EFFECTS OF SHOT PEENING ON THE CORROSION FATIGUE LIFE OF AL 7075-T6

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ABSTRACT

The effect of shot peening on fatigue life of Al 7075-T6 under corrosive environment is investigated. Impeller type shot peening machine and spherically conditioned cut wire shot were used for the process. Before fatigue testing, specimens were submerged in 3.5% NaCl solution from one week to one year under room temperature. Rotating beam fatigue test machine was used to evaluate the fatigue life. Experimental results show that shot peening has superior effectiveness to increase the corrosion fatigue life of Al 7075-T6. In case of shot peened specimen, only 18% of the fatigue limit was reduced even after submerging for one year. In contrast, 42% of the fatigue limit was reduced in case of un-peened specimen.

Key words: pre-corrosion, fatigue life, fatigue limit, S-N curve

INTRODUCTION

Corrosion is a term defined as oxidation of a metal, which is observed in many parts of our living, and is greatly influenced by the surface state of the metal and its surrounding environment. Economic loss caused by corrosion is enormous (Jones, 1996), of which examples include leakage of water caused by corrosion of water-supply pipes and damages caused by corrosion of steel in the steel-reinforced concrete structure.

In general, a structure is subject to fatigue crack when a certain load is applied repeatedly. If the structure under fatigue load is subject to corrosion, it reaches destruction far faster than in an inert environment. This phenomenon is called corrosion fatigue. Damage of a material caused by corrosion fatigue is much more severe and faster than a simple sum of damages caused separately by fatigue and corrosion, so that corrosion fatigue can cause unexpected damages in industrial sites or engineering fields (Lee, 1988). Especially, corrosion fatigue life of a metal is known to be greatly affected by the surface state of the metal (Kwon, 1989). Therefore, mechanical structures should be designed in consideration of corrosion fatigue damage.

Preliminary studies have demonstrated that shot peening has excellent effects on fatigue life of parts by increasing the parts' resistance to corrosion (Koehler, 1984; Speidel, 1981; Kirt and Jarrett, 1984). Shot peening usually increases hardness and induces compressive residual stress in the material's surface. When repeated load of sufficient magnitude is applied to a material, a slip bands are formed. If the material is shot-peened, a protective layer is formed on the material's surface and the resistance to corrosion fatigue increases (Koehler, 1984; Mueller, Verpoort and Gessinger, 1981). This paper examines the effect of shot peening on the corrosion fatigue life of Al-7075-T6 by investigating fatigue life characteristics of unpeened and shot-peened specimens depending on pre-corrosion time.

EXPERIMENT

Specimens used in this experiment were prepared with the high-strength aluminum alloy Al 7075-T6. Fatigue specimens were machined to have a minimum diameter of 8mm as shown in Fig. 1. Specimens were polished with #2000 sand paper and then with metal polish solution.

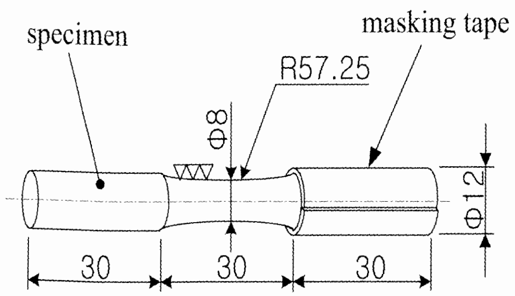

Figure 1. Rotating beam fatigue specimen.

Based on a preliminary study in which peening conditions resulting in the longest fatigue life were studied, 0.8mm diameter shot was used with the peening time fixed at 4 min. From this study, it was verified that an arc height of 0.341 mmA was optimal for this alloy (Cheong and Kim, 2003).

An impeller type shot peening machine and spherically conditioned cut-wire of hard-drawn steel wire cut into a certain size were used. 3.5% NaCl solution made of a mixture of NaCl for reagent and distilled water (Aydin and Savaskan, 2004 ; Huneau and Mendez, 2003) was prepared as corrosive environment in this experiment. The test specimens were made airtight free of dissolved oxygen and had been kept under water for one week to one year at room temperature. While the test specimens were kept under water, the NaCl solution was agitated every 24 hours in consideration of NaCl corrosion. The test specimens that reached the pre-set corrosion time were removed from the NaCl solution, and were washed until salt product that had formed on their surface was completely removed. After washing, the specimens were dried in air for moisture to evaporate and were fatigue tested at room temperature.

The change of hardness distribution in the material's surface before and after shot peening was evaluated. To do so, the specimens were cut at the center using a diamond cutter and the cut faces were press-mounted and finely polished. Then, with Micro Vickers hardness tester MOK-E3, the hardness distribution was measured in the direction from the surface to the center of the specimens. The measurement conditions were 50 gf compressive load and 20 s holding time Measurements were taken at distances of 0.02 mm from the surface to a depth of 0.4mm.

Fatigue tests were performed with the rotating beam fatigue machine in order to determine the fatigue life before and after shot peening. An Ono type 4-node rotary bending fatigue tester (SHIMADZU, H7) was used. Tests were performed in fully reversed loading (R = -1) and the increase and decrease of the applied stress was controlled with pendulum weights based on the tensile strength at break. In order to obtain the fatigue strength, the specimens were tested up to 10^6 cycles. Rotatio count of the fatigue tester was set to 1,800~2,200 rpm (30-37 Hz).

RESULTS AND DISCUSSION

Surface hardness of the un-peened specimens was about 186 HV while that of the shot peened specimens was about 217 HV showing about 17% increase. This increase in surface hardness due to shot peening is caused by the kinetic energy of the shot causing plastic deformation and work-hardening in the material's surface.. The difference of hardness between un-peened and shot peened specimens became smaller with increasing distance from the surface because of the decreasing energy transfer from the shot into the surface layer.

Surface residual compressive stress as-measured on shot peened specimens gradually increased with increasing Almen intensity from 0.126 mmA to 0.498 mmA. At the lowest Almen intensity of 0.126 mmA, the surface residual compressive stress was the largest and as Almen intensity increased, the surface residual compressive stress decreased. This supports results of several preliminary studies in that surface residual compressive stresses become smaller and maximum residual compressive stresses directly below the surface become larger as Almen intensity increases. At the optimum peening condition, the surface compressive residual stress was measured to -87.3 MPa.

Figure 2 shows S-N curves for un-peened specimens pre-corroded for one week to one year. As shown in the S-N curves, the fatigue strength decreased considerably as the exposure time for pre-corrosion increased. Figure 3 shows S-N curves for shot-peened specimens pre-corroded for one week to one year. As shown in the S-N curves, the fatigue strength of shot peened AL 7075-T6 did not decrease significantly. As illustrated in Figures 2 and 3, the fatigue strength of un-peened specimens was 206 MPa while that of shot-peened specimens was 315 MPa showing 52% increase.

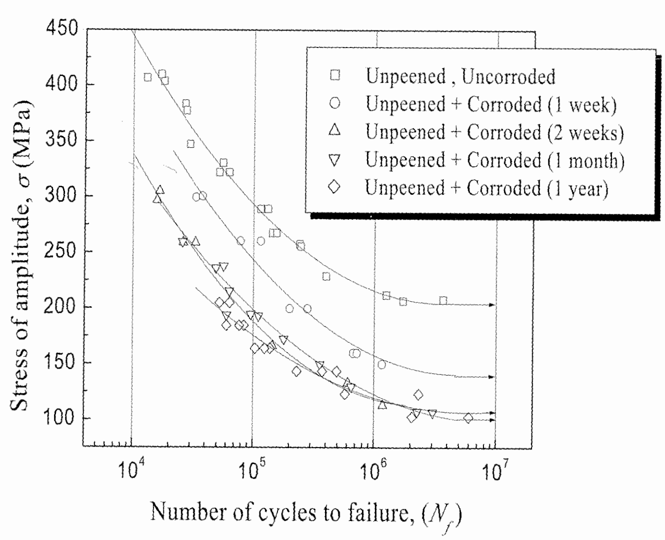

Figure 2. S-N curves of unpeened specimens of Al 7075-T6, effect of pre-cor

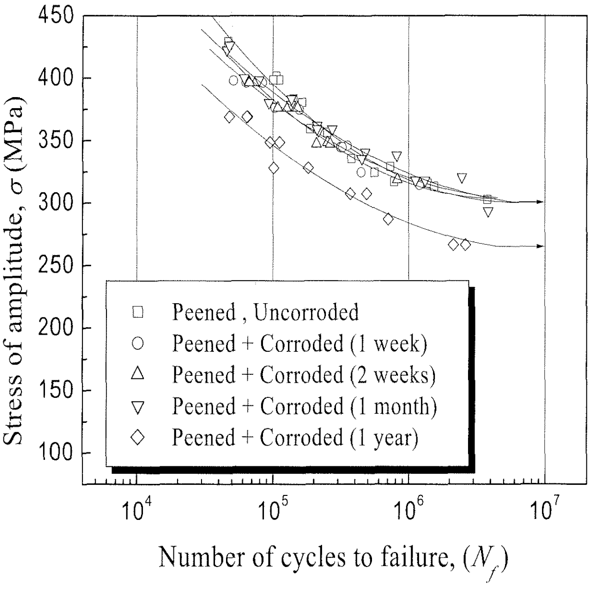

Figure 3. S-N curves of shot peened specimens of Al 7075-T6, effect of pre-corrosion.

Figure 4 illustrates the change in fatigue strengths of shot peened and un-peened specimens depending on pre-corrosion exposure from one week to one year. For un-peened specimens without pre-corrosion, the fatigue strength was 206 MPa. The fatigue strengths after one week and two months exposure to the corrosive environment decreased to 150 MPa (about 27% loss) and 125 MPa (about 39% loss), respectively. However, the fatigue strengths of specimens pre-corroded between one month and one year did not show a big difference. For shot peened specimens without pre-corrosion, the fatigue strength was 315 MPa which only slightly changed after pre-corrosion up to 6 months. After extending the exposure to pre-corrosion from 6 months to one year, it decreased by only about 16% to 266 MPa. Taking a one year pre-corrosion as the reference, the fatigue strength of un-peened specimens decreased by about 42% while that of shot peened specimens decreased by only about 16%. This demonstrates that shot peened specimens have better characteristics under corrosion than un-peened specimens. It is thought that the shot peening-induced residual compressive stresses at and below the surface form a protective layer resulting in an increase of the resistance to corrosion fatigue crack initiation (Lifka and Sprowls, 1970; Sprowls and Brown, 1962).

As discussed above, shot-peened specimens have better resistance to corrosion fatigue characteristic which is thought to be applicable afterwards to actual structures under corrosion.

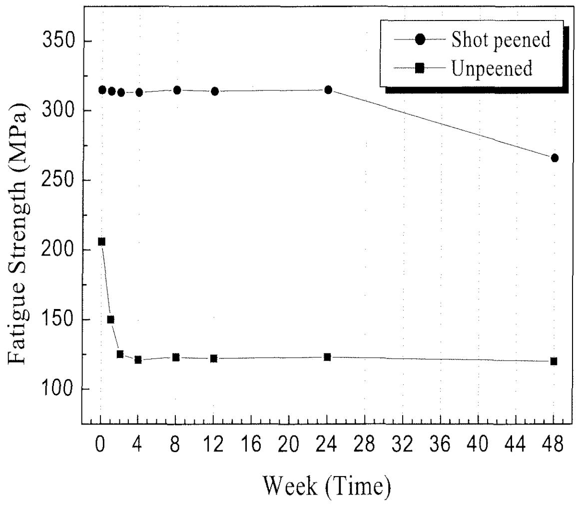

Figure 4. Fatigue strengths of un-peened and shot peened specimens of Al 7075-T6, effect of exposure time to pre-corrosion.

CONCLUSIONS

From this investigation on the effect of pre-corrosion on the fatigue performance of un-peened and shot peened specimens of Al 7075-T6, the following can be concluded:

(1) Compressive residual stresses created on the surface of shot-peened specimens and their high hardness seem to be factors increasing fatigue strength and fatigue life.

(2) Fatigue strength and fatigue life of un-peened specimens are greatly decreased by pre-corrosion while those of shot peened specimens are only slightly decreased.

(3) Un-peened specimens under corrosion show marked decrease of fatigue characteristics already after short pre-corrosion while shot peened specimens did not show any significant change in fatigue characteristics even after long-term exposure. This demonstrates that shot peening can be a useful processing method for structures under corrosive environments.

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