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NATIONAL TRANSPORTATION SAFETY COMMITTEE

AIRCRAFT INCIDENT REPORT

Japan Airlines Flight JL726

B747-300 JA8178

Tangerang, West Java, Indonesia

5 September 2000

NATIONAL TRANSPORTATION SAFETY COMMITTEE
DEPARTMENT OF COMMUNICATIONS
REPUBLIC OF INDONESIA
2001

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This report was produced by the National Transportation Safety Committee (NTSC), Gd. Karsa Lt.2 Departemen Perhubungan dan Telekomunikasi, Jalan Medan Merdeka Barat 8 JKT 10110 Indonesia.

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GLOSSARY OF ABBREVIATIONS

AGB	Angle Auxiliary Gear Box
ATC	Air Traffic Controller
ATPL	Air Transport Pilot License
C/ cont	Cycles Continuation
CSN	Cycles Since New
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
EGT	Exhaust Gas Temperature
F/O	First Officer
FT	Flight Time
HPC	High Pressure Compressor
HPT	High Pressure Turbine
hrs	time (24 hour clock)
IAS	Inner Air Sealant
IIC	Investigator-In-Charge
ITB	Institut Teknologi Bandung
JCAB	Japan Civil Aviation Bureau
LPT	Low Pressure Turbine
LSV	Last Shop Visit
LTS	Low Turbine Shaft
MGB	Main Gear Box
NDI	Non Destructive Inspection
NTSB	National Transportation Safety Board
NTSC	National Transportation Safety Committee
OAS	Outer Air Sealant
^{o}C	Degree Celsius
PIC	Pilot-In-Command
R/ Shaft	Rear Shaft
RTB	Return To Base
SDR	Service Difficulty Report
SEM	Spectra Electron Microscopy
T/ cont	Time Continuation
TCAR	Turbine Cooling Air Ratio
TEC	Turbine Exhaust Case
TIGV	Turbine Inlet Guide Vane
TSN	Time Since New
UTC	Universal Time Coordinated
VOR	Very-high-frequency Omni-directional Range
VSV	Variable Stator Vanes
XRD	X-Ray Diffraction

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CONTENTS

SYNOPSIS

On September 5, 2000, a Boeing B747-300 of Japan Airlines (JAL) registration JA8178 was operating on a scheduled international passenger flight, with flight number JL726. The aircraft, which departed from Soekarno-Hatta International Airport, Jakarta, experienced a serious incident shortly after take-off at 23:39 LT (Local Time) or 16:39 UTC, in which the No 1 engine's fifth low pressure turbine (LPT) disk failed, ejecting debris damaging the airframe structure and several houses in a village.

There were a total of 377 persons on board including a crew of three and 14 cabin attendants. No persons on board or on the ground were injured.

The engine was shut down, and after dumping 163,000 lbs. of fuel the aircraft returned to Soekarno-Hatta Airport and safely landed at Soekarno-Hatta airport at 17:36 hrs UTC.

The National Transportation Safety Board conducted the incident investigation according to the standards and recommended practices of the Annex 13 to the Convention on International Civil Aviation. All the investigation activities in Japan and the United States were conducted under the supervision of NTSC, Indonesia, the JCAB, Japan, and the NTSB, USA.

Preliminary inspection of the failed disk by visual and binocular microscope technique was done at the Institut Teknologi Bandung. The fractured disk was subsequently examined at the National Transportation Safety Board laboratory in Washington DC, using microscope, XRD and SEM techniques. Additional examinations were also conducted by Pratt & Whitney, East Hartford, Connecticut USA, using microscope, SEM, creep tests and elevated temperature fatigue tests.

The CVR and FDR readouts were performed in the Japan Aircraft Accident Investigation Commission laboratory at Haneda, Japan, while the engine teardown was performed at the JAL Maintenance Facility at Narita.

The findings of the examinations revealed that the failure of the disk was attributed to intergranular, elevated temperature fatigue, which had progressed from the surface of the web. The fracture originated in a blended repaired area on the front surface of the disk.

The investigation concluded that blending operation, in particular on a disk or on a highly stressed part carries a high risk of residual damage (worked material or shallow cracks) remaining and these sites are potential sites for fatigue crack initiation. Therefore, the NTSC recommended that;

1. Residual damage seems to be the origin of the fatigue crack on this disk. Such damage could not be detected by available NDI method. To prevent similar occurrence, blending operation on such a particular disk should be reviewed.
2. A disk design review should be undertaken.

1 FACTUAL INFORMATION

1.1 History of Flight

On September 5, 2000, a Boeing B747-300 of Japan Airlines (JAL) registration JA8178 was operating on a scheduled international passenger flight, with flight number JL726. The aircraft, which departed from Soekarno-Hatta International Airport, Jakarta, experienced a serious incident shortly after take-off at 23:39 LT or 16:39 UTC, in which the No 1 engine's fifth low pressure turbine (LPT) disk failed, ejecting debris damaging the airframe structure and several houses in a village.

There were a total of 377 persons on board including 360 passengers, 3 cockpit crews and 14 cabin attendants. No persons on board or on the ground were injured.

The engine was shut down and after dumping 163,000 lbs. of fuel over the open sea in an area north of DKI VOR the airplane returned to Soekarno-Hatta Airport. The landing at 17:36 UTC was uneventful and no problems were encountered.

Flight 726 originated from Ngurah Rai International Airport of Denpasar, where a normal routine transit maintenance check was carried out. The check did not reveal any abnormalities. Additional 101 passengers boarded in Jakarta and the flight departed Jakarta with a total of 377 persons on board including a crew of three and 14 cabin attendants.

Fragments of the failed engine separated from the engine and were ejected through the exhaust nozzle, damaging the aircraft lower L/H wing, the L/H flaps, and the L/H side of the airframe skin at several places. Fragments fell on the ground damaging 21 houses. No injuries were reported among the passengers and crew, and persons on the ground.

Actions taken by the PIC and the cabin crew prevented panic to spread among the passengers during the one hour long fuel dumping.

1.2 Injuries to Persons

Injuries	**Crew**	**Passengers**	**Other**	**Total**
Fatal	—	—	—	—
Serious	—	—	—	—
Minor / None	17	360	—	377
Total	17	360	—	377

1.3 Damage to Aircraft

1.3.1 Engine No. 1

The 5th stage LPT disk of No. 1 engine failed, broke into two parts, both parts were ejected out from the inboard side of LPT case with heavy damage sustained by the inboard LPT casing.

Most of the 4th, the 5th and the 6th stage vanes were missing. The fragments of the blades and vanes were ejected out of the inboard LPT engine casing and impacted the left flaps, the left side of the fuselage and over a wide area of the left side of the empennage. With the exception of the damage to the L/H flaps panels, and the spoilers, the damages caused were mostly minor in nature, such as dents and small cuts.

The tail cone was completely detached from the engine and was found on the ground. The bolts that secured the tail cone to the exhaust case were all fractured. Part of the inboard engine cowling was torn loose and fell to the ground. The engine pylon appeared to be distorted.

1.3.2 Airframe

With exception of the damages to the L/H flaps panels and the spoiler, the majority of the damages inflicted to the aircraft, are minor in nature, albeit covering a very wide area of the airframe body as follow:

a. The L/H side of the Vertical Stab. Trailing Edge Panel has a relatively large hole, 2.75 inch in length and 3.50 inch wide.

b. The L/H OUTBD FORE Flap, the L/H OUTBD MID Flap, the L/H OUTBD AFT Flap were all damaged and were to be replaced.

c. Several parts associated with the flaps or flap mechanism are to be replaced e.g. No. 3 Canoe Flap Track Aft Roller Support, Rod and Attach Bracket, No 3 Canoe/Mid Flap Link Rod, Canoe Bell Crank and Attachment Fitting, No 2 Flap Transmission Drive and Drive Screw. No. 2 Flap Track Fitting.

d. L/H. Aileron No 2 FWD and No. 2 AFT Canoe Fairing were damaged and were to be replaced.

e. L/H WING – No. 3 Canoe has 33 punctures, the largest of which is 2.5 x 2.5 in.

f. No. 2 Spoiler was damaged and was to be replaced.

g. L/H WING No. 1 STRUT is twisted, buckled, torn and wrinkled. The strut to wing fairing has large cracks. The Nose Fairing is bend.

Minor gouges, dents and cuts covering a very wide area of the L/H Side Aft Part of the Airframe Body.

1.3.3 Engine Tear Down

The engine tear down focused on the rear end of the engine to the rear of the combustion chamber. The forward section of the engine was completely intact with no evidence of any damage or FOD (foreign object damage).

The engine tear down showed the following results (see Reference 5, P & W Tear Down Report):

A. Turbine Exhaust Case (TEC). Strut No. 1, No.2 and No. 3 separated from the outer wall near the outer weld joint, other struts and the TEC front outer flange showed damage consistent with the liberated LPT debris. There are 15 struts in the TEC.

B. 6^{th} Stage Vanes. The 6^{th} stage vanes located at 7:00 – 8:00 o'clock were fracture or missing.

C. LPT Case. The LPT case was damaged in the plane of all four stages of the LPT rotors, the damage was consistent with the turbine debris impact. About 6.0 inches forward of axial section of the LPT case was missing between 11:30 and 2:30 o'clock and there were several circumferential fractures. The six 3^{rd} stages segmented OAS was present.

D. 4^{th} and 5^{th} Stage OAS. All the 4^{th} and 5^{th} stage OAS were missing, all in the plane of the 5^{th} stage rotor. From the recovered debris found on the ground all eleven segmented outer seals and various heat shields from the LPT case were recovered.

F. 3^{rd} Stage vanes. All 3^{rd} stage vanes were present but generally damaged/ fractured and varied in length. The forward inner duct knife-edge (KE) was damaged and distorted. The 3rd inner air seal (IAS) honeycomb land was intact but heavily damaged. The damage was consistent with impact by turbine debris or by contact with the 3rd and 4th disks after these disks became free from the rotor support.

F. 4th and 5th Stage vanes. Most of the 4th and 5th stage vanes were missing. The vanes that were still with the engine were fractured and were varied in length.

G. No 4 bearing. Bearing No. 4 assembly was heavily damaged. The inner race was dislocated from the roller bearing plane. About 70% of the rollers were out of the bearing cage, but were generally in good condition. No evidence was found of heat distress in the plane of the rollers. Damages were all due to heavy rubbing.

H. Low Turbine Shaft (LTS). The LTS was intact with surface damage at several locations due to hard rubbing. A 21-inch circumferential flange section at the 5th disk flange at the rear LPT rotor hub flange was missing. All 14 bolts threaded end with the nuts from the missing section of the 5th stage disk flange were recovered, all inside of the engine. The 14 bolts of the missing section were fractured by shear and bending. The remaining upright portion of the 5th stage was still bolted in place showing several damaged marks.

I. T Rotor Assembly. The fifteen 4th to 5th rotor tie bolts were recovered in the LPT case. The bolts were still intact although the majority were bent The 3rd disk rotating front knife edge (KE) seals were fractured off. The 6th stage disk was still attached to the LPT rear hub. The 4th to 5th and the 5th to 6th inner air seal were missing. The 4th stage rear flange that mates with the 5th disk was fractured off. There was no evidence of heat damage.

J. PT Rotor Assembly. All the 2nd stage HPT blades were in place with the forward KE rubbed or damaged. The rear KE were all fractured. One blade was fractured and broken to about 60 % of the airfoil. The adjacent blade trailing edges were damaged by turbine debris. The rear HPT side plate and the aft side of the HPT disk showed damage due to turbine debris. The rear LPT side plate and the aft side of the HPT disk showed damage due to heavy rubbing.

The 1st stage HPT blade tips showed hard rub with OAS (Outer Air Seal) Melted blade tip material was deposited on the 2nd vane on the convex surface at the outer diameter. Several 2nd vane trailing edges showed evidence of heat distress, or were fractured off. The inner air seal was rubbed. Three turbine inlet guide vanes (TIGV) showed heat distress or cracks, but most of the vanes were generally in good condition.

The rear shaft under both the HPT disk and the No 3 inner heat shield was rubbed 360 degrees of the circumference in two places.

K. No 3 Bearing. The No 3 bearing was disassembled. The carbon seal support outer heat shield showed a blue discoloration. on the outer side. The carbon seal was however intact. There was no other evidence of heat stress discoloration and no evidence of burned or melted metal (no evidence of high-grade fire). The No. 3 bearing was in good condition and was undamaged with the outer racetrack showed the normal running position.

I. Magnetic Plug and Main Oil Filter examinations. Metal was detected in the Main Gear Box (MGB) oil filter. No traces of metal were found in the Angle Gear Box (AGB) or in Main Bearing No. 3 or in Bearing No. 4.

1.4 Other Damage

The fragments of the failed engine parts were distributed over a relatively wide area on the ground approximately 1 km x 1 km (see Appendix A). A survey found 21 houses damaged by the falling debris. The largest debris found were the engine tail cone, 2 fragments of the 5th stage turbine Disk and torn sheet metal from the L/H Side Engine Cowling. A very big number of small turbine blade fragments were found causing relatively very minor damage to roof tiles of a total of 21 houses. The more serious damage consisted of serious damage to the roof and cracked walls of one house.

1.5 Personnel Information

1.5.1 Cockpit Crew

1.5.1.1 Pilot in Command

Gender	:	Male
Age	:	54 years old
Nationality	:	Japanese
Address	:	Japan
Certificate Number	:	002433
License Category	:	Airline Transport Pilot License
Type Rating	:	B747
Medical Certificate	:	First Class
Date of Last Medical	:	17 August 2000
Flight Time		[hours]
Total Time	:	16,063
Pilot in Command	:	15,194
Instructor	:	-
This Make & Model	:	9,990
Last 90 Days	:	191
Last 24 Hours	:	1
Last Proficiency Check	:	20 May 2000

1.5.1.2 Flight Officer

Gender	:	Male
Age	:	48 years old
Nationality	:	Japanese
Address	:	Japan
Certificate Number	:	013954
License Category	:	Commercial Pilot License
Type Rating	:	B747
Medical Certificate	:	First Class
Date of Last Medical	:	26 July 2000
Flight Time		[hrs]
Total Time	:	10,802
Pilot in Command	:	-
Instructor	:	-
This Make & Model	:	3,203
Last 90 Days	:	193
Last 24 Hours	:	1
Last Proficiency Check	:	14 June 2000

1.5.1.3 Flight Engineer

Gender	:	Male
Age	:	42 years old
Nationality	:	Japanese
Address	:	Japan
Certificate Number	:	002359
License Category	:	Flight Engineer License

Type Rating	**:**	B747
Medical Certificate	**:**	First Class
Date of Last Medical	**:**	21-12-1999
Flight Time		[hrs]
Total Time	**:**	9,605
Instructor	**:**	-
This Make & Model	**:**	9,374
Last 90 Days	**:**	134
Last 24 Hours	**:**	1
Last Proficiency Check	**:**	15 August 2000

1.5.2 Cabin Crew

The cabin crew consisted of one supervisor, seven senior cabin attendants and six junior cabin attendants.

1.6 Aircraft Information

1.6.1 Aircraft Data

Registration Mark	:	JA8178
Manufacturer	:	Boeing Aircraft Company
Type/ Model	:	B747-300
Serial Number	:	23639
Category	:	Transport
Cockpit Crew	:	3
Pax seats	:	393
Time Since New	:	61,446
Cycles Since New	:	8,617
Last A-Check	:	22 August 2000 (TT 61,269 hrs)
Last C-Check	:	31 March 2000 (TT 59,615 hrs)

Engine Type	:	Turbofan
Manufacturer	:	Pratt & Whitney
Type/ Model	:	JT9D-7R4G2
Serial Number #1	:	P715225
Serial Number #2	:	P715276
Serial Number #3	:	P725308
Serial Number #4	:	P715279

1.6.2 Engine No. 1

1.6.2.1 Particular Data

Engine Type	Turbofan
Manufacturer	Pratt & Whitney
Type/ Model	JT9D-7R4G2
Serial Number #1	P715225
Time Since New	55,191 hours
Cycles Since New	9,017 cycles
Last Shop Visit (LSV)	JAL Engineering Maintenance Center, 13 September 1997
Hours Since LSV	12,198
Cycles Since LSV	2,301
Installation on JA8178	11 November 1997

1.6.2.2 Maintenance History of Low Pressure Turbine 5th Disk of Engine No. 1

The engine last shop visit on 13 September 1997 was due to 2nd stage turbine blades damaged by missing 2nd turbine nozzle airfoil. After the engine was released from its shop visit, it was installed on JA8178 on 11 November 1997.

This engine was operated on the airplane JA8178 until this serious incident occurred.

This LPT disk (P/N 787905-001; S/N M43709) was assembled at the module S/N LD 15112 and this module was installed on engine S/N P715112. At the time of the serious incident, total part time was 54251 hrs and 11881 cycles. On 13 October 1984, the engine (S/N P715112) was installed on JAL Boeing 747-300 registration No. JA8162 at position No. 3.

On 16 January 1986 the engine S/N P715112 was removed from JA8162 due to oil leak in weep drain No.3. The module S/N LD15112 (including the LPT) was removed from the engine then installed in engine S/N P715029. The LPT disk total time was 5946 hrs or 523 cycles. On 21 May 1986 engine S/N P715029 was installed at position No.4 of the JAL Boeing 747-300 registration No. JA8163.

On 10 August 1986 the engine S/N P715029 was removed from the airplane due to metal found in the angle gearbox (AGB). During the shop visit, the inspection also revealed that one ball of bearing No.1 was expelled. At that time, the LPT disk total time was 7063 hrs or 650 cycles. On 27 November 1986, the engine S/N P715029 was installed at position No. 2 of JA812N.

On 10 December 1988 the engine S/N P715029 was removed from airplane JA812N due to metal found in the AGB. During the shop visit, the inspection also revealed that all case pockets of the bearing No.2 were pitted. At that time, the LPT disk total time was 17210 hrs or 1880 cycles. The module S/N LD-15112 was removed from the engine S/N P715029 and then installed in engine S/N P715131. On 22 March 1989 this engine was installed at position No. 3 of JA8177.

On 26 November 1990 engine S/N P715131 was removed due to the T/cont - VSV 7th stage. Engineering Order No. EV-MPE/E-8588 was issued due to TCAR low, and the LPT module continued to be used. At that time, the LPT disk total time was 25445 hrs or 2734 cycles. On 4 July 1991 the engine was installed at position No. 3 of the JA8186.

On 2 November 1992 engine S/N P715131 was removed from JA8186 due to C/cont – high-pressure compressor (HPC) R/shaft. During the shop visit, the inspection also revealed that one LPT 4th to 5th stage tie bolt was broken. Heavy maintenance was carried out by rework. The LPT total time was 28564 hrs or 5171 cycles. The module S/N LD-15112 was removed from the engine S/N P715131 and then installed in engine S/N P715274. On 25 December 1992 engine S/N P715274 was installed at position No. 2 of the JA8183.

On 22 March 1995 engine S/N P715274 was removed from airplane JA8183 and installed at position No. 4 of airplane JA8179 for maintenance convenience (staggering). The LPT disk total time was 32259 hrs or 7932 cycles.

On 20 August 1997 the engine S/N P715274 was removed from airplane JA8179 due to C/cont – 14th stage disk. LPT module heavy maintenance was carried out. The LPT disk total time was 42053 hrs or 9580 cycles. The module S/N LD-15112 was installed in the engine S/N P715225. On 11 November 1997, this engine was installed at position No. 1 of airplane JA8178 and remained there until it fractured in the incident on 5 September 2000, shortly after take off from Soekarno-Hatta International Airport, Jakarta.

1.7 Meteorological Information

Wind	:	190°/ 3 knots
Visibility	:	3500 m

Weather	:	Fair
Cloud	:	No cumulonimbus
Temperature	:	27°C

1.8 Aids to Navigation

Not relevant.

1.9 Communications

The communication transcript indicated that the cockpit crew had established good communication with the ATC during RTB and fuel dumping.

1.10 Aerodrome Information

Airport Name	:	Soekarno-Hatta International Airport, Jakarta
Airport Identification	:	WIII
Airport Operator	:	PT. Angkasa Pura II
Runway In Use	:	25R
Runway Length	:	3,600 m
Runway Width	:	60 m
Surface Condition	:	Concrete

1.11 Flight Recorders

1.11.1 Flight Data Recorder

The DFDR was in good condition. It recorded 128 parameters for duration of 25 hours. Engine vibration and exhaust gas temperature parameters were not recorded.

The recorded parameters showed no significant items prior to the occurrence.

1.11.2 Cockpit Voice Recorder

The CVR was in good condition. The recording was for the last 30 minutes of the flight since the early portion of the flight was over written because of the CVR tape design. No significant items, which may have endangered or degraded the safety level of the flight operation, had been found in the recording.

1.11.3 Aircraft Log Book

Examination of the aircraft logbook during three months flights indicated a slightly higher Exhaust Gas Temperature (EGT) of the No. 1 engine as compared to the EGT's of the other three engines. The Exhaust Gas Temperature was however still well below the maximum allowed.

1.12 Wreckage and Impact Information

Table 1 **Distribution of the engine fragments on the ground**

No.	Item	Dimension / Condition	Location
#1	Tail/ exhaust cone	Approximately 30cm into the ground	Village of Minyak / Jati Mulya
#2	Stator vane		Village of Utan Jati/ Kedaung Barat

#3	Debris	Approx. 20cm x 30cm	Fell on the bed through the roof of Mr. Buang, in the village of Minyak (RT02/03)/ Jati Mulya. The pieces fell through the roof, impacted on the wall and then crashed on a bed (5 roof tiles were broken)
#4	Torn sheet of cowling	200cm x 100cm	Village of Utan Jati/ Kedaung Barat
#5	Debris	Thin & long in dimension	Village of Utan Jati/ Kedaung Barat
#6	Canoe debris		Fell in a garden in the village of Utan Jati/ Kedaung Barat

1.13 Medical and Pathological Information

Not applicable.

1.14 Fire

Some witnesses saw a fire behind the Outer L/H Engine. There was however no physical evidence of fire.

1.15 Survival Aspects

Not relevant.

1.16 Inspection and Test

1.16.1 Laboratory Work

Laboratory examination and tests were conducted at the Institute of Technology, Bandung (ITB), Indonesia, the NTSB laboratory in Washington DC, USA and at the Pratt and Whitney laboratory, USA. A preliminary examination was performed at ITB, Bandung, Metallurgical Laboratory (see Appendix D – ITB Report), with visual observation, aided by macro lens camera and stereomicroscope.

The laboratory works focused on the 5th stage LPT disk. The significant findings are as follows:

The fractures of the two pieces of the 5th disk revealed the respective ends of the two pieces mated with each other. It indicated that no pieces of the 5th disk were missing. One fracture contained blue and gold tint (consistent with exposure to an elevated temperature) and the other one features typical of overstress separation with no evidence of heat tinting.

1.16.1.1 Visual Observation

The part of the 5th stage LPT disk (Figure 1) contained fracture at two location indicated by arrows "1"and "2". The fractures were oriented in radial direction and extended to the bore, web, and rim. The retention post for the blades at the rim location contained a fir-free configuration. Each fracture intersects the bottom radius located between the retention posts for a blade. The bigger disk pieces had deformed due to being stretched outward until broken (see Figure 1).

One pair of the fracture surfaces revealed a typical fatigue pattern fatigue which had a flat surfaces and different color (blue & gold tint) as compared to the adjacent area (see Fig. 2).

1.16.1.2 Bench Binocular Microscopy [ref: NTSB and P&W Reports]

After ultrasonic cleaning, the examination revealed that the front of the disk, in the area of the 0.4” long intergranular fracture, which is considered to be the initiation region, exhibited a smooth polished-appearing texture, rather than the typical machining marks, which are characteristic of the remainder of the web. It appears to be a local blended area. Micrometer measurements in the subject area indicated a thickness of 0.001” to 0.003” thinner than the remainder of the disk web.

It was estimated that 40 to 50 blends had been performed on the disk surface. All were shallow and conformed to the requirement that the width of the blends be at least 15 times greater than the depth. Fluorescent penetrant inspection of the disk piece revealed no residual crack indications.

A closer evaluation of several of the blended areas away from the fracture showed two blends that had evidence of what appeared to be residual mechanical damage (dents), that were oxidized, showing the same type of discoloration as the remainder of the disk surface.

The 5^{th} stage disk was reported as having been blended at a previous heavy maintenance visit to remove mechanical damage. It was performed on 2 November 1992 in JAL Engine Maintenance Facility to repair damage caused by a broken tie-bolt [ref 4: JAL Work Order].

1.16.1.3 Scanning Electron Microscopy [see Appendix C: NTSB Report]

SEM examination of the excised fracture face from the smaller piece of disk revealed:

1. Shear lip areas containing crack arrest marks typical of fatigue cracking. It was found at the outboard area of the fracture origin area.
2. Intergranular fracture features at the flat region of the excised fracture. In referring to the origin region, it was found to be 1.6” to the outboard and 0.42” inboard from the midpoint of the flat region.
3. Transgranular fatigue cracking in the inboard area was found between 0.42” and 1.32” from the origin.
4. A ductile dimple feature was found at a distance 1.32” inboard from the midpoint of the flat fracture region.
5. The microstructure of all examined sections contains carbides, both at the grain boundaries and within the grains and also spherical and elongated particles of what appeared to be delta phase at the grain boundaries.

No evidence of non-metallic inclusions or other pre-existing manufacturing flaws were found.

1.16.1.4 Photomicrograph [see Appendix C: NTSB Report]

The micrograph revealed that the web area of the fracture origin area has grain size 5, with several grains size 4. Meanwhile, Pratt and Whitney Specification PWA 1085 titled “Alloy Bars, Forging, and Rings, Corrosion and Heat Resistant”, indicated that the grain size should be “6 or finer, with occasional grains as large as 5 permissible”. Therefore, the grains found were larger than permissible.

1.16.1.5 Engine-Relevant Temperature Fatigue Test [see Appendix B: P&W Report]

Fatigue specimens were machined from the web of the subject disk and tested to determine whether intergranular fracture characteristics could be produced at engine-relevant temperatures. Testing at 1000°F, with five minutes dwell at maximum stress, produced intergranular features, which closely matched those on the disk fracture surface.

2 ANALYSIS

On the disk, there were several spots or locations at which blending operation had been performed previously as shown in Figure 4. The crack on the disk was initiated from such a position, and then propagated further toward the inner and outer radial direction, and finally resulted in a catastrophic failure.

Further examination on the thickness section at the blended location shows that residual damages from previous impacts were still present. In other words, some of the residual damage sites caused by the impacts with a fractured bolt were not totally removed by the blending operation. Such residual damages are potential sites for fatigue crack initiation

The residual damage was of microscopic scale and was not removed using the approved manufacturer's blending procedures and was not possible to be detected by NDI techniques. Although their sizes are microscopic, it may initiate a fatigue crack at a component section having a high level of stress.

3 CONCLUSION

3.1 Findings

1. The Flight Crew and the Cabin Crew were all qualified
2. The airframe, the engines and the aircraft systems were all properly maintained to the Maintenance Program including compliance with the essential service bulletins and the Airworthiness Directives. All aircraft systems operated normally before the incident. No Service Difficulty Report (SDR) was reported to JCAB.
3. The Soekarno-Hatta airport air traffic and ground services all complied with the standard procedures for emergency situations.
4. The findings of the engine tear down inspections may briefly be summarized as follows:
5. The engine forward of the high-pressure turbine section was found intact and complete with no missing parts and did not suffer any apparent damage.
6. All the components i.e. Turbine Exhaust Case (TEC), Low Pressure Turbine Case (LPT), No. 4 Bearing Assembly, Low Turbine Shaft (LTS), LPT Rotor Assembly, High Pressure Turbine (HPT) Rotor Assembly, and No. 3 bearing and including the recovered debris were found complete with no components missing. All showed severe damage due to hard rubbing, or were fractured (blade tips). The fractures were all consistent with impact related fracture by turbine debris. Most of the components were dislocated with retention bolts sheared off. Heat distress was found on two 2nd vane trailing edges (TE) and melted blade tips material (1st stage blade tips) were deposited on the 2nd vane of the convex surface outer diameter.
7. The teardown inspection confirmed that no pieces of the engine were missing.
8. The trace of metal that is found in the oil filter did not appear to have a direct bearing to the cause on the failure of the 5th stage LPT disk. It appeared to be the result of the highly dynamic imbalance loading due to the 5th disk failure.
9. Tensile and stress-rupture were performed on specimens machined from the disk showed that its mechanical properties conformed to the requirements of PWA 1085 specification.
10. The laboratory tests showed that the failure of the 5th turbine disk was due to intergranular elevated temperature fatigue. The crack originated from a blend-repaired area.
11. The cabin crew handled the emergency situation quite well.

3.2 Safety Threats

A. The fallen debris may have caused injury or death to person on the ground.

B The fatigue crack propagation on the turbine disk was undetected.

C. The uncontained engine failure may cause severe damage to the airplane affecting the safety of the aircraft.

4 RECOMMENDATION

Blending operation, in particular on a disk or on a highly stressed major part carries a high risk of residual damage (work material or shallow crack) remaining and these residual damage are potential sites for fatigue crack initiation, therefore two recommendations are proposed:

1. Residual damage seems to be the origin of fatigue crack on this disk. Such a residual damage could not be detected by available NDI method. To prevent similar occurrence, blending operation as described by engine manufacturer on such a particular disk should be reviewed.

2. It found necessary the disk design should be reviewed by the manufacturer.

Note: *P&W has already recalled similar repaired disks from operators for further study and has subsequently issued an All Operator Wire regarding the above matter, i.e. "Management of Tie Bolt Fracture Damage on JT9D-Turbine Disks" No. JT9D/72-52/CTS: TMT: 3-8-01-1 dated March 8, 2001.*

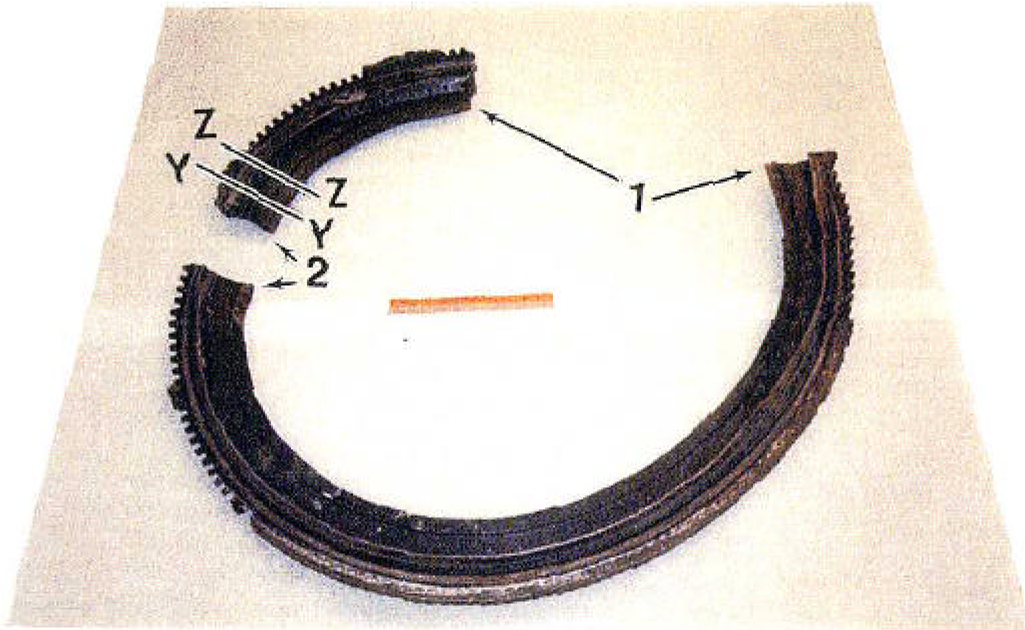


Figure 1. The 5th stage disk (source: NTSB Report)

Figure 2. Fracture surface of the fatigue area (source: ITB Report)

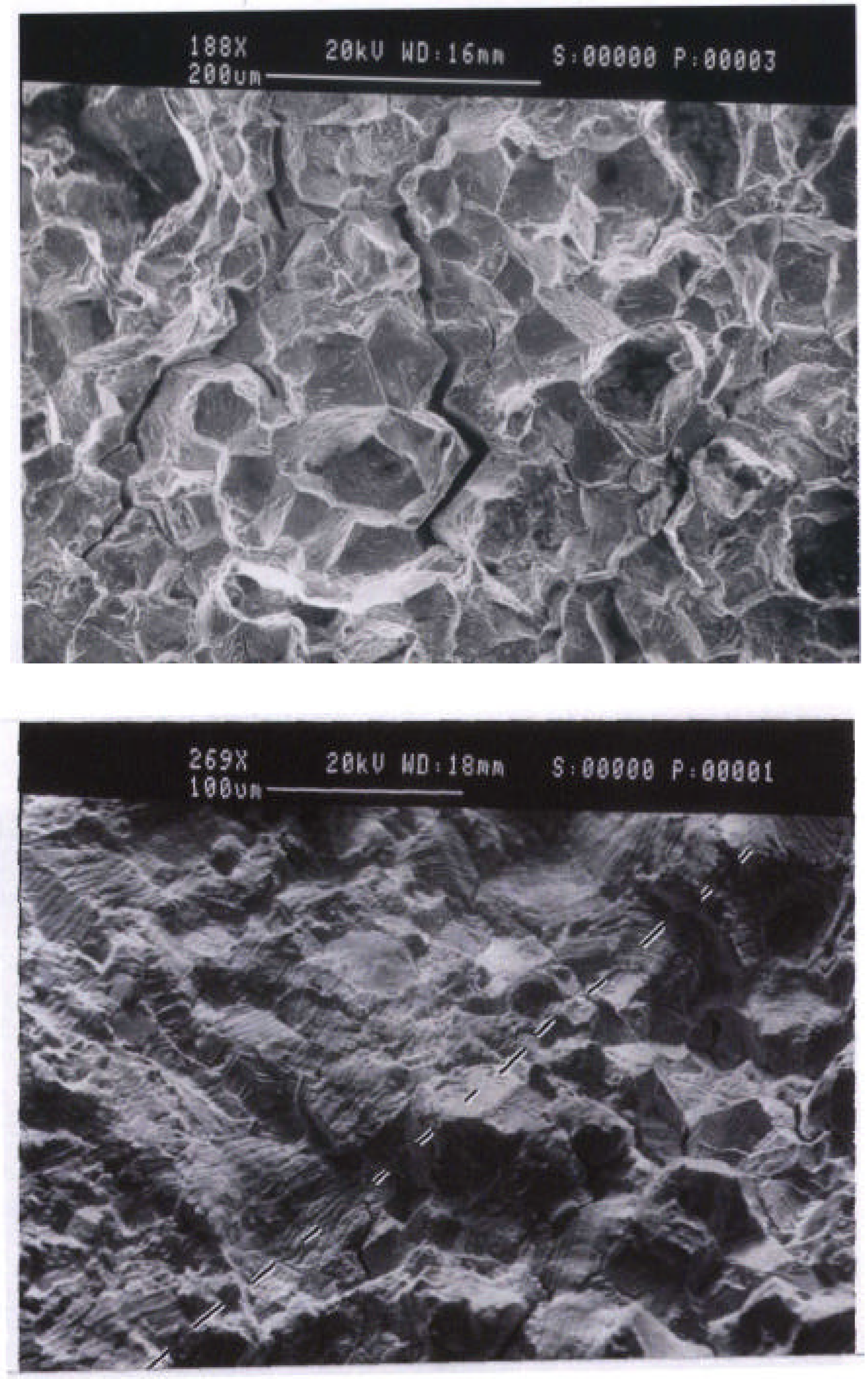


Figure 3. Fracture surface of SEM, the intergranular surface (top) and transition surface (bottom) (source: NTSB Report)

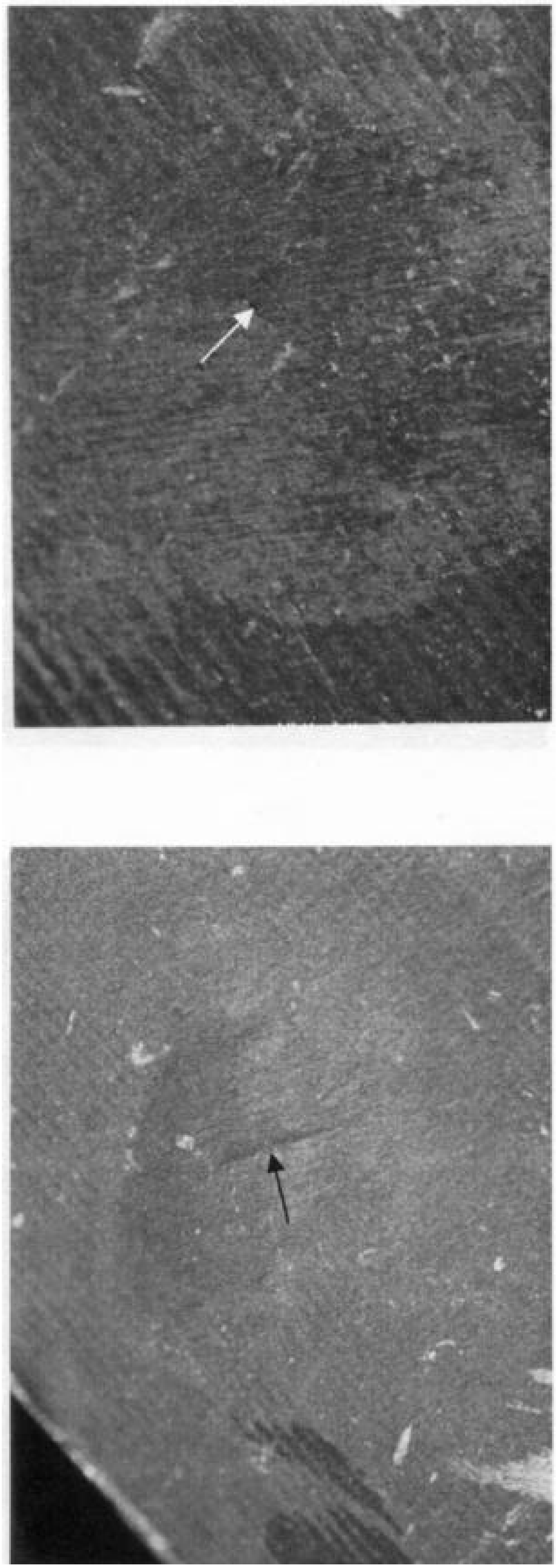
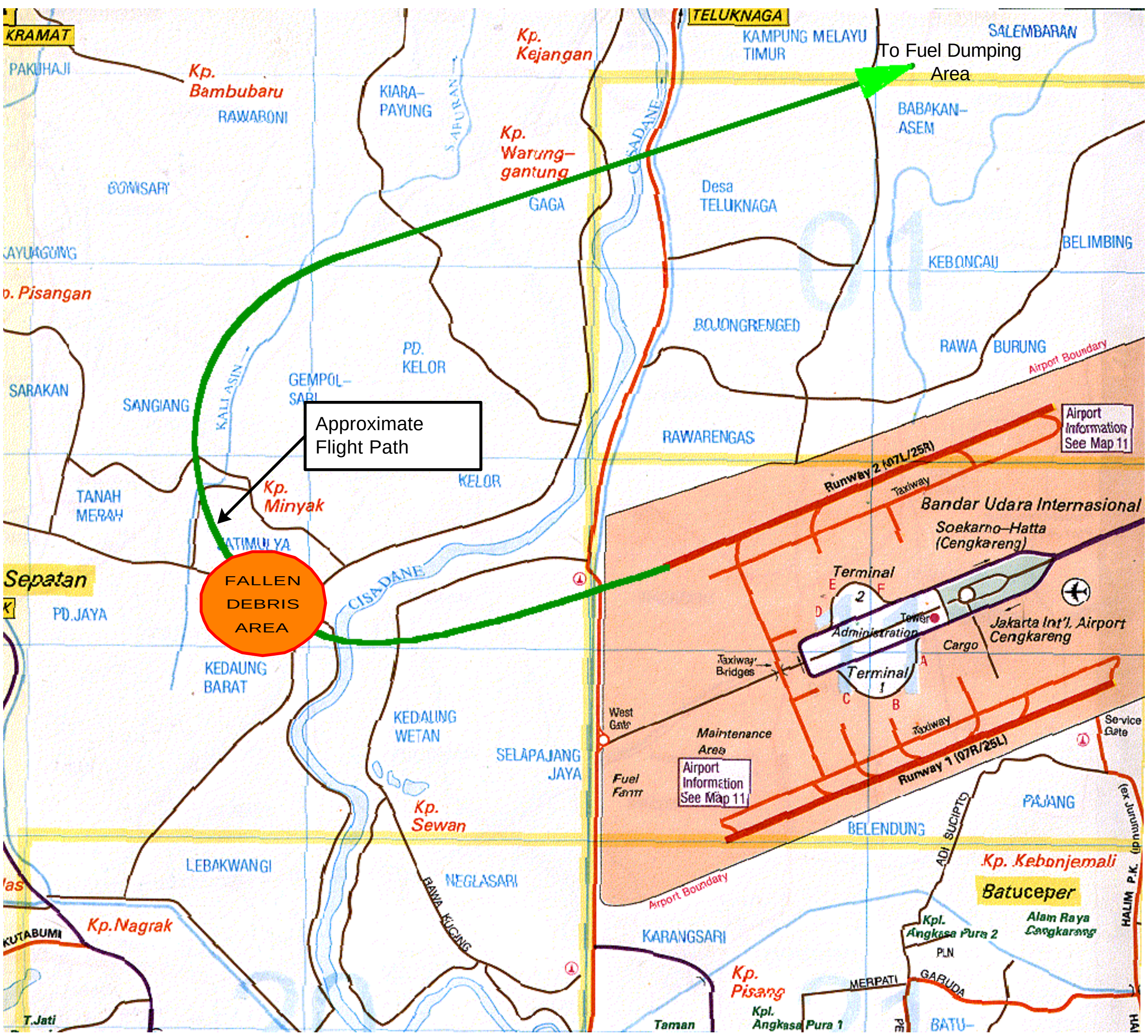


Figure 4. Blending area of the disk (source: P&W Report)

APPENDICES

Appendix A. Location map of the debris field



Appendix B. P&W Report

P&W Service Investigation

Part Name: Disk – Low Pressure Turbine, 5th Stage

Part Number: 787905-001

Part Serial Number: M43709

Total Part Time: 54219 Hours / 11873 Cycles

Installed Engine Module: JT9D-7R4G2

Installed Engine Serial Number: P-715225

SUMMARY AND CONCLUSIONS :

Radial fracture through the subject fifth stage turbine disk was due to intergranular, elevated temperature, fatigue which progressed from the outer portion of the web, approximately 0.5 inches inboard of the web-integral spacer "wing" radius. The fracture originated in a blend-repaired area on the front surface of the disk.

It was reported that blending of the rear of the 4th stage and front of the 5th stage disks had been accomplished to remove local mechanical damage at a previous overhaul, and numerous blended areas were visible on the disk surfaces. Examination of other blends revealed two which exhibited residual damage (worked material or shallow cracks), which apparently was not removed during blending.

The presence of damage and cracking in intact blends suggests that some type of residual damage may also have been present at the fracture origin. Secondary damage at the edge of the fracture origin area, which occurred after liberation of the disk, may have obscured evidence of shallow surface discrepancies.

The grain size of the disk material was slightly larger than specification requirements, but is not considered to be a significant factor contributory to crack initiation or propagation. Otherwise, the disk material conformed to PWA 1085 requirements.

DETAILS OF EXAMINATION:

The subject fifth stage turbine disk fractured radially in two locations. Initially, metallurgical examination was performed at the National Transportation Safety Board (NTSB) laboratory in Washington, D.C. Examination concentrated on the smaller of the two segments which were liberated. Subsequently, the larger portion of the fractured disk, and later the metallurgical mount from the smaller portion, were received at P&W Materials and Processes Engineering for additional examination. A photograph showing the appearance of the larger portion of the fractured disk is shown in Figure 1.

Examination at the NTSB had revealed that one of the two radial fractures had progressed from a granular area, approximately 0.4 inches long, in the outer portion of the web, approximately 0.5 inches inboard of the web-integral spacer "wing" radius. The other radial fracture and other fractures through the integral spacer "wings" were typical of overload, and were considered secondary.

The primary radial fracture was sectioned from the larger disk piece at MPE, then sectioned further to permit examination using binocular microscopes and a Field Emission Scanning Electron Microscope (FESEM). Binocular microscope examination revealed a flat, granular appearing, oxidized area in the web, identical to the area documented similarly at the NTSB (Figures 2 and 3). FESEM examination of this area revealed an intergranular fracture appearance (Figure 4). Some areas of secondary damage were present on the fracture and along the edges; however there was no evidence of non-metallic inclusions or other pre-existing manufacturing flaws.

After ultrasonic cleaning of the piece with the fracture, binocular microscope examination revealed that the front surface of the disk, in the area of the 0.4-inch long intergranular fracture considered to be the initiation region, exhibited a smooth, polished-appearing texture, rather than the typical machining marks which are characteristic of the remainder of the web. The condition, shown in the accompanying photo, appears to be indicative of local "blending" (Figure 5). Micrometer measurements in the subject area indicate a thickness 0.001" to 0.003" thinner than the remainder of the disk web. Disk web thickness away from blended areas, 0.110", conformed to drawing requirement of 0.100" – 0.110". It was reported that blending of the rear of the 4th stage and front of the 5th stage disk had been accomplished at a previous overhaul, to remove local shallow mechanical damage.

Metallographic examination of a serially polished section through the origin area of the fracture revealed no evidence of material or processing anomalies. Secondary mechanical damage, seen during SEM examination, hampered examination in some areas. However, in areas that were free of secondary damage, no surface anomalies were found (Figures 6 and 7). The fracture path was intergranular. The microstructure exhibited a relatively moderate amount of "needle" delta phase, which conformed to the requirements of MCL Manual Section E-107. Grain size averaged ASTM 6, with occasional grains as large as 3 to 4, as measured by the Linear Intercept Method. The grain size was slightly coarser than the PWA 1085 requirement of 6 or finer, with occasional grains as large as 5.

A series of 41 electron microprobe analyses were conducted at and away from the fracture surface, evaluating areas including grain boundaries and areas in centers of grains. Comparison of the fracture area and areas away from the fracture showed no significant compositional differences.

Visual examination of the remainder of the disk revealed numerous other blended areas on the front surface of the web and the adjacent front face of the bore section. It was estimated that 40 to 50 blends had been performed on the disk surface. All were shallow and conformed to the requirement that the width of the blends be at least 15 times greater than the depth. Fluorescent penetrant inspection of the disk piece revealed no crack indications.

An area with several "blends" was sectioned out for closer evaluation (Figure 8). Binocular examination revealed that two blends showed evidence of what appeared to be residual mechanical damage ("dents") (Figure 9). These dents were oxidized, showing the same type of discoloration as the remainder of the disk surface. This appearance indicated that they were present prior to the fracture event. One of the two dents was visible at relatively low magnifications, while the other was seen only by binocular microscope examination at higher magnifications.

Metallographic examination of sections through blends which contained mechanical damage revealed evidence of worked material at the base of one of the dents (Figure 10). The remainder of the blend surface was free of any evidence of worked material. The other blend exhibited three small intergranular cracks near the center of the blended region (Figure 11). Maximum crack depth was 0.002".

Tensile and stress-rupture specimens were machined from the disk to evaluate mechanical properties. Results, shown in Table I, conformed to the requirements of PWA 1085 specification.

DISCUSSION:

Fatigue specimens were machined from the web of the subject disk and tested to determine whether intergranular fracture characteristics could be produced at engine-relevant temperatures. Testing at 1000°F, with five minutes dwell at maximum stress, produced intergranular features which closely matched those on the disk fracture surface (Figure 12).

TABLE I

PROPERTIES OF SPECIMENS MACHINED FROM FRACTURED JT9D-7R4G2 FIFTH STAGE TURBINE DISK P/N 787905-001, S/N M43709

[illegible]	Temp (F)	[illegible] (KSI)	[illegible] (KSI)	[illegible]	RA (%)
Round From Flange Area	Room	177.6	199.2	21.1	34.1
Round From Flange Area	Room	171.3	201.7	22.0	38.4
Round From Flange Area	1200	145.1	166.6	25.9	50.0
Round From Flange Area	1200	138.7	169.8	26.7	49.6

[illegible]	Temp (F)	Stress (KSI)	Life (Hours)	[illegible]
Combo Bar From Flange Area	1200	110	98.0	18.0
Combo Bar From Flange Area	1200	110	98.1	33.9
Flat Bar From Web	1200	110	50.3	7.1
Flat Bar From Web	1200	110	84.3	10.1

[illegible]	Temp (F)	[illegible] (KSI)	[illegible]	[illegible]
Combo Bar From Flange Area	1300	65	486	33.9
Combo Bar From Flange Area	1300	65	422	28.4

Grain Size by Linear intercept Method
Bore – Average ASTM 8
Web – Average ASTM 6
Rim – Average ASTM 6.5

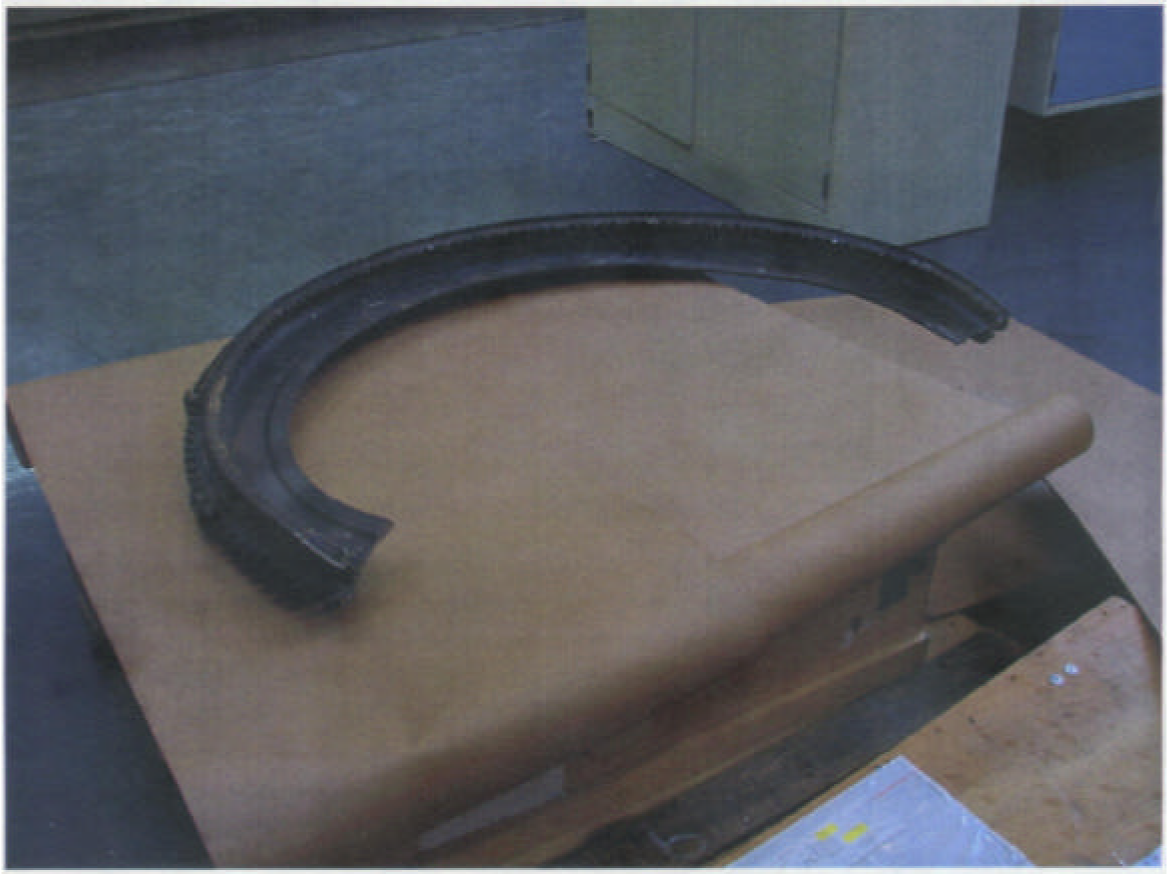


FIGURE 1

PHOTOGRAPH SHOWING APPEARANCE OF LARGE PORTION OF FRACTURED JT9D FIFTH STAGE TURBINE DISK WHICH WAS RECEIVED FOR EXAMINATION IN MATERIALS AND PROCESSES ENGINEERING

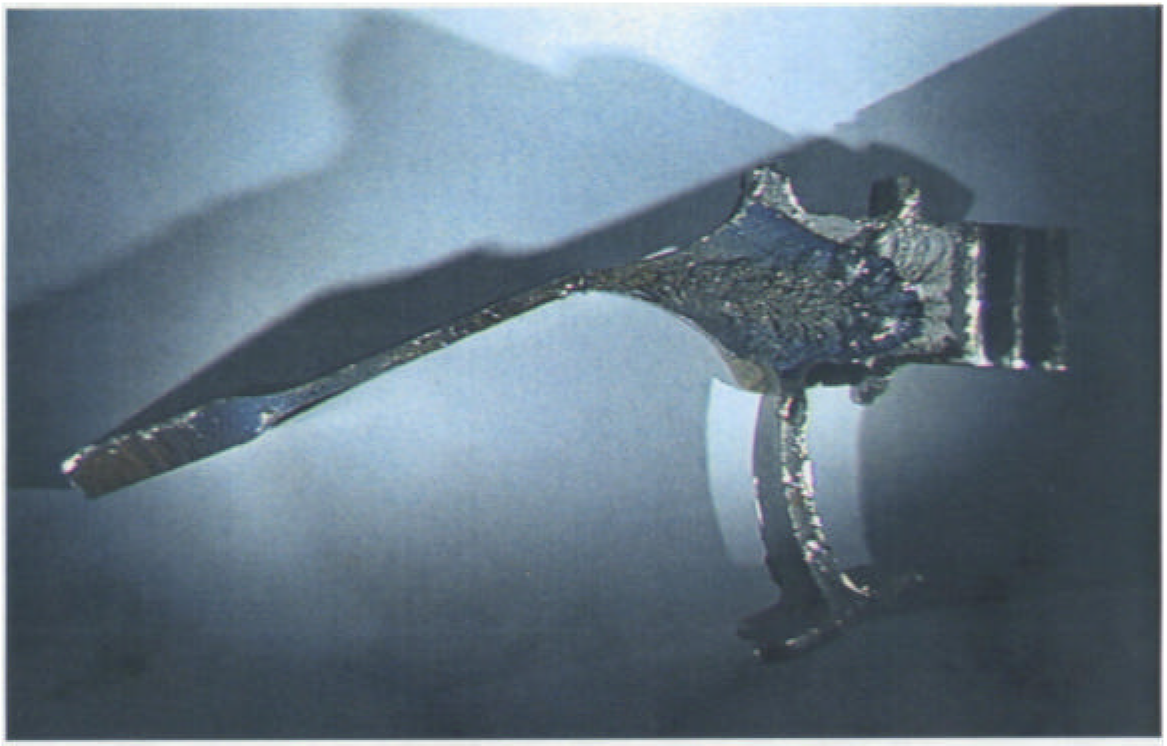


FIGURE 2

OVERVIEW OF PRIMARY RADIAL FRACTURE SHOWING LOCATION OF FLAT, GRANULAR APPEARING, OXIDIZED AREA IN THE WEB.

FIGURE 3

CLOSE-UPS OF FRACTURE SURFACE IN ORIGIN AREA, SHOWING FLAT, GRANULAR, OXIDIZED APPEARANCE

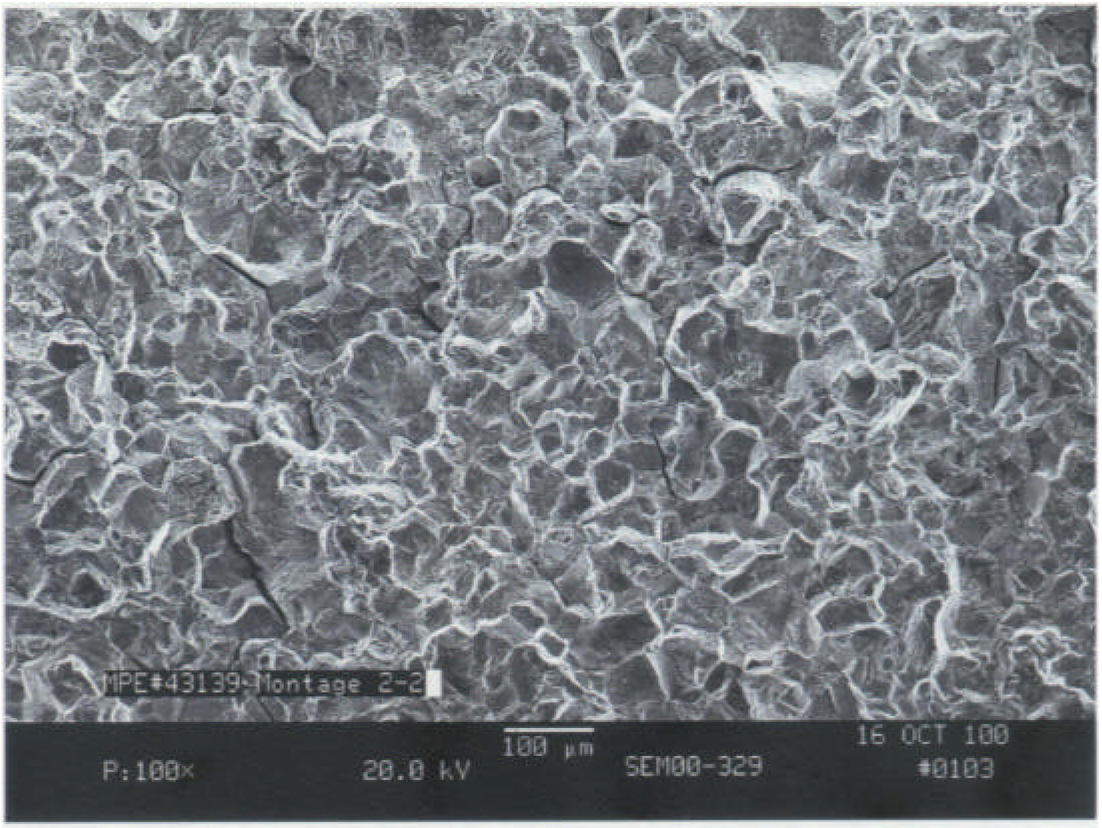


FIGURE 4

SCANNING ELECTRON MICROSCOPE PHOTOGRAPH OF FRACTURE SURFACE IN OUTER PORTION OF WEB, SHOWING INTERGRANULAR FRACTURE APPEARANCE WHICH WAS PRESENT THROUGH THE WEB THICKNESS FOR APPROXIMATELY 0.4 INCHES OF RADIAL DISTANCE.

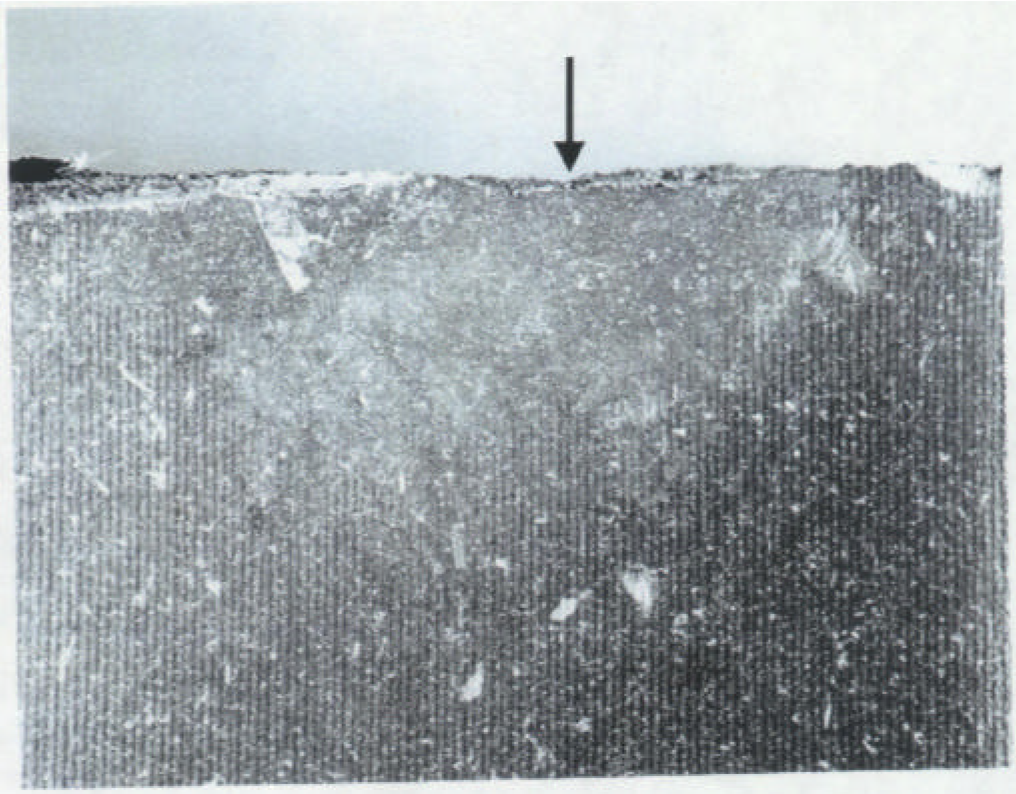


FIGURE 5

CLOSE UP OF FRONT SURFACE OF WEB IN THE AREA OF THE FRACTURE INITIATION, SHOWING SMOOTH, POLISHED APPEARING AREA WHERE ORIGINAL MACHINING LINES HAD BEEN REMOVED, INDICATIVE OF LOCAL BLENDING. ARROW SHOWS APPROXIMATE LOCATION OF FRACTURE ORIGIN.

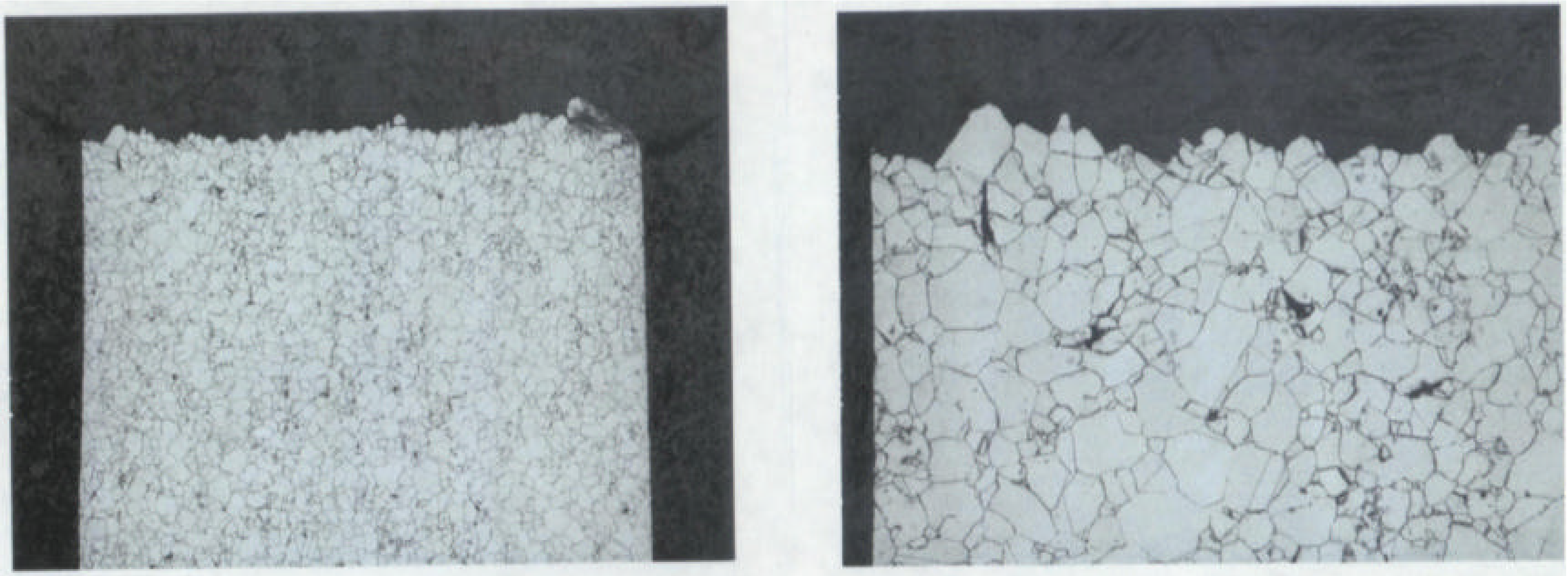


FIGURE 6 MAG: LEFT - 32X; RIGHT- 100X

PHOTOMICROGRAPHS OF SECTIONS THROUGH VICINITY OF FRACTURE ORIGIN SHOWING INTERGRANULAR FRACTURE PATH, AND APPEARANCE OF MICROSTRUCTURE

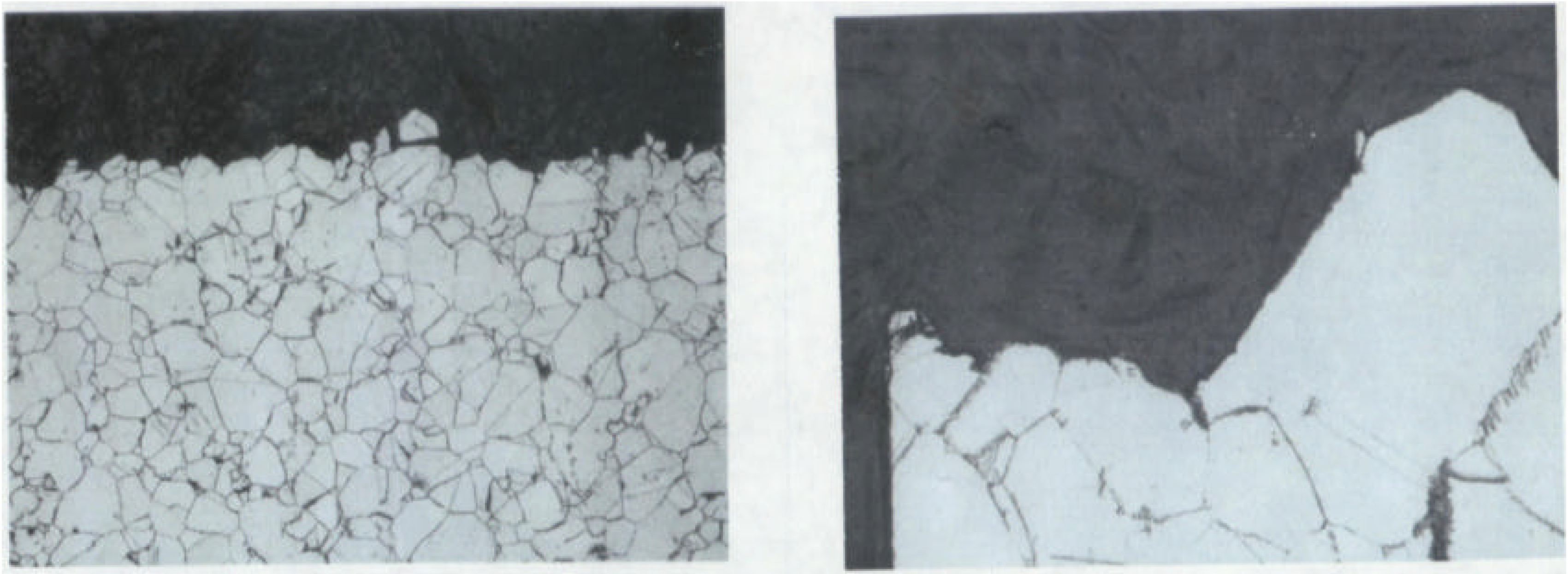


FIGURE 7

MAG: LEFT – 100X; RIGHT – 500X

PHOTOMICROGRAPHS OF SECTIONS THROUGH VICINITY OF FRACTURE ORIGIN SHOWING INTERGRANULAR FRACTURE PATH, AND APPEARANCE OF MICROSTRUCTURE

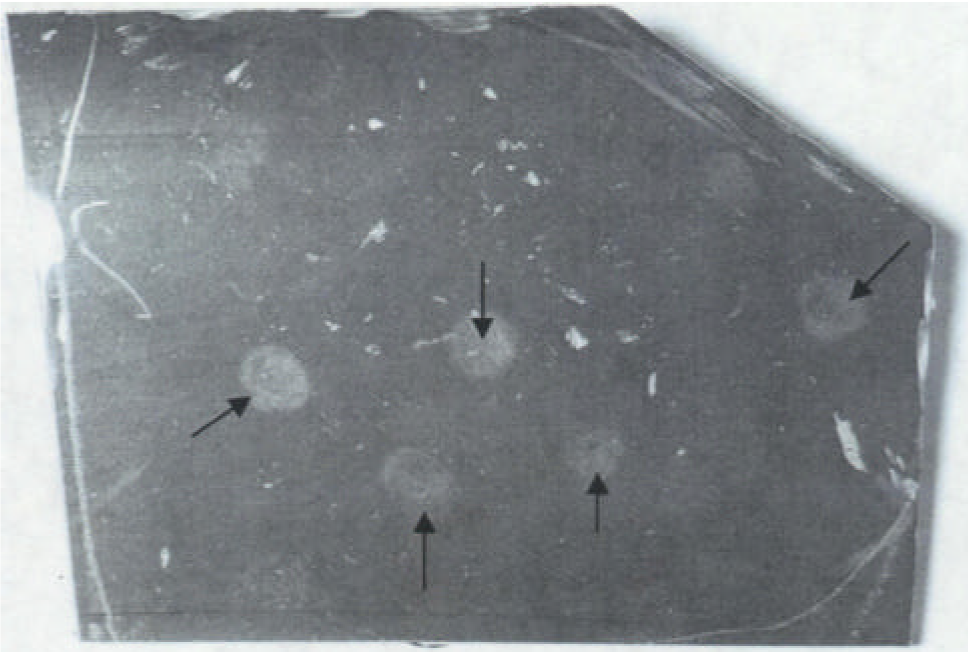
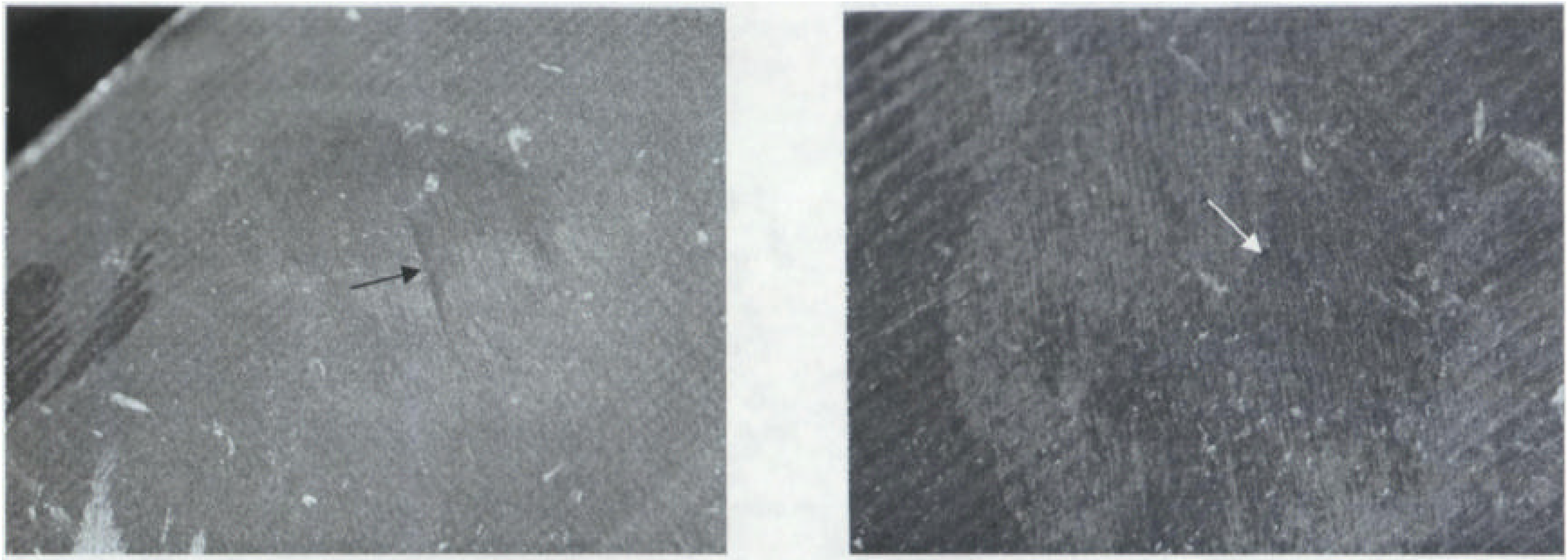


FIGURE 8

VIEW SHOWING APPEARANCE OF SECTION OF DISK WEB WHICH WAS SECTIONED OUT FOR EXAMINATION OF BLENDS (ARROWS)



<u>FIGURE 9</u> MAG: LEFT – 16X; RIGHT – 10X

CLOSE-UPS OF TWO BLENDS WHICH SHOWED EVIDENCE OF RESIDUAL MECHANICAL DAMAGE (ARROWS)

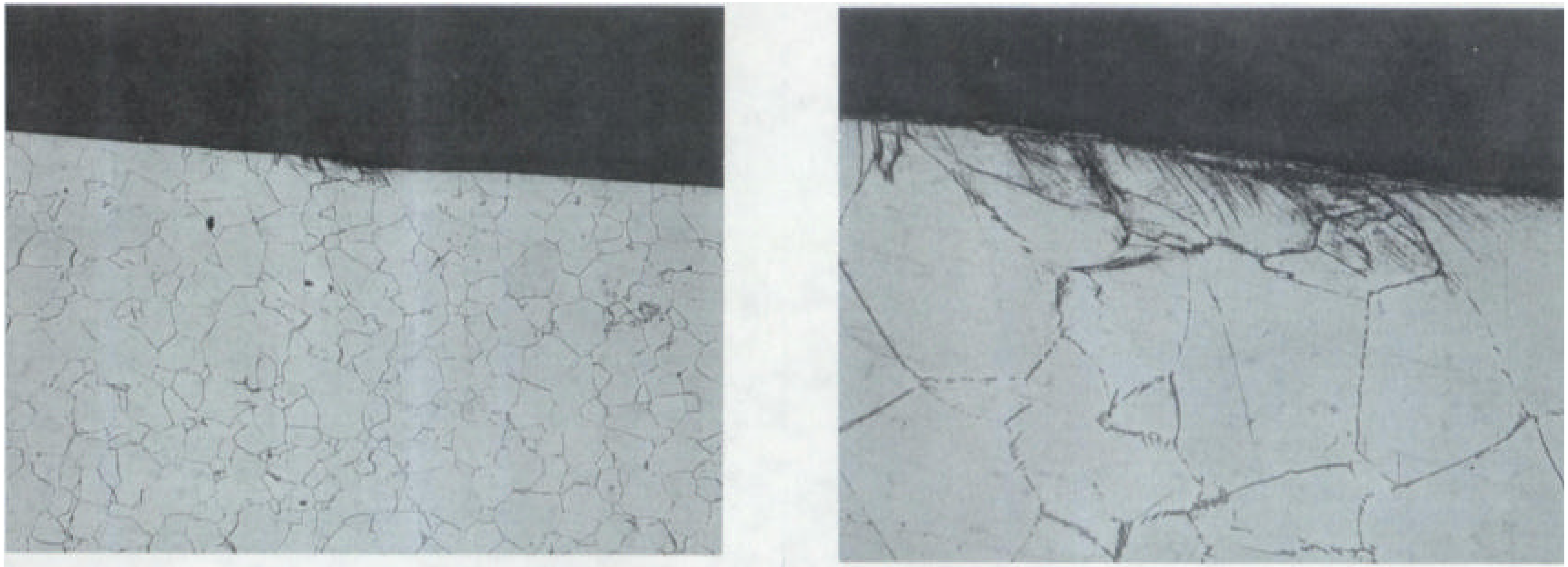


FIGURE 10

MAG: LEFT – 100X; RIGHT – 500X

PHOTOMICROGRAPHS OF SECTIONS THROUGH BLEND AT LEFT IN FIGURE 9, SHOWING APPEARANCE OF WORKED MATERIAL AT THE BASE OF THE AREA OF MECHANICAL DAMAGE

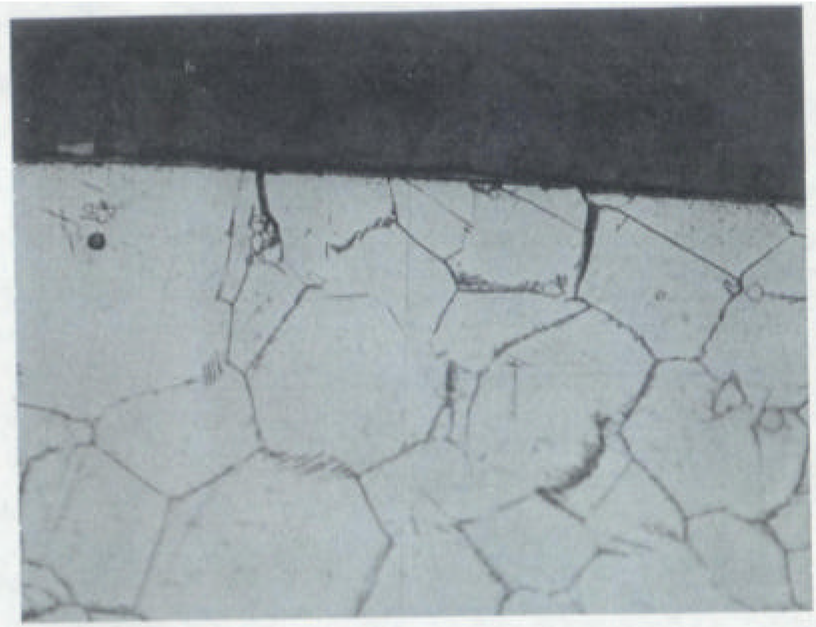


FIGURE 11

MAG: LEFT – 100X; RIGHT – 500X

PHOTOMICROGRAPHS OF SECTION THROUGH BLEND AT RIGHT IN FIGURE 9 SHOWING SHALLOW INTERGRANULAR CRACKS NEAR CENTER OF THE BLENDED REGION

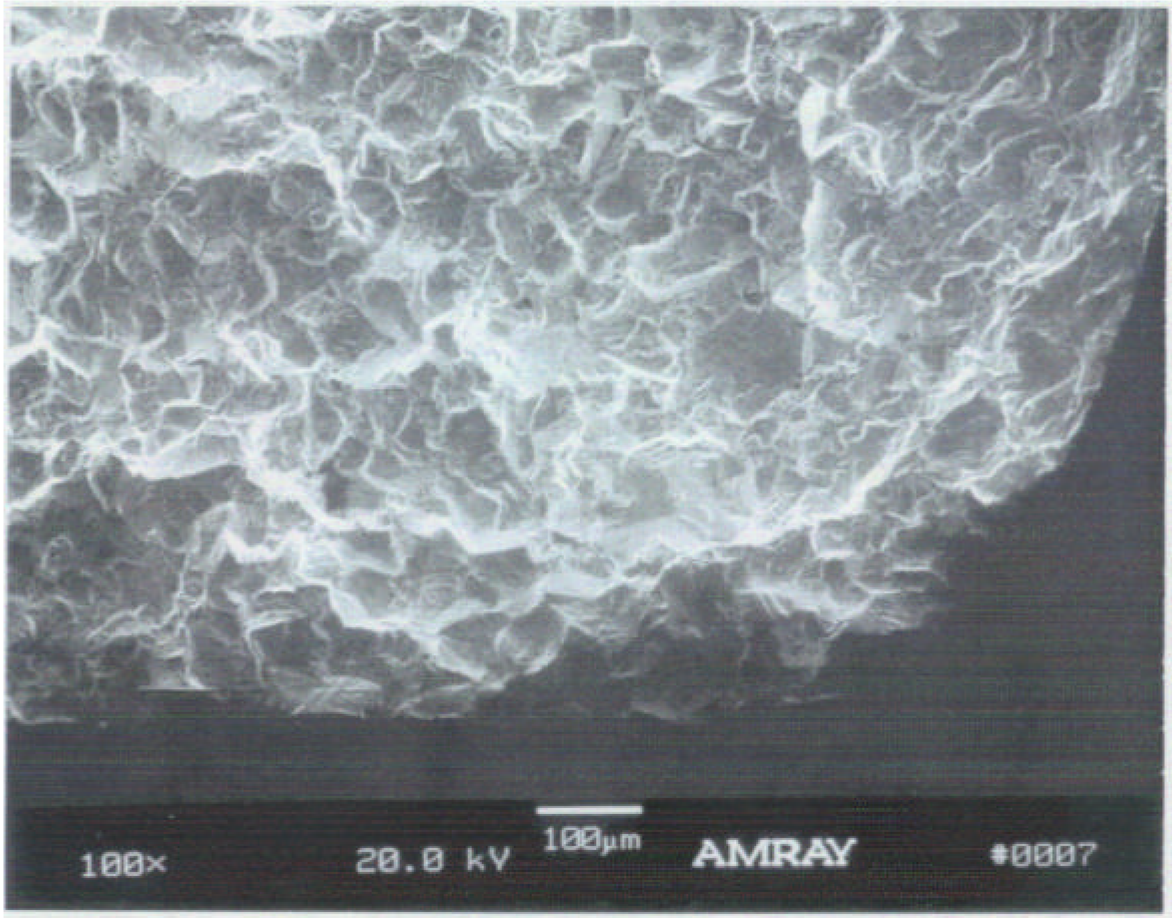


FIGURE 12

SCANNING ELECTRON MICROSCOPE PHOTOGRAPH OF FATIGUE SPECIMEN TESTED AT 1000°F, WITH FIVE MINUTES DWELL AT MAXIMUM STRESS. NOTE INTERGRANULAR FRACTUE APPEARANCE.

Appendix C. NTSB Report

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

December 22, 2000

MATERIALS LABORATORY FACTUAL REPORT

Report No. 00-169

A. ACCIDENT

Place	:	Jakarta, Indonesia
Date	:	September 5,2000
Vehicle	:	Boeing 747-300, registration JA8178
NTSB No.	:	DCA00-R-A009
Investigator	:	Jim Hookey (AS-40)

B. COMPONENTS EXAMINED

Two pieces of a 5th Stage Low Pressure Turbine (LPT) disk from Pratt and Whitney JT9D-7R5G2 engine.

C. DETAILS OF THE EXAMINATION

Two pieces of the 5th Stage LPT disk are shown in figure 1. The disk contained fractures at the two locations indicated by arrows "1" and "2". The fractures in the disk were oriented in a radial direction and extended through the bore, web, and rim. The retention post for the blades at the rim location contained a fir-tree configuration. Each fracture intersected the bottom radius located between retention posts for a blade. The disk pieces contained deformation as if the two pieces had stretched outward.

Visual examination of the fractures revealed the respective ends of the two pieces mated with each other, indicating no pieces of the disk were missing. Portions of the fracture indicated by arrows "2" contained blue and gold tint consistent with exposure to an elevated temperature. The fracture indicated by arrows "1" contained features typical of overstress separation, and no evidence of heat tinting.

Visual Examination of the Tinted Fracture

Figure 2 shows a photograph of the face of fracture "2" that was located on the smaller piece of the disk. This fracture was chosen because it was located on the smaller portion of the fractured disk, and was easier to handle compared to the larger piece. The web portion contained bow deformation with the convex side located on the aft face of the disk. The bore and most of the web were deformed forward relative to the disk rim. The fracture contained blue and gold heat tint that extended between the inside diameter surface of the bore and the rim to the location indicated by a dash line in figure 2. In an undeformed disk, the total length of the heat tint area would have been approximately 4 inches. A circumferential crack, indicated by arrow "C" in figure 2, intersected the fracture surface in the transition area between the web and rim.

The fracture face shown in figure 2 was excised from the smaller piece of the disk. This was achieved by making a cut approximately 0.4 inch below and parallel to the fracture, in the area indicated by line "Y-Y" in figure 1. The cut intersected a circumferential crack, causing the bore and lower web portion to separate from the upper web portion and rim. The excised fracture pieces were ultrasonically cleaned in acetone. Visual and bench binocular microscopic examination of the excised fractures revealed a flat region at the web portion in the area. This flat region will be further referred as the fracture origin area and is indicated by bracket "O" in figures 2 through 4. The fracture origin area extended completely through the web and was perpendicular to the surface of the web. The radial length of this flat region was approximately 0.4 inch. Where the flat region intersected the forward and aft surfaces of the web, there was no evidence of a shear lip. Shear lips were found where the remainder of the fracture surface intersected the forward and aft surfaces of the web (see figure 4). The flat region and absence of a shear lip in the flat region is consistent with a brittle fracture mechanism. The flat region exhibited granular features, and contained no evidence of ratchet marks or river patterns, that would indicate crack propagation directions.

Several reflective facets in the flat region contained a silver-like luster indicated by unmarked arrows in figure 5. Closer examination of these silver-like grains revealed mechanical damage that resulted from relative movement between the mating fracture faces. The mechanical damage areas were verified by scanning electron microscope examination (SEM) performed at a later time.

The forward and aft faces of the disk web in the fracture origin area contained no evidence of gouging or dent damage. The forward and aft faces contained an orange peel texture in the area of the bow deformation area. The wall thickness of the web in the fracture origin area and away from the origin area measured between 0.108 and 0.110 inch, which was within the specified range of 0.100 to 0.110 inch. The wall thickness of the web in the larger piece was also within the specified range.

The rim portion of the fracture was on a flat radial plane. This portion of the fracture contained crack arrest marks in the area indicated by arrows "P" in figure 2, and chevron marks near the center of the rim. The portion of the fracture that extended inboard of the fracture origin area towards the disk's bore was not perpendicular to the web and was gradually tilting to approximately 45 degrees relative to the flat region. The slant area in the bore portion of the disk contained crack arrest marks, consistent with the crack propagating inboard. The location and orientation of the chevron and crack arrest marks indicated that the fracture propagation was away from the fracture origin "O" in the general directions indicated by unmarked arrows in figure 2.

Scanning Electron Microscope Examination of the Tinted Fracture

SEM examination of the excised fracture revealed that the flat region contained intergranular fracture features with secondary cracking extending below the fracture surface (see figures 6 and 7). Intermittent intergranular fracture features were found in areas well beyond the origin region. In the inboard direction the intergranular features were found as far as 0.42 inch inboard of the midpoint of the flat region. In the outboard direction, the intergranular features were found as far as approximately 1.6 inches outboard of the midpoint of the flat region. The dashed line in figure 2 indicates the outboard extent of the intergranular features, which is coincident with the extent of the heat tinting in this direction.

The forward and aft edges of the fracture in the transition between the web and rim portion contained shear lips. The SEM examination showed that the shear lip areas contained crack arrest marks typical of fatigue cracking. The crack arrest marks on the forward shear lip propagated slightly outboard and forward. The crack arrest marks on the aft shear lip propagated slightly outboard and aft. The area between the forward and aft shear lips contained only intergranular fracture features with no evidence of crack arrest marks. Figure 8 shows a photograph of the transition between intergranular fracture and shear lip fatigue features. Figure 9 shows a photograph of typical fatigue striations in the shear lip area. The area located outboard of the dashed line in figure 2 contained ductile features typical of overstress separation.

A portion of the fracture located between 0.42 and 1.32 inches inboard of the midpoint of the flat fracture region contained some areas of mechanical damage. The fracture features in undamaged areas of this portion of the fracture were not typical of intergranular fracture or overstress, but contained some striation-like features, indicative of transgranular fatigue cracking (see figures 10 and 11). The distance 1.32 inches from the midpoint of the flat fracture region corresponds to the transition between the web and bore. The fracture located inboard of this transition area (to the inside diameter surface of the bore) contained ductile dimple features, see figure 12.

Metallographic Evaluation, Hardness Testing, and EDS Analysis

Another saw cut was made approximately 0.5 inch below the first saw cut, in the area indicated by line "Z-Z" in figure 1. Again, this cut was made parallel to the first cut. The face of the first cut, indicated by sectional line "Y-Y" in figure 1, was polished and etched with Tuckers reagent for metallographic evaluation. The metallographic evaluation consisted of measuring the grain size and comparing the microstructure between the bore, web, and rim portion of the disk.

To estimate the grain size, photographs were taken at 100X magnification from typical areas of the bore, web, and rim portions of the disk. These photographs were then compared to ASTM grain size standards[1]. Pratt and Whitney Specification PWA 1085,

[1] Used ASTM charts from reference literature: "Principles of Metallographic Laboratory Practice", George Kehl, Third Edition, McGraw Hill Book Company.

titled "Alloy Bars, Forgings, and Rings, Corrosion and Heat Resistant, (Inconel 718)", indicated that the grain size should be "6 or finer, with occasional grains as large as 5 permissible." Examination of section "Y-Y" in figure 1 revealed that the grain size in the web portion at the fracture origin area was predominantly 5 with several grains that were 4. This grain size is larger than permissible. All areas within the bore, the inboard portion of the web, and the inboard portion of the rim contained equiaxed grains whose size was within the specified range. The outboard portion of the web contained equiaxed grains that were larger than permissible. The mid and outboard portion of the blade retention post contained equiaxed grains; however, these areas also contained several elongated grains that were larger than permissible. The result of the grain size evaluation is summarized in Table 1. Figures 13 through 20 contain typical photomicrographs at various areas of the disk.

Table 1.Summary of Grain Size Evaluation

Location	Grain Size Number
Inboard portion of bore	Generally 8
Outboard portion of bore	7 , with several grains that are 6
Inboard portion of web	6 , with several grains that are 5
Web in area of fracture origin area	5 , with several grains that are 4
Outboard portion of web	6 , with several grains that are 5 and 4
Inboard portion of rim	6
Mid portion of rim	7 , with several that are 4
Most outboard portion of blade retention post	Typically 8, and several elongated (not completely recrystallized) grains that range from as small as 6 and as large as 2

PWA 1085 indicated that the material should have a hardness of not less than 331 HB (converts to an approximate Rockwell "C" 36). Rockwell hardness testing of the surface of section "Y-Y" generated values that ranged between HRC 43 and 46, above the specified minimum hardness. Energy dispersive X-ray spectroscopy analysis of the web portion produced a spectrum that contained major peaks of nickel and minor peaks of chromium, iron, niobium, molybdenum, titanium, oxygen, tantalum, and aluminum, consistent with the specified Inconel 718 alloy.

Portions of the inboard portion of the bore and outboard portion of the rim were cut into smaller pieces so that they could be incased in a metallurgical mount. The sections were polished and etched first with Tucker's reagent and then electrolytically with a phosphoric acid solution. The phosphoric acid etch darkens the grain boundaries and increases the contrast between the grain boundaries and grains. The metallographic examination of the sections was performed at magnifications up to about 1,500X. The section was also examined with the SEM at magnifications up to 2,030X. At these magnifications, no fine microstructural constituents such as gamma prime and gamma double prime were resolved[2]. The microstructure of all examined sections contained carbides, both at the grain boundaries and within the grains and also spherical and

[2] Examination of the microstructure at high magnifications (10,000X and above) using high resolution scanning and/or transmission electron microscopes will be performed by Pratt and Whitney.

elongated particles of what appeared to be delta phase at the grain boundaries. The delta phase at the grain boundaries reportedly is used to control grain size in wrought materials. The typical microstructure of the sections is shown in figures 21 through 29.

Section through the Fracture Origin

A section was made through the approximate center of the fracture origin area, in the location indicated by line "T-T" in figure 3. The section was encased in a metallurgical mount, polished and etched with Tucker's reagent. Examination of the section revealed intergranular cracking at the fracture surface. The cracking extended between grains and typically did not exceed the thickness of two grains. The cracking at the grain boundaries generally was oriented nearly perpendicular to the fracture surface, with no evidence that these intergranular cracks extended parallel to the fracture surface. The grain boundaries contained no voids. The microstructural constituents in the section through the fracture origin area appeared similar to those found in the metallographic sections from the bore and rim portions of the disk. Figures 32 through 34 show photographs of typical microstructure of the section through the fracture origin.

Service History of the Disk

A representative from Japan Airlines, operator of the accident airplane, indicated that the disk reportedly was manufactured in 1984. The disk, P/N 787905-001, S/N M43709, operated a total of 54,251 hours and accumulated a total of 11,881 cycles. The disk was inspected by the fluorescence penetrant method, once at 12,198 hours prior to the accident and once at 2,301 cycles prior to the accident. The disk has a retirement life of 15,000 cycles. A representative from Pratt & Whitney indicated the heat code for this disk was AGXS7.

Additional Examinations

The larger portion of the disk, and section "Y-Y" was sent to Pratt & Whitney. Pratt & Whitney proposed to inspect the larger piece by a non-destructive inspection method. Plans would include manufacturing specimens and performing tensile, stress rupture, and fatigue testing, to determine what conditions would create stress rupture in the disk, and correlate that information with that of the accident disk.

The microstructure of the disk will be examined with a replica transmission electron microscope to evaluate the appearance of gamma prime and gamma double prime precipitates. Further work will involve an electron microprobe analysis to conduct "rastering scans," or area scans, to compare material composition at and away from the fracture origin area. Depending on the results of this analysis, quantitative metallography may be conducted to compare the amount of delta phase in the respective areas at and away from the fracture. Pratt & Whitney will provided a report on their findings.

Frank P. Zakar

Frank P. Zakar
Senior Metallurgist

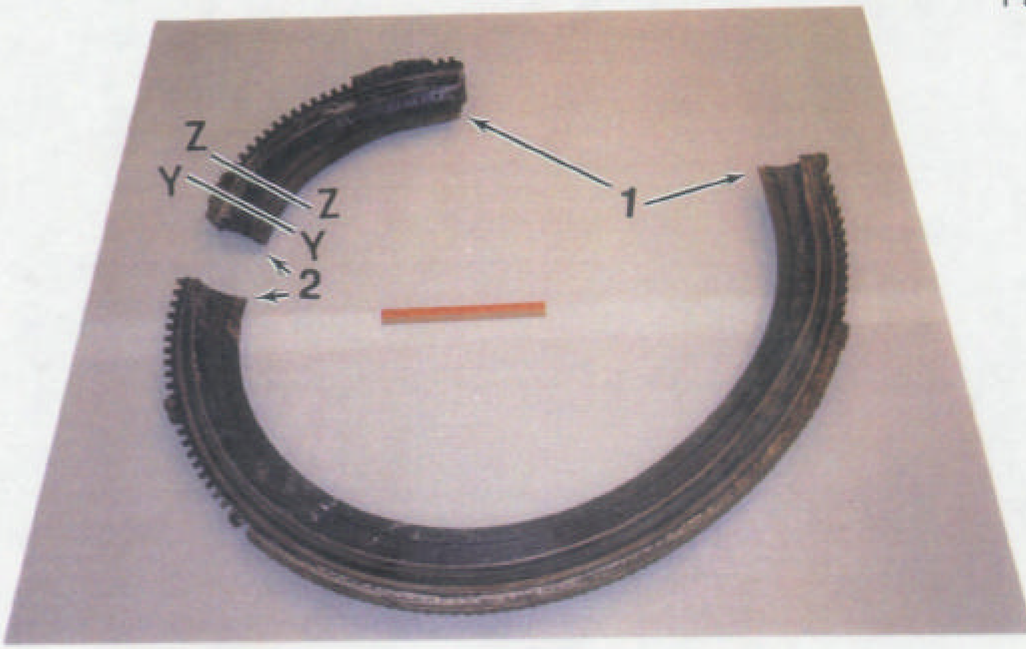


Figure 1. As-received disk that separated in the areas indicated by arrows "1" and "2".

Figure 2. Photograph of fracture "2" on the smaller piece of the disk.

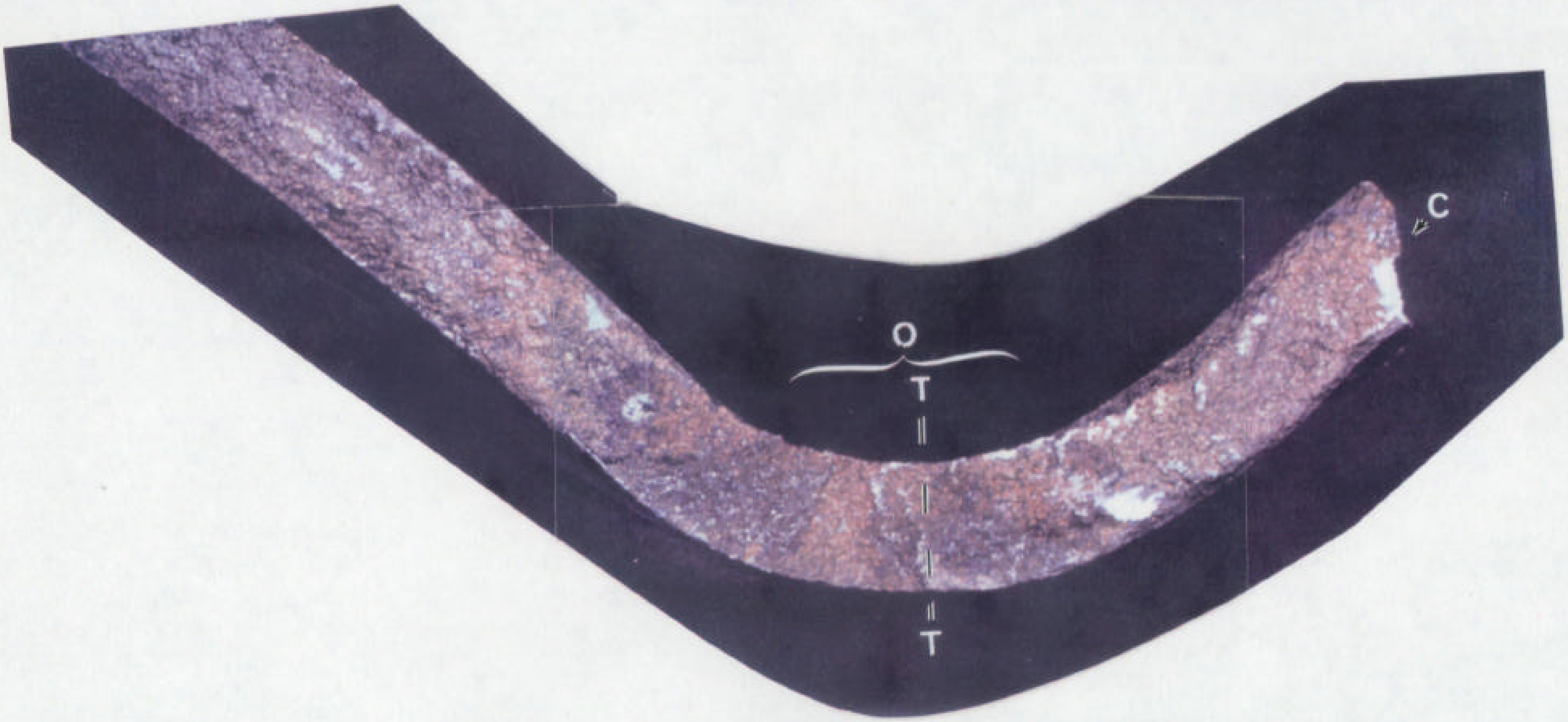


Figure 3. Close-up photograph of the fracture origin indicated by bracket "O". Arrow "C" indicates a circumferential crack that intersected the radial fracture face. (7.5X)

Figure 4. Higher magnification photograph of the fracture origin area, indicated by brackets "O" in figure 3. Areas between dashed lines and outside edges indicate location of shear lips. (15X)

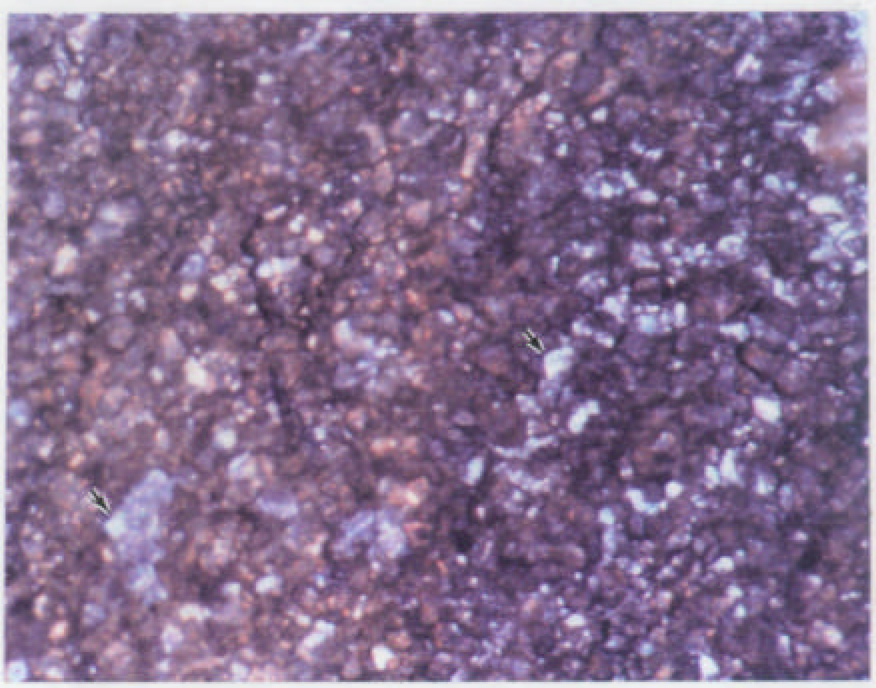


Figure 5. Close-up photograph of the granular features in the fracture origin area. (55X)

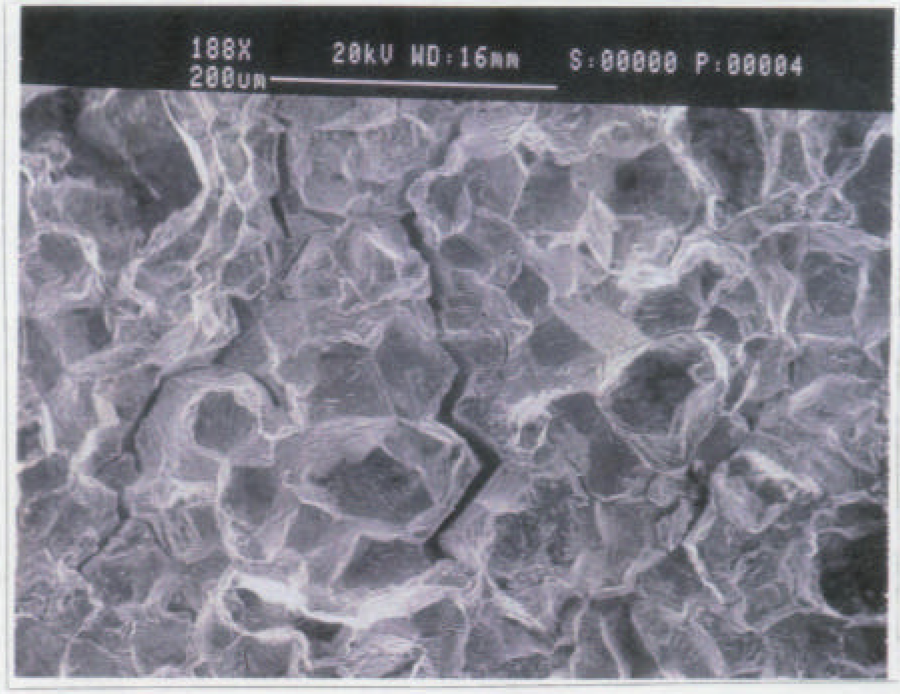


Figure 6. Scanning electron microscope (SEM) photograph of typical intergranular fracture features in the fracture origin area. (188X)

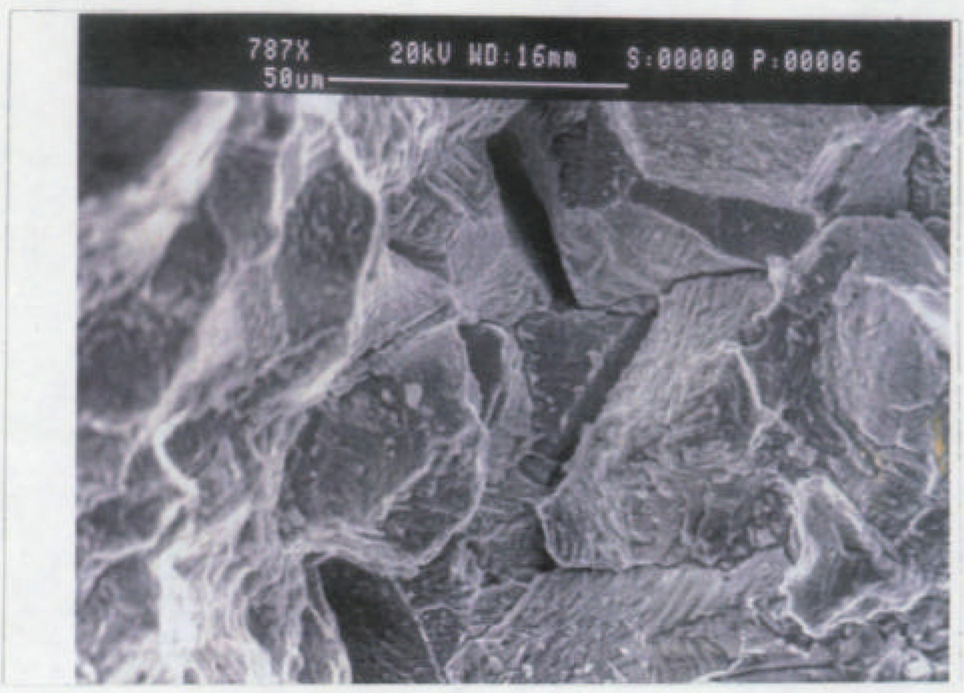


Figure 7. Higher magnification SEM photograph of the intergranular fracture features in the origin area. (787X)

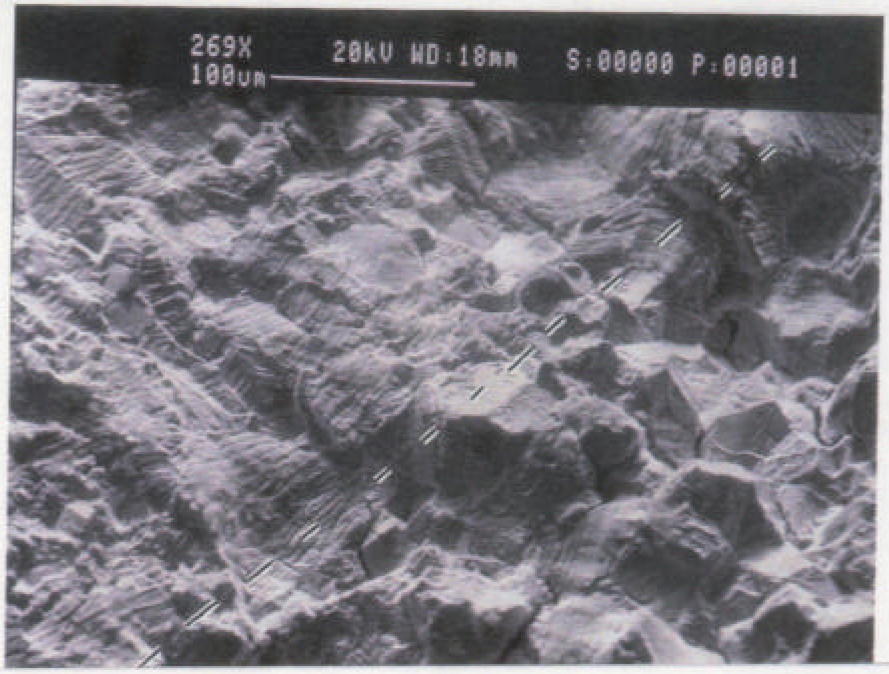


Figure 8. SEM photograph of the transition region, indicated by dashed line, between the shear lip at the forward edge of the disk (left of the dashed line) and the rim (right of the dashed line). Note the fatigue striations at the left and the granular features at the right. (269X)

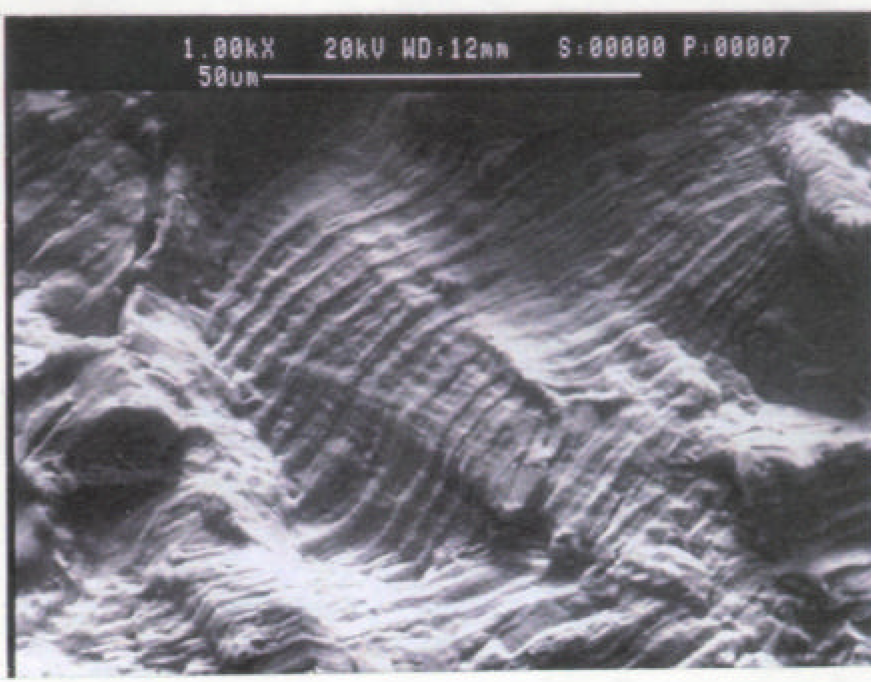


Figure 9. Higher magnification SEM photograph of the fatigue striations in figure 8. (1,000X)

Figure 10. SEM photograph of the fracture features in the web in an area located between the fracture origin area and the bore showing mechanical damaged areas ("D") and striation-like features. (1,110X)

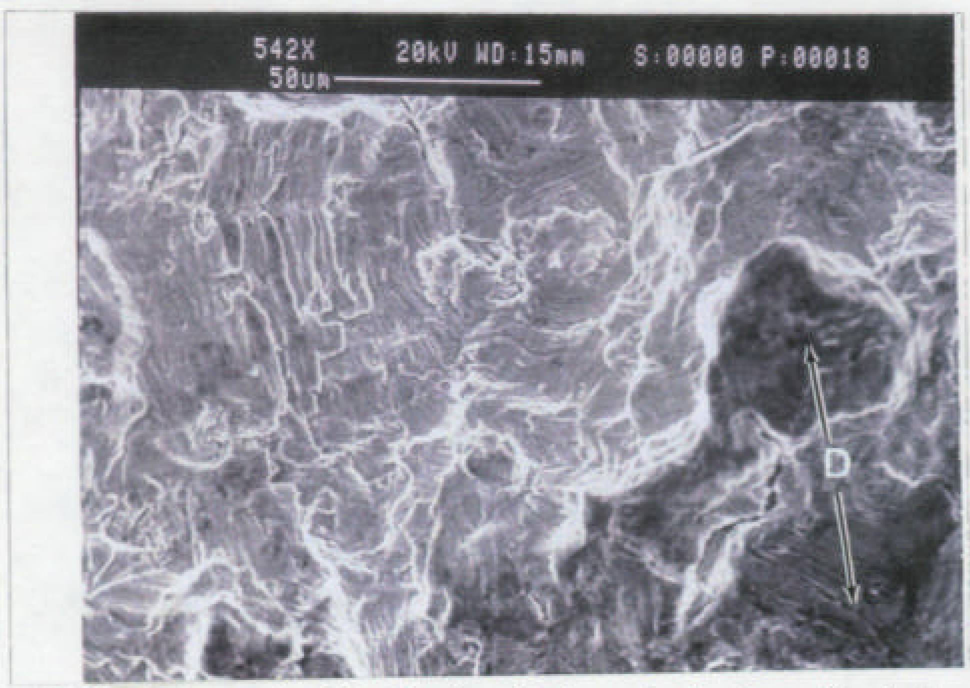


Figure 11. SEM photograph of the fracture features in the transition between the web and the bore showing mechanical damaged areas ("D") and striation-like features. (542X)

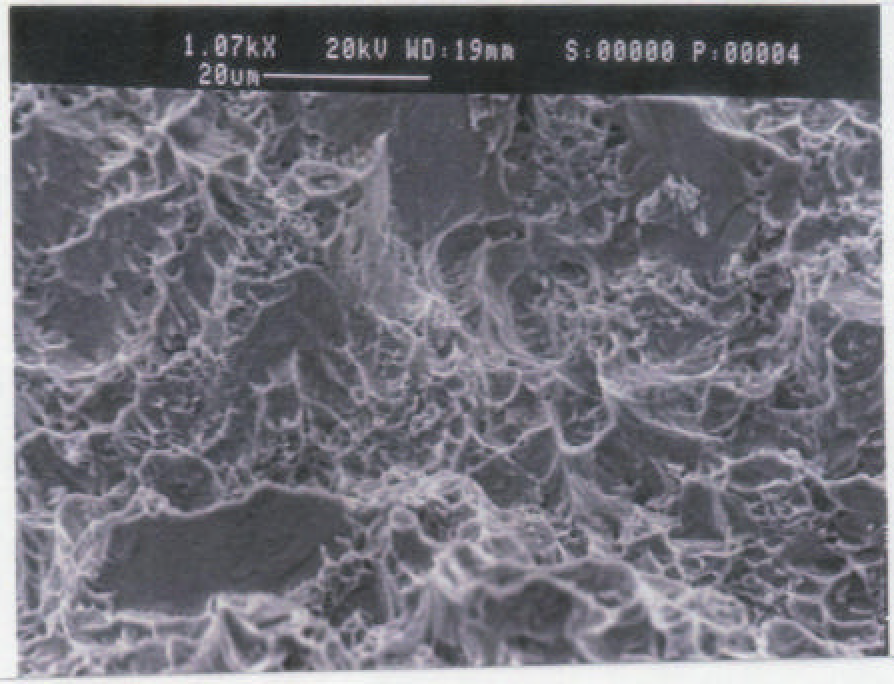


Figure 12. SEM photograph of ductile dimple features in the bore area (1,070X)

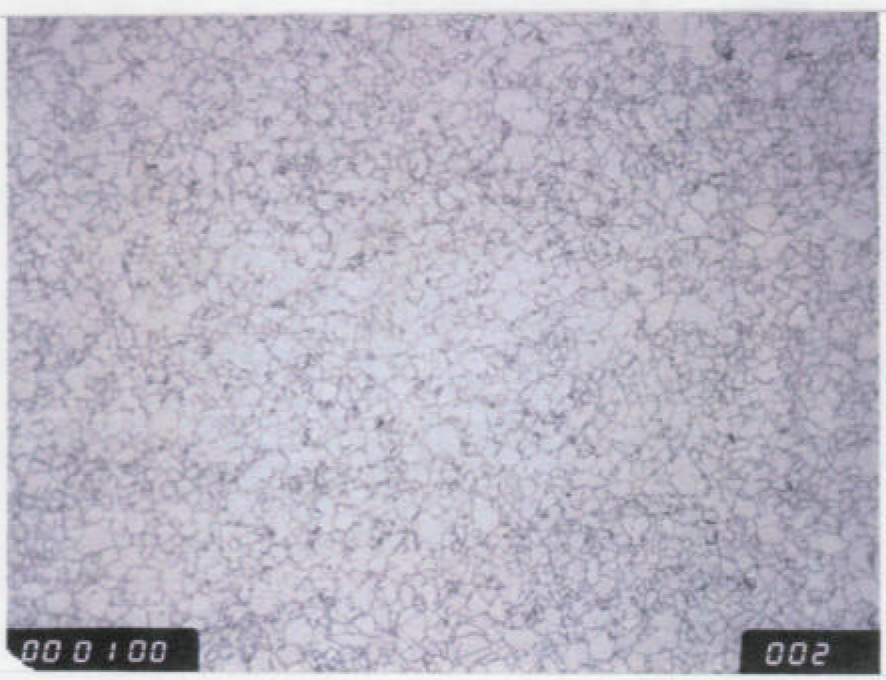


Figure 13. Photomicrograph of section "Y-Y" (see figure 1 for location) at the inboard portion of the bore showing typical grain size. Etched with Tucker's reagent. (100X)

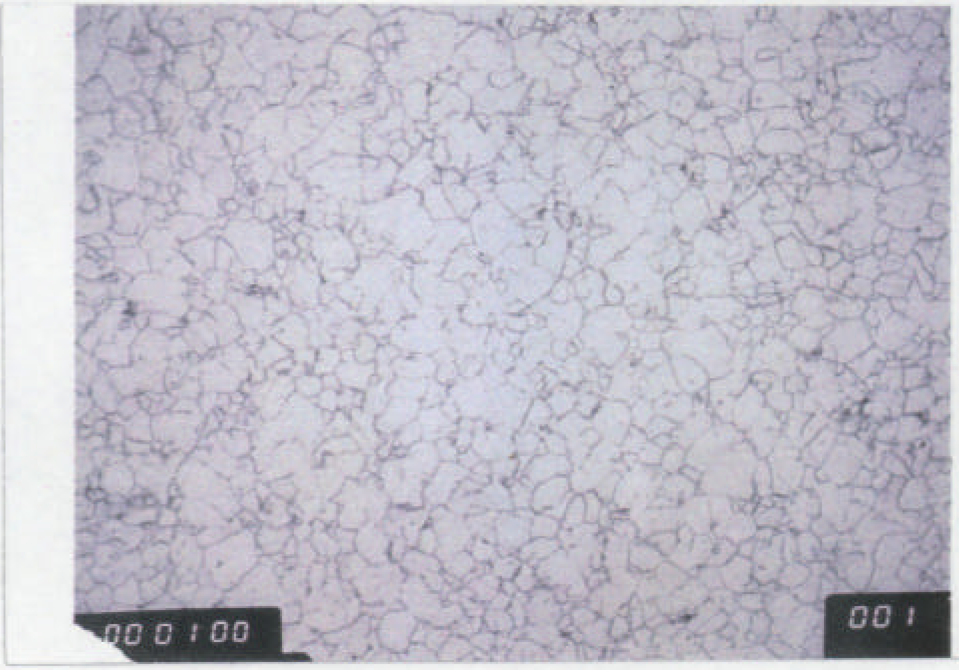


Figure 14. Photomicrograph of section "Y-Y" at the outboard portion of the bore showing typical grain size. Etched with Tucker's reagent. (100X)

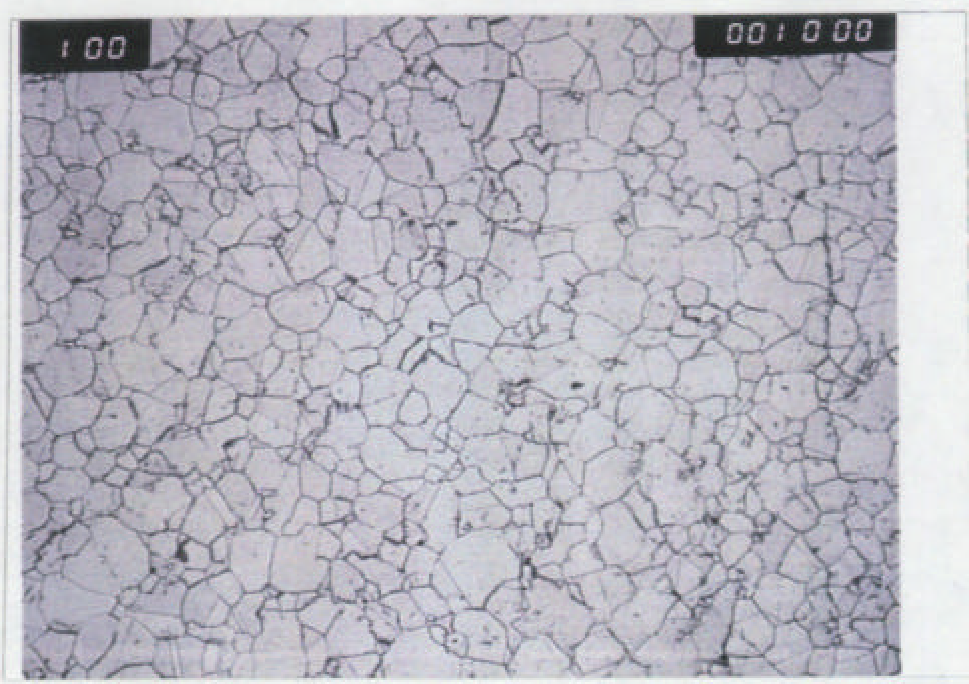


Figure 15. Photomicrograph of section "Y-Y" at the inboard portion of the web showing typical grain size. Etched with Tucker's reagent. (100X)

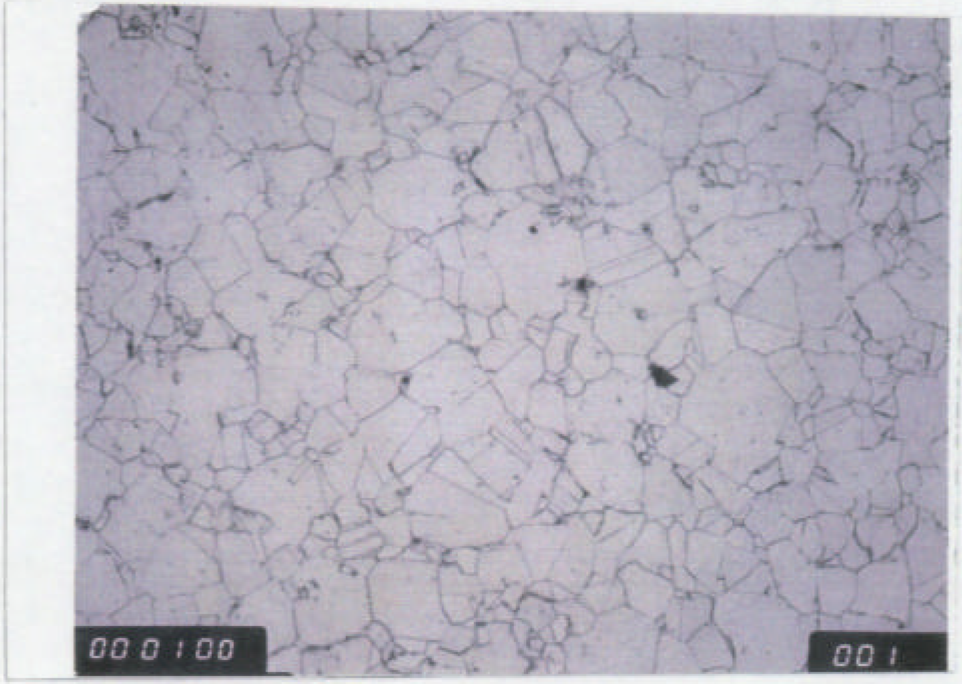


Figure 16. Section "Y-Y" at the web and in the area below the fracture origin area showing typical grain size. Etched with Tucker's reagent. (100X)

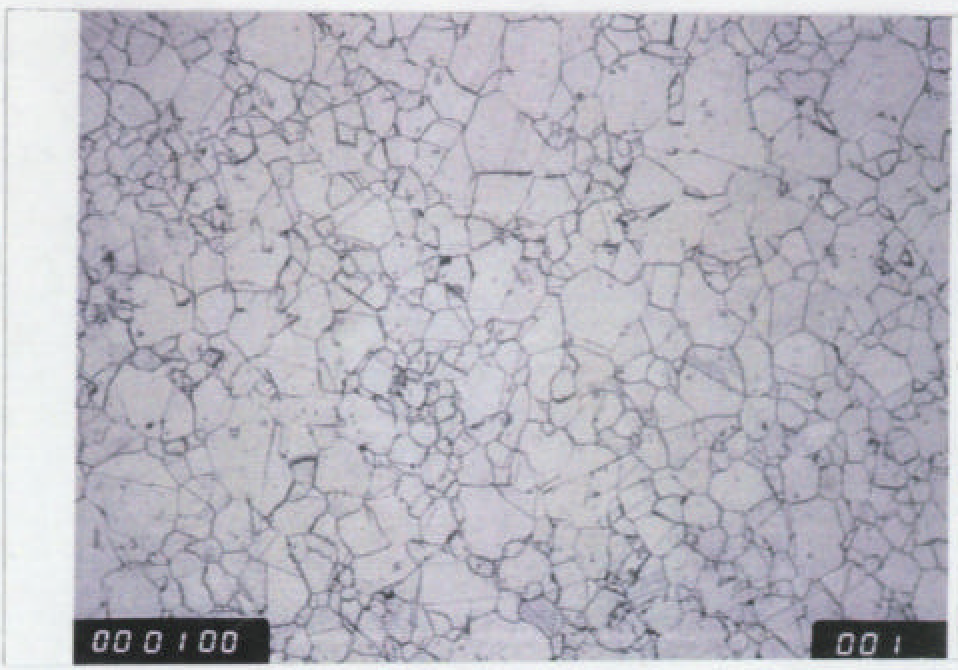


Figure 17. Section "Y-Y" at the outboard portion of the web showing typical grain size. Etched with Tucker's reagent. (100X)

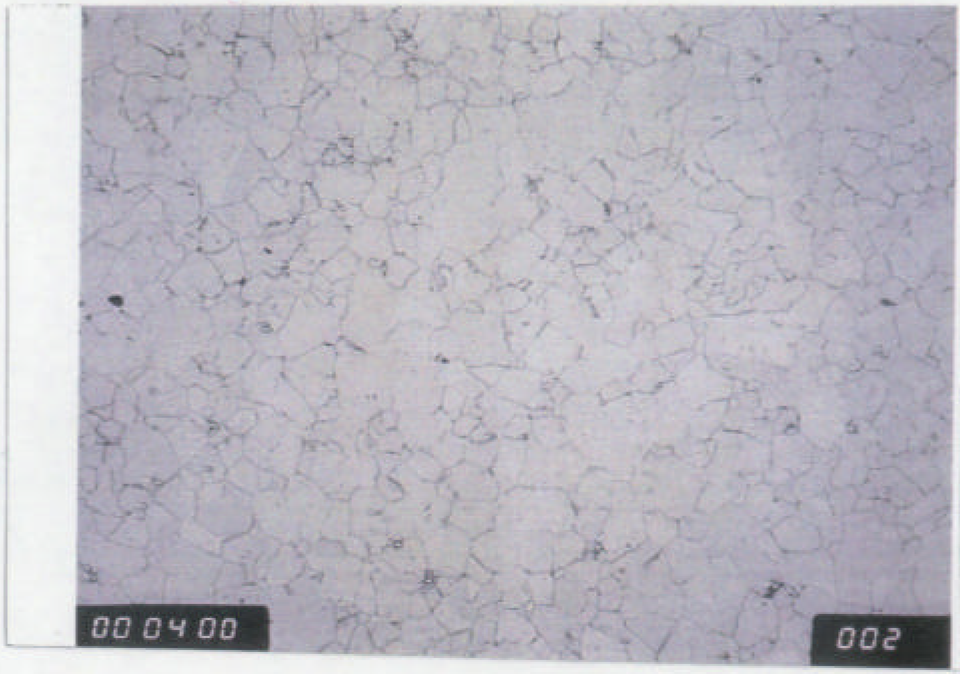


Figure 18. Section "Y-Y" at the inboard portion of the rim showing typical grain size. Etched with Tucker's reagent. (100X)

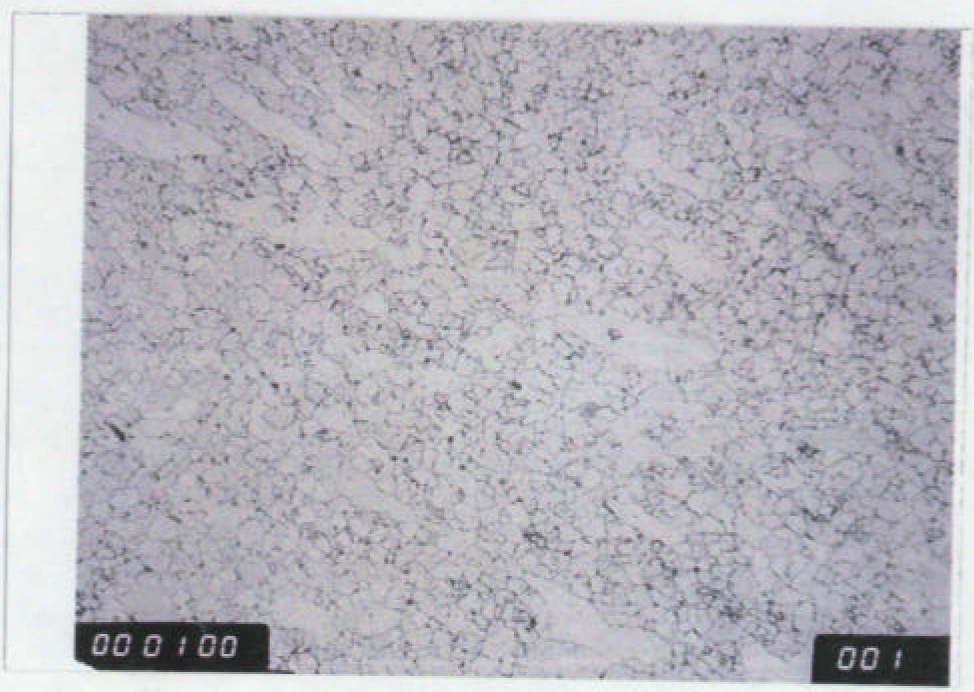


Figure 19. Section "Y-Y" at the mid portion of the rim showing typical grain size. Etched with Tucker's reagent. (100X)

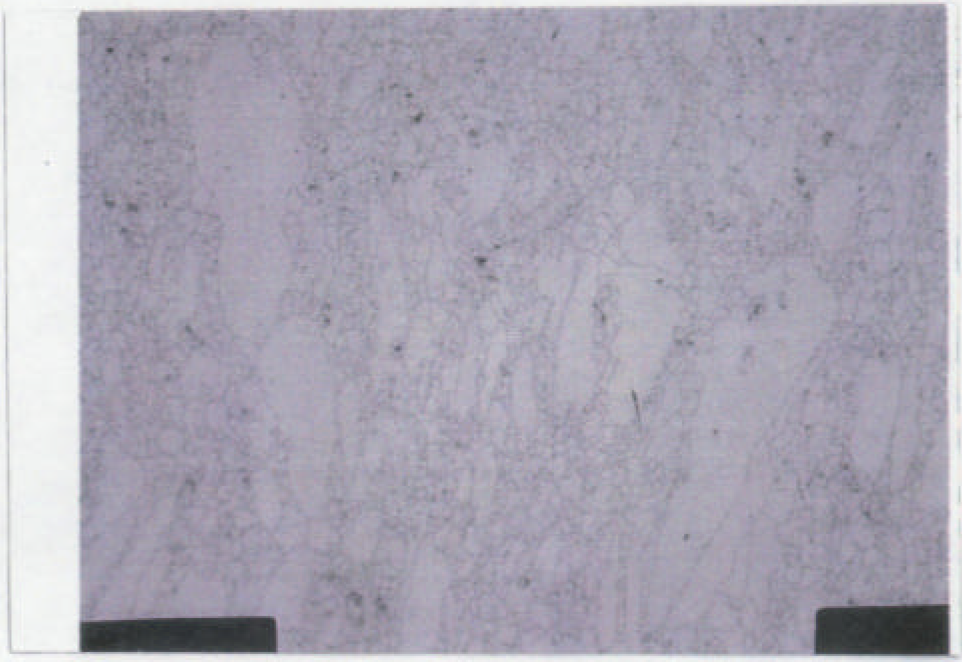


Figure 20. Section "Y-Y" at the most outboard portion of the blade retention post showing typical grain size. Etched with Tucker's reagent. (100X)

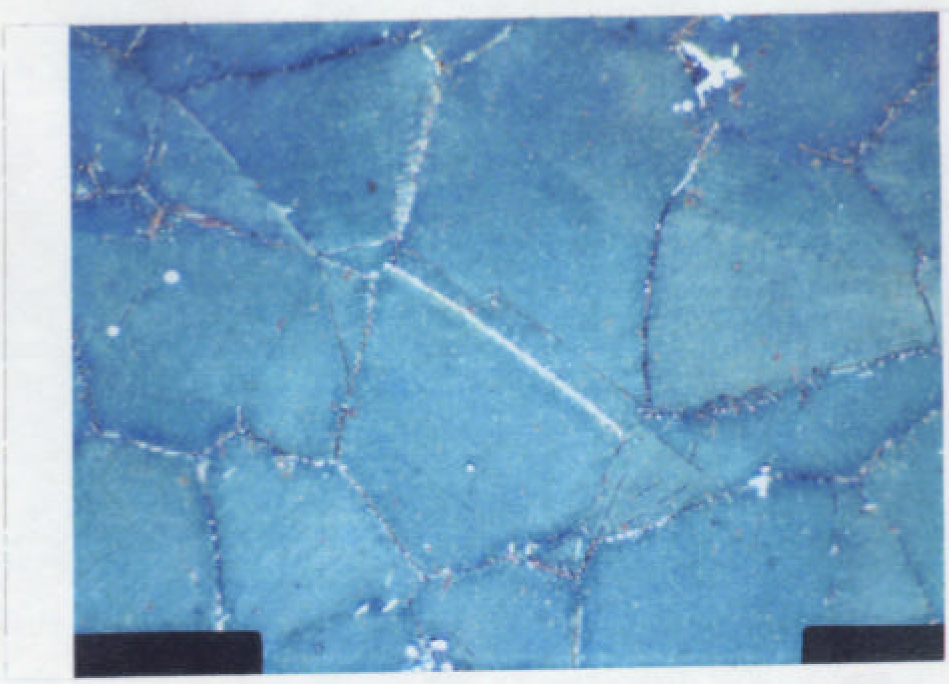


Figure 21. Section "Y-Y" at the web in the area below the fracture origin area showing typical microstructure. Etched with Tucker's reagent and followed by electrolytic etch with a phosphoric acid reagent. (500X)

Figure 22. Higher magnification photomicrograph of the area in the center of figure 21. (1,500X)

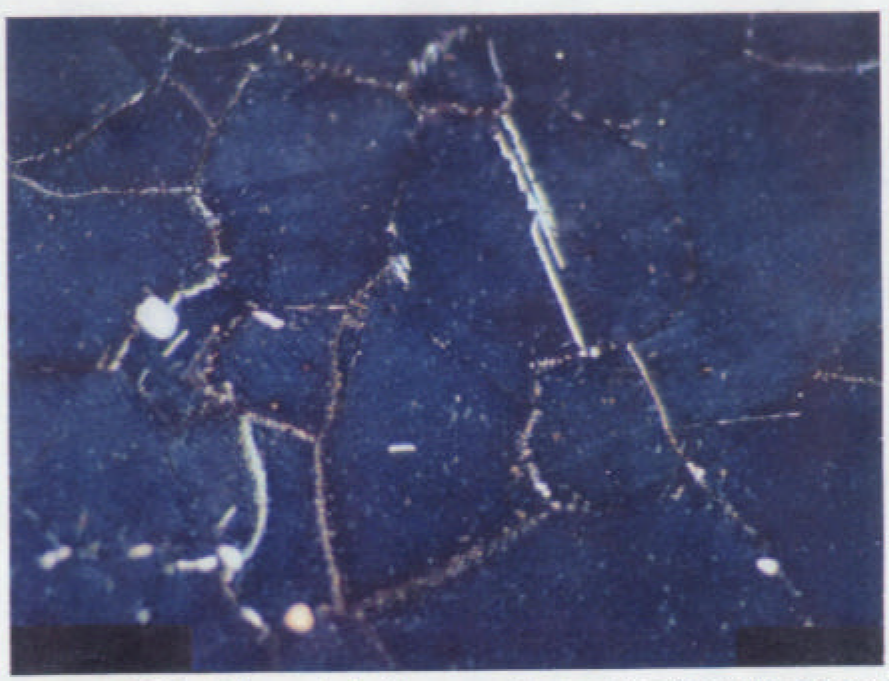


Figure 23. Section "Y-Y" at the web in the area below the fracture origin area showing typical microstructure. Etched with Tucker's reagent and followed by electrolytic etch with a phosphoric acid reagent. (500X)

Figure 24. Higher magnification photomicrograph of an area located at the left lower corner in figure 23. (1,500X)

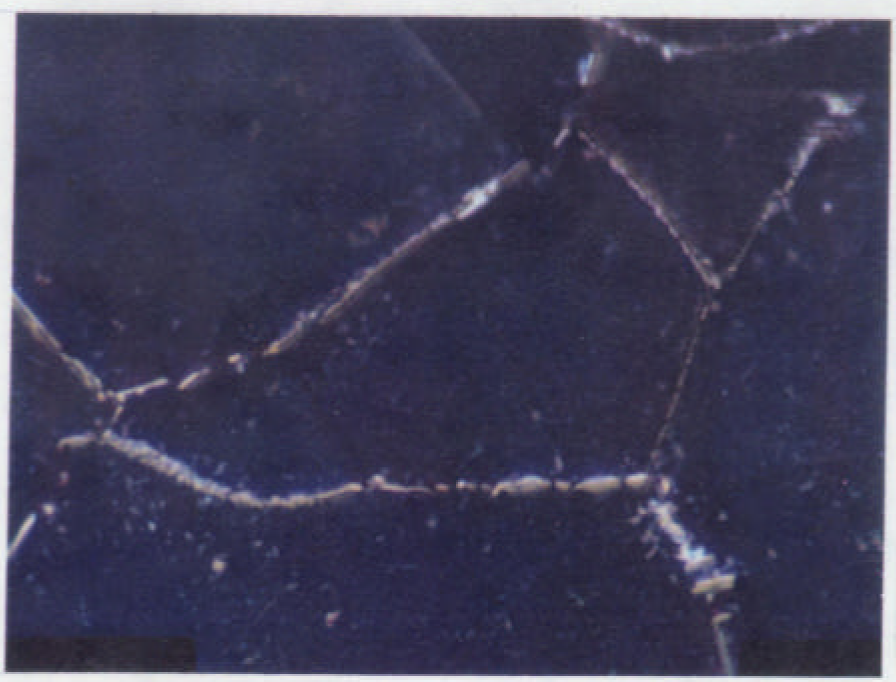


Figure 25. Higher magnification photomicrograph of an area located at the left upper corner in figure 23. (1,500X)

Figure 26. Higher magnification photomicrograph of an area located at the mid upper edge in figure 23. (1,500X)

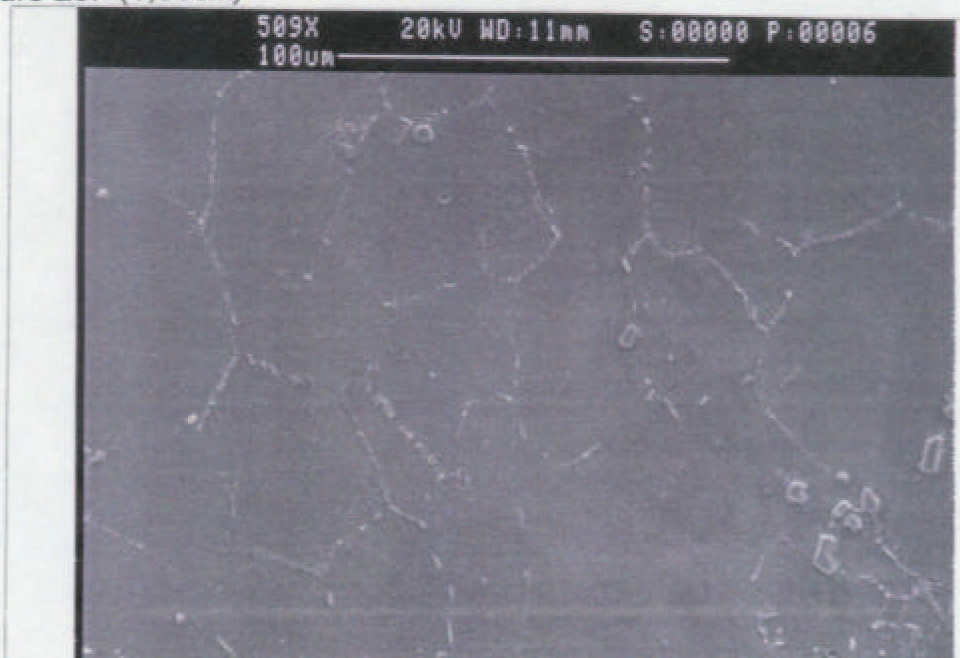


Figure 27. SEM photograph of section "Y-Y" at the web in the area below the fracture origin area. The section was etched with Tucker's reagent, followed by electrolytic etch with a phosphoric acid reagent, and sputter coated with gold-palladium. (509X)

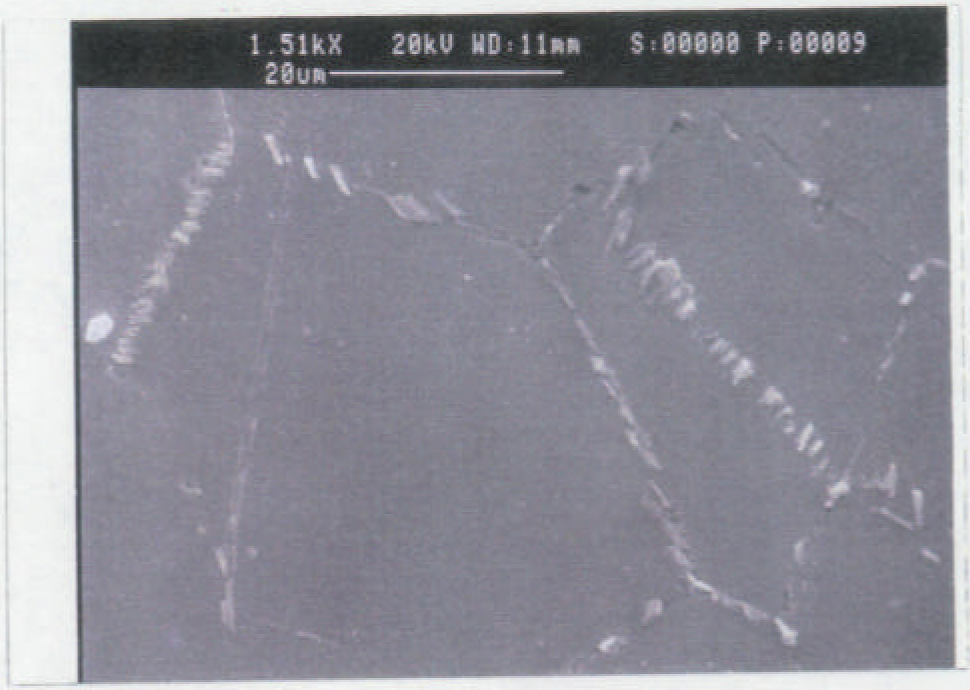


Figure 28. Higher magnification SEM photograph of an area located at the left lower corner in figure 27. (1,501X)

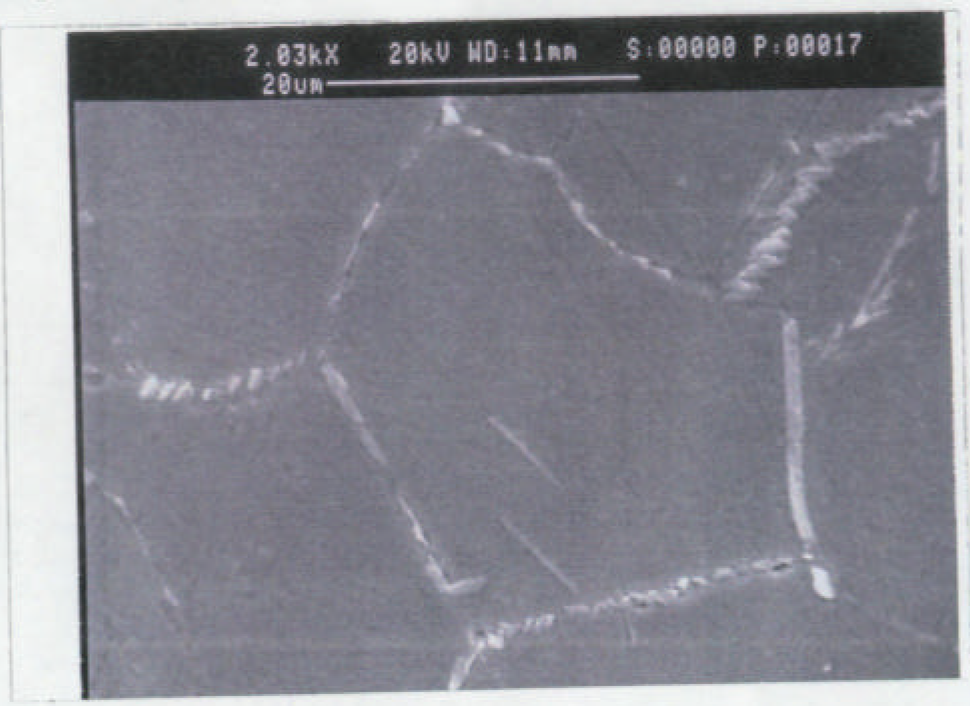


Figure 29. SEM photograph of section "Y-Y" located at the web and below the fracture origin area showing a typical microstructure. (2,030X)

Figure 30. SEM photograph of section "Y-Y" located at the web and below the fracture origin area showing typical microstructure. (1,650X)

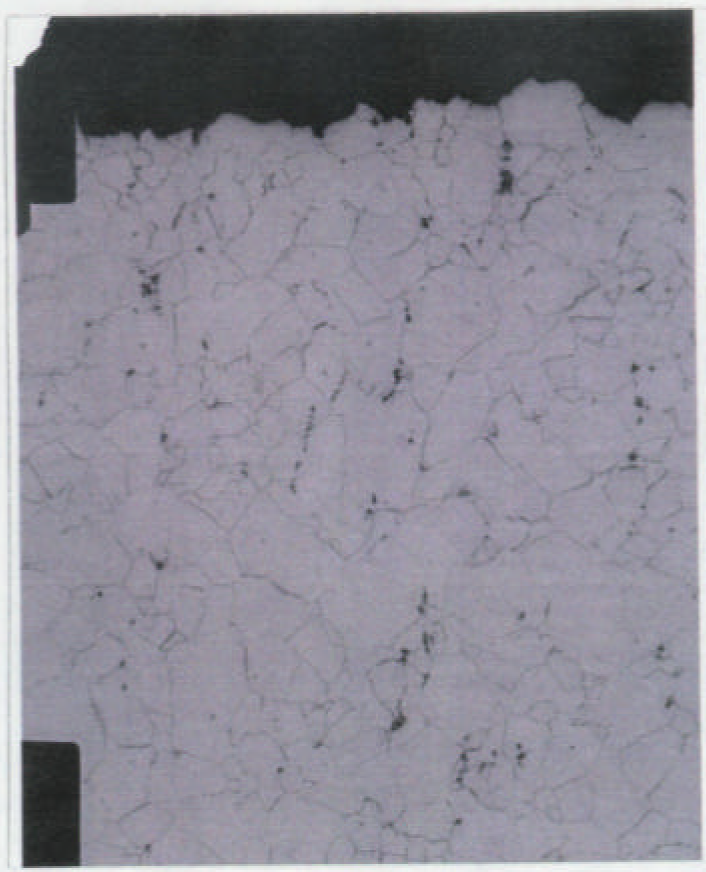


Figure 31. Section through the approximate center of the fracture origin area at the location indicated by section line "T-T" in figure 3, showing typical grain size in the area adjacent to the fracture surface (top of photograph). Etched with Tucker's reagent. (100X)

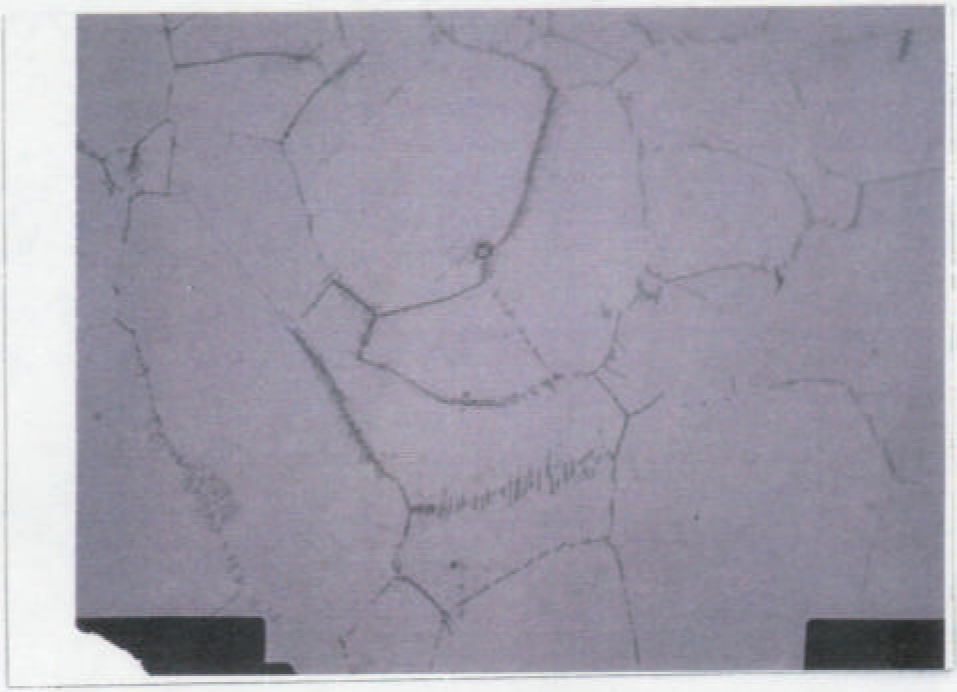


Figure 32. Typical microstructure near the fracture origin area. Etched with Tucker's reagent. (500X)

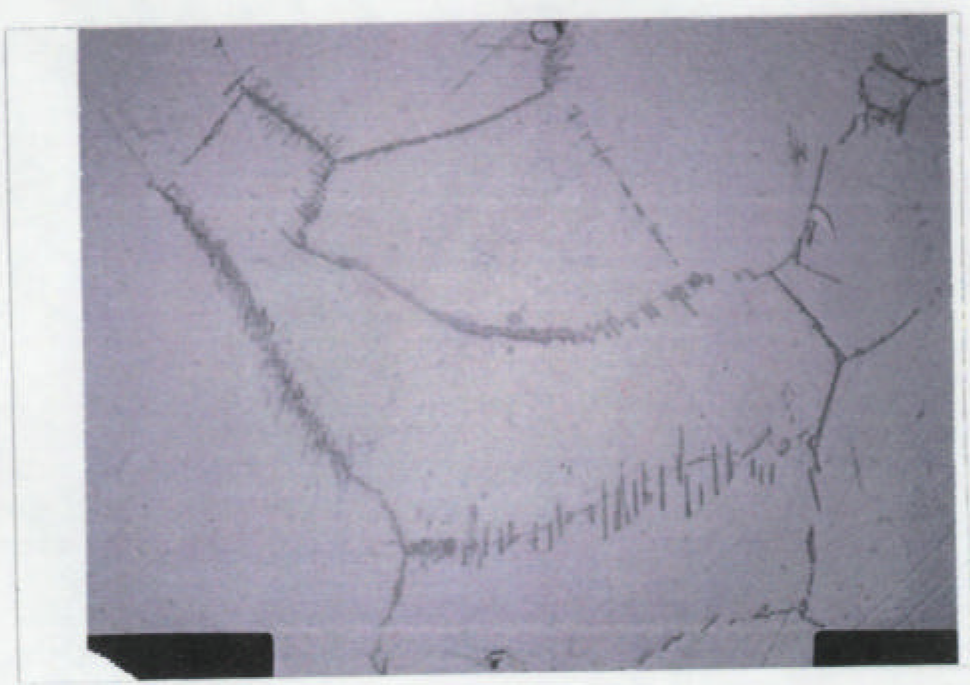


Figure 33. Higher magnification photomicrograph of typical microstructure near the fracture origin area. Etched with Tucker's reagent. (1,000X)

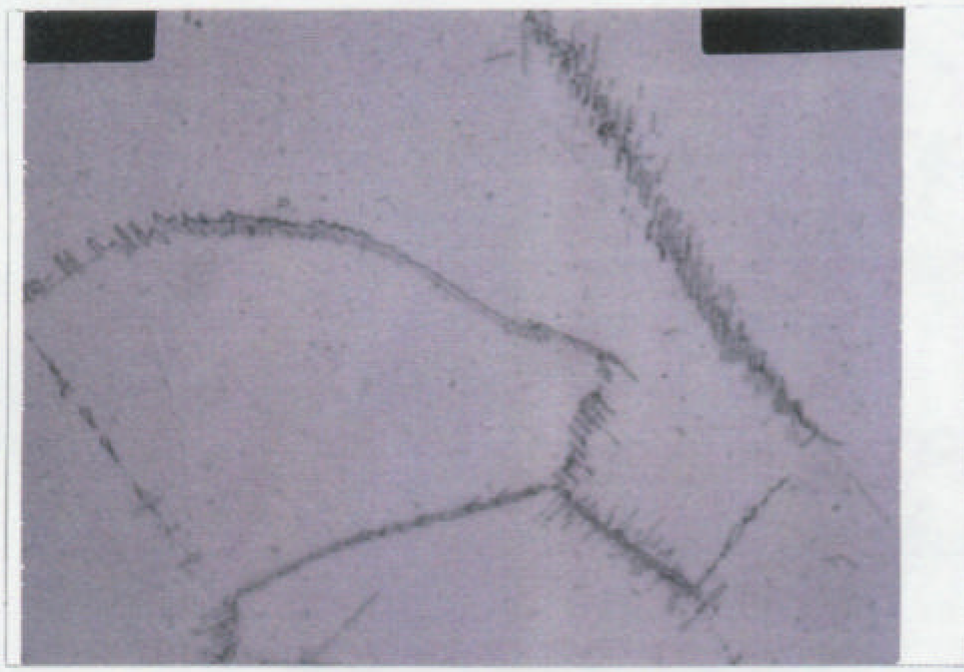


Figure 34. Higher magnification photomicrograph of typical microstructure near the fracture origin area. Etched with Tucker's reagent. (1,500X)

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No : 051/Met/Exp/IX/2000

EXAMINATION REPORT ON THE 5-TH STAGE DISK OF PW JT9D-7R4G2 OF THE JAPAN AIRLINES B747-300

1.DESCRIPTION OF THE PART

The 5-th stage disk of the PW JT9D-7R4G2 (Engine #1 of JAL B747-300, Tail number JA8178) was detached from the engine. The disk was found broken in two pieces. Both pieces were sent by the AAIC to the Laboratory of Metallurgy of the Mechanical Engineering Department, Institute Technology, Bandung, for an examination.

2.OBSERVATION ON FRACTURE SURFACE

A visual examination (including using a stereo microscope) was performed on the two pairs of fracture surfaces. One pair of fracture surface revealed a typical fatigue failure, while the other pair showed a static mode of failure.

The fatigue mode of failure was indicated by the dark colored fracture surface. The final stage of fracture occurred at the lighter fracture surface. [Fig.1]

The dark colored fracture surface was orientated radial, approximately at 90°. The inner part of the fracture surface is inclined at about 45°, indicating a shear mode of the fast fracture.

3.ANALYSIS

The fatigue crack was initiated from the web, then the crack propagated in two directions, i.e. outward and inward. The initiation of the fatigue crack should be determined by a SEM examination. (ITB has a Philips XL20 Scanning Electron Microscope, but it is to small for the disk fracture surface. Therefore the pieces were sent to the US for a further examination). The rate of the crack propagation should also be determined.

It is recommended to examine whether the failure was in a mixed mode, i.e. fatigue and creep. The exposure temperature at which the disk was in operation has to be

4.CONCLUSIONS

From the visual examination it can be concluded that:

a). The failure of the 5-th stage disk was due to a fatigue mode.

b). The fatigue crack was initiated from the web section, propagated outward and inward.

c). A SEM observation should be perform to reveal the details of the fracture surface.

Bandung, 15 September 2000

Head of the Laboratory of Metallurgy,

Prof.Dr.ir.Mardjono Siswosuwarno

REFERENCES

1. P & W Service Investigation Report on the 5-th stage disk of PW JT9D-7R4G2 of the Japan Airline B 747-300, No: (see Appendix B)
2. NTSB Report No. 00-169, Material Laboratory Factual Report, by Frank Zakar (RE 30) (see Appendix C)
3. ITB, Bandung Report No. 051/Met/Exp/IX/2000
4. JAL Work Order 92-11-02 dated 3 October 2000
5. P & W Tear down Report