Structural analysis of a Body in White for battery integration using Finite Element and Macro Element with the focus on pole crash optimization

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ABSTRACT

This paper deals with high voltage battery integration in a vehicle within the FP7th EU-Project “SmartBatt”. The objectives of the project are to develop a battery housing for an electric energy storage system (EES) that will be safe, lighter than state of the art housings and shows innovative design solutions. The focus of this work lies on the safety aspect of the battery housing. It was developed as an integrated structure for the Body in White (BiW) of an actual internal combustion engine driven car (SLC – Super Light Car [1]). The requirements for this structure were different impact scenarios, for example the Euro-NCAP Front Offset Deformable Barrier (ODB, 64 kph) or the Euro-NCAP Side Pole (29kph) test [2]. The relevant test for this paper will be the Pole test which is a very critical loadcase due to the high intrusions.

Generally the battery integration process is subjected to multi criteria limitations coming from functional, ecological, safety or technological reasons, which make the design process complex and potentially increases the number of design iterations between groups of competences taking a part in the overall vehicle design process. Reduction of the design iteration time is therefore very important. For this purpose, a macro element (ME) model was set up in the Visual Crash Studio (VCS) environment. A strong advantage of this method is the computing time, two orders of magnitude shorter than for FE simulations, and easiness of body development in the step by step, iterative process of structural design. The Dynamic ME model uses elements called Super Beams, rigid bodies, user-defined elements (i.e. wheels) and mechanical contacts. Super Beam elements were developed for simulation of thin walled prismatic beam members in elastic, limit load, post collapse and deep collapse range, including axial, bending and torsional interactions of forces [3,4].

For the validation of the ME-model a valid FE-Model of the SLC was used. Due to this approach the FE-model should consider potential EES locations as good as supposable. For the evaluation of safe EES locations the Finite Element (FE) model of the car was investigated in different crash scenarios considering the baseline conventional vehicle and a simple remodeled electric vehicle. In accordance with the predefined requirements (range, weight, crash safety, …) and boundary conditions (space restrictions) a list of possible smart housing concepts were derived from the CAD-data of the SLC-BiW.

SLC – FE-Model	SLC – ME-Model

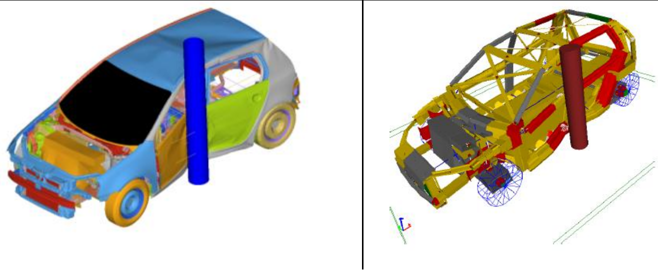

Figure 1: Finite Element and Macro Element Model

In a next step the ME model was validated against these FE simulation results in all considered crash scenarios. So the ME models were subjected to analysis of first order crash effects and used for assessment of new design of the vehicle floor panel.

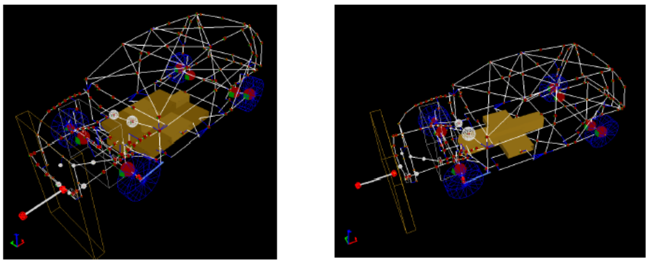

Figure 2: Example illustrations of the concept implementation processes

Figure 2 depicts a comparison between FE and ME simulation results, and two implementations of concepts configured to frontal ODB crash test in the VCS. During the concept phase, a large design sensitivity space was examined in detail to identify all impact threats to the battery pack, and determine quasi-optimal, basic structural properties of the design versions. Several novel solutions were tested. Among others, side crash energy absorbers and moving rear battery pack concepts where noticeable. All those steps led to a selection of leading design configuration, whose new structural members and their parameters used in VCS were added to the detailed FE model, replacing a floor panel of the internal combustion vehicle with the new design incorporating battery housing. The FE simulations were used for further analysis and design improvements, allowing for detailed design of the floor panel with battery housing incorporated in its structure.

It can be successfully shown that the combination of FE and ME models can be used for structural integration of the EES into a conventional vehicle.

References

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