THE INFLUENCE OF IN718 ALLOY ANNEALING ON FATIGUE LIFETIME CHANGES

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1. Introduction

Alloy IN718 is widely used Ni – Cr – Fe hardenable material used mostly up to 700°C working temperature. Its microstructure is well described in works of authors [1-3]. Generally, as hardened conditions consist of solid solution gamma (FCC γ – phase, NiCr(Fe)), semi-coherent precipitate gamma prime (L1$_2$ γ' – phase Ni$_3$Al(Ti)), main strengthening also semi-coherent phase gamma double prime (BCT DO$_{22}$ γ'' – phase Ni$_3$Nb), and incoherent delta (orthorhombic δ – phase Ni$_3$Nb). All mentioned phases above are responsible for alloy's unique properties. However, not all phases are considered as helpful for mechanical properties. The influence of δ-phase is questionable, in small amounts situated at grain boundaries improves mechanical properties – especially ultimate tensile strength (UTS). At higher content may act as crack initiation site when cyclic loading is applied. There are two possible ways how to artificially increase the δ-phase amount. The first one is to vary the chemical composition, mainly the Nb content. δ-phase at temperature range 1010°C-870°C needs at least 6 to 8% of niobium to crystalize.
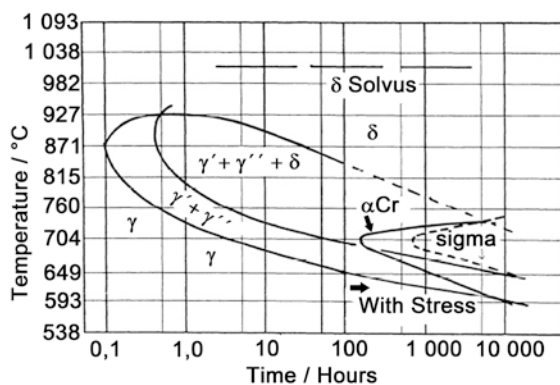

Fig. 1. T-T-T diagram according to work of and Armida Oradei-Basile and J. F. Radavich [4]

The second, easier way is to apply annealing at approximately 800°C for time over 50 hrs., Fig. 1 [4].

The aim of article is to provide a TEM (Transmission Electron Microscopy) and SEM (Scanning Electron Microscopy) analysis of applied annealing to increase δ-phase volume. The simple blocky samples were loaded with three-point flexure cyclic loading after annealing to evaluate positive or negative influence of increased volume of δ-phase onto fatigue lifetime.

2. Experimental

The experimental material, alloy IN718, with chemical composition, see Tab. 1, were annealed at 800°C/72 hrs.

C	Ni + Co	Mn	Ti	Al	B	Co
0.026	53.46	0.07	0.96	0.57	0.004	0.14
Ta	**Nb + Ta**	**Cr**	**Cu**	**Mo**	**Nb**	**Ni**
<0.01	5.31	19.31	0.03	2.99	5.30	53.32

Tab. 1. Chemical composition of IN 718 (wt. %)

Specimens for SEM observation were prepared via regular metallography steps and etched with 10g CrO_3 + 100ml H_2O electrolyte reagent. Specimens for TEM observation were cutted as thin cuts and next electrolytic thin foils at 18V and reagent 10% $HClO_4$ + 90% CH_3OH were prepared.

The ZWICK/ROELL Amsler 150 HFP 5100 were used as experimental machine for three-point flexure loading. Parameters for high cycle fatigue low frequency loading were set as follows:

- the static force F_{static} = -15 kN;
- the dynamic force $F_{dynamic}$ = 6.31 to 12.8 kN;

- the cycle limit $N_c = 2.10^7$;
- frequency $f = 150$ Hz.

3. Results

The tested alloy microstructure at the starting stage is presented in Fig. 2a, and Fig. 2b shows it after applied annealing at 800°C/72 hrs. Generally, the microstructure consists of very fine grain sizes according to ASTM = 12 (length of grains is around 10 μm), and various forms of segregated δ-phase (light gray particles). The δ-phase is presented mainly at grain boundary in a needle-like shape and in form of fine blocks inside the grains.
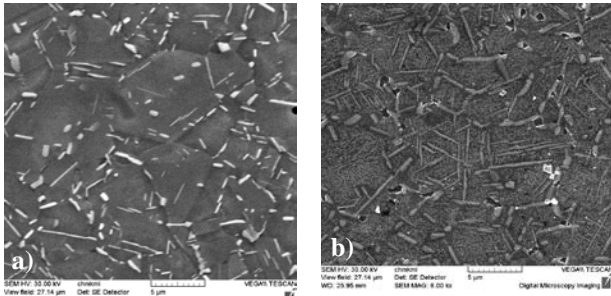

Fig. 2. SEM micrographs of wrought IN718 alloy, 10g CrO_3 + 100ml H_2O etch.

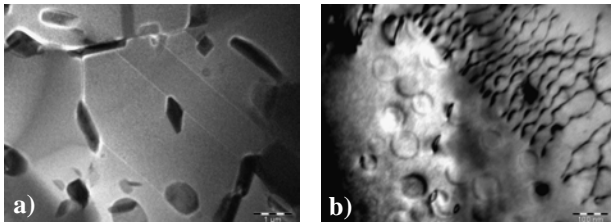**Fig. 3.** TEM micrographs of wrought IN718 alloy, 10% $HClO_4$ + 90% CH_3OH etch.

After application of annealing at 800°C/72 hrs. the main strengthening phase γ'' became more obvious because of temperature and δ- phase grew as well, Fig. 2b. According to reference [3], mechanical properties should deteriorate due to the δ-phase presence at grain boundaries and its growth. Moreover, with TEM analysis employed is clear to see the δ-phase of various shapes and formatted at grain boundary or inside grains, Fig. 3a. The microstructure is polyedric with deformation twins. Also note the higher volume of dislocation, which are cutting through the γ'-phase after applied annealing, Fig. 3b. Increasing the dislocation volume due to annealing increased mechanical properties as well, especially UTS

and fatigue properties, even if more δ-phase presented in alloy structure. These results confirm the S-N curve obtained after fatigue tests, Fig. 4.
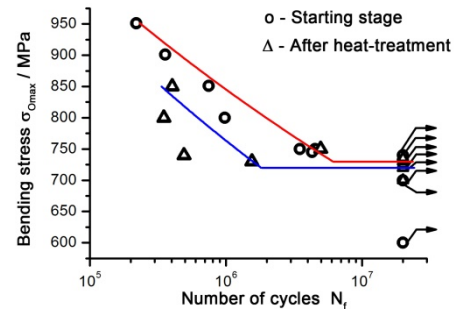

Fig. 4. The S-N curve plotted after three-point flexure fatigue tests.

4. Conclusions

Well known Ni – Cr – Fe alloy, IN718, was used for experimental procedure. Brief conclusions can be drawn. Applied annealing has influence on increasing the volume of δ-phase. The fact, that it causes decreasing mechanical properties (UTS or fatigue lifetime) was not confirmed. The most probably reason is higher volume of dislocation anchored to γ'-phase. This theory confirms the results after three-point flexure fatigue tests.

Acknowledgements

References

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