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CHARACTERIZATION OF FRACTURE OF SUPERALLOY INCONEL 718DOUBLE AGED AFTER CREEP TESTS AT650°C AND 675ºC[1]

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Abstract

Creep phenomenonduring few past decadeshas its importance raised especially due to the increase of working temperature in aerospace and land based turbines.This study aimsto characterize the fracture of the superalloyInconel718doubleaged after creep experiments at 650°C and 675ºCwith load of625MPa. A solid solution of 1095ºC for 1 hour treatment (air cooling) was applied initially and followed by double aging treatment at 955°C/1h (air cooling) - 720ºC/6.5h +720ºC/1.5h (furnace cooling) + 620ºC/8h (air cooling). The Inconel 718 double aged presented higher creep resistance than the Inconel 718 as received. The lower values of true strain in the alloy after double aging demonstrated that the heat treatment was more effective and increased the mechanical properties at high temperature. The creep testswere performed accordingto ASTME139-06 at650°C and 675ºC and constant load of 625MPa. The fracture characterization was done in the samples aftercreep testsunder all conditionstested. It was observed intergranular fractures after creep tests.

Keywords: Superalloys;Fouble-aged; Inconel 718;Creep test.

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1 INTRODUCTION

Inconel 718 is a precipitation-hardening superalloy developed by Internacional Nickel Coin the 50s.(1) This alloy is a Nb-modified Fe-Cr-Ni-base superalloy and has been widely used in gas turbine and related applications due to its good mechanical properties and structural stability at elevated temperatures (~650°C).Superalloys are generally applied in heat treatment equipment, aeronautics gas turbines, nuclear power plants, medical components, chemical and petrochemical industries.(2) It is used under high homologous temperatures (T_h> 0.5), showing high stress-rupture and good oxidation resistance, good creep and low cycle fatigue behavior. In 1989,(3) the Inconel 718 alloy represented 45% of all wrought nickel-iron base superalloys produced in the world.

Inconel 718 has crystallographic lattices face-centered cubic (fcc), body-centered cubic (bcc), hexagonal close-packed (hcp) and body-centered tetragonal (bct), among others. This niquel-iron superalloys are made of austenitic fcc matrix γ (gamma phase), as well as secondary phases: gamma prime γ' face ordered $Ni_3(Al,Ti)$; gamma double prime γ" bct ordered Ni_3Nb; eta η hexagonal ordered Ni_3Ti; delta δ orthorhombic Ni_3Nb intermetallic compounds and other topologically closed-packed structures such as μ and Laves phases. δ, μ and Laves phases have low ductility, cause losses in mechanical and corrosion properties and provide grain size control.(2) In addition, these phases appear in alloys containing high level of bcc transition metals (Ta, Nb, Cr).(3)

Superalloys have their microstructure characteristics improved by using heat treatment techniques. Solution treatment, usually the first step in heat treatment of precipitation hardening alloys, aims to: recrystallize, homogenize and dissolve phases in fcc matrix structure, dissolving carbides in grain boundaries and the grain-growth results in high creep-rupture resistance.(3) The purpose of aging treatments is the increasing of the strength through the precipitation of additional quantities of secondary phases, from the supersaturated matrix, developed by solution treating. For Inconel 718 more than one phase can precipitate, so double aging is applied in order to enhance the formation of both γ'and γ" phases. Secondary phases γ'and γ" play a main role in the strengthening mechanism of Inconel 718, mainly γ", a coherent disk-shaped precipitate.

Changzeng et al. highlighted the structural stability dependence with secondary phases production on aging heat treatments, as well the competition of γ'/γ" and delta phase δ formation.(4) By comparison of three kinds of double aging techniques, the optimized technique of double aging under 720ºC/8h+620ºC/8h is identified due to the fact that it can get higher contents of the γ' and γ" phases, the lowest content of the δ phases and optimum structure in Inconel 718 alloy using this technique. Inconel 718 creep´s behavior has only rarely been investigated. In this context, the purpose of this preliminary study is to characterize the fracture of thesuperalloy Inconel 718 double agedafter creep testsin the temperatures of 650ºC and 675ºC with constant load of 625MPa focusing on the determination of the type of fracture.

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2 MATERIALS AND METHODS

The material used for the present study was Multialloy bars machined by FautecFerramentariaAutomação e Usinagem Ltda. The superalloy was obtained by VIM/VAR process. A solid solution of 1095ºC for 1 hour treatment (air cooling) was applied initially and followed by double aging treatment at 955°C/1h (air cooling) - 720ºC/6.5h + 720ºC/1.5h (furnace cooling) + 620ºC/8h (air cooling). The thermal treatments were conducted at Escola de Engenharia de Lorena (EEL-USP), using a Lindberg/Blue M - Tube Furnace 100V/50A/5kW.

Samples with a gage length of 18.5mm and a diameter of 3.0mm, according to ASTM E-8,(5) were used for all tests as shown in Figure 1.

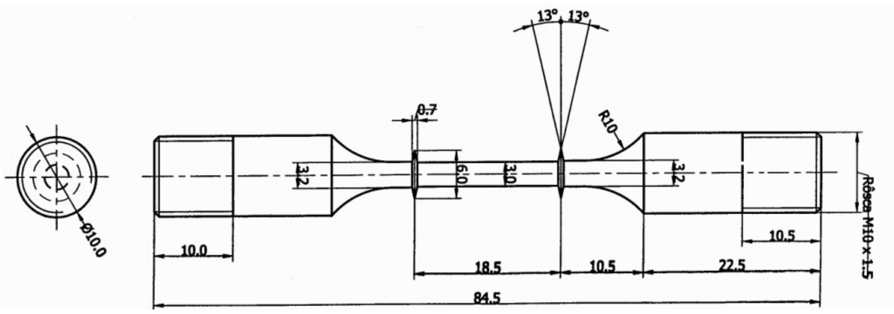

Figure 1 – Specimen dimensions.

The creep experiments were conducted at 650°C and 675ºC withconstant load 625MPa at InstitutoTecnológico de Aeronáutica (ITA/DCTA), using a furnace from EMEC (The Electronic and Mechanical Engineering Co. Ltda.) with controllers and electrical system, according to ASTM E139/83.(6) The results were analyzed with the software Antares.

The fracture characterization of the Inconel 718 double aged superalloy before and after double aging treatment were analyzed via scanning electron microscopy secondary mode (SEM) using an acceleration voltage of 20 kV. These images were conducted in a LEO 1450VP SEM model equipped with Oxford Instruments energy-dispersive X-ray spectrometry system at InstitutoNacional de PesquisasEspaciais (INPE).

3 RESULTS

The composition of the superalloy used in this study is summarized on Table 1.

Table 1: Inconel 718 composition

Analyse %wt														
Ni	Cr	Ti	C	Al	Nb	Mo	Mn	Si	P	Cu	Co	B	Ta	Fe
52.83	18.39	0.95	0.03	0.48	5.05	3.01	0.03	0.03	0.004	0.03	0.23	0.001	0.01	bal.

The creep parameters are summarized in Table 2.

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Table 2: Creepparameters of the Inconel 718superalloy at 650^{o}C and 675ºC and constant stress level of 625MPa in air conditions

σ (MPa)	T (ºC)	INCONEL 718	t_f (h)	$\acute{\varepsilon}_f$ (mm/mm)
625	650	As received	10.43	0.175
		Double aged	230.80	0.013
625	675	As received	0.08	0.169
		Double aged	45.00	0.007

Figure 2 (a and b) show the curves of creep tests for the temperature of 650◦C and 675ºC and constant stress level of 625MPa in air conditions as received and double aged respectively.

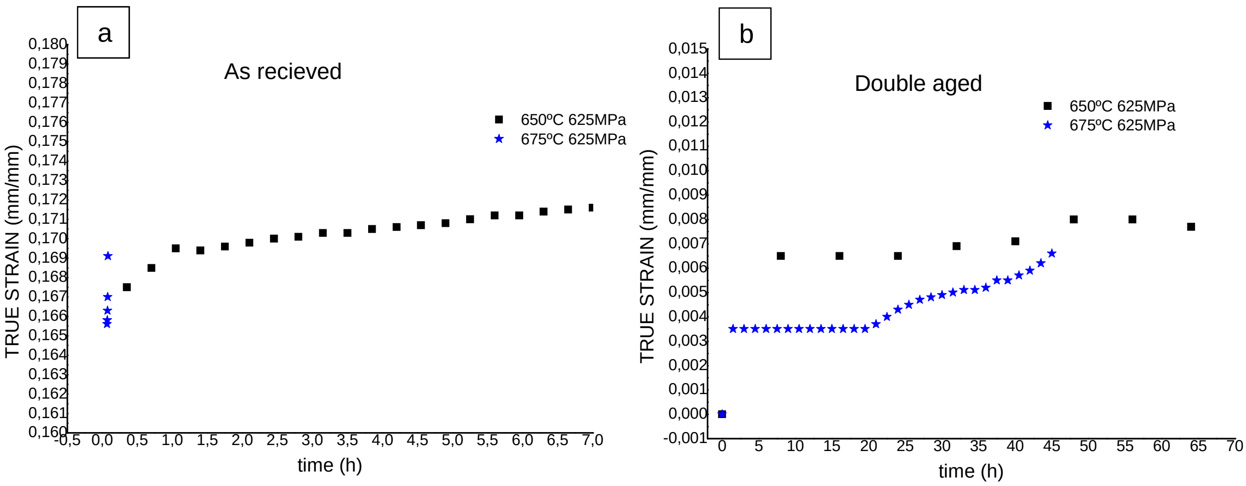

Figure 2 – Creep curves obtained at 650ºC and 675ºC and constant sress level of 625MPa(a)as received and (b) double aged.

Figure 3 to 7 (centerand sidelong) show the fracture images of the Inconel 718 after creep tests.

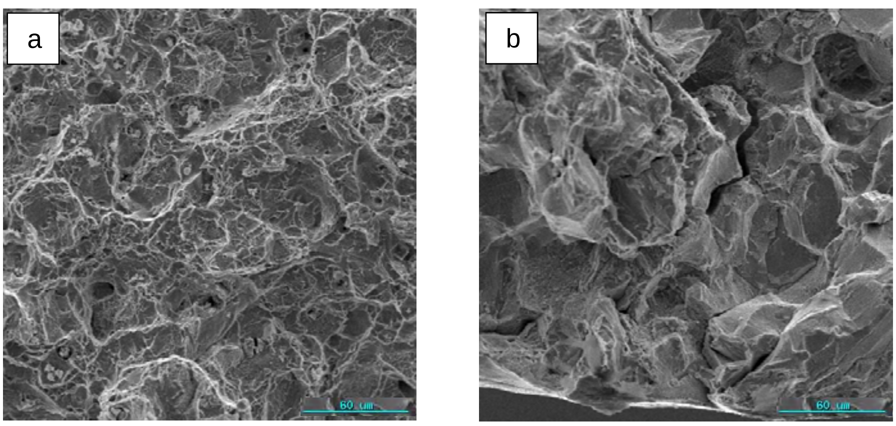

Figure 3 – Inconel 718 at 650^{o}C with constant stress level of 625MPa - as received (a)center and (b) sidelong.

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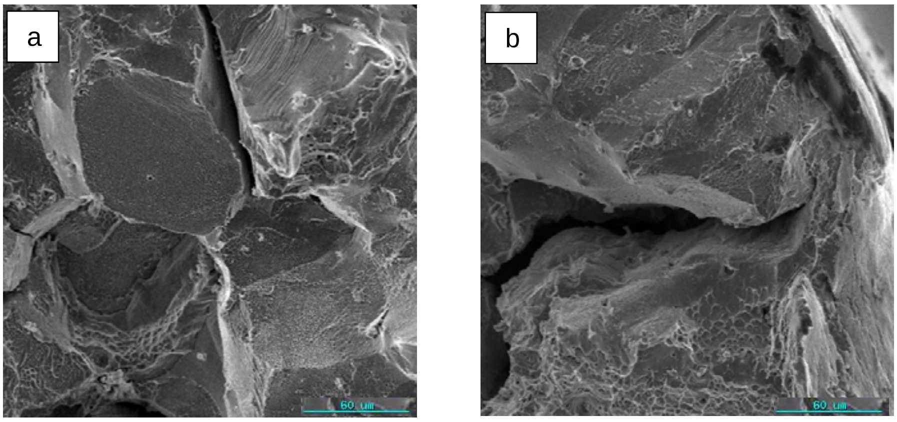

Figure 4 – Inconel 718 at 650°C with constant stress level of 625MPa - double aged (a)center and (b) sidelong.

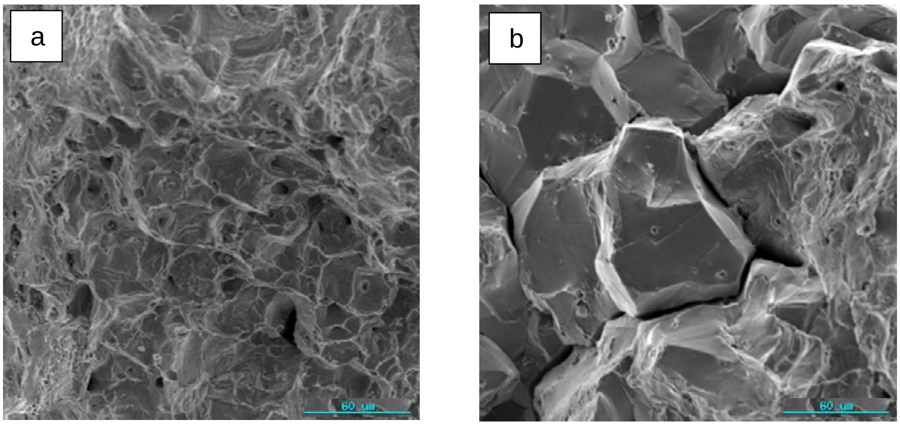

Figure 5 – Inconel 718 at 675°C with constant stress level of 625MPa - as received (a)center and (b) sidelong.

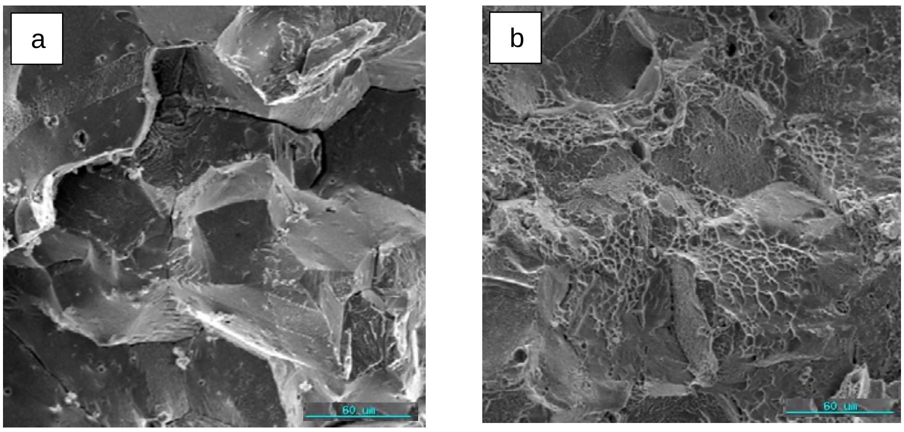

Figure 6 – Inconel 718 at 675°C with constant stress level of 625MPa - double aged (a)center and (b) sidelong.

4 DISCUSSIONS

The double aging treatment conferred an increasing of the rupture time for all conditions of load. It can be observed that the rupture time decrease as the temperature increase.

The lower values of steady-state creep rate in the alloy after double aging demonstrated that the heat treatment was more effective and increased the mechanical properties at high temperature of the Inconel 718.

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It can be observed in Figures 3 and 5 (as received condition) two types of fractures, grain boundary cavitation mode that characterize ductile fracture and intergranular fracture that characterize brittle fracture. For the fractographies of the double aged conditions (Fig. 4 and 6) it can be observed the same two types of fracture, but mainly the fractures occurred as intergranular characterizing brittle material.

5 CONCLUSIONS

In this work was studied the creep behavior of the Inconel 718 superalloy after double aging. A solid solution of 1095ºC for 1 hour treatment was applied initially and followed by double aging treatment at 955°C/1h - 720ºC/6.5h +720ºC/1.5h + 620ºC/8h. The alloy was submitted to creep tests at 650ºC and 675ºC with constant load mode 625MPaand the creep behavior was evaluated in the Inconel 718. The double aging treatment presented higher creep resistance than the Inconel 718 as received. The lower values of true strain in the alloy after double aging demonstrated that the heat treatment was more effective and increased the creep resistence at high temperature. Results of fractographies show mainly intergranular, grain boundary cavitation mode in the double aged condition.

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