THE EFFECTS OF 650℃ LONG EXPOSURE ON ALLOY 718 DA DISK

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Abstract

An isothermal aging study was carried out on alloy 718 DA disk for up to 1000 hours at the temperature of 650℃. There was almost no changing in the size and main amount of strengthening phase γ'', and the mechanical properties are also unchanged when alloy 718 DA disk was exposed for 500 hours at the temperature of 650℃. When the disk was exposed to 1000 hours at the temperature of 650℃, although tensile properties remained stable, but γ'' size became increasing, γ'' amount decreasing and stress rupture, creep and low cycle fatigue properties had a evident changing. The stress rupture time only had about a half of the rupture time of DA718 disk. The remained plastic strain had a larger increase in the creep tests and the ability of resistance against plastic strain weakened at 650℃ low cycle fatigue experiment when the DA disk was exposed to 1000 hours at the temperature of 650℃. The change of strengthening phase γ'' in size and amount will cause the variation in some mechanical properties on alloy 718 DA disk.

Superalloys 718, 625, 706 and Various Derivatives
Edited by E.A. Loria
TMS (The Minerals, Metals & Materials Society), 2001

Introduction

Alloy718 is a high strength precipitation-hardened Ni-base superalloy that over a period of almost 40 years has gained huge acceptance for intermediate temperature applications in the aircraft industry, for example as disks, axises and bolts et al in airplane engine. Now, many alloy 718 disks have acquired thousands of hours of operation and their degree of structural response to service temperatures would be important to design and material engineers. After a long-time heat exposure of alloy 718, the better understanding of the changing of the phases and mechanical properties is important, which would be necessary to the predict the useful life and reliability of the component.

Materials and Procedure

The alloy 718 DA disk used in the present investigation was produced by 63T-M high-speed hammer, and the diameter of the disk is about 520mm. The chemical composition of the disk is listed in Table Ⅰ. The δ-Ni_3Nb morphology and grain size of the disk is shown in Figure 1. The microstructure is uniformity. Grain size is ASTM NO.10 or finer and the δ phases within graines or at grain boundaries represent a short bar or globular shape.

Table Ⅰ Chemical Composition of the DA718 disk (wt.%)

Nb	Ta	Mo	B	Al	Ti	Cu	Mn
5.34	<0.05	3.03	0.0034	0.55	1.02	0.03	0.03
C	Ni	Cr	Fe	Bi	Pb	Ag	Tl
0.029	52.32	18.94	18.55	<0.00003	<0.0001	<0.00004	<0.0001
Co	Si	S	P	Sn	Mg	O	N
<0.05	0.15	0.003	0.0017	0.0024	0.0013	0.0002	0.0016

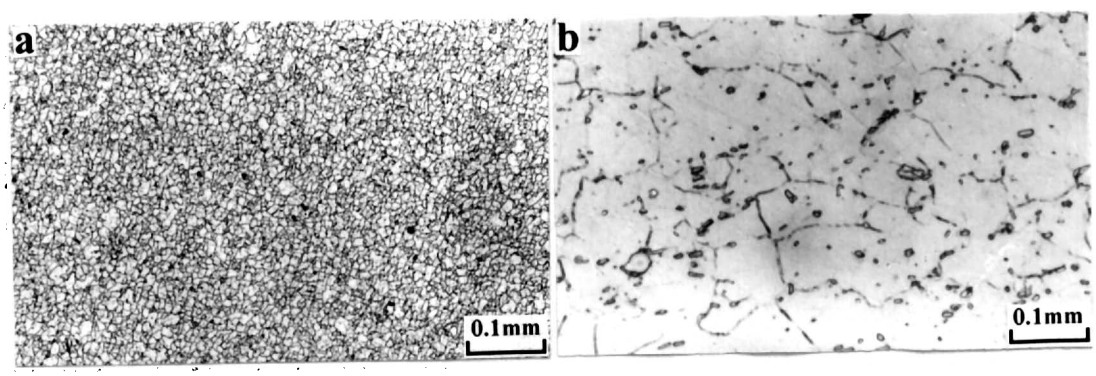

Figure 1 The microstructure of alloy 718 DA disk
a) grain size (ASTM 10)
b) δ-Ni_3Nb morphology

To study the effect of elevated-temperature exposure on the microstructure and mechanical properties of alloy 718 DA disk, the samples were cut from the DA disk and aged at 650℃ for 500 hours and 1000 hours. Then the changing of samples' microstructure and tensile, stress rupture, creep and low cycle fatigue properties was studied.

Results and Discussion

Structure Examination

The thin foils from the alloy 718 DA disk and the aged sample were examined by transmission electron microscope. The strengthening phase in alloy 718 was metastable body-centered tetragonal(DO22) Ni_3Nb precipitates γ″ and ordered fcc(LI2) γ′. The predominant precipitate phase was bct γ″. A typical [001] diffraction pattern and 1 1/2 0 superlattice reflection are shown in Figure 2. Figure 2 (b),(C),and (d) are the dark field imagines, which clearly show the disk-shaped γ″. The relative amount and size of γ″ can be get from figure 2. Figure 2 (b) is the 1 1/2 0 superlattice refection of the sample from alloy 718 DA Disk, (c) from the DA disk aged 650℃×500 hours, and (d) from the DA disk aged 650℃×1000hrs. Figure 2 (b) suggests that the disk-shaped γ″ precipitates are very fine and well-distributed. The precipitates have about a mean disk thickness of 30 A and diameter of 100~200A. Figure 2(c) doesn't show evident difference to Figure 2(b) at γ″ amount and size. But comparison of Figure 2(d) and Figure 2(b) shows that Figure 2(d) have a larger size and less amount of γ″, about the mean disk thickness 100A and diameter 300~450A. It is apparent from these comparisons(figure 2) that considerable coarsening of the bct γ″ phase occurred after the 1000 hours aging at 650℃, and the particle numbers get decreased.

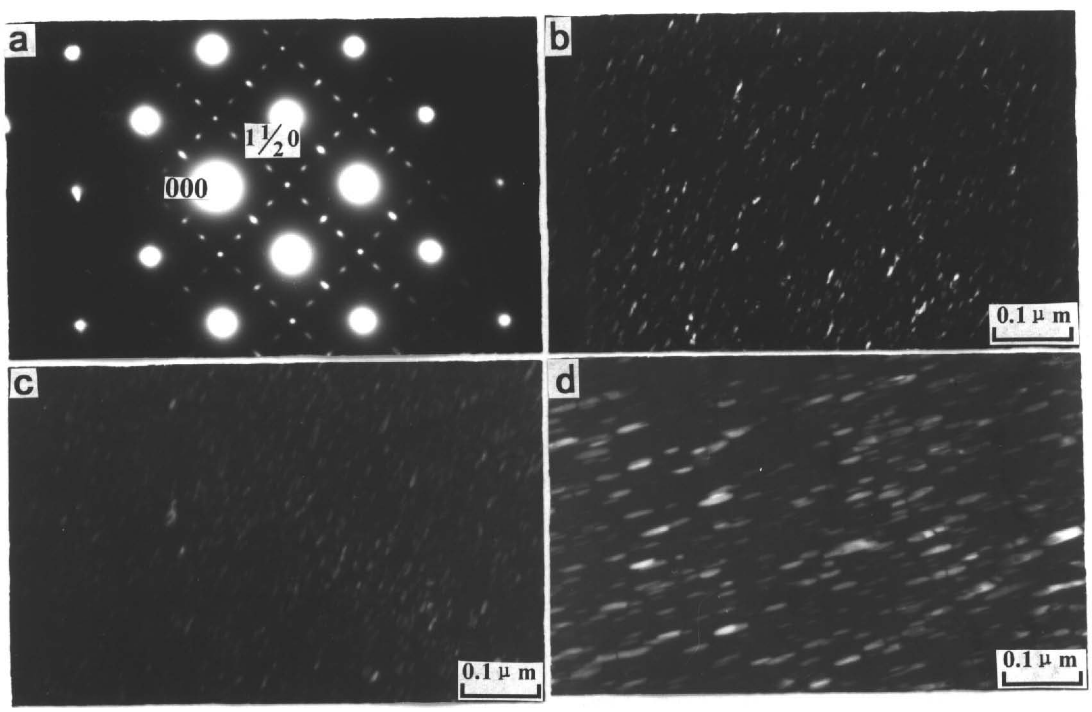

Figure 2 TEM microstructure of alloy 718 DA disk
(a) [001] diffraction pattern (b) DA(g=11/20 dark field imagine)
(c) DA+650℃×500hrs(g=11/20 dark field imagine)
(d) DA+650℃×1000hrs(g=11/20 dark field imagine)

Mechanical Properties

Tensile Properties. Table Ⅱ lists the tensile results for DA718 disk and aged specimens at the temperature R.T. and 650℃. The data of ultimate strength ,yield strength, elongation(δ)and reduction of area (ψ) show little variation between DA 718 disk and the aged specimens. That indicates although DA718 disk have a coarsening of strengthening γ″ phases after aging 1000 hours at 650℃, the tensile properties didn' t be affected by that variation.

Table Ⅱ Tensile Properties of Alloy 718 Disk

Condition	Temperature (℃)	UTS MPa	YS MPa	δ %	RA %
DA	RT	1350	1483	17.7	39.9
DA+650℃×500hrs	RT	1346	1470	17.3	39.4
DA+650℃×1000hrs	RT	1365	1498	17.4	36.6
DA	650	1127	1251	18.2	26.2
DA+650℃×500hrs	650	1138	1246	18.9	29.8
DA+650℃×1000hrs	650	1146	1260	19.0	33.5

*The every data of Table Ⅱ is average value of the two specimens

Stress Rupture Properties. Table Ⅲ lists the results at 650,700MPa stress rupture tests on the DA718 disk and aged specimens. The trends for the stress-rupture life and plastic value(δ , ψ) after aging for 1000hours at 650℃ are plotted in figure 3.The stress rupture life starts to

Table Ⅲ Stress Rupture Properties of Alloy 718 Disk

Condition	Temperature (℃)	Stress MPa	Fail Time (hrs:minutes)	δ %	RA %
DA	650	700	127:42	13.36	26.04
DA+650℃×500hrs	650	700	129:18	18.0	29.72
DA+650℃×1000hrs	650	700	61:00	20.0	36.26

*The every data of Table Ⅲ is average value of the two specimens

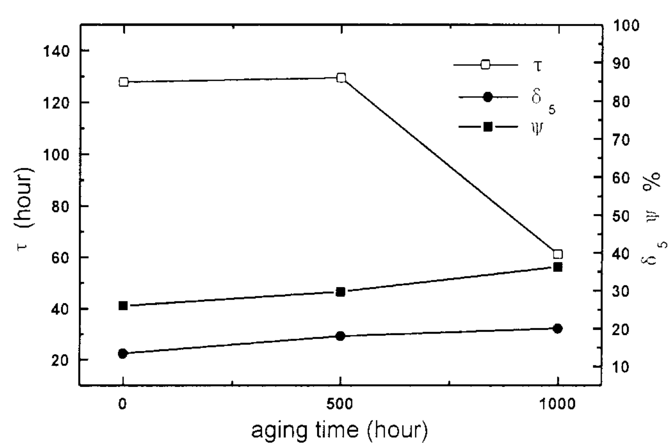

Figure 3 Effects of thermal aging on the stress rupture life of DA718 disk

decrease after 500 hours aging and decreases in 1000 hours aging to about 50% of its original value, yet the ductility and elongation does not change apparently for the same aging time. Although the coarsening and decrease of γ'' didn' t affect tensile properties, the variation of γ'' phase did produce an effect on the stress-rupture life, or the material ability to resist rupture at elevated temperature under the stress.

<u>Low Cycle Fatigue.</u> On alloy 718 DA disk and aged specimens, low cycle fatigue tests were conducted at 650℃ using total strain control, and the results are shown in figure 4.Comparing the results of the DA disk and the DA disk aged 650℃×500hrs, figure 4(a) indicates three curves of the DA disk, $\Delta\varepsilon t/2$-2N, $\Delta\varepsilon p/2$-2N and $\Delta\varepsilon e/2$-2N, is overlap with same ones of the aged samples in large parts, which suggests the LCF of DA718 disk keep stable when aging 500hrs at 650℃.

Figure 4(b) shows that after aging 1000hrs at 650℃, $\Delta\varepsilon p/2$-2N line of the specimens is under the one of DA disk at the most part. The transition life of the LCF on DA718 disk, overlap point of lines $\Delta\varepsilon p/2$-2N and $\Delta\varepsilon e/2$-2N, is about 133, but the transition life of the specimens aged 1000 hours at 650℃ is about 70. It is supported that the ability of DA718 disk to resist cycle strain drops after aging 1000 hours at 650℃. In the large strain stage of figure 4(b), the LCF property of DA disk decrease, but in other stage, smaller strain stage, the LCF of DA718

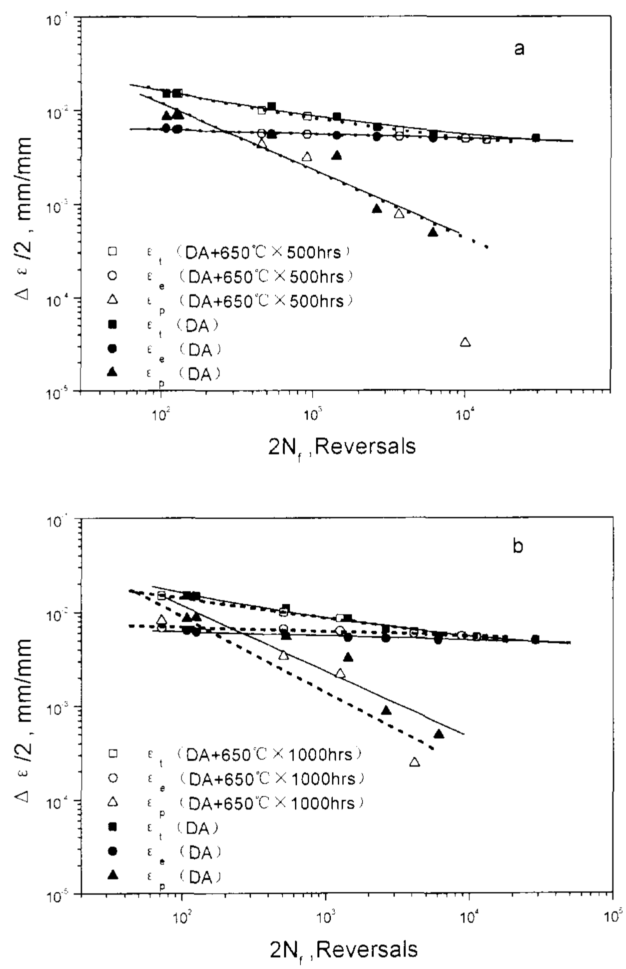

Figure 4 Effects of thermal aging on 650℃ low cycle fatigue of DA718 disk
(a) DA, DA+650℃×500hrs (b) DA, DA+650℃×1000hrs

disk keeps stable. The DA718 disk is used in the condition of elasticity-plasticity strain, and plastic strain takes a smaller portion. So, to actually used condition, a smaller plastic strain, the LCF of the DA718 disk didn' t change apparently after 1000hrs at 650℃, which didn' t have an influence on the safe use of DA 718 disk.

<u>Creep Properties.</u> Table Ⅳ lists the results of the creep tests on the DA718 disk and aged specimens, which is conducted at 595℃ under 825 MPa. The changing trends of creep property in aging for 1000hrs at 650℃ on the disk is shown in figure 5. After aging 500 hours at 650℃, remains elongation(δ_p) of the creep test keep stable, but the δ_p increases apparently when the specimens aged for 1000hrs at 650℃. In table Ⅳ, the mean δ_p of the DA718 disk is 0.041% after 25 hours testing, 0.050% after 50 hours, but the mean δ_p becomes greater after 1000 hours aging, 0.24% after 25 hours, 0.32% after 50 hours.

Table Ⅳ Creep Properties of Alloy 718 DA Disk

Condition	Temperature (℃)	Stress MPa	Last Time (hrs:minutes)	δ_t %	δ_e %	δ_p %
DA	595	825	25:00	0.539	0.498	0.041
DA	595	825	50:00	0.557	0.507	0.050
DA+650℃×500hrs	595	825	25:00	0.587	0.521	0.066
DA+650℃×500hrs	595	825	50:00	0.610	0.519	0.091
DA+650℃×1000hrs	595	825	25:00	0.704	0.463	0.241
DA+650℃×1000hrs	595	825	50:00	0.862	0.543	0.32

*The every data of Table Ⅳ is average value of the two specimens

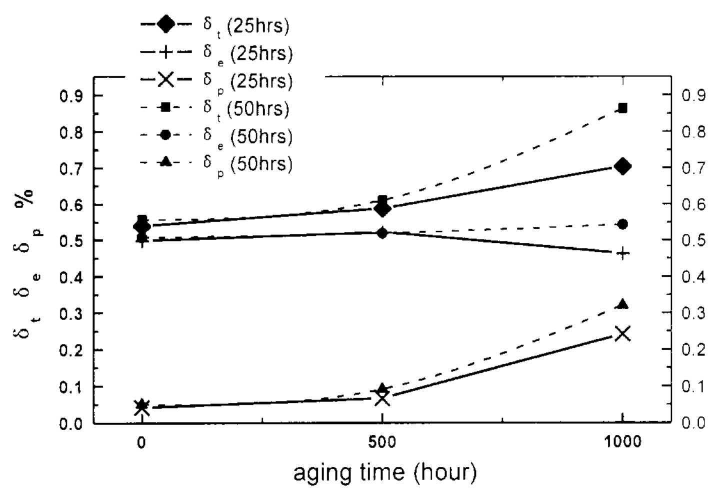

Figure 5 Effects of thermal aging on creep properties of DA718 disk

The increasing of the remains elongation(δ_p) on the DA718 disk shows the drop of material ability to resist plastic deformation under stress after aging for 1000 hours at 650℃. That can be explain by the coarsening of γ'' . In material, the creep deformation proceeds through the slip and climb of dislocations and moving of grain boundaries. The strengthening phases γ'' can resist above moving. When γ'' become larger in size and less in number, this resistance weakens. So, the decrease of creep properties on the DA718 disk after aging accorded with coarsening of γ″. The decrease in creep properties is due primarily to a coarsening of the bct γ″.

Conclusions

1. For aging 500 hours at 650℃, alloy 718 DA disks have a stability on microstructure and mechanical properties.
2. For aging 1000 hours at 650℃, the strengthening phases γ″ in alloy 718 DA disks became larger in size and less in number, the stress rupture life became shorter and the ability of material to resist cycle plastic deformation and plastic deformation at the certain stress weakened, but the tensile properties remained stable.

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