

Application Strategies for Aluminum-Foam-Sandwich Parts (AFS)

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1. Abstract

Two car components have a major impact on fuel consumption: on the one hand, the drive-train, and on the other hand the car body, with the parameters aerodynamics and weight.

Whereas aerodynamics was the main topic in last years body development, lightweight body design is now the target of many research programs.

Increasing demands in car safety and vehicle dynamics have constantly been pushing up the car mass. Especially measures to improve torsion stiffness contribute to this trend. This is even more significant, as the body structure is weakened due to concept features with respect to convertibles.

To find the solution to the target conflict of high body stiffness at low weight, led to use of the sandwich panel principal.

The first effort to implement sandwich structures was stopped by the lack of economical ways to manufacture these mostly three-dimensional shaped parts. In a second step investigations in metal foams took place, especially in aluminum foams. Because of its manufacturing process aluminum foam is well suitable for complex shaped parts and energy absorbing components. (Figure 1)

The joint development of a new sandwich material by the Karmann GmbH, Osnabrück, and the Fraunhofer Institute in Bremen (IFAM), soon showed the immense potential concerning formability, manufacturability, efficiency and economy.

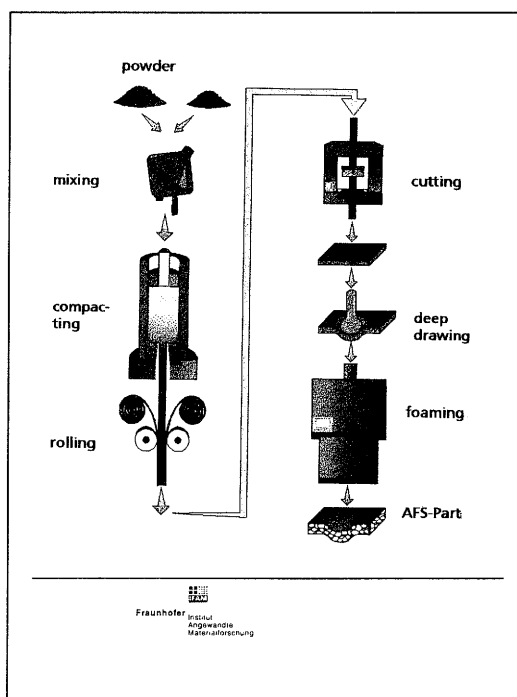


Figure 1: Manufacturing Process AFS

Sandwich panels and aluminum foam are not new discoveries. Aluminum foam and conventional sandwich panels have been around for more than forty years. Conventional sandwich panels have the inherent problems of low durability, high production costs, and lack the possibility to be formed into complex shapes. To date aluminum foam has had the major disadvantage that in the production process entrained gases must be introduced into the molten aluminum. This resulted in the production of an foam ingot. From this ingot the part must be cut out.

A new process, developed in conjunction with the *Fraunhofer Institute in Bremen* makes it possible for the first time to produce complex formed sandwich panels with an aluminum foam core. What is new is the process by which the aluminum foam is produced employing powder metal technology. With only a forming tool and without additional adhesives between the outer layers and the core foam it is possible to produce the desired complex shaped sandwich panel parts, as shown in figure 1 (See Baumeister in this volume)

The outer layers are stamped into the desired shape in the same manner as a normal aluminum press part. Then through an endothermic reaction the aluminum powder melts and expanding gases are trapped in the molten mass causing a porous foam, which expands between the two aluminum sheets to the final height of the sandwich.

The production costs for aluminum foam sandwich parts using this new process are reduced in comparison to the conventional method.

The question, in which cases the implementation of AFS-components is useful, depends to a large extent on the peripheral conditions. This paper describes the benefits and the limitations of the AFS-Technology and gives examples for possible applications.

2. Technological Benefits

Besides the already known advantages – combining high torsion stiffness with low weight – more properties are to be taken into account. They, too, can have a major impact on the implementation strategy.

2.1. Acoustic Properties

First the good acoustic properties should be mentioned. In this context, especially cars with aluminum bodies, show problems due to their poor damping properties. To improve this situation, a large amount of damping material must be added thus the mass saving potential is sacrificed. Considering the customers comfort requirements, a new lightweight body material must not show worse acoustic properties than steel.

A joint research by the TU Dresden and Karmann displayed that AFS offers significantly better acoustic behavior especially in the range of 50-400 Hz.(Figure 2)

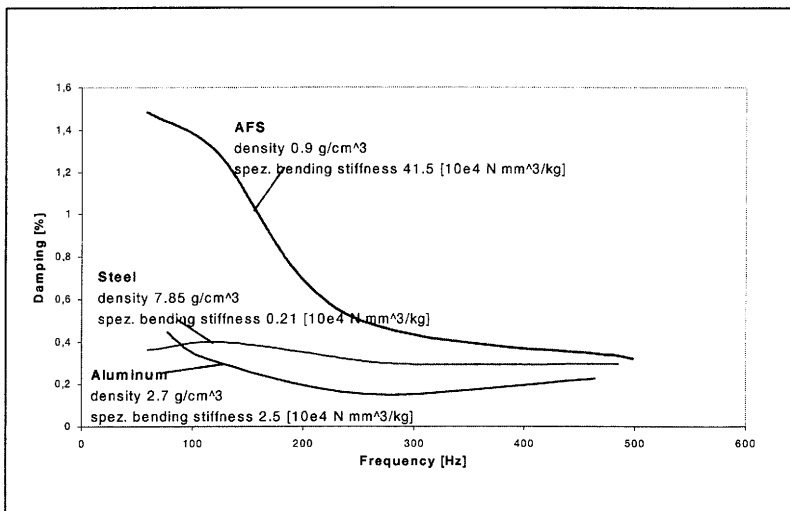


Figure 2: Acoustic Properties of AFS

Additional insulation measures can be reduced and weight is saved.

Of course, the acoustic performance of special insulation materials can not be attained. So AFS could not serve exclusively as a sound damping material.

2.2. Thermal Properties

Thermal conductivity is another important consideration in, selecting body materials. Due to the entrained air bubbles in foams heat transport is poor. Depending on the density, the thermal conductivity of AFS is reduced to $1/12 - 1/20$ of that of aluminium.

Furthermore AFS fulfills most of the fire protection regulations. No glues are contained and the AFS components keep their shape up to the melting point of 600°C and in some cases even above. The exceptional welding characteristics with minimal distortion underlines the thermal qualities of AFS.(Figure 3)

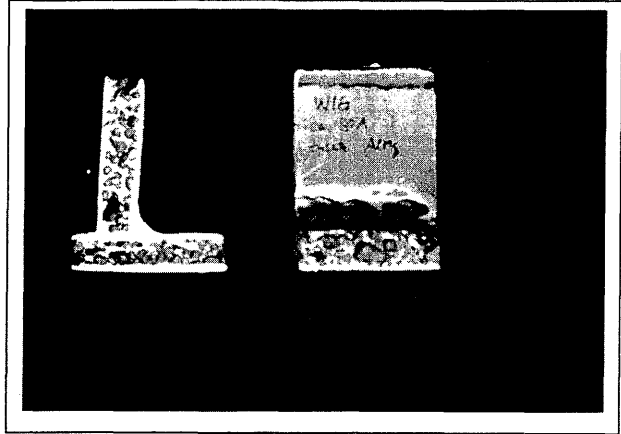


Figure 3: AFS welded pattern

2.3. Solidity

Sandwich components, as known from aero-space technology, are relatively vulnerable towards physical impacts. Even small damages at honeycomb panels can lead to a total breakdown of the core-panel structure.

This can not occur in an AFS panel, as a result of the metallic link between core and panels. Cracks may only occur in the core and their growth is limited. A delamination from core and panels has not been detected with parts manufactured and tested to date.

This is very important because structural body components are not subject to special checks during the product life cycle.

2.4. Enhanced Properties

Additional properties of AFS that enhance product performance are *good energy adsorption*, *recycability* and *low manufacturing time periods* for the sandwich components. The foaming process, for instance, takes only 30 to 45 seconds.

3. Technical Limitations

The choice of applications for AFS components must consider the formability and the geometry after the foaming process. A constant component thickness can only be achieved with plane sheets. Complex formed structures will have variable thickness in different areas of the component, however, these thickness variations are predictable and can be adjusted to component loads by simulations. This is caused by the upper layers, which maintain their original geometry during the foaming process. The form tolerance after foaming is ± 1 mm and drills and trim cuts must be performed. This will be done with a trimming/calibration tool so that additional reference surfaces and flanges can be established.

Generally shapes that a U-form have an adverse relation between the side and base surfaces and should be avoided because this leads to different thickness' of the foam. (Figure 4) This is primarily due to the stiff inner layer which should shorten up if the thickness is constant.

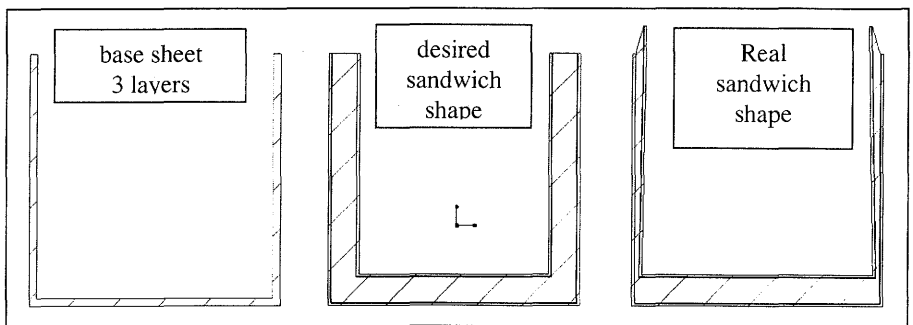


Figure 4: limitations of manufacturability

There are limitations in the determination of the gage relation between outer layers and core due to current processing techniques. The minimum thickness of the outer layer is limited to 0.6mm. Skin thickness less than this cause a degradation of the alloy during foaming and are unavoidable. Under optimal process conditions the foam can expand up to 7 times of its original thickness. The maximum achievable height is ranges from 25 to 30mm because of thermodynamical effects. Thicker foam cores are prevented due to different cooling rates throughout the foam resulting in a non-uniform core porosity.

4. Application Strategies

From technology advantages and limitations application strategies have to be developed to simplify the decision whether or not AFS components should be applied and to prevent unrealistic decisions.

The use of light weight materials is often combined with higher costs and, compared to steel, eventually loss of stiffness and manufacturing problems. For a technically and economically successful application of AFS components a new approach to vehicle body architecture is required.

For an application in the BIW about 90% of the current design concept needs a complete change. The space frame, for instance, should be designed considering the stiff AFS components so that the special properties of the AFS can be used optimally. A simple replacement of steel parts by AFS parts will not lead to success because, the benefit of the stiffened planar surfaces are not used effectively. Therefore new BIW architecture must be developed. Examples are shown in 'Section 5,' Applications'.

In case of the simple replacement of materials by AFS it must be considered that the property spectrum of AFS includes some characteristics that were previously achieved by additional parts. For example at the *fire wall use of AFS* could mean elimination of *heat shields* and the associated connecting parts and elimination of *noise attenuation materials* because of the low structure-borne sound characteristics of AFS.

Another area of interest to be investigated in the future is that of exterior panel closures, e.g. doors, hoods and decklids. This application is dependent on achieving a Class-A surface with stamped AFS panels. Taking a hood stamped out of AFS as an example, due to the inherent stiffness of the AFS outer there is no longer a need for an inner panel thus saving costs for material, tool and assembly of inner and the complete assembly. In spite of higher material costs an AFS bonnet may be - dependent of the shape - more cost-effective up to a production volume of 100,000 units than a steel hood. This is attributed to the savings in manufacturing and tooling costs. This means that light weight AFS construction may be applied economically in low and middle production volumes due to the reduced investments when compared to conventional steel components.

In general applications additional costs of AFS panels should be compared to realized advantages. Even if only one of the improved characteristics of AFS is required for a particular application the associated cost penalty may be of secondary interest.

In general AFS components will have increased overall material costs so that enhanced performance must be justified. In the future the situation may change when vehicle operating costs gain relevancy due to the higher costs for energy. In consequence this will mean that the available money for the use of light materials, which is right now about 5-10 DM/kg weight saving, will increase.

5. Applications

The following examples explain the demands mentioned in the previous chapter.

The Showcar with the aluminum spaceframe technology and sandwich components for all planar surfaces that was exhibited at the Detroit Motor Show in 1998 was the first application. In this case the AFS components contribute 30% to the overall stiffness of the body structure. Because of their complex three-dimensional shape, the firewall and the rear floor were made in the AFS technology.(Figure 5)

Under lab conditions the foaming time of the 700 x 1400 x 12 mm sized component was 45 Seconds. The material thickness of the cover layers was 1 mm each; the foam core reached a thickness of 10 mm.

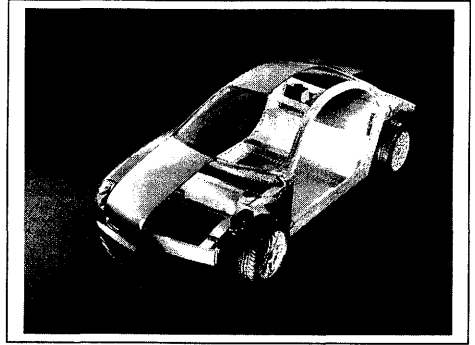


Figure 5: AFB Karmann, Detroit Motor Show 98

The rear close-out-panel (between trunk and rear seats) of the Mercedes-Benz CLK Convertible, which has been developed and is built by Karmann in Osnabrück, has been chosen as an example part for developing the production technology. The AFS component uses the same part layout as the steel panel; the package space requirements have been increased by only 3 mm.(Figure 6)

The weight has been reduced by 25% whilst the stiffness reached is seven times that of the steel stamped original.

This rear close-out-panel is a mere replacement part, chosen just to determine vehicle and production specific questions.

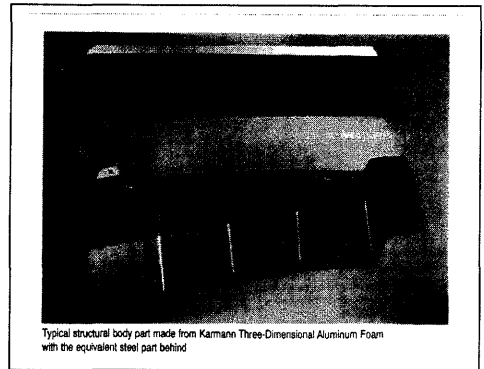


Figure 6: Comparison between Steel and AFS component

Another application to investigate AFS's potentials is in motor sports. In co-operation with Dallara, Pininfarina and VAW Bonn, Karmann took part in the EUROOC project and developed a roadster spaceframe. The frame was presented the first time at the Salon de l'Automobile at Geneva 1999. Dallara will begin their driving tests in July 1999. (Figure 7)

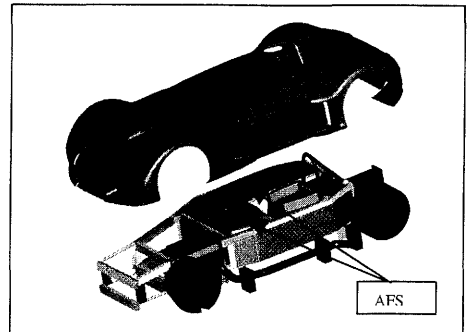


Figure 7: EUROOC 99

The BIW weight is 115 Kg with a torsion stiffness of 50 kNm/degree. This could only be reached strictly implementing spaceframe technology. The frame as shown in Figure 8 will be brought in each of the 28 racecars when the series starts in the year 2000.

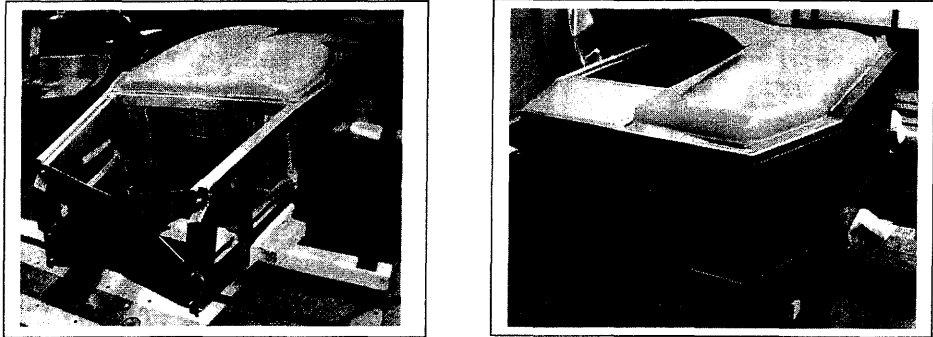


Figure 8: EURO C Aluminum Space Frame with AFS-Parts

Last but not least possible applications in trucks and busses have to be mentioned. Figure 9 shows the future design for truck cab floor panel. In this application AFS offers advantages in acoustic and thermal insulation as well as in manufacturability. In addition to that weight can be reduced which could lead to lower overall lifetime costs in spite of higher production costs.

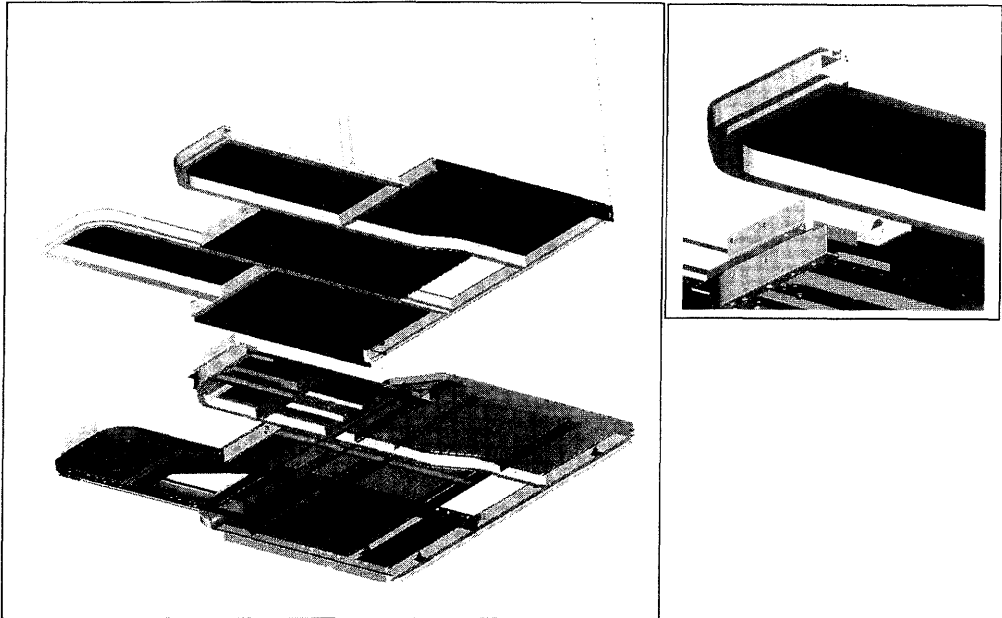


Figure 9: Truck Floor Structure, AFS compared to traditional Technology

Here, too, AFS components are embedded in an aluminum spaceframe concept. The number of parts is reduced because some functions of secondary structural profiles are now integrated in the sandwich panels. Manufacturing costs and times are reduced.

6. Summary

The potential of future lightweight technologies can only be utilized if custom design concepts are invented and strictly implemented. Examples given in this paper show convincingly that – with a little risk and creativity - this is possible. AFS is only a small contribution to lightweight body design amongst many others. Due to the manufacturing technology AFS has to reach the target of weight reduction and remain economically cost competitive.

This is absolutely necessary because automobiles are mass products and are not investment goods like for example airplanes.