Modelling And Testing for Improved Safety of key composite StructurEs in alternatively powered vehicles

Reporting

Project information

MATISSE

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Final Report Summary - MATISSE (Modelling And Testing for Improved Safety of key composite StructurEs in alternatively powered vehicles)

Executive Summary:
At present, the ability to model, simulate and predict the behavior of fibre reinforced polymer (FRP) structures lags markedly behind the capabilities for pressed steel bodies. MATISSE will improve the capability of the automotive industry to model, predict and optimise the crash behaviour of mass produced FRP composite structures, which will be extensively used in alternatively powered vehicles (APV). MATISSE leverages the knowledge from the aeronautical sector (where FRP structures are widely used) while assuring that advances in modelling, simulation and testing capabilities will be directly applicable to automotive applications, reinforcing the European automotive sector.

Project Context and Objectives:
The ability to investigate crashworthiness of FRP vehicle structures by numerical simulation is crucial for these lightweight materials to see widespread use in future cars. Modelling tools developed will be further validated through two automotive solution components, adaptive crash structures and high-pressure storage tanks. Future crash scenarios will be assessed and new evaluation criteria regarding safety will be developed.
The main objectives are:

- Development and testing of modelling techniques for fabric reinforced structures
- Development of modelling techniques for thick composites with unidirectional fibers
- Design & assessment of structural specimen/sub-component & inflators
- General virtual testing procedure for Type IV CNG tanks
- High-pressure storage tanks FE models and experimental testing

More specifically, MATISSE takes into account the changes towards alternative powered vehicles (APVs) and small electric vehicles

(SEVs) in the vehicle fleet, in order to define new crash scenarios considering future developments and, evaluate possible new hazards resulting from the operation of alternatively powered vehicles. Furthermore, MATISSE deals with the development of modelling techniques for composites and their joining methods, i.e. material models, which are essential to facilitate the numerical simulation of composite components (which will be designed and validated) subject to impact or severe static loads leading to failure and/or fracture of the composite. The objectives are to develop improved material modelling techniques capable of predicting failure initiation as well as the subsequent material degradation during the damage evolution, determine the needed material parameters for selected composite materials. This will require the development of new testing methods in some instances.
MATISSE also aims at identifying and assessing the concrete structural components for adaptive crash structures. This includes the design, assessment and integration of an adaptive inflator for pressurising the developed structure. Structure and inflator have to be defined to fulfil requested technical demands like maximum pressure, pressure vs. time characteristic, etc. In this sense, there are different concepts for pressurisation and two different principles will be investigated. The benefit of this pressurisation is an improved stability of the structure in case of crash and/or a mass reduction respectively a tighter packaging.
As a second application high-pressure storage tank will be considered. So, the main objective here is to improve the capability to predict (through the operational use of adequate/suitable FE models) weakness points in the composites high-pressure storage tank designs, when dynamically loaded according to the real operational conditions resulting from full vehicle crashes. This enables new approaches to more efficient, lighter and crash safer designs for the vehicles having the high-pressure storage tank(s) on board and the tank(s) itself (themselves).
MATISSE comprises 11 partners from 6 countries, including four high ranking European universities/research centres, three SMEs, two innovative tier-1 suppliers and two major European vehicles manufacturers. MATISSE is coordinated by Forschungsgesellschaft Kraftfahrwesen mbH Aachen and cooperates with existing parallel projects through a specific clustering committee.

Project Results:
New crash scenarios and hazards for occupants of alternative powered vehicles (APV) were analysed and assessed, in order to find suitable locations for the application of composite structures. A Delphi study, supported by a public survey, estimated future mobility and city-layouts and helped to identify boundary conditions. Reviews of current heavy vehicle accidents and their relevance for future scenarios and identification of critical accidents for high-pressure storage tanks by an expert brainstorming and finite element methods were carried out. The result is, that driver assistance systems (DAS) will lead to enormous reduction of the accident occurrence. Doubtlessly there will still be accidents, which cannot be prevented. At least for those accidents the collision velocity and linked with that, the injury risk for car occupants will reduce. Furthermore, it comes out that CNG vehicles currently have to withstand the forces on the storage cylinder in case of a frontal, side and rear collision w.r.t. avoiding leakage and fire. Based on these results the most critical crash location of a vehicle could be found out.
In the simulation part of the project suitable materials for two possible applications (inflatable structures and CNG tanks) were considered, assessed and pre-selected. Based on the LS DYNA software suitable material models and the corresponding model parameters were defined by extensive literature studies and workshops within the project. These material models were validated by literature values and component testing.
For the CNG tanks a subsystem experimental test set-up based on the numerical simulation results was proposed. The experimental testing campaign (quasi-static three point bending tests) on glass fibre reinforced polymers (GFRP) and carbon fibre reinforced polymers (CFRP) tubes (specimen for material model validation) was performed. In total 15 tests for GFRP tubes (five repetitions for each of the three tube laminate set-ups) and 13 for CFRP ones (five repetitions for laminate set-up 1 and four for both set-ups 2 and 3) were executed. The corresponding material models were validated.
In parallel to the virtual development of the adaptive structure and the CNG tank, the extended FEM (XFEM) approach and the mesomechanical composite modelling (BPRCM) were finalised. Both methods allow the simulation of delamination effects and cracks in a very detailed way. Both methods were implemented in the commercially used software LS DYNA resp. Abaqus.
The final selection of a suitable inflatable structure was in addition to the results from a brainstorming session based on criteria such as structural requirements, benefits, gas generator requirements, manufacturing and process criteria. It was decided that an active expandable and pressurised door beam made in FRP will be developed and evaluated virtually and mechanically. Front and rear bumper beams will be developed and evaluated virtually. So, a simple generic adaptive door beam was designed, simulated, built up and tested. For that a test method was developed and a suitable composite material as well as a gas generator were selected.
For the adaptive door beam the final selection of the FRP material was done. The TU Munich thermoset material was chosen. Furthermore, coupon testing was executed in cooperation with the project ENLIGHT in order to validate the material models. With these results the simulation models were continuously refined. In addition a proper inflation mechanism was developed for the adaptive door beam. Furthermore, several further suitable beams were built and tested (inflated and non-inflated) in comparison to a reference beam. The adaptive door beam designed and built by TUM/LCC showed a great potential to achieve reduced weight with maintained deformation force and energy absorption compared to a state of the art door beam. A demonstrator was built by TUM/LCC. The

expandable prototype beam was mounted in a series vehicle door.
Concerning the analysis of CNG tanks, a virtual testing methodology for the identification of the main load paths insisting on the composite tank during full vehicle crashes was defined. Crash scenarios relevant w.r.t. the potential to induce damages on the composite compressed natural gas (CNG) tanks were considered and simulated. This methodology was developed further and validated by several series of practical tests. Many suitable test configurations were defined for the execution of these tests.
Possible simulation options offered by LS DYNA in order to realise the stage 1 tank model were considered and the first version of this model were released. The most complete and complex detailed FE model of the composite tank to be used in the project was generated. In this model, the fibre orientation/distribution was defined according to stage 1 model and refined on the basis of orientation and geometry data provided by Xperion. Furthermore, the FE models of the CNG composite tanks were brought to a more detailed level. The so called stage 2 and stage 3 were developed. The stage 2 model represents the most detailed model. The reduced stage 3 model allows the simulation of the tank in a full vehicle. The virtual evaluation was done by full car crash simulations. In a final step optimised vessel designs were developed, produced and tested.
Within WP5 virtual evaluation methods for safety-relevant components specific to alternatively powered vehicles were defined. Furthermore, their benefits accentuating cost and weight savings were analysed. Finally, guidelines and recommendations that derive from the work of MATISSE as the associated FP7 project SafeEV were compiled within this work package.
Concerning the evaluation of the dynamic loading capacity of CNG tanks evaluation criteria on the vessel level were presented that are on the one hand derived from the ECE R110 standard drop test set-up. On the other hand the most relevant test conditions for the simplified impact test-rig developed within MATISSE were identified.
In a TCO analysis it could be proven that for CNG as well as for battery electric vehicles significant cost savings in relation to reduced vehicle mass are possible over the vehicle's lifetime. However, it was also stated that for a comprehensive weight reduction high additional production costs are in many cases not avertable. In scenarios for mass production it was shown that material prices play an important role in relation to FRP components. For that reason the development of these factors can highly influence the cost of the analysed components in the future. Especially fibre costs and availability are to be named. Using highly predictive simulation models in the development phase of a vehicle offers also high cost reduction potentials.
In order to summarise, condensate and specify the results gained in the projects SafeEV and MATISSE guidelines and recommendations for the various topics of two projects were collected and were brought in a form that is applicable in future work.

Potential Impact:
The final goal of MATISSE is to provide advanced capabilities and tools that allow OEM car designers to model, simulate and test the safety aspects of APVs in the same way as they can currently analyse and assess pressed steel bodies. This will allow them to make better design choices, which means that the impact of MATISSE will be mainly felt indirectly, through the ability of car makers to design, build and sell better and safer APVs.
Furthermore, CNG tanks could be made lighter, and could possibly be more tightly integrated into the vehicle structure then is the case at present. This would mean that for a given car size the CNG fuel tank can be allowed to be larger, which extends the range of the vehicle. This extended range leads to an increased take-up of CNG as an alternative fuel to petrol, which not only has environmental benefits but also increases safety.
MATISSE will deliver reference designs for adaptive crash structures and the modelling and simulation tools to predict the level of crash safety they offer to occupants, pedestrians and other vulnerable road users, and partners. These adaptive structures have the potential to greatly increase vehicle safety for all parties involved in a wide range of real-life crash configurations without the weight and size penalties of static crash structures. The reference designs coming out of MATISSE are furthermore likely to find use in non-APV cars.
The development engineers of the OEMs can use the validated models for their simulations for developing composite structures. Engineers might choose to optimise occupant safety while maintaining weight below a set limit. Or they might try to meet top marks in occupant safety rating while minimising weight or cost.
In the scope of the dissemination activities a large amount of publications was prepared and executed. Amongst others these were conference papers, articles in journals and magazines, conference presentations as well as participations at exhibitions. Furthermore, a training session was developed and executed. At the end of the project a public final workshop was organised together with the SEAM cluster project SafeEV in order to present the results to a broader audience. The workshop was attended by 46 participants from research and automotive organisations around Europe.

List of Websites:
http://www.project-matisse.eu

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