Simulation of a Selected Real World Car to Bicyclist Accident using a Detailed Human Body Model

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I. INTRODUCTION

While the total number of road fatalities decreased in the European Union by 45% between 2004-2013, the number of bicyclists was decreased by only 32% [1]. Therefore, it is important to understand the injury mechanisms of bicyclists. In the reconstruction of accidents multibody models are common, sometimes combined with simulations of isolated Finite Element (FE) head models [2-3]. The Total Human Model of Safety (THUMS) v4 developed by Toyota Motor Corporation and Toyota Central R&D Labs, Inc is a very detailed Human Body Model (HBM) validated with several PMHS tests. It has been used previously by [4] to simulate generic bicycle accidents.

The current study aims to analyse the head injury mechanism of a selected real world accident with THUMS v4 and to compare the outcome of kinematic and strain based injury predictors.

II. METHODS

One representative real world accident suitable for the reconstruction was selected from the Austrian Central Database for In-Depth Accident Study (CEDATU). The database includes a comprehensive description of the situation prior to the impact and the accident outcome (reports, pictures of the scene). The initial boundary conditions were established through accident reconstructions with PC Crash using the multibody bicyclist model achieving similar final positions and impact points at the vehicle as described in the documentation of the scene.

In the case under study, the driver of a Renault Megane was overtaking another vehicle. At the same time a bicyclist was crossing the road from the left side. The driver applied the brakes (with 6.5 m/s²), but was not able to avoid the accident and hit the bicyclist at 60 km/h. The bicyclist was riding at approx. 10 km/h and impacted close to the vehicle centreline. The 65-year-old female bicyclist sustained fatal injuries to the thorax and the head. The following injuries were documented: subarachnoid bleeding, cerebral bleeding, multiple skull fractures, multiple rib fractures left (≥ 3 ribs) and a pneumothorax left.

Simulation Models

The THUMS AM50 v4.01 was used as bicyclist as it matched the size and weight of the injured bicyclist. The model was positioned on a simplified bicycle model through pre-simulations (pre-strains through seating simulations were not considered in the main simulations). The same frame type as in the real world accident was used and the saddle height was adjusted to meet the accident reconstructions.

The initial boundary conditions from the accident reconstruction were applied and the bicyclist model was impacted with a parameterisable generic car front as shown in Fig. 1. The parameters controlling the geometry of the car front were selected such to replicate a Renault Megane. The stiffness of the car was modelled with a large penetration contact and calibrated to the median and maximum force-deflection corridors of current cars [5].

Postprocessing

The strains in the brain and the skull were evaluated using the internally developed postprocessing tool DYNASAUR written in Python. DYNASAUR was used to calculate Maximum Principal Strains (MPS), 95th percentile and 99th percentile strains (PS) as well as the Cumulative Strain Damage Measure (CSDM) from the element history within the binary output file. Kinematic head injury criteria were evaluated using an accelerometer sensor located at the head's COG and connected to the skull via an interpolation constraint. The AIS risk associated to the Head Injury Criterion (HIC15) and Brain Injury Criterion (BrIC) was calculated as described in [6] and [7], respectively.

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III. INITIAL FINDINGS

The impact location of the hip and thigh of THUMS (Fig. 2) matches with the dents on the car (see Fig. 3). The damage to the bicycle model (Fig. 2) was also comparable with the real world damage shown in Fig. 4.

t0

Fig. 1: Simulation setup at t0.

t=50 ms t=100 ms t=120 ms

Fig. 2: Accident simulation

Fig. 3: Car damage from real world accident.

Fig. 4: Damaged bicycle from real world accident.

Although the head was not impacting the car, high strains in the brain were observed (MPS=0.89, 99th PS=0.63, 95th PS= 0.45). In total 43% of the brain volume was experiencing a strain in excess of 0.25. The maximum number of elements exceeding a strain of 0.25 was reached at 122 ms (Fig. 7). No risk for skull fracture was predicted as no critical strains (above 0.015) were observed (MPS=0.008).

HIC is indicating a moderate injury risk (Fig. 5), while BrIC is predicting a risk of 100% even for AIS5 (Fig. 6). Additional to the time independent evaluation of BrIC, BrIC was also calculated at each time step using the current rotational velocities (bottom of Fig. 6). The highest rotational velocity was 137 rad/s around the y-Axis and was measured at 108 ms. Once the left shoulder contacted the A-pillar at 100 ms (Fig. 2), a whiplash-like movement of the head was observed. The time of the max. linear acceleration is observed slightly later at 115 ms, reaching a second peak when the head is hitting the shoulder at 140 ms.

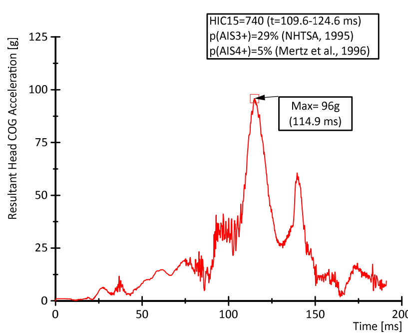

Fig. 5: Resultant linear acceleration of the head COG.

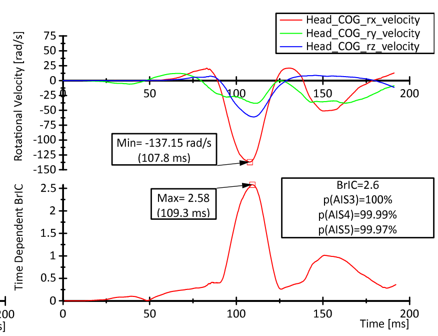

Fig. 6: Rotational velocities and BrIC as a function of time.

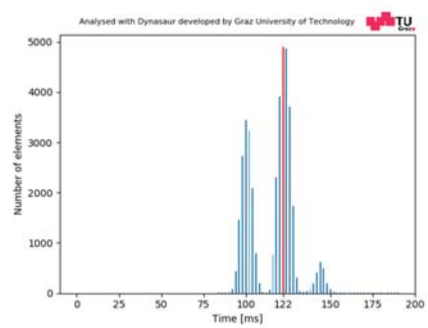

Fig. 7: Number of brain elements exceeding a PS of 0.25.

IV. DISCUSSION

BrIC and strain based injury criterions indicated high injury risk, but differed in terms of timing. For the analysed case time dependent and time independent BrIC values were very similar, as the maximum rotational velocities occurred nearly at the same time. No direct contact between the bicyclist's head and the vehicle was observed in simulation and post-impact vehicle examination. In this case one would expect that all head injuries were caused by the secondary impact. While this may be true for the skull fractures, the simulations indicate that high rotational loads can also be induced in a phase without any contact to the car through whiplash-like head kinematics. This highlights the difficulty of assigning injury sources in accident reconstructions.

V. REFERENCES

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