Engine failure on takeoff, Boeing 777-200, G-VIIH, 12 March 1998 at 1900 hrs

Micro-summary: **This boeing 777-200 experienced an engine failure on takeoff.**

Event Date: **1998-03-12 at 1900 UTC**

Investigative Body: **Aircraft Accident Investigation Board (AAIB), United Kingdom**

Investigative Body's Web Site: **http://www.aaib.dft.gov/uk/**

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Boeing 777-200, G-VIIH, 12 March 1998 at 1900 hrs

AAIB Bulletin No: 8/98 Ref: EW/C98/3/3 Category: 1.1

Aircraft Type and Registration:	Boeing 777-200, G-VIIH
No & Type of Engines:	2 General Electric GE90-85B turbofan engines
Year of Manufacture:	1997
Date & Time (UTC):	12 March 1998 at 1900 hrs
Location:	London Heathrow Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 15 - Passengers - 230
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Damage to turbine sections of left-hand (No 1) engine
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	47 years
Commander's Flying Experience:	9,800 hours (of which 380 were on type) Last 90 days - 20 hours Last 28 days - 9 hours
Information Source:	AAIB Field Investigation

History of flight

The aircraft and crew were planned to fly a scheduled passenger flight from London (Heathrow) to Boston, USA. The aircraft was serviceable with no reported defects to either the engines or their associated systems. The reported weather prior to the engine start included a surface wind of 270_/07 kt with a temperature of +7_C and the QNH was 1027 mb.

The aircraft was on a northerly heading when the engines were started at 1854 hrs. An auto-start, using APU air, was completed for each engine in turn and all indications were normal. Light rain

was falling so the crew selected the engine anticing to 'On' after engine start. Engine anticing is selected when the air temperature is 10_C or less with visible moisture present and with the switch in the 'On' position the system uses engine bleed air to prevent ice forming on the forward edge of the engine cowl. The aircraft was then taxied the short distance from the Victor pier to the holding point for Runway 27L with only minimum power settings required during this phase.

When the aircraft was cleared to line up, at 1900 hrs, the surface wind was 240_/07 kt and it had stopped raining. The commander, however, decided to retain the On selection for the engine anticing as they were likely to enter cloud shortly after take off. He briefed the first officer that during the take off run the 'Anti-ice On' EICAS warning would probably appear as a result of the rise in total air temperature.

Once cleared for take off both engines were set to approximately 55% N1 and when they were stable the commander selected take off power. In the prevailing conditions and using the actual aircraft weight the crew had selected an assumed temperature of +44_C, thus derating the engine power used for take off. Shortly after the first officer had called "Power Set" there was a loud bang and the aircraft swung to the left. Both pilots called "Stop" as the commander closed the thrust levers and the first officer selected reverse idle. As the aircraft decelerated the commander heard the aural warning "Engine Fail" and saw the associated EICAS warning; the master caution light had also illuminated. Once stationary the commander ordered the engine fail drill for the left engine and called for the fire service to attend, he then spoke to the fire chief. Meanwhile the commander had detailed two cabin crew members to monitor the front and rear of the left (No 1) engine for signs of fire. After discussion with the fire crew and ATC it was decided to start the APU and taxi clear of the runway. Since the commander experienced little difficulty in taxying the aircraft on the right engine power only, he elected to continue to the stand, with the fire services following, where the passengers were disembarked. The commander reported that during the engine failure and associated stop he experienced little handling or control problems.

The initial examination showed that the engine had ejected turbine debris into its tailpipe and onto the runway but there was no failure of the engine containment. There had been no secondary damage caused by the engine failure.

Flight Recorder Information

The aircraft was fitted with a Solid State CVR, model A200S, with a recording duration of 2 hours and a Sundstrand Solid State FDR. Both recorders were replayed satisfactorily and data was also obtained from the airlines Optical Quick Access Recorder. The data showed that the aircraft accelerated normally until, at an airspeed of 71 kt, there was a sudden decrease in N1 on No 1 engine from 93%, N2 was 106.5 %. The throttles were both retarded one second later and the maximum EGT on No 1 engine was 965.5°C. The maximum recorded airspeed was 75 kt.

Technical examination

The No 1 engine was a GE90-85BG04, serial no. 900158, fitted since aircraft delivery. The engine had been operated for 3,166 hours over 511 cycles since new and there was no maintenance record of any significant defect. The data from the engine condition monitoring showed no unusual features.

There was an initial borescope inspection of the engine before it was removed from the wing. This inspection showed that the HPT (high pressure turbine) could be rotated freely and appeared to be undamaged whereas the LPT (low pressure turbine) was seized and there was extensive damage within the LPT, from stage 1 aft. Inspection of the segments of the nozzle guide vanes immediately forward of the LPT stage 1 showed that at least one segment of nozzle vanes had migrated aft, into the plane of the LPT stage 1 blades. Damage caused in this blade row had cascaded rearwards through the engine, propagating the damage in the subsequent stages of the LPT and resulting in the debris which had exited the engine. In contrast, the stator vanes in the LPT had sustained less damage.

The initial indications of the displaced vane segment were noted by the operator and the engine manufacturer as very similar to an incident in 1997 when another GE90-85B engine, No 900114, had failed on a testbed run at the manufacturer's test facility following overhaul. Investigation of that failure had shown that the engine had been misassembled when the LPT module had been fitted, with one segment of vanes not properly engaged in position. The nozzle guide vane segments are normally located in position radially and longitudinally at their outer diameter (OD) by the mating flanges of the LPT and TCF (turbine centre frame) modules and longitudinally at their inner diameter by a pair of radial 'fish lip' seals which allow some radial movement. Following the failure in engine No 900114 the manufacturer and operator had initiated a special borescope inspection to check for proper installation of the vane segments and this was found to be practical and effective. Engine No 900114 had failed after 4 hours of running and the manufacturer's technical assessment at the time was that a loose vane segment would rapidly result in a stage 1 LPT blade failure. The borescope inspection recommended by the engine manufacturer was, therefore, to be applied to new engines, rebuilt engines and those engines having less than 25 hours in service. There was, however, an exception for those new engines which had been built at the manufacturer's production facility at Durham, NC, because of differences in the assembly technique for the LPT and TCF modules. Thus engine No 900158 was not inspected at that time as this engine was from the Durham facility.

Engine serial No 900158 (from B777 G-VIIH) was returned to the manufacturer's facilities in the USA for disassembly and examination under AAIB supervision. This examination confirmed that failure of the engine had, in fact, been initiated by **two** of the nozzle guide vane segments, around the 12 o'clock position, being displaced aft and interfering with stage 1 of the LPT. The geometry of the TCF/LPT mating flanges confirmed that the two vane segments could only have come adrift through misassembly and this was supported by the lack of witness marking at the flanges. The

vane segments had then migrated aft and, in a similar manner to engine No 900114, disrupted the stage 1 LPT blades. As engine No 900158 had accumulated some 3166 hours up to its failure it appeared that the subsequent failure mechanism was slightly different to that in engine No 900114, taking much longer to disrupt the stage 1 LPT blades, one possibility being that the two vane segments had locked against each other as they moved aft.

Subsequent airworthiness action

As a result of this second failure, to G-VIIH, the borescope inspection was issued as an Alert Service Bulletin, ASB 72-A405, on 28 March 1998, covering all engines in service. This fleet inspection was completed by the end of March, with no further instance found of displaced vane segments. The engine manufacturer has also formalised the borescope inspection, of the mating flanges of the LPT and TCF modules, into the procedures for engines at production and at overhaul. The engine manufacturer is also evaluating design and tooling changes to reduce further the possibility of displaced vane segments or other installation damage.