

COMPARATION BETWEEN PULSED Nd:YAG LASER SUPERFICIAL TREATMENT AND CERAMIC COATING IN CREEP TEST OF Ti-6Al-4V ALLOY

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Keywords: creep, plasma-sprayed coatings, pulsed laser, titanium alloy.

Abstract: The objective of this work was evaluating the creep resistance of the Ti-6Al-4V alloy with superficial treatment of pulsed Nd:YAG laser and ceramic coating in creep test of Ti-6Al-4V alloy. It was used Ti-6Al-4V alloy as cylindrical bars under forged and annealing of 190°C by 6 hours condition and cooled by air. The Ti-6Al-4V alloy after the superficial treatment of pulsed Nd:YAG laser and ceramic coating was submitted to creep tests at 600°C and 125 at 319 MPa, under constant load mode. In the Nd:YAG pulsed laser treatment was used an environment of 40 % N and 60 % Ar, with 2.1 W of power and 10 m/s of speed. Ytria (8 wt.%) stabilized zirconia (YSZ) with a CoNiCrAlY bond coat was atmospherically plasma sprayed on Ti-6Al-4V substrates by Sulzer Metco Type 9 MB. The obtained results suggest the laser treatment on Ti-6Al-4V alloy improved its creep resistance.

Introduction

Development of alloys to increase creep strength, so permitting the use of higher turbine entry temperatures, has resulted in a general reduction in chromium and increase in aluminum content of nickel superalloys. This has had relatively little effect on high-temperature oxidation resistance, but has had a very significant adverse effect on corrosion resistance in the lower temperature range in salt-contaminated environments. Such environments are experienced by aircraft operating between airfields with approaches low over the sea with relatively short sector times. Improvements in aero gas turbine performance in terms of power, efficiency and weight have necessitated the use of high specific-strength, low-density materials [1,2].

One of the major factors limiting the life of titanium alloys in service is their degradation due to gaseous environments, in particular, the one containing oxygen, especially at elevated temperatures, during the long term use [3]. The sensitivity of titanium alloys to high temperature exposure is a well-known phenomenon. When titanium alloys are heated to temperatures above approximately 800°C, oxygen, hydrogen and nitrogen penetrate into them. The penetration of the above elements is thought to be undesirable because it increases hardness and brittleness while decreasing the toughness of the alloy [4]. Interaction of titanium alloys with oxygen not only causes loss of the material by formation of oxides, but also causes embrittlement in the subsurface zone of the component due to oxygen enrichment [3].

Titanium alloys is one of the most technologically important materials in the aeronautic and aerospace field for its high strength and lightweight. However, this material does not possess satisfactory tribological property. For this reason, surface strengthening of titanium alloys has attracted much attention [5].

Laser oxidation or nitridation of titanium surfaces are interesting for local hardening and improvement of wear resistance. It is known that melting of the surface layer to enhance the chemical reactions, avoiding significant vaporization and particulates removal, represents the main requirement in direct laser surface oxidation or nitridation of metallic targets in controlled reactive atmospheres [6,7].

To prevent the superficial oxidation and in the grain boundary the sample is plasma sprayed coated Yttria (8 wt%) stabilized zirconia (YSZ) with CoNiCrAlY (AMDRY 995C), an technique studied recently named thermal barrier coating (TBC). The YSZ ceramic coating, which is the outer layer, is used to insulation and the CoNiCrAlY metallic coating, which is the inner layer, prevent corrosion/oxidation at high temperatures and stick the YSZ ceramic coating to the titanium alloy. These characteristics provide an improvement in the creep resistance [8-12].

The aim of the present paper was to measure the creep resistance of the Ti-6Al-4V alloy with superficial treatment of pulsed Nd:YAG laser and ceramic coating in creep test of Ti-6Al-4V alloy. A substantial part of the creep research has been devoted to Ti-6Al-4V due to its industrial and technological importance.

Experimental Procedure

The chosen material for the present study was hot-forged 12.7 mm diameter rod of commercial Ti-6Al-4V alloy with the same specifications as published by ASTM [13]. The microstructure (Fig. 1) consists of equiaxed α grains with average size about 10 μm . The transformed β phase is present

in the α grain boundaries [14]. Tensile testing was performed at 600°C in air according to ASTM standard E 21 specification [15]. The tensile properties are summarized in Table 1 namely, 0.2% yield stress (YS), ultimate tensile stress (UTS), elongation (EL) and reduction of area (RA). The initial creep stress levels were determined from the elevated temperature tensile properties given in Table 1. The Nd:YAG laser treatment parameters used are presented in Table 2, it was used ROFIN DY 033 laser and Talymap Silver 4.0 software. Ytria (8 wt.%) stabilized zirconia (YSZ) (Metco 204B-NS) with a CoNiCrAlY bond coat (AMDRY 995C) was atmospherically plasma sprayed on Ti-6Al-4V substrates by Sulzer Metco Type 9 MB. Constant load creep tests were conducted with Ti-6Al-4V alloy at 600°C. The creep tests were conducted on a standard creep machine at stress of 250 and 319 MPa. Samples with a gauge length of 18.5 mm and a diameter of 3.0 mm were used for all tests. The creep tests were performed according to ASTM E139 standard [16].

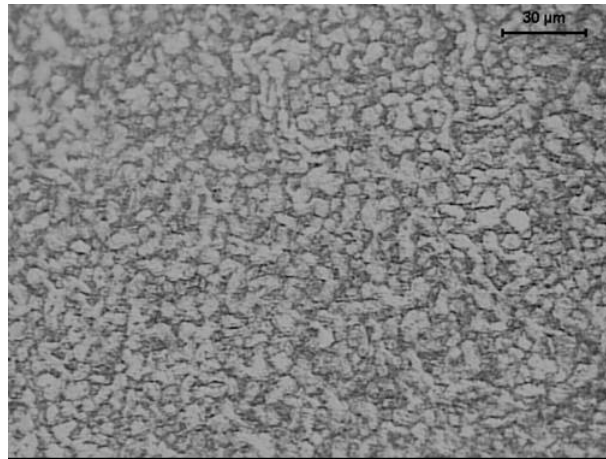


Fig. 1. Micrograph of Ti-6Al-4V alloy as-received.

Table 1 - Tensile properties of Ti-6Al-4V alloy.

T [°C]	YS [MPa]	UTS [MPa]	EL [%]	RA [%]
600	377	407	46	85.7

Table 2 – Laser treatment parameters.

Parameters	Nd-YAG Laser
Power	1.6 - 10 W
focal length lens	100-160 mm
laser scanning speed	50 mm/s
environment	40% N + 60% Ar
depth above the specimen surface	0.2-4.5 μ m
distance between focusing lens - target	89 mm
laser pulsed energy	1.9-9.0 mJ
diameter laser spot	0.17-0.98mm

diameter central zone	0.04-0.24 mm
incident laser intensity	$3.1 \times 10^9 \text{ W/cm}^2$
distribution	Gaussian

Results

Representative creep curves of Ti-6Al-4V are showed in Fig. 2.

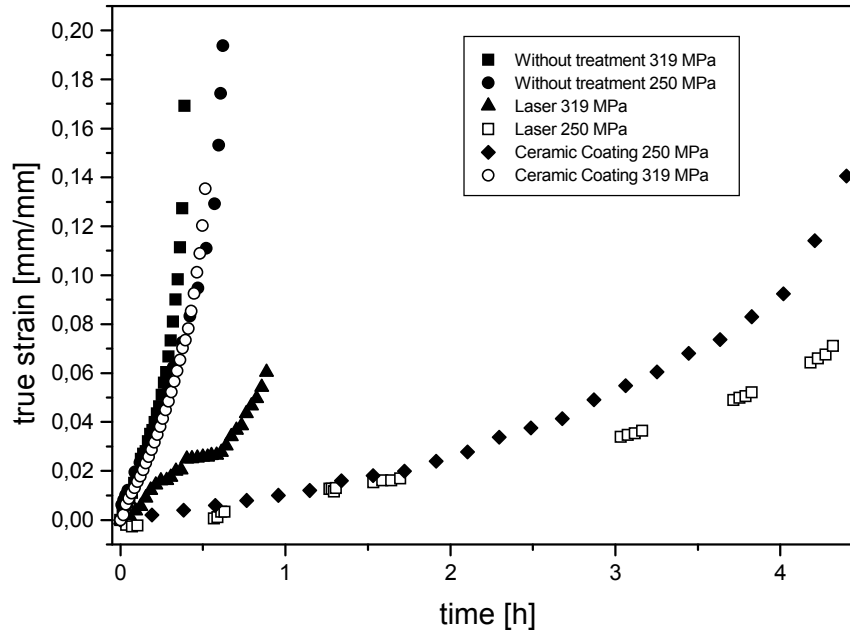


Fig. 2. Typical creep curves of Ti-6Al-4V at 600°C.

Results from the creep tests at 600°C are summarized in Table 3, which shows the values of stress (σ), primary creep time (t_p), secondary creep rate (ϵ'_s), final creep time (t_f), final strain (ϵ_f) and reduction of area (RA).

Figure 2 shows that most of the creep life of this alloy is dominated by a constant creep rate that is thought to be associated with a stable dislocation configuration due to recovery and hardening process [9-10, 17]. The higher creep resistance of Ti-6Al-4V is observed in laser treated samples in all cases.

The reduction of the steady-state creep rate (Table 3) demonstrates that the higher creep resistance of Ti-6Al-4V is observed in laser treated samples. This fact is related to the hardening superficial formed in Ti-6Al-4V alloy by the laser treatment. It is a well known fact that hard surface and interstitial solid solutions increase the creep resistance of certain alloys. The hardening superficial during creep tests, increases rupture life. It is possible that controlled penetration of oxygen into the alloy Ti-6Al-4V could increase its creep resistance without seriously altering its ductility [4].

Table 3 - Creep data at 600°C.

Treatment	σ [MPa]	t_p [h]	$\epsilon \cdot s$ [1/h]	t_f [h]	ϵ_f [mm/mm]	RA [%]
Without treatment	250	0.03	0.1906	0.62	0.1938	75.83
Ceramic coating		0.38	0.0104	4.59	0.1490	71.91
Laser		0.63	0.0127	4.32	0.0711	12.73
Without treatment	319	0.01	0.5698	0.39	0.1742	62.99
Ceramic coating		0.03	0.1401	0.51	0.1353	69.75
Laser		0.21	0.0357	0.92	0.0627	11.51

Conclusions

Constant load creep tests were conducted with Ti-6Al-4V alloy at 600°C and stress of 250 and 319 MPa. When the Ti-6Al-4V laser treated alloy was tested the effect of the oxidation was smaller and the behavior of the creep curves showed that the life time was better. There was an increasing of life time. Occurred a decreasing of steady state creep in function of the reduction of oxidation process, showing that for the Ti-6Al-4V alloy their life time was strongly affected by the superficial treatment that was submitted because the oxidation suffered by the material.

Acknowledgment

FAPESP, CAPES and CNPq for financial support.

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Advanced Powder Technology VII

doi:10.4028/www.scientific.net/MSF.660-661

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doi:10.4028/www.scientific.net/MSF.660-661.229