THE EFFECT OF THE FMVSS201U FREE MOTION HEADFORM LEGISLATION ON HEAD INJURIES: A DISCUSSION BASED ON NUMERICAL SIMULATIONS

A. Eichberger, J. Steiner, W. Breitenhuber, J. Wernig
Magna Steyr Engineering Graz, Austria

ABSTRACT

UNTIL 2002 THE COMPLETE CAR fleet to be sold on the US market has to fulfill FMVSS201u (Free Motion Headform) legislation (DOT, 2000). It includes a test procedure using a free flying headform (FMH) that impacts several specified points on the upper car interior with a speed up to 24kph. Injury criterion is HIC(d), a modified HIC with a tolerance limit of 1000. The purpose of this paper is to give an idea if this legislation has potential to reduce head injuries, based on Finite-Element calculations.

KEYWORDS: HIC, Angular, Head Injuries, FMVSS, Finite Element Method

INTRODUCTION

HIC (DOT, 1972) is a criterion that is calculated on linear accelerations of the center of gravity of the human head. The modified HIC(d) is calculated according to the following formula to correlate HIC (as measured with the FMH) to results with complete dummies:

$$HIC(d) = HIC_{36} \cdot 0.75446 + 166.4 \qquad \text{(DOT, 2000)}$$

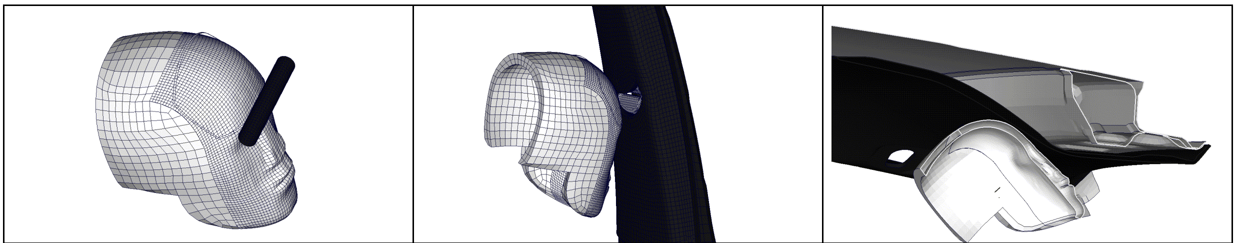
The FMH is a headform which kinematics is not restrained by a neck as it is in a human being. Therefore it provides the possibility of producing unrealistic test results by rotation of the headform.

METHODS

The kinematics of FMH testing was investigated by the Finite-Element-Method (FEM) using the PAM-Crash explicit FEM solver. A validated FEM model of the headform was used. All together three impact scenarios were investigated: A simple tube and two impact points from a real car (see fig.1).

1.) TUBE MODEL: To have a clear picture, the impact scenario was reduced to a simple model. The car interior was modeled by a simple tube with rigid constraints.
2.) BP2: a point of the upper belt anchorage on the B-pillar
3.) UR: upper roof in the area of the rear header

The models from the real car were compared against hardware tests and have acceptable correlation. The tube model was not verified, but - due to its simplicity - the correlation to a hardware test should be good. All models were calculated with an impact speed of 24kph.



1.) Tube model	2.) BP2	3.) UR

Fig.1: impact scenarios

RESULTS

1.) TUBE MODEL

Such a scenario would suggest a rather high injury risk. As expected the HIC(d) value is 1875 and above the tolerance limit of 1000. The peak of the rotational acceleration is 11460 rad/sec^2

(rotational velocity change: 24 rad/sec). The same model was calculated with locked rotational degree of freedom, that means a rotation of the headform was prohibited (comparable to a linear bearing). The HIC(d) increases from 1875 to 3579 for the locked scenario.

2.) BP2
On BP2 a HIC(d) of 679 and a peak rotational acceleration of 7214 rad/sec^2 (rotational velocity change: 21 rad/sec) was calculated, whereas with constrained rotational DOF the HIC(d) increased to 3567.

3.) UR
On UR a HIC(d) of 822 and a peak rotational acceleration of 4282 rad/sec^2 (rotational velocity change: 14 rad/sec) was calculated, whereas with constrained rotational DOF the HIC(d) increased to 3571.

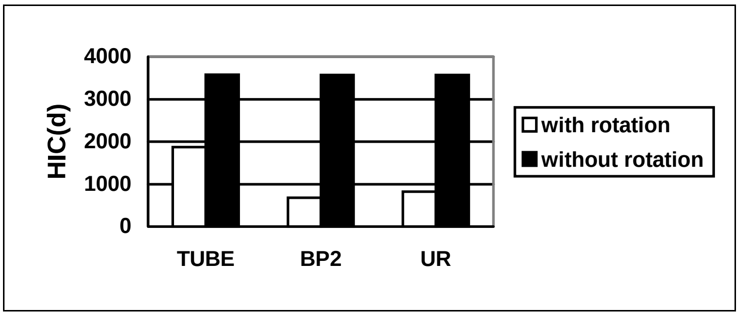


Fig.2: HIC(d) results of the FEM models

DISCUSSION

Restraining the rotational DOF has negative influence on HIC results. A typical FMH impact already creates rotational acceleration/velocity around the head center of gravity that offers some potential for head/brain injury. Some indications for tolerance criteria of diffuse axonal injury (DAI) have been reported (Margulies, 1992), mentioning DAI tolerance for man approximately 10000 rad/sec^2 peak rotational acceleration and approximately 100 rad/sec rotational velocity change.

Since HIC is based on linear accelerations we propose to modify the test setup and use a spherical headform with locked rotational DOF (e.g. linear bearing). A sphere would have the additional advantage that geometrical influences are isolated and the test repeatability improved. Another option would be to define a Injury Criterion that takes into account also rotational kinematics, for example the peak rotational acceleration. The disadvantage is that Injury Criteria for inclusion of head rotation have to be established before.

CONCLUSION

Results of this paper suggest that FMVSS 201u should be updated in order to more precisely evaluate the risk for head/brain injury. We propose either to replace the test object by a spherical headform that has only one degree of freedom in the impacting direction or - in case of keeping the 201u test setup - to modify the injury criterion by a combination of HIC and rotational tolerance criteria. We are planning to extent this study with hardware testing.

REFERENCES

Sheps Margulies, S.; Thibault L. E. (1992): A proposed Tolerance Criteria For Diffuse Axonal Injury. Journal of Biomechanics Vol 25, No.8, pp 917-923

Department of Transportation (DOT), National Highway Traffic Safety Administration(2000): CFR 49 FMVSS 571.201 Occupant Protection in Interior Impact, release 16.6.2000

Department of Transportation (DOT), National Highway Traffic Safety Administration(1972): CFR 49 FMVSS 571.208 Occupant Crash Protection

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