BMW is experimenting the H-Model to optimize occupant protection in car crashes

BMW is carrying out scientific tests to study the response of both dummy and human models in side impact scenarios.

Current investigations should greatly enhance future safety design for improved human occupants' security.

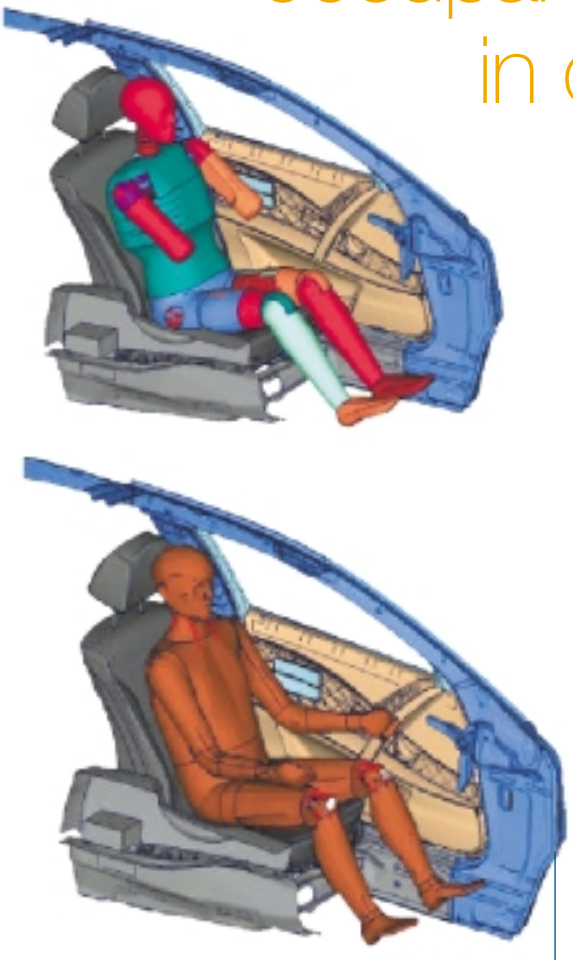


Fig.1 : Simulation set-up with the EuroSID (high) and the H-Model (low)

How to get more insight into possible human injuries in car crashes? How to reproduce the complex interaction of the human body with the vehicle to design safer restraint systems? All of these issues are at the heart of BMW Group's research for optimized protective equipment.

Full-scale crash tests use dummies to assess the likelihood of injury to a human occupant. Providing valuable insight into crash dynamics and occupant kinematics, digital simulation with dummy models is commonly used for safety features design. But as dummies have to fulfill the requirements of technical measuring devices, like durability and repeatability, they do not always adequately reproduce the complexity of the human body, and its interaction with the vehicle.

In a joint effort to improve the biofidelity of design tools, BMW and the Institute for Forensic Medicine in Munich are using PAM-SAFE and finite element models to investigate the differences between the physical dummy and the human body.

BMW first evaluated the response of a FAT EuroSID I v.3.1 dummy model and compared it to the the ESI Group H-Model 2003.1 for a complex impact configuration. The human model is developed by ESI Group and IPS-I. It contains a deformable skeleton with thoracic and abdominal organs, flesh, skin, muscles, and ligaments. Hard and soft tissues are modeled by various types of finite elements and material properties to represent adequate mechanical behavior.

Then, the human model is used to compare the effect of the barrier geometry on rib cage and pelvis loading for a sled-test configuration.

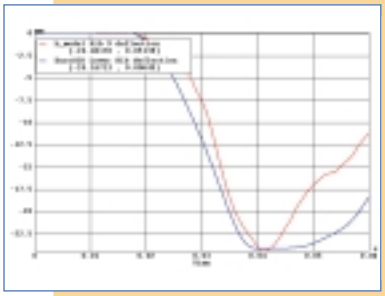
Lateral EuroNCAP Barrier Test

A validated PAM-CRASH finite element vehicle model of a BMW is used to simulate vehicle motion and intrusion in a standard side crash test scenario, with airbag, at 50 km/h (according to the EuroNCAP barrier testing protocol). In a first step, a simulation with the EuroSID dummy model is performed to evaluate loads, accelerations and injury values. In a second step, the dummy model is replaced by the H-Model, with the same output values as the instrumentation channels in the physical dummy (Fig.1). Rib deflections, shear force and acceleration of the twelfth thoracic (T12) vertebra, and the acceleration of the pelvis, are specifically analyzed.

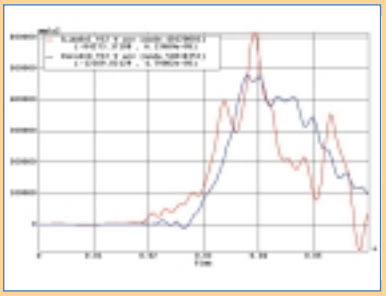
The behavior of the dummy and of the H-Model are comparable and show a lot of similar responses, such as lower rib deflection, T12 and pelvis acceleration (Fig.2, a, b, c). Some other parameters are significantly lower with the H-Model, such as upper and middle rib deflection, and T12 shear force (Fig.2, d, e, f).

Glossary

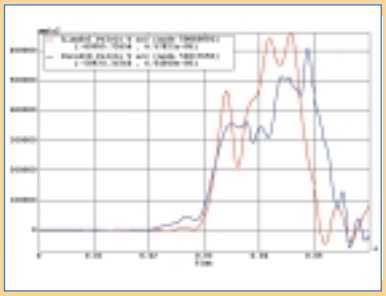
- ***FAT:*** *Forschungsvereinigung Automobiltechnik*
- ***EuroSID:*** *European Side Impact Dummy (SID)*
- ***EuroNCAP:*** *European New Car Assessment Program*
- ***IPS-I:*** *Integrated Professional System International*
- ***NHTSA:*** *National Highway Traffic Safety Administration*



a) lower rib deflection

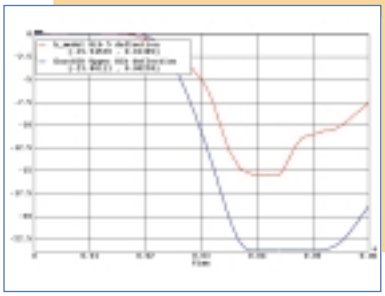


b) T12 acceleration

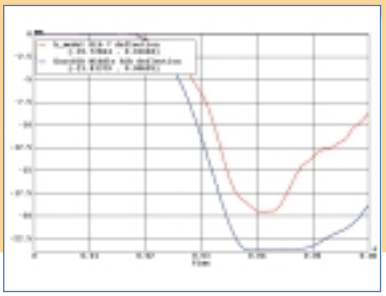


c) pelvis acceleration

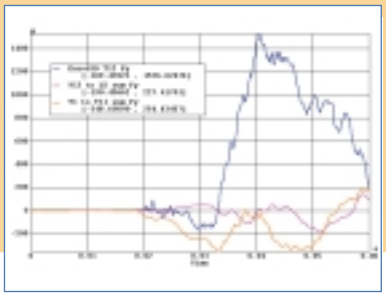
Fig.2 Output signals versus time: red curve H-Model, blue curve EuroSID Model



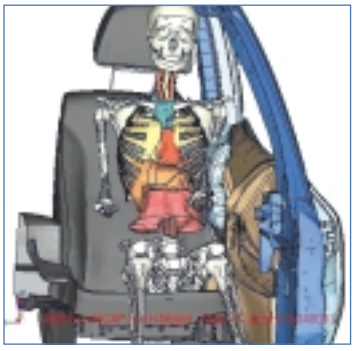
d) upper rib deflection



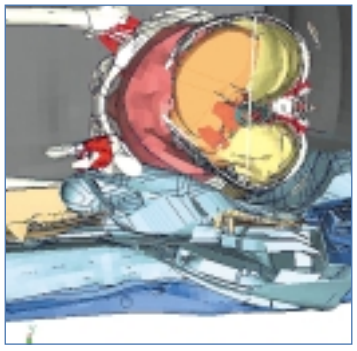
e) middle rib deflection



f) T12 shear force



a) front view



b) cut view

Fig.3 : Interaction between the airbag, the arm and the rib cage of the H-Model

> "The behavior of the dummy and the H-Model are comparable and show a lot of similar responses, but the H-Model gives more information about the injury mechanisms and the complex interaction of the human with the vehicle."
>
> *BMW's head of occupant simulation in side crashes and roll over*

Upper and middle rib deflections in the H-Model may be influenced by the biofidelic arm position, more than in the EuroSID (Fig.3 a and b).

Another reason for differences may be the way rib deflections are measured, only in the lateral direction, whereas the human thorax exhibits more complex deformations modes (Fig.4 a and b).

The higher T12 shear force in the dummy may be due to an artifact of the dummy design, in which a rigid thoracic spine is attached to a stiff lumbar spine. In the H-Model, all vertebrae and in-between joints are modeled, leading to a more progressive curvature (Fig.5 a and b).

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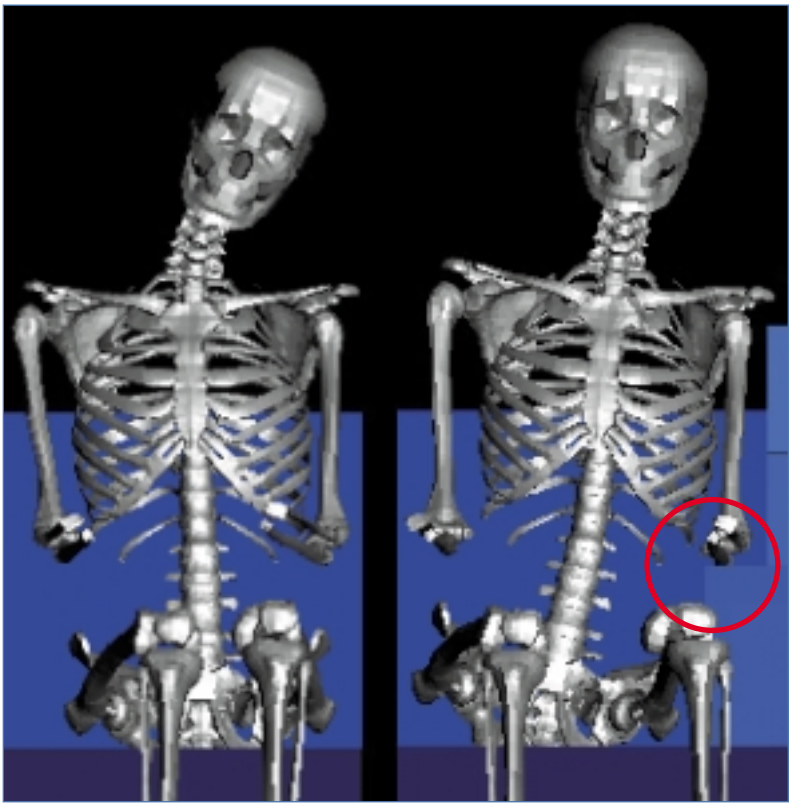
a) initial, undeformed state

b) after 37 ms

Fig.4 : Comparison of the middle rib deflection of the dummy with the complex 7th rib deformation of the H-Model

Fig.5 : Comparison of dummy spine (left) and human spine (right)

Fig.6 : H-Model behavior without (left) and with (right) pelvis offset



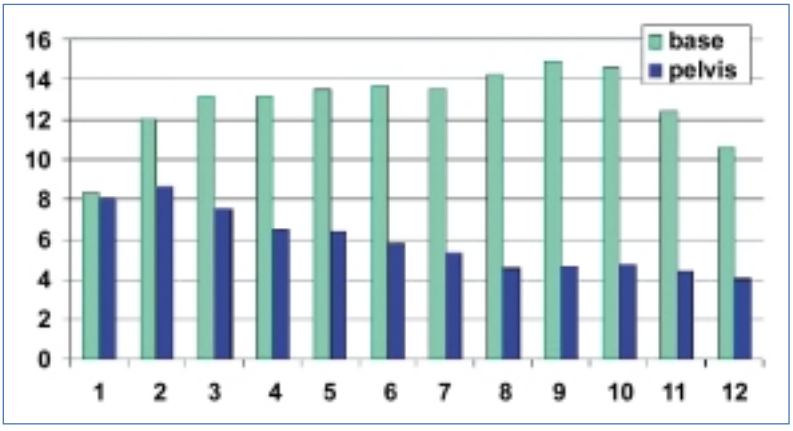


Fig.7 : Rib deflection (in mm, for each rib) with (blue) and without (green) pelvis offset

About BMW Group

The BMW Group is a leading high standard German car manufacturer, representing 1.7% of the worldwide automotive market, with more than 1.1 million vehicles sold. The BMW Group's market position relies on its business strengths which are high-performance, safety, innovation and precision. Its product line portfolio, falling into two main automotive sectors: cars and motorcycles, inspires seduction, sport, power and harmony. The BMW Group also owns the Mini and Rolls-Royce brands.

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Modified NHTSA lateral sled test

Sled-test simulations are performed with the H-Model according to a modified NHTSA procedure. The barrier has a mass of 1,000 kg and a velocity of 18 km/h. Two barrier shapes are investigated: one flat wall, and one wall with an offset of 70 mm in the pelvis area. The kinematics of the H-Models with and without pelvis offset are shown on Fig.6.

Comparison between the two shapes for all 12 ribs (Fig.7) shows that the pelvis offset improves the rib deflections and the viscous criterion without increasing the pelvis load. Lower rib deflection decreases by 62%; upper rib deflection, which is influenced by the contact of the shoulder with the upper wall, is unchanged; viscous criterion decreases by over 90%.

Initial simulations carried out with the H-Model in complex load cases, such as side crash tests, yield promising results. According to the head of occupant simulation in side crashes and roll over at BMW: "We get more understanding about the crash, the dummy and the human. The dummy is a reproducible measurement tool which cannot show any injury, whereas the H-Model allows valuable insight into possible injury mechanisms."

Conclusion

Optimizing occupant protection in side impact scenarios requires valid information about occupant behavior. Resulting from long-term partnerships with research institutions, laboratories and industries, ESI Group's H-Model helps to provide realistic kinematics as well as access to injury mechanisms and classical injury criteria.

Considering the complexity of the human body, future BMW investigations will focus on the further validation of the H-Model, using injuries produced during well documented real-world accidents.