Pedestrian Head Injuries in Ground Contact: a Cadaver Study

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I. INTRODUCTION

Pedestrian injuries occur from both vehicle and ground contact, but the latter remain poorly understood. Cadaver impact tests are a valuable approach to reconstructing pedestrian ground contact, but only limited ground contact information is available from previous cadaver tests [1-2]. Computational models have predicted ground contact kinematics, but validation is also limited [3]. The main aims of this work are to study the pedestrian post-impact kinematics as well as head ground contact in detail, especially the linear velocity and angular velocity change of the head.

II. METHODS

Cadaver Tests

Six staged tests were performed at LBA IFSTTAR, Aix-Marseille University, France (Table I). Three vehicle types were tested to cover different normalised bonnet leading edge heights (NBLEH = BLEH/hip height), and each vehicle type was tested twice with the same conditions (different cadavers but approximately the same initial stance). A braking of 0.8 g was applied on the vehicles. The ground is close to rigid. Five video cameras were used to record kinematics over the full trajectory and a triaxial accelerometer fixed in each cadaver's mouth was used to capture head accelerations. Skull fracture risk was assessed using the 3 ms criterion with a threshold of 80 g [4].

TABLE I THE INFORMATION OF PEDESTRIANS AND VEHICLES USED IN PLANNED PMHS TESTS

Test number	Vehicle speed (km/h)	Pedestrian / vehicle size	NBLEH
Test 01	30.5	Peugeot 307 + Tall pedestrian	0.7
Test 02	30.4	Peugeot 307 + Tall pedestrian	0.7
Test 03	20.4	Citroën C4 + Short pedestrian	0.9
Test 04	21.0	Citroën C4 + Short pedestrian	0.9
Test 05	30.1	Renault Kangoo II + Short pedestrian	1.2
Test 06	30.0	Renault Kangoo II + Short pedestrian	1.1

Model-Based Image Matching

Model-Based Image Matching (MBIM) [5-6] was used to analyse three-dimensional head rotation during vehicle and ground contact. Multiview videos are imported in a virtual lab environment based on markers and lines on the ground for each test. Next, the orientation of a multibody head model is manually matched to the cadaver head positions on a frame-by-frame basis. Customised Matlab code is then used to predict time-histories of body local head angular velocities, which are used to assess the rotational head injury risk via the Brain Injury Criteria (BrIC) [7].

III. INITIAL FINDINGS

Figure 1 shows a sample sequence of pedestrian kinematics at different timings and phases during the vehicle impact process: t0 is the first vehicle-pedestrian contact time and t1 is first vehicle-head impact time. Then the pedestrian moves together with the car until t2, when they separate. The first pedestrian ground

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contact occurs at t3, and t4 is the first head ground contact. The pedestrian stops moving at t5. Figure 2 shows the body orientation along with the MBIM fit for the head at the instant of ground contact for all six cadaver tests. Figure 3(a) shows the 3 ms peak acceleration of the head for both vehicle and ground contact. Figure 3(b) shows the computed probability of an AIS3 using the (BrIC) scores from head angular velocities.

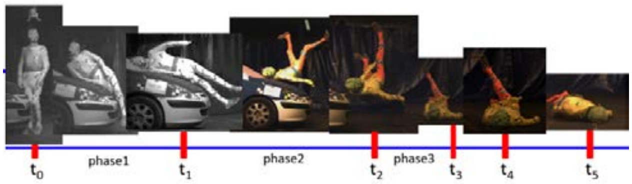
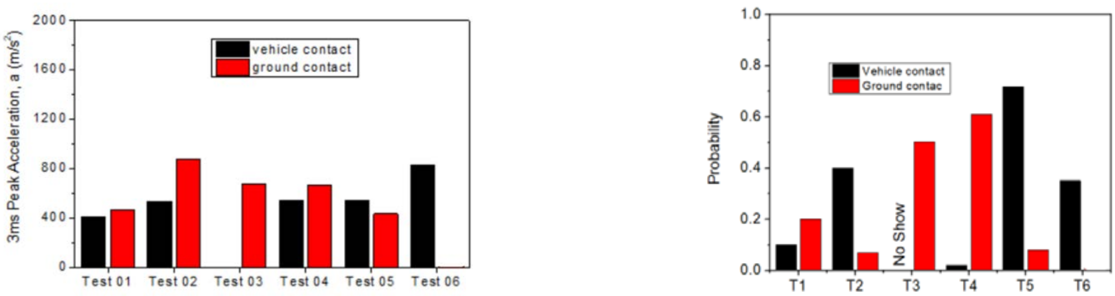


Fig. 1. Sequence of vehicle-pedestrian impact (PMHS test).

Fig. 2. Still shots of head ground contact with MBIM fit at instant of ground contact.



(a) 3 ms Peak Acceleration (b) Probability of AIS3 Brian Injury

Fig. 3. Summary of head injury assessment.

IV. DISCUSSION

The kinematics of the whole body can be classified into several critical moments and phases common to all tests. Preliminary analysis does not show a clear relationship between vehicle shape and injury outcome. However, the 3 ms accelerations from ground contact are generally higher than from vehicle contact, which does not correspond to head-ground versus head-vehicle injury outcomes in the GIDAS database at 20 kph and 30 kph (data not shown here). The BrIC scores from ground contact in 30 kph cases are (surprisingly) substantially lower than those in 20 kph cases, while BrIC scores from vehicle contact in 30 kph cases are substantially higher than those in 20 kph cases.

V. REFERENCES

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