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INJURY CRITERIA FOR OBLIQUE HELMET IMPACTS

Magnus Aare, Svein Kleiven and Peter Halldin
Division of Neuronic Engineering, CTV – Centre for Technology within Health Care,
Royal Institute of Technology and Karolinska Institute, Stockholm, Sweden

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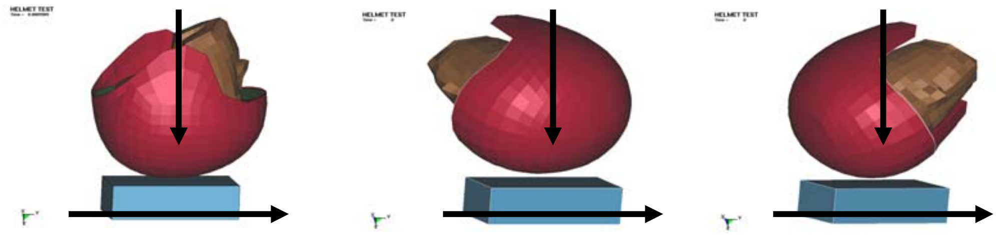
INTRODUCTION

THE MOST FREQUENT SEVERE INJURIES in motorcycle crashes are injuries to the head (Aare and von Holst, 2003) and many of these are caused by rotational violence (Gennarelli, 1987). Rotational violence is most commonly a result of oblique impacts, which is the most frequent impact in motorcycle crashes (Otte et al, 1999). Today there is a lack of good test methods for evaluating the effects of such impacts. There is also a need for a better understanding of the effects on the human head subjected to oblique impacts. In today's helmet standards no rotational effects are measured in the headform, partly because there are no accepted global injury thresholds for rotations. However, rotational violence to the head results in large shear strains in the brain, which has been proposed as a cause for traumatic brain injuries like DAI. Bain and Meaney (2000) presented a local injury criterion for strains in the brain tissue. Their study showed that strains in the brain tissue of more than 20% could cause injuries.

METHODS

In this study, Finite Element Models of: 1 the human head (Kleiven and von Holst, 2002), 2 a Hybrid III dummy head (HIII head) (Fredriksson, 1996), and 3 an experimental helmet were used. Impacts where simulated both on the human head and on the HIII head, wearing the helmet. The model of the helmet has been validated against both radial and oblique helmet impact tests (Aare and Halldin, 2003). Three different impacts were tested (see Figure 1). For impact 1 and 3, three different speeds (5,7 and 9m/s) where tested. For Impact 2 an additional speed of 3m/s where also tested. For all three impacts and all impact velocities, four different impact angles between the head and the impactor were tested, 30°, 45°, 60° and 90°. These impact angles were induced by altering the speed of the head and the speed of the impactor. These specific scenarios were chosen to cover the span of the most commonly observed impacts in real life motorcycle accidents (Otte et al, 1999).



Impact 1 Impact 2 Impact 3

Fig. 1 - The three different impacts.

To be able to correlate impacts to a helmeted HIII head to load levels in a human brain, simulations are necessary on both the FE model of the human head and the FE model of the HIII head. Comparisons were made between the strains in the brain tissue of the human head model and the change of rotational velocity and the HIC value in the HIII head model for similar impacts. These comparisons were made in order to be able to show a relationship between load levels in a HIII head and injuries in a human head. For short duration rotational impulses, the change in angular velocity has shown to correlate best with the intracranial strains found in the FE model (Kleiven and von Holst, 2003), which is in agreement with Holbourn's hypothesis (1943). For translational impulses, on the other hand, the HIC and the HIP has shown the best correlation with the strain levels found in the model. For the simulations, the non-linear and dynamic code LS-DYNA was used.

RESULTS

Comparing the results from the different impacts in figure 2, it is quite clear that the change in the rotational velocity has a big influence on the strain levels in the human brain.

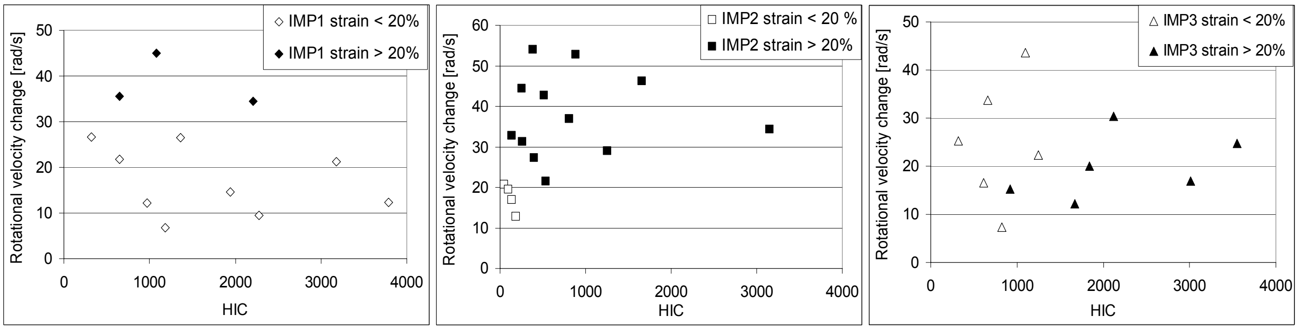


Fig. 2 - Results from the three different impacts. To the left impact 1, in the middle impact 2, and to the right impact 3. The levels on the axes are computed levels in the FE Model of the HIII head. Filled points represent injurious strain levels in the brain.

DISCUSSION

The tested impacts where chosen to cover rotations around all three axis. Impact 2 was according to statistics the most common one in real life accident. Of course it is not possible to cover all impact directions and impact speeds, but the presented results gives a good clue about what load levels that are acceptable in a HIII head. The human head is most vulnerable for translational accelerations in lateral direction (Gennarelli et. al. 1982, 1987), which can explain the stronger dependency between high strain in the FE-model and the HIC value for impact 2 and 3 than for the impact 1. Even if the head is dropped vertically (90°), rotations are induced for all impacts and in particular for impact 2 and 3. These rotations occur because the impact point is not situated straight under the center of gravity.

CONCLUSIONS

When measuring the strains in the brain tissue in the Finite Element model of the human head subject to oblique impacts, it could be seen that injury thresholds should include rotational parameters as well as translational parameters. In this study it could be seen that, for impact 1, changes of the rotational velocity is a critical parameter, for impact 2, changes in rotational velocity as well as the HIC value are important, and for impact 3, the HIC value is more critical than for the other impacts. A new injury criterion should therefore include both rotational and translational parameters, such as the change in rotational velocity and HIC and should probably be dependent of direction. The presented results can be helpful in predicting head injuries and when setting future standards for oblique helmet impact tests. An injury criterion for an oblique impact helmet test must be simple and easy to use for comparisons. A nine-accelerometer system can give good input to compute rotations and translations in a dummy head.

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