Reconstruction of 24 Real-World Motorcycle Collisions to Determine Facial Impact Conditions

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I. INTRODUCTION

Motorcycle helmets are a major focus for improving motorcyclists' safety in road traffic collisions (RTC), as they can significantly reduce the rate of head injuries [1]. However, facial impacts are minimally tested in helmet safety standards, despite having been reported to account for over 50% of head impacts [2]. Facial impacts often present together with injuries remote to the location of impact, such as basilar skull fracture (BSF), which is in turn associated with brain stem injuries [3]. There is therefore a need to better understand the loading conditions around facial impacts, and associated injuries, to inform future helmet standards.

Real-world RTCs databases can provide information on vehicle impact conditions and resulting injuries. However, they do not provide rider's head conditions during the collision, which is required to design representative lab test methods and understand mechanisms of injuries. Computational modelling has been leveraged to reconstruct RTCs and determine these conditions [2][4]. However, none of the previous studies have focused on facial impact. The aim of this study is to reconstruct real-world motorcycle collisions leading to facial impacts to determine impact conditions, which can inform future test standards.

II. METHODS

The cost-free UK Road Accident In-Depth Studies (RAIDS) database was parsed for motorcycle collisions involving a facial impact. Cases with high uncertainty, such as decapitation, or the involvement of a pillion rider or more than two vehicles, were excluded. Photographic evidence, description of rider injuries, and incident summaries were analysed to determine the positions, orientations, and velocities of the vehicles involved.

Reconstructions were developed in Madymo (Siemens, Germany) (Fig. 1). The rider was represented by the Madymo 50th percentile ellipsoid pedestrian model. The helmet and motorcycle were created by overlaying ellipsoids on a model of a generic helmet, and the motorcycle model reported in the RTC. The helmet was assigned directional stiffness properties [5], and a chinstrap modelled as a belt [6]. The motorcycle mass and moments of inertia and stiffness properties of the frame, front and rear suspension were based on an existing model [7]. The car was represented by Madymo's facet elements, with centre of mass and moments of inertia calculated as if the car was an ellipsoid, and stiffnesses were replicated from [4].

Reconstruction from post-hoc analysis of RTCs introduced uncertainties in impact conditions. Therefore, an uncertainty analysis was performed by varying the motorcycle impact velocity (±20% of the baseline value) and orientation (±5° yaw angle). Following reconstruction, the impact conditions of the rider's head were extracted.

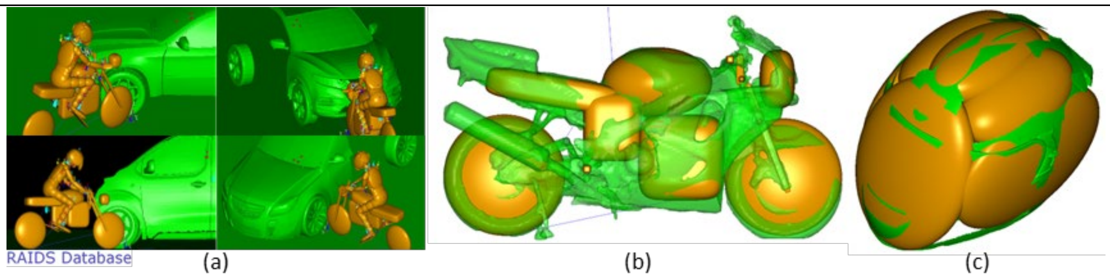

Fig. 1 – 24 cases of real-world road traffic collisions with facial impacts were identified from the Road Accident In-Depth Studies database. (a) Four typical cases reconstructed in Madymo. Ellipsoid models of (b) the motorcycle, and (c) the helmet, created based on the geometry of real-world models.

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III. INITIAL FINDINGS

Twenty-four motorcycle collisions with confirmed facial impacts were identified from RAIDS. BSF was present in 6 (25%) cases, with mild or moderate-severe traumatic brain injury reported in 16 (67%) cases. The median impact speed of the motorcycle was 13.4m/s (interquartile range (IQR) 10.5-25.3m/s). The collision in 17 (71%) cases were side impacts, 4 (17%) cases were head-on, 1 (4%) to the rear, and in 2 (8%) cases the rider flipped over the handlebars. The angle of the head velocity vector to the surface, where smaller angles indicate glancing impact, had a median of 49° (IQR 34-68°) (Fig. 2). The impact speed between the head and surface had a median of 8.3m/s (IQR 3.9-12.9m/s). In 19 (79%) cases, impacts were to the chinbar or lower facial area, 4 (17%) cases had impacts to the side of the facial area and 1 (4%) impact was to the upper facial area.

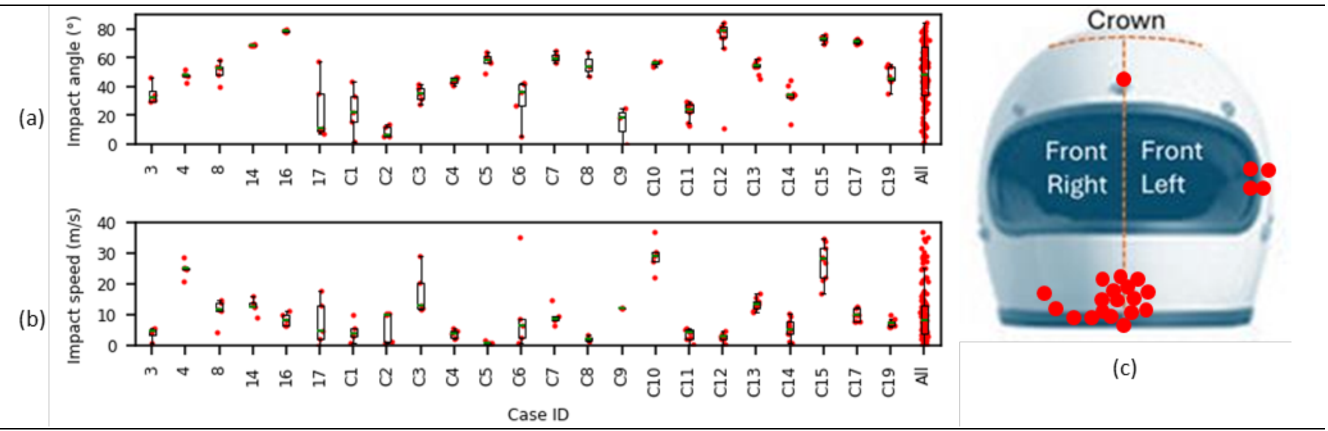

Fig. 2 – Plots of (a) impact angles between the head velocity vector and surface, (b) impact speeds between the head and surface, and (c) helmet impact locations. Cases without prefix "C" involved basilar skull fracture.

IV. DISCUSSION

This study reconstructed 24 real-world motorcycle collisions with facial impacts to determine impact angles and speeds of the rider's head, and impact locations on the helmet. The extensive details provided in RAIDS allowed us to create accurate simulations using Madymo multibody modelling. Although other studies have reconstructed motorcycle collisions [8], this is the first study to focus on collisions leading to facial impacts.

The upper quartile of impact speeds in this study (12.86m/s) is similar to median facial impact speeds (13.61m/s) in a retrospective study of European motorcycle collisions [2]. The impact locations on the helmet, which are clustered around the chinbar, agree with a study which found that collisions between a motorcycle and vehicle present a higher proportion of lower facial impacts than collisions involving an isolated motorcycle [9]. Interestingly, the single reconstructed collision where impact occurred at the upper facial area was due to the rider flipping over the handlebars and impacting the ground.

A limitation of the current study is the use of a 50th percentile human body model without muscle activation, a single rider posture, and generic car and motorcycle mass and stiffness properties. These uncertainties may affect the impact configuration of the rider. This has been mitigated by reconstructing each case with varying impact velocities and angles to capture a range of possible rider impact responses.

The next steps are to analyse the kinematics and orientations of the head, neck and torso during impact, to help inform lab methods. Additionally, comparing the loading of the head and neck to the resulting injuries may provide insight into injury mechanisms and aid development of injury risk curves. Overall, this study provides impact location, speed and angle in a range of motorcycle collisions with facial impacts. Our vision is to guide the design of a representative test method for facial impacts, helping to improve facial protection measures.

V. REFERENCES

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