Title

Development and Application of Pedestrian Protection Impactor Models

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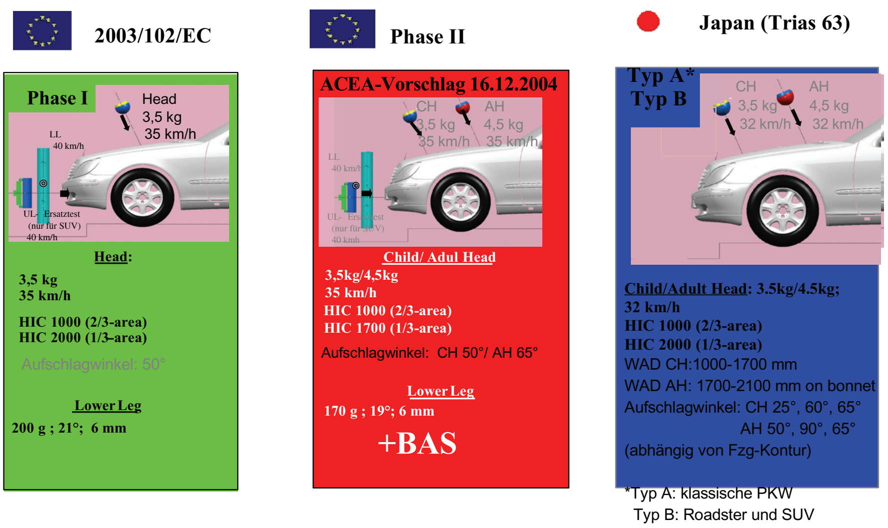


Introduction

➔**During this year (2005) the first car lines have been certified according to EU-Phase I-Pedestrian-Protection legislation**

➔**Phase II-Pedestrian-Protection legislation will be active from 2010 on; the following requirements are in discussion (ACEA-Proposal)**

- **3.5kg-Child-Headform to bonnet test (HPC 1000/67% - /1700/33%, WAD 1000-1700)**
- **4.5kg-Adult-Headform to bonnet test (HPC 1000/67% - /1700/33%, WAD > 1700)**
- **Legform to bumper test (170g/19°/6mm) (UpperLeg to bumper test - SUV)**

Introduction

➔ **Compared to typical impact configurations there is a different situation for Pedestrian Protection Applications :**

- **System Energy less than 1000 J**
- **A lot of components involved are non metallic (plastics, foam)**
- **Not global, but local results are needed**

➔ **Requirements for very detailed models of**

- **Car front structure and**
- **Impactor**

Introduction

➔ **Focus in development of Pedestrian Impactor Models**

- **Performance in real car application**
- **Improvement and maintenance based on feedback of users and results of different car lines**

- **Impactor suite is used at DaimlerChrysler, Porsche**
- **This presentation is an extension of "Development and Validation of Numerical Pedestrian Impactor Models" , Th. Frank et. al. at 4th European LS-DYNA Users Conference 2003**

Headform

➔**Pedestrian Headform Models**

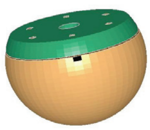
- **Small-Adult-Headform/Child-Headform (3.5 kg, Phase I, Phase II)**
- **Adult-Headform (4.5kg, EU-Phase II)**
- **Child-Headform (3.5kg, Japan)**
- **Adult-Headform (4.5kg, Japan)**

- **2.5kg Child- and 4.8kg Adult-Head according to Euro-NCAP**

Headform

➔**Performance of Headform is mainly depending on**

- **Rubber Skin**
- **Friction (Rubber/Aluminium-Headform-Inlay and Rubber/Bonnet)**



➔**Rubber Skin Evaluation**

- **Component Tests**
- **Original LS-DYNA implementation => MAT_OGDEN_Rubber**

Headform

➔**Rubber Skin Evaluation**

- **Problem : Difficulty in determination of Material-Parameters according to strain energy functional :**

$$W=\sum_{i=1}^{3}\sum_{j=1}^{n}\frac{\mu_j}{\alpha_j}\left(\lambda_i^{\alpha_j}-1\right)+\frac{1}{2}K\left(J-1\right)^2$$

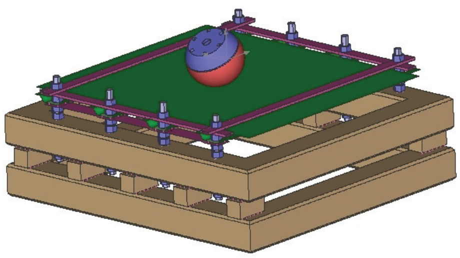
- **Material-Constants μ_j, α_j can not be derived directly from test results**

Headform

➔**Use of MAT_SIMPLIFIED_RUBBER**

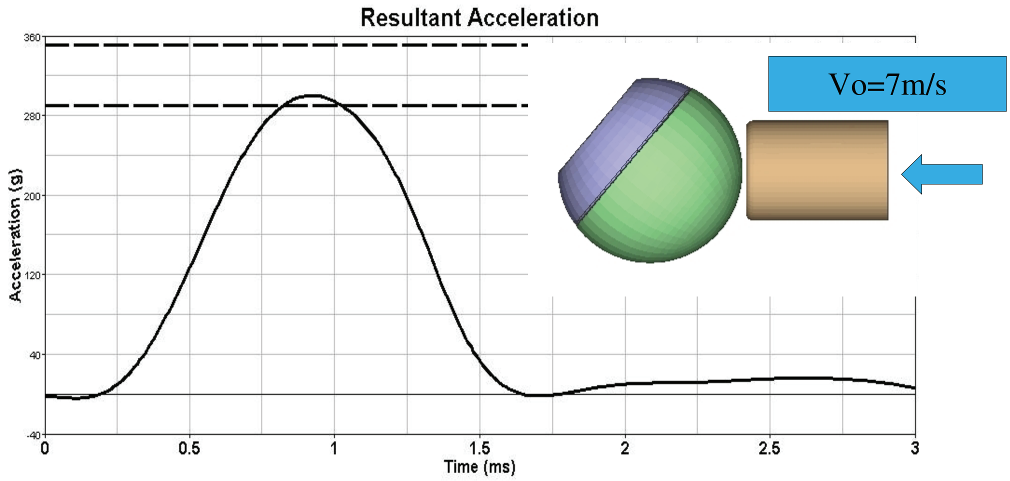
- **Direct input of test results**
- **Table-ID accounts for strain rate effects**

➔**Validation of Headform Impactor has been performed with respect to test results of Headform to "Porsche-Box"**



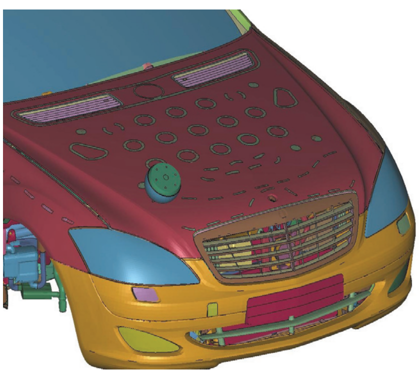
Headform

➔Small Adult-Headform – Results of Certification Test

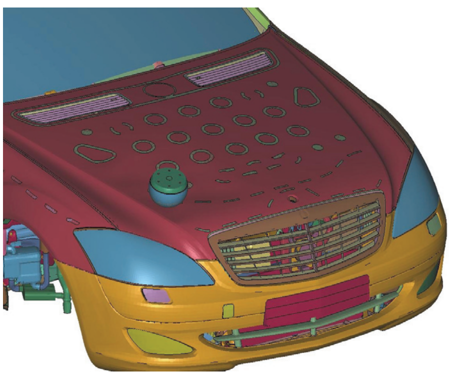


Headform

Example 1 : 3.5kg-Head-Impact (DaimlerChrysler - S-Class)

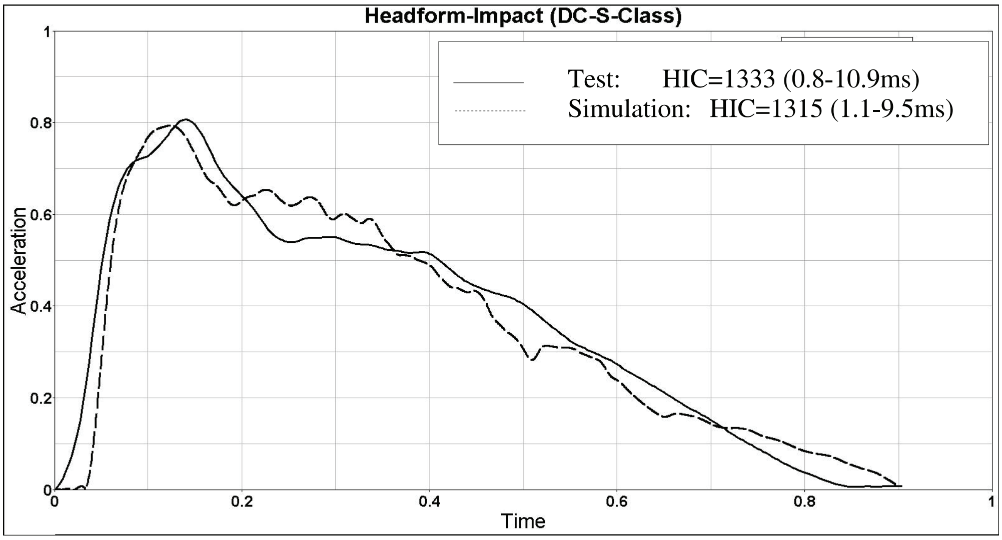


Initial Configuration



Deformed State

Headform



Legform

➔**<u>Performance</u> of Legform is mainly depending on**

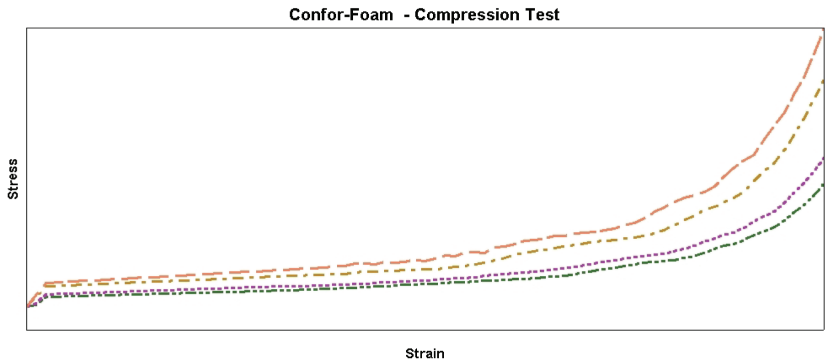
- **Confor-Foam/Neoprene-Skin**
- **Ligament-Stiffness**
- **(Shear Damper)**

➔**Tension and compression tests at different strain rates and hydrostatic tests have been performed in order to determine the material data of Confor Foam and Neoprene-Skin**

Legform

➔Confor Foam shows dependency on

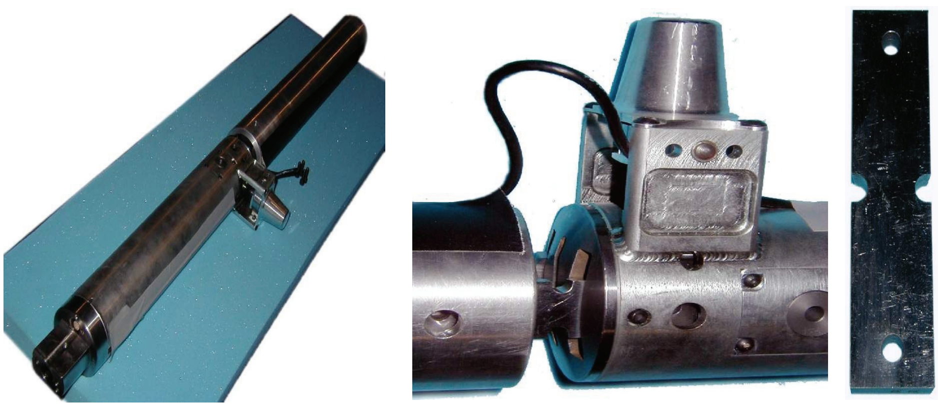
- Strain rates, Humidity, Temperature
- LS-DYNA implementation uses MAT_FU_CHANG_FOAM with Table-ID to take into account strain rate effects



Legform

➔Ligament

- 2 Steel-Plates (Thickness : 7mm; Notch-Diameter : 6mm)



Legform

➔Ligament

- **The determination of the Ligament-Bending-Stiffness follows 3 Steps (see detailed discussion on the next slides) :**

Material Characterization based on Tension Tests

↓

Determination of Ligament-Bending-Stiffness with FE-Component model

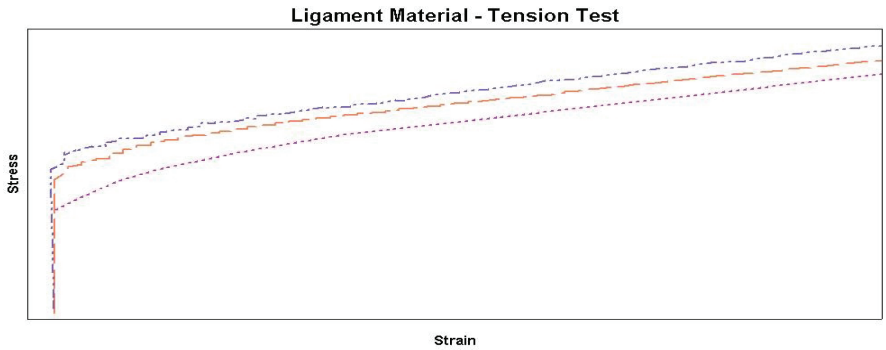
↓

Results of FE-Component model are basis for validating the discrete ligament representation of the Legform Impactor

Legform

➔Ligament

- **Material Data has been evaluated by performing tension tests at different strain rates**



- **LS-DYNA MAT_PIECEWISE_LINEAR_PLASTICITY with Table-ID to account for strain rate effects**

Legform

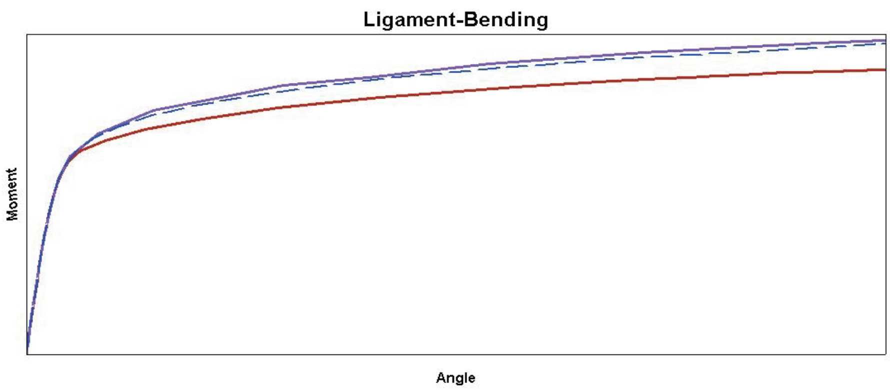
➔Ligament

- Simulation of Ligament-Bending at different velocities using LS-DYNA (implicit) and Ligament-Material-Data from tests
- Detailed Component-Model of Ligament includes more than 10.000 Solidelements

Legform

➔Ligament

- Results of component analyses characterizes the Ligament-Bending-Stiffness



Legform

➔**Ligament**

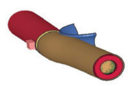
- **The Ligament representation of the Legform Impactor consits of a combination of rotational spring and damper**
- **Results of FE-Ligament-Component-Model are used to validate spring and damper where the spring represents the quasistatic curve and the damper accounts for strain rate effects of the Ligament**

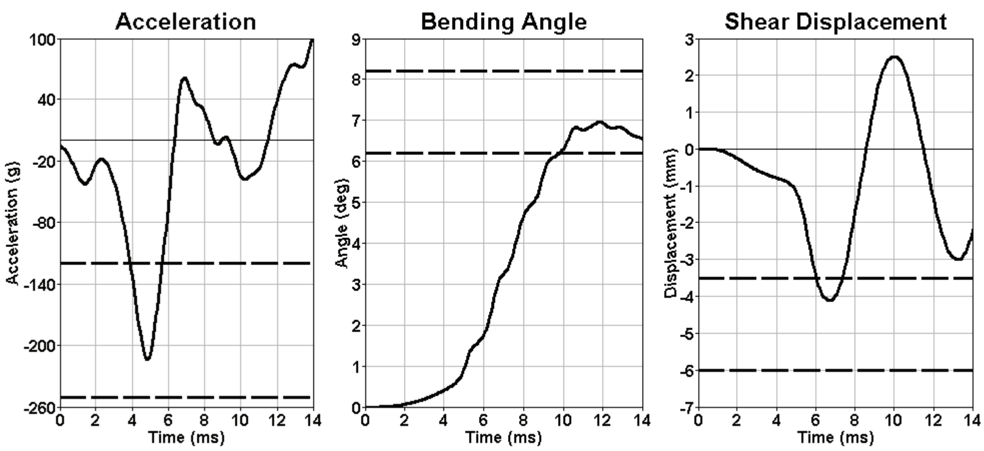
➔**Shear-Damper**

- **The Damping coefficient of the Shear Damper can be found from the shear displacement versus time curves by calculating the so called logarithmic decrement**

Legform

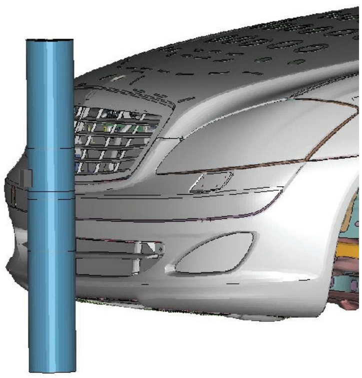
➔**Legform – Results of Dyn. Certification**



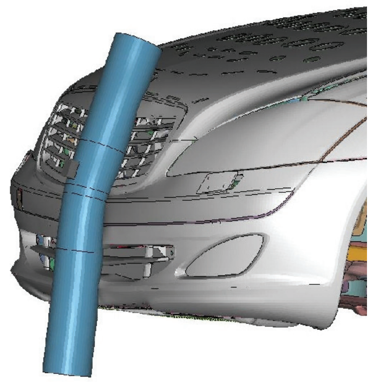


Legform

Example 2 : Legform-Impact (DaimlerChrysler - S-Class)

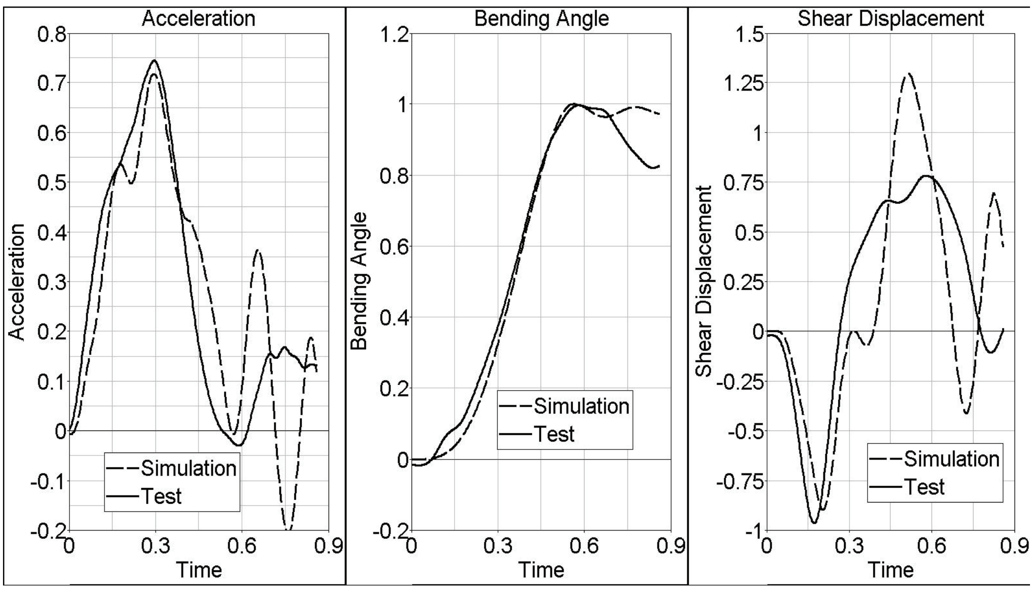


Initial Configuration



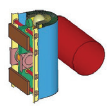
Deformed State

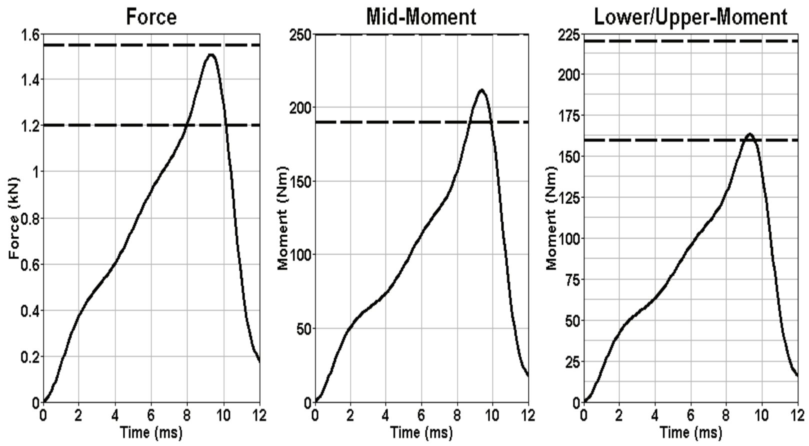
Legform



UpperLeg

➔UpperLeg – Results of Dynamic Certification Test





Conclusion

➔A suite of Numerical Pedestrian Impactor Models has been presented which is available to other customers

➔Main Improvements :

- Headform-Rubber-Skin
- Legform-Ligament

➔The development has been focused on performance in real car application

➔Maintenance and improvement will be carried out based on feedback of the users