DEVELOPMENT AND VALIDATION OF A BICYCLE HELMET FE MODEL

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INTRODUCTION

Parallel to head biomechanics, LSBM also investigates head protection systems. The main objective of this project is to use FE modelling techniques to investigate the performance of existing and other prototype helmet design. Such models, coupled with a head FE model, could constitute in the future a powerfull tool for accident reconstruction and helmet optimisation.

Recent work dealing with helmet modelling concern much more motorcyclist's helmets (Gilchrist et al 1994, Yettram et al. 1994 and Brandt et al 1996). At our knowledge no bicycle helmet model has been proposed in the literature. Such helmets are more worn and will be subjected to new developments in a near future. The bicycle helmets under study is quite different from motorcycle helmets in conception. Its expensed polystyrene (EP) liner is of a much higher density and the external polycarbonate (PC) shell is less then 1 mm against 3 to 5 mm for a motorcycle helmet.

In a first step, we present the tests conduced in order to define the constitutive equations of the EP liner and the PC shell. After modelling of the helmet and the head form, impact tests on two separate anvil geometry are simulated in order to validate the model against head acceleration and permanent helmet deformations in an impact environment.

MATERIAL PROPERTIES AND MODELLING

Dynamic compression tests at different speeds are conduced on EP samples from the helmet liner. This tests reveal low load rate sensitivity and show a relative homogeneity of the helmet with a EP specific mass of 85+5 g/l.

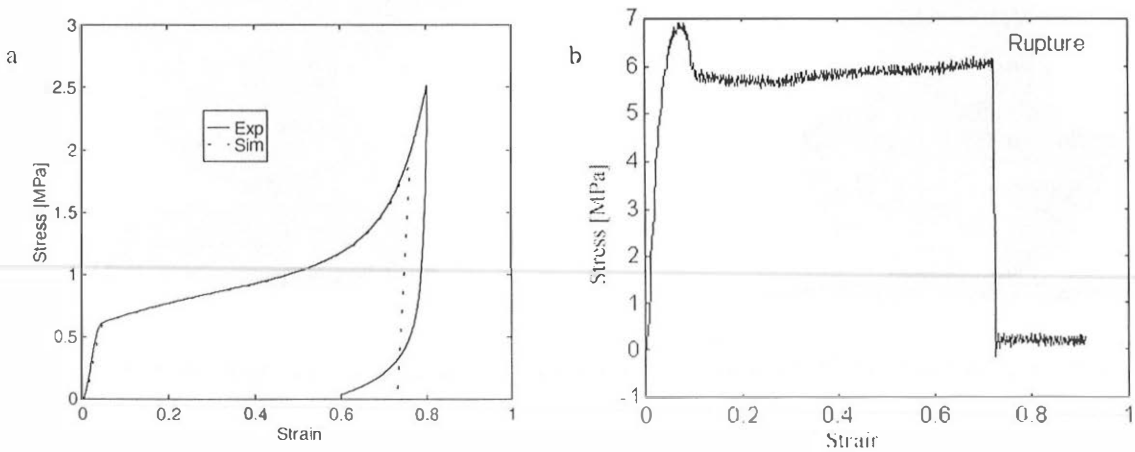

Figure 1 : Expensed polystyrene compression test a), and polycarbonate tensile test b).

The non linear stress-strain curve is digitalized and introduced in the RADIOSS explicite FE code. Compression tests are numerically simulated and an example of experimental-numerical compression curve superimposition is produced on figure 1. This figure presents also the result of a tensile test conduced on a PC sample. This material is modelled by a typical elastoplastic constitutive equation characterised by its Young modulus (164 M Pa), its yield stress (5.1 MPa) and its strain rate at rupture (70 %).

The helmet and hybrid 2 geometry are obtained by the digitalisation of there external surfaces and with the aid of 3D meshing program HYPERMESH. Helmet shell and headform are represented by shell elements and the helmet liner is modelled by 1088 solid elements (figure 2). Boundary conditions are defined by a no slide condition between helmet shell and liner and a detection algorithm for the headform-liner surface to surface interface.

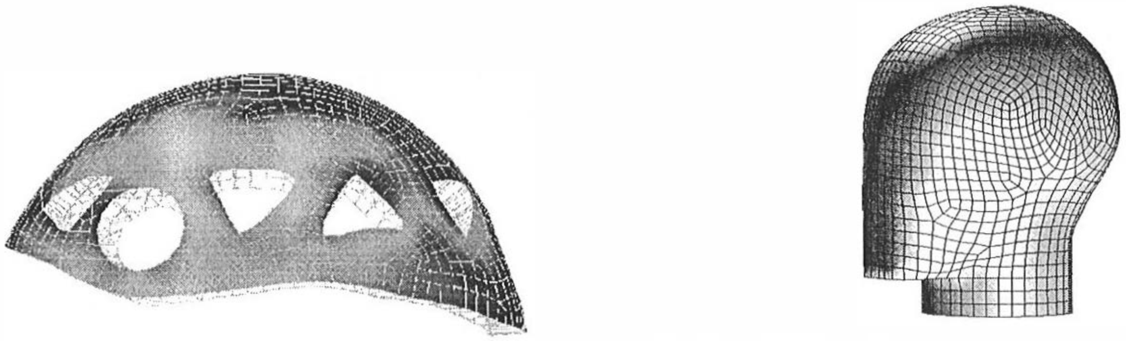

Figure 2 : Meshing of the helmet and the Hybid 2 headform.

MODEL VALIDATION

The validation process consists in simulating two real impacts. The first is a crown impact on a flat anvil at 5.56m s^{-1} and the second a lateral one on a curved anvil (R= 15 mm) at 4.64 ms^{-1} dropping speed. The numerical simulation of this two tests are illustrated in figure 3. Both anvils are supposed infinitely rigid and initial velocity of the model are those encountered in the experimental test. The calculated head form accelerations are plotted against experimental ones in figure 4.

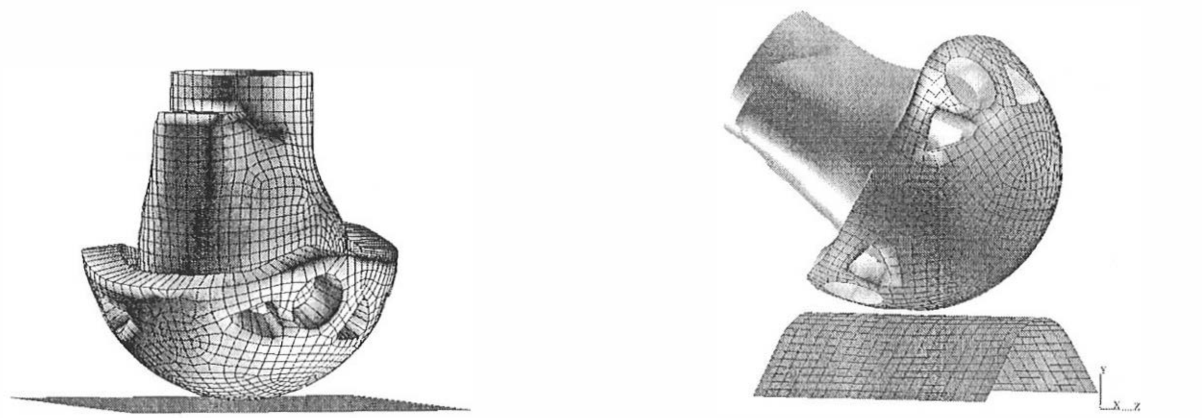

Figure 3 : The helmet-headform model under impact condition for the validation process.

Maximum values and shock durations are reasonably estimated. For the crown impact two maximum are observed in conformity with the experiment. In deep analysis of head and helmet displacement shows that this phenomenon is due to a helmet rebound before the main deceleration of the head. The second validation parameter is much more qualitative than quantitative and consists in comparing the outer helmet surface deformation after impact. In both, calculated and experimental deformations, the order of magnitude for the crown impact are 2 mm and 5 mm for the lateral impact.

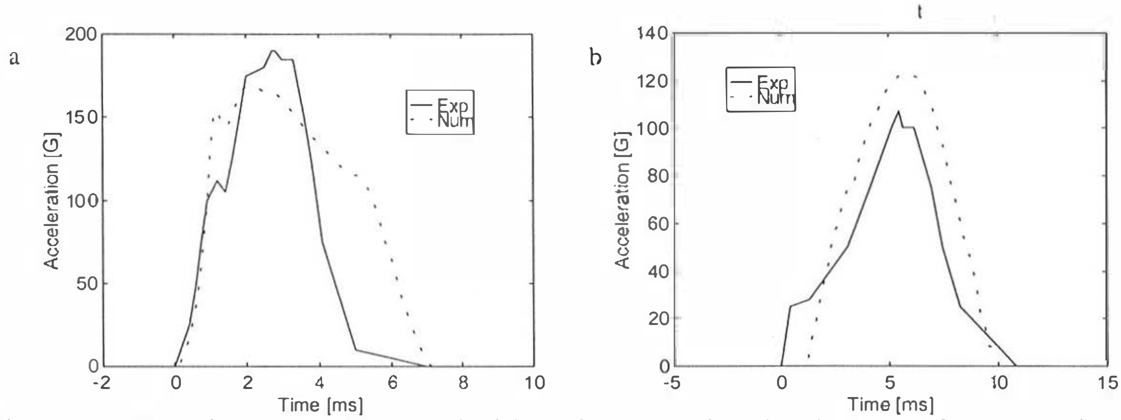

Figure 4 : Experimental and numerical headform acceleration in case of a crown impact on the flat anvil a) and a lateral impact on the curved anvil b).

CONCLUSION

This work presents the development and validation of a bicycle helmet FE model. Non linear constitutive equations are determined experimentally for the helmet liner (expended polystyrene) and for the shell (polycarbonate). After meshing of the helmet and the Hybrid 2 headform, a surface to surface interface was introduced between both models in order to constitute the global model. The validation procedure under impact environment against a flat and a curved anvil shows reasonable agreement at both head acceleration and post impact helmet deformations levels. This promising results permits a help in novel helmet design without expensive prototype construction. Such kind of "numerical prototype" seams able to predict protection level offered by a given helmet. Moreover, the coupling of the helmet model with a 3D human head FE model, will able an optimisation of a helmet vis-à-vis biomechanical parameters. A second future development of this work is found at the head tolerance limit investigation level, were realistic accident reconstruction involving helmeted cyclists are now possible.

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