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CHARACTERISATION OF THERMOPLASTIC FOAM CORE MATERIALS FOR SANDWICH APPLICATIONS UNDER CRASH LOAD

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1. ABSTRACT

Based on the requirements on the overall vehicle like driving dynamics, comfort, safety, ergonomics, costs, environmental safety and image the specific requirements on body-in-white components can be derivate. An important task of the material pre-selection is the mechanical properties and the structural requirements for each specific component. In the presented talk the developed method for material pre-selection is described for a firewall, which functions as a shear field. A firewall influences significantly the torsional stiffness of the body-in-white and as secondly protects the occupants during for all front crash load cases. Due to the main advantages of fiber reinforced thermoplastics, which have improved impact resistance compared to thermoset composites, a thermoplastic composite, consisting out of a PA6 skins and a homogeneous PA6 core is chosen as material.

In the presentation the characterization of the foam material and the subsequent development of the numerical description of PA6 sandwich core for dynamic loading conditions are shown.

2. INTRODUCTION

In the research project Next Generation Car (NGC) at the German Aerospace Center (DLR), three different novel vehicle concepts are being developed: Urban Modular Vehicle (UMV), Safe Light Regional Vehicle (SLRV) and Inter Urban Vehicle (IUV). The objective of this project is the cross-linking of different technologies, methods and tools for the holistic development of vehicles of the future in terms of vehicle design, vehicle structure, power and thermal management, vehicle intelligence and power train. The concept considered in this work is the Urban Modular Vehicle (Fig. 1) with a modular and multimaterial body-in-white.

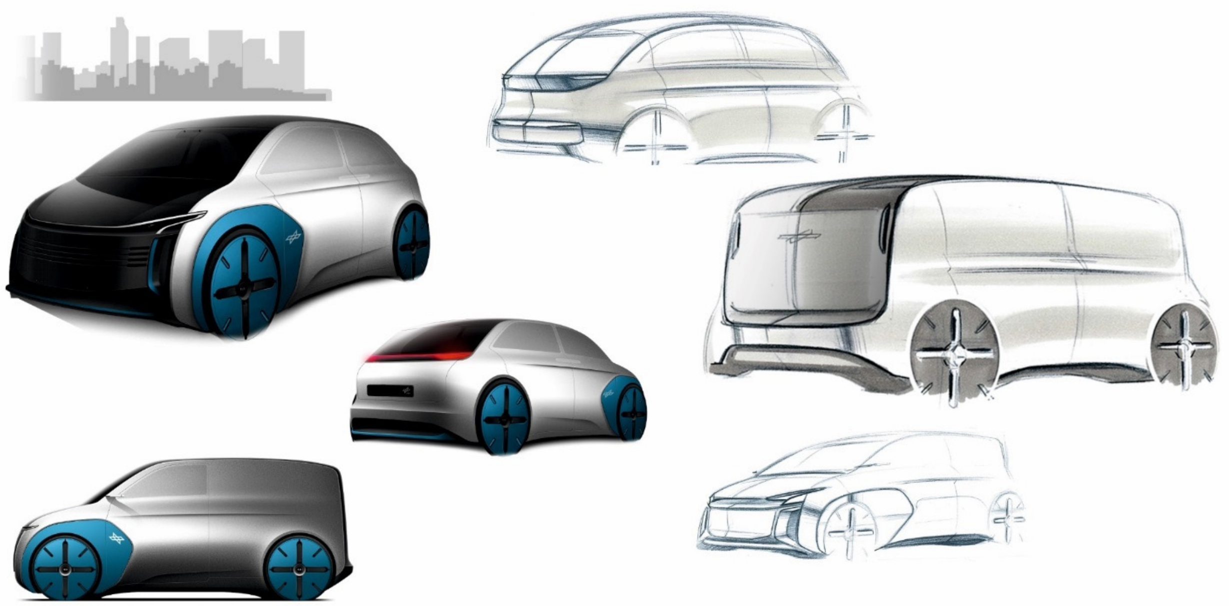

Fig. 1: Concept design of the Urban Modular Vehicle [1].

One starting point to reduce CO2 emissions is to reduce vehicle mass and related driving resistances by using lightweight construction methods and new material combinations and manufacturing technologies [2].

3. REQUIREMENTS FOR BODY-IN-WHITE PARTS UNDER CRASHLOAD

Based on the requirements on the overall vehicle like driving dynamics, comfort, safety, ergonomics, costs, environmental safety and image the specific requirements on body-in-white components can be derivate. An important issue of the pre-selection is the mechanical property objective (Fig. 2) of the specific component which will be investigated. The different body-in-white components can be divided into several groups. For example, a firewall is especially a shear field. It influences the torsional stiffness of the body-in-white and as a second objective it has to have low intrusions to protect the occupants during a front crash load case.

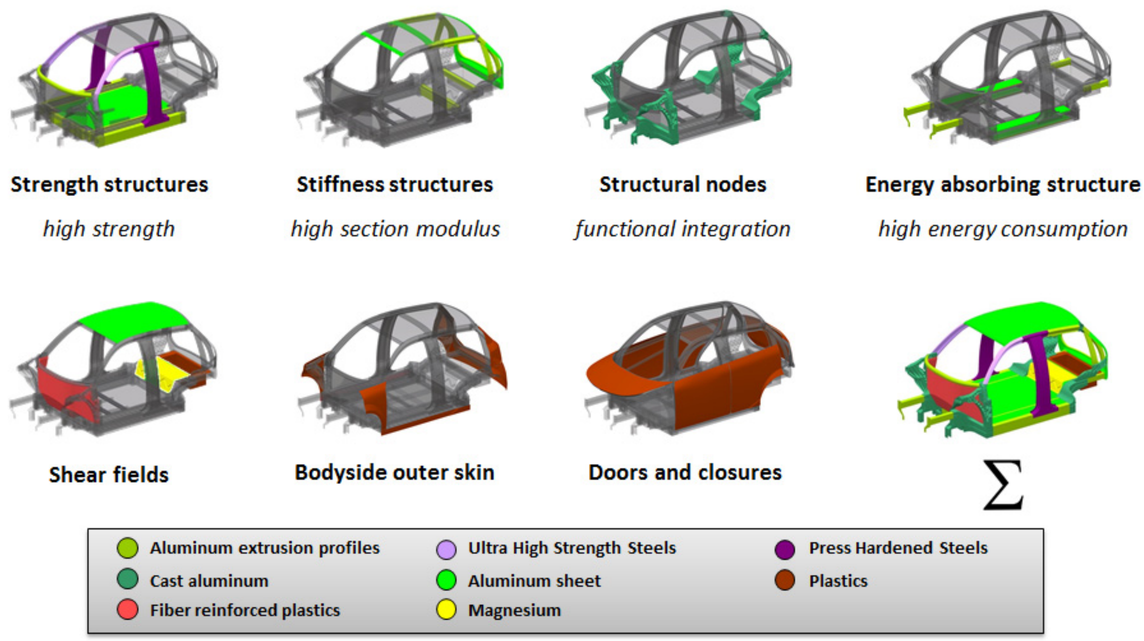

Fig. 2: Specific requirements of body-in-white components [3].

Taking into account the further requirements of the firewall (separation of front end and passenger compartment, low noise emissions, integration of attachment parts and etc.) the sandwich construction is preferred due to the offer of major potential for weight reduction, the possibility of the integration of different functions, high energy absorption capacity as well as the high thermal and acoustic isolation [4].

Due to the variety of core geometries and the materials available, there is a wide range of cores that can be used for sandwich structures.

In terms of geometric design, sandwich can be distinguished at the macroscopic level between homogeneous and structured cores. If they are further classified according to the degree of support / stabilization to the face sheets, they can be derived into five core geometries [2, 5-7]:

1. Cores with a homogeneous structure and therefore providing homogeneous support (e.g. balsa wood and various polymer foams)
2. Cores providing local support for the face sheets (e.g. textile and wire cores)
3. Cores providing partly local support (e.g. 'drilled out' foam and balsa cores, hump plates and hollow cone structures)
4. Cores providing unidirectional support (e.g. corrugated sheet, longitudinal bars or tubular structures)
5. Cores providing multidirectional support for the face sheets (e.g. core materials with a honeycombed structure)

Due to the major advantages of thermoplastics a thermoplastic PA6 composite with a homogeneous PA6 core and PA6 composite skin was selected for this application. The main advantages of thermoplastic resins are its less brittle which results in a higher toughness than thermosets and are improved impact resistance compared to thermoset composites [8].

Another advantage is that thermoplastic composites can be shaped easily after heating up. Using this technique complex three-dimensional shaped sandwich parts can be created [8].

4. CHARACTERISATION OF THE THERMOPLASTIC CORE MATERIAL

For the evaluation of the potential of possible sandwich structure three different PA6 core densities (35 kg/m³, 50 kg/m³ and 70 kg/m³) were characterized. The closed cell and cross-linked polyamide-6 foams were tested under the following test conditions:

- Compression test perpendicular to DIN EN ISO 604 [9]
- Dynamic compression test according to [10]
- Tensile test perpendicular to DIN EN ISO 1798 [11]

Some results of the tensile tests are shown in Fig. 3. The results indicate a significant influence of the specimen preparation procedure on the material behavior under tension loading. A further strain-rate dependent material behavior was identified under tensile loads.

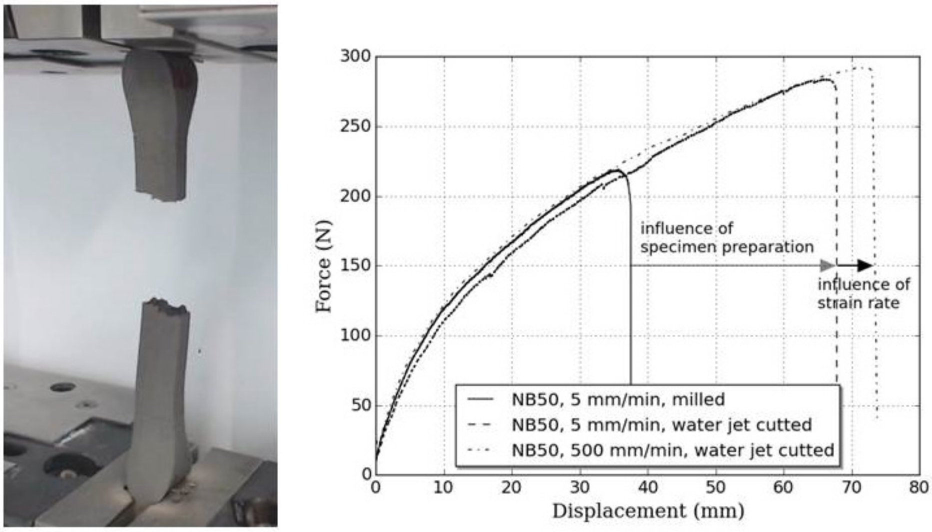

Fig. 3: Results of the tensile tests with influences of specimen preparation and strain rate.

5. SIMULATION OF THE MATERIAL BEHAVIOUR

For the simulation of the sandwich structure three virtual material descriptions have to be developed. Firstly, the facesheets made of fiber reinforced thermoplastics, secondly the thermoplastic foam core, which has a recoverable material behavior. And finally the interface between these two partners. The scope of this presentation is on the dynamic material behavior of the thermoplastic foam.

For the generation of the strain rate dependent foam material card the 4a impetus was used. This system enables the automatic mechanical characterization of dynamically loaded test specimens [10].

For the simulation a strain rate dependent hyperelastic material description was selected which is implemented in the nonlinear FEM Solver LS-DYNA from LSTC.

6. APPLICATION IN CRASH

For the evaluation of the potential of the thermoplastic sandwich structure under crash load a thermoplastic sandwich firewall will be virtually tested in a full vehicle crash simulation and finally compared with a currently build version made out of steel.

For the comparison the mass and the intrusions into the passenger compartment are considered. It is expected that the sandwich solution has less weight by similar mechanical performance. Due to the use of thermoplastics this solution is also suitable for a high-volume production.

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