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ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation AO-2009-061
Final

Engine failure, VH-SBA
Wagga Wagga Aerodrome, New South Wales
4 October 2009

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608
Australia
1800 020 616
+61 2 6257 4150 from overseas

www.atsb.gov.au

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Abstract

On 4 October 2009, at 1217 Eastern Standard Time, the flight crew of a SAAB Aircraft Co 340B aircraft, registered VH-SBA noted abnormal left engine temperature indications during initial climb-out on a scheduled passenger flight from Wagga Wagga Aerodrome, New South Wales to Melbourne, Victoria.

The flight crew later reported that they noticed abnormally high indications from the left engine inter-turbine temperature, before shutting down the left engine and returning to the aerodrome for landing. Subsequent inspection of the left engine indicated internal damage, specifically to the stage 1 compressor section blisk blade.

The left engine damage was the result of the fatigue-related failure and separation of four of the stage 1 compressor blisk blades. There was no evidence that material defects or abnormalities contributed to the failures.

FACTUAL INFORMATION

The information presented below, including any analysis of that information, was prepared principally from information supplied to the Australian Transport Safety Bureau (ATSB).

On 4 October 2009, at 1217 Eastern Standard Time[1], the flight crew of a SAAB Aircraft Co 340B (SAAB 340) aircraft, registered VH-SBA noted abnormal left engine temperature indications during initial climb-out on a scheduled passenger flight from Wagga Wagga Aerodrome, New South Wales to Melbourne, Victoria. The flight crew later reported that following retraction of the landing gear, and while passing through about 400 ft above ground level, they heard a popping sound and noticed abnormally high indications from the left engine inter-turbine temperature (ITT).

The flight crew also observed the left propeller feathering and then slowing, eventually coming to a stop in the feathered position[2]. As the aircraft was being operated with the autopilot and yaw damper engaged, the flight crew noticed very little yaw of the aircraft. The first officer, who was the flying pilot at the time, later reported that during the event, he instinctively followed through with right rudder.

The flight crew followed the operator's one engine inoperative procedures, shut down the left engine and continued the climb. They then notified Air Traffic Control by declaring a PAN-PAN[3] and

1 The 24-hour clock is used in this report to describe the local time of day, Eastern Standard Time (EST), as particular events occurred. Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours.

2 Turning propeller blades to feathering angle, following engine failure or apparent malfunction, to minimise drag and prevent further damage.

3 Radio transmission indicating uncertainty or alert.

returned to the aerodrome for landing. The flight crew reported that during the event, all of the other left engine parameters were consistent with the engine decelerating.

Of the 34 passengers[4] and three crew members on board, there were no reported injuries. However, unrelated to the event, one passenger suffered an epileptic seizure and following the landing, was removed by emergency medical personnel and transported to hospital for observation.

Subsequent inspection of the left engine indicated internal damage, specifically to the stage-1 compressor section blisk[5] blade. The damage to the engine was contained to within the engine and there was no damage to the aircraft.

The flight data recorder (FDR) was removed from the aircraft and the data downloaded by the operator's personnel, then provided to the Australian Transport Safety Bureau (ATSB) for analysis.

The left engine was removed from the aircraft and transported to the operator's preferred engine repair facility in the United Kingdom (UK), where it was placed into quarantine pending technical examination.

Pilot information

The flight crew were appropriately qualified for the flight. The captain had approximately 14,000 hours total flying experience, with about 3,500 hours on type and 54 hours on type in the last 30 days. The first officer had approximately 1,882 hours total flying experience, with about 685 hours on type and 50 hours on type in the last 30 days.

Aircraft information

The aircraft, serial number 340B-311 was built in Sweden in 1992, first registered in Australia on 1 July 1994 and was a low-wing, twin-engine turboprop regional airliner with a tricycle-type landing gear (Figure 1). It had a capacity of two flight crew and up to 37 passenger seats or, more typically 33 to 35 passenger seats with a galley.

Figure 1: VH-SBA[6]

At the time of the occurrence, the aircraft's total time in service (TTIS) was about 34,390 hours, with 41,810 cycles since new (CSN).

Engine information

General

The General Electric Company, model CT7-9B, serial number GE-E-785210 free turbine turboprop engine produced up to 1,750 shaft horsepower and was installed new in the aircraft on 8 May 1990. At the time of the occurrence, the engine had accumulated about 23,027 hours TTIS and 24,313 CSN.

Airflow entered the engine via an inlet under the propeller hub, where it was regulated into the compressor section via variable inlet guide vanes (IGV). The IGV operated in conjunction with the engine anti-ice/start bleed valve to restrict or dump[7] engine bleed air as necessary. The compressor section comprised five axial and one centrifugal stages that were driven by a two-stage gas generator turbine.

Left engine maintenance

Recent significant maintenance on the left engine is listed at Table 1. A review of the engine's maintenance documentation/records found no entries that indicated the rectification of an engine airflow blockage had been warranted.

4 One company crewmember was travelling as a passenger.

5 Axial turbine rotor stage (rarely, compressor stage) in which disc [US= disk] and blades are fabricated as single piece of material.

6 Photo courtesy of Mr Roger Lung.

7 To release part of the engine compressor bleed air overboard.

Table 1: Significant engine maintenance history

Date/ Engine TTIS/ CSN	Event
18 May 2009/ 22,437 hours/ 23,665 CSN	Anti-ice/start bleed valve replaced.
20 April 2009/ 22,299 hours/ 23,513 CSN	Anti-ice/start bleed valve replaced.
11 September 2008/ 21,576 hours / 22,680 CSN	Digital electronic engine control unit replaced.
11 April 2007/ 20,357 hours/ 21,360 CSN	No 4 bearing/digital electronic engine control unit replaced.

In addition, periodic engine compressor washes were completed as required.

Blisk history

On 14 June 1996, the stage 1 compressor blisk was installed into the engine cold section module. At the time of the failure, it had accumulated about 13,080 hours TTIS and 14,530 CSN.

Recorder information

Examination of the FDR showed that the aircraft took off from runway 05 with the flaps retracted and at an airspeed of 130 kts. The recorded altitude at takeoff was 576 ft above mean sea level (AMSL). The left and right engine torque values, ITT, gas generator speeds, fuel flows and propeller speeds were closely matched during the takeoff and initial part of the climb.

Twenty-four seconds after takeoff, while climbing at 151 kts through 1,078 ft, the left engine ITT, which had been averaging between 860 °C and 876 °C during the initial climb, increased rapidly (from 861 °C to 893 °C in 1 second)[8]. Simultaneously, the fuel flow and gas generator speed decreased rapidly with an associated immediate torque reduction. Fuel flow to the left engine ceased within 4 seconds, with the left propeller speed reducing to 21 RPM within 8 seconds. The left engine ITT was above the maximum recordable temperature of 999 °C for 18 seconds.

8 The torque values on both engines were 96.6%.

The aircraft climbed to a maximum of about 3,000 ft before returning to the aerodrome. The aircraft touched down on runway 05 using flaps 22 (flap 20 had been selected) after a total flight time of 24 minutes 53 seconds.

Examination of components

Engine

The engine disassembly, examination and inspection were completed on behalf of the ATSB under the supervision of the United Kingdom Air Accidents Investigation Branch (UK AAIB). The observations from that examination included that:

- the bearing races[9], balls and rollers of all of the engine's bearings (including the disrupted No 3 bearing) exhibited no surface damage
- all of the compressor blades were either impact or scoring damaged
- four of the stage 1 compressor blisk blades were broken off about mid-span, while the remainder showed tip damage and diameter reduction; consistent with the impact with and trapping of debris
- the four failed stage 1 blades showed similar fracture surfaces
- the stage 2 compressor blades showed similar damage as found in the stage 1 compressor blisk
- the turbine blades showed clear overheat damage and probable debris-related damage.

Metallurgical examination of the failed stage 1 compressor blisk blades

A metallurgical examination of the failed stage 1 compressor blisk blades was performed in the UK. That examination confirmed that the four failed blades from that blisk exhibited a fatigue mechanism.

The examination report concluded that:

- the failures of the four blades on the subject blisk were the result of reverse-bending

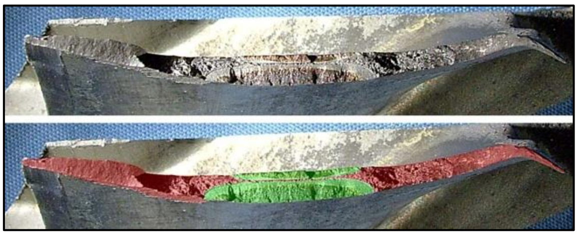
9 The rolling-elements of a rolling-element bearing ride on races. The large race that goes into a bore is called the outer race, and the small race that the shaft rides in is called the inner race.

fatigue, under the influence of high frequency aerodynamic vibrations

- fatigue cracks were present on both sides of each fractured blade
- the overall period of stable crack growth was most likely in the hundreds of flight (engine) cycles
- the rate of fatigue crack growth abruptly and significantly increased six flight cycles before the separation of the blades
- there was no evidence that material defects or abnormalities had contributed to the failures (Figures 2 and 3).

Figure 2: Failed compressor blisk (fractured blades indicated)

Figure 3: Typical failure blade cross-section



Previous event

On 23 May 2001, the flight crew of SAAB 340 aircraft, registered VH-EKX discontinued the takeoff after a right engine failure. Subsequent examination revealed a failure of the stage 1 compressor blisk. At the time of the failure, the engine had accumulated a total of 13,931 hours TTIS and 16,226 hours CSN.

A technical investigation report on the failure was completed by the ATSB and noted[10]:

- no anomalies within the blisk material
- failure of the aerofoil section resulted from the growth of reverse-bending fatigue cracking at the mid-span location
- vibratory loading, exciting blade resonance was the principal source of stress driving the fatigue cracking (Figures 4 and 5).

Figure 4: Compressor blisk – VH-EKX

Figure 5: Failed blade cross-section – VH-EKX

Engine manufacturer's advisories

The engine manufacturer reported that similar failures had occurred previously that related to the blockage of the engine's airflow path due to foreign objects. In response, additional maintenance manual instructions were developed

10 See http://www.atsb.gov.au/publications/2001/tr200102263.aspx

requiring engine inspection for such blockages. Those instructions were included in the *Engine Inlet Blockage and/or Foreign Object Damage* section of the engine maintenance manual and noted that airflow blockages could result in the reverse bending that was noted in the metallurgical reports on the failed blades in this occurrence.

ANALYSIS

There was no evidence that material defects or abnormalities contributed to the failure of the compressor blisk blades, or that routine maintenance activity would have identified the pending failure. Assisted by the correct operation of the aircraft's autofeather system, the flight crew's action in response to the unalerted engine failure was in accordance with the aircraft operator's one-engine-inoperative procedures.

The failure of four of the left engine's stage 1 compressor blisk blades was consistent with the findings of the technical investigation into a May 2001 occurrence. In both cases, the blade failures were related to high-frequency vibratory aerodynamic loading of the stage 1 compressor blisk, which resulted in the development of reverse-bending fatigue cracks in the blisk blades.

The impact damage to the reminder of the compressor and turbine blades resulted from the movement of the separated stage 1 blisk blades through the engine in the direction of the engine airflow. The overheat damage to the turbine blades was consistent with the elevated inter-turbine temperature during the event.

As no previous airflow blockages were recorded in the engine's maintenance documentation, it was unlikely that a previous blockage contributed to the reverse bending of the stage 1 compressor blades.

FINDINGS

From the evidence available, the following findings are made with respect to the engine failure that affected SAAB 340B aircraft, registered VH-SBA on initial climbout from Wagga Wagga Aerodrome, New South Wales on 4 October 2009 and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The failure of the left engine was related to high-frequency vibratory aerodynamic loading of the stage 1 compressor blisk, which resulted in the development of reverse-bending fatigue cracks in the blisk blades.

Other key findings

- The flight crew's action in response to the abnormal engine indications was in accordance with the operator's one-engine inoperative procedures.
- There was no evidence that material defects or abnormalities contributed to the failure of the compressor blisk blades.
- It was unlikely that a blockage of the engine's airflow contributed to the reverse bending of the stage 1 compressor blades.

SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included the:

- flight data recorder
- operator of VH-SBA (SBA)
- operating crew of SBA
- engine manufacturer
- United Kingdom (UK) engine overhaul facility
- UK Air Accidents Investigation Branch (AAIB)
- United States National Transportation Safety Board (NTSB).

References

Australian Transport Safety Bureau (ATSB) Technical Analysis Report No. BE/200100016.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the operating crew and operator of SBA, the aircraft and engine manufacturers, the UK engine overhaul facility and AAIB, the NTSB and the Civil Aviation Safety Authority.

Submissions were received from the engine manufacturer and the aircraft operator. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.