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Balancing Ballistic and Back-Face Deformation in Helmets: The Role of Alternative Resins, Fibers, and Fiber Architecture in Mass-Efficient Head Protection

26^{tth} International Ballistics Symposium

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Historically, aramid-based fibers with thermoset-based matrixes have been the material of choice for ballistic helmets in the United States. Developed by DuPont, Kevlar was the first commercial aramid fiber that was used significantly in both military and commercial applications; eventually, Twaron emerged as an alternative aramid fiber source. In the interim, entirely different classes of ballistic materials emerged, including ultra high molecular weight polyethylene (UHMWPE) materials such as Dyneema and Spectra. The "palette" from which to construct mass-efficient ballistic protection for both head and torso body armor protection has grown, and the availability of these fibers in various formats (unidirectional, tapes, woven fabrics) and host resin systems (thermoset, thermoplastic) offer entirely new, hybridized options for balancing both ballistic resistance and back face deformation response. Indeed, the challenge in providing increasingly lighter armor is not in simply arresting projectiles, but in ensuring the associated dynamic deflections do not induce trauma such as skull fracture or excessive acceleration of the head or brain. Recent results suggest that varying the content and type of resin and fiber, together with the orientation and fiber architecture, can provide a more robust and desirable combination of ballistic and dynamic deflection behavior at reduced weight.

The present goal is to produce a helmet that is significantly lighter than the current Army Combat Helmet (or ACH as it is known). The goal is to deliver all current specifications of the ACH but at an areal density 80% or less of the incumbent ACH. This is a nontrivial challenge. Reducing weight will likely indicate a reduction of thickness (though lightweight foam core concepts are under consideration). Thus, less mass and volume are available to successfully arrest not only the projectile(s) but also manage both the static and dynamic back face deformations so they do not exceed the current ACH requirements. Future helmet requirements (Figure 1) are also being tasked to consider other factors, such as mitigating adverse blunt impact and blast impulses. The current research has developed an integrated suite of material and characterization techniques to serve as tools in the development of new material systems and head protection concepts. Figure 2 is an example of a modal survey technique developed to examine the coupled response of the ballistic shell and suspension materials. A host of additional techniques such as Digital Image Correlation, (DIC), impact testing, ballistic characterization, multi-scale hybridization, and fiber architecture indexing have been used to identify promising candidates to meet future weight goals and protection levels.

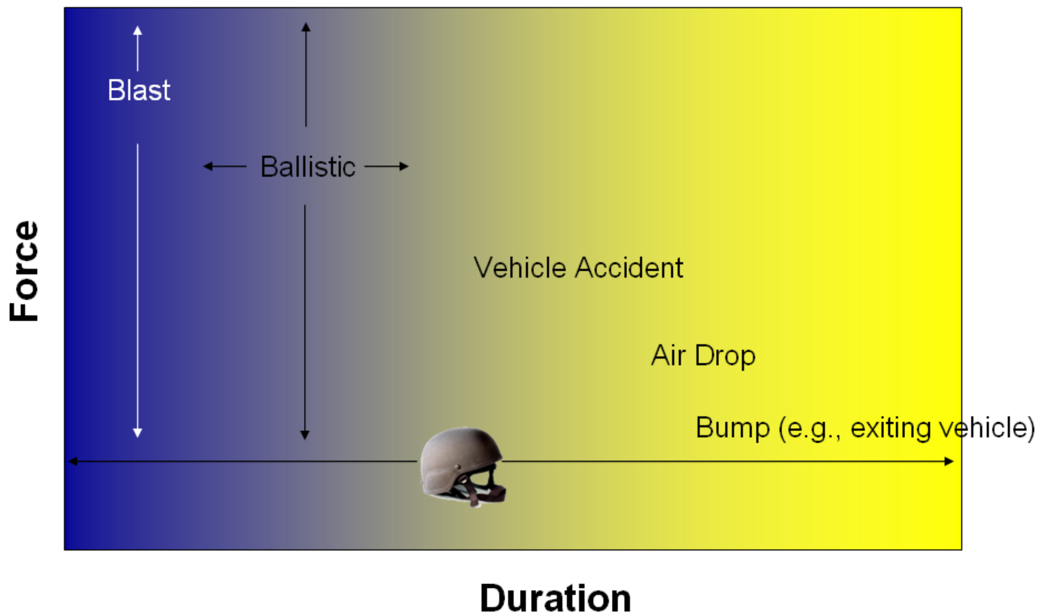

Figure 1. Future Helmets Demand Robust Protection

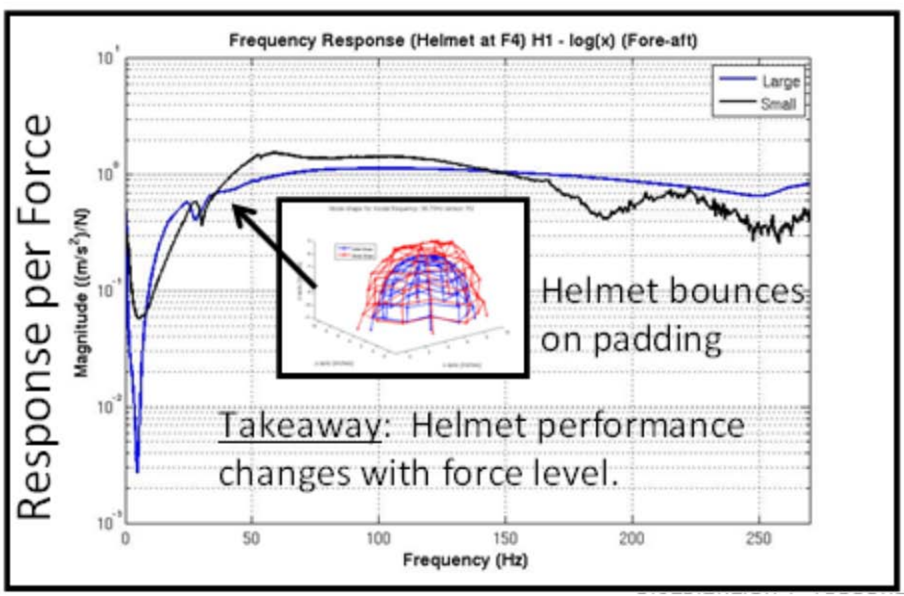

Figure 2. Development of Test Methods for New Lightweight Material and Design Helmet Concepts