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The most dangerous factors for child passenger collisions in the interior of a rail vehicle

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This contribution is focused on the most dangerous factors for child passenger collisions in the interior of a rail vehicle. The actual legislation deals only with an injury of an average adult male, but the evaluation for the wider population (5 and 95 percentile) will be other logical steps in the near future. It is possible to overtake the current trends and to carry out an rail interior safety assessment for children due to the excellent scalability of the VIRTHUMAN model. The virtual assessment of passive safety continues to increase its role in transport. Hence finite element method and multibody simulations are used for the safety risk assessment. The injury criteria are used for probability of injury evaluation. The vehicles, which are used in this research, were developed recently and they are currently in operation.

The simulation of the rail vehicle collision scenario is provided according to the acceleration pulse by the GMRT 2100 standard. Only 50-percentile adult male is considered in current standards, [2]. The developers of rail vehicles are usually inspired by the European Standard EN 1176-6:2017 "European Safety Standard for playground equipment and impact absorbing playground surfacing„, when a new vehicle with compartments intended for child passengers is designed. Although requirements in this standard are not connected with rail transportation, it is possible to overtake the current trends and to carry out a rail interior safety assessment for children. For these simulations, an interior model consisting of seats with seat tables was created. Interesting part of the modelled interior is the seat padding foam material, which was validated experimentally in previous work, [3]. Part of the description is a chosen geometry, material constants, and a finite element calculation network. In addition, the report describes the scaling of the VIRTHUMAN human body model to represent a child passenger. For the explicit simulations the commercial SW VPS was used, [1]. The scaled child model is seated in the seat. Two variants representing the actual seating of the child on the seat are considered. The standard simulations themselves are presented in two configurations, with a folded and unfolded table. The simulations results are significantly influenced by the passenger initial position. It is obvious that this position is difficult to predict. Therefore the two standard initial positions (observed by experiment) and more non-standard positions are considered. The results are evaluated in terms of kinematics and prediction of injury to the passenger. Based on these, a general recommendation is made to improve the safety of the selected interior type. Some recommendations for rail interior design safe for children are provided at the end of this paper.

The final consideration is based on the results of the simulations. The rail transportation is very different in the contrast with automotive industry. The requirement for special child restraint system in rail vehicle is unreal. Although the safety performance of standard interior (not designed for child passenger) is not as bad, there exist significantly worst scenarios. The most significant safety risk for child passenger is connected wit the table in the open position

(see Fig. 1 right). This part represents significant safety risk for child passenger which is amplified significantly if the child passenger is sitting on the knee of adult passenger. The table can be partially closed after collision, what is also prohibited by standard GM/RT2100. It can be shown that this collision scenario can be still dangerous even during emergency barking (statistically more often). The considered table design is reason of significant head injury even in the closed position. This result is caused by one design of table and cannot predict result for very different design, but the change is highly recommended. For example very simple step will be to omit the tables in the departments intended for child passengers.

Another simulations has as the aim to show safety risk of standing passenger. It this type of simulations exist real risk of non-precious results (in longer time). Therefore the simulation time was significantly reduced. After the fall over the next seat the model is able to show very different results for very small changes in initial conditions (see Fig. 1 left). This problem must be studied in the next research to exclude the influence of possible chaotic behavior.

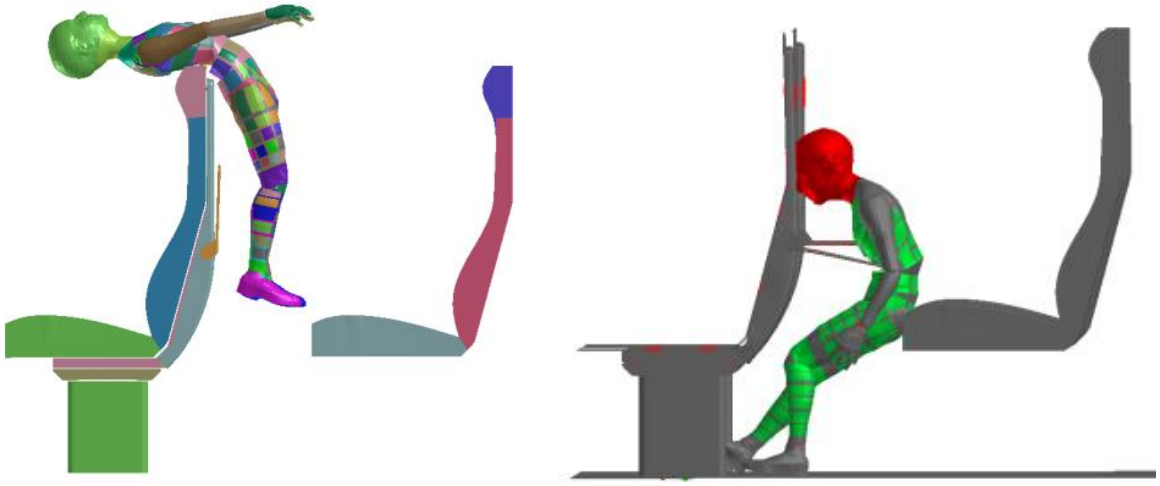

Fig. 1. The example of two results of collision simulations with 6 years old child

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