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CREEP BEHAVIOR OF TITANIUM ALLOY WITH ZIRCONIA PLASMA SPRAYED COATING[1]

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Abstract

The influence of the plasma-sprayed coatings for oxidation protection on creep of the Ti-6Al-4V alloy and the determination of its creep mechanism were studied. The material used was commercial Ti-6Al-4V alloy. Yttria (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. Constant load creep tests were conducted on a standard creep machine in air and nitrogen atmospheres on uncoated samples and in air on coated samples, at stress levels of 291-520 MPa at 500ºC, 125-319 MPa at 600ºC and 14-319 MPa at 700ºC to evaluate the oxidation protection on creep of the Ti-6Al-4V alloy. Results indicate that the creep resistance of the coated alloy was greater than uncoated alloy and more efficient in oxidation protection. Analysis of the steady-state creep suggests that the creep mechanisms are related to dislocation climb.

Keywords: Creep; Plasma-sprayed coatings; Oxidation; Titanium alloy.

COMPORTAMENTO EM FLUÊNCIA DA LIGA Ti-6Al-4V COM RECOBRIMENTO CERÂMICO DE ZIRCÔNIA POR ASPERSÃO TÉRMICA

Resumo

O objetivo deste trabalho foi estudar a influência de recobrimentos obtidos por aspersão térmica na fluência da liga Ti-6Al-4V, focando na determinação dos parâmetros experimentais relacionados aos estágios primário e secundário de fluência. Zircônia parcialmente estabilizada com ítria (8% peso) (Metco 204B-NS) com CoNiCrAlY (AMDRY 995C) foram depositados por aspersão térmica em um substrato de Ti-6Al-4V. Testes de fluência com carga constante foram realizados na liga Ti-6Al-4V em amostras recobertas em níveis de tensão de 291-520 MPa a 500ºC, 125-319 MPa a 600ºC e 14-319 MPa a 700ºC. Valores maiores de t_p e a redução da taxa de fluência secundária demonstraram uma maior resistência à fluência da liga Ti-6Al-4V em amostras recobertas. Os resultados indicaram que a resistência à fluência da liga recoberta foi maior que a não-recoberta, sendo este recobrimento mais eficiente na proteção da oxidação da liga.

Palavras-chave: Fluência; Recobrimento cerâmico por aspersão térmica; Oxidação; Ligas de titânio.

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1 INTRODUCTION

Usually the Ti-6Al-4V alloy is used in the aeronautic and aerospace industry, mainly applied where high oxidation resistance is needed, like aero gas turbine component.[1] The titanium affinity for oxygen is one of the principal factors that limit the titanium alloys applications as structural material at high temperatures.[2] Advances in the development of titanium alloys have turned possible a better resistance in proprieties at high temperatures and creep resistance. However, the superficial oxidation is increased with temperatures up to 600˚C[3] that limit the titanium alloys applications. The oxygen interaction with the titanium alloys causes loss of weight due to oxide formation and embrittlement of the alloy by dissolved oxygen in the grain boundary.[4]

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).[5-7] 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.[8-11] These characteristics provide an improvement in the creep resistance.[12]

In this paper is showed a study about the creep mechanisms in Ti-6Al-4V alloy plasma sprayed at 500, 600 and 700ºC in air and the determination of the first and second creep stage experimental parameters at these conditions.

2 MATERIALS AND METHODS

The commercial Ti-6Al-4V alloy samples have been hot-forget with the dimension and shape shown in Figure 1.

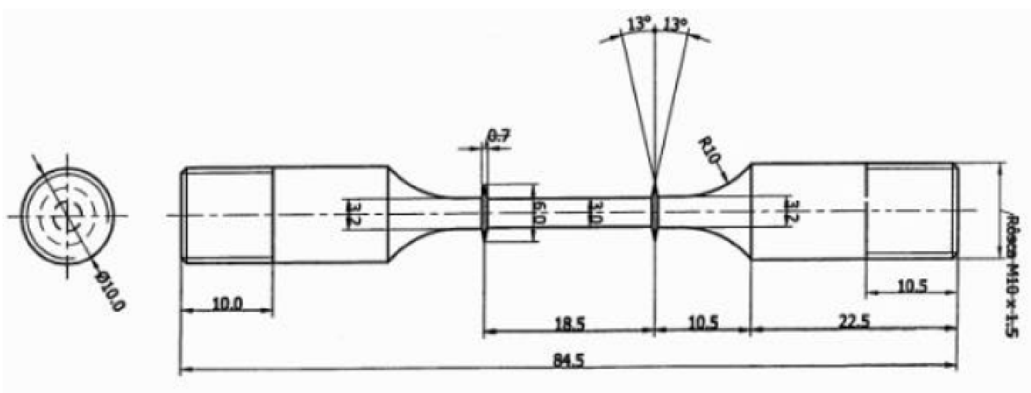

Figure 1. Ti-6Al-4V sample dimensions and shape.

Yttria (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.

Using a MAYES creep machine adapted with electrical systems and controllers developed by BSW Tecnologia, Indústria e Comércio Ltda following specifications by ASTM E139/83[13] and Antares software, developed by BSW too, to collect the test temperature and strain. Constant creep test has been done with stress levels of 291-520 MPa at 500ºC, 125-319 MPa at 600ºC and 14-319 MPa at 700ºC.

3 RESULTS AND DISCUSSION

The creep curves at 500ºC and stress from 291 to 520 MPa; 600ºC at 125 to 319 MPa; and 700ºC at 14 to 219 MPa is shown in Figure 2, 3 and 4. As could have been observed when bigger the stress, smaller the creep resistance. Furthermore the coated sample has shown a higher creep resistance when the temperature decrease.

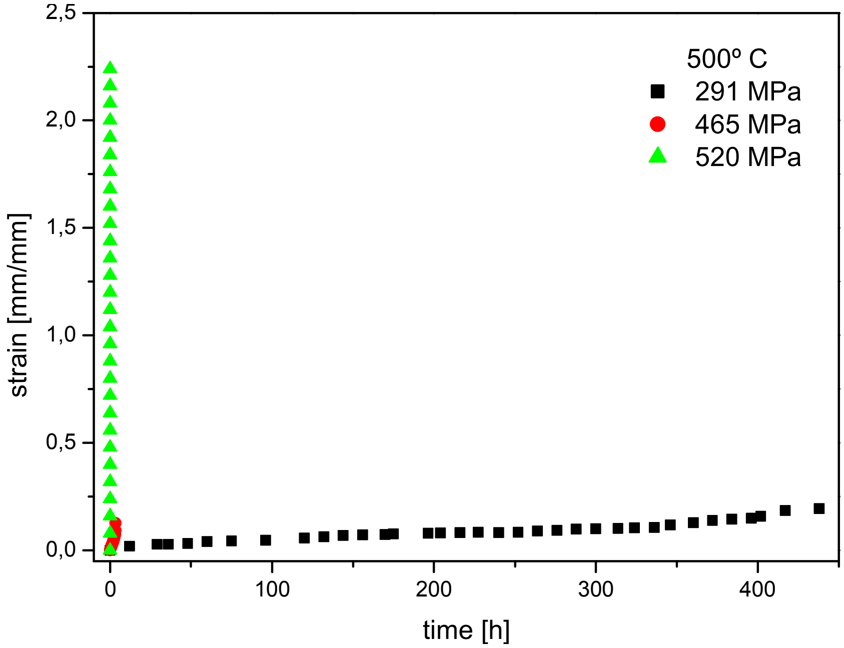

Figure 2. Creep curves at 500˚C, from 291 to 520 MPa.

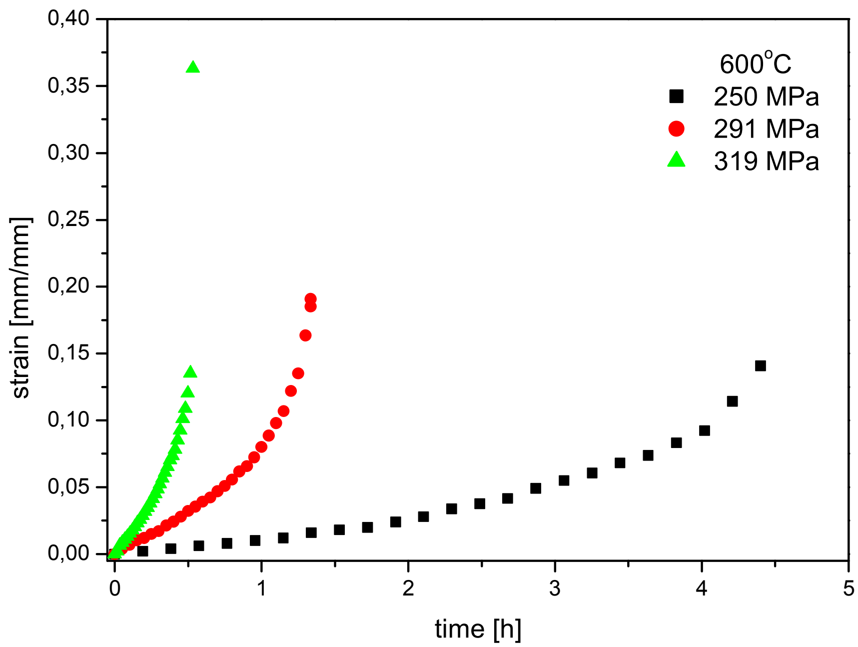

Figure 3. Creep curve at 600ºC, from 125 to 319 MPa.

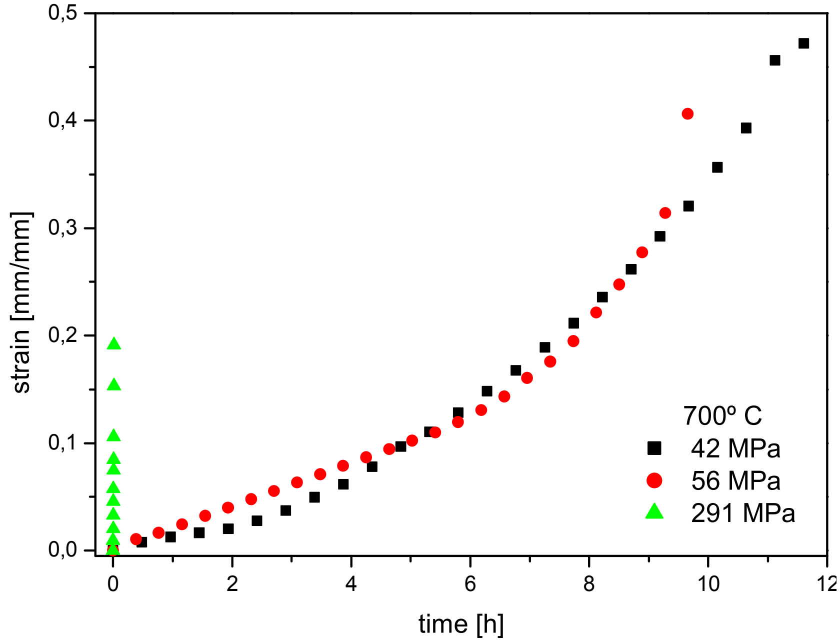

Figure 4. Creep curve at 700ºC, from 14 MPa to 291 MPa.

Results from the creep tests at 500ºC, 600ºC and 700ºC are summarized in Table 1, which shows the experimental creep parameters.

Table 1. Comparative table for the experimental parameters

Temperature [ºC]	σ[MPa]	t_p [h]	$\dot{\varepsilon}_s$ [1/h]	t_r [h]	ε_r [mm/mm]
500	291	36	0,02876	438	0,1936
	465	0,2667	0,02041	3,45	0,1272
	520	0,56	0,0304	2,24	0,1056
600	250	0,38	0,0104	4,59	0,1490
	291	0,25	0,0797	1,33	0,1908
	319	0,03	0,1401	0,51	0,1353
700	42	0,967	0,00912	11,61	0,4719
	56	0,389	0,02025	9,66	0,40636
	291	0,003	9,4262	0,0139	0,1914

Starting the data above has been possible calculate the creep mechanisms, using a liner fit of a potential law and an Arrhenius` equation has found the two

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parameters associated with the creep mechanisms, it is the stress exponent (n) and the activation energy (Q_c). Figures 5, 6 and 7 shows the linear fit to obtain the stress exponent at 500, 600 and 700ºC. Figure 8 shows the linear fit of the activation energy.

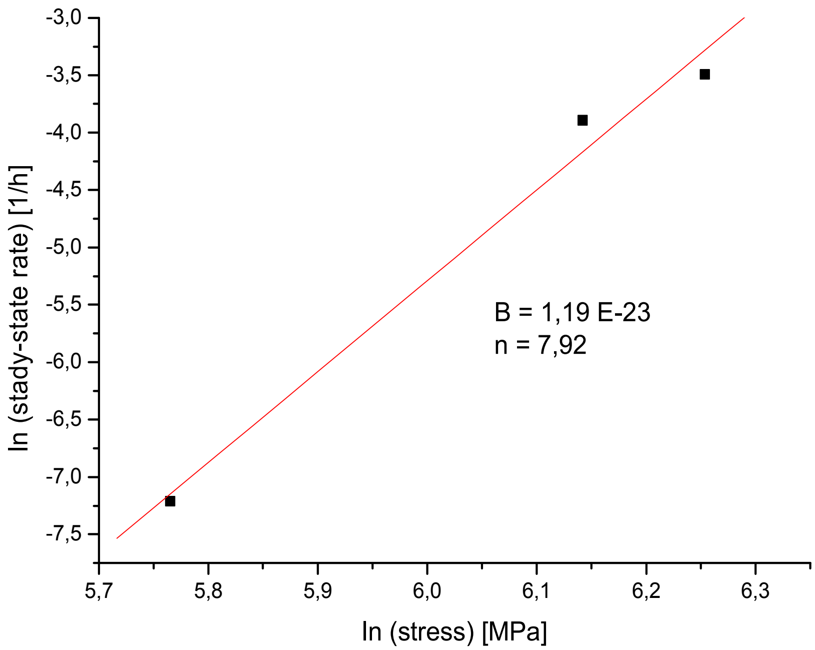

Figure 5. Linear fit to obtain the stress exponent at 500ºC.

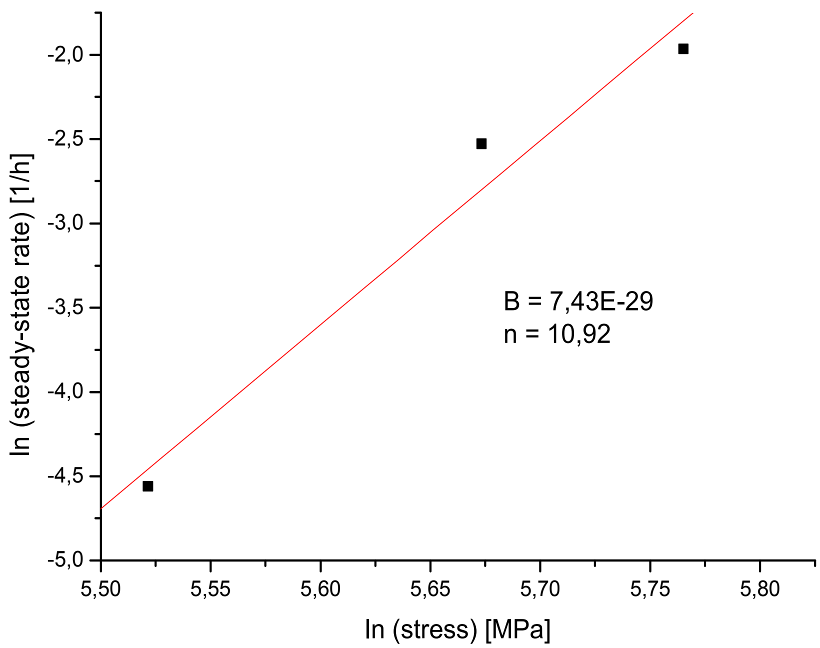

Figure 6. Stress exponent at 600ºC.

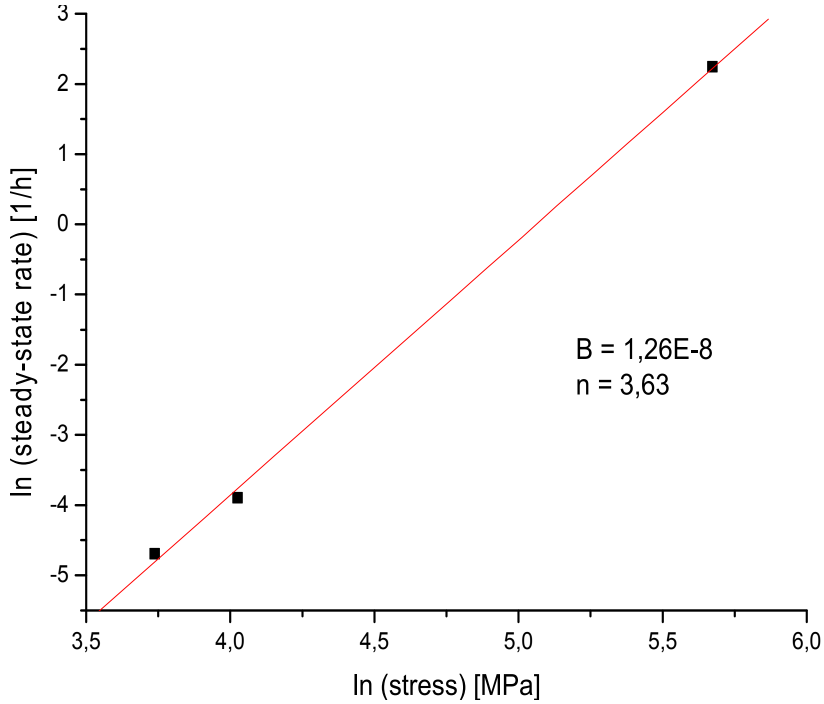

Figure 7. Stress exponent at 700ºC.

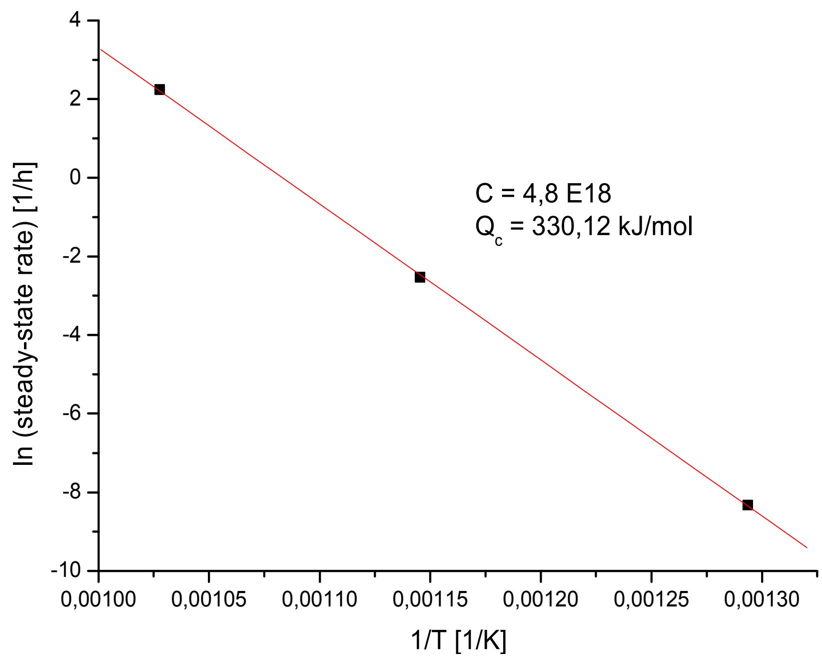

Figure 8. Linear fit to obtain the activation energy.

The analysis of the parameters obtained has driven to the conclusion that the probable creep mechanism in these conditions is related with dislocation climb.

4 CONCLUSIONS

The creep experimental parameters of the Ti-6Al-4V coated could have been determined to stress from 291 to 520 MPa at 500ºC; from 125 to 319 MPa at 600 ºC; and form 14 to 319 MPa at 700ºC. From this parameters, it was possible to obtain the stress exponent and the activation energy that define the creep mechanism. Thus, the probable creep mechanism associated at these conditions is dislocation climb.

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