Investigating the Effect of Buckling Initiators on 3D-Printed Honeycomb Cell Structures for Improving Crashworthiness

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Introduction

- Cellular solids are materials consisting of an interconnection network of solid cells or plates.
- A hexagonal-cell material will be the focus of this research because its geometry minimizes the material cost and weight.
- The honeycomb sandwich structure is a form of the composite structure. This structure is widely used in the aerospace industry, where weight is a primary concern. Most commercial airliners, helicopters, and almost all military air and space aircraft have used this honeycomb sandwich structure in many places of their structures.
- The honeycomb sandwich structure consists of three discrete structural elements: two thin facings with adhesive films and a lightweight honeycomb core. Depending on the condition that a plane or a missile is exposed to, the face material may be aluminum alloys, reinforced plastic, titanium alloys, heat resistance steel, etc.

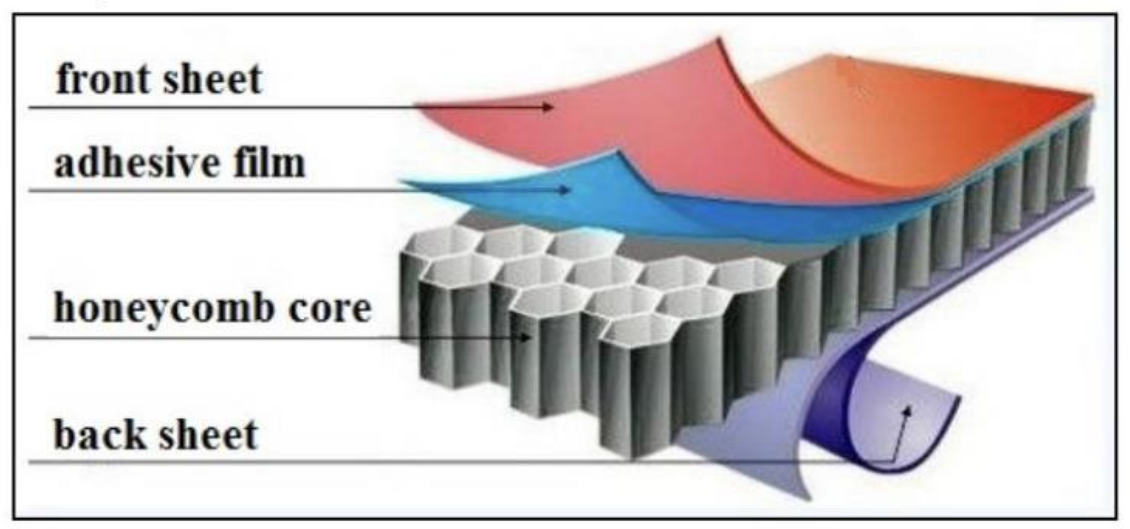


Figure 1. Honeycomb sandwich structures in Reference [1]

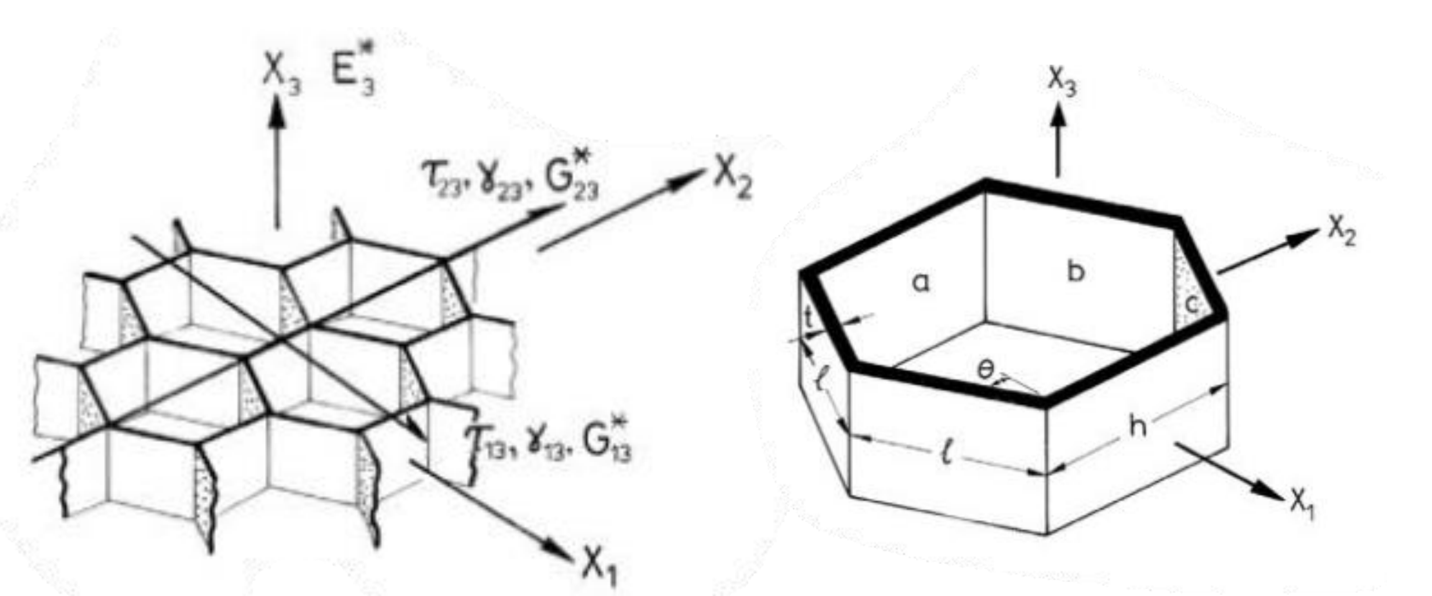


Figure 2. Loading directions of honeycomb structures in Reference [2]

Objectives

- Experimentally investigate the effects of the buckling initiator (BI) sizes and locations on the stress-strain behavior of the honeycomb structures.
- Present a honeycomb structure design with better crashworthiness capability.

Methodology

- The honeycomb structures were manufactured using the fused deposition modeling (FDM) 3D-printing method.
- Testing was done on 10mm and 12.5mm cell diameters with 1 mm, 2 mm, and 3 mm BIs diameters located at the top and/or bottom of the structures.
- The force-displacement curve testing was conducted by using the MTS (Materials Test System) machine.
- The force-displacement curve data was converted to the stress-strain curve data by post-processing.

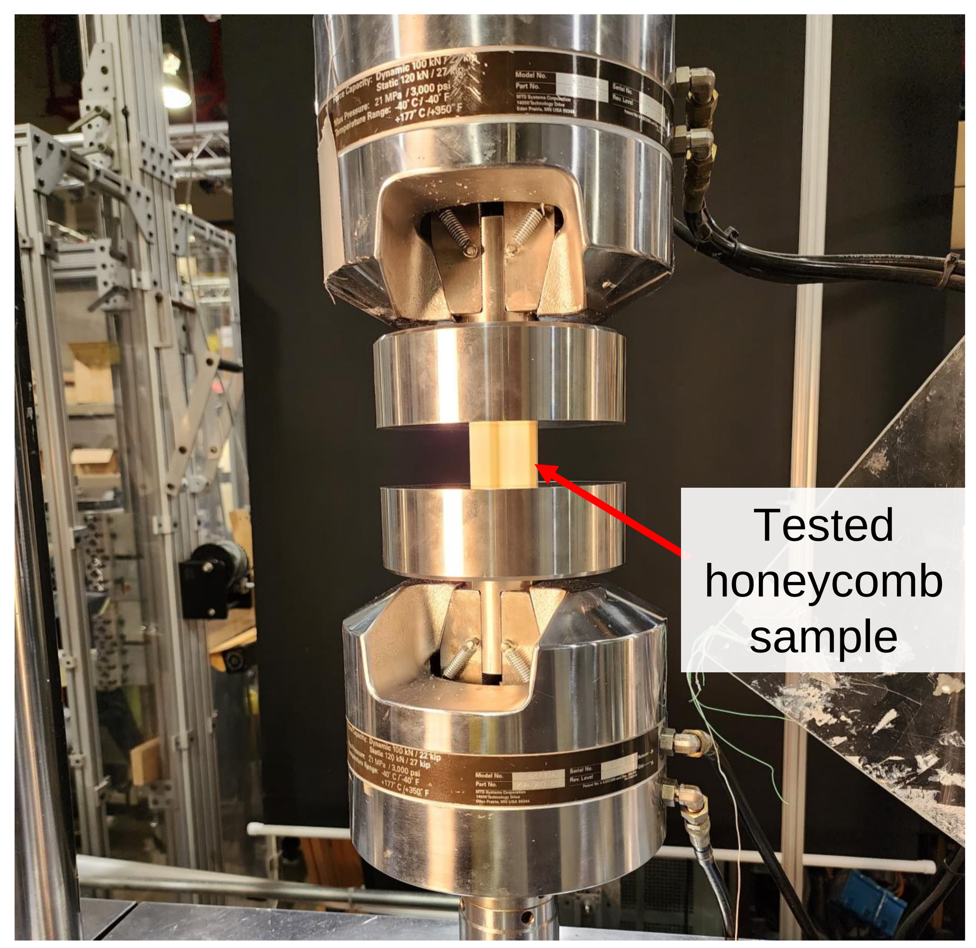
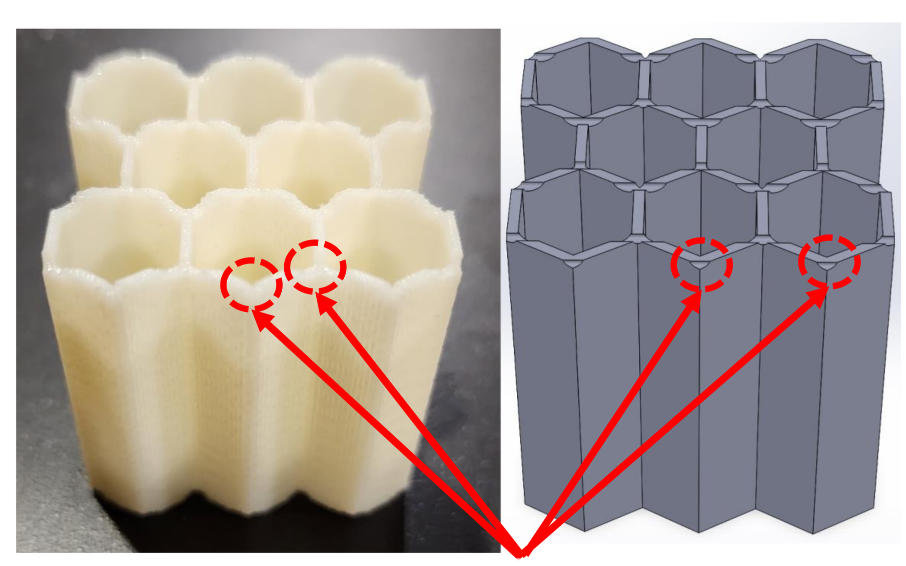


Figure 3. MTS Machine used to perform testing.



Buckling Initiators (BIs)

Figure 4a (left). Photograph of 3D printed honeycomb cell structure tested in this study.

Figure 4b. (right). 3D CAD model of the honeycomb cell structure

- 1 mm diameter of BIs at the top of the structure.

Results

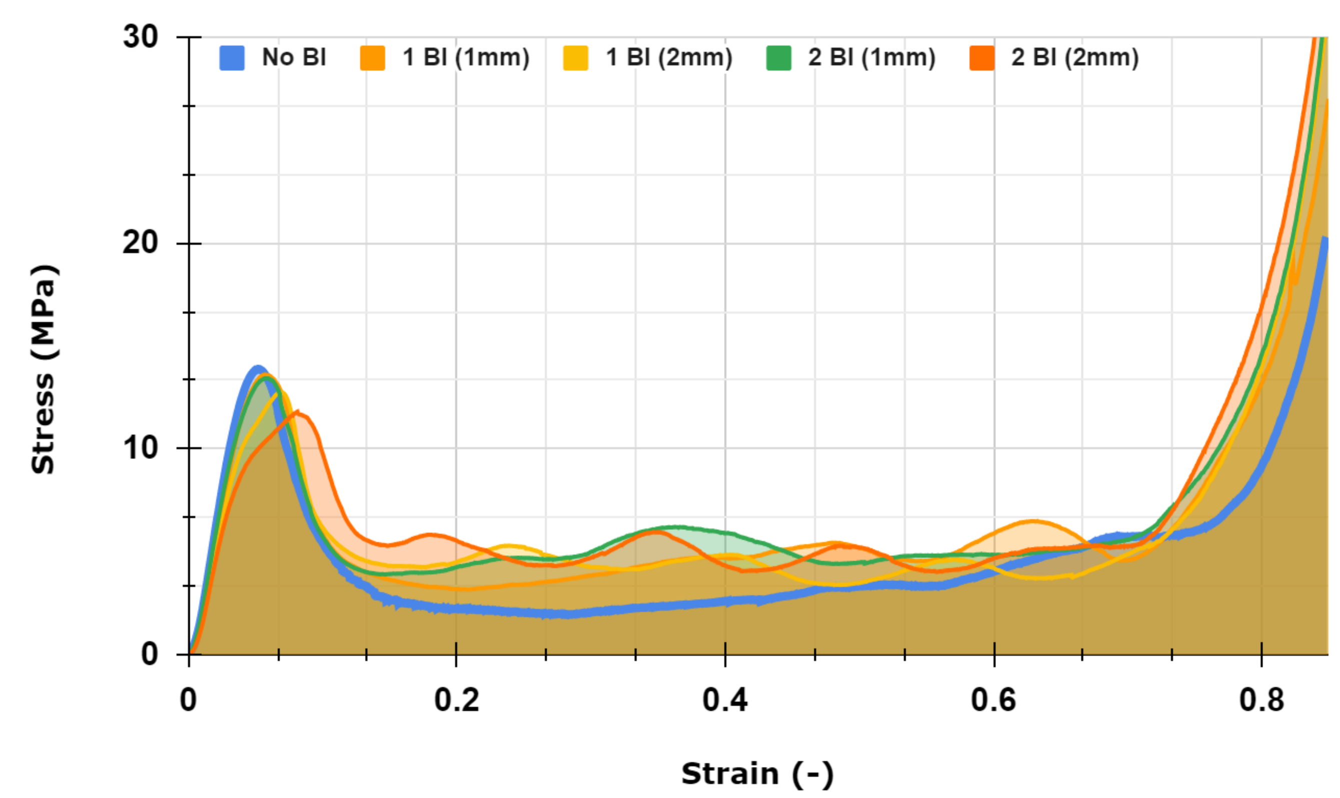


Figure 5a. Stress-strain curve for honeycombs with different BI diameters and locations (cell dia.: 10 mm)

- As the BI diameter increased, the initial peak stress decreased.
- BIs at the top location could reduce the initial peak stress just a little bit more than the no BI case.
- BIs at the top and bottom locations could not only reduce the initial peak stress than the no BI case but also increase the plateau stress more than the no BI case.

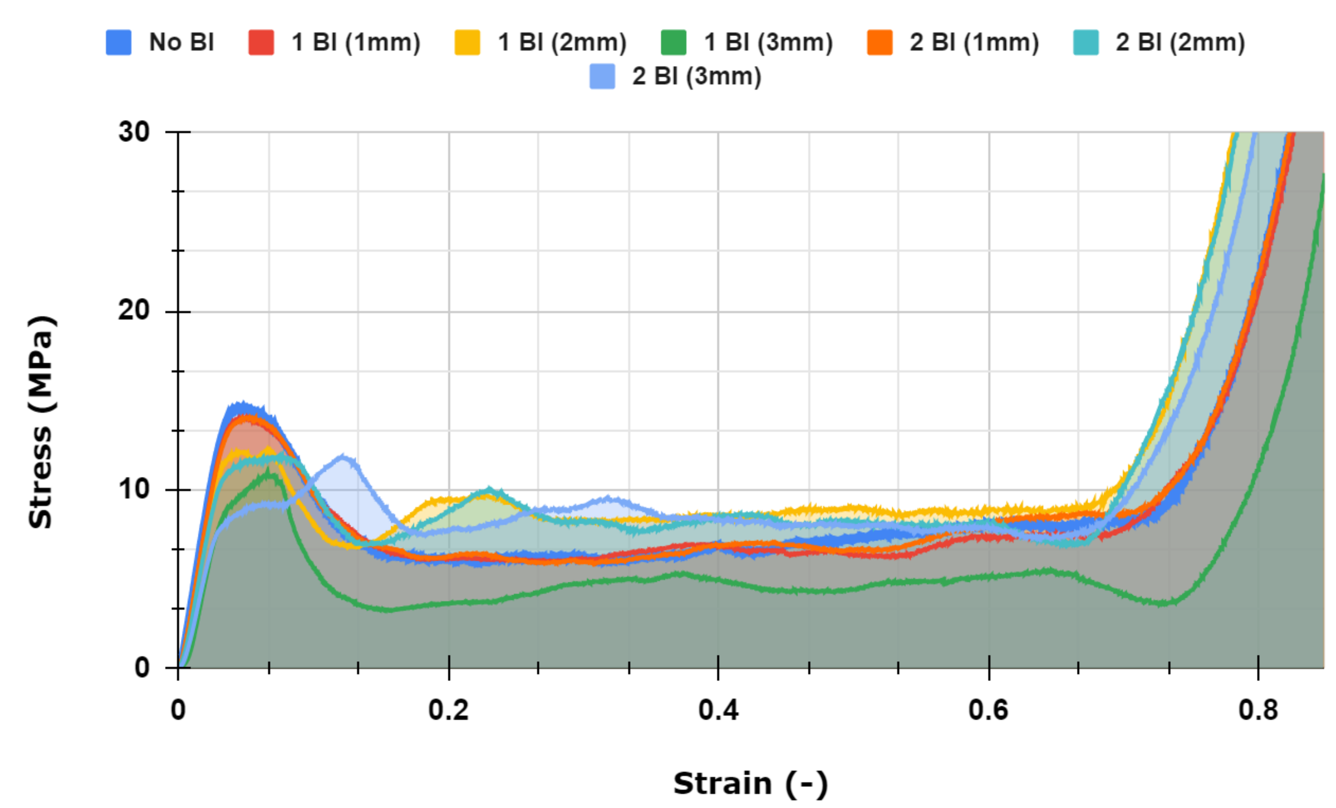


Figure 5b. Stress-strain curve for honeycombs with different BI diameters and locations (cell dia.: 12.5 mm)

- The initial peak stresses could be reduced in both BI cases: the BIs at the top location and the BIs at the top and bottom locations.
- Except for 1 BI (3 mm) case, both BI cases could increase the plateau stress than the no BI case.

Results (contd.)

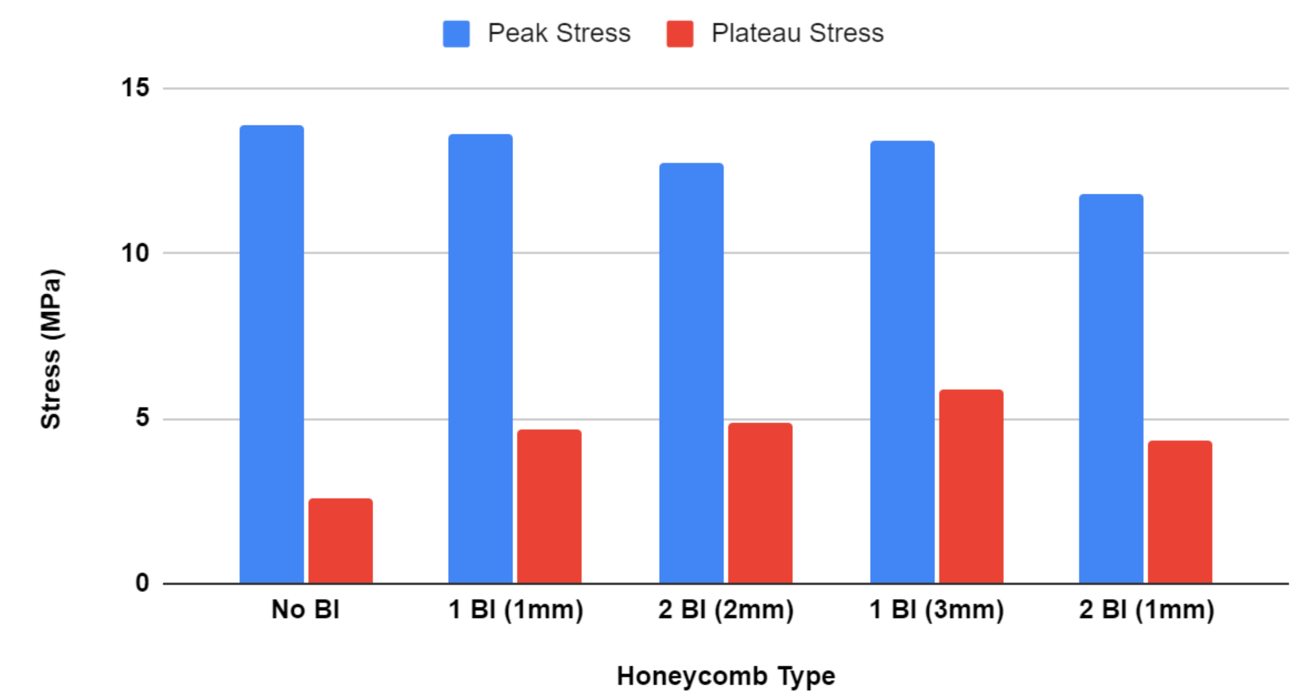


Figure 6a. Peak stress and plateau stress (cell dia.: 10 mm)

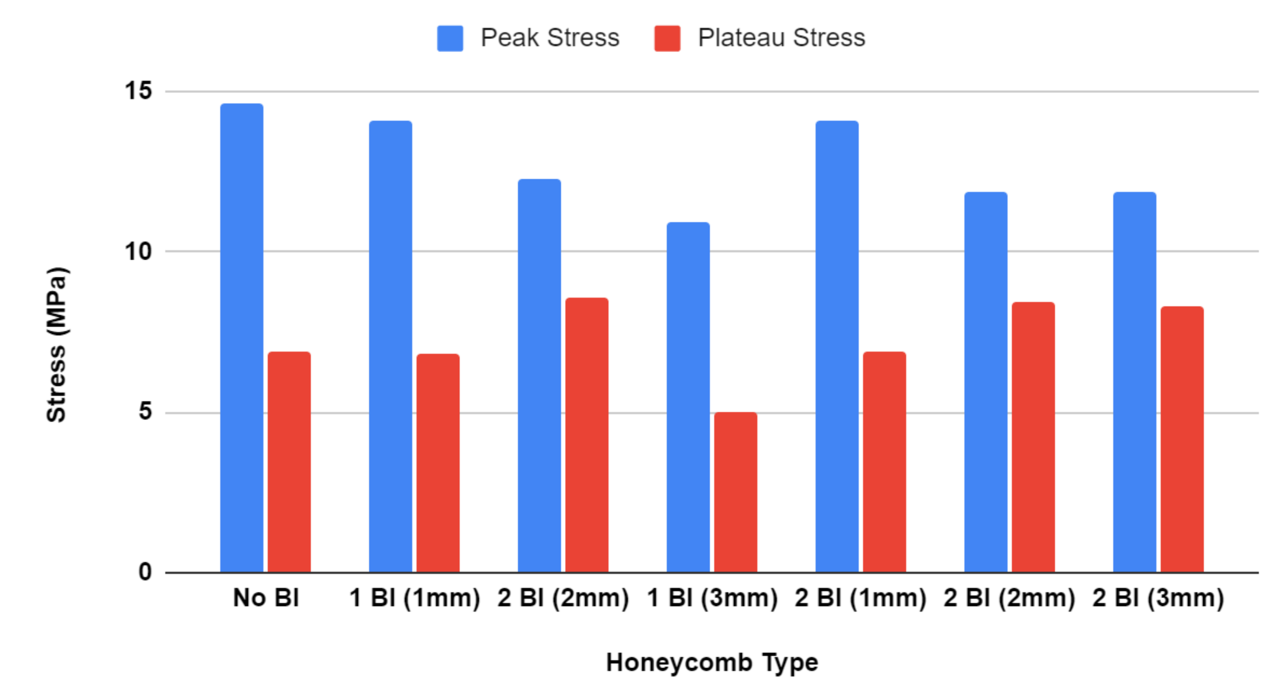


Figure 6b. Peak stress and plateau stress (cell dia.: 12.5 mm)

Conclusions

- Buckling initiators (BIs) could strongly influence the stress-strain curves of 3D-printed honeycombs
- Initial peak stress are decreased by BIs decreasing the elastic collapse stress. To maintain a similar area under curve, or energy dissipated, plateau stresses are raised.
- BIs allow stress-strain curves to become more constant, minimizing the acceleration during crushing

Future works

- Test honeycombs of different materials with BIs.
- Test honeycombs with different BI diameters and locations.

References

1. Petrovicand Lazarevic in Scientific Technical Review 2015, Vol.65, No.1, pp.50-56.
2. Gibson and Ashby in Cellular Solids: Structure and Properties. 2ndEd. Cambridge University Press, 1997