EFFECT OF ULTRASONIC SHOT PEENING ON MICROSTRUCTURE, LOW CYCLE FATIGUE AND CORROSION BEHAVIOR OF AA7075 ALUMINIUM ALLOY

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CHAPTER 9
SUMMARY AND SUGGESTIONS FOR FUTURE WORK

9.1 Introduction

This chapter summarizes the important observations from the thesis and comprises suggestions for the future research.

9.2 Summary

A detailed study on the nanostructuring at the surface resulting from ultrasonic shot peening was carried out and its effect on the Low cycle fatigue behavior and corrosion behavior of AA7075 aluminium alloy. Nanostructuring near the surface region was observed from USSP treatment with 3 mm hard steel balls. The thermal stability of the nanostructured surface layer was also studied at a temperature range of 150-350°C. LCF behavior of AA7075 in un-USSP and USSP treated for different durations of treatment was carried out at room temperature, at different total strain amplitudes and a constant strain rate of 5×10^{-3} s^{-1}. The effect of heat treatment pre- and post- USSP treatment on LCF behavior was also taken into consideration. The important observations made on different aspects are listed at the end of the respective chapters and the major findings are summarized below:

9.2.1 Surface modification

Nanostructuring near the surface region of AA7075 resulting from ultrasonic shot peening treatment was observed for different durations, from 15 seconds to 300 seconds. Near surface microstructure was examined using TEM and XRD and a nanostructure of 19-28 nm in size was developed with no evidence of phase transformation in the surface region. However, surface cracking was observed in the sample subjected to USSP for long duration of 300 seconds. The gradient microstructure formed can be distinguished from the top surface as equiaxed nanograins, equiaxed ultrafine grains, elongated ultrafine grains and strain free matrix. The depth of deformation increased with increase in USSP duration. Surface roughness and compressive residual stress also increased with the duration of USSP. Microhardness of the USSP 300 specimen was increased by $\sim 20\%$ and found to be maximum at the surface region and it gradually reduced from surface towards the interior.

9.2.2 Thermal stability

Nanograins were thermally stable upto 250°C, beyond which grain coarsening occurred but still the size was in ultrafine regime (<100 nm) even after annealing at 350°C for 30 minutes. The process of USSP accelerated the precipitation kinetics but did not alter the sequence of precipitation. The high thermal stability of the nanograins was due to the pinning effect of the precipitates at the grain boundaries which retarded the grain growth. For USSP treated specimen the major strengthening mechanism was dominated by the grain boundary strengthening and dislocation strengthening whereas the contribution of solid-solution strengthening and precipitate strengthening was relatively less.

9.2.3 Low Cycle Fatigue behavior

Pronounced enhancement in LCF life resulted from the USSP treatment for 180 seconds. Enhancement in LCF life in the USSP 180 was due to combined beneficial effect of grain refinement in the surface region and the associated compressive residual stresses without damage of the treated surface. Initially there was mild cyclic softening, followed by stabilization of the cyclic stress response in the un-USSP condition whereas, there was initially cyclic hardening in the USSP treated condition followed by stabilised stress response. USSP treatment for 300 seconds (USSP 300) caused damage to the surface, cracks were developed and fatigue life was reduced. For pre- and post- USSP treatment, in ST-USSP-PA condition the high density of η' precipitates along with nanograined surface layer resulted in delaying the process of crack initiation and thus LCF life was enhanced. Pinning of dislocations due to precipitates led to increase in the ductility and simultaneous increment in LCF properties. Decrease in dislocation density and relieving of compressive residual stress was observed after the stress relieving treatment which resulted in decrease in the LCF life.

9.2.4 Corrosion and stress corrosion behavior

The USSP 15 sample exhibited best corrosion resistance among all the samples, including the un-USSP in 3.5 wt.% NaCl solution. Higher passivation resulting from the nanostructured surface layer, lower plastic deformation, less microstrain, lower dislocation density and compressive stress promoted formation of dense, stable and tenacious passive film of aluminium hydroxide. USSP treatment for long duration of 300 seconds developed largest surface roughness, which acted as active site for pitting and led to lowering of the corrosion resistance.

After prolonged immersion of 360 hours in 3.5 wt.% NaCl, the USSP 15 sample exhibited superior corrosion resistance which confirms that this surface treatment is effective even for longer service period. For optimization of USSP duration the sample USSP treated for 15 seconds showed the best corrosion resistance amongst the all even after prolonged immersion in aggressive environment. The SEM/EDS results confirmed that pitting was probably associated with the cathodic second phase precipitates. The passive layer mainly constituted $Al(OH)_3$ with Al_2O_3 which was confirmed by XPS analysis. The enhanced stress corrosion resistance of USSP treated sample is mainly due to the combined effect of compressive residual stress and nanostructured surface layer.

9.3 Suggestions for Future Work

The following suggestions are made for future investigations based on the presentinvestigation:

1. Corrosion behavior of the AA7075 aluminium alloy after pre- and post- USSP heat treatment.

2. Detailed study on the effect of USSP on stress corrosion cracking behavior of AA7075 aluminium alloy.

3. Role of USSP treatment on high cycle fatigue behavior of AA7075 aluminium alloy at different stress levels.