OmniShield: A Geometry-Driven Combat Helmet Padding for Multi-Threat Protection

Morteza Seidi, Ph.D., P.E.,[1], Alireza Abbasi Ghiri1, MS[1], Daniel Portillo, Ph.D.[2]
[1]University of Texas at San Antonio, San Antonio, TX ; [2]Southwest Research Institute, San Antonio, TX

Introduction

Combat helmet padding must address competing mechanical requirements under ballistic and blunt impact conditions including ballistic impact, blunt impact, and blast wave (Fig. 1). Under localized, high-energy ballistic loading [1], the padding system must provide sufficient local resistance to support helmet shell deformation and reduce force transmission to the head. In contrast, under distributed, lower-energy blunt impact [2], the padding should provide controlled compliance to absorb impact energy and reduce transmitted force. Under blast loading [3], the padding should help attenuate rapid pressure-wave transmission and reduce the pressure transmitted to the head. Conventional foam- [3] and lattice-based [4] padding systems (Fig. 2a) rely primarily on material viscoelasticity, which can limit their ability to adapt distinct deformation-mode and load-path across fundamentally different impact regimes.

Fig. 1: Primary Military Helmet Threats: Loading Dynamics and Characteristics.

Design Concept and Objective : This study presents OmniShield (Fig. 2a), a passive geometry-driven combat helmet padding architecture based on pre-curved buckling columns, designed to produce distinct boundary-condition-dependent deformation-modes and mechanical responses (Fig. 2d) under ballistic and blunt loading. OmniShield units consist of interconnected, pre-curved polyurethane columns with thin curved connectors near the upper region (Fig. 2a). Under distributed blunt impact, the main columns buckle inward while the connectors undergo near-zero-force local buckling, producing a compliant response (Fig. 2b). Under localized ballistic impact, shell indentation and lateral **wave propagation** engage the upper columns and tension the connectors, reconfiguring the load path to provide greater local resistance. The objective of this work is to experimentally evaluate whether a geometry-programmed padding design with deformation-mode switching can improve multi-threat helmet performance compared with commercial foam- and lattice-based padding systems.

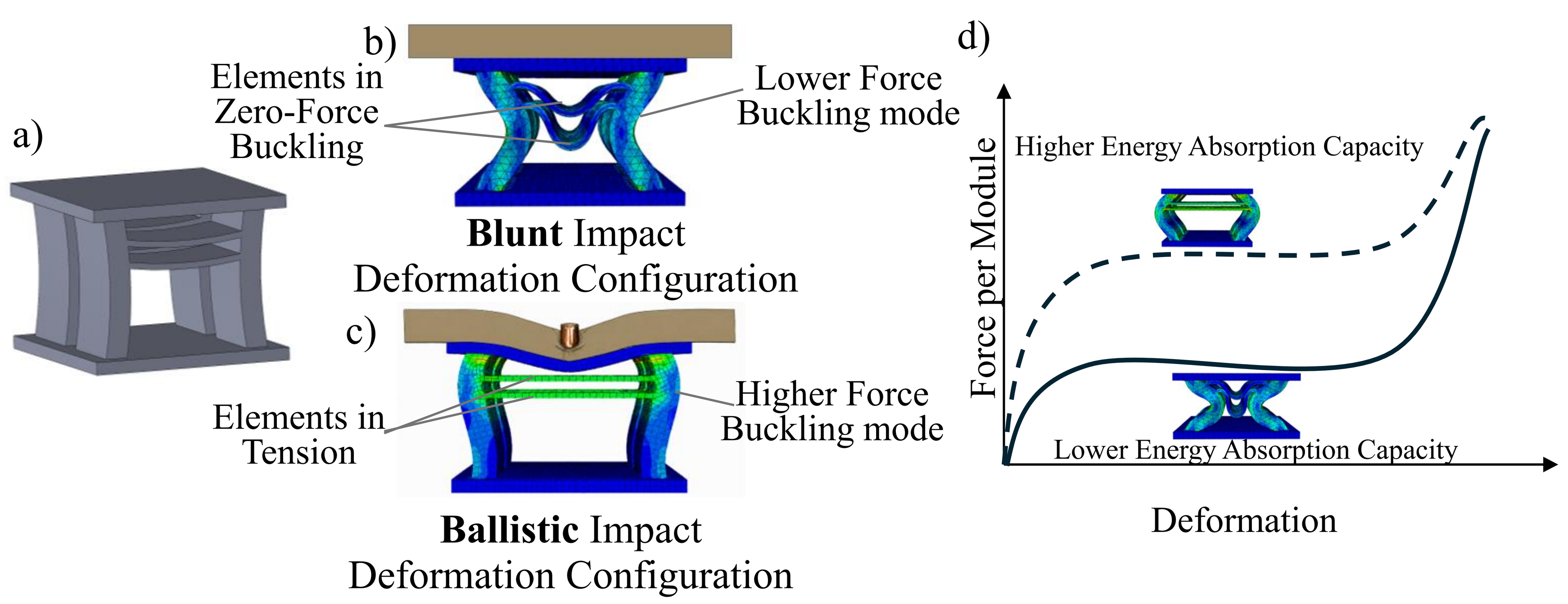

Fig. 2: OmniShield unit design and expected deformation modes under blunt and ballistic impact.

Method

OmniShield was compared with three commercial padding systems: GN-ATP Type III, MICH basic foam, and Hard Head Veterans lattice padding (Fig. 3c). Each system was installed in a large MICH helmet and tested using a Hybrid III 50th-percentile head–neck assembly. Ballistic tests used 124-grain 9 mm FMJ rounds at 1400 ft/s under NIJ-relevant Level III-A conditions (Fig. 3a) [5], while blunt tests used a linear impactor at 17 ft/s following the Army standard (Fig. 3b) [2]. Front, side, and rear impacts were evaluated using peak linear acceleration (PLA), peak angular velocity (PAV), and Head Injury Criterion (HIC) as brain injury metrics.

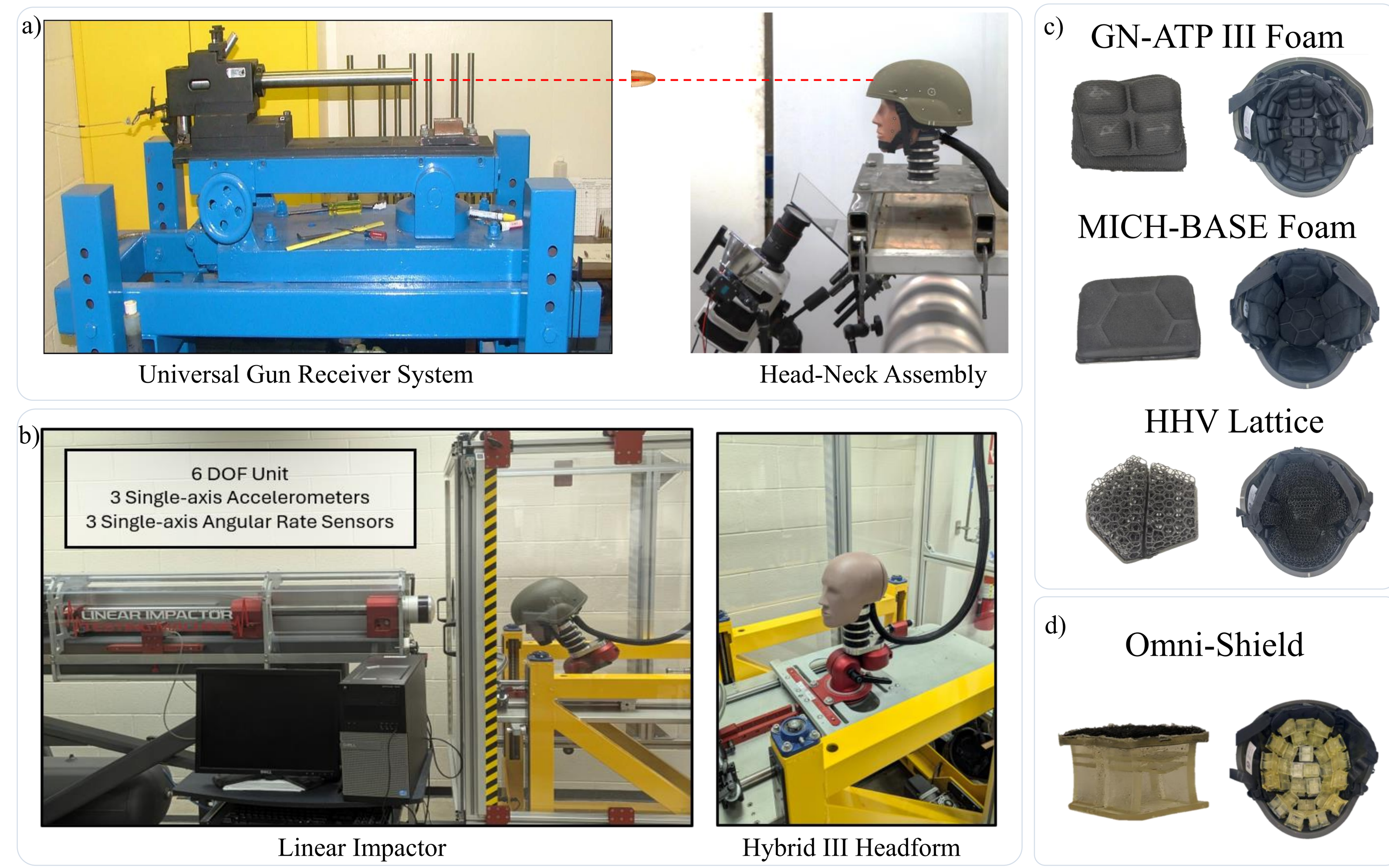

Fig. 3: Experimental setups for (a) ballistic impact and (b) blunt impact testing; Combat helmet padding systems evaluated in this study: c) commercial baseline padding d) the proposed OmniShield geometry-driven padding system.

Results and Discussion

High-speed imaging confirmed that OmniShield produced distinct deformation modes under ballistic and blunt impact conditions (Fig. 4). Under localized ballistic impact, helmet shell indentation and lateral wave propagation engaged the upper column regions and placed the curved connecting elements in tension, producing a more resistant deformation mode. In contrast, under distributed blunt impact, the helmet shell compressed the padding over a larger contact area, promoting inward buckling of the main pre-curved columns and zero-force engagement of the connecting elements. This response demonstrates that OmniShield can reconfigure its load path based on impact boundary conditions, enabling a stiffer localized response under ballistic loading and a softer response under blunt loading.

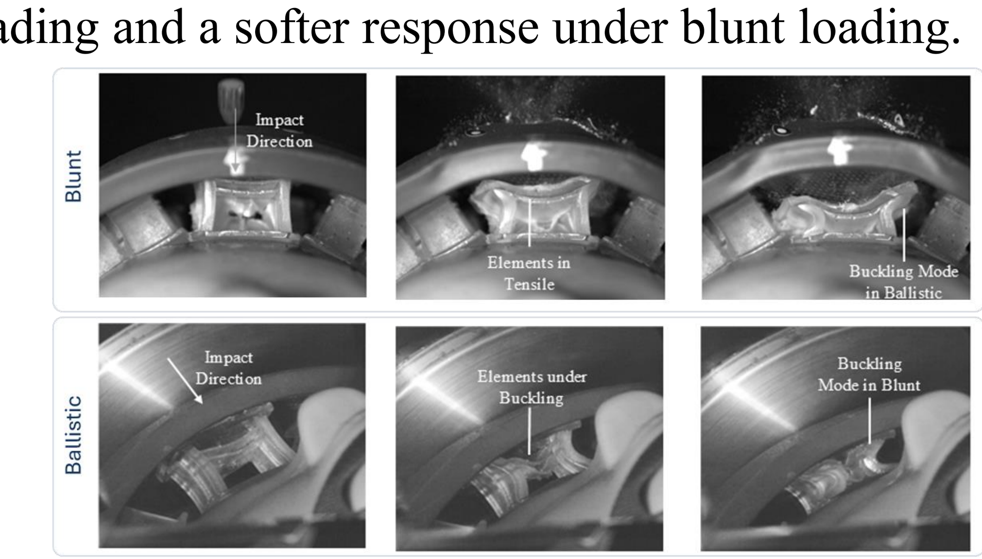

Fig.4. High-speed images confirming the distinct deformation modes of OmniShield under blunt and ballistic impacts

Results and Discussion

Blunt Results: At 17 ft/s, OmniShield provided strong blunt-impact attenuation, with performance varying by impact location (Fig. 6a). At the front, it produced the lowest PLA, HIC, and PAV among all four padding systems, demonstrating effective control of both linear and rotational head motion. At the side, OmniShield maintained lower PLA and HIC than the MICH-BASE foam and HHV lattice, although the GN-ATP III foam performed better; its PAV was higher than those of the baseline systems. At the rear, OmniShield substantially reduced PLA, HIC, and PAV relative to the HHV lattice, but the foam systems generally produced lower PLA and PAV. These location-dependent trends show that OmniShield provides competitive blunt protection, particularly at the front, while side and rear rotational performance may benefit from further optimization of module placement and orientation.

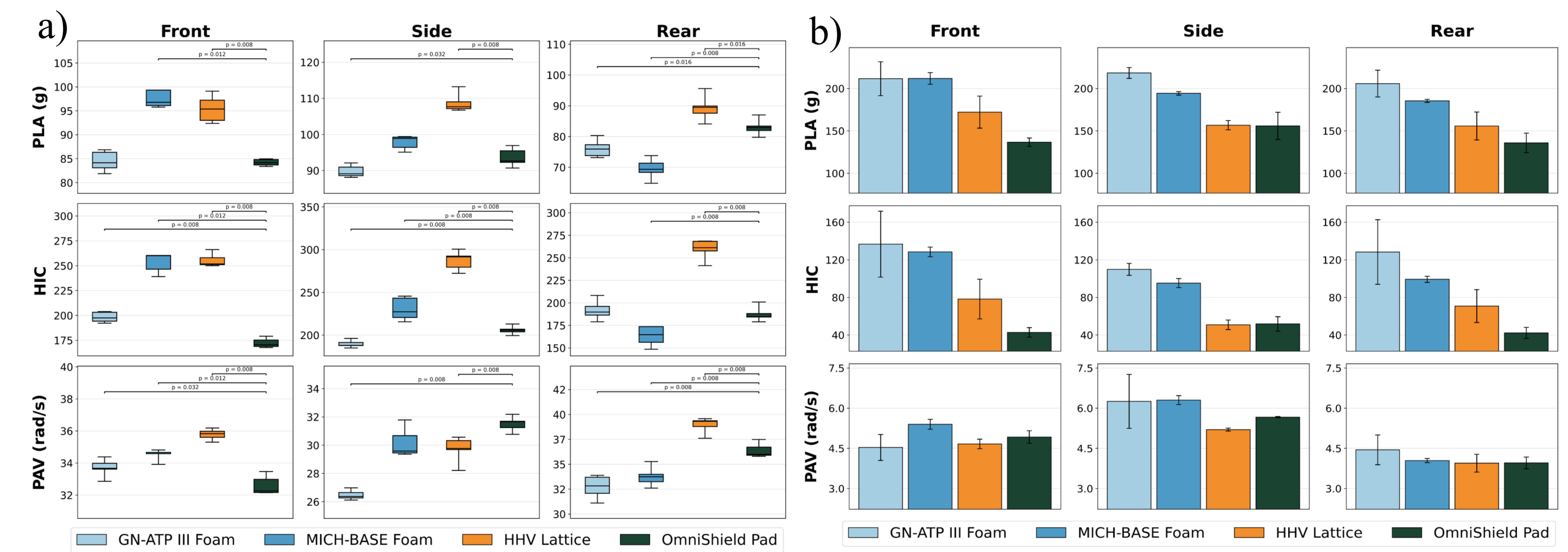

Fig.6: a) Blunt impact b) Ballistic impact responses of baseline & OmniShield pads

Ballistic Results: Under ballistic impacts, OmniShield consistently produced the lowest peak linear acceleration (PLA) and Head Injury Criterion (HIC) across the front, side, and rear locations (Fig. 6b). Compared with the GN-ATP III and MICH-BASE foam systems, OmniShield **reduced PLA by 20–36%** and **HIC by 46–69%.** Relative to the HHV lattice, it reduced **PLA by 1–21%** and provided HIC values that were **comparable to or up to 45% lower,** depending on impact location. Differences in peak angular velocity (PAV) were smaller and location-dependent; OmniShield remained within −9% to 11% of the baseline systems, indicating similar rotational response. Across all tested locations, the reductions in linear response demonstrate that tensile connector engagement and outward upper-column deformation provide effective local support during ballistic loading.

Conclusion: The study introduces a paradigm shift in combat helmet design by showing that a geometry-programmed padding system can switch deformation modes and mechanical responses to better match different loading conditions. This mode switching allows the padding to absorb energy efficiently under both blunt and ballistic impacts while reducing dependence on material properties alone, pointing to a more adaptable approach to multi-threat protection.

Acknowledgement

Supported by the UT San Antonio-Southwest Research Institute CONNECT Grant.

References

[1] Li, Y., et al., Compos. B Eng. **238**: p. 109890, 2022.
[2] Neice, R., et al., PASS, 2020.
[3] Hsieh, Y.-C., et al., J. Chin. Inst. Eng.. 1–14, 2025.
[4] Fisher, T., et al., Compos. Struct. **376**: p. 119846, 2026.
[5] National Institute of Law, E., et al. 1978, U.S. DOJ.