In: MRS Symposium Proceedings, ed. by D.S. Schwartz, D.S. Shih, A.G. Evans and H.N.G. Wadley, Vol. 521, Materials Research Society, Warrendale, Pennsylvania, 1998, p. 151

COMPLEX FOAMED ALUMINUM PARTS AS PERMANENT CORES IN ALUMINUM CASTINGS

F. SIMANČÍK *, F. SCHOERGHUBER **
* Institute of Materials & Machine Mechanics, Račianska 75, SK-830 08 Bratislava 38, Slovak Republic, e-mail: simancik@umms.savba.sk
** Illichmann GmbH, A-4813 Altmünster, Austria

ABSTRACT

The feasibility of complex shaped aluminum foam parts as permanent cores in aluminum castings has been investigated. The foamed samples were prepared by injection of the foam into sand molds. It turned out that sound castings can be produced if the foam core is properly preheated and/or surface treated before casting. The effect of the foam core on the performance of the casting was evaluated by in compression testing and by measuring structural damping. The gain in the related properties turned out to be much higher than the weight increase of the casting due to the presence of the core. The weight increase may be partially offset through a reduction of the wall-thickness of the shell.

INTRODUCTION

A new injection-molding technique has recently been developed for the production of complex foamed aluminum parts with a density of 0.5-1.0 g.cm^{-3} in various shapes and sizes [1]. The technique combines powder metallurgical and casting methods. The starting material is aluminum powder mixed with a foaming agent and continuously extruded into a compact foamable precursor. The precursor is then heated in a foaming chamber up to the melting temperature of the alloy. This leads to the formation of a liquid foam, which is injected in a controlled manner into the desired cavity. Metal or even sand molds can be used as a cavity, thus allowing cost effective large and small scale production and prototyping.

The foamed parts have a surface skin which improves their properties and gives them an appearance of normal aluminum castings (Fig. 1). However, this skin is relatively thin and sometimes contains small cracks, especially when the foam is made of aluminum casting alloys. Such foamed parts alone are therefore not suitable for highly loaded structural components, such as subframes, crossmembers, control arms etc. However, they could be effectively used instead of sand cores which are usually applied in various components to obtain weight-saving cavities. In this case the foam core will remain in the casting. Pouring aluminum around the foam improves the thickness and the properties of its outer skin, thus providing a unique possibility for the production of three dimensional sandwiches with isotropic core properties.

Some of the expected advantages of foam-cored castings are for example:

- Avoid costs of sand cores, sand removal and sand reclamation.
- Improve stiffness and crashworthiness of components.
- Accomplish internal casting configurations not feasible with sand cores.
- Accomplish completely closed lightweight sections in a casting
- Apply casting methods like squeeze casting, so far not accessible with sand cores.
- Improve noise, vibration and harshness performance.

The aim of this work is to

- Investigate the feasibility of aluminum foam parts as permanent cores in a casting.
- Determine the integrity of castings made with foam cores.
- Investigate if a reduction of the wall thickness of the shell would be possible.
- Determine the effects of foam cores on component performance.

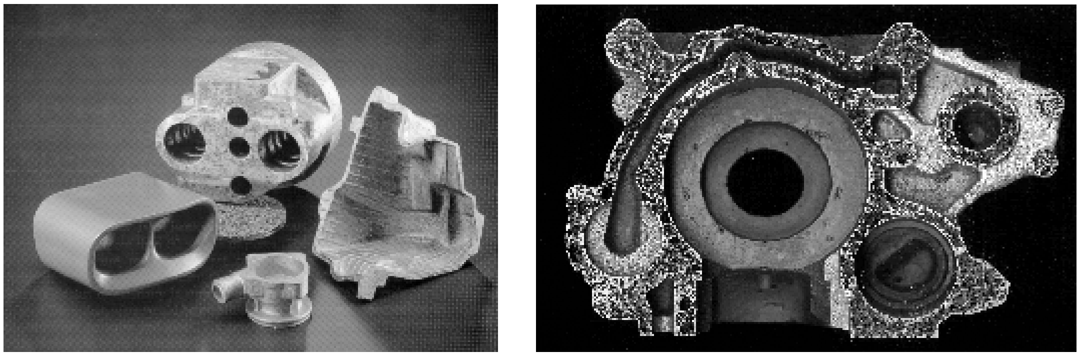

Fig. 1 Various types of complex shaped aluminum foam parts.

EXPERIMENTAL

The precursor for the foaming of core samples was made of two different aluminum alloys, the casting alloy AlSi12 and the wrought alloy AlMg1Si0.6. The samples with a density of 0.8-0.9g/cm^3 were prepared by injection of the foam into sand molds. Then they were inserted into an existing gravity die with conventional gating and risering (Fig. 2). The casting alloy AlSi9Cu3 at 740°C was used to cast the outer shell around the foam cores. Some of the cores were preheated at 400°C before casting. During the casting the mold was kept at its usual operating temperature. In order to improve the bonding between the shell and the core, some of the foam cores were surface treated by sand-blasting or coating with various diffusion supporting agents.

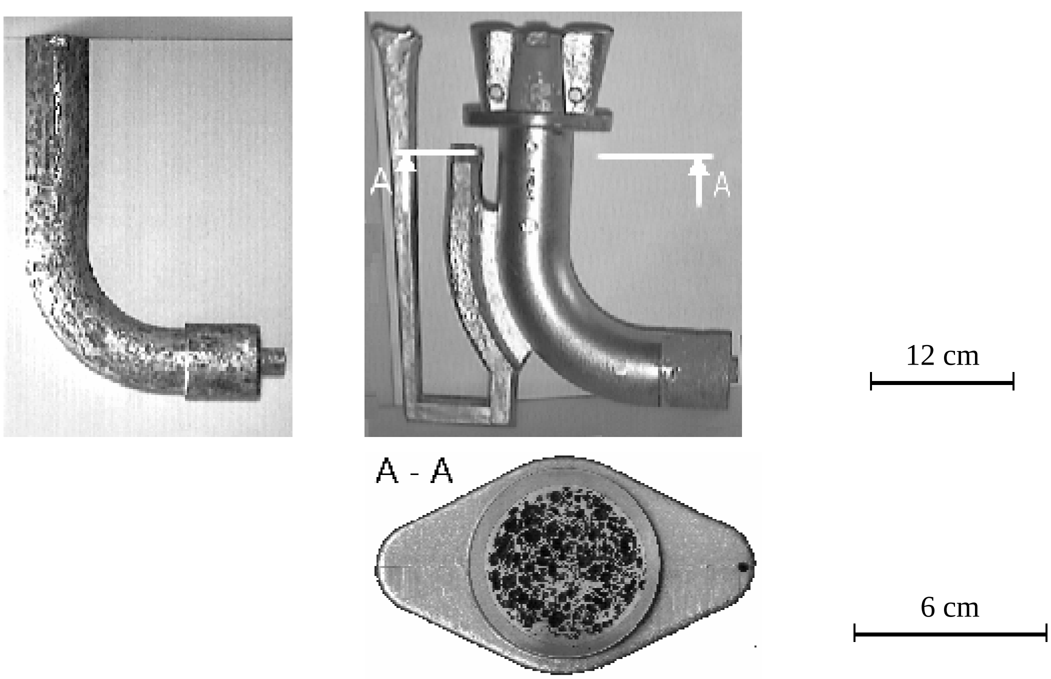

Fig. 2 Foam-cored aluminum casting.

The foam-cored samples were visually and metallographically examined to determine the influence of technological parameters on the integrity of the casting and on the bonding between the core and the shell. The effect of the foam cores on the performance of the castings was tested by measuring the structural damping using the "impact hammer" method. The original hollow serial-production parts with identical shell geometry were also tested for comparison. The cylindrical samples with a diameter of 60 mm and a length of 13 mm were cut from the casting and were subjected to a compression load in the direction perpendicular to the main axis of the core.

RESULTS AND DISCUSSION

None of the foam cores, neither cold nor preheated, have been melted during the pouring of the hot metal, neither have they been infiltrated. The skin of the core remained intact. A small gap could be detected between the shell and the cores prepared from wrought aluminum alloy. This is because of higher coefficient of thermal expansion of the core than of the shell (Fig. 3).

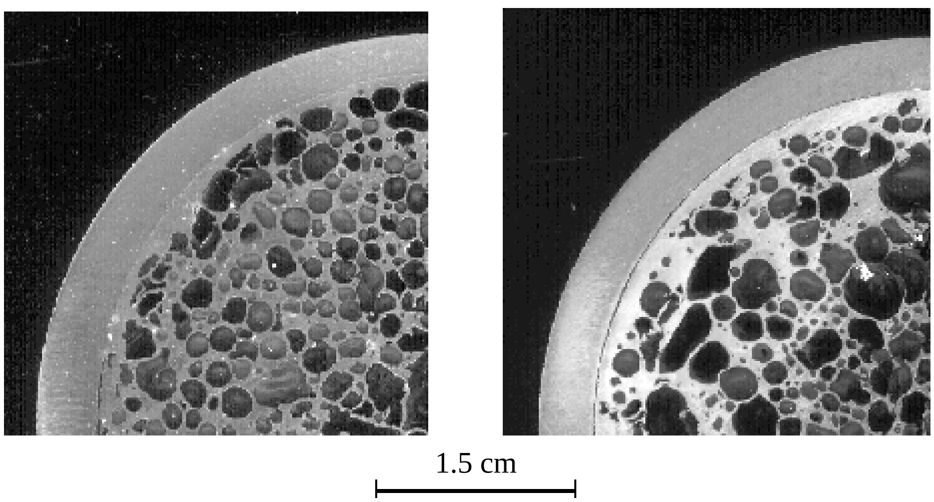

Fig. 3 Aluminum casting with different foam cores:
left - AlSi12-foam, right - AlMg1Si0.6-foam

When the foam cores were inserted at room temperature, cold shuts appeared in some regions of the castings, especially in those with lowest thickness of the shell. This problem had not been observed when the foam cores were preheated before casting. The preheating of the cores leads to a lower heat flow from the melt into the core, thus enabling considerable reduction of the wall thickness (Fig. 4) in comparison with usual sand cores which cannot be preheated. This is a very important, since it is obviously very desirable to offset the weight of the foam core through a reduction of the shell thickness.

Pouring liquid metal around the foam core will result in heating up and consequent expansion of the gas inside the pores. The expanding gas can cause porosity in the shell or even destroy the integrity of the casting because of gas bubbles (Fig. 5). This expansion of gases and the deterioration of the shell can be minimized by preheating the cores before insertion, because a gas inside the pores is already expanded.

Generally no bonding has developed between the core and the shell after casting because of the continuous aluminum oxide layer which prevents the core surface from a reacting with the molten metal. There are two possible ways how to improve the bonding:

- a mechanical bonding can be established by the penetration of the liquid metal into the outer foam structure after opening the surface skin, e.g. by sand-blasting (Fig. 6a). This type of bonding leads to an increase in the weight of the casting of about 5%.
- a metallurgical bonding can be achieved by coating the cores with various agents supporting diffusion through the aluminum oxide layer (Fig. 6b). Further research in this field is needed to find a suitable agent which will provide a good bonding between the shells and the cores, improving mechanical properties and corrosion resistance.

It should be noted that the absence of bonding can sometimes improve structural damping of the part because of better energy dissipation at the separated interfaces.

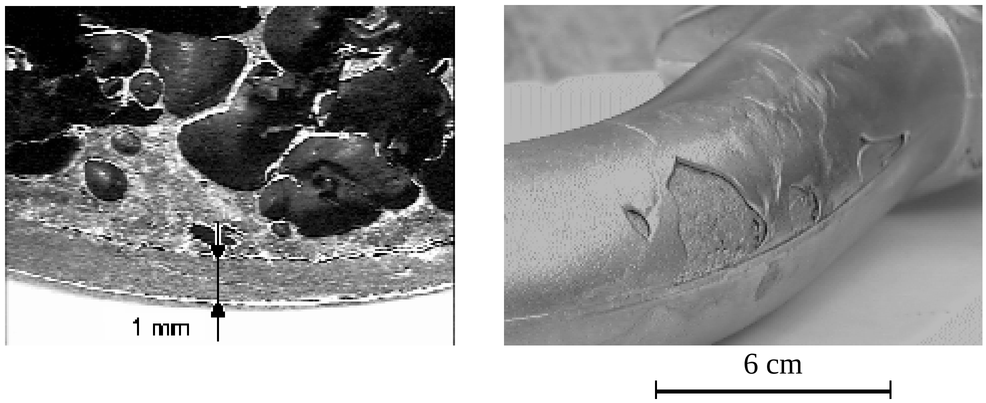

Fig. 4 Effect of the preheating of the foam core on the casting integrity:
left - preheated core (400 °C), right - cold core (room temperature).

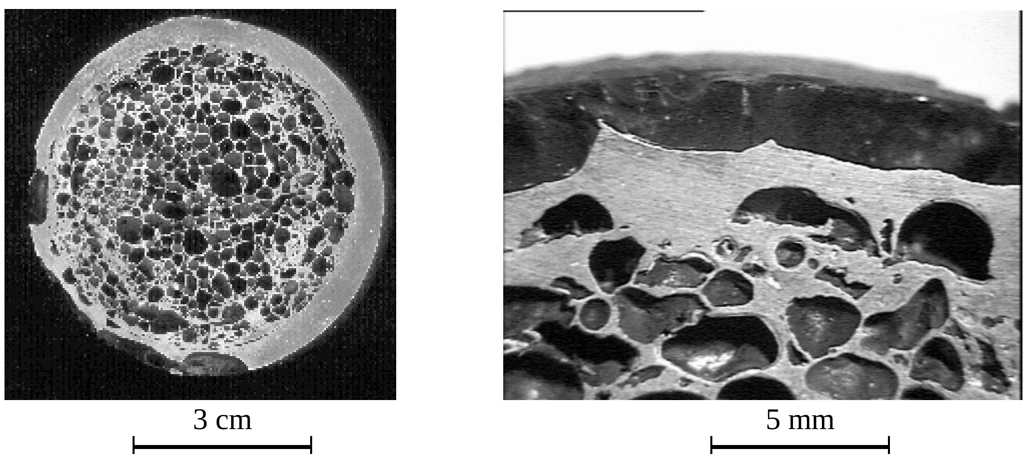

Fig. 5 Effect of the expanding gases on the porosity of the shell.

The results from the testing of the aluminum castings containing foam cores are summarized in Fig. 7 and compared with the properties of the hollow parts. As can be seen, the effect of the foam core on the investigated properties is much higher than the relative increase of the weight of the casting. It can be anticipated, that the increase of the total weight of the component due to the presence of the foam core can be offset by a reduction of the shell thickness without a reduction of the gain in the properties.

Fig. 8 illustrates the performance of the foam core during compression load. In comparison with the hollow part, the foam-cored sample was able to withstand considerably higher deformation at higher stress levels even without the presence of any bonding between the core and the shell. This effect could be utilized for components where higher strength and energy absorption is an important issue.

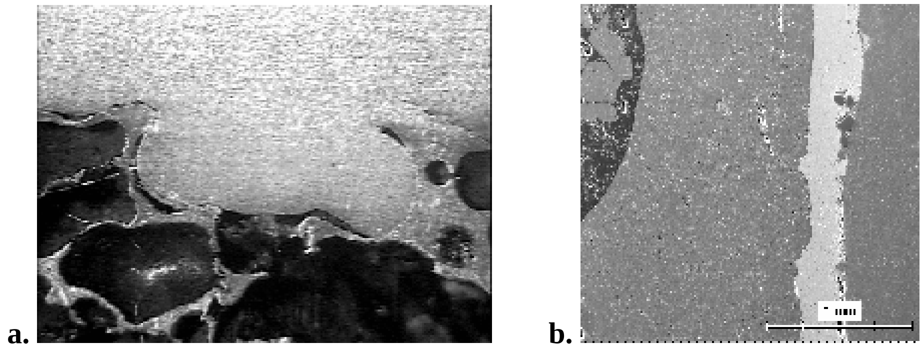

Fig. 6 Various types of bonding between the foam core and the shell:
a - mechanical bonding, b - metallurgical bonding.

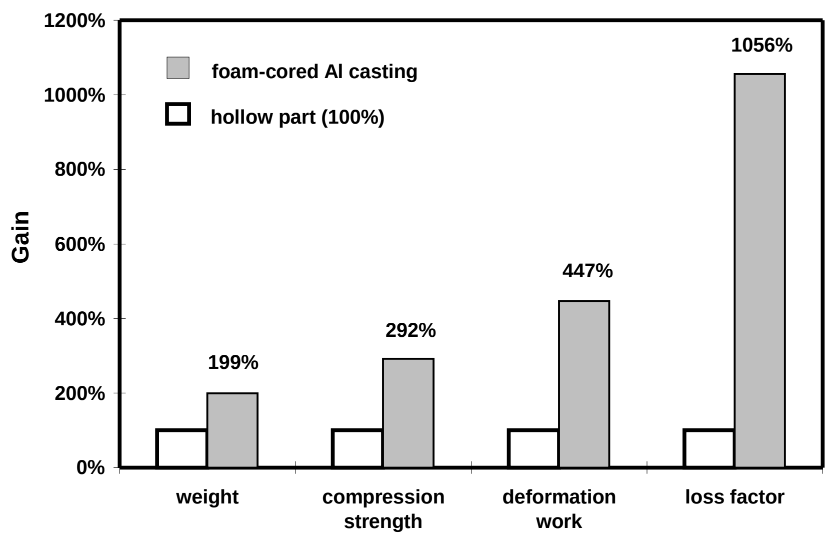

Fig. 7 The properties of the foam-cored casting in comparison with the hollow part.

CONCLUSIONS

It has been shown that complex shaped foams made of both cast and wrought aluminum alloys could replace sand cores in cast aluminum parts. Sound castings can be produced if the foam core is properly preheated and/or surface treated. The gain in the investigated properties is much higher than the weight increase due to the presence of the core. The weight increase may to some extent be offset by a reduction of the wall-thickness of the shell which is possible if a preheated foam core is used.

ACKNOWLEDGMENTS

Authors gratefully acknowledge the financial support of Illichmann GmbH, Altmünster.

REFERENCES

1. F. Simančík, J. Kováčik and F. Schoerghuber in Metalschäume, edited by J. Banhart (Proc. Symposium Metallschäume Bremen, 6.-7.3.1997) pp.171-176.

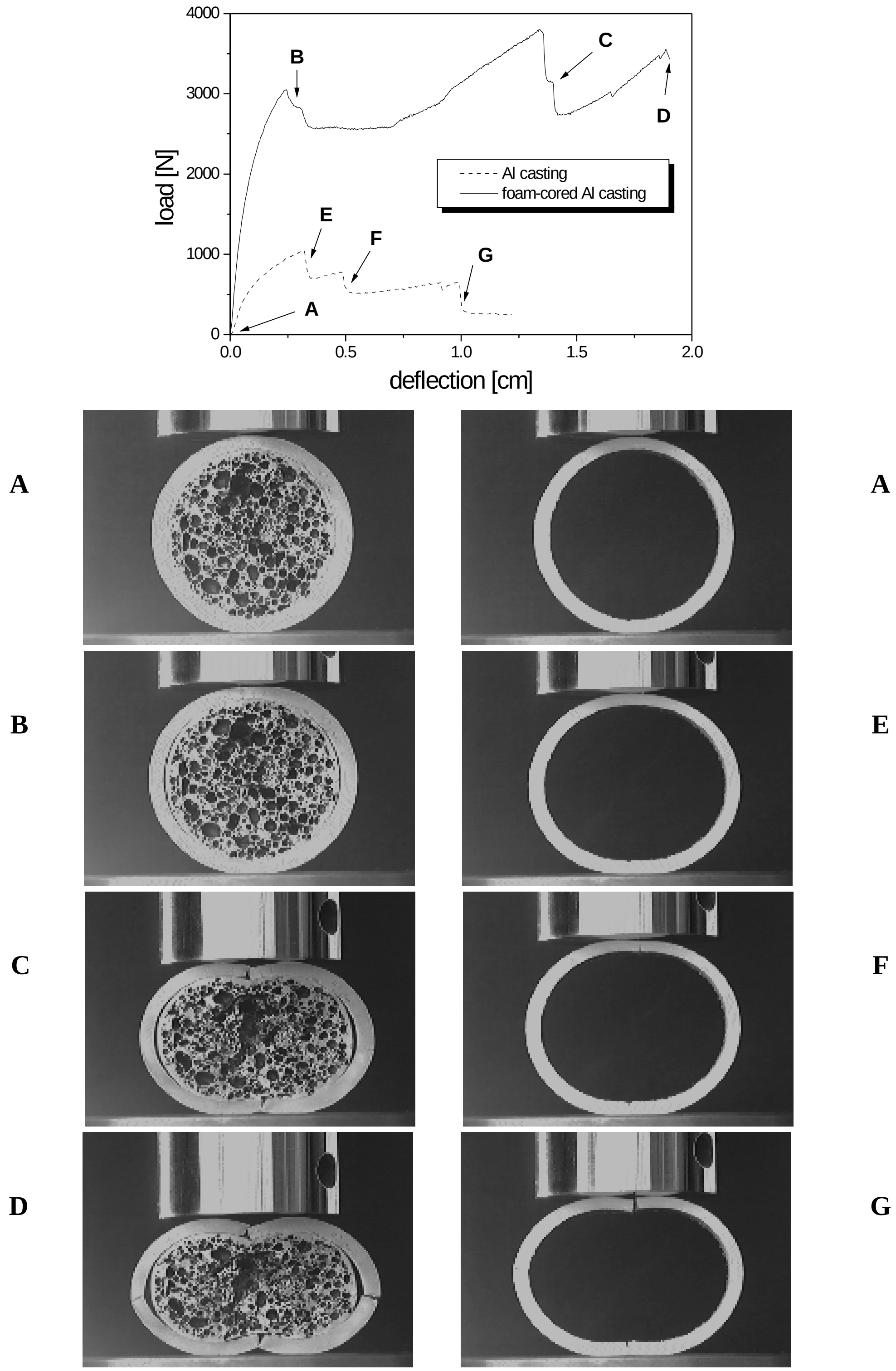

Fig. 8 Compression test of foam-cored casting in comparison with the hollow shell (sample geometry ϕ 60 x 13 mm, ram speed 1cm/min)