Havarikommissionen
Accident Investigation Board Denmark

BULLETIN

Serious incident

30-1-2013

involving

BOEING MD-82

SE-DIK

ECCAIRS Release 5

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FOREWORD

This bulletin reflects the opinion of the Danish Accident Investigation Board regarding the circumstances of the occurrence and its causes and consequences.

In accordance with the provisions of the Danish Air Navigation Act and pursuant to Annex 13 of the International Civil Aviation Convention, the investigation is of an exclusively technical and operational nature, and its objective is not the assignment of blame or liability.

The investigation was carried out without having necessarily used legal evidence procedures and with no other basic aim than preventing future accidents and serious incidents.

Consequently, any use of this bulletin for purposes other than preventing future accidents and serious incidents may lead to erroneous or misleading interpretations.

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BULLETIN

General

File number:	HCLJ510-2013-183
UTC date:	30-1-2013
UTC time:	16:00
Occurrence class:	Serious incident
Location:	Copenhagen Airport, Kastrup (EKCH)
Injury level:	None

Aircraft

Aircraft registration:	SE-DIK
Aircraft make/model:	BOEING MD-82
Current flight rules:	Instrument Flight Rules (IFR)
Operation type:	Commercial Air Transport Revenue operations Passenger
Flight phase:	Take-off
Aircraft category:	Fixed wing Airplane
Last departure point:	Denmark EKCH (CPH): Copenhagen, Kastrup
Planned destination:	Ireland EIDW (DUB): Dublin
Aircraft damage:	Substantial
Engine make/model:	PRATT & WHITNEY (USA) JT8D-217C

Notification

All times in this report are UTC.

The Aviation Unit of the Danish Accident Investigation Board (AIB) was notified of the serious incident by the Area Control Center (ACC) at Copenhagen Airport, Kastrup (EKCH) on 30-1-2013 at 16:15 hrs.

The International Civil Aviation Organization (ICAO), the European Aviation Safety Agency (EASA), the Directorate-General for Mobility and Transport (DG MOVE), the National Transport Safety Board (NTSB) and the Swedish Accident Investigation Board (SHK) were notified about the serious incident 31-1-2013.

FACTUAL INFORMATION

History of the flight

The serious incident flight was a commercial scheduled IFR flight from Copenhagen Airport, Kastrup (EKCH) to Dublin Airport, Ireland (EIDW).

When applying take-off thrust on runway 22R at EKCH, the flight crew observed a loud "bang” and the aircraft started veering to the left. The take-off was aborted at 76 knots Indicated Air Speed (IAS).

The flight crew made a “cabin crew at station” call. Since neither fire nor smoke was imminent, the commander decided to vacate the runway via taxiway A6.

The flight crew performed the checklists for “engine failure” and “engine shut down” and via the Air Traffic Control, the flight crew requested an external inspection of the left engine. Shortly after, the fire brigade arrived and confirmed that there were no signs of either fire or smoke.

Since nobody observed fire or smoke, the passengers remained on board the aircraft. The flight crew ordered bus transportation for the passengers.

After the arrival of the bus, the crew instructed the passengers to calmly disembark the aircraft through the passenger entrance door.

The serious incident did not cause any injuries.

Severe internal engine damage resulted in a failure of the left engine.

A runway inspection of runway 22R revealed a lot of engine debris.

The serious incident occurred in twilight and under visual meteorological conditions (VMC).

Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal			
Serious			
None	5	104	

Damage to aircraft

The damage to the aircraft was limited to a contained failure of left engine.

Flight recorders

On the day of the serious incident, the AIB removed the Digital Flight Data recorder (DFDR) and the Cockpit Voice Recorder (CVR) from the aircraft. The retrieved data from the DFDR and the CVR was of good quality and used in the investigation.

Engine information

General

The affected engine was a Pratt & Whitney low-bypass turbofan JT8D-217C with the Serial Number P726044D.

The JT8D-200 series family was an axial-flow front turbofan engine incorporating a dual-spool design.

There were two coaxially-mounted independent rotating assemblies:

- One rotating assembly for the low pressure compressor (LPC), driven by the second turbine (Low Pressure Turbine, LPT) which consisted of three stages.
- A second rotating assembly for the high-pressure compressor (HPC) section. The high-pressure compressor was driven by the first turbine (High Pressure Turbine, HPT), which had a single stage.

Maintenance history of the engine, serial number P726044D

The engine date of manufacture was 09-08-1991 and the engine had at the time of the serious incident 37.664 flight hours since new (TSN) and 37.335 cycles since new (CSN).

The engine maintenance shop visits are listed below.

	Reason for back shop visit	TSN / CSN	Shop actions
January 2006	Repair: C8 stator crack	26.024 / 27.858	88 overhauled blades installed
February 2008	Repair: High Pressure Compressor damage	29.296 / 30.408	T-3 & T-4 blade, A inspected. Blades not disassembled.
August 2008	Repair: Excessive notch wear	30.014 / 31.170	T-4 blades replaced with new blades.

On the day before the serious incident, the latest maintenance check of the aircraft and of the engines was performed without any remarks.

Technical investigation of the engine

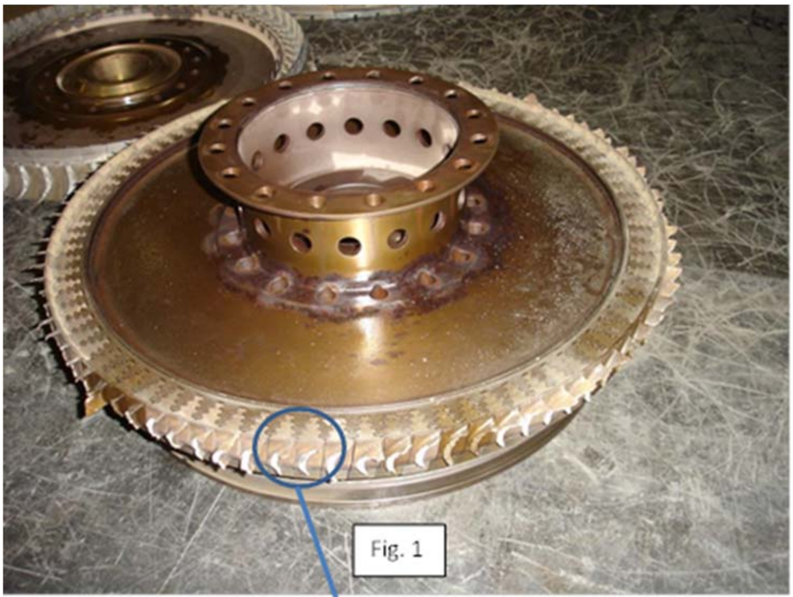
The engine was shipped to an overhaul facility for a tear down and technical investigation.

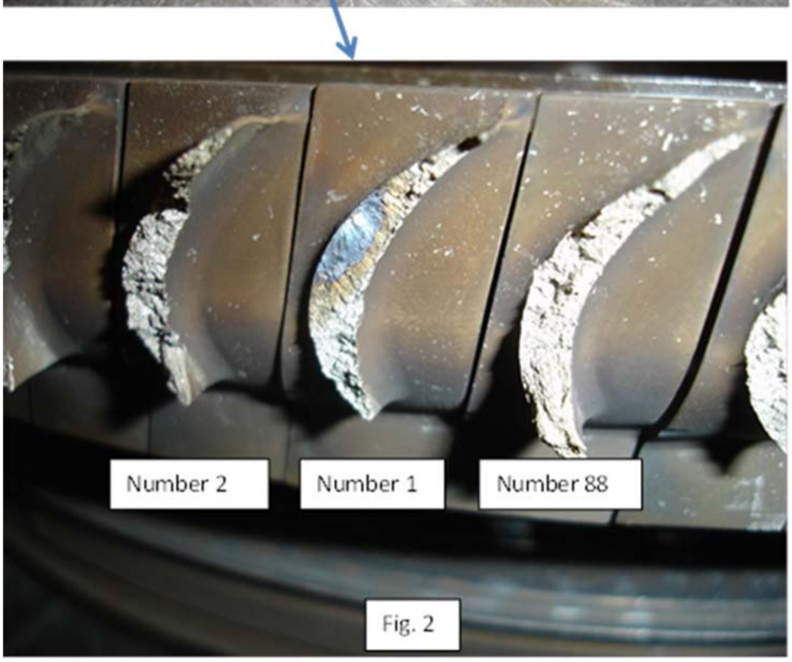
An investigator from the AIB supervised the tear down and the engine examination as part of the technical investigation.

The visual examination of the engine revealed that all 3rd stage low pressure turbine (LPT) 88 blades were fractured at or near the airfoil root above the flowpath platform. See figure 1.

The examination revealed that one of the 3rd stage LPT blades (blade number one) had signs of heat and fatigue in the fractured area, see figure 2.

There were no indications or signs of fatigue on the remaining parts of the other 3rd stage LPT disk blades.





All 4th stage LPT blades were fractured at the blade airfoil roots. See figure 3.

The remaining parts of the 4th stage LPT disk blades did not reveal any evidence of fatigue.

There were no observed signs of LPT or exhaust case breaches, no signs of case flanges breaches, and all observations indicated a contained engine.

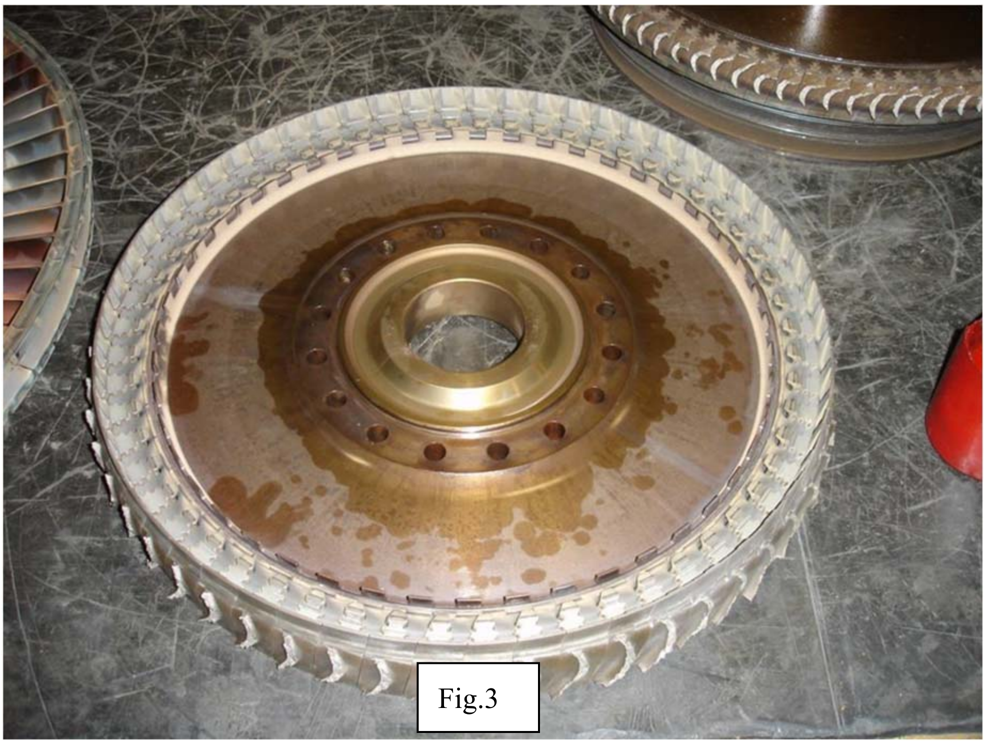


Fig.3

Visual examination

The suspected blade (number one) and the blades next to (number 88 and number two) were removed from the disk and examined. The three blades are shown in figure 4.

Clear signs of fatigue were observed on blade number one. The fracture surface was oxidized to various degrees and beach marks were visible.

The fatigue crack initiation point is marked with an arrow in figure 5. The fatigue part of the fracture was relatively plane and smooth, whereas the final fracture was rough and serrated. Fatigue crack showed in figures 6 and 7 with various magnifications.

Blades number 88 and number two are shown in figures 8, 9 and 10. There were no signs of fatigue. In the stereo microscope in some parts of the fracture surfaces dendrite-like appearances were observed as illustrated in figure 9.

Scanning electron microscopy (SEM) – blade number one

The SEM revealed a crack initiation area in blade number one (is shown in figure 11). No material defects - which could have caused the crack initiation - were observed.

In the yellow tinted part of the fracture surface (figures 5, 6 and 7) faint signs of fatigue striation were observed. An example is shown in figure 12.

A part of the final fracture close to the leading edge is shown in figure 13. The rough nature of the fracture surface from this part of the fracture was evident. In higher magnification, dimples, characteristic of ductile overload were observed. Figure 14 shows an example.

Examination of microstructure blade number one

A section of blade number one was cut out through the crack initiation area and perpendicular to the fracture surface in order to examine whether any structural abnormalities might be present in the microstructure.

Figures 16, 17 and 18 show the section perpendicular to the fracture surface in increasing magnification. No material defects or structural abnormalities were observed at the crack initiation shown in figure 18.

The structure displays primarily carbides in a γ-γ′ (gamma – gamma prime) matrix. The structure is shown in higher magnification in figure 19.

Chemical analysis – blade number 1

The chemical composition of blade number one was determined by EDX (Energy Dispersive analysis of X-rays) on a polished surface. The results showed that the turbine blade was most probably made of Inconel 713C.

SEM – blade number 88

Blade number 88 was SEM analysed as a reference.

Part of the fracture surface, which in stereo microscope displayed a dendrite like appearance (figure 9), was further examined in SEM. A section of the fracture surface is shown in figure 15.

Dimples, characteristic of ductile overload were observed but no inter dendritic shrinkage cavities were found.

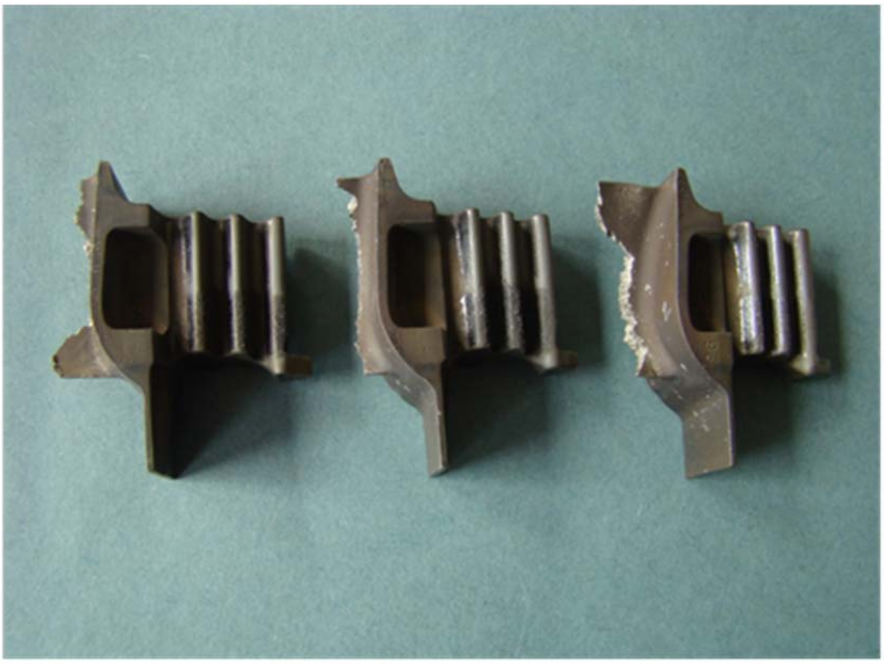


Fig. 4	LPT 3rd stage blades. From left: Blade 2, 1 and 88.

Fig. 5 Blade 1.

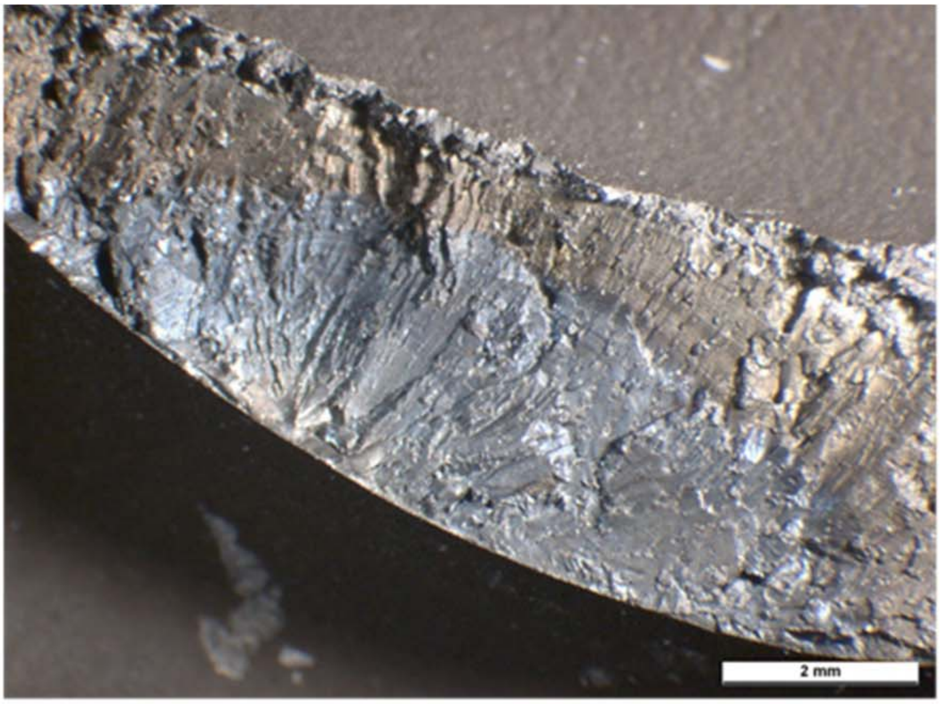


Fig. 6	Blade 1. Enlarged section of figure 5.

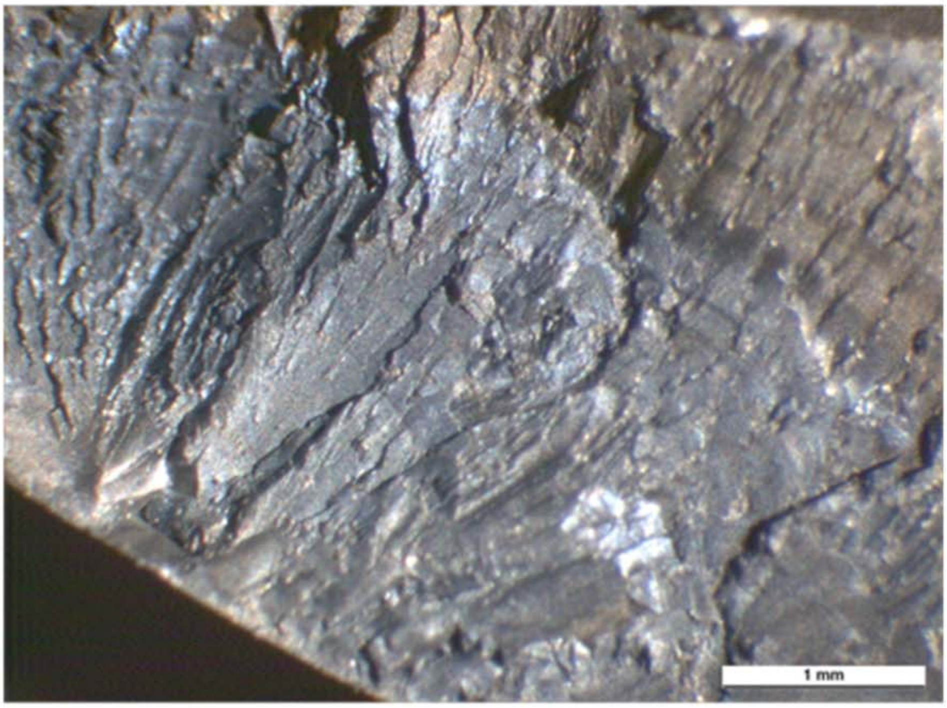


Fig. 7	Blade 1. Enlarged section of figure 6

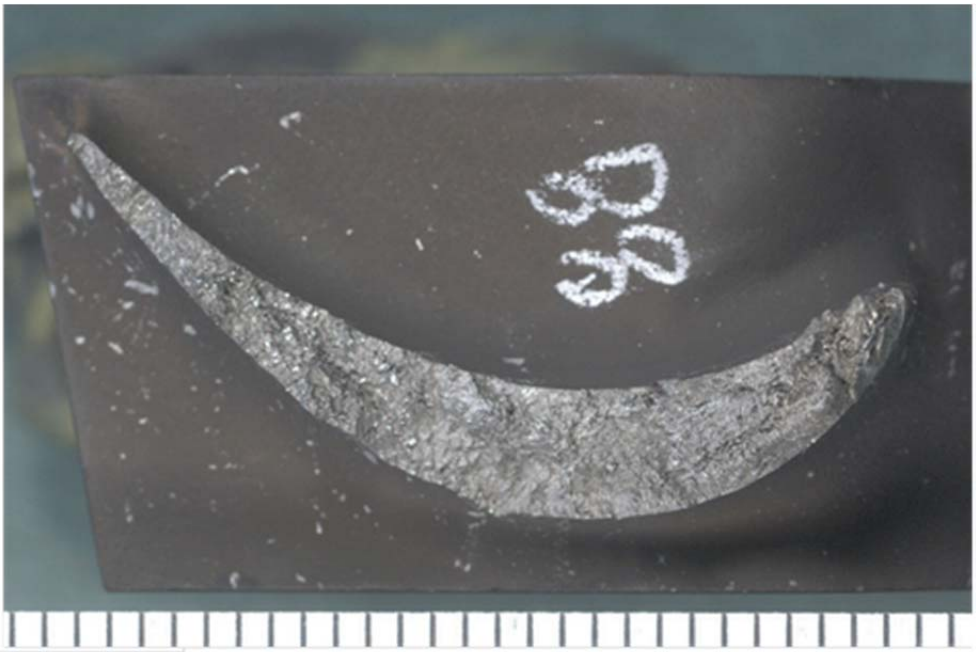


Fig. 8 Blade 88.

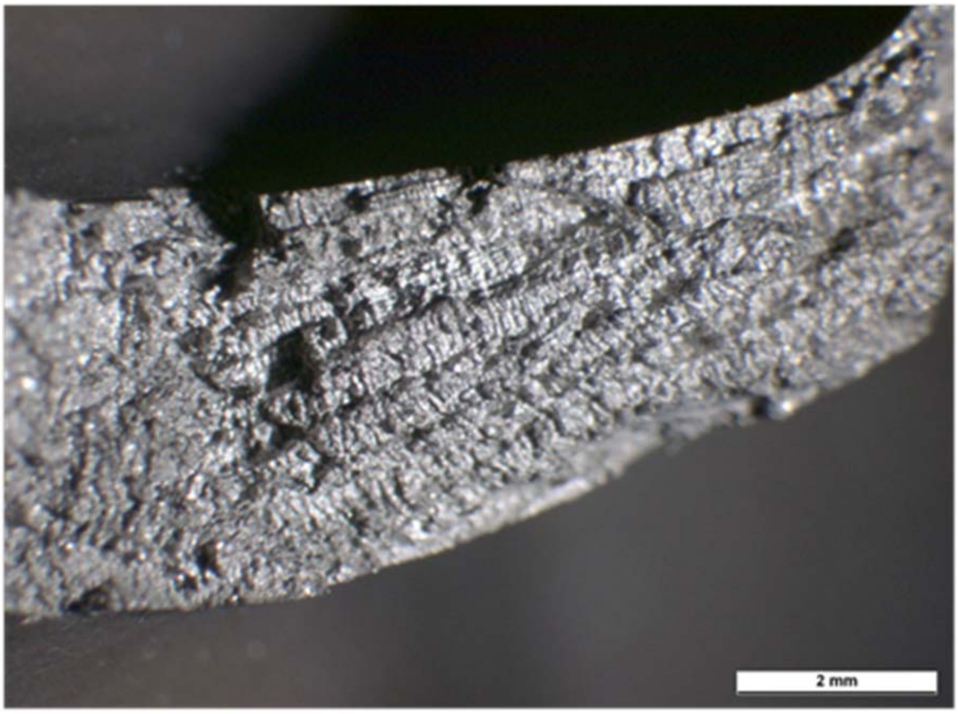


Fig. 9 Blade 88. Enlarged section of figure 8

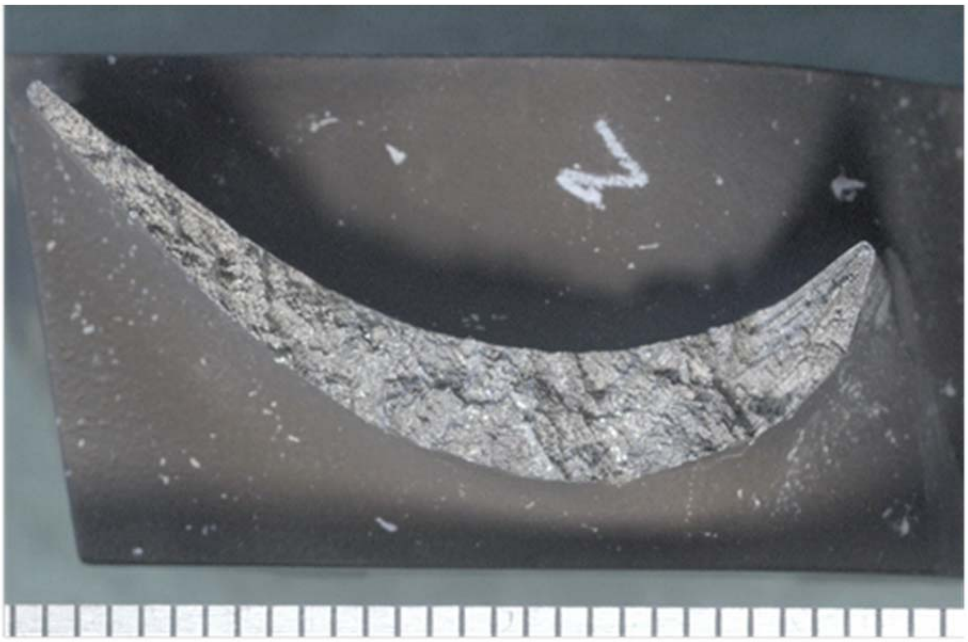


Fig. 10 Blade 2.

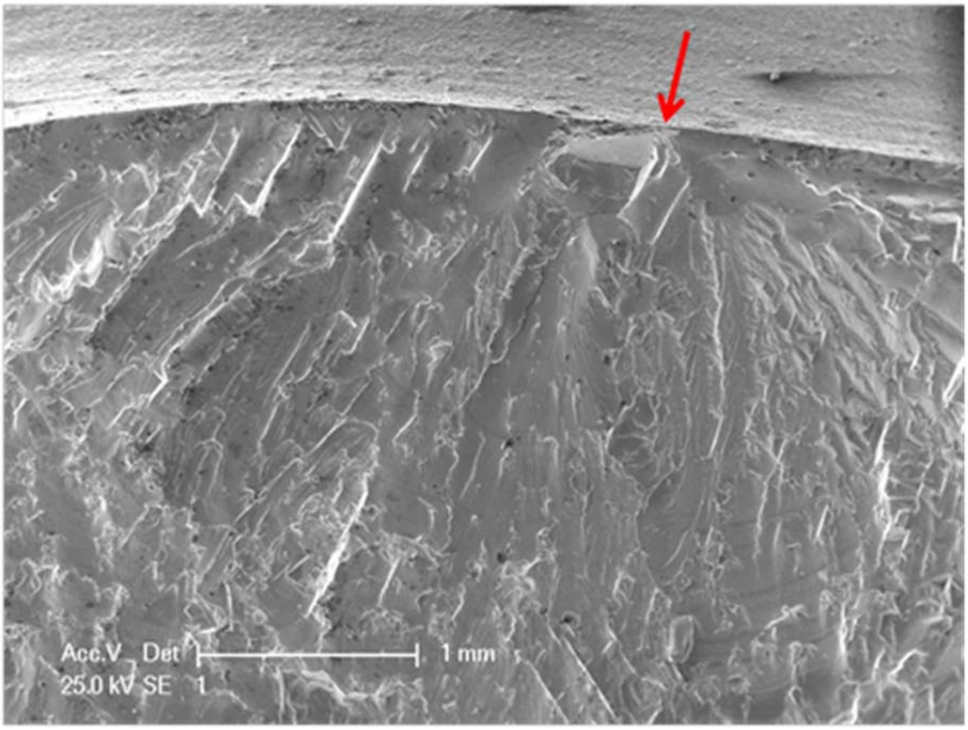


Fig. 11 Blade 1. Fatigue initiation point is marked by arrow.

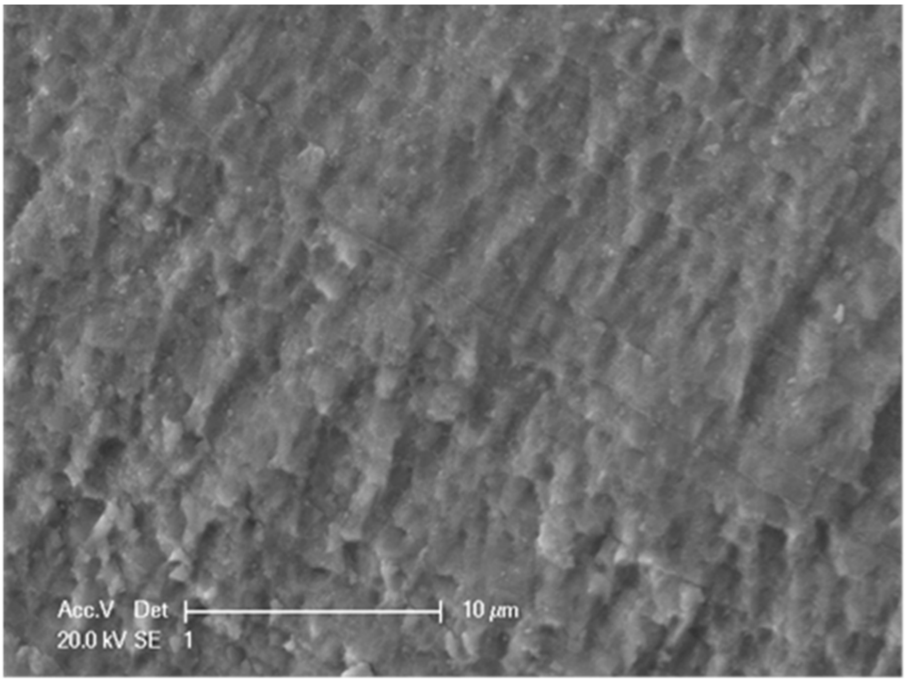


Fig. 12	Blade 1. Fatigue stirations.

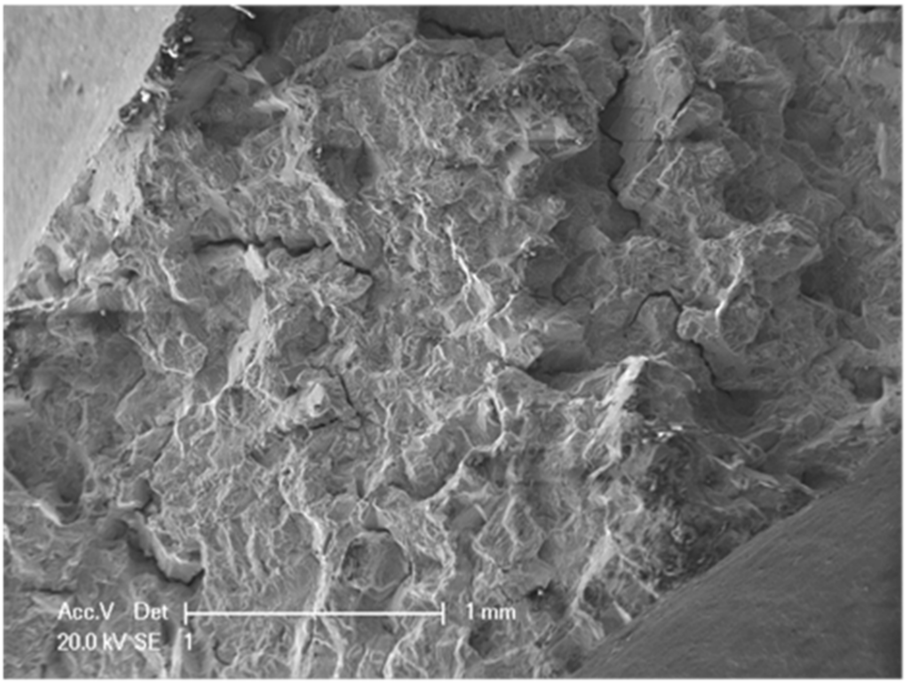


Fig. 13	Blade 1. Part of the final fracture close to the leading edge.

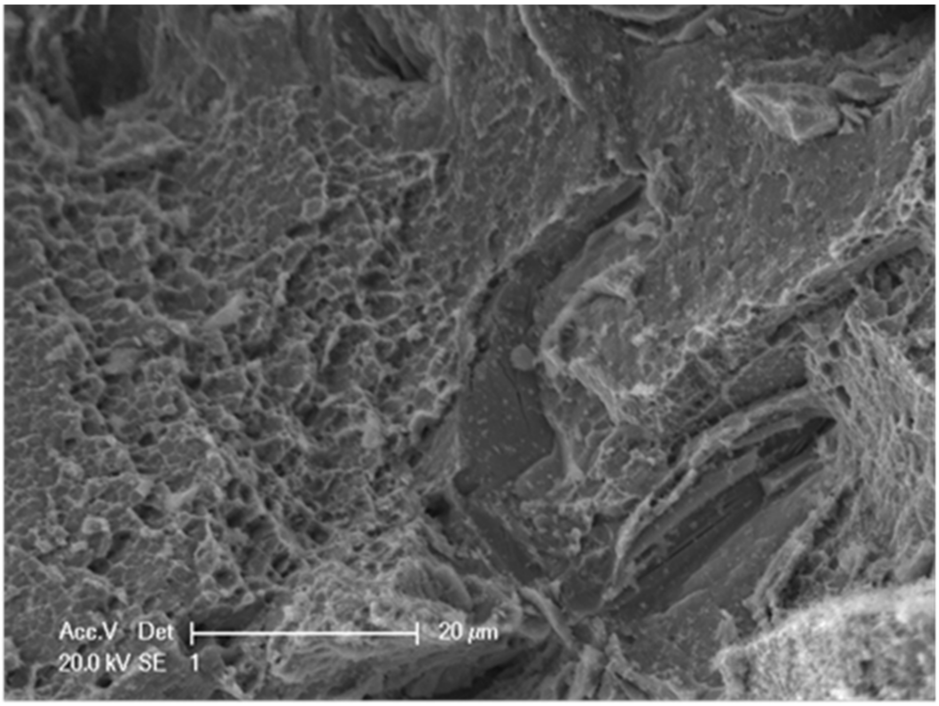


Fig. 14 Blade 1. Enlarged section of figure 13.

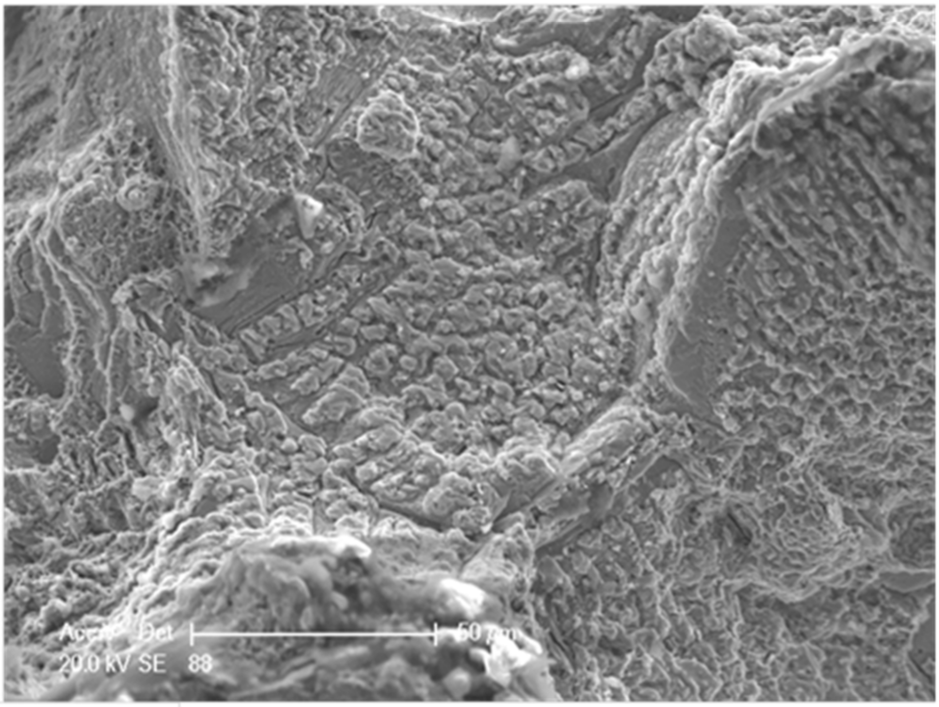


Fig. 15 Blade 88. Section of the fracture surface displaying a dendrite-like appearance. Dimples, characteristic of ductile overload are also seen.

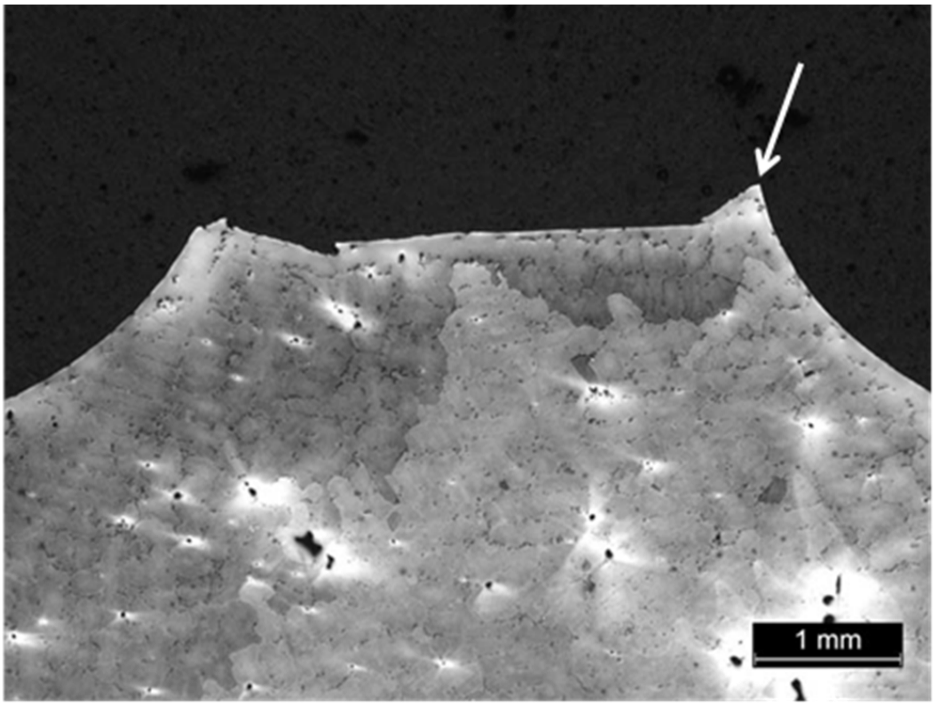


Fig. 16

Blade 1. Section through the fracture surface in blade 1. Crack initiation at arrow.

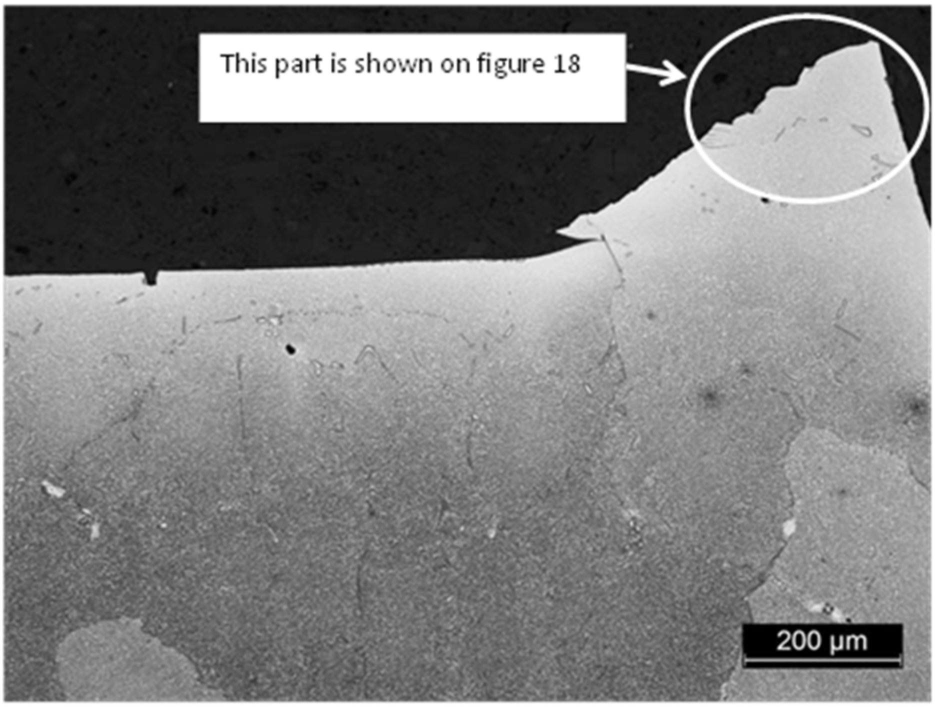


Fig. 17

Blade 1. Enlarged section of figure 16

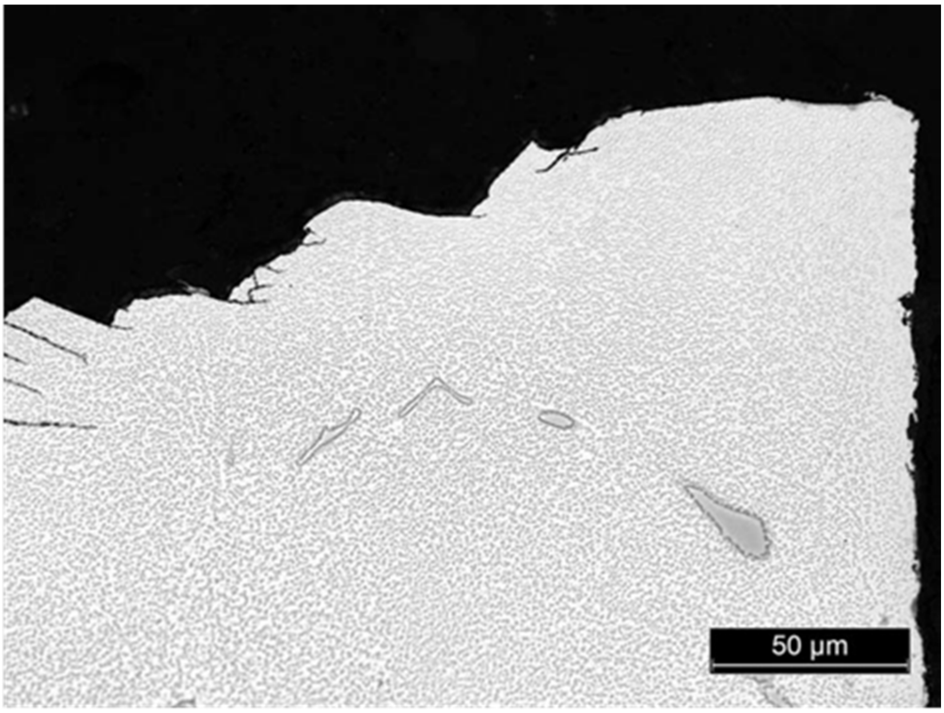


Fig. 18 Blade 1. Enlarged section of figure 17.

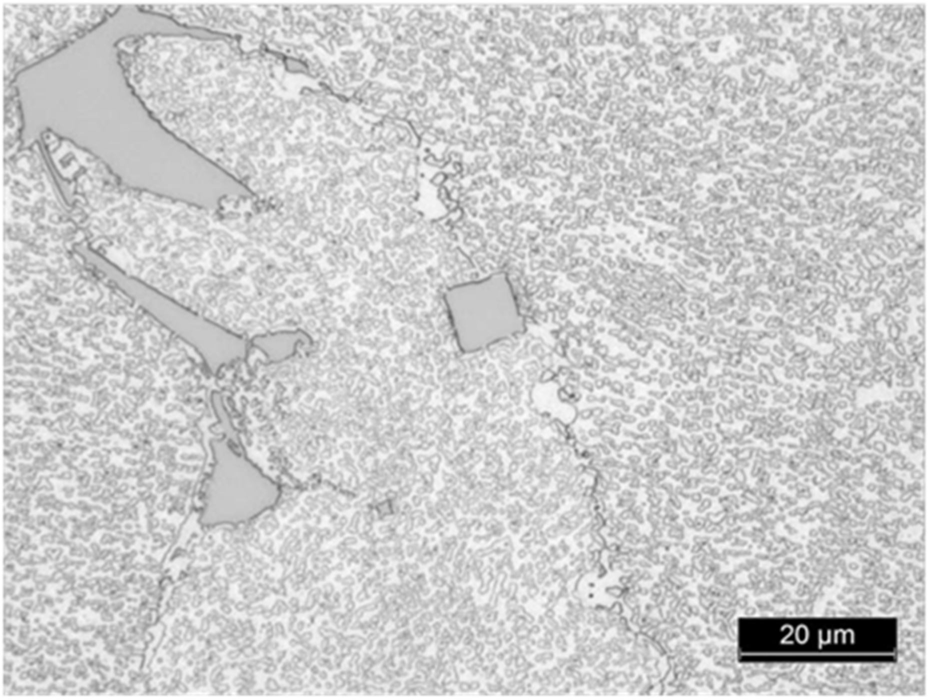


Fig. 19 Blade 1. The structure of the blade.

<u>Blade markings</u>

Marks on blade number 88, one and two:

Blade No. 88: T347 G697 92 AOUR
798403C 33963 T347
A
Blade No. 1: Y172 95 M744 N A38
1185 J798403L ARGK AORZ

Blade No. 2: J625 96 T397
SCOX T D
798403 33963 T 397

Almost all 3rd stage LPT blades had unique markings. The marking on the suspected blade number one is shown in figures 20 and 21.

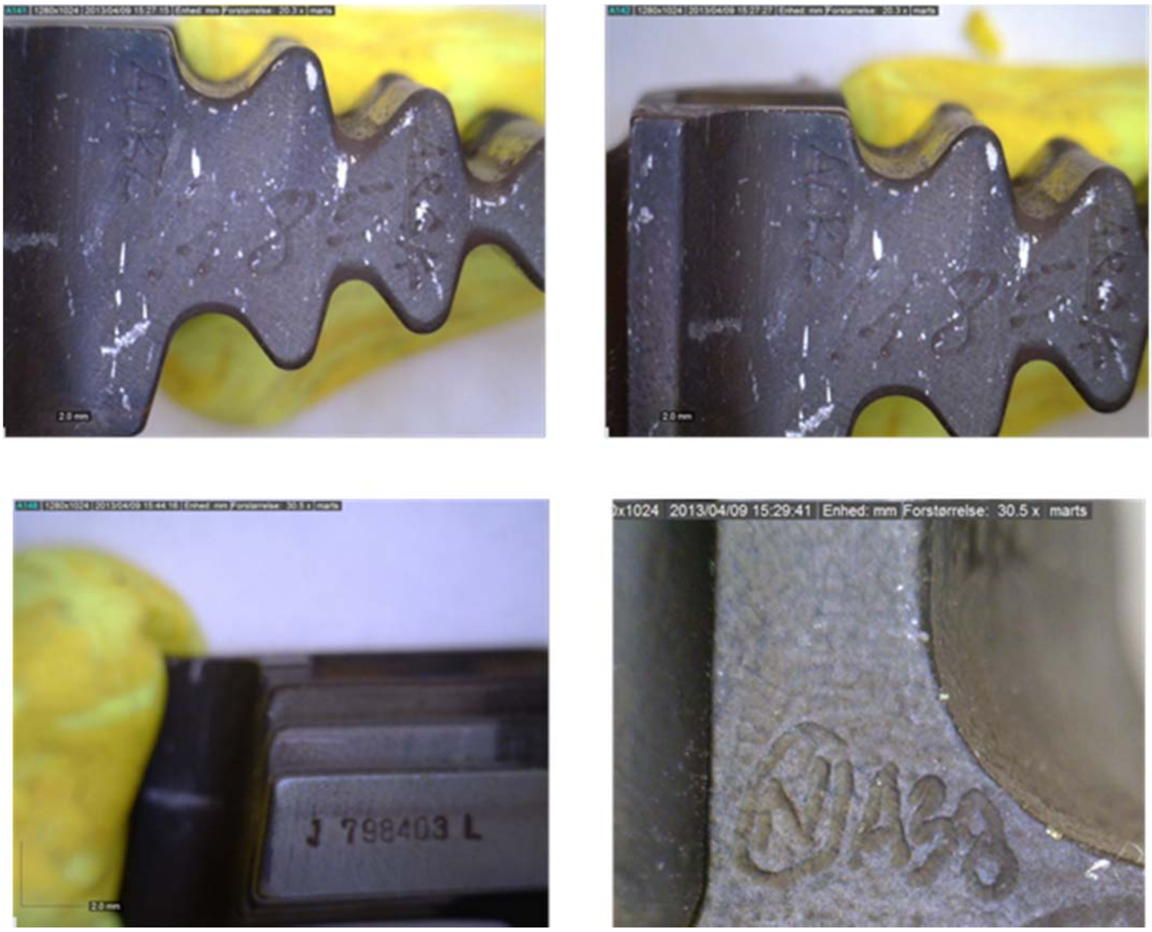


Fig. 20

Fig.21

The engine manufacture was requested to clarify what the marks on the blade referred to. The following in *Italic* is an extract from the manufacture`s clarification:

The 3rd stage blade includes multiple areas designated for marking information with respect to this part. A figure 22 provides a diagram for the markings in the areas of interest on this blade.

Blade No. 1, 2, and 88 the “798403” marking is in the Part Number (P/N) marking area and is consistent with the P/N used in the JT8D-217C model engine.

Blades of P/N 798403 are interchangeable with any other blades with the same P/N.

The markings “Y 172” & “M 744” (blade No. 1), “J 625” & “T 397” (blade No. 2), and “T 347” & “G 697” (blade No. 88) are in areas of the blades designated for Heat Code and X-Ray Film marking, per figure 22.

The "1185", "ARGK", and "AORZ" markings are in the area of the blade designated for Service Time Marking per figure 22. The overhaul records should be reviewed to determine if the "1185" is related to service time on this blade.

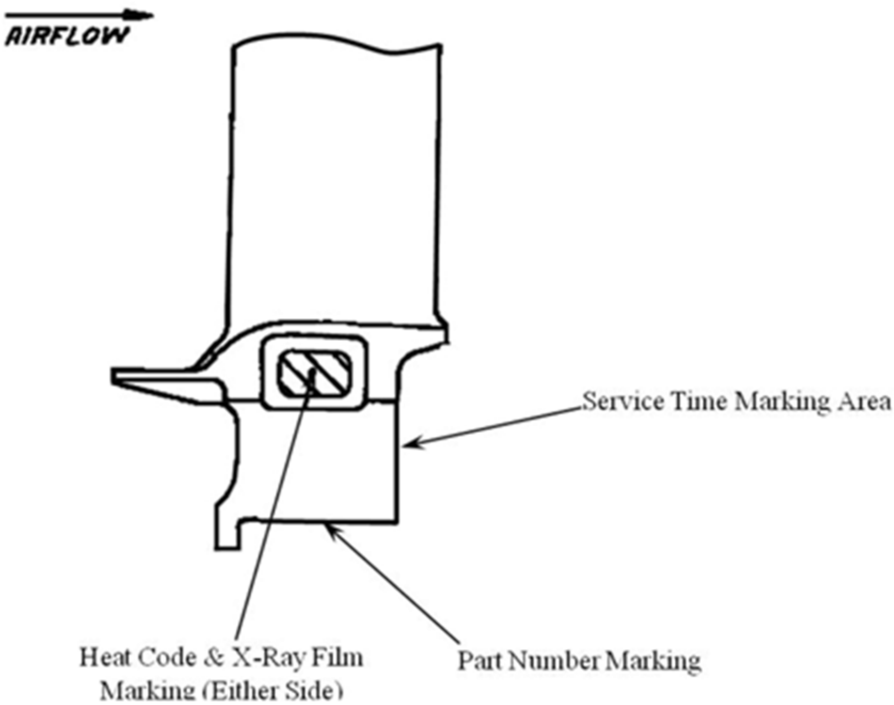


Fig. 22

Figure 22 is an excerpt from the part detail drawing utilized at Original Equipment Manufacturer (OEM). There are other opportunities in the life of a blade where markings could be applied that are not specified on the part detail drawing, including at the time the casting from which the finished part is produced, during the inspection process, and during overhaul.
Specifically with respect to overhaul, the following is the engine manufacturer interpretation of certain specific markings on the blades:

The "AORZ" and "AOUR" markings on blade No. 1 and 88, respectively, is consistent with a "lot code" used by Turbine Overhaul Services (TOS) and represents a customer code for the OH facilities .
The "ARGK" marking on blade No. 1 is not a current "lot code" being used by TOS, but it could have been in the past.
The "circled S" marking in the vicinity of the "circled N A38" marking is consistent with a TOS marking indicating blending and shot-peening in the root front face area.

3rd stage LPT blade data

All of the 3rd LPT blades PN 798403 were installed as overhauled (OH) at the shop visit in January 2006.

The cycles since installation were 9.477. The interval between OH was 20.000 cycles. The remaining cycles to the next OH was 10.523 cycles.

The 20.000 cycles was a target limit cycles which was depending on the operators experiences, or an overhaul shop recommendation with regard to the environmental engine operation condition.

In accordance to the manufacturers Services Bulletin (SB) A6224, there is lower inspection thresholds for OH blades than new blades.

Overhaul facilities

It has not been possible for the AIB to obtain information from the engine shop visits. The OH facilities went bankrupt in December 2009. Therefore, no further investigation of the failed blade was possible.

For that reason, the AIB was not able to determine, if the "1185" marking was related to service time.

3rd stage LPT blades shroud notch wear

It has not been possible to determine the extent of the shroud notch wear of the remaining parts of the 3rd stage blades due to the fact that the remaining parts were found in heavily damaged fragments.

The tear down did not reveal any breaches of the LPT or the Turbine Exhaust Case (TEC) or of the LPT/TEC flange nor were there any bent or broken bolts in the LPT/TEC flange.

Federal Aviation Administration Airworthiness Directive (AD)

The engine was in compliance with all applicable ADs. The only AD, which contained 3rd stage and 4th stage LPT blades inspection on JT8D-200 series engines was FAA AD 2011-07-02, which superseded AD 2005-02-03.

The AD 2011-07-02 currently required initial and repetitive torque inspections of the 3rd stage and the 4th stage LPT blades for shroud notch wear. Replacement of the blade are required if wear limits are exceeded.

The AD referred to Service Bulletin JT8D A6224 for procedure and accomplishment instructions.

The Service Bulletin contained inspection of the 3rd stage and the 4th stage LPT blades on engines as shown below:

Engine type	Inspection of the 3rd stage blades	Inspection of the 4th stage blades
JT8D-209	Yes	Yes
JT8D-217	Yes	Yes
JT8D-217A	Yes	Yes
JT8D-217C	No	Yes
JT8D-219	No	Yes

The Service Bulletin did not contain inspection for shroud notch wear for the 3rd stage blades on JT8D-217C engines.

Information from the engine manufacture

The engine manufacturer informed that in the past, a number of JT8D engine LPT blades fractures did cause in-flight engine shutdowns.

Until 2007, data from 40 set of 3rd stage blades from JT8D-217C/-219 engines have been collected. The data showed little wear and untwist on the affected 3rd stage blades. At that time, an evaluation concluded that a torque check would not reduce 3rd stage LPT blade fractures.

Between May 2008 and June 2013, ten events of JT8D-217C/-219 engine 3rd stage turbine blade fractures have been reported. According to data provided from operators to the engine manufacturer, 245 active JT8D-217C engines and 1363 active JT8D-219 engines were in service per June 2013. These numbers did not include spares.

Finally, the engine manufacturer did not specifically segregate -217C and -219 LPT 3rd stage blade fractures from one another due to similarity between the engine models and commonality of the LPT 3rd stage blade part numbers.

Additional information about JT8D engines

The primary cause of fractured LPT blades was shroud wear.

The JT8D engines LPT blades had shrouds at the outer extremities of the associated airfoils. The blade shrouds were nested in close proximity to each other. The turbine blade shrouds had a mechanical interlocking feature in the form of a notch that allowed each blade to be physically interlocked at its shroud with an adjacent blade.

A variety of mechanisms might have caused wear in the mechanical interlocking feature. For example, during operation of the turbine there might have been vibration of adjacent blades with respect to each other and the hub. The aforementioned interlocking feature might have facilitated mitigation of airfoil vibration such that the stresses induced within the blades during operation were in turn mitigated. The close tolerances of the interlocking features might have increased wear in the vicinity of the interlocking features as the adjacent notches rub against each other.

Figure 23 shows in general the above description in sequence.

Shroud wear = Loss of damping = Fatigue fracture

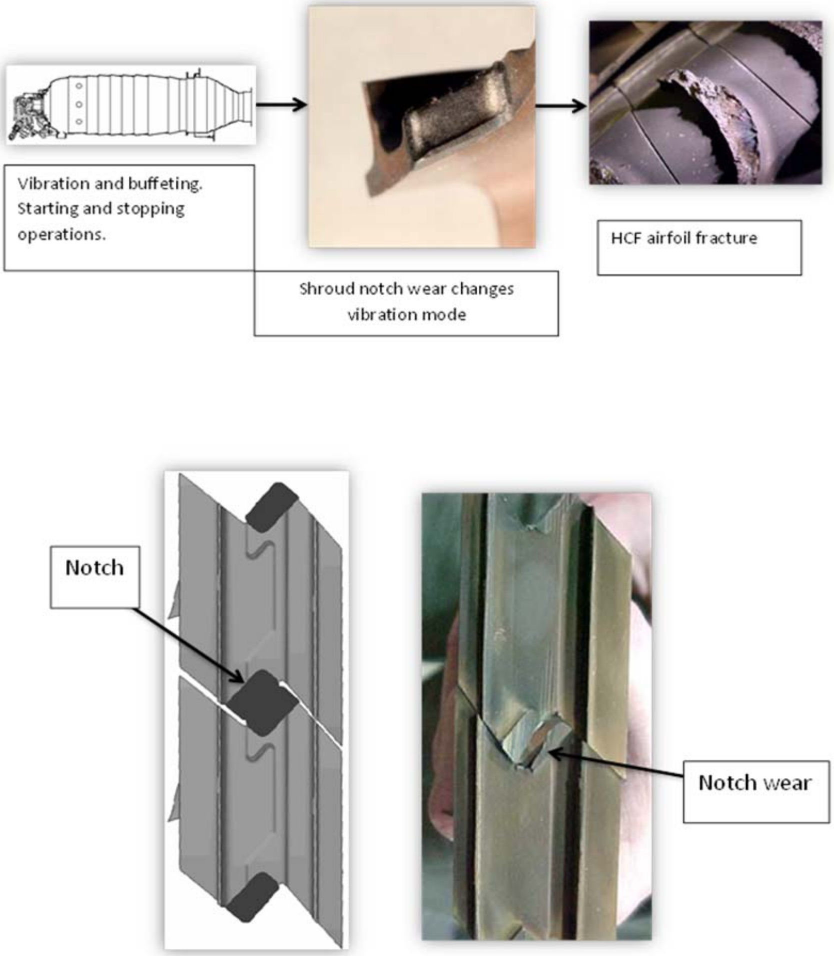


Fig.23

ANALYSIS

After the engine failure and when the flight crew had verified that there was no smoke or fire present, the commander decided to vacate the runway and to stop the aircraft on taxiway A6.

An external inspection of the aircraft was conducted by the fire brigade and there were no signs of either smoke or fire.

Without any injurious the passengers disembarked the aircraft through the entrance door.

With reference to this appropriate flight crew action, the AIB decided not to investigate the operational aspect any further.

All the 3rd LPT blades were installed as OH blades during a back shop visit in 2006.

The visual examination of the 3rd LPT revealed that one (blade number one) of the 88 3rd LPT blades had signs of fatigue. The SEM confirmed the fatigue area and the microstructure examination clarified that there was no material or structural abnormalities present.

The blade marking on the three LPT blades (one, two and 88) was consistent with the “lot codes” used by the Turbine Overhaul Services and represented a customer code for the OH facilities.

However, “ARGK” marking code on blade number one was not a current “lot code” being used by TOS and the “1185” marking on blade number one as well could not be determined, because the OH facilities went bankrupt in 2009 and for that reason, it has not been possible to obtain information about this issue.

The indications for 3rd stage LPT blades notch wear could not be observed.

The root cause to the fatigue could not be exactly determined.

However, a possible scenario, which might have led to fatigue, might be a result of wear in the mechanical blade interlocking feature during normal operation. This might have led to worn 3rd stage LPT blade notches and loss of vibration damping.

CONCLUSIONS

Findings:

1. All LPT T-4 blades were fractured
2. No sign of fatigue on the remaining LPT T–4 blades
3. All LPT T-3 blades were fractured
4. One of the 88 LPT T-3 had signs of heat in the fractured area (blade number one)
5. No structural abnormalities were present in the microstructure for blade number one
6. No materials defects were present on blade number one
7. The SEM revealed a crack initiation area in blade number one
8. Blade number one had a faint sign of fatigue striation
9. No history of the LPT T-3 blades, due to the fact that engine overhaul facility went bankrupt
10. It could not be determined whether or not the “1185” was related to service time on the affected blade

11. Pratt & Whitney Service Bulletin A6224 referenced in FAA AD 2011-0702 does not contain a notch wear inspection for the 3rd stage LPT blades in the JT8D-217C engine
12. No signs of LPT or exhaust case breaches
13. No signs of case flanges breaches
14. It was not possible to determine the extent of the shroud notch wear of the remaining found parts of the 3rd stage blades
15. The left engine was in compliance with all applicable ADs
16. Per June 2013, 245 active JT8D-217C engines and 1363 active JT8D-219 engines were in service

Based on the findings, the AIB concludes that the fracture in the 3rd stage LPT blade number one was caused by fatigue. Neither defects nor structural abnormalities explained the initiation of the fatigue crack.

FOCUS AREA

Pratt & Whitney provides practices and guidance for operators and Maintainers of the engine with respect to the JT8D-200 series LPT blades, including the 3rd stage blades in the JT8D-217C, in Special Procedure-01 in section 72-53-00 of the JT8D-200 series Engine Manual and in JT8D Service Bulletin A6224.

However, since a number of JT8D-217C/-219 engines are still in service, the AIB encourages the type certification holder (TCH) of the involved engine type (PW JT8D-217C) that they should evaluate the need for mandating shroud notch wear inspections on stage 3 LPT blades. Currently these inspections are mandatory only at stage 4 LPT blades.