FRAUNHOFER INSTITUTE FOR MANUFACTURING TECHNOLOGY AND ADVANCED MATERIALS IFAM

Development of CFRP - hybrid foam composites for improved light-weight design of electric vehicles

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Cellmat 2020, Erlangen, Germany

Abstract

The use of electric driven cars has been increasing significantly in the last few years. However, several challenges have still to be addressed as e.g. increasing battery capacity and range of the car, ensuring battery safety in crash events and providing comfort in all kinds of passenger vehicles in a wide range of operating conditions without consuming a significant amount of energy from the battery. The European project QUIET aims at developing an improved and energy efficient electric vehicle with increased driving range under real-world driving conditions. This is achieved by exploiting the synergies of a technology portfolio in several areas, among those e.g. lightweight materials with enhanced thermal insulation properties, and optimised vehicle energy management. The developed technologies are integrated and qualified in a Honda B-segment electric vehicle validator. One of the project's targets is the development of a light-weight side door with improved thermal insulation and keeping the strength of the baseline steel construction besides good crashworthiness. The technological concept comprises a door structure with face sheets made of CFRP composites combined with two internal crash beams. Latter were also produced using CFRP. For improved energy absorbing performance under bending loads the beams were filled with APM aluminium foam rods. Aluminium foam granules of 4 mm were coated with polyamide and cured in the shapes of cylindrical rods. Subsequently, the APM foam rods can be inserted and bonded into the pre-manufactured CFRP tubes. In the presentation the production and properties of the foam cores and the overall demonstrator door will be illustrated.

Motivation

Electro-mobility offers a high potential for a sustainable mobility. One of the main reasons for the slow development of electro-mobility is the limited driving range of the vehicles. A way to increase the driving range is to reduce the weight of the vehicle components. This can be accomplished by utilisation of lightweight materials like CFRP and/or metal foams.

Aim

One of the aims of the present project is to develop a light-weight side door structure with face sheets made of CFRP composites combined with two internal crash beams. The crash beams (tubes) should exhibit a high energy absorption performance, therefore it was decided to fill them with aluminium foam. Because of the easier manufacturing method the APM foam technology was chosen, where small aluminium foam elements are bonded to each other and to the surrounding structure.

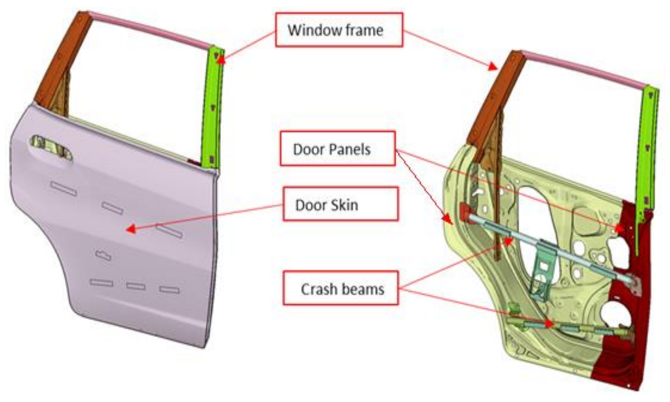

Fig. 1: Schematic of the side door with crash beams

Material selection

Using the APM foam technology (aluminium foam spheres) there are a number of parameters which can be chosen freely for the crash beams:

- type and thickness of the tube material (Al, steel, CFRP,…),
- bulk density and diameter of the spheres
- type of adhesive (EP, PA), foamable/non-foamable

Selected materials:

- tube material: CFRP (EP, woven CF, 3 mm of thickness)
- APM sphere diameter: 4 mm, bulk density: 0,5 g/cm³
- type of adhesive: polyamide (PA12)

Production of aluminium foam spheres

- cutting of foamable aluminium to granules
- foaming the granules in a continuous process
- coating with thermally activated adhesive powder
- curing in-situ at moderate temperatures of 120-190°C

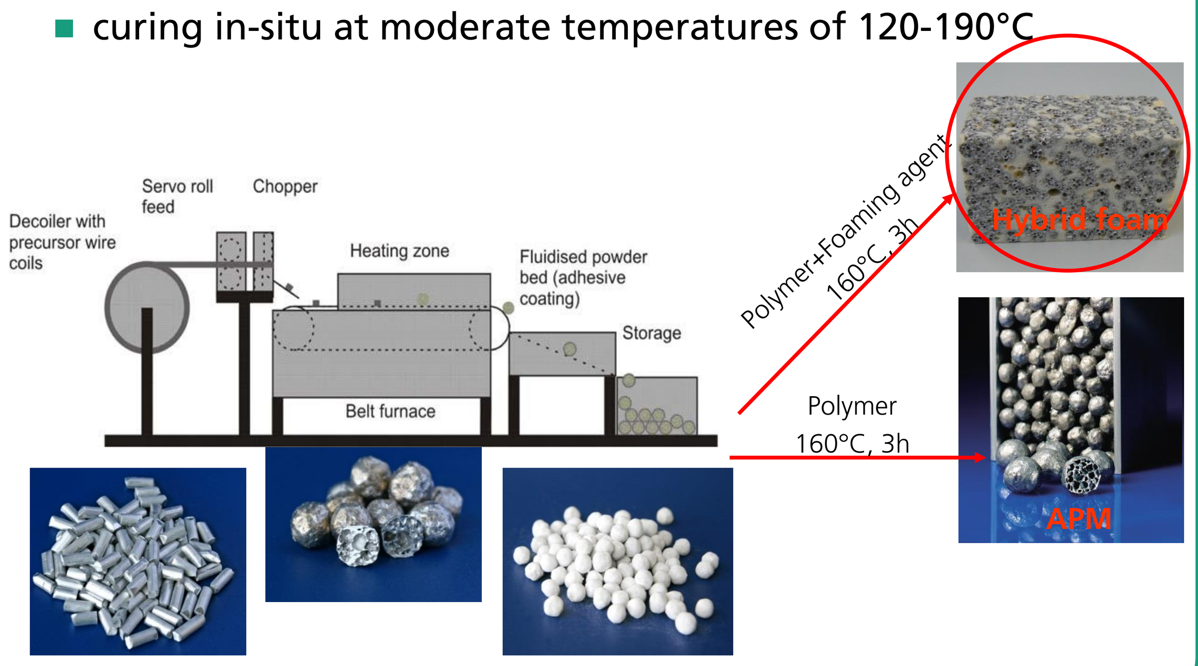

Fig. 2: Manufacturing of APM foams for filling the crash beams

Manufacturing of the crash beams filled with aluminium foam

Various types of adhesives were tested:

- foaming epoxy adhesive was cured at 160°C/2h
- polyamide adhesive was activated at 200°/1h

Based on the results of mechanical testing, fig. 3, PA12 was selected as adhesive coating.

The coated aluminium foam spheres were filled into a tube of 24 mm inner diameter.

The assembly was placed into a furnace to activate and cure the adhesive.

After removal from the tube, the obtained APM foam rods were inserted as a core into CFRP tubes to yield the finished crash beams, fig. 4.

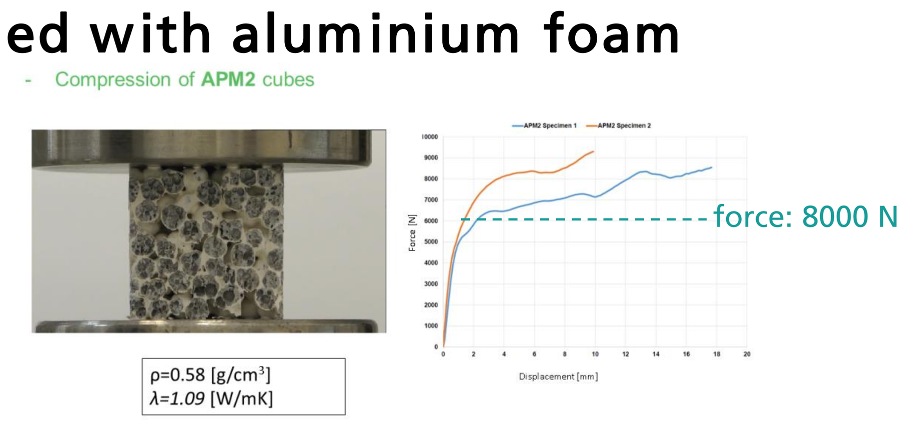

Fig. 3: Mechanical testing for selection of the adhesive

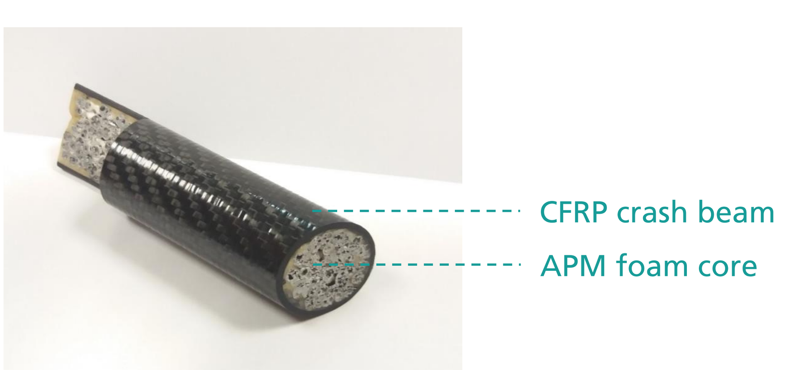

Fig. 4: Section of the CFRP crash beam with APM foam core

Summary

- The APM technology provides a simple way to realise complex engineering structures with a core of aluminium foam.
- Various types of adhesives can be used, depending on the application and its specific requirements.
- Based on the results of mechanical testing, for the present application PA12 was selected as adhesive.
- Prototype crash beams made of CFRP with APM aluminium foam cores were manufactured and integrated into the side door of an electric vehicle.
- As a result a calculated reduction of the structural weight of the side door of 30% could be achieved.
- This in turn will lead to an increased driving range of the electric vehicle.

Acknowledgements

This work has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 769826. The content of this publication is the sole responsibility of the QUIET consortium partners and does not necessarily represent the view of the European Commission or its services..

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