PEDESTRIAN PASSIVE SAFETY: FINITE ELEMENT AND MULITBODY SIMULATIONS

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1. Abstract

The paper presents the evaluation of the pedestrian safety, during a collision with a road vehicle with the high bonnet leading edge. A Sport Utility Vehicle (SUV) was chosen to investigate the influence of vehicle front design on the pedestrian lower extremity injuries. The Finite Element Method (FEM) was utilized in order to reduce the costs and time needed to carry out a pedestrian-to-car front aggressiveness test. The virtual tests carried out by means of the numerical, certified Finite Element (FE) lower leg impactor were further contrasted with the results of the multibody (MB) simulation. While the FE impactor gives in-depth data about leg fractures and knee joint injuries, further MB simulations present the complete, post-impact pedestrian kinematics. Finally, the critical points in SUV design, in terms of pedestrian passive safety enhancement, were indicated.

2. Introduction

Pedestrian safety has become a key issue in the field of vehicle safety regulations in European Union, where 12-25% of seriously injured or killed people on roads account for pedestrians [1]. However there is still lack of data measuring the performance of the frontal protection systems, also known as bull bars (fig. 1), in the vehicle to pedestrian collision.

Fig. 1: The frontal protection system fitted to Nissan Navara, close-up

In this paper a novel approach has been presented – the combinations of the FE impactor subsystem test and MB simulation with the standing Hybrid III 50th percentile dummy.

3. Finite Element approach

Once the discrete model of the Sport Utility Vehicle (SUV) and frontal protection system were completed, the authors had to verify the parameters encompassed in the Regulation (EC) 78/2009 [2]. The explicit LS-DYNA code was used to verify the frontal protection system performance against the biomechanical limits. Fig. 2 depicts the visualization of the collision between the SUV, with the bull bar fitted, and the pedestrian's virtual leg. The numerical impactor, which imitates the performance of the lower extremity, can be spotted in the figure.

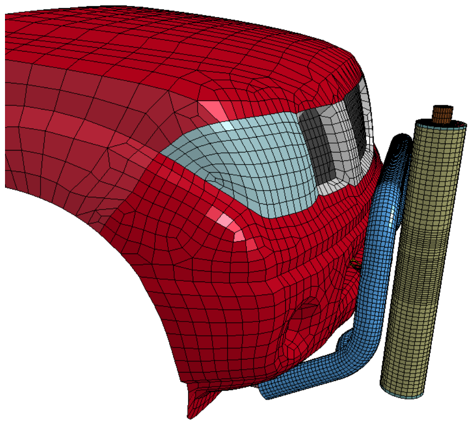

Fig. 2: Discrete model of Nissan Navara and lower legform impactor

The FE simulation brought some crucial data concerning the lower leg injury risk [3]. It is especially important since a bumper of a SUV strikes usually pedestrian's thigh. This leads to complicate ligament injuries and, what is worse, the reaction and friction force may cause the pedestrian to be dragged under the car chassis. However, it is not possible to investigate the kinematics of the pedestrian using only the impactor. Hence, the full dummy model was further used.

4. Multibody approach

Although the current regulations make the vehicle manufactures to test the vehicle fronts with the impactors, the examination might not mirror the actual kinematics of an impacted pedestrian. Therefore, the authors carried out a multibody simulation by means of MADYMO.

The vehicle front-end was modelled with simple ellipsoids and surfaces. The attention was paid to reflect the dimensions, not the material properties of the vehicle and bull bar. As the distinct from the FE, for the kinematic analysis evaluation there is no need to model detailed material characteristics [4]. The geometry of the impacting body – i.e. the vehicle – is the key factor for ensuring the pedestrian safety post-impact trajectory.

5. Conclusion

The increasing number of SUVs has a serious implication on pedestrian passive safety. The carried out FE and MB simulations highlighted some drawbacks of the compulsory impactor subsystem tests for new, high bumper vehicles (SUVs). It has been proved that the kinematic of the lower leg differs from dummy model (fig. 3).

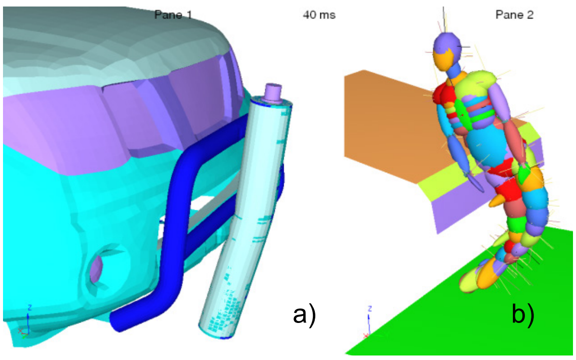

Fig. 3: a) lower leg imactor behavior (FE)
b) dummy model kinematics (MB)

Hence, despite of meeting the biomechanical criteria obtained from the FE impactor test, the pedestrian actual post-impact kinematic cannot be accurately verified. Consequently, for vehicles with high bumpers and high bonnet leading edges, the test procedure proposed in current regulations may not fully asset the pedestrian safety (fig. 4).

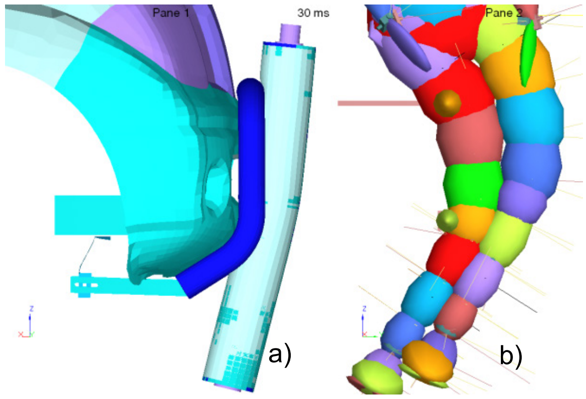

Fig. 4: Differences in post-impact kinematics in FE (a)) and MB (b)) numerical models

The obtained and presented results suggest that for SUV-type vehicles the dummy test would be recommended. The great development of computation power and expansion of FEM and MB analyses enable to widen the possibilities and application field of numerical simulations [5]. While FE impactor can in-depth check the injury risk of lower legform, the MB simulation validates the overall pedestrian kinematics which is directly related to the vehicle's front geometry.

References

[1] European Commission, Move to improved pedestrian safety, IP/08/964, Brussels 2008

[2] European Parliament, Regulation (EC) No 78/2009 of the European Parliament and of the Council, Official Journal of the European Union, Brussels 2009

[3] Ptak M., Karliński J., Kopczyński A., Analysis of pedestrian passive safety with the use of numerical simulation, Journal of KONES 2010, vol. 17

[4] Simms C., Wood D., Pedestrian and Cyclist Impact: A Biomechanical Perspective, 2009

[5] Rusiński E., Czmochowski J., Smolnicki T., Advanced finite element method, Wrocław University of Technology, Wrocław 2000