Pedestrian head translation, rotation and impact velocity: The influence of vehicle speed, pedestrian speed and pedestrian gait

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ABSTRACT

In road traffic collisions, pedestrian injuries and fatalities account for approximately 11% and 20% of casualties in the USA and the EU, respectively. In many less motorised countries, the majority of victims are pedestrians. The significant influences of vehicle speed, pedestrian speed and pedestrian gait on pedestrian post-impact kinematics have been qualitatively noted in the literature, but there has been no quantitative approach to this problem. In this paper, the MADYMO MultiBody (MB) pedestrian model is used to analyse the influences of vehicle speed, pedestrian speed and pedestrian gait on the transverse translation of the pedestrian's head, head rotation about the vertical head axis and head impact velocity. Transverse translation has implications for injury severity because of variations in local vehicle stiffness. Head rotation is related to pedestrian stance at impact, which is known to affect the kinematics of a collision. Increased head impact velocity results in greater head injury severity. The results show that transverse translation of the head relative to the primary contact location of the pedestrian on the vehicle decreases with increasing vehicle speed and increases linearly with increasing pedestrian speed. Head rotation decreases with increasing vehicle speed and increases linearly with increasing pedestrian speed, but these variations are small. The range of head rotation values decreases with increasing vehicle speed. Head impact velocity increases linearly with vehicle speed and is largely independent of pedestrian speed. Transverse translation, head rotation and head impact velocity all vary cyclically with gait in clearly definable patterns.

1. Introduction

The World Health Organisation has reported that 1.2 million people die in road traffic accidents every year (WHO, 2009). Pedestrians are a significant proportion of road fatalities (OECD, 2008). Preventing or reducing the effects of these collisions requires a clear understanding of the collision events. This is generally pursued through simulation using either physical or computational models. While physical testing using cadavers or dummies carries clear benefits (Kerrigan et al., 2005, 2009; Kerrigan and Crandall, 2007, 2008; Serre et al., 2007), the very high cost associated with this approach means that only a limited number of collision scenarios can be investigated. In contrast, sophisticated computational models allow complex vehicle–pedestrian collisions to be modelled over a broad range of input conditions to quantify the influence of the many input parameters in vehicle pedestrian collisions. In recent years, MADYMO has been the most popular modelling tool for pedestrian collision and injury evaluation.

The MADYMO pedestrian model (MADYMO, 2009) (hereafter referred to as 'the MADYMO pedestrian model') implemented in the MultiBody (MB) software code Madymo is frequently employed for kinematic predictions (e.g. Simms and Wood, 2006a,b,c; Untaroiu et al., 2009), but other pedestrian models, with a different basis to *the* Madymo pedestrian model, have also been implemented using the MADYMO environment (e.g. Svoboda et al., 2003; Anderson et al., 2005a,b; Linder et al., 2005a,b; Guo et al. 2006; Yao et al., 2008a,b). Pedestrian models in MADYMO have been compared to data from staged tests using Post Mortem Human Subjects (PMHS), dummy and headform tests. The MADYMO pedestrian model response has been compared to PMHS test data for a variety of impact conditions (van Hoof et al., 2003). The global kinematics and body segment trajectories of the model generally showed good agreement with the test data, with a 'global correlation score' of over 90% achieved for head impact locations. For bumper forces and accelerations (head, chest, pelvis, and legs), the global correlation scores were lower (47–64%). Leglatin et al. (2006) found that the overall kinematics of the MADYMO pedestrian model matched collision sequences from PMHS tests. According to Anderson et al. (2005a,b), the response of their pedestrian model in MADYMO was generally in accordance with head velocity corridors from

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