AIRCRAFT INCIDENT REPORT AND EXECUTIVE SUMMARY

					Reference:	CA18/3/2/0965	
Aircraft Registration	ZS-ZWP	**Date of Incident**	27 February 2013		**Time of Incident**	1155Z	
Type of Aircraft	Boeing 737-800		**Type of Operation**		Domestic Schedule		
Captain Licence Type	Airline Transport Pilot		**Age**	43	**Licence Valid**	Yes	
Captain Flying Experience	Total Flying Hours		7 738,0		Hours on Type	450,5	
First Officer Licence Type	Airline Transport Pilot		**Age**	32	**Licence Valid**	Yes	
First Officer Flying Experience	Total Flying Hours		6 700,0		Hours on Type	570,0	
Last point of departure	Cape Town International Airport (FACT)						
Next point of intended landing	OR Tambo International Airport (FAOR)						
Location of the incident site with reference to easily defined geographical points (GPS readings if possible)							
On Runway 01 at Cape Town International Airport (FACT)							
Meteorological Information	Surface wind: 330˚/22 kt, Temperature: 24 ˚C, Dew point: 16 ˚C, Cloud cover: 1-2 octas, Cloud base: 3500 feet AGL						
Number of people on board	6 + 181	**No. of people injured**	0	**No. of people killed**	0		

Synopsis

On 27 February 2013, a Boeing 737-800 (registration ZS-ZWP, serial number 28612), operating as flight CAW104, was scheduled to depart from Cape Town International Airport (FACT) with the intention of landing at OR Tambo International Airport (FAOR). On board the aircraft were 181 passengers and six crew members. During the take-off roll at approximately 30 kt, there was a loud bang and a vibration was felt throughout the aircraft. The crew noticed that the No. 2 engine had spooled down (N1 and N2 engine gauges indicated a zero reading). The crew complied with the rejected take-off (RTO) procedure and the aircraft was brought to a stop on the runway.

The crash alarm was activated by air traffic control (ATC) and the aerodrome rescue and fire fighting (ARFF) personnel responded in two vehicles to the aircraft on the runway. Engine debris was found scattered over a substantial area of the runway surface. Nobody was injured in the incident and damage to the aircraft was contained to the No. 2 engine.

Probable cause

Aborted take-off as a result of the No. 2 engine failure due to the failure of the HPT blade.

Contributory factor

Failure of the HPT blade coating resulting on a corrosion and a subsequent failure of the blades

IARC Date		Release Date	

AIRCRAFT INCIDENT REPORT

Name of Owner	**:**	Comair Ltd
Name of Operator	**:**	Kulula
Manufacturer	**:**	Boeing Aircraft Company
Model	**:**	737-800
Nationality	**:**	South Africa
Registration Marks	**:**	ZS-ZWP
Place	**:**	Cape Town International Airport
Date	**:**	27 February 2013
Time	**:**	1155Z

All times given in this report is Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

*In terms of Regulation 12.03.1 of the Civil Aviation Regulations (1997) this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and **not to establish legal liability**.*

Disclaimer:

This report is produced without prejudice to the rights of the CAA, which are reserved.

1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On 27 February 2013, a Boeing 737-800 (registration number ZS-ZWP, serial number 28612), operating as flight CAW104, was scheduled to depart from Cape Town International Airport (FACT) with the intention of landing at OR Tambo International Airport (FAOR). On board the aircraft were 181 passengers and 6 crew members.

1.1.2 The aircraft taxied to the holding point and awaited take-off instructions at the intersection of Charlie (C) taxiway and Runway 01. A few minutes later, ATC cleared the aircraft for take-off. The crew selected full thrust for take-off and the aircraft accelerated to approximately 30 kt when a loud bang was heard, followed by a vibration. The take-off was aborted within 50 meters. The No. 2 engine's N1 and N2 engine instrument readings rapidly spooled down to zero and the crew followed the RTO procedure. The aircraft was brought to a stop on the available runway surface. According to the flight performance data sheet, V1 was calculated to be 136 kt, VR 141 kt and V2 147 kt.

1.1.3 ATC activated the crash alarm at 1255Z. ARFF personnel responded swiftly and two vehicles were dispatched to the aircraft on the runway. Engine debris was found scattered over a substantial area of the runway surface.

1.1.4 The flight crew completed the "engine severe damage memory items" checklist and taxied off the runway to an allocated parking bay at 1315Z.

1.1.5 A runway inspection was carried out and a substantial amount of engine debris was found on the eastern side of the Charlie intersection of the runway.

Figure 1: Engine debris found on the runway surface

1.1.6 The runway was closed in order to conduct a proper clean-up of the surface. It was confirmed during the removal that the debris was parts of the turbine blades. The runway was re-opened at 1336Z.

Figure 2: Engine debris collected from the runway during the clean-up operation

Figure 3: Google earth image of Cape Town International Airport

1.1.7 The flight was conducted under the provisions of Part 121 of the Civil Aviation Regulations of 2011, as amended, and the operator was in possession of a valid air service licence as well as an air operating certificate (AOC) at the time of the incident.

1.1.8 The incident occurred during daylight conditions while the aircraft was on the take-off roll on Runway 01. The aircraft came to a stop on the runway at a geographical position determined to be 29˚36’42.38” South 031˚07’09.59” East at an elevation of 304 feet above mean sea level (AMSL).

1.2 Injuries to Persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	-	-	-	-
None	2	4	181	-

1.3 Damage to Aircraft

1.3.1 The damage was limited to the No. 2 engine.

Figure 4: The damaged engine before it was removed from the aircraft

1.4 Other Damage

1.4.1 Apart from a substantial spread of engine debris on the runway surface, which was cleaned up following the occurrence, no other damage was caused.

1.5 Personnel Information

1.5.1 Pilot-in-command (PIC):

Nationality	South African	Gender	Male	Age	43
Licence number	0270408099	Licence type	Airline Transport Pilot, Private Pilot – helicopter		
Licence valid	Yes	Type endorsed	Yes		
Ratings	Instrument, Instructor Grade 2 and Flight Test Ratings				
Medical expiry date	30 November 2014				
Restrictions	None				
Previous incidents	None				

Flying Experience:

Total hours	7 738,0
Total past 90 days	212,0
Total on type past 90 days	60,1
Total on type	450,5

1.5.2 First Officer (FO):

<table>
<tr><td>Nationality</td><td>South African</td><td>Gender</td><td>Male</td><td>Age</td><td>32</td></tr>
<tr><td>Licence number</td><td>0270500788</td><td>Licence type</td><td colspan="3">Airline Transport Pilot</td></tr>
<tr><td>Licence valid</td><td>Yes</td><td>Type endorsed</td><td colspan="3">Yes</td></tr>
<tr><td>Ratings</td><td colspan="5">Instrument, Instructor Grade 2 & Flight Test Ratings</td></tr>
<tr><td>Medical expiry date</td><td colspan="5">31 January 2015</td></tr>
<tr><td>Restrictions</td><td colspan="5">None</td></tr>
<tr><td>Previous incidents</td><td colspan="5">None</td></tr>
</table>

Flying Experience:

Total hours	6 700,0
Total past 90 days	160,0
Total on type past 90 days	120,0
Total on type	570,0

1.6 Aircraft Information

1.6.1 Aircraft description

The Boeing 737-800 is a popular twin-engine, short- to medium-range airplane renowned for its reliability, simplicity and low maintenance and operating costs. The Boeing 737-800 is further known for its reliability, fuel efficiency and economical performance. It is a single-aisle jet, powered by two CFM56-7B engines.

Figure 5: A photo of the aircraft as it came to rest on the runway

1.6.2 Airframe

Type	Boeing 737-800	
Serial number	28612	
Manufacturer	Boeing Aircraft Company	
Year of manufacture	1999	
Total airframe hours (At time of incident)	39 024,33	
Last phase inspection (date & hours)	38 365,51	19 December 2012
Hours since last phase inspection	658,82	
C of A (Issue date)	28 January 2010	
C of A (Expiry date)	27 January 2014	
C of R (Issue date) (Present owner)	26 January 2010	
Maximum take-off weight	79 015 kg	
Maximum landing weight	66 360 kg	
Airworthiness directive status	Complied with	
Type of fuel recommended	Jet A1	
Fuel used	Jet A1	
Operating categories	Standard Part 121	

1.6.3 The aircraft was imported to South Africa in 2010 and was issued with a certificate of registration (C of R) on 26 January 2010. The South African Civil Aviation Authority (SACAA) Airworthiness department inspected the aircraft and issued a certificate of airworthiness (C of A) on 28 January 2010. From this date onward, the owner, who was also the operator of the aircraft, used it for commercial air transportation operations, in accordance with the applicable regulations CAR, Part 121 of 2011.

1.6.4 All relevant aircraft documentation e.g. Certificate of Registration (C of R), Certificate of Airworthiness (C of A), Radio Stations License, Mass and Balance Certificate were inspected during the on-site investigation and were found to be valid in accordance with requirements of applicable regulation CAR Part 91.

1.6.5 The aircraft maintenance documents, such as airframe logbooks, engine logbooks and work packs, were obtained from the aircraft maintenance organisation (AMO) and inspected:

i. All maintenance entries made in the logbooks were appropriately certified in terms of the requirements of the applicable regulations, CAR Part 43.

ii. All scheduled (phase inspection programme) and unscheduled (defects) inspections were maintained in accordance with applicable CAR, Part 42 requirements.

iii. The AMO was requested to submit copies of the ZS-ZWP aircraft flight folio for review. Upon inspection, the ZS-ZWP aircraft flight folio was found to be in compliance with the applicable regulations in CAR Part 43.

1.6.6 Description of engines

Engine No. 1

Type	CFM 56-7B26
Serial number	890815
Last phase inspection (A3 check) (date & hours/cycles)	CKA024/2014-01-15/39 714,43/18 821
Hours & cycles since new	40 111/19 105
Hours & cycles since overhaul	TBO not yet reached
Maintenance concept	A-check

Engine No. 2

Type	CFM 56-7B26
Serial number	890816
Last Phase Inspection (A3 check) (date & hours/cycles)	CKA015/2014-01-08/39 200,24/18 544
Hours & cycles since new	39 637/18 866
Hours & cycles since overhaul	TBO not yet reached
Maintenance concept	A-check

1.6.7 Engine No. 2 History (Affected engine)

Date removed	Ex A/C	Position	H.S.L S.V	Total hours	C.S.L S.V	Total cycles	Reason for removal	Work done	Date completed
Ex Jet Airline				22 625		14 166	Repaired by Aeroturbine		2011-05-04
N/A	N/A	N/A	0	22 625	0	14 166	Accepted by Comair and installed on ZS-ZWR #1		2011-09-03
2011-10-02	ZS-ZWR	1	300	22 925	219	14 385	Removed from ZS-ZWR due to service requirements and installed on ZS-ZWO		2011-10-08
Not removed	ZS-ZWO	2	1568	24 193	1105	15 271	Not removed. Bird strike	Fan blades replaced. Qty 4	2012-03-22
2012-04-23	ZS-ZWO	2	1857	24 482	1302	15 468	Removed from ZS-ZWO due to service requirements and installed on ZS-ZWP. SB 72-0324 was embodied on T/C 16350		2012-05-08

1.6.8 Maintenance

1.6.8.1 The engine had a shop visit for performance restoration in 2011 at GE Wales. At that point, the engine total time since new was 26 961 hours and the cycles since new (CSN) was 17 164.

1.6.8.2 Boroscope information on the affected engine

Date	Inspection details
23 March 2012	Full hot boroscope inspection

1.6.9 Weight and balance

1.6.9.1 The investigating team requested that the operator to submit a copy of the load sheet applicable to the incident flight. The aircraft was found to be correctly loaded. The maximum take-off weight for this aircraft type was not allowed to exceed 79 015 kg.

1.7 Meteorological Information

1.7.1 The meteorological information was obtained from the South African Weather Services (SAWS) as well as ATC data provided during the take-off clearance. The prevailing weather conditions were as follows:

Wind direction	330˚	Wind speed	22 kt	Visibility	CAVOK
Temperature	24 ℃	Cloud cover	1–2 octas	Cloud base	3 500 feet AGL
Dew point	16 ℃				

1.8 Aids to Navigation

1.8.1 The aircraft was fitted with the following navigational aids:

- Magnetic compass
- Panel-mounted Garmin GPS
- Mode S transponder
- ADF (automatic direction finder)
- DME (distance measuring equipment)
- VOR (variable omni-range) finder
- ILS (instrument landing system)

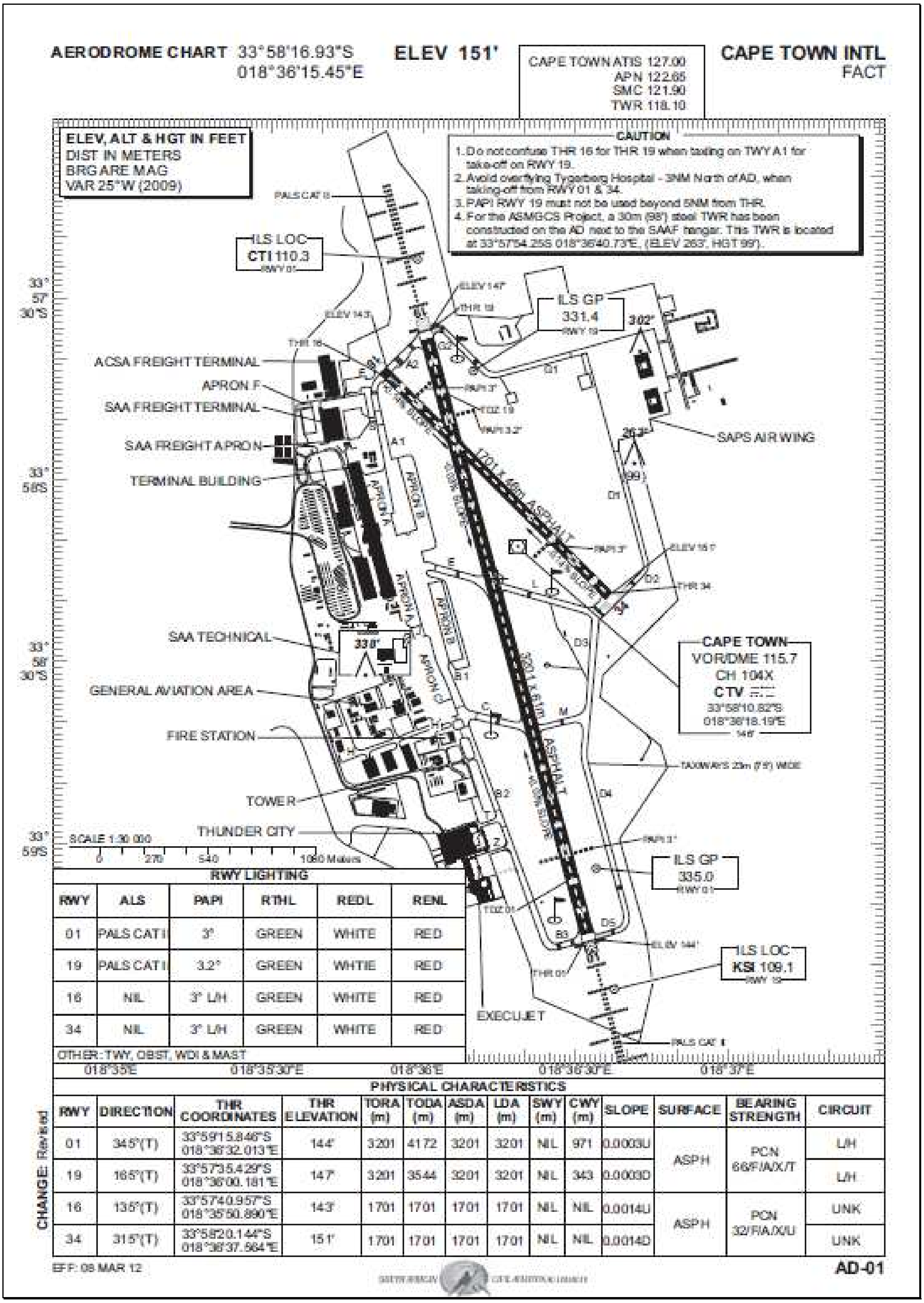
1.9 Communications

1.9.1 The crew communicated with ATC on the VHF radio aerodrome frequency 118, 10 MHz. The ATC recordings of the radio communications were consistent with the transmissions recorded. All radio communication from the aircraft was performed by the First Officer, as a function of the pilot not flying this sector.

1.9.2 A transcript of the communication between ATC FACT and the crew of CAW104 is attached to this report as Appendix A.

1.10 Aerodrome Information

Aerodrome location	Cape Town International Airport	
Aerodrome co-ordinates	33˚57’53” South 018˚36’06” East	
Aerodrome elevation	151 feet AMSL	
Aerodrome status	Licensed	
Runway designations	01/19	Primary runway
Runway dimensions	3 201 x 61 m	
Runway designations	16/34	Secondary runway
Runway dimensions	1 701 x 46 m	
Runway used	01	
Runway surface	Asphalt	
Approach facilities	NDB, ILS, VOR, DME, Runway lights and PAPIs	



RWY LIGHTING					
RWY	ALS	PAPI	RTHL	REDL	RENL
01	PALS CAT II	3°	GREEN	WHITE	RED
19	PALS CAT II	3.2°	GREEN	WHTIE	RED
16	NIL	3° L/H	GREEN	WHITE	RED
34	NIL	3° L/H	GREEN	WHITE	RED
OTHER: TWY, OBST, WDI & MAST					

PHYSICAL CHARACTERISTICS

RWY	DIRECTION	THR COORDINATES	THR ELEVATION	TORA (m)	TODA (m)	ASDA (m)	LDA (m)	SWY (m)	CWY (m)	SLOPE	SURFACE	BEARING STRENGTH	CIRCUIT
01	345°(T)	33°59'15.846"S 018°36'32.013"E	144'	3201	4172	3201	3201	NIL	971	0.0003U	ASPH	PCN 66/F/A/X/T	L/H
19	165°(T)	33°57'35.429"S 018°36'00.181"E	147'	3201	3544	3201	3201	NIL	343	0.0003D			L/H
16	135°(T)	33°57'40.957"S 018°35'50.890"E	143'	1701	1701	1701	1701	NIL	NIL	0.0014U	ASPH	PCN 32/F/A/X/U	UNK
34	315°(T)	33°58'20.144"S 018°36'37.564"E	151'	1701	1701	1701	1701	NIL	NIL	0.0014D			UNK

Figure 5: Aerodrome Chart for Cape Town International Airport

1.11 Flight Recorders

1.11.1 The aircraft was equipped with a Honeywell solid state flight data recorder (FDR) and Honeywell solid state cockpit voice recorder (CVR) as required by the regulations.

Figure 6: Flight data recorder

1.11.2 The solid state CVR, which uses a modular crash-survivable memory unit (CSMU) for protection of the recording memory, retains the most recent 30 or 120 minutes of audio, digital, and timing information, with an underwater locator beacon. It currently includes provisions in anticipation of future legislation making the recording of data-linked ATC messages mandatory.

1.11.3 The solid state FDR uses a CSMU for protection of the memory. The CSMU retains the most recent 25 hours of digital flight data and timing information. The solid state FDR can be configured for 64 words per second (1X), 128 words per second (2X), or 256 words per second (4X) data recording. It meets or exceeds all industry crash-survivability requirements. It is available with an underwater locator beacon and includes interfaces for a flight data acquisition unit (FDAU).

1.11.4 On 27 February 2013, after the on-site investigation, the investigator-in-charge requested the aircraft maintenance engineer based at FACT to remove both flight recorders from the aircraft for data downloading.

1.11.5 Both flight recorders were then removed as per the aircraft/manufacturer's maintenance manual and taken to Johannesburg, where the units' data were downloaded.

1.11.6 An external examination on both recorders revealed that both units were in good condition. The underwater locator beacons on both recorders were also not damaged.

Figure 7: Flight data recorder (FDR) recovered from the aircraft

1.11.7 The FDR data download did not show any abnormalities before the event occurred.

Figure 8: Cockpit voice recorder recovered from the aircraft

1.11.8 Recorder Information:

Flight Data Recorder

Type/Model	Honeywell
Part Number	980-4700-042
Serial Number	SSFDR-18454

Cockpit Voice Recorder

Type/Model	Honeywell
Part Number	980-6022-001
Serial Number	SS120-04565

1.11.9 Flight data recorder (engine information)

Time	Occurrence
11:55:09	First split between the two engines N1 and N2 values noted.
11:55:10	Fuel flow indication drop to zero on engine No. 2.
11:55:14	Sudden drop in engine oil pressure on the No. 2 engine noted.
11:55:50	No. 2 engine oil pressure reading zero.
11:56:22	No. 2 engine N2 value indicates zero.
11:56:35	No. 2 engine N1 value indicates zero.

1.12 Wreckage and Impact Information

1.12.1 The aircraft came to a stop on Runway 01 following a RTO by the crew, as the speed was still fairly slow (before V1) when the engine failed.

1.12.2 The damage caused to the aircraft was limited to the No. 2 engine. Debris (consisting mostly of fragmented turbine blades) was scattered over a substantial area of the runway surface after being ejected via the tailpipe.

1.13 Medical and Pathological Information

1.13.1 None.

1.14 Fire

1.14.1 There was no pre- or post-impact fire.

1.14.2 ARFF personnel responded swiftly to the aircraft following the activation of the crash alarm by ATC. They followed the aircraft, as it was able to vacate the runway utilising the engine thrust delivered by the No. 1 engine.

1.15 Survival Aspects

1.15.1 Nobody was injured in the incident. All the occupants were using the aircraft-equipped safety harnesses. There was no fuselage damage. The incident occurred at a fairly slow speed before V1.

1.16 Tests and Research

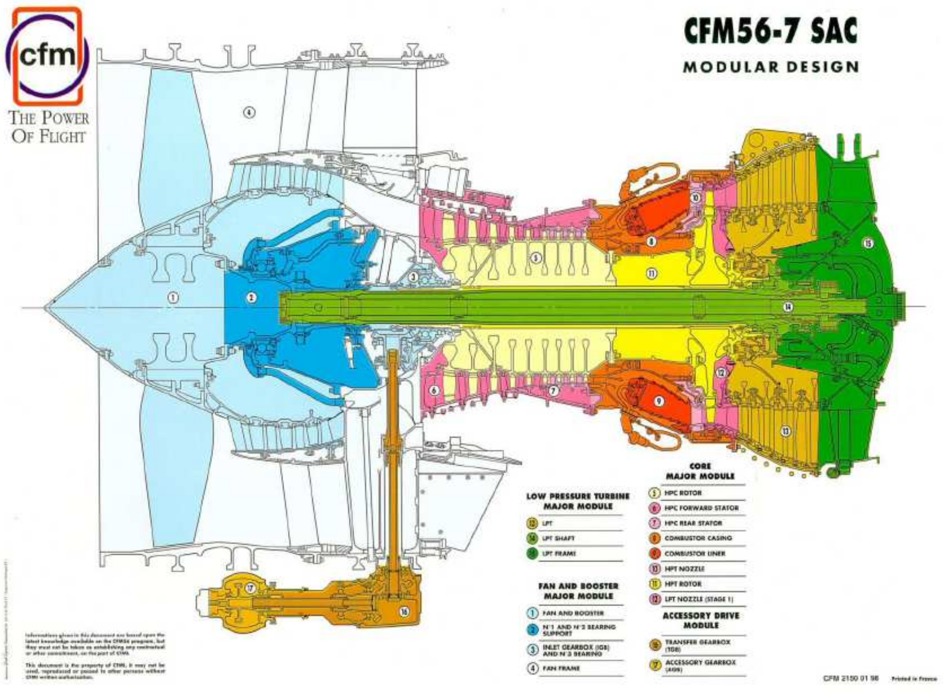


Figure 9: Cross-sectional view of the CFM56 engine

1.16.1 Inspection of the No. 2 engine revealed that the engine had sustained excessive damage, but that no other damage was caused to the aircraft

Figure 10: Deformed engine casing

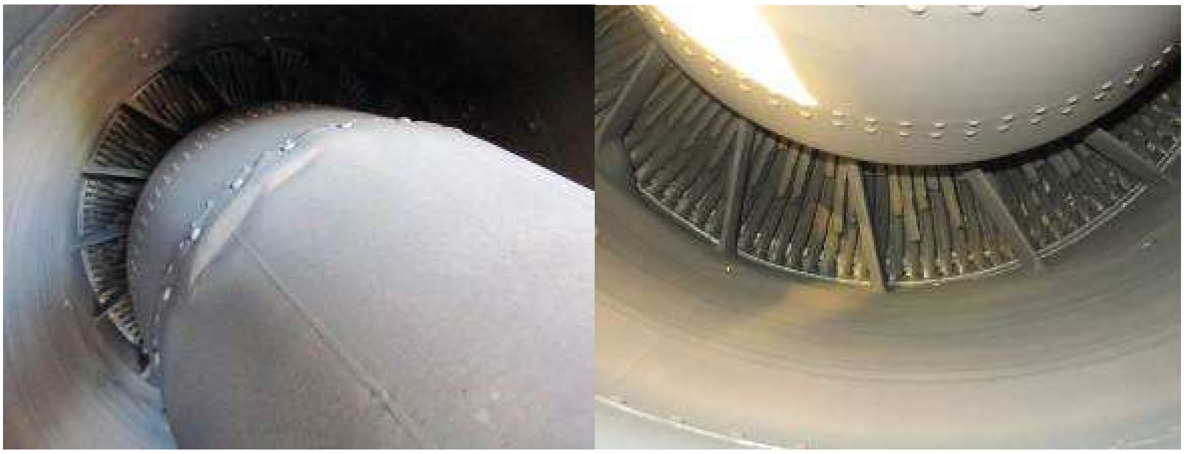


Figure 11: Damaged turbine blades viewed via the tailpipe

1.16.2 The engine forward sump scavenge strainer plug was removed and checked in the presence of the IIC by a CFM engine specialist. Upon investigation it was found that the plug was contaminated with a composite material from the high pressure turbine seal. The forward sump scavenge strainer plug along with the contaminated evidence was returned to its original position for transportation to an engine maintenance facility in Johannesburg.

Figure 12: Contaminated forward sump scavenge strainer plug

1.16.3 Figure 13 below shows two studs (part number J1074P10) were found lying at the bottom of the engine cowling. The nuts (part number J149P07) were still attached to the studs, which displayed evidence of deformation (bending) as well as shearing. The studs are made of a material called Inconel 718 and the nut is AMS 5735 which is Stainless Steel A268.

Figure 13: The loose studs with nuts attached found in the engine

1.16.4 There were also pieces of composite material found in the engine. The material was the same colour as evidence found in the forward sump scavenge strainer.

Figure 14: Fragments of composite material found

1.16.5 After the engine was completely stripped the position of the studs were confirmed. The composite material was also identified as a seal. Refer to figure 16 for a schematic diagram showing the location of the stud and nut and seal.

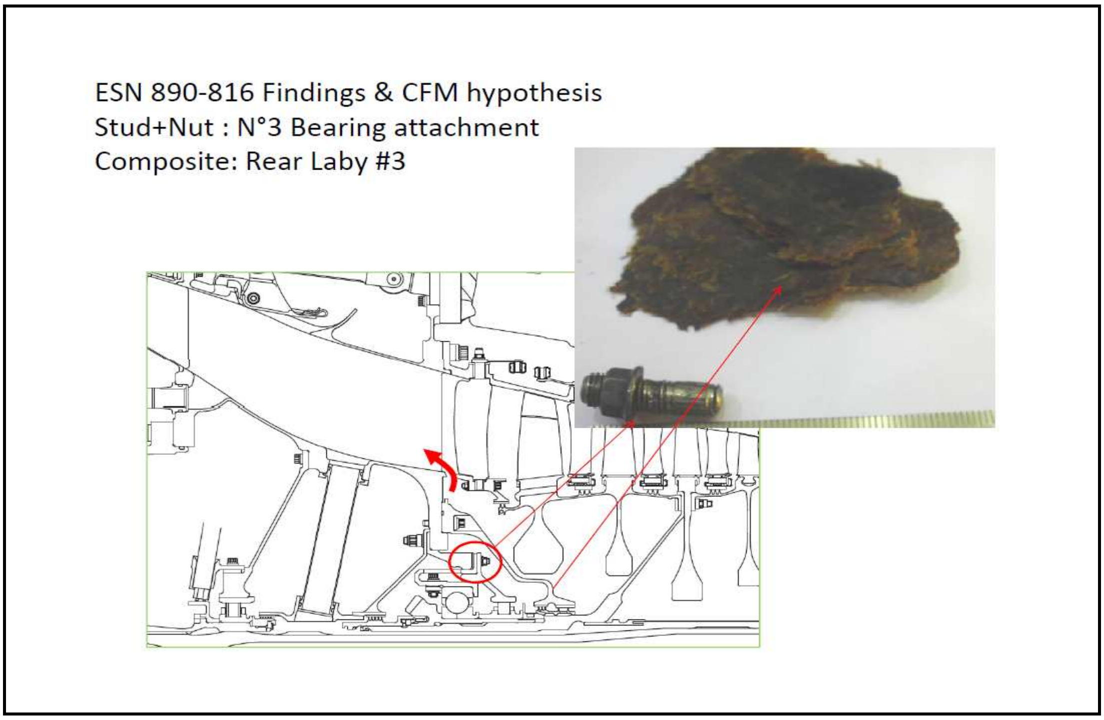


Figure 16: Schematic diagram showing the location of the stud and nut and seal.

1.16.6 A team of aircraft maintenance engineers flew to Cape Town to remove and replace the failed engine. The replacement engine was shipped by road to Cape Town.

1.16.7 The engine CFM56-7B26, Serial Number 890816, was removed from the aircraft and replaced with a serviceable engine. The affected engine was shipped by road to an engine maintenance facility in Johannesburg for further investigation.

1.16.8 On 5 March 2013, a detailed boroscope inspection was carried out by certified engineers in the presence of the IIC and the following observations were made:

- Low-pressure compressor
    - Stage 2: Tip rub evident. Blades not aligned with normal run path.
    - Stage 3: Tip rub evident. Blades not aligned with normal run path.
    - Stage 4: Tip rub evident. Blades not aligned with normal run path.

- High-pressure compressor
    - Stage 1: Severe tip rub evident. Outer air seal with signs of severe rub. Disc contact with inner air seal.
    - Stage 2: Slight tip curl. Metal splatter evident on convex side.
    - Stage 3: Severe tip rub and metal splatter evident. Trailing edge tip liberated. No gap between blade tips and outer air seal.
    - Stage 4: Leading edge tips and outer air seal with severe rub. Trailing edge tips display damage.

- Stage 5: Rotor and stator contact. No gap between blade tips and outer air seal. Trailing edge: no significant defects.
- Stage 6: Severe tip curl evident. Axial cracks evident. Outer air seal with severe rub. Trailing edge: no significant defects.
- Stage 7: Leading edge impact damage. Tip curl evident. No gap between blade tips and outer air seal. Seal (J-hook) liberated. Trailing edge severe rotor stator contact. Severe damage to trailing edge.
- Stage 8: Leading edge with severe impact damage, tip rub and tip curl evident. Outer air seal with severe rub evident. Rotor stator contact. Trailing edge rotor stator contact. No gaps between blade tip and outer air seal.
- Stage 9: Impact damage with material loss. Trailing edge stator case seal adrift.

\- Fuel nozzles
- Metal particles evident in swirlers.
- No significant defects noted.

\- Combustion chamber
- No significant defects noted.
- Metal scratch marks evident on inner and outer case.
- Metal particles evident.

\- Nozzle guide vanes
- Several vanes with leading edge cracks.
- All vanes trailing edge with severe damage.

\- High-pressure turbine
- All blades corncobbed.
- All outer air seals severely damaged but not one seal completely liberated.

\- Low-pressure turbine
- Stage 1: Severe damage evident
- Stage 2: Severe damage evident
- Stage 3: Severe damage evident

- Stage 4: Severe damage evident

- Declaration

  This engine had a severe failure and was rejected. The boroscope inspection was carried out without rotating N1 and N2. The engine could not be rotated by hand.

1.16.9 On 7 March 2013, a non-destructive inspection (NDI) was also carried out on the engine oil samples taken. Higher solid material values were evident in the forward sump. The rear sump showed higher values of aluminium. However, it was noted that all properties of the engine oil samples were within limits. The analysis of the NDI showed that the metal particles analysed matched the composition of 17-4 Ph. A material glass fibre with polyamide and phenolic/plastic was present in large quantities.

1.16.10 During the period 25–28 March 2013, a detailed engine teardown procedure was performed at an engine overhaul facility in Wales to determine the cause of the failure. Attached to this report as Appendix C is a detailed report on the findings.

1.16.11 On disassembly at GE Wales 3 HPT blades P/N 1957M10P03 were found to have liberated below the platform. The engine had a shop visit for performance restoration in 2011 at GE Wales. Fracture analysis of the 3 HPT blades (S/N BWHN3C97; BWHN8C60 & BWHN9B89) revealed presence of fatigue characteristics on the fracture surface of all three blades. Blade BWHN3C97 was identified as the prime blade based on the extent of fatigue crack propagation on the fracture surface prior to blade eventual separation by tensile overload. The prime blade showed primary fatigue crack initiation via multiple origins from internal surface of cavity #1 shank transition zone. Evidence of secondary fatigue crack initiation was also observed from the internal surface of cavity #1 shank transition zone. Overall fracture morphology was consistent with a slower moving, higher stress low cycle fatigue mechanism progressing through the wall then crack propagation forward and aft until final separation by tensile overload. Fatigue crack propagation of the prime blade encompassed approximately 65% of the fracture surface prior to final separation. The other two blades also had primary fatigue cracking on cavity #1 transition zone wall. Majority of the fracture surface showed characteristics of tensile overload as a result of secondary impact damage. All 66 M10P03 blades in this blade set were coated by Coating 1 process while 14 M10P04 blades were coated with Coating 3 process.

1.16.12 This incident was the fourth CFM56-7B engine failure event related to M10P03 blade shank transition zone cracking.

1.16.12 As a result, CFM revised Service Bulletin SB72-0821 in March 2013, where they reduced the recommended removal time from 25 000 CSN to 16 500 CSN for a specific population of 1957M10P03 blades. The number of blades in circulation is approximately 6 100. In addition, repairs for these serial numbers have been cancelled.

1.17 Organizational and Management Information

1.17.1 This was a scheduled domestic flight operated from FACT to FAOR. The operator was in possession of a valid air service licence as well as an AOC at the time of the incident. The aircraft was accordingly authorised to operate under AOC No. CAA/N067D.

1.17.2 The aircraft was maintained by an approved AMO that was in possession of a valid AMO approval certificate under AMO No. 001.

1.18 Additional Information

1.18.1 The engines that were fitted to the aircraft at the time of the incident were on lease from easyJet Airline Co Ltd.

1.18.4 Following an assessment of the engine in Johannesburg, it was shipped to an engine overhaul facility in Wales where a teardown inspection was performed in the presence of the IIC.

1.19 Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1 The Man

The PIC and FO were licensed and qualified for the flight in accordance with existing regulations. They were in compliance with the flight and duty time regulations. Their actions and statements indicated that their knowledge and understanding of the aircraft systems was adequate. The PIC was the holder of an airline transport pilot licence, as well as a private pilot licence for helicopters. He had a total of 7 738 hours, of which 450,5 hours were on type. The FO was the holder of an airline transport pilot licence. He had a total of 6 700 hours of which 570 hours were on type. A rejected take-off procedure was performed by the crew following the cockpit indication that the No. 2 engine had failed. This was in accordance with the procedures in the company operations manual. The flight crew maintained normal radio communication with the relevant ATC units.

2.2 The Machine

During the take-off roll, the No. 2 engine failed, associated with a loud bang. The crew aborted the take-off within 50 meters and it was possible to vacate the runway on the engine power delivered by the No. 1 engine. Engine debris was ejected via the tailpipe. The runway had to be closed after the incident. ARFF personnel responded swiftly and a runway clean-up was initiated and completed within 25 minutes. The flight crew, cabin crew members and passengers sustained no injuries and no further damage was caused to the aircraft.

The CVR and DFDR were removed from the aircraft following the incident and data was downloaded at an approved facility. The DFDR data download did not show any abnormalities before the event occurred. An NDI was also carried out on the engine oil samples taken. Higher solid material values were evident in the forward sump. The rear sump showed higher values of aluminium. However, it was noted that all properties of the engine oil samples were within limits. The NDI showed that the metal particles analysed matched the composition of 17-4 Ph. A material glass fibre with polyamide and phenolic/plastic was present in large quantities. A boroscope inspection was carried out by certified engineers in the presence of the IIC at an approved facility in Johannesburg. The engine in question had a severe failure and was rejected. The boroscope inspection was carried out without rotating N1 and N2, as the engine could not be rotated by hand. Video and still photos were taken.

The engine was then shipped to GE Wales for further inspection. Another boroscope inspection was carried out. On disassembly of the failed engine, 3 high pressure turbine (HPT) blades (Part number 1957M10P03) were found to have liberated below the platform. The engine had had a shop visit for performance restoration at GE Wales in 2011. This was the fourth CFM56-7B engine failure event related to M10P03 blade shank transition zone cracking. The 3 former failures occurred between 16 900 and 17 700 CSN. Fracture surface analysis of under-platform separated blades revealed that the primary fatigue crack initiation occurred via multiple origins from the internal surface located within the cavity. The analysis also showed evidence of secondary fatigue crack initiation on the internal surface of the cavity. Heavy oxidation was observed on the crack surface and most of the blade fracture surface showed characteristics of tensile overload as a result of secondary impact damage. Blade BWHN3C97 was identified as the prime blade to have failed, based on the extent of fatigue crack propagation prior to eventual separation by tensile overload. Visual inspection of the remaining 77 blades (63 M10P03 and 14 M10P04 blades) found 11 additional M10P03 blades with visible through-wall transition zone cracks on the external wall.

This incident was the fourth CFM56-7B engine failure event related to M10P03 blade shank transition zone cracking. As a result, CFM revised Service Bulletin SB72-0821 in March 2013, where they reduced the recommended removal time from 25 000 CSN to 16 500 CSN for a specific population of 1957M10P03 blades. The number of blades in circulation is approximately 6 100. In addition, repairs for these serial numbers have been cancelled.

2.3 The Environment

Fine weather conditions prevailed at the time of the serious incident and did not contribute to the cause of serious incident.

3. CONCLUSION

3.1 Findings

Flight Crew

3.1.1 The PIC and FO were licensed and qualified for the flight in accordance with existing regulations.

3.1.2 The PIC and FO were in compliance with the flight and duty time regulations.

3.1.3 The actions and statements of the PIC and FO indicated that their knowledge and understanding of the aircraft systems was adequate.

3.1.4 An RTO was performed by the crew following the cockpit indication that the No. 2 engine had failed. This was in accordance with the procedures in the company operations manual.

3.1.5 The flight crew maintained normal radio communication with the relevant ATC units.

Aircraft

3.1.6 The aircraft had a valid certificate of airworthiness and had been maintained in compliance with the regulations.

3.1.7 The mass and balance of the aircraft were within the prescribed limits.

3.1.8 The No. 2 engine suffered a failure during the take-off roll at intersection ‘C’ on runway 01 and the take-off was aborted within 50 meters.

3.1.9 The aircraft was equipped with an FDR and CVR and both units were removed from the aircraft and their data downloaded.

3.1.10 The 30-minute closed-loop CVR tape was of adequate duration to be helpful in the investigation of this incident.

3.1.11 The incident was survivable because the engine event was fully contained and resulted only in a single engine loss of thrust.

3.1.12 The video boroscope carried out in Cape Town revealed HPT blade failure. This was confirmed at the CFM engine overhaul facility in Wales.

3.1.13 The investigation revealed that a transition zone crack had occurred in one of the HPT blades.

3.1.14 This incident was the fourth CFM56-7B engine failure event related to M10P03 blade shank transition zone cracking.

ATC

3.1.15 ATC provided prompt and effective assistance to the flight crew.

Aerodrome

3.1.16 FACT was a licensed aerodrome.

3.1.17 ARFF personnel responded swiftly following the activation of the crash alarm by ATC.

3.1.18 Runway 01 at FACT was closed for 25 minutes after the incident and reopened following a runway clean-up.

3.2 Probable Cause/s

3.2.1 Aborted take-off as a result of the No. 2 engine failure due to the failure of the HPT blade.

3.3 Contributory factors

3.3.1 Failure of the HPT blade coating resulting on corrosion and a subsequent failure of the blades

4. SAFETY RECOMMENDATIONS

4.1 It is recommended that the manufacturer look into revising the time intervals to overhaul the blades from 25 000 CSN to 16 500 CSN for a specific population of 1957M10P03 blades. After the forth incident occurred CFM revised Service Bulletin SB72-0821 in March 2013, where they reduced the recommended removal time from 25 000 CSN to 16 500 CSN for a specific population of 1957M10P03 blades. The number of blades in circulation is approximately 6 100. In addition, repairs for these serial numbers have been cancelled.

5. APPENDICES

5.1 Appendix A - Laboratory Report on SOAP Analysis

5.2 Appendix B - Engine Failure Investigation Report A

5.3 Appendix C - Engine Failure Investigation Report B

5.4 Appendix D - Letter to all CFM56-5B/7B Operators

Compiled by: Natasha Kisten-Skuce

....

N. Kisten-Skuce Date: …………………….……..

For: Director of Civil Aviation

Investigator-in-charge: N. Kisten-Skuce Date: ……………………….…..

Co-Investigator: F. Motaung Date: …………………………

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TECHNICAL

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Email: alwynfouché@flysaa.com

7 March 2013

Aero Turbine, Attention Ian Nicholson

RE: Result of SOAP Analysis

Engine	Serial No.	Fe	Cr	Pb	Cu	Sn	Al	Ni	Ag	Si	Mg	Zn	Ti
890816	Main Oil	2.211	0.000	0.000	0.101	2.621	0.996	0.000	0.433	0.791	0.162	0.000	0.773
	Scv Oil	5.678	0.110	0.000	0.204	3.444	3.265	0.000	1.171	3.859	0.246	0.000	1.612
	Rear Sump	6.427	0.287	0.000	0.385	2.247	25.58	0.387	4.030	6.849	0.550	0.000	0.837
	Fwd Sump	23.07	1.943	0.000	0.548	3.187	4.754	0.860	11.00	11.60	0.831	0.308	7.091
	Agb/Tgb Sump	4.566	0.096	0.000	0.174	2.800	1.362	0.000	1.552	0.604	0.327	0.128	0.654

Note: Higher values in Forward Sump are Evident. Rear Sump Higher Value Aluminium.

RE: Result of Engine Oil samples.

Main Oil Supply:
Moisture: 0.049 PPM
Viscosity @ 38°C: 29.020 mm2/sec
Tan: 0.01 mg KOH
Density @38°C: 0.977 g/ccm

Scavenge Oil:
Moisture: 0.061 PPM
Viscosity @38°C: 28.85 mm2/sec
Tan: 0.09 mg KOH
Density @38°C: 0.978 g/ccm

Forward Sump:
Moisture: 0.064 PPM
Viscosity @38°C: 28.87 mm2/sec
Tan: 0.09 mg KOH
Density @38°C: 0.978 g/ccm

Rear Sump:
Moisture: 0.069 PPM
Viscosity @38°C: 28.80 mm2/sec
Tan: 0.09 mg KOH
Density @38°C: 0.978 g/ccm

Rear Sump:
Moisture: 0.071 PPM
Viscosity @38°C: 28.80 mm2/sec
Tan: 0.09 mg KOH
Density @38°C: 0.977 g/ccm

Note: All properties are in limits.
Filter Inspection: Supply filter found to be clean, Scavenge Filter had Silver particles and Fibers present.
XRF Analysis: Particles Analysed matched the composition of 17-4 Ph. Material Glass Fiber with Polyamide and Phenolic/Plastic was present in large quantities.

Regards,

Mr. AJ Fouché
Senior Inspector.

SAA 3177 AMO-1

5.2 Appendix B - Engine Failure Investigation Report A

The Power of Flight

Comair CFM56-7B 890-816

Failure investigation after ATO with a loud bang and power loss

25-28 March 2013

Comair CFM56-7B ESN 890-816

1- Background

February 27 2013 during the take-off roll the No. 2 engine failed, the failure was associated with a loud bang. The crew aborted the take-off and it was possible to vacate the runway on the engine power delivered by the No. 1 engine. Engine debris was ejected via the tailpipe. The runway had to be closed after the incident. Aerodrome rescue and fire fighting (ARFF) personnel responded swiftly and a runway clean-up process was initiated and completed within 25 minutes. Nobody was injured in the incident. This was a domestic scheduled flight operating as flight CAW104.

The engine had a Shop visit for performance restoration in 2011 at GE Wales.

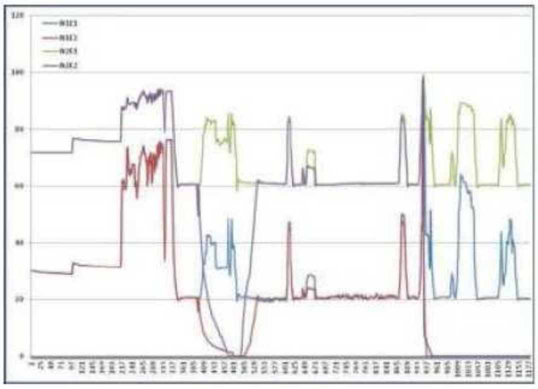
Engine TSN/CSN: :26,961/17,164

2- Preliminary inspection (including BSI) found:

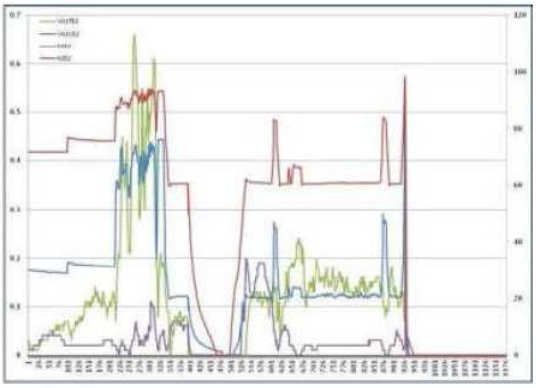
- No N2 rotation – N1, and N2 rotors interlocking
- LPT blades on stage 4 damaged/separated on various length and various position
- #3 bearing damaged
- HPC flowpath damaged
- HPT blades damaged - liberated

2 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816



N1 & N2 speed on #2 engine vs. #1



Engine 2 vibrations vs. N1 & N2

DFDR data doesn't show any abnormal before the event occurred.

Comair CFM56-7B ESN 890-816

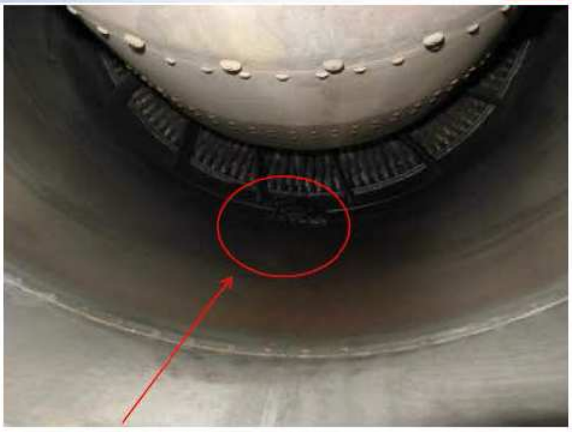
3- Engine findings during investigation at GE Wales

3-1 External condition

- Engine on pedestal prepared to be disassembled in major module.
- Fan module in good condition in general, with rubs, and gouges on abradable. It is a result of Fan case radial distortion. Blades in good condition.
- HPTACC valve housing cracked 360 degree..
- No external damages visible on HPC section, HPT section, VSV actuators
- No abnormal discoloration, or fire findings
- Exhaust nozzle distorted-crumpled as a result of vibrations
- LPT blades on stage 4 damaged/separated on various length and various position

MCD inspection performed by customer. No findings in AFT sump. Contamination reported in FWD sump.

Comair CFM56-7B ESN 890-816



Debris outside the LPT in tailpipe.

Deformation with cracks

Comair CFM56-7B ESN 890-816

HPTACC housing cracked

6 / CFM Proprietary information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

Fan module in general good condition. Damaged Abradable by the blades due to Fan case distortion

7 / CFM Proprietary Information subject to restrictions on the cover

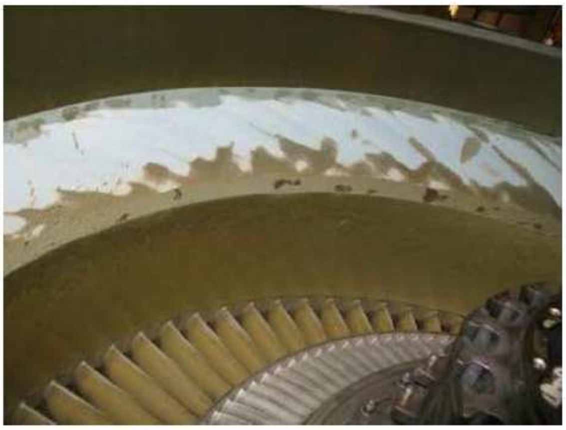
Comair CFM56-7B ESN 890-816

3-2 Engine disassembly

- During the disassembly process hard to remove LPT module due to identified #4 bearing damage - roller and outer race interlocking. After LPT module removal, occurred that #4 bearing roller cage was damaged, (in two pieces), and damaged outer race of the bearing.
- On the outer race of #4 bearing there are groves and wear from the rollers. As groves are located at the position which is correct from normal position of the rollers it means that these occurred without axial movement.
- #4 bearing damaged condition looks like secondary damage, as a effect of HP rotor unbalance.
- Air oil separator has been found worn on forward face - caused by #5 bearing. #5 bearing retainer ring with deformation, and one bolt shared.
- No evidence of LPT axial displacement
- All LPT blades from Stage 1 damaged close to the tip
- LPT shaft with wear in two locations – caused by HP shaft orbiting motion.

8 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816



Booster in general good condition. Abradable damage visible after blades removal

9 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

Deformation of #5 bearing retainer ring – one bolt sheared

Silver seal on Oil inlet cover with wear

10 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

Air-Oil separator with wear

11 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

All LPT blades damaged – mostly close to blade tip

12 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

No 4 bearing rollers homogeneously damaged – flat wear spots on both sides inner and outer races. Rollers cage in two pieces, this condition can occurred during LPT disassembly process – fresh and clean condition of cage rail fracture surfaces.

13 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

No4 bearing outer race with tracers, and groves from rollers. This condition with HPT shaft wear, has been concluded as a effect of HP rotor unbalance

14 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

HPT shaft – wear on 3 o'clock position ALF

LPT shaft with wear

15 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

3-2 Engine disassembly – cont.

- Due to impossibility to rotate the N2, and in order to apply tooling correctly booster, No1 and No 2 bearing supports were disassembled.
- After booster disassembly fwd stationary oil seal found cracked around 360 degree – on the flange , and missed in material
- Core removed with HBG and No 3 (ball and roller) bearing sited on HPC front shaft due to the separation of all 24 attachment studs from No 3 bearing support.
- #3 bearing rear stationary seal totally damaged - separated
- RDS in good condition
- No 3 ball bearing squirrel cage distorted and separated at flange junction.
- No 3 roller bearing in good shape in general. It shows that it is secondary damage as result of outer race displacement, post stud rupture, with roller rear face periphery rubbed with outer race FWD chamfer and outer race way rubbed by interference with No 3 roller deflector. Caused by HP shaft movement.
- In fact that all the rollers No 3 roller bearing remain in place within cage indicates that the outer race backward escaping occurred at low speed, such a phenomenon at high speed would have lead to the liberation of the rollers by centrifugal effect.

16 / CFM Proprietary Information subject to restrictions on the cover

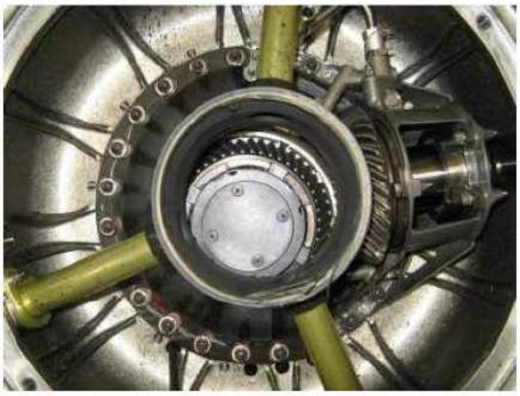
Comair CFM56-7B ESN 890-816

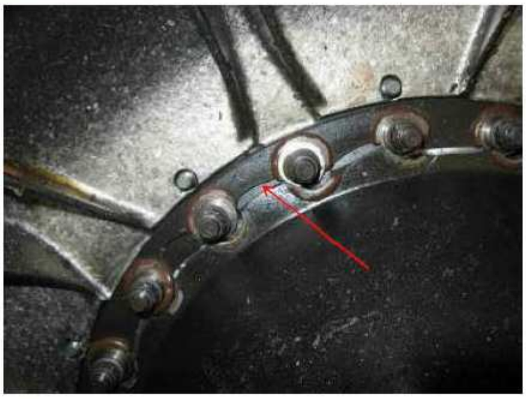
3-2 Engine disassembly – cont. core disassembly

- LPT St 1 nozzle damaged at leading edge as results of HPT blade liberation and pieces impact.
- HPT nozzle damaged also by impacts at trailing edge.
- HPT shrouds heavy damaged, with missed material around the circuit
- HPT blade liberated
- 3 blades separated below platform. All 3 blades have evidence of fatigue cracking starting from convex inner side of forward cavity.
- Further examination of disassembled HPT blades showed addition 11 blades with cracks below the platform
- All of the cracked blades – 14 in total – are P03 blades installed initially on 890-816 engine
- Combustor case in general good condition without abnormal findings
- HPC stator damaged as a result of RTS contact due to HP shaft movement
- HPC blades exhibit tip wear, mostly on St 1. as a result of HPC rotor orbiting motion, and separation of forward and rear stationary seals.

17 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

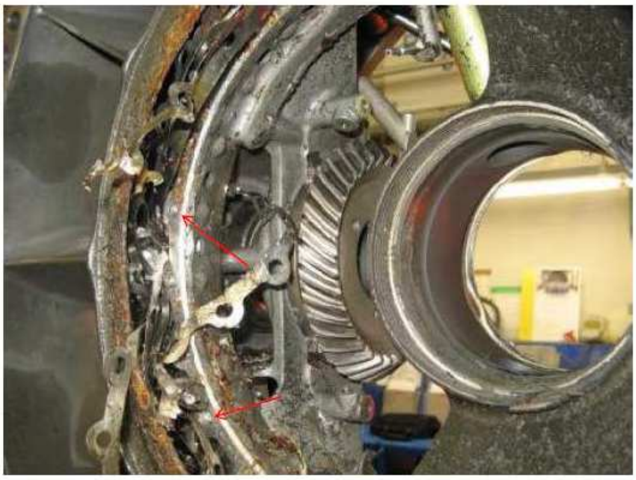




Fwd oil stationary seal cracked around 360 degree. Some parts missed

18 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816



All 24 attachment studs broken off

No 3 bearing rear stationary seal separated

19 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

RDS

Front view of HPC with IGB bevel gear, locking nut and bearing still sited on HPC shaft

20 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

Separated attachment studs

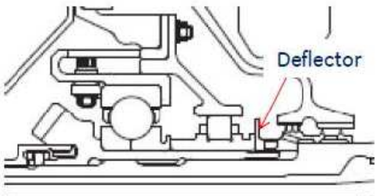
No 3 bearing

21 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

No 3 roller bearing outer race

Wear from deflector



22 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

No 3 bearing rollers – general in good condition with small defects/deformation as a result of outer race replacement

23 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

HPT shrouds with LPT St 1 nozzle damaged

24 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

HPT disk rear view showing residual high unbalance induced by the snail shape rupture of the blades with max length measured ~31mm

25 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

Below the platform

HPT blades liberation

26 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

HPT blades with pre-existing cracks under the platform

29 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

Combustor case in good condition

30 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

HPC rotor

HPC blades with tip wear

31 / CFM Proprietary Information subject to restrictions on the cover

Comair CFM56-7B ESN 890-816

HPC forward stator case

HPC rear stator case stators

32 / CFM Proprietary Information subject to restrictions on the cover

5.3 Appendix C - Engine Failure Investigation Report B

The Power of Flight

Comair CFM56-7B ESN 890-816

HPT Blade Under Platform Separation

P/N: 1957M10P03

S/N's: BWHN3C97; BWHN8C60; BWHN9B89

TSN/CSN: 26,808/17,049

SR # 7-1-2978265869

Introduction

On 02/27/2013, Comair aircraft 737-800 experienced No.2 engine failure (CFM56-7B ESN 890-816) during take-off in Cape Town International Airport. The failure was associated with a loud bang. The crew aborted the take-off and it was possible to vacate the runway on the engine power delivered by the No.1 engine. Engine debris was ejected via the tailpipe. The runway had to be closed after the incident. Aerodrome rescue and fire fighting (ARFF) personnel responded swiftly and a runway clean-up process was initiated and completed within 25 minutes. This was a domestic scheduled flight operating as flight CAW104.

The failed engine was inducted into GE Wales and on disassembly 3 HPT blades P/N 1957M10P03 were found to have liberated below the platform. The engine had a shop visit for performance restoration in 2011 at GE Wales. The engine and HPT blade history are as follows:

Engine
- TSN/CSN: 26,808/17,049; TSSV/CSSV: 4,182/2,883

HPT blade P/N 1957M10P03 (66)
- TSN/CSN: 26,808/17,049; TSSV/CSSV: 4,182/2,883

HPT blade P/N 1957M10P04 (14)
- TSN/CSN: 4,182/2,883

Evaluation and Findings

Fracture surface analysis of three below platform separated HPT blades (S/N's BWHN3C97; BWHN8C60; BWHN9B89) revealed presence of fatigue characteristics on the fracture surface of all three blades. Blade BWHN3C97 was identified as the prime blade based on the extent of fatigue crack propagation on the fracture surface prior to blade eventual separation by tensile overload.

Prime blade BWHN3C97 showed primary fatigue crack initiation via multiple origins from internal CVX surface of cavity #1 shank transition zone. Evidence of secondary fatigue crack initiation was also observed from internal CCV surface of cavity #1 shank transition zone. Overall fracture morphology was consistent with a slower moving, higher stress low cycle fatigue (LCF) mechanism progressing through the wall then crack propagation forward and aft until final separation by tensile overload. Fatigue crack propagation of the prime blade encompassed approx. 65% of the fracture surface prior to final separation.

Blades BWHN8C60 and BWHN9B89 also had primary fatigue cracking on cavity #1 transition zone CVX wall. Fatigue cracks propagated thru cavity #1 CVX wall but the majority of the fracture surface showed characteristics of tensile overload as a result of secondary impact damage.

All 66 M10P03 blades in this blade set were PtAl coated by Coating 1 process while 14 M10P04 blades were PtAl coated with Coating 3 process. (In the time frame of the manufacture of the M10P03 blades, there were 3 different coating processes used)

Evaluation and Findings (Cont'd)

Visual inspection of remaining 77 blades (63 M10P03 and 14 M10P04 blades) found 11 M10P03 blades with visible thru wall transition zone cracks on the external CVX wall. In addition, 6 M10P03 blades (without visible thru wall cracks) and all 14 M10P04 blades were sectioned in the shank transition zone and step polished 4 times (40-50 mils each step) in the upward direction for evaluating transition zone crack depth and internal coating thickness.

All 6 M10P03 blades showed no internal coating in the shank transition zone area but all 14 M10P04 blades had internal coating in the shank transition zone area. These internal coating thickness results are consistent with the capability of aluminide coating processes used by Coating 1 and 3 processes used to coat M10P03 and M10P04 blades, respectively.

4 out of 6 sectioned M10P03 blades had transition zone cracks > 10 mils with the maximum crack size of ~ 54 mils. The maximum transition zone crack in M10P04 blades was found to be ~ 3.0 mils but these crack sizes are exaggerated by secondary impact damage. These 6 sectioned M10P03 blade data, together with the three under platform separations and 11 thru wall transition zone crack M10P03 blades, suggest that M10P03 blades coating with Coating 1 process have higher tendency of developing deeper transition zone cracks; this observation is consistent with previous M10P03 blade evaluation results.

Evaluation and Findings (Cont'd)

This is the 4th CFM56-7B engine failure event related to M10P03 blade shank transition zone cracking.

ESN	Date	Event	Blade CSN
890833	11-Mar-11	IFSD	17100
890848	11-Sep-12	IFSD	17700
890853	26-Oct-12	IFSD	16900
890816	27-Feb-13	IFSD	17049

- CFM revised SB 72-0821 in March-2013
  - Reduced recommended removal time from 25,000 CSN to 16,500 CSN for a specific population of 1957M10P03 blades
    - Number of blades in population = ~6,100
    - Blades identified by Blade Serial Number and original ESN installation
- Repairs cancelled for these S/N blades

Figure 1. Overviews of ESN890-816 HPT rotor assembly after removal from the event engine. Three HPT blades (two of them shown in the pictures above) had under platform separation. The remaining HPT blade set had missing/broken airfoil above platform as a result of secondary impact damage.

Table 1. A list of HPT blade P/N, S/N, repair code, and cage code.

Pos.	P/N	S/N	Rapair Code	Cage Code	Pos.	P/N	S/N	Rapair Code	Cage Code
1	BWHN3C94	1957M10P03	G12 142	59669	41	FEL57EC8	1957M10P04	N/A	324H3
2	BWHN0A90	1957M10P03	G12 142	59669	42	BWHN8C31	1957M10P03	G12 142	59669
3	BWHN7B18	1957M10P03	G12 142	59669	43	FEL69EC3	1957M10P04	N/A	324H3
4	FEL57EC7	1957M10P04	N/A	324H3	44	BWHN4C13	1957M10P03	G12 142	59669
5	BWHN7B07	1957M10P03	G12 142	59669	45	FEL13DY1	1957M10P04	N/A	324H3
6	BWHN0A91	1957M10P03	G12 142	59669	46	BWHN7B28	1957M10P03	G12 142	59669
7	BWHN8B03	1957M10P03	G12 142	59669	47	FEL24DA2	1957M10P04	N/A	324H3
8	BWHN8B40	1957M10P03	G12 142	59669	48	BWHM9W52	1957M10P03	G12 142	59669
9	FEL14BN0	1957M10P04	N/A	324H3	49	FEL19BN4	1957M10P04	N/A	324H3
10	BWHN3C87	1957M10P03	G12 142	59669	50	BWHN3B99	1957M10P03	G12 142	59669
11	FEL24DA3	1957M10P04	N/A	324H3	51	FEL24DA0	1957M10P04	N/A	324H3
12	BWHN9B62	1957M10P03	G12 142	59669	52	BWHN3B91	1957M10P03	G12 142	59669
13	FEL13BN9	1957M10P04	N/A	324H3	53	FEL57EC5	1957M10P04	N/A	324H3
14	BWHN8C93	1957M10P03	G12 142	59669	54	BWHN0A74	1957M10P03	G12 142	59669
15	BWHN1D41	1957M10P03	G12 142	59669	55	BWHN0A83	1957M10P03	G12 142	59669
16	BWHN3C88	1957M10P03	G12 142	59669	56	BWHN3B84	1957M10P03	G12 142	59669
17	BWHN1D32	1957M10P03	G12 142	59669	57	FEL10DY7	1957M10P04	N/A	324H3
18	BWHN8C85	1957M10P03	G12 142	59669	58	BWHN9B81	1957M10P03	G12 142	59669
19	BWHM9W28	1957M10P03	G12 142	59669	59	BWHN9C07	1957M10P03	G12 142	59669
20	BWHN0C26	1957M10P03	G12 142	59669	60	BWHN0C36	1957M10P03	G12 142	59669
21	BWHN8B98	1957M10P03	G12 142	59669	61	BWHN0A79	1957M10P03	G12 142	59669
22	BWHN0A89	1957M10P03	G12 142	59669	62	BWHN3B81	1957M10P03	G12 142	59669
23	BWHN0C40	1957M10P03	G12 142	59669	63	BWHN9B98	1957M10P03	G12 142	59669
24	BWHM9W12	1957M10P03	G12 142	59669	64	BWHM9W61	1957M10P03	G12 142	59669
25	BWHN8B31	1957M10P03	G12 142	59669	65	BWHN7B46	1957M10P03	G12 142	59669
26	BWHN0A92	1957M10P03	G12 142	59669	66	BWHM9W24	1957M10P03	G12 142	59669
27	BWHN7B62	1957M10P03	G12 142	59669	67	BWHN3C97	1957M10P03	G12 142	59669
28	BWHN7B04	1957M10P03	G12 142	59669	68	BWHN9C05	1957M10P03	G12 142	59669
29	BWHN9B69	1957M10P03	G12 142	59669	69	BWHN7B40	1957M10P03	G12 142	59669
30	BWHN0C39	1957M10P03	G12 142	59669	70	BWHN0C20	1957M10P03	G12 142	59669
31	BWHM9W18	1957M10P03	G12 142	59669	71	BWHN8B21	1957M10P03	G12 142	59669
32	BWHN9B78	1957M10P03	G12 142	59669	72	BWHN9B96	1957M10P03	G12 142	59669
33	BWHN9B89	1957M10P03	G12 142	59669	73	BWHN7B58	1957M10P03	G12 142	59669
34	BWHN8B00	1957M10P03	G12 142	59669	74	BWHM9W17	1957M10P03	G12 142	59669
35	BWHN0A99	1957M10P03	G12 142	59669	75	FEL7YT46	1957M10P04	N/A	324H3
36	BWHN9C12	1957M10P03	G12 142	59669	76	BWHN4C18	1957M10P03	G12 142	59669
37	BWHN7B42	1957M10P03	G12 142	59669	77	BWHM9W15	1957M10P03	G12 142	59669
38	BWHN8C60	1957M10P03	G12 142	59669	78	BWHN8C34	1957M10P03	G12 142	59669
39	BWHN8B15	1957M10P03	G12 142	59669	79	FEL13DY3	1957M10P04	N/A	324H3
40	BWHM9W38	1957M10P03	G12 142	59669	80	BWHM9W09	1957M10P03	G12 142	59669

Prime blade

Additional U/P separated blade

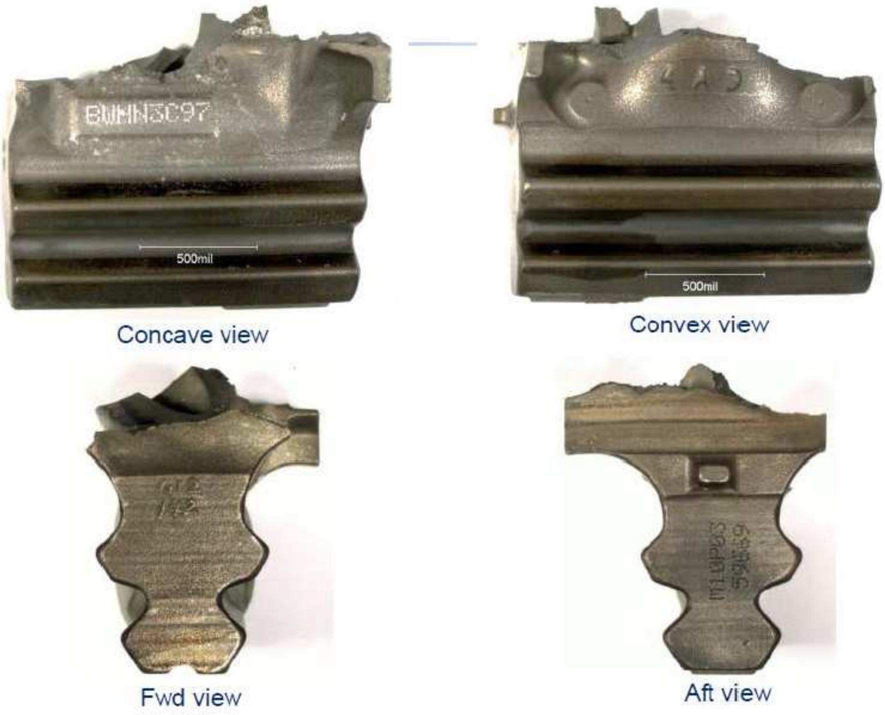


Figure 2. Overviews of blade BWHN3C97 that separated under the platform.

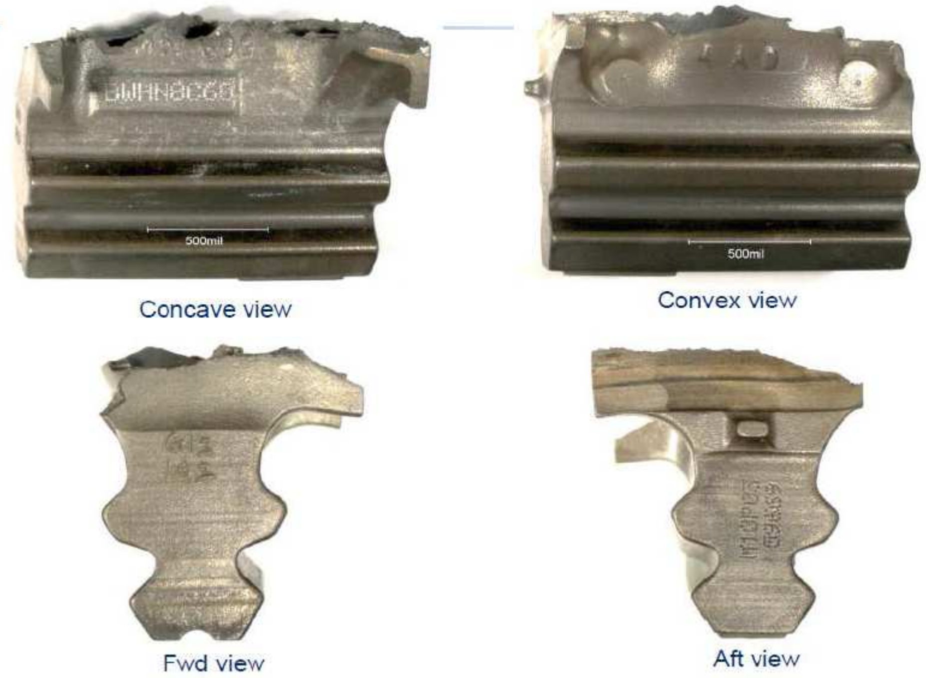


Figure 3. Overviews of blade BWHN8C60 that separated under the platform.

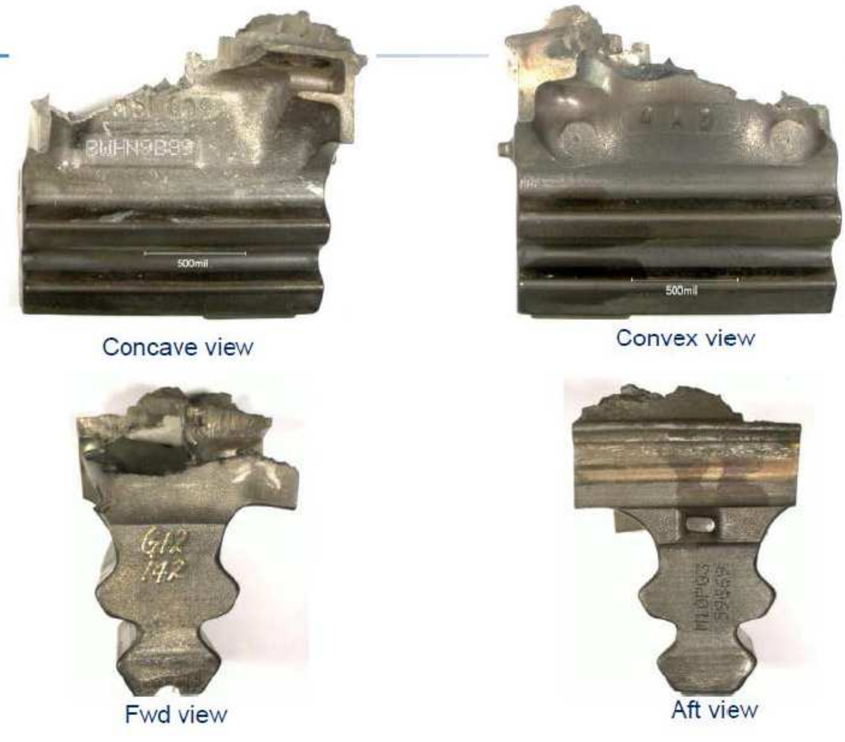


Figure 4. Overviews of blade BWHN9B89 that separated under the platform.

Fracture Surface Analysis of Under Platform Separated Blades

- BWHN3C97
- BWHN8C60
- BWHN9B89

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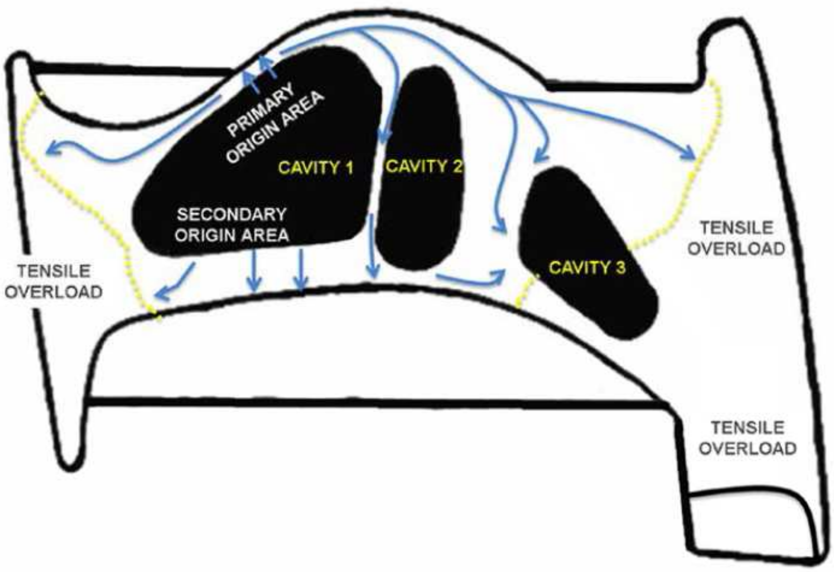

Figure 5. Top view of blade BWHN3C97. Primary fatigue crack initiation occurred via multiple origins from internal CVX surface located within cavity #1 shank transition zone. Evidence of secondary fatigue crack initiation was also observed from internal CCV surface of cavity #1 shank transition zone. White arrows indicate fatigue crack propagation directions. This blade was identified as the prime blade based on the extent of fatigue crack propagation (- 65% of fracture surface) prior to eventual separation by tensile overload.

Figure 6. SEM photomicrographs showing primary fatigue crack initiation region on CVX internal surface located within cavity #1 shank transition zone of prime blade BWHN3C97. Fatigue cracks initiated via multiple origins from internal surface and propagated thru CVX wall. Heavy oxidation was observed on the crack surface.

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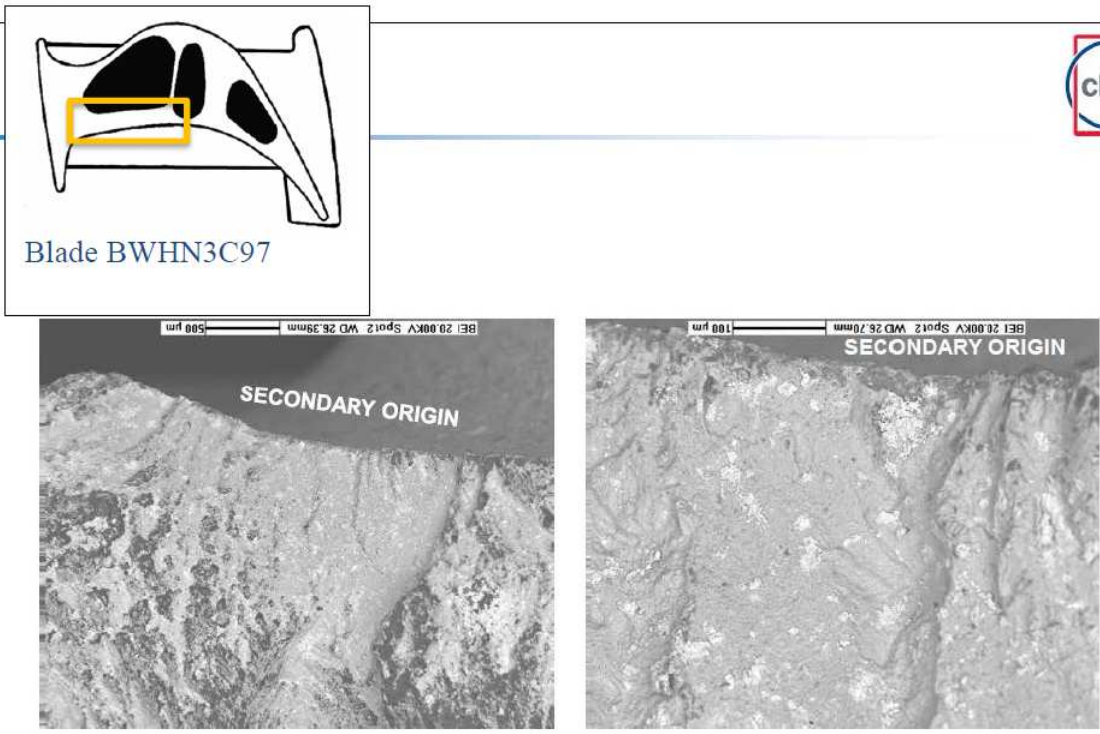

Figure 7. SEM photomicrographs showing secondary fatigue crack origins on CCV internal surface located within cavity #1 shank transition zone of prime blade BWHN3C97. Fatigue cracks initiated via multiple origins from internal surface and propagated thru CCV wall. Heavy oxidation was observed on the crack surface.

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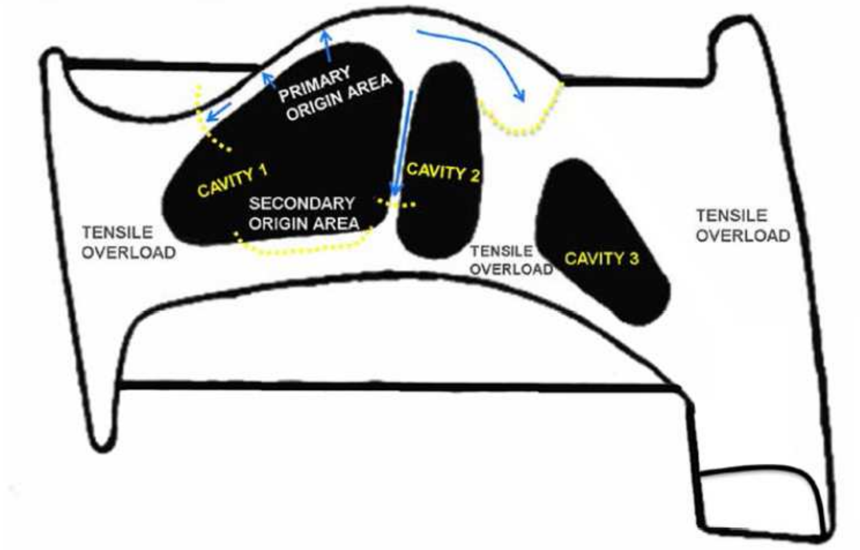

Figure 8. Top view of blade BWHN8C60. Primary fatigue crack initiation occurred via multiple origins from internal CVX surface located within cavity #1 shank transition zone. Fatigue cracks propagated thru cavities #1 & #2 CVX wall but the majority of the blade fracture surface showed characteristics of tensile overload as a result of secondary impact damage.

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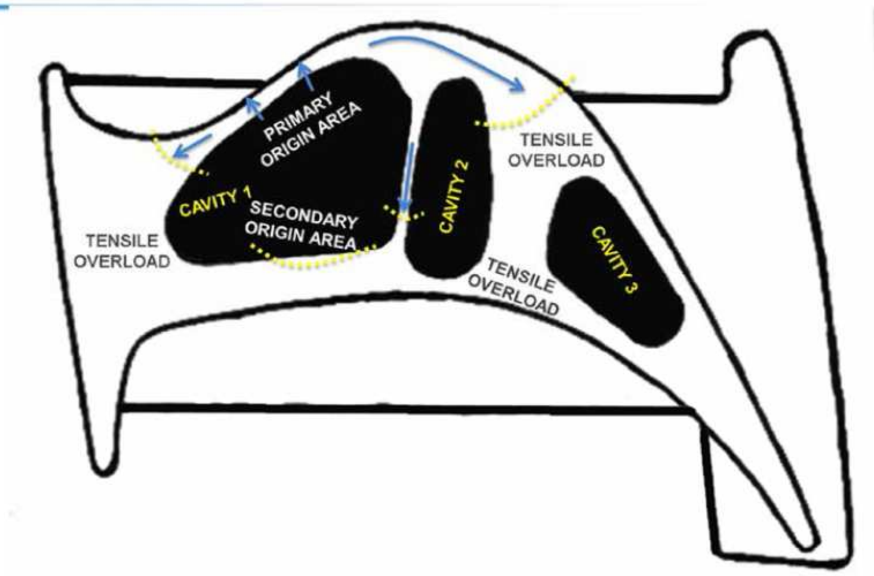

Figure 9. Top view of blade BWHN9B89. Primary fatigue crack initiation occurred via multiple origins from internal CVX surface located within cavity #1 shank transition zone. Fatigue cracks propagated thru cavities #1 & #2 CVX wall but the majority of the blade fracture surface showed characteristics of tensile overload as a result of secondary impact damage.

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Photo Documentation of
Thru Wall Transition Zone Crack Blades

Visual inspection of remaining 77 blades (63 M10P03 and 14 M10P04 blades) found 11 additional M10P03 blades with visible thru wall transition zone cracks on the external CVX wall:

- BWHN3B81
- BWHM9W12
- BWHN9C12
- BWHN3B84
- BWHN7B46
- BWHN8C31
- BWHN9B98
- BWHN0A99
- BWHN8B03
- BWHN0C20
- BWHM9W17

Figure 10. Macro photos showing additional M10P03 blades with visible thru wall transition zone cracks on CVX walls (S/N's BWHN3B81, BWHM9W12, BWHN9C12, and BWHN3B84).

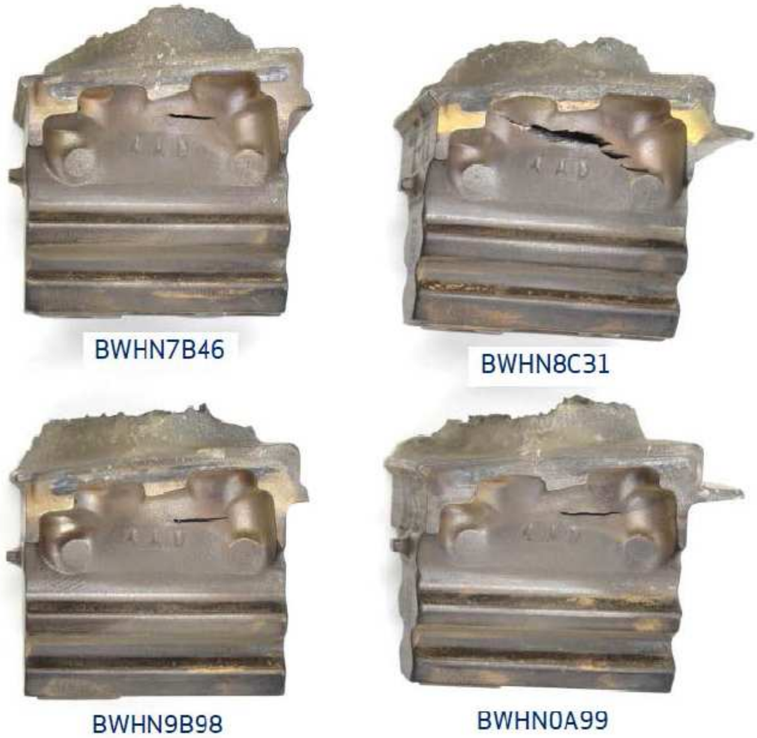

Figure 11. Macro photos showing additional M10P03 blades with visible thru wall transition zone cracks on CVX walls (S/N's BWHN7B46, BWHN8C31, BWHN9B98, and BWHN0A99).

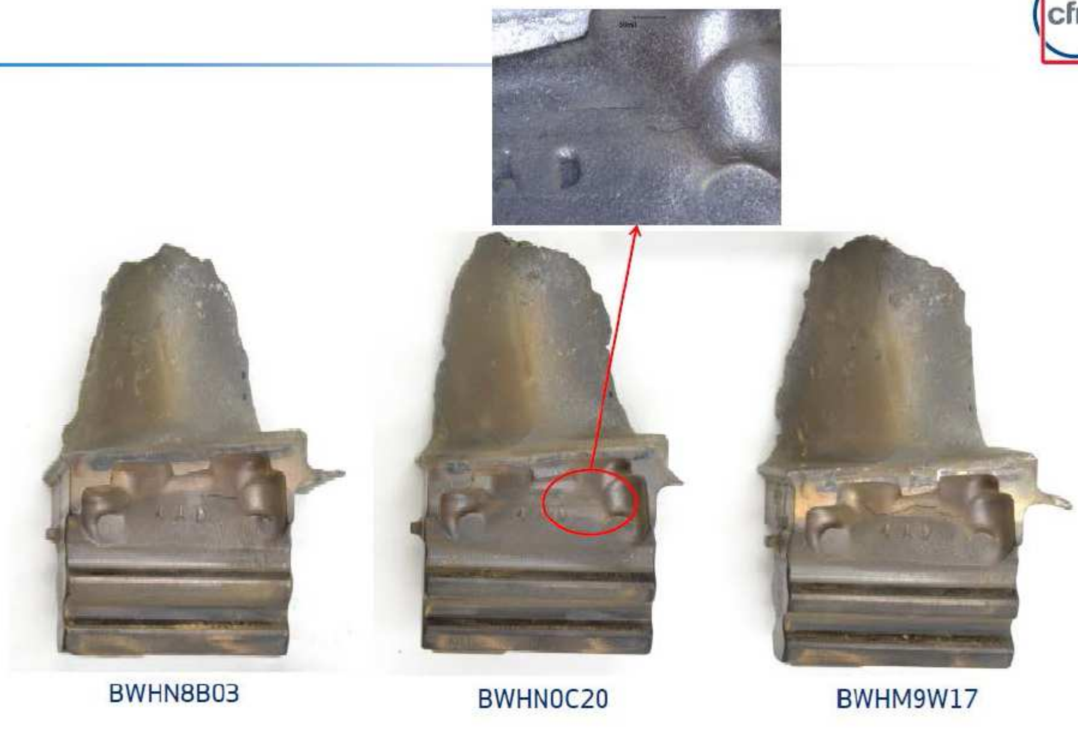

Figure 12. Macro photos showing additional M10P03 blades with visible thru wall transition zone cracks on CVX walls (S/N's BWHN8B03, BWHN0C20, and BWHM9W17).

Cut-Up Evaluation of Transition Zone Cracks and Internal Coating

6 M10P03 blades (without visible thru wall cracks) and all 14 M10P04 blades were sectioned in the shank transition zone per diagram shown on the right and step polished 4 times (40-50 mils each step) in the upward direction for evaluating transition zone crack depth and internal coating thickness.

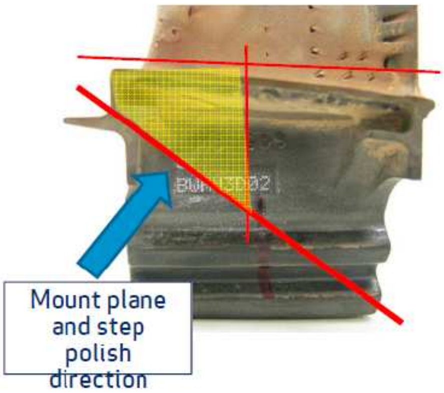

Table 2. Transition zone crack depth and internal coating thickness measurement data.

All 66 M10P03 blades in this blade set were PtAl coated with Coating 1 process while 14 M10P04 blades were PtAl coated with Coating 3 process. The measured TZ internal coating thicknesses shown in this table are consistent with the capability of aluminide coating processes used to coat the blade internal passages by Coating 1 and 3 processes, respectively.

The TZ crack sizes found in M10P04 blades (particularly for those > 1.0 mil) are exaggerated by secondary impact damage (see Figure 13 on next page).

4 out of 6 sectioned M10P03 blades had transition zone cracks > 10 mils with the maximum crack size of ~ 54 mils, suggesting that Coating 1 coated M10P03 blades have high tendency developing large size TZ cracks.

ESN	TSN	CSN	P/N	S/N	Measurement (mils)			PtAl Coating Vendor
					TZ Coating	Max CCV TZ Crack	Max CVX TZ Crack	
890-816	4182	2883	1957M10P04	FEL57EC5	0.9	0.0	1.0	Praxair
				FEL57EC8	0.8	0.0	2.2	
				FEL7YT46	0.8	0.0	1.0	
				FEL10DY7	1.1	1.0	2.7	
				FEL24DA3	1.0	1.0	3.0	
				FEL13DY3	0.7	1.0	1.0	
				FEL24DA2	0.7	1.0	1.0	
				FEL13DY1	0.7	1.0	1.0	
				FEL24DA0	0.8	1.0	1.0	
				FEL69EC3	0.7	1.0	1.0	
				FEL14BN0	1.0	1.0	1.0	
				FEL13BN9	0.8	0.0	1.0	
				FEL57EC7	0.6	1.0	1.0	
				FEL19BN4	0.9	1.0	2.4	
	26808	17049	1957M10P03	BWHN8C85	0.0	6.1	40.1	Howmet
				BWHN9B62	0.0	3.0	45.2	
				BWHN9B78	0.0	0.0	6.0	
				BWHM9W52	0.0	2.0	10.3	
				BWHN8B98	0.0	2.0	53.7	
				BWHN9B69	0.0	6.0	6.0	

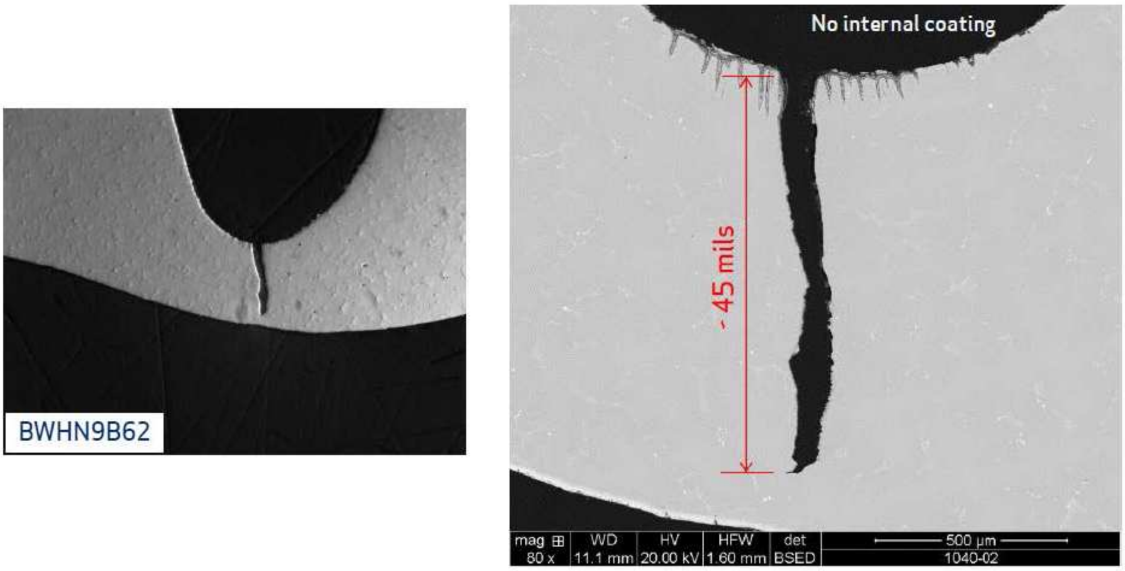

Figure 15. Optical and SEM photomicrographs showing a large size transition zone crack found in M10P03 blade BWHN9B62 that was sectioned in the shank transition zone. No internal coating was observed on internal cavity wall surface. See Figures 16 and 17 for detailed SEM/EDS analysis of the transition zone crack surface.

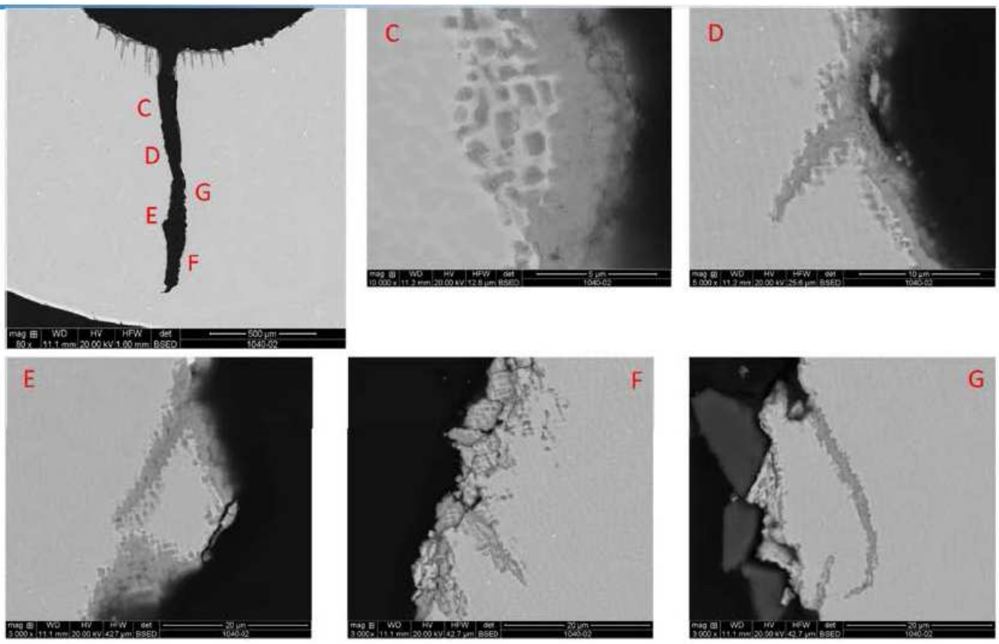

Figure 16. SEM photomicrographs showing oxidation at various locations of transition zone crack surface of M10P03 blade BWHN9B62. See Figure 17 for EDS chemistry analysis of the transition zone crack surface oxide layers.

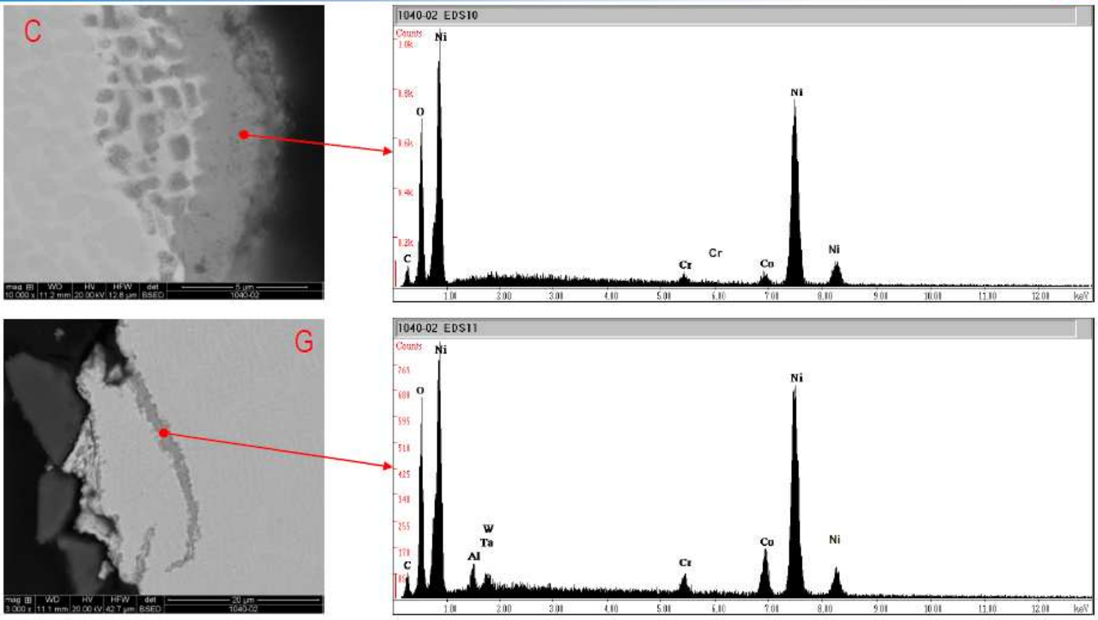

Figure 17. Representative EDS spectrums of the transition zone crack surface oxide layers of M10P03 blade BWHN9B62. No evidence of corrosion elements (e.g. sulfur) was detected in the oxide layers.

5.4 Appendix D - Letter to all CFM56-5B/7B Operators

The Power of Flight

Date: March 25th/2013

To: All CFM56-5B /7B Engine Operators
Copy: All Reps (information only)

Message No: 13/CFM/692

Subject: CFM56-5B/7B HPT Rotor Blades

The CFM fleet experienced three HPT rotor blade separation events with P/N 1957M10P03 blades during 2011 and 2012 due to transition zone cracking. These separations occurred on HPT rotor blades that had accumulated from 16,900 to 17,700 CSN. CFM has conducted a field sampling plan and engineering investigation and has identified that these events are isolated to a specific population of approximately 6,100 HPT rotor blades, originally delivered in 2004 and 2005.

The Purpose of this All Operator Wire is to inform the operators that CFM is revising CFM56-5B Service Bulletin 72-0803 and CFM56-7B Service Bulletin 72-0821 to recommend that these specific 1957M10P03 HPT rotor blade serial numbers be removed from service at or before the accumulation of 16,500 cycles since new. CFM is targeting late March for Service Bulletin revision.

For engines that have accumulated more than 16,500 cycles since new on these HPT blades, it is encouraged that operators work with their customer support manager to develop an expedited removal plan.

Customer Support Director
CFM International