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National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: January 31, 1994

In reply refer to: A-94-9 and 10

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

On March 31, 1993, the No. 2 engine and engine pylon separated from Japan Airlines, Inc., flight 46E, a Boeing 747-121 that had been wet leased from Evergreen International Airlines Inc., shortly after departure from Anchorage International Airport (ANC), Anchorage, Alaska. The accident occurred about 1234 Alaska standard time. The flight was a scheduled cargo flight from Anchorage to Chicago-O'Hare International Airport, Chicago, Illinois. On board the airplane were the flightcrew, consisting of the captain, the first officer, and the second officer, and two nonrevenue company employees. The airplane was substantially damaged during the separation of the engine. No one on board the airplane or on the ground was injured as a result of the accident.[1]

The accident airplane departed ANC about 1224 local time. The flight release/weather package provided to the pilots by Evergreen operations contained a forecast for severe turbulence and indicated that severe turbulence had been reported by other large airplanes. As the flight taxied onto the runway to await its takeoff clearance, the local controller informed the flightcrew that the pilot of another Evergreen B-747, flight 42E, had reported severe turbulence at 2,500 feet while climbing out from runway 6R.

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[1]For more detailed information, read Aircraft Accident Report--"Japan Airlines, Inc., Flight 46E, Boeing 747-121, N473EV, In-flight Engine Separation, Anchorage, Alaska, March 31, 1993" (NTSB/AAR-93-06)

After takeoff, at an altitude of about 2,000 feet, the airplane experienced an uncommanded left bank of approximately 50°. While the desired air speed was 183 knots, the air speed fluctuated about 75 knots from a high of 245 knots to a low of 170 knots. Shortly thereafter, the flightcrew reported a "huge" yaw, the No. 2 throttle slammed to its aft stop, the No. 2 reverser indication showed thrust reverser deployment, and the No. 2 engine electrical bus failed. Several witnesses on the ground reported that the airplane experienced several severe pitch and roll oscillations before the engine separated.

On October 13, 1993, the National Transportation Safety Board determined that the probable cause of this accident was the lateral separation of the No. 2 engine pylon due to an encounter with severe or possibly extreme turbulence that resulted in dynamic multi-axis lateral loadings that exceeded the ultimate lateral load-carrying capability of the pylon, which was already reduced by the presence of a fatigue crack near the forward end of the pylon's forward firewall web.

As a result of its investigation of this accident, the National Transportation Safety Board made seven recommendations to the Federal Aviation Administration regarding the inspection of B-747 engine pylons, the potential meteorological hazards to aircraft, increasing the lateral load capability of engine pylon structures, and the modification of the aircraft departure routes at Anchorage International Airport during periods of moderate or severe turbulence. The Safety Board recommended that the National Weather Service use the WSR-88D Doppler weather radar system at Anchorage, Alaska, to document mountain-generated wind fields in the Anchorage area and to develop detailed low altitude turbulence forecasts. Additionally, the Safety Board reiterated to the Federal Aviation Administration Safety Recommendation A-92-58, which urged the development of a meteorological aircraft hazard program for airports in or near mountainous terrain.

At the time of the accident, the airplane had accumulated 83,906 flight hours and 18,387 cycles. All of the midspar fuse pins on the accident airplane 46E had been replaced on January 14, 1993, with the "new type" pins as part of the compliance with Airworthiness Directive (AD) 93-01-05. At that time, the aircraft had accumulated 83,262.8 flight hours and 18,280 cycles. The midspar fuse pins on airplane designated as flight 42E were also of the "new type" and had been installed as part of the compliance with AD 93-01-05.

During the investigation, the fuse pins holding the engine pylons to the wings were removed from the accident airplane. The inboard midspar fuse pin for the

No. 1 engine was found to be substantially deformed. There was slight damage to the two midspar fuse pins for the No. 2 pylon, which was probably caused during the separation of the engine. None of the other fuse pins on the airplane had any indications of damage or deformation. Additionally, the airplane operating as flight 42E received a thorough inspection after reaching its destination. That inspection found that the midspar fuse pins for the No. 2 engine were slightly deformed. No other damage was found during that inspection.

The fuse pins were returned to the Safety Board's materials laboratory for examination. The inboard midspar fuse pin from the No. 1 engine of the accident airplane had a crescent shaped circumferential distortion on one of the shear planes.[2] The maximum amount of this displacement from one side of the damage area to the other was 0.0664 inches. No evidence of cracking was found on the pin.

The inboard and outboard midspar fuse pins from the No. 2 engine of flight 42E were also examined in the laboratory. Examination of the fuse pins revealed that one of the shear planes on each pin contained a slight deformation. Although the deformation was not discernible when the pins were viewed with the unaided eye, the deformation could be noticed by tactile examination along the shank of the cleaned pin. Using an optical comparator, it was estimated that the maximum offset in the surface of the pin from one side of the deformation to the other was between 0.002 inches and 0.003 inches on both pins. The material from the sections of all three fuse pins was found to be within applicable manufacturer's specification requirements for composition, conductivity, and hardness.

The flight data recorder (FDR) data from both airplanes were not significantly different, and all parameters appeared to be within the normal range for safe operation. The data indicated that both airplanes encountered moderate to severe turbulence shortly after they departed ANC. The acceleration data recovered from the FDRs show that the dynamic loads at the airplanes' center of gravity (CG) were vertical 0.5 G to 1.8 G;[3] lateral +/- 0.25 G; and longitudinal 0.1 G to 0.3 G. However, it is possible that the acceleration loads were greater than indicated by the recorded data. The acceleration data are sampled at four times a second, allowing sufficient time intervals for greater accelerations to occur without being sampled.

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[2] Because the orientation of the pin was not documented when it was removed, it was not determined which was the inboard end of the pin or how the pin may have been aligned in the fitting.

[3] "G" is a unit of acceleration equal to the acceleration of the Earth's gravity, used to measure the force on a body undergoing acceleration, and expressed as a multiple of the Earth's acceleration.

Therefore, it is possible that momentary periods of extreme turbulence could have been encountered and not necessarily recorded by the FDRs.

Boeing's review of the G loads recorded by the two FDRs indicated that the equivalent loads (aerodynamic plus inertia) at the CG of the No. 2 engine nacelle could have been as high as -2.5 G vertical, 2.1 G to 3.0 G outboard lateral, and 0.1 G to 0.3 G longitudinal. These loads may or may not have been acting on the pylon at the same time. Once again, the calculated G loads do not necessarily represent the peak or maximum loads experienced by the pylon because of the FDR sampling rate of the recorded G data.

Boeing's records indicated six cases in which deformed midspar pins were discovered during a scheduled inspection. In all of the cases, there were no reports of hard landings, engine surges, or encounters with severe turbulence. Two cases involved deformed midspar pins at the No. 2 engine position, two were at the No. 3 engine position, and there was one report each for the No. 1 and No. 4 engine positions. There were nine cases in which pilots or mechanics reported that visual examination indicated that the pylon was drooping. Upon inspection, it was disclosed that structural failures had occurred within the pylon. There were no reports that any of these airplanes had experienced hard landings, severe turbulence, or engine surges prior to the time that the droop was detected In an additional 11 cases, during a maintenance inspection, midspar lugs were found to be damaged.

Acceleration loading at the CG of the airplane will produce dynamic and harmonic motion at other positions on the airplane, resulting in higher acceleration loading at those positions. During certification of the B-747, Boeing developed a finite element computer model that would calculate the acceleration loading throughout the airplane. The model found that lateral loading at the CG may induce lateral and vertical loads at the engine/pylon. In addition, vertical loading at the CG may produce vertical and lateral loading at the engine/pylon, primarily as a result of wing bending. In addition, engine weight, thrust, and aerodynamic loads produce loads at the engine/pylon.

The pylon is designed to carry the thrust and torque loads of the engine as well as lateral, longitudinal, and vertical loads from maneuvers and gusts. Lateral loads are ultimately absorbed by the midspar fuse pins and side brace. According to Boeing, the fuse pins can withstand an ultimate lateral load of more than 2.8 G on the engine[4]. Boeing reported that all structural strength calculations are based on unidirectional loading and that calculations for structural response to bidirectional or multi-directional loads are not required by Federal Aviation Regulations (FARs).

Based on the FDR data, the maximum combined lateral loads on the pylon, assuming maximum time phasing, are about 2.1 G to 3.0 G, which is close to or above the ultimate load (2.8 G) for the pylon in the lateral direction. The severe damage to the midspar fuse pin of the No. 1 engine pylon of the accident airplane indicates that the loads were sufficient to deform the pin and, therefore, were near the ultimate design load.

The Safety Board is concerned that if the engine pylon had not separated from the accident airplane, the airplane operated as flight 42E would not have received such a thorough severe turbulence inspection, and the damage to its No. 2 engine midspar fuse pins would not have been detected. Therefore, the midspar fuse pins would not have been removed and inspected, and the airplane could have continued in service with deformed fuse pins. Although the pins were not severely deformed, the deformation may have resulted in a stress raiser that could have increased the pins' susceptibility to fatigue, thereby reducing their service lives. Additionally, it was noted that a midspar fuse pin from the No. 1 engine position on accident airplane was severely deformed. The Safety Board is concerned that if the No. 2 engine had not separated from the accident airplane, that both airplanes would have continued in service with severely deformed or mildly deformed pylon midspar fuse pins. In both these cases, external examination of the pylons did not reveal any problem. Only when the pins were removed were the deformations found.

The Safety Board notes that Boeing has recently proposed a change to Chapter 5 of the Boeing 747 Maintenance Manual that will provide for the two-phased inspection of the engine pylons following an encounter with severe turbulence when accompanied by large variations in airplane roll and yaw attitude. In the first phase, the proposed inspection provides for a close visual inspection of the pylons before the next flight. If no damage is noted, the second phase then requires a detailed inspection within 500 flights. If damage is found during the first phase, the operator is directed to conduct the second phase before the next flight. The inspections provided during the second phase include removing all of the fuse pins

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[4] 14 CFR Sections 25.301 and 25.303 provide that the limit loads on a structure are the maximum loads to be expected in service and ultimate loads are the limit loads multiplied by a factors of safety of 1.5.

and examining them for cracks, wear, deformation, evidence of excessive loading, or other damage.

The damage found on the fuse pins from JAL the flight 46E airplane and the flight 42E airplane clearly indicates that the midspar fuse pins on a Boeing 747 can be deformed during an encounter with severe or possibly extreme turbulence. Such damage, if undetected, could eventually result in the failure of the fuse pin. The Safety Board believes that following an encounter with severe turbulence in which the airplane experiences large variations in roll and yaw attitude, the pylons should be inspected visually before the next flight, and within 500 flights, the midspar fuse pins on the B-747 series airplanes should be removed and inspected for deformation.

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

> Issue an Airworthiness Directive to require that the midspar fuse pins on Boeing 747 airplanes be removed and inspected for deformation following an encounter with severe turbulence in which the airplane experiences large variations in roll and yaw attitude, as provided in the Boeing Commercial Airplane Company's proposed modifications to the Boeing 747 Maintenance Manual, Sections 5-51-03 and 5-51-06. (Class II, Priority Action) (A-94-9)

> Review the service experience of other types of airplanes to determine if similar inspections of the engine mount structures should be conducted following encounters with severe turbulence in which the airplane experiences large variations in roll and yaw attitude. (Class II, Priority Action) (A-94-10)

Chairman VOGT, Vice Chairman COUGHLIN, and Members LAUBER, HALL, and HAMMERSCHMIDT concurred in these recommendations.

By: Carl W. Vogt
Chairman