FATIGUE BEHAVIOUR OF TWO CAST ALUMINIUM - SILICON ALLOYS

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The fatigue behaviour of two cast aluminium-7% silicon with magnesium contents of 0.3 and 0.45% has been studied. The 0.3% magnesium alloy was analysed after artificial ageing treatment (T6) while the 0.45% one was tested in both as cast and artificially aged conditions. A very strong influence of casting defects on fatigue life was observed that even hides the effect of composition or heat treatment. Under high loading amplitude condition the alloy with the highest magnesium content exhibited a better fatigue behaviour which was associated with the higher mechanical strength of this alloy. However, near the fatigue limit very similar behaviour was observed in the T6 heat treated condition. An improvement of fatigue behaviour by means of T6 heat treat. can be observed.

INTRODUCTION

The development in light alloys continue to be dominated by aluminium with aluminium castings having an important role in the growth of the overall aluminium industry. Among the commercial aluminium casting alloys, Al - 7Si -Mg is probably the most widely used, mainly because of its good castability and excellent mechanical properties in the heat treated condition. As a high strength alloy, it is suitable for components under stressed conditions and, therefore, is used extensively in the automobile, aircraft and defence industries where it has been steadily replacing many conventional ferrous alloys (1).

Almost all of the steps in processing the alloy from establishing its composition to heat treating produce a variation in mechanical properties. The properties depend on the alloy structure and especially on the eutectic silicon morphology. This morphology can be modified by small addition of some elements such as Na, Sr or Sb which promote a finely dispersed eutectic silicon distribution in the casting. This modification enhances the mechanical properties due to the microstructural refinement (2).

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Moreover, it is well established that with the present production technology the dissloved gases and shrinkage lead to porosity and to a decrease in the fatigue strength of the material. In addition to chemical composition and melting and casting techniques heat treatment is another important parameter which influences the mechanical properties. Thermal modification of the eutectic silicon contributes largely to a marked improvement in strength (1, 3 - 5), although an insensivity of the fatigue behaviour to heat treatment has been claimed (3).

The aim of the present paper is to investigate the influence of chemical composition and heat treatment on the 4 fatigue behaviour of two cast Al - 7% Si alloys.

EXPERIMENTAL PROCEDURE

Two Al - 7% Si, with Mg contents of 0.30 (marked as Al.1) and 0.45% Mg (Al.2) were chosen for the present study. The chemical compositions of these materials are listed in Table 1. Permanent mould cast samples were produced with.a small amount of Sr added to the alloys to modify the morphogy of eutectic silicon. Al.1 alloy was only analised in the T6 condition, after solution treating at 540° C for 8 hours and artificial ageing for 4 hours at 170° C while Al.2 was tested in both as cast (Al.2.B) and artificially aged conditions (Al.2.T).

TABLE 1 - Chemical Composition (wt%) of the Alloys

Ref	Mg	Si	Mn	Fe	Zn	Ti	Cu	Sr	Al
Al.1	7.0	0.30	<0.05	0.20	<0.01	0.16	<0.05	0.02	Bal
Al.2	7.8	0.45	<0.05	0.20	<0.01	0.14	<0.05	0.02	Bal

For each alloy and heat treating condition 2 tensile and 20 fatigue specimens were machined from the cast samples. Tensile tests were carried out at room temperature according to ASTM E - 8M (6). Fatigue behaviour was characterized by means of rotating bending tests with zero mean stress and various stress amplitudes. The R stress ratio was held at - 1. This study was complemented by metallographic analysis of the various materials and fractographic examination of the failed specimens in the scanning electron microscope.

RESULTS AND DISCUSSION

Table 2 summarizes the average values of those obtained in the two tensile tests corresponding to each material and heat treating condition. It can be easily seen that an increase in the Mg content leaded to a rise in strength, although the higher Si content in the Al.2 alloy may have also contributed to this difference. A similar trend has been reported in some previously published papers (1, 7, 8).

However, the loss in ductility claimed in these papers has not been observed in the present work and even a very slight increase can be detected. A plausible explanation can be given based on the examination of the tensile tests specimens in the scanning electron microscope that revealed the presence of significant amount of porosity in the fracture surfaces of the Al.1 alloy ones which could justify this lower ductility. Nevertheless, it must be indicated that a positive influence of porosity on fracture elongation has been claimed in another paper (9).

Moreover, a strong effect of heat treatment on mechanical properties is evident in this Table 2 leading to a very marked increase in the values of tensile strength and, mainly, yield stress with just an insignificant decrease in ductility. Consequently a benefit of heat treating is obtained.

TABLE 2 - Average Mechanical Properies of the Samples in the Different Conditions

Reference	Yield Strength (MPa)	U.T.S. (MPa)	Elongation (%)
Al.1	208	286	5.5
Al.2B	140	240	7.0
Al.2T	250	317	6.2

Moreover, metallographic examination revealed that even if Sr was added to the alloy to modify the morpholgy of the eutectic some zones of acicular microstructure are yet present in the untreated material. Heat treatment eliminated these unmodified zones and homogeneized the microstructure of the alloy with more fine rounded silicon particles. Comparison between figures 1 and 2 allows to check this point. Some large acicular particles constituted by Al, Fe and Si that can be identified as beta phase (Al_5FeSi) although significant differences in the percentage of these elements are found among the various particles (10)

Results of the fatigue tests are shown in figures 3 for Al.1, Al.2B and Al.2T samples, respectively, having been plotted the number of cycles to failure against the alternating stress amplitude. A very strong scatter in the fatigue lives is evident in this figures. Fractographic examination of the different specimens helps to find a plausible explanation to this scatter, having been associated with the amount of porosity in the specimen. This negative effect of porosity on fatigue behaviour was claimed in other previuos papers (1, 3, 11). Moreover, this analysis clearly reveals the importance of the number, size and position of the casting defects on the fatigue performance of the alloys. When these defects emerge to the surface of the specimens, as that shown in figure 4, their negative effect is more marked. On the other hand, in those samples whose fatigue life is greater than 10 millions cycles, no sign of casting defects or just very small ones, that were sited in the nucleus of the specimen, were found. A more detailed fractographic analysis was presented in another paper (12).

This influence of the porosity on the fatigue life clearly overrides those of chemical composition and heat treatment. Nevertheless, when sound specimens results are compared a better fatigue behaviour of the Al.2 alloy for large stress amplitude can be detected, having been attributed to the higher mechanical strength of this alloy. However, for low stress amplitudes, near the fatigue limit, very similar results are obtained in both alloys.

A positive influence of the heat treatment on the fatigue life can be observed if only sound specimens are considered. These results seem to contradict those reported in a recently published paper where very similar fatigue limits were obtained fo all the studied heat treating conditions (3). A very likely reason for this discrepancy must be found in the stronger effect of porosity that near hides the influence of heat treatment when all the results are included in the analysis. It is necessary to separate the strong contribution of porosity in order to detect any effect of heat treatment on the fatigue performance of the alloys.

CONCLUSIONS

1.- A beneficial effect of both Mg content and, mainly, heat treatment on mechanical strength has been observed. Moreover, heat treated samples exhibited a more uniform microstructure without signs of unmodified eutectic silicon.

2.- Fatigue tests results showed a large scatter due to the strong influence of casting defects on the fatigue life. Fractographic examination of the failed specimens revealed that the fatigue performance was not only influenced by the presence of this casting defects but also by their number, size and position. Those sited at or near the surface of the specimen induced a more marked decrease in fatigue life.

3.- The alloy with the highest Mg content showed a better fatigue behaviour under high stress amplitude although near the fatigue limit very similar results were obtained in both alloys.

4.- T6 heat treatment leaded to an improvement in the fatigue performance of the Al.2 alloy although this positive effect is near completly hidden by the stronger one due to the porosity on the fatigue life of the alloy. It is necessary to exclude this more marked influence in order to detect that of the heat treatment.

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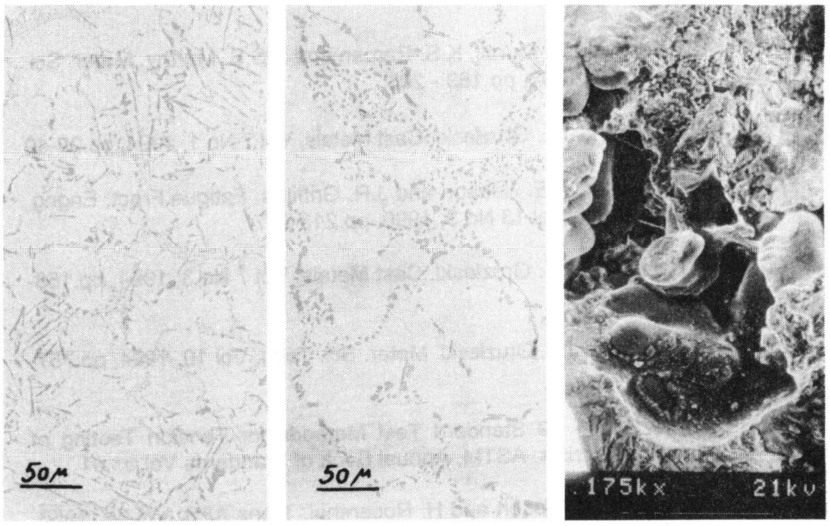
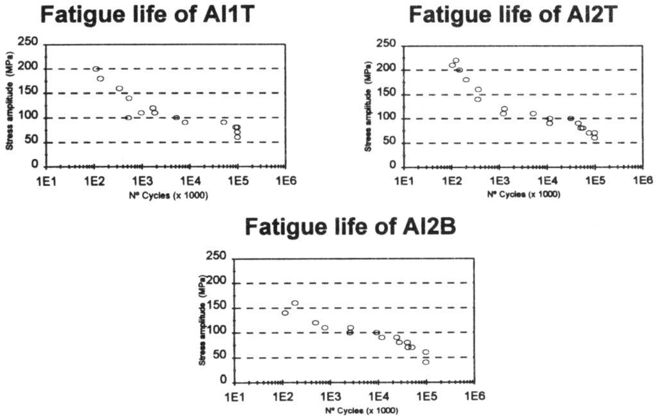


Figures 1, 2 and 4.


Fatigue life of Al1T

Fatigue life of Al2T

Fatigue life of Al2B

Figure 3. Fatigue life of Al1T, Al2T and Al2B.