Sensitivity analysis of the newly design tram front-end with respect to variations of the pre-impact conditions

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I. INTRODUCTION

The purpose of this paper is to investigate the pedestrian to tramway crash scenario via a simulated model that tests various initial conditions of the pedestrian in front of the vehicle. The tramway was simplified into a model of the front end only, based on the real geometry data of the Skoda tram. Virthuman, a fully validated model of a human body, was used for the simulations in ESI Virtual Performance Solution software [1]. Real experimental data of the human gait phases were investigated for the sensitivity analysis, as well as the effect of various initial conditions and different pedestrian sizes. The study examined three different tramway designs for the analysis, in order to ascertain how all the above-mentioned conditions affect the results and either fulfil or exceed the defined threshold for the pedestrian safety.

II. METHODS

This work is connected with the prepared EU regulation [2] for tramway safety. The regulation defines particular collision scenarios and the safety limits that must be fulfilled. In the case of frontal collision, the parameters used are a tramway of 42,000 kg with initial velocity of 20 km/h impacting an average male [2][3]. However, it has previously been shown [4] that the initial position of the pedestrian with respect to the vehicle and the particular gait phases of the pedestrian can significantly affect the results (kinematics, dynamic and injury sustained by the pedestrian). The numerical model used as a human body model (HBM) in this study is the Virthuman [4][5], a hybrid (combination of FE and MBS) scalable HBM used for safety assessment [6][7][8] (Fig. 1).

Fig. 1. Virthuman family.

Volunteer was used to measure locomotion and the data then used to model the various positions of the extremities when walking [4] (Fig. 3). It was found that the results can change only with the modification of the initial positions of the pedestrian. In addition to the average male, a 6yo child HBM was also tested in the specified collision scenarios. Since this study forms part of a project focused on developing a new tram design, three different tramway designs were tested. In terms of pedestrian injury, the focus was on the head injury criteria (HIC), therefore this value was monitored. Consequently, the Virthuman model (VPS) software implemented an algorithm to evaluate injury prediction, based on the EuroNCAP rating [9], where the thresholds of the particular mechanical quantities (displacement, velocity, acceleration, force etc.) are specified. It results in the probability of the human injury (condition of survivability for various body segments). The conditions of survivability are illustrated using the same colour coding as the EuroNCAP, where green indicates a good chance of survival, yellow indicates an acceptable chance of survival, orange indicates a marginal chance of survival and red indicates a poor chance of survival [9].

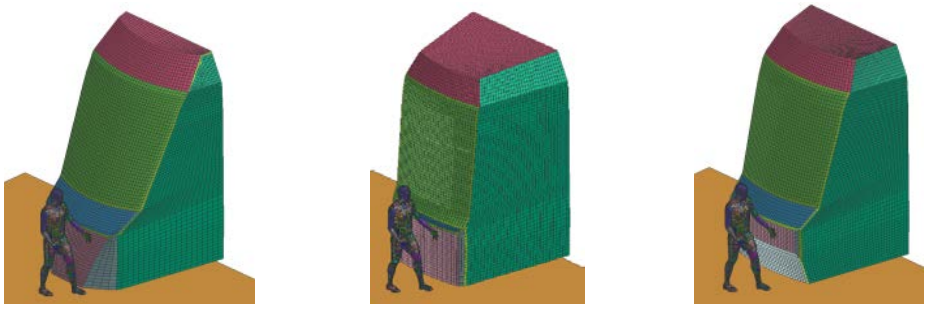

Fig. 2. Tramway designs and the collision scenario.

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III. INITIAL FINDINGS

The injuries sustained by the pedestrian (Male 25yo and Child 6yo) during standard frontal impact with the pedestrian in the centre line of the tramway and the left leg moving upwards while walking (based on the representational figure in the regulation [2]) are shown in Table I.

TABLE I

THE INJURY PROBABILITY FOR THE THREE TRAM GEOMETRIES IN CASE OF AVERAGE MAN (25YO, 178 CM, 76 KG) AND CHILD (6YO, 120 CM, 23 KG)

Left-side Impact, 20 km/h							Right			Left		
		Head	Neck	Chest	Abdomen	Pelvis	Femur	Knee	Tibia	Femur	Knee	Tibia
Model 1	M 25yo, 178 cm, 76 kg	1395										
	Ch 6yo, 120 cm, 23 kg	169										
Model 2	M 25yo, 178 cm, 76 kg	212										
	Ch 6yo, 120 cm, 23 kg	305										
Model 3	M 25yo, 178 cm, 76 kg	1621										
	Ch 6yo, 120 cm, 23 kg	185										

IV. DISCUSSION

The main aim of this work is to develop a broad understanding about the passive safety of the tramway front-end in an impact scenario with a pedestrian. The recently updated regulation treats the safety of the pedestrian as one aspect of consideration, but it is not precisely defined. There is a definition of the type of impact, velocity and position of the pedestrian with respect to the vehicle, but this study has found that the outcome can change depending on variations in pedestrians' initial positions (extremities, gait phases). Consequently, the tramway design that seems safe for the adult pedestrian might be very dangerous for the adolescent, child or elderly pedestrian. This work presents a very suitable tool for the numerical calculation, especially when the kinematic, dynamic and global injuries are in the main interests. The model Virthuman, which runs under VPS software, has the advantage of scaling and positioning algorithms, which allow the user to define any size of pedestrian in any physiological position and to obtain results in a relatively short calculation time. The first results delivered by this study show that the size of the pedestrian, the phase of the gait cycle and the transversal position of the pedestrian with respect to the vehicle significantly affect the overall motion and the injury sustained.

V. ACKNOWLEDGEMENTS

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