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Virthuman application for family safety in highly automated vehicle's frontal crash

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Abstract

Highly automated vehicles' occupants will have more comfortableness because common interior elements such as steering wheel will not be existing anymore. It provides extra room to change their seats' location for sitting in either Face-to-Face or Living Room configuration. This study compares occupants' injury index in non-standard configurations with a standard one. A frontal crash is modelled by Low- and high-speed crash acceleration's pulses. Virthuman models in different ages and genders are chosen for modelling occupants in a simplified schematic of an autonomous vehicle's interior. Numerical simulations elaborate that there are no noteworthy changes for Rear-row occupants in non-standard seating configurations rather than a standard one in a low-speed crash. Moreover, at a high-speed crash scenario, non-standard seating configurations can decrease injury indexes for Front-row occupants' Head & neck and Rear row occupants' Legs.

1. Introduction

By the end of the first quarter of the twenty-first century, it is expected that fully automated safety features are seen in most of the vehicles on roads [4]. Vehicle's interior is going to be changed in consequence and some elements such as steering wheels will not exist anymore. Occupants shall have such flexibility to rotate/relocate their seats freely in a vehicle's interior. New seating configurations provide a comfortable long-travel for passengers.

Passengers' seats in almost all of the private vehicles have been facing to the front windshield. We name it standard seating configuration. Whenever the front row seats are rotated 180^{o} one can say occupants sit in Face-to-Face seating configuration. If occupants' seats in lately mentioned configuration rotate 30^{o} inward it is called Living Room seating configurations. Participants who attended in a study have shown their interests in non-standard seating configurations [3]. It was acceptable from their point of view to have extra restrains if occupants are allowed non-standard seating configurations.

A crash is unavoidable in some occasions if the automated driving system (ADS) may not work precisely. One may wonder how safe is these non-standard seating configurations for occupants in comparison with the standard one? For doing crash tests it is possible to use Post-mortem human subjects (PMHS) but keeping them in good conditions for a long time is difficult. On the other hand, full-scale anthropomorphic dummies lose their measurements' accuracy after several tests. Henceforth, Finite Element human body models have been introduced to overcome these limitations but simulation's time is an important matter. For reducing computation's time hybrid models such as Virthuman have being developed [2]. Virthuman model itself, which possesses a decent capability to present different ages and

genders in crash scenarios. It is made on a Multi-Body-System basis and able to evaluate body injuries regarding kinematic values and loads on some certain nodes/joints. It has worth to mention that Virthuman does not model tissues, muscles, brain, etc. None of these bodily injuries is considered by the algorithm for evaluating injury indexes.

For the present study, we ran simulations in the Virtual Performance Solution environment, PAMCRASH module. Bodies are fastened by three-points seat belts with standard materials to seats made by Polyurethane foam (PUR). The test was done for two crash acceleration pulses [5] in the frontal direction. Finally, by the help of an embedded algorithm [1] in the software for Virthuman, models' injury indexes are assessed for body's parts. In consequence, bodies' Injury indexes in non-standard seating configurations are compared with standard one for three dominant bodies' parts.

2. Simulation

Four Virthuman models were located in a simplified interior of an autonomous vehicle Fig. 1. Man (50th percentile male, 35-45 years old) and girl (50th percentile female, 10-11 years old) models were located in the front row. Rear row occupants were a boy (53rd percentile male, 6-7 years old) and woman (52nd percentile female, 30-35 years old). Three-point seat belts were the only elements which restrict bodily motion. Models' feet were not affixed to the interior's bottom. An extra cushion was added to common seat's cushion for the boy model. A two-step simulation was planned for doing a crash test. At first, bodies fall from rest slightly above seats meanwhile seat belts' retractors pull back them to affix on seats. Then seatbelts are locked. Secondly, the crash acceleration pulse [5] is applied to bodies and seats as well as the vehicle's interior.

Fig. 1. Seating configurations in a highly automated vehicle

3. Injury assessment

A post-processing algorithm is available for evaluating Virthuman's injury indexes [1]. It collects injury index of the body's parts according to their degree of injury at the current time. Therefore, a particular segment's degree of injury is its worst injury's degree in the time interval from the beginning to the current time step. Colour evaluation according to the degree of injury is returned by four basic levels according to EuroNCAP consumer rating. A small degree of injury or none is given by *Good*. An injury level can be either *Acceptable* or *Marginal*. However fatal injuries are presented by *Poor* level because make a serious degree of injuries Fig. 2. Head's injury index is evaluated by the Head Injury Criterion. Bending moment, as well as shear and tension forces of upper neck's joints, are used for injury index of a model's neck. Injury of the model's thorax is determined based on ribs' deflection and parts' Viscous Criterion. Compression and pubic forces are important parameters to

investigate index of injury for abdomen and pelvis respectively. Femurs, knees and tibiae' injury indexes are related to compression force and moments in these parts.

Here we divide Virthuman's body parts to three dominant sections: a) Head & Neck, b) Trunk (thorax, abdomen and pelvis), c) Legs (femurs, knees and tibiae). Each sections' injury index is its the worst injury's degree of its parts. For instance, in Head & Neck case if Neck's injury index is Acceptable but Head's injury index is Poor, the section's final assessment is Poor.

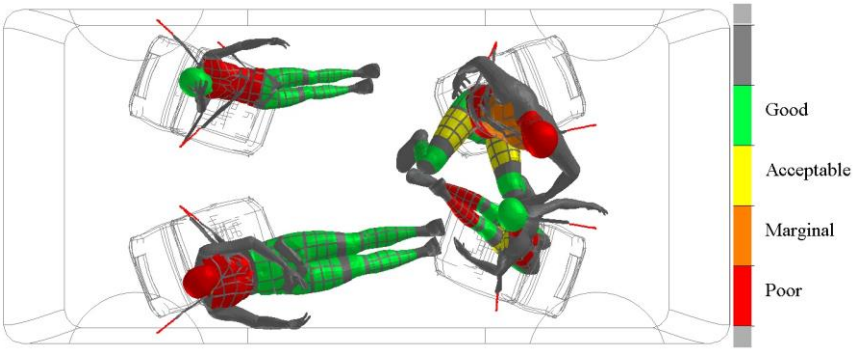

Fig. 2. Body part's injury indexes evaluation, (Living Room at 30 km/h)

Body sections' injury index in non-standard seating configurations is compared with the standard one. Safety of body's section in a seating configuration is worse than another one if its injury index is increased. On the other hand, whenever a section's injury index is decreased, the safety of body's section is improved Fig 3.

Fig. 3. Injury indexes' changes evaluation

Injury indexes comparisons per body sections are given in Table. 1 for two crash speeds. In where no sign is put in the table it means no changes were seen between two seating configurations from the body section's injury index point of view.

4. Discussion

Occupant's safety in non-standard seating configuration for highly automated vehicles was compared with standard seating configuration from an injury index point of view. Three sections of a model's body (Head & neck, Trunk and Legs) were considered for injury indexes evaluation. Simulation's data were collected for two impact pulses in a frontal crash direction. Results have not been validated against experimental tests which keep the study's topic open for further investigations.

Returning to numerical results for low-speed crash (30 km/h), because models' feet were not affixed to interior's bottom, the chance of legs' injury for front-row occupants (Girl and Man) is increased. Besides changing the orientation of Man's seat in Face-to-Face and living Room seating configurations causes its head hit to seat's headrest and experiencing a rotation on its neck respectively. These events increased the Head & neck section's injury index. On the other hand, man's trunk in Face-to-Face seating configuration hits to its seat's back and will not be in contact with shoulder belt. Therefore its injury index is decreased. All in all

non-standard seating configurations are not as safe as the standard one for front-row occupants (Girl and Man).

Based on simulation's outcome for high-speed crash (50 km/h) Face-to-Face seating configurations can improve Head & neck's safety of occupants who sit in front of the vehicle's interior (Girl and Man). Furthermore, it is expected rear-row passengers (Boy and Woman) have a safer condition in Living Room seating configuration from the legs' injury index point of view.

Table 1. Injury index comparison between seating configurations

		Boy			**Girl**			**Woman**			**Man**		
		Head & neck	*Trunk*	*Legs*	*Head & neck*	*Trunk*	*Legs*	*Head & neck*	*Trunk*	*Legs*	*Head & neck*	*Trunk*	*Legs*
30 km/h	*Face-to-Face vs. Standard*						✗				✗	✓	✗
	Living Room vs. Standard						✗				✗		✗
50 km/h	*Face-to-Face vs. Standard*				✓						✓		
	Living Room vs. Standard			✓						✓			✗

Acknowledgements

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