HS125-700A, N125XX

AAIB Bulletin No: 6/2004	Ref: EW/C2003/06/01	Category: 1.1
SERIOUS INCIDENT		
Aircraft Type and Registration:	HS125-700A, N125XX	
No & Type of Engines:	2 Honeywell TFE731 3R 1H turbofan engines	
Year of Manufacture:	1980	
Date & Time (UTC):	13 June 2003 at 0740 hrs	
Location:	Runway 26, London (Luton) Airport, Bedfordshire	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 2	Passengers - 5
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Severe damage to right engine and thrust reverser	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	57 years	
Commander's Flying Experience:	25,000 hours (of which 1,000 were on type)	
	Last 90 days - 100 hours	
	Last 28 days - 30 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft suffered an uncontained failure of the right engine, at 60 kt during the take-off roll, on Runway 26 at Luton Airport. The takeoff was abandoned, the engine was shutdown and the aircraft taxied clear. Subsequent examination revealed high cycle fatigue failure of the 1st stage Low Pressure Turbine (LPT) disc.

The engine had undergone a Major Periodic Inspection (MPI) and Compressor Zone inspection some 107 hours before the incident. This identified the requirement to replace the LPT 1 disc and nozzle assembly. The replacement LPT 1 disc was a new item from the manufacturer. The replacement nozzle assembly, manufactured as a one piece ring of 67 vanes, was an item overhauled by an FAR Part 145 approved repair station, not on the manufacturer's list of authorised organisations, operating under a Designated Engineering Representative (DER) system. During overhaul the nozzle assembly is 'tuned' by deflecting the trailing edges of individual vanes, opening or closing the area of each nozzle throat, to ensure the correct total effective area of the nozzle ring. A computer programme called 'NAPOLI', developed by the manufacturer in response to previous fatigue failures of nearly-

new discs, fed with flow rig measurements and the measured distances between vanes, calculates the vane deflection required and which vanes need adjusting.

Inappropriate nozzle adjustment could create LPT 1 disc resonance initiating and propagating fatigue. A Service Bulletin (SB), issued by the manufacturer, detailed instructions for correct nozzle adjustment and another highlighted the possible consequences if this was not carried out correctly. The repair station, not being authorised by the manufacturer, were not aware of the contents of the former SB and therefore were ignorant of the manufacturer's requirement for vane adjustment and the 'NAPOLI' programme.

The AAIB has recommended that the Federal Aviation Administration (FAA) ensure that 'FAR Part 145' repair stations are in possession of all the manufacturer's documentation covering the tasks for which they are approved.

History of the flight

The aircraft completed 3 uneventful flights on the day before the incident and was parked for the afternoon and overnight at Luton Airport. At 0730 hrs the following day the crew carried out a normal start on each engine, were cleared by ATC to taxi for departure and at 0738 hrs were cleared to takeoff from Runway 26. The weather was CAVOK with a surface wind of 320°/05 kt, a temperature of +14°C and a QNH of 1024 hPa.

After line up the crew smoothly advanced the thrust levers to the take off setting of 97% N1 and checked that the engine parameters were stable during the aircraft's initial acceleration. At approximately 60 kt the crew heard a loud bang and the aircraft yawed to the right. The commander immediately closed both thrust levers, applied the brakes and brought the aircraft to a stop. Both crew members noted that the oil pressure warning light for the right engine had illuminated and that the engine fire warning bell had began to sound. The commander completed the shutdown drill for the right engine, silencing the engine fire warning bell once the high pressure and the low pressure fuel cocks had been closed. The crew informed ATC of their situation and requested taxi clearance. ATC had already noticed that the aircraft had stopped on the runway and reported to the crew that smoke had been seen emanating from one of the engines.

Examination of the aircraft

Initial examination revealed that No 2 engine had suffered an uncontained failure in the region of the Low Pressure Turbine (LPT). There was a gaping hole in the engine cowling extending from approximately the 9 o'clock to the 11 o'clock position when viewed from the front. It was possible to see into the interior of the engine through a further rupture in the engine casing. Closer inspection showed that the 1st stage of the LPT was missing. A segment equating to approximately 120° of the LPT 1 disc was recovered from the runway. The remainder of the disc could not be found, despite an extensive search. Other damage to the airframe was limited to a small debris impact on the right wing flap.

The engine was removed and despatched to its manufacturer for strip examination under AAIB, National Transportation Safety Board (NTSB) and Federal Aviation Administration (FAA) supervision. The segment of fractured LPT 1 disc was submitted for an initial metallurgical examination that identified three areas containing probable fatigue damage on the fracture face.

History of the engine

The failed engine, serial number P-80213, had accumulated 8,792 hours and 5,205 cycles since new. Some 107 hours and 98 cycles earlier, it had undergone a Major Periodic Inspection (MPI) and Compressor Zone inspection at the premises of an overhaul agency in the USA. This had identified the requirement for a replacement LPT 1 disc and nozzle assembly. The LPT 1 disc was obtained as a

new item from the engine manufacturer. The nozzle assembly however, was obtained in an overhauled condition from a spare parts dealer. The nozzle assembly had been overhauled by an FAR Part 145 approved repair station operating under a Designated Engineering Representative (DER) system. This agency was not on the list of manufacturer authorised organisations for this type of work.

In addition to the normal inspection and repair and refinishing work performed as part of the overhaul process, the nozzle assembly (manufactured as a one-piece ring of 67 vanes) was subjected to a 'flow check'. This led to the adjustment of individual vanes to achieve an overall nozzle area. A more detailed description of this process follows later in this Bulletin.

The LPT 1 nozzle assembly bore the part number 3072319-11 and the serial number 7-01345-11066. The component card supplied with it was ostensibly an Allied Signal (Honeywell) Life Limited Part Log indicating that the component was made in 1990 to a '-11' standard. It had been removed from the engine in which it had been installed in 1998 whence it was overhauled before being installed in engine P-80213 in February 2001. Cross-checking the Honeywell records for this serial number revealed several anomalies. Firstly, not being a life-limited component, the nozzle was issued by Honeywell on a Component Maintenance/Modification Record card, not a Life limited Part Log card. Secondly, the '-11' modification standard was not released until November 1992 and serial number 7-01345-11066 was manufactured in 1978 as a '-4' standard, passing through their Phoenix overhaul workshops twice (the last being in 1994 when it was modified to '-11' standard). Their last records showed, at that time, that it was issued as a spare and after that they had no knowledge where it went.

Nozzle flow checking and adjustment.

Following manufacture or overhaul, the nozzle assemblies are placed in a rig that blows air through the vanes and thereby calculates the total effective area of the nozzle ring, presenting this as a figure in square inches. Organisations re-building an engine may require a nozzle of a specific area in order to 'tune' the engine to a particular parameter, such as spool speed or exhaust gas temperature. Altering the nozzle total area can be achieved, within prescribed limits, by deflecting by a calculated amount the trailing edges of individual vanes so as to open or close the area of that nozzle throat. This is achieved by a simple device that grips the trailing edge and bends the vane in the required sense.

Honeywell and their authorised agents employ a computer programme called 'NAPOLI', developed in 1988, when they overhaul LPT 1 nozzles. This programme, provided with the measured total nozzle area from the flow rig and the measured distances between each vane (using a ball gauge), calculates the number of vanes and deflection required to achieve a final total area. In addition, the programme calculates *which* vanes should be altered. 'NAPOLI' was developed in response to three occurrences of LPT 1 disc failures on TFE731 engines in the 1980's when nearly-new discs had failed due to fatigue cracks.

Common amongst these occurrences was the fact that the recorded disc hours, after fitment with an overhauled (and flow-adjusted) nozzle ring, were in the low hundreds. Furthermore, the fatigue cracking, not associated with any material defects, had been high-cycle in nature.

Investigation strongly suggested that unequal individual nozzle throat areas, when situated at particular locations around the ring of vanes, could excite a resonant condition in the LPT1 disc, causing fatigue to initiate and propagate. Consequently, in September 1988, Honeywell issued a Service Bulletin (SB) TFE731-72-3367 that is a public document approved by the FAA. This outlined the situation described above and warned of the possible consequences of operation with LPT 1 nozzles that had been flow adjusted since manufacture. Such nozzles were to be checked against criteria outlined in the SB "at next access to the affected part or next MPI". The SB referred customers to authorised Honeywell repair centres and did not contain instructions for adjusting the vanes. The Light Maintenance Manual (LMM) and Inspection/Repair Manual (IRM) did not include information on this subject.

In July 1990, a further SB, TFE731-72-3369RWK, was issued with instructions for adjusting nozzle throat openings, using Honeywell-devised tooling and the 'NAPOLI' programme. This, however, was only issued to authorised Honeywell repair centres and was classed as a proprietary document.

Strip examination of the engine

The engine was shipped to Honeywell for strip examination under AAIB, NTSB and FAA supervision. Also present were representatives from the company that had re-built the engine. The examination found no evidence of anomalies outside the damaged LP turbine area. This damage was consistent with a primary uncontained failure of the LPT 1 disc. Although most of the LPT 1 nozzle assembly (commonly referred-to by the manufacturer as the A-5 nozzle) was recovered, it was too damaged and distorted to make any meaningful measurements of the throat areas for comparison with the 'NAPOLI' criteria.

Laboratory examination of the LPT 1 disc fragment recovered from the runway at Luton revealed four areas of high-cycle fatigue, originating alternately on opposite sides of the disc. Although the majority of the disc was not recovered, it is suspected that this would also have borne similar evidence of fatigue cracking. Such fatigue cracking is consistent with operation of the disc with an incorrectly adjusted LPT 1 nozzle assembly. No material defects or other anomalies were found.

Discussion

In the absence of any other possible causal factors, it has to be assumed that the LPT 1 disc failed due to disadvantageous adjustment of the throat areas of individual nozzles of the A-5 assembly. This resulted in a resonant excitation of the disc that applied stresses, beyond the design requirement, initiating and propagating high-cycle fatigue cracks that failed the disc at little more than 100 hrs running time from new.

The repair station that performed the last overhaul had been supplied with the A-5 nozzle assembly by the spares dealer. The dealer required that it be overhauled, repaired as necessary and then adjusted to a particular total area before its return. The repair station was not aware of the contents of either SB TFE731-72-3367 or SB TFE731-72-3369RWK. Indeed, not being a Honeywell authorised repair station, they would not have been informed of the latter and not only remained ignorant of the manufacturer's required method of adjusting the vanes but also the correct tooling for the process and the 'NAPOLI' programme. When asked about the method they employed, the repair station replied that they had adjusted the nozzle area by "tweaking all the vanes an equal amount." They also admitted that they were ignorant of a Honeywell applied limit of 0.010 inches maximum differential between the largest and the smallest throat opening.

It is deemed acceptable for some repair stations in the USA to operate without the benefit of all, or even any, Original Equipment Manufacturer (OEM) data; Airworthiness responsibility falling to the DER. This investigation demonstrates that important procedures, known only to the manufacturer and its approved agencies, were not performed by the repair station. This is considered potentially hazardous, particularly in the case of turbine engine parts that can be apparently very sensitive to minor variations in material or dimensions.

The discrepancy between Honeywell's records for the A-5 nozzle and those supplied with the part remains a concern. The part may well have been the one to which the serial number referred, but its history clearly was not related.

Post-incident remedial actions.

The manufacturer intend to revise the LMM/IRM manuals adding a caution concerning the adjustment of nozzle vanes. They will also require inspection of all TFE731-2A/3 engine A-5 nozzles at the next MPI (or next access) to measure throat openings and evaluate using 'NAPOLI'. They are

also considering a requirement to scrap the LPT 1 disc if an unacceptable 'NAPOLI' solution is recorded.

Additionally, the repair station involved is negotiating with Honeywell the purchase of a copy of the 'NAPOLI' programme and the associated tooling. Honeywell are also attempting to locate other agencies that may be performing work on the A-5 nozzle to ensure that they too are aware of the potential problems following vane adjustment. In the longer term, a new LPT 1 disc is being developed that will seek to avoid the resonance problems even with a disadvantageous arrangement of differential throat openings. It is understood however, that the requirement to work in accordance with the 'NAPOLI' criteria will remain.

Safety Recommendation

The measures to be taken by Honeywell to prevent similar incidents are detailed above. These however, cannot address the wider issues of repair stations operating in relative ignorance of the experience and expertise of the manufacturer. The AAIB therefore make the following Safety Recommendation:

Safety Recommendation 2004-34

The Federal Aviation Administration should ensure that 'FAR Part 145' repair stations are in possession of all the manufacturer's documentation covering the tasks for which they are approved.