모터싸이클 헬멧의 충격 해석

Impact Analysis of Motorcycle Helmet

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ABSTRACT

Finite element analysis of impact response of a motorcycle helmet is presented in this paper. The finite element LS-DYNA3D code is used to simulate the impact response of the helmet including of plastic shell, foam liner, and magnesium headform. Since the maximum accelerations at center of gravity of the headform obtained by numerical analysis and experiment agree well, the numerical simulation is proved to be valid.

Keywords: *Motorcycle helmet; Finite element modeling; Impact analysis; LS-DYNA3D.*

1. Introduction

Several studies on the impact response of motorcycle helmet have been carried out. Gilchrist and Mills (1994) performed impact analysis of a motorcycle helmet by using an equivalent model of mass, spring, and damper. Yetham et al. (1994) carried out a finite element parametric study on impact response of the helmet. They used the head injury criterion for judging the protective performance of helmet. Recently, Kostopoulos et al. (2002) performed impact analysis of a helmet-headform system using the finite element code LS-DYNA3D, and the dynamic response of different helmet-headform systems was judged in terms of the maximum acceleration at the central gravity of the headform.

In this paper, the rear impact of a motorcycle helmet consisting of plastic shell, foam liner, and magnesium headform is performed using finite element simulation of drop test. A comparison of the maximum accelerations at central gravity of the headform obtained by numerical analysis and experiment is presented to evaluate accuracy of the numerical analysis.

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2. Finite element modeling

2.1. Geometry

The original model of helmet is taken from Thai and Kim (2007). A foam liner and a headform are constructed by importing 3D SCAN data using pre-processor module of LS-DYNA3D. A flat anvil and a seatbelt are also added to simulate the real impact response of the helmet. The three-dimensional finite element model of the helmet, as shown in Fig. 1, consists of four parts: the shell of the helmet, the foam liner, the headform, and the flat anvil. The plastic shell is modeled with a set of 3,544 shell elements. The foam liner made of expanded polystyrene (EPS) consists of two different parts. The EPS-Top and EPS-Bottom are modeled using 996 and 2676 solid elements, respectively. The magnesium headform is modeled by 2112 shell elements, and the flat anvil is modeled by 384 solid elements.

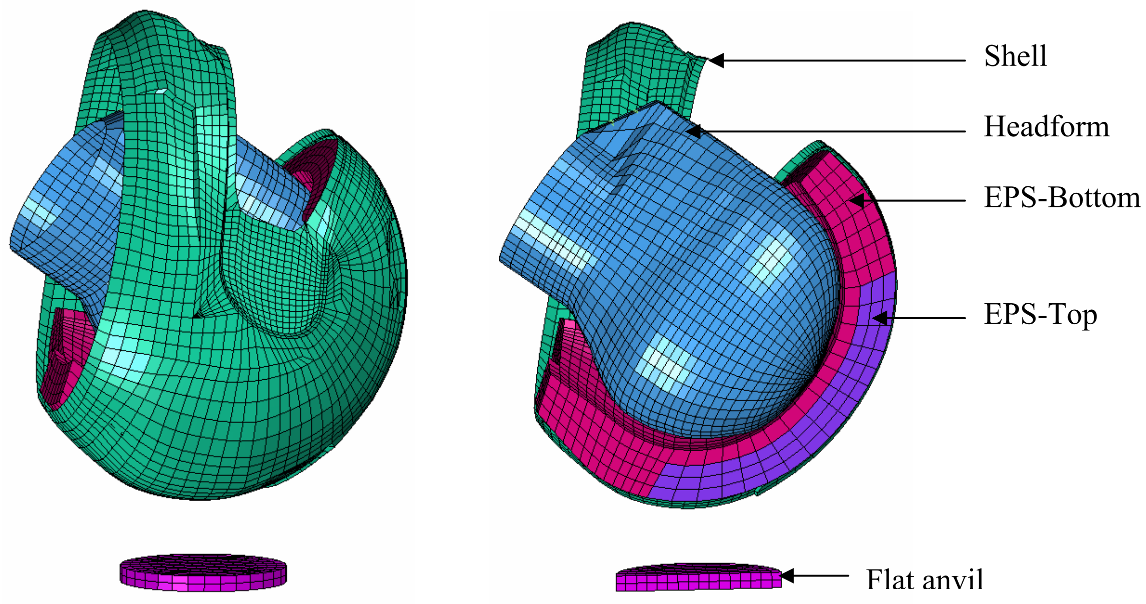

Fig. 1. The finite element model of the helmet

2.2. Boundary and loading conditions

The helmet is freely dropped from the drop height of 3.06 m onto the fixed flat anvil. The value of drop height is chosen based on the mass of the headform (5.0 kg) corresponded to impact energy of 150 J. The *AUTOMATIC_SURFACE_TO_SURFACE contact in LS-DYNA3D recommended for most dynamic simulations is used to present contacts between the headform and foam liner, as well as between the foam liner and shell. All contact parameters used in the analysis are taken the default settings except that the SOFT option is chosen of 2 to activate the segment based contact formulation which is an appropriate contact algorithm for the contact between shell and solid elements.

2.3. Material properties

The expanded polystyrene (EPS) is used for the liner part of the helmet to absorb the impact energy. The mechanical properties of EPS as well as its density and compaction rate vary significantly regarding the production procedure. The stress-strain behavior of EPS obtained by experiment is given in Fig. 2. The *MAT_LOW_DENSITY_FOAM model in LS-DYNA3D is used for highly compressible low density foams. The material properties are given in Table 1.

Table 1: Material properties

Mechanical properties	Unit	Plastic shell	EPS-top	EPS-bottom
Mass Density	kg/m^3	1140	22	58
Poisson's ratio	-	0.4	-	-
Young's modulus	MPa	2000	87.5	37.6
Tension cut-off stress	MPa	-	0.5	0.5
Yield stress	MPa	48	-	-

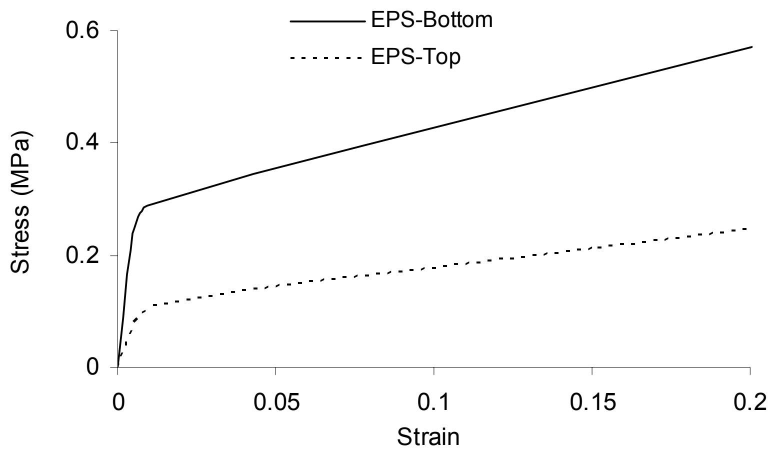

Fig. 2. Stress-strain curve of EPS obtained by experiment

3. Results and discussion

As stated above, the helmet is freely dropped at the height of 3.06 m and impacts onto the fixed flat anvil at the rear of the helmet. The Vonmises stress of the helmet at the impact time is presented in Fig. 3. It can be seen that the maximum stress concentrates at the contact area between the shell and the flat anvil. The maximum value of Vonmises stress at the time of impact is 47.81 MPa (99.6% of yield stress).

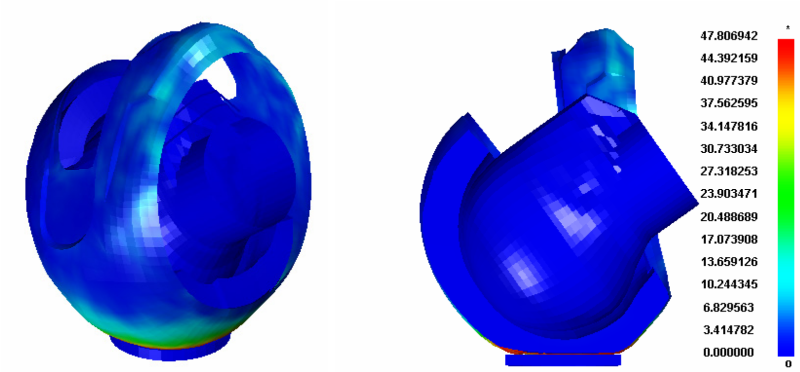

Fig. 3. VonMises stress at the time of impact

The drop simulations of VonMises stress and corresponding deformation at different time intervals are presented in Fig. 4 and Fig. 5, respectively.

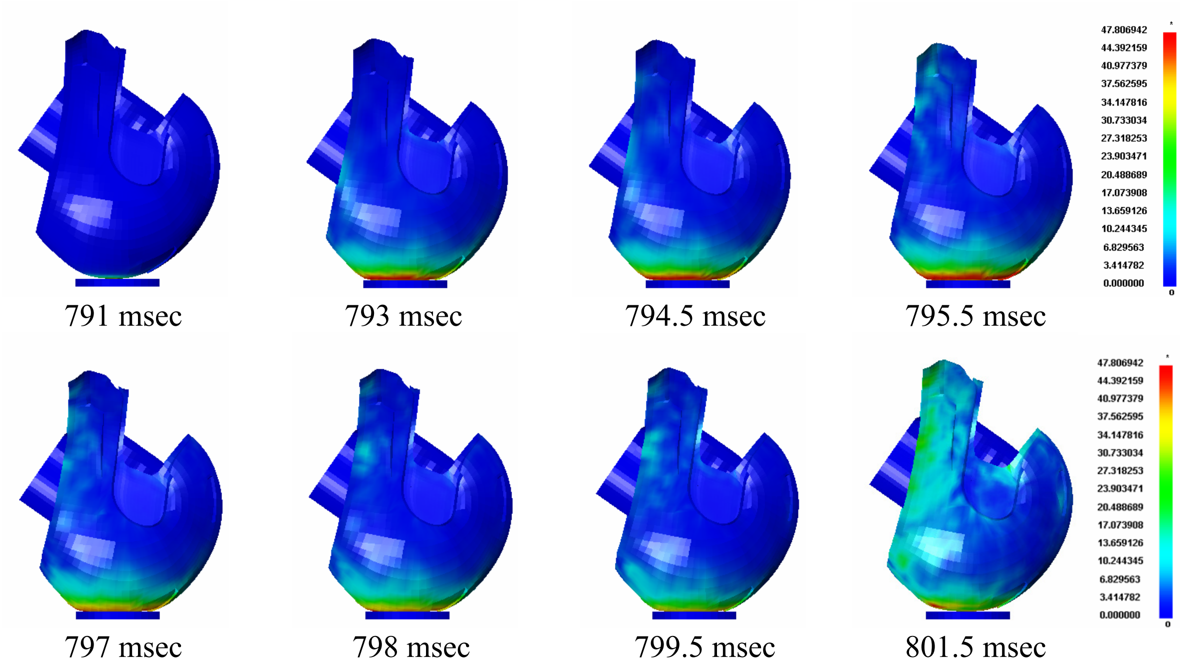

Fig. 4. The drop simulation of VonMises stress

To evaluate the performance and impact response of the helmet-headform system, the peak acceleration value at the mass center of the headform is used. A comparison of acceleration obtained by numerical analysis and experiment is presented in Fig. 6. The good correlation can be clearly seen between the experimental and the simulation results. The peak values of acceleration generated by analysis and experiment are 232.4 G and 234.0 G, respectively (G is the gravity acceleration). This value does not exceed the maximum allowable acceleration of 290 G given by Snell standard (2005).

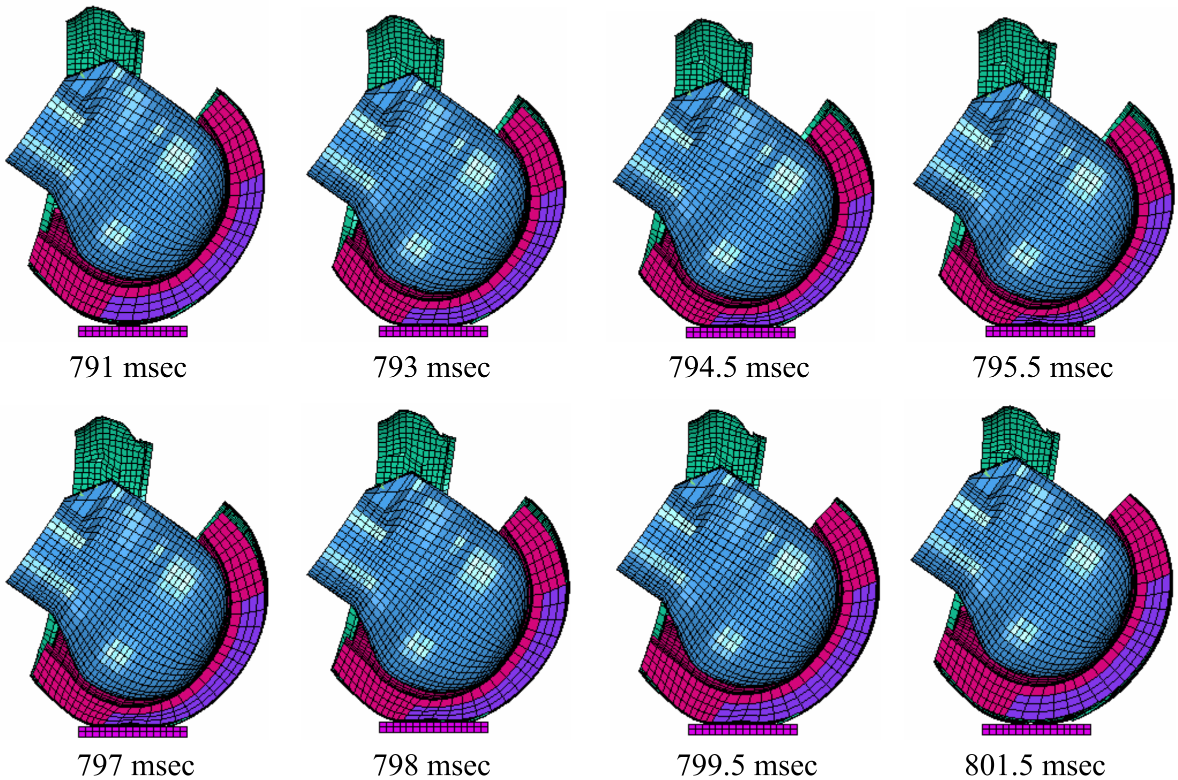

Fig. 5. The drop simulation of deformation

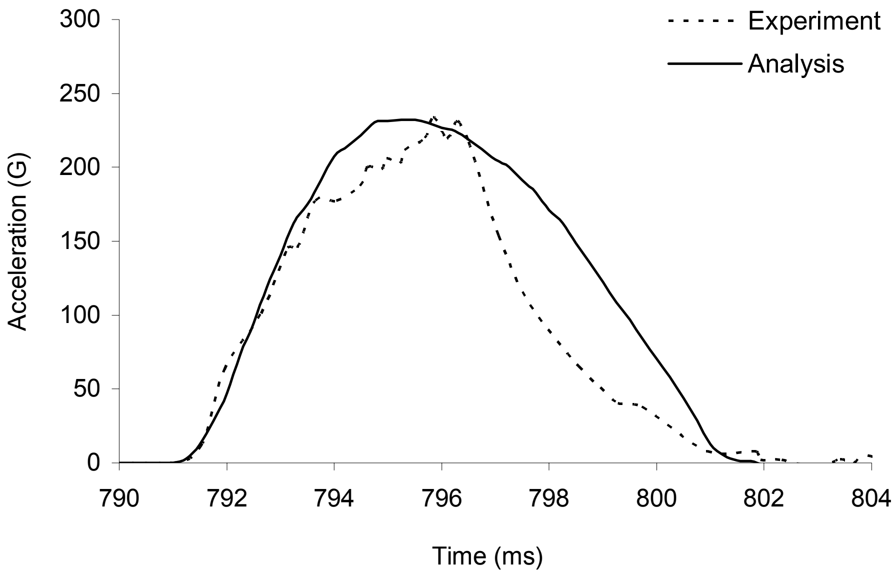

Fig. 6. Comparison of acceleration at center of gravity of the helmet

4. Conclusions

The three-dimensional finite element analysis of impact response of the motorcycle helmet has been presented in this paper. The impact response of the helmet-headform system obtained by numerical analysis and experiment is well compared in term of peak acceleration value at the mass center of the system. It can be concluded that the finite element results are reliable and accurate.

Acknowledgements

The support of the research reported here by Ministry of Commerce, Industry and Energy thought Grant 10020379-2006-12 is gratefully acknowledged.

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