

# Manufacturing and testing of aluminium foam structural parts for passenger cars demonstrated by example of a rear intermediate panel

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## **Abstract**

An aluminium foam rear intermediate panel for a Mercedes Benz SLK roadster was manufactured to investigate the suitability of this new material for the application in car body structural parts. The re-design of the component led to material-optimised geometry, which was made in a net shape aluminium foam manufacturing process. The panel was mounted on a component testing device to evaluate its mechanical behaviour in comparison to the magnesium series panel. The geometrical stiffness of the Magnesium high pressure die casting component obtained by several ribs was reached by the foamed aluminium component as well, due to the higher thickness.

## **1 Introduction PM aluminium foam parts made in steel moulds and in grey iron moulds**

Development of powder metallurgical aluminium foams has been carried out by a couple of European companies and institutes and pushed by a lot of customer inquiries [1],[2]. The Center of Competence on Light Metals, a department of the Austrian Research Centers, is specialised in manufacturing of 3-dimensional net shape aluminium foam parts, made from extruded powder mixtures using the Alulight<sup>®</sup>-process. In this process aluminium powder is mixed with a foaming agent powder and compacted to profiles by a conventional extrusion process. These profiles are cut into pieces and heated up to the melting temperature of aluminium in steel moulds or in grey iron moulds, where the foaming process is going on.

Based on the experiences of previous foaming trials in the lab, LKR designed and built a special foaming furnace, where parts up to max. 2.000 x 1.000 x 500 mm can be foamed. Aluminium foam is considered for a couple of particular applications in the next future. Energy absorbing components improving the safety of passenger cars, commercial vehicles, trucks and even rail vehicles can be made from this material as well as self supported structural parts with high specific stiffness or improved damping behaviour. Further use may be heat insulating shields.

## 2 Aim of the Project

To test aluminium foam as a material for passenger car structural parts, LKR manufactured an aluminium foam rear intermediate panel in charge of DaimlerChrysler, who made comparing component tests to evaluate the differences between various materials concerning this application. In series production this part is made in Magnesium high pressure die casting, so this material was the reference for the investigations.

The component test results, described below show, that aluminium foam can be a suited material for structural parts in passenger cars. For a series production the economic conditions of the process have to be developed to be able to compete with other solutions.

## 3 Making of the mould

The project had to start with the re-design of the part to meet the demands of this lightweight material. The density of aluminium foam is approximately  $0,5 \text{ g/cm}^3$  and its advantage related to this particular application is high specific stiffness, but to fulfil the expected properties the wall thickness of aluminium foam parts has to be higher than the thickness of comparable castings. Whereas the Magnesium die casting part is approx. 3,5 mm thick, the thickness of the aluminium foam part had to be increased up to a mean value of approximately 8 mm, in some high load sections even of 10 mm. Gaps and mounting bracket areas, which are necessary for assembling the part in the body of the car or in the testing device were considered in the new design because aluminium foam usually cannot be formed by bending or deep-drawing.

The foamed part was produced in net shape and no machining except the fixing bore holes had to be done. The fact, that the product can be made in net shape, differs the Alulight process from other aluminium foam processes for manufacturing of structural parts, which include also forming steps. Karmann [3] showed an aluminium foam intermediate panel, which is made by cladding and forming to get a precursor material, which is foamed in a further process step. On the other hand some people think about forming of flat aluminium foam semi-product plates by a modified deep-drawing process or similar forming processes.

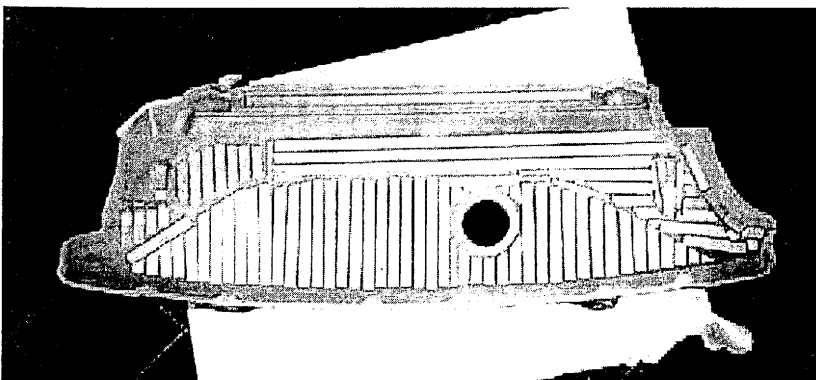


Figure 1: Foaming mould

The original CAD data of the Mg - series component of the Mercedes-Chrysler car were modified with respect to manufacturing demands, strength, stiffness respectively [4].

Based on the new CAD surface data the mould was designed in a two-piece cast iron version. Two cast iron shells, fit out with a special frame create the mould cavity of the aluminium foam intermediate panel.

The CAD-data of these shells were given to the Institut für Umformtechnik at Stuttgart University (Prof. Siegert), who made the patterns for the cast iron mould shells on a special CAM lost foam pattern manufacturing machine. In a foundry near Stuttgart the shells were cast in GG25 by lost foam process and a machining specialist machined the cavity of the mould. Figure 1 shows the panel foam mould consisting of 2 shells, ready for foaming

#### 4 Foaming of 3-dimensional net shape parts

By manufacturing of aluminium foam parts by the Alulight process, a certain amount of special precursor material which is described above is put into a mould. This mould is heated up to the melting point of aluminium in a furnace. In the case of the panel the precursor material profile pieces had to be adapted to the shape of the part, so that they were distributed uniformly within the mould. The two shells of the cast iron mould had a weight of 170 kg including the precursor material, so they were placed in the furnace by using a forklift piler.

After calculation of the thermal conditions in the furnace and in the mould, some first trials were made to find out the optimal foaming parameters. The foaming process took about 30 minutes. In all 12 pieces of the panel were produced in LKR, 5 pieces were supplied to DaimlerChrysler. 3 of the parts delivered to DC were mounted on a special component testing device in the lab of DaimlerChrysler in Munich. In Figure 2 the aluminium foam rear intermediate panel is shown.

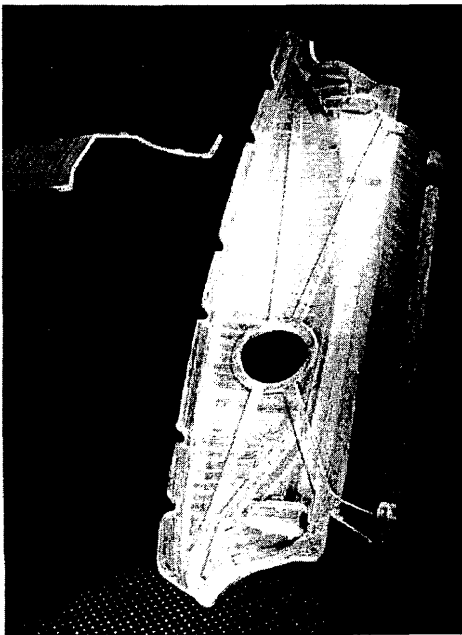


Figure 2: Aluminium foam rear intermediate panel

## 5 Joining of aluminium foam components

For testing of the rear intermediate panel it had to be mounted on the component testing device. Joining systems for aluminium foam parts have to meet some requirements which are different to conventionally systems in car body structures. Basically there are a couple of suitable joining systems available for joining aluminium foam to other components. Gluing, soldering and even special welding processes can be applied as well as screwing or push fittings, where fitting elements are positioned in the foam part during the foaming process similar to insert technologies in castings.

The application of a screwing system using M6 screws was a precondition of the customer. The joining system for mounting the panel in the testing device had to be developed simultaneous to the development of the component. The mechanical properties of aluminium foam did not allow to use conventionally body sheet screws, because the face pressure under the screw head is higher than the compression strength of the aluminium foam. The foam would be deformed, when the screws are tightened. After a lot of practical testing two adapted screw joining systems have been found as suitable for this application. On the one hand base discs with diameter 30 mm (also with reduced surface) can be applied to assemble the parts, on the other hand bushing sleeves with a diameter of 16 mm fulfil the requirement to avoid foam damage and durable life cycles. Figure 3 shows the suitable joining methods.

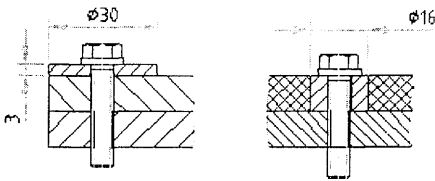


Figure 3: Suitable joining methods

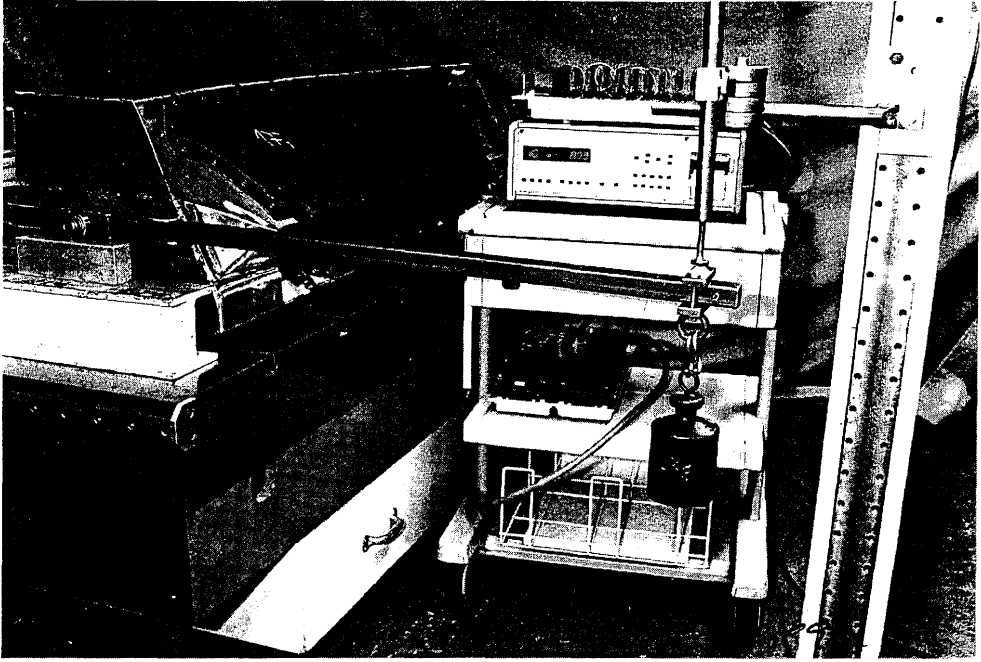
## 6 Testing of torsional stiffness

To evaluate the potential of the rear wall made by aluminium foam a test concerning static torsional stiffness of the mounted component was carried out. The test was suggested for the assessment of the aluminium-foam components by the passenger car pre-development. For comparison the Magnesium high pressure die casting rear wall used for series production of the Mercedes Benz SLK was chosen. The Magnesium rear wall is a (1400 mm x 600 mm) thin-walled, geometrically stiffened component with a very low weight of 3.5 kg. The foamed aluminium rear wall has the same size but a higher thickness of 8 – 10 mm.

## 7 Testing equipment

A testing device which replaces the structure of the car body was used to attach the rear walls to be tested. The points of fixture were identical to the joining areas during production. The component to be tested was fixed to the testing device by using inserts and screws with constant torque. The whole device together with the rear walls was distorted by a lever of 1 m and

an increasing mass up to about 25 kg (Figure 4). The component was loaded and relieved in steps and two testing series. The diagram shows the average values of these two testing series.



**Figure 4: Testing device with adapted measuring equipment**

## **8 Results of testing**

For all tested components mounted on the special device, the same torsional stiffness was determined (Fig. 5). Therefore the geometrical stiffness of the Magnesium high pressure die casting component obtained by several ribs was reached by the foamed aluminium component as well, due to the higher thickness. By the use of the powdermetallurgical process the aluminium foamed rear wall for the SLK roadster of Mercedes Benz could be produced showing a comparable behaviour to the Magnesium high pressure die casting series part. The required weight of 3.5 kg was obtained together with at least the same torsional stiffness of the mounted component.

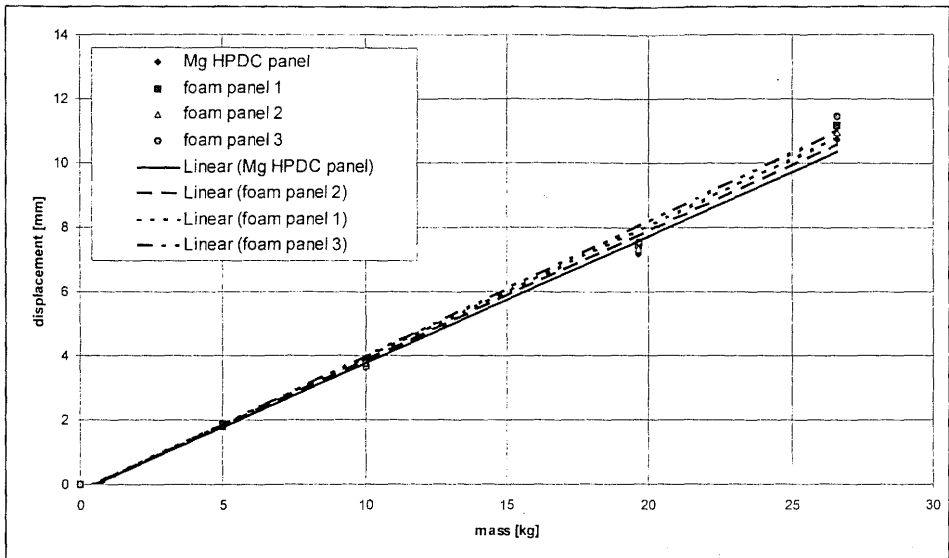


Figure 5: Comparison of aluminium foam panel and Magnesium HPDC panel

## 9 Conclusions

aluminium foams can be produced by a PM route, where aluminium powder is mixed with an agent powder, then extruded to profiles and foamed up to very different shaped 3-dimensioal parts within steel or cast iron moulds. The mechanical properties e.g. the stiffness related to the weight, promise to fulfil the requirements of components of car body structures. So this very new material has the potential to be applied in series production in future. Nevertheless development work has to be done to improve the reproducibility of the production process and to reduce the material and production costs. Another task to be investigated is the fatigue behaviour of such components.

## References

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