EFFECTS OF DEGASSING PROCESS ON HIGH CYCLE FATIGUE PROPERTY IN CASTING ALUMINUM ALLOY

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ABSTRACT

Rotating bending fatigue tests were performed in order to investigate effects of degassing process on a casting aluminum alloy. Degassing process was used for decreasing casting defects in casing aluminum alloys. It was clear that the degassing process had a remarkable effect for the reduction of casting defects and the fatigue strength of degassed alloys was improved in the whole range of fatigue life and the fatigue strength at 10^7 cycles in comparing with those of non-degassed alloys.

1 INTRODUCTION

Casting aluminum alloys are used for structural materials of transportation machines and other industrial materials [1-3]. Most of their structural components are subjected to fatigue load. But it has been known that the fatigue strength of casting aluminum alloys is affected by casting defects such as micro shrinkage and porosity. Therefore, hot isostatic pressing (HIP) [4,5], squeeze casting [6-8] and semi-liquid casting [9] have been practically examined to improve the fatigue strength on the basis of a decrease in casting defects until now. In this study, a degassing process was used as a method for reducing casting defects of aluminum alloys. Rotating bending fatigue tests were performed on aluminum-silicon-magnesium casting alloy in order to investigate the influence of degassing process in the high cycle fatigue properties such as fatigue strength and crack properties.

2 EXPERIMENTAL PROCEDURE

The material used in this study is a aluminum-silicon-magnesium casting alloy (JIS AC4CH). Non-degassing (ND) materials and degassing process (DG) materials were prepared with using same dies. Casting blocks shown as in Figure 1 were processed by a

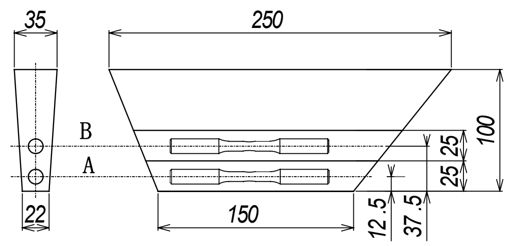


Figure 1. Extracted position of specimens.

gravity casting, and after that the T6 treatment (solution heat treatment 813K×4hrs → water cooling and aged treatment 433K×4hrs) was performed. Chemical compositions of NG and DG materials are shown in Table 1. Degassing process system is shown in Figure 2. Argon gas is poured with bubbling into molten melt, and a hydrogen gas in the molten melt is diffused in the argon gas bubbles, and also, other impurities are attached by the argon gas bubbles. And those bubbles floated up on the molten melt surface, and after that the melt is filtered with ceramic filter. And then, higher purity molten melt will be obtained. As the degassing process is possible treatment in the casting process, it is available from points of cost decrease and production improvement in comparing with the case of secondary production systems.

Test specimens were made from the positions of Figure 1. The specimens of the upper position (12.5mm from the bottom of casting block) are the specimens A, and ones of the lower position (37.5mm from the bottom) are the specimen B. The shape and size of the test specimens is shown in Figure 3. Rotating bending fatigue tests were performed in conditions of frequency 2760 rpm in air at room temperature. Fracture surfaces are observed after the tests by a field-emission type scanning electron microscopy(FE-SEM) in order to specified the fracture sites.

Table 1. Chemical compositions(wt.%).

	Cu	Si	Mg	Zn	Fe	Mn
DG	0.032	6.92	0.307	0.009	0.158	0.007
ND	0.029	7.26	0.328	0.009	0.163	0.006

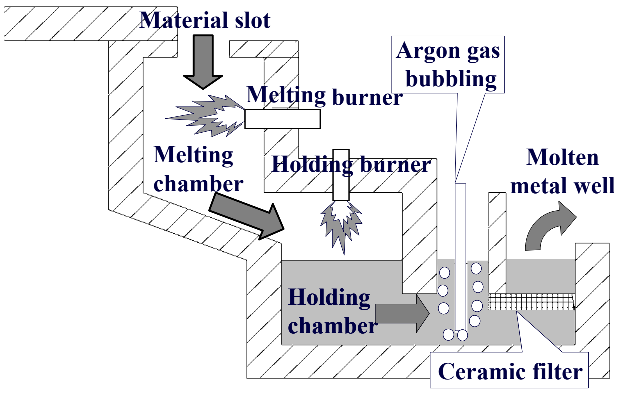


Figure 2. Schematic degassing process system.

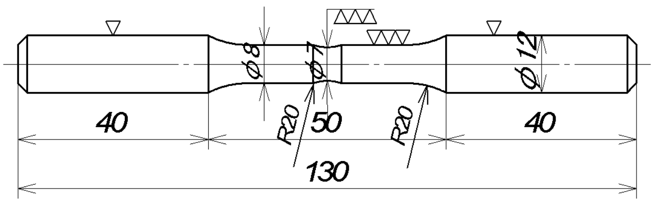


Figure 3. Shape and size of fatigue test specimen. unit:mm

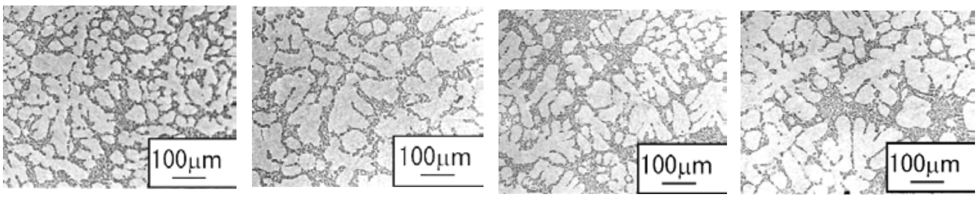
3 RESULTS AND DISCUSSION

3.1 Microstructure and mechanical property

Figure 4 shows microstructures of each material. All of microstructures show typical dendrite structures with aluminum matrix and eutectoid silicon structures. There does not seem so clear difference in DG and ND materials, but the A (the lower position) specimens shows a little fine dendrite structures in comparing with that of the B (the upper position) specimens by reason of difference in cooling rate. Table 2 shows the mechanical properties of each material. They show almost same strength and hardness, but there is a little difference in reduction of area ϕ(%) because of existence of a number and larger sizes of casting defects in non-degassing process materials as showing in the following section.

3.2 Measurement of casting defects

In order to investigate the decreased effect of casting defects by the degassing process,



(a)DG-A (b)DG-B (c)ND-A (d)ND-B

Figure 4. Microstructure of all materials.

Table 2. Mechanical property.

Materials		Proof strength $\sigma_{0.2}$ (MPa)	Tensile strength σ_B (MPa)	Reduction of area ϕ (%)	Vickers hardness Hv
DG	A	233	302	15.3	111
	B	235	279	6.5	114
ND	A	243	288	5.6	109
	B	232	274	3.1	110

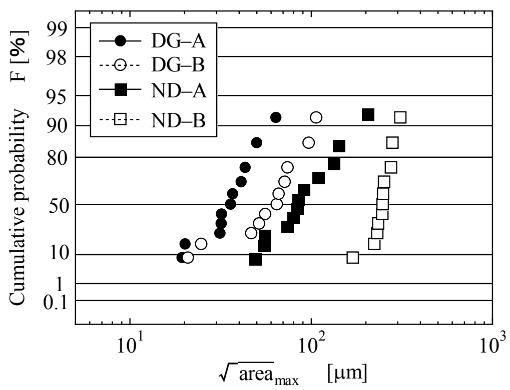


Figure 5. Plots of maximum defect size in Extreme statics paper.

several number of tablet with 8mm in diameter were cut from four kinds of material(DG-A, DG-B, ND-A and ND-B). Sample numbers are 10~11 for each materials. The maximum defects size $\sqrt{area}_{max}$ (μm) in each tablet was measured and plotted on Extreme statistical paper as shown in Figure 5. From these results, it is clear that the degassing process was effective treatment for decreasing the size of casting defects.

3.3 Fatigue test results

Figure 6 shows a S-N diagram of fatigue tests. Although data of fatigue lives of all materials show a scatter, the average lives of DG materials show clear the longer lives in comparing with those of NG materials in all range of fatigue lives. And also, the A specimens (the lower position) show the longer lives than those of the B specimens (the upper position) in DG and NG materials. The fatigue strengths at 10^7cycles were about 130MPa for DG-A material, about 120MPa for DG-B materials, 100MPa for NG-A materials and about 80MPa for NG-B materials. From these results, as it is clear that the degassing process increase the fatigue live and the fatigue strength at 10^7 cycles, the degassing process is effective treatment for the improvement of fatigue property. And about the influence of the position of test specimens, the A specimens is superior property for fatigue strength as the crack propagation resistance because of finer dendrite microstructure in comparing with the B specimens.

3.4 SEM observation of fracture surface

Some examples of observation results are shown as Figures 7 and 8. Figure 7 (a) and (b) show the crack initiation sites of ND-A and ND-B materials, respectively. In the ND materials, all of the crack initiation sites were casting defects near the surface or on the surface such as shown in Figure 7 (a) and (b), respectively. Figure 8 (a) and (b) show the crack initiation sites of DG-A and DG-B materials, respectively. In the DG materials, there are two types of initiation sites, one is the case of surface slip without defects as shown in Figure 8(a), the other is the case of smaller defects in comparing with that of NG materials as shown in Figure 8(b). From these results, the degassing process is effective treatment to make smaller the number and the size of casting defects, and then it seems to restrict the fatigue crack initiation as resulting to the improvement of the fatigue strength.

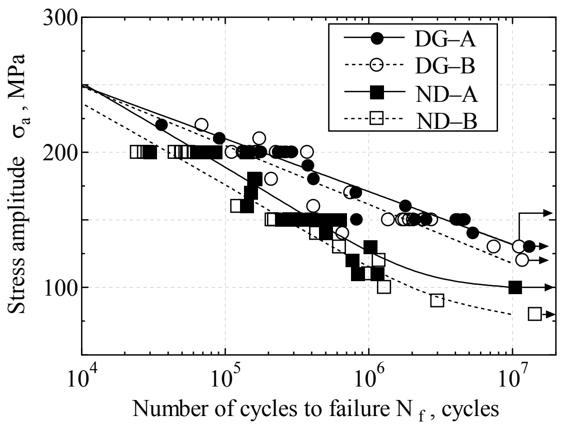
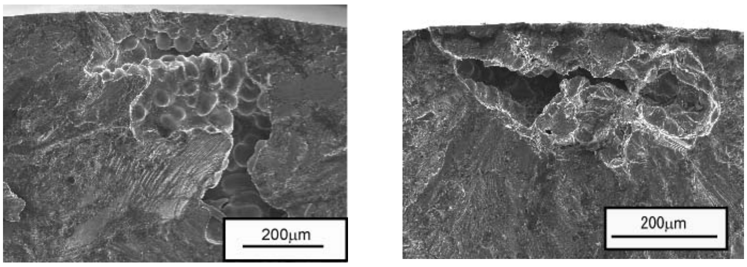


Figure 6. S-N diagrams of all materials.

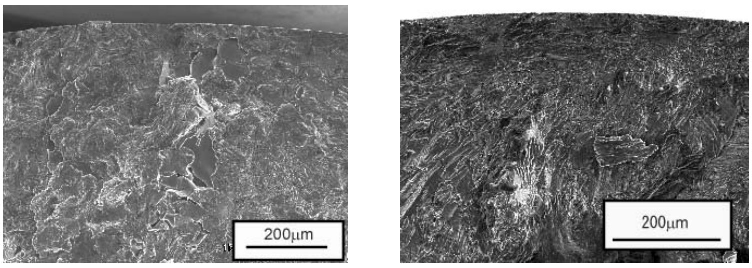
3.5 Fatigue life distribution

In order to investigate the fatigue life distribution for DG and ND materials, and A and B specimens, fatigue tests were performed for 9 to 10 number of specimens for the higher level (200MPa) and the lower level (150MPa) stress amplitudes. The results were plotted



(a)ND-A (150MPa, 2.47×10^5)　　(b)ND-B (130MPa, 6.23×10^5)

Figure 7. Crack initiation sites of ND materials.



(a)DG-A (170MPa, 8.16×10^5)　　(b)DG-B (150MPa, 4.06×10^5)

Figure 8. Crack initiation sites of DG materials.

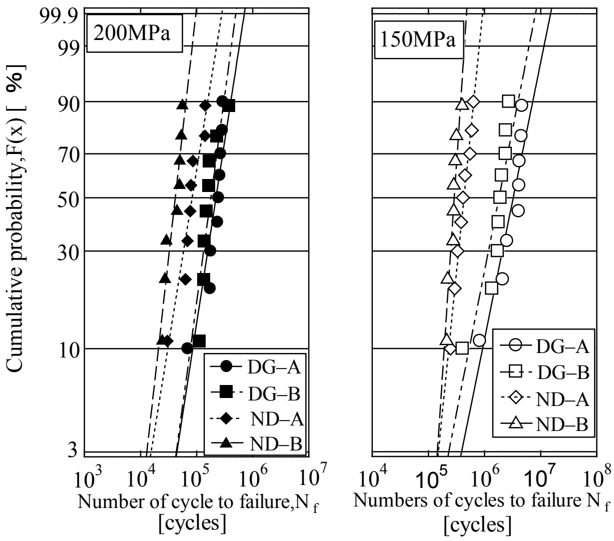


Figure 9. Fatigue lives distribution.

on Weibull statistical paper as shown in Figure 9. Figure(a) shows the case of 200MPa, and (b) shows the case of 150MPa. From the results, there is no clear difference in DG and ND materials and A and B specimens for the case of 200MPa, but the scatter of fatigue lives in ND materials are smaller those of DG materials for the 150MPa. This means that all of the crack initiation sites of ND materials were casting defects, on the other hand, crack initiation sites of DG materials were two cases, one was the case of surface slip without defects, the other was the case of smaller defects. Therefore, for the DG materials, the crack initiation period and the small crack propagation behavior might be affected from microstructure, and then, the fatigue lives of DG materials had the larger scatter than those of ND materials.

4 CONCLUSUION

Rotating bending fatigue tests in the degassed process aluminum alloy were performed in order to investigate the degassed effects on the high cycle fatigue property. The results are summarized as the followings,

(1) It is clear that the degassing process was effective treatment for decreasing the size of casting defects.
(2) The fatigue lives and the fatigue strength at 10^7 cycles of the degassing process materials were higher than those of non-degassing process materials.
(3) The crack initiation sites of the degassing process materials were two cases; one was the case of surface slip without defects on the fracture surface, and the other was the case of smaller defects in comparing with non-degassed materials. On the other hand, all of initiation sites were casting defects on the fracture surface in the non-degassing process materials.
(4) The scatter of fatigue lives of the degassing process materials was higher than those of non-degassing process materials because of difference in the crack initiation sites.

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