NATIONAL TRANSPORTATION SAFETY BOARD

AIRCRAFT INCIDENT REPORT

NORTHWEST AIRLINES, INC.
BOEING 747–151, N607US
HONOLULU, HAWAII
MAY 13, 1971

NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D. C. 20591
REPORT NUMBER: NTSB-AAR-71-16

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16. Abstract Northwest Airlines Flight 9, a Boeing 747-151, N607US, was a scheduled passenger flight from Honolulu, Hawaii. Its destination was Tokyo, Japan. At departure from Honolulu, at 1330 H.s.t., 31 revenue passengers and 11 crewmembers were on board.

After take-off at 1,300 feet m.s.l., a separation of the second-stage turbine disk occurred rupturing the high pressure turbine case and cowling.

A fire warning and severe vibration ensued. The flight returned to Honolulu at 1351 H.s.t. There were no injuries to crew or passengers.

The National Transportation Safety Board determines that the probable cause of this incident was the in-flight separation of the second-stage turbine disk of the No. 3 engine. The separation of the disk was the result of a fatigue crack in a nickel-plated area of the turbine air seal land and progressed into the base material under operating loads.

In view of the potentially catastrophic consequences of a disk failure, the Board expresses concern over the inability of present turbine engine installations to protect airframe and system components from damage caused by turbine disk failures and strongly urges manufacturers and operators of turbine powered aircraft to make every effort to produce an acceptable and effective rotor burst protection system.

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Adopted: December 15, 1971

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SYNOPSIS

Northwest Airlines Flight 9, a Boeing 747-151, N607US, was a regularly scheduled passenger flight between San Francisco, California, and Tokyo, Japan, with an intermediate stop at Honolulu, Hawaii. At departure from Honolulu, 31 revenue passengers and 11 crewmembers were on board.

During takeoff from Honolulu at 1330 H.s.t., it was necessary to reduce power on the No. 3 and No. 4 engines from the predicted 1.395 to 1.33 engine pressure ratio in order to maintain exhaust gas temperature within operating limits. Power adjustment was also made during climb after takeoff for the same reason.

Shortly after takeoff, while the aircraft was in a right turn at 1,300 feet m.s.l., a separation of the second-stage turbine disk occurred and pieces penetrated and raptured the high-pressure turbine case and engine cowling.

A fire warning and severe vibration ensued which terminated following fire extinguisher discharge and engine shutdown procedures. Fuel jettison was accomplished to reduce weight to the maximum allowable for landing. The flight returned to the Honolulu International Airport and landed safely at 1351 H.s.t. There were no injuries to passengers or crew.

The National Transportation Safety Board determines that the probable cause of this incident was the in-flight separation of the second-stage turbine disk of the No. 3 engine. The separation of the disk was the result of a fatigue crack which originated in a nickel-plated area of the reworked turbine air seal land and progressed into the base material under operating loads.

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INVESTIGATION

Northwest Airlines Flight 9 of May 13, 1971, was a regularly scheduled passenger flight between San Francisco, California, and Tokyo, Japan, with an internediate stop at Honolulu, Hawaii. The flight from San Francisco to Honolulu was routine. During the takeoff and initial climb from Honolulu, it was necessary to adjust power frequently on the No. 3 and No, 4 engines to prevent them from exceeding exhaust gas temperature limits. The predicted engine pressure ratio for the Honolulu takeoff was 1.39. Due to the temperature limitations, Nos. 3 and 4 engines were maintained at 1.33 engine pressure ratio. At 1333 1/ H.s.t., 3 minutes after takeoff, while the aircraft was climbing in a right turn at 1,300 feet m.s.l., a loud explosion occurred. This was accompanied by yaw to the right, No. 3 engine fire warning, and moderate aircraft vibration. Engine emergency fire procedures were initiated and the No. 3 engine was shut down. The combined effect of the explosion and airplane yaw led the crew to believe that they had collided with another airplane.

Fuel jettisoning was initiated to reduce gross weight to within allowable landing limits. Approximately 54,000 pounds of fuel were jettisoned and the airplane landed safely at 1351. It was taxied to the terminal where the passengers deplaned.

The No. 3 engine, Pratt & Whitney JT9D-3A, serial No. P-662573, had accumulated a total operating time of 660 hours and 201 operating cycles since new. A segment of the second-stage turbine disk had separated, rupturing the high-pressure turbine case and causing massive internal damage to both the high- and low-pressure turbine modules. A section of outer rim, approximately 4 inches deep (measured radially) and 17 inches long, and 23 blades were missing from the turbine disk: All other blades were broken off. The separated fragments were not recovered. The high-pressure turbine module disclosed no evidence of improper assembly.

Structural damage to the aircraft resulting from the failure of the No. 3 engine was confined to the No. 3 strut, engine cowl, and lower surface of the wing adjacent to and outboard of the No. 3 engine. The right (outboard) side cowl of the No. 3 nacelle was torn completely in half and had numerous smaller tears, punctures, and dents. The left side cowl also had numerous large holes and dents. The No. 3 engine tail cone had several punctures and dents. The outboard (right side) skin of the No. 3 strut was buckled and scraped near the lower end. Access doors were missing in seven places on the inboard side of the strut. The right side outboard leading edge flap had two small holes, and the right side trailing edge midflap was punctured in three places adjacent to the flap track fairing. The No. 7 and

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1/ All times used herein are Hawaii standard, based on the 24-hour clock.

No. 8 flap track fairlings had several small holes, cuts, and scratches. The lower wing skin adjacent to the No. 3 strut near the leading edge was gouged and scratched. Several rivets were popped and a fairing was buckled.

The No. 4 engine incurred minor foreign object damage to the fan blades.

The No. 3 engine was removed and shipped to the manufacturer, Pratt & Whitney Aircraft, East Hartford, Connecticut, for disassembly and further examination. This included an examination of the failed disk in the manufacturer's metallurgy laboratory.

RECORDS REVIEW

The production, overhaul, and repair records relative to this disk were reviewed.

The review disclosed that the disk was an early production configuration which had been reoperated to the JT9D-3A configuration per sketch layout SL81559. The reoperation involved machining to remove a flange on the forward face and to provide a pilot land and snap diameter for mating with a new configuration air seal and disk spacer. It also involved a buildup on the land and its blend radius by nickel plating to provide material for the fit of the new air seal.

The disk was assembled in high-pressure turbine module C-62205 which was assembled in engine P-662205. On July 6, 1969, this engine was installed by Boeing on aircraft RA002, which was being used in the B-747 flight test program. Flight testing included airplane and powerplant performance, sound measurements, and demonstration flights. During this period, the engine experienced one hot start, three compressor stalls, and two instances of overtemperature.

Following the second overtemperature, a borescope inspection revealed damage to the first-stage turbine nozzle guide vanes. The high-pressure turbine module, including the disk, serial No. OW 5073, was returned to Pratt & Whitney for repair on August 13, 1969. A Zyglo 2/ inspection of the disk showed a crack indication in the nickel-plated area. This was judged to be entrapment of the fluorescent oil in the fringe of the plating. Pratt & Whitney engineering personnel directed that the indication be blended and the disk returned to service. The disk was reassembled in the module and returned to the Boeing Company in August 1969.

In August 1970, JT9D-3 engine P-662205 was returned to Pratt & Whitney from the Boeing Company for conversion to -3A configuration. The engine contained the subject second-stage turbine disk. The disk received a normal overhaul inspection, which included a 100 percent Zyglo inspection. No indications were found.

The disk at that tine was machined to remove a counterweight flange from

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2/ Zyglo is a nondestructive test method using fluorescent dye penetrant and ultraviolet light. Indication refers to discontinuities and imperfections disclosed by this method.

the rear face in accordance with Service Bulletin 2759. It was again inspected by the fluorescent penetrant method and no indications were found,

The disk was subsequently assembled in engine P-662573. This engine was rejected twice during test runs. It was partially disassembled each time for replacement of parts. At each disassembly, the second-stage turbine disk was fluorescent penetrant inspected in the area reworked per Service Bulletin 2759. No indications were found. The engine subsequently passed final test and was shipped to the Boeing Company on November 6, 1970.

Engine No. P-662573 was eventually delivered to Northwest Airlines where it accumulated 660 hours of operation and 201 operating cycles prior to failure of the second-stage turbine disk at Honolulu.

LABORATORY EXAMINATION

A detailed laboratory examination confirmed that the disk was of the proper material (PWA 1007 nickel-base alloy) as specified by the manufacturing drawing, and the hardness was within the range specified by the drawing. The tensile and stress-rupture properties of the disk materialwere found to be above the minimums specified by the Pratt & Whitney materials manual. The microstructure of the disk material and the nickel platewere found to be normal with no defects noted.

The fracture originated from a 5.75-inch circumferential fatigue crack in the nickel-plated area of the turbine air seal contact land. The fracture was a rapid tensile failure which progressed outward to the rim from each end of the fatigue crack at approximately 45°. Eight cracks were found in the air seal land nickel plate to web blend radius, and two cracks in the flat-plated surface of the land. Galling was evident on the air seal land nickel plate adjacent to the blend radius, and the plate adjacent to the fatigue origin was severely galled and smeared.

A radial section through the air seal land revealed two layers of nickel plate, the first 0.017 to 0.025 inches thick and the second 0.0135 to 0.020 inches thick. Microscopic examination of other radial sections through the air seal contact land and blend radius revealed fatigue cracks in the nickel plate which had progressed into the base material. These cracks originated in the galled area of the surface of the nickel plate and from a separation between the two layers of plating.

A series of tests were conducted by the engine manufacturer, intended to compare the relative fatigue strength of the disk material with and without nickel plate. Test specimens were taken from the failed disk and from a similar but unplated disk. They were taken from the air seal land area in order to duplicate the geometry of the failed area, and were subjected to high-frequency cyclic loads. The unplated specimens failed in an area outboard of the snap air seal land area. The plated specimens failed and initiated cracks in the plated area of the seal land (same area as failed disk) and the failure occurred at lower stress levels than in the unplated specimens.

Several flat specimens of disk material with no nickel plate, 0.010-inch, 0.020-inch, and 0.040-inch thick nickel plate were tested. These tests showed that fatigue strength of the nickel-plated disk material was reduced appreciably. The fatigue strength of the unplated specimens was approximately twice that of the specimen with a 0.040-inch thick plate.

ANALYSIS AND CONCLUSIONS

Of primary concern in this analysis are the conditions leading to the separation of the second-stage turbine disk and the effect of the nickel plate on the fatigue strength of the disk.

The use of nickel plate to build up galled and worn areas on turbine disks has been a successful, widely used repair method for many years. It is sometimes used to salvage an otherwise scrappable disk at initial manufacture. However, this repair normally results in a plating thickness of only 0.005 to 0.010 inches.

In electrodeposited nickel, residual stress of from 2,000 p.s.i. to as high as 45,000 p.s.i. can be present, the level depending on the plating process used. These residual stresses tend to make the nickel plate susceptible to fatigue cracking. A fatigue crack propagating through the nickel plate acts as a stress riser, which ultimately leads to reduced fatigue strength of the base metal.

The tests conducted by the manufacturer were conclusive in establishing that the fatigue strength of the plated disk was reduced considerably from that of an unplated disk. These tests also demonstrated that an unplated disk subjected to the same type of loading would fail in an area other than the air seal land blend radius.

The laboratory analysis of the failed disk revealed numerous fatigue cracks in the layers of nickel plate, many of which had progressed into the disk material. Some of these cracks originated at the extremity of a separation between layers of nickel plate. Others originated in a heavily galled area of the outer layer of plate at the air seal land blend radius. It is significant that the nickel plate at the origin of the failures was also severely galled. The galling and cracking are indicative of a high-compression'loading, which resulted from axial forces imposed by the first- to second-stage air seal.

The combination of these loads and normal vibratory loads resulted in the progression, with each succeeding operating cycle, of the cracks through the nickel plate and into the base material. Ultimately the disk was weakened sufficiently so that it could no longer sustain the normal rotational loads, at which time a portion separated, penetrated the high-pressure turbine case, and caused varied degrees of secondary damage to the cowling, wing, and pylon, From the investigation of this incident, the Board concludes the following:

1. The disk was nickel-plated as part of a reoperation to a newer configuration.

2. The nickel plate was more than twice as thick as that normally used in turbine disk repair, and was applied in two separate layers.

3. Effects of the thicker nickel plate on the strength of the disk were not sufficiently evaluated before this incident.

4. The nickel plating contributed to reduce fatigue life of the disk.

PROBABLE CAUSE

The National Transportation Safety Board determines that the probable cause of this incident was the in-flight separation of the second-stage turbine disk of the No. 3 engine. The separation of the disk was the result of a fatigue crack which originated in a nickel-plated area of the reworked turbine air seal land and progressed into the base material under operating loads.

CORRECTIVE ACTION

The engine manufacturer identified six other part No. 159802 second-stage disks which were suspected of having been plated per SL 81559. Two of these had previously been scrapped by the manufacturer for reasons other than cracks, and one was scrapped by an overhaul agency.

The three remaining in service were recalled by the manufacturer. Two were found not to have been plated in the snap blend radius and fluorescent penetrant inspection showed no crack indications. The third disk had been plated, and examination revealed numerous crack indications in the plate, some of which had progressed into the base metal. As a precautionary action, all disks eligible for nickel plating according to the manufacturer's overhaul manual were also reviewed. Only one was found which had been plated in the air seal land area, and it was removed from service.

The manufacturer has stopped plating JT9D turbine disks and has advised users and overhaul agencies to do the same.

RECOMMENDATIONS

In this and previous turbine disk failures, varying degrees of damage have been inflicted on adjacent aircraft structures. In some instances, systems have been disabled and serious fires have ensued which endangered the fuel tanks. The potential for massive structural damage cannot be too strongly emphasized.

The National Transportation Safety Board is aware of the penalties in weight and cost imposed by features which would successfully contain the fragments produced by a turbine disk failure. However, in view of the potentially serious consequences, the Board is concerned about the inability of present turbine engine installations to protect airframe structure and system components adequately from damage caused by turbine disk failure. It urges manufacturers and operators of turbine-powered aircraft, in collaboration with the Federal Aviation Administration and the National Aeronautics and Space Administration programs, to make a concerted effort to produce an acceptable and effective rotor burst protection system.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

December 15, 1971