EXPOSURE OF A HUMAN SKULL SUBSTITUTE TO BLAST

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Abstract: On the battlefield, soldiers may be exposed to the detonation of explosive charges and consequently injured by several factors. The current study focuses on the shock waves propagation that may cause severe Traumatic Brain Injuries, which symptoms include headaches as well as convulsions and cerebral edema [1]. Injury mechanisms were thus proposed in literature to explain the observed cerebral lesions. In particular, one hypothesis will be further investigated: the skull deflection.

In order to investigate this injury mechanism, the human skull was approximated by a truncated spherical shell with dimensions in accordance to those of a 50th percentile man. The objective of this new substitute was to have a similar modal behavior as to a human cranium. Therefore, numerical tools such as finite element modelling were used to determine the optimal thickness and diameter of the substitute [2].

This new substitute, illustrated on Figure 1, was developed in two copies to be exposed to shockwaves in free-field conditions. Both copies were filled with water to mimic the brain and then embedded on a rigid mount. Concerning the instrumentation, accelerometers, strain gauges, as well as internal and external pressure sensors were used and placed in several positions. The substitutes were then placed on an experimental ground and subjected to the detonation of 21 explosive charges. The proposed experimental campaign included 7 scenarii of exposure in free-field conditions, with C4 masses going from 0.15 kg to 1.5 kg, incident pressures between 75 kPa and 180 kPa, and two blast durations of 1.2 ms and 1.9 ms. Each scenario was repeated 3 times to ensure the repeatability and robustness of experiments.

Recorded experimental signals were finally analyzed in the time domain. First, an ipsi-controlateral effect is attested on internal pressures while a slight underestimation of first peaks is observed in comparison with results obtained on Post-Mortem Human Subjects in the literature. For shell strains, there is an overestimation of maximal and first peak values compared to bibliographic data. Hence, according to current results, the newly designed skull substitute can approximate the behavior of Post-Mortem Human Subjects exposed to the propagation of shockwaves with minimum error.

Figure 1: Photography of the skull substitute.

[1] Rosenfeld, J.V., McFarlane, A.C., Bragge, P., Armonda, R.A., Grimes, J.B., and Ling, G. S. (2013) *Blast-related traumatic brain injury*, in *The Lancet Neurology*, vol.12, no.9.

[2] Elster, N., Boutillier J., Bourdet N., Magnan P., Naz, P. Willinger R., and Deck, C. (2022) *Design of a simplified cranial substitute and Modal Analysis,* in *DYMAT 26th Technical Meeting Conference Proceedings.*