Transportation Safety Board of Canada
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AVIATION INVESTIGATION REPORT
A05P0132

LOSS OF OIL PRESSURE ON TWO ENGINES

CASCADE AEROSPACE INC.
BOMBARDIER DHC-8-402 C-FBAM
TOFINO, BRITISH COLUMBIA, 5 nm W
07 JUNE 2005

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Summary

The flight departed Abbotsford International Airport, British Columbia, on an instrument flight rules flight plan at 1331 Pacific daylight time to conduct flight tests in the vicinity of Tofino, British Columbia. There were two pilots and two contract flight test engineers on board. A certification flight testing program was being conducted by Cascade Aerospace Inc. with the Bombardier DHC-8-402 (registration C-FBAM, serial number 4040) modified for air tanker operations. The flight test program included a series of increasing amplitude push-over/pull-up manoeuvres to evaluate stick force per g (gravity) and to demonstrate satisfactory handling characteristics during a push-over to 0 g with a water/retardant load on board.

At about 1532, during the third and final push-over, both the No. 1 and No. 2 engine low oil pressure annunciators illuminated. Then, uncommanded, the speed of both propellers reduced by about 300 rpm, and the engine torques increased proportionately. A recovery to a normal attitude was completed during which both engine low oil pressure annunciators extinguished. The No. 1 propeller recovered to the selected speed of 1020 rpm. However, the No. 2 propeller went into an overspeed condition and was governed at 1060 rpm by the overspeed governor. The No. 2 propeller was then intentionally feathered, the engine was shut down, and the water/retardant load was jettisoned. The No. 2 engine was subsequently re-started. However, the propeller could not be unfeathered, so the engine was again shut down. The flight returned to Abbotsford International Airport with one engine inoperative and landed at about 1640. Air traffic control was advised of the condition, but an emergency was not declared.

Ce rapport est également disponible en français.

Other Factual Information

Meteorological Information

The weather conditions for Tofino at the time of the incident were as follows: wind 270° true (T) at 11 knots gusting to 17 knots; visibility 15 statute miles; a few clouds at 2400 feet above sea level, scattered cloud at 5000 feet, broken cloud at 15 000 feet, temperature 15°C, dew point 10°C.

Operations

Cascade Aerospace Inc. provides engineering services for custom product design, manufacturing, and certification. The company is an approved Design Approval Organization (DAO) as well as an Approved Manufacturing Organization (AMO). The Q400 Airtanker conversion of the initial Bombardier DHC-8-400 design was undergoing supplemental type certificate (STC) certification flight testing for the fire-fighting role at the time of the incident. The pilot crew was employed by the Conair Group Inc. Both pilots had completed the Dash 8 Q400 initial pilot course at the FlightSafety International Toronto Learning Centre in November 2004.

Aircraft

The Bombardier DHC-8-400 is a current production regional airliner in the 70 seat market. It is powered by two Pratt & Whitney Canada (P&WC) PW150A turboprop engines and is operated by a two-pilot crew. The Cascade Aerospace Inc. Q400 Airtanker conversion included the installation of a 10 000 litre retardant delivery system. The aircraft departed Abbotsford International Airport at a gross weight of 68 200 pounds and the load was configured at the most aft centre of gravity limit for the test flight. Part of the STC modifications included an increase in the aircraft gross take-off weight to 68 200 pounds.

The aircraft was being operated under the authority of a Transport Canada (TC) Flight Permit – Experimental. This was the eighth test flight in the development of an STC for an aerial tanker conversion. Subsequent to the flight, a maintenance interrogation of the recorded engine monitoring unit (EMU) data did not identify any component faults.

Flight Recorders

The aircraft was equipped with a Honeywell solid-state cockpit voice recorder (CVR) and an Allied Signal solid-state flight data recorder (FDR). Information was recovered from the FDR but not from the CVR. The pertinent information from the CVR was overwritten while external electrical power was applied to the aircraft following the incident flight.

Powerplants

The aircraft was equipped with two P&WC model PW150A engines. The PW150A consists of a free-turbine turbo machine (TM) module driving a Dowty Aerospace model R408 six-bladed propeller through a two-stage reduction gearbox (RG) module. The TM module includes the low-pressure (LP) compressor and its LP turbine, the single-stage centrifugal high-pressure (HP) compressor and its HP turbine, and the two-stage power turbine (PT) and its PT shaft, which drives the RG module. The three rotating assemblies are not connected together and rotate at different speeds and in opposite directions. An accessory gearbox (AGB) is driven by the HP turbine shaft through a tower shaft and angle gearbox. The AGB drives the fuel metering unit, which incorporates the fuel pump, the starter/generator and other accessories.

Engine Pitch Angle Limit

A series of flight test cards was produced during the development of the flight test program. A flight test card outlined the objectives, procedures, and safety concerns of each flight. The Cascade Aerospace Inc. flight test engineering group referenced flight test guidance material produced by TC, the United States Federal Aviation Administration (FAA) and the manufacturer's aircraft flight manual (AFM). The AFM was the primary document used to determine aircraft operating limitations. Section 2.2.5 of the AFM, Manoeuvring Limit Load Factors, indicates that the load factor limits for the aircraft in the clean configuration are +2.5 g to -1.0 g. The section further states that these figures limit the permissible bank angle in turns and limit the severity of pull-up and push-over manoeuvres.

Cascade Aerospace Inc. self-imposed another condition on the TC flight permit that limited the minimum manoeuvre limit load factor to 0 g. Flight test card No. 8 did not contain any pitch angle limitations. Data recovered from the FDR indicated that, during the manoeuvres, pitch-up angles of about 43° and 46° were achieved in the second and third pull-ups respectively, and a minimum load factor of -0.08 g was recorded during the last push-over. The FDR and the captain's attitude indicator normally receive pitch information from the same-side attitude and heading reference unit.

The engine manufacturer's Engine Installation Manual (EIM) (a proprietary document provided to the aircraft manufacturer but not normally distributed to aircraft owners/operators) contained static engine operating limitations regarding the demonstrated pitch and roll angles and related time frames at which satisfactory engine lubrication could be lost. This manual was not offered to, nor requested by, the Cascade Aerospace Inc. flight test engineering group. Although the aircraft did not exceed the limit load factor prescribed in the AFM, the engine static pitch angle limitation was, unbeknownst to the flight test crew, exceeded during the flight test manoeuvre. Although the physical pitch-up angle reached as high as 46°, when acceleration and deceleration forces are taken into account, the net effect on the engine was equivalent to a steady-state pitch-up angle of about 8°. The pitch-up limitation for normal steady-state operation is 25° according to the EIM.

Engine Oil Pressure/Propeller Relationship

Each propeller and engine (combined RG module plus TM module) shares the same oil, so when both engines lost oil pressure, both propellers did as well. The loss of oil pressure resulted in each propeller counterweight mechanism and rotational forces driving the respective propeller in the coarse pitch direction and resulted in an underspeed condition (< 80 per cent Np [power turbine]). This event was not an auto-feather since the auto-feather system had been disarmed as per normal procedures. The FDR data show that, before the loss of oil pressures, the engines were operating at less than 50 per cent torque. At about the time the engine oil pressures were recovering and the low oil pressure annunciators were being extinguished, the No. 2 power lever was advanced about 8° (48° to 56°) followed shortly by the advance of the No. 1 power lever.

During this period of two or three seconds, the No. 2 engine torque increased to above 50 per cent, and the conditions (torque > 50 per cent and propeller speed < 80 per cent for more than one second) were fulfilled to activate the hardware-based automatic underspeed protection circuit (AUPC) for the No. 2 propeller system. This circuit effectively disables the propeller electronic control (PEC) software control and continuously drives the propeller blade pitch at a controlled rate in the fine direction, and forces it to operate on the hydro-mechanical overspeed governor at 1060 rpm. A similar AUPC activation and respective fault code was not recorded for the No. 1 engine, indicating that the conditions required for the activation of the No. 1 AUPC were not met during the transient. In the case of the No. 1 engine, once oil pressure was restored, the propeller simply resumed normal operation.

Propeller Unfeathering

After confirming that the No. 1 engine/propeller system was operating normally, the crew complied with the checklist in the AFM by manually feathering the No. 2 propeller and shutting down the No. 2 engine. Following an in-flight maintenance consultation, the No. 2 engine was subsequently re-started; the propeller could not be unfeathered so the engine was again shut down. In accordance with the design of the system, the propeller was inhibited from unfeathering following the AUPC activation. The philosophy of the aircraft manufacturer is that certain propeller system fault conditions are automatically accommodated by the control system, feathering the propeller until the fault conditions are corrected by appropriate maintenance action. The AUPC triggers this accommodation mode and prevents propeller unfeathering since its activation is equivalent to a loss of blade pitch control by the PEC software.

Aircraft and Maintenance Records

Aircraft records indicate that the left engine, serial number PCE-FA0020, had about 1952 flight hours of total time since new (TTSN) and the right engine, serial number PCE-FA0015, had about 1991 flight hours of TTSN. Service Bulletin (SB) 35038, Revision 3, had been incorporated into both engines and was applicable to all production PW150A engines. This SB required replacement of the original engine oil pressure relief valve (PRV) with a modified PRV. The modification was in response to an oil smell in the passenger cabin due to oil leakage into the bleed-air stream while engine bearing seals were unpressurized during the start-up and shutdown sequence. The function of the modification was to prevent excessive oil supply to the engine bearing cavities, which could cause oil flooding during engine start-up and shutdown by relieving residual oil pressure more quickly.

Research

A search of the TC service difficulty reporting database did not produce any similar occurrences in Canada or the United States. At this time, the only civilian aircraft equipped with the PW150A engine is the DHC-8-400 model.

During this investigation, it was noted that the outcome in this occurrence was different from the outcome of previous 0 g certification flight test demonstrations conducted by Bombardier in 1999. Following this incident, P&WC conducted a series of tests on an experimental engine of the same model to determine whether the PRV modification (SB 35038, Revision 3) affected the propeller operation and how this sequence of events compared to the original certification flight test demonstrations with the original PRV.

The original PRV configuration was installed in the engine used in the P&WC propeller test stand. During those demonstrations, the power plant and propeller continued to perform as it did during the original certification tests throughout the artificially induced temporary low engine oil pressure condition. This testing artificially induced the loss of oil pressure by introducing pressurized air at the oil pump inlet until the main oil pressure dropped to 10 psi, and, therefore, any effects of flight under conditions of less than 1 g were not present. With the original PRV configuration, tested at two different power levels, there was no change in propeller operation throughout the loss of oil pressure and recovery cycle.

With the modified PRV configuration, there were fluctuations in propeller operation, and the engine main oil pressure dropped to below 10 psi and took longer to recover. The propeller operation recovered about four seconds after the main and reduction gear oil pressure recovered.

The testing confirmed that the modified PRV does cause the propeller blade angle to move toward the feather position under conditions of low engine oil pressure. The propeller does recover to the prior operating state once oil pressure is restored. However, a loss of oil pressure for a duration longer than 3 or 4 seconds may result in activation of the AUPC.

Analysis

Data from the FDR indicated that the aircraft did not exceed any limitations prescribed in the AFM, yet propeller operating disturbances occurred. Although the static engine pitch angle limitation was unknowingly exceeded and might have contributed to a simultaneous temporary loss of engine oil pressure in both engines, the resolution of acceleration vectors showed that the effect of the pitch angle was equivalent to a steady-state pitch-up angle within limitations during the manoeuvre.

Low oil pressure conditions are known to occur during negative g manoeuvres with the original PRV but the low oil pressure condition did not last long enough to affect propeller operation. Data suggest that the modified PRV contributed to the propeller speed disturbance by prolonging the low oil pressure conditions. This result has been replicated in subsequent flight testing involving push-overs to about -0.10 g from positive pitch angles of about 23° and demonstrates that propeller operating disturbances can be anticipated any time that negative g conditions are encountered. This previously unknown consequence is the subject of discussions between the manufacturer and TC.

Section 2.2.5 of the AFM, Manoeuvring Limit Load Factors, indicates that the allowable load factors limit the permissible bank angle in turns and limit the severity of pull-up and push-over manoeuvres. Bank angles were not an issue in this incident, and it is true that load factor limits would restrict the severity of a pull-up or push-over manoeuvre. While the flight test load factor targets were within the limits specified in the AFM, the AFM is not produced as a flight test design guide. Certification flight testing programs could involve manoeuvres considered to be extreme for the category of aircraft. The Cascade Aerospace Inc. flight test engineering group did not know exactly what pitch angle would be achieved during the planned series of manoeuvres. Therefore, it would be prudent for engineering groups to fully research the limits of systems, such as lubrication and fuel systems, when designing such flight testing programs and incorporate such information in the flight test cards applicable to each flight.

The airframe manufacturer concluded that the pitch-up attitude achieved was extreme and is not likely to be encountered in normal operations for this type of aircraft. However, a query of another DHC-8 operator (not a Q400 model) indicated that high positive pitch angles (30° or more) could be achieved in flight training manoeuvres. Therefore, it is not beyond reason for load factors of less than 0 g to be induced during a training exercise or actual traffic or terrain avoidance manoeuvre. Without knowledge of the associated consequences, an already abnormal manoeuvre could involve much higher risks if an unsuspecting flight crew encountered a single or double loss of engine oil pressure and subsequent propeller overspeed condition(s).

The original certification flight test demonstrations conducted by Bombardier did not result in any abnormalities of propeller operation with the original PRV installation in the engines. Since the introduction of the modified PRV (SB 35038, Revision 3), this in-flight incident and subsequent test cell results demonstrate that the loss of engine oil pressure was prolonged by the modified PRV and resulted in the propeller underspeed when the blades were driven in the coarse pitch direction. This effect of the PRV modification had not been foreseen. When this event occurred, the balance of the system performed as designed as evidenced by the recovery of the No. 1 engine/propeller to its prior operating state. Because the engines were operating at less than 50 per cent torque, had it not been for the increase in torque due to the advancement of the No. 2 power lever—which completed the conditions required for activation of the AUPC—the No. 2 engine/propeller system likely would have recovered to its prior operating state as well. Had the engines been operating at more than 50 per cent torque, both propellers could have been forced to operate on the overspeed governors. This is not a critical event, and the aircraft could have continued flight to an aerodrome under this condition.

Following an intentional in-flight shutdown and subsequent in-flight re-start of the No. 2 engine, the crew found that the propeller could not be unfeathered. None of the aircraft manuals or training material, nor the FlightSafety International pilot training course inform flight crews that, when the PEC detects a failure condition that requires propeller feathering, the ability to subsequently unfeather the propeller will be lost, even in the case of a greater emergency. Just such a greater emergency occurred with this same aircraft about 30 flight hours later (TSB report A05P0137) when the No. 1 engine suddenly shut down in flight without warning.

Findings as to Causes and Contributing Factors

1. During the flight test manoeuvre, both aircraft engines developed a loss of oil pressure when exposed to a high pitch-up angle along with a brief and small negative g condition. When exposed to low oil pressure conditions, the modified engine oil pressure regulating valve allowed the low oil pressure condition to exist long enough to affect propeller operation.

2. The extended low oil pressure condition resulted in propeller speed fluctuations, and caused both propellers to enter an underspeed condition. This fulfilled one of three requirements for the subsequent No. 2 propeller overspeed condition.

3. While the No. 2 propeller was in the underspeed condition, advancement of the No. 2 power lever resulted in the engine torque exceeding 50 per cent. This fulfilled the second requirement for the subsequent No. 2 propeller overspeed condition. The occurrence of these two conditions simultaneously for more than one second completed all of the requirements for activation of the No. 2 automatic underspeed protection circuit (AUPC) and resulted in the No. 2 propeller overspeed condition.

Findings as to Risk

1. Any load factors below 0 g, such as during a training exercise or an actual traffic or terrain avoidance manoeuvre, could involve much higher risks if an unsuspecting flight crew became distracted by a second unexpected event such as a single or double loss of engine oil pressure and subsequent propeller overspeed condition(s).

2. None of the aircraft manuals or training material, nor the FlightSafety International pilot training course, inform flight crews that, when the propeller electronic control (PEC) detects a failure condition that requires propeller feathering, the ability to subsequently unfeather the propeller will be lost, even in the case of a greater emergency.

Other Finding

1. Information was not recovered from the cockpit voice recorder (CVR) since it was overwritten while external electrical power was applied to the aircraft following the incident flight.

Safety Action Taken

Following this incident, Transport Canada (TC) cancelled the flight permit until it could be shown that adequate inspections had determined that the aircraft was safe to operate. A new flight permit was issued on 10 June 2005 for the balance of the flight test program.

Cascade Aerospace Inc. instituted a self-imposed restriction limiting the balance of the flight test program to an intentional manoeuvring minimum limit of +0.5 g as opposed to the previous self-imposed limit of 0 g.

On 21 July 2005, the TSB Pacific regional office distributed two occurrence bulletins. One addressed the issue of the availability of information regarding the engine pitch-up limitation. The other addressed the issue of the availability of information to flight crews regarding the inability to unfeather a propeller subsequent to a fault condition that requires a propeller to be feathered.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 02 August 2006.

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