Aluminium foam sandwich (AFS) - ready for market introduction

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A novel production process for aluminium foam sandwich panels (AFS) is described. As an example for a serial application of AFS a support for a mobile telescope arm on a small lorry is presented and discussed.

1 Introduction

AFS are sheet-shaped structures comprising two layers of aluminium sheets and a core of aluminium foam in between giving the structure a high degree of stiffness (Fig. 1). As raw product for the manufacture of AFS pre-manufactured sandwich precursors are used [1,2]. In contrast to the final AFS structure, the core layer of the raw product consists of compacted aluminium powder having a density of almost 100%. Already in the raw product, the core layer is metallically bound to the external sheets without using any adhesive. This raw product has the appearance of conventional aluminium sheets and allows almost the same methods of reshaping as ordinary sheet material. During the actual foaming process, the raw product is heated up and the core is transformed into a liquid. Simultaneously a gas releasing additive causes the core to expand resulting in a porous core structure on cooling. By adequate control and modification of the process parameters, the porosity of the core layer can be adjusted according to the specific demand of the application.

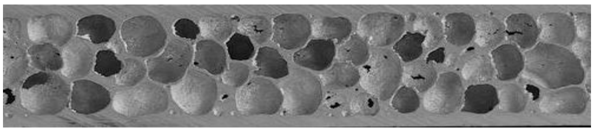

Fig. 1. Section of AFS material.

2 AFS production at alm

Despite strong efforts in industry and research, so far the manufacturing methods available for AFS did either not allow for series production of AFS or resulted in a poor reproducibility of the material. Based on our long experience, a new method of manufacturing was developed overcoming the problems existing so far. Fig. 2 gives a short schematic description of the manufacturing process. The route consists of compacting mixtures of aluminium alloy and blowing agent powders and to bond them to face sheets in one step. After this the structure is mechanically processed to the desired geometry and foamed.

Applied Light-weight Materials (alm) was founded in December 2002. Its head quarters are located on the campus of Saarbrücken University, with a preliminary production site close to Osnabrück. The company has specialised on AFS technology. Beside the actual manufacture of AFS material and structures based on AFS, alm has the capability to supply its customers with full engineering support for all aspects of AFS application including material selection, stress and strain analysis and 3D-CAD. The company's principle is to supply a complete technical solution – not just a product. Currently a new production site is being set up in Saarbrücken allowing alm to further extend its production capacity. In this way it has become possible to go into series production with AFS now.

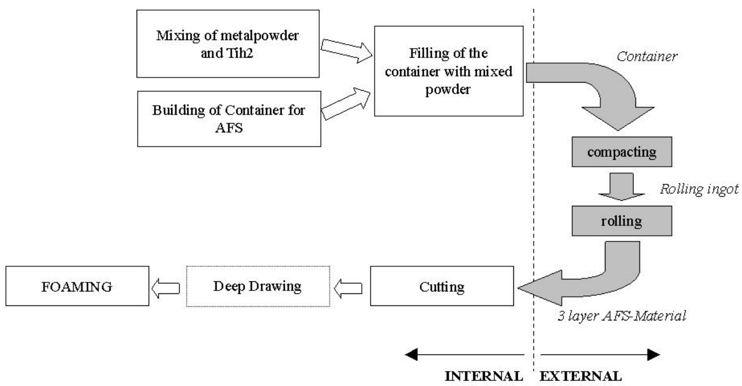

Fig. 2. Production process for AFS as developed by alm GmbH

Giving the example of a product application, the support of a telescope arm mounted on a lorry, we will demonstrate how aluminium foam sandwich parts can be optimally manufactured and how the final product should be designed to make the most of the advantages inherent in the material in order to create an economically competitive product. In this example, we will compare a regular assembly group with an optimised AFS assembly group with respect to their mechanical characteristics and the production process.

3 AFS properties

During the last decade a number of companies and research facilities all over the world have shown high interest in the development of AFS. To one part the interest shown was and is due to the specific material properties expected, namely the

- low material density,
- high material stiffness,
- good impact resistance,
- high energy absorption.

Although those properties can also be found with other sandwich materials, AFS shows advantages which can hardly be beaten by any sandwich structure commercially available today. While most sandwich materials allow only limited variations in geometry and shape, AFS can be reshaped in almost the same way as conventional metal sheets applying the same tools and manufacture steps (Fig. 3). This fact opens a wide range of potential applications for AFS.

Moreover, in contrast to most other sandwich materials for AFS the individual layers are not bound together by any adhesive but have a metal bonding resulting from the specific manufacturing process. This absence of adhesives makes AFS suitable for manufacturing steps involving elevated temperatures including joining procedured such as welding.

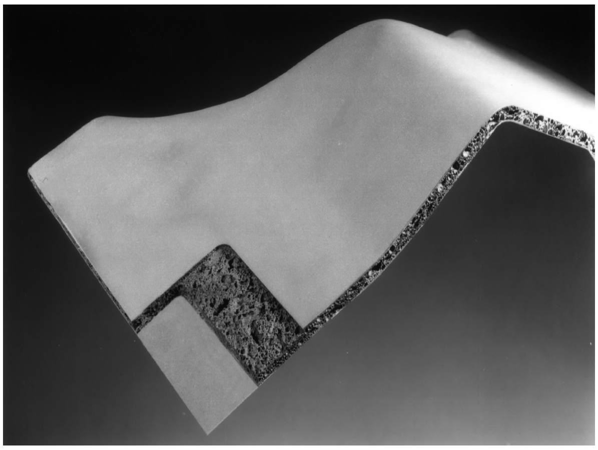

Fig. 3. 3-dimensional AFS-part [3]

4 AFS - advantages for industry

Today's cars still show a strong functional separation of individual structures. As an example, one can refer to the load carrying structure of cars on the one hand and their external contour on the other. A considerable reduction in weight and also in production costs appears to be possible if one succeeds in unifying various functions in a single structure. This is where the strength of AFS is found. While reshaping of the material as well as joining fits into conventional manufacture as known from metal sheets, AFS can unify a number of functions which today are still fulfilled by different functional components (Fig. 4).

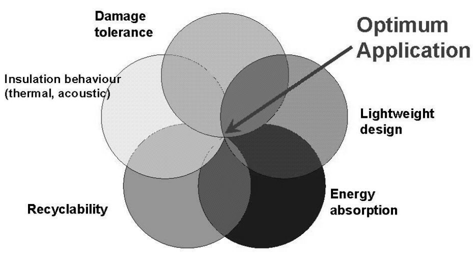

Fig. 4. Application areas of AFS.

This is one reason why a number of projects in the European car, shipping, train and aeronautical industry have been initiated which examine potential applications of AFS. However, the main draw-back in all of these studies appears to have been the availability of the material. This problem we consider as being solved with the latest improvement of manufacturing technology.

One of the most important aspects of a successful AFS application is an optimum exploitation of the material characteristics. Fig. 5 groups the characteristics of AFS in various categories, namely "unique, better, equal or poor" in comparison to existing engineering solutions. Surprisingly, the characteristic feature “weight reduction“ only achieves an "equal or poor". The reason for this is that AFS was not developed for extreme light-weight construction but for optimised processing characteristics and economy.

When looking for an AFS application, one should first check, whether a conventional solution like a sheet metal shell structure/construction, a frame structure/construction or a common honeycomb structure does not already lead to a satisfactory result. In such a case one would only chose AFS for considerable advantages concerning processing or costs. As shown in Fig. 5, the application of AFS makes sense if two „unique“ characteristics can be combined.

The current cost situation with AFS suggests an application only with combinations of at least two “unique” characteristics in order to replace conventional solutions and to guarantee a considerable technical and economical advantage for the user.

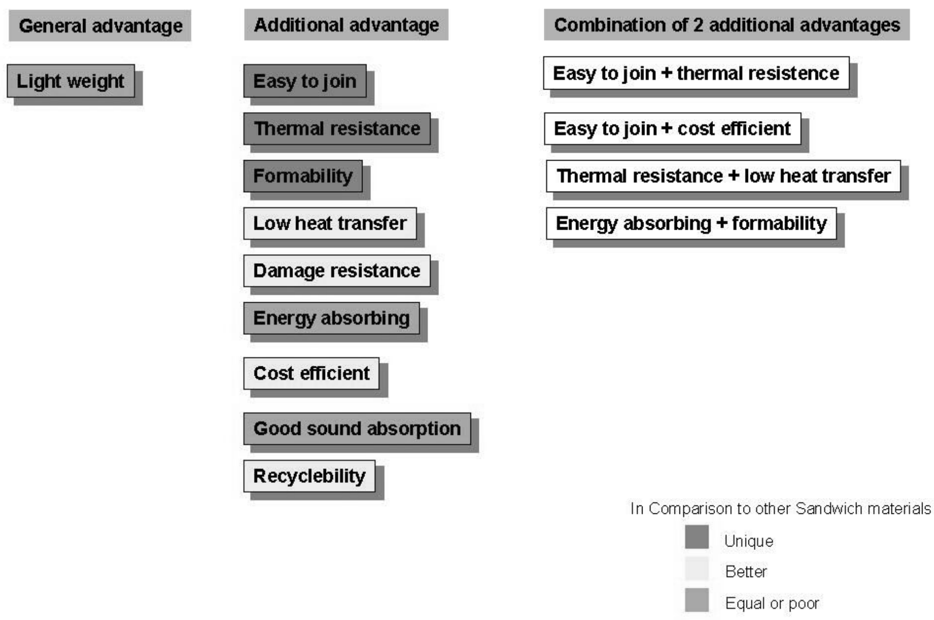

Fig. 5. Advantages by using AFS

5 AFS - state of the art

As first real series application of AFS, the support of a telescope working platform, has emerged from many design studies. The goal at the beginning of the project was to develop a working platform mounted on a small lorry with a total weight less than 3.5 tons in order to comply with the new and more restrictive weight limits of European driving licences. At the same time a working range of 25 m was required. At first, these requirements appeared to be not feasible by conventional technologies. After a careful design analysis in co-operation with the end user at the beginning of 2003 an AFS prototype could be built and intensively tested. The series production giving the end user an important advantage over his competitors on the market. Due to the application of AFS, his working platform is the only one on the market having a range of 25 meters and fulfilling the 3.5 tons weight limit.

Fig. 6. Support of a working platform made of AFS.

Three development steps had to be taken:

First, a virtual prototype was developed using suitable software (Fig. 7). We developed a conventional structure without AFS in parallel in order to be able to compare weight and processing expenditure directly. The support structure made of AFS proved not only to have weight but also processing advantages. The steel variant had a weight disadvantage of 95 kg, compared to the AFS structure.

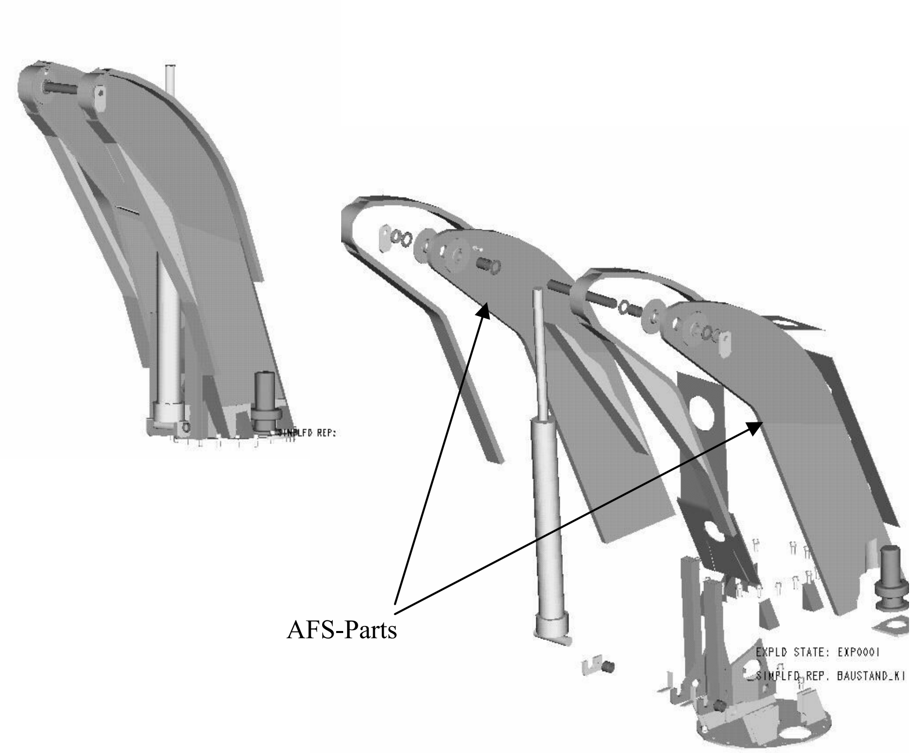

Fig. 7. CAD model of the support structure

The **second** step was the calculation of the support of the telecope arm. Best results were obtained with an idealized sandwich structure with solid elements for the kernel and shell elements for the surface layers. The kernel should consist of at least two solid elements. The results of these calculations are given in Fig. 8. Areas with high stress are represented in light colour. The testing loads were 65 kNm at the lower part and a side impact at the top pivot of 1.4 tons. The calculation showed that the deformation of the AFS structure was 15% less than that of the steel structure. The alternatively calculated aluminium frame structure did not withstand the stress at all. This comparison proves the potential of AFS when correctly applied.

The **third** step was the construction and test of the telescope arm support support (see Fig's 9 and 10). The maximum permitted operational loads were exceeded by 150% - in the construction as well as in the calculation - and were applied in the statistic and dynamic tests.

Important advantages showed up in the processing of AFS, e.g., a complex welded structure could be established without having to take into account the usual problems with welding distortion. Fixtures were needed only to a minimal extent, since the aluminium foam core has only a low heat conductivity and serves as a kind of fixture itself, avoiding a distortion of the parts.

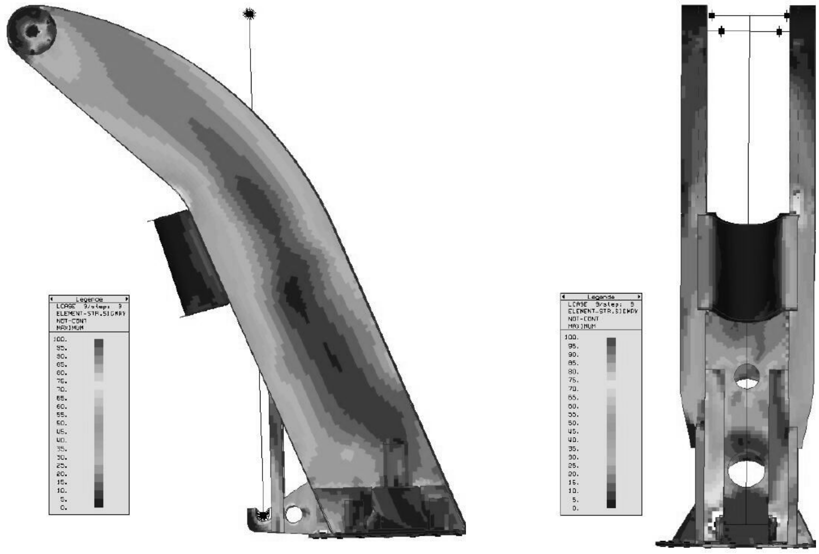

Fig. 8. FEM-Analysis of telecope arm support

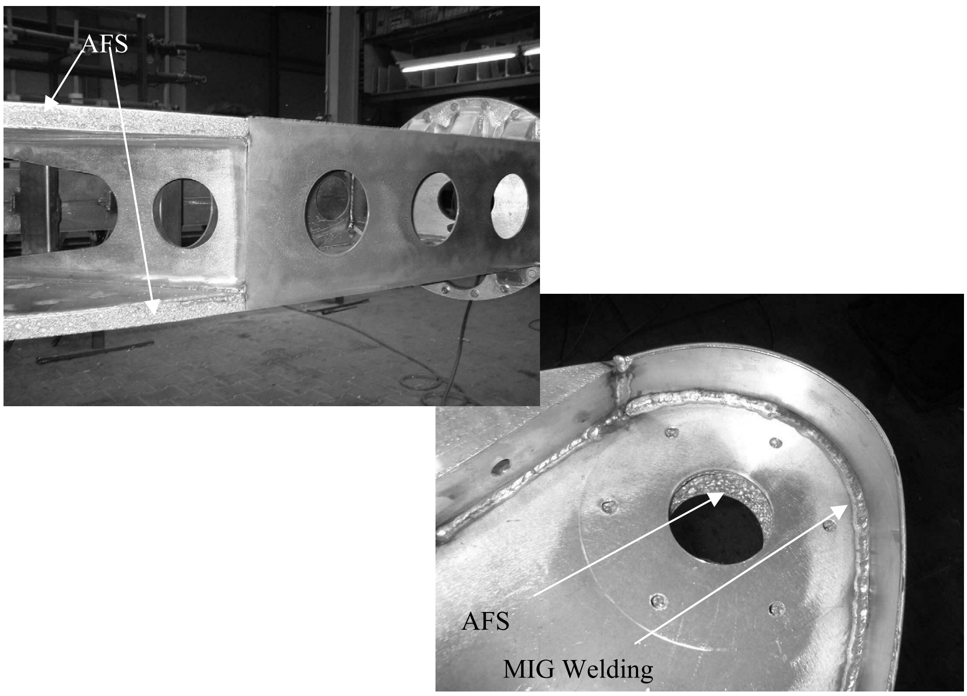

Fig. 9. Manufacturing of telescope arm support.

In the tests, the stress was measured with elastic measuring strips at significant points of the assembly and compared to the calculations. The difference to the calculated results was max. 5 MPa. The load collective for the fatigue limit test was taken with 150 % of the maximum operational load. The load frequency of 40000 load changes was exceeded by 250 % and even then the AFS structure didn't show any cracking.

Fig. 10. Fatigue test on telescope arm support.

6 Conclusions

The given example of the telescope arm support shows that an application-driven material development which is optimally adjusted to the construction inevitably leads to success. This was the first series production of an AFS part. This is especially remarkable because the material costs are by far higher than those for a steel structure. Easier processing and better mechanical properties were decisive in this case. It also became evident that simple replacement of components by AFS is not feasible: the complete construction has to be redesigned. A new material does not only have to have better characteristics than standard materials such as steel or aluminium but also has to fit into the manufacturing process in a better way to make success on the market possible.

References

[1] J. Banhart, Prog. Mater. Sci. **46**, 559-632 (2001)
[2] W. Seeliger, MetFoam 1999 and 2001 proceedings
[3] Courtesy by Karmann GmbH, Osnabrück (Germany)