ModelCompare

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Abstract ModelCompare is a plugin for post-processing software, which provides a seamless interface to compare two similarly discretized finite element models and visualizes their differences in terms of geometry, thickness, material properties, rigid body elements and spotwelds. The tool compares the geometry of two models based on their discretization meshes and is independent of meta data of the parts. From the ground-up, the software has been designed to be efficient and easy to use, by employing modern mapping techniques which result in extremely short runtimes.

1 Introduction

Numerical simulations have been an essential tool in the virtual product development for many years now. Here, an approximate representation of a product by a finite element (FE) model is employed and, based on a mathematical model of the physical process, a numerical simulation is performed. For example in the automotive industry, the research and development process consists of generating multiple variants of a car CAE-model representing different configurations [5]. Furthermore, different operating conditions of the car and different situations, so-called load cases, are investigated, multiplying the amount of data once more. Post-processing software tools are readily available to display the 3D geometrical information of such a model and the results of the numerical simulation.

The complex structure of the data and its sheer size, the required 3D visualization of the geometry and the needed inspection of the associated design variables of each configuration prohibit a detailed comparative analysis by hand. For instance, in the automotive industry, different versions of a FE model are generated by morphing the geometry (mesh), re-meshing, altering the material data, thickness data and so on.

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Several tools, that are available in the market to record the changes made over time, are often time consuming and cumbersome to work with. However, our ModelCompare tool automatically determines the differences in the configurations and provides an easy and interactive access to the difference data and its visualization.

2 Development History

Fraunhofer SCAI has a long history of data analysis and data processing in the automotive industry, which for example resulted in the spin-off SIDACT[1] with its software products FEMZIP (for data compression) and DiffCrash (for an analysis of the robustness of crash simulation models). In the course of several projects in the past years (FEMMINER, SIMDATA-NL) and ongoing ones (VAVID), which were and are supported by the German Bundesministerium für Bildung und Forschung (BMBF), new data analysis techniques were studied and developed for the investigation of bundles of large scale numerical simulation data [1, 2, 3, 4]. The efficient and easy identification of changes in the configuration of a numerical simulation was, and is, needed for the more advanced data analysis procedures developed in these projects. But as it turned out, it is on its own already a technology which is of use for the engineer in the automotive industry.

3 Capabilities

The ModelCompare software developed by SCAI supports the engineer in analyzing the configurations obtained from the pre-processing step in the product development chain, where these configurations would then be used for the actual numerical simulation. Already at this step, automated processing scripts, meshing, parametrized localized plate thickness changes, or spotweld placements can result in a large number of changes. ModelCompare assists the user by providing elegant visuals of the differences in two similarly discretized FE models while seamlessly integrating with the specialized visualization software Animator[2]. During a product development cycle, several design modifications are made over a period of time by one or many users. Although several PLM tools are available in the market to record the design changes made over time, a quick interactive view of all the changes made between two design setups, in particular including the effect of parametrized changes within the post-processor, is so far not available.

Roughly speaking, based on previous designs, a concept design is first set that will be subsequently refined in several phases of the product design by changing the geometry, material data and other design related parameters in order to fulfill

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[1] www.sidact.com

[2] Animator4 from GNS mbH, gns-mbh.com/animator.html

functional or regulatory constraints. The steps involved in the pre-processing include geometry decomposition, discretization by a FE model, setting up connecting elements such as rigid body elements (RBEs) and spotwelds, defining boundary conditions as well as material parameters. New input models may be generated by varying one or many of the steps involved in the pre-processing. Note that this step is often given to engineering companies by the OEMs in the development process, further increasing the need for an easy investigation tool for determining the changes in configuration.

The ModelCompare software analyzes two models to detect changes in geometry and in attributes such as material property and part thickness. In the following we give examples for the different type of changes, illustrated on a model for the Toyota Camry from the Center for Collision Safety and Analysis (CCSA) repository[3].

Detection of Geometry Changes

Geometry changes, or changes in the mesh, occur primarily due to morphing or remeshing of certain patches or surfaces in a part. ModelCompare identifies the changes made in the corresponding part(s) of the other model, based on the geometry (mesh) of the parts, and is independent of meta data of the parts such as their identifier or name. Geometrically changed parts have a one-to-one correspondence, i.e. for a part in one model exactly one part is found in the other model. Examples of geometry changes performed in the front of a car are shown in Figs. 1 and 2.

Note that some parts, which have the same mesh configuration in both models, might have one or a few new or missing finite elements. In physical terms, an element has material in the one model, while it has no material in the other one, i.e. it is a hole. The ModelCompare tool also detects such situations and finds the position of such elements.
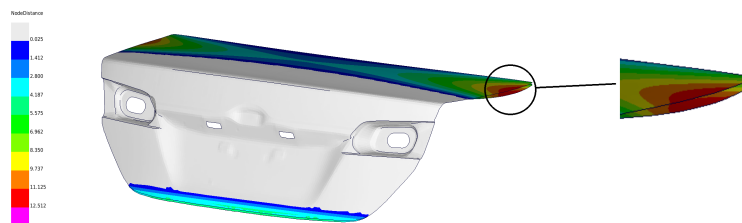

Fig. 1 The bonet of a Toyota Camry is morphed slightly at three positions to fit new design requirements, as identified by ModelCompare.

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[3] Finite Element Model Archive, `www.ccsa.gmu.edu/models/2012-toyota-camry/`
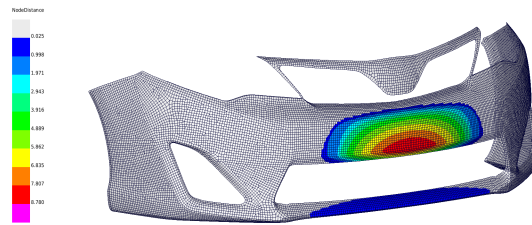
Fig. 2 The bumper of a Toyota Camry is morphed to fit new design requirements, as recognized by ModelCompare.

Detection of MultiParts

A part in one model can be split into many parts in the other model. Here the parts have one-to-many correspondence, i.e. one part in one model corresponds to a combination of some parts in the other model. This is illustrated in Fig. 3. Note that establishing such a correspondence between a part and parts that are merged together in the other model is based on certain assumptions, which can be problematic, i.e. bigger changes can result in misclassifications. Finally, parts which appear only in one of the two models are also identified and categorized accordingly.

For both, the geometry changes and the 'MultiParts' changes, the tool can also give a measure of the uncertainty of the matching, which becomes relevant for larger changes.
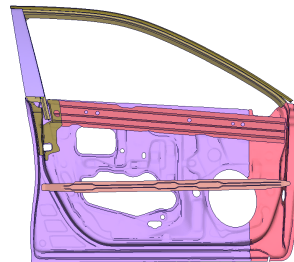
Fig. 3 The front door assembly of a Toyota Camry model, which was described as a single part in one model, was found to be described as a group of sub parts.

Spotwelds and Rigid Body Elements

Spotwelds and rigid body elements (RBEs) are also diagnosed for changes in their configuration, different positions or connections. In Fig. 4 we show a change in the spotwelds, while Fig. 5 shows corresponding RBEs from the two models that have

different so-called master node positions. ModelCompare determines such differences automatically, thus giving the engineer important insight about changes in the model. All these differences are organized and presented in several categories, as can be seen in Fig. 6.
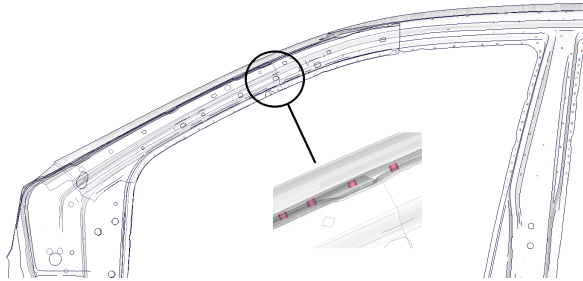

Fig. 4 Spotwelds on the A-Pillar which have no direct correspondence in the other model.
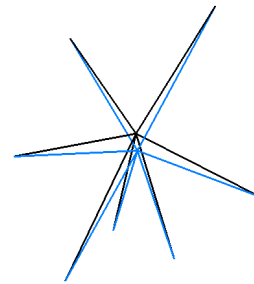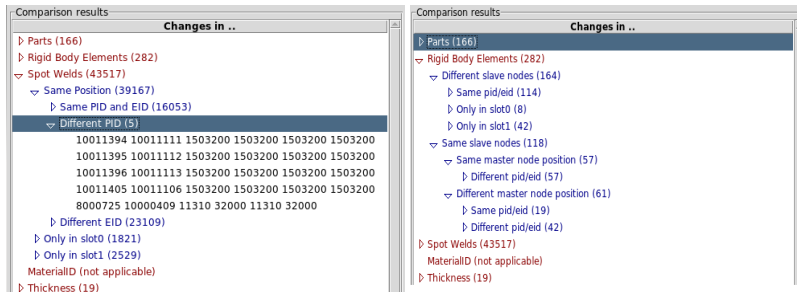

Fig. 5 RBEs from the two models with different master node position.

(a) Differences in the spotweld configuration   (b) Differences in the RBE configuration

Fig. 6 Changes to spotwelds and rigid body elements as shown in the plugin GUI.

Detection of Material-ID and Thickness Changes

In addition to changes in geometry or position, differences in attributes such as material properties and thickness are also identified. While material properties are per part, the thickness can be given per part or per element (described by a parametrized local thickness). Besides the information per part, it is also helpful to show all parts with changes in the full car, with the remaining parts greyed out, as is shown in Fig. 7.
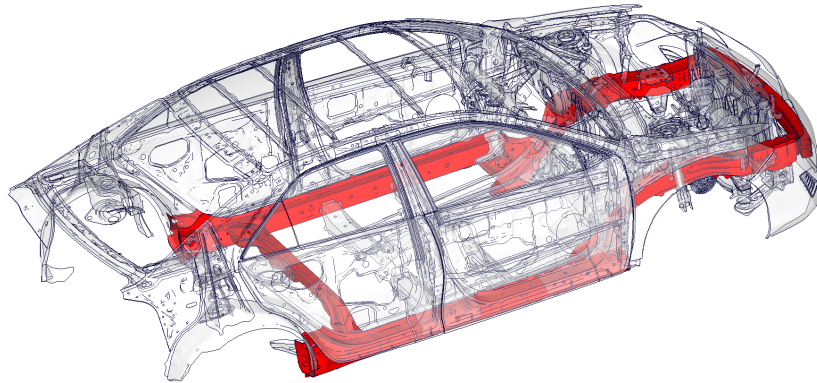

Fig. 7 All parts with thickness changes can be displayed for visual identification.

4 Outlook

Nowadays, engineers often analyze and compare different numerical simulation results using their own engineering knowledge. This is generally limited to the simultaneous analysis of only a very few full simulation results at a time or of simplified scalar quantities of interest, which describe the full complexity of the simulation results only in a limited fashion. Therefore, there is need for a more efficient product development process which overcomes the current limitations. For example, the use of post processing quantities, that are single scalar quantities or vectors, does not allow an in-depth analysis of 3D deformations. Indeed, an efficient and detailed analysis of this type for hundreds of design changes is nowadays a challenge in industrial practice.

The described ModelCompare plugin allows the comparison of two input configurations for a numerical simulation. A natural extension is such a comparison, or data

organisation, over a bundle of configurations, which would allow an easy overview of the design changes made by engineers, alone or in a group.

Besides such an investigation of the input configuration, the comparison of multiple simulation data sets using the full output data of the numerical simulation, or large parts of it, is currently being investigated and developed, see e.g. [2, 3, 4]. It is envisioned that the combination of data analysis for the results of a numerical simulation and the data organization and analysis of the input configurations will provide essential software components for the virtual product development process, both enhancing and simplifying the work for an engineer.

References

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