Aviation Investigation Final Report

Location:	Long Beach, California	**Incident Number:**	ENG14IA028
Date & Time:	September 18, 2014, 16:30 UTC	**Registration:**	N656JB
Aircraft:	Airbus A320 232	**Aircraft Damage:**	Minor
Defining Event:	Loss of engine power (partial)	**Injuries:**	147 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

On September 18, 2014, at approximately 0930 Pacific standard time (PST), an Airbus A320-232, registration number N656JB, flight number 1416, powered by two International Aero Engines (IAE) V2527-A5 turbofan engines, experienced a No. 2 (right) engine failure and subsequent undercowl fire during initial climb after departing Long Beach Airport (LGB), Long Beach, California The flightcrew shutdown the No. 2 engine, discharged both fire bottles, and performed an air turnback to Long Beach. The airplane made a successful and uneventful single-engine landing at LBG The incident flight was a 14 Code of Federal Regulations (CFR) Part 121 domestic passenger flight from LGB to Austin-Bergstrom International Airport (AUS) Austin, Texas. Day visual meteorological conditions prevailed at the time, and an instrument flight rules flight plan was filed. Examination of the outside of the engine revealed a fractured fuel pressure line to the station 2.5 low pressure compressor bleed valve slave actuator and evidence of thermal distress such as consumed, partially-consumed or oxidized insulation blankets, loop clamps cushions, wiring harness sheathing, and sooting of various components and cases. No case breaches or penetrations were noted although the LPT case did exhibited a localized outward bulge. Disassembly of the engine revealed that a single fir tree blade retaining lug from the high pressure turbine stage 2 disk had fractured and 2 HPT stage 2 blades had released. Metallurgical examination of the fractured HPT stage 2 disk lug revealed evidence of fatigue from multiple origins that propagated from the pressure side (PS) of the middle (No. 2) fillet towards the suction side (SS) almost through the entire width of the lug before finally fracturing due to progressive tensile overload. Closer examination of the fractured lug revealed a concave 'divot'/groove in the PS No. 2 fillet, immediately adjacent to the fracture surface that ran the entire length of the fillet. It was concluded that the groove appeared to be a tool mark resulting from the machining (broach) operation during the original manufacturing of the disk. Inspections of other HPT stage 2 disks manufactured using the same broaching tool at the fractured disk found the same grooving. Based on this event, the disk broaching procedures were reviewed and best practices were implemented to address these manufacturing deficiencies.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be:

The probable cause of the engine failure and subsequent undercowl engine fire was due to the fatigue fracture of a high pressure turbine stage 2 disk blade retaining lug that released two blades which impacted the low pressure turbine case causing a fuel line to fracture spraying fuel on the hot engine cases where it ignited. During a machining operation of the disk lug, a tool mark was introduced that set up the area for fatigue cracks to initiate.

Findings

Aircraft	Turbine section - Fatigue/wear/corrosion
Organizational issues	Equipment manufacture - Manufacturer
Personnel issues	(general) - Not specified

Factual Information

History of Flight

Initial climb	Loss of engine power (partial) (Defining event)
Initial climb	Engine shutdown
Initial climb	Fire/smoke (non-impact)
Initial climb	Cabin safety event

HISTORY OF FLIGHT

On September 18, 2014, at approximately 0930 Pacific standard time (PST), a jetBlue Airways Airbus A320-232, registration number N656JB, flight number 1416, powered by two International Aero Engines (IAE) V2527-A5 turbofan engines, experienced a No. 2 (right) engine failure and subsequent undercowl fire during initial climb after departing Long Beach Airport (LGB), Long Beach, California. According to the flightcrew, just prior to reaching 10,000 feet above ground level, they received several cockpit Electronic Centralized Aircraft Monitor (ECAM) messages relating to the No. 2 engine including an "ENG 2 FIRE WARNING" and were informed of smoke in the cabin. The flightcrew shutdown the No. 2 engine, discharged both fire bottles, and performed an air turnback to Long Beach. The airplane made a successful and uneventful single-engine landing at LBG and Aircraft Rescue and Fire Fighting (ARFF) personnel met the aircraft and observed no damage. Of the 142 passengers and 5 crewmembers on board the flight, no injuries were reported. The incident flight was a 14 Code of Federal Regulations (CFR) Part 121 domestic passenger flight from LGB to Austin-Bergstrom International Airport (AUS) Austin, Texas. Day visual meteorological conditions prevailed at the time, and an instrument flight rules flight plan was filed.

ENGINE DAMAGE EXAMINATION

On-site examination of the airplane revealed that the No. 2 engine (right) thrust reverser had considerable heat distress and some delamination, and small impact marks (no skin penetrations) on the right hand side aft fuselage near the rear cargo door and to the right hand horizontal stabilizer. Examination of the No. 2 engine revealed considerable low pressure turbine (LPT) blade damage and a fractured fuel pressure line to the station 2.5 low pressure compressor bleed valve slave actuator.

The engine was removed from the airplane and shipped to MTU in Germany for detailed examination. Examination of the outside of the engine revealed evidence of thermal distress such as consumed, partially-consumed or oxidized insulation blankets, loop clamps cushions, wiring harness sheathing, and sooting of various components and cases. No case breaches or penetrations were noted although the LPT case did exhibited a localized outward bulge. Disassembly of the engine revealed that all high pressure turbine (HPT) stage 2 blades were present except for two that were full length releases which included the root. A single fir tree blade retaining lug from the HPT stage 2 disk had fractured between the inner and middle attachment teeth of the fir tree slot and released two HPT stage 2 blades on either side of that fractured disk lug. Turbine hardware upstream of the HPT stage 2 disk did not exhibit any damage as a result of the HPT stage 2 blade releases; however, the remaining HPT stage 2 blades, along with

downstream turbine hardware, all exhibited varying degrees of heavy secondary impact damage, tears, and material loss.

TEST AND RESEARCH

Metallurgical examination of the fractured HPT stage 2 disk lug by IAE revealed evidence of fatigue from multiple origins that propagated from the pressure side (PS) of the middle (No. 2) fillet towards the suction side (SS) almost through the entire width of the lug before finally fracturing due to progressive tensile overload. The fractured disk lug was sectioned from the rest of the disk via wire electrical discharge machining to facilitate examination of the fracture surface. Closer examination of the fractured lug revealed a concave 'divot' in the PS No. 2 fillet, immediately adjacent to the fracture surface. The depth of the 'divot' measured up to 0.0008 inches at the fracture origin site and the 'divot' was confirmed to run the entire length of the fillet. Visual examination of all the other remaining lugs revealed that same 'divot' on PS No. 2 fillet and based on this IAE concluded that the groove appeared to be a tool mark resulting from the original machining (broach) operation. Visual inspection using a shadowgraph revealed that the groove/tool mark created an irregular profile and appeared as 'divots' at three locations within the compound radius. Bulk microstructure appeared typical of properly processed IN-100 powder metal.

ADDITIONAL INFORMATION

Since IAE identified the possible source of the 'divot' defect to be attributed to the broaching operation, the HPT stage 2 disk broached before (referred to as disk 7.1) and after (referred to as disk 7.3) the failed disk (referred to as disk 7.2) were initially considered suspect because they were on the same reconditioning/sharpening cycle as the failed disk, meaning that the broaching tool was not removed and sharpened between machining of the three disks. The broaching tool can finish machine 3 disks or 216 slots before it is removed and reconditioned (sharpened) and it can be reconditioned 12 times before it is discarded. Disks 7.1 and 7.3 were removed from service and evaluated by IAE in March 2015. Disk 7.1 had the first 52 blade slots free of defects; however, the last 20 blade slots exhibited the same tool marks, 'divots', observed on the failed disk. Disk 7.3 had all 72 disk slots with the same tool marks that were observed on the failed disk.

Since disk 7.3 had the 'divot' in all the blade slots, IAE had the next sequential disk broached (referred to as disk 8.1), the first disk broached after the broaching tool was reconditioned, removed from service and inspected to determine if the reconditioning of the broaching tool would eliminate what was creating the 'divot' in the blade slots. Disk 8.1 was evaluated by IAE in June 2015 and the examination revealed that all 72 slots exhibited the tool marks on the PS fillet No. 2 as did the failed disk; however, an additional unique tool mark located on the PS No. 3 fillet was found that was not initially found on the failed disk or the other previously examined HPT stage 2 disks. IAE reexamined the previously inspected disks and found traces on the PS No. 3 fillet tool mark on all the disk; qualitatively, the tool mark was more prevalent on Disk 8.1 than on any of the others. According to IAE, the PS No. 3 fillet radius tool mark observed on all the inspected disks, except for Disk 8.1 would not have been a rejectable anomaly.

Reconditioning of the broaching tool did not correct the 'divot' problem, so an audit team made up of IAE, Avio Aero (performed the finished machining/broaching operation), and General Electric (owner of Avio Aero) evaluated the entire manufacturing process with an emphasis on the broaching operation. The evaluation of the Avio disk machining process revealed the following primary contributing factors: 1) cutter tool draft angle design leading to scuffing/sliding along the relief surfaces with associated side

loading/deflection and rapid tool wear, 2) a non-optimized tool redressing process resulting in uneven material removal and non-uniform cutter tool profiles, and 3) procedural issues with inspection of tooling, set-up and final parts. Based on these findings, the best practices from GE and IAE have been implemented to address these manufacturing deficiencies.

Based on the findings from disk 7.3 and 8.1, IAE proposed a fleet management plan that would include the issuance of a Non-Modification Service Bulletin (NMSB), anticipated in the first quarter of 2016, for a once-through the fleet inspection of all HPT stage 1 and 2 disks manufactured by Avio at the next engine HPT overhaul. According to IAE, Avio manufactured over 4,000 HPT stage 1 and 2 disks. Discussions with the Federal Aviation Administration indicated that they intend to issue an Airworthiness Directive (AD) mandating the inspection of Avio manufactured V2500 HPT stage 1 and 2 disk based on the IAE NMSB.

Information

Certificate:	**Age:**
Airplane Rating(s):	**Seat Occupied:**
Other Aircraft Rating(s):	**Restraint Used:**
Instrument Rating(s):	**Second Pilot Present:**
Instructor Rating(s):	**Toxicology Performed:**
Medical Certification:	**Last FAA Medical Exam:**
Occupational Pilot:	**Last Flight Review or Equivalent:**
Flight Time:	

Aircraft and Owner/Operator Information

Aircraft Make:	Airbus	**Registration:**	N656JB
Model/Series:	A320 232 232	**Aircraft Category:**	Airplane
Year of Manufacture:	2007	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	3091
Landing Gear Type:	Tricycle	**Seats:**	
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	169756 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:		**Engine Manufacturer:**	IAE
ELT:		**Engine Model/Series:**	V2527E-A5
Registered Owner:	JETBLUE AIRWAYS CORP	**Rated Power:**	9895 Horsepower
Operator:	jetBlue Airways	**Operating Certificate(s) Held:**	Flag carrier (121)

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:		**Distance from Accident Site:**	
Observation Time:		**Direction from Accident Site:**	
Lowest Cloud Condition:		**Visibility**	
Lowest Ceiling:		**Visibility (RVR):**	
Wind Speed/Gusts:	/	**Turbulence Type Forecast/Actual:**	/
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:		**Temperature/Dew Point:**	
Precipitation and Obscuration:			
Departure Point:	Long Beach, CA (LGB)	**Type of Flight Plan Filed:**	IFR
Destination:	AUSTIN, TX (AUS)	**Type of Clearance:**	Unknown
Departure Time:		**Type of Airspace:**	Class A

Airport Information

Airport:	LONG BEACH /DAUGHERTY FIELD/ LGB	**Runway Surface Type:**	
Airport Elevation:	60 ft msl	**Runway Surface Condition:**	Unknown
Runway Used:		**IFR Approach:**	Unknown
Runway Length/Width:		**VFR Approach/Landing:**	Unknown

Wreckage and Impact Information

Crew Injuries:	5 None	**Aircraft Damage:**	Minor
Passenger Injuries:	142 None	**Aircraft Fire:**	In-flight
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	147 None	**Latitude, Longitude:**	33.818332,-118.144721(est)

Administrative Information

Investigator In Charge (IIC):	Scarfo, Jean-pierre
Additional Participating Persons:	
Original Publish Date:	January 20, 2016
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB did not travel to the scene of this incident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=90094