Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A05P0298

ENGINE FAILURE – DESCENT INTO TERRAIN

NAV AIR CHARTER INC.
MITSUBISHI MU-2B-36 C-FTWO
TERRACE, BRITISH COLUMBIA
20 DECEMBER 2005

Canada

Aviation Investigation Report

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Summary

At 1834 Pacific standard time, the Nav Air Charter Inc. Mitsubishi MU-2B-36 aircraft (registration C-FTWO, serial number 672) took off from Runway 15 at the Terrace Airport for a courier flight to Vancouver, British Columbia. The left engine lost power shortly after take-off. The aircraft descended, with a slight left bank, into trees and crashed about 1600 feet east of the departure end of Runway 15 on a heading of 072° magnetic. The aircraft was destroyed by the impact and a post-crash fire, and the two pilots were fatally injured.

Ce rapport est également disponible en français.

Other Factual Information

The aircraft departed Vancouver, British Columbia, as flight number FCV830 at 0637 Pacific standard time[1] on 20 December 2005, landed at Terrace, British Columbia, at 0810, departed Terrace at 0845, and landed at Smithers, British Columbia, at 0906. The captain flew the aircraft from Vancouver to Smithers from the left seat. The crew spent the day in a hotel and departed Smithers as flight number FCV831 at 1732. In accordance with company policy, the first officer was flying the aircraft for the return portion of the flight from the left seat. The aircraft landed at Terrace at 1803. The aircraft was being operated under the self-dispatch system.

The Terrace Airport is located in mountainous terrain at an elevation of 713 feet above sea level (asl). Runway 15 at Terrace is 7500 feet long by 150 feet wide and is the longest available runway. The runway has both a 1/2 and a specified take-off minimum visibility (SPEC VIS) procedure for instrument departures.[2] Night circuits are to be conducted left hand at an altitude of 1700 feet asl and within the perimeter of hazard beacons located approximately two statute miles (sm) from the departure end of Runway 15.

The terminal area forecast (TAF) for Terrace, issued at 1824 and valid until 0400 the next morning, was as follows: wind 020° True (T) at 8 knots; visibility greater than 6 sm; scattered clouds at 1500 feet above sea level (asl); temporarily between 1600 and 1800, visibility 3 sm in light freezing rain, broken clouds at 1500 feet asl.

At the time of departure from Smithers, the latest aviation routine weather report (METAR) available for Terrace, issued at 1700, was as follows: wind 110°T at 2 knots; visibility 15 sm; a few clouds at 1500 feet above ground level (agl); scattered clouds at 4000 feet agl; broken clouds at 8000 feet agl; temperature -1°C; dew point -2°C; altimeter setting 29.44; remarks: 1 okta [3] stratus fractus, 2 oktas stratocumulus, 3 oktas altocumulus, sea-level pressure 980 hectopascals.

Upon making radio contact with the Terrace Flight Service Station (FSS), the crew was provided with a special METAR issued at 1744, which was as follows: wind 090°T at 4 knots; visibility 15 sm in light freezing rain; a few clouds at 1500 feet agl; scattered clouds at 4000 feet agl; broken clouds at 5200 feet agl; remarks: 1 okta stratus fractus, 2 oktas stratocumulus, 3 oktas stratocumulus.

The Terrace 1800 METAR was as follows: winds calm; visibility 10 sm in light freezing rain; a few clouds at 600 feet agl; a few clouds at 1500 feet agl; scattered clouds at 3600 feet agl; broken clouds at 4800 feet agl; temperature 0ºC; dew point -1ºC; altimeter setting 29.46 in. The 1900 METAR was as follows: winds calm; visibility 10 sm in light freezing rain; a few clouds at

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1 All times are Pacific standard time (Coordinated Universal Time minus eight hours).

2 Instrument flight rules (IFR) departures will be assured of obstacle clearance if either of the described procedures is followed.

3 The cloud layer amounts are reported in eighths (oktas) of sky coverage.

600 feet agl; a few clouds at 1500 feet agl; scattered clouds at 3200 feet agl; broken clouds at 4600 feet agl; overcast cloud layer at 5500 feet agl; temperature 0ºC; dewpoint -1ºC; altimeter setting 29.47.

The wings of the aircraft were wet and free of ice just before it departed Terrace, even though light freezing rain was falling. During flight, as air passes over the top of an aircraft's wing, there is drop in pressure, which corresponds to a decrease in temperature; this is known as the Bernoulli effect. Company records document that both pilots had completed the required icing training.

Autopsies and full toxicology examinations were carried out on both pilots. Nothing significant was found that could have led to or contributed to the accident.

The captain had been employed by Nav Air Charter Inc. for three years and was certified and qualified for the flight in accordance with existing regulations. His pilot proficiency check (PPC) on the MU-2B was conducted by a company check pilot (CCP) on 11 February 2005. He was employed as a first officer on the MU-2B and captain on the Piper PA-31 until 24 October 2005, when his employment was then as an MU-2B captain only. His total flying time was 2111 hours, including 655 hours on the MU-2B, with 140 hours as captain. The captain flew the day before the accident but was free of duty on 17 and 18 December 2005. Occasionally, the captain worked at a second job as an ambulance technician but was careful to ensure that this did not affect his flying fitness; he had only rarely so worked in the previous two months. He was careful to ensure he got sufficient sleep and was usually able to sleep during daytime layovers. There was nothing in his 24-hour history to suggest that fatigue was involved in the occurrence. The captain was considered by the company to be a competent and careful pilot.

The first officer had been employed by Nav Air Charter Inc. for almost two years, and was certified and qualified for the flight in accordance with existing regulations. His PPC on the MU-2B was conducted by a CCP on 05 January 2005. He was employed as a Britten-Norman Islander captain and an MU-2B first officer until 05 October 2005, when his employment was then as an MU-2B first officer only. His total flying time was 2000 hours, including about 500 hours as first officer on the MU-2B. On the day before the accident, he flew but was free of duty on 17 and 18 December 2005. The first officer lived alone, and it was not possible to determine his rest pattern over the days leading up to the accident. Nothing was found to suggest that fatigue was a factor in the occurrence. The company believed that the first officer required more experience on the high performance MU-2B aircraft before he could be considered for upgrade to captain.

Training on the Nav Air Charter Inc. MU-2B was conducted in house without the use of a simulator. Engine failure after take-off training was simulated in the aircraft by means of exercises conducted at an altitude of 5000 to 6000 feet, at an indicated airspeed (IAS) of 110 knots and flap 20, after the landing gear was selected up. A common problem reported by the company during this drill was that some pilots would allow the airspeed to decay after the engine failure, with the result that the drag caused the aircraft to descend instead of climb.

Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The aircraft was manufactured in 1975 and had flown a total of 23 033 hours as of 19 December 2005. The aircraft was equipped with two

Honeywell model TPE331-6-252M engines. The left engine (serial number P-20190C) had accumulated 4742 hours since the last continuous airworthiness maintenance (CAM) operation. The right engine (serial number P-20362C) had accumulated 3007 hours since the last CAM inspection. These engines are equipped with a negative torque sensing system (NTS) that provides automatic propeller drag limiting. The NTS rotates the propeller blades to their high-pitch (coarse) position, but it does not feather the propeller, which must be done manually. A review of the airframe, engine, and propeller logbooks showed nothing remarkable, except as indicated below.

The wreckage was sent to the TSB regional wreckage facility for further examination. Both power levers were in the take-off (full forward) position and both condition levers were in the take-off/land position. Both T-handles were recovered and disassembled. It was determined that the left T-handle was likely in the pulled position. This position would have closed the left engine fuel shut-off valve. It was determined that the landing gear was retracted with the landing gear doors closed, and the flaps were in the 20° position. The trim aileron actuator was measured and found to be in the neutral position.

Both propellers had separated from their engines. A teardown was accomplished, assisted by a representative of the propeller manufacturer. No discrepancies were found that would have precluded normal operation, and all damage was consistent with impact damage. No blade angle witness marks were found on either propeller that could be used to calculate power output. All witness marks appeared to be post-impact.

The right propeller blades were severely damaged, but the pitch change mechanism and spinner were reasonably intact. The blades had multiple bends, chord wise bending of the airfoil, twisting, and tearing of the tips, all of which is consistent with high power at impact.

The piston/cylinder had separated from the hub of the left propeller. Blade damage to the left propeller was limited to fore and aft bending of the blades and was noticeably less severe than that of the right propeller. The fore and aft bending indicates rotation at impact, while the relative lack of damage indicates that the left engine was generating little or no power. The blades were not in the feather position.

The engines were shipped to the TSB Engineering Laboratory in Ottawa, Ontario, where a teardown examination took place. The left engine and some of its components had been partially consumed by the post-crash fire. It was determined that the left engine combustion chamber plenum had cracked and split open, sufficient to cause the engine to flame out. The crack originated in a filler weld between the P3 and bleed air welded bosses. The crack, which was both horizontal and circumferential, was determined to be fatigue in nature, its length approximately 0.76 cm. The rest of the split was 62.23 cm and determined to be fast fracture due to overstress. The fatigue portion of the crack was mildly oxidized, indicating that it had developed over time. TSB Engineering Laboratory report LP 009/2006 notes in section 3.12 that it is likely that the plenum was cracked, and that the crack was missed during a number of the more recent inspections.

Engine records indicate that this plenum, part number (P/N) 893973-5, was inspected on 20 February 1992 and installed on the left engine during a hot section inspection (HSI) on 21 October 1992. The last HSI on the left engine was completed on 23 December 2003. No records documenting the history of this plenum before 20 February 1992 could be found except for the original date of manufacture.

The right engine was intact with minimal visible damage. There were indications found, as part of the post-teardown investigation, that the engine was producing high power on impact. The P3 and bleed air boss welds were examined, both visually and by fluorescent dye-penetrant inspection (FPI), with no cracks noted. This area had no reinforcing weld between the two bosses. The location between the welds was sectioned to examine the material. A small crack about 0.5 mm deep at midpoint and 3.5 mm long was visually detected along the toe of the P3 boss weld. The crack opened as a result of stress relief during a material analysis sectioning process, as part of this investigation. It was examined in the scanning electron microscope (SEM) and found to be fatigue in nature.

Canadian, Australian, and United States databases for 1974 through 2005 were examined in order to better understand the history of plenum failure for the TPE331 series engine. Sixty service difficulty reports (SDR) were found covering cracked, damaged and ruptured plenums and broken bosses. In addition

- A Service Bulletin, dated 20 May 1970 and applicable to the Shorts SC-7 series III airplanes equipped with the TPE331 series engine, was issued by Short Brothers and Harland Ltd. The bulletin was to prevent cracking around the drain boss of the engine plenum chamber. This Service Bulletin was later the subject of Airworthiness Directives 70-15-12 issued by the FAA and AD/SC7/4 issued by the Australian Civil Aviation Safety Authority.

- Service Bulletin TPE331-72-0373 was issued by the Garrett Turbine Engine Company regarding cracks found at the forward plenum chamber drain boss and was the subject of Airworthiness Directive AD/TPE 331/29 issued by the Australian Civil Aviation Safety Authority.

- On 08 November 2003, a Shorts Skyvan SC7 aircraft, registered in Guyana as 8R-GMC, suffered a fatal accident on take-off when the right TPE331-2-201A engine plenum ruptured. The installed engines had been modified by National Flight Services of Swanton, Ohio, under Supplementary Type Certificate (STC) SE383CH. As a result of this accident, National Flight Services issued a Service Information Letter NF-TPE331-SIL-11031 notifying TPE331 operators to visually inspect their plenums for cracks. Ninety plenums on TPE331 engines installed on eight different aircraft types were inspected; eight cracked plenums were found.

In 1977, the manufacturer changed the plenum drawing to show that, thereafter, the plenum should be manufactured with a single machined casting that incorporates both the P3 and bleed air bosses. No record was found that cracks have occurred in this single machined casting although plenums incorporating it are known to crack at bosses in other locations on this plenum. This change was considered a manufacturing improvement, and there was no requirement to modify existing in-service plenums.

The take-off weight at Terrace was calculated to be 10 272 pounds, 1303 pounds below the maximum allowable take-off weight. It was not possible to calculate the centre of gravity (CG) position, since the load distribution was unknown. However, there was nothing found to indicate that the CG was outside limits.

The MU-2B-36 Aircraft Flight Manual (AFM) permits a take-off using either flap 5 or 20. However, the Nav Air Charter Inc. standard operating procedures (SOPs) state that, for take-off, "The standard take-off in the MU-2 will be made with flap setting of 20 as approved in the Aircraft Flight Manual." Apparently, the procedure was in place to reduce wear and tear on the brakes and tires. The crew used flap 20 for take-off. Based on the environmental conditions at the time of the occurrence, the aircraft would have required a take-off distance of 3400 feet with flap 20 and 3480 feet for flap 5.

The climb performance for two engines operating, flap 20 or flap 5, is approximately 1900 feet per minute (fpm). The single-engine climb performance, with full power on the operative engine, the inoperative propeller feathered, and the landing gear retracted for flaps 20 is approximately 200 fpm and for flap 5 is approximately 400 fpm.

The MU-2 AFM gives pilots the choice between three alternatives following an engine failure on take-off. Should the failure happen before lift-off, the pilot flying (PF) is expected to stay on the runway and stop the aircraft as soon as possible, while maintaining directional control. Should the failure happen after lift-off with the gear down or in transit to up and continued flight is not possible, the PF is expected to put the gear down and land straight ahead. A warning note is added: "If flaps 20° take-off is selected and engine failure occurs after lift-off, continued climb performance is not assured unless the landing gear has completely retracted, the gear doors are closed, and the flaps have reached 5° or less." The third alternative, engine failure after take-off with the gear fully retracted, is covered by the Nav Air Charter Inc. Engine Failure/Fire Emergency procedure.

The NAV Air Charter Inc. MU-2B Engine Failure/Fire checklist requires the crew to accomplish, in part, the following items in the event of an engine failure or fire:

- Maintain 125 knots minimum
- Trim aircraft laterally for wings level
- Power levers maximum continuous
- Landing gear up
- Failed engine condition lever to emergency stop[4]
- Failed engine T-handle pull
- Flaps to 5, then up while increasing airspeed
- Increase airspeed to 148 knots CAS (calibrated airspeed), wings level

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4 This causes the propeller blades to feather.

Examination of the wreckage showed that the lateral trim was set at neutral, indicating that the aircraft wings were not trimmed after the engine failed, the failed engine condition lever was not selected to emergency stop, the flaps were not selected to flaps 5, and based on the fact that the aircraft was not cleaned up to reduce drag, the airspeed probably never increased to 148 knots.

The Nav Air Charter Inc. operations manual, Section 4.22.1, states "Take-off in freezing rain . . . is prohibited in all company aircraft."

Analysis

While approaching the Terrace Airport, the flight crew received the latest METAR, which indicated that light, freezing rain was falling. Even though the company operations manual prohibits take-offs in freezing rain, the crew elected to land and depart the Terrace Airport in reported light freezing rain.

During the take-off from Terrace, the left engine plenum ruptured, which caused the engine to flame out. While the TPE331 engines on the MU-2B aircraft are equipped with an NTS, it is a drag reduction system only and does not include an automatic feathering system. To obtain minimum drag on a failed engine, the propeller must be manually feathered (condition lever to emergency stop). It was determined that the left propeller was rotating at a low speed and was not feathered at impact. The right propeller was rotating at high speed, probably maximum, at impact.

When the left engine failed, there would have been a loss of climb performance because of the increased drag compared to the climb performance with the left propeller feathered. There also would have been a significant loss of climb performance because the crew left the flap at flap 20 following the engine failure.

While the top of the aircraft's wing was wet and free of ice, it is possible that, as the aircraft accelerated down the runway, ice could have formed on the wing as the temperature decreased, thereby reducing the aircraft's performance even further. Once airborne, the aircraft heading changed from 150° M to approximately 070° M in a relatively short time. This heading change would require a moderate bank that would adversely affect climb performance. As a result of the above factors, the aircraft could not climb.

It could not be determined why the aircraft entered a left-hand turn after take-off, although it is possible that the crew members were trying to return to the airport. However, the aircraft climb performance would not be assured until the crew had completed the engine failure checklist items, in particular, the feathering of the left engine and raising the flaps to 5°. Based on the runway length and climb requirements, the use of flap 5 for take-off would have been more advantageous to the crew.

The first officer was flying the aircraft when the left engine failed. It would have been a challenge to control the aircraft in a degraded-performance configuration while trying to complete the engine failure checklist during a turn. The first officer had received his training on engine failures almost a year earlier. If the first officer was having difficulty handling the emergency, the captain may not have had time to take over control. The left engine condition lever was not set to emergency stop; yet, the next item on the checklist "pull T-handle" had been completed. This would suggest that there was some uncertainty in the cockpit. The captain was sitting in a seat he normally did not occupy when flying the aircraft or conducting the engine failure checklist, and it had been 10 months since he had last practised this drill, which may have contributed to the uncertainty.

It is evident that the TPE331 series engine plenum is prone to developing cracks at bosses, particularly in areas where two bosses are in close proximity and a reinforcing weld has been made. Cracks that develop in this area cannot necessarily be detected by visual inspections or even by FPI inspections.

The following TSB Engineering Laboratory report was completed:

LP 09/2006 – Engine Examination

This report is available upon request from the Transportation Safety Board of Canada.

Findings as to Causes and Contributing Factors

1. During the take-off, the left engine combustion chamber plenum split open due to a fatigue crack. The rupture was so extensive that the engine flamed out.

2. The crew did not feather the left engine or retract the flaps, and the aircraft entered a moderate left-hand turn after take-off; the resulting drag caused the aircraft to descend until it contacted trees.

3. The first officer's flying skills may have been challenged during the handling of the engine failure, and the checklist was conducted out of sequence, suggesting that there may have been uncertainty in the cockpit. A contributing factor may have been the captain's unfamiliarity with handling an emergency from the right seat.

4. The use of flap 20 for take-off, although in accordance with company policy, contributed to the difficulty in handling the aircraft during the emergency.

Findings as to Risk

1. The TPE331 series engine plenum is prone to developing cracks at bosses, particularly in areas where two bosses are in close proximity and a reinforcing weld has been made. Cracks that develop in this area cannot necessarily be detected by visual inspections or even by fluorescent dye-penetrant inspections (FPIs).

2. Because the wing was wet and the air temperature was at 0°C, it is possible that ice may have formed on top of the wing during the take-off, degrading the wing's ability to generate lift.

3. Being required to conduct only flap 20 take-offs increases the risk of an accident in the event of an engine problem immediately after take-off.

Other Finding

1. The plenum manufactured with a single machined casting, incorporating the P3 and bleed air bosses, is an improvement over the non-single casting boss plenum; however, cracks may still develop at bosses elsewhere on the plenum.

Safety Action Taken

On 06 July 2006, the TSB issued Safety Advisory A060025-1 suggesting that Transport Canada (TC) may wish to remind MU-2B and other twin-engine operators of the importance of ensuring that the required checklist items are completed immediately after recognition that an engine has failed on take-off.

On 08 September 2006, TC issued Service Difficulty Advisory (SDA) AV-2006-07 regarding Mitsubishi MU-2B cracked combustor plenums (Honeywell TPE-331-6-252M engines). The SDA recommended compliance with the manufacturer's (Honeywell) service bulletin (SB) TPE331-72-2023 to change the combustion chamber from a 3102613-1 (multi-casting boss plenum) to a 3102613-2 (single-casting boss plenum). TC also recommended that maintenance personnel be extra attentive to boss welds when inspecting TPE331 series engines for plenum cracks.

On 14 November 2006, the TSB re-issued Safety Advisory A060025-1 suggesting that TC may wish to remind MU-2B and other operators of the effect of flap settings on achieving a required climb gradient following an engine failure in varying ambient conditions.

On 18 May 2007, the TSB issued Safety Advisory A06P0298-D2-A2 (C*racks in TPE331 Series Engine Plenum).* The advisory described the history of plenum cracking with the TPE331 series engine, particularly in areas where two bosses are in close proximity and a reinforcing weld has been made. Cracks that develop in this area cannot necessarily be detected by visual inspections or even by fluorescent dye-penetrant inspections (FPIs). The advisory suggested that TC may wish to advise commercial operators of the circumstances of this occurrence. Additionally, it suggested that TC may wish to consider the requirement for discussion with the FAA regarding the effectiveness of the maintenance instructions for identifying cracks in the TPE331 series engine plenum.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 13 June 2007.

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