MADYMO Dummy Models

Latest Update

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Summary:

This paper gives an insight in the latest developments of the MADYMO Dummy Database. Special attention will be paid to new facet Quality Rated dummy models. These models are perfectly suitable to be used in coupling between MADYMO and other structural codes like LS Dyna. The Quality dummies are delivered with a detailed report including all relevant information about the validation set that is used for dummy development, the correlation level with these experimental results including objective rating values, and rated curves showing the correlation of the model output with the measured signals from the experiment.

Keywords:

numerical dummy models, MADYMO, coupling, simulation, quality, objective rating, finite elements (FEA), multi-body (MB), facet, ATD

1 Introduction

Virtual testing of crash safety is accepted all over the automotive industry as very valuable besides physical testing. However, since the demands increase and the solutions to meet all different aspects of crash safety become more and more complex, there is a request for fast simulation tools that accurately predict the behaviour of a dummy in hardware experiments.

MADYMO has built a name with the extensive dummy model database. The dummies in this database are used worldwide in the automotive industry. The numerical models help to solve the safety design challenges that manufacturers face nowadays when building vehicles.

Fig. 1: MADYMO facet Quality models, the latest generation predictive and fast models

This paper provides an overview of the current dummy models available in the MADYMO database. A new generation of models is recently introduced: the facet Quality models (see figure 1). These models are introduced in more details and the pro's and cons are listed. All MADYMO dummy models can be used in other structural codes using the coupling functionality.

2 Ellipsoid, facet or finite elements models?

MADYMO offers the largest database of world-class dummy models that includes models of all dummies that are currently used in automotive regulatory and consumer (NCAP) tests and dummies that are being considered for upcoming updates of these test procedures. The MADYMO dummy models are extensively validated to ensure that they accurately represent the hardware dummies.
In order to give an impression of the dummy model database: in MADYMO R6.3 more than 70 models are available, excluding a series of different human body models and barrier models.

The MADYMO software developed by TASS is the worldwide standard for occupant safety analyses, renowned for its fast simulations, high-quality dummy models, and accurate restraint system modelling techniques. Through its combination of multibody and finite element (FE) techniques, MADYMO optimally combines efficiency, accuracy, and reliability.
MADYMO delivers three different types of models: classical multibody (MB) models, facet models and finite elements (FE) models. The choice of the modelling technique depends largely on the typical application or methodology in which the product is used. Some models are even available in more than one type.

The computationally fast multibody (MB) technique is particularly suited for concept design and large parametric studies. The MADYMO ellipsoid (multibody) dummy models have become a standard in occupant safety design due to their unique balance of computational speed and accuracy.

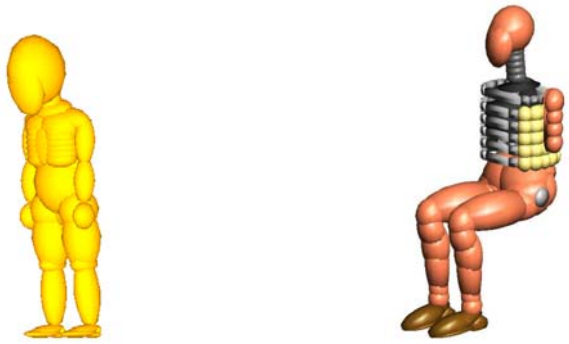

Fig. 2: Examples of MADYMO ellipsoid (MB) models: CRABI 12-months (left) SID-IIs (right)

The finite element technique is significantly slower than multibody techniques, but allows for much more detailed and accurate modelling of deformable structures. Where the ellipsoid model surface is approximately described using many ellipsoid shapes, the geometry of an FE model is represented by a detailed mesh. From the CAD data and 3D laser scanning the geometry is accurately captured and then meshed. This results in better contact surface modelling, and therefore potentially offers more accuracy. Finite elements models are mainly offered by MADYMO for models that are used in combination with detailed airbags (GasFlow), like the Hybrid-III 3yo and 6yo child dummies and the Hybrid-III 05th which are used in FMVSS214.
Furthermore, in applications already including many finite elements like a complete vehicle structures, the additional CPU consumption when using a detailed finite elements dummy model might also not be a real issue. In most cases the design has passed its concept phase by then.

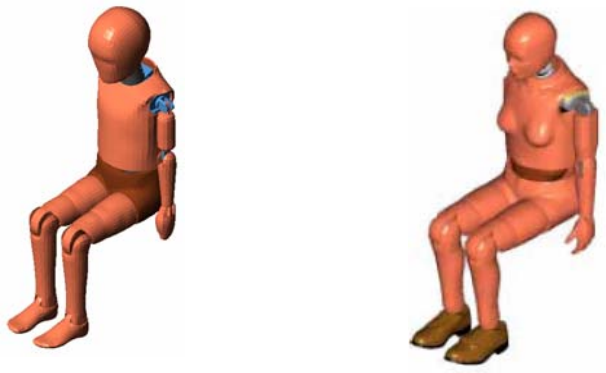

Fig. 3: Examples of MADYMO FE models: Hybrid-III 6yo (left) Hybrid-III 05th (right)

Since numerical simulations are commonly used to design and evaluate restraint systems, the increasing safety requirements put high demands on the accuracy of numerical models of crash dummies. In addition, the large number of simulations that are needed to design an occupant safety system that complies with the range in regulated crash conditions requires fast and accurate simulations combined with efficient optimization techniques to enable vehicle developers to balance system performance with development costs while meeting legislation requirements at a global level.

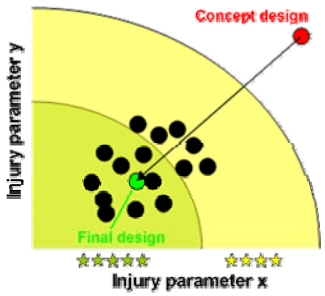

Fig. 4: Efficient optimization techniques are needed to design occupant safety systems that meet legislation requirements, with robust performance

The third category of MADYMO dummy models is based on the wish to combine the accuracy and level of detail of finite elements models with the CPU efficiency of the classical multibody models. These models are based on the facet methodology: the geometry is represented by a finite elements mesh with material_null that is coupled with a detailed multibody skeleton. This technique allows to put in much more details for contact modeling than is possible with classical multibody techniques, such as different element thicknesses (influencing the contact stiffenss) and flexible bodies that can take into account the effect of typical deformation. But since the model is still primarily a multibody model, the CPU efficiency is very strong compared to finite element models.

Recently TASS has invested significantly in the facet modelling techniques. Also a new suite of premium MADYMO dummy models has been released: the Facet Quality dummy models. All Facet Quality models are delivered with an extensive Quality Report that contains a transparent overview of the data set used for model validation, signal comparison plots (experimental signal versus numerical model signal) and the results of objective rating evaluations. The objective rating is used to quantify how well the model predicts the peak magnitude, peak timing, and overall shape of the experimental signals.

The facet MADYMO models can easily be used in FE environments. Furthermore, since the geometry of the hardware dummy is fully represented using meshing techniques, it allows detailed visual analysis in commonly used post-processing tools as MADPost and Altair's Hyperview. The accuracy and geometric detail of the Facet Quality dummy models make them much more suitable for virtual prototyping and design verification than the traditional MADYMO ellipsoid models. However, the ellipsoid dummy models remain the excellent solution for concept design and large parametric studies. Up till now it offers more or less the same benefits as the finite elements models, but there is a bonus: the highly predictive Facet Quality dummy models are fast enough to be used in DoE/optimization runs as well. The much higher computational speed and numerical stability make the Facet Quality models a much more efficient tool for DoE analyses and design optimization than finite element dummy models.

Facet Quality dummy models of the Hybrid-III 50th, EuroSID-2(re), BioRID-II and the WorldSID 50th are currently available in MADYMO R6.3 and this set will be continuously extended in the coming period.

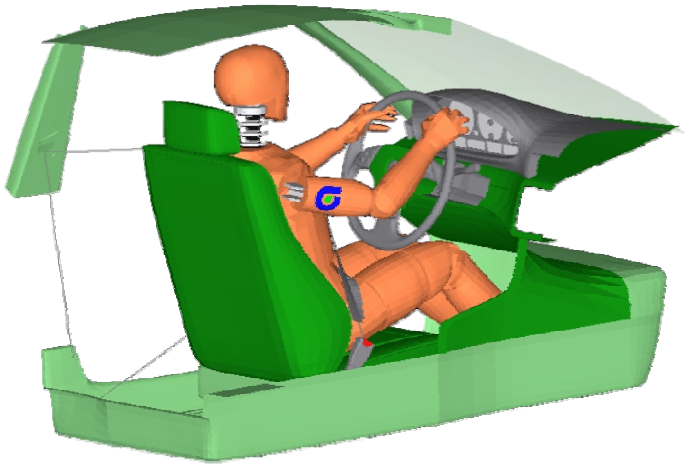

Fig. 5: Example of an application using the Hybrid-III 50th facet Q dummy

2.1 Coupling with MADYMO and other structural codes

All MADYMO models, including the latest MADYMO Facet Quality dummy models, can be used in your preferred structural crash code. This enables engineers to use dummy models that are not available or don't have the required quality in their preferred FE code. In addition, the use of MADYMO dummy models in both the optimisation of the restraint system (which is typically done in MADYMO) and the subsequent restraint verification in a FE structural code prevents issues related to the interpretation of responses obtained from different dummy models (MADYMO vs. FE code dummy

models). Consequently, MADYMO Facet Quality dummy models facilitate a controlled and reliable modelling approach for your occupant safety design and verification.

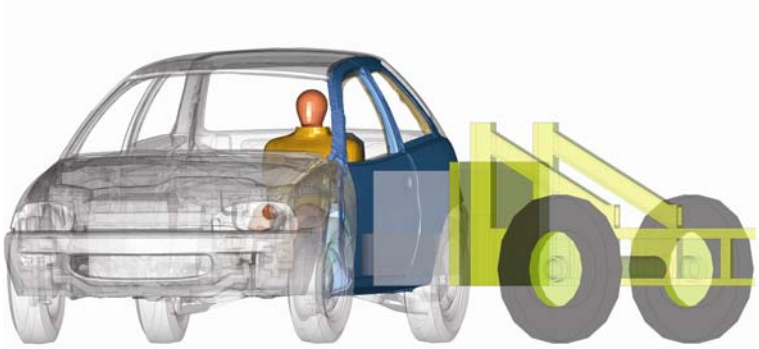

Fig. 6: Example of a MADYMO dummy model in a LS-DYNA environment using coupling

3 Dummy model development

Over the last decades an extensive validation set has been developed for dummy model validation purposes. To be able to fullfill the demanding requirements from industry with respect to numerical dummy models, a complete new process including dedicated software tools are developed. The complete process is referred to as ‘datastorage’, and is developed in-house at TNO MADYMO BV. The unique tool combines version management with all practical functionality to develop and maintain new or existing MADYMO dummy models in large teams without overwriting issues and with an automatic quality evaluation. Furthermore the tool is able to automatically produce a ‘MADYMO Quality Report’ that is delivered with the Facet Quality dummies.

Base of the tool is a standardized way of storing the data in the development environment. Every dummy model is split up in different input decks for every physical dummy part, see figure 7. If a certain component model is updated, the datastorage tool will automatically detect this and run the simulations of the experiments in the validation set that uses the updated component.

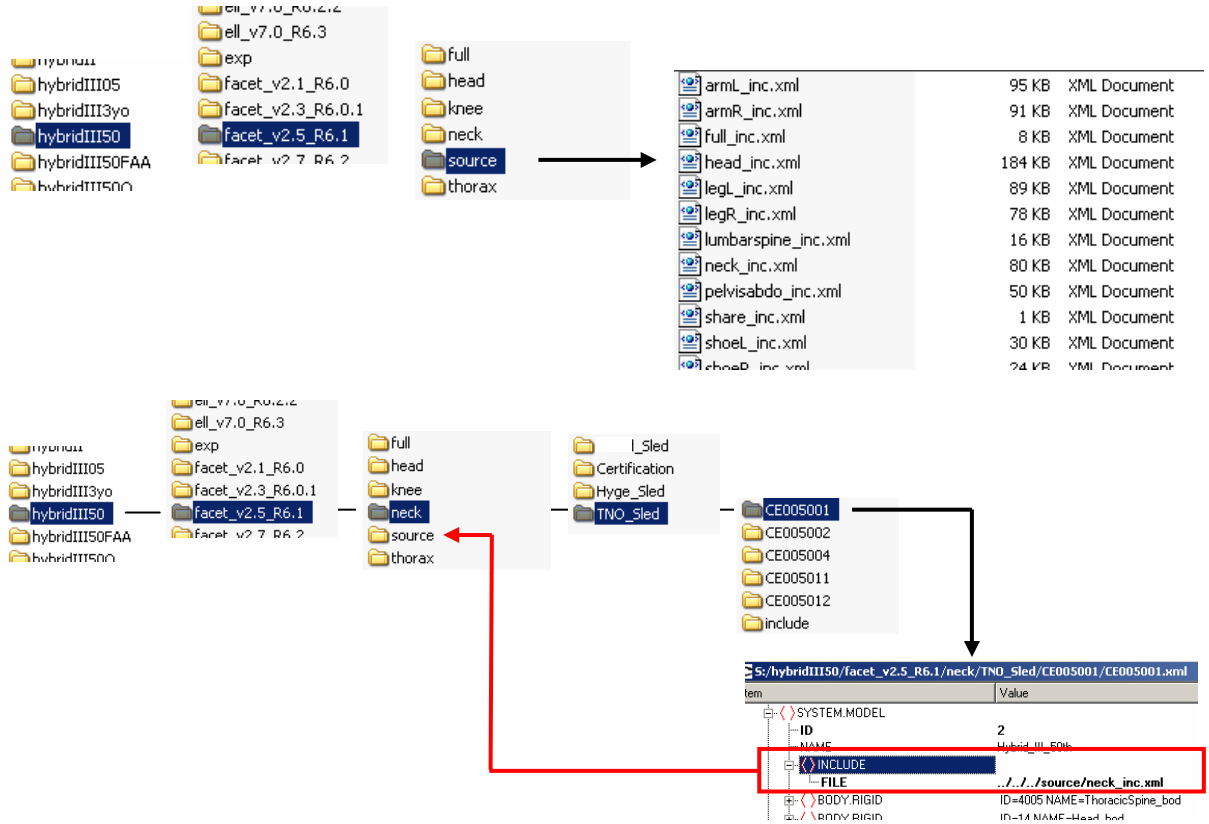

Fig. 7: Example of a MADYMO dummy model tree in datastorage

When a model is updated, the tool automatically compares the updated and original model on quality, based on objective rating methods that are developed by TASS and described in [1]. If the development engineer has analyzed the results and accepted the changes, the datastorage tool is able to produce the new _usr.xml and _inc.xml file automatically together with a quality rating report comparing both models. In Figure 8, the generated plots and rating values are shown for updated thorax and tibia of two different models of the Hybrid-III 50th dummy.

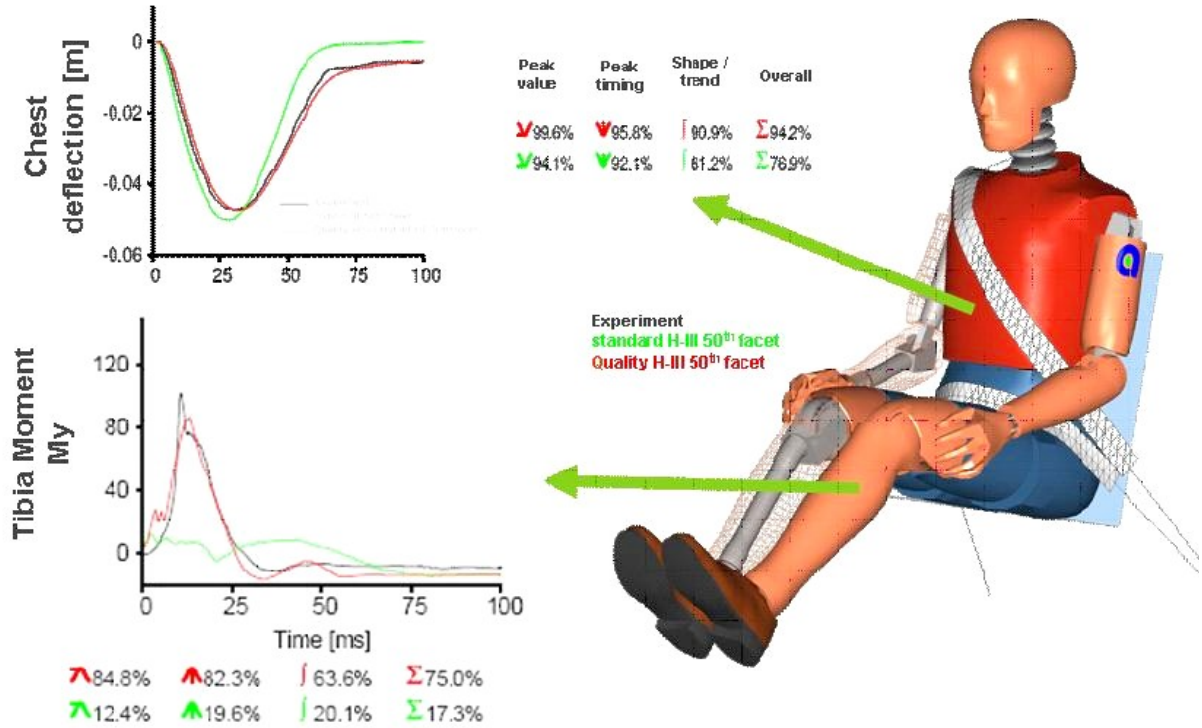

Fig. 8: Example of an automated curve and rating comparison using datastorage

3.1 Partners in development

To strengthen our ambition to provide the best quality dummy models, TASS signed a Technology Agreement with Denton ATD at the end of 2005. This strategic move by two of the global leaders in automotive safety resulted in the marriage of over 30 years of industry knowledge and experience – Denton ATD as experts in crash test dummies and TASS as experts in virtual crash testing. The relationship aims to improve the design, quality and accuracy of crash test dummies and their calibration equipment, and to design and continuously improve the corresponding virtual dummy models. A first success story resulting from the Denton-TASS collaboration is the quality-rated MADYMO BioRID-II Facet Quality model for which Denton provided hardware data and TASS developed the numerical model (see Fig. 9). As part of the collaboration, Denton and TASS have started an extensive study on improving dummy repeatability.

Fig. 9: BioRID-II FE Quality dummy model (left) and a detail of the spine column (right)

Another important milestone for TASS last year was the alliance with the German Partnership for Dummy Technology and Biomechanics (PDB). This alliance permitted the sharing of an invaluable collection of 400 dummy component and sled test data, which were obtained through a consortium of German automotive companies including Audi, BMW, DaimlerChrysler, Porsche, VW, AUTOLIV, Karmann, Takata-Petri and TRW. This set of data was used to further improve the performance of the MADYMO Hybrid-III 50th dummy model. The resulting Hybrid-III 50th Facet Quality v2.0 is available for all customers worldwide and is delivered with a detailed validation and rating report (printed MADYMO Quality Report) with about 300 pages, in order to give all customers fully insight in the models quality level.

4 Summary

Using the MADYMO coupling an extensive database of MADYMO dummy models is available for crash safety analysis in all structural crash codes like LS-DYNA, PAMCrash and Abaqus.
Three different types of models are available: ellipsoid (classical MB), facet and finite elements models. The ellipsoid models are perfectly suitable to be used in the conceptual phase and/or in large DoE studies, due to their combination of accuracy with optimal speed. Finite element models are a good alternative when details in local contact areas are important and the CPU efficiency is much less of an issue. Facet models provide a robust alternative with acceptable CPU. Due to recent MADYMO code investments facet models compete on quality with the latest finite elements models as well, for example because accuracy does not need to be compromised for robustness.

MADYMO dummy models are developed in a very controlled environment calling ‘datastorage’. This process enables to develop and improve models with objectively rated quality and can automatically generate MADYMO Quality Reports. These reports include all information engineers will need judging the level of validation, like an extensive description of the validation set, all signal curves and numerical model and experiment objective rating.

5 Literature

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