Autodesk® Moldflow 2023

3D Grill Element for Thermoplastics Injection Molding Process

Executive summary

This report is about the implementation of 3d grill elements. It gives an introduction, and then describes example cases.

Contents

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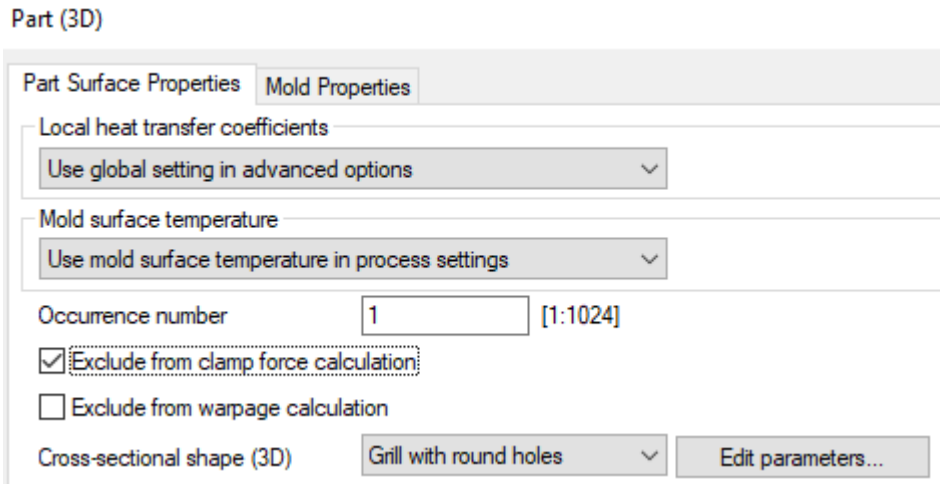
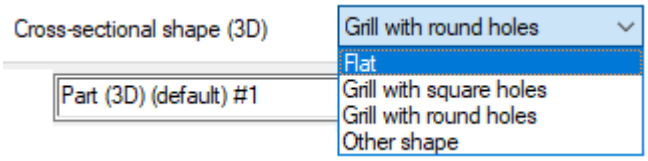
Introduction

In Autodesk Moldflow 2023, the feature of 3d grill elements is implemented for Moldflow Insight. The Grill element property has been available for Midplane meshes in previous releases. In Moldflow Insight 2023, this functionality is extended to 3D mesh types. Grill element can be used to simplify a model where there are many small repeating features in the model. The features might be holes which penetrate either fully or partially through the part thickness Use of a simplified model can reduce the time required to create the model, create the mesh, and perform an analysis using that mesh.

The grill element property can be assigned to each tetrahedral element. Tetrahedral elements where the grill properties are to be assigned can be selected, and properties can be assigned as shown in Figure 1. Grill element properties can be specified in the “Cross-sectional shape(3D)” section (Figure 1(a)). 4 types of cross-sectional shape can be specified as in Figure 1(b). The 4 types include “Flat”, “Grill with square holes”, “Grill with round holes” and “Other shape”. “Flat” is for the case where regular properties will be used for the tetrahedral element (no grill properties are used).



(a)



(b)

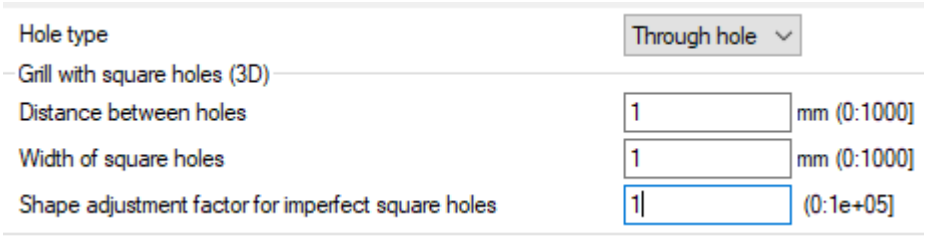
Figure 1: (a) Cross-sectional shape(3D) data which can be specified in “Part(3D)” properties, and (b) 4 options for the cross-sectional shape (3D).

Figure 2 shows additional data which are needed for “Grill with square holes”, “Grill with round holes” and “Other shape” cases.

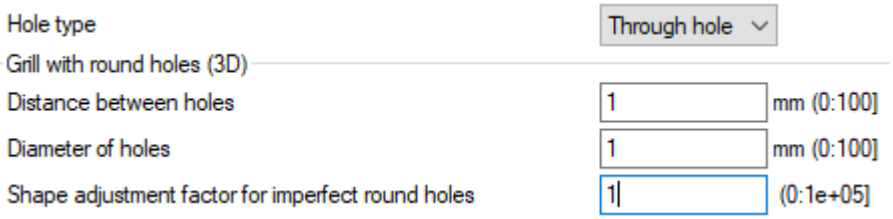
Figure 2(a) is for “Grill with square holes”. For this, 4 data are needed (hole type, distance between holes, width of square holes and shape adjustment factor for imperfect square holes. Hole type is whether the hole is a through hole or a blind hole. The selection can be made as in Figure 3. “Distance between holes” and “width of square holes” are illustrated in Figure 4(a). “Shape adjustment factor for imperfect square holes” is a factor to handle imperfect square holes (holes which are not perfectly square). If the hole shape is somewhat close to square but not perfectly square, this factor (whose value is generally greater than 1) can be used. This factor can be determined heuristically for each case.

Figure 2(b) is for “Grill with round holes”. For this, similar data are needed as those for square holes. “Distance between holes” and “diameter of holes” for round holes are illustrated in Figure 4(b).

Figure 2(c) is for other shape holes. For this, hole type, part volume fraction, flow resistance factor and shape factor are needed. Part volume fraction is the fraction of the modelled volume which is to be filled with polymer in a grill element region. Flow resistance factor is the factor which can be used to change the flow resistance locally. If the value is greater than 1, the flow resistance will be higher at that location compared to a regular non-grill region. At the grill region, the local cooling rate may increase because the grill pattern may increase the mold contact surface area. Shape factor is used to account for the change of local cooling rate. If the value of shape factor is greater than 1, the local region will cool faster than a regular non-grill region.



(a)



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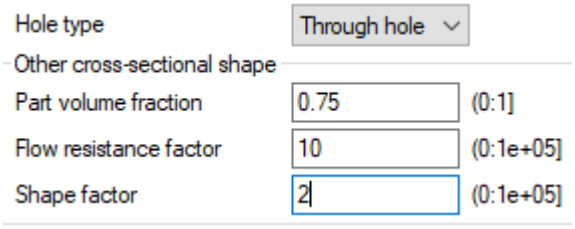
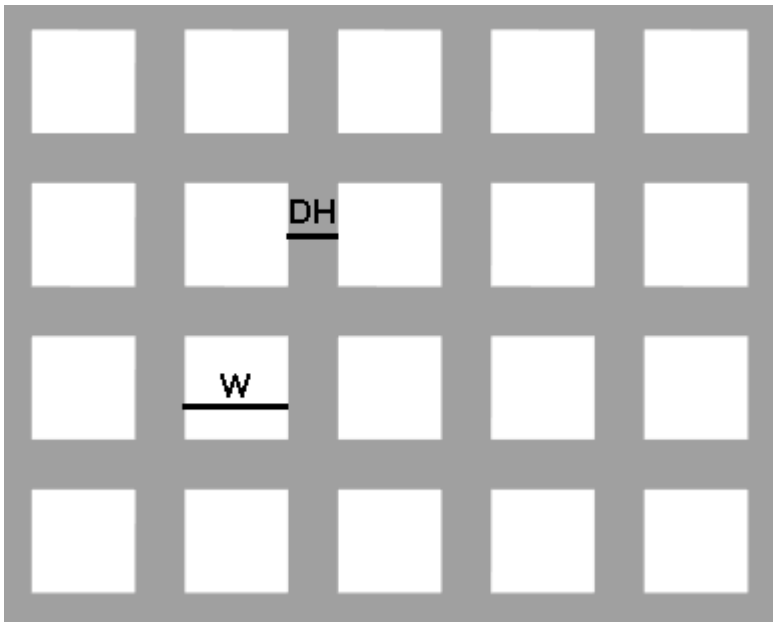


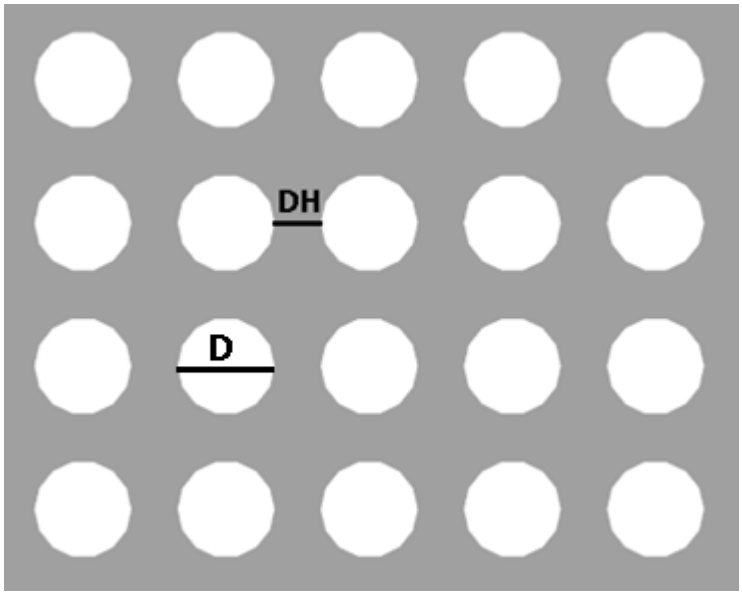
(c)

Figure 2: Different types of grill properties: (a) for grill with square holes, (b) grill with round holes and (c) other shape.

Figure 3: Hole type (through hole or blind hole).



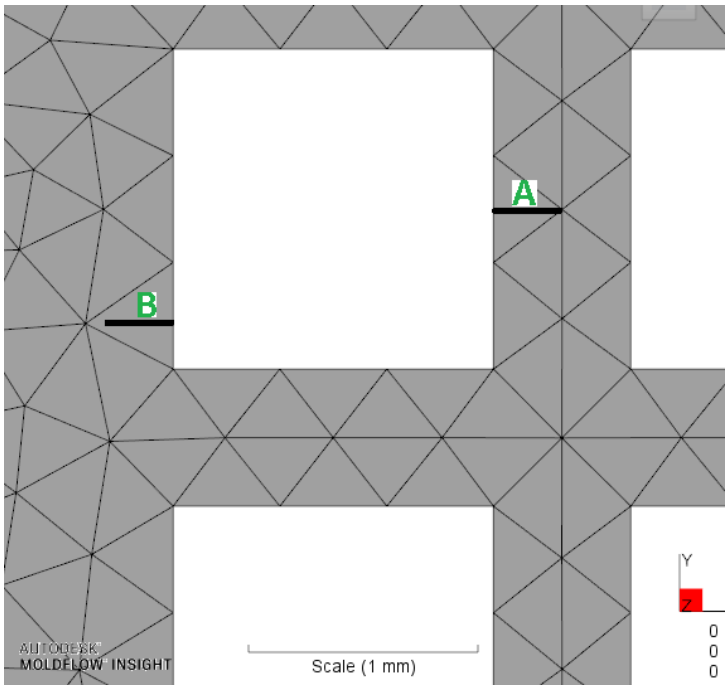
(a)



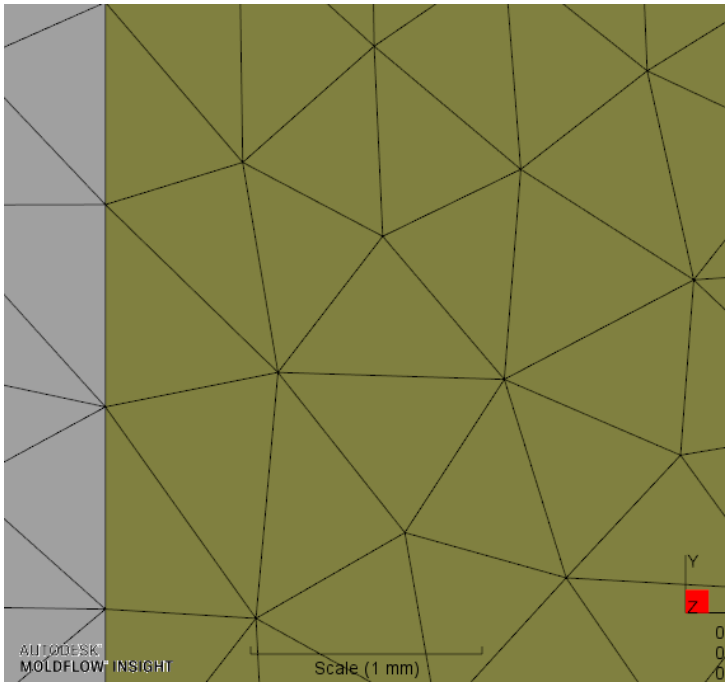
(b)

Figure 4: (a): A typical grill with square holes (“DH” is the distance between holes, and “W” is width of square holes) and (b) a typical grill with round holes (“DH” is the distance between holes, and “D” is diameter of round holes).

Figure 5 shows how the boundary of the grill region in the simplified model can be determined. As shown in this figure, the boundary of the grill region in the simplified model should extend by half the distance between holes (“indicated as “A”) from the outer hole (so B = A = DH/2 in Figure 5(a)).



(a)



(b)

Figure 5: (a) Full model, (b) simplified model. The grill region (shown as gold color) in simplified model needs to be extended to outside the hole in the full model by “half of distance between holes” (indicated as “A”).

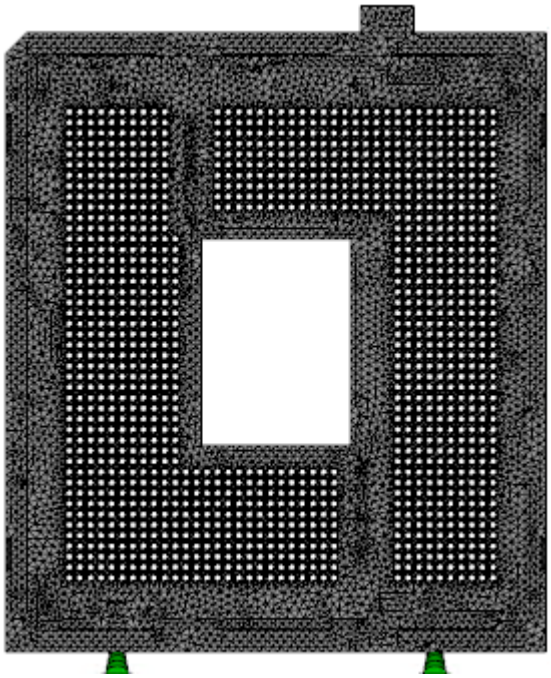
Example Cases

Some case studies will be shown to demonstrate the outcomes of analysis with 3d grill elements.

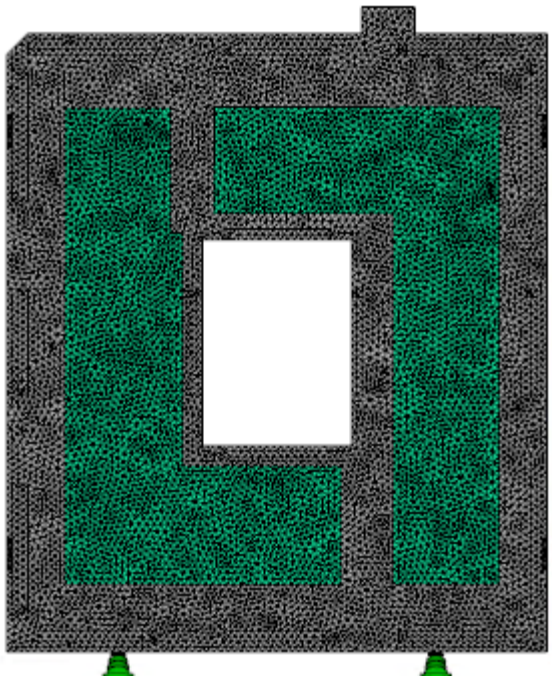
Case Study 1

The model used in the first case study is shown in Figure 5. Figure 5(a) shows the full model which includes each hole in the model. For this case, the diameter of each hole is 0.7 mm, distance between holes is 0.3 mm, and depth of hole is 2.4 mm (which is the same as the part thickness at that location). Figure 5(b) is a simplified model where the holes are not modeled. Instead, the region where the holes are located is modeled with grill element properties. The grill region is shown as a green color in Figure 5(b). “Grill with round holes” properties are assigned in the grill region (as in Figure 5(c)).

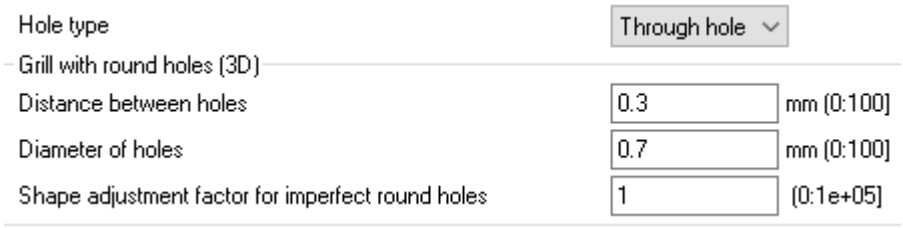
The material used in this case study is a PP (unfilled). The mold temperature was 50^{o}C, the initial melt temperature was 220^{o}C, and the fill time was 0.5 sec. For this case, packing time was applied for 10 sec.



(a)



(b)



(c)

Figure 6: Models used in the analysis. (a) full model, (b) simplified model (the grill region is shown as green color), and (c) grill properties assigned for the simplified model at the grill region.

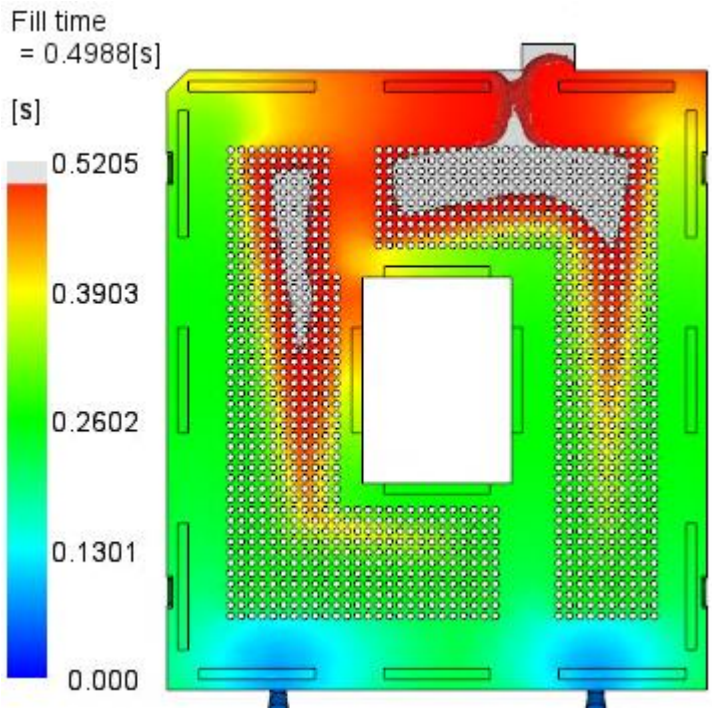
The number of elements and the calculation time used for the full model and the simplified model for this case are compared in Table 1. Also shown in the table is the ratio of values for the full model and the simplified model.

Table 1: Comparison of element number and calculation time for the full model and the simplified model.

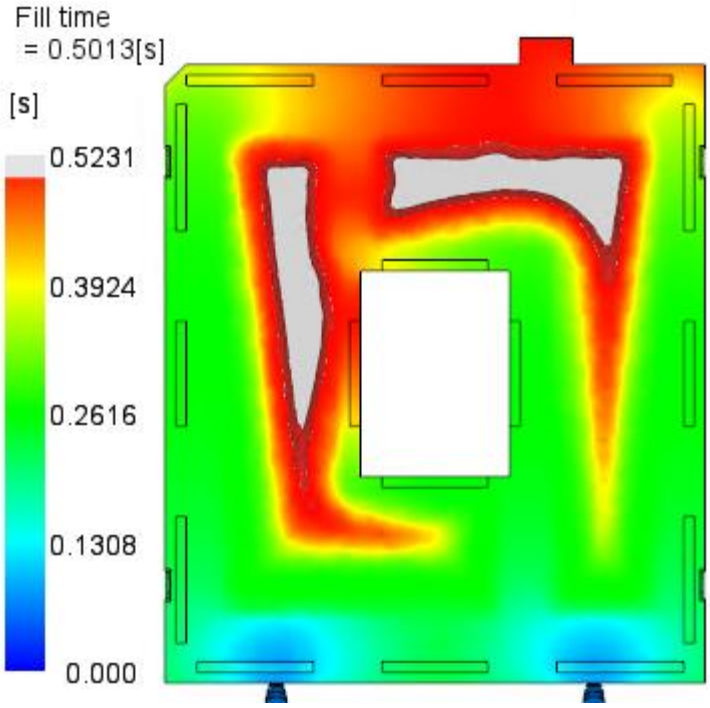
	Full model	Simplified model	Ratio (Full model / Simplified model)
Number of elements	4758764	797761	5.97
Calculation time (s)	31628	2945	10.73

The simulation results are shown in Figures 7 and 8. Figure 7 is the fill time. Figure 7(a) is for the full model, and 7(b) is for the simplified model. Although there are some differences, overall, they look similar. The fill time plot shown here is one animation step

from the end of fill. Figure 8 is the pressure at V/P switchover. Figure 8(a) is for the full model, and 8(b) is for the simplified model. For the full model, the injection pressure is 25.28 MPa, and for simplified model, the injection pressure is 29.7 MPa. This includes the pressure drop through the feed system (not shown).

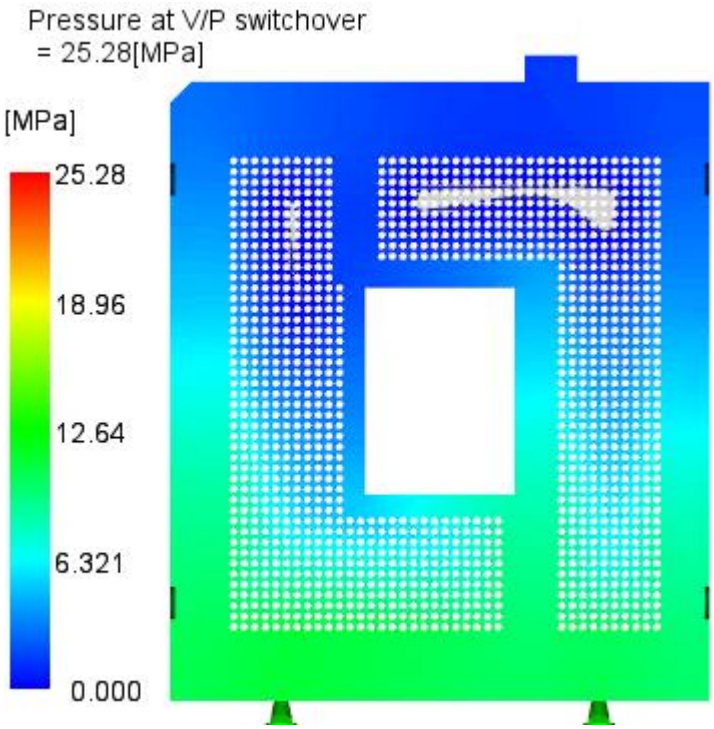


(a)

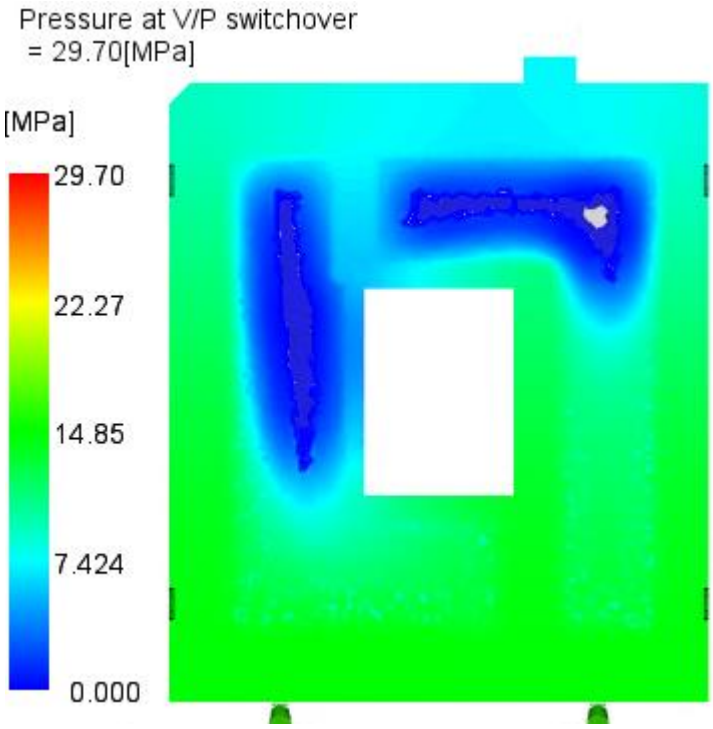


(b)

Figure 7: Fill time plot: (a) full model (b) simplified model.



(a)



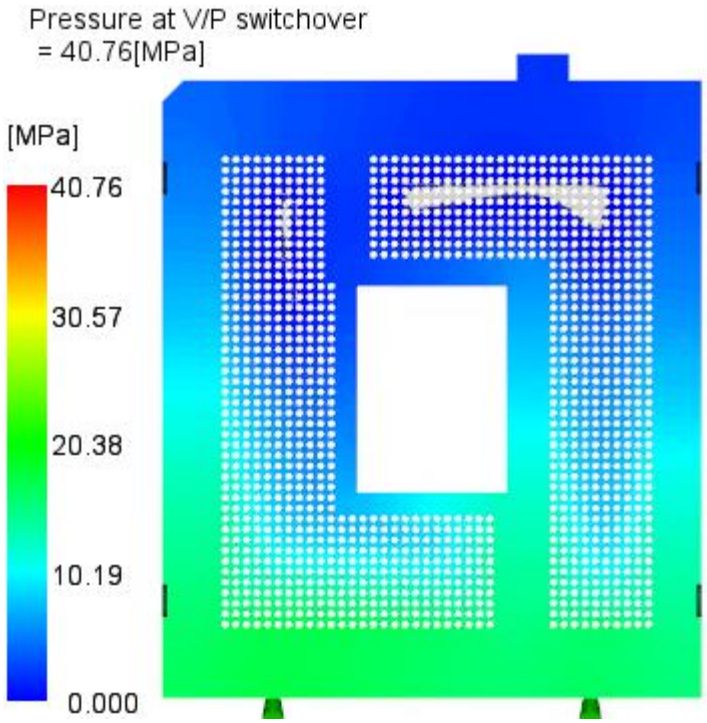
(b)

Figure 8: Pressure at V/P switchover: (a) full model (b) simplified model.

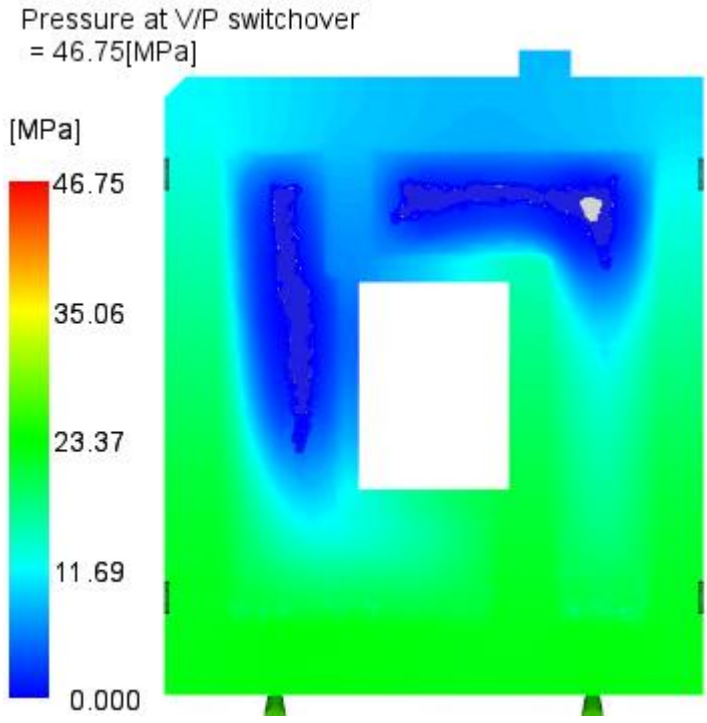
Case Study 2

The case used in this study is similar to case 1, but for this case study, a fiber-filled PP (glass fiber with 30% by weight) is used. The mold temperature was 45^{o}C, the initial melt temperature was 230^{o}C, and the fill time was 0.5 sec. For this case, packing time was applied for 10 sec. The packing pressure was 40.76 MPa.

Some simulation results are shown in Figures 9 – 12. Figure 9 is the pressure at V/P switchover. For the full model, the injection pressure is 40.76 MPa, and for the simplified model, the injection pressure is 46.75 MPa. Figure 10 is fiber orientation in x direction (Txx). We can see some difference in fiber orientation in the grill region. Figure 11 is the total deflection result. The difference between the full model and the simplified model is relatively small. Figure 12 is deflection in Z direction.

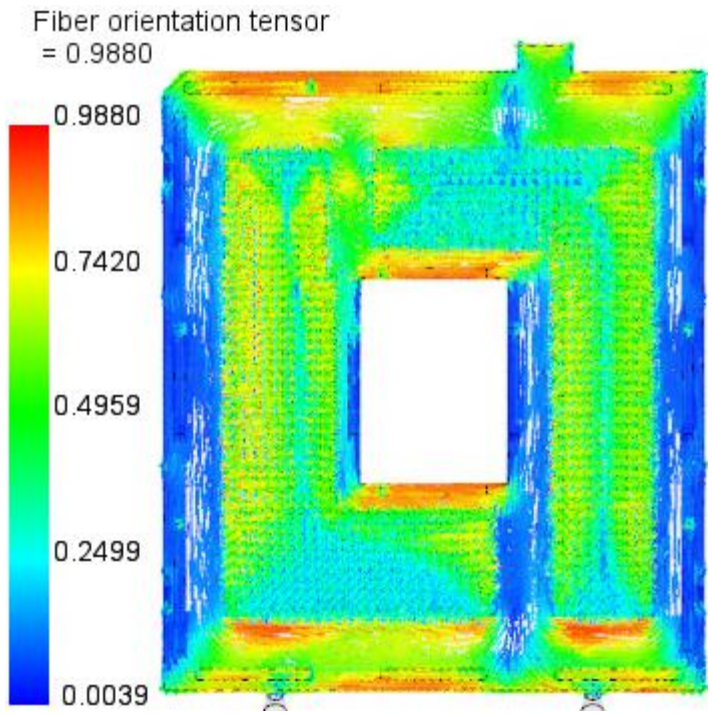


(a)

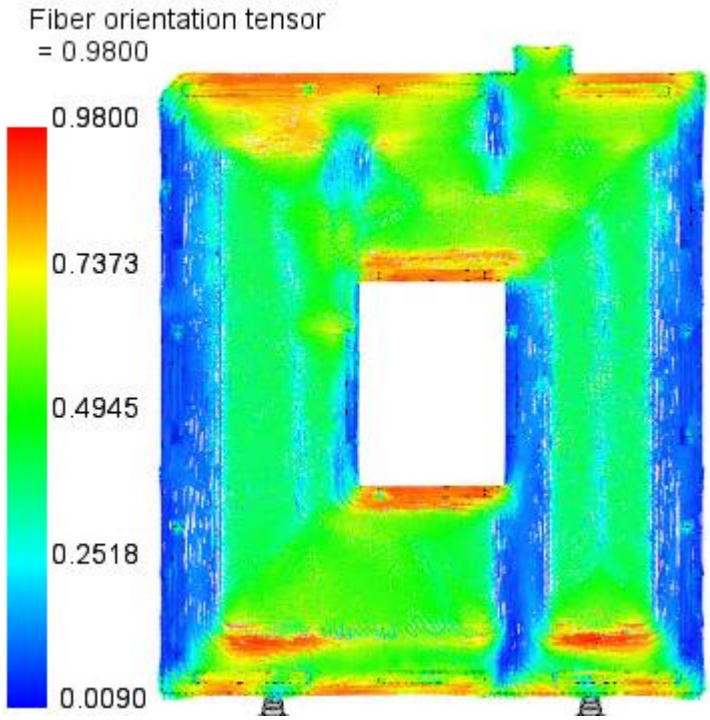


(b)

Figure 9: Pressure at V/P switchover: (a) full model (b) simplified model.



(a)



(b)

Figure 10: Fiber orientation in x direction (Txx): (a) full model (b) simplified model.

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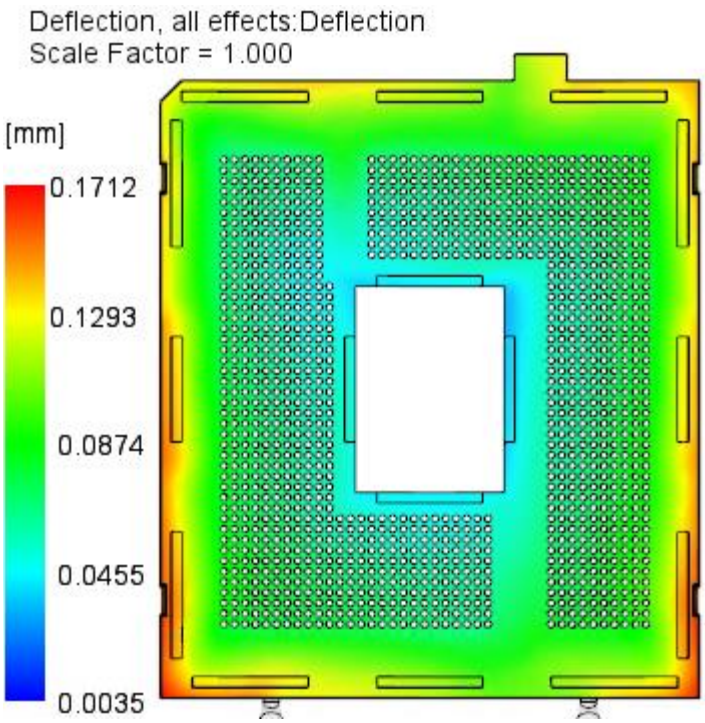
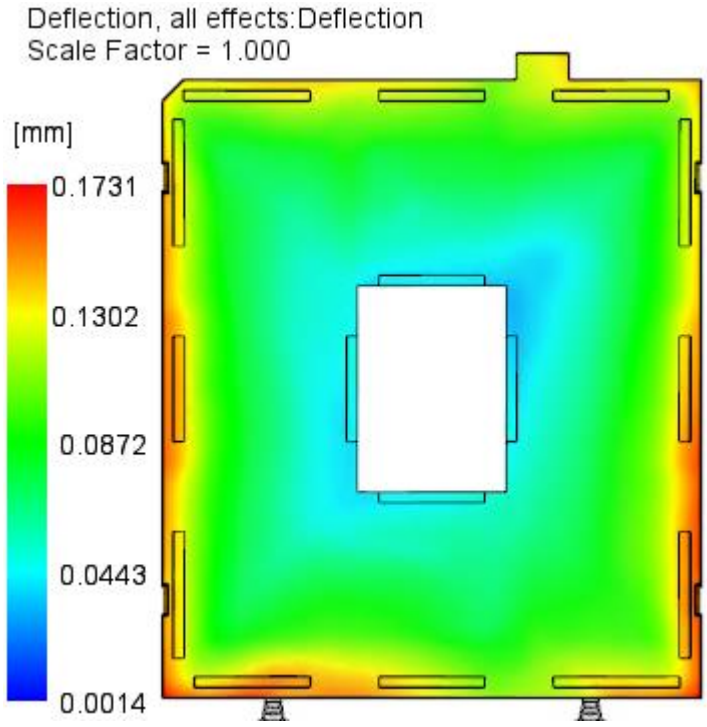


(a)



(b)

Figure 11: Deflection results: (a) full model (b) simplified model.

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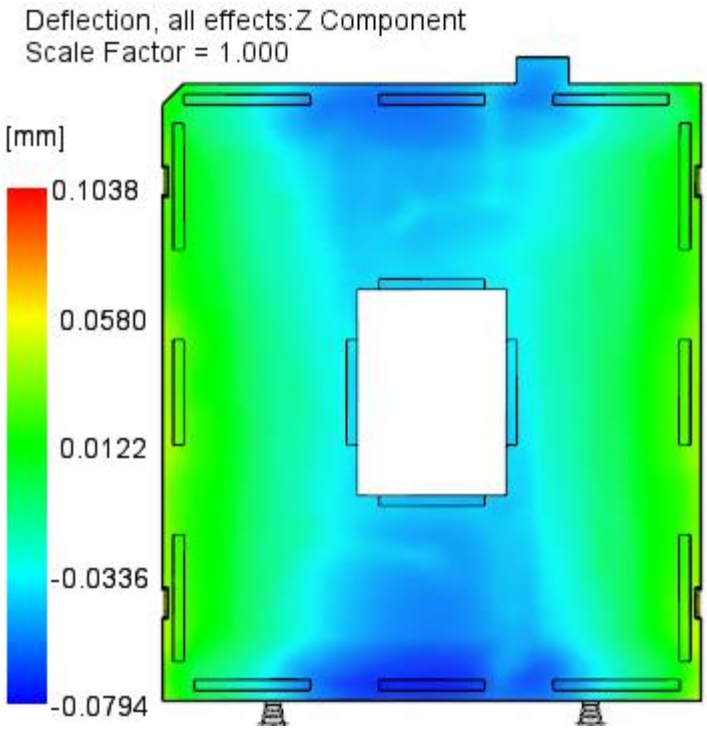
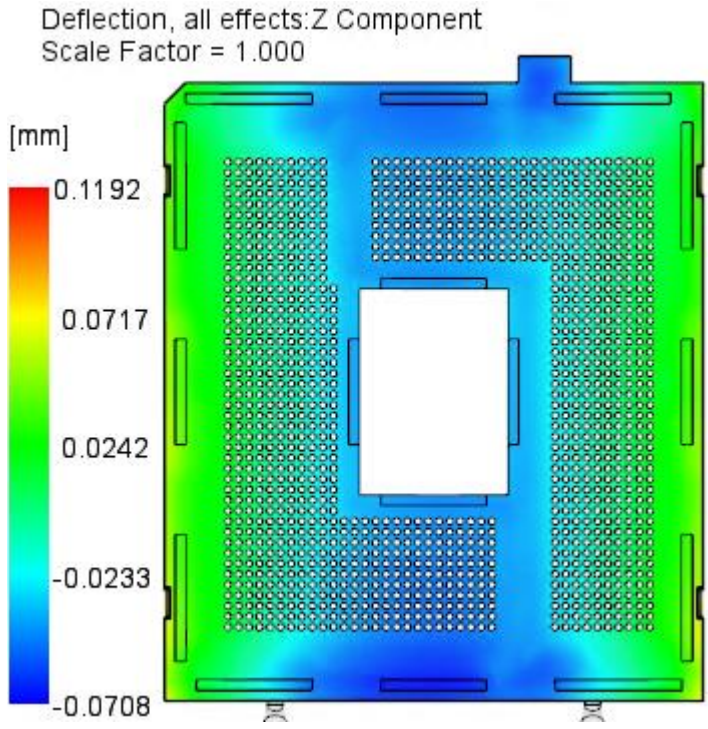


(a)



(b)

Figure 12: Deflection results in Z direction: (a) full model (b) simplified model.