THE STRUCTURE AND MECHANICAL PROPERTIES OF ALLOY 718 DA DISK ON HAMMER

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ABSTRACT

Generally, Alloy 718 DA disks are forged by means of hydraulic press. However this paper investigates the forging of Alloy 718 DA disk on hammers. The structure and mechanical properties of this DA disk are present. The final forming was carried out on the 63T-M hammer. Structure analysis showed successful results, grain size was very fine and especially did not have cold-die structure. Mechanical properties can all meet the requirements of Alloy 718 DA disks. This metal forming process is acceptable for Alloy 718 DA disks production.

Superalloys 718, 625, 706 and Various Derivatives
Edited by E.A. Loria
The Minerals, Metals & Materials Society, 1994

Introduction

Although the production and application of Alloy 718 have 30～40 years history, DA 718 process development was only about fifteen years. Alloy 718 DA process makes the properties of forges to a higher level. However the control of DA technology is difficult. It demands good quality of stocks (For example uniformity of structure and composition, purity etc.) and strict control of forging temperature and deformation degree. As the process parameter can be easily controlled on the press, it is obvious that the press is suitable for DA forging. Many countries use the press for Alloy 718 DA forging. But forging on the press has its disadvantage than on the hammer. Alloy 718 DA forging on the press has larger region of cold-die structure than on the hammer. Another advantage on the hammer is lower cost. Therefore if the selection of process parameter is suitable, Alloy 718 DA forging can be carried out on the hammer. Many research works on Alloy 718 DA process on hammer have been done in China and satisfied results have been obtained, which has been successfully applied in production of Alloy 718 disks.

Materials and Processing

Materials

The material used in the present investigation was produced by Shanghai Fifth Steel Plant, China, the heat number is 343-2, the diameter of the ingot is 423mm. The ingot was VIM +VAR melted and homogenized by double homogenization process 1150℃～1160℃ and 1180 ℃～1190℃. The ingot was drawn into 200mm diameter billet through severel forging processes. The chemical composition of the alloy is listed in Table 1. The carbide morphology and grain size of the billet is shown in Figure 1.

Table 1 Chemical Composition of Heat 343-2 Alloy 718 (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

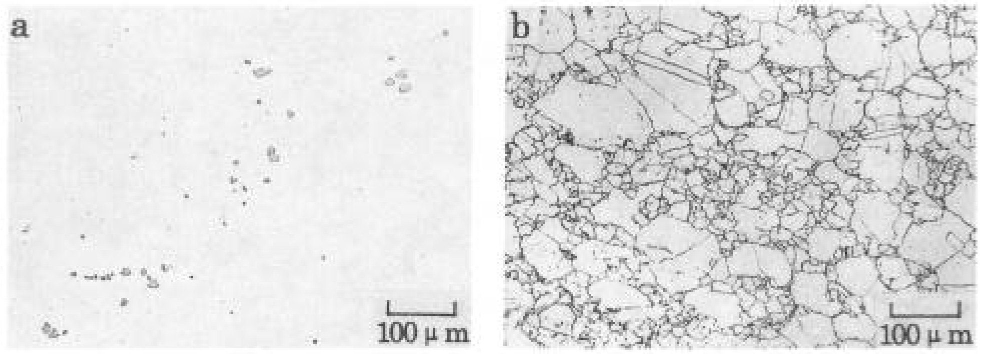

Fig. 1 The microstructure of 200mm diameter billet
a) MC morphology
b) grain size (ASTM 5)

Processing

Alloy 718 DA disks were forged on the 63T-M hammer through two forging operations. The disks were heat-treated, directly aged processing (DA). The microstructure examination and mechanical properties of the disks were carried out. The first upset was pancake forging, 200mm diameter billet was forged into pancake. The initial upset temperature is 1010℃, the reduction in height is 75%, and the flat-die temperature for the first forging is about 350℃. The first upset was followed by air cool. The surface of the billet was coated with glass lubricant, insulting cloth and steel sheet during initial forging to ensure the uniformity of the temperature and strain of the billet during the forging, improving structure uniformity and minimizing cold-die structure. The final upset temperature is 990℃. The reduction in height in the most parts of the disk is 50~60%. The die temperature is about 350 ℃. As the first forging, during the final upset the glass lubricant, insulting cloth and steel sheet were used. Figure 2 illustrated the process of the two forging operations. After the initial upset the pancake was lathed a bore in the centre to improve the deformation of the final forging. The second upset was followed by a water quench. The disks were heat-treated using the standard Alloy 718 duplex age cycle, 1325°F/8hrs, furnace cool at 100°F/1hr to 1150°F, hold 8hrs at 1150 °F, air cool. Finally the disks were evaluated by microstructure examination and mechanical properties tests including macrostructure, MC morphology, grain size, δ phase morphology, size and shape of $\gamma' + \gamma''$precipitates, tensile, stress rupture and LCF tests, etc.

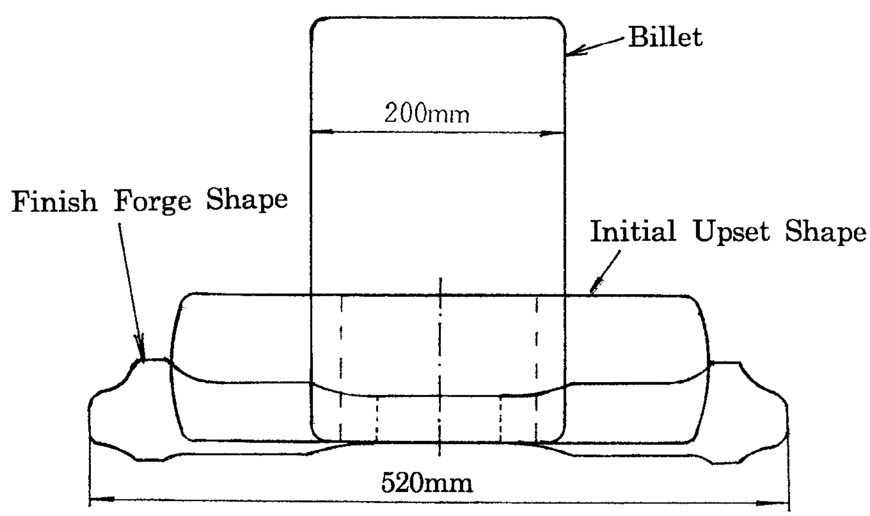

Fig. 2 Schematic drawing of DA disks two forging operations on 63 T-M hammer

Results and Discussion

Structure Examination

The macrosturcture of the disks on 63T-M hammer (Figure 3) revealed that good structure uniformity was achieved in all parts of the disks, and grain size is very fine. It is noticeable that the disks have no cold-die structure. This is due to the rational choices of forging operation parameters and proper use of the glass lubricant, insulting cloth and steel sheet in the first and final upset, the fact that the stocks were kept in a complete envelope of steel sheet during all forging processing, which led to the uniformity of the temperature and strain of the stocks. Figure 4 shows the small and randomly distributed MC. The grain structure of all regions of the disk is shown in Figure 5. In the regions closed die grain size is ASTM 10-10.5. In the central regions of the disk the grain size is about ASTM 9.5. This difference of the grain size was caused by the forging heat effect that made the temperature of the central region rise. The better uniformity of the grain structure can be obtained by adjusting the forging processing parameters. The morphology of the δ-Ni_3Nb phase of the DA disks on 63T-M hammer is shown in Figure 6. There is a number of δ-Ni_3Nb phase precipitates at grain boundaries and within grain. The δ phases within the grain are discontinues and occur in short bar shape and the morphology of the grain boundary δ phases is discrete globular form which along or eminate the grain boundary (Figure 7). The morphology of the δ phase is important to the mechanical properties. The delta phase spheroidization is a preferred morphology[4], The discrete globular form of grain boundary δ phase has a retardation effect on intergranular fracture in stress rupture[3]. The best combination of tensile, creep and low cycle fatigue properties needs a limited amount of the delta phase precipitates[1]. The thin foils from the DA disks were examined by transmission electron microscope. A typical[001]

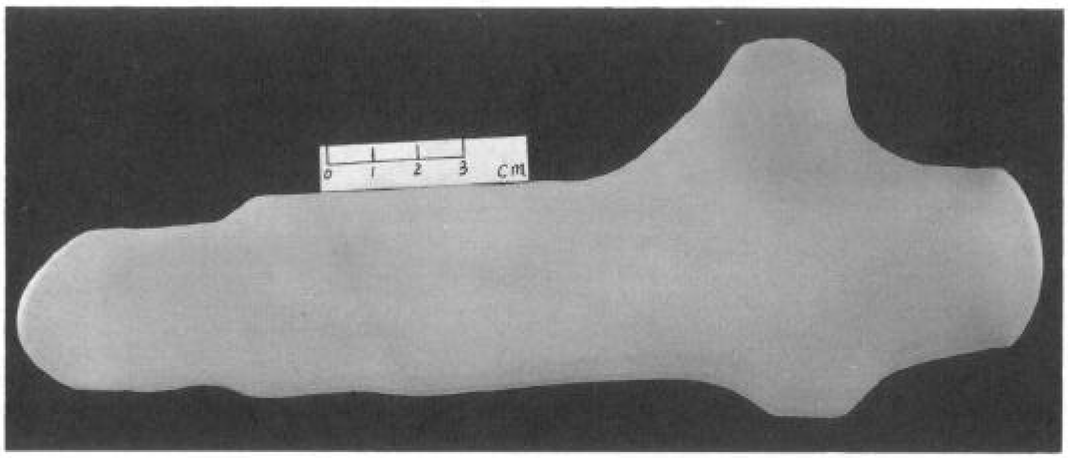

Fig. 3 The cross-section macrostructure of DA disk on 63T-M hammer

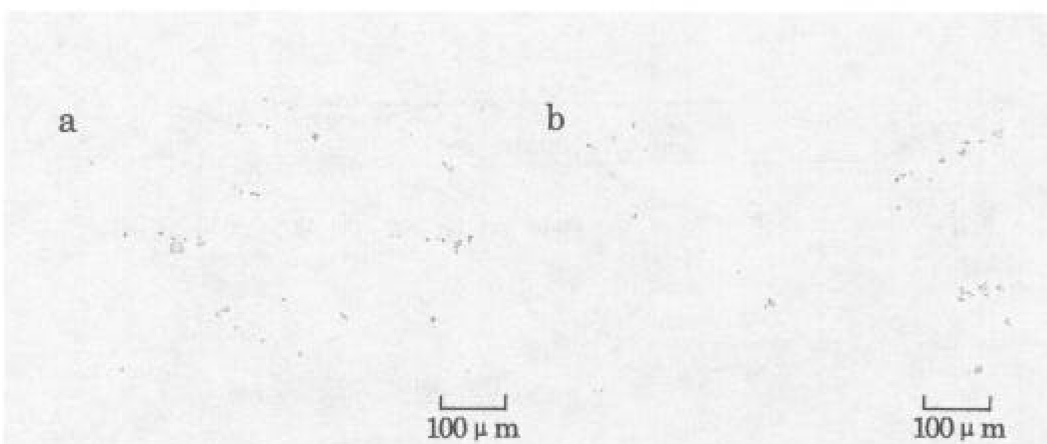

Fig. 4 The MC Morphology of the DA disks on 63T-M hammer.
a) rim b) web

diffraction pattern and the $1\frac{1}{2}0$ superlattice reflection are shown in Figure 8. Figure 8(b) suggests that the disc-shaped γ'' precipitates are very fine and well-distributed. The γ'' precipitates have about a disc thickness of 30 Å and diameter of 100 Å ~ 200 Å. The major strengthening phase in Alloy 718 is a disc-shaped body-centered tetragonal (DO22) precipitate Ni_3Nb-γ'' phase[5]. The smaller size of γ'' phase will improve the mechanical properties of the Alloy 718.

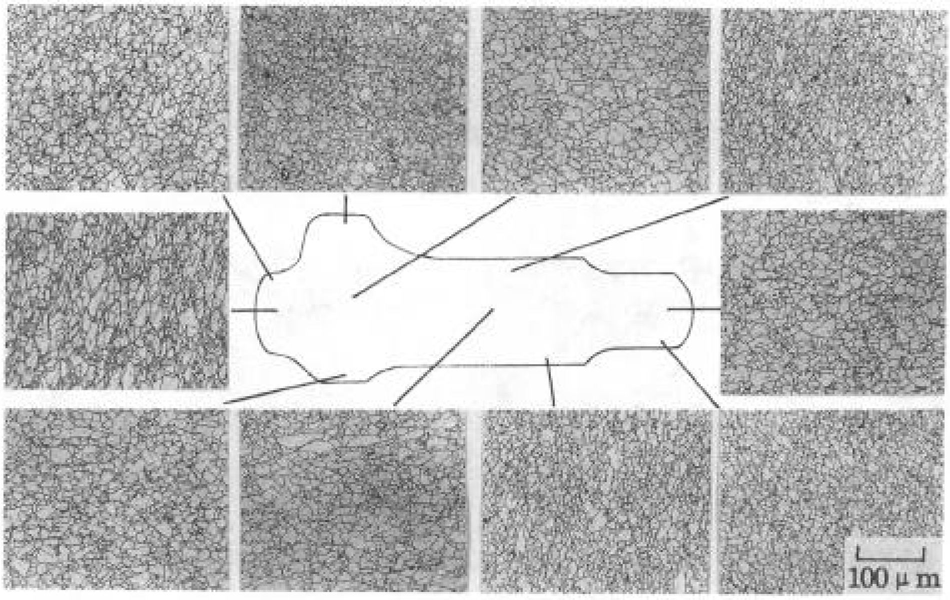

Fig. 5 The grain structure of the DA disks on 63T-M hammer

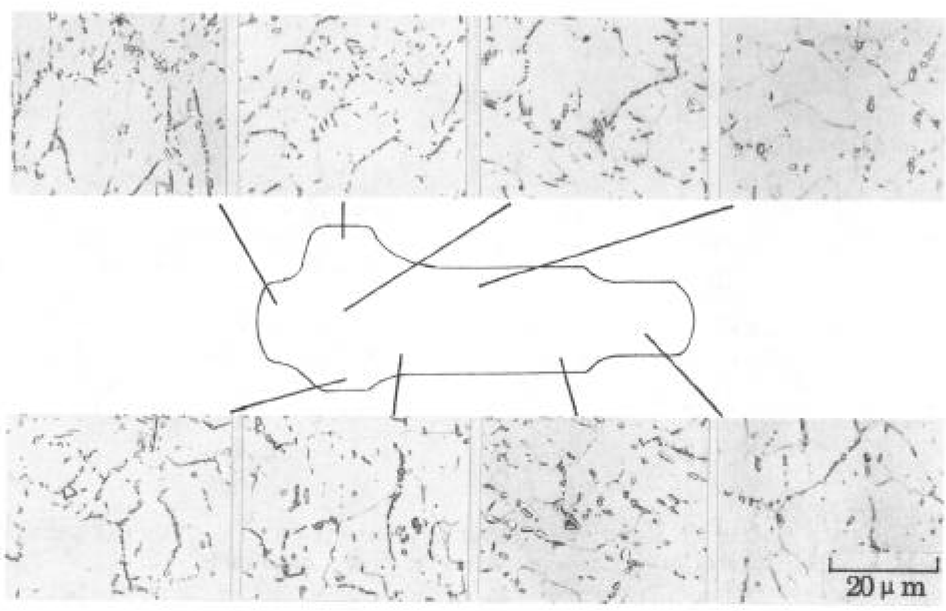

Fig. 6 δ phase distribution at different locations of the DA disks on 63T-M hammer

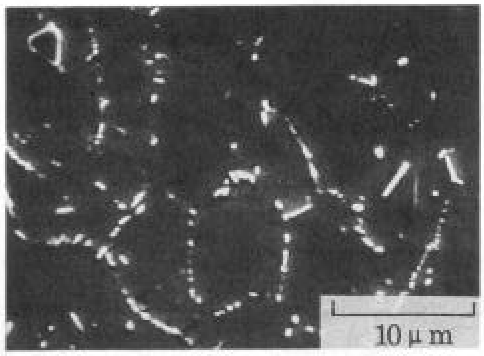

Fig. 7 The SEM micrograph of δ phase

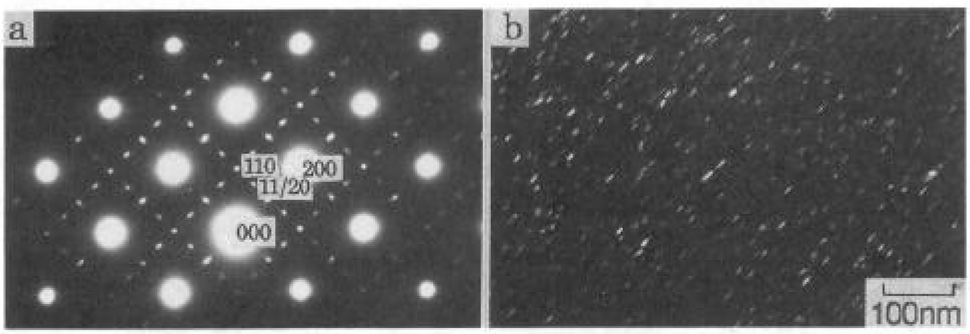

Fig. 8 TEM microstructure of the DA disk on 63T-M hammer
a) [001] diffraction pattern b) $\bar{g}=1\frac{1}{2}0$ dark field micrograph

Mechanical Properties

Tensile Properties

Table 2 lists the tensile results for the DA718 disk on 63T-M hammer performed at the temperature range from R. T. to 1292°F. The room temperature and 1202°F tensile specimens were machined respectively from the examinating ring, rim, web and bore region. The data of ultimate and yield strengths show little variation between the different regions of the DA 718 disk. This is consistent with the structure uniformity of the DA 718 disk. Figure 9 shows the average tensile strength curves compared with the curves supplied by Kruger [3], the UTS and YS curves of the DA 718 disk on 63T-M hammer correspond to Kruger's. According to Barker [6], at room temperature the UTS of the DA718 disks is typically 210Ksi. Hence the DA 718 disk on 63T-M hammer possesses quite high UTS and YS with adequate ductility.

Stress Rupture Properties

Table 3 lists the results for stress rupture tests which performed over the temperature range from 823K to 973K at different stresses. The specimens tested under 923K/101.6Ksi were machined from the different regions of the DA 718 disk, and the specimen consists of two sections smooth and notch (Figure 10). All the fractures occured on the smooth sections. All the results are presented on a larson-Miller curve (Figure 11). The DA 718 disks on 63T-M hammer exhibit good behavior for stress rupture. The good creep properties are associated with a uniform recrystallized grain structure containing a low amount of the δ phase [1].

Table 2 Tensile Properties of the DA 718 Disk

Region	Temperature (°F)	UTS (Ksi)	YS (Ksi)	Ductility δ%	Ductility DA%
Examinating					
ring	68	224.52	204.06	15.0	37.35
Rim	68	225.54	207.1	15.65	31.4
Web	68	215.38	195.78	17.7	39.9
Bore	68	220.46	203.18	13.8	40.8
Web	572	191.58	169.22	19.45	38.45
:	752	186.93	169.8	18.3	40.55
:	932	185.5	170.82	15.3	36.15
:	1022	188.67	171.25	15.0	34.9
:	1112	186.06	167.04	15.0	35.9
Examinating					
ring	1202	187.37	171.55	12.7	29.0
Rim	1202	180.11	166.46	13.9	27.13
Web	1202	176.92	160.37	15.5	25.0
Bore	1202	179.96	164.29	13.75	18.7
Web	1292	154.86	143.4	19.85	17.65

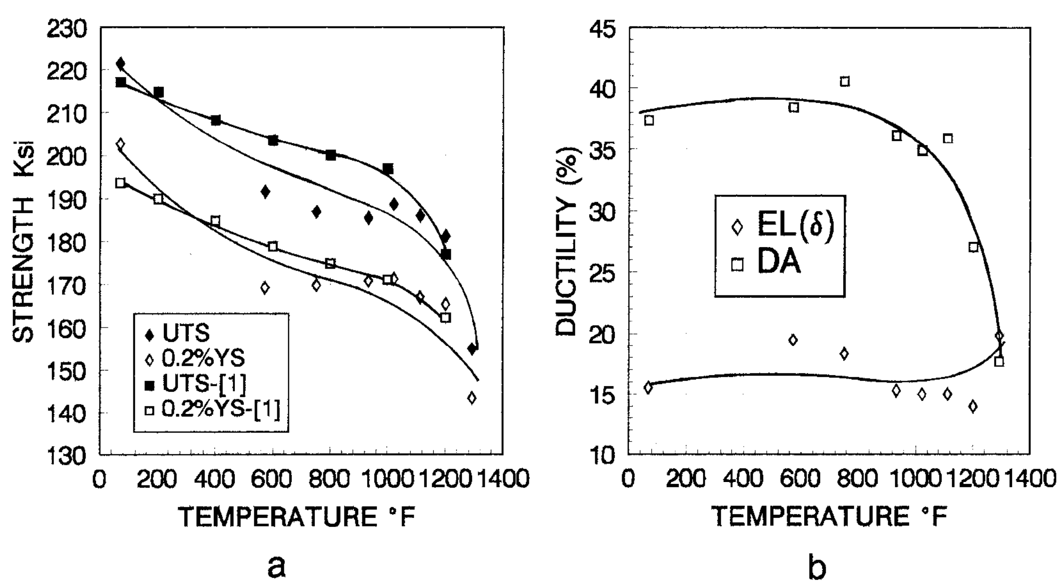

Fig. 9 Tensile date curves for the DA 718 disks
a) UTS Ksi and b) 0.2%YS Ksi

Table 3 Stress Rupture Properties of the DA 718 Disk

Region	Temperature (K)	Stress (Ksi)	Fail time (hrs : minutes)	Ductility δ%	DA%
Examinating ring	923	101.6	109 : 20	13.68	20.55
Rim	923	101.6	127 : 42	13.36	26.04
Bore	923	101.6	131 : 15	8.68	19.3
Web	923	105.22	115 : 1	8.4	21.17
Web	923	100.14	132 : 00	7.2	12.17
:	823	152.4	596 : 54	5.65	9.06
:	873	123.36	501 : 18	9.4	16.88
:	973	71.12	186 : 40	17.28	27.96

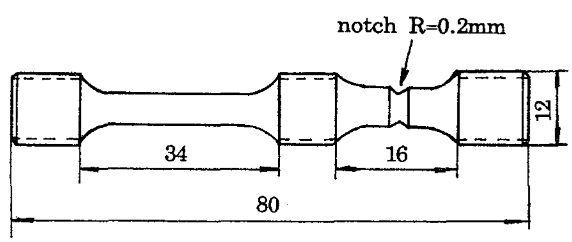

Fig. 10 Stress rupture specimen of a Larson-Miller curve

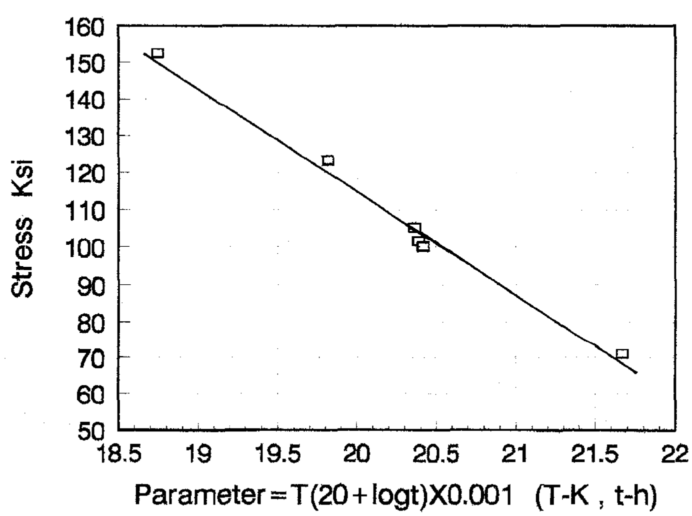

Fig. 11 Stress rupture data for the DA 718 disk

Low Cycle Fatigue

Low cycle fatigue tests were conducted at 650℃ using total strain control, and the results are shown in Figure 12. The LCF results are very satisfactory. The SEM study of the fracture surfaces of the LCF specimens revealed that a great majority of the failures initiated at the specimens surface (Figure 13).

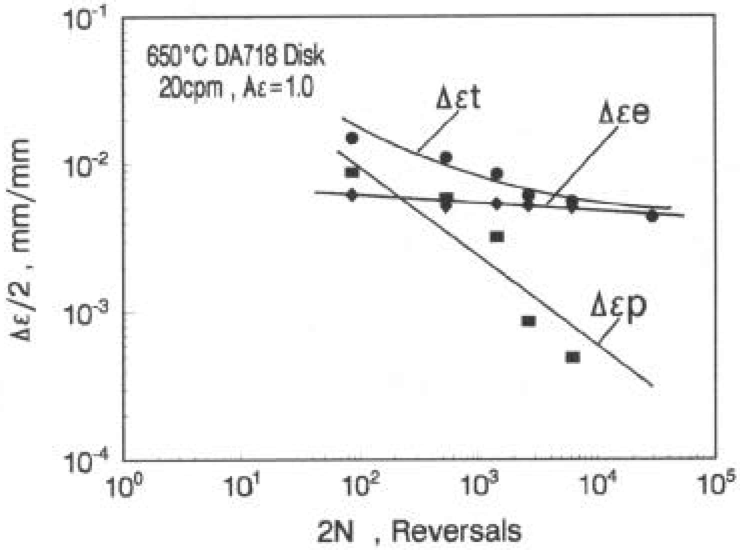

Fig. 12 650℃ low cycle fatigue data for the DA718 disk

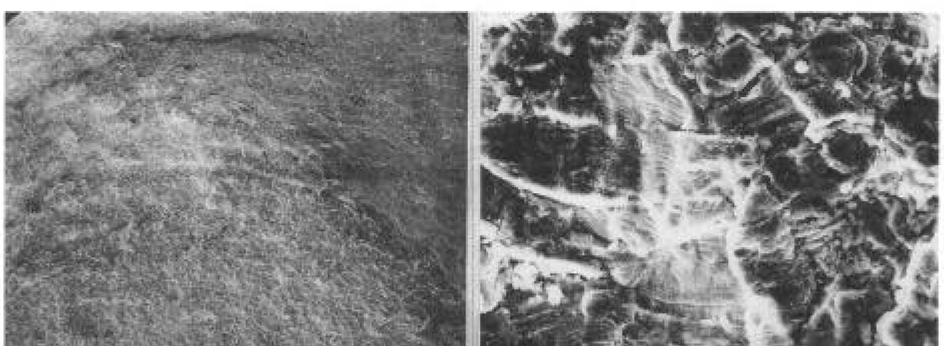

Fig. 13 The SEM Micrographs of the fracture surface

Conclusions

1. The DA718 disks on 63T-M hammer have very fine grain structure and does not have cold-die structure. The average grain size of ASTM 10 or finer grain size in the disks can be obtained.
2. The DA718 disks on the 63T-M hammer possess quite high UTS and YS with adequate ductilities. The stress rupture and LCF properties also exhibit satisfactory results.

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