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Analysis of Standing Occupant Collision in Rail Vehicle with Influence of Deformable Floor Assessment

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Abstract: The free fall is serious type of passenger accident. The collision of standing passenger with floor is solved during rail vehicle emergency braking. For this purpose the rail vehicle interior model with rigid and deformable floor is created. The deformable FE model behavior during the impact can provide useful information for experimental validation.

Keywords: Crash; Passive Safety; Rail Vehicle; Biomechanics.

1 Introduction

This paper is focused on the passive safety of the railway vehicles interiors. The aim of this abstract is to present the standing passenger safety risk assessment. The virtual model of a railway vehicle floor is created for this purpose. The data of the vehicle constructions were obtained from the local developer. The considered vehicle has recently been developed and used in operation now. The safety assessment was carried out by FE and Multibody simulations. The simulations were performed by the software environment VPS (Virtual Performance Solution, using solver PAM-CRASH). The combination of rigid and deformable parts was intended for the interior modeling. The new human body model (called "VIRTHUMAN") is used for the evaluation of the safety risk in common crash scenarios [1]. The shape of the model is based on the real data from a scanned human body (database CESSAR) with parameters close to 50th percentile figurine [2].

2 The Collision Scenarios

As a result of the applied acceleration occurs occupant fall. Progress of the fall depends on many factors. The mechanism of the fall is most significantly affected by the position of the passenger. Response of the human muscle is not considered, because it is difficult to determine the average reflex of average human body. It would be necessary to obtain measurement results on a statistically significant sample. The Higher value of deceleration (e.g. by vehicle collision) is associated with a large displacement of passenger's body. Passenger's collision with interior feature is more probable than collision with floor due to the large displacement. Therefore is emergency braking situation suitable for first simulation of standing passengers collision. In the bus transport more than half (54 %) were injured because the bus was braking or accelerating [3]. It is assumed a deceleration during rail vehicle emergency braking. Free fall is quite serious type of passenger accident. Falls are a common and often devastating problem among older people [5]. The deceleration of the rail vehicle increases up to 2.4 mm/s^2 after brake entering. This occurs at a speed of 30-40 kmph. Reaction time of acceleration is longer than 2 ms, it can be shown by a simple calculation. The constant acceleration during the breaking is assumed as the boundary condition.

The initial position of the standing occupant affects the process of the fall significantly. It is appropriate to consider all the starting positions at the beginning of the calculations. Standing passengers can take up a position facing the direction of travel, sideways to the direction of travel, or back in to the direction of travel.

3 Computer Simulation

3.1 The Rigid Floor Model

The most significant injury risk is connected with passengers head. Therefore the head injury is evaluated. The HIC and 3MS injury criterions are used for probability of head injury assessment [2]. The injury severity will be result of head velocity immediately before impact. The most significant influence is human body kinematic. Three initial positions of human body are considered (passenger standing in the driving direction, passenger standing in the opposite to the driving direction, passenger standing sideways to the driving direction). The simulation with rigid floor usage is useful for human body kinematic exploration. The collision of standing passenger standing in the driving direction is shown in the Fig. 1.

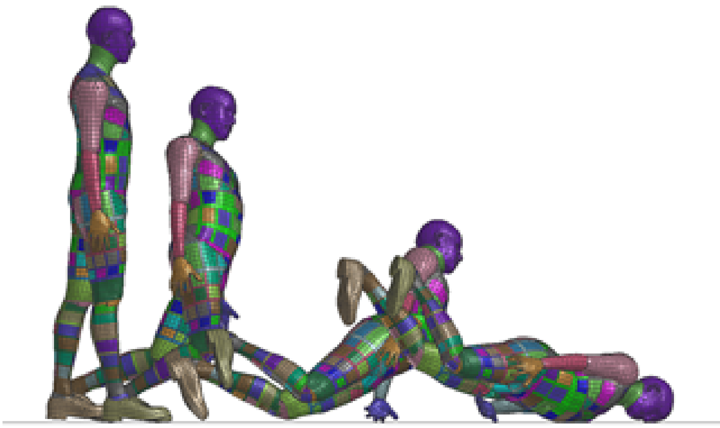

Fig. 1: Passenger movement in time 0 ms, 630 ms, 1260 ms, 1890 ms.

3.2 The Deformable FE Floor Model

The idealized model of the floor (Fig. 2) is based on parameters of the actual operated vehicle. For simulation is prepared a viewport with dimensions 720 $\times$ 900 mm. All significant construction parts are included in the viewport. The first layer of floor is made of an altro (Anti Slip Vinyl material). The next layer if made of the plywood. Under plywood are situated blocks made of wood and rubber. The last layer is vehicle construction made of aluminum alloy. The most significant result of simulation of collision with deformable floor is safety risk assessment. It is possible to compare all resultant values of head injury criteria. The differences between results from simulations with rigid and with deformable floor models are expected. In center of interest is the influence of deformable floor model rigidity. For the future usage is useful to known how much complex model is adequate. Thanks to FE model it is possible to assess dynamic response of each layer of the floor. This assessment can show exactly the floor layers with the significant influence on impact results. It will give very useful information for validation experiment with suitable anthropomorphic test device.

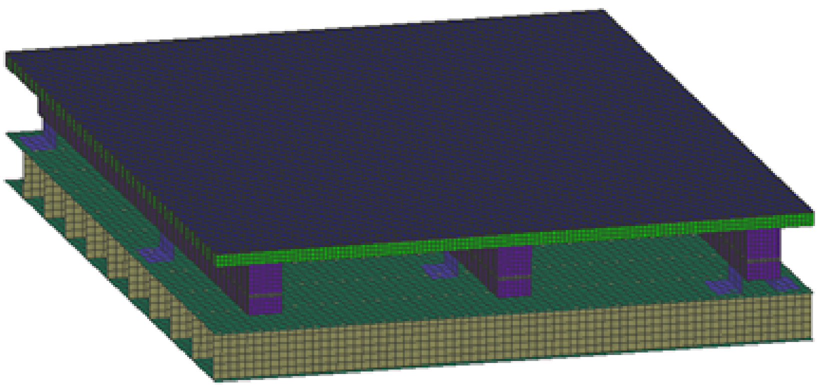

Fig. 2: The deformable floor model for computer simulation.

4 The Results of the Computer Simulations

The head injury poses the most significant danger for the passenger during the fall. The highest acceleration was found during the fall of the passenger standing back in to the direction of travel (Fig. 3). The important result for head injury assessment is the acceleration of the head COG (head center of gravity). The injury severity is evaluated using injury criteria HIC and 3MS (for detail information see [6]). The HIC criterion is calculated from the acceleration/time history in selected time range. For the contact type of head injury is more feasible HIC15 criterion with time-window 15 ms long. The 3MS criterion is simply defined as acceleration level exceeded for the duration of 3 ms and should not exceeded 80 g. Calculated values of the criteria are very high. This suggests a risk of fatal consequences.

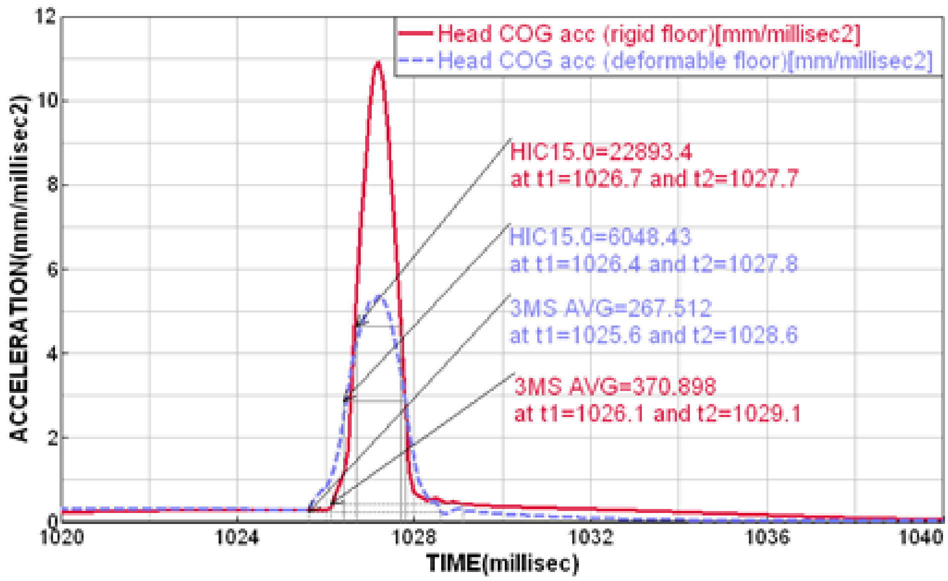

Fig. 3: The comparison of head COG accelerations and injury criteria for rigid and deformable floor model.

5 The Influence of Deformable Floor

Rigidity of the floor has a very significant influence on the results. This fact is obvious from a comparison of head COG acceleration curves (Fig. 3). As expected, the head acceleration is significantly higher in the simulation with the rigid floor. The main question is which parts of rail vehicle floor has the most significant influence. This problem can be solved through analysis of stress or strain, but more direct way is to evaluate the displacement of floor parts (Fig. 4). The parts with significant displacement in vertical direction have greater influence on the results.

6 Conclusion

The computer simulations results show, that free fall is serious type of passenger accident. Influence of floor rigidity is actually important. Computer simulation allows the use contact for rigid bodies, but the definition of this type of contact must be validated experimentally. The mechanical properties of individual parts of floor should be measured. The model of whole floor of rail vehicle is created, but it is clear, than some parts of floor construction would be removed during model idealization. The assessment of influence of each part is possible by computer simulation, where each material definition is based on data available from literature. As expected, the top layer of floor made from altro has the most significant influence during the impact. An interesting result is that the influence of plywood is almost the same as the effect of the upper layer. Results from multiple points top layer show that besides the pressure at the point of impact on the results participates also bend. Wooden block carrying the floor is divided by the rubber cushion layer. Influence the top of the wooden block is significant, while the influence of the bottom of the wooden block is only small. This knowledge of

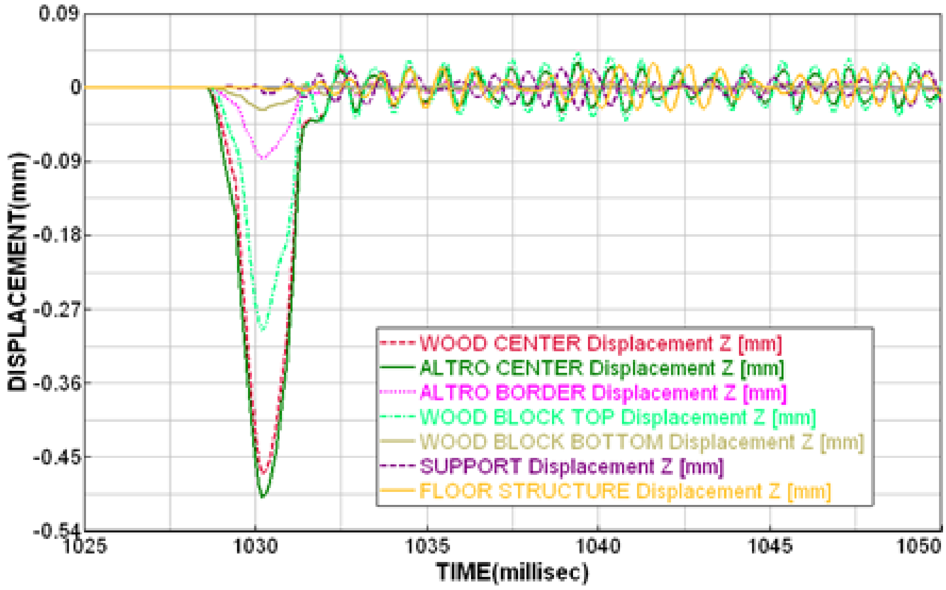

Fig. 4: Displacement in vertical direction of selected parts of rail vehicle floor.

the behavior of the floor of a railway vehicle will greatly affect proposal validation experiment and tests of mechanical properties.

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