The Face Airbag: A Novel Concept for Facial Impact Protection

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I. INTRODUCTION

Vulnerable road users frequently sustain injuries to the head [1]. Simulation of e-scooter falls and motorcyclist-to-vehicle collisions has demonstrated that many head impacts are to the face [2-3]. Facial impacts can lead to traumatic brain injury, basilar skull fracture or facial fracture [4-5]. In particular, the lower part of the face, i.e. the mandible and maxilla, is a vulnerable region that will generate head rotation from normal impact forces [6]. Despite these observations, conventional urban bicycle and open-face motorcycle helmets have a limited coverage area, with little to no protection for impacts to the mandible and maxilla (which are below the standard test line [7]). A permanent protection structure in front of the face can hinder ventilation and field of vision during normal use. We present a novel concept that holds potential to overcome these limitations.

II. METHODS

An inflatable structure – the face airbag – that can be integrated or used separately with a helmet was designed and tested. Two consecutive verification steps were taken, which are based on simulation and experimental testing. The human surrogate test device and impact conditions were chosen such that biofidelic responses from direct facial loading could be retained and the injury mechanism replicated.

The THOR-50M dummy has higher biofidelity scores for impacts to the face than the HIII-50M dummy [8]. Comparing with PMHS tests where a 13 kg rigid disk impactor was delivered to the face at 6.7 m/s, both the physical THOR-50M (SBL-B) and the virtual counterpart (version 1.8.1) from Humanetics Innovative Solutions, Inc. showed good agreement with the response corridor in terms of force-time history and peak force (Fig. 1).

Identical impact conditions were adopted for simulation and experimental verification (Fig. 2), with a 100 mm diameter cylinder representing vehicle aggressivity, for example, coming from a roof rail. The bottom edge of the impactor was positioned 10 mm below the chin, thereby targeting approximately mandible and maxilla region.

Experiments were performed using a pendulum test rig, as per THOR-50M face qualification requirements. An open-face motorcycle helmet (AGV RP60) was positioned such that the upper rim of the helmet was measured 160 mm from the bottom edge of the chin. The helmet was fastened manually through its double-D ring.

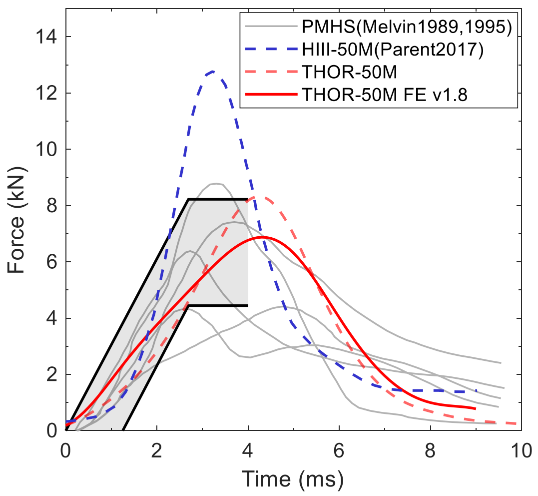

Fig. 1. Face rigid disk impact response.

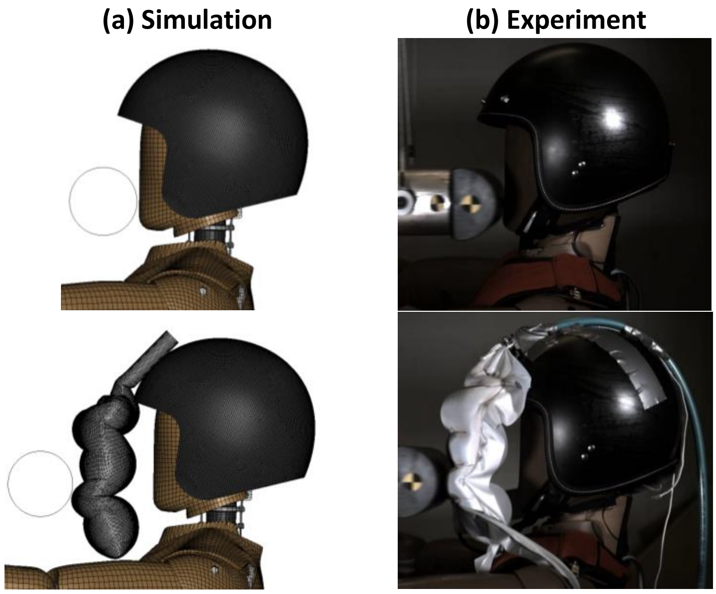

Fig. 2. Verification of the face airbag concept through simulation and experiment testing.

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The THOR-50M FE model was coupled with a generic open-face motorcycle helmet model. To simplify the head-helmet retention system, the helmet model was rigidly coupled with the head. Hence, the purpose of the helmet model was to add weight (0.85 kg) to the head and provide fixation for the airbag model. To simulate a fully inflated bag, the uniform-pressure technique was used, and no gas leakage was assumed. The designated pressure was 70 kPa. Simulations were conducted using LS-DYNA (LST, Livermore, CA, USA) MPP R9.3.1 Single Precision. Six degree-of-freedom head kinematics were extracted from both simulations and experiments as input to the KTH head model [9] to calculate maximum principal strain (MPS) of the brain indicative of brain injury.

III. INITIAL FINDINGS

The face airbag reduced MPS by 45% (simulation) and 33% (experiment), see Fig. 3. In addition, comparing the strain pattern (averaged strain for visualization purpose), the face airbag reduced the strain intensity and area of high strain levels. Reduction in MPS can be explained by the head rotation: peak head angular velocity during the flexion phase was reduced by more than 50% while the peak angular velocity during the extension phase remained similar.

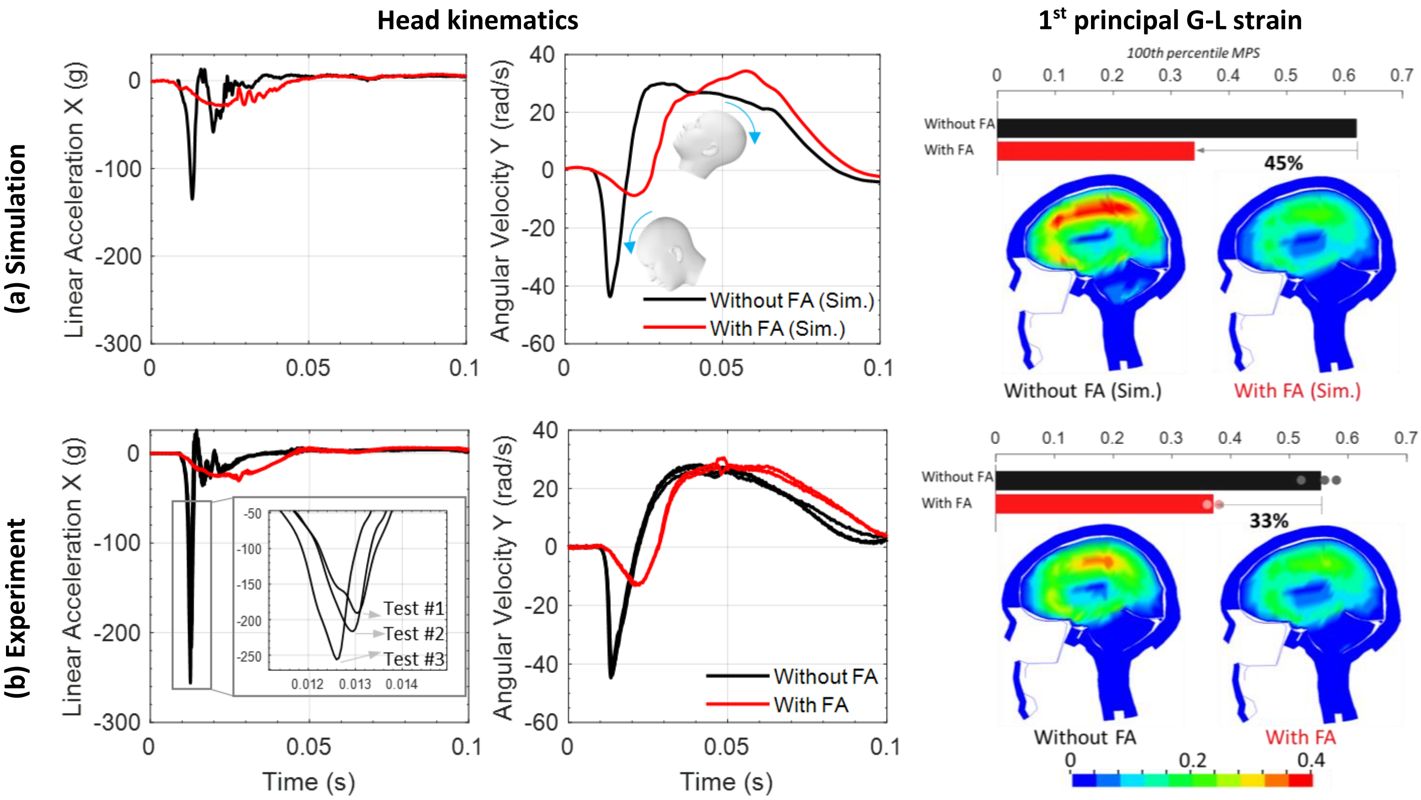

Fig. 3. Comparison of head kinematics (dominant components for brevity) and the brain strain for both simulation and experiment verification, with and without the face airbag (FA).

IV. DISCUSSION

The face airbag reduced brain strain and hence traumatic brain injury risk. Given a large design space with an inflatable structure, variations of the face airbag can be tuned and verified. However, it is not obvious how to demonstrate the benefits of a face airbag, or an alternative protection device, in regulation and consumer testing. Current standard test methods for facial impact (also called “chin bar impact test”) lack biomechanical assessment requirements and lack a neck surrogate. Future research needs to link real-world facial impact conditions for different vulnerable road users and collision types to a simplified, yet biofidelic, test method.

V. REFERENCES

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