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The influence of casting process on quality and performances on Al based automotive components

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Abstract: Aluminium alloys are more and more increasing their importance in different industries, in particular, in the automotive field, where castings represent extremely interesting solutions especially for those applications in which the necessity of high mechanical properties is combined with the need of a substantial weight saving. In this work, investigations on fatigue and microstructural characteristics were done on specimens drawn directly from production components, samples dimensions were the maximum allowed by component dimensions. The influence of different casting processes are here compared.

Keywords: Aluminium alloys, Casting processes, Fatigue behaviour, Casting defects, porosity.

1. INTRODUCTION

The application of aluminium alloy casting in many mechanical components, especially for cars and rail vehicles, has gradually increased in the last years, thanks to the great potential of these materials as replacements for ferrous alloys. In particular, for those applications in which the necessity of high mechanical properties is combined with the need of a substantial weight saving, aluminium castings are extremely interesting solutions. Moreover, the opportunity of producing cast components in a finished or semi-finished shape permits a high reduction of the production costs.

Different casting processes are available, sand casting, loast foam, low pressure mould casting, rheocasting, squeezecasting, high pressure diecasting, this last one being a process with the highest productivity and the lowest variable cost.

At present, the main demand toward a wide use of aluminium alloys for high performance products requires the complete understanding of their properties and of the relationship to casting process and defects, together with microstructural features, in particular fatigue behaviour being among the most appreciated aspects.

The lower mechanical properties and reliability of the aluminium cast alloys can be principally caused by the presence of defects and inhomogeneities, which could be preferential fatigue initiation sites. Recently, many studies have been carried out on the influence of microstructure and microporosity on the mechanical properties of aluminium cast alloys [1-4]. In some cases, the influence of casting pores and of secondary dendrite arm spacing on the fatigue crack initiation and propagation in cast aluminium alloys has been evaluated. It is well known that, controlling the cooling rate during solidification of cast structures, it is possible to control the microstructural constituent sizes, in particular secondary dendrite arm spacing. Flemings [5] found that the SDAS of cast structures usually has a stronger influence on mechanical properties than the grain size has.

The present work addresses the comparison of characteristics and of cycle fatigue properties of aluminium-containing silicon alloys produced by different casting processes, namely sand casting, lost foam, low pressure mould casting, reocasting, squeezecasting and high pressure die casting. A main material defect in cast components is porosity, which is caused by micro-shrinkage and by dissolved gases leading to voids.

2. EXPERIMENTAL AND RESULTS

The studies have been performed on A 356 T6 alloy, widely used in industrial application due to the favourable strength/weight ratio and good manufacturability.

Following the ASTM E 466 standard cylindrical shaped specimens (8 mm diameter) have been machined from different cast parts, used in the automotive industry. The considered cast parts haves been heat treated before machining the samples.

In figure 1 are represented some parts used as a source of specimens. Optical microscopy and SEM analyses have been performed together with mechanical and fatigue tests.

The specimens for optical microscope were prepared by the normal metallographic technique of mounting, polishing and etching, while the surface finish of the fatigue test samples was obtained with special care to avoid undesired fracture primers along surface. Fifthteen samples for each production process have been tested to obtain an indication of the fatigue strength at 10 million cycles.

To obtain these results, data have been elaborated following the stair case method (UNI 3964 Italian standard). In this protocol, the first specimen is tested at the estimated fatigue strength of the material. The remaining specimens are tested sequentially, decreasing or increasing in steps of 10MPa the test stress for each specimen depending on whether the previous specimen fails or survives cyclic loading within the pre-determined number of cycles (10 million).

After the determination of the fatigue threshold another ten samples from each production process have been tested at higher stresses than the calculated fatigue strength at 10 million cycles in order to draw a Wöhler diagram and to understand the fatigue behaviour.

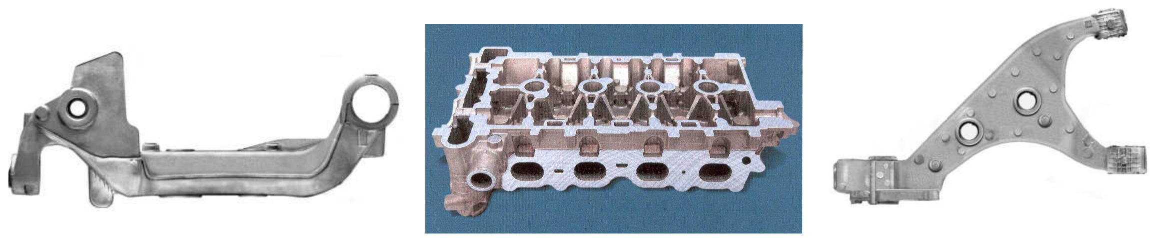

Figure 1. Some components used to draw the test samples

The microstructure after T6 heat treatment of rheocast parts is shown in fig. 2. There is evidence of the eutectic microstructure with round shaped silicon particles in a globular Al matrix. Eutectic segregations and blistering are also evident. While in figure 3 the microstructure of sand casting parts and of low pressure permanent mould parts show similar features.

The morphology of fracture surfaces is helpful to highlight the presence of defects on the castings, in figures 4 and 5 the fracture features of sand cast and low pressure mould samples shown the presence of shrinkage porosity as a nucleation site of the fatigue crack, no particular features appears in the propagation zones, while final fracture zone morphology clearly is of the ductile type.

In figure 6 the Wöhler curves of samples obtained from components produced using rheocasting, low pressure mould casting and sand casting processes are compared, it is evident the superior behaviour of the rheocast parts, while in the histogram the comparison of fatigue strength allowed by different processes is highlighted, it is quite easy to individuate a relation between the strength and the soundness of casting as allowed by the process. In particular, while the strength of rheocast and squeeze cast parts are substantially equivalent, the lowest fatigue strength belongs to parts obtained with the lost foam process, this is because of the high percentage of defects, mainly porosity, characterizing the process.

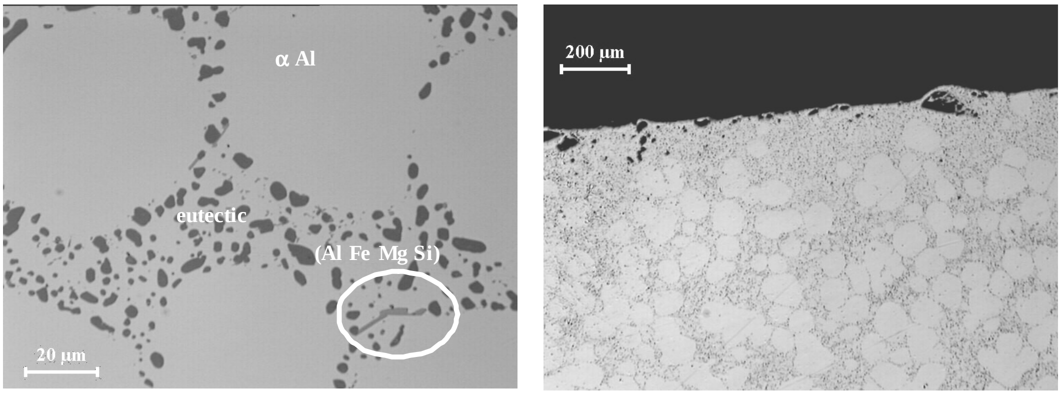

Figure 2. The microstructure after T6 heat treatment of rheocast parts. (a): eutectic microstructure; (b): eutectic segregations and blistering

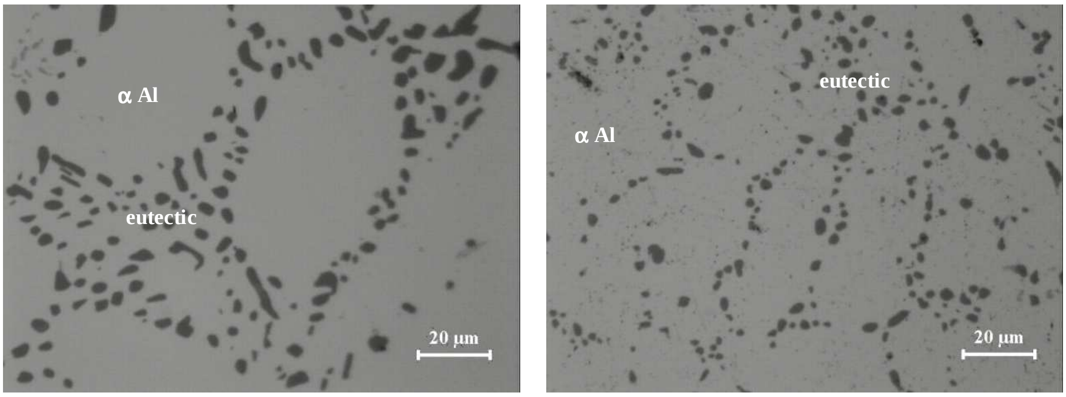

Figure 3. Microstructure of T6 (a) sand casting and (b) low pressure permanent mould parts.

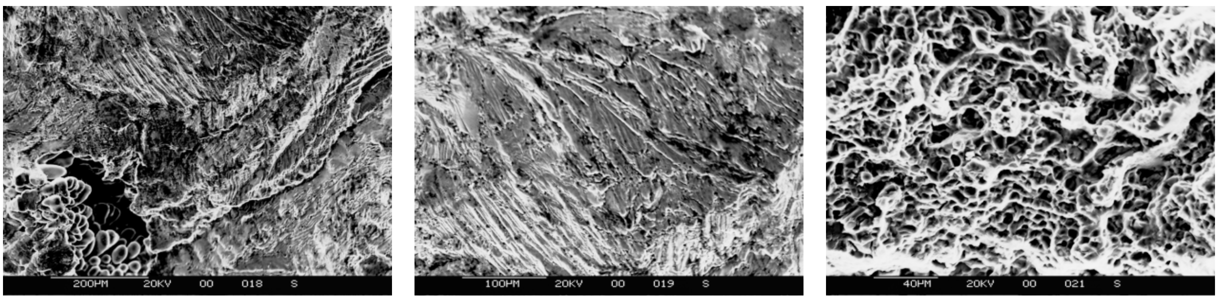

Figure 4. Fractography features on fatigue tested samples produced with sand casting process. The primer zone of the crack initiation (left), the propagation zone (centre) and the final ductile fracture zone (right).

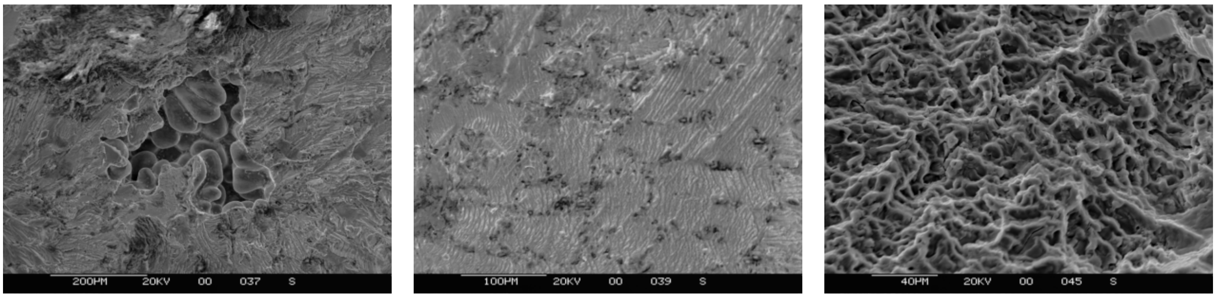

Figure 5. Fractography features on fatigue tested samples produced with low pressure permanent mould process. The primer zone of the crack initiation (left), the propagation zone (centre) and the final ductile fracture zone (right)

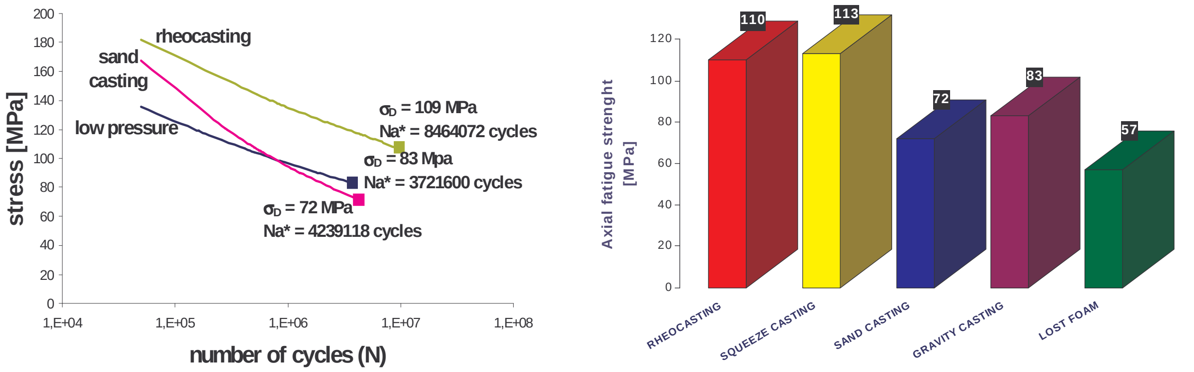

Figure 6. Wöhler curves related to rheocasting, low pressure mould casting and sand casting processes. Comparison of the fatigue strength at 10 million cycles allowed by different processes

3. CONCLUSIONS

The fatigue behaviour of different A 356 T6 aluminium alloys castings for automotive applications has been investigated. In particular this study dealt with axial high cycles number fatigue tests performed on a servo-hydraulic machine.

The research has shown that the casting process exerts high influence on the fatigue strength properties, in particular the presence of defects, especially shrinkage cavities, contributes to decrease the fatigue strength, because they aid fracture initiation and propagation. Rheo and squeezecasting processes produce the highest fatigue resistance in aluminium alloy castings, this is because of their more homogeneous microstructure and of their higher soundness.

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