Application of MADYMO Occupant Models in LS-DYNA/MADYMO Coupling

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ABSTRACT

The LS-DYNA – MADYMO coupling has been extended so that users gain maximal flexibility in their choice of software and models. Where the traditional coupling allowed only MADYMO ellipsoids and planes to contact entities in the coupled code, now contact can also be defined with MADYMO FE. This enables state of the art MADYMO dummy models, subsystem models, barrier models and human models to be applied in the coupling with LS-DYNA.

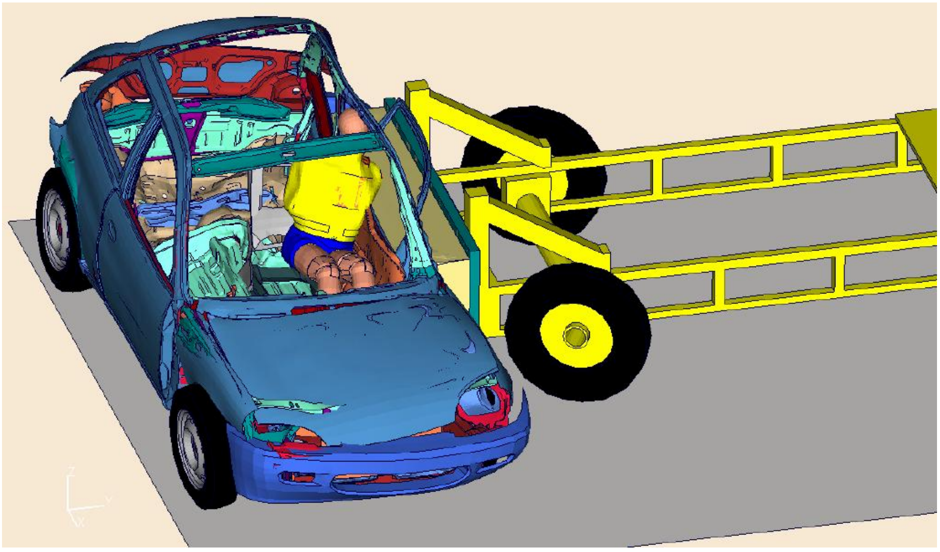
INTRODUCTION

The LS-DYNA - MADYMO coupling has been introduced to effectively combine validated models in the two codes. Instead of converting component models such as airbag models, or substituting dummy models from different sources, the coupling enables to flexibly combine models in the preferred code.

MADYMO is renowned for its multibody dummy models using rigid bodies and ellipsoids as well as flexible bodies and facets (Koppens et al, 1993, Fountain et at. 1996). In addition to these well-known multibody models, Finite Element dummy models have been introduced in MADYMO.

The “traditional LS-DYNA/MADYMO coupling” as released with MADYMO v5.0 enabled contact of MADYMO ellipsoids with LS-DYNA FE entities. The traditional coupling was successfully applied for frontal occupant safety analysis. One of the limitations of the traditional coupling was the linear contact stiffness of ellipsoids resulting from using the Penalty Based Contact Method. Furthermore the traditional coupling could not handle the latest MADYMO dummy technologies and, particular, FE dummy models for side impact and OOP.

Therefore LSTC and TNO have jointly developed the “extended coupling” which allows contact between almost all MADYMO & LS DYNA geometric entities. This gives LS-DYNA users access to the most advanced MADYMO dummy & human models, airbag functionality, etcetera. In the “extended coupling” the MADYMO contact algorithm is used to calculate loading between the two models. Thereby the validated contact properties of the MADYMO dummy models are now used by default in the coupling. In addition the thickness and bulk modulus of the LS-DYNA elements is taken into account.

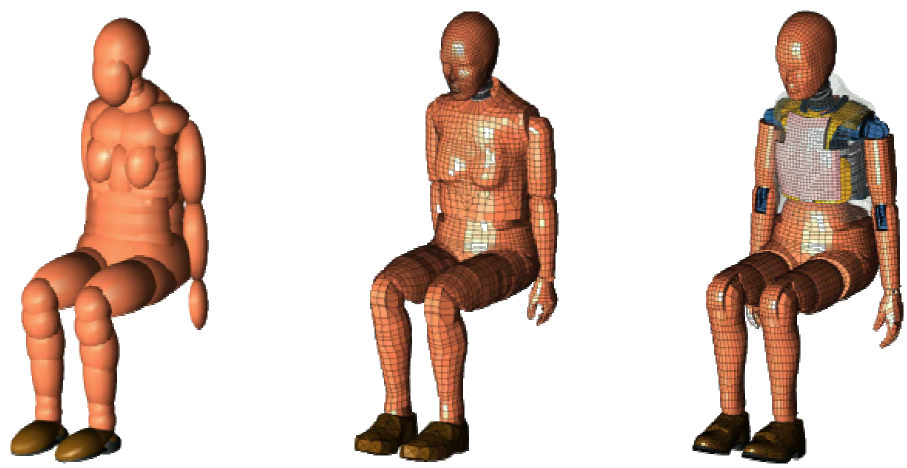


LS-DYNA Vehicle & Barrier model coupled to MADYMO FE US-SID model

MULTIBODY AND FE DUMMY MODELS

The following three MADYMO dummy model types are supplied by TNO:
1. Ellipsoid dummy models
2. Facet dummy models
3. Finite Element dummy models

The main difference between the model types lies in the modelling techniques applied to represent the geometry and the mechanical properties of the dummy components. All MADYMO dummy models have a construction consisting of chains of rigid bodies with inertial properties, which are connected by kinematic joints. This allows for a general positioning procedure for the three model types. Instrumentation is also modelled the same way (with minor exceptions) in the three model types.



Ellipsoid Model *Facet Model* *Finite Element Model*

Hybrid III small female, three model types

ELLIPSOID MODELS

Ellipsoid models are based fully on MADYMO's rigid body modelling features. The inertial properties of the dummy components are incorporated into the rigid bodies of the model. Their geometry is described by means of ellipsoids, cylinders and planes.
Structural deformation of flexible components is lumped in kinematic joints in combination with dynamic restraint models. Deformation of soft materials (flesh and skin components in the dummy) is represented by force-based contact characteristics defined for the ellipsoids. These characteristics are used to describe contact interactions within the dummy and between the dummy and the environment.

FACET MODELS

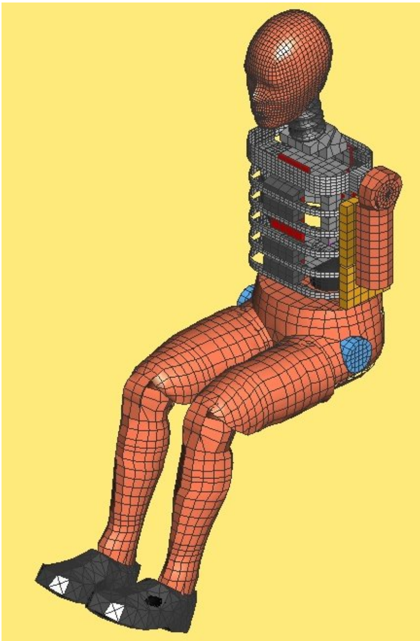
Facet models are also multibody models, but compared to the ellipsoid models they benefit from more advanced multibody technology. The inertial properties of the dummy are incorporated into the rigid and deformable bodies of the model. In facet models the outer surfaces of the dummy are described with meshes of 2D, massless contact elements (further referred to as facet surfaces). These facet surfaces are fully supported to rigid bodies and/or deformable bodies. Facet surfaces allow a more accurate geometric representation in compared to ellipsoids.
Structural deformation of flexible components such as ribs, is represented by deformable bodies. These deformable bodies enable a more realistic representation of structural deformation than the joints and restraint models used in the ellipsoid models. Deformation of soft materials (flesh and skin components in the dummy) is represented by stress-based contact characteristics defined for the facet surfaces. Using these contact characteristics in contact definitions, soft material deformation is represented accurately through the contact interactions within the dummy model and between the dummy model and its environment.

FINITE ELEMENT MODELS

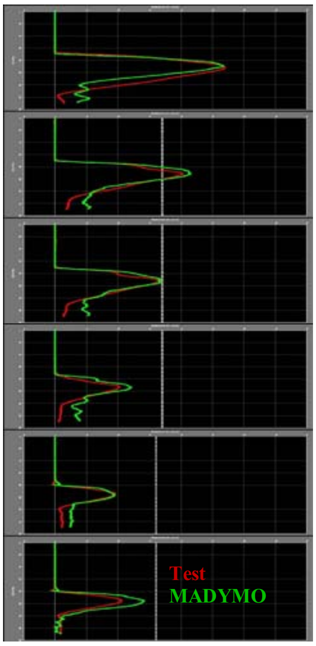
In the MADYMO FE models important deformable parts are modelled with finite elements. Inertial properties of dummy components are represented by the inertial properties of both the rigid bodies and the FE meshes. Compared with ellipsoid and facet models, the FE models are able to reproduce accurately not only kinematics and global deformations, but also local deformations of components and flesh/skin materials. The FE meshes are defined with respect to those bodies of the rigid body chain to which they are connected. This enables the FE dummy model to be positioned in the same manner as the ellipsoid and facet model by specifying the dummy joint positions.

What model type to use

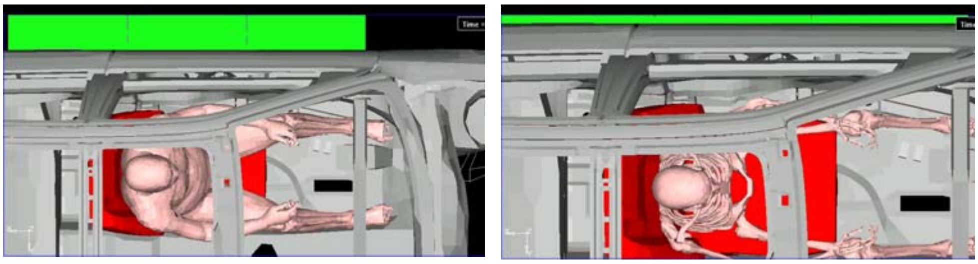
Ellipsoid dummy models are the most CPU-time efficient type of models. Therefore, they are particularly suitable for concept, optimisation and extensive parameter sensitivity studies. Their speed has the most benefit in a multibody environment that is modelled similarly by ellipsoids, planes and cylinders. Nevertheless, ellipsoid models have been successfully applied in a facet or FE environment and in coupling with other FE codes.
Facet dummy models are more realistic and detailed than ellipsoid models, but are still very CPU-time efficient compared to FE models. They include a number of degrees of freedom that is comparable to that of the ellipsoid models. The limited increase in CPU costs is mainly due to the additional evaluations performed in the contact algorithm. Nevertheless, the facet models are still suitable for use in optimisation and parameter variation studies. Most benefit is gained from facet models when the environment is represented in similar or higher level of geometric detail, either by facet surfaces or finite elements. Thereby facet models are effectively applied in the coupling, supplying efficient solutions in relatively simple environments.
FE dummy models incorporate a vast amount of degrees of freedom and require a small timestep. As a result of this, they are much less CPU-time efficient than the ellipsoid and facet models. FE dummy models are recommended for use in the most detailed studies, where local effects of contact interactions and local material deformations are of interest for the user. FE dummy models are typically applied for full vehicle structural crash, which is a key application of the couplin. FE dummy models are not particularly suitable for concept, optimisation and extensive parameter sensitivity studies.



FE SID2s model



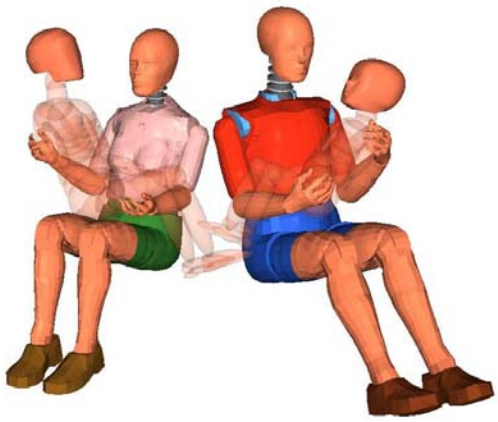
Rib deflection validation



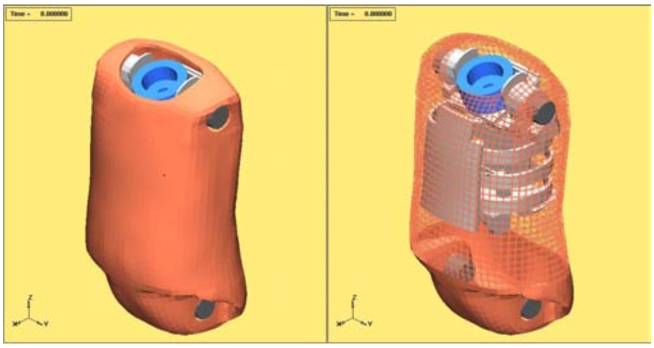
LS-DYNA vehicle model coupled to MADYMO FE Human model with soft tissues shown (left), and with soft tissues not shown (right)

DUMMY MODELLING FOR OOP

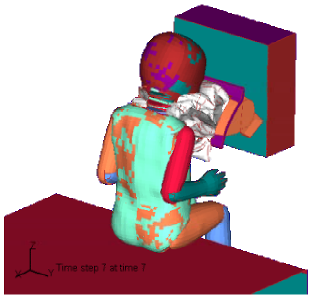
Since the introduction of OOP requirements, TNO has launched and rapidly upgraded models of the Hybrid III child dummies and the Hybrid III small female dummy.



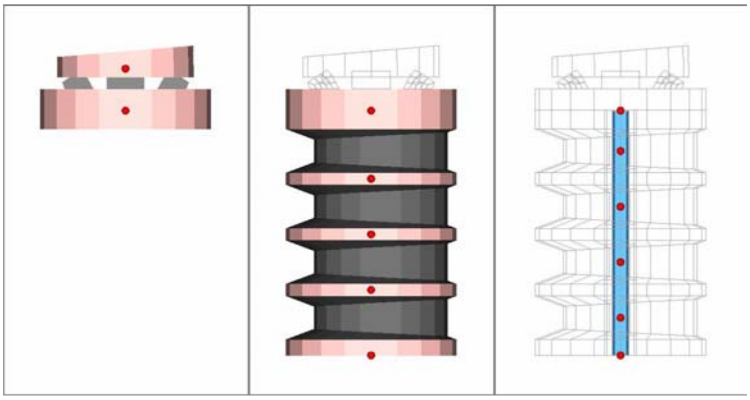
Development programs have been performed in co-operation with several industrial partners. Based on actual OOP applications, component and full dummy validation sets with representative loading severity and loading rate have been gathered. The thorax and the neck are the most critical components for OOP simulation. This justified the introduction of full FE models of the dummy thorax. For the neck a detailed multibody approach was found to be most robust and accurate.



FE Thorax Hybrid III 3 year old



Hybrid III 3yo in OOP (MADYMO only)



Multibody neck sub models (Left: nodding joint, middle: nodding joint and neck-column without neck cable, right: complete neck including the neck-cable)

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MADYMO DUMMY MODELS, SUBSYSTEM MODELS AND HUMAN MODELS

Frontal / Rear Impact dummies Hybrid-III 5th female Hybrid-III 50th Hybrid-III 95th Hybrid-III 50th standing Hybrid-III 50th + thor lower legs THOR Hybrid-II Hybrid-III 50th FAA (aircraft) Hybrid-III 50th + TRID neck RID-II BioRID-II MATD (motorcycle dummy)	***Side Impact dummies*** EUROSID-I ES-2 US DoT-SID SID-H3 SID-IIs SID-IIs + airbag interaction arm BioSID	***Child dummies*** Hybrid-III 3YO Hybrid-III 6YO CRABI 12MO Q3 P3/4 P1 1/2 P3 P6 P10
Subsystems FMVSS 201 headform Pedestrian child headform Pedestrian adult headform Pedestrian ACEA headform 3.5kg Pedestrian legform Pedestrian upper legform ECE-R12 Bodyblock	***Barriers*** Offset deformable barrier (ODB) FMVSS-214 MDB EEVC-WG13 MDB IIHS-SUV MDB FMVSS-201 impact pole	***Human models*** Occupant 5th female Occupant 50th male Occupant 95th male Occupant 50th male - comfort Pedestrian 3y/6y/5/50/95% Detailed leg/foot Detailed arm Detailed neck Brain / skull

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