LOG-2599

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: MAY 31 1996

In reply refer to: A-96-21 and -22

Honorable David R. Hinson
Administrator
Federal Aviation Administration
Washington, D.C. 20594

On January 30, 1996, during the takeoff roll at LaGuardia International Airport, Flushing, New York, a Boeing 727-232 airplane, N413DA, operated by Delta Air Lines as flight 1836, and equipped with Pratt & Whitney (P&W) model JT8D-15 engines, experienced an uncontained failure of the number 1 engine. In response, the crew executed a rejected takeoff procedure and the airplane stopped on the runway. The passengers and crew evacuated the airplane without injury. Post-incident inspection of the number 1 engine revealed that the rear turbine hub[1] contained a radial fracture that extended from the bore of the disk portion to a blade slot. Blades had been ejected from the turbine hub, producing a large hole on the top portion of the engine cowling and small dents and holes on the left side of the airplane's vertical stabilizer.

The turbine hub, which contains a disk at its forward end, a shaft at its aft end, and a conical extension between the disk and shaft, was manufactured in 1980 or 1981 from a one-piece machined forging of Incoloy 901 alloy.[2] Records indicate that the turbine hub accumulated a total time of 22,022 hours and 19,381 flight cycles. The accumulated flight cycles represent 97 percent of its service life limit of 20,000 cycles, after which retirement is mandatory.

Metallurgical examination of the fractured turbine hub, P/N 629404, S/N K47376, at the National Transportation Safety Board laboratory revealed that a fatigue crack emanated from the bore of the disk portion in an area containing inclusions rich in cerium and lanthanum. The primary inclusion on the fracture measured about 0.3 inch long with a maximum width of 0.07 inch. However, the primary inclusion intersected the bore surface over only a very small length (0.001 inch). Fatigue striations progressed in all directions away from the primary

[1] The rear turbine hub is also known as the fourth-stage, low-pressure turbine disk.

[2] Incoloy 901 alloy is a nickel-based alloy containing 35 percent iron, 13 percent chromium, 6 percent molybdenum, and 2.5 percent titanium.

inclusion. After initiation, the fatigue crack propagated radially outward almost to a blade slot at the rim, and aft through most of the conical section and partially through the shaft. Three other similar, but much smaller, inclusions were also found on the fracture surface in the vicinity of the primary inclusion.

The turbine hub is a part of the T2 engine module. The hubs are not required to be inspected for cracks at specific intervals; however, the hubs are required to be inspected any time that the T2 turbine module is disassembled for any reason. According to task 72-53-15-22-000-A in the P&W engine manual, a disassembled turbine hub is to be inspected by the fluorescent penetrant method prior to visual and dimensional inspection. Delta Air Lines reported that the T2 turbine module involved in the incident had last been disassembled 5,897 cycles (about 3.4 years[3]) prior to the accident, and that the turbine hub was inspected visually and by a nondestructive method for cracking at that time. Delta Air Lines maintenance records reportedly did not specify what method of nondestructive testing was performed on the turbine hub. However, fluorescent penetrant would most likely have been the inspection method used, based on the instructions in the P&W engine manual.

A striation count was performed on a fracture surface of the turbine hub. The measured striations exceeded the total accumulated flight cycles of the turbine hub indicating that factors other than takeoff and landing cycles—for example, changes in throttle power—may have been responsible for the additional striations on the fracture. Although the inspection of the disassembled turbine hub 5,897 cycles earlier did not reveal a crack, the large inclusion at the initiation, the extent of fatigue cracking, and the large number of striations suggest that a crack may have existed along the bore surface during the last overhaul.

The Safety Board could not precisely determine the size of the fatigue crack at the last overhaul; nevertheless, the probability that a crack was present raises questions about the adequacy of the fluorescent penetrant inspection performed 5,897 cycles before the incident. Fluorescent penetrant inspection is appropriate for detecting a discontinuity (such as a crack) that is open to the surface, but the detection and interpretation of a discontinuity is dependent on the skill and alertness of the operator performing the inspection. A similar event could happen in the other turbine hubs in less than 5,900 hours. Even if the inspection is performed correctly, the Safety Board believes that turbine hubs processed with cerium and/or lanthanum should have mandatory recurring inspections for cracking at intervals substantially less than 5,900 flight cycles with emphasis placed on inspecting the bore area.

The Incoloy material for the turbine hub is initially cast as an ingot. Cerium and lanthanum were reportedly added in the foundry process to deoxidize the alloy.

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[3] The 3.4 years are based on data obtained from Delta Air Lines indicating that its fleet of Boeing 727 airplanes make an average of 4.8 landings (cycles) per day.

When the ingot is first cast, these two elements rise to the top of the ingot and are contained in the dross.[4] After solidification, the ingot is drawn down to a 9-inch-diameter billet, and the top portion of the billet containing the dross is cropped and discarded. Each billet is cut into 20 to 30 forging blanks, called mults. Reportedly, the fractured turbine hub was made from the uppermost mult adjacent to the area were the dross was cropped. P&W indicated that use of a cerium-lanthanum mixture in the ingots was changed to only cerium in 1985 and that the sole use of cerium as a deoxidizer ceased in 1989. After this date, the use of cerium and/or lanthanum to deoxidize Incoloy 901 alloy was discontinued.

P&W indicated that each billet from which turbine hubs are manufactured is ultrasonically inspected for discontinuities in the material. It is believed that the inclusion in the incident turbine hub probably was not detected because of the orientation or a lack of voids associated with the inclusion. The turbine hub in the final machined form was also subjected to an anodic etch, and no anomalies were found on the surface. As stated earlier, the metallurgical examination revealed that only a small portion (0.001 inch) of the inclusion intersected the surface of the bore. This size was probably too small to be detected by low-power magnified visual inspection.

P&W reported that during inspections prior to the incident of January 30, 1996, two other turbine hubs were found to have fatigue cracks that emanated from inclusions rich in both cerium and lanthanum in the disk bore. A similar[5] turbine hub, P/N 539004, installed on a JT8D-9 engine, was forged in May 1979 and operated for a total time of 7,843 hours and 7,991 flight cycles; it was manufactured from the third mult from the top of the billet. The other turbine hub, P/N 629404, installed on a JT8D-17 engine, was forged in September 1980 and operated for a total time of 11,472 hours and 10,559 cycles; it was manufactured from the first mult on the top of the billet. P&W records do not provide flight time and cycles since the last inspection for these two turbine hubs. These two turbine hubs and the one from the N413DA airplane were made from different ingots.

There is no apparent common factor, such as flight hours/cycles or crack propagation rate, between the fractured turbine hub in the January 30, 1996, event and the two other hubs found with a fatigue crack during inspection. This strongly suggests that a fatigue crack can emanate from a cerium- and/or lanthanum-rich inclusion at any time during the service life of the turbine hub.

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[4] Dross is a mixture of solids, containing oxides and lighter, intermetallic compounds, that float on the molten Incoloy material.

[5] Throughout the manufacturing history of the turbine hub, minor variations were performed in the final machining of the part. Each time a minor variation was made the turbine hub was assigned a different part number.

The fracture history of the turbine hubs clearly shows that turbine hubs made prior to 1989, when cerium and lanthanum were added to deoxidize the alloy, could have substantial inclusions if the hubs were made from any of the top three mults of a billet. The Safety Board is concerned that these turbine hubs could develop fatigue cracking from the inclusions and without repetitive inspection, could fracture in operation. Although the fractured turbine hub did not cause a serious or catastrophic accident, the potential for such an accident exists.

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

Require an immediate inspection (by a nondestructive method such as fluorescent penetrant or ultrasonic) of turbine hubs on Pratt & Whitney model JT8D engines that were manufactured from Incoloy 901 alloy and made from one of the top three mults of a billet in which cerium and/or lanthanum was used as a deoxidizing agent and that have not been previously inspected within a reasonable cyclic interval (substantially less than 5,900 flight cycles). (Class I, Urgent Action) (A-96-21)

Require periodic inspections (by a nondestructive method such as fluorescent penetrant or ultrasonic) of turbine hubs on Pratt & Whitney model JT8D engines if the hubs were manufactured from Incoloy 901 alloy and made from one of the top three mults of a billet in which cerium and/or lanthanum was used as a deoxidizing agent. The interval for the periodic inspection should be substantially less than 5,900 flight cycles. (Class I, Urgent Action) (A-96-22)

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

By: Jim Hall
Chairman