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Microstructural Characterization of Inconel 718 for Aeronautical Use

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The Inconel 718 alloy is a nickel-based superalloy used to a large extent in the manufacture of critical parts for aircraft turbine engines due to its high mechanical properties, as well as good corrosion resistance. The main hardening phase in this alloy is the metastable γ''- Ni_3Nb phase with tetragonal body centered arrangement (DO_{22}). After treatment at temperatures equal to or higher than 750°C, the particle size of the γ'' phase increases rapidly, then the precipitates begin to dissolve in a stable orthorhombic phase (DOa) δ-Ni_3Nb.

In this work, the main interest has been the study of precipitates resulting from several isothermal aging performed after the homogenization, as well as the identification of the phases responsible for the different hardening stages γ'', γ' and δ. The analysis was made by SEM, dilatometry and Vickers hardness tests. The samples were brought to a homogenization annealing heat treatment at a temperature of 1060°C; then they were thermally aged at temperatures of 500, 600, 648, 700, 800, and 900°C.

It was found that all samples contain the same amount of carbides and nitrides with a size no greater than 15 μm, which means that these are stable at the temperatures of aging. These findings are in agreement with the results of Zhang [1]. It is concluded that these precipitates were formed during the manufacturing process. It is worth mentioning that under the SEM these primary carbides are spherical and light colored, while the nitrides are polygonal and dark colored [2] (Figure 1).

A relationship between the hardness (Table 1) and the precipitation of secondary carbides $M_{23}C_6$ and M_6C in the temperature range of 520 to 640°C was found. Figure 2a reveals that there are not carbides in the grain boundaries, while Figure 2b shows the presence of precipitates, which is in agreement with the results of the derivative in the dilatometric curve (Figure 3). This small material expansion is due to the phase precipitation, which coincides with the work of Zheng [3], who found that the formation of carbides $M_{23}C_6$ and M_6C occured at temperatures of 600 to 670°C. This means that samples aged at 600 and 648°C are mainly strengthened by these carbides. At 800°C there is a rapid growth of γ'', which can be verified by the hardness results, since γ'' is the main strengthener of the Inconel 718 alloy, and therefore the maximum hardening of the alloy is reached (360 HV). This fact is also suggested by the dilatometric curve, where it is observed a material expansion in the range from 760 to 820°C, indicating a phase change. At 900°C it is observe that the hardness decreases to 230 HV, due to the solubilization temperature of the γ' and γ'' phase between 900 and 920°C, according to Chamanfara [4]. The precipitation velocity of the δ phase is higher (Figure 1), which is related to the material shrinkage in the dilatometric curve at the temperature range of 820 to 950°C.

[1] Y. Zhang *et al*, Optics & Laser Technology 52 (2013) p. 30.

[2] J. Lambarri *et al*, Optics and Lasers in Engineering 51(7) (2013) p. 813.
[3] W. Zheng *et al*, Journal of Iron and Steel Research, 22(1) (2015) p. 78.
[4] A. Chamanfar *et al*, Materials & Design 52(2013) p. 791.

Table 1. Ratio of hardness per stage and aging temperature.

Sample	Homogeneous	500°C	600°C	648°C	700°C	800°C	900°C
Accumulated (h)	1	8	6-8	4-8	6-8	1	8
Hardness (HV)	165	165	185	215	290	360	230

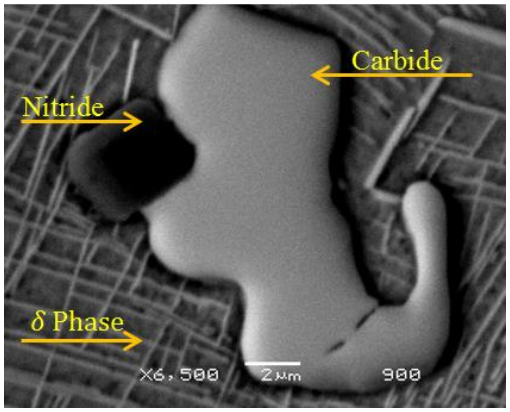

Figure 1. SEM micrograph of Inconel-718 where a carbide, a nitride and the δ phase are observed after an aging temperature of 900°C for 8 h.

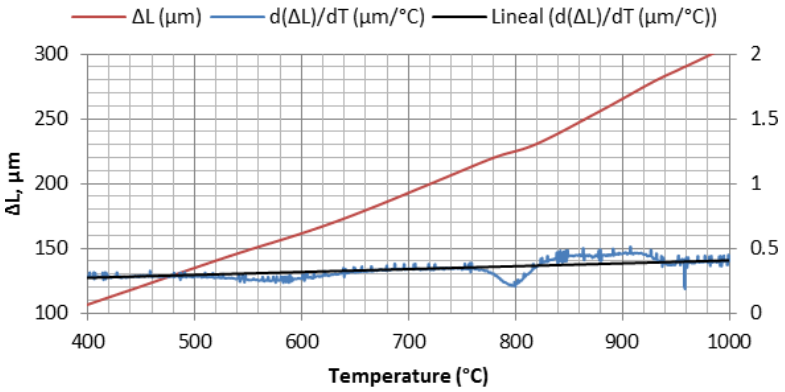

Figure 3. Dilatometric curve and the derivative of the length with respect to the temperature d(ΔL)/dT.

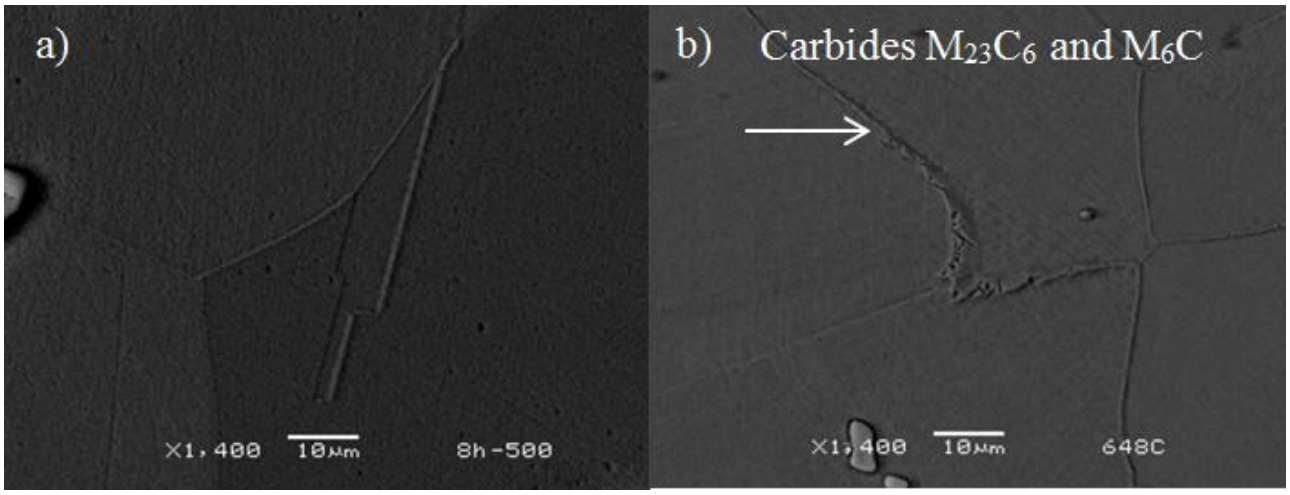

Figure 2. Inconel 718 alloy treated at a) 500°C and b) 648°C.

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