MATISSE: Design concepts and modelling approaches for increasing the safety of alternatively powered vehicles

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Abstract

MATISSE aims to improve the capability of the automotive sector to model, predict and optimise the crash behaviour of mass produced fibre reinforced polymer (FRP) composite structures, which will be used in alternatively powered vehicles (APV). The ability to investigate crashworthiness of FRP vehicle structures by numerical simulation is important for these lightweight materials to see widespread use in future vehicles. By delivering this ability MATISSE will lead to safer, more efficient and more desirable vehicles. 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.

Keywords: electric vehicle, composites, modelling, simulation, validation, safety

Résumé

MATISSE vise à améliorer la capacité du secteur de l'automobile à modéliser, prévoir et optimiser la réaction en cas d'accident des structures composites en polymères renforcés de fibre qui seront utilisés dans les véhicules à énergie alternative (APV). La possibilité de tester la résistance aux chocs des structures de tels véhicules par simulation numérique est essentielle pour que l'utilisation de ces matériaux légers se généralise. En offrant cette opportunité, MATISSE mènera au développement de véhicules plus sûrs, plus efficaces et plus enviables. Les outils de modélisation développés seront validés au travers de deux composants du véhicule: les structures adaptatives en cas d'accident et les réservoirs de stockage à haute pression. D'autres scénarios d'accidents seront évaluées dans le futur et de nouveaux critères d'évaluation en matière de sécurité seront développés.

Mots-clé: véhicule d'électricité, composites, modélisation, simulation, validation, sécurité

1. Introduction

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. 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.

In this paper the work of the different partners of the first 12 months of the project is described. Based on analysis about the initial situation concerning the safety of alternatively powered vehicles (APVs) and small electric vehicles (SEVs) highly affected areas in those vehicles are identified and characterised. To protect the passengers and the electrical energy storage systems light and safe structures are necessary. Those structures made of FRP will be developed by designing, modelling, simulating, validating and testing. Furthermore, the safety of CNG tanks shall be enhanced by increasing the predictability. So, those tanks will be modelled, simulated, validated and tested as well.

2. Safety of alternatively powered vehicles

2.1. State-of-the-art situation

Increasing energy costs and emission targets aiming for reduced CO_2 emissions continuously are fuelling a migration from traditional vehicles with an Internal Combustion Engine (ICE) running on petrol or diesel fuel to ones with alternative power trains. A number of hybrid and fully electric vehicles based on conventional ICE car platforms and architectures are present on today’s market. Their take-up will no doubt gradually increase, but in order for alternatively powered vehicles (APVs) to become an important presence on European roads new car concepts that from the outset are designed and optimised for alternative power trains are required. A very important contribution to lowering energy consumption by future vehicles will come from the reduction of vehicle weight. To achieve this reduction, future cars - including APVs - will make extensive use of Fibre-Reinforced Polymers (FRP) for structural components.

2.2. Definition of the relevant most likely crash scenarios for APVs

Most appropriate accident scenarios at urban sites were identified as turn in/off and cross accidents, longitudinal accidents and pedestrian accidents, mentioned in quantitative order (pedestrian accidents were not considered). The most frequent turn in/off and cross accident types are accidents between a non-priority vehicle and a priority vehicle approaching from right/left, which is not overtaking and proceeding at 90° to each other. Accidents between a non-priority vehicle turning to left and a priority vehicle coming from left, which is not overtaking and accidents between a non-priority vehicle turning off to the left and priority oncoming traffic are further relevant. These four subtypes represent in total roughly two-third of turn in/off and cross accidents in Austria.

The most relevant accident type comprises the accidents between a vehicle which is braking, standing or going slow due to a traffic jam and a following vehicle; and accidents between a vehicle and another vehicle driving in front on the same lane. These accident types represent more than two-third of accidents in longitudinal traffic. Accidents with two head-on encountering vehicles on straight roads or bends are the second most accident types within longitudinal traffic. Even if these types of accidents were assessed from the Austrian’s national statistics only similar accident scenarios can be found in the literature. In the EU funded projects ASSESS (Assessment of Integrated Vehicle Safety Systems for improved vehicle safety)*, CHAMELEON (Pre-crash Application All Around The Vehicle)†, eVALUE (Testing and Evaluation Methods for ICT-based Safety Systems) and vFSS (Advanced Forward-Looking Safety Systems)‡§ similar accident types were determined. With the findings in MATISSE and the other projects subsequent accident scenarios can be summarized.

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[*] ASSESS Deliverable D1.2: Specifications for scenario definitions
[†] CHAMELEON Final Report (http://www.transport-research.info/web/projects/project_details.cfm?ID=2653)
[‡] Leimbach F., Lauterwasser C.: Advanced Forward-Looking Safety Systems – Working Group – Status of Work; RCAR Annual Conference, Merida, Mexico, October 2011

Table 1. Relevant accident scenarios

60 vehicle driving in front	conflict between a vehicle and another vehicle driving in front on the same lane	30 from the left	conflict between a non-priority vehicle and a priority vehicle coming from left proceeding at 90° to each other
61 traffic jam	conflict between a vehicle which is braking, standing or going slow due to a traffic jam and a following vehicle	32 from the right	conflict between a non-priority vehicle and a priority vehicle coming from right proceeding at 90° to each other
68 head-on encounter	conflict between two head-on encountering vehicles on straight roads or in a bend	21 oncoming traffic on road	conflict between a non-priority vehicle turning off to the left and priority oncoming traffic
21 oncoming traffic on road	conflict between a non-priority vehicle turning off to the left and priority oncoming traffic		

2.3. Future collision speed in urban area

In the ASSESS project the impact speed of real world accidents on different accident sites were analysed (urban, rural roads and motorways). Data about impact speed was derived from different in-depth databases (GIDAS – German In-Depth Accident Study, OTS – On The Spot). In GIDAS rear-end impacts have an arithmetic mean impact speed of about 29 km/h (median 26 km/h). The impact speed for the 75th percentile is at about 37 km/h. The figures of OTS show a lower impact speed for all percentiles. The arithmetic mean is identified at about 14 km/h (median 11 km/h). 75 % of the accidents have an impact speed below 19 km/h. For lateral impacts GIDAS show an arithmetic mean impact speed of about 32 km/h (median 33 km/h) where again OTS shows lower impact speeds. The arithmetic mean is at about 16 km/h (median 13 km/h). In frontal impact situations GIDAS arithmetic mean impact speed is at about 31 km/h (median 29 km/h). GIDAS compared to OTS shows a tendency of higher impact velocities for all three impact situations.

In MATISSE a stochastic accident prediction simulation was performed for lateral impact situations only. If the collision cannot be avoided the stochastic simulation showed a tendency to lower impact speed for vehicles which are equipped with a driving assistance system i.e. emergency brake assist. The arithmetic mean impact speed of the stochastic simulation matched well with the findings of GIDAS collision speed. Due to vehicle crash avoidance and severity mitigation systems (here referenced as a generic system) the collision velocity might be reduced by approximately 15-20 % at average. 90 % of the simulations had a collision velocity of up to 60 km/h where GIDAS figures for lateral collisions show a collision velocity of about 62 km/h for the 95th percentile value. Real-world accident analysis showed that the impact speed of different impact configurations draw a similar picture. The arithmetic mean impact speed has a range between 15 km/h and 32 km/h. The 75th percentile has a range between 19 km/h and 43 km/h and the impact speed at the 95th percentile was calculated between 30 km/h and 64 km/h. For the baseline scenario the simulations show a change of velocity up to 30 km/h for roughly 90 % of the simulations. That means 90 % of the simulations have a change of velocity lower than 30 km/h. However, in accidents with low weight vehicles i.e. a mass of 500 kg the change of velocity might increase. In future accidents due to the lower weight of the vehicle having the same share of simulations (90 %) a change of velocity increase to 40 km/h which is an increase of up to 17 %. That means 90 % of the simulations have shown a change of velocity lower than 40 km/h. A similar approach would be feasible for rear-end impacts. It is assumed that a reduction of the collision speed might be up to 20 %.

2.4. Future impact location in urban area

The impact location of the different scenarios in real world accidents could be observed from four different accident data bases (see Table 2). Besides GIDAS and OTS, data is available from EDA (in-depth accident causation survey) and ONISR (National Interministerial Road Safety Observatory, Nation accident database). The information was obtained from the ASSESS project. Table 2 shows the impact locations dedicated to different accident scenarios (rear, lateral, front) based on the different data bases (GIDAS, OTS, EDA, ONISR).

[§] Stanzel M.: Advanced Forward-Looking Safety Systems – Working Group – Introduction and Status update; eVALUE Final Event, November 2010

Table 2. Impact locations in real world accidents according to the identified accident scenarios

Rear-end impacts		
GIDAS	2%	
OTS	5%	
EDA	0%	
ONISR	18%	
2%		1%
3%		5%
18%		0%
3%		3%
	95%	
	87%	
	82%	
	76%	
60 vehicle driving in front	61 traffic jam	

Lateral impacts		
GIDAS	29%	
OTS	19%	
EDA	15%	
ONISR	69%	
38%		31%
30%		42%
43%		41%
14%		10%
	2%	
	9%	
	1%	
	7%	
30 from the left	32 from the right	21 oncoming traffic on road

Frontal impacts		
GIDAS	86%	
OTS	83%	
EDA	89%	
ONISR	86%	
9%		3%
6%		8%
5%		5%
5%		4%
	2%	
	3%	
	1%	
	5%	
68 head-on encounter	21 oncoming traffic on road	

The simulations within MATISSE showed that no significant change in impact direction will be found in future scenarios. The impact direction will remain between 10 and 2 o'clock depending on the collision type. Depending on the appropriate accident situation, there is a tendency that the principle direction of force will slightly change from i.e. 2 o'clock to 1 o'clock or 10 to 11 o'clock. The same methods which were used in MATISSE were applied to real-world accidents of ZEDATU (Zentrale Datenbank zur Tiefenanalyse von Verkehrsunfällen), showing similar tendencies. 60 cases of this in depth database were reconstructed to support the findings of the stochastic simulation method.

2.5. Future accident scenarios and recommendations for further work

Based on the findings in previous projects and the stochastic simulation results of MATISSE following accident scenarios are suggested:

- Frontal impact
  - with an overlap of 30 % with a change of velocity of 50 km/h and an impact direction of 0°
  - an overlap of 100 % with a change of velocity of 50 km/h and an impact direction of 30°
- Side impact
  - to the passenger compartment with a change of velocity of 40 km/h and an impact direction of 90°
  - to the passenger compartment with a change of velocity of 40 km/h and an impact direction of 30°
- Rear end impact
  - an overlap of 100 % with a change of velocity of 25 km/h

The need for light and small vehicles, APV as ICE, reducing fuel consumption, CO_2 emission and pollution asks for newly developed vehicle platforms. Reducing weight suggests the use of lightweight FRP, where reduced packaging size induces the possibilities to include adaptive structures in such vehicles. One possible solution could be the development of inflatable components, which has been proven to be a working concept with conventional steel components. Also the integration of electric energy storage systems (EESS) bears challenges for which structural integrity must not be compromised in any case. Considering these preconditions, a selection of suitable vehicle structure components designed with FRP should be made. In further investigations, a proof of principle should be sought to show that inflatable structural components show a potential to improve crashworthiness combined with reduced weight and packaging size.

3. Concept development of adaptive, fibre reinforced safety components

3.1. Component selection process

One aim of MATISSE is, based on the future crash scenarios, to define an adaptive vehicle member, made of carbon fibre reinforced plastic (CFRP), which will reduce the vehicle weight and improve the crash worthiness of APVs. The selected adaptive CFRP vehicle member will be developed, built and tested. For the selection a vehicle member that will reduce the weight and improve crash worthiness of a vehicle in 2025 when designed to be an adaptive CFRP member was targeted. Parameters like the types of crashes in 2025, the potential benefits of structural adaptivity, the benefits and limitations with CFRP structures compared to steel and aluminium and the integration of the CFRP structures into the vehicle have to be taken into account.

The most appropriate accident scenarios at urban sites in 2025 were identified to be turn in/off and cross accidents as well as longitudinal accidents. It was also defined that adaptive vehicle members which are primarily loaded in bending are more feasible to be made in CFRP than members loaded by axial crushing. The benefits can be two fold. Either, the injury risk for the car occupants can be reduced by developing a vehicle that can adjust its stiffness depending on the crash resulting in optimised structural energy absorption and minimized occupant injury risk. Or, it might be possible to implement a more compact structural member. Due to its geometrical expansion and the internal pressure as a result of the deployment of a gas-generator, comparable or even better mechanical properties could be reached at lower packaging volume and possibly lower weight.

A number of vehicle structural members were investigated for the applicability of fulfilling the benefits above. These members were side member, A-Pillar, B-Pillar, floor, wheel house, front cross member and rear cross member. These members were rated respective to their applicability, qualification and conformity of the identified demands. Based on this rating the vehicle members that were found to be most suitable to be designed in CFRP were cross-beam front, cross-beam rear and side member. Therefore it was decided that an active side member (door beam) will be developed and evaluated virtually and physically. In addition virtual development and evaluation of front and rear cross-beams (bumper beams) will be carried out.

3.2. Testing of simple adaptive fibre reinforced structures

In MATISSE generic expandable CFRP beams were developed. The expansion and deformation performance of these beams were evaluated by a set of mechanical tests. The geometry of the beam was 1000x40x80 mm with a U-shaped fold (Fig. 1 and Fig. 2). The wall thickness was 2 mm. No radius was defined for the fold.

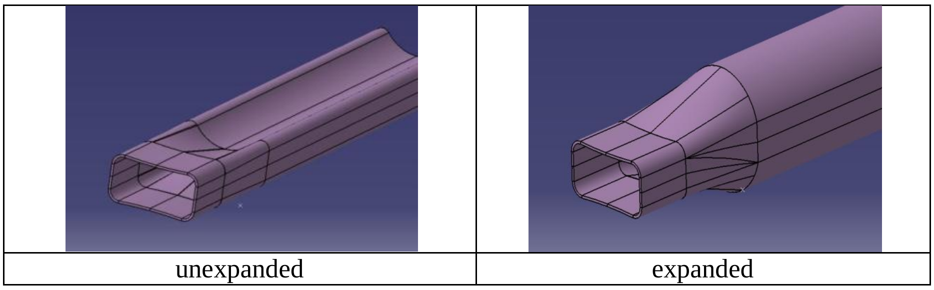

Fig. 1. Geometry of generic active beam

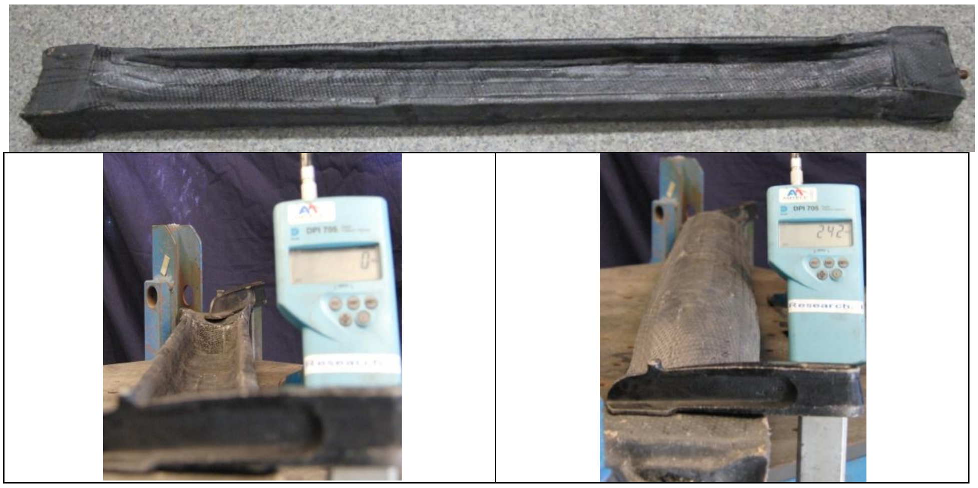

Fig. 2. Expansion of generic expandable fibre reinforced plastic beam

When expanded the dimensions are 1000x80x80 mm. The beams were sealed to be air tight. An elastic liner might also be necessary to make the beams air tight. The first step was to evaluate the expansion performance of the beam by means of pressurising it with water. The second step was a dynamic expansion evaluation by means of pyrotechnic gasgenerators. The starting point for the gasgenerator performance was based on the results from the water pressurisation tests. The third step will be dynamic 3-pt bending tests with unexpanded and expanded beams. Generic expandable FRP beams were built (Fig. 2). Initially the beam was expanded by air. However there was significant leakage of gas through the walls of the expanded beam. Subsequently the beams were expanded using gasgenerator technology. Different types of gasgenerators with 6, 8 and 14 grams propellant were evaluated. Peak pressure was 400 kPa for the 14 gram gasgenerator which was reached at 14 ms (Fig. 3).

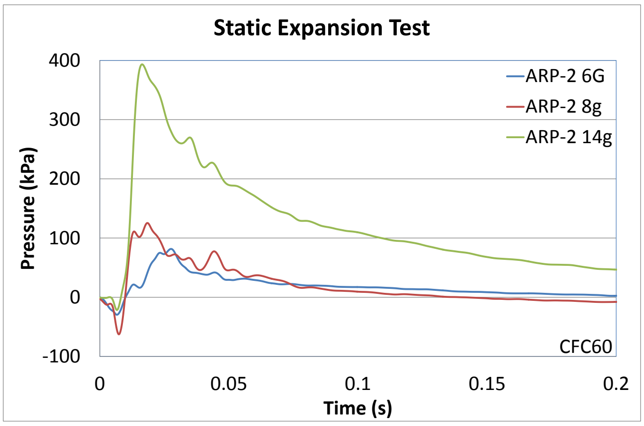

Fig. 3. Pressure of gasgenerators

3.3. Modelling of fibre reinforced structures under short-time pressurization

3.3.1. Mechanisms and possibilities of pressurized components

The aim is to develop FRP longitudinal beams which increase stiffness and rigidity by pressurization. In the theory there are three different ways to reach that goal (Fig. 4). First is only a pressurization of the beam without a geometry change. This increases the stiffness and the beam withstands higher loads. Another option is to expand the cross section by a pyrotechnical device. In this case, the moment of inertia increases and the beam become stiffer. Normally FRPs are very stiff and brittle. So, they can take high loads with less deformation.

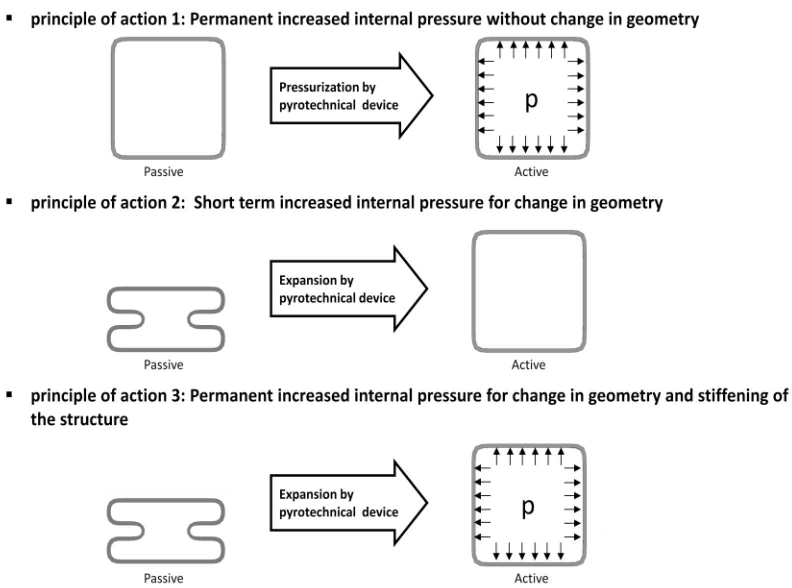

Fig. 4. Pressurisation of components

The advantage of composite materials is that, if well designed, they usually exhibit the best qualities or components of their constituents. To create a composite which is intended to deform under a short-term pressurization it is necessary to adapt the material selection. One possibility is the implementation of joints to the geometry to ensure the changes in the cross-section without damaging the composite (Fig. 5). The elastic regions take over the large deformation. This allows the use of stiff fibre reinforced composite in the areas in which the highest stresses occur in the case of a crash without damaging those areas during pressurization.

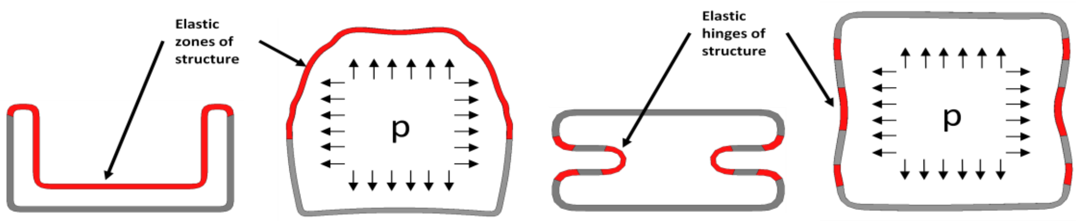

Fig. 5. Deployment of components with flexible areas hinges

A further possibility is to change the matrix material and to adjust the layer setup so that small deformation can be absorbed by the matrix. For this thermoplastic and thermoset materials are used for the matrix. These materials provide larger deformation with less damage in the inflation process.

3.3.2. Effects and issues in the simulation

For the simulation of the highly special components, several important aspects must be observed. The very short inflation process (a few ms) occur in very large dynamic effects in the beam. The pressure wave of the pyro-technic reaction in the gasgenerator passes through the beam and thus can occur in a pre-damage of the structure. To estimate and predict this effect is an important aspect in the simulation. Furthermore, thermoplastics and thermosets have a pronounced strain rate dependency. At present it is very difficult to simulate these effects. Part of the EU project MATISSE is to consider such highly dynamic effects to create a forecast capable simulation model. These issues will play a major role in future developments for dynamic pressurized FRP components.

4. Modelling and testing of compressed natural gas tanks

Besides the electrification of the drive train a conversion of conventional systems to an operation with natural gas is very promising. Especially the CNG (compressed natural gas) pressure vessel has found application in Europe because of its good usability in hot climate. Currently there are four different design types of CNG pressure tanks which differ in the applied materials. Especially type 4 offers a very low structural weight. It comprises of a polymeric liner in combination with glass and/or carbon fibre reinforced polymers. These components produced via filament winding allow operating pressures around 200 bars. In the current project stage the development of simulation approaches and the calibration of material parameters is executed. Thus will be presented here followed by an outlook to the application of the modelling approaches and the validation via testing.

4.1. Development of simulation approaches for CNG tanks

Based on the high pressure and the resulting high stresses on the liner and the winding layers an adequate prediction of the areas of the highest demand in a crash incident is essential. In this context the finite element method (FEM) using the explicit solver LS-DYNA is suitable since it offers several material models for the simulation of FRP structures. Due to their mostly anisotropic behaviour and various failure criteria the numerical investigation of FRPs is far more complex than of the metals classically applied as structural materials in automobile components. Especially continuous unidirectional (UD) fibre reinforced laminates show highly anisotropic and complex, interacting failure effects based on tension, compression as well as shear loading like laminate, fibre and matrix rupture, crushing, delamination and kinking (Fell et al., 2011; Pinho, 2005).

Depending on the manufacturing method, the applied materials, the laminate structure and the load cases that have to be evaluated, diverse FEM modelling approaches are possible. Furthermore, the desired prediction quality, including deformation and loading simulation as well as failure prediction, and on the other hand simulation time are important parameters for the definition of the adequate approach. Here, the right combination of the right element type, element size, material model and layer definition has to be detected to ensure a certain quality in a reasonable calculation time. In this project a modelling approach for structures made of GFRP and CFRP is to be defined and validated. A full model of a structural material comprises not only the choice and calibration of a solver material model card but also additional cards like element type and part definition. Overall the material modelling process is considered here as the evaluation of an adequate combination of different model definitions that are provided with the available material data. This process leads into a validation process that is necessary for the definition of the full set of model parameters. The material validation process for the thick wound materials of the MATISSE project is currently under investigation. In the following a conventional approach is described and an approach that is appropriate for the MATISSE boundary conditions is derived.

4.1.1. Conventional validation process

Typically the validation process of an FRP material model for the solver LS-DYNA can be subdivided in a testing and a simulation phase. First, a number of quasi-static tests is conducted in order to obtain the basic material parameters. The test types depend on the values that are required by the material model. Typical tests that investigate the tensile, compression and shear behaviour are conducted. Furthermore, a test that aims at the delamination behaviour should be foreseen if this failure type is of interest. Besides the quasi-static tests another test should also be conducted which provides a combination of the load directions tested before. This test is necessary since a mere entering of material values into the material cards does not lead to appropriate simulation results for most load cases. On one hand this is due to the interaction of the stress directions and on the other hand due to the fact that the more complex material models often require parameters that cannot be directly extracted from tests and have to be calibrated iteratively. Therefore, a test for a calibration of the simulation approach is recommended. This test should be as comparable as possible to the structural component application of the material. Here a possible test set-up could be a three point bending (3PB) test. With the results derived from the test program the process of material calibration and eventual validation can be carried out. A typical iterative approach is presented on the left side of .

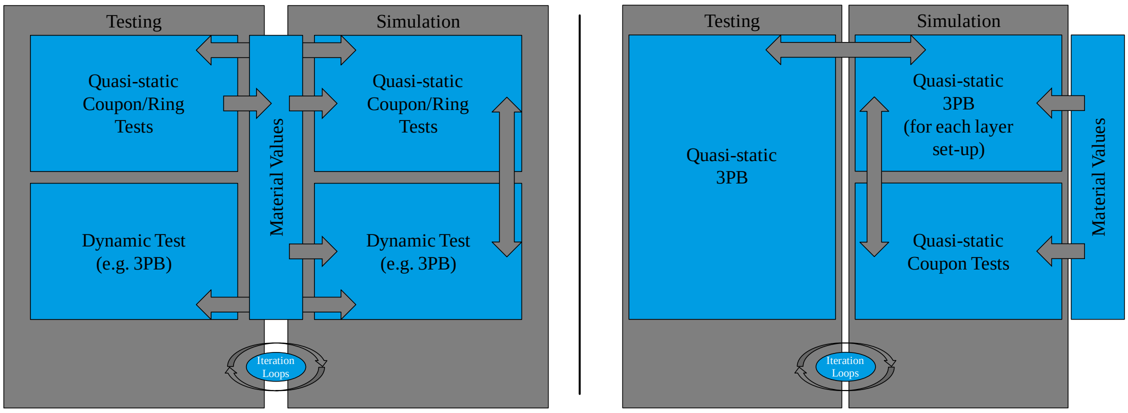

Fig. 6. Conventional material validation process and MATISSE thick UD approach

4.1.2. Process for thick UD composites within MATISSE

For the here investigated structures a different approach is followed. This is mainly based on the applied production process used to manufacture type 4 CNG tanks (wet filament winding). The process does not allow the production of flat specimens for tensile, compression or shear tests that are comparable to the material structure that is actually present in the tank's mantle. The production of flat specimen by employing the filament winding process and the resulting material values are controversial issues being discussed among experts in this research field. Furthermore, the material values of flat specimens are not comparable to those of rotationally symmetrical components. For flat specimens, the laminate needs to be compressed using mould plates in order to achieve coplanar surfaces. This additional compression influences the laminate, which is not the case with pressure vessels. Another possibility is the production of ring shape specimens. In this case, no unidirectional materials can be produced since the lay-down in the filament winding can only take place under longitudinal movement of the fibre. This would only provide unidirectional structures that are radial reinforced. This very weak laminate structure would not provide much information about the material properties in tensile or compression test.

For this reason the material properties are acquired in a reverse FEM approach that is based on the comparison to a quasi-static three point bending test (3PB) of a tubular specimen which is conducted on a servo-hydraulic test bench (right side of). The validation process is executed for CFRP as well as for GFRP. In order to have a broader test basis, different winding structures are investigated (see Fig. 7). In this approach the material values in the material card are assumed for a first loop. The basic mechanical values derive from literature, preliminary work of the project partners or are calculated using general relations (Schürmann, 2007) and assumptions.

Set-up Type [-]	Layer [-]	Angle [°]	Layer Thickness [mm]	Laminate Thickness [mm]
1	1	+/- 10	1.04	2.1
	2	+/- 10	1.04	
2	1	+/- 10	1.04	2.1
	2	90	0.53	
	3	90	0.53	
3	1	+/- 30	1.05	1.6
	2	90	0.53	

Fig. 7. 3PB test

With the preliminary material values the quasi-static 3PB is simulated for all three layer set-ups. Furthermore the quasi-static coupon tests that could not be conducted in reality are simulated in order to evaluate the models plausibility in a first step. The simulation results are then evaluated concerning force, displacement, stress, elongation and failure behaviour. If the material parameters lead to implausible results for these load cases an adaption of material values has to be carried out. Here the basic values like modules or strength values should remain untouched and the values that are not physically determinable should be adapted. Different models are considered in order to find an appropriate material model. This comprises the element type (various types of shell, solid and t-shell elements) as well as the material model (conventional models and newly implemented models (Maier et al., 2007) based on the state of the art of micromechanics (Pinho, 2005; Maimi et al., 2007).

4.2. Application of simulation approaches for CNG tanks

Subsequently the simulation approaches investigated before have to be evaluated concerning their applicability on full FEM models of CNG tanks and APVs equipped with them. The application is carried out in four different stages of FE modelling (). After general assumptions based on a generic model that uses a reduced modelling complexity (stage 1), a very detailed model of an isolated composite CNG tank is generated (stage 2), in order to analyse the full dynamic loading condition and to predict failure under impulsive loads. Here a full modelling approach that considers all relevant failure mechanisms is applied. This comprises also a very fine mesh that allows a good correlation to all winding directions. This is followed by the generation of an equivalent reduced/simplified FE model of tanks, capable to maintain adequate failure predictability.

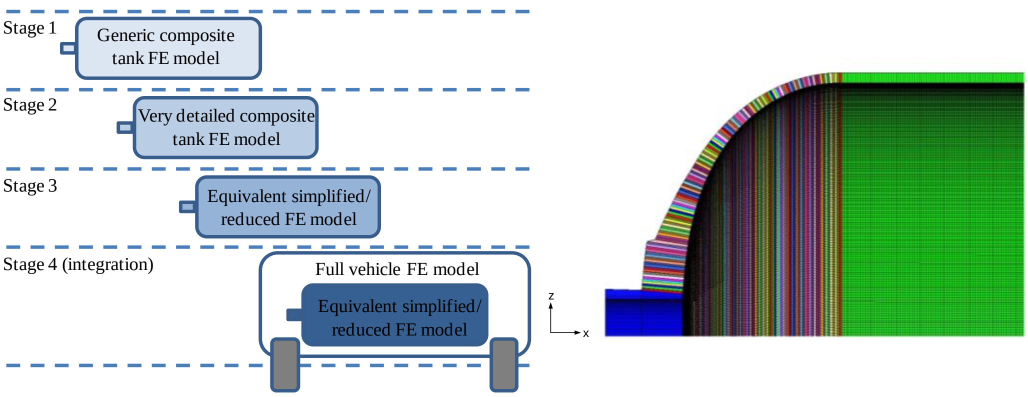

Fig. 8. Stages of CNG tank modelling and detail of stage 1 model

Furthermore, the computational effort needed for the numerical simulations shall be reduced (stage 3). Finally, the equivalent reduced/simplified composite high-pressure storage tank model is integrated into a reference full vehicle model, which is used to drive/support the studies leading to an optimised CNG pressure tank design and to new and safer solutions of APVs (stage 4).

4.3. Experimental verification of CNG tank safety

In parallel the testing on composite CNG tanks is executed. The tank models are validated against these results. The new experimental test set-up for testing dynamically CNG composite tanks are identified and used thanks to the improved models and to a virtual testing methodology. Based on this the analysis of full vehicle simulation allows conclusion on the loading on the vessel structure and the definition of adequate component tests of reduced complexity. First those test definitions are simulated and investigated concerning their comparability to the full vehicle tests. Subsequently adequate test facilities are prepared and the component tests executed.

5. Conclusions

In this paper the work of the first 12 months of the MATISSE consortium is described. An analysis of the relevant most likely crash scenarios for APVs results in a suggestion for the consideration of future accident scenarios. In total five different scenarios for frontal, side and rear crashes were developed. For these crash scenarios the protection of the passengers and the electrical energy storage systems with adaptive inflatable structures based on CFRP materials is focused. After several investigations and based on the results of the first work package it was decided to develop and evaluate a door side member. So, several generic door beams made of CFRP were built and tested. In a further step simulation models with different CFRP materials will be generated and a validation process will be started. In order to predict the behaviour of CNG tanks whose materials (CFRP and GFRP with unidirectional wound fibres) shall be modelled. For the validation it was decided to use a reverse FEM approach based on a quasi-static three point bending test with tubular specimens with different winding layouts. The right simulation approach will be found based on the solver LS-Dyna. For all topics of this project further research will be executed in the final 24 months.

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