“Cellular Metals - Applications in Mining and Railway Industry”

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1 Introduction

The automobile industry shows us the direction. Vehicles shall continually become lighter, more efficient, ecologically and, at the same time, stay affordable. The customer’s increasing ecological sensibility and a general social responsibility in the use of resources bring issues such as electro mobility or the application of high-performance materials into the focus of developmental work. Automobile manufacturers such as BMW are implementing what no one deemed to be possible before – the production of car bodies made of carbon fiber reinforced plastic (CFRP) in series. A comparable light weight innovation technology was generated by researchers of the Fraunhofer Institute of Machine Tools and Forming Industry with a different kind of material: metal foams. The following two examples are taken from two different industries and shall illustrate the application of metal foam.

2 Front Cap of a High-Speed Train

The human need of mobility – to travel long distances within a short travel time – as well as high expectations on environmental friendliness, crash behavior, fire protection and comfort, create all new demands for rail vehicles. The already existing material concepts do only fulfill these demands conditionally. Up till now no more than two material strategies were used – the fiber composite technology and the metallic construction. The advantage of fiber reinforced plastics (FRP) is minor weight and with regard to fatigue strength and thermal expansion, superiority in comparison to conventional materials. However, disadvantages exist as well. Particularly noteworthy here is a deficiency of the concept concerning reparability and recycling.

The weakness of metallic design with a pure metal skin is different. To meet the extraordinary requirements in the high-speed sector, complex stiffing elements in form of extrusion profiles are providing a substructure. Thick-walled sheets have to be used additionally. This construction results in an increased total mass which has to be speed up and slowed down constantly.

2.1 Material

Aluminum foam as sandwich material is not completely new. The material is already established in some fields. Since 2004, Aluminum foam, together with steel top layers, has been used in Niles-Simmons‘ serial tool slide. The shipbuilding industry and building industry, as examples of other industry sectors, use this material as well. Plane sheets are in these sectors the most frequently requested material form.

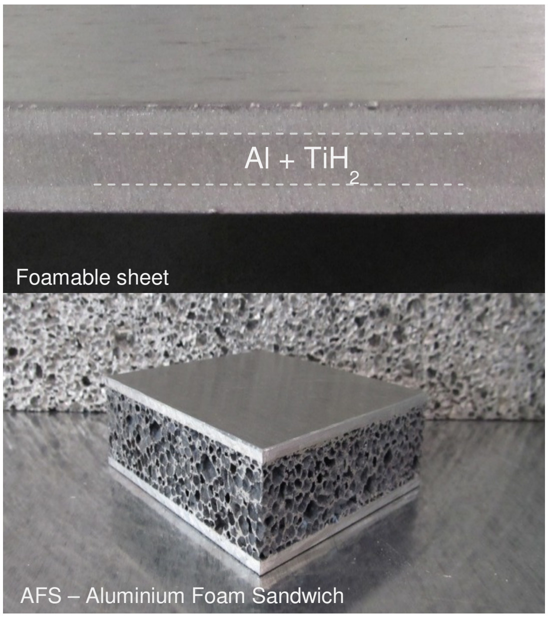


Figure 1: Aluminum Foam Sandwich – AFS structure

It was not difficult for the Fraunhofer Institute of Machine Tools and Forming Industry IWU in Chemnitz to find competent partners in the traditional industrial region like Saxony. Voith Engineering Services the full-range supplier in rail vehicle construction, who is a development service contractor of bogie frames and completes trains and KUKA Systems GmbH could be won as partners. The business domain of tool construction in Schwarzenberg is one of the worlds' leading suppliers of cutting and forming tools for body sheet parts for the automobile industry. The Leipzig Institute for Materials Research and Testing (MFPA Leipzig GmbH) toke over the material characterization.

2.2 Construction

The first step was to develop a front cap of a high-speed train. At that, a certain recognition effect should be achieved without committing to a potential end customer in advance. The designer's choice was to imply design features of already existing vehicles of high-speed trains. The essential constructional difference of the concept draft towards the conventional construction is the disappearing substructure with its frames and a skin that is carried through the sandwich structure only. Merely the area surrounding the windshield is additionally stabilized by a frame.

2.3 Calculation

In addition to technological and economical guidelines, the mechanical behavior and the security are of critical importance, especially in the high-speed train sector. Typical loading conditions had been assembled. The conceptual constructive interpretation specifies the transfer of the concept draft into a calculable model. To construct this model as realistic as possible, non-structural masses such as the engineers control desk and seat with the engineer himself have been integrated into the modelling.

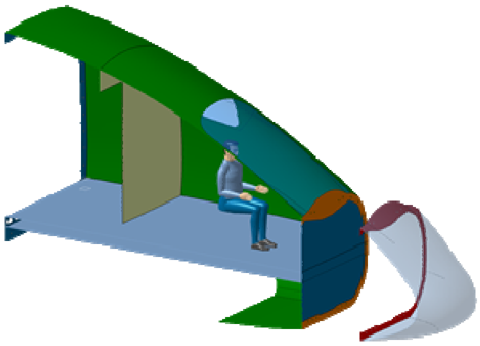


Figure 2: AFS design

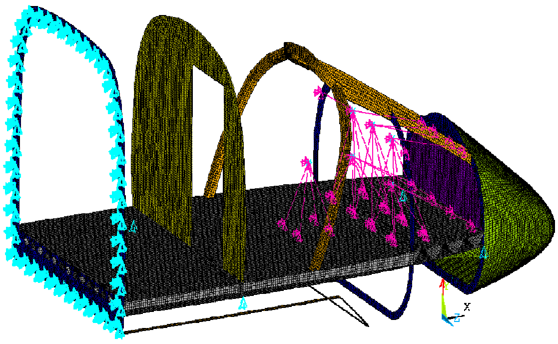


Figure 3: Meshed FE-Model

2.3 Model Demonstrator

As the production technology has a huge influence on the constructive realization of the front cap, new technologies were developed in an earlier phase. The size of 6.000 mm x 3.000 mm x 2.800 mm and the form complexity of the demonstrator demanded a skin division of the front cap. Technological constraints such as the maximum width of the AFS pre-products or the maximum possible usable area of the oven chamber of the Fraunhofer IWU, limited the maximum segment size to 1.900 mm x 1.100 mm. All in all, the skin consists of 22 curved segments.
„Shaping before foaming“ was the preferred method. Due to this method, every segment needed a near shape foam form. The engineers of the Fraunhofer institute developed a form system made of intertwined laser blanks that can be positioned into a frame. A particular advantage of this implementation is that the majority of the symmetrical segments of the front cap can easily be foamed by repositioning the cartridges of one configuration set. As a result, this method allowed to foam 22 segments with only 12 configuration sets. The plane cartridges are inexpensive in their production and can easily be piled up.

It is planned to implement this system together with a big OEM in a serial version any time soon.

Figure 4: Demonstrator before coating with paint, with add-on parts made of GRP; like front, wiper case, shell for front and side lights

3 Light Weight Solutions in Mining

When extracting mineral resources – especially coal and salts – chain conveyors are an essential equipment. They are tough and optimally adapted to the mining requirements. 3 billion tons of coal alone are mined via chain conveyors out of longwall faces all over the world.
A motor capacity between 5 and 15 kW m^{-1} is necessary for a save run of a chain conveyor. A reduction of the dead load of chain systems leads to the decreasing of the energy demand or in the case of an unchanged motor capacity to an increasing mining capacity. In both cases, the result of the energy efficiency of chain conveyors is improved in considerable dimensions. The aim of the development of flight bars in light weight design is to reduce the flight bar mass about 25 to 30 per cent. Depending on the conveyor width and the chosen employee distance, energy savings are possible between 10 to 15per cent.

3.1 Design

First of all, it was necessary to proof whether foamed hybrid flight bars basically have the same load carrying ability and resistance against damage and failure when running under the same conditions as massive flight bars, or not. Joint tests of flight bars in anglo-american design with unfavorable low tails for foaming have already proven these features.

Table 1 shows the comparison of masses between the original forged part and the foamed hybrid part. The body weight of the flight bar could be reduced about 26 per cent. The total mass of the complete flight bar assembly could be reduced about 19 per cent, due unmodified assembly components. There were no other mass reducing steps for the first start up. After investigating the deployed test flight bars and after a technological evaluation, further mass reducing steps should be realized.

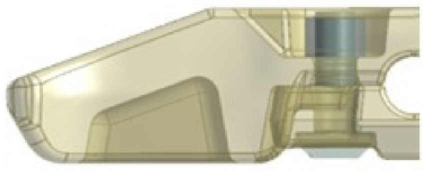
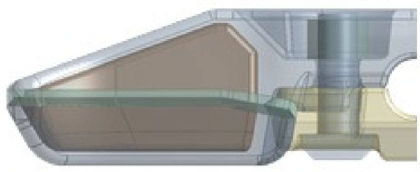
Forged Flight Bar (massive)		Hybrid Flight Bar (multi-part design, foamed)
		
total mass [kg]		
53		42,9
	split	
43,3	Flight Bar	31,9
	upper part	*24,5*
	Bottom part	*2 x 3,5*
	Weld seam	*2 x 0,2*
-	Aluminum foam core	2 x 0,66
7,8	Connecting link	7,8
1,9	fasteners	1,9
19 per cent mass reduction		

Table 1. Comparison massive flight bar with hybrid flight bar

3.2 Product Testing

During 2012, six test flight bars in hybrid design were produced in total. For this purpose, massive flight bars were separated at the tails. The tails of the flight bar top were hollow milled. The lower closing pieces were also made by milling out of bulk material. This process will be substituted by forging in the future series. After the insertion of the foamable precursor, the tails were welded and finished in a foaming furnace. Two flight bars were directly tested in flexural strength. Two other test flight bars were inductively hardened to optimize the abrasive wear of the tails in operation. Two massive flight bars were tested for comparison in advance.

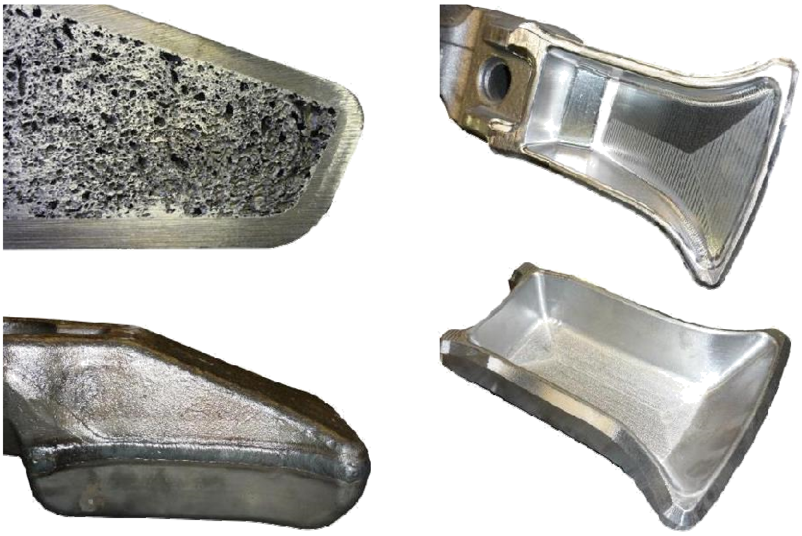


Figure 5: Flight bar with metal foam

The simulated running situation of one sided clamping in the conveyor was not testable in existing testing facilities. Therefore, an own test and a test set-up was developed. For the test – of originally heavy anchor chains – THIELE owns a 5.000 kN test station. Nevertheless, only single flight bars could be tested there. Therefore, the test parts had been fixed at the tails. The load was applied by two link assemblies that were fastened to the mounting points on the middle of the flight bar. Subsequently the load was increased until the flight bar broke.

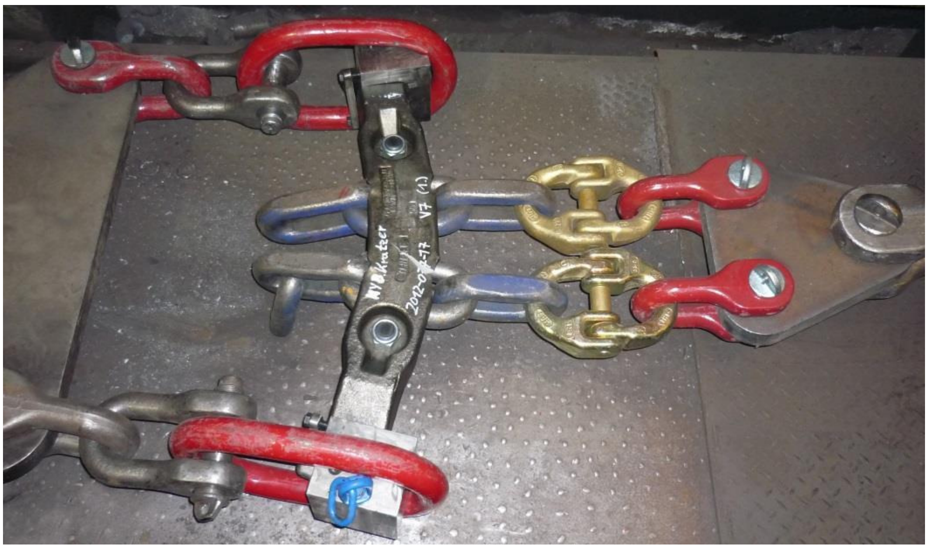


Figure 6: Constraints for the most extreme loading condition: one-sided clamping

The achieved breaking forces vary between 781 kN and 918kN. It is noticeable that the serial massive flight bars feature minor breaking forces than the hybrid flight bars. Expectably, the crack location is, as the calculation predicted, in the chain bed. The top of only one of two hybrid flight bars broke. A closer examination revealed the crack as a result of the inductive hardening process. Through a coil geometry adjustment of the induction facility, a mistake for the following production of the test flight bars could be excluded.

All in all, the calculations as well as the practical test undoubtedly proof the principal suitability of hybrid flight bars and show that there are no disadvantages for the serial launch to be expected.

4 References

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