Log 2308

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: September 17, 1991
In Reply refer to: A-91-85
and -86

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

On March 29, 1991, a Garrett Auxiliary Power Division (Garrett) auxiliary power unit (APU) Model TSCP700-5 (serial number P-80186) high-pressure turbine (HPT) disk ruptured and was uncontained on an Air Inter Airbus A300 airplane. Fragments of the disk separated from the APU and caused minor airframe damage. The incident occurred during pushback from the gate at Nice, France, when the APU was used to start an engine. The APU was running at 91 percent N_1 (gas generator) speed and 100 percent N_2 (output shaft) speed when it experienced a failure and separation of its P/N 977156-1, S/N 4-18040-1554, HPT disk. The attending ground mechanic heard a loud bang from the APU compartment and observed flames and smoke coming from the APU exhaust. The fire warning sounded in the cockpit and the crew discharged the APU fire extinguisher bottle. A similar uncontained HPT disk failure of a Garrett APU model TSCP700-4B (S/N P-90473) also occurred on April 28, 1989 at Honolulu International Airport, Hawaii, on a United Airlines (UAL) DC-10 airplane under similar circumstances.

These incidents involve two safety issues that concern the Safety Board: (1) the failure of the HPT disk and subsequent release of high-energy fragments and (2) the failure of the APU's HPT containment ring to contain these fragments within the APU casing.

The Air Inter incident was investigated by the French Bureau Enquetes-Accidents (BEA) with Safety Board participation. The investigation identified two separate locations, near the compressor/turbine split line, where a piece of the disk had exited the APU casing. The separated HPT disk was recovered within the APU compartment of the airplane in two large segments. One segment of the disk exited the APU at approximately the 9 o'clock location (aft looking forward) and contacted the APU starter motor

before striking airplane structure. The other disk segment exited the APU at approximately the 3 o'clock location and struck the APU compartment shield. The disk segments caused minor airframe damage, including damage to the firewall, compartment doors, and the APU fire warning loop. The Air Inter HPT disk rupture and the 1989 UAL event were nearly identical in all respects.

The Garrett metallurgical examination of the separated Air Inter HPT disk revealed that the fracture contained a low cycle fatigue crack which was between 0.20 and 0.50 inch in length on the bore surface of the disk. Examination indicated that the fatigue crack had initiated from an approximately 0.10 inch long inclusion located in the disk bore. This inclusion, as well as some other inclusions on the fracture surface and in the base material were identified as oxide and carbide stringer type inclusions. Trace amounts of phosphorous found on the fracture surface indicated that the crack was present but not detected during the last fluorescent penetrant inspection. A striation count performed in the fatigue crack region indicated that the actual disk total fatigue cycles were close to the reported engine operating cycles, and indicated that the crack probably initiated early in the life of the disk. At the time of separation, the disk had a total of 16,377 hours since new and 4,741 hours since the last penetrant inspection.

The Air Inter APU S/N P-80186 was last removed from service in February, 1988, after it experienced a failure of a 2nd stage low pressure turbine blade. During this shop visit, the HPT disk (S/N 4-18040-1554) received a level 2 fluorescent penetrant inspection and subsequently was reinstalled in the subject TSCP700-5 APU. Garrett estimated that a fatigue crack of at least 0.20 inch long existed at the time of this inspection. They also state that a level 2 fluorescent penetrant inspection is generally only capable of detecting a crack greater than 0.50 inch long. A level 3 fluorescent penetrant inspection, which was not required at the last examination, generally will detect a crack in the range of 0.180 inch and greater in length.

Garrett determined that the separated P/N 977156-1 HPT disk involved in the Air Inter incident was manufactured from a Teledyne Allvac Waspalloy heat (melt lot) made in 1974. One hundred sixty-three P/N 977156-1 HPT disks, S/N 4-18040-1510 thru -1672, were produced from that 1974 Teledyne Allvac melt lot. The Safety Board is concerned that other disks produced from the 1974 Teledyne Allvac melt lot may also have non-metallic inclusions similar to those found in the bore of disk S/N 4-18040-1554. The Safety Board believes that these disks should be promptly located and inspected; any disk found to be cracked should be removed from service.

A Safety Board review of the UAL DC-10 APU disk separation in 1989 disclosed that the HPT turbine disk failure was also initiated by an inclusion in the disk material. Garrett reported that the melt lot from which this disk originated was different from that of the Air Inter APU disk. Garrett also reported that the DC-10 APU disk material was contaminated by a 0.316-inch-long piece of stainless steel weld rod that had dropped into the melt and went undetected during processing. Garrett

believed that this defect was an isolated incident and that it was confined to a small group of disks that have since been removed from service. Garrett records indicated that the Air Inter and UAL APU HPT disk material was supplied by different vendors.

Currently there are 614 TSCP700-4B model APUs on DC-10/KC-10 airplanes, 351 TSCP700-5 model APUs on A300 airplanes, and 42 TSCP700-4E model APUs on MD-11 airplanes. On APUs installed in these airplanes the authorized service life of a P/N 977156-1 HPT disk is 30,000 cycles (cycle/hour ratio on these APU's is approximately 1:1). In the two cited incidents the HPT disk failed at approximately 15,000 operating cycles or prior to their planned service lives. The Safety Board concludes that because these two failures were related to undetected anomalies that occurred during the initial material processing and not because of design or subsequent manufacturing deficiencies, their failures may not be relevant to the authorized operating life of all P/N 977156-1 disks. However, the Safety Board believes that all disks that were forged and manufactured from the 1974 Teledyne Allvac heat lot should be inspected at the next opportunity for cracks in the disk bore area in accordance with Garrett Alert Service Bulletin TSCP700-49-A6581 dated July 1, 1991.

During the investigation of both of these failures, it was determined that when the liberated segments of the disk contacted the HPT containment ring, the containment ring was deflected radially outward and rolled rearward allowing disk segments to escape the APU casing. The Safety Board is concerned that in both of these incidents the APU HPT containment ring did not prevent the fragments of the failed disks from exiting the APU casing and contacting airplane structure. The Garrett model TSCP700 APU was qualified under the provisions of Federal Aviation Agency, Technical Standard Order TSO-C77, Part 514, effective May 20, 1963. TSO-C77 specified the minimum requirements for gas turbine power units for use in civil aircraft, and under section 3.0 provided the following definitions; sub-section 3.10 Containment. "Parts being contained may penetrate containing components but shall not have passed clear through such components" and sub-section 3.13 High energy rotors. "A rotating component or assembly which, if it ruptures, will generate particles with sufficient energy as to cause secondary damage to the rotor housing." By definition, the APU HPT rotor in both of these incidents failed to meet the containment requirements specified in TSO-C77.

As a result of the 1989 UAL disk failure, Garrett designed and substantiated[1] an improved containment ring, P/N 3614975-1, which is considered more capable of containing the fragments from a failed turbine disk. Garrett Service Bulletin TSCP700-49-5892 provided the new containment ring and recommended that operators install it in all

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[1] TSO-C77 defines substantiate, "To prove on the basis of adequate evidence obtained by demonstration or analysis or both". Garrett qualified the new containment ring design to TSO-C77 by analysis. No additional containment testing was required or accomplished.

applicable APUs at the next opportunity. Installation of the new containment ring was not mandated for retrofit by the FAA. However, Garrett specified this design in its bill of materials for its model TSCP700-4E APU, which is installed on MD-11 airplanes. The Safety Board is not aware of any Garrett APU turbine failure incidents on the recently introduced MD-11 airplane.

The Safety Board believes that to improve the safety of these APUs an airworthiness directive is needed to ensure the installation of the P/N 3614975-1 containment ring in Garrett model TSCP700 APUs already in service on McDonnell Douglas DC10/KC10 and Airbus A300 airplanes. The Safety Board concurs with the intent of the recently announced NPRM (Airworthiness Rules Docket No. 91-NM-151-AD) addressing Garrett APU containment rings.

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

> Require the Garrett Auxiliary Power Division to identify those P/N 977156-1 APU high-pressure turbine (HPT) disks manufactured from the 1974 Teledyne Allvac heat melt that are most likely to contain anomalies, such as large foreign material inclusions that would initiate fatigue cracks; issue an airworthiness directive to require inspection of all suspect disks for cracks in accordance with Garrett Alert Service Bulletin TSCP700-49-A6581 and remove from service of any disk found to contain defects. (Class II, Priority Action) (A-91-85)
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> Issue an airworthiness directive, based on Garrett Service Bulletin TSCP700-49-5892, to require the installation of a P/N 3614975-1 HPT containment ring in all applicable APUs not so equipped. (Class II, Priority Action) (A-91-86)

Chairman KOLSTAD, Vice Chairman COUGHLIN, and Members LAUBER, HART, and HAMMERSCHMIDT concurred in these recommendations.

By: James L. Kolstad
Chairman