A MICROSTRUCTURAL AND MECHANICAL PROPERTIES COMPARISON OF P/M 718 AND P/M TA 718

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Abstract

The effects of Ta on phases and mechanical properties in conventional 718 type compositions have not been fully explored. While Ta and Nb have similar atomic sizes, the solubility of Ta in nickel is much greater than that of Nb. This difference in solubility would affect the initial segregation on solidification and subsequent phase reactions. To study the role of Ta in phase reactions and on alloy stability in a homogeneous material, a comparative study of conventional P/M 718 and P/M Ta 718 was undertaken.

The results of this study showed that the heat treatment used for conventional 718 did not produce an significant strengthening phases in Ta 718 and a modified heat treatment was necessary to precipitate γ' and γ' strengthening phases. The γ'' phase in Ta 718 is still present at 1750°F. The γ'' to delta transition in Ta 718 is more sluggish and occurs at higher temperatures than in conventional 718 materials. Data from tensile tests at 1400°F indicates that Ta 718 has a higher temperature capability than conventional 718.

Introduction

Ta and Nb atoms are generally believed to have similar effects on structures in high temperature superalloys, largely because of their similar atomic size and location in the periodic table. The role of Ta in Ni-based superalloys has been the subject of numerous papers, but the effect of Ta in Alloy 718 has not been fully explored. In Alloy 718, Nb has been shown to be not only part of the strengthening phases, but also the main cause of segregation because of its limited solubility in γ matrix. Homogenization efforts to eliminate the Laves phase and diffuse the Nb are time consuming since the rate of diffusion of Nb is slow, and large amounts of residual segregation are commonly found in so-called homogenized materials.

Recently, Loewenkamp, Radavich, and Kelly studied the effects of a one to one atomic base substitution of Ta for Nb in cast Alloy 718. Their study showed that Ta reduced the amount of initial segregation which they attributed to the higher solubility of Ta in the γ matrix. More importantly, Ta additions, similar to Nb, were found to produce strengthening γ'' phase. This γ'' phase was still present at temperatures up to 1800F. The transition of the γ'' to δ phase found in Alloy 718 was not obvious in the cast Ta-modified 718.

In the study by Loewenkamp, Radavich, and Kelly, the pattern of γ'' precipitation at 1800F suggested that residual segregation was present and that it would influence the temperature of stability of both the δ and γ'' phases. To eliminate the segregation effects on

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phase behavior, especially the strengthening γ' phase, a program was carried out to characterize the phases formed in alloy 718 to the phases in Ta 718 using homogeneous consolidated powder samples. The important goals of this program were to study the effect of Ta on the precipitation and stability of γ' and relate the γ' behavior to mechanical properties.

Materials Preparation

The Alloy 718 and Ta 718 powders were produced using argon atomization and commercial rapid solidification processes. The compositions of the powders produced are shown in Table 1.

Table 1: Alloy Compositions

wt%	Ni	Cr	Fe	Nb	Ta	Mo	Ti	Al	B	C	S
TA 718	48.5	20.4	18.9	-	7.2	3.3	0.9	0.5	0.001	0.03	0.01
Alloy 718	52.5	18.5	18.5	5.1	-	3.0	0.9	0.5	0.005	0.04	0.003

Both powder products were consolidated at atmospheric pressure (CAP) and were hot rolled at 2025F and heat treated at 1825F/1 hr./WC + 1325F/8 hrs./FC to 1150F/8 hrs./AC.

Room temperature tensile, 1200F tensile, and stress rupture tests were carried out. For Ta 718, 1400F tensile tests were also conducted. Microstructural characterization was performed using scanning electron microscopy, and phase identification was carried out using EDAX analysis and X-ray diffraction. Diffraction samples were prepared from residue of phase extractions using a 10% HCl-Methanol solution with a Ta cathode at 5 volts for approximately 2 hours.

The sample preparation for the SEM study was as follows:

1. Mechanical polish to 600 grit SiC paper and 6µ diamond polish.
2. Electropolish using a stainless steel beaker as the cathode and a solution of 20% H_2SO_4 and 80% Methanol. Polishing time was 20 seconds at 5 volts.
3. Electrolytic etch in a CrO_3 etchant (172cc H_3PO_4, 10cc H_2SO_4, 16g CrO_3) for 10 seconds at 5 volts.

Mechanical Properties Analysis

The results of the room temperature tensile and 1200F tensile tests for both conventional 718 and Ta 718 are shown in Figure 1 along with comparative literature values for the same heat treatment. The lower results for the Ta-modified product are due to the lack of adequate strengthening precipitates and porosity resulting from low densification of the Ta 718. The conventional Alloy 718 properties are also lower than comparative literature values as a result of the same low densification.

Fractography micrographs of the room temperature tensile samples, Figures 2A and 2B, illustrate the presence of residual porosity due to the lack of complete consolidation of the powder. When the consolidated samples were fully 100% dense, the mechanical properties improved dramatically. The important effect of densification on mechanical properties is shown in Figure 3.

Heat Treatment Study

SEM studies of the heat treated Ta 718 material showed very little precipitation of the γ'' and γ' strengthening phases when given the standard 1325°F to 1150°F age. The comparison in strengthening phase precipitation between Alloy 718 and Ta 718 is shown in Figures 4A and 4B. The precipitation in the Ta 718 is very difficult to resolve even at 30K magnification indicating the standard heat treatment was too low for Ta 718. Both figures show precipitated particles that are finely dispersed. Although Alloy 718 shows a greater dispersion of strengthening particles, neither alloy shows sufficient precipitation for optimum mechanical properties as evidenced by the high magnification necessary to view the γ'' and γ' particles.

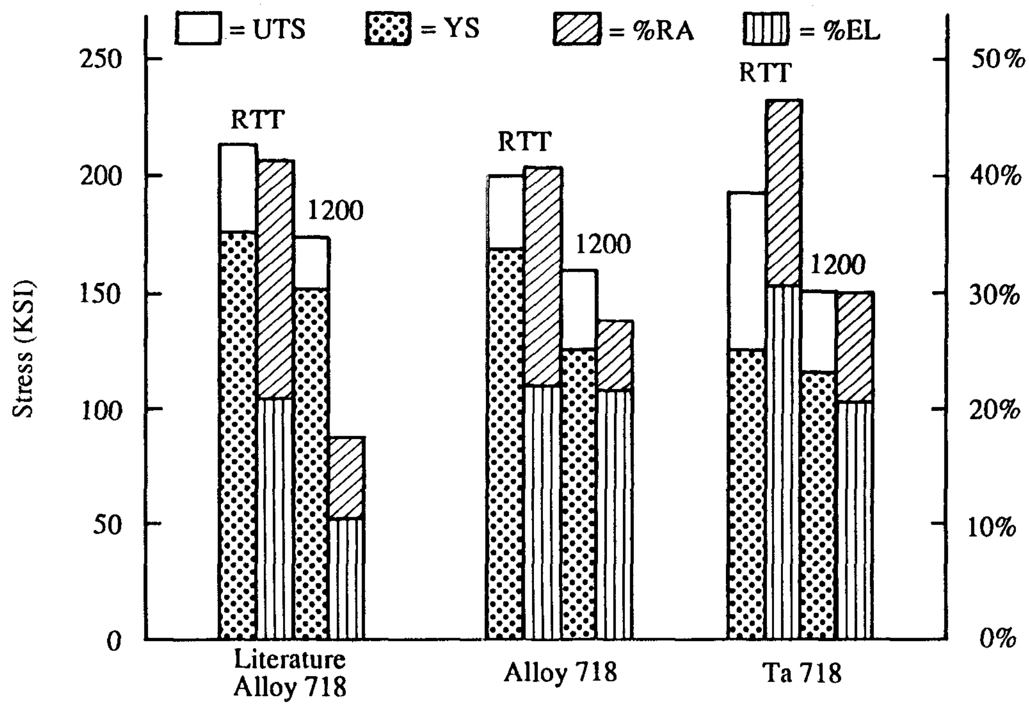


Figure 1: Mechanical Properties at Conventional Heat Treatment

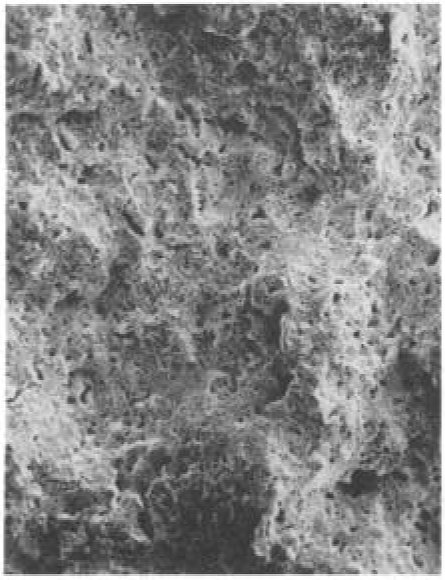
In order to optimize the mechanical properties of Ta 718, a series of heat treatments were carried out to produce a strengthening phase in Ta 718. Hardness tests were run to verify hardness changes which would indicate the precipitation of strengthening phases. As a result of these tests, a modified heat treatment of 1600F/ 1 hr. + 1350F/ 6 hrs. was selected and given to the Ta 718 samples and additional mechanical testing was performed.

Figure 4C shows the precipitation in the Ta 718 samples given the modified heat treatment. The size of the γ'' is much larger than in the conventional 718 heat treatment. The response of the γ'' to the modified heat treatments suggests that the size of the γ'' precipitation can be modified further for higher strengthening. A comparison of mechanical properties, shown in Figure 5, indicates higher tensile strengths with the new heat treatment. In addition, a 1400F tensile test on the modified heat treatment samples showed a substantial strength retention at elevated temperatures than found in comparable alloy 718.

Stability Testing

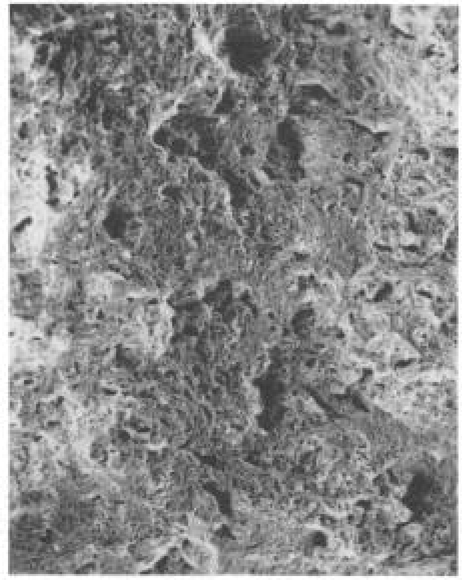
The mechanical properties analysis and the structures formed in the modified heat treatment study provided convincing evidence that the strengthening phases of Ta 718 do not precipitate in the same low temperature ranges as the conventional alloy. This indicated a greater potential for phase stability at higher temperatures compared to the conventional alloy. It has been shown that in the 1500F to 1600F temperature range, the $\gamma'' \rightarrow \gamma' + \delta \rightarrow \delta$ transition occurs rapidly in Alloy 718. In the final stage of the δ plate phase transition some γ' is left in the matrix before complete transformation to δ plates. In the transition of $\gamma'' \rightarrow \delta$ phase in the Ta 718, the precipitation of the γ' is absent near the δ plates.

Figure 6A shows microstructural changes for conventional 718 when exposed to 1500F for 100 hours. These structures show the final stages of the δ plate phase transition. The effects on microstructure in Ta 718 exposed for 100 hours are shown in Figure 6B. These micrographs indicate that almost no δ plate phases have formed in the Ta-modified product. γ'' particles are still present in the matrix indicating that the mechanical properties of Ta 718 after this exposure would be higher than those of conventional 718.



100X 100μm

Figure 2A: Fracture Surface of Alloy 718 RTT Sample



100X 100μm

Figure 2B: Fracture Surface of Ta 718 RTT Sample

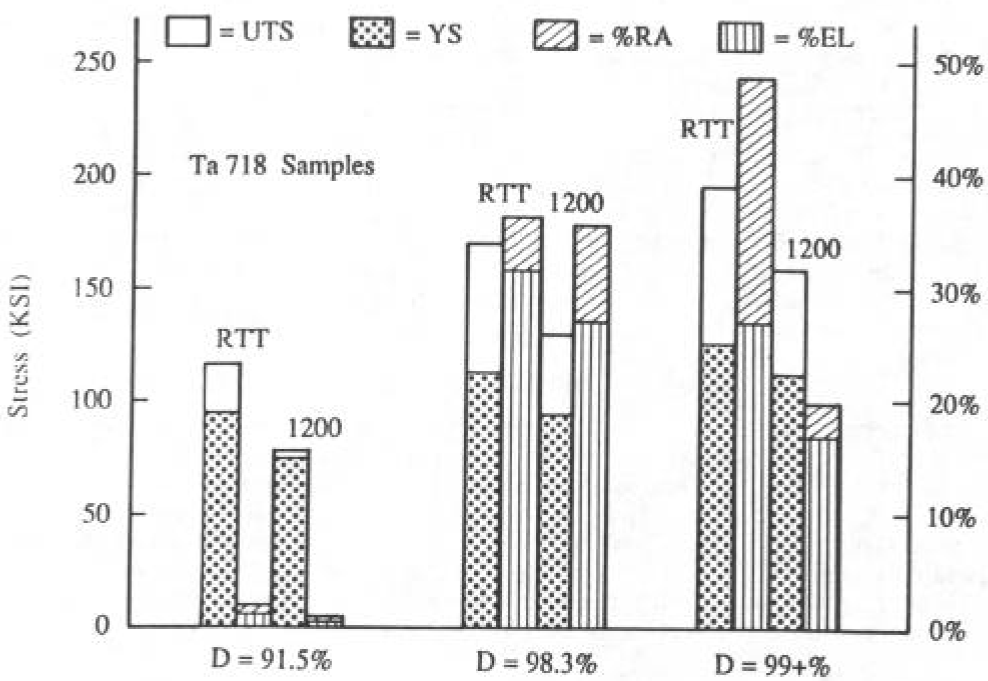
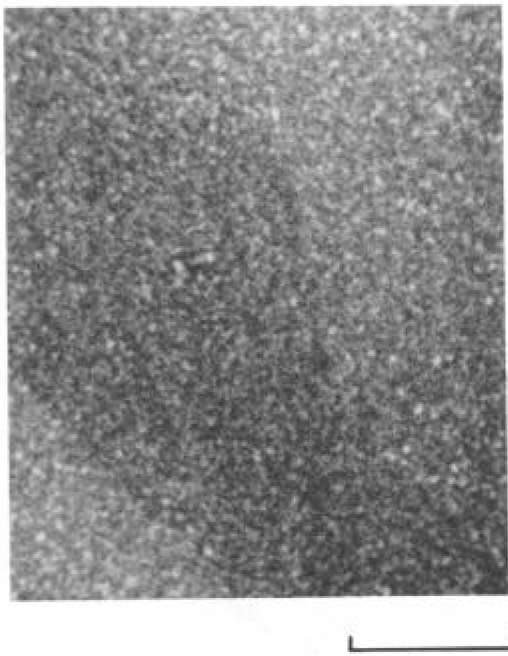


Figure 3: Comparison of Mechanical Properties with Densification



30000X 1μm

Figure 4A: Alloy 718 with Conventional Heat Treatment

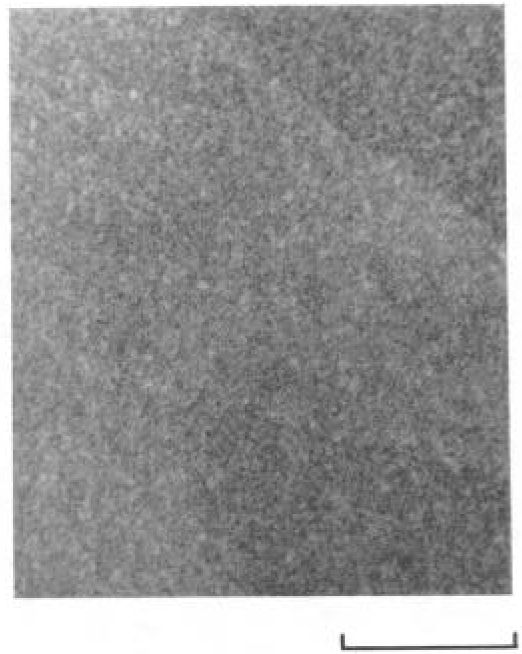


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Figure 4B: Ta 718 with Conventional Heat Treatment

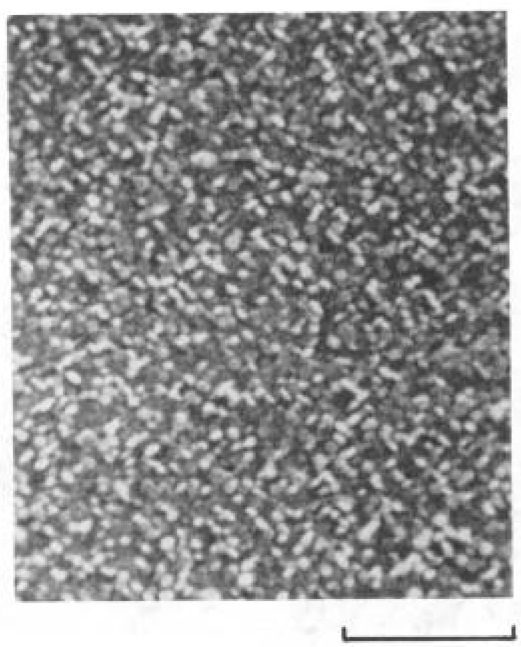

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Figure 4C: Ta 718 with Modified Heat Treatment

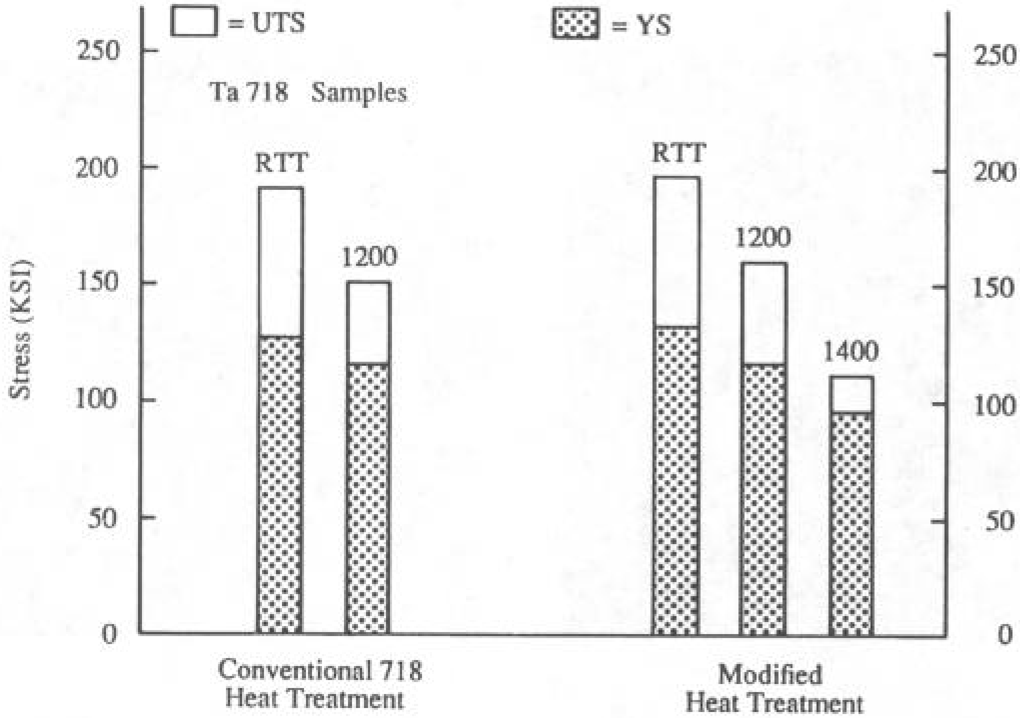


Figure 5: Comparison of Mechanical Properties at Modified Heat Treatment

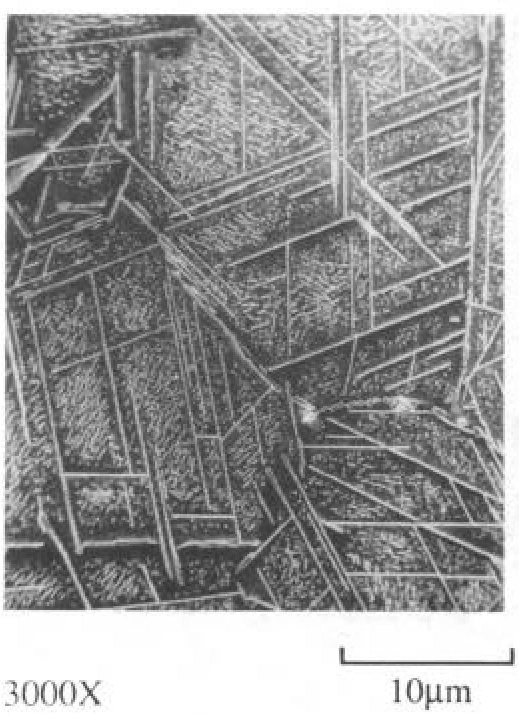


Figure 6A: Alloy 718 1500F / 100 hrs.

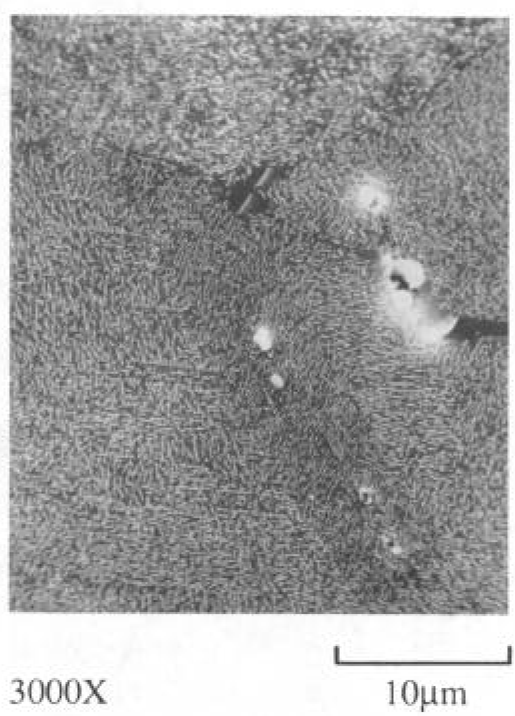
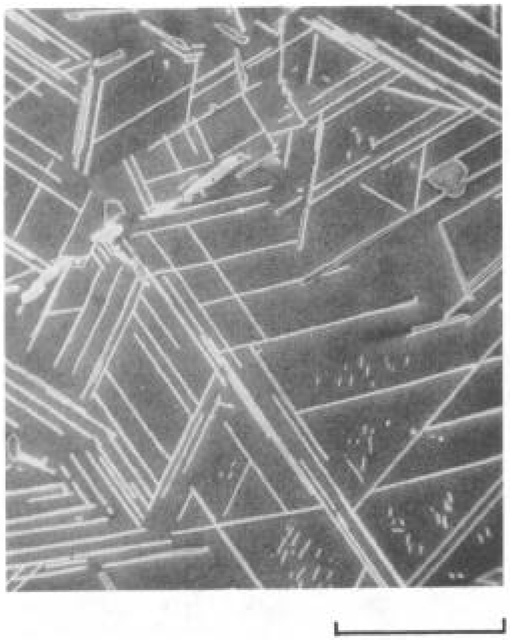
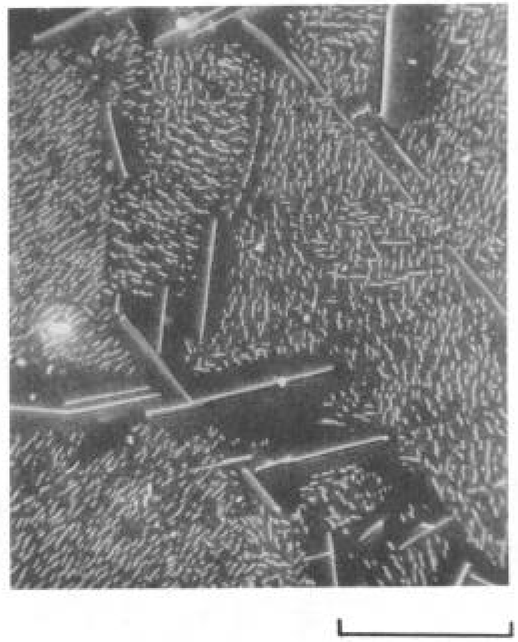


Figure 6B: Ta 718 1500F / 100 hrs.



3000X 10μm

Figure 6C: Alloy 718 1600F / 50 hrs.



3000X 10μm

Figure 6D: Ta 718 1600F / 50 hrs.

The structures formed after a 1600F/ 50 hr. exposure on Alloy 718 is shown in Figure 6C. All the strengthening phases have completely transformed to δ plates. For Ta 718, some δ plates have formed, but the matrix still contains many γ' particles as shown in Figure 6D. These stability photographs convincingly indicate the greater phase stability of the Ta-modified alloy in the 1500-1600F range.

Conclusions

The following conclusions may be drawn from this work:

- Mechanical properties for Ta 718 were not optimum because of porosity and the use of a non-optimal heat treatment
- For the same low temperature heat treatments, Ta 718 showed less response to phase precipitation than conventional 718 indicating higher temperature stability of precipitating phases
- A modified heat treatment of 1600F / 1 hr. + 1350F / 6 hrs. produced γ″ precipitation which gave more reproducible properties.
- Data from the 1400F tensile test indicated higher strengths potential in Ta 718 than conventional Alloy 718.
- Elevated temperature exposures shows less tendency toward δ transition in Ta 718

Acknowledgements

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