

## Computational modelling of oblique impacts on helmets with a new add-on lining system

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### I. INTRODUCTION

This study presents the experimental and computational results of oblique impacts on a motorcycle helmet with and without a new add-on liner [1]. The aim is to use computer-aided engineering techniques to understand energy absorption mechanisms of the new liner, which can help optimise it for complex events beyond linear impacts, including considerations of rotational accelerations [1-4]. Modelling the liner material and helmet in combination with computational modelling of traumatic brain injury (TBI) [1] can assist in developing better strategies to protect certain regions within the brain that have been linked to brain injury [5, 6].

### II. METHODS

#### *Experimental Testing*

Helmets were placed on a Hybrid III headform/neck assembly (Fig. 1). The neck was attached to a pendulum structure in order to account for effects equivalent or similar to those of the human body [1, 7]. Half of the helmets were fitted with Armougel (revolver) liner at approximately consistent locations (Fig. 1). An oblique metal equipped with load cell was fitted on a drop tower. The impact was delivered by releasing the anvil from a measured height. The velocity of the anvil (4.35 m/s) was measured by interrupting a light beam placed at a distance from the impact point (according to regulations). High-speed photography was also used (Fig. 1).

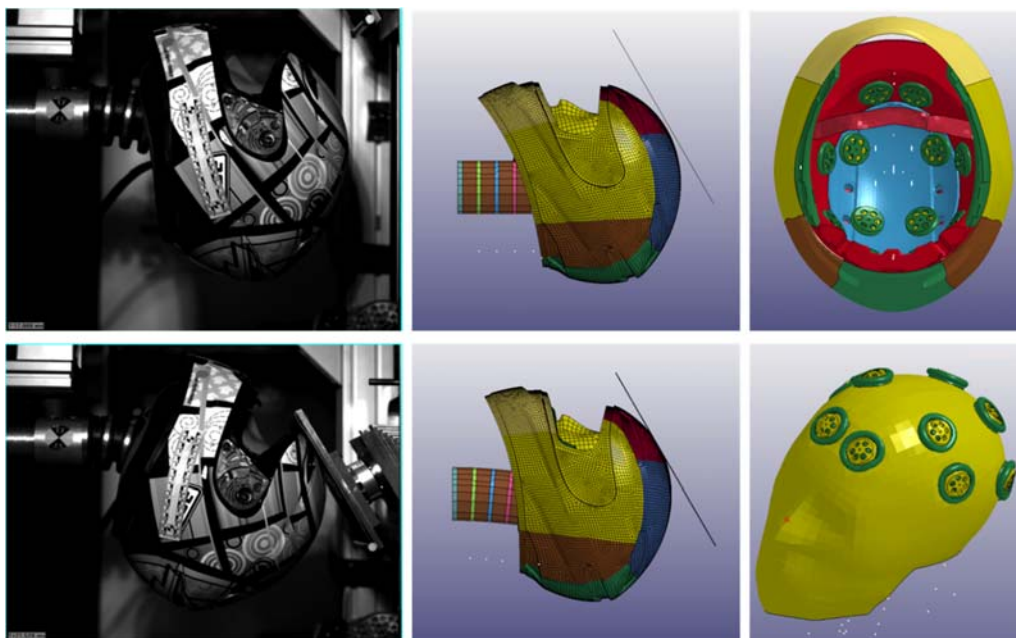


Fig. 1. High-speed camera frames during oblique impact testing of helmet (left), FE model of oblique impact of helmets (centre), FE model of Armougel liner configuration (top right), and FE model of the Armougel liner configuration during impact (bottom right).

### Computational Modelling

A model for the helmet was provided by AGV-Dainese. The model included meshed geometries and material models of the helmet constituent parts. The model was fitted on a validated finite element (FE) model of a Hybrid III head/neck assembly (Fig. 1). The neck was attached to an inertia part on which the pendulum moment of inertia was applied [1]. A chin strap with realistic geometry and material properties was added to the model. The anvil was considered as a rigid shell at an angle of 30° from vertical. The Armourgel revolvers were modelled using a hyper-viscoelastic material model, with constants determined from curve fitting to quasi-static and stress relaxation test data.

### III. INITIAL FINDINGS

Experiment and FE model results are compared between helmets with and without the added liner (Fig. 2). The experimental average peak improvement for the liner performance was 27% in translational acceleration, and 22% in rotational acceleration. The translational peak acceleration improvement was predicted by the model at 27.6 %. Peak rotational acceleration improvement was predicted to be 18.6 %.

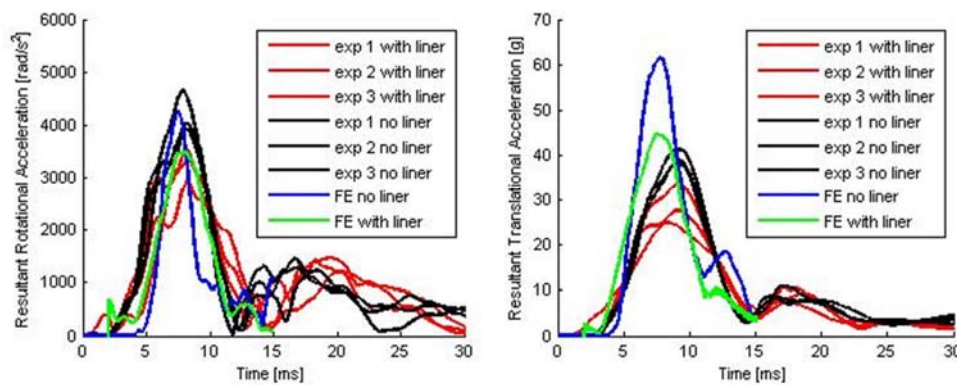


Fig. 2. Comparison between experiments and FE model on helmets with and without added liner.

### IV. DISCUSSION

Rotational accelerations were in better agreement between model and experiments than translational accelerations. Translational accelerations were overestimated by the model, but the relative improvement was accurately predicted (i.e. 27% in tests vs. 27.6% model). This would suggest that the liner mechanism for energy dissipation in the event was captured by the model. Part of the reason for overestimation of the translational acceleration could have been the exclusion of gravity from the model, which changes the initial configuration of the head and neck (Fig. 1). Based on the FE analysis, the added liner part seems to be more efficient in comparison to the EPS foam regarding specific internal energy (J/kg); the specific internal energy was 599.2 J/kg in the added liner at the time of the peak acceleration, and larger by a factor of 5.8 than that in the EPS foam. A possible reason is the compliance of the revolvers in comparison to the EPS, particularly with respect to motion tangential to the head. These findings and the computational model can be used to guide liner system optimisation.

### V. REFERENCES

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