Basic Assessment of the Injury Risk to Pedestrians Struck by Non-Standard, Autonomous Vehicles

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I. INTRODUCTION

There is a new emerging market for small, light automated delivery vehicles (ADV), which can travel at various speeds, and no longer have a human driver. This new type of vehicle will no longer need to be equipped with parts like windscreen or hood. These parts are often replaced by innovative front-end designs that differ from the traditional vehicle geometry. Several initial designs (Fig. 1) feature low ground clearance, a relatively flat front end, and a relatively low roof height as well as altered front-end materials that may be chosen to mitigate pedestrian injury risk. How this uniquely shaped vehicle will perform in the event of pedestrian collision is not yet well understood. Traditional pedestrian kinematics, which involve lower extremity-to-bumper impact, followed by wrapping around the front of the car, will no longer be applicable. In contrast, pelvis, torso and head will be involved in the initial impact. The objective of this study was to evaluate the performance of different front-end parameters, and geometries in reducing pedestrian injury severity, across population, for impacts involving ADVs.

II. METHODS

A simplified front-end multi body model representing the geometry of various ADVs was developed. The overall vehicle geometry was represented by its four major components: front foam, roof foam, headlight, and bumper (Fig. 1). Generic material models [1-2], available from existing literature, were used for the definition of the different vehicle components. University of Virginia (UVA's) pedestrian human body models; 5th female, 50th and 95th male [3], were used with the developed multibody vehicle model. A design of experiment study was conducted by varying the vehicle and pedestrian parameters using the 40 km/h vehicle-pedestrian impact scenario [Table I]. A series of vehicle pedestrian impacts were simulated using the MADYMO multibody solver.

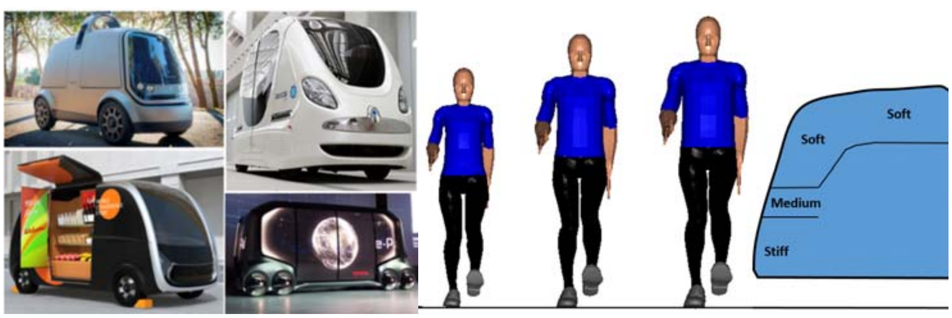

Fig. 1. Representative ADVs (left), baseline vehicle model with three pedestrian anthropometries (right).

TABLE I
SIMULATION MATRIX

Parameter	Unit	Variable		
Dummy model	-	AF05	AM50	AM95
Roof foam depth	[mm]	0	100	200
Foam depth	mm	100	200	
Foam stiffness, baseline EPP 20g/l	[%]	50	100	200
Grill stiffness	[%]	50	100	200
	Total: 162 simulations			

To quantify risk of injury for pedestrians, the Abbreviated Injury Severity score (AIS) was calculated for head, neck, thorax and pelvis [4]. Next, in order to identify the least injurious vehicle design, an objective function was developed.

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This function assigns a high weighting factor for AIS5+ injury risk exceeding 10% (head, neck) and a regular weighting factor for AIS3+ injury risk in the head, thorax, and pelvis.

$$Objective_{Ped} = H + X + Y + Z \text{ (Eq.1)}$$

In the objective function H was set to 4 for cases with at least a 10% probability of AIS5+ injury for head and neck. X, Y and Z were set as probabilities of AIS3+ associated with maximum injury metric for head, pelvis and thorax respectively. Since the goal of this study was to asses pedestrian injury risk across three anthropometries, an overall objective function was also introduced. This function takes into account the objective functions for the different anthropometries tested with the same vehicle design parameters.

$$Overall\ Objective = \text{Objective}_{Ped}(5^{th}) + \text{Objective}_{Ped}(50^{th}) + \text{Objective}_{Ped}(95^{th}) \text{ (Eq.2)}$$

The injury severity trends for head, thorax and pelvis (X, Y and Z) for a specific front-end design will be presented and discussed.

III. INITIAL FINDINGS

Preliminary results show that foam parameters (depth and stiffness) influence injury risk outcome for all considered body regions. Across all the pedestrian anthropometries softer foam lead to lower injury severity prediction for the head and thorax. The opposite trend for larger anthropometries, showing reduction of injury severity, is observed for pelvis region with the increase of foam stiffness (Fig. 2).

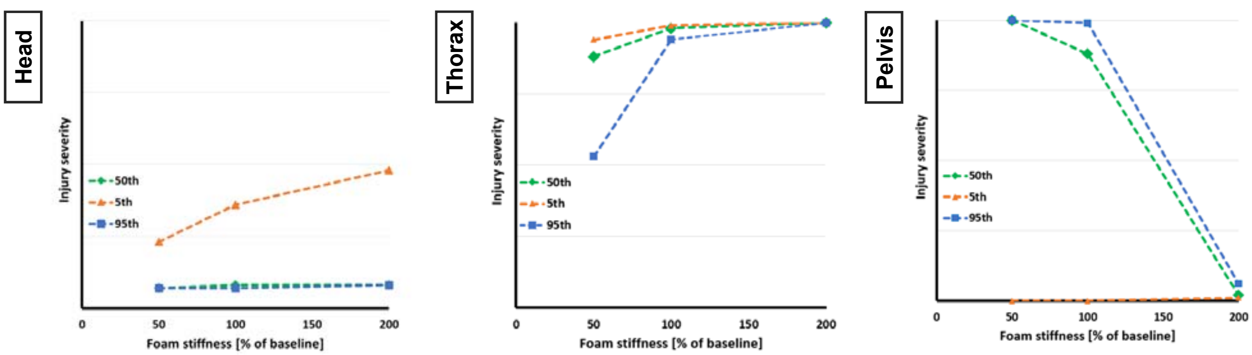

Fig. 2. Comparison of head (left), thorax (middle) and pelvis (right) injury severity trends, for three foam stiffness's across pedestrian anthropometry for the vehicle with roof and front foam depth equals to 200mm.

IV. DISCUSSION

This study shows conflicting trends in thorax and pelvis protection, suggesting a trade-off in performance between these regions. A softer foam tends to improve thorax safety, however, this is problematic for the pelvis injury prediction (for larger anthropometries), since it allows the pelvis to bottom-out the foam and engage the stiff vehicle frame located underneath. These findings highlight the challenges these types of vehicles will have to overcome in order to provide an optimized level of protection across the pedestrian population. Further investigations will include different front-end material and geometric characteristics and vehicle speeds. Additionally more pedestrian anthropometries, and postures will be included, along with lower extremity injury risk assessment.

V. REFERENCES

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