Development of 3D Printed Honeycombs for Crash Mitigation Applications

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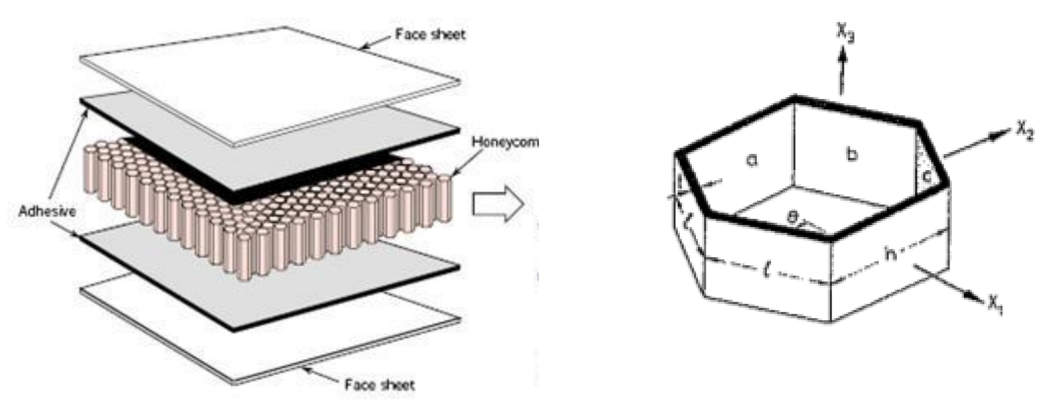
ABSTRACT

Honeycomb structures have been studied thoroughly to understand their in and out-of-plane mechanical properties. The ability of honeycombs to effectively absorb energy makes them ideal for usage in crash mitigation, particularly for helicopters and automobiles. Currently, when crushed by a dynamic load, there is an impulse in force prior to a steady absorption – which could be detrimental in such crash mitigation applications. In this study, 3D printed honeycombs are investigated for subsequent crush efficiency with quasi-static and dynamic crush tests. 3D printing, rather than conventional manufacturing, allows for structural modifications within the honeycomb that influence its force-displacement profile. Buckling initiators on the face and/or vertex of honeycombs should reduce the initial peak stress and increase the strain at which densification, the point at which the stress once again increases, begins. The experiment is not complete, but thus far, buckling initiators have proven to decrease the initial peak stress of tested honeycombs. Future directions for the project include testing honeycombs of other materials with buckling initiators, and the implementation of variations of current buckling initiator designs.



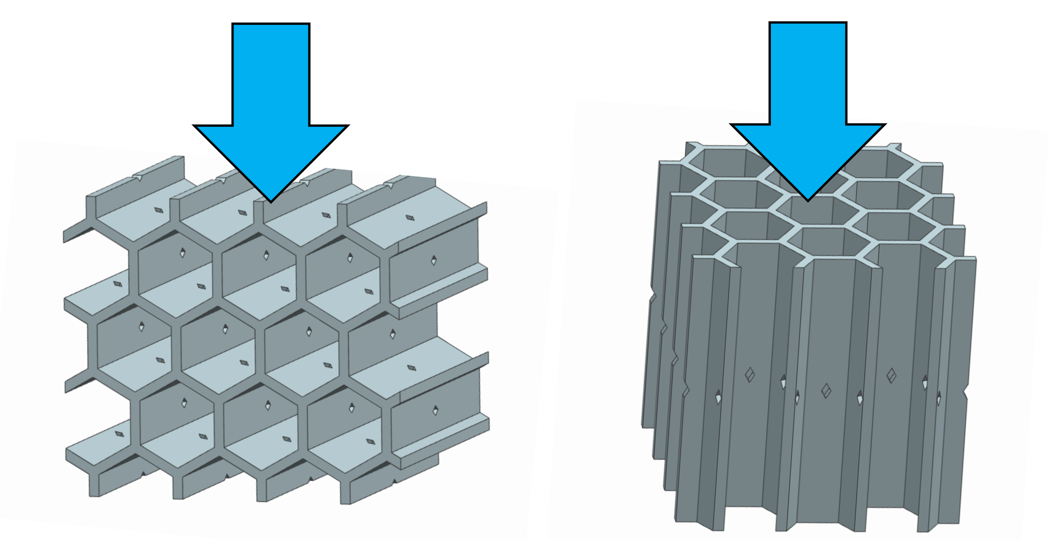


Figure 2a (left) and 2b (right) – 30mm tall honeycombs shown with diamond-shape vertex buckling initiators crushed in-plane (left), and diamond-shape face buckling initiators crushed in the out-of-plane direction (right)

OBJECTIVES

- Design 3D-printed honeycombs with buckling initiators
  - Test in out-of-plane direction to assess crush efficiency and energy absorption
  - Test out-of-plane properties for comparison with Gibson and Ashby equations and previous data

MATERIALS AND METHODS

- Honeycombs were printed on a uPrint SE 3D Printer with ABSplus filament and solid infill
- Honeycombs were printed with 1mm cell wall thickness, and were 30mm tall

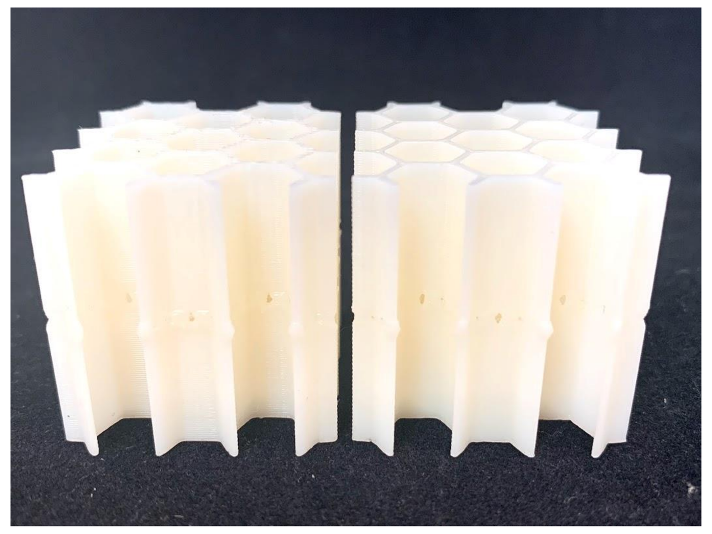


Figure 3 – 30mm tall honeycombs with .65mm diamond-shaped face buckling initiators

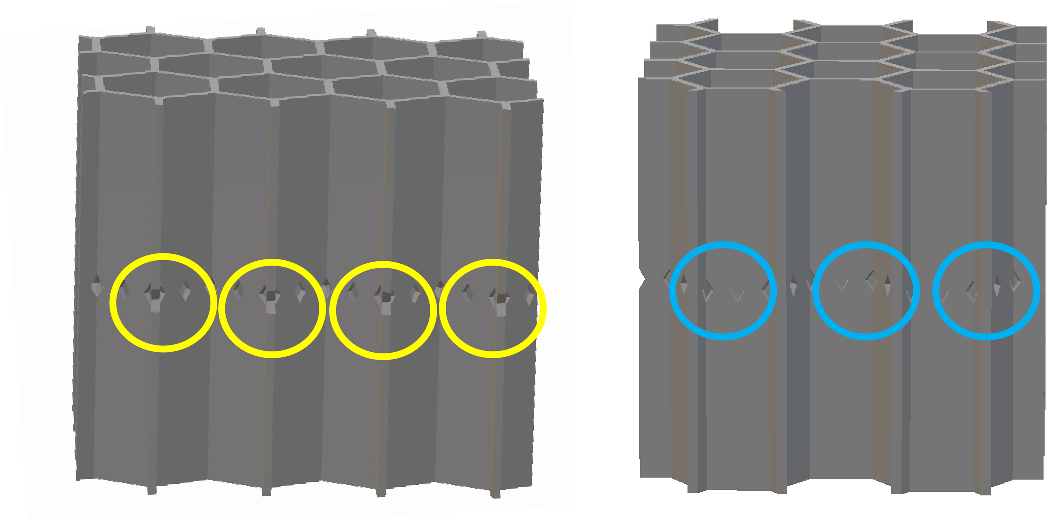
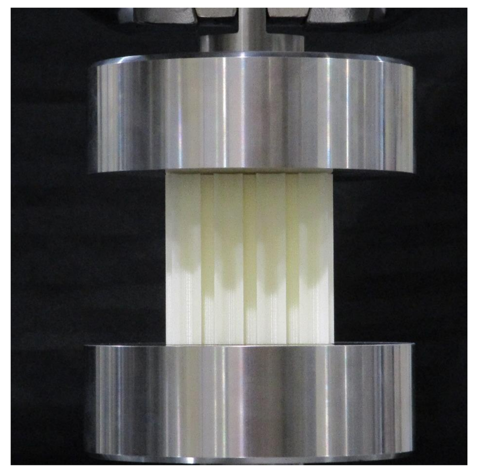
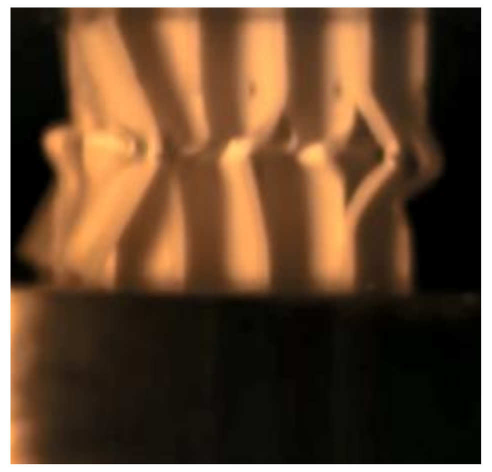


Figure 4a (left), 4b (right) – 30mm tall honeycomb with diamond-shape vertex buckling initiators (left) and diamond-shape face buckling initiators (right)

- Out-of-plane testing was conducted on a 20,000lb MTS Machine
- Testing procedures consisted of placing the honeycomb between two compression platens of the MTS machine, with a displacement of .002in/sec, .02in/sec, .2in/sec, and 2in/sec
- Compression platens were raised 1in above samples prior to testing began
- Dynamic testing was recorded with a high-speed camera to document crush testing



(above) 20,000lb MTS Machine Out-of-Plane Testing Configuration



(above) Diamond-shaped face and vertex buckling initiator crushed at .2in/sec

RESULTS

Face and Vertex Diamond Buckling Initiators Stress vs Strain

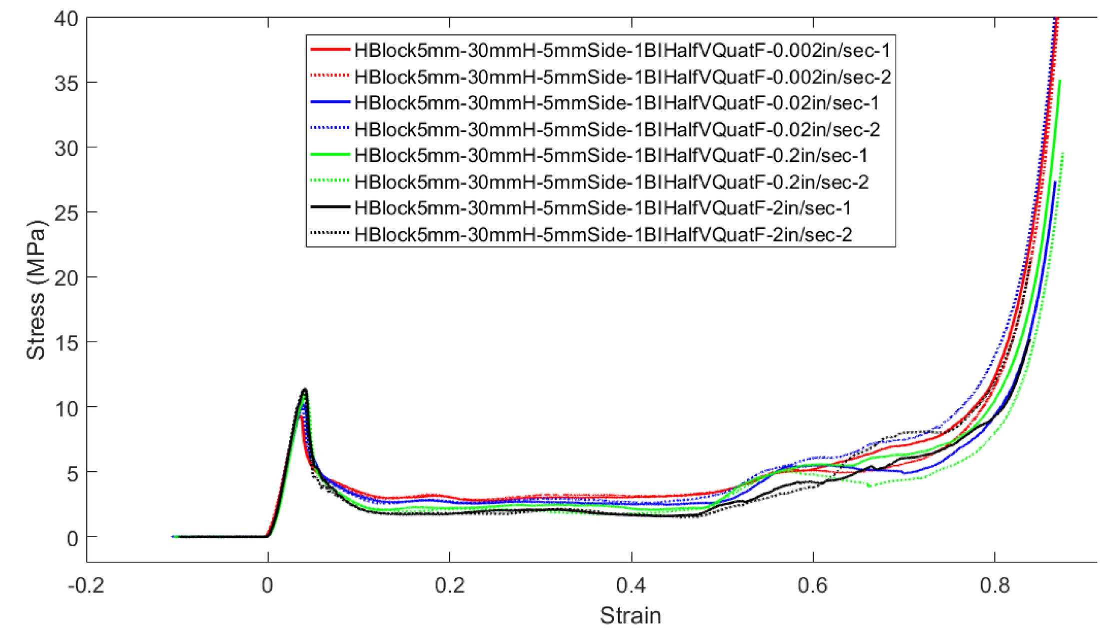


Figure 5. The resultant stress-strain curve from out-of-plane face and vertex diamond buckling initiators displays a minimized initial peak stress at all crush rates, with significant variation in the densification points for crush speeds of .2in/sec and 2in/sec.

Face/Vertex Circular Buckling Initiators Stress vs Strain

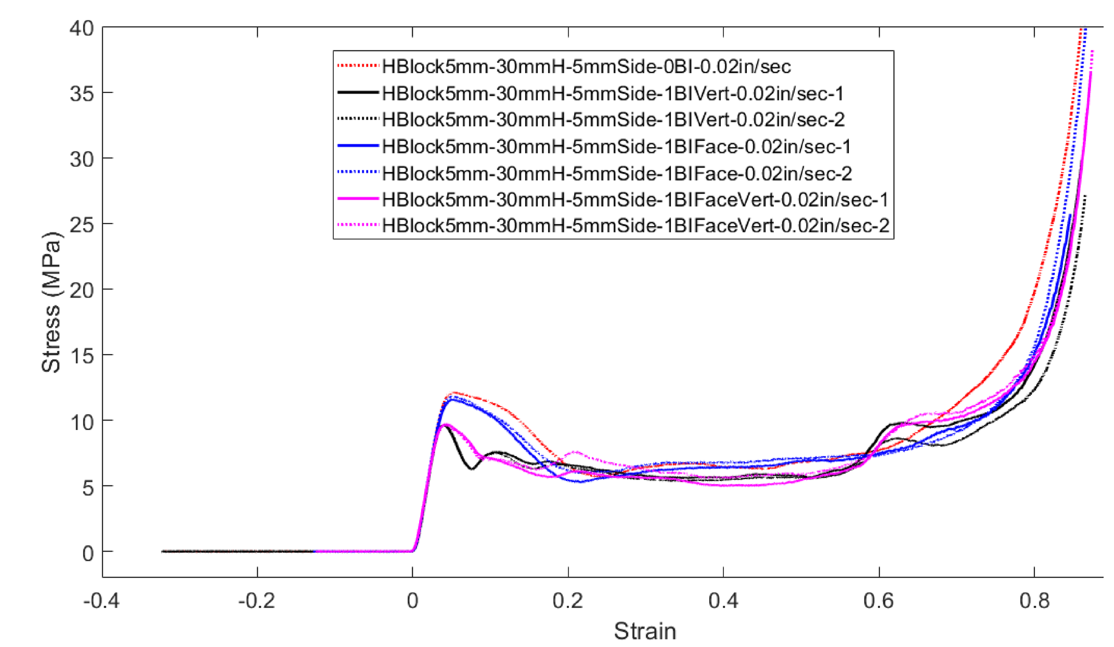


Figure 6. The resultant stress-strain curve from out-of-plane testing on 30mm tall honeycombs with 5mm face and/or vertex circular buckling initiators displays that circular face and vertex buckling initiators performed the best at decreasing the initial peak stress. The tested buckling initiators had comparable densification points.

Face/Vertex Diamond Buckling Initiators Stress vs Strain

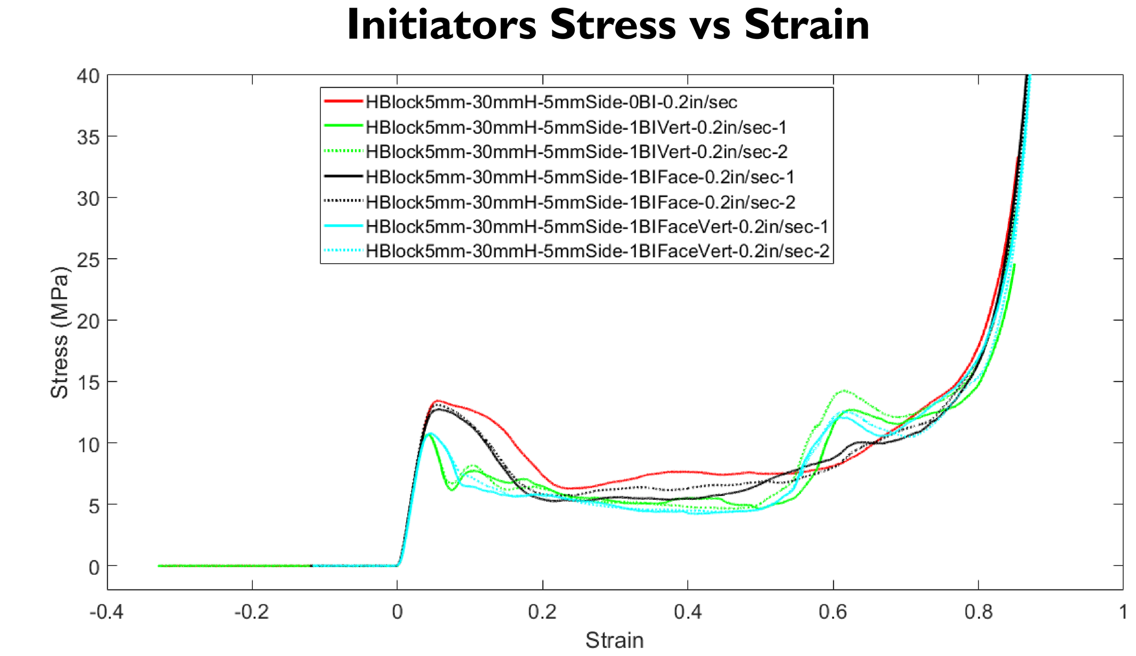


Figure 7. The resultant stress-strain curve from out-of-plane testing on 30mm honeycombs with 5mm diamond buckling initiators on the face and/or vertex indicates that at a crush of .2in/sec, face and vertex buckling initiators greatly decreased the initial peak stress compared to honeycombs with only face or vertex buckling initiators.

CONCLUSIONS

- Buckling initiators have shown to influence the stress-strain curves of 3D printed honeycombs
  - Initial peak stress has shown to decrease with the implementation of buckling initiators, along with later points of densification

FUTURE WORK

- Continue testing previously designed honeycombs to compare design efficiency
- Test honeycombs of various materials (aluminum, foam, etc.) with buckling initiators
- Test honeycombs of various cell-design (flower petal)
- Conduct drop tests on printed honeycombs with high-speed camera

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