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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ISSUED: April 16, 1982

Forwarded to:

Honorable J. Lynn Helms
Administrator
Federal Aviation Administration
Washington, D.C. 20591

SAFETY RECOMMENDATION(S)

A-82-38 and -39

As a result of its investigation of an uncontained engine failure involving an Air Florida DC-10-30F, N101TV, at Miami International Airport on September 22, 1981, 1/ and in view of other cases of uncontained engine turbine rotor disk failures on wide-bodied aircraft, (see attachment), the National Transportation Safety Board believes that design precautions must be emphasized in future certification programs to minimize the effects of engine rotor disk failure.

Air Florida Airlines Flight 2198 experienced the uncontained failure in the right underwing engine (No. 3) during the takeoff roll at about 90 knots indicated airspeed. The pilot rejected the takeoff and the aircraft was stopped safely. As a low pressure turbine (LPT) rotor failed, it released high energy fragments damaging the wing leading edge structurally and causing an uncommanded retraction of the right outboard wing leading edge slats and failure of two of the aircraft's three hydraulic systems.

Studies of Uncontained Rotor Failures

The serious damage-causing potential of uncontained turbine engine rotor failures has been a long-standing concern of the Safety Board, and in 1971, it recommended renewed efforts by the Federal Aviation Administration (FAA) to produce an effective rotor burst protection system. 2/ Also in 1975, based on its Special Study, "Turbine Engine Rotor Disk Failures," (NTSB-AAS-74-4), the Safety Board recommended that the blade containment requirement in the Federal Aviation Regulations (FAR) be upgraded. Industrywide concern about uncontained rotor failures and their possible consequences has been reflected by the number of studies and research projects pursued during the late 1970's. 3/ Studies have indicated consistently that while the rotor failure problem is not statistically alarming (.66 failures per million engine hours for the 1962 to 1975 period and a factor in 0.22 percent of all fatalities 4/), it certainly has the potential for causing serious aircraft damage, such as fuel-fed fires, loss of critical systems, or loss of structural integrity.

1/ For more detailed information, read Aircraft Accident Report—"Air Florida Airlines, Inc., DC-10-30CF, Miami International Airport, Florida, September 22, 1981." AAR-82-3
2/ Aircraft Incident Report - "Northwest Airlines Inc., Boeing 747-151, N607US, Honolulu, Hawaii, May 13, 1971."
3/ NASA CP-2017 "An Assessment of Technology for Turbojet Engine Rotor Failures," Workshop at Massachusetts Institute of Technology, March 29-31, 1977, 24 research papers presented.
4/ Society of Automotive Engineers Aerospace Information Report AIR 1537, "Report on Aircraft Engine Containment," 1977.

Efforts to reduce the hazards posed by uncontained rotor failures have been concentrated in three basic areas: (1) improvement of engine rotor reliability including basic design concepts, manufacturing processes, and maintenance factors to detect and prevent failures; (2) development of lightweight, effective rotor fragment containment systems; and (3) evaluation of possible aircraft design precautions which would minimize the hazards to the aircraft of an uncontained rotor failure. Research has been pursued in engine component reliability through the National Aeronautics and Space Administration's (NASA) aeronautical propulsion programs in areas such as: engine component life prediction; factors limiting bearing life, reliability, and performance; and development of methods to diagnose engine performance deterioration. However, government-sponsored fragment containment research has not been actively pursued in recent years because of the apparent inability, within current technological limitations, to develop a lightweight material suitable for the high temperature environment of the turbine case and which is also capable of containing the higher energy-type rotor fragments that inflict the most severe damage to the airplane.

Aircraft Design Precautions

Since the rate of uncontained engine failures has remained stable for many years, such failures will probably continue at similar rates 5/ unless technological breakthroughs are made in the area of engine reliability. If current material technology continues to limit containment capability, the probability of continued uncontained engine rotor failures emphasizes the importance of aircraft design precautions taken to minimize hazards posed by engine rotor fragmentation. Applicants for type certificates are required to take such precautions by 14 CFR 25.903(d)(1); however, the regulation is general and is not accompanied by any published guidelines describing acceptable methods of demonstrating compliance. In January 1981, the FAA requested comments on proposed Advisory Circular (AC) 25.903X, which would have provided some compliance and design guidelines; however, final action to issue the AC has not been taken.

The effects of of uncontained rotor failures on aircraft structural integrity are considered in 14 CFR 25.571(e)(3), which requires that structural damage tolerance to an uncontained engine failure be evaluated. Guidance material for showing compliance with this regulation is published in AC 25.571-1, "Damage Tolerance and Fatigue Evaluation of Structure;" this AC refers to uncontained engine failures in paragraph 4(g)(2):

> In the case of uncontained engine failures, the fragments and paths to be considered should be consistent with those used in showing compliance with §25.903(d)(1) of the FAR's, and with typical damage experienced in service.

This explicit guidance material provided for aircraft structural damage tolerance analysis specifies analytical consistency with rotor failure design precaution requirements of 14 CFR 25.903(d)(1); therefore, the Safety Board believes that explicit regulatory compliance guidance material also should be provided for 14 CFR 25.903(d)(1). Such guidance material should assure that fragment energy levels and paths used in demonstrating regulatory compliance are representative of worst-case rotor fragmentations experienced in service, instead of only the typical cases, and should provide for analytical completeness through detailed design substantiation methods, such as failure mode and effect analyses.

5/ NASA CP-2017, "Rotor Burst Protection Criteria and Implications," R.B. McCormick, Boeing Commercial Airplane Company, March 1977.

Guidelines for Future Design Precaution Analyses

As a result of the uncontained engine failure incident at Miami on September 22, 1981, the Federal Aviation Administration has asked McDonnell-Douglas to study the probability of an uncontained engine failure's causing a retraction of the outboard wing leading edge slats during the critical phase of flight. The study was completed using very severe conditions for rotor fragment size and path to assure a conservative result. Because of the need to rely on design precaution until advances are made in containment technology, the Safety Board believes that the rigorous fragment size and path conditions of the McDonnell-Douglas probability analysis should be considered as a possible basis for future certification programs, since they are consistent with cases of severe in-service damage rather than typical damage.

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

> Expedite the publication of guidance material for acceptable means of compliance with 14 CFR 25.903(d)(1), which includes compliance documentation by failure mode and effect analysis, provides for rotor fragment energy levels and paths based on cases of severe in-service damage, and reflects advances in analytical techniques and concepts which have taken place since certification programs of the early 1970's. (Class II, Priority Action) (A-82-38)
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> Actively encourage research and development in containment technology and engine reliability, including basic design concepts, manufacturing processes, and maintenance factors to detect and prevent impending failures. (Class II, Priority Action) (A-82-39)

BURNETT, Chairman, and McADAMS and GOLDMAN, Members, concurred in these recommendations. BURSLEY, Member, did not participate.

Patricia A. Goldman for

By: Jim Burnett
Chairman

Uncontained Turbine or Rotor Disc Failures In High Bypass Ratio Engines

RB 211

Date	Aircraft	Engine No. and Failed Part
2/28/72	L1011	No. 3, fan disc
1/11/73	L1011	No. 1, fan disc
11/25/76	L1011	No. 1, high pressure turbine disc
1/28/80	L1011	No. 2, high pressure compressor disc

CF6

Date	Aircraft	Engine No. and Failed Part
8/9/74	DC-10	No. 1, high pressure compressor rotor
8/1/76	DC-10	No. 3, high pressure compressor rotor
10/26/76	DC-10	No. 3, high pressure compressor rotor
4/14/77	DC-10	No. 3, low pressure turbine rotor
6/12/77	DC-10	No. 1, high pressure compressor rotor
7/28/77	DC-10	No. 2, high pressure compressor rotor
3/14/79	DC-10	No. 3, high pressure compressor rotor
6/9/80	DC-10	No. 3, high pressure turbine disc
7/3/81	A-300	No. 1, high pressure turbine disc
9/22/81	DC-10	No. 3, low pressure turbine disc

JT9D

Date	Aircraft	Engine No. and Failed Part
8/17/70	B747	No. 3, second turbine disc
9/18/70	B747	No. 1, second turbine disc
5/3/71	B747	No. 3, second turbine disc
5/20/71	B747	No. 4, second turbine disc
4/1/73	B747	No. 3, second turbine disc
5/25/75	B747	No. 3, seventh high pressure compressor disc
11/7/75	B747	No. 2, sixth low pressure turbine disc
3/16/77	B747	No. 4, sixth turbine disc
3/7/78	B747	No. 4, fifth turbine disc