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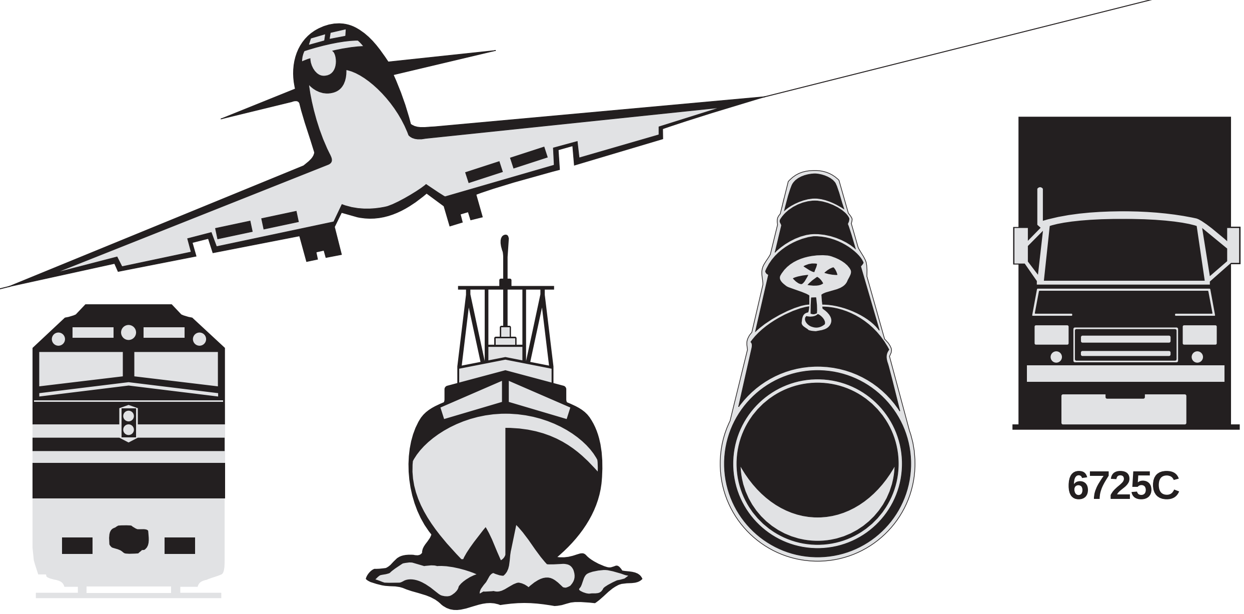
NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C. 20594

AIRCRAFT ACCIDENT REPORT

UNCONTAINED ENGINE FAILURE
DELTA AIR LINES FLIGHT 1288
MCDONNELL DOUGLAS MD-88, N927DA
PENSACOLA, FLORIDA
JULY 6, 1996



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EXECUTIVE SUMMARY

On July 6, 1996, at 1424 central daylight time, a McDonnell Douglas MD-88, N927DA, operated by Delta Air Lines Inc., as flight 1288, experienced an engine failure during the initial part of its takeoff roll on runway 17 at Pensacola Regional Airport in Pensacola, Florida. Uncontained engine debris from the front compressor front hub (fan hub) of the No. 1 (left) engine penetrated the left aft fuselage. Two passengers were killed and two others were seriously injured. The takeoff was rejected, and the airplane was stopped on the runway. The airplane, which was being operated by Delta as a scheduled domestic passenger flight under the provisions of Title 14 Code of Federal Regulations Part 121, with 137 passengers and 5 crew on board, was destined for Hartsfield Atlanta International Airport in Atlanta, Georgia.

The National Transportation Safety Board determines that the probable cause of this accident was the fracture of the left engine's front compressor fan hub, which resulted from the failure of Delta Air Lines' fluorescent penetrant inspection process to detect a detectable fatigue crack initiating from an area of altered microstructure that was created during the drilling process by Volvo for Pratt & Whitney and that went undetected at the time of manufacture. Contributing to the accident was the lack of sufficient redundancy in the in-service inspection program.

Safety issues discussed in this report include the limitations of the blue etch anodize process, manufacturing defects, standards for the fluorescent penetrant inspection process, the performance of nondestructive testing, the use of alarm systems for emergency situations, and instructions regarding emergency exits. Recommendations concerning these issues were made to the Federal Aviation Administration.

3. CONCLUSIONS

3.1 Findings

1. The flightcrew was properly certified and trained for the flight, and was in compliance with Federal flight and duty time regulations.

2. The airplane was properly certificated and maintained in accordance with applicable Federal regulations, including a Federal Aviation Administration-approved airworthiness maintenance program.

3. Visual meteorological conditions prevailed, and weather was not a factor in the accident.

4. The oil observed preflight by the first officer came from the No. 1 bearing housing and, therefore, was not a precursor to the accident.

5. Some form of drill breakage or drill breakdown, combined with localized loss of

coolant and chip packing, occurred during the drilling process, creating the altered microstructure and ladder cracking in the accident fan hub.

6. Fatigue cracks initiated from the ladder cracking in the tierod hole and began propagating almost immediately after the hub was put into service in 1990.

7. Although the altered microstructure in the accident hub tierod hole was detectable by blue etch anodize inspection methods, Volvo did not identify it as rejectable because the appearance of the tierod hole did not match any of the existing inspection templates showing rejectable conditions.

8. Although the additional templates will assist blue etch anodize inspectors in detecting potential defects similar to the one that existed on the accident hub, this accident suggests that there may be additional rejectable conditions that have not yet been identified.

9. Drilling damage in this accident hub extended much deeper into hole sidewall material than previously anticipated by Pratt & Whitney.

10. The crack was large enough to have been detectable during the accident hub's last fluorescent penetrant inspection at Delta.

11. Significant questions exist about the reliability of flash drying in removing water from cracks.

12. Better techniques are needed to ensure the fullest possible coverage of dry developer powder, particularly along hole walls.

13. Although it could not be conclusively determined whether this played a role in the nondetection of the crack in the accident hub, the absence of a system that formally tracks the timing of the movement of parts through the fluorescent penetrant inspection process was a significant deficiency.

14. Fluorescent penetrant inspection indications remain vulnerable to manual handling, and fixtures used to support the part during inspection may obstruct inspector access to areas of the part.

15. One or more procedural deficiencies in the cleaning, drying, processing, and handling of the part might have reduced or prevented the effectiveness of Delta's fluorescent penetrant inspection process in revealing the crack.

16. The potential deficiencies identified in the Delta fluorescent penetrant inspection process may exist at other maintenance facilities and be, in part, the reason for the failure to detect cracks in other failed engines identified in this investigation.

17. No personal or physical factors would have prevented the FPI inspector from detecting a visible crack in the accident hub.

18. An inadvertent failure of the inspector to systematically search and complete followup diagnosis when necessary on all surfaces of the hub might have caused the FPI inspector to overlook the crack.

19. A low expectation of finding a crack in a -219 series fan hub might have caused the FPI inspector to overlook or minimize the significance of an indication.

20. The duration of inspections and the amount and duration of rest periods may indeed affect inspector performance, but this potential has not been adequately studied in the aviation domain.

21. Because of the potentially catastrophic consequences of a missed crack in a critical rotating part, testing methods that evaluate inspector capabilities in visual search and detection and document their sensitivity to detecting defects on representative parts are necessary.

22. Delta's nondetection of the crack was caused either by a failure of the cleaning and fluorescent penetrant inspection processing, a failure of the inspector to detect the crack, or some combination of these factors.

23. Manufacturing and in-service inspection processes currently being used do not provide sufficient redundancy to guarantee that newly manufactured critical rotating titanium engine parts will be put into service defect-free and will remain crack-free through the service life of the part. Further, all critical rotating titanium engine components are susceptible to manufacturing flaws and resulting cracking and uncontained engine failures that could potentially lead to catastrophic accidents.

24. Although during the preflight inspection the first officer found a small amount of oil on the bullet nose of the left engine and two missing rivets, these were not factors in the subsequent engine failure.

25. There is a lack of clarity in written guidance in the flight operations manual to Delta flightcrews on what constitutes maintenance "discrepancies" and "irregularities" and when to contact maintenance personnel and to log anomalies.

26. The captain shut down the engines in a timely manner when he became aware of conditions in the aft cabin.

27. Neither the aft flight attendants' decision to evacuate nor the captain's decision not to evacuate was improper in light of the information each of them had available at the time.

28. Every passenger-carrying airplane operating under 14 Code of Federal Regulations Part 121 should have a reliable means to ensure that all crewmembers on board the airplane are immediately made aware of a decision to initiate an evacuation.

29. Safety could be enhanced if all cockpit crews were immediately made aware of when exits are opened during an emergency.

30. Guidance provided to passengers on Delta Air Lines MD-88s regarding when emergency exits should and should not be opened is not sufficiently specific.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the fracture of the left engine's front compressor fan hub, which resulted from the failure of Delta Air Lines' fluorescent penetrant inspection process to detect a detectable fatigue crack initiating from an area of altered microstructure that was created during the drilling process by Volvo for Pratt & Whitney and that went undetected at the time of manufacture. Contributing to the accident was the lack of sufficient redundancy in the in-service inspection program.

4. RECOMMENDATIONS

As a result of the investigation of this accident, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

Form a task force to evaluate the limitations of the blue etch anodize and other postmanufacturing etch processes and develop ways to improve the likelihood that abnormal microstructure will be detected. (A-98-09)

Inform all manufacturers of titanium rotating engine components of the potential that current boring and honing specifications may not be sufficient to remove potential defects from holes and ask them to reevaluate their manufacturing specifications and procedures with this in mind. (A-98-l0)

Establish and require adherence to a uniform set of standards for materials and procedures used in the cleaning, drying, processing, and handling of parts in the fluorescent penetrant inspection process. In establishing those standards, the FAA should do the following:

> Review the efficacy of drying procedures for aqueously cleaned rotating engine parts being prepared for fluorescent penetrant inspections; (A-98-l1)

Determine whether flash drying alone is a sufficiently reliable method; (A-98-12)

Address the need to ensure the fullest possible coverage of dry developer powder, particularly along hole walls; (A-98-13)

Address the need for a formal system to track and control development times; (A-98-14) and

Address the need for fixtures that minimize manual handling of the part without visually masking large surfaces of the part. (A-98-15)

Require the development of methods for inspectors to note on the part or otherwise document during a nondestructive inspection the portions of a critical rotating part that have already been inspected and received diagnostic followup to ensure the complete inspection of the part. (A-98-16)

Conduct research to determine the optimum amount of time an inspector can perform nondestructive testing inspections before human performance decrements can be expected. (A-98-17)

In conjunction with industry and human factors experts, develop test methods that can evaluate inspector skill in visual search and detection across a representative range of test pieces, and ensure proficiency examinations incorporate these methods and are administered during initial and recurrent training for inspectors working on critical rotating parts. (A-98-18)

Require that all heavy rotating titanium engine components (including the JT8D-200 series fan hubs) receive appropriate nondestructive testing inspections (multiple inspections, if needed) based on probability of detection data at intervals in the component's service life, such that if a crack exists, but is not detected during the first inspection, it will receive a second inspection before it can propagate to failure; assuming that a crack may begin to propagate immediately after being put into service, as it did in the July 6, 1996, accident at Pensacola, Florida, and in the July 19, 1989, United Airlines accident at Sioux City, Iowa. (A-98-19)

Require, as an interim measure, pending implementation of Safety Recommendation A-98-19, that critical rotating titanium engine components that have been in service for at least 2 years receive a fluorescent penetrant inspection, eddy current, and ultrasonic inspection of the high-stress areas at the engine's next shop visit or within 2 years from the date of this recommendation, whichever occurs first. (A-98-20)

Require Delta Air Lines to review its operational procedures, with special emphasis on nonmaintenance stations, to ensure that flightcrews have adequate guidance about what constitutes a maintenance irregularity or discrepancy (including the presence of fluid drops in unusual locations) before departure, and that following this review Delta should, contingent on FAA approval, amend its flight operations manual to clarify under what circumstances flightcrews can, if at all, make independent determinations to depart when maintenance irregularities are noted. Further, the FAA should have its principal operations inspectors review these policies and procedures at their respective operators to clarify, if necessary, these flightcrew responsibilities. (A-98-21)

Require that all newly manufactured passenger-carrying airplanes operated under 14 Code of Federal Regulations Part 121 be equipped with independently powered evacuation alarm systems operable from each crewmember station, and establish procedures and provide training to flight and cabin crews regarding the use of such systems. (A-98-22)

Require that all newly manufactured airplanes be equipped with cockpit indicators showing open exits, including overwing exit hatches, and that these cockpit indicators be connected to emergency power circuits. (A-98-23)

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