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Numerical analysis of a passenger safety during a railway vehicle collision: The effect of safety belts

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In automotive industry, safety belts are with no doubts established and inherent part of passive safety elements [1]. They keep the occupant at his or her seated position during the impact scenario. However, application of such safety elements in railway vehicles is questionable. There is an important aspect of the passenger comfort in railway vehicles which might be affected. Also, application of safety belts represents additional cost for manufacturer. Hence, the crucial question is related to the potential benefit of safety belts. Would their application increase passenger safety in a collision scenario of a railway vehicle? The study presented here aims to answer that question using numerical simulations.

As a representative of a passenger, the Virthuman model is used in the Virtual Performance Solution (VPS) software. It is based on multi-body structure with deformable segments. It is easy to position, it requires low computational time and it includes automatic algorithm for injury criteria evaluation, see e.g. [3]. In this case we evaluate the criteria described in the GMRT2100 regulation for railway vehicles such as HIC15, neck axial force and moment, thorax deflection, etc [2]. An important feature of the Virthuman model is the scaling algorithm that enables to represent any passenger of given age, height, weight and gender. For this particular study, 25-year-old male of a 50th percentile is considered, that is, an average male with the height of 178 cm and the weight of 76 kg.

An open coach type interior is considered. Its FE model is developed in the VPS software. It includes the passenger's seat and the seat in front of the passenger with folding table. Two-points or three-points belts are fixed to the passenger's seat in a common sense including retractors and sliprings. The collision scenario is considered in a configuration with no belt, two-points belt and the three-points belt. Each of these cases is considered in a configuration with folded and unfolded table at the backrest in front of the passenger. It means, 6 configurations of numerical simulations are considered in total. The acceleration pulse is prescribed for the vehicle interior as defined in GMRT2100 regulation. It corresponds to a frontal collision scenario of a railway vehicle. The simulation time is 300 ms.

The results are evaluated in terms of passenger's kinematics and injury risk. As an example, kinematics of the passenger at 150 ms for each belting option is provided in Fig. 1. The case with unfolded table is illustrated here. In case with no belt, knees impact the backrest possibly causing the injury of both femurs at approximate time of 95 ms. At the approximate time of 150 ms, the head hits the headrest causing the possible neck injury. In case with unfolded table, the thorax and abdomen hit the backrest just in the location of the table at approximate time of 185 ms. Since the table is made of steel, the impact causes higher injury risk of these two body parts. In case of folded table, no impact of the thorax and abdomen with the backseat occurs.

In case with two-points belt, no primary impact of lower limbs and the backrest occur. Hence, no injury risk of the lower limbs is indicated. The body of the passenger is fixed by the two-point belt at the abdomen area. However, the torso and lower limbs are thrown against the backrest. The abdomen is compressed by the belt causing higher injury risk of this body part. At the approximate time of 150 ms, the head hits the backrest. In the configuration with unfolded table the head hits right the table causing serious risk of head injury. In the configuration with folded table the had hits the plastic part of the backrest which does not increase the head injury risk.

In case with three-points belt, whole upper part of the body is fixed with the belt, hence it does not impact the backrest in front of the passenger. Slightly increased injury risk of abdomen and thorax only is predicted due to their compression with the belt.

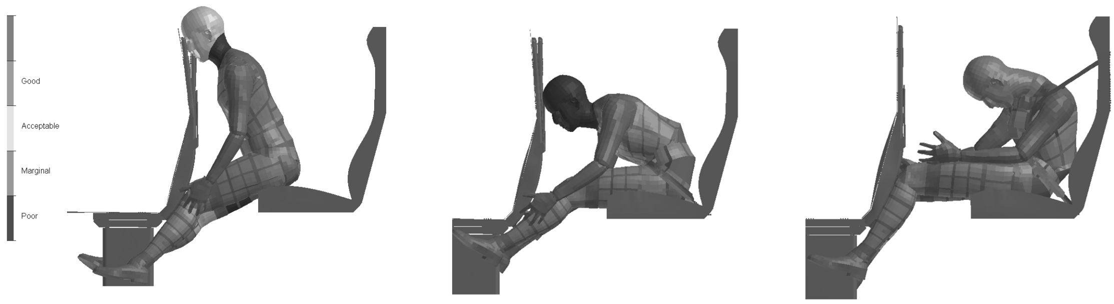

Fig. 1. Passenger's kinematics during collision scenario at 150 ms; configuration with no belt (*left*), the two-points belt (*middle*) and the three-points belt (*right*)

With respect to the results obtained, following conclusions can be formulated. With no seatbelt, high injury risk of lower limbs is predicted as a result of the impact with steel profiles. The head impact with the headrest leads to increased head injury risk. Injury risk of lower limbs is completely reduced in case of a two-point belt. However, this type of belt significantly increases the head injury risk in case of unfolded table. Also, significant neck injury risk is predicted in case of a two-point belt for both folded and unfolded table. Application of a three-point belt minimizes injury risk of both head and neck. Therefore, in case of mounting setabelts in the railway vehicle interior of an open coach type, three-point belts should be preferred to two-point belts. In case of a frontal collission scenario as defined by the GMRT2100 regulation, the overall injury risk of a passenger is lower for the three-point belt when compared to a two-point belt.

Acknowledgement

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