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Effect of Aging Treatment 0n Inconel 718 Superalloy: Application in Elevated Temperatures

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Abstract. This work studies the effect of double aging heat treatment on superalloy Inconel 718. The heat treatment followed two steps: Solid solution at 1095ºC for 1h, and two steps of aging 955ºC/1h - 720ºC/6,5h - 720ºC/1,5h + 620ºC/8h. Parameters such as grain size, secondary phases distribution and qualitative analysis via SEM/EDS and Vickers hardness are used in order to evaluate the microstructural evolution. The results show increase of grain size and Vickers hardness, as well as a better distribution of secondary phases along the matrix.

Introduction

The heat treatments applied to the Inconel 718 superalloy have been studied [1, 2] regarding the optimization of secondary phases formation - gamma prime γ', double prime γ" and eta η - which improve mechanical properties, as well as controlling the formation of delta δ, Laves and other topologically closed package (TCP) phases, that cause loss in rupture life. Nevertheless, a previous study [3] describes the contribution of the delta phase in the grain size control, working as a barrier to the grain sliding.

The heat treatment steps conventionally used for precipitation hardening alloys are solid solution and aging. The temperature of the solid solution treatment must be carefully selected, because temperatures close to the *solvus* line provide increase of creep resistance [3] and lower temperatures result in higher fatigue resistance [4]. C.-M. Kuo et al reported [5] the increase of solid solution temperature used over time, in order to dissolve the deleterious phases such as delta, TCP and Laves.

The aging treatment promotes the precipitation of γ' and γ" and grain size growth. The metastable phase γ" with bct ordered structure has low misfit degree [3] in relation to the Ni-Cr-Fe matrix and is the most important phase on the strengthening mechanism of Inconel 718. This work aims to analyze qualitatively the effect of each step of double aging heat treatment, using images obtained by optical and scanning electron microscope, Vickers hardness and ASTM grain size number.

Experimental procedure

Composition of Inconel 718

The superalloy Inconel 718 was furnished by Multialloy Co., was obtained by VIM/VAR process and then annealed. The chemical composition of the superalloy is presented in Table 1.

Table 1: Composition of Inconel 718 superalloy.

Inconel 718 (wt %)							
Cr	Ni	Si	Mo	Ti	Nb	Fe	Al
18.94	54.47	0.04	1.35	1.05	5.89	17.99	0.27

Heat treatment steps

The double aging heat treatment was performed in tubular furnace Lindberg/Blue M (100V/50A/50kW), in the Escola de Engenharia de Lorena (EEL/USP/DEMAR). The steps of heat treatment are detailed in Fig. 1:

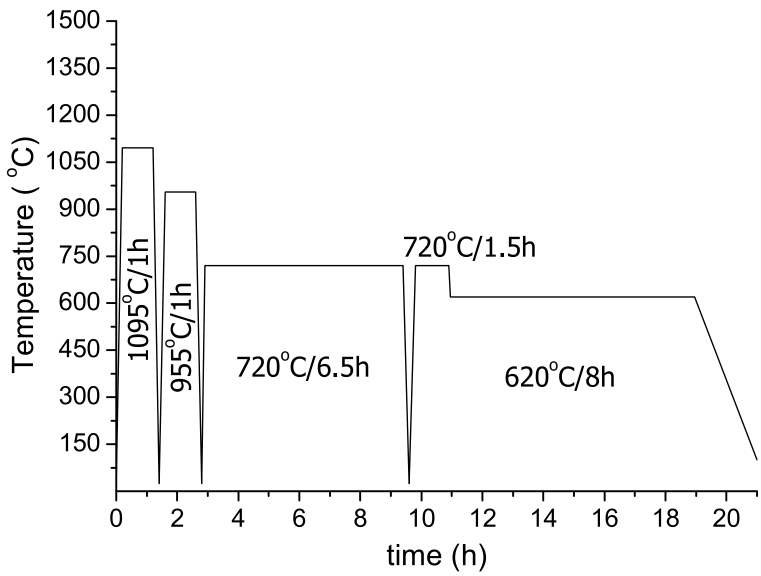

Fig. 1: Double aging heat treatment.

Microstructural preparation

The samples were prepared by conventional metallographic procedure using 320, 600 and 1200 griding steps. Polishing was made with cloth of 6 and 1 μ and diamond paste of 6 and 1 μm respectively. Between all steps the samples were cleaned with ultrasound. Chemical etch was performed using Glyceregia solution.

Experimental procedure

The micrographies of each step of double aging heat treatment are represented in Fig. 2-5 below:

- Figure 2: As received condition (AR);
- Figure 3: The solid solution at 1095ºC;
- Figure 4: After the first aging step at 955ºC;
- Figure 5: Inconel 718 double aged.

From the images obtained, one can notice the better dispersion of secondary phases.

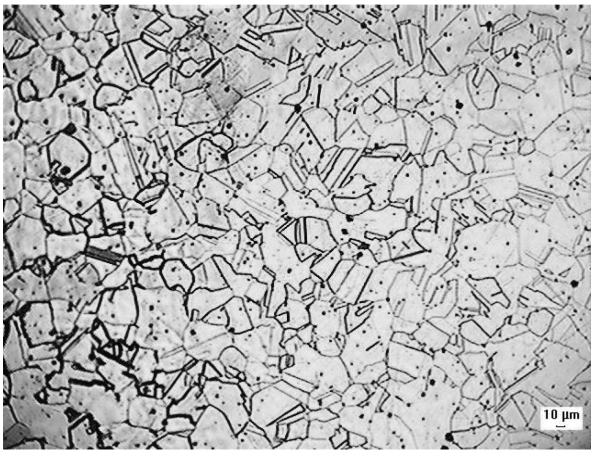

Fig. 2: As received condition.

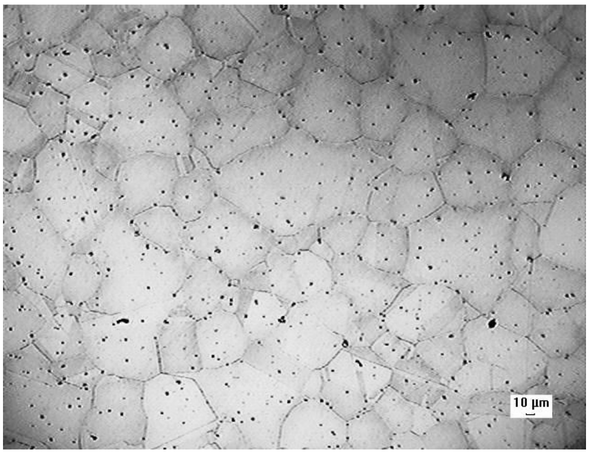

Fig. 4: After the first aging step at 955ºC.

Fig. 3: The solid solution at 1095ºC.

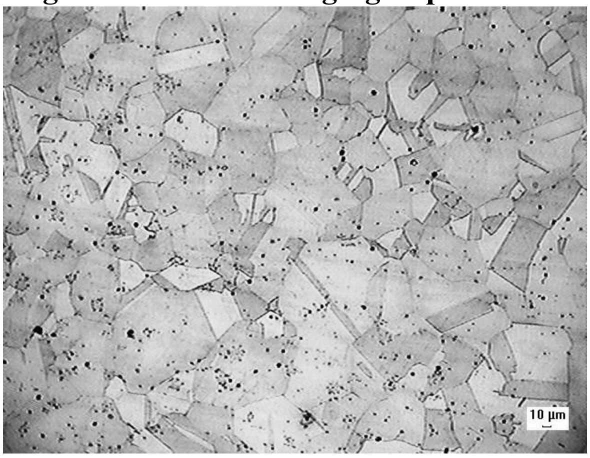

Fig. 5: Inconel 718 double aged.

The results of scanning electron microscope (SEM/EDS) are represented in Figures 6-9. Images were obtained via backscattered electron mode (Figures 6 and 7). It is noticed the presence of clear precipitates, rich in titanium (see spectrum in Figure 8), and precipitates rich in niobium (see spectrum in Figure 9).

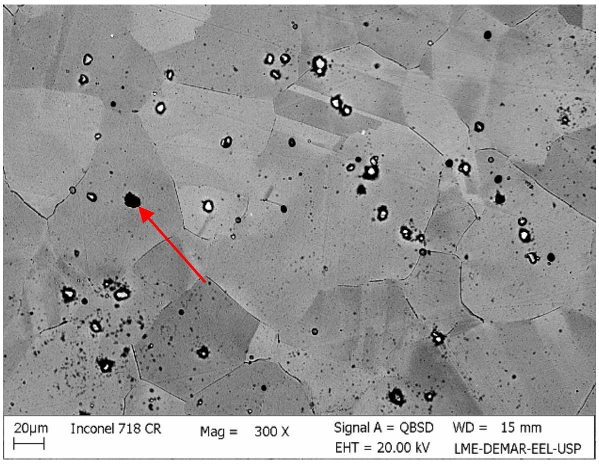

Fig. 6: SEM image of Inconel 718 as received.

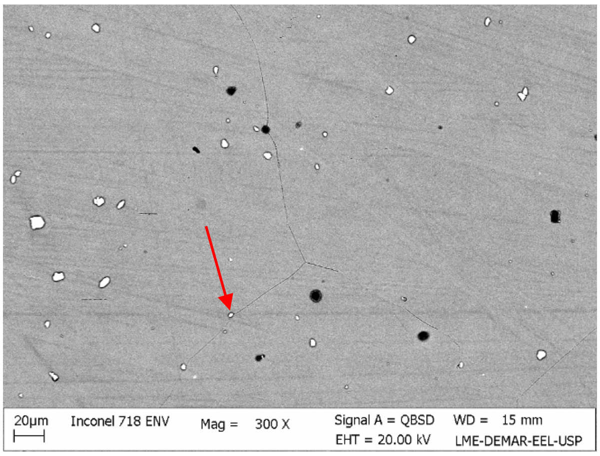

Fig. 7: SEM image of Inconel 718 after double aging.

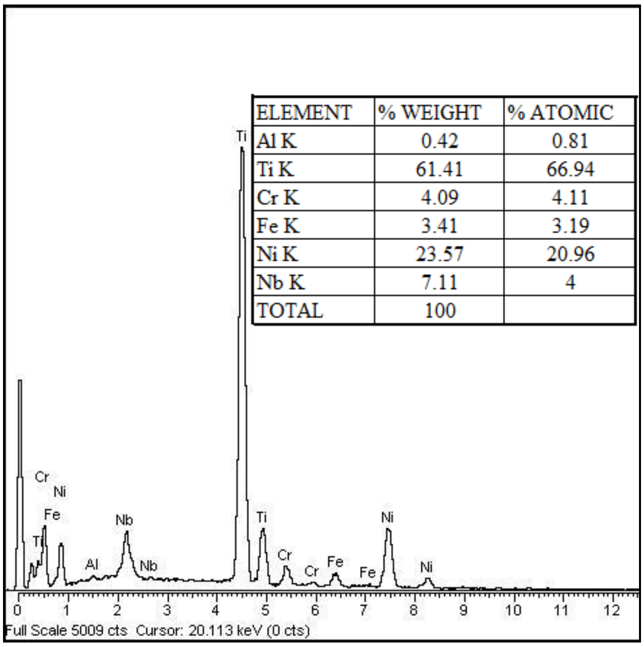

Fig. 8: EDS representing the chemical composition of dark precipitate from Fig. 6.

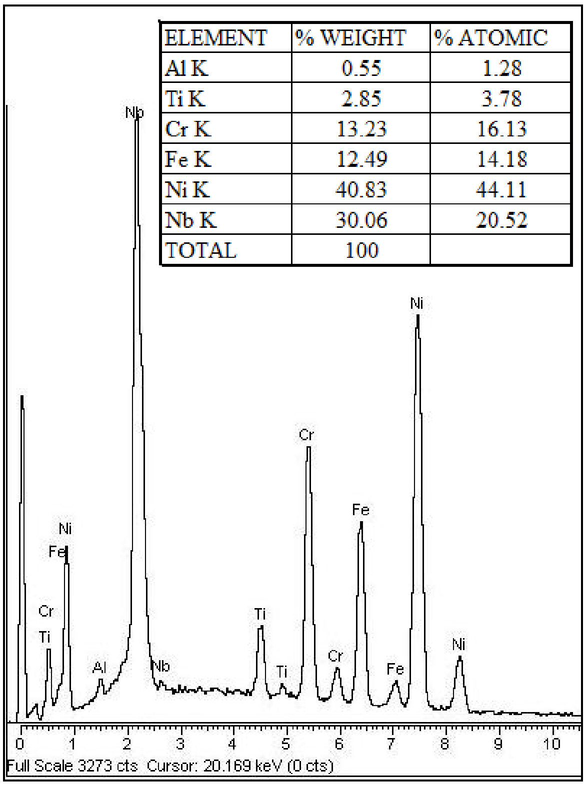

Fig. 9: EDS representing the chemical composition of clear precipitate found in grain boundary, from Fig. 7.

Table 2 present results of Vickers hardness for each step of double aging. It can be noticed a decrease in hardness after the solid solution step, probably due to the promotion of high diffusion of species, which results in a supersaturated matrix. In the end of heat treatment it is observed an increase of almost 100% in hardness, mainly due to the precipitation of γ' and γ''.

Grain size was calculated for each step of heat treatment and the values are represented in table 3.

Inconel 718	**ASTM grain size**
As received	8.20
Solid solution at 1095ºC	7.50
After the first aging step at 955ºC	7.23
Double aged	7.23

Discussion

The results obtained for grain size after full double aging heat treatment are coherent with those described by Kuo et al [5] which is an increase of grain size of 9% in the solid solution step. The progressive increase of hardness, mainly during the aging steps, indicates an effective increase of mechanical resistance and is associated to the formation of secondary phases. The figures 2-5 reinforce this conclusion, by showing a fine dispersion of precipitates along the matrix. It is also observed in the micrographies the formation of annealing twins, a typical defect found in structures that have their grain grown, usually associated with low stacking fault energy structures. The semi-quantitative analysis by SEM/EDS indicates the presence of precipitates based on niobium and titanium.

Conclusion

The double aging heat treatment has changed the characteristics of the microstructure of Inconel 718 superalloy, by showing increase of hardness and grain size growth. Those characteristics are desired when materials are submitted to deformation by creep.

Acknowledgments

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