The Influence of Shot Peening Process Parameters on Fatigue Strength of Ti-6AL-4V

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Abstract: Compressive residual stress is the major aspect in the extension of the fatigue life of aeroengine components. A common cold working method used to extend the fatigue life of machine components and decrease early fatigue failure is shot peening. Small metallic pellets that are moving quickly strike the material surface during shot peening, creating compressive forces. In this study, shot Peening surface treatment was proposed to improve surface integrity characteristics such as surface finish, hardness, and stable, advantageous compressive residual stress in turned Cylindrical Ti-6AL-4V specimen. The residual stress level in these specimen is evaluated accurately by X-ray diffraction, before and after the surface modification.

Keywords: *Shot peening, Residual stress, Fatigue Life*

1. Introduction

Materials that are repeatedly subjected to cycles of stress and strain display a process known as fatigue, which leads to gradual fracture and localized structural degradation. Fatigue happens at strains that are well within the material's tensile strength. Tensile stresses cause the material to separate when the component is bent or subjected to torsion, which starts the crack from spreading. Fatigue life is the number of cycles of varying loads and strains that a material will withstand before failing. Surface residual stress is one of the primary variables influencing fatigue life [1].

In engineering components, residual stresses are locked-up stresses that mostly arise from non-uniform volumetric change in metallic components. In the heat-affected zone, the differential weld thermal cycle causes residual strains to accumulate in the welds. As the welding process heats up and cools down, the kind and amount of residual stresses change constantly. Tensile residual stresses form during cooling when the metal begins to shrink, and they continue to grow in size until room temperature is reached. When residual stresses are applied in opposition to load-related stresses, they are generally considered advantageous. The influence of external tensile stresses can be neutralized or diminished by the introduction of compressive residual stresses within the work piece's outer layer [2].

2. Material :

The samples were prepared from Ti-6Al-4V forged plate, which is the same material that is used to manufacture turbine blades. In this investigation, ASTM Grade 5 Ti-6Al-4V was chosen because of its versatility and because it is the most often used alloy in aero engineering applications.

Table 1 Ti-6Al-4V material : Chemical composition

Elements (Wt.%)	**C**	**Al**	**H**	**Fe**	**O**	**N**	**V**	**Ti**
	0.031	5.81	0.0041	0.211	0.17	0.01	4.08	Balance

3. Methodology

The above defined objectives were accomplished by adopting a methodology for Experimental analysis. Brief description of the methodology followed during the course of this study is as follows;

a) Carry out the surface modification/enhancement of Dog Bone Specimen by Shot peening.
b) Conduction of Impact Test on the Specimens, before and after shot peening.
c) Conducting Fatigue Test and comparing the fatigue life of component before and after shot peening.
d) Microstructural Study of Specimen material before and after impact.

4. Microstructure Study

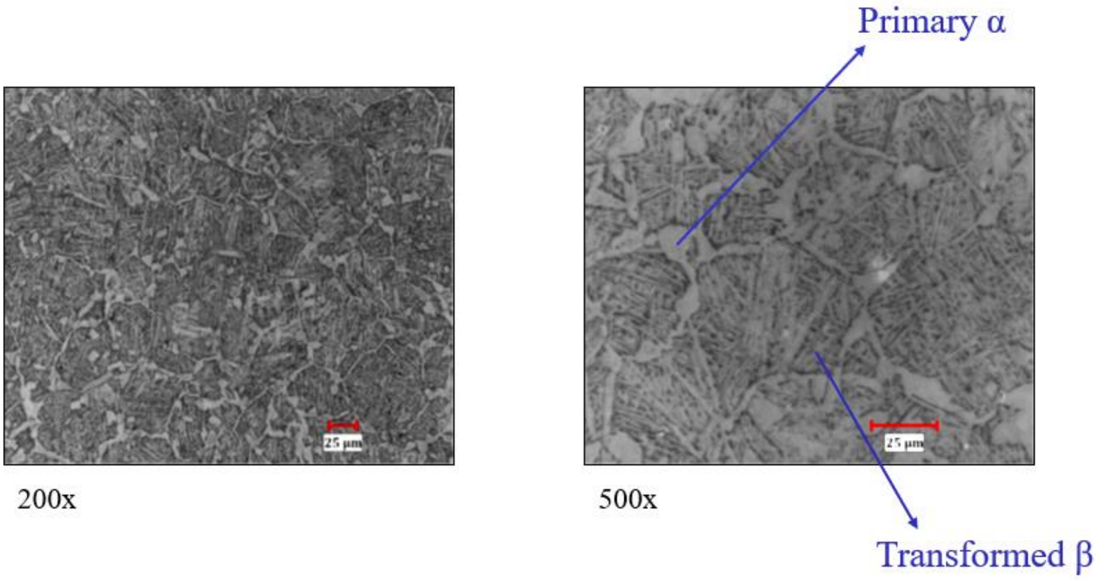

Figure 1 :Microstructure view of Ti-6Al-4V

The metallurgical phases present in an alloy have a huge impact on the properties of a metal component. Ti-6A-4V repeatedly undergoes the β ↔ α phase transformation upon rapid heating and cooling. This alloy is an α+β alloy, with 6 wt% aluminium stabilizing the α phase and 4 wt% vanadium stabilizing the β phase. At room temperature the microstructure at equilibrium consists mainly of the α phase (hcp) with some retained β phase (bcc). Aluminium and vanadium are the most frequently used substitutional alloying elements. Aluminium is an alpha stabilizer and vanadium is a beta stabilizer.

5. Fatigue Test

Uni-axial fatigue tests were conducted on as received, FOD impacted samples in an MTS servo-hydraulic testing machine at room temperature under load control condition and at a frequency of 10 Hz as per ASTM E466 test standard [3] . Three maximum stress levels namely 350, 450 and 650 MPa were employed at R = 0.5. On the average, three tests were conducted at each stress level[4,5].

6. Experimentation Details

The specimen to be shot peened is set up on the machine fixture. An S330 type shot ball with a diameter ranging from 0.3 to 1.10 mm is then shot at the specimen at a 40° angle, 49 m/s, for 3 seconds, with an intensity of 0.13 mm.

7. Results And Discussion

In this section the results obtained from various experimental tests are tabulated. The residual stress value, fatigue life and microstructure of two given specimens before and after shot peening are tabulated and compared as follows.

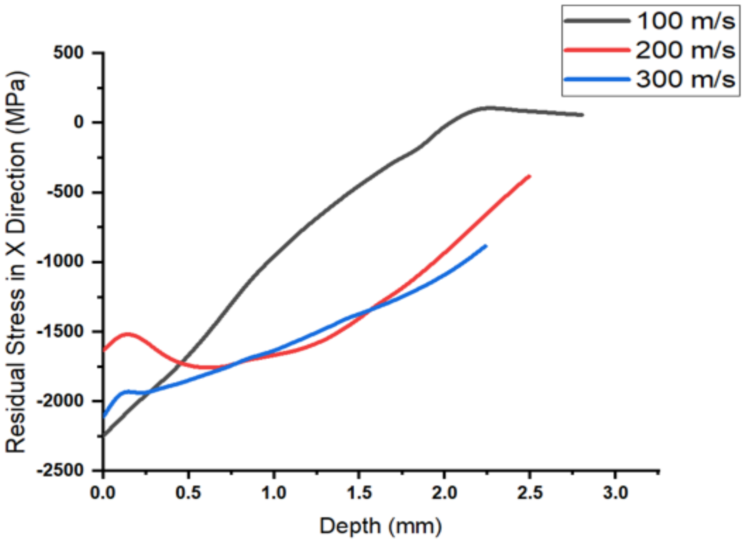

Figure 2 : Residual Stress in X direction vs Depth

Table 2 Fatigue Test Results

Stress Amplitude (Mpa)	**Number of Cycles to Failure**	
R=0.5	**Untreated**	**Surface Treated (Shot Peened)**
90% of UTS	9,190	11,777
80% of UTS	29,179	38,954
70% of UTS	48,253	69,386

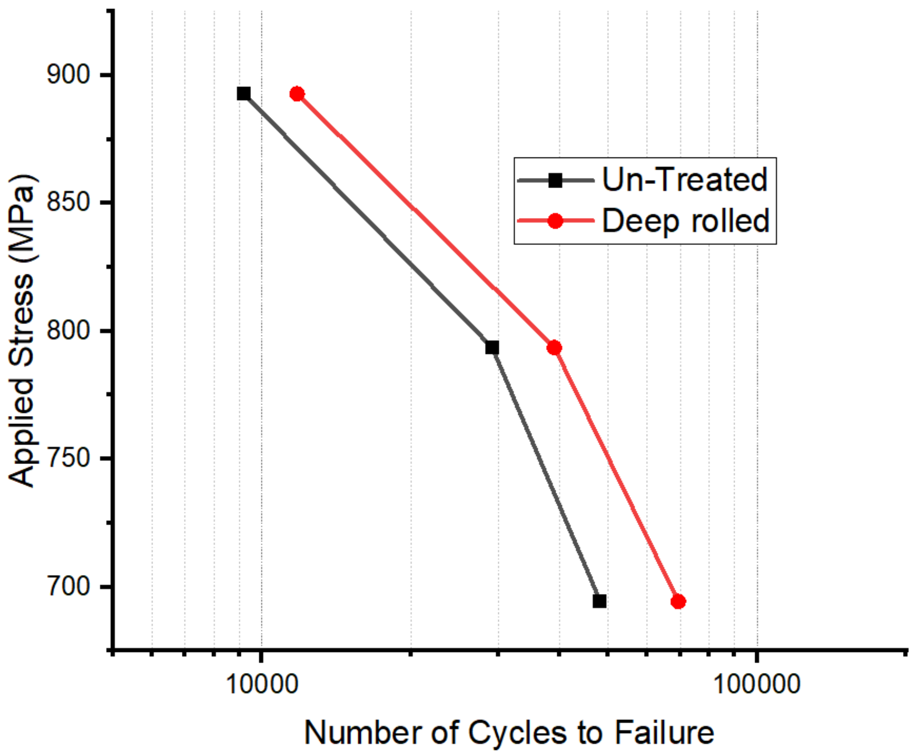

Figure 3 ***Logarithmic Graph of Fatigue Test Results***

8. Conclusion

- Residual stress varies with depth, and is maximum at a distance of 0.2-0.3 mm from point of impact in all the three directions considered in the present study.
- The number of cycles to failure of deep rolled specimen under 90%, 80% and 70% of UTS showed an improvement of 28.15%, 33.50% and 43.79% respectively.
- It is observed that the Number of cycles to failure of deep rolled specimen was improved by an average 35.1466%, when compared to that of the untreated specimen.

9. Reference

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