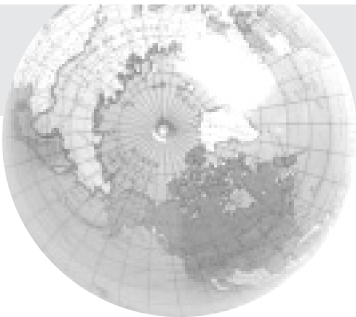

You will find the figures mentioned in this article in the German issue of ATZ 02/2006 beginning on page 116.

Erweiterter FEM-Entwicklungsansatz
für einen Free-Motion-Headform-Impaktor

Advanced FEM Development Approach for a Free Motion Headform Impactor Model

In automotive research and development, engineers are increasingly being expected to give precise forecasts of simulation results. The ability to numerically simulate more complex body structures and materials is growing in parallel with the rise in computing power and the development of FEM codes. This report by Imperia GmbH examines the importance of an FMH test within the framework of the EU Directive for interior impact.

Authors:
Carsten Tragsdorf, Marian Bulla and Niels Nowack

1 Introduction

When designing vehicle interiors with the aim of ensuring occupant safety, engineers are increasingly making use of various composite materials such as foam-backed covers, films or sandwich designs.

Optimising occupant protection by selecting the right material in the right place even at the pre-development stage requires precise material data as well as the use of validated impactors. In order to satisfy the high requirements of the automotive industry regarding occupant impactors, a validation procedure for the Free Motion Headform Impact has been developed by Imperia GmbH in association with BAST (Bundesanstalt für Straßenwesen) and BGS Böhme & Gehring GmbH.

2 The Future EU Directive

Since the 1990s, the FMH (free-motion headform) test has been mandatory for all interior components of vehicles registered on the US market, as determined by the National Highway Traffic Safety Administration (NHTSA). However, no standardised legal regulations that impose the testing of automobile interior components currently exist in Europe. The US testing regulation mandates that all interior surfaces be impacted with a free-flight rubber-coated aluminium head. This head has a weight of 4.54 kg and impacts the testing surface with its forehead at a velocity of 24.1 km/h. To assess the occupant load, the HIC value (Head Injury Criterion) is taken into account.

The European EEVC13 working group, to which BAST also belongs, is currently creating an EU Directive for interior impacts. The goals of the working group are the reproducibility of the tests and the definition of a "clean contact" for surface areas that are difficult to reach. The "clean contact" is an impact within the application boundaries defined by the NHSTA.

3 Advanced FEM Development Approach for a Free Motion Headform Impactor Model

The validation procedure defined by the NHSTA specifies an impact with a velocity of 2.72 m/s against a flat steel plate. The accelerometer in the head is calibrated with reference to a calibrating signal provided by the NHTSA. The few commercially available virtual FMH impactors are typically validated by this procedure and always reach the value of 254 g. In the validation of the model according to this procedure, however, some aspects are not taken into account, **Figure 1**:

- Model response without “clean contact”
- Model behaviour with a variable impact angle and/or axis offset
- Strain rates of the head materials (VCALIB ≠ VTEST)
- Influence of friction.

It is impossible to make verified statements about the modelling techniques employed or the behaviour of the virtual head during the impact with a realistic vehicle or substitute structure. For that reason, Imperia GmbH uses an alternative validation procedure. In this procedure, the head is shot with a predefined testing velocity of 24.1 km/h against the simplified structure of an interior vehicle part, such as an A-pillar. The advantages of the structure shown in the figure are its simple configuration and a mix of components commonly found in vehicle interiors, such as a core of sheet metal, an energy-absorbing polyurethane foam and a polypropylene cover, **Figure 2**.

Using the afore-mentioned approach, the following additional information is obtained:

- Sensitivity of results
- Usage range of the FMH impactor
- Material and structural analysis of the carrier structure.

Explanations of the advanced validation procedure and the sensitivity of the results are explained below by means of simulation examples.

3.1 The Advanced Validation Procedure

In order to accurately measure the surface of the testing head, a real FMH impactor was dismantled. The rubber skin and the aluminium body of the head were measured using a 3D measuring device. The inner geometry of the aluminium core is modelled using technical drawings of the head. The predetermined inertia and the position of the accelerometer with respect to the NHSTA guidelines are taken into account.

The material properties are determined by uni-axial compression/tension tests. Taking these parameters into account, a simulation model for the MECALOG FE solver Radioss V4.4 is created.

In contrast to the FMVSS201 guideline, the impactor velocity is set to the testing velocity of 24.1 km/h and the head is rotated 10° from the horizontal. With these settings, the impactor is shot against the test sample. The test sample is mounted to a fixed frame at each end. This configuration facilitates an impact at the forehead of the impactor.

The result of this measurement, **Figure 3**, is an acceleration/time plot that shows a delay between the impact of the forehead and that of the nose/chin region. The kinetic energy of the head is converted as follows: 41.6 % reversible energy and 58.4% internal energy. The measurement of the plastic deformation of the test sample allows the creation of an energy balance and a correct validation of the material properties. In the energy balance, the behaviour of the elastic deformation of the mounting frame is modelled by springs. The acceleration plots and the HICd values of the FE model correlate quantitatively and qualitatively with those of the physical test results. The computed HICd value of 1465 correlates with the test results and a real vehicle interior structure, although it exceeds the permitted HICd value of 1000.

3.2 Sensitivity of Results and Ranges of Usage of the FMH Impactor

The reproducibility of the results depends on the accuracy of the execution of the test, since the geometry of the FMH impactor is not rotationally symmetrical but is modelled on the shape of the human head. The calculated and experimental results may show scattering as a result of their dependency on variables such as the impact angle and axis offset.

The validated FMH model enables the user to evaluate the stability of the CAE results, as well as the sensitivity of the physical test and the estimation of the ranges of the physical test.

In order to determine the ranges of the physical experiment, four simulations are needed, two with angle variations of -2° and +5° and two with offset variations of 5 mm and 15 mm.

The lower values of the variations represent the test tolerances and are the result of difficulties in positioning the FMH impactor with respect to real interior parts. For a successful measurement, a “clean contact” is necessary. This is achieved in the case of the impact of the forehead plate with the structure (impact area according to the FMCSS214 test). The simulation results should indicate whether the clean contact is achieved with the chosen configuration.

The acceleration plots of both simulations with angle and offset variations show a high sensitivity of the results. The lateral offset variations of 5 mm and 15 mm correspond to a constant increase in the HICd values of approximately 85 and 163 points respectively. The angle variation of the impactor shows an arbitrary result variation.

With an angle variation of -2° (8° from the horizontal = 8° projection angle), the resultant HICd value increases dramatically by 143 points. With a rotation of +5° (15° from the horizontal = 15° projection angle), the relative change in the HICd value decreases to -11 points.

Considering the developed model of the FMH impactor with relation to the advanced validation process, the following conclusions can be made, **Figure 4**:

- The results from the impactor model are within the range of the test results
- With additional refinement, the FMVSS201 validated impactor model fulfils the requirements of the advanced validation procedure
- The results are sensitive to minor changes in the prescribed test configuration.

The usage ranges and the information value of the FMH test are not clearly defined. Therefore, the impactor model is used only to evaluate interior parts of vehicles for the US market. As a result of many tests, the results of the FMH impactor are highly sensitive to geometric changes in the test configuration. For a stable test procedure for interior structures, the use of a spherical impactor is advisable. ■