Protective Equipment

Polymer Coating for Protection against Traumatic Brain Injury (TBI)

The Office of Naval Research (ONR) supported efforts at Naval Surface Warfare Center, Carderock Division (NSWCCD), Naval Research Laboratory (NRL) and Naval Surface Warfare Center, Dahlgren Division (NSWCDD) to develop and optimize low-cost helmet coatings that exploit the shock and ballistic performance of highly rate-sensitive polymer coatings (HRSPC), developed under ONR Science and Technology (S&T) investments. HRSPC have been demonstrated to provide added protection against shock wave-induced mild TBI (mTBI), along with ballistic protection, without additional weight added to the helmet. Results were shared with the Natick Soldier Research and Development and Engineering Center (NSRDEC). Earlier investigations by NSWCCD and NRL showed that HRSPC applied to an existing helmet could provide significant reductions in intracranial impulse during blast tests using full-scale instrumented head-neck manikin surrogates. However, the added coating resulted in a heavier helmet. New underweight helmets were fabricated from conventional Kevlar, Kevlar XP H170 and Tensylon fabric, which were coated with the selected HRSPC to the equivalent weight of a standard helmet, and tested for the ballistic requirements. Blast tests were performed at NSWCCD test pit and at Naval Surface Warfare Center, Indian Head Explosive Ordinance Disposal Technology Division using larger improvised explosive devices (IEDs) at a defined range of blast conditions. Blast pressures selected were based on likelihood of generating mTBI conditions using Bowen Blast Curves and findings from Army Research Office Multidisciplinary University Research Initiative (University of Pennsylvania, Columbia University, Duke University). Measurements on the test manikins included pressure, impulse, acceleration, and power intensity at different intracranial sites. Examination of different coatings and thicknesses showed that certain thin coatings could reduce intracranial power intensity by 23 percent, but an even better result of 38 percent was realized when ballistic fabric material was coupled with the coating. These combinations met ballistic specifications. NRL developed hollow silicon carbide spheres that were embedded in the HRSPC applied to the helmets. These coatings provided improved performance for blast mitigation of tested Kevlar designs, reducing acceleration by 30-40 percent when compared to the standard Advanced Combat Helmet (ACH). Ballistic tests were done to enumerate different mechanisms of energy absorption/deflection at different temperatures and different coating glass transition temperatures. Hopkinson-bar tests were used to study various design parameters and to optimize performance, including: (1) effect of molecular weight and blending of the components of the polymer coating; (2) composition and layering variations of laminate coatings; and (3) substrate hardness and its coupling to the coating. NSWCDD conducted a series of blast attenuation tests on several Kevlar composites and HRSPC/composite combinations. Tests were done in a single stage gas gun with a shock tube to simulate low-amplitude planar blast waves at 0.5 – 2.5 bar. This blast range is required for studying material effectiveness for TBI mitigation. The planar blast waves induced one-dimensional strain in the target materials. HRSPC applied to the impact side of Kevlar composites can reduce output stress of Kevlar, thus mitigating TBI pressures.

Lightweight ACH and Enhanced Combat Helmet designs that reduce the possibility of mTBI results were verified against actual IEDs and close-in explosive tests using acceptable intracranial exposure levels, impulse, and acceleration criteria. The proposed polymer coated helmet exceeds military standards (MIL-STDs) ballistic requirements, while satisfying all other MIL-STDs. In addition, the coating, while enhancing the helmet performance for protection against mTBI, ballistic, and weight requirements, offers at the same time protection against sharp-edged flechette-type devices. Researchers at NSWCCD and ONR received the 2014 Vice Admiral Harold G. Bowen Award for Patented Inventions for their contributions to the patent “Armor Including a Strain Rate Hardening Elastomer.”