NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

February 14, 2014

POWERPLANT FACTUAL REPORT

NTSB No: ENG11IA043

A. INCIDENT

Location: Atlanta, Georgia

Date: August 6, 2011

Time: 1142 Eastern Standard Time (EST)

Aircraft: McDonnell Douglas DC-9-51, Registration No. N676MC, Delta Air Lines

B. POWERPLANTS GROUP

Member: Jeff Kennedy
National Transportation Safety Board
Miami, Florida

Member: Christopher Demers
Pratt & Whitney
East Hartford, Connecticut

Member: Steven Armstrong
Delta Air Lines
Atlanta, Georgia

C. SUMMARY

On August 6, 2011, about 1142 EST, a Delta Air Lines McDonnell Douglas DC9-51, registration N676MC, equipped with two Pratt & Whitney (P&W) JT8D-17 turbofan engines, rejected takeoff from Hartsfield-Jackson International Airport (ATL), Atlanta, Georgia after experiencing a No. 2 (right) engine uncontained failure. The flight crew reported that, during the takeoff roll, at about 80 knots, a "bang" was heard and the airplane shuddered. The captain rejected the takeoff and stopped on the runway. The airplane was unable to taxi due to a brake lockup. Passengers were deplaned and bussed to the terminal. There were no injuries reported. An inspection of the airplane identified a penetration in the No. 2 engine cowling and an impact scar on the outer pane of a window on the right side of the airplane fuselage, forward of the engine. Examination of the engine found that one of the fan blades had separated below the platform and three small holes were observed in the compressor case. The flight was being operated in accordance with *14 Code of Federal Regulations Part 121* as a regularly scheduled flight from ATL to Pittsburgh International Airport (PIT), Pittsburgh, Pennsylvania.

The engine was removed from the airplane and shipped to the Turbine Engine Center in Miami, Florida for inspection and disassembly from September 20-21, 2011. During the engine examination the separated fan blade was recovered in three pieces, the blade root that was still present in the fan hub blade slot and two sections of the airfoil that were recovered loose inside the engine. Damage was observed to the inlet guide vanes (IGV's), remaining fan blades, fan exit guide vanes (FEGV's) and visible low pressure compressor (LPC) stages aft of the fan. The separated fan blade pieces, seven additional damaged but intact fan blades and the fuel oil cooler aft mounting bracket were shipped to the P&W materials lab for analysis.

Metallurgical analysis concluded that the separated fan blade failed due to a high cycle fatigue crack that originated approximately 0.9375 inch aft of the leading edge on the suction side of the blade. Replicas (molds) were taken on six fan blades at points along the leading edge that were undamaged during the event and then superimposed over a representative new fan blade profile to measure leading edge erosion. Four of the six fan blade replicas were at points along the leading edge that are considered repairable in accordance with the JT8D-17 repair manual. Measurements indicated that all four blades had leading edge erosion that was within allowable limits, but three of the four blades exceeded P&W's chord erosion estimate of 0.035 inches at 11,000 engine cycles.

Fan blade fatigue fracture due to excessive leading edge erosion was addressed by P&W in maintenance advisory notice MAN-JT8D-2-06, released on November 20, 2006. The advisory notice recommends fan blade refurbishment every 4,000 cycles to reduce fatigue fractures due to vibratory stress caused by leading edge erosion. The Federal Aviation Administration (FAA) subsequently released Airworthiness Directive (AD) 2010-21-17 for all JT8D engines on November 12, 2010, mandating fan blade leading edge overhaul after 4,000 cycles since the last blade overhaul was performed.

D. DETAILS OF THE INVESTIGATION

1.0 ENGINE INFORMATION

1.1 ENGINE HISTORY

According to Delta Air Lines maintenance records, engine serial number (ESN) 686229 had accumulated the following hours and cycles: 73,976 hours time since new (TSN), 72,839 cycles since new (CSN), 9,677 hours time since overhaul (TSO), and 11,350 cycles since overhaul (CSO).

The LPC module had accumulated 17,851 hours TSN and 14,752 CSN and was installed on the event engine on April 28, 2009. The LPC rotor was not debladed at the last shop visit.

1.2 ENGINE DESCRIPTION

The JT8D-17 series engine is a dual spool axial-flow turbofan engine featuring a six-stage low pressure compressor (LPC), a seven-stage high pressure compressor (HPC), a nine can (can-annular) combustion chamber, a single-stage high pressure turbine (HPT), and a three-stage low pressure turbine (LPT). The engine is equipped with a full length annular fan discharge duct. The low pressure system is comprised of the LPC and the LPT and is mechanically independent of the high pressure system which consists of the HPC and the HPT. The engine flange positions are illustrated in (**Figure 1**).

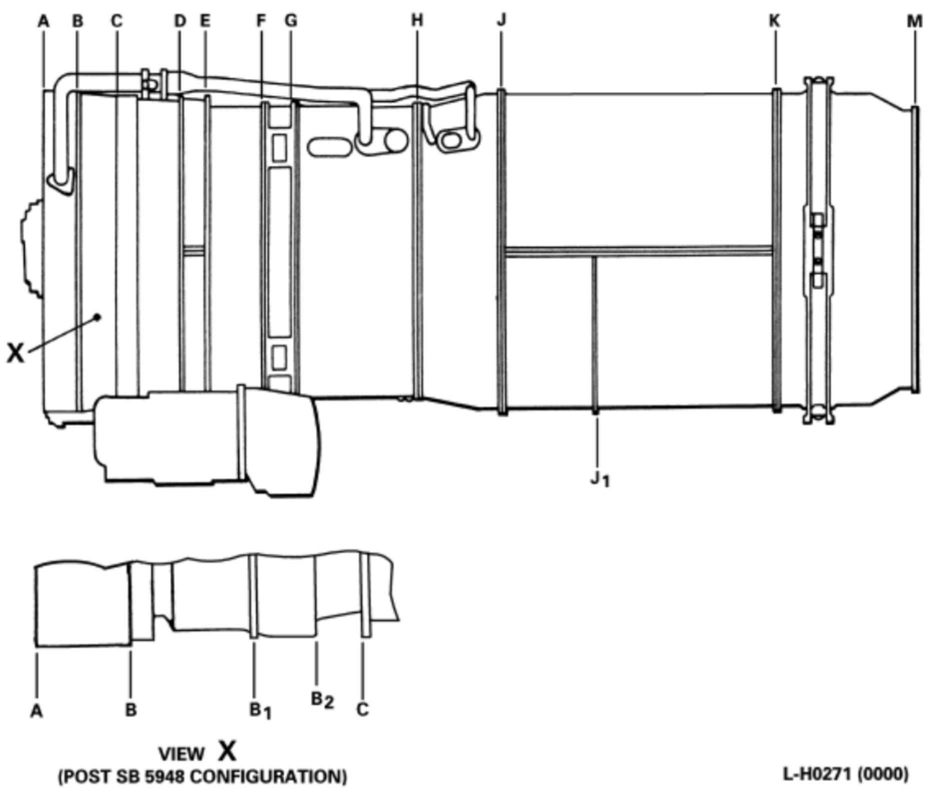

Figure 1- JT8D-17 Flange Diagram

According to the FAA Type Certificate Data Sheet, E2EA, Revision 31, dated August 28, 2007, the JT8D-17 engine has a sea level static takeoff thrust rating of 16,000 pounds and a sea level static continuous thrust rating of 15,200 pounds, both are flat rated to 77°F.[1]

All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF).

2.0 NACELLE EXAMINATION

2.1 AS RECEIVED

The upper cowling exhibited multiple dents and penetrations 6 to 8 inches aft of the cowl leading edge, from the 1 to 2 o'clock positions (**Photo 1**). The largest cowl penetration point aligned with a hole in the engine case aft of the B1 flange (**Photo 2**). The lower cowling was intact and in good condition.

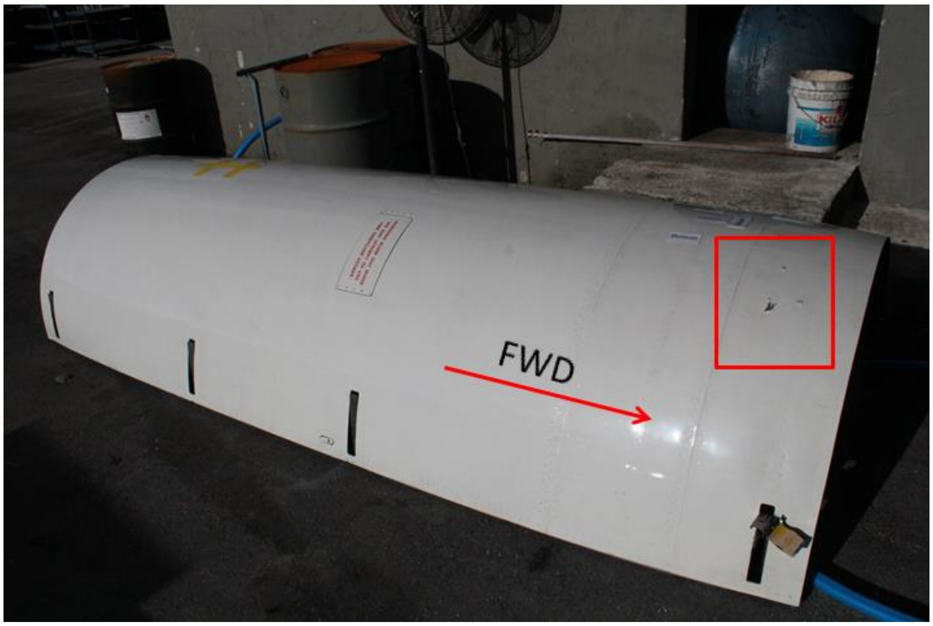

Photo 1- Upper Cowling Damage

[1] Flat-rated to a specific temperature indicates that the engine will be capable of attaining the rated thrust level up to the specified inlet temperature.

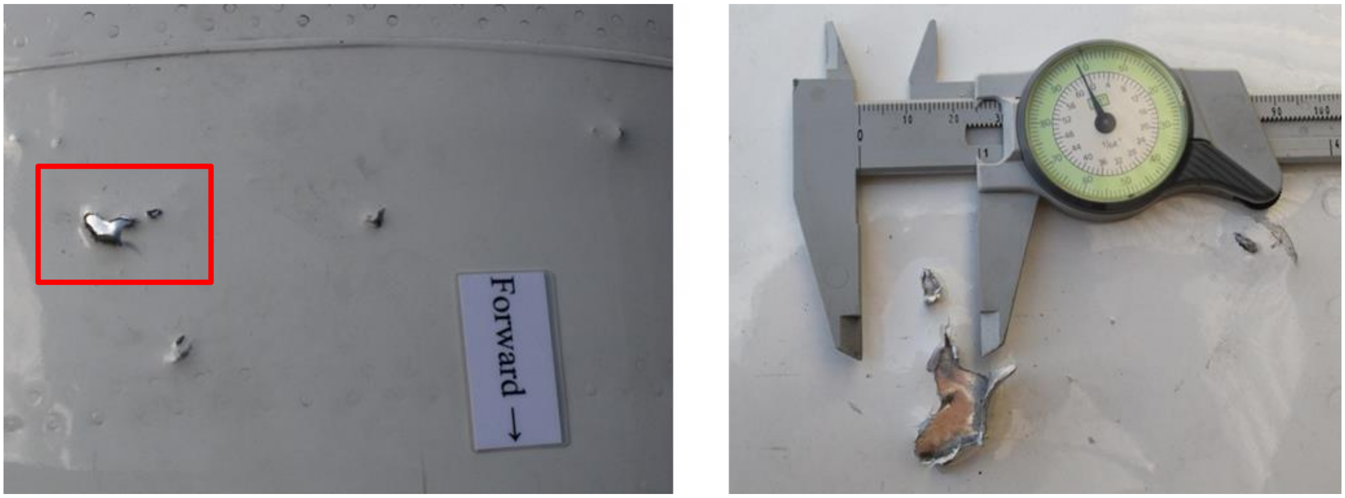

Photo 2- Upper Cowling Punctures

3.0 ENGINE DISASSEMBLY AND EXAMINATION

3.1 As Received

The engine was kept in its shipping stand for inspection and limited disassembly (**Photos 3 and 4**).The engine did not exhibit indications of an under cowl fire but had multiple compressor case breaches. A case penetration was located at the hush kit inlet extension, aft of the B flange at the 1 o'clock position (**Photo 5**). Small non-penetrating interior impacts were located in the same axial location from the 2 to 4 o'clock and 6 to 12 o'clock positions. Between the C and D flanges, there was a non-penetrating case dent 8 inches in length at the 2 o'clock position. Between the D and E flanges there was a small dent at the 2 o'clock position, a small penetration at the 5 o'clock position, and an airfoil fragment was found sticking out of the case at the 6 o'clock position. There were multiple small case dents with cracks extending from the dent impacts between the 1 and 5 o'clock positions.

Photo 3- Right Side of Engine, As Received

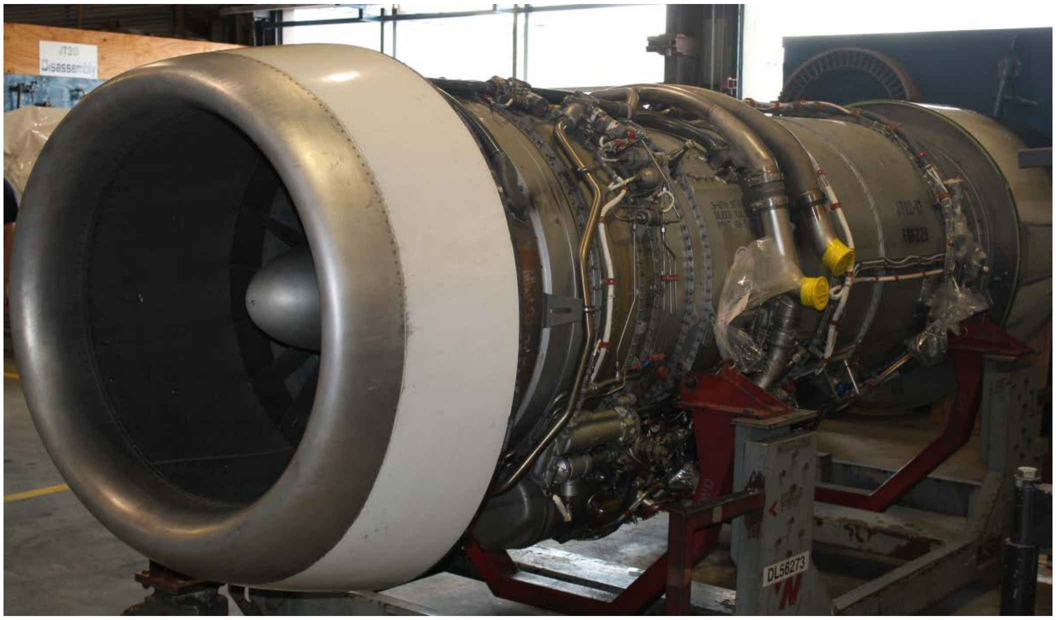

Photo 4- Left Side of Engine, As Received

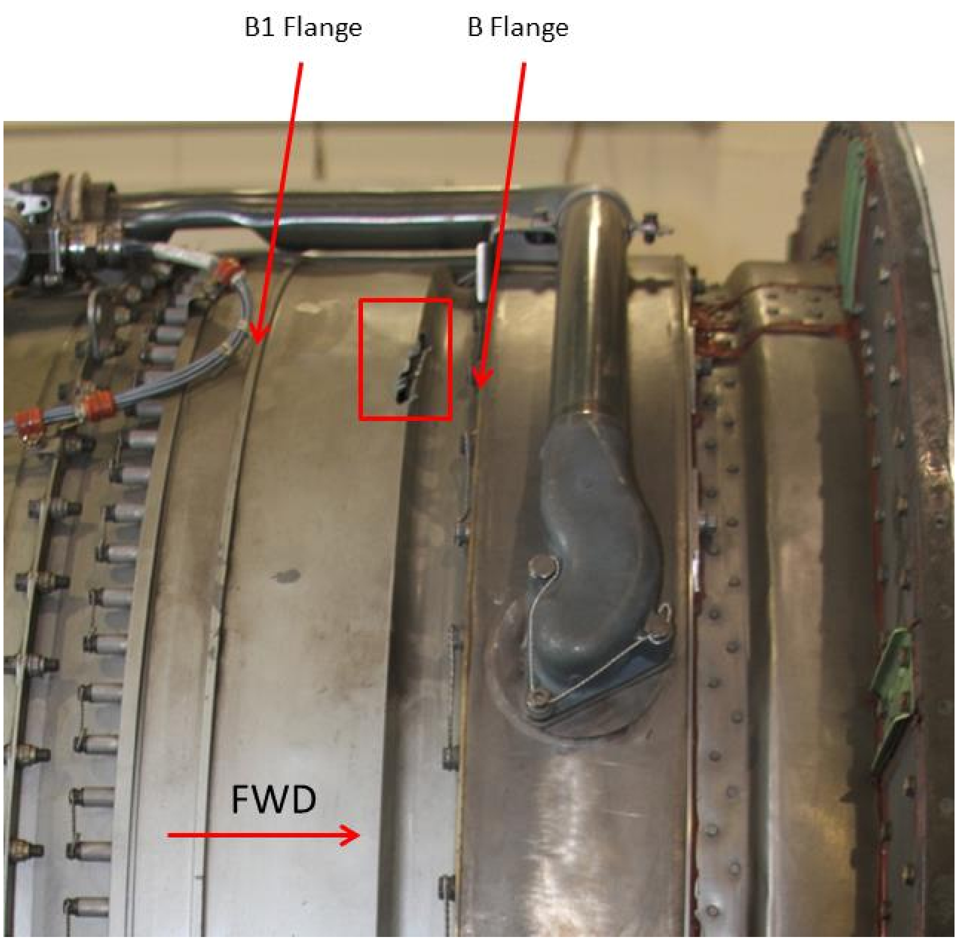

Photo 5- Compressor Case Puncture, Aft of B Flange

The fuel control, generator, hydraulic pump and other external components were intact and in place with no visible damage. The fuel oil cooler aft mounting bracket was buckled and fractured at two locations (**Photo 6**). The fuel oil cooler oil outlet tube was dented near the quick engine change throttle flex cable bracket, which had been removed prior to engine shipment. The forward nut on the oil pressure transmitter was found loose.

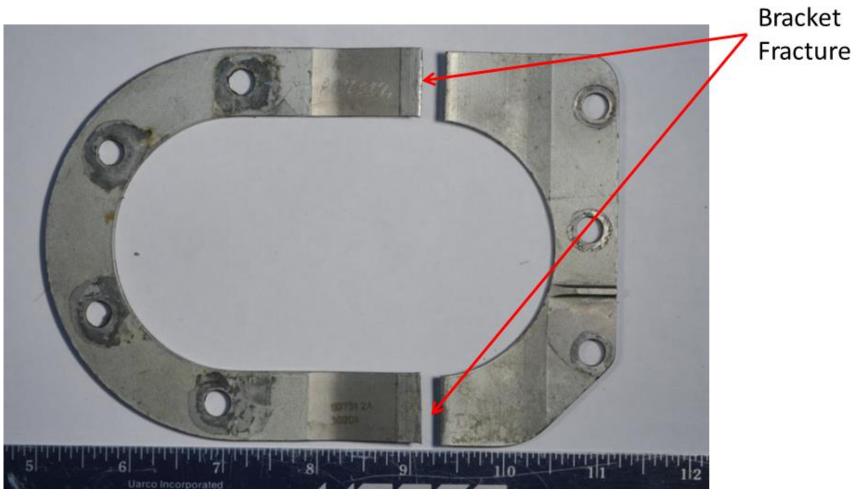

Photo 6-Fuel Oil Cooler Aft Mounting Bracket, Fractured Two Locations

The LPC and LPT rotated concurrently, verifying LPT shaft continuity. There was a small metallic fragment found in the bypass duct. Light metal splatter was noted on the exhaust duct interior surface. A FEGV fragment was found at the 6 o'clock position in the exhaust duct, and another at the 12 o'clock position leaning against an outer duct support strut.

3.2 Low Pressure Compressor

One IGV at the 5:30 position was partially separated at the outer diameter attachment and bent at the trailing edge outer span, consistent with impact. The remaining IGV's had impact damage including gouges, scrapes, and dents along the trailing edge concentrated along the outer half of the vane span. A majority of the IGV case sound absorbing liner material aft of the vanes was missing, except a small section at the 12 o'clock position. The inner sound absorbing liner had multiple dents, dings, and cuts around the circumference. An ultraviolet light inspection of the IGV's and fan blades did not identify organic deposits.

The fan rotor exhibited extensive damage, and one fan blade was separated below the platform. The separated blade root was still present in the fan hub blade slot (**Photos 7 and 8**). Two sections of the separated blade airfoil were recovered within the engine at ATL and sent in a separate box with other collected engine debris. The separated blade was labeled as blade No. 1 and the remaining 26 blades were numbered sequentially in the clockwise direction.

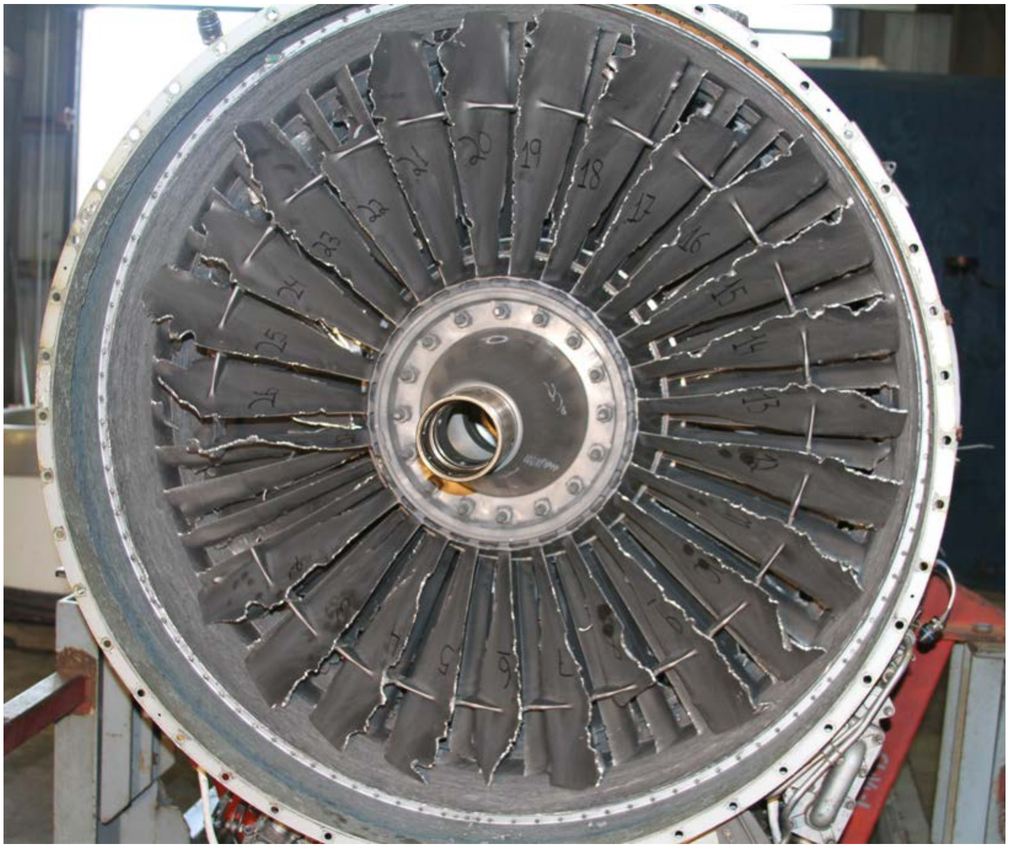

Photo 7- Fan Rotor Damage

Photo 8- Fractured Fan Blade, Blade Root Still Present in Slot

The No. 1 bearing was exposed and found intact and oil wetted. The bearing rotated freely without indications of binding. The bearing labyrinth seals exhibited slight, non-typical wear including scuffing of seal material.

The fan hub was intact and in good condition. A nick was noted on the blade No. 1 dovetail slot exit and radial scoring was observed on the blade slot pressure (concave) side attachment face. The outer tang (rail) of the adjacent blade (No. 27) exhibited rub damage. The fan blade retaining ring had a small piece of raised material on the aft surface.

The fan exit stator had three vane airfoils, including the inner attachments, separated from the case. The outer shrouds of the missing vanes remained intact and in place. Two of the three vanes were later recovered behind the LPC 2nd stage rotor. The inner and outer fan exit stator cases were intact and in good condition.

A visual examination of the LPC 2nd stage rotor revealed blade tip bending opposite the direction of rotation 360 degrees around. The leading edge of all blades exhibited extensive gouging, tearing, and missing material. One blade was found twisted opposite the direction of blade camber. All blades had impact damage along the trailing edge and multiple blades were missing material at the trailing edge tip.

Fan exit guide vanes were found separated from the 11 to 2 o'clock positions. Two vanes were recovered from the turbine exhaust case. One piece of a FEGV attachment was located in the box of debris collected on scene at ATL.

3.3 Low Pressure Turbine

The LPT 3rd stage blades were intact and in good condition as viewed through the exhaust. No damage was noted to LPT stages visible through the 3rd stage blades.

4.0 METALLURGY

4.1 Fan Blades

Visual and binocular examination of the separated No. 1 fan blade pieces identified two chord-wise fractures, one at the root and a second just below the blade mid-span (**Photo 9**). The root fracture origin was located approximately 0.9375 inch aft of the leading edge on the suction side of the blade. Examination by scanning electron microscope noted feathery cleavage features progressing from the origin consistent with high cycle fatigue. No anomalies were identified around the crack origin that may have contributed to the blade failure. The failure mode of the two airfoil sections could not be determined due to secondary damage to the fracture surfaces.

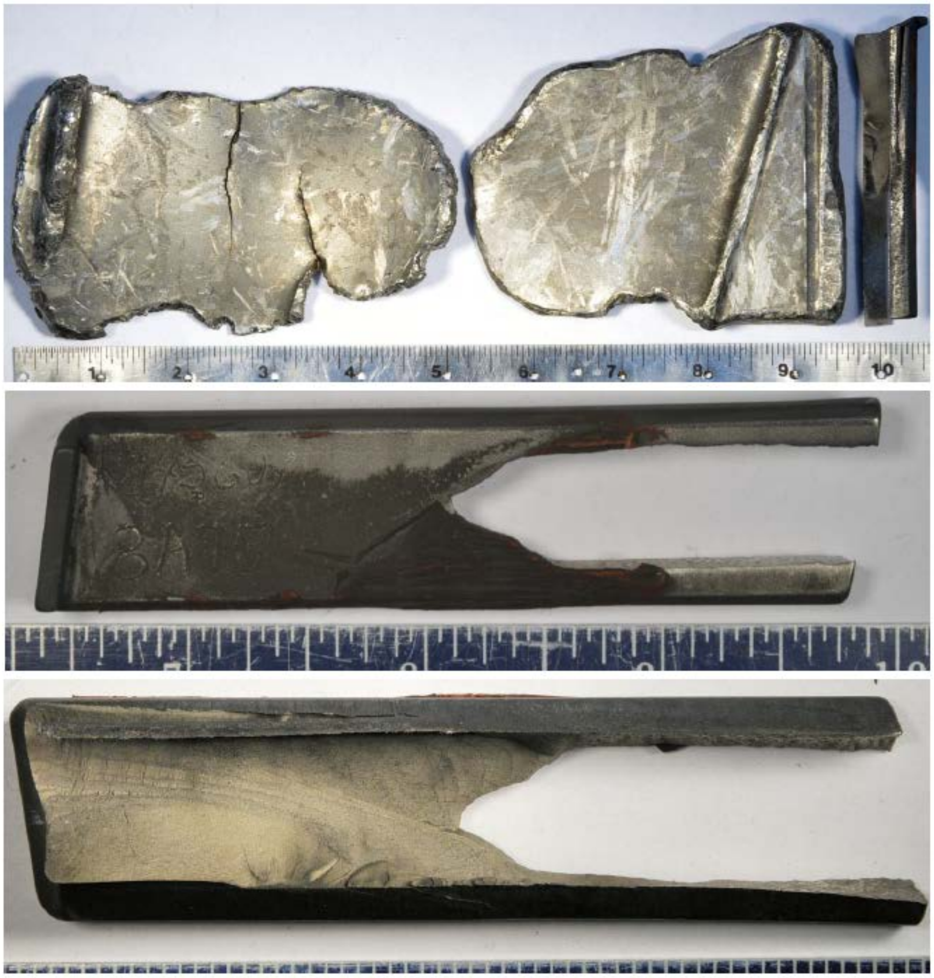

Photo 9- Fractured No. 1 Fan Blade Recovered in Three Pieces

A total of eight fan blades (Nos. 1, 5, 12, 16, 24, 25, 26, and 27) were submitted to the P&W materials lab for non-destructive evaluation. All fan blades exhibited impact damage to the leading and trailing edges and several blades were missing portions of the airfoil. Multiple blades exhibited visible erosion along the leading edge and blade shroud. Two of the blades (Nos. 5 and 24) had indications of previous leading edge airfoil repair/blending. The shrouds on all the blades exhibited witness marks and impact damage consistent with shingling[2] during the event.

Replicas were taken on six fan blades (Nos. 5, 12, 24, 25, 26 and 27) at points along the leading edge that were undamaged during the event using Dentsply caulk[3]. Four of the six replicas (Nos. 12, 24, 25 and 26) were taken at locations along the leading edge that are repairable in accordance with the JT8D-17 repair manual. The replicas were superimposed over a representative new fan blade profile to measure leading edge erosion. The measurements indicated that all four blades had leading edge erosion that was within allowable limits, but three of the four blades exceeded the P&W chord erosion estimate of 0.035 inches at 11,000 cycles.

[2] Shingling refers to a condition where fan blade shrouds overlap beyond the installed position.

[3] Dentsply caulk is a dental supply material typically used to take impressions of teeth. The material was selected because it releases well from airfoil surfaces and remains rigid enough to take accurate dimensional measurements.

P&W has identified excessive leading edge erosion as a contributing factor in fan blade high cycle fatigue fractures due to a flutter like vibratory response it causes in the blade. According to the P&W JT8D-17 repair manual during the blade overhaul procedure each individual blade must be removed from the fan disk and measured to ensure the chord length at multiple locations along the blade span are within allowable limits. If the fan blade meets minimum chord length requirements, a combination of tools are used to reshape the leading edge profile to optimize aerodynamic performance. A nominal leading edge thickness measurement between 0.024 and 0.030 inches at a point 0.030 inches from the leading edge of the blade is required for the fan blade scraping tool to properly seat on the blade surface. If the fan blade leading edge thickness measurements exceed 0.030 inches, sanders and files are used to decrease the thickness to nominal levels. Fan blade leading edge erosion, thickness and radius measurements collected from the incident engine are listed in **Table 1**. A complete copy of the P&W materials report is available as **attachment 1** to this report.

Fan Blade Number/ Distance From Blade Root	Replica A Chord Erosion (inch)	Replica B Chord Erosion (inch)	Leading Edge Thickness (inch)
No. 12 at 8.0 inches	0.120	0.062	0.042
No. 24 at 7.6 inches	0.020	0.017	~0.024-0.030
No. 25 at 8.7 inches	0.080	0.094	0.048
No. 26 at 7.5 inches	0.084	0.060	0.041

Table 1- Fan Blade Leading Edge Erosion Measurements

4.2 FUEL OIL COOLER AFT MOUNTING BRACKET

The fuel oil cooler aft mounting bracket fracture surfaces exhibited smearing and ductile dimples consistent with rapid tensile overload.

5.0 PRATT & WHITNEY MAINTENANCE ADVISORY AND FAA AIRWORTHINESS DIRECTIVE

Pratt & Whitney released JT8D maintenance advisory notice, MAN-JT8D-2-06, on November 20, 2006. The notice recommends leading edge fan blade refurbishment every 4000 cycles to ensure the aerodynamic properties of the blade are maintained and is critical in avoiding excess erosion levels that cause increased blade vibration and high cycle fatigue cracks. The FAA subsequently released AD 2010-21-17 with an effective date of November 12, 2010 mandating fan blade leading edge overhaul after 4,000 cycles since the last blade overhaul was performed.

ATTACHMENTS

1. Pratt & Whitney Materials and Processes Engineering Service Investigation Report #51596-NTSB, 6 February 2012