Fatigue Strength of Al Cast Alloy in Bio-Diesel Fuel

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Abstract. In order to investigate the effect of bio-diesel fuel (BDF) on fatigue strength of a squeeze cast Al alloy, AC4CH-T6, rotating bending fatigue tests were carried out using plain specimens in BDF made by rapeseed oil. The results were compared with those in turbine oil and in ambient air. Fatigue life was longer in turbine oil and shorter in BDF than that in ambient air. Fatigue life in each environment tested was mainly occupied by the growth life of a crack smaller than 1mm, meaning that the difference in fatigue strength affected by environment was mainly yielded in the growth process of a small crack. The crack growth rates were suppressed in turbine oil and accelerated in BDF in comparison with those in air. BDF contained much water dissolved from air in the early stage of fatigue process. The suppression of crack growth was caused by wedging effect of oil and the acceleration was caused by corrosion due to dissolved water in BDF, which was larger than the suppression due to the wedging effect.

Introduction

Bio-diesel is a renewable fuel for diesel engines, which is made from agricultural co-products and byproducts such as soybean oil, other natural oils, and greases. Bio-diesel Fuel (BDF) is better for the environment because it is made from renewable resources and has lower emissions compared to petroleum fuel [1-5]. Since it is invented from renewable resources, nowadays it has been widely used in many countries around the world. Many studies have also been carried out on manufacturing method and process, combustion characteristic and waste gas pollution on BDF. However, research on service properties of materials and equipments with BDF is quite limited, although it is very important due to the raw materials and components of BDF is complex considerably, especially BDF has high hygroscopicity, easy to absorb water from the atmosphere to generate organic acid during the storage and use lead to cause corrosion [6-12]. There is also need to discuss the corrosion and fatigue properties to ensure the safety of BDF devices.

In present study, in order to investigate the effect of BDF on fatigue strength of a squeeze cast Al alloy, AC4CH-T6, rotating bending fatigue tests were carried out using plain specimens in BDF based rapeseed oil. The effect of dissolved water in BDF on fatigue strength was also discussed based on the results the fatigue test in high humidity of 85%.

Material and experimental procedures

The material used in this study was a squeeze cast Al alloy, AC4CH-T6, with the chemical composition (wt. %) of the alloy being 7.02Si, 0.08Fe, 0.37Mg, 0.12Ti, and the remainder Al. The alloy was solution treated at 535°C and aged at 180°C for 2 hr, then machined to specimens. The mechanical properties of aged alloy were 222MPa of 0.2% proof stress, 307 MPa of tensile strength, 712 MPa of true fracture strength and 14.5% of reduction of area, respectively.
Figure 1 shows shape and dimensions of specimen. The specimen has a circumferential notch with a blunt and shallow shape to localize the crack initiation site and make easier the crack observation. However the stress concentration factor due to this notch is about 1.04, so this specimen can be regarded as a plain one. Prior to fatigue testing, all of the specimens were slightly electro-polished by 20 µm to secure the direct surface observation. Fatigue tests were carried out using an Ono-type rotating bending fatigue testing machine operated at 50 Hz repetition in controlled humidity (RH) of 85% and distilled water, and trickles oil into the specimen central part continuously at flow about 240 (cm³/min) rates during the fatigue tests in oil conditions. The deviation of humidity was RH±5% and temperature of water was 30℃±3℃. The kinetic viscosities and test temperatures of all kinds of oil were shown in Table 1, BDF used in this study was produced based the rapeseed oil with the content of 60% methyl oleate through transesterification. The observations of the crack morphology and the fracture surface were conducted under a scanning electron microscope (SEM) or under an optical microscope by using the plastic-replica technique.

<table>
<thead>
<tr>
<th>Oil Type</th>
<th>Turbine oil</th>
<th>Light oil</th>
<th>BDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity</td>
<td>88.6</td>
<td>3.8</td>
<td>6.1</td>
</tr>
</tbody>
</table>

Experimental Results and Discussion

Figure 2 shows the S-N curves in all test conditions. Fatigue life was longer in turbine oil and shorter in BDF than that in ambient air. Increasing rate of fatigue lives in all kinds of oils against those in air was shown in Fig.3. The influence of oil on fatigue life in higher stress was larger than that in lower level, which indicated this effect also has stress dependency, same to the wedging effect of oil on fatigue crack growth.
The observation results of the crack morphology shows cracks occurred from $\alpha$ phase or boundary of eutectic Si and $\alpha$-phase and rectilinear crack propagation in a zigzag type similar to the sliding characteristic of aging specimens, meaning cracks initiation and propagation were dominated by the microstructure of material and there were no differences in each environment.

Figure 5 shows crack growth curves in oil and in air. Fatigue life in each environment tested was mainly occupied by the growth life of a crack smaller than 1mm, meaning that the difference in fatigue strength affected by environment was mainly yielded in the growth process of a small crack. The crack growth rates were suppressed in turbine oil and accelerated in BDF in comparison with those in air. Fig. 6 shows fatigue fracture surfaces in all conditions. Many cracking in $\alpha$-phase or boundary of eutectic Si and $\alpha$-phase were observed same to the cracking morphology in microscope described above, meaning that difference of environment on cracking initiation and propagation cannot be confirmed. Moreover, more striations were observed in oil and in air.

![Fig.5 Crack growth curves in oil and in air.](image)

![Fig.6 SEM micrographs showing fatigue fracture surfaces in air and in BDF.](image)
BDF contained much water dissolved from air in the early stage of fatigue process. The suppression of crack growth was caused by wedging effect of oil and the acceleration caused by corrosion due to dissolved water in BDF which was larger than the suppression due to the wedging effect [13-16].

It is very necessary to further study on fatigue strength and fracture mechanics of BDF devices because those were affected by many factors such as raw materials, temperature and humidity and so on during practical application [17-20]. Therefore, the decrease of fatigue strength caused by dissolved water in BDF must be considered when engineers design new Bio-diesel Fuel equipment.

Summary

Fatigue life was longer in turbine oil and shorter in BDF than that in ambient air. Fatigue life in each environment tested was mainly occupied by the growth life of a crack smaller than 1mm, meaning that the difference in fatigue strength affected by environment was mainly yielded in the growth process of a small crack. The crack growth rates were suppressed in turbine oil and accelerated in BDF in comparison with those in air. BDF contained much water dissolved from air in the early stage of fatigue process. The suppression of crack growth was caused by wedging effect of oil and the acceleration was caused by corrosion due to dissolved water in BDF which was larger than the suppression due to the wedging effect.

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References


