National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: May 27, 2003

In reply refer to: A-03-18 through -21

Honorable Marion C. Blakey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On March 27, 2003, about 1636 central standard time, a Bell 407 helicopter, N175PA, registered to I, Inc., of Kirkland, Washington, and operated as a public-use flight under contract to the U.S. Forest Service, lost engine power and crashed into heavily wooded terrain while conducting low-level flight operations in support of an interagency mission to recover debris from the Columbia space shuttle accident near Broadus, Texas. The helicopter pilot and one crewmember were killed, and three other crewmembers sustained serious injuries. Visual meteorological conditions prevailed, and a visual flight rules flight plan was filed for the flight. Surviving passengers and witnesses on the ground reported that the engine lost power during a hover and that the helicopter descended into the trees.

Background

The Bell 407 helicopter is equipped with a Rolls-Royce 250-C47B series IV engine, which incorporates a full authority digital electronic control (FADEC) system[1] that electronically controls engine fuel flow via a hydromechanical unit (HMU) and an electronic control unit (ECU). The FADEC system can operate in automatic or manual mode; it operates in automatic mode by default, using the cockpit throttle position angle (PLA), among other inputs, to determine the engine fuel metering requirements necessary to maintain efficient engine operation. A potentiometer mounted on the HMU detects[2] the PLA and generates a signal that is sent to the ECU, which processes the PLA signal (and other engine information) and generates a signal that is sent to the HMU to control fuel flow. When operated in the manual mode, the ECU deactivates the auto/manual solenoid on the HMU, eliminating electromechanical metering of the fuel. The fuel flow is then hydromechanically controlled via the throttle position and the HMU.

[1] The same FADEC system and components are used in all Rolls-Royce 250 series IV engines. Other single-engine applications include the McDonnell Douglas (Boeing) MD-600 helicopter, which is equipped with a Rolls-Royce 250-C47M engine, and the U.S. Army version OH-58 helicopter, which is equipped with a Rolls-Royce 250-C30R/3 engine.

[2] The PLA is transmitted via a mechanical link between the cockpit and a shaft contained within the HMU.

The FADEC system automatically switches from automatic to manual mode if it detects certain faults. Otherwise, the pilot may choose to switch to manual mode by pushing a FADEC mode switch button on the forward instrument panel. In either case, the full effect of the transition to manual mode may take from 1.6 to 5.8 seconds, depending on the altitude and power setting of the engine.

Discussion

Postaccident testing of the engine and the FADEC system (comprising the ECU, HMU, and wiring harness) recovered from the wreckage revealed that the engine did not accelerate properly when the FADEC system was operated in the automatic mode. Specifically, the engine ran erratically and, at times, rolled back (that is, lost power) when the throttle was advanced. A discrepancy was noted between the actual PLA (measured at the HMU/PLA shaft protractor) and the potentiometer PLA signal obtained from the ECU. During the engine tests, the potentiometer PLA signal was erratic and fluctuated between 39° and 98° while the actual PLA remained at 55º. When the FADEC system was tested in manual mode, the engine operated normally and correctly responded to throttle inputs.

The wiring harness, which provides the connection between the HMU, ECU, airframe, and the engine, was tested and found to perform normally. The suspect HMU and potentiometer were removed from the engine, visually examined, and functionally tested. The HMU performed normally when operated in the manual mode but not when operated in the automatic mode. Test results confirmed a faulty potentiometer. The potentiometer output signal was erratic, experiencing sudden sharp spikes in the positive and negative directions. These spikes were observed when the PLA shaft was rotated and also when the shaft was stationary. All other aspects of the HMU functionally tested within limits.

Although the National Transportation Safety Board's investigation of this accident is ongoing and it has not determined the role that the erratic potentiometer PLA signals observed during testing may have played in the accident, the Safety Board notes that an erroneous or erratic potentiometer PLA signal may cause an uncommanded increase or decrease in fuel flow, either of which may result in a potentially drastic reduction in engine power. In addition, the Board's examination of the FADEC system architecture revealed that the potentiometer failure noted during testing is not a recognized hard-fault condition[3] within the FADEC system's coding.[4] As a result, the system does not generate a fault warning in the cockpit to alert the pilot if this failure occurs nor does it automatically transition to manual mode operation. Therefore, the only remedy available to a pilot in this circumstance is to switch to manual mode once he has somehow determined that the automatic fuel control system has failed. In certain flight regimes (for example, low-level hover), engine power may not recover in time to prevent a crash; thus, this deficiency in the FADEC system's design represents a catastrophic failure mode.

[3] A hard-fault condition is a failure that does not allow continued operation of the FADEC system in automatic mode.

[4] The Safety Board notes that a potentiometer PLA signal that is greater than 110º is recognized by the FADEC system as a hard-fault condition. The erratic potentiometer PLA signals noted during testing were well within the acceptable range.

The Safety Board understands that modifying the FADEC system in question to address this issue is a long-term solution. However, interim action is needed to make sure that pilots and operators of single-engine helicopters equipped with Rolls-Royce Model 250 series IV engines are aware that this potential failure exists. Therefore, as an interim action, the Safety Board believes that the FAA should issue a flight standards information bulletin (FSIB) informing operators and pilots of single-engine helicopters equipped with Rolls-Royce Model 250 series IV engines of the circumstances of this accident and indicating that a potential fault with the FADEC system may cause a sudden, uncommanded decrease of engine power without any identified cockpit indication or warning. The FSIB should also note that switching to manual mode may correct the engine power problem but that recovery to full power may take 2 to 6 seconds, thus possibly precluding a successful recovery to normal flight while operating in those altitude/airspeed combinations under which a safe autorotational landing is not probable. The Board also believes that the FAA should require the manufacturer of the FADEC system installed on helicopters equipped with Rolls-Royce Model 250 series IV engines to modify the system such that an erroneous or erratic in-range potentiometer PLA signal will not cause an uncommanded increase or decrease in fuel flow, which could result in a drastic reduction in engine power.

The Safety Board is aware that Rolls-Royce issued a commercial service letter (CSL), dated April 8, 2003, and revised April 29, 2003, to all operators of helicopters equipped with Model 250 series IV engines informing them of the accident discussed in this letter. The CSL reminds operators to review and adhere to warnings contained in their operations and maintenance manuals regarding when it may be necessary for a pilot to switch to manual mode and the altitude/airspeed combinations under which a "safe autorotational landing might not be possible." Despite these reminders, the Board does not believe that this CSL adequately emphasizes that a pilot may not be able to recover to normal flight conditions if an undetected potentiometer fault occurs while operating at those altitude/airspeed combinations under which a safe autorotational landing is not probable. Because helicopters commonly perform these operations and the nature of this potentiometer failure mode is not yet known, the Board believes that the FAA should prohibit the operators of single-engine helicopters equipped with Rolls-Royce Model 250 series IV engines from operating in those altitude/airspeed combinations under which a safe autorotational landing is not probable until it is shown that the operation of these engines provides an adequate margin of safety.

Following this accident, Rolls-Royce developed an on-aircraft test procedure to evaluate the HMU potentiometer PLA signal in FADEC systems installed on Bell 407 helicopters. The procedure requires operating the throttle without the engine running, capturing data using existing maintenance test equipment, and sending these data to Rolls-Royce for analysis. Rolls-Royce distributed this procedure via a customer support instruction letter to selected Bell 407 operators requesting that they obtain data, on a one-time basis, from as many HMUs as possible by April 25, 2003. Safety Board staff tested the accident potentiometer and an exemplar potentiometer using a procedure very similar to the one contained in Rolls-Royce's letter, compared the results, and found the procedure to be effective.

It is not clear at this time that the procedure developed by Rolls-Royce will capture all potentially catastrophic failure modes of these potentiometers. Further, it is not clear if the erratic

nature of the accident potentiometer was present on previous flights or if it developed shortly before the accident. However, given that the test procedure developed by Rolls-Royce has been shown to be effective in identifying potentiometers that exhibit the erratic characteristics observed in the accident potentiometer and may help prevent an uncommanded reduction in engine power, the Safety Board sees no reason to perform this procedure for only some Bell 407 helicopters. This procedure should be accomplished on all HMUs installed on Bell 407, MD-600, and OH-58[5] helicopters as soon as practicable. Therefore, because of the importance of a correct potentiometer PLA signal, the Safety Board believes that the FAA should require, on an expedited basis, that the on-aircraft test procedure developed by Rolls-Royce to identify faulty potentiometers be performed, on a repetitive basis at a conservative interval, on all Bell 407, MD-600, and OH-58 helicopters to determine if the potentiometer contained in the HMU is working properly. HMUs with faulty potentiometers should be replaced.

Because the accident discussed in this letter is the only case in which erratic potentiometer PLA signals have been noted, the Safety Board has not designated these safety recommendations urgent. However, the Board urges the FAA to process these recommendations on an expedited basis.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Issue a flight standards information bulletin (FSIB) informing operators and pilots of single-engine helicopters equipped with Rolls-Royce Model 250 series IV engines of the circumstances of this accident and indicating that a potential fault with the full authority digital electronic control system may cause a sudden, uncommanded decrease of engine power without any identified cockpit indication or warning. The FSIB should also note that switching to manual mode may correct the engine power problem but that recovery to full power may take 2 to 6 seconds, thus possibly precluding a successful recovery to normal flight while operating in those altitude/airspeed combinations under which a safe autorotational landing is not probable. (A-03-18)
>
> Require the manufacturer of the full authority digital electronic control system installed on helicopters equipped with Rolls-Royce Model 250 series IV engines to modify the system such that an erroneous or erratic in-range potentiometer throttle position angle signal will not cause an uncommanded increase or decrease in fuel flow, which could result in a drastic reduction in engine power. (A-03-19)
>
> Prohibit the operators of single-engine helicopters equipped with Rolls-Royce Model 250 series IV engines from operating in those altitude/airspeed combinations under which a safe autorotational landing is not probable until it is shown that the operation of these engines provides an adequate margin of safety. (A-03-20)

[5] The OH-58 helicopter is the military version of the Bell 407 model. The U.S. Army Safety Center has been advised of the Safety Board's concerns.

Require, on an expedited basis, that the on-aircraft test procedure developed by Rolls-Royce to identify faulty potentiometers be performed, on a repetitive basis at a conservative interval, on all Bell 407, MD-600, and OH-58 helicopters to determine if the potentiometer contained in the hydromechanical unit (HMU) is working properly. HMUs with faulty potentiometers should be replaced. (A-03-21)

Chairman ENGLEMAN, Vice Chairman ROSENKER, and Members CARMODY, GOGLIA, and HEALING concurred with these recommendations.

Original Signed

By: Ellen G. Engleman
Chairman