Thin Walled Part Warping Overcoming by Honeycomb Ribs Design

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Abstract

Thin walled plastic parts are subjected to warpage after injection. Warpage can be overcome by the ribs features. This experimental project is to design a honeycomb ribs replacing the normal ribs to overcome part warping. The parameters included ribs height, the ribs thickness and the honeycomb size. Finite Element Analysis (FEA) simulations for each honeycomb ribs design are analyzed with Autodesk Moldflow Insight software and the part which result the worst warping value, part with medium warping value and part with less warping value were chosen to validate them by fabricating the core and cavity inserts to produce the actual product. The part warping is measured and then compared with the data from the simulation. Thus, the best design parameter of honeycomb ribs is identified.

Introduction

Injection moulding is a common batch process to fabricate the plastic products and has been used in more and more fields. However, the manufactured parts, especially the thin-walled ones, usually tend to be warped, which is highly desired to be addressed. Theoretical research paid attention to shrinking and stress distribution influence to the warpage deformation [1].

Plastic Injection Moulding is considered the most prominent process for mass producing plastic parts. More than one third of all plastic products are made by injection moulding, and over half of the world's polymer processing equipment is used for the injection moulding process [2].

Warpage can be defined as a distortion of the shape of the final injection moulded item caused by differential shrinkage. During plastication, injection, packing, cooling and ejection processes, the residual stress is produced due to high pressure, temperature change, and relaxation of polymer chains, resulting in warpage of the part.

Honeycomb is two-dimensional, prismatic cellular materials with a regular and periodic microstructure [3]. Honeycomb structures are widely used in structural applications because of their high strength per density. Meanwhile, conventional honeycomb structures can be fabricated to have a negative Poisson's ratio. A finite element method (FEM) technique developed for the study of spatially periodic materials is applied to the analysis of the linear elastic responses of regular and re-entrant honeycomb structure [4].

Experimental Method

The experiment started from the designing the thin walled plastic part product including the honeycomb ribs structure and normal honeycomb ribs using CAD modeling software. In this project, thin wall product with size 100mm x 40mm that has nominal thickness of 1mm is designed with the honeycomb ribs as shown in Figure 1.

Ribs design guidelines are implemented for both normal ribs and honeycomb ribs design. The design of ribs is varies based on different parameters which are ribs height, ribs thickness and honeycomb size as shown in Figure 2. In addition, the draft angle of the ribs for both normal ribs and honeycomb rib are remains constant which is 1.5 °.

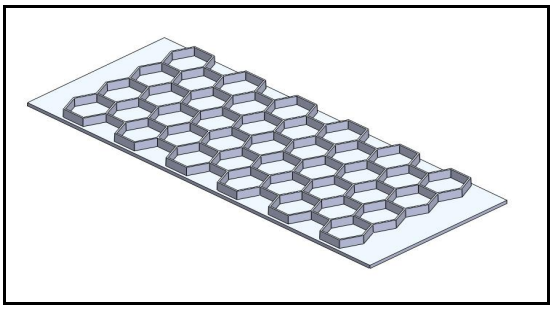

Figure 1: Thin walled part with honeycomb ribs.

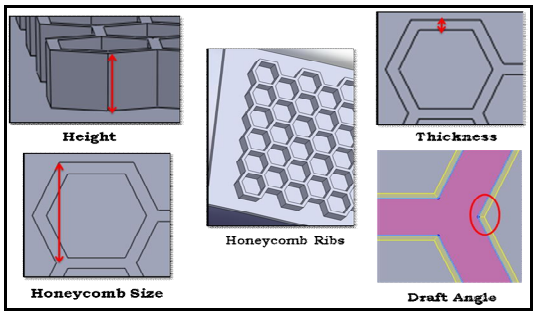

Figure 2: Ribs design.

The mould insert is fabricated based on the rib design. Injection moulding process takes place after the mould is fabricated. Parts injected from the mould are collected and the warping value is measured and compared with the simulation results. The plastic material that used for this experiment is Polypropylene.

Results and Discussion

Honeycomb Rib Parameters. The analysis is based from different parameters which are ribs height, ribs thickness and honeycomb size. The parameters of the ribs are shown at Table 1.

Table 1: Honeycomb Rib Parameters

Size (mm)	Thickness (mm)	Height (mm)	Draft Angle (°)
8	0.5	2.5	1.5
	0.5	3.0	1.5
	0.6	2.5	1.5
	0.6	3.0	1.5
10	0.5	2.5	1.5
	0.5	3.0	1.5
	0.6	2.5	1.5
	0.6	3.0	1.5

MoldFlow Analysis. The variation of the rib design is analyzed by using the MoldFlow software and gives different result for each parameter.

8mm Honeycomb Ribs. The first honeycomb rib design parameters are designed with the 0.5mm thickness and 2.5mm height resulting the warping of 1.025mm as shown in Figure 3. The thickness of 0.5mm and 3.0mm height of the ribs is then analyzed resulting the warping of 0.9475mm as shown in Figure 4. 1.098mm of warping recorded as shows the increment of the warping value when the ribs design with the 0.6mm and 2.5mm height as shown in Figure 5. The warping value decrease when the 3.0mm ribs height and 0.6mm ribs thickness is designed resulting of 0.9844mm warpage value as shown in Figure 6.

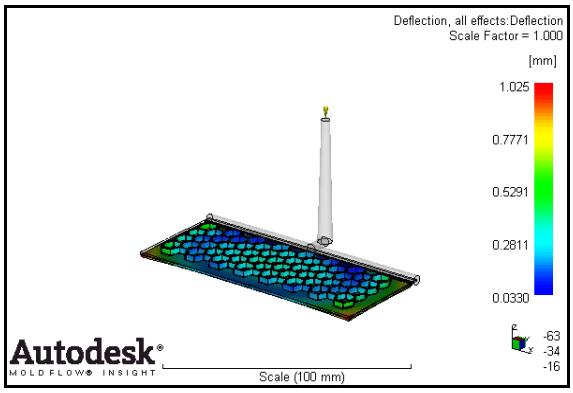

Figure 3: 0.5mm thickness and 2.5mm height ribs.

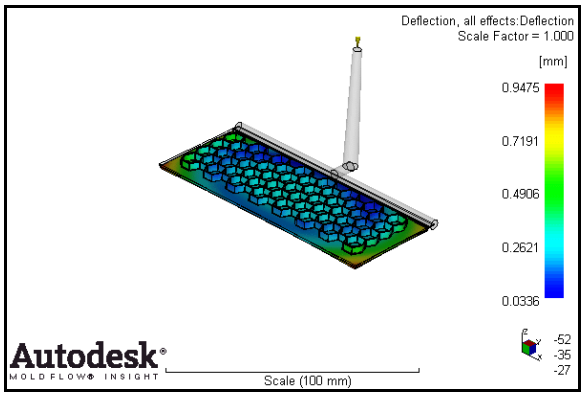

Figure 4: 0.5mm thickness and 3.0mm height ribs.

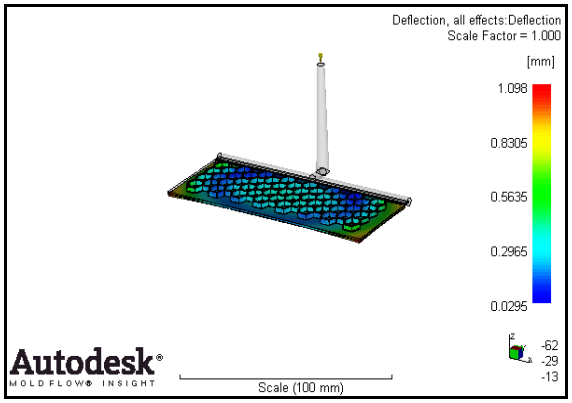

Figure 5: 0.6mm thickness and 2.5mm height ribs.

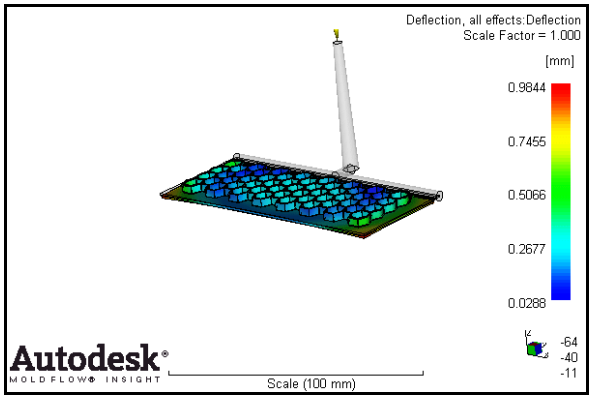

Figure 6: 0.6mm thickness and 3.0mm height ribs.

10mm Honeycomb Ribs. The 10mm of ribs size is design and analyzed. The warping value shows increment if compared with the 8mm ribs size when the ribs dimension is designed with 0.5mm thickness and 2.5mm ribs height as shown in Figure 7 and contributed the warping value value of 1.253mm. The warping value is slightly decrease when 3.0mm ribs height and 0.5mm ribs thickness is designed resulting of 1.131mm warpage value as as shown in Figure 8. The 1.177mm of warping recorded when the ribs analyzed with the 0.6mm and 2.5mm height as shown in Figure 9. The warping value is decrease when 3.0mm ribs height and 0.6mm ribs thickness is designed resulting of 1.113mm warpage value as as shown in Figure 10.

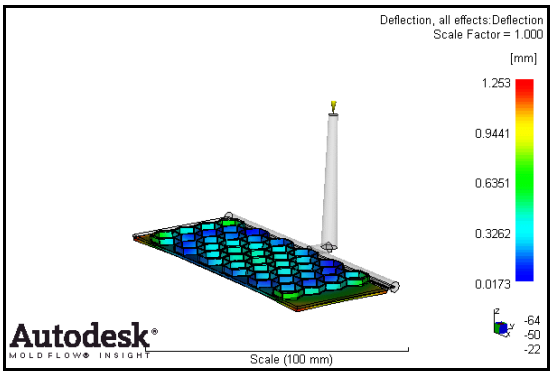

Figure 7: 0.5mm thickness and 2.5mm height ribs.

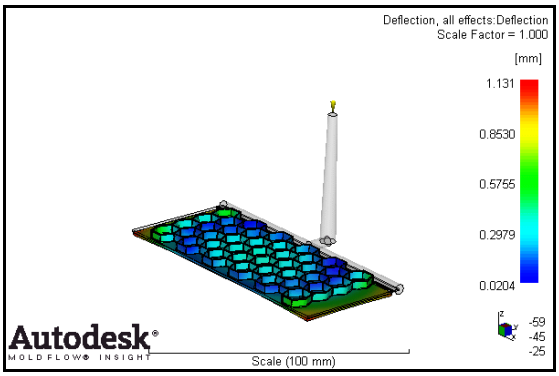

Figure 8: 0.5mm thickness and 3.0mm height ribs

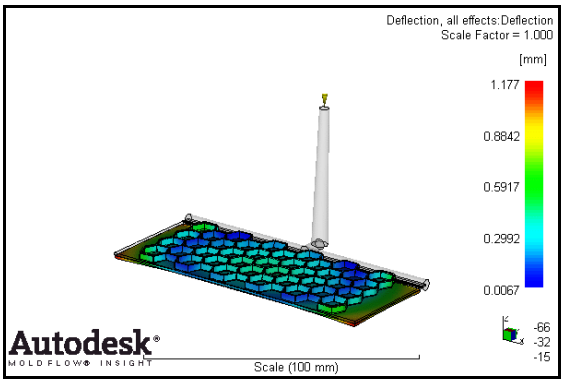

Figure 9: 0.6mm thickness and 2.5mm height ribs

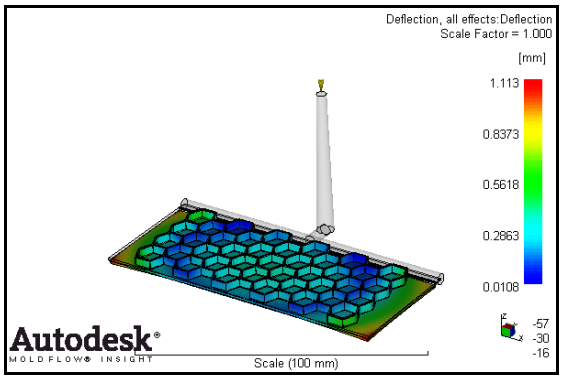

Figure 10: 0.6mm thickness and 3.0mm height ribs.

Validation. Three thin walled parts with honeycomb ribs were chosen to be validated by the injection moulding. From the result, the part with honeycomb ribs of 8mm size, 3.0mm ribs height and 0.5mm thickness shoes less warping value. The part that has median warping value is honeycomb ribs size of 10mm, 3.0mm height and 0.6mm thickness while for the highest warping value is part with honeycomb size 10mm, height 2.5mm and thickness 0.5mm.

Electrode and insert preparation. The electrode is machined based on the dimension of the ribs as shown in Figure 11. Three different sizes of electrodes are machined to be used on the EDM Die Sinking machine for producing the insert. Sparking takes places after the electrodes is machined at the mould inserts as shown in Figure 12. The sparking gap is controlled to ensure the dimension of the ribs follows the exact dimension of the ribs.

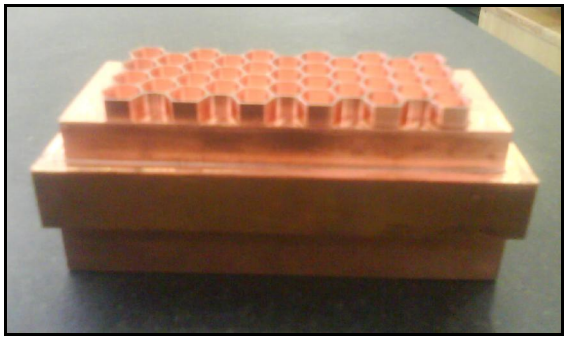

Figure 11: Electrodes.

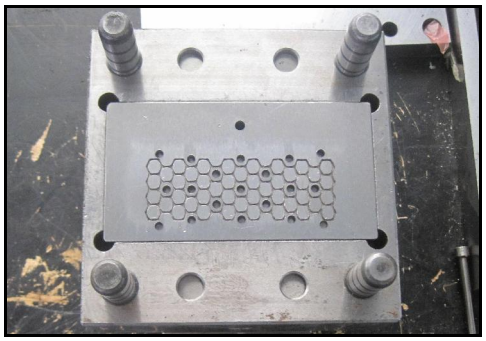

Figure 12: Insert machining.

Injection Moulding. The inserts is assembled with the mould base for injection. The mould is injected with the Polypropylene material. Ten samples for each ribs parameters is injected and collected for measurement in Figure 13 and 14.

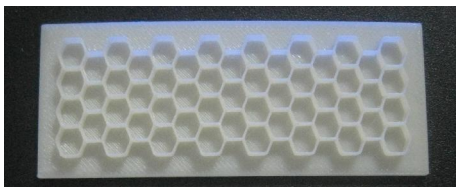

Figure 13: 8mm Ribs Part samples

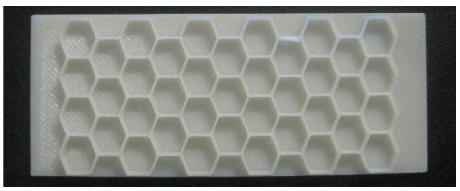

Figure 14: 10mm Ribs Part samples

Warping Measurement. The samples are collected for warping measurement. Figure 15 shows the samples are measured with the optical measuring equipment. The value of the warping is shown in Table 2. The MoldFlow analysis results are then compared with result gained from the measurement. The result is shown at Table 3.

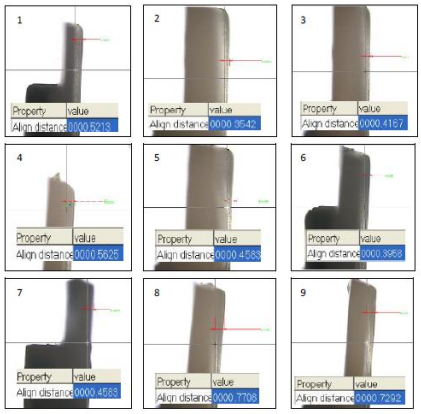

Figure 15: Warpage measurement

Table 2: Warping measurement results

Value of warping (mm) / Parameters	1	2	3	4	5	6	7	8	9	10	Mean (mm)
Size: 8mm thickness: 0.5mm Height : 3.0mm	0.1250	0.1667	0.0833	0.1458	0.1250	0.1672	0.1042	0.1875	0.0625	0.1458	0.1313
Size: 10mm thickness: 0.5mm Height :2.5mm	0.5213	0.3542	0.4167	0.5625	0.4583	0.3958	0.4583	0.7708	0.7292	0.4167	0.5084
Size: 10mm thickness: 0.6mm Height :3.0mm	0.1875	0.2083	0.2708	0.2292	0.2917	0.2500	0.2292	0.3542	0.1667	0.1870	0.2375

Table 3: Warping comparisons

Honeycomb Ribs Parameters	Measurement Result (Warping value)	Moldflow Analysis (Warping Value)
Size: 8mm Thickness: 0.5mm Height: 3.0mm	0.1313mm	0.9475mm
Size: 10mm Thickness: 0.5mm Height: 2.5mm	0.5084mm	1.253mm
Size: 10mm Thickness: 0.6mm Height: 3.0mm	0.2375mm	1.113mm

Result Analysis. Based on the results, the graph is plotted to identify effects of the ribs parameters to the part warping.

Warping Versus Height. As the height increase, the value of warping is decrease. The honeycomb ribs with height 3.0mm have less warping value compared to honeycomb with height 2.5mm as shows in Figure 16. The height of honeycomb plays an important role in choosing the best parameters of suitable honeycomb ribs design because the higher the honeycomb, the better the ability to overcome the bending and higher toughness of the plastic product part.

Warping Versus Thickness. Figure 17 shows that when the thickness increase, the value of warping is decrease. Honeycomb ribs with thickness 0.6mm have lower warping value compared to honeycomb ribs with thickness 0.5mm. Meanwhile, increasing part thickness can make the product have less warping as the warping tends to become lower at thicker part.

Warping Versus Size. Graph in Figure 18 shows when the size of the ribs increase, the value of warping on the product also increases. Honeycomb ribs size 8mm has the lowest warping effect on the final product whereas for the product with honeycomb size 10mm. As the size of honeycomb increase, the area that tabulated by the honeycomb ribs are decrease while for smaller honeycombs, they can tabulate more on the plastic product. Thus, the warping effect to the plastic product with smaller honeycomb size is smaller.

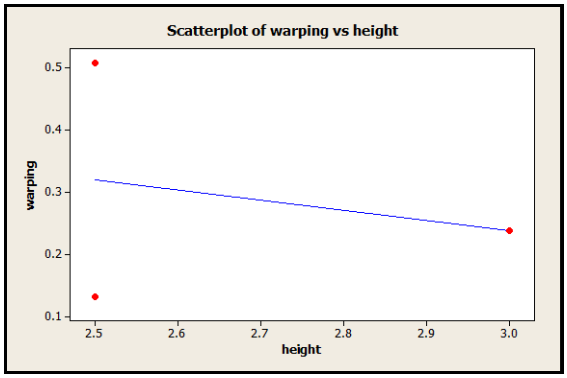

Figure 16: Warping versus ribs height graph

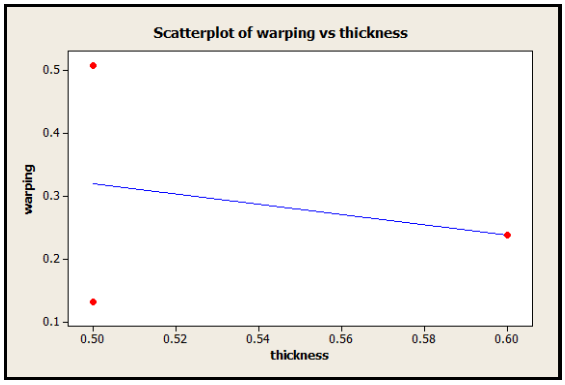

Figure 17: Warping versus ribs thickness graph

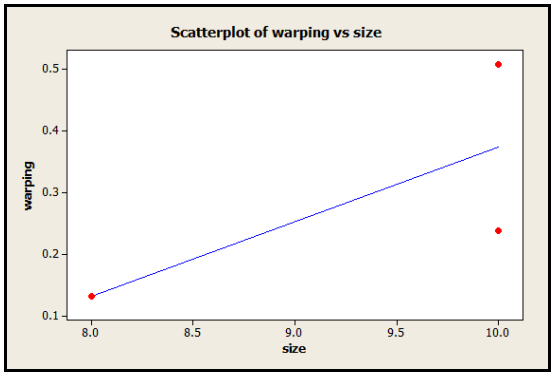

Figure 18: Warping versus ribs size graph.

Conclusion

The experiment result shows the relationship between the honeycomb ribs parameters to the warping effect of thin walled plastic part.

The height and the thickness of the ribs play important roles in preventing the part warping as the height and thickness increase, the warping value is increase. With these results, the optimum ribs size can be determined.

References

[1] X.M Cheng, L. Zhou, N. Y Sheng. (2009). Injection Moulding and Warpage of Thin Walled Part Based on Simulated Deformation. Natural Science Foundation, 1 to 4.

[2] B. Sidda Reddy, J. Suresh Kumar, Vijaya Kumar Reddy, G. Padmanabhan. (2008). Application of Soft Computing for the Prediction of Warpage of Plastic Injection Molded Part. Journal of Engineering Science and Technology Review, 62.

[3] Xiu hui Hou et al. (2010). Frequency and response analysis for cellular honeycomb structures under Hamilton System. Emerald , 14.

[4] Jin Hee Lee, J.B Choi, K. Choi (1996). Application of Homogenization FEM Analysis to regular and re-entrant Honeycomb Structure. Journal Of Material Science, 1.