National Conference with International Participation
ENGINEERING MECHANICS 2006
Svratka, Czech Republic, May 15 – 18, 2006
paper no. **299**

DROP TESTS USED FOR VALIDATION OF FE MODELS OF HUMAN HEAD FOR HIC ASSESSMENT

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Summary: *Head injuries are the most often causes of death in traffic accidents. To develop better interiors of cars or new protective devices (e.g. helmets) there is a need to quantify the mean criteria of injury. Most of today used head injury criteria use an integral value of acceleration of the head during a certain time interval. The main drawback of these criteria is the fact, that they use only linear acceleration of the head. For better HIC assessment there is a need to use different measures, e.g. combination of translational and rotational acceleration or criteria based on strain energy. For these purposes complex FE models are used. To verify the behavior of these FE models, drop tests with different drop height are usually used. The paper presents results of drop tests used to validate FE models of human head. According to data obtained from accelerometers the HIC was computed and the critical height was determined.*

1. Introduction

Many thousands people die every year because of traffic accidents. One of the most frequent causes of death are the injuries of head. During the impact the brain undergoes strong acceleration which can cause severe injuries although the skull or other part remains intact. Due to this phenomena the protective devices are designed for the protection of skull as well as for reducing the brain's acceleration peak. For the assessment to which extent the brain can be exposed to acceleration there have been developed several injury cirteria. However, mostly used are the head injury criteria (HIC):

$$HIC = \left\{ (t_2 - t_1)\left(\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a dt\right)^{2.5} \right\}_{max}$$

where the time interval $(t_2 - t_1)$ is the impact duration chosen as to maximize the HIC value and a is the acceleration. The HIC value determines from a measured acceleration history the probability of the brain injury. As critical the value of 1000 can be considered. Recent studies show that these criteria consider only translational accelerations despite of substantial influence of more dangerous rotational ones.

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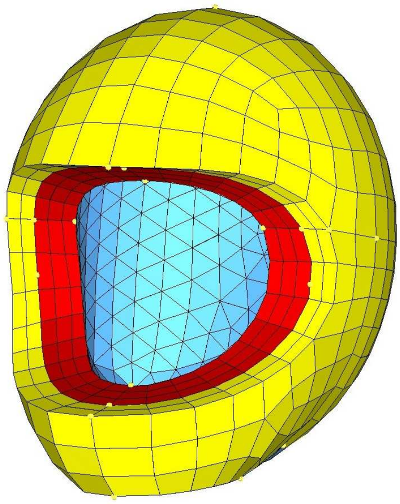

Figure 1: Meshed model

The HIC have been incorporated to many countries traffic safety standards [LS-DYNA]. HIC determination finds its main application in passive safety, crash tests and testing of protective means in general. Every helmet entering a market has to be proved using a drop test. The motivation of the work was to develop and verify useful numerical model intended for drop tests simulation. Experiments are unsufficient if there is need to better understand the mechanics of impact and the influence of the layers in the helmet on the magnitude of acceleration peak. Numerical model is advantageous because of its ability to show only poorly measurable quantities. The paper presents the verification of numerical model compared to real drop tests based on HIC assessment. The values of virtual drop test obtained from FE analysis were confronted with experimental results.

2. Methods

The HIC determination is essentially based on the acceleration curve, thus the goal of the validation was to obtain the acceleration history from both methods.

2.1. FE model

The dummy head form was constructed according to ČSN EN 960/1994. The standard determines the geometry using coordinates of points on the surface. The isocurves were created from the point cloud and the outer surface was built. The whole preparation of the model geometry was made using NURBs modeling software which is especially intended for industrial design. The helmet was constructed using NURBs surfaces and closed volumes. The geometry was set to be similar to the helmet used in the experiments. Three layers were modeled: the outer shell of thickness 3 mm, the polystyrene liner (20 mm) and the comfort foam (25 mm). The meshing was made using Altair Hypermesh and was focused on two goals; to have good element shape and to have low number of brick elements. Only the head form was meshed with tetrahedras. The model consisted of 6000 elements (Fig. 1).

Following material properties were assigned: the glassy polycarbonate of shell as linear

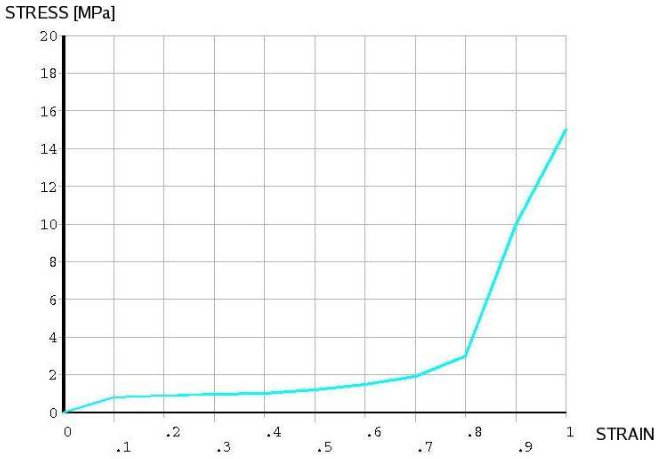

Figure 2: Material model used for crushable foam modeling

Figure 3: The test set

isotropic material (E=70 GPa, μ=0.3, ρ=1 g/cm3), the liner was modeled as elastoplastic material (E=50 MPa, σ_{yield}=50 MPa, $\sigma_{tangent}$=200 MPa, μ=0.3, ρ=1 g/cm3) and the comfort foam was defined using LS-DYNA pre-defined crushable foam model with stress-strain curve shown in Fig. 2. The head form was modeled as steel (E=210 GPa, μ=0.3, ρ=7.8 g/cm3).

The analysis was performed in ANSYS/LS-DYNA environment [LS-DYNA]. The LS-DYNA solver is intended for modeling of short time intervals, especially impacts and highly nonlinear problems. To set the proper duration time and the contacts (helmet-head form), the drop attributes were assigned. The solution took 60 seconds. The acceleration history of specified element was listed as a single file and the HIC was computed according to above mentioned formula. The integral was interpolated using numerical integration.

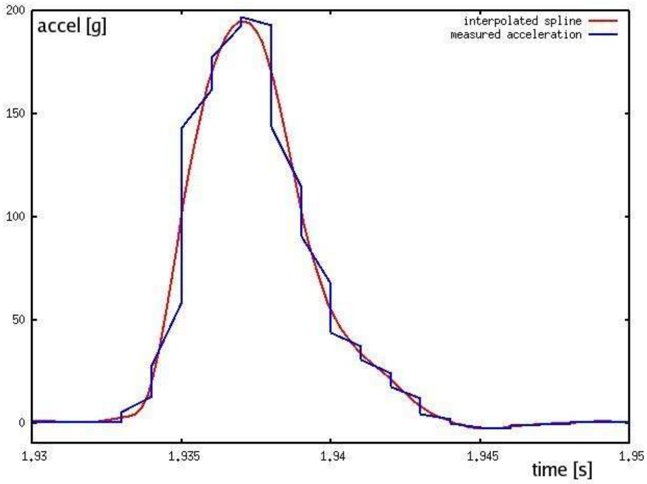

Figure 4: Measured acceleration history

2.2. Experiments

The experiments were performed using drop test machine situated in ÚMSD, a.s. Standard head form made of a metal alloy was enclosed in motorcycle helmet (Fig. 3). A three-axial accelerometer was embedded in the head form cavity. The sample rate of the accelerometer was set to 12000 Hz, drop heights were chosen as 0.95 m and 1.67 m. The drop board was made of rigid metal material. After the acceleration acquistion, the HIC value was determined using formula mentioned above. The acceleration magnitude was computed as vector sum of all three components (Fig. 4). The area below acceleration curve was computed using numerical integration. The time interval of maximal HIC value was determined using script which tried all the possibilities of HIC values and the maximal one was found.

3. Results and conclusion

After the numerical and experimental results had been gathered, the HIC values were compared. The comparison is shown in Tab. 1. The results show a slight difference caused by inaccurate assignement of material properties. The materials are mostly defined using tabular data, which can be a little bit different from those used in the real helmet. The model was validated using HIC assessment, although other quantities (stresses etc.) had not been taken into account. The model is in development.

4. Acknowledgment

The research has been sponsored by Grant Agency of the Czech Republic: grant. No. 103/05/1020.

5. References

[LS-DYNA] *Livermore Software Technology Inc.* http://www.lstc.com

[NHTSA] *Standard No. 208 - Occupant Crash Protection*, National Highway Traffic Safety Administration (NHTSA), http://www.nhtsa.dot.gov

Table 1: Results of analysis

Drop height	Experiment based HIC assessment	Numerical HIC assessment
1.67 m	795.11	629.15
0.95 m	441.27	400.37