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Cessna 404's Left Engine Fails on Takeoff, Captain Feathers Propeller on Right Engine

Fatigue cracks caused the teeth on the starter-motor gear to break, resulting in excessive damage to the left engine's accessory gear train. The progressive failure of the left engine and the feathering of the propeller on the right engine resulted in total loss of thrust. The aircraft stalled when the crew attempted to turn back and land at the departure airport.

FSF Editorial Staff

At 1136 local time Sept. 3, 1999, a Cessna 404 operated by Edinburgh Air Charter struck terrain during takeoff from Glasgow (Scotland) Airport. The commander [captain], second pilot [first officer] and six passengers were killed; three passengers received serious injuries. The aircraft was destroyed.

The U.K. Air Accidents Investigation Branch (AAIB) said, in its final report on the accident, that the following were causal factors:

- "The left engine suffered a catastrophic failure of its accessory gear train, leading to a progressive but complete loss of power from that engine;
- "The propeller of the failed engine was not feathered, and therefore the aircraft was incapable of climbing on the power of one engine alone;
- "A total loss of thrust occurred once the left engine had failed and the right propeller had been feathered; [and,]
- "The commander attempted to return to the departure airfield but lost control of the aircraft during a turn to the right."

The accident aircraft had been chartered to fly an airline crew from Glasgow to Aberdeen. Although the Cessna 404 was certified for single-pilot operation, the airline required that the charter company dispatch two pilots for the flight. The commander and second pilot frequently had flown the aircraft together.

The commander, 49, held a commercial pilot license, an instrument rating and flight instructor ratings for single-engine airplanes and for multi-engine airplanes weighing less than 5,700 kilograms/12,500 pounds. He had 4,190 flight hours, including 173 flight hours in type. He was the company's managing director, chief pilot and training manager.

The second pilot, 54, held a commercial pilot license and a flight instructor rating for single-engine airplanes weighing less than 5,700 kilograms. He had 2,033 flight hours, including 93 flight hours in type.

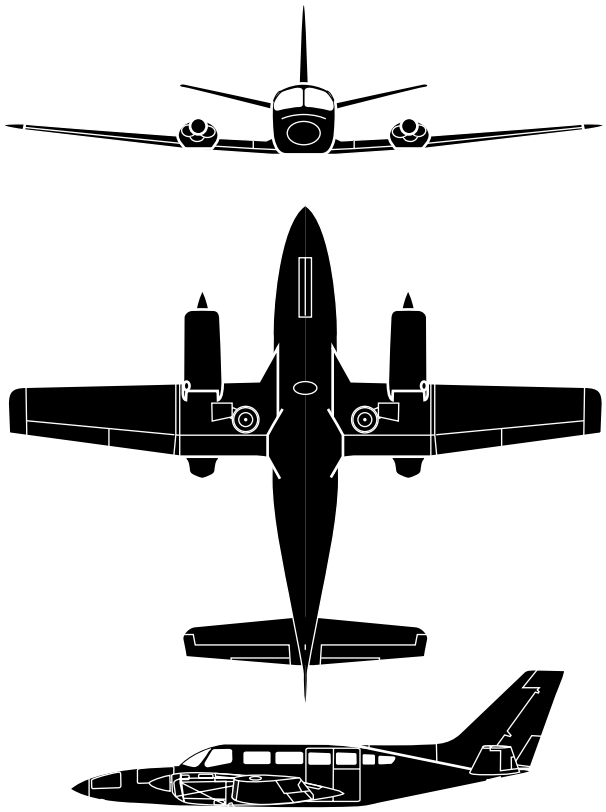
The report said that the second pilot was qualified to fly 400-series Cessnas, but he was not qualified to fly the Cessna 404 on single-pilot revenue flights because he had not completed the required type-specific tests and check rides.

"His duties were chiefly to assist the commander with radio telephony and administration," the report said.

The accident aircraft was manufactured in 1980 and was operated in the United States until 1991, when it was exported

to Germany. Edinburgh Air Charter acquired the aircraft in 1998. At the time of the accident, the aircraft had accumulated 6,532 operating hours.

The commander completed a proficiency check in the Cessna 404 five days before the accident. He then was off duty for four days.



Cessna 404 Titan

Cessna Aircraft Co. began production of the Model 404 Titan in 1977. The aircraft is certified for single-pilot operation and can be configured to carry up to 10 passengers or freight.

The aircraft is powered by two Teledyne Continental Motors GTSIO-520M reciprocating engines, each of which is rated at 375 horsepower (280 kilowatts). Each of the turbocharged, six-cylinder engines drives a three-blade, constant-speed McCauley propeller through a reduction gearbox.

Standard fuel capacity is 344 gallons (1,302 liters). Maximum takeoff weight is 8,400 pounds (3,810 kilograms). Maximum landing weight is 8,100 pounds (3,674 kilograms).

Maximum rate of climb is 1,575 feet per minute. Best rate of climb airspeed with one engine inoperative is 109 knots. Maximum single-engine rate of climb is 230 feet per minute.

At 75 percent power and 20,000 feet, cruise speed is 213 knots and range is 1,050 nautical miles (1,945 kilometers). Service ceiling is 26,000 feet. Stall speed with power off and flaps retracted is 85 knots. Stall speed in landing configuration is 70 knots.♦

On the day of the accident, the commander flew a Cessna 310 on a traffic-survey flight in Glasgow from 0710 to 0800. He then drove from Glasgow to the company's headquarters in Edinburgh [a distance of about 60 kilometers (37 statute miles)]. At 0935, he drove back to Glasgow, where he met the second pilot, who also had driven to Glasgow from Edinburgh.

"No one paid much attention to the aircraft or [to] the preflight activities of the crew," the report said. "The passengers were collected in a minibus from their offices near the airport's main terminal and were driven to the aircraft, where they met the crew and handed over their bags."

The pilots loaded the bags in the aircraft's nose baggage compartment. The report said that to calculate aircraft weight and balance, the commander recently had begun determining each passenger's weight because he believed that using the nominal passenger weights allowed by regulations was "inaccurate and operationally restrictive." The commander previously had flown the passengers in the Cessna 404; on the day of the accident, he did not determine each passenger's weight.

"A weighing device [a bathroom scale] was carried on the aircraft, but none of the survivors recalled anyone being weighed or asked to give their weight to the handling agent or [to] the crew before the flight," the report said.

The crew did not give a copy of the weight-and-balance sheet for the flight to the handling agents in Glasgow. The aircraft's technical log, which likely contained the weight-and-balance sheet, was destroyed by a post-impact fire. The report said that the weight and balance of the accident aircraft therefore could not be determined accurately. Maximum takeoff weight of a Cessna 404 is 8,400 pounds (3,810 kilograms). Investigators calculated that the takeoff weight of the accident aircraft was between 8,320 pounds and 8,600 pounds (3,774 kilograms and 3,901 kilograms).

Investigators calculated that the aircraft's center of gravity (CG) on takeoff was between 175.4 inches (aft of datum) and 178.9 inches, and was within the certified CG range of 170.5 inches to 179.2 inches.

The crew started the engines at 1126. The survivors told investigators that the crew had no difficulty starting the engines. A witness who observed the aircraft taxiing said that he heard engine speed increase and decrease, and that the engines appeared to misfire as their speed changed.

"[The] noises reported by [this] witness during the taxiing phase were most likely due to normal engine-testing procedures," the report said. The captain usually checked the engine magnetos and the propeller-control system while taxiing the aircraft.

The report said that the engine noises heard by the witness also could have been caused by temporary spark plug contamination.

At 1133, the crew began the takeoff near the approach end of Runway 23. The runway was 2,658 meters (8,721 feet) long. At the time, the temperature was 19 degrees Celsius (66 degrees Fahrenheit), and the surface wind was from 220 degrees at 14 knots. Airport elevation was 26 feet.

The aircraft lifted off the runway after a ground roll of about 1,090 meters (3,576 feet). The airplane information manual indicates that, under the existing conditions, the takeoff ground roll should have been about 730 meters (2,395 feet) — or about 360 meters (1,181 feet) less than the accident aircraft's ground roll. The airplane information manual takeoff data are based in part on the application of full power before brake release and liftoff at the recommended safe single-engine speed.

The report said that the pilot likely released the brakes before applying full power and might have caused the aircraft to lift off at a higher-than-recommended airspeed.

"Where runway length is not a limiting factor, it would be reasonable for the commander deliberately to remain on the runway while accelerating from the recommended safe single-engine speed of 102 KIAS [knots indicated airspeed] to the one-engine inoperative best rate of climb speed of 109 KIAS," the report said. "The distance traveled during this acceleration could have been consistent with the extra 360 meters.

"Low engine power is an alternative explanation for the increased ground roll, but it would have had to be a near-symmetric loss of power for the commander not to have noticed it."

After liftoff, the aircraft entered what the surviving passengers described as a gentle climb.

"According to survivors, the takeoff proceeded normally until shortly after the aircraft became airborne, when they heard a thud or bang," the report said.

The surviving passengers, who were in the rearmost cabin seats, believed that the sound came from the right engine. One passenger observed the commander looking in the direction of the right engine.

"It is possible that the bang came from the left engine but sounded as if it came from the right engine … ," the report said. "A transient fault in the right engine could have caused a bang. For instance, the aircraft had not [been] flown for several days. Water might have condensed in the fuel tanks and, although the operator's standard preflight checks included a fuel check and the draining of any water from the tanks, there was no way of knowing if the crew had drained any water from the tank sumps. If they had not, a small quantity of water could have entered the fuel lines during taxiing or takeoff and made its way to the right engine. Once in the injector lines, it could have caused a temporary interruption in power, followed by a loud bang from the exhaust as engine power was restored.

"No inference that this happened is intended. It is simply a plausible explanation, and there might be other reasons for a temporary malfunction that left no trace."

Investigators calculated that the aircraft was between 200 feet above ground level (AGL) and 660 feet AGL — "likely nearer 200 feet than 660 feet," the report said — when the bang was heard. After hearing the bang, one passenger observed the right propeller turning slowly.

"There followed a 'lurch,' and the propeller stopped," the report said. "[The passenger] could see the commander rapidly working the controls, including the levers between the pilots' seats, and he became aware of a burning smell in the cabin."

At 1135, the airport local controller told the crew that when they were ready, they could conduct a right turn toward their first navigational fix.

The commander told the controller, "We do have an emergency. Just like to return." The controller cleared the crew to return to the airport.

A motor-vehicle driver told investigators that his attention was drawn to the accident aircraft by the sound of a "spluttering" engine.

"He could see [that] the right propeller was slowing, but the left engine and propeller seemed to him to be behaving normally, and the aircraft was still climbing, albeit at an odd angle towards the pilot's right side," the report said.

The witness said that when the aircraft began to turn right, the right propeller stopped rotating. Several other witnesses also heard spluttering noises and observed the right propeller rotating slowly and then stopping.

The flight crew of a Boeing 767, which was holding in position for takeoff on Runway 23, observed the Cessna 404 flying left of the extended runway centerline in a wings-level attitude at 400 feet AGL to 500 feet AGL. The B-767 pilots said that the aircraft was not climbing and that it then banked right.

"Initially, [the aircraft] appeared to be under control, but it steadily lost height in the turn," the report said. "The angle of bank increased until it was near vertical, and then the nose dropped. [The B-767 pilots] saw the aircraft enter a steep dive before disappearing behind trees."

The aircraft was banked about 10 degrees right and was pitched about five degrees nose down when it struck a flat, turf field and then a thick hedge on a slight embankment. The landing gear and flaps were retracted, and neither engine was producing power on impact.

"No objective indications were obtained to quantify the speed at impact or the rate of descent," the report said.

Investigators determined that the left propeller was windmilling [i.e., not powered and not feathered] and that the right propeller blades were near the feathered position when the impact occurred.

"The aircraft had no automatic feathering mechanism," the report said. "Therefore, the right propeller lever must have been selected to 'FEATHER.' The commander was seen moving engine control levers after the bang was heard, and so he must have deliberately or inadvertently feathered the right propeller."

The report said that when the aircraft struck terrain, the right propeller blades were moving either toward the feathered position or away from the feathered position. The latter might have resulted from an attempt by the commander to restart the right engine.

The aircraft decelerated rapidly when it struck the hedge and then slid about 30 meters (98 feet) in a cultivated field before coming to a stop.

The report said that all the occupants were retained in their seats by their seat belts and that all the passenger seats and one pilot seat became detached from the floor during the accident.

"The result was that the seats, and their occupants, had moved forward and become compressed into a smaller area forward in the cabin," the report said.

Both pilots and one passenger in a forward passenger seat died from traumatic impact injuries — primarily, severe chest injuries and severe head injuries. The other eight passengers received a variety of serious impact injuries; five of them died as a result of the post-impact fire.

The three survivors exited the wreckage with the help of a farm worker who had observed the accident and had driven his tractor to the site.

"He saw that the aircraft was severely damaged and on fire," the report said. "One of the survivors was crawling clear of the wreckage. He helped him to safety, then went back to the wreckage and found another survivor lying against the disrupted fuselage. He dragged this survivor clear and returned to look for further survivors.

"Seated in one of the rear seats, with his clothing on fire, was another survivor. The tractor driver removed the survivor from the wreckage, smothered his clothing with wet grass and then dragged him clear of the wreckage to join the other survivors.

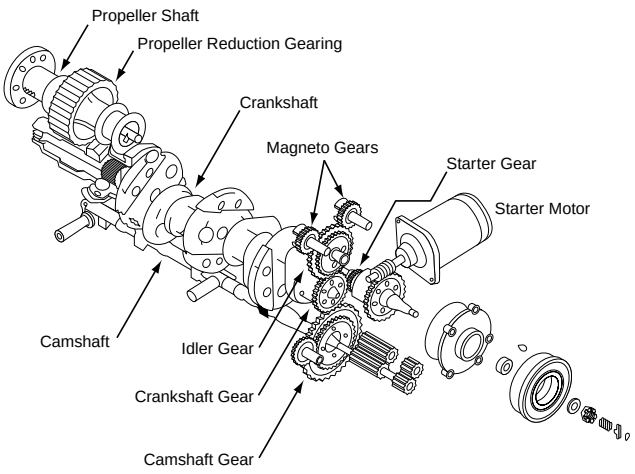
"By this time, he could hear explosions from within the wreckage and the fire was becoming intense. He did not see anybody else within the wreckage and was unable to approach the wreckage because of the now-intense heat."

Aircraft rescue and fire fighting (ARFF) personnel arrived at the accident site at 1146. They extinguished the fire with foam and administered first aid to the survivors until paramedics arrived in an ambulance.

Postaccident examination of the left engine showed that the accessory gear train was damaged extensively. The report said that the damage was precipitated by failure of the starter motor adapter shaft gear (starter gear).

The accessory gear train, which is mounted in a gearbox at the rear of the engine, also includes a gear that drives the camshaft and an idler gear that drives the two magneto gears (see Figure 1). The accessory gear train is driven by a gear on the engine crankshaft.

Teledyne Continental Motors GTSIO-520 Engine Drive Train



Source: U.K. Air Accidents Investigation Branch

Figure 1

Investigators found that all the teeth on the starter gear and all the teeth on the camshaft gear had broken off. Some teeth on the crankshaft gear and some teeth on the idler gear also had broken off.

"Examination of the starter gear revealed that there was evidence of fatigue cracking in some of the tooth failures," the report said. "The presence of such progressive fatigue cracking in the starter gear, compared with the gross overloading which was seen in the other gears, indicated that the starter gear was the first gear to fail."

The accessory gear train on Teledyne Continental Motors GTSIO-520 engines in Cessna 404s and other aircraft was the subject of a critical service bulletin issued by the engine manufacturer in 1994. The bulletin, CSB94-4, recommended inspections every 200 hours of the crankshaft gear, the starter gear and a needle roller bearing that supports the starter adapter shaft. The bulletin said that the 200-hour inspections could be discontinued after a modified crankshaft gear and a modified starter gear were installed.

"[The bulletin] contained a warning that 'compliance with this bulletin is required to prevent possible failure of the starter adapter shaft gear and/or crankshaft gear, which can result in engine failure and/or metal contamination," the report said.

[Teledyne Continental Motors has issued several revisions of the bulletin. As of Aug. 5, 2002, the most recent revision was CSB94-4D, issued by the engine manufacturer on Feb. 14, 2001.]

A modified starter gear and a modified crankshaft gear were installed in the accident airplane's left engine when the engine was remanufactured in July 1995. The engine had accumulated 1,030 service hours since the remanufacture when, in February 1999, the starter adapter assembly was removed for repair because of engine-starting problems. While the starter adapter assembly was being repaired, the left engine was operated for 38 hours with an unmodified starter gear.

"The mixing of modified [gears] and unmodified gears was not envisaged in the manufacturer's service information, but there were no instructions which prohibited it," the report said. "Given the nature of the modifications made to the gears (re-profiling to decrease backlash between the gears and shot peening of tooth root surfaces), it is considered that mixing the two modification standards would not have had a detrimental effect on, in this case, the crankshaft gear."

After the repaired starter adapter assembly was reinstalled with a new (modified) starter gear, the engine was operated for 255 hours before the accident.

"The crankshaft gear reportedly appeared satisfactory when the new starter gear was fitted, but the engine manufacturer considered that the distress suffered by the new starter gear within this relatively short period of time [i.e., the 255 hours of operation preceding the accident] could have been attributable, in part, to its meshing with a used gear which would have been worn to some extent."

The accident aircraft's right engine was remanufactured and was installed on Aug. 5, 1999. The engine was operated for 35 hours before the accident.

"The right engine was stripped and examined at an overhaul facility in the U.K.," the report said. "No failures, defects or signs of unusual operation were found."

Investigators found the fuel selectors for both engines positioned to the opposite fuel tanks — that is, the fuel selector for the left engine was positioned to the "RIGHT MAIN" tank setting and the fuel selector for the right engine was positioned to the "LEFT MAIN" tank setting.

"Both fuel selector valves were found at the crossfeed position, and a reason for both to be so selected is not readily apparent," the report said. "However, the left system had not been trapped in any way by impact damage, and it might well have been moved by airframe distortion during the crash. The actuating cable of the right side was trapped in this position, and there is therefore a possibility that crossfeeding of the right engine from the left tank was a pre-impact in-flight selection by the pilot."

The aircraft was not equipped with — and was not required to be equipped with — a flight data recorder (FDR) or a cockpit voice recorder (CVR).

"The paucity of 'firm' data, particularly the absence of any flight data or cockpit voice recording, frustrated efforts to reconstruct precisely the flight path and sequence of events which led to the accident," the report said.

The report said that if the failing engine had been identified and if the propeller on the failing engine had been feathered, the aircraft, "if properly flown … should have been able to climb, albeit slowly, and subsequently make a safe landing back at Glasgow Airport."

The airplane information manual indicates that at maximum takeoff weight and under the conditions that existed during the accident, maximum single-engine rate of climb is 200 feet per minute. The report said that this rate is "almost exactly the same" as the single-engine climb rate observed by investigators during postaccident flight tests of a Cessna 404. (The climb rate observed during the flight tests was 196 feet per minute.)

"Interpolation of the [airplane information manual data] for a weight of 8,600 pounds shows a scheduled climb rate of 160 feet per minute, so the aircraft should still have been able to climb had it been 200 pounds overweight," the report said.

The report said that when the accident aircraft stopped climbing, an emergency landing in a field more or less straight ahead, rather than an attempt to turn back and land at the airport, might have resulted in a different outcome.

"There would still have been a fire risk and probably a rapid longitudinal deceleration, but the vertical speed at impact could have been low, the wings could have been leveled, and the hedgerows might have been avoided," the report said. "This would have made the end of the flight far more survivable for all on board."

Based on the findings of the accident investigation, AAIB made the following recommendations:

- "The U.S. Federal Aviation Administration [FAA] and the U.K. Civil Aviation Authority [CAA] should make mandatory the revised critical service bulletin, CSB94-4B, which requires a repetitive inspection of GTSIO-520 starter gears and crankshaft gears. [Recommendation 2000-12];[1]

- "The CAA should take forward to the JAA [Joint Aviation Authorities] a proposal to re-examine the criteria for the carriage of flight recorders by

multi-piston-engine aircraft, which have in force a certificate of airworthiness in the Transport Category (Passenger) and are certified to carry more than nine passengers, with a view to requiring all aircraft, whether piston[-powered] or turbine-powered, to carry at least a [CVR]. [Recommendation 2001-38];[2] [and,]

- "The CAA should undertake a study to identify those elements of the current JAR [Joint Aviation Requirements] 25 seat standards which may be used for retrofit into existing airplanes whose maximum certified takeoff mass is less than 5,700 kilograms [and], separately, for those designs *in continuing production* which are not covered by the current JAR 23 standards. These elements should then be applied at least to those that are operated in the Transport Category (Passenger). [Recommendation 2001-40]."[3]♦

[FSF editorial note: This article, except where specifically noted, is based on U.K. Air Accidents Investigation Branch Aircraft Accident Report No. 2/2001 (EW/C99/9/01). The 80-page report contains illustrations and appendixes.]

Notes

1. In response to Recommendation 2000-12, the U.S. Federal Aviation Administration (FAA) on Feb. 7, 2002, told the U.K. Air Accidents Investigation Branch (AAIB) that "the recommended mandatory action is not necessary." FAA said that on March 2, 2001, it published a special airworthiness information bulletin (SAIB NE-01-17) that recommends compliance with the revised Teledyne Continental Motors (TCM) critical service bulletin, CSB94-4D. FAA told the AAIB that "the service bulletin, proper maintenance procedures and the SAIB have combined to reduce the risk" of an accident or an incident. The U.K. Civil Aviation Authority (CAA) on July 10, 2000, issued Additional Airworthiness Directive 004-06-2000, which requires operators of TCM GTSIO-520 engines in aircraft registered in the United Kingdom to comply with CSB94-4D.

2. In response to Recommendation 2001-38, the CAA told the AAIB that on July 9, 2001, it requested that the Joint Aviation Authorities Flight Recorders Study Group "re-examine the criteria for the carriage of flight recorders in line with this recommendation."

3. In response to Recommendation 2001-40, the CAA told the AAIB that it would conduct a study to identify any relevant parts of current JAR [Joint Aviation Requirements] 25 seat standards that could effectively be applied to aircraft weighing less than 5,700 kilograms/ 12,500 pounds. The study was completed in March 2002. As of Aug. 5, 2002, the CAA was conducting further study of JAR 25 aircraft-seat standards that might be useful to apply to JAR 23.

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