Identification of Railway Vehicle Interior Model for Occupant Passive Safety

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The study presented here concerns the identification of improved coach interior layouts, in particular the inline seating layout, during crash of railway vehicles, focusing the protection of its occupants. A railway accident is described by the primary collision, in which the vehicle is subjected to a sudden deceleration causing the unrestrained occupants to continue their original motion until the secondary collision, in which the railway passengers come into contact with some part of the vehicle or with other occupants.

Hence, the seating layout plays a major role in the process. The strong knowledge in vehicle modelling, numerical analysis and experience in simulation techniques and control is a requirement for the work presented here. Moreover, the lack predictability on the kinematics of the occupants when a railway accident occurs, involves applications much more complex than just conventional rail vehicle dynamics software. The real challenge for this kind of problems is to deliver reliable simulation results in the face of many uncertainties. This requires the choice of appropriate modelling techniques, the application of skill and care to develop the model and simulation inputs, and to establish the relevant measurable output criteria, in order to obtain simulation scenarios that attest the reality [1,2]. Furthermore, the integration of nonlinear finite elements for the description of the plastic deformation of the structures with conventional rigid multibody descriptions for the large rigid body displacements results in general in better vehicle models, being used the commercial code MADYMO for the coupling of the finite element and multibody models. This integrated simulation environment is an advantage, avoiding numerical problems such as stability issues and the influence of the extrapolation order in the information exchange between the modules in a modular co-simulation setting [3].

The numerical model of the inline seating layout selected for this work has been developed previously by the authors [4,5] using a coupled environment with multibody description for the Hybrid III dummies [6] and a finite element approach for the seats and structural features of the vehicle interior. The crash pulse used for the crash scenario simulation corresponds to that accepted by the industry and operators as being representative of the most relevant accidents.

Though the current injury criteria [7] have been identified in road and aerospace occupant passive safety, in which the occupants are belted and have their kinematics guided, they are also used in railway transportation where seat belts are not used and where different interior layouts are present. These layouts may include standing passengers, front and side facing occupants, a diverse furniture such as tables, poles and partitions as potential target surfaces during impact and no particular posture for their resting positions. However, the injury mechanisms for unrestrained occupants between rail and road accidents also present some similarities. During the primary collision, the vehicle is subjected to an abrupt deceleration causing the unrestrained occupants to continue the original motion. Then the occupants are projected through the vehicle until the secondary collision occurs with their contact with some part of the interior of the vehicle or with other occupants.

The use of optimisation procedures for complex crash scenarios, in which each analysis may take between many hours and many days, is limited. Although a body of literature on optimisation methods in crashworthiness exists, mostly the models are simplified to allow for faster analysis so that the optimisation iterations can be solved in acceptable time [8,9]. The approach taken here diverges from the current optimisation approaches in the sense that the models used are the most detailed possible and it is the biomechanical injury criteria that form the spaces of the objective functions approximated by second order polynomial functions as done in the previous works of the authors [10], involving then only one real computational cost in the number of the analysis of the detailed model for the identification of the quadratic surface parameters. This process, known as meta-modelling, solves an optimisation problem defined by surrogate objective functions containing all injury criteria to be minimized based on data points taken from simulations and producing a *n*-dimensional response surface, where design variables are varied inside a specific domain [11]. A multiobjective genetic algorithm [12] is used to find the best design solutions. Thus, these solutions are tested in MADYMO not only to check deviations between the surrogate optimisation model and the interior layout model, but also to identify divergences between the surrogate and realistic models. The results show that the optimal designs of the interior seating layout are obtained with relevant decreases of the injury indices.

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