Increasing Passive Safety in Railway Traffic

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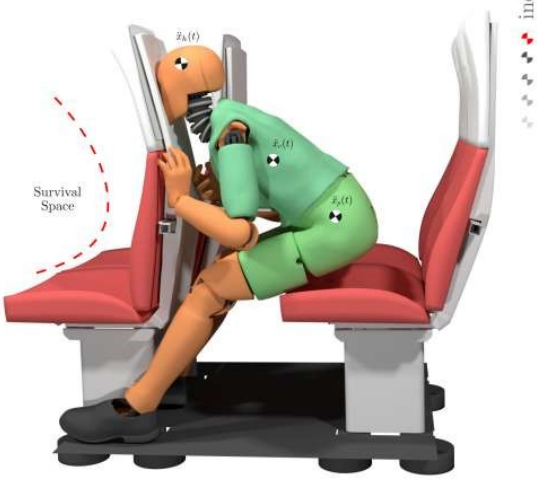

Fig. 2 - Injury prevention test - table down

Safety of passengers is one of the key issues of transport industry. In automotive industry the design of safe vehicles is a must and it is governed by many standards. Surprisingly, it does not apply for railways although millions of people commute by trains every day. There are no standards for crash test similar to in automotive, except for UK, where very strict rules defined by GM/RT2100 apply.

Injury Prevention Tests in Railway Trafic

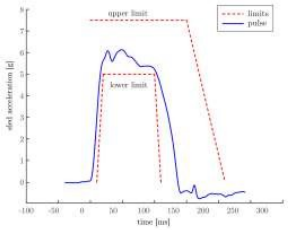

Fig. 1 Test pulse

For each type or design of seat used in a vehicle (fist class, standard class) is nessesary to test seats for dynamic structural integrity and injury potential caused by a specific impulse of acceleration. The both tests are applied in rearward and forward projection of movement. Integrity tests determine the strength of the seat structure that must be very stiff, while injury potential tests define safety of seat - seat structure must be very flexible too. These two requirements are in conflict and depend on manufacturers how to solve this problem.

The classical tests can be modified by including the folding seat back table. Then each type of the folding table shall be dynamically tested in both situations - the fully deployed and fully stowed positions of the table. The main problem is the contact of the open folding table with abdomen/chest of passengers.

Forward Injury Prevention Test - table up

Fig. 3 Kinematic frames comparison - table up

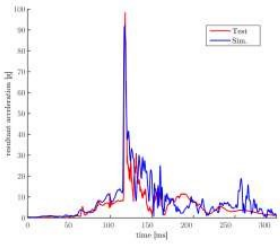

Fig. 4 Head resultant acceleration - table up

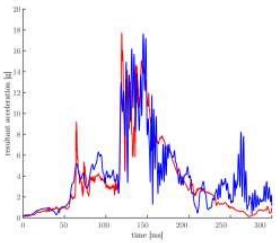

Fig. 5 Chest resultant acceleration - table up

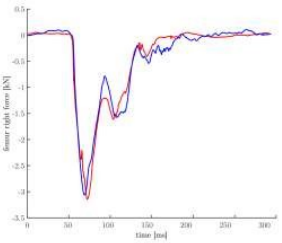

Fig. 6 Femur force - table up

Our goal is to analyse and simulate the laboratory experiments with dummies so as to meet all the injury criteria. The experimental crash tests then will be performed (with high probability) only once. These numerical simulations save costs of manufacturers. For implementing these demanding simulations, we use LS-Dyna solver module on IT4Innovations National Supercomputing Center, Salomon cluster.

For determining the safety of seats with folding table up, the worst thing is to the meet with limits of the Head injury criterion (HIC) specified as

$$\mathrm{HIC} = \left\{ \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} |\ddot{x}_h(t)|_2 \, \mathrm{d}t \right]^{\frac{5}{2}} (t_2 - t_1) \right\}_{\max}.$$

Head	MIRA - Test	IT4I - Sim.	Safety Limits
Peak Resultant Acceleration	96.4 g	91.9 g	-
Head Injury Criterion	**176**	**183**	**500**
Neck			
Peak Bending Moment	71 Nm	105 Nm	310 Nm
Chest			
Peak Resultant Acceleration	17.7 g	17.6 g	-
Pelvic			
Peak Resultant Acceleration	20.3 g	26.5 g	-
Femur			
Peak Femur Force	**-3.15** kN	**-3.10** kN	**-4.30** kN

Tab. 1 Injury criteria - table up

Forward Injury Prevention Test - table down

As is apparent from *fig. 7*, at the moment of contact edge of table with the dummy abdomen/chest ($t = 105$ ms), there is significant compression of human body. In experimental practise, a cube made from thin aluminum plates, which is measured after test, is placed to dummy.

In case that the geometry and stiffness of the folding table is sufficiently low (according to the standard), we know that the fully open table is not dangerous for humans and also reduces the risk of head injuries. According to the available parametric studies, the results show that the size of abdominal compression does not significantly affect the increase seat pitch as is the case with other injury criteria.

Head	MIRA - Test	IT4I - Sim.	Safety Limits
Peak Resultant Acceleration	62 g	77 g	-
Head Injury Criterion	68	123	500
Neck			
Peak Bending Moment	77 Nm	76 Nm	310 Nm
Chest			
Peak Compression	-	**-22** mm	**-63** mm
Pelvic			
Peak Resultant Acceleration	19.1 g	26.0 g	-
Femur			
Peak Femur Force	**2.92** kN	**3.00** kN	4.30 kN

Tab. 2 Injury criteria - table down

Fig. 7 Kinematic frames comparison - table down

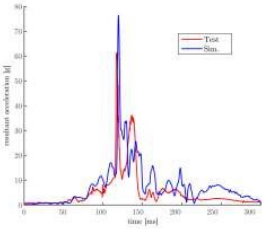

Fig. 8 Head resultant acceleration - table down

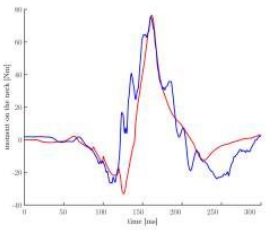

Fig. 9 Moment on the neck - table down

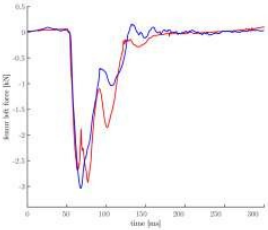

Fig. 10 Femur force - table down

Acknowledgements

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