A New Helmet-liner Design for Improved Survivability

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I. INTRODUCTION

Helmets are the only piece of personal protective equipment (PPE) used to protect the brain against the effects of head impacts. Studies have shown that helmets can effectively reduce the risk of skull fracture and severe brain injuries [1-2], but their capability in avoiding milder brain injuries, particularly those caused by head rotation, is yet to be improved. In this study we used a new polymeric damping material, Armourgel [3], to test the feasibility of improved impact protection of motorcycle helmets.

II. METHODS

New Helmet-liner Design

Injection-moulded components made of Armourgel were placed inside the existing EPS liner of a motorcycle helmet, beneath the comfort padding, to form a new energy-absorbing liner system (Fig. 1, *left*). Armourgel is a highly energy-absorbing viscoelastic material, which dissipates energy as it deforms. Anisotropic damping elements called Revolvers were designed and moulded in Armourgel such that they provided different responses under linear and shear deformations, allowing us to enhance the performance of the helmet for translational and rotational head motions separately.

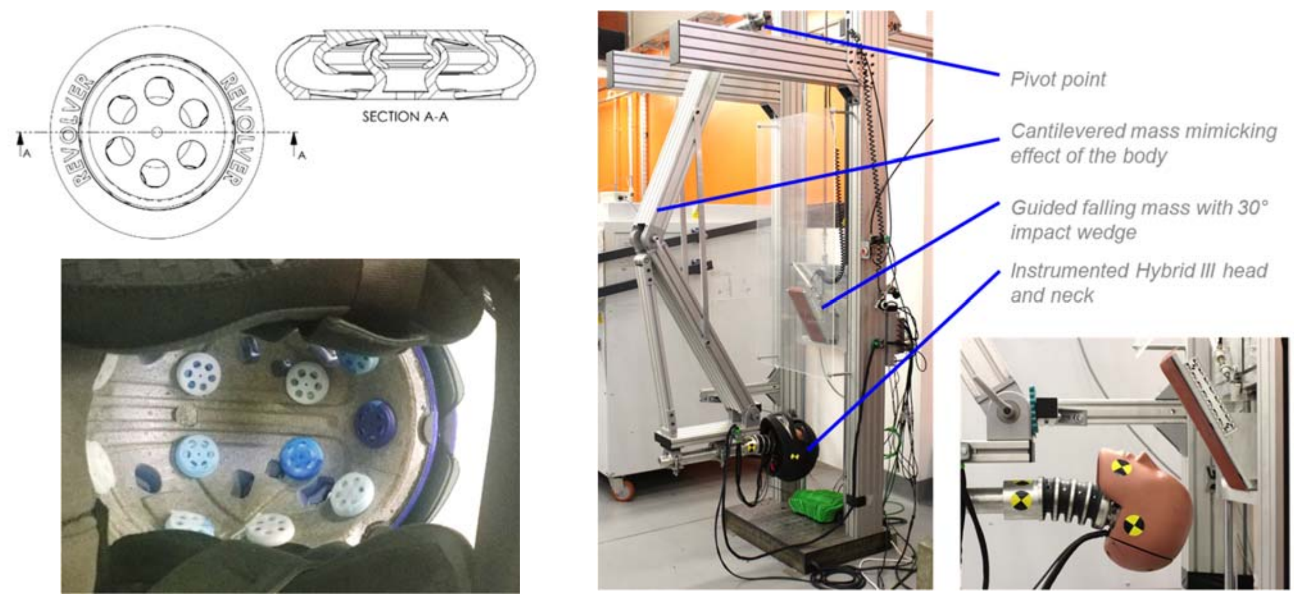

Fig. 1. Armourgel Revolvers (*left*) and the new helmet testing apparatus (*right*).

Impact Testing

We tested helmets under oblique impact conditions using a new test rig that mimics the effects of the body (Fig. 1, *right*). The tests consisted of impacts at velocities of 4.4 m/s and 6.2 m/s, with a falling flat plate striker at 30 degrees to vertical. The apparatus features a fully instrumented (6-DOF) Hybrid III dummy head/neck system suspended on a pendulum to mimic the effect of the body in real-world crash scenarios [4].

Brain Injury Prediction

Translational and rotational head accelerations measured during impacts were used to load a high fidelity finite element (FE) model of traumatic brain injury (TBI) to predict strain fields across the brain. The volume of the brain exceeding a 0.18 Green-Lagrange strain threshold, above which structural brain injury is thought likely to occur [5], was then determined.

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III. INITIAL FINDINGS

The reduction of peak translational and rotational accelerations was up to 40% for the helmets with the Armourgel liner compared to the reference helmets (Fig. 2, *left*). At 4.4 m/s the volume fraction of brain matter exceeding the suggested threshold was 14% with the reference helmet and 2% with the new helmet (Fig. 2, *right*).

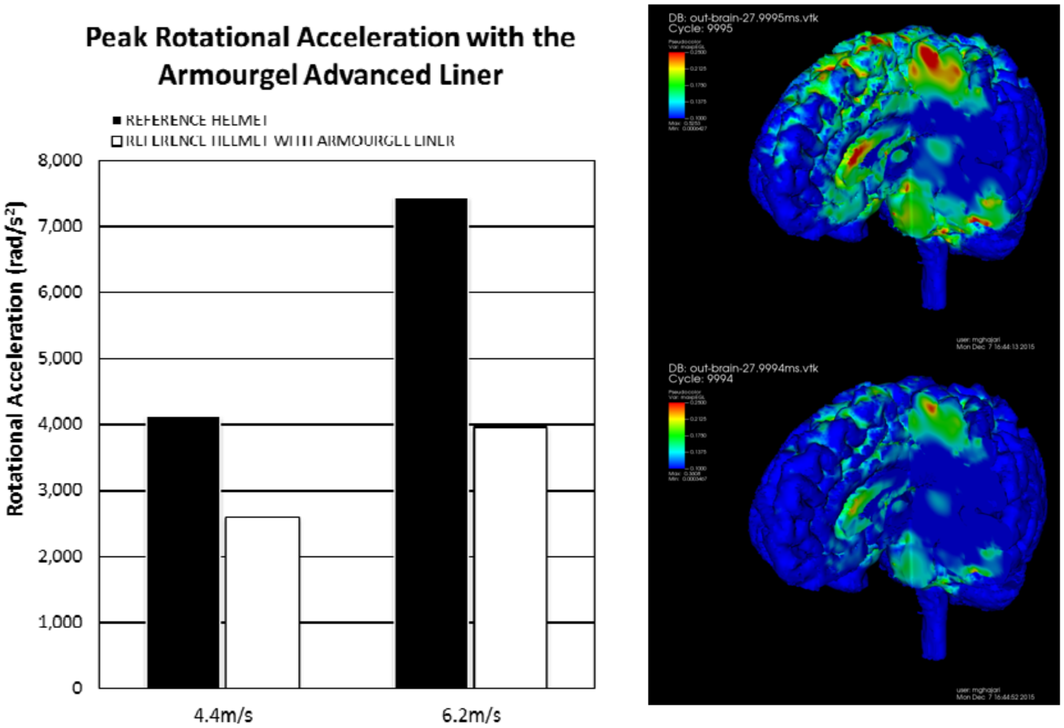

Fig. 2. Initial test results for the reference helmets and reference helmets with the Armourgel liner; peak rotational acceleration results (*left*) and strain contours across the brain for the 4.4 m/s impacts (reference helmet, *top right*; reference helmet with Armourgel liner, *bottom right*).

IV. DISCUSSION

The results show the potential for Armourgel components to reduce the probability of a helmeted user sustaining brain injury during an impact to the head. The results presented for impacts at 4.4 m/s show the significant reduction in the strain field within the brain (14% to 2% volume fraction over the suggested injury threshold) and thus the expected injury mitigation effects of the advanced liner.

The results presented for impacts at 6.2 m/s show a reduction in rotational acceleration from 7300 rad/s^2 to 3900 rad/s^2, representing a reduction in the probability of mild TBI from almost 80% down to less than 25% according to suggested injury thresholds [6]. Future work will focus on modelling the brain response at a number of additional impact velocities and optimising the geometry of the anisotropic damping components for maximised protection.

V. REFERENCES

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