Foamed aluminium cores for aluminium castings

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Abstract

Complex lightweight components used for load-bearing structures in land vehicles are often made of castings having weight-saving cavities. The wall-thickness of such parts is usually limited by the technology used and thus cannot be designed according to loading requirements. Usually it is determined by the most heavily loaded part of the component, which leads to additional weight in cross sections where it is not necessary. The bending stiffness of cast aluminium parts depends on Young's modulus of aluminium and on moment of inertia of the loaded cross section. Hence the Young's modulus of aluminium is constant, the bending stiffness can be improved only by changing the cross section. To do that without weight increase only two ways are possible:

- thickness and to an increase of part's volume (this way is limited by available volume and minimum possible wall-thickness for given casting process)
- introduce the ribs or another stiffeners into the cavity, which also leads to the reduction of shell thickness but without changes in overall volume (this way is only limited by the possibility to prepare a suitable core)

1. Foamed-core castings

A new concept for the design and manufacturing of lightweight load-bearing structures presented here is based on the utilisation of complex shaped aluminium foam parts instead of weight-saving cavities in aluminium castings. The complex foamed part replaces the sand core which is usually used for the preparation of cavities and remains in the casting. The main goal is the possibility to accomplish completely closed lightweight sections in the casting and to create internal configurations (stiffeners) not feasible with sand cores. Also relatively small cross-sections can be filled up with foamed core. Due to the additional stiffening effect of the foam and the possibility to preheat it, significant reduction of the shell thickness can be expected. This will allow the distribution of load-bearing material in most convenient weight according to loading conditions without the need to increase the overall weight or volume of the part. This effect can be further enhanced by applying foams with gradient and anisotropic distribution of cell-wall material thus simulating optimum bone-like structure [1], [2].

The use of foamed cores offers also another benefits:

- increase in the capability of component to absorb crash energy
- suppression of the noise and vibration of the structure
- avoidance of costs for sand cores, sand removal and sand reclamation
- application of casting techniques so far not accessible with sand cores (squeeze casting, HPDC, thixocasting)

The foam-cored castings are expected to be effectively applied as highly loaded structural components, such as subframes, crossmembers, control arms etc.

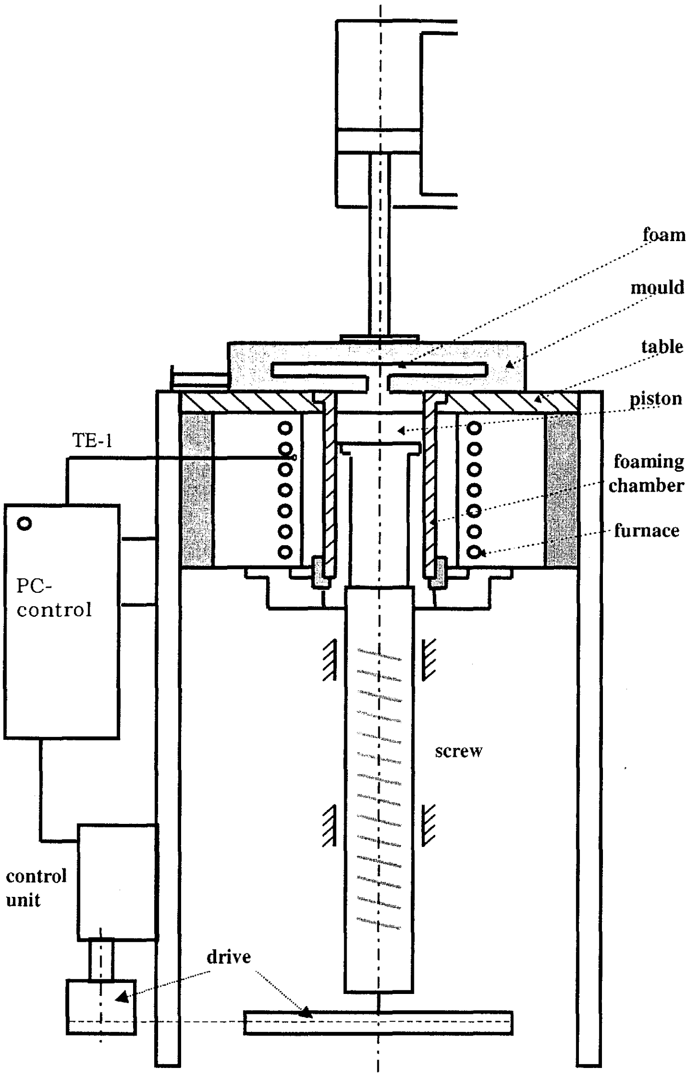

Fig. 1: The scheme of the casting machine for injecting of aluminium foam

The experimental work was aimed to investigate the feasibility of aluminium foam parts as a permanent core in aluminium castings and to determine the benefits gained in component performance. Complex 3D-shaped foams from both cast and wrought aluminium alloys with gradient distribution of cell wall material were prepared by recently developed injection moulding technique (see Fig. 1). The technique combines powder metallurgical and casting methods. The starting material is powdered mixture extruded into a foamable precursor. The precursor is heated in a foaming chamber and during foam formation injected in a controlled manner from the chamber into the desired cavity. Metal or even sand moulds can be used, thus allowing cost effective large and small scale production and prototyping. Size and orientation of pores can be to some extent controlled by injection conditions. The foamed parts have a surface skin with a thickness which can also be affected by the process (Fig. 2). These are some of the attractive aspects of this foaming technique not attainable with another one.

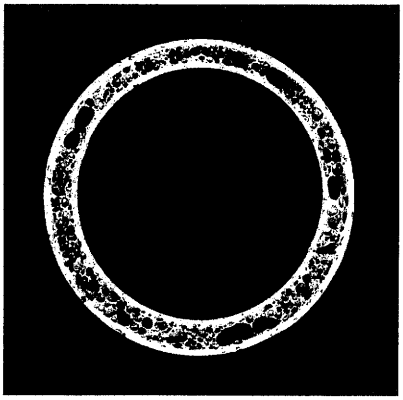

Fig. 2 Cross section of the foam core (thick surface skin, low-weight foam core)

The thickness of the surface skin allows to pour liquid metal around the foam core without danger of infiltration. Sound castings can be produced if the core is properly preheated. The preheating of cores prevents excessive heat flow from the melt into the core, thus enabling considerable reduction of the shell thickness in comparison with usual sand core, which cannot be preheated (Fig. 3). This is a very important, since it is desirable to offset the weight of the foam core through a reduction of the shell thickness.

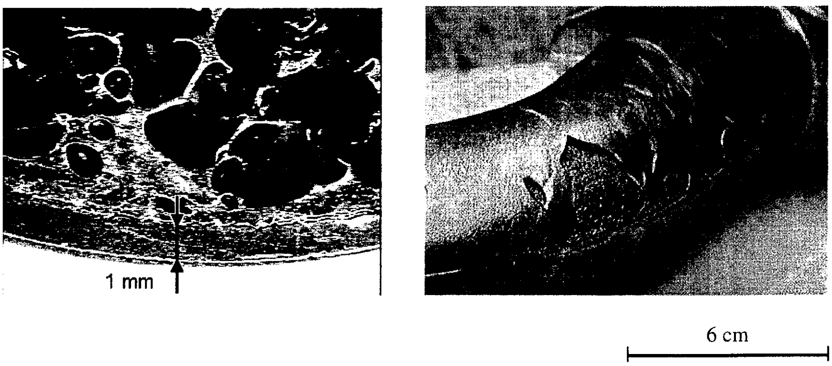

Fig. 3: Effect of the preheating of the foam core on the casting integrity: left - preheated core (400 °C), right - cold core (room temperature).

Generally no bonding has been developed between core and shell by casting because of the continuous alumina layer which prevents the core surface from reaction with the molten metal. However, the bonding can be established; either by controlled penetration of liquid metal into the foamed structure after opening the surface skin, or by a special coating of the foamed core. Results from testing aluminium castings containing foam cores [2] are summarised in Fig. 4 and compared with the properties of the hollow part. The gain in the properties is much higher than the weight increase due to the presence of the core.

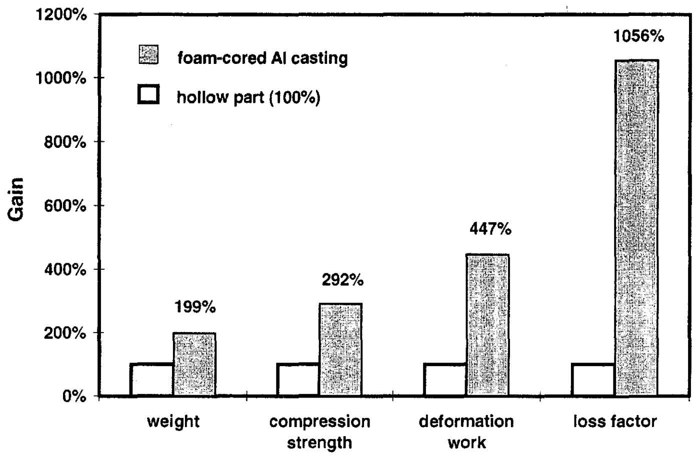

Fig. 4: The properties of the foam-cored casting in comparison with the hollow part.

2. Future Work

The following problems should be solved in future to succeed with foam-cored castings:

- reduce apparent density of foamed part
- reduce costs for foam core manufacturing
- establish process parameters leading to reproducible foam structure
- develop a method for casting quality control (the procedure must distinguish between pores of foamed core and failures in a shell)

References

[1] Simančík F., Kovacík J., Schörghuber F.: Porosity in complex 3D-parts prepared from aluminium foam, In: Metallschäume, Symposium Metallschäume, Bremen, 1997, p. 171

[2] Simančík, F., Schörghuber, F.: Complex foamed aluminium parts as permanent cores in aluminium castings. MRS -Symposium Proceesings Vol. 521, 1998, p.151.