ENGINEERING MECHANICS 2009
National Conference with International Participation
Svratka, Czech Republic, May 11 – 14, 2009

pp. 785–788
Paper **#272**

NUMERICAL MODELING OF PROTECTIVE SPORT HELMETS

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Summary: *The paper describes development of advanced methods used in research of protective devices. Explicit FE analysis is used for modeling of drop tests. Drop tests are one of common testing procedures used in the standards and are intended for testing of device's protective properties. If we were able to assess the acceleration history from numerical analysis with given geometry and material properties, we can also perform optimization procedure and design "optimal" protective helmet.*

1. Introduction

Number of victims of traffic accidents increases every year, probably because of increasing number of cars and traffic size. 80 percent of deaths caused by traffic injury are due to head injury. However, it is possible to lower the number of victims using protective helmet. According to present methods of how to design a helmet, it is clear, that there are possibilities in improving the design method. The goal of the work is to develop a methodology to design an optimal protective helmet.

2. Methods

Finite Element Method (FEM) is able to compute complex model quantities while giving the information about linear and angular acceleration history. From this point of view it could be advantageous to use it the design of protective helmets. In spite of the advantages, it is still very complicated technique. Complex models with irregular curved shape and material nonlinearities cost a lot of time, and only few papers were published in this field (Kunecký et al., 2006). Kostopoulos et al. in 2002 made FE parametric study with different shell materials. Leading work has been done by Mills et al. (2007) while introducing the "real" shape of the helmet.

The equation of motion in FE could be computed using two different techniques. First an implicit method or, second, an explicit method. Implicit methods are conditionally stable and have higher computational cost because of needed inversion of the stiffness matrix. Explicit methods have constant time step and could be very unstable, the time step should be less than critical timestep. But, highly nonlinear problems involving large deformations, rapid dynamic behaviour etc. are implicitly nearly unsolvable. The work is based on use of LS-DYNA code because of the need of explicit solution.

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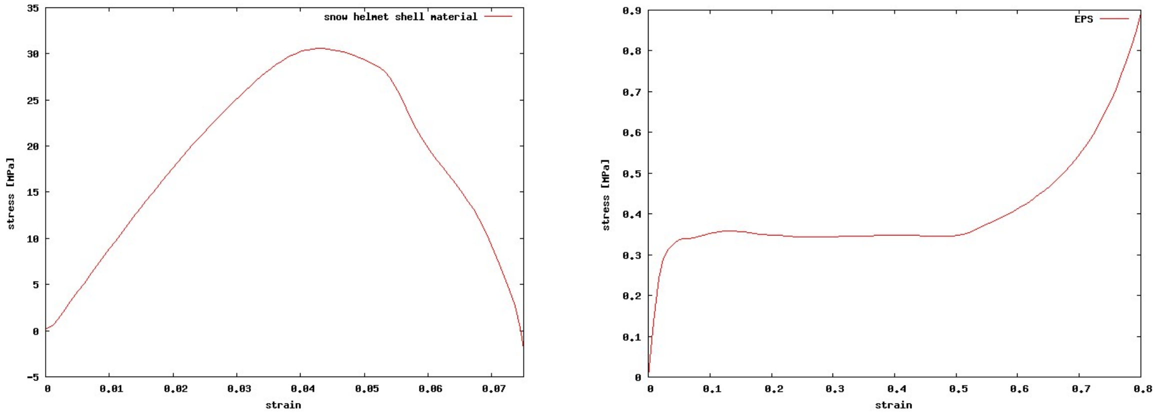

Fig. 1 Material properties measured for use in the FEA for shell (left) and liner foam (right)

For the FE model preparation and solution the ANSYS software was used. The FE model of human head was constructed according to the standard CSN EN 960 (2007). Headform with circumference 575 mm was chosen. First, points lying on the surface were created and the curves were interpolated through these points (B-splines). Curves were later lofted and the resulting surface was created. The model was meshed using elements of tetrahedral shape and prepared for use in ANSYS. Material model was chosen linear elastic (made of steel). The density was computed to reach the overall mass of the headform of 4.7 kg.

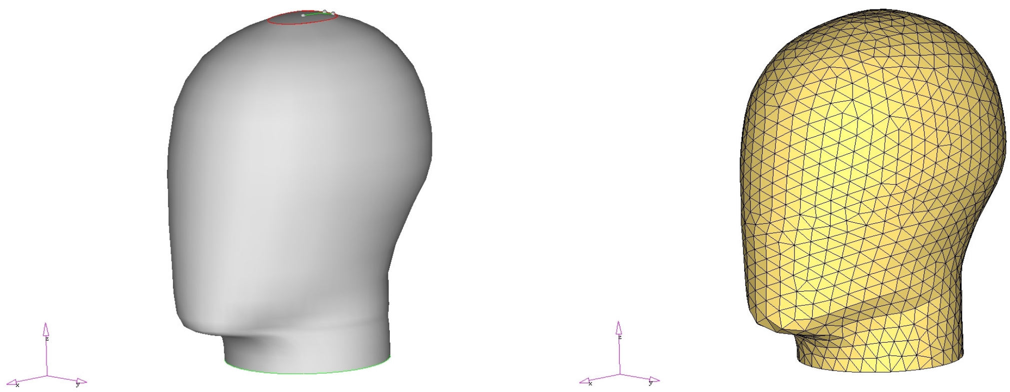

Fig. 2 NURBs (left) and FE model of dummy head (right)

The FE model of motorcycle helmet was made using Rhinoceros (NURBs modeller) and was based on the data obtained by optical measurement. Next, it was improved and meshed using Altair Hypermesh software. The model consists of the outer shell, liner and comfort foam. The model of headform was inserted. The ANSYS LS-DYNA product was used for the solution. Three materials were used. Linear elastic for the shell, two LS-DYNA CRUSH-ABLE_FOAM materials for the liner and comfort foam. The analysis was performed.

Next, the experiment with the helmet was performed. Drop test from the height of 2 m was measured using three-axial accelerometer Entran placed at the centre of gravity. The history curve was recorded. After the solution, acceleration curves were compared.

Fig. 3 Experimental set-up for drop testing

3. Conclusion

The results show that there is the possiblity to improve the method by acquiring right material properties using measurement of material properties at deformation rates near those of the experiments. Despite the fact, that all the materials were tested in our laboratory to get the correct material properties, it is possible, that some part has strong viscoelastic/viscoplastic response, that is, up to date, not measurable in our laboratory. The machine for such a testing is developed in our laboratory. However, it is planned to improve the model.

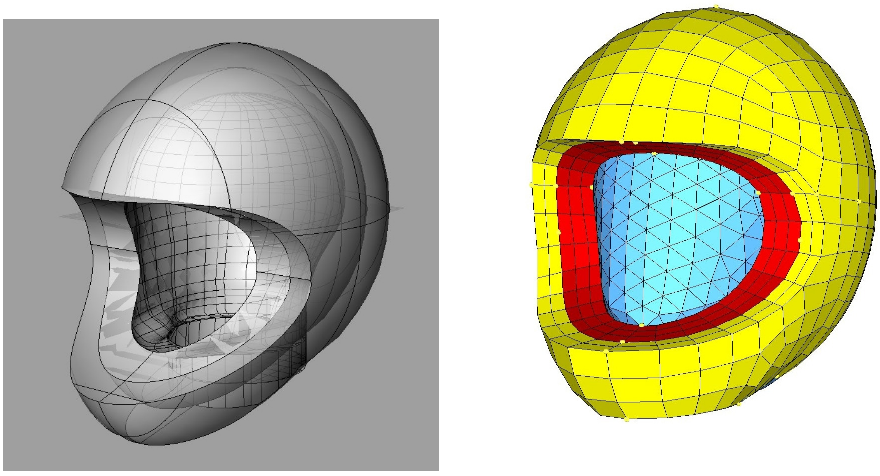

Fig. 4 NURBs model (left), FE with dummy head inserted (right)

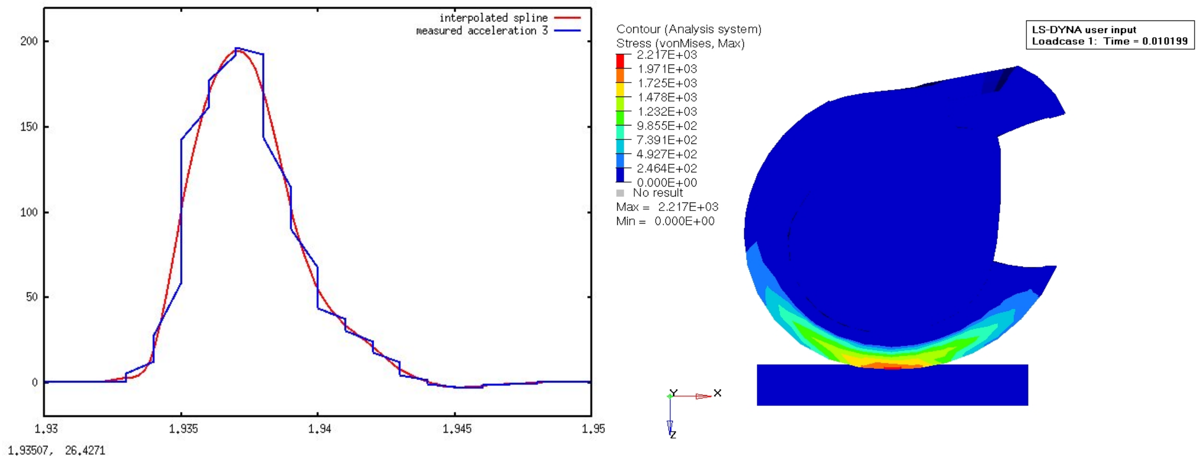

Fig. 5 Acceleration history measured (left), after analysis (right)

4. Acknowledgement

Authors would thank for support to grants MSM6840770043, GAČR 103/05/1020, IGS ČVUT CTU0709016 and GA CR 103/07/P483.

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