National Transportation Safety Board
Washington, D.C. 20594

Safety Recommendation

Date: August 11, 1998

In reply refer to: A-98-67 through -70

Honorable Jane F. Garvey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On September 6, 1997, a Saudi Arabian Airlines (Saudia) Boeing 737-200, powered by two Pratt & Whitney (P&W) JT8D-15 engines, experienced an uncommanded acceleration of the No. 2 (right) engine during takeoff roll at Najran, Saudi Arabia. The captain reported that he noticed that the exhaust gas temperature (EGT) overtemperature light for the No. 2 engine was illuminated during the takeoff roll at approximately 110 knots. The captain reduced thrust on the No. 2 engine, but the EGT indication remained at the maximum EGT limit. The takeoff was rejected and the thrust levers were retarded to idle; however, the No. 2 engine remained at a high power level. Further attempts to retard the power were unsuccessful and the airplane departed the left side of the runway, resulting in damage to the landing gear and separation of the No. 2 engine. Four of the 79 passengers sustained minor injuries during the evacuation, and the airplane was destroyed by a postcrash fire. The National Transportation Safety Board is participating in the Presidency of Civil Aviation of the Kingdom of Saudi Arabia's investigation in accordance with the provisions of Annex 13 to the Convention on International Civil Aviation.

The fuel pump and fuel control for the No. 2 engine were removed and later disassembled during an inspection. Included in the JT8D engine fuel pump assembly is a splined control shaft[1] that transmits the N_2[2] signal from the fuel pump to the fuel control. The control shaft is splined on one end where it mates with the fuel pump and on the opposite end where it mates with the fuel control. Although damage to the housing precluded a bench test of the fuel control, no wear of the mating splines between the fuel control and the control shaft was observed. However, the splines where the control shaft mates with the fuel pump were almost completely stripped. This damage allowed the splines of the fuel pump gear shaft to rotate past the splines of the control shaft.

[1] A shaft containing a set of integral keys, or teeth, that fit within corresponding grooves on a mating shaft or gear.
[2] Rotational speed of the high-pressure compressor. The N_2 signal is one of several inputs used by the fuel control to schedule fuel delivery.

Following a series of control shaft spline failures in the late 1970s attributed to misalignment of the control shaft, Argo-Tech Corporation, the manufacturer of JT8D fuel pumps, conducted tests on the fuel pump to determine the cause of the failures. The testing indicated that torque generated during operation of the pump was causing misalignment between the control shaft and the mating gear in the fuel pump, which was leading to premature wear of the control shaft splines. To address this problem, Argo-Tech issued Service Bulletin (SB) 73-34 on January 15, 1980. The SB specifies a 0.0036-inch lateral shift of the fuel pump's gear train to reduce control shaft spline wear problems (with no tolerance allowed). Records indicated that after installation of a new control shaft on the fuel pump from the Saudia airplane in 1993, the gear train was offset per the SB by an overhaul facility. However, postaccident measurement showed that the centerline shift of the gear train was 0.0030 inch, which is outside the allowable tolerance. The pump had been operated 3,237 hours since the SB modification.

The centerline shift recommended by SB 73-34 was established to reduce wear of the control shaft splines caused by misalignment resulting from normal operation. The SB is applicable to all JT8D-1 through -15 engines, which are installed on Boeing 727, 737-100/-200, and DC-9 series airplanes, but is not required. The SB action was incorporated as a production modification on all JT8D-17 engines and -200 engines. JT8D-17 engines are installed on some Boeing 727-200, 737-200, and DC-9-50 series airplanes. JT8D-200 engines are installed on advanced 727-200 and MD-80 series airplanes.

The Safety Board requested information from P&W and Boeing on incidents involving known or suspected[3] fuel pump control shaft failures on JT8D engines. P&W's database contained 39 incidents since 1980 in which JT8D control shaft malfunctions were involved or suspected. Of the 26 incidents reported by Boeing on 727, 737, and DC-9 airplanes, only 6 also appear on the P&W list. It is not known how many of the reported control shaft failures included pumps that had previously been modified per SB 73-34. However, the data provided by P&W include two incidents involving JT8D-17 engines, indicating that even fuel pumps with the SB modification incorporated during original production might be susceptible to control shaft spline wear.

Argo-Tech stated that it is aware of three confirmed fuel pump failures related to misalignment of the control shaft. Argo-Tech's database, which only dates back to 1993, also shows that four of the fuel pumps returned to its facilities contained excessive (90 to 100 percent) control shaft spline wear. It should be noted that at least 10 control shaft spline failures were reported in 1978 before the issuance of SB 73-34 and that the frequency of failure or excessive wear of the control shaft might be higher because of a lack of reporting.

The incidents involving the JT8D fuel pump malfunctions have occurred during takeoff, climb, cruise, descent, and approach flight segments. The Safety Board is aware of two U.S. incidents that have occurred since the Saudia accident. The most recent incident occurred on October 17, 1997, and involved a Delta Airlines Boeing 727, equipped with JT8D-15 engines, that experienced an uncommanded acceleration of the No. 1 engine during cruise flight. The

[3] Incidents in which an uncommanded thrust increase or a loss of power lever control occurred.

engine pressure ratio (EPR)[4] reportedly increased to 2.4 during the incident. The engine did not respond to throttle inputs, and the crew shut down the engine and diverted from their scheduled landing at New York's La Guardia Airport to New York's John F. Kennedy International Airport. Although no problems were found during a bench check of the engine's fuel pump and fuel control, subsequent examination of the fuel pump revealed wear of the control shaft splines. Delta indicated that SB 73-34 had been incorporated on their entire fleet of affected airplanes, including the incident airplane. However, the cause of the control shaft spline wear was not determined.

To further address wear of control shaft splines on JT8D fuel pumps, Argo-Tech issued SB 73-40 on May 4, 1998. The SB provides information to replace existing control shafts with a new control shaft made from through-hardened H11 steel. The new material offers better resistance to spline wear and should increase the control shaft's service life. The new control shaft was introduced into service under a controlled service use (CSU) program with two operators. As part of the CSU program, one of the control shafts was removed for examination after approximately 2,600 hours of operation; no wear of the shaft splines was detected.

P&W recommends that the fuel pump receive a bench test at 6,000 flight hours and an overhaul at 12,000 flight hours. Argo-Tech indicated that some airlines establish their own times between overhauls but that most fuel pumps are repaired or inspected only when they malfunction. Consequently, control shaft damage is not likely to be detected before failure.

The lack of required periodic fuel pump inspections and continuing problems related to control shaft spline wear indicate that action should be taken to ensure proper alignment and reduce wear of the fuel pump control shaft on all JT8D engines. Therefore, the Safety Board believes that the FAA should require that the fuel pumps on all P&W JT8D engines be modified in accordance with Argo-Tech SBs 73-34 and 73-40 to reduce operating misalignment of the control shaft and wear of the shaft splines. In addition, although incorporation of the SB modification should substantially address spline wear of the control shaft, recurrent inspections of the control shaft should also be required because of shaft wear or failure involving fuel pumps that had previously been modified per SB 73-34 and because long-term performance of the new control shaft has not been demonstrated. Pumps that have not been modified per the SBs should be subject to more frequent inspections. Accordingly, the Safety Board believes that the FAA should require recurrent inspections of the fuel pump control shaft on all P&W JT8D engines and replacement of control shafts exhibiting spline wear. Fuel pumps that have not been modified per SBs 73-34 and 73-40 should be subject to more frequent inspections.

The Safety Board is also concerned about a design feature incorporated on JT8D engine fuel controls called "zero speed protection." Zero speed protection occurs when the N_2 signal to the fuel control is lost, which results in an automatic shift in the fuel delivery schedule on the affected engine to approximately 90 to 95 percent takeoff power. When this occurs, engine thrust no longer responds to throttle movements. Fracture of the fuel pump control shaft or severe wear of the shaft splines will result in complete loss of the N_2 signal to the fuel control.

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[4] The ratio of turbine exhaust pressure to fan inlet pressure.

According to P&W, the zero speed protection feature was incorporated to ensure that the engine would deliver high thrust during a critical flight phase following loss of the N_2 signal to the fuel control. Although the function of an automatic engine response such as this may be beneficial at takeoff, there are situations in which such a feature could lead to asymmetric thrust and directional control difficulties, including landing, taxi, and engine reverse operations. Directional control difficulties could also be exacerbated by contaminated runway surfaces or during any operation near other aircraft. In addition, because this type of engine response can occur whenever the engine is being started or operated, a potential hazard to personnel exists during operations at the gate or during maintenance activities.

A partial loss of the N_2 signal, which can occur if the control shaft splines are severely worn, can also trigger a shift in the fuel delivery schedule. A partial loss of the N_2 signal would be interpreted by the fuel control as a low-speed signal and would result in an increased fuel flow to regain the targeted N_2, which might also cause an exceedance of N_2, EPR, and EGT limits. The only method of reducing thrust after partial or complete loss of the N_2 signal is to shut off fuel to the affected engine through the fuel cutoff lever or the fire handle.

Identification of a failure in which zero speed protection engages might initially be difficult because the resulting thrust on the affected engine might differ little from the thrust requirements at the time of failure. However, when zero speed protection results in a large deviation from the desired thrust setting, quick and proper action by the flightcrew may be required to maintain directional control of the airplane. The Safety Board is concerned that flightcrews might not be properly informed about the zero speed protection feature and its effect on throttle authority.

A review of Saudia's 737 flight handbook, as well as flight manuals for the other affected airplanes, revealed no reference to the zero speed protection feature. Boeing has indicated that the zero speed protection feature is not addressed in its flight manuals for 727, 737, DC-9, and MD-80 airplanes. Following the Saudia accident, P&W issued an all operators wire on November 20, 1997, to recommend that all personnel operating JT8D-powered airplanes be informed about the zero speed protection feature and the corresponding ineffectiveness of the throttle. The only operator information issued by Boeing has been In-Service Activities Report (ISAR) 93-07, which was issued to 737 operators in 1993 following an in-flight event in which a fractured fuel pump shaft caused the loss of throttle lever control, and ISAR 97-24, which was issued to 737 operators in December 1997 following the Saudia accident. However, the ISARs offered only a minimal review of the circumstances of the accident and the zero speed protection feature. The Safety Board believes that the FAA should issue a flight standards information bulletin to the principal operations inspectors of all operators of 737-100/-200, 727, DC-9, and MD-80 airplanes informing the operators about the circumstances of the Saudia accident and the zero speed protection feature on P&W JT8D engines. The information should note the ineffectiveness of the throttle following engagement of zero speed protection.

P&W has further indicated that incorporation of the zero speed protection feature is not unique to the JT8D engine. The same philosophy is incorporated on JT3D and JT9D engine fuel controls and may also be incorporated on other in-service engine models. It is not known whether or to what extent this type of failure and engine response is addressed in crew training programs and flight manuals for airplanes equipped with other engine types. Therefore, the

Safety Board believes that the FAA, in conjunction with representatives from engine and airframe manufacturers and pilot groups, should address the issue of automatic engine response following the loss of inputs such as the N_2 signal by studying events in which uncommanded and uncontrollable engine power excursions have occurred and, based on the results of the study, make appropriate recommendations that address the following: 1) automatic engine response following the loss of certain inputs; and 2) crew operating and training issues related to uncommanded engine power excursions in which the throttle is ineffective.

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

> Require that the fuel pumps on all Pratt & Whitney JT8D engines be modified in accordance with Argo-Tech Service Bulletins 73-34 and 73-40 to reduce operating misalignment of the control shaft and wear of the shaft splines. (A-98-67)
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> Require recurrent inspections of the fuel pump control shaft on all Pratt & Whitney JT8D engines and replacement of control shafts exhibiting spline wear. Fuel pumps that have not been modified per Argo-Tech Service Bulletins 73-34 and 73-40 should be subject to more frequent inspections. (A-98-68)
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> Issue a flight standards information bulletin to the principal operations inspectors of all operators of Boeing 737-100/-200, 727, DC-9, and MD-80 airplanes informing the operators about the circumstances of the Saudi Arabian Airlines Boeing 737 accident and the zero speed protection feature on Pratt & Whitney JT8D engines. The information should note the ineffectiveness of the throttle following engagement of zero speed protection. (A-98-69)
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> In conjunction with representatives from engine and airframe manufacturers and pilot groups, address the issue of automatic engine response following the loss of inputs such as the N_2 signal by studying events in which uncommanded and uncontrollable engine power excursions have occurred and, based on the results of the study, make appropriate recommendations that address the following: 1) automatic engine response following the loss of certain inputs; and 2) crew operating and training issues related to uncommanded engine power excursions in which the throttle is ineffective. (A-98-70)

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman