Session

Computational Modeling of Human Effects due to Low-Level Blast Exposure
Blast-related Injuries - Prevention, Mitigation & Treatment
Abstracts submitted to this session should address any of the following topics:
(1) Computational methods to capture low level blast shockwave interaction with the human body & military environments,
(2) Computational modeling of injury prediction related to low-level exposure of blast, or
(3) Computational modeling of how mitigation strategies reduce exposure & potential injuries.

Title

Why the Helmet Military Specification Test Should be Revised to Include a Rotational Component

Authors

Chad Hovey PhD(1), Alice Fawzi(2), Ron Szalkowski(3), Sushant Malave(3), Ryan Terpsma(1), Christian Franck PhD(4)

1 Sandia National Laboratories, Albuquerque, NM
2 Brown University, Providence, RI
3 Team Wendy, Cleveland, OH
4 University of Wisconsin-Madison, Madison, WI

Abstract

Human blast exposure can lead to serious and life-threatening injuries, typically classified as primary, arising from the blast wave, and targeting the lungs, middle ear, and brain; secondary, caused from flying debris; tertiary, resulting in blunt impact of the body with its environment; and quaternary, resulting in all other sequelae. In this cascade of potential injuries, blunt impact to the head remains a primary concern, given the critical nature of the brain. The warfighter's helmet is the main method for head protection, yet much remains to be learned about how well the helmet actually protects the brain.

The Advanced Combat Helmet ("ACH") military specification ("mil-spec") requires a helmeted magnesium Department of Transportation ("DOT") headform be dropped vertically, with an impact speed of 10 ft/s (3.1 m/s), onto a steel hemispherical target. The pass/fail criteria is based on translational acceleration (150G) alone, absent of any rotational component.

Without a rotational component, the specification's injury risk application is limited to skull fracture and peripheral hematomas (subdural, subarachnoid), since this translational acceleration injury risk assessment draws origins from the Wayne State Tolerance Curve

(WSTC). To provide a more comprehensive view of injury for the entire brain, an alternative approach is needed.

We have developed a prototypical injury risk criteria based on the neuronal response to abrupt changes in general motion (translation, rotation, or both). The cellular-based mild traumatic brain injury (cbmTBI) criterion utilizes both the strain and strain rate of brain tissue to account for the stretch and rate of stretch that occurs throughout the brain as a result of blunt impact through the ACH.

We ran physical experiments of an ACH-fitted magnesium headform, which produced repeatable headform peak accelerations. Then, we developed a simulation of the experiment, and validated the simulation output with the experimental data. We then substituted the magnesium headform with a human headform, consisting of skin, muscle, bone, gray matter, white matter, and cerebral-spinal fluid.

We quantified brain injury risk using the cbmTBI criterion, both using the current mil-spec test and a modified test. The modified test used a hemispherical target that was located posterior to the crown of the helmet in the axial plane. While the current mil-spec test produced brain deformation from translation alone, the modified test produced brain deformation from translation and rotation, which is closer to most real world and combat theater impacts (e.g., such as occur in tertiary blast exposure).

Compared to the current mil-spec test, the modified test produced elevated strain and strain rates in the human digital twin. These data, mapped to the cbmTBI criterion, suggest increased injury risk for blunt impacts that cause rotation and translation, rather than just translation alone. Moreover, these data lead to a rotational performance metric, which is rooted in the actual biology and pathology of the brain's response to impact and blast, and which should be used to improve next-generation helmet designs.

LO:
Learn why helmet testing should be revised to include rotation
Learn how translation and rotation contribute to brain injury differently
Understand that the brain is preferentially injured during rotations, not translations

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