Energy Absorption of Standard and Origami-Inspired Honeycomb Structure

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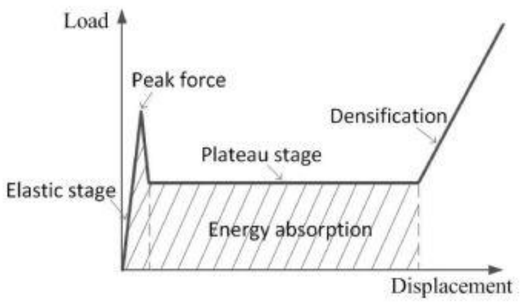
Abstract

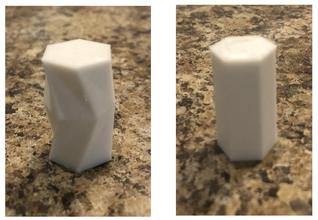
The goal of this experiment was to examine the energy absorption properties of origami-inspired and standard honeycomb structures varying the materials and wall thickness. The results indicate that origami-inspired structures perform best at energy absorption at a higher wall thickness with a rigid material. The results also indicated that standard honeycomb structures perform better with lower wall thickness, but still with a rigid material. In vehicles with structures of a sufficiently high wall thickness with a rigid material, origami-inspired honeycomb structures could be used instead of current structures in order to better protect the passengers.

Background

Previous studies have investigated the energy absorption of origami-inspired structures. Origami-inspired honeycomb structures have been examined on their own [1], as well as in a sandwich structure [2]. A common theme of these studies is that origami-inspired structures seem to have better energy absorption than their standard honeycomb counterparts. Energy absorption is a structural property that acts as a measure of how much impact from a load a structure can take before it reaches densification [3]. This is typically calculated from a force-displacement curve, as shown in the figure below:

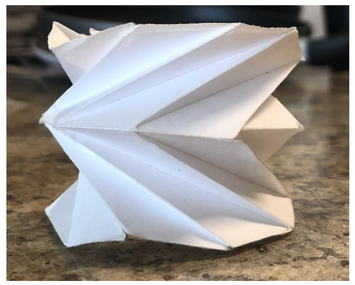


Before Testing



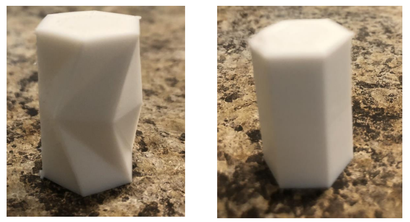
Origami Standard

Shown above are the structures before testing. The origami-inspired honeycomb was designed based on the paper origami below. This was chosen due to the simplicity of having a constant area as it folds as well as its close resemblance to the honeycomb unit. These structures were then modelled, and both were printed using an FDM printer, initially with TPU and later with ABS.



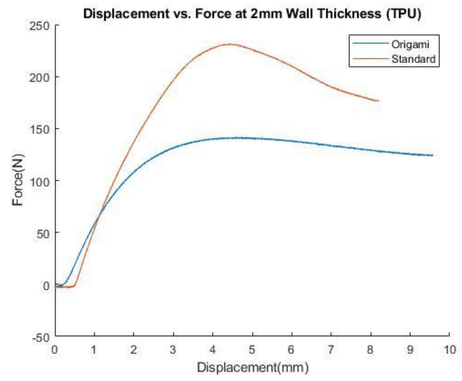
Results

TPU Structures



Origami Standard

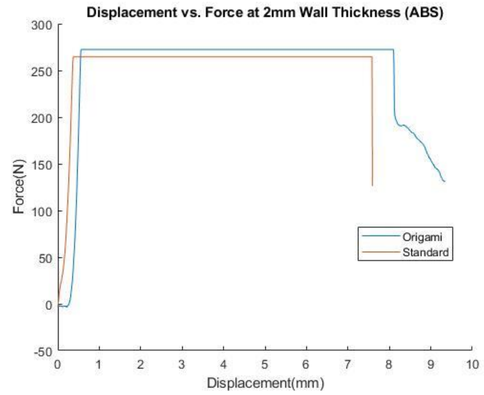
The first structures were printed from TPU, a flexible material, which was thought to potentially be better at demonstrating the unique properties of origami-inspired structures. While it did demonstrate interesting recovery properties, the origami-inspired structure did not perform better at energy absorption until the highest wall thickness. Overall, standard honeycomb structures performed better when made of TPU. A sample of the force-displacement curves are shown below:



ABS Structures

Origami Standard

After, the TPU structures were tested, the same structures were tested with ABS, a more rigid material for comparison. These were a lot more visibly damaged after testing, but the origami-inspired honeycomb units performed better at energy absorption than their standard counterparts. A sample of the force-displacement curves is shown below:



Conclusion

It was determined that origami-inspired structures are best suited for energy absorption at higher wall thicknesses with ABS. Additionally, the folding and recovery properties of the origami-inspired structures were much better demonstrated with TPU. This research has applications wherever honeycomb structures are used. In vehicles with a sufficiently high wall thickness, these origami-inspired honeycomb structures could be used in place of current ones to better protect passengers and delicate payloads, especially in aerospace vehicles where these structures are commonly used.

References

[1] Townsend, S., Adams, R., Robinson, M., Hanna, B., and Theobald, P., “3D printed origami honeycombs with tailored out-of-plane energy absorption behavior,” *Materials & Design* Available: https://www.sciencedirect.com/science/article/pii/S0264127520304640.

[2] Qi, J., Li, C., Tie, Y., Zheng, Y., and Duan, Y., “Energy absorption characteristics of origami-inspired honeycomb sandwich structures under low-velocity impact loading,” *Materials & Design* Available: https://www.sciencedirect.com/science/article/pii/S0264127521003907.

[3] Xiang, X. M., Lu, G., and You, Z., “Energy absorption of origami inspired structures and materials,” *Thin-Walled Structures* Available: https://www.sciencedirect.com/science/article/pii/S026382312031003X.

Acknowledgements

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