Materials Science and Engineering A 429 (2006) 30–35

MATERIALS SCIENCE & ENGINEERING A

www.elsevier.com/locate/msea

Enhancement of fatigue and corrosion properties of pure Ti by sandblasting

X.P. Jiang [a], X.Y. Wang [b], J.X. Li [a], D.Y. Li [b], C.-S. Man [c], M.J. Shepard [d], T. Zhai [a,*]

[a] *Department of Chemical and Materials Engineering, University of Kentucky, 177 Anderson Hall, Lexington, KY 40506, USA*
[b] *Department of Chemical and Materials Engineering, University of Alberta, Edmonton, Alta., Canada T6G 2G6*
[c] *Department of Mathematics, University of Kentucky, 757 Patterson Office Tower, Lexington, KY 40506, USA*
[d] *Air Force Research Laboratory, Materials and Manufacturing Directorate, WPAFB, OH 45433-7817, USA*

Received 9 January 2006; accepted 7 April 2006

Abstract

Commercially pure titanium was sandblasted with SiO_2 particles of 200–300 μm in diameter. It was found that the sandblasted samples exhibited an increase in fatigue strength by 11% over that of the untreated samples. The peak subsurface compressive residual stress produced by sandblasting was measured by XRD to be around 480 MPa. Three distinct regions were observed in the sandblasted samples, namely the severely deformed surface layer, the region deformed mainly by twinning, and the substrate. After recovery treatment below 300 °C, the surface layer of the sandblasted samples was transformed into a nano-crystalline structure, and its corrosion resistance was significantly improved.

Keywords: Sandblasting; Residual stress; Nano-surface layer; Surface enhancement

1. Introduction

Titanium and its alloys are widely used in aircraft engine applications for their high specific strength and good corrosion resistance. However, engine components such as blades and disks are subjected to high cycle fatigue (HCF) loading induced by high frequency vibrations within the engine. The resistance to failure due to HCF of engine components is currently one of the most critical challenges in turbine engine designs [1].

It has been demonstrated that surface enhancement treatments can play an important role in retardation of fatigue crack initiation and growth. These treatments, such as shot peening [2,3], laser shock peening [4], and low plasticity burnishing [5] are effective methods to enhance the fatigue properties, by inducing a compressive residual stress in the subsurface of metallic components.

Sandblasting as a surface treatment method is primarily used for surface cleaning and corrosion removal [6]. In this method, the sample surface is blasted repeatedly by high-speed sand particles, leading to the removal of surface oxide scale and generation of local plastic deformation in the surface layer. In addition to removing the surface corrosion, a compressive residual stress layer is often formed in the subsurface region. Microstructural changes due to sandblasting have also been reported. As an example, Wang and Li reported that nanometer-sized grains were formed in the surface layer of the sandblasted and subsequently annealed 304 stainless steel [7]. The nano-crystalline layer was found to improve the mechanical behavior and corrosion resistance. Suresh and co-workers have found that a nano-crystalline structure generally results in an increase in resistance to crack initiation under stress-controlled fatigue in pure Ni, but deteriorates the resistance to fatigue crack growth in this material [8].

The purpose of this work was to study changes of microstructure, fatigue properties, and corrosion properties in sandblasted commercially pure titanium.

2. Experimental procedure

2.1. Surface enhancement treatments and residual stress measurement

The material used in the present investigation was 35A commercially pure titanium with a thickness of 0.8 mm. The as-received material was annealed to recrystallize at 700 °C for 5 min. It was subsequently sandblasted with SiO_2 particles of 200–300 μm in diameter as shown in Fig. 1. The pressure of

* Corresponding author. Tel.: +1 859 257 4958; fax: +1 859 323 1929.
E-mail address: tzhai@engr.uky.edu (T. Zhai).

0921-5093/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.msea.2006.04.024

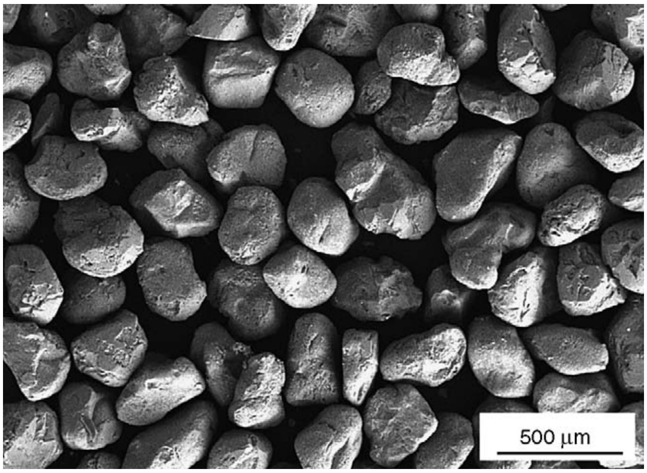

Fig. 1. Micrograph of sandblasting particles.

the compressed air used for sandblasting was about 300 psi. The magnitude of the compressive stress induced by sandblasting was typically controlled by varying air pressure, and the size and shape of the particles. In order to estimate the compressive residual stress after sandblasting by theoretical calculation, some titanium samples were sandblasted only on one side, which bent these samples. From the measurement of the bending curvature, the average residual stress induced by sandblasting could be estimated. The specimens for fatigue tests were all sandblasted on their both surfaces and showed no bending after sandblasting due to the balance of compressive residual stresses in both surfaces.

The average surface roughness, R_a, of the sandblasted sample was measured by a Taylor–Hobson Form Talysurf-50 machine. To calculate R_a, a mean line was set parallel to the general surface direction in a measured surface profile. R_a was then given by the sum of the absolute values of all the areas above and below the mean line divided by the sampling length. The size of the probe used in the roughness measurement was 16 nm in diameter.

X-ray diffraction residual stress analysis was performed to measure the profile of the subsurface residual stress due to sandblasting. A two-angle sine-squared-psi technique, in accordance with SAE HS-784 [9], was employed using the diffraction of Cu Kα radiation from the $(2\,1\,\bar{3}\,3)$ planes.

2.2. Fatigue tests

Tension and tension fatigue tests on the pure titanium before and after sandblasting were conducted in an Instron 8802 servo-hydraulic machine at room temperature with a frequency of 20 Hz and a load ratio (minimum load/maximum load) of 0.1. S–N curves were developed, based on the results of these tests.

2.3. Microstructure

In order to investigate the effects of heat treatment after sandblasting, the sandblasted sheet was annealed at 150 °C, 200 °C,

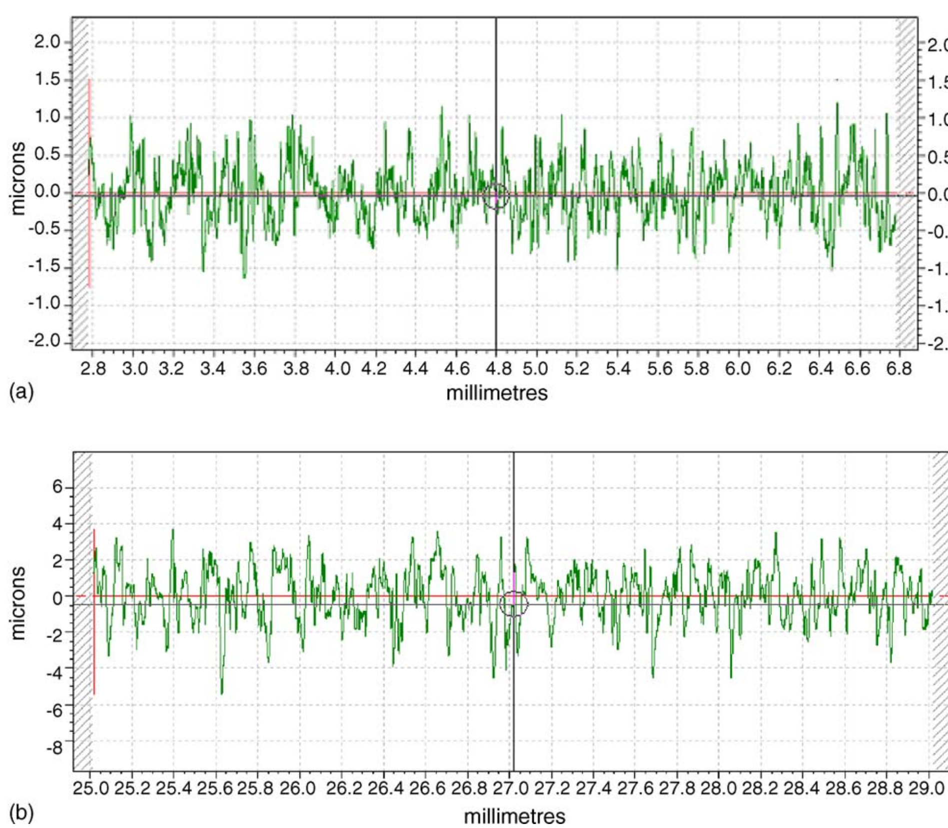

Fig. 2. Surface roughness of: (a) the untreated titanium and (b) sandblasted titanium.