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THE EFFECT OF AGING IN MICROSTRUCTURES AND CREEP BEHAVIOR OF INCONEL 718[1]

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Abstract

A superalloy is an alloy developed for elevated temperature service, where relatively severe mechanical stressing is encountered, and where high surface stability is frequently required. High temperature deformation of Ni-base superalloys is very important since the blades and discs of aeroengine turbine, because need to work at elevated temperature for an expected long period. The nickel-base alloy Inconel 718 has being investigated because it is one of the most widely used superalloys. This alloy is also competitively priced due to the fact that the alloy contains no cobalt and has a relatively high content of iron. The objective of this work is to evaluate The aim of the work was study the influence of the γ' and γ'' phase on the Inconel 718 microstructure and the creep behavior of the alloy. Constant load creep tests were conducted at 650℃ and 750 MPa. Samples with a gage length of 18.5 mm and a 3.0 mm diameter were used for all tests. Creep tests were performed according to ASTM E139 standard.

Key words: Inconel 718; High temperatures; Superalloy; Heat treatment.

EFEITO DO ENVELHECIMENTO SOBRE A MICROESTRUTURA E O COMPORTAMENTO DE FLUÊNCIA DO INCONEL 718

Resumo

Superligas à base de níquel são conhecidas desde a década de 1930, e utilizadas principalmente em aplicações aeroespaciais. Estas aplicações requerem um material com elevada resistência mecânica, boa resistência à fadiga e à fluência, boa resistência à corrosão e capacidade de operar continuamente em temperaturas elevadas. A liga a base de níquel Inconel 718 tem sido investigada, pois é uma das superligas mais utilizadas. O objetivo deste trabalho foi estudar a influência da fase γ' e γ'' sobre a microestritura do Inconel 718 e o comportamento à fluência da liga. O teste de fluência foi realizado sobre carga constante a 650 ^{o}C e 750MPa. As amostras apresentam um comprimento de 18,5 mm e um diâmetro de 3,0 mm, os ensaios foram realizados de acordo com norma ASTM E139.

Palavras chaves: Inconel 718; Alta temperatura; Superligas; Tratamento térmico.

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1 INTRODUCTION

The successful application of some nickel-chomium and iron-base alloys as high temperature components of arcraft, marine and land-based power systems, led to the designation of "superalloys". The Inconel 718 is a relatively recent alloy as is industrial use started in 1965. It is a precipitation hardnable alloy, containng significant amounts of Fe, Nb and Mo. Minor contents of Al and Ti are also present. Inconel 718 combines good corrosion and high mechanical properties ith and excellent weldabilitty. It is employed in gas turbines, rocket engines, turbine blades and in extrusion dies and containers.(1-4)

The most important precipitate in of either Ni_3Al or Ni_3Ti. The γ' phase is precipitate by heat treatments. The important strengthening precipitate in the iron-nickel based alloy Inconel 718 is γ'' (Ni_3Nb).(5)

Ni and Cr contribute to the corrosion resistance of this superalloy. They crystallize as a γ phase (face centred cubic). Nb is added to form hardening precipitats γ'' (a meta stable intermetallic compound Ni_3Nb, centred tetragonal crystal). Ti and Al are added to precipitate in the form of intermetliic γ' Ni_3Al or Ni_3Ti, (simple cubic crystal).

The C is also added to precipitate in the form of MC carbies (M=Ti or Nb). In this case the C content must be low enough to allow Nb and Ti precipitation in the form of γ' and γ'' particles. Mo is also added to increase the mechanical resistance by solid solution hardening. A β phase (intermetallic Ni_3Nb), can also appear.

Aging treatment are used to strengthen precipitation-strengthened alloys by precipitation one or more phases (γ' and γ'').(3-9)

There are some discrepancies in the literature the precipitation kinetics of these phases. Some authors(2) affirm that γ' and γ'' particles precipitate between 550℃ and 660 °C at large aging times, while other says that they can precipitate between 700℃ and 900 °C at short aging times as far as the relation (Ti + Al)/Nb = 0.66 (in at. %) is maintained. If this ratio goes up to 0.8 γ' precipitation time temperature (PTT) diagram(3) for this alloy is shown in Figure 1.

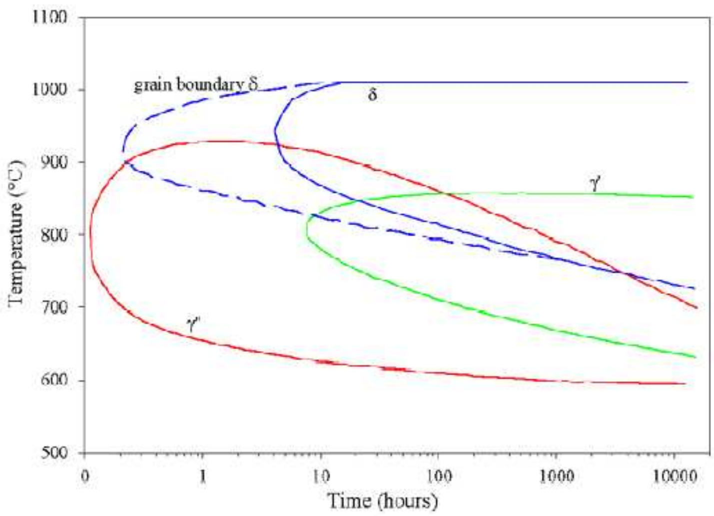

Figure 1. PTT diagram of different phases in Iconel 718.(5)

The aim of the work was study the influence of the γ' and γ'' phase on the Inconel 718 microstructure. and the creep behavior of the alloy.

2 EXPERIMENTAL PROCEDURE

Superalloy Inconel 718 used in this work was provided for the Company Villares S.A. (Sumaré-SP). The material was melting in furnace VIM, remelting in furnace VAR, after was done a heat treatment of homogenization, hot forging plain open die for drafting, hot rolling for drafting and hot rolling finish. Table 1 shows the composition of superalloy Inconel 718.

Table 1. Chemical composition (% weight) of superalloy Inconel 718

Ni	Fe	Cr	Mo	Ti	Al	Nb	C
53.4	18.8	18.6	3.0	1.0	0.5	5.1	0.03

Tensile testing was performed at 650 ℃ in air acco rding to ASTM standard E 21 specification.[6] The tensile properties at 650℃ are 0.2% yield str ess 820 MPa (*YS*), ultimate tensile stress 974 MPA (*UTS*), and 28.37% reduction of area (*AR*). The initial creep stress levels were determined from the elevated temperature tensile properties.

It was used a Lindberg/Blue refractory furnace to thermal treatment of the Inconel 718 superalloy. The Inconel 718 were encapsulated in a quartz tube and argon gas was injected to avoid the oxidation of the samples during the treatment. A pickling solution of HF- 0.2 mL/HNO_3- 2 mL/ H_2O- 30 mL was used to wash the samples after the treatment. To obtain the γ' and γ'' phase structure the furnace was heated I - solubilization 1095°C/1h (water), then aging at 720°C/8h + 620°C/8h (air) and other II - solubilization 975ºC/1h (water) + 720ºC/8h + 620ºC/18h (air).

The creep tests were performed under constant load in a stress to 750 MPa at 650ºC for two heat treatment. 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.[10] The samples were prepared using the usual methods of metallographic preparation to observe them at optical microscopy and scanning electronic microscopy.

3 RESULTS

Figure 2 shows the microstructure of Inconel 718 alloy (as received). It could be observed heterogeneous grains. Besides, it could be observed a few fraction of carbides particles not uniform distributed by matrix. The γ phase appears in clear regions on micrograph and γ' phase appears in dark regions (fewer quantity, because don't performed an aging heat treatment).

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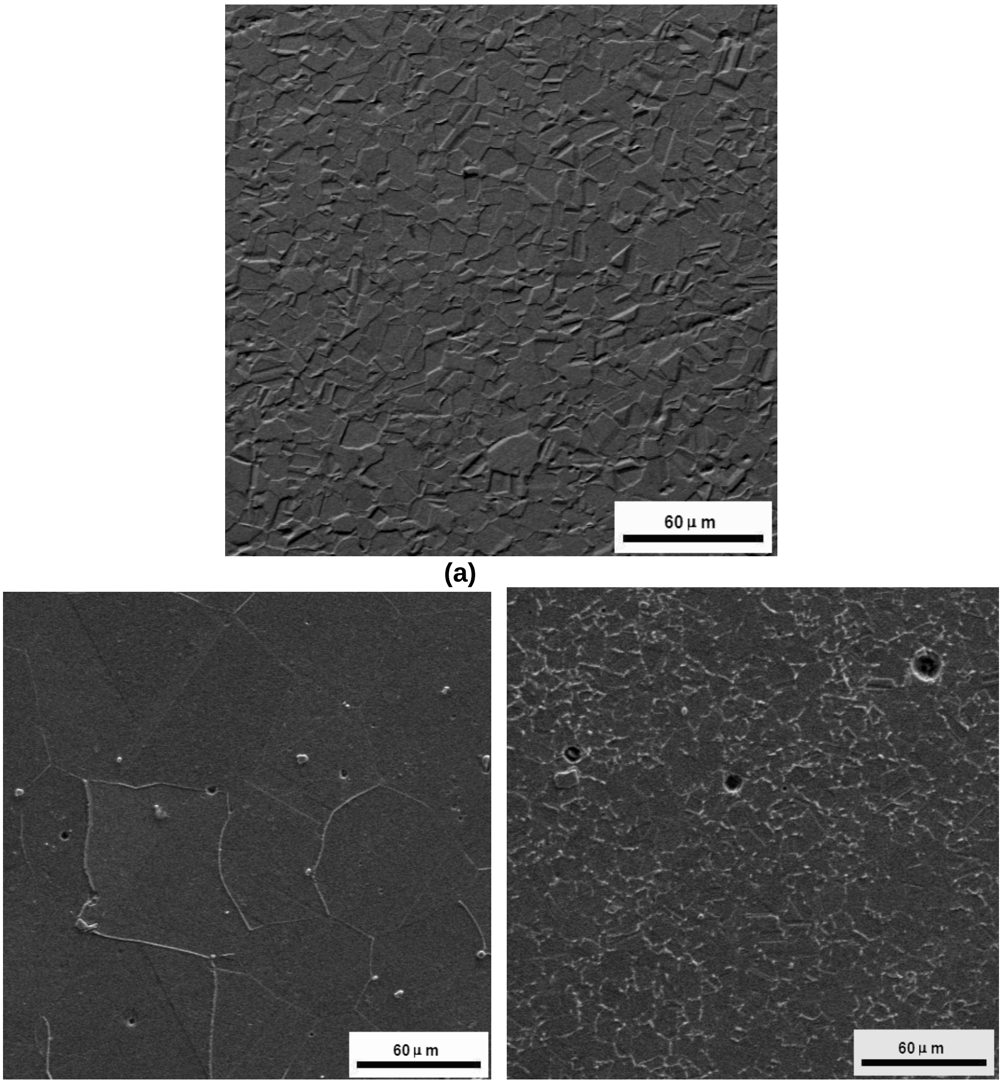

(a)

(b) (c)

Figure 2 – Inconel 718 increase 500X (a) Microstructure of Inconel 718 alloy, as received (b) I - solubilization 1095^{O}C/1h (water), then aging at 720^{O}C/8h + 620^{o}C/8h (air) (c) other II - solubilization 975ºC/1h (water) + 720ºC/8h + 620ºC/18h (air).

Table 2 presents the mean values (10 measurements) of hardness to the samples of Inconel 718. Show which with treatment aging I and II the increase of hardness.

Table 2 – Microhardness Vickers of Inconel 718

Inconel 718	Microdureza
As- received	344.06
Aging - I	446.38
Aging - II	482.12

3.1 Creep tests

Representative creep curves of Inconel 718 are showed in Figure 3. The creep tests were done at 650℃ and 750 MPa for both heat treatment conditions.

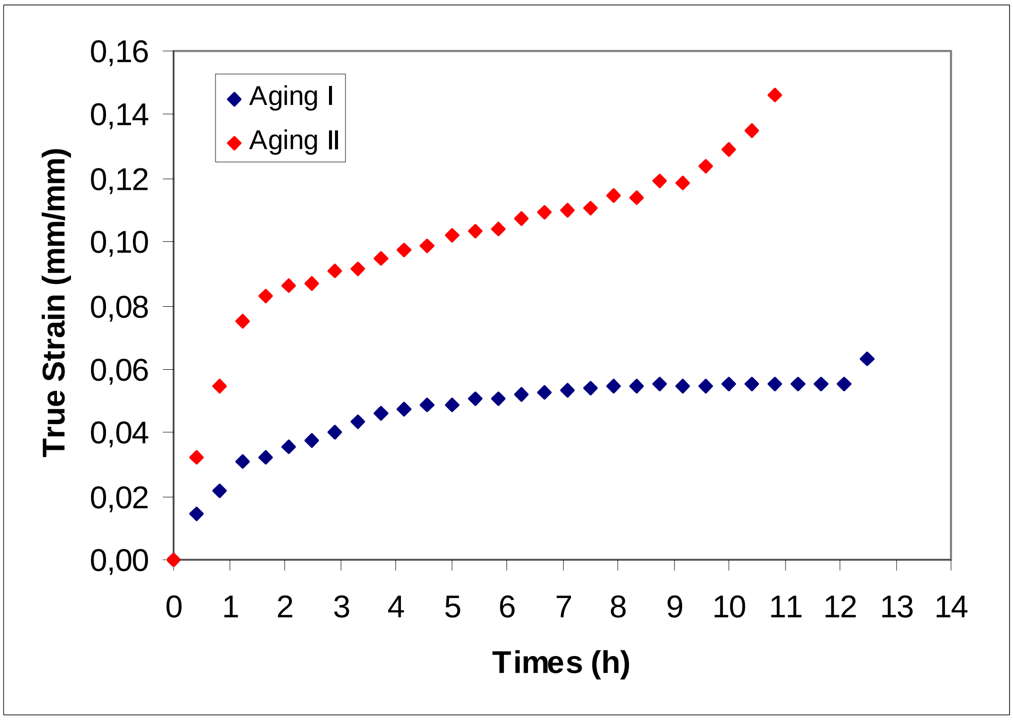

Figure 3 - Creep curves of the Inconel 718 at 650ºC and 750 MPa.

The Table 3 shows the relationship of the main experimental parameters obtained at 650℃ from experimental curves. When σ is the applied stress, $\dot{\varepsilon}_s$ is the stationary creep rate, obtained from the slope of the linear creep curve (secondary stage). The value of t_p is the constant relative time to primary time, obtained in the final stage of primary and / or in the beginning of secondary stage. The value t_f is the final time of fracture, ε_f correspond to the fracture strain and AR the percentage reduction in area at fracture.

Table 3. Creep data of Inconel 650℃ a 750 MPa

Samples	σ (MPa)	t_p (h)	$\dot{\varepsilon}_s$ (1/h)	t_f (h)	ε_f (mm/mm)	AR (%)
Aging I	750	2.92	0.0014	11.60	0.0635	6.3%
Aging II	750	2.50	0.0045	9.58	0.1460	5.0%

4 DISCUSSIONS

In Figure 2 can be observed that the condition aging I the alloy has a coarser grain and free of stage Delta. The amount of precipitated γ''is much smaller than in condition II. The condition II the alloy has a very fine grain (6 to 7 ASTM) containing Delta acircular phase at grain boundaries (so the grain is finer-stage Delta has the effect of "pinning" at grain boundaries).

Figure 3 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. The higher life-time in creep of Inconel 718 was observed in Aging I. The Aging I increased the grain size of the alloy and led to higher creep resistance.

The reduction of the steady-state creep rate (Table 3) demonstrates that the higher creep resistance of Inconel 718 was observed in Aging I. It is a well known

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fact that interstitial solid solutions increase the creep resistance of certain alloys. The microstructure with higher grain size during creep tests, increases rupture life. It is possible that grain boundary mechanism is hindered into the alloy Inconel 718 could increase its creep resistance without seriously altering its ductility.

5 CONCLUSION

Constant load creep tests were conducted with Inconel 718 alloy at 650℃ and stress of 750 MPa. The higher life-time in creep of Inconel 718 was observed in Aging I. The Aging I increased the grain size of the alloy and led to higher creep resistance. It is possible that grain boundary mechanism is hindered into the alloy Inconel 718 could increase its creep resistance without seriously altering its ductility.

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