Log 2609

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: July 29, 1996

In reply refer to: A-96-74 through -77

Honorable David R. Hinson
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On July 6, 1996, Delta Air Lines flight 1288, a McDonnell-Douglas MD-88 airplane, experienced an uncontained failure of the No. 1 (left) engine front compressor front hub (fan hub) during takeoff at the Pensacola Regional Airport, Pensacola, Florida. Flight 1288 was a regularly scheduled passenger flight from Pensacola to Atlanta, Georgia, operating under the provisions of Title 14 Code of Federal Regulations (CFR) Part 121. On board the airplane were the 2 pilots, 3 flight attendants, and 142 passengers. The airplane was equipped with Pratt & Whitney JT8D-219 engines, which are part of the JT8D-200 engine series.

The captain rejected the takeoff following the engine failure and stopped the airplane on the departure runway. Engine fragments penetrated the aft fuselage, killing two passengers and seriously injuring one passenger. An engine fire ensued, however, it self-extinguished within moments. The investigation of this accident is continuing; however, information gathered thus far raises serious concerns for which immediate action is needed by the Federal Aviation Administration (FAA).

The investigation has determined that during the initial part of the takeoff roll, just as the engines were reaching peak thrust, the fan hub on the No. 1 engine separated into two large pieces; one was about 2/3 of the hub (containing 20 complete fan blade slots) and the other was about 1/3 of the hub (containing 12 fan blade slots). Other pieces of the fan hub, fan blades, and/or other engine debris penetrated the aft cabin area.

The fan hub design for the JT8D-200 series engine is different from other JT8D engines. According to Pratt & Whitney officials, about 2,600 JT8D-200 series fan hubs have been produced and are operating worldwide on about 1,200 MD-80 series airplanes.

Maintenance records at Delta Air Lines indicate that the fractured fan hub was inspected in December 1995, after accruing 12,693 flight cycles,[1] and was installed on the accident engine on December 29, 1995. The hub was inspected at Delta Air Lines using a florescent dye

[1]One flight cycle is equivalent to one takeoff and landing

penetrant inspection (FPI) procedure.[2] The hub failed at 13,835 cycles, which was 1,142 cycles since the last inspection. Maintenance records indicate that all work on the hub after delivery of the engine was performed by Delta.

Metallurgical examination of the fan hub, part number 5000501-01, serial number R32971, at the Safety Board's Materials Laboratory revealed that the fracture originated in one of the 24 tierod holes in the hub. The tierod holes, which are aligned parallel to the engine shaft, are located around the circumference of the hub bore and alternate with 24 smaller diameter stress redistribution (SR) holes.[3] The tierod and SR holes cannot be inspected without disassembling the fan hub from the engine; however, an inspection technique (eddy current) being developed by Delta Air Lines will permit inspection of the fan hub tierod holes "on-wing" without moving the fan hub into an engine shop.[4]

The metallurgical examination showed that the hub separation stemmed from low cycle fatigue (LCF) cracking that originated from abusive machining[5] that created a localized area of ladder cracking and cold working of the underlying material in the microstructure inside one of the tierod holes about ½ inch from the aft face. A fatigue striation count using the scanning electron microscope disclosed a number of striations roughly equivalent to the total number of flight cycles for the fan hub. The number of striations and the appearance of the fracture surface suggest that the crack was present on the aft face of the hub for a distance of 0.46 inch at the time of the last FPI. The length of the crack along the wall of the hole was about 0.9 inch at the time of the FPI.

The investigation has revealed that the failed hub was manufactured in 1989 in Trollhattan, Sweden, by Volvo Flygmotor, which is the current manufacturer of Pratt & Whitney JT8D-200 series fan hubs. A review of Volvo's records for the accident hub indicates that following manufacture, a blue etch anodize (BEA)[6] inspection and an FPI were performed on June 14, 1989. During BEA, mechanical marks were detected inside the tierod hole where the fatigue crack originated and were referred to a visual inspection process where the marks were accepted because the part satisfied all Pratt & Whitney BEA and visual inspection criteria. The part was subsequently forwarded to Pratt & Whitney for installation into a production engine.

The Safety Board believes that the FAA should conduct a review of the processes used by Volvo and Pratt & Whitney that allowed a fan hub to be placed in service with anomalies that led to the failure of the hub on Delta flight 1288. Based on the review, the FAA should require as

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[2]FPI refers to the submersion of the hub into low viscosity florescent dye bath, followed by washing with high viscosity solution. The florescent dye, which is retained by cracks or other surface defects, luminesces under black light inspection.

[3]"Stress redistribution holes" are sometimes referred to as balance weight holes, cooling holes, lightening holes, or shielding holes.

[4]The hub would be removed from the engine, although the engine would not be removed from the airplane.

[5]Local surface hardening and cracking created during the drilling of the holes.

[6]BEA is an inspection process intended to detect microstructure anomalies on the surface of a titanium component It is not intended to detect marks left by the machining process

necessary that Pratt & Whitney modify its quality assurance standards and practices for inspection of the JT8D-200 series engine fan hubs.

The fact that the hub failed from fatigue cracking at the location of a BEA indication raises immediate concerns about other fan hubs that also had BEA indications during inspection and entered into airline service. However, on July 15, 1996, Pratt & Whitney advised the Safety Board that a review of the production records had identified six additional fan hubs in service that had exhibited similar BEA indications after manufacture. Pratt & Whitney immediately contacted the affected airlines and strongly urged them to remove those hubs from service before further flight. The airlines voluntarily complied with the request on July 15, 1996. On July 16, 1996, the FAA formalized this action by issuing Airworthiness Directive (AD) 96-15-06 mandating removal of the six fan hubs from service. The six hubs are being forwarded to Pratt & Whitney for a detailed inspection and analyses to determine what corrective actions are required. The Safety Board is pleased that immediate actions to reduce the safety hazards associated with those hubs were taken.

Nonetheless, the Safety Board remains concerned about the potential for cracking in tierod holes in other JT8D-200 series fan hubs that may have been exposed to abusive machining or other damage that occurred during production or subsequent overhaul or rework that has not been detected by BEA and/or FPI inspections. Further, the Safety Board is concerned that fatigue cracking could also occur in the SR holes. Although the SR holes are smaller in diameter, and the related stresses should be less than in the tierod holes, the potential for catastrophic failure of the fan hub from undetected cracking in those holes should be addressed. The Safety Board is aware that inspection of the SR holes is complicated by the placement of balance weights in some of the holes and that the removal of the weights leaves copper residue that makes eddy current inspection unreliable. Regardless, the Safety Board believes that the need to identify any fatigue cracking that may exist in the SR holes warrants cleaning and inspecting the SR holes.

The Safety Board is concerned that enhanced visual inspection techniques, including the FPI technique currently used for JT8D-200 series engine fan hubs, may not be adequately performed to detect cracking that can lead to catastrophic failure of the hub. The FPI method used at the Delta Air Lines engine repair station should have readily detected the crack on the surface of the aft face of the hub; however, there are mitigating circumstances that may have prevented the detection of the existing crack. For example, FPI relies on an inspector visually detecting surface cracks in units that are typically crack free. According to Pratt & Whitney, there has never been a crack found on a JT8D-200 series fan hub during its service life. Consequently, the expectation of finding a crack is reduced. Moreover, the Safety Board is concerned that the procedures used by inspectors may make it difficult to view cracking in the tierod holes. Further, the training provided to the inspectors, which includes the syllabi and any visual aids, may not be sufficiently specific with regard to the most likely locations of cracks, orientation of a crack in a disk, the difficulty of detecting a crack in a hole (particularly high aspect ratio holes), and the appearance of cracks in rotating parts.

This accident, as well as past accident experience,[7] has shown that existing cracks have been missed during other visual inspections using FPI. As a result, the Safety Board is concerned that procedures and inspector training and supervision may not be fully adequate to ensure reliable FPI of critical rotating engine parts. The Safety Board appreciates the important role of FPI in the inspection of critical aircraft parts, including the JT8D-200 series fan hub. Therefore, pending the development and implementation of a more definitive and reliable non-destructive inspection procedure, the FAA should review and revise, in conjunction with engine manufacturers and air carriers, the published guidance, inspection procedures, inspector training including any visual aids, and supervision currently in place for performing FPI and other non-destructive testing of high energy rotating engine parts. Particular emphasis should be placed on the FPI procedures for detecting cracks on JT8D-200 series fan hubs.

The Safety Board is aware that Pratt & Whitney is currently developing an eddy current inspection procedure for the JT8D-200 series fan hub tierod and SR holes to supplement the existing FPI technique being used by operators. Pratt & Whitney officials report that development and implementation of the eddy current inspection procedure to inspect the tierod and SR holes, may take "weeks or months" to complete. They also report that they intend for the newly developed procedure to be implemented as a "soft time" inspection whenever the engines are removed for other scheduled maintenance. The Safety Board believes that the eddy current inspection procedure in development at Delta Air Lines, in cooperation with Pratt & Whitney, that will permit "on-wing" inspection of fan hub tierod holes offers an opportunity to detect cracks in these holes in a relatively short time (reportedly 14 hours per engine) before a method involving inspection of all SR holes may be developed and implemented by Pratt & Whitney. Delta reportedly plans to begin this inspection as soon as it is fully developed and approved by Pratt & Whitney and the FAA. Such an "on-wing" inspection may be the only means to inspect tierod holes in the fan hubs without substantial grounding of MD-80 airplanes because of the very limited number of spare hubs to replace hubs removed and taken into an engine shop.

Review of JT8D-200 engine fleet size, fan hub life cycle data, the crack propagation rate of the accident engine fan hub, and consultation with industry indicate that the proposed on-wing tierod hole eddy current inspection could be accomplished within the next 500 flight cycles with minimal impact on airline revenue service operations. Some data suggest that hubs that have between 10,000 and 15,000 cycles may be at greater risk than those with more than 15,000 cycles, the latter having passed the point where cracks caused by manufacturing flaws would be expected to cause failure of the hub. The Safety Board believes that inspection of all hubs with more than 10,000 cycles should be an FAA priority but that inspections should be prioritized to ensure that the fan hubs most at risk are inspected first.

Based on the evidence and data available at this time, the Safety Board believes that the FAA should require inspection of the tierod and SR bolt hole cracking potential in two stages. First, the FAA should require, on a schedule that would give priority to fan hubs presenting the highest risk, as an interim measure, within 500 cycles of the approval of a validated inspection

[7]Previous accidents in which inspectors failed to identify detectable fatigue cracks using FPI techniques: United Airlines DC-10, Sioux City, Iowa, GEAE CF6-6, July 19, 1989; Egypt Air A-300B4, GEAE CF6-50C2, April 10, 1995; and ValuJet DC-9, Atlanta, Georgia, Pratt & Whitney JT8D-9A, June 8, 1995.

process that can be accomplished without having to send the fan hub to an engine shop, an eddy current inspection of the tierod holes of JT8D-200 series fan hubs that have accumulated over 10,000 cycles. Secondly, the FAA should require, as a terminating action, both an FPI and eddy current inspection of all fan hub tierod and SR holes. The scheduling of the redundant inspections should be commensurate with the risk associated with propagation of a fatigue crack from a manufacturing defect in the holes.

Therefore, as a result of its ongoing investigation of this accident, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Require that, within 500 cycles of FAA approval of an engine "on wing" eddy current inspection process for Pratt & Whitney JT8D-200 series engine fan hub tierod holes, this inspection be performed on those hubs that have accumulated more than 10,000 cycles since new; prioritize the inspections to ensure that the fan hubs most at risk (data suggest those hubs with 10,000 to 15,000 cycles since new) are inspected first. This inspection can be superseded by the redundant inspection urged in safety recommendation A-96-75. (Class I, Urgent Action) (A-96-74)

> Require an inspection of all Pratt & Whitney JT8D-200 series engine fan hub tierod and stress redistribution holes by means of FPI and eddy current by a fixed number of flight cycles based on the risk of crack propagation from manufacturing flaws. (Class II, Priority Action) (A-96-75)

> Review and modify the processes as necessary by which Volvo and Pratt & Whitney permitted JT8D-200 series fan hubs to be placed in airline service following indications of mechanical damage in the tierod holes based on a blue etch anodize inspection. (Class II, Priority Action) (A-96-76)

> Review and revise, in conjunction with the engine manufacturers and air carriers, the procedures, training that includes the syllabi and visual aids, and supervision provided to inspectors for performing FPI and other non-destructive testing of high energy rotating engine parts, with particular emphasis on the JT8D-200 series tierod and stress redistribution holes. (Class I, Urgent Action) (A-96-77)

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

By: Jim Hall
Chairman