

Log 2178



National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: August 17, 1989

In reply refer to: A-89-95 through -97

Honorable James B. Busey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

The National Transportation Safety Board's investigation of the United Airlines DC-10 accident at Sioux City, Iowa, on July 19, 1989, is continuing. The investigation thus far indicates that most of the fan rotor assembly separated from the No. 2 engine in flight. The separation, fragmentation, and forceful discharge of fan rotor parts severed or loosened hydraulic lines associated with all three hydraulics systems, which resulted in the loss of all hydraulic services including those to the flight controls. Following the loss of the hydraulic services, the airplane could be controlled only by the flightcrew's use of differential thrust from the Nos. 1 and 3 engines. The airplane crashed during an attempted emergency landing at Sioux City. Of the 296 persons on board, 111 died from injuries received in the crash, and 185 persons survived.

An extensive search of the farmland below where the No. 2 engine failed has continued since the crash, but critical fan rotor parts from the No. 2 engine have not yet been recovered. The missing pieces from the General Electric (GE) model CF6-6 engine include the front portion of the fan, first-stage fan disk, many fan blades, front flange of the fan forward shaft, a portion of the second-stage fan disk, and 18 of the 20 bolts and 17 of the 20 nuts that attach the fan disk to the front flange of the fan forward shaft. Although the Safety Board has not yet determined the reason(s) for the release of the fan assembly from the No. 2 engine, the catastrophic circumstances of this event call for every effort to be made to preclude a similar occurrence.

One possible fan section failure mode being evaluated by the Safety Board's investigation that matches available evidence is that a separation of a section of the first-stage fan disk occurred, which severed the fan containment ring and created high imbalance in the remainder of the 1st-stage disk. The forces associated with high disk imbalance would have torn the fan section loose from the fan forward shaft and the engine. However, it is important to recover the critical missing pieces and examine them to substantiate the actual failure mode in this accident.

Recently, the United Airlines (UA) San Francisco maintenance facility reported that while performing a routine magnetic particle inspection on a fan forward shaft from another CF6-6 engine, indications of multiple radial cracks were discovered emanating from the holes of several of the 20 bolt holes located in the front face of the shaft flange. The radial length of the cracks varied, with at least one about 1/2 inch long; the cracks also extended axially approximately 1/4 inch into material around the hole. The shaft flange has GE part number 9010M20G05. Engine records indicate that it has accumulated 45,182 operating hours (hours) and 18,111 operating cycles (cycles) since new, and 13,490 cycles since its last detailed part inspection.

The shaft flange has been returned to the GE facility in Evendale, Ohio, for investigation and metallurgical examination to confirm the cracks and to determine the cause of the fractures. GE's preliminary magnetic particle inspection of the flange indicates that at least eight nonadjacent holes have cracks, most of which extend from the holes into the flange between the 12 to 3 o'clock positions¹ with the longer cracks at the 3 o'clock position extending circumferentially toward the next adjacent hole as well as axially into the material around the hole. More recent metallurgical examination has confirmed the existence of the cracks but has not clearly identified the fracture mode of the cracking.

Engine records indicate that the fan forward shaft in the No. 2 engine of the accident airplane had GE part number 9080M28G07, and that it had accumulated 40,621 hours and 15,792 cycles since new, and 23,235 hours and 8,359 cycles since its last detailed part inspection. The approved life limit for the fan forward shaft is 30,000 cycles. It has been reported that no fan forward shafts have, as yet, been retired from service based on the current life limit.

The GE CF6-6 shop manual recommends that the fan forward shaft be dimensionally checked and given a fluorescent magnetic particle inspection any time it is removed from the low-pressure turbine (LPT) shaft assembly. GE does not specify or provide a time or cycle interval for an interim inspection of the fan forward shaft. Engine disassembly for other maintenance operations may be such that the fan forward shaft is not necessarily removed from the LPT shaft assembly during an engine shop visit. However, UA shop procedures require that any time the fan forward shaft is exposed, even if not removed, a visual inspection of all visible areas must be accomplished.

Both GE and UA have indicated that this is the first instance of cracks reported in the front flange of a fan forward shaft in any CF6-6 engine. Metallurgical examination and analysis of the cracked flange have not been completed, and the cause of the cracking is not yet known. Further, until

¹12 o'clock position is noted as the position of the bolt hole diameter nearest to the outside circumference of the flange when looking aft. The 3 o'clock position is displaced 90° clockwise when looking aft at the front face of the shaft.

the missing critical pieces of the No. 2 engine are found, recovered, and examined, it will be difficult to determine if fan forward shaft distress was involved in the separation of the fan rotor. However, the Safety Board is concerned that the possibility exists that the fan forward shaft flanges of other CF6-6 engines may have experienced similar cracking and that progression of existing cracks to failure of the flange during engine operation could cause catastrophic release of the fan section.

The Safety Board believes that the absence of definitive findings to date concerning the fan section failure which preceded the DC-10 accident of July 19, 1989, and the catastrophic nature of a fan section failure, dictates the need for the Federal Aviation Administration (FAA) to initiate a directed safety investigation of the CF6-6 engine that includes close scrutiny of the design, certification, manufacture, inspection, and maintenance of the fan section of the engine.

On September 22, 1981, fan shafts of the empennage-mounted No. 2 engine (Rolls Royce RB 211-22B turbofan) of an Eastern Airlines Lockheed L-1011 failed as the airplane was climbing through 10,000 feet following departure from the Newark International Airport, Newark, New Jersey. The fan assembly was released from the shafts and broke apart as it traveled about 9 feet forward through the engine inlet duct, causing extensive damage to the airplane's structure and flight control systems. Three of the airplane's four hydraulic systems were lost when tubing was severed; the fourth hydraulic system sustained damage to tubing but retained fluid integrity. With an alternate power supply for the fourth system activated, sufficient flight control authority was available to land the airplane without further incident. The Safety Board acknowledged in its report that, while the accident demonstrated the potential for a catastrophic accident as a result of a separation of a major engine component, it also demonstrated the value of system redundancy in the design philosophy of modern transport-category airplanes.

The Safety Board recognizes that current certification rules view engine failures that result in the liberation of high-energy rotating parts as an intolerable event for which total protection cannot be practically provided. However, the Safety Board believes that the lessons learned from the L-1011 fan separation in 1981 and the DC-10 accident can be used to improve flight control systems so that the airplanes are more tolerable to massive failures. The Safety Board understands that the FAA under the aegis of an Aviation Safety Advisory Committee is undertaking a review of certain transport-category airplanes to identify possible design modifications to flight control systems and to engines. The purpose of the modifications will be to provide greater redundancy or protection of essential flight control systems and to provide for improved containment of engine failures that involve the release of high energy rotating parts. The Safety Board strongly urges the FAA to expedite and fully support this effort and to take actions as appropriate to require such design modifications when identified.

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

Conduct a directed safety investigation (DSI) of the General Electric CF6-6 turbine engine to establish a cyclic threshold at which the fan forward shaft and the fan disks should be separated and inspected for defects in the components. The DSI should include a review and analysis of:

- (a) the certification, testing, and stress analysis data that were used to establish the life limits of the fan disks and fan shaft components and the recommended inspection frequencies for these components;
- (b) the manufacturing processes associated with the production of the fan assembly and fan forward shaft;
- (c) metallurgical analysis of the front flange of the fan forward shaft in which cracks were recently discovered;
- (d) the maintenance practices involved in the assembly and disassembly of the fan disks and the fan forward shaft for the potential to damage the components during these processes;
- (e) nondestructive inspection of spare fan disks and fan forward shafts beginning with those components with the highest number of cycles in service; and
- (f) nondestructive inspections of fan disks on installed engines that may be performed by an approved inspection procedure.

(Class I, Urgent Action) (A-89-95)

Following completion of the directed safety investigation of the General Electric CF6-6 turbine engine discussed in A-89-95, issue an airworthiness directive to require appropriate inspections of the fan disks and the fan forward shaft at appropriate cyclic intervals. (Class I, Urgent Action) (A-89-96)

Evaluate, because of similarities in design, manufacture, and maintenance, the need for a directed safety investigation of all General Electric CF6-series turbine engines with the objectives of verifying the established life limits for rotating parts of the fan modules and establishing appropriate cyclic inspection requirements for these parts. (Class II, Priority Action) (A-89-97)

KOLSTAD, Acting Chairman, and BURNETT, LAUBER, NALL, and DICKINSON, Members, concurred in these recommendations.

for 
By: James L. Kolstad
Acting Chairman