Saab-Scania SF340A, G-GNTE

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Aircraft Type and Registration:	Saab-Scania SF340A, G-GNTE
No & Type of Engines:	2 General Electric CT7-5A2 turboprop engines
Year of Manufacture:	1988
Date & Time (UTC):	15 July 1999 at 0626 hrs
Location:	Aberdeen Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 3 - Passengers - 14
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Engine damaged beyond economic repair, puncture holes in engine cowling and damage to tailplane leading edge de-icer boot
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	4,680 hours (of which 2,811 were on type) Last 90 days - 180 hours Last 28 days - 57 hours
Information Source:	AAIB Field Investigation

History of the flight

Approximately two minutes after take off, the crew felt a 'thump' from the right side of the aircraft which they considered felt like a bird strike. This was followed by the No 2 engine turbine over temperature light illuminating, however the engine instruments did not show any abnormal indications. Whilst the commander was communicating with the cabin attendant, the first officer visually checked the No 2 engine for signs of damage, but none was seen. The commander then reduced the power on the No 2 engine to 20%, but some 10 to 20 seconds later the engine lost power and failed. The commander declared a Mayday and then carried out a visual return to the Aberdeen Airport where the aircraft later landed without further incident. There was no fire and no injuries to the passengers or crew.

Initial examination of the No 2 engine

Initial examination of the engine revealed that there had been an uncontained failure in the Gas Generator Turbine (GGT) which had resulted in a hole approximately 25 mm by 12 mm in the engine casing. This rupture was at approximately the 9 o'clock position when viewed from the rear of the engine. The uncontained parts that had broken through the engine casing had also passed through the steel engine IPS duct and an aircraft de-icing pipe that were located within the engine nacelle. One fragment had passed through the nacelle cowling and damaged the de-icing boot on the leading edge of the right tailplane. None of the uncontained material that had been ejected through the engine casing was found.

Strip inspection of the engine

The engine was dispatched to an overhaul organisation approved by the manufacturer where a strip examination took place under AAIB supervision. This strip examination was also attended by representatives of the engine manufacturer, the aircraft operator and, for part of the time, a representative of the Civil Aviation Authority.

The strip examination revealed that there was a radial fracture in the Aft Cooling Plate (ACP) of the second stage turbine (S2) of the Gas Generator. This fracture extended through one of the three air cooling holes, and approximately 15 cm of the ACP rim was missing. The fractured S2 ACP had achieved 11,454 cycles since new at the time of this incident. The retirement life for the S2 ACP is 12,000 cycles. Examination of the manufacturing and service records for this ACP's showed nothing unusual.

There was severe heat and foreign object damage (FOD) to the turbine blades of both the first and second stage (S1 and S2) turbines, in addition to the nozzles and the other cooling plates of the GGT. There was severe heat and FOD damage to the stage three (S3) and stage four (S4) Power Turbine (PT) blades and guide vanes. The GGT stage 1 nozzle assembly was found to be loose with its retaining bolts at about half their specified torque. The head of one of the retaining bolts had broken off. There were multiple fractures of B-sump inner heat shield, some pieces of which were missing.

Metallurgical examination of the S2 turbine ACP

After the strip examination findings, the AAIB inspector and a consultant metallurgist travelled to the manufacturer's facility in the USA to conduct a joint examination of the failure with the manufacturer's metallurgical specialists. This joint analysis of the radial fracture through the S2 ACP revealed that it had been caused by a fatigue mechanism which had propagated radially inboard and outboard from one of the three air holes. At least two adjacent fatigue origins inside this air hole were initiation sites of the radial inboard fracture. In addition there were two fatigue origins near the aft and forward corners of the air hole which were the initiation sites of the radial outboard fracture. Parallel axial grooves, up to 0.5 millimetres in depth, were found all around the bores of all of the air holes, and these extended over the full length of the bores. Many very small crack-like indications were observed at the base of these axial grooves. A remnant 'recast layer' appeared to be present in the area of the two adjacent inboard fatigue origins. Metallurgical examination of the material of the S2 ACP showed that it had a satisfactory microstructure and hardness.

Investigation of defective air holes in the ACP

The S2 ACP was machined by the engine manufacturer at its main facility. The air holes had been produced by electrical discharge machining (EDM), followed by an abrasive flow process. The engine manufacturer investigated the EDM and abrasive flow processes in an attempt to establish how the axial grooves had been formed in the air holes. Part of their investigation also included whether electrode tool and/or machining parameter anomalies could have been the source of these axial grooves. Although they could not positively identify the mechanism that had inadvertently produced these axial grooves at manufacture, they concluded that the fatigue cracking had initiated from an anomaly in the EDM process that had remained after the abrasive flow and which had resulted in reduced material fatigue capability. The AAIB concurred with this conclusion.

Assessment of effects of grooved air holes

The engine manufacturer conducted a life and fracture mechanics analyses of the S2 ACP. Baseline analysis indicated that the boltholes used to attach the ACP to the S2 turbine disc, and not the air holes, were the life limiting feature of the disc, by a substantial margin. Efforts to model the observed grooved air hole conditions to evaluate the associated effects on the life of the S2 turbine disc were unsuccessful. A fracture mechanics analysis was performed to correlate with the actual ACP life and predict both crack initiation and crack growth lives. The result of this analysis indicated that the crack had initiated during the manufacturing process and that the crack had then continued to propagate during the service life of the turbine disc.

Safety action

Since this incident, the engine manufacturer has introduced a 100% inspection of the air holes during production of all new ACP's, in addition to continuous monitoring of the EDM process. They are also conducting a quality review for potential improvements to the current air hole machining process. Alternative air hole designs and production methods, which would not require EDM, were being evaluated with a target introduction date of June 2000.

The S2 ACP's which had their air holes machined by the EDM process were those produced since January 1993. Prior to this date, the air holes were produced by electro chemical machining (ECM). Before this incident the S2 ACP's were removed from service at 12,000 cycles. However, as a result of this incident and the associated findings the manufacturer has required replacement, at 4,000 cycles, of all in-service S2 ACP's which had their air holes machined by the EDM process.