Aviation Investigation Final Report

Location:	Pittsburgh, Pennsylvania	**Incident Number:**	ENG11IA021
Date & Time:	March 17, 2011, 16:40 UTC	**Registration:**	N339NG
Aircraft:	BOMBARDIER INC DHC 8 402	**Aircraft Damage:**	Minor
Defining Event:	Powerplant sys/comp malf/fail	**Injuries:**	40 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

A left engine aft thrust rotor bearing incipient spalling condition progressed to failure during cruise flight. The loss of rotor thrust support caused the rotor to displace aft and contact adjacent stationary structures, including structures in the No. 2 bearing area. The resulting machining-type contact damage generated metal debris that contaminated the engine oil. Metal particles in the oil scavenged from the No. 2/2.5 bearing oil cavity damaged the engine oil pump and arrested its rotation, which caused torsional separation of the oil pump driveshaft, cutting off oil supply to the engine. The left engine oil pressure master warning activated. The flight crew did not shut down the engine. The engine operated 84 seconds without oil flow, until combustor and turbine component fire damage disrupted combustor flame stability and the engine flamed out. The continued operation without oil flow elevated engine operating temperatures, and the No. 5 engine bearing cavity temperature increased beyond the material properties of the No. 5 bearing seal runner. The seal runner expanded radially and caused a hard rub against the (titanium-alloy) No. 5 bearing flexible support. The local temperature at the contact point rapidly reach its ignition temperature. The resulting titanium fire consumed the No. 5 bearing flexible support and progressed to adjacent thin-walled titanium components, including the diffuser diaphragm. Molten titanium droplets falling onto diffuser exit ducts located directly beneath the No. 5 bearing area melted through three of the exit ducts and penetrated the gas generator case. The titanium fire self-extinguished when the conditions required for sustained titanium combustion were altered by the flameout and the case burn-through. The lack of circumferential titanium droplet distribution, the undamaged condition of the diffuser ring bore internal surfaces, and the gravity-driven nature of the case penetration indicate that the titanium fire originated external to the diffuser/engine gas path. The cockpit engine fire warning remained active when no fire was present because one of the nacelle fire/overheat detector elements was unable to reset due to a permanently deformed switch diaphragm.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: the flight crew's delay in shutting down the left engine following an engine oil pressure master warning, which led to a hard rub inside the engine that served as an ignition point for a titanium fire. Contributing to the event was a PW150 No. 5 seal design vulnerability to titanium ignition that can occur with continued engine operation following an engine oil pressure loss event.

Findings

Aircraft	Turbine section - Damaged/degraded
Aircraft	Oil system - Damaged/degraded
Aircraft	Oil system - Inoperative
Personnel issues	Decision making/judgment - Flight crew
Aircraft	Compressor section - Design
Aircraft	Detection system - Design

Factual Information

History of Flight

Enroute-cruise	Powerplant sys/comp malf/fail (Defining event)
Enroute-cruise	Fire/smoke (non-impact)
Enroute-cruise	Loss of engine power (total)
Enroute-cruise	Engine shutdown
Enroute-cruise	Sys/Comp malf/fail (non-power)

HISTORY OF FLIGHT

On March 17, 2011, about 1640 UTC, a Colgan Air DeHavilland DHC-8-400Q, N339NG, powered by two Pratt & Whitney Canada (PWC) PW150A turboprop engines, made a precautionary landing after experiencing an engine casing burn-through. The airplane was operating under the provisions of 14 *Code of Federal Regulations* Part 121 as scheduled passenger service from Cleveland Hopkins International Airport, Cleveland, Ohio (CLE) to Baltimore-Washington International Airport, Baltimore, Maryland (BMI). The flight crew reported that, during cruise flight at FL230, the left engine oil pressure master warning activated and the left engine oil temperature rapidly increased. The left engine lost power and the engine fire warning activated. The flight crew declared an emergency and the flight was diverted to Pittsburgh International Airport (PIT), where a single-engine landing was performed without incident. There was minor damage to the airplane, and no injury to the two flight crew, two cabin crew, and 36 passengers. A post-flight airplane inspection found a hole in the left engine gas generator case. The left engine and the two left nacelle Kidde Aerospace & Defense UTC (KAD) pneumatic fire/overheat detection elements were removed for further investigation.

AIRCRAFT INFORMATION

At the time of the incident, the airplane and the engine had accumulated 551 hours and 551 cycles since new. A review of the Colgan Air airplane maintenance records found no discrepancies.

AIRCRAFT DAMAGE

There was minor scorching damage to the airplane's left nacelle.

RECORDERS

The airplane was equipped with a digital flight data recorder (FDR) and two engine monitoring units (EMUs). Data extracted from the FDR and the left engine EMU showed that a left engine oil system (chip detector) fault was recorded about 20 minutes after takeoff and that the left engine oil pressure master warning activated about five minutes later (T+0). The data also showed that the left engine flamed out 82 seconds after activation of the left engine oil pressure master warning (T+82), the left engine power lever was retarded at T+85, and the airplane fire detection system left engine nacelle

fire/overheat warning activated at T+90. The left engine power lever was further decreased to FLIGHT IDLE at T+98. Fuel to the left engine was shut off (condition lever moved to FUEL OFF) at T+114.

FIRE

Both left nacelle fire suppression bottles were fired. After landing, airport fire and rescue personnel responding to the aircraft determined that no fire was present in the left nacelle. The left nacelle fire warning remained active until airplane power was shut down. A single burn-through hole was noted at the bottom of the left engine gas generator case. The nacelle and the engine showed scorching damage consistent with exposure to elevated temperatures. There was no evidence that molten metal spray or torching flame had emanated from the engine.

TESTS AND RESEARCH

The engine was examined at a PWC facility in St-Hubert, Quebec. There was an approximately 3.5-inch (axial) by 4.5-inch (circumferential) burn-through hole in the gas generator case axially in line with the engine diffuser pipe exit ports at 6 to 7 o'clock. The edges of the hole were irregular and charred, with deposits of molten material characteristic of a fire burning through the case wall from the inside. There was minor thermal damage to some of the engine external components in the vicinity of the hole. The engine oil was heavily contaminated with metal particles. The oil pump was seized and the oil pump drive shaft was separated at its calibrated shear point. The No. 1 (power turbine rotor rearward thrust support) bearing was destroyed; its outer race (OR) and its retention hardware were loose, the inner race (IR) and ball elements were heavily worn and heat-discolored, and the cage and OR were fractured. Metallurgical examination of the bearing fracture surfaces found that the OR had failed in fatigue from a crack initiating in a spalled area on the center of the raceway. The advanced stage of the raceway component deterioration and the loose OR retention hardware indicated that the cage and OR had fractured late in the failure sequence. Due to the severe damage, the root cause of the spalling could not be determined.

PT damage. Aft surfaces of the PT rotor assembly were rotationally scored and torn; the damaged parts included the No. 1 and No. 2 bearing retention hardware, several No. 7 bearing components, and the PT stage 2 blade trailing edges. Stationary structures just aft of the damaged rotor parts exhibited corresponding circumferential damage signatures.

Dry bearing cavities. The Nos. 4 and 5 main bearings exhibited the dull gray coloration, destroyed bearing elements, and wear damage characteristic of operation without adequate lubrication. All of the bearing cavities were dry. The remaining main engine bearings were dry, but intact.

Thermal damage. The No. 5 bearing area was extensively damaged. The No. 5 bearing housing assembly was thermally destroyed. The No. 5 bearing (titanium alloy) flexible support housing and the No. 5 bearing front carbon seal and cover were partially consumed/melted together and were no longer recognizable. The No. 5 bearing front air seal runner was scorched and the runner section was eroded/missing. The No. 5 bearing oil nozzle housing, housing outer cover, rear carbon seal, and outer race were severely heat damaged. The No. 5 bearing IR, OR, and cage were intact but were thermally damaged, and the rollers were disintegrated. The No. 5 bearing pressure and scavenge oil tubes were largely consumed. The integral diaphragm section of the gas generator diffuser assembly, a thin-walled titanium-alloy structure linking the No. 5 bearing support housing diameter with the gas generator shield

at the diffuser apex diameter, was entirely consumed. Large sections of the combustion section large exit support duct (LESD) inner and outer walls were thermally consumed/melted. The thermal damage exposed the back face of the (titanium-alloy) impeller, which showed a rough and eroded surface texture and exducer vane tip erosion, but was otherwise intact. The three diffuser exit ducts located bearing at 6 to 7 o'clock and immediately inboard of the gas generator case burn-through hole were thermally consumed/melted. Diffuser ring bore inside surfaces exposed at the apex end of two of the melted exit ducts were in good condition. The remaining 20 diffuser exit ducts located around the circumference of the gas generator case were intact. The HPT front cover was partially oxidized and the HPT airfoil tips and leading edges were eroded. The gas generator case exhibited no significant thermal damage other than the burn-through hole at 6 to 7 o'clock. Re-solidified metal splatter was fused to the diffuser, diffuser exit ducts, LESD outer wall, combustion chamber inner liner and small exit duct, HPT disk nozzle housing assembly, HPT disk bore, HPT shroud segments, LPT airfoils and LPT shroud segments. The engine exhibited no circumferential melting damage or other evidence of high-velocity, 360 degree distribution of molten particles.

Left oil pump failure investigation. Teardown of the seized engine oil pump found that a vane in the pump element that scavenges oil from the engine's No 2/2.5 bearing cavity had not fully retracted due to metal contamination. The protruding vane struck the element rotor and arrested pump rotation, causing torsional overload separation of the pump driveshaft and cut-off of oil supply to the engine.

Nacelle pneumatic fire/overheat detection elements. Examination of the KADS pneumatic fire/overheat detection elements removed from the left nacelle found that one of the elements was stuck in the alarm state. The element was unable to return to the non-alarm state because of a permanently deformed detector switch diaphragm. The investigation also found that KAD pneumatic fire/overheat detection element detector switch diaphragms had failed to reset after activation during other DHC-8 series 400 airplane fire events.

ADDITIONAL INFORMATION

PWC's analysis of the titanium fire included an examination of a No. 5 bearing seal runner and No. 5 bearing flexible support removed from a non-fire damaged PW150 engine that had operated without oil pressure for a similar period of time as the Colgan engine, but at a lower power setting. Dimensional checks of the No. 5 bearing seal runner showed that it was radially deformed (coned) sufficient to permit contact with the No. 5 bearing flexible support during operation. The thin-walled sections (ribs) of the titanium alloy No. 5 bearing flexible support exhibited rubbing and erosion consistent with oxidation. Examination of the No. 5 bearing seal runner found microstructure consistent with exposure to excessive temperatures during operation. According to PWC, No. 5 bearing seal runner material properties can be exceeded when the No. 5 bearing cavity temperatures are abnormally elevated.

Airplane operating instructions for engine oil pressure loss. The DHC Q400 Quick Reference Checklist (QRC) states that indicated oil pressure below 44 psi or continuous illumination of an engine oil pressure warning light requires the flight crew to complete the QRC ENGINE FAIL/FIRE/SHUTDOWN (engine shutdown) checklist.

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:	BOMBARDIER INC	**Registration:**	N339NG
Model/Series:	DHC 8 402 402	**Aircraft Category:**	Airplane
Year of Manufacture:	2010	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	4339
Landing Gear Type:	Tricycle	**Seats:**	
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	64501 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo prop
Airframe Total Time:		**Engine Manufacturer:**	P&W CANADA
ELT:		**Engine Model/Series:**	PW150A
Registered Owner:	Regional Equipment Trust	**Rated Power:**	0 Horsepower
Operator:	Colgan Air, Inc.	**Operating Certificate(s) Held:**	Commuter air carrier (135)
Operator Does Business As:		**Operator Designator Code:**	9L

Meteorological Information and Flight Plan

Conditions at Accident Site:	Unknown	**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:	Cleveland, OH (CLE)	**Type of Flight Plan Filed:**	VFR/IFR
Destination:	Baltimore, MD (BMI)	**Type of Clearance:**	Unknown
Departure Time:		**Type of Airspace:**	

Wreckage and Impact Information

Crew Injuries:	4 None	**Aircraft Damage:**	Minor
Passenger Injuries:	36 None	**Aircraft Fire:**	In-flight
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	40 None	**Latitude, Longitude:**	40.431667,-80.034446(est)

Administrative Information

Investigator In Charge (IIC):	Horgan, Carol
Additional Participating Persons:	Tony James; AVP-100, FAA; Washington, DC James Lawrence; FAA Engine & Propeller Directorate; Burlington, MA Beverley Harvey; TSB of Canada, Accredited Representative; Gatineau Richard Berg; Transport Canada; Ottawa AK Durrani; Transport Canada; Ottawa Glenn Hansen; Bombardier; Toronto Marc Hemmings; Pratt & Whitney Canada; Longueuil Jean-Francois Houle; Pratt & Whitney Canada; Longueuil Albert G Whitty; Pratt & Whitney Canada; Mississauga Ricardo Pereira; Pratt & Whitney Canada; Longueuil
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