INCIDENT

Aircraft Type and Registration:	Boeing 737-236, G-BKYB
No & Type of Engines:	2 Pratt and Whitney JT8D-15A turbofan engines
Year of Manufacture:	1984
Date & Time (UTC):	21 February 1994 at 1705 hrs
Location:	Glasgow Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 5 Passengers - 68
Injuries:	Crew - None Passengers - None
Nature of Damage:	Severe damage to the No 1 engine's turbine section and damage to the aft fuselage and empennage from engine debris
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	8,500 hours (of which 400 were on type) Last 90 days - 92 hours Last 28 days - 44 hours
Information Source:	AAIB Field Investigation

History of flight

The aircraft was scheduled to fly from Glasgow Airport to Birmingham Airport. A full power takeoff using flap 5° was planned from Runway 05; the target EPR (Engine Pressure Ratio) was 2:1 and the commander was the handling pilot. Shortly after 1703:10 hrs the aircraft entered the runway from Link 7 for a rolling takeoff. The thrust levers were advanced to the near vertical position and the engines were allowed to stabilise at an EPR of about 1:4. The commander checked that the engines were performing normally and engaged the autothrottle take-off mode by pressing the take-off/go-around (TOGA) switch. The thrust levers advanced towards take-off thrust; however, the EPRs only reached 'about 2:03' and so the commander moved both levers manually to achieve the target EPR of 2:1, noting that the left lever was about $^1/_2$ inch forward of the right one. The first officer was about to confirm that take-off power was set when there was a 'loud crash', the origin of which it was not possible to discern. The commander immediately decided to abandon the takeoff; he called "STOP", retarded the thrust levers and applied maximum wheel braking. The first officer selected the reverse thrust levers to the maximum reverse thrust position but before the engines had fully spooled up the commander ordered the reverse thrust to be cancelled. The first officer deployed the speedbrakes manually and, as the aircraft slowed, he selected flap to 40° and opened his direct-vision (DV) window. The commander closed both engine start levers and the first officer selected the standby power switch to 'BAT' in order to supply battery power to the DC and AC standby busbars. At 1703:57 hrs the first officer told ATC that they had aborted the takeoff and requested that the AFS be sent immediately; the AFS watchroom was informed at 1704:09 hrs and the first two vehicles were in attendance before 1706:00 hrs.

Once the aircraft had stopped, the commander set the parking brake and evaluated the situation. The emergency services were quickly on the scene and, based on observations by himself, the first officer, the purser and the fire chief, the commander decided that the occupants were in no immediate danger and an evacuation was not necessary. The aircraft was towed to the stand and the passengers disembarked in the normal manner. The runway was swept to remove debris which had been ejected from the exhaust duct of the No 1 engine and, after inspection, was re-opened at 1740 hrs.

Flight Recorders

Data from the Quick Access Recorder was obtained from British Airways and showed the maximum speed reached was 58.3 kt CAS. There was a slight decrease in heading (turn to the left) and a rapid decrease in EPR on No 1 engine from around 2:08, followed by an EGT (Exhaust Gas Temperature) rise to a maximum of 621°C. Reverse thrust was used on No 2 engine during the deceleration.

Technical examination

Examination of the aircraft after the incident showed extensive damage within the turbine section of the No 1 engine. Debris from the engine had passed along the exhaust duct and had caused minor damage to the left-hand tailplane and lower elevator surfaces, the left-hand side of the rudder and the aft fuselage. These areas of damage, particularly on the rudder and fuselage, were consistent with the debris which had travelled down the exhaust duct of No 1 engine while the thrust reversers were deployed.

The turbine section of the JT8D engine consists of one high pressure turbine (HPT) stage and three low pressure turbine (LPT) stages, referred to as second, third and fourth stage LPT. The examination after the incident, and the subsequent strip examination of the engine, indicated that the major damage was confined to the third and fourth stages LPT. The fourth stage LPT blades had all fractured at the root ends just above the blade platforms and the fourth stage guide vanes were very heavily damaged along both the leading and trailing edges. There was extensive abrasion all around the circumference of the fourth stage LPT, including two penetrations of the air seal, indicating that a 'bundle' of engine debris had been trapped between the blades and guide vanes while the LP shaft was still rotating.

At the third stage LPT, the blades had all separated close to the blade platforms but the third stage guide vanes were damaged only at their trailing edges. The failures in the third stage turbine blades were consistent and generally had the appearance of rapid tensile failures. One blade, however, was distinctive in having a 'V'-shaped feature at the fracture surface's trailing edge; the rear portion of the fracture surface also had a dark discoloration distinctly unlike the rest of that fracture and the fractures in the other blades.

Detailed examination of this third stage turbine blade was performed at the engine manufacturer's facility. This examination confirmed that the transverse fracture had originated at the trailing edge of the blade in an area of crystallographic fatigue facets and that, after propagating forward approximately 0.06 inch in fatigue, the remainder of the fracture had been in rapid tensile overload. Scanning Electron Microscope (SEM) examination showed no evidence of material or processing defects nor of any foreign object damage. A metallographic section through the fracture origin showed that there were no casting or processing anomalies and that the blade was made from the correct alloy. According to the engine manufacturer, fatigue fractures originating in this area of the turbine blades indicate loose or worn blade outer shroud 'cross-notches'; loose or worn blade shroud cross-notches have reduced damping capability and tend to increase the stresses in the blades.

Service History

There have been a number of similar failures in the low pressure turbine blades of this model of engine and in April 1990 the engine manufacturer published PW Alert Service Bulletin (ASB) No A5913, entitled 'Engine - Blade, Turbine Rotor, 3rd and 4th Stage - Uncontained Blade Fracture Management', applicable to the JT8D series engines. The ASB noted that a number of the high cycle fatigue failures of the 3rd and 4th stage turbine blades had been uncontained and that the objective of the ASB was to establish a periodic inspection and maintenance programme for these blades, to reduce operation of blades with excessively worn shroud 'cross-notches'. In 1992 the content of ASB No A5913, Revision 4, was issued as an Airworthiness Directive, 92-10-05.

The procedure set out in ASB No A5913 was for an initial 'on-wing' inspection within a set number of hours, the hours or cycles to each subsequent inspection being based on the result of the previous inspection. For the inspection, a 'blade notch gage' is attached to a torque screwdriver and inserted from the rear of the engine so that the 'gage bar' rests between adjacent turbine blades. At a torque setting of 10 lb-in the operator attempts a complete rotation of the tool; if the torque screwdriver slips, the indication is that the 'gage bar' is not spreading apart the pair of LPT blades whereas rotation of the screwdriver indicates that the 'gage bar' is spreading the blades apart. The inspection is repeated at approximately 60° spacings, giving a total of six locations for each blade set.

ASB No A5913 further specifies that, if the torque screwdriver rotates at any of the six locations, the procedure is to be repeated at a torque setting of 5 lb-in at the same locations and, if there are rotations at 5 lb-in, there is a further repetition at 2 lb-in. With no rotations at 10 lb-in, the next inspection would be within 1,000 hours or cycles (whichever came earlier) whereas, for example, rotation at 5 lb-in at one to three of the locations would require re-inspection within 375 hours or cycles. Rotation of the tool at 2 lb-in at any location requires removal of the engine within 20 hours or cycles.

The operator of G-BKYB had implemented ASB No A5913 as a Maintenance Manual revision, with one slightly reduced inspection period and inspections at 12 points (rather than the six in the ASB) on engines showing wear. The left-hand engine from G-BKYB was inspected on 5 September 1993 and showed two rotations at 10 lb-in; re-inspection was required, therefore, within 750 hours or cycles. The subsequent 12-point inspection was performed on 2 February 1994 and showed five rotations at 5 lb-in, thus requiring re-inspection within 250 hours or cycles. The failure of the third stage turbine on 21 February occurred within this period.

Subsequent actions

Following the failure of the No 1 engine on G-BKYB on 21 February 1994, the operator rapidly developed a revised procedure and this was implemented on 28 February. This procedure involves the same physical inspection as that specified in ASB No A5913 but uses 12 locations rather than six and substantially reduces the re-inspection periods. Thus, for example, any rotation at 5 lb-in would now require removal of the engine within 20 hours or cycles and rotation of the tool at 2 lb-in at any location would require removal of the engine before further flight. A further provision of the operator's revised procedure is that 'any sudden shift in notch-wear inspection intervals must be notified to Propulsion Engineering' and thus, under this procedure, the inspection of 2 February 1994 would have been notified to the operator's Development engineers.

The engine manufacturer notes that almost all similar failures within third and fourth stage turbines occur to blades which have undergone overhaul. Thus the previous re-inspection periods within ASB No A5913. have not been changed, while the manufacturer seeks to reduce or eliminate these failures by improvement of the overhaul inspection, repair procedures and tooling.