Passive Terminal Decelerator

Blue Origin Industry-Sponsored Capstone
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Introduction/Motivation

Background:

- The Blue Origin New Shepard Crew Capsule lands in the desert with redundant safety systems: parachutes, active deceleration, and passive deceleration.
- To minimize astronaut sensed acceleration, an aluminum Passive Terminal Decelerator (PTD) absorbs any remaining impact energy.
- The PTD is replaced every flight. Reusing the PTD would minimize waste and help lower overall launch expenses.

PROBLEM STATEMENT

Blue Origin seeks to understand how the PTD performs after experiencing partial damage and to assess reusability.

Testing Criteria:

- Record acceleration data for impact at low and high speeds
- Apply damage to core and characterize compressive behavior change.
- Use FEM to model the behavior of the PTD

Figure 1: Side View of the PTD

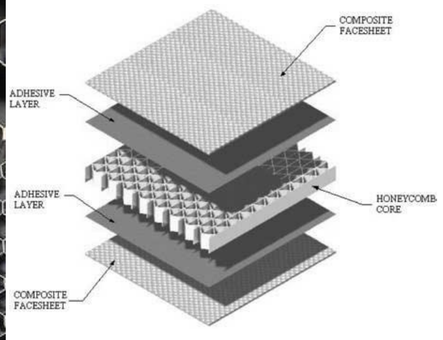

Figure 2: Examples of aluminum honeycomb crushables

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Testing/Data Processing

Compression Testing:

We used an Instron Load Frame to verify the mechanical properties of the PTD and to determine the energy absorbed by the material.

Figure 3: Sample in Instron Load Frame

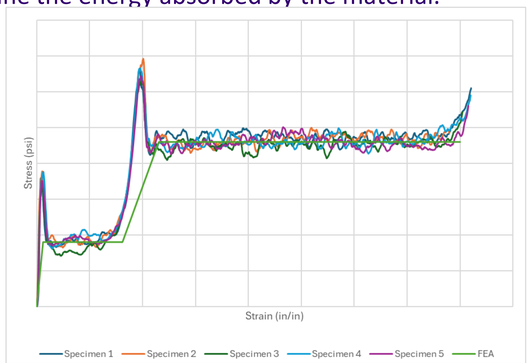

Figure 4: Stress vs Strain Plot of Five Samples

Impact/Compression After Impact Testing:

We designed and built an impact frame to compare mechanical behavior after a dynamic impact load with the undamaged quasi-static behavior.

Figure 5: Sample on Impact Frame

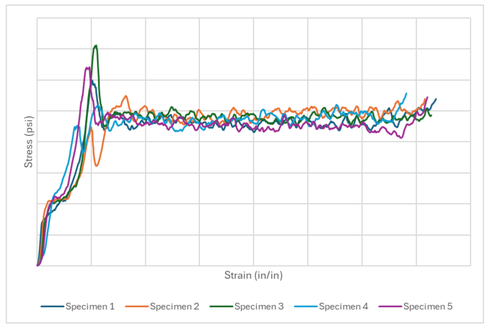

Figure 6: Stress vs. Strain from post-impact compression testing

Energy Absorbed Comparison:

Test Type	Crush Test Energy Absorbed	Percent Deformation
Crush Test	100%	80%
Impact	4.1%	7.4%
Post Impact Crush Test	98.2%	72.6%

Results/Validation

Harry-Turner Equation to Predict Energy Absorption:

$$E = A \cdot \int_{d}^{0.8*(t_2+t_1)} \frac{\Delta\sigma}{1+e^{-(\frac{4\cdot E_2}{\Delta\sigma})(x-(\frac{\Delta\sigma}{2*E_2}+0.8\cdot t_1))}} + \sigma_1\left(1-\frac{2\cdot\sigma_1}{E_1\cdot t_1}\right) dx$$

E = Energy

A = Area

- $\sigma 1$

t1 = bottom core thickness

t2 = top core thickness

$\sigma 1$= first core crush strength

$\Delta\sigma = \sigma 2$

E 1,2 = Core Young's Modulus

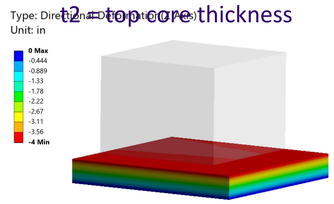

Figure 7: FEA Simulation of PTD Sample

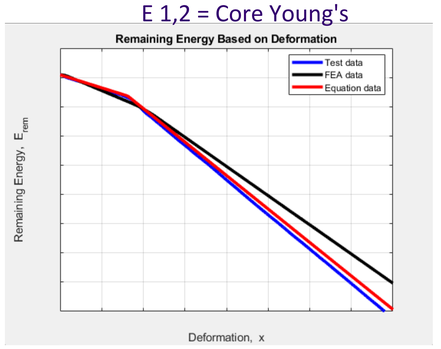

Figure 8: Comparison of FEA vs Impact vs Crush testing data

Conclusion & Next Steps:

- Data collected from this study is scalable to other crushables used at Blue Origin. Our data suggests that at a ratio of 45-lbs to 25 square inches, the PTD can be reused once after being impacted at nominal speed with uniform crushing before the PTD will not absorb energy; it will instead transfer it to the crew capsule.
- The final determination for reusability will be left to the discretion of the client, as that is proprietary information.

Acknowledgements:

A big thank you to Dr. Sayem Bin Abdullah, Prof. Junlan Wang, Prof. Eli Patten, Veasna Thon, Eamon McQuaide, and Bill Kuykendall of the UW Seattle ME Department. A thank you as well to Connor Caler, Keith Anderson, Sara Olsen, and the rest of the Blue Origin team!

Sources:

Mechanical Engineering Capstone Exposition
June 3, 2025, Husky Union Building, University of Washington, Seattle