary, customization capability within MetaPost is used to depict the results of a molding simulation in various forms.

1. INTRODUCTION

MetaPost [1] is a powerful and versatile post processor for viewing results from various types of analyses. It is easily amenable to use of special scripts by use of Python programming language. Complex numerical and user-defined calculations can be done within Python and the inherent functionality of MetaPost with its numerous features can be used to look at the results in various forms. Another feature of MetaPost is automatic generation of customized reports in power point and excel formats. In this paper, MetaPost is used to customize results from an injection molding simulation and display them in different formats along with automatic generation of reports. An example of a mouse coffin, which showcases these features, is given.

Injection molding simulation is widely used in the plastic industry to simulate the manufacturing (filling) process and assess the filling time, part geometry, tooling requirements etc. As part of the simulation, deformation of the part as it comes out of the mold is also obtained. This deformation, which deviates from the original design, is a critical piece of information and helps in the design of the molds. It contains two pieces of information namely the shrinkage and warpage of the part. A brief definition of these two terms is given here [2]. Shrinkage is the “act or process of becoming smaller in amount, size or value”. The molded part after being taken out from the mold has a tendency to shrink as it cools down and this depends on the coefficient of linear thermal expansion of the polymer and glass fibers. A uniform reduction in size or shrinkage can be obtained by using a scale factor as shown in Figure 1. Non-uniform shrinkage gives rise to warpage. Warpage or warp is defined as “twist or curve in something that is usually flat or straight” or “twist or bend into a different shape”. This distortion in shape is more associated with change in angles or rotation of the edges as shown in Figure 2.

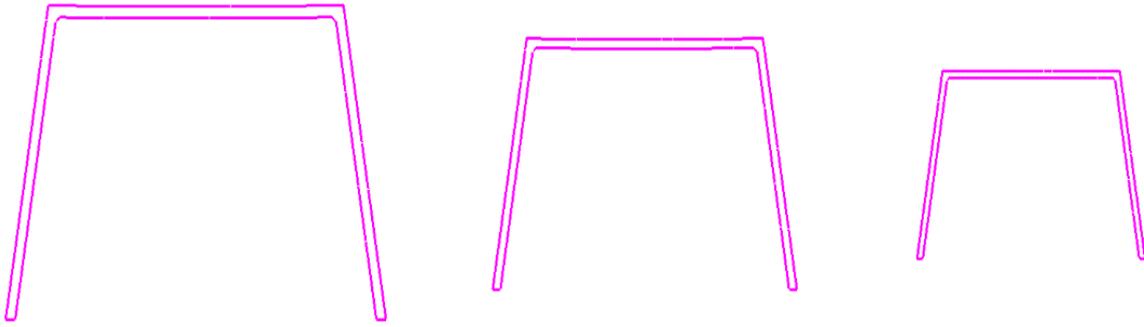


Figure 1. Example of shrinkage of a 2-D section by scaling

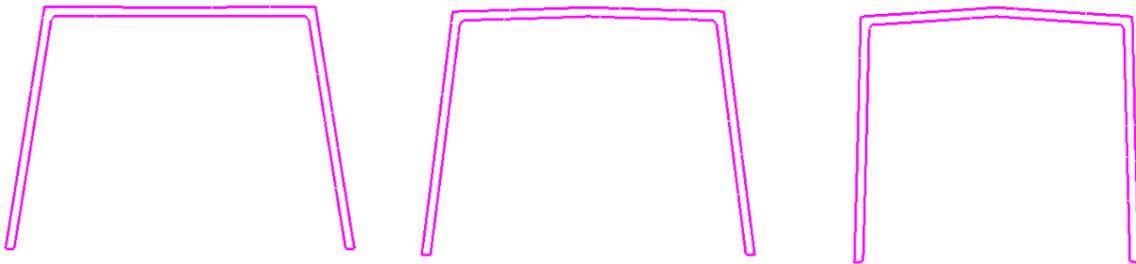


Figure 2. Example of warpage of a 2-D section due to distortion

Currently, tools or molds are cut accounting for the shrinkage in an approximate way so the final part is of the right size. There is a need to decompose the deformation obtained from a molding simulation so that the results can be viewed in various forms. By splitting up the deformation into its shrinkage and warpage parts, detailed information can be gleaned to help in the decision making process regarding tooling, gating and design changes.

2. PROCEDURE

The first step in the process is to carry out a mold filling simulation using standard software and get the deformed state of the part after it comes out of the mold. Only the surface mesh is considered here. Beam elements are placed on the edges of the surface triangular mesh for calculation and visualization purposes. For each beam element, the shrinkage is calculated based on the reduction in length in the deformed state compared to the undeformed state. The shrinkage is normalized by the original length to get percentage shrinkage. The Python script does this calculation within MetaPost, which can then contour these values over the whole part. This helps to view the shrinkage locally at various points of the part. Further, by isolating beams with dominant orientation in any of the major directions, contour of shrinkage along these directions can also be plotted. The warpage or distortion in shape is associated with change in angles of the beams. The change in absolute angles of the beam elements from the undeformed to the deformed state is calculated within MetaPost. The warpage is assessed by plotting the absolute rotation of the beams in degrees. This helps to visually see how the part is warping or rotating locally at various points in the part. Again by isolating beams with dominant orientation in a certain coordinate direction, rotation can be plotted with respect to that direction. The other feature that has been incorporated in this utility is the analysis of sections. A section can be created within MetaPost and analysed for shrinkage and warpage. For any two points in the section, the

deformation due to shrinkage and warpage can be calculated. Further, two indices called the shrinkage and warpage index are calculated. These show the percentage contribution of the shrinkage or warpage towards the deformation between the two points. The warpage can positively or negatively affect the deformation and this is captured. The un-deformed and deformed section can be plotted simultaneously to view how the part is shrinking or warping. All the above functionalities are incorporated within MetaPost.

3. EXAMPLE

An example of a mouse coffin as shown in Figure 3 is considered for showing the features of Molding Post-Processing Toolbar in MetaPost. As a first step, a mold filling simulation is carried out using standard Autodesk Moldflow software [3]. Un-deformed and deformed stl (Stereo Lithography) files are exported from Moldflow. Only the surface triangular mesh is considered and beams are placed on the edges of the mesh. All calculations in MetaPost are carried out based on relative positions of the beams in the un-deformed and deformed state.

Figure 4 shows the total shrinkage contour as a percentage for the whole part. The contour is visualized only on the beams and the direction of the shrinkage is along the beam axis. Hence at the same point, the shrinkage may be different in different directions. While evaluating, it is important to keep a note of the beam directions. The zoomed view in Figure 4 indicates the center region has high shrinkage along the Y-axis. In general, a good idea of the local shrinkage is obtained throughout the surface of the part. In order to assess the shrinkage in different directions, beams with orientations dominating in a certain direction are isolated and shrinkage along that direction is calculated. Since the total shrinkage is different in each of the coordinate directions, it is important to know the shrinkage in each of these directions. Figures 5, 6, and 7 show the contour of shrinkage in X, Y and Z direction, respectively. Comparing Figures 6 and 7, it is obvious that on the end wall, the shrinkage in the Y direction is much higher than shrinkage in the Z direction, particularly in the center.

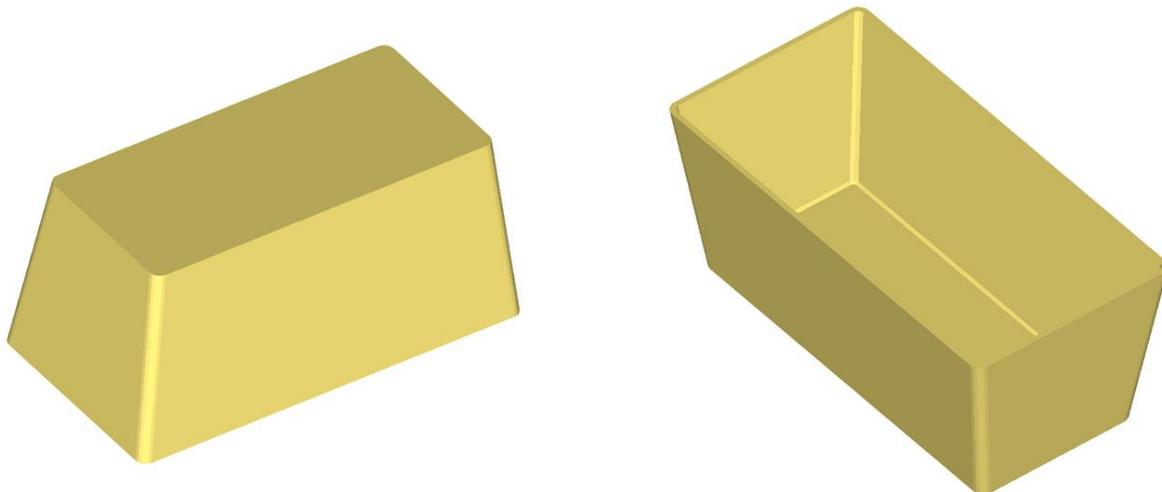


Figure 3. Example of a mouse coffin

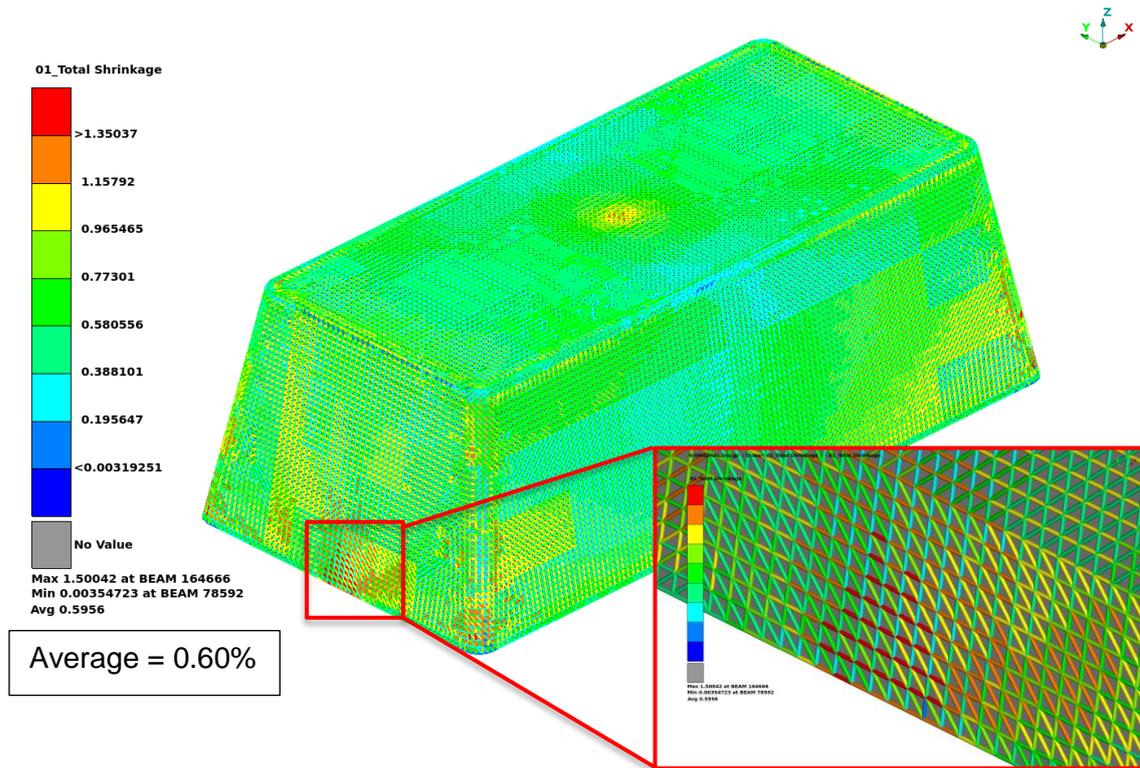


Figure 4. Shrinkage contour plot on mouse coffin

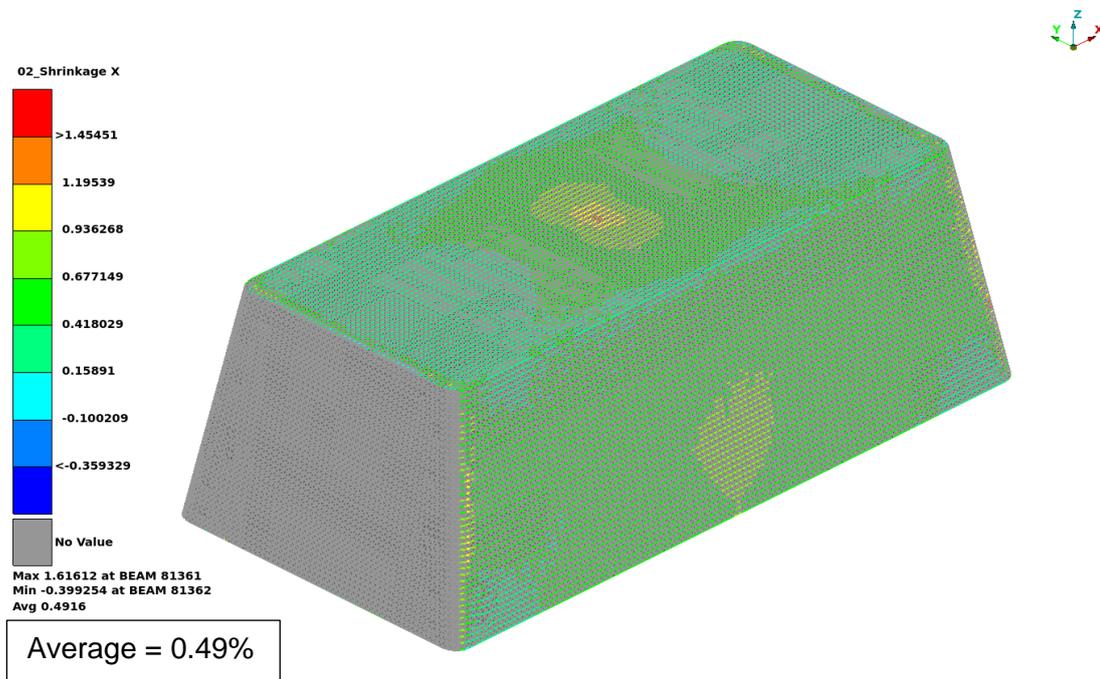


Figure 5. Shrinkage along X direction

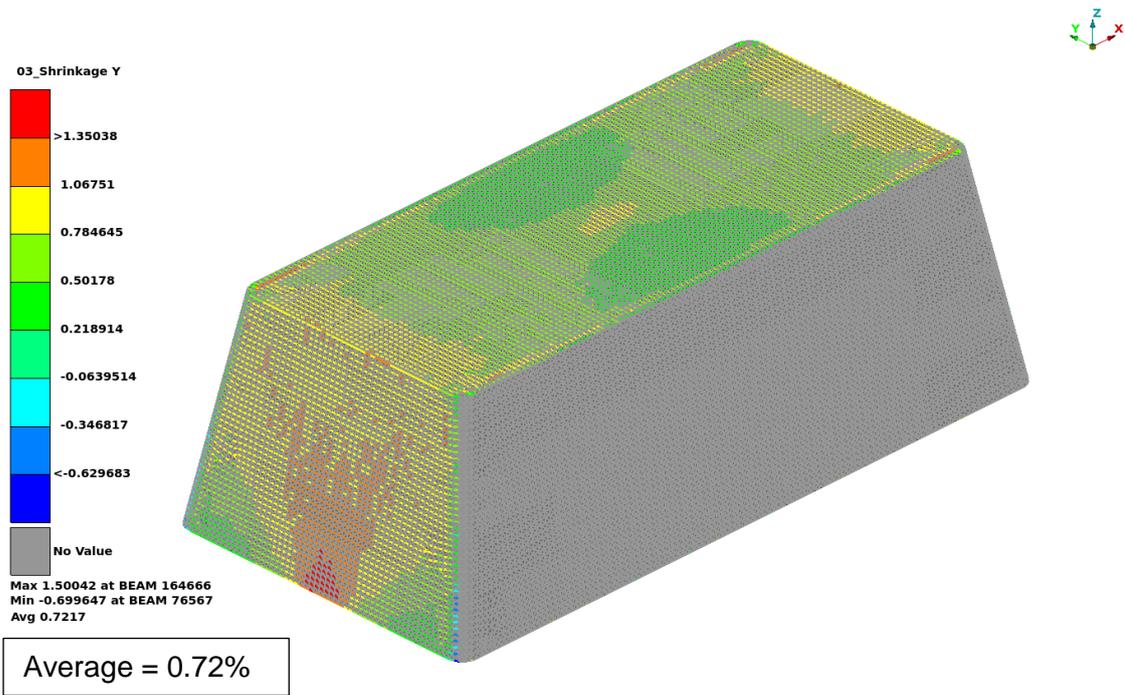


Figure 6. Shrinkage along Y direction

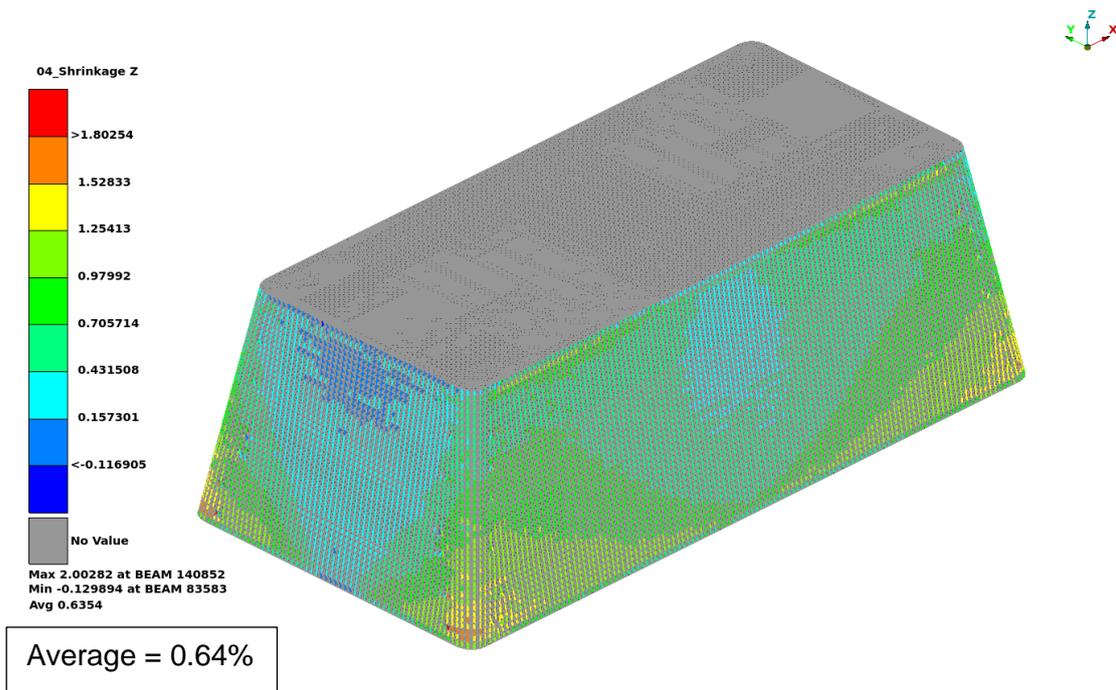
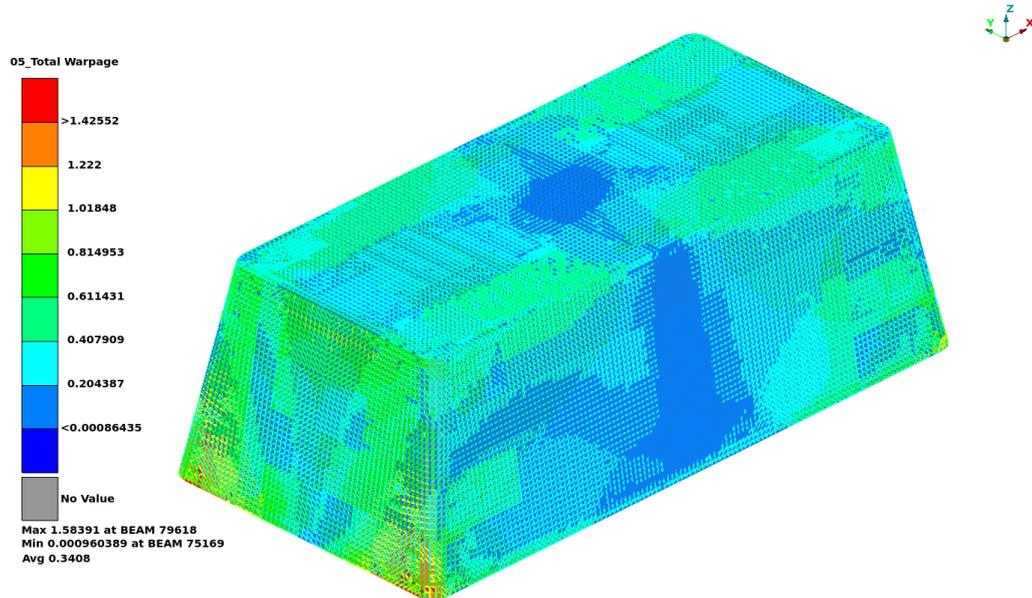


Figure 7. Shrinkage along Z direction

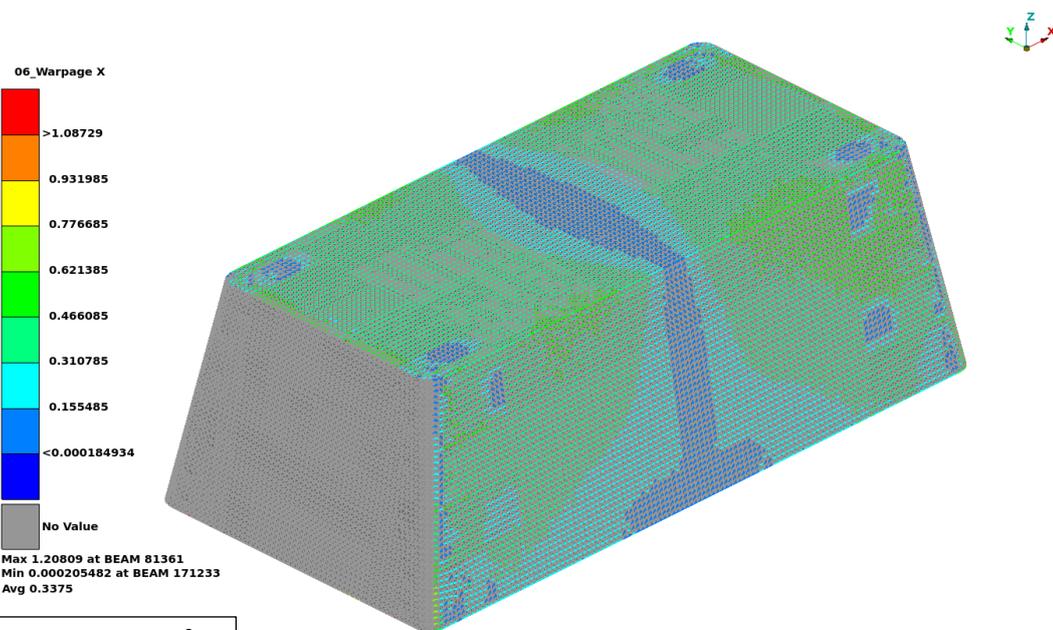
Another quantity of importance is warpage. As explained earlier, the rotation of the beams in degrees is used to quantify warpage, as it is a good indicator of distortion of the part. Figure 8 shows the contour of the rotation of the beams (warpage) throughout the part. It appears that the corner region on the front face has a higher rotation compared to center region of the top and sidewalls.



Average = 0.34⁰

Figure 8. Contour of total rotation (warpage) of beams on mouse coffin

In Figure 9, beams with dominant orientation in the X direction are considered. The rotation with respect to X-axis is plotted for these beams. It shows that the rotation is lower in the center portion compared to the end regions.



Average = 0.34⁰

Figure 9. Contour of rotation (warpage) with respect to X-axis for beams in X direction

Similarly, Figure 10 shows the rotation with respect to the Y-axis for beams with dominant orientation in the Y direction. The Y direction being along the shorter width of the mouse coffin has lower rotation with respect to Y-axis particularly on the top surface.

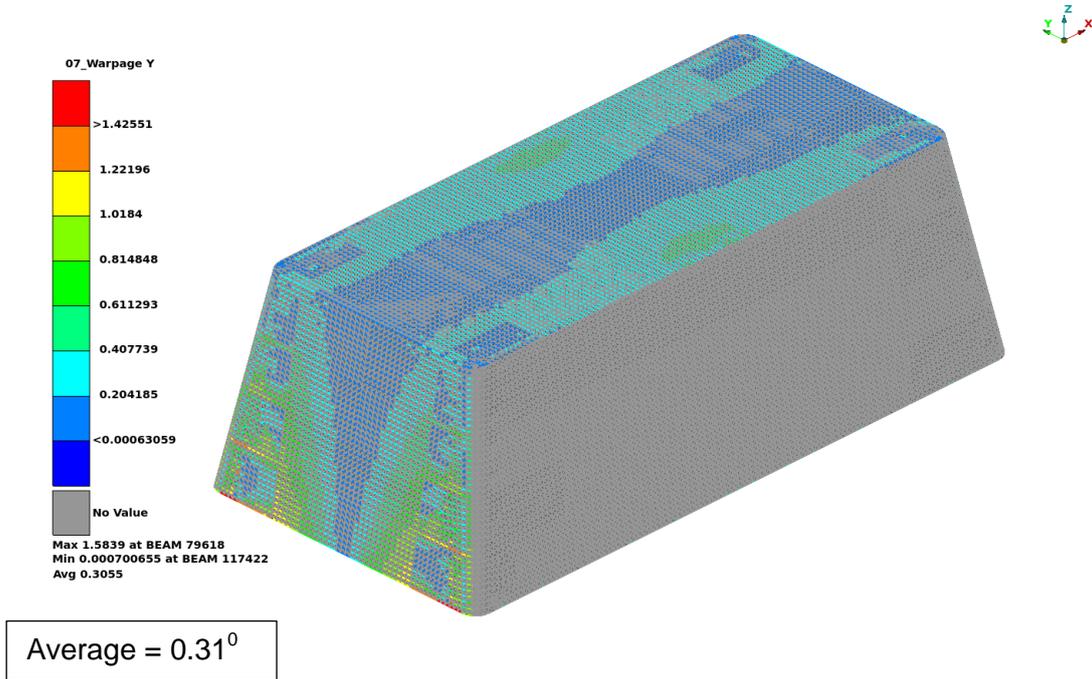


Figure 10. Contour of rotation (warpage) with respect to Y axis for beams in Y direction

Figure 11 depicts the rotation with respect to the Z-axis for beams with dominant orientation in the Z direction. Since warpage is an unwanted outcome of the injection molding process, the rotations shown here can help with the strategy for tooling and gating decisions and also any design modification that will help in its mitigation.

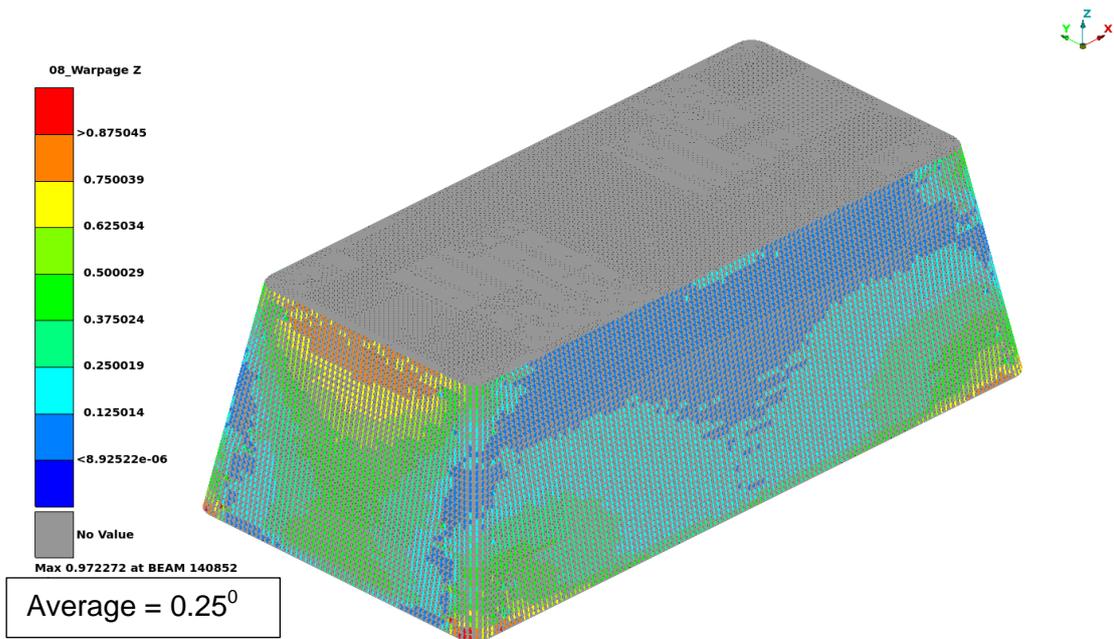


Figure 11. Contour of rotation (warpage) with respect to Z axis for beams in Z direction

One of the elegant features of the toolbar is the analysis of 2-D sections for shrinkage and warpage. Examples of sections taken across the width and length of the mouse coffin are given here. Figures 12 and 13 show the decomposed shrinkage and warpage, respectively, superimposed on the original section. The scaling is exaggerated for better clarity. As discussed earlier, the warpage can affect the deformation between any two points positively or negatively. In this case, warpage affects the deformation negatively as seen in the images. The deflection due to warpage is opposite to that of shrinkage. The shrinkage and warpage indices are also listed for the two selected nodes. The shrinkage index is 185 % and the warpage index is -85% and the sum is 100%, which is the total deformation. The shrinkage and warpage decomposition of the long section of the mouse coffin is shown in Figures 14 and 15, respectively. In this case, the warpage contributes positively to the total deformation as is seen in the images. As indicated, the shrinkage index is 42% and the warpage index is 58% with the sum equal to 100%.

Figure 16 shows multiple sections of the mouse coffin that were analyzed. The two selected nodes were the end points of the section in each case. Table I lists the shrinkage and warpage for each section along with their indices. The sum of the shrinkage and warpage matches the total deformation as obtained from Moldflow software. This indicates the decomposition to be quite accurate. As is evident, warpage contributions are positive for some sections and negative for others.

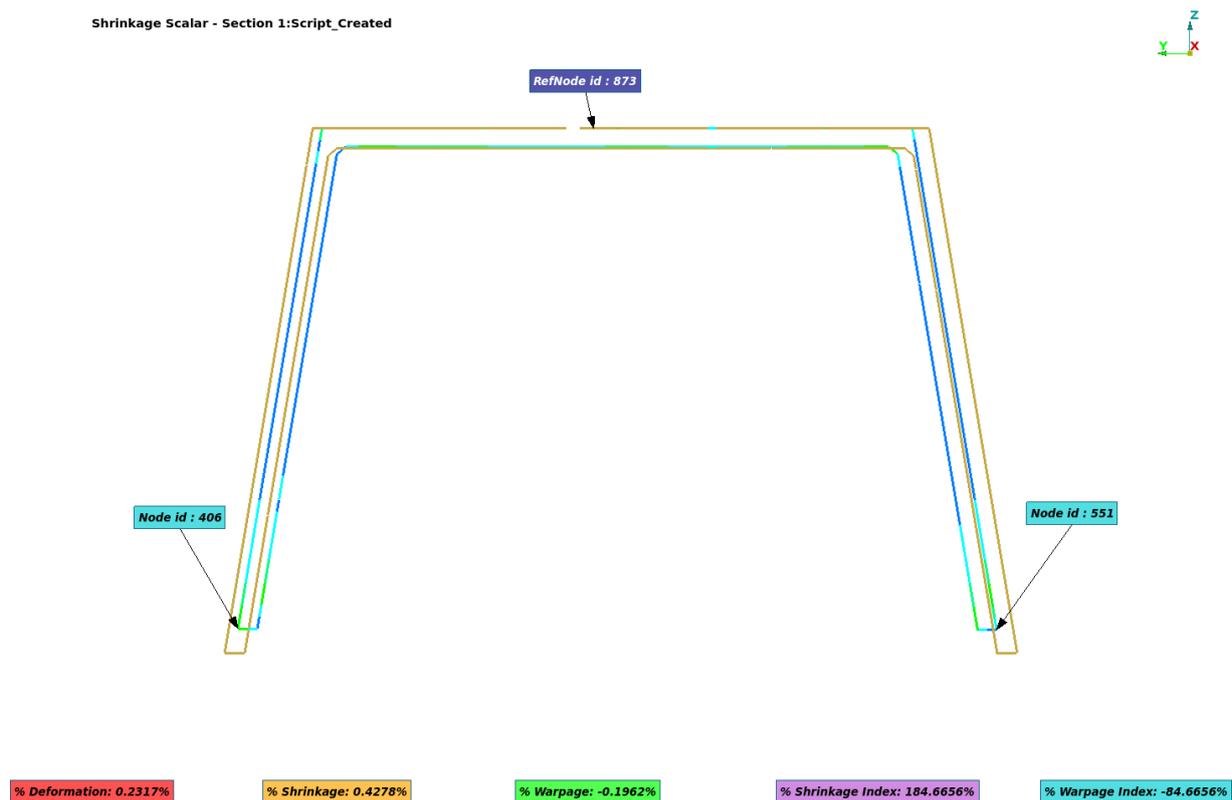
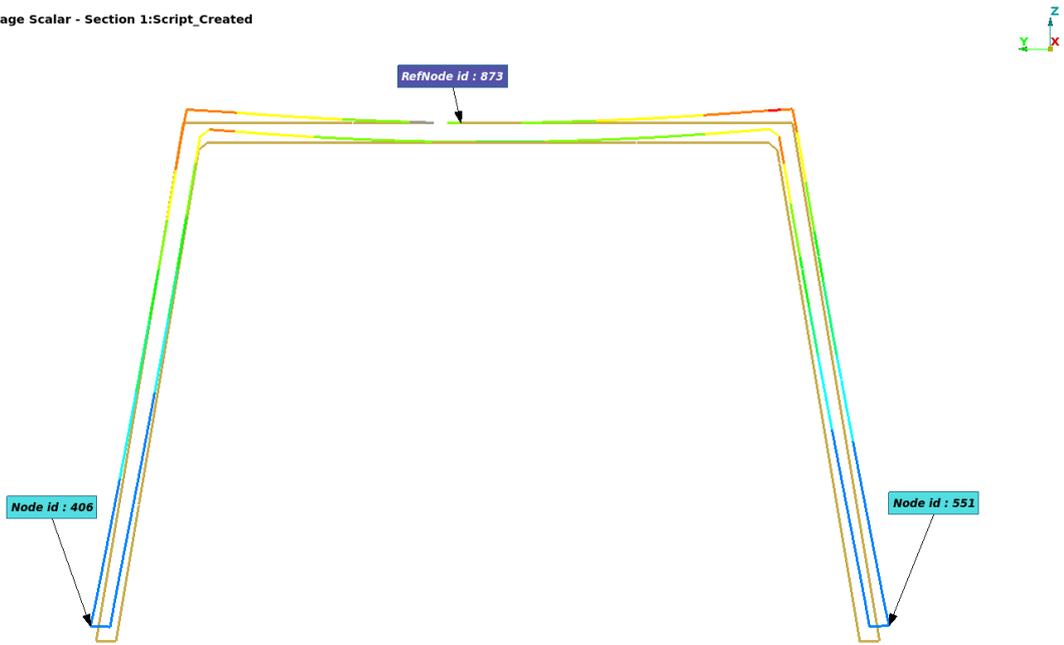


Figure 12. Shrinkage of a section across width of the mouse coffin

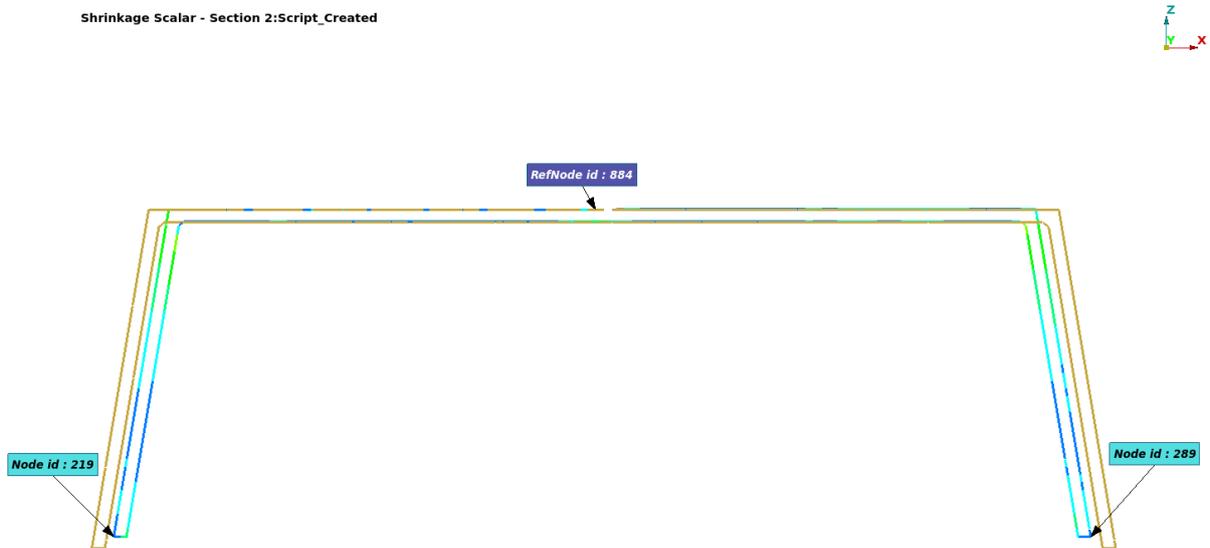
Warpage Scalar - Section 1:Script_Created



% Deformation: 0.2317% % Shrinkage: 0.4278% % Warpage: -0.1962% % Shrinkage Index: 184.6656% % Warpage Index: -84.6656%

Figure 13. Warpage of a section across width of the mouse coffin

Shrinkage Scalar - Section 2:Script_Created



% Deformation: 1.0904% % Shrinkage: 0.4562% % Warpage: 0.6342% % Shrinkage Index: 41.8362% % Warpage Index: 58.1638%

Figure 14. Shrinkage of a section across length of the mouse coffin

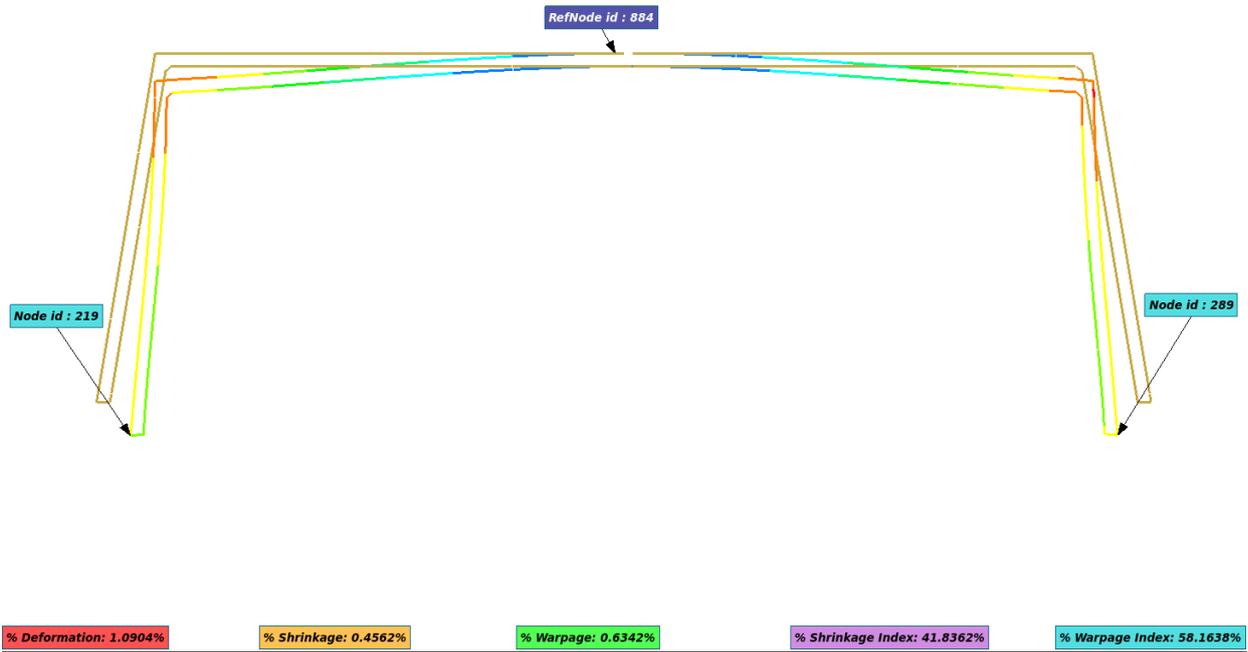


Figure 15. Warpage of a section across length of the mouse coffin

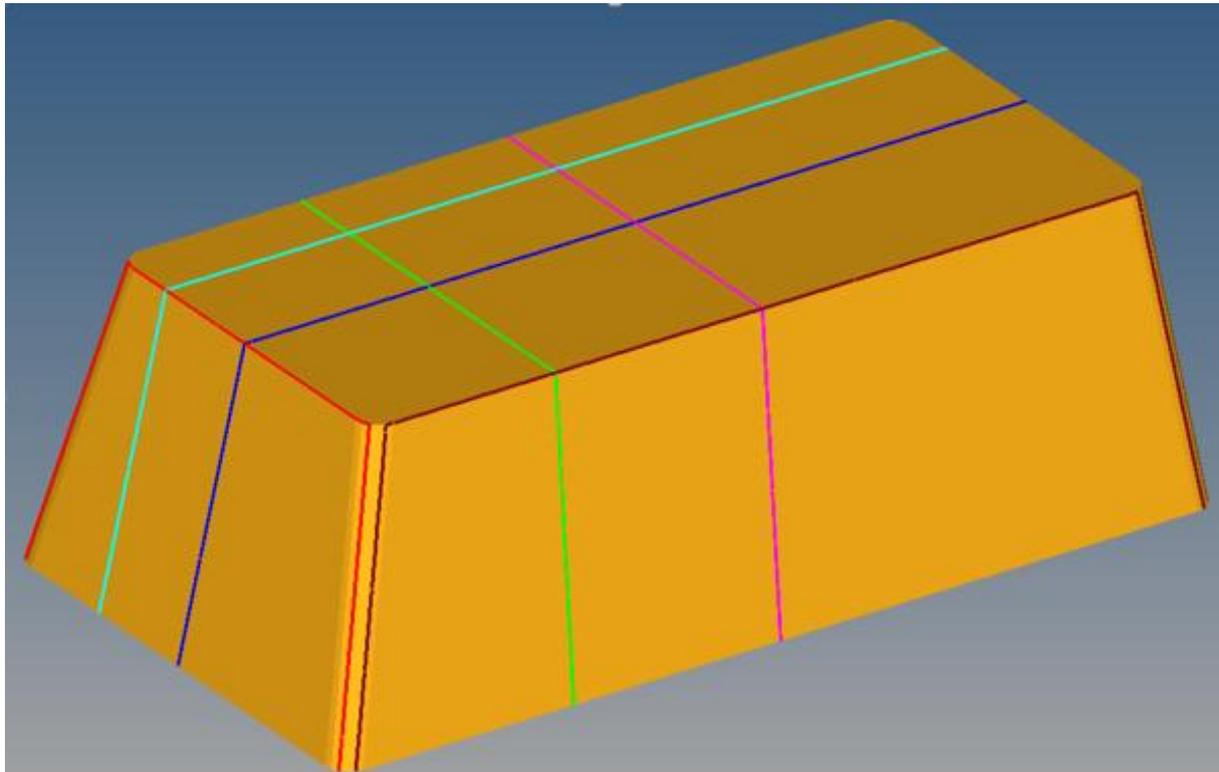


Figure 16. Multiple sections across the mouse coffin

S.No	Section Name	Node1	Node2	%Deformation	%Shrinkage	%Warpage	Shrinkage Index	Warpage Index
1	Section 9 873	406	551	0.2317%	0.4278%	-0.1962%	184.6656%	-84.6656%
2	Section 10 884	219	289	1.0904%	0.4562%	0.6342%	41.8359%	58.1641%
3	Section 11 3568	450	15786	0.3420%	0.7428%	-0.4008%	217.1738%	-117.1738%
4	Section 12 36030	25	43	0.5560%	0.5308%	0.0252%	95.4746%	4.5254%
5	Section 13 35894	42	47	0.4988%	0.4856%	0.0132%	97.3586%	2.6414%

Table 1. Shrinkage and warpage decomposition of sections

4. CONCLUSION

A Molding Processing Tool Bar, by use of a Python script, has been incorporated within MetaPost to view the deformation from a molding simulation in various forms. It has specialized functions to decompose the deformation into its shrinkage and warpage parts. The visualization of these values is done on beams placed on the edges of the triangular mesh. The local shrinkage is calculated by the reduction in length in the deformed state compared to the un-deformed state. Warpage is assessed in terms of rotation of the beams in degrees with respect to the un-deformed state. With the inherent functionality of MetaPost, contouring of these quantities can be done easily. The ability to create sections in MetaPost is a useful feature for analyzing them. An example of a mouse coffin is considered and all the functionalities of the tool bar are shown. Section analysis is carried out to show the decomposition in terms of shrinkage and warpage indices.

5. REFERENCES

- (1) μ ETA PostProcessor version 15.1.x. User's Guide, BETA CAE Systems S.A., June 2014.
- (2) <http://www.merriam-webster.com/dictionary>
- (3) Autodesk Simulation Moldflow Insight 2015, SP2