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Development and Validation of a Finite Element Model for a Head Protection Airbag

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INTRODUCTION

TO address the increasing number of bicycle and e-scooter accidents (Burford, 2024), In&motion is developing an airbag designed to deploy around the head and thorax of the rider (STAN). Finite element modelling offers a cost-effective approach to evaluate and optimize this prototype. This study presents two key scientific steps towards the development and experimental validation of the airbag model for head impact protection.

METHODS

A surface mesh composed of 3 mm three-node triangles was generated on the airbag's flat pattern. In a pre-simulation phase, the fabric sections were digitally sewn by connecting them with springs and merging nodes to form the 3D geometry, with the 'Airbag' tool in Hyperworks 2024®. The airbag was then uniformly inflated, with various CO2 pressures.
Experimental tests were performed with four rear, four lateral, and three typical frontal head impact conditions. A 16 kg pendulum dropped from 1.5 m struck the head of a Hybrid III dummy wearing the airbag prototype. The airbag was inflated with an air compressor at pressures ranging from P0 to 2.30*P0. The head accelerations and angular velocities were then compared to the response of the numerical model and used to asses airbag model efficiency.

RESULTS - DISCUSSION

Numerically, the maximum linear accelerations and angular velocities obtained were relevant with the experimental 24 g and 1084°/s respectively, for all pressure levels for the rear impacts. For side and frontal impacts, the airbag pressure has a major influence on the head acceleration at the moment of impact; higher pressures resulted in lower linear accelerations. The linear acceleration ranged from 97g to 242g for side impacts and from 188g to 236g for frontal impacts. Regarding experimental and numerical data, the shape of the airbag, with a smaller volume at the sides and front should be carefully investigated as it could lead to a lower level of protection during frontal and side impacts, potentially leading to a "bottom-out" phenomenon (Kurt, 2017).

CONCLUSION - PERSPECTIVES

A first inflated airbag model for cyclists was designed and evaluated in multidirectional impacts conditions. Experimental dataset was obtained to complete airbag model validation. Simulation results confirmed the dissipation capabilities of the airbag in rear impacts, while highlighting the necessity for further investigation into the bottom-out phenomenon in frontal and side impacts, with particular regard to the thickness and pressure of the airbag. This promising methodology will be used to digitally evaluate and optimize future airbag solutions.