Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report – 200607815

Final

Engine failure – Kununurra Airport, WA
29 December 2006
VH-FNP
Embraer EMB-110P2 Bandeirante

Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report
200607815

Final

Engine failure
Kununurra Airport, WA
29 December 2006
VH-FNP
Embraer EMB-110P2 Bandeirante

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office location: 15 Mort Street, Canberra City, Australian Capital Territory
Telephone: 1800 621 372; from overseas + 61 2 6274 6440
Accident and incident notification: 1800 011 034 (24 hours)
Facsimile: 02 6247 3117; from overseas + 61 2 6247 3117
E-mail: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

ISBN and formal report title: see 'Document retrieval information' on page iii.

DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
200607815	2 November 2007	13	978-1-921165-44-3

Publication title

Engine failure - Kununurra Airport, WA, 29 December 2006, VH-FNP, Embraer EMB-110P2 Bandeirante.

Prepared by

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Reference No.

Nov2007/DOTARS50388

Abstract

On 29 December 2006 at 1330 Western Daylight-saving Time, an Embraer EMB-110P2 Bandeirante aircraft, registered VH-FNP, departed Kununurra Airport, WA, enroute to Argyle. The aircraft was being operated on a charter flight with two pilots and one passenger onboard. The pilots later reported that, during climb out following takeoff, while passing through 500 ft above ground level, the right engine lost power. The pilots confirmed the power loss, completed emergency procedures, that included shutting down the right engine, and returned to Kununurra Airport. There were no injuries to the flight crew or passenger and no damage to the aircraft.

Subsequent examination of the engine compressor turbine (CT) blades from the engine indicated that they had been subjected to a 'high temperature creep' event, leading to stress rupture of the CT blade assembly.

The investigation could not determine when the engine had sustained the localised high temperature heating of the compressor turbine components.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the Transport Safety Investigation Act 2003 and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

1 FACTUAL INFORMATION

History of flight

On 29 December 2006 at 1330 hours Western Daylight-saving Time[1], an Embraer EMB-110P2 Bandeirante aircraft, registered VH-FNP, departed from Kununurra Airport, WA, enroute to Argyle. The aircraft was being operated on a charter flight with two pilots and one passenger onboard. The pilots later reported that, during climb out following takeoff, while passing through 500 ft above ground level, the right engine lost power. The pilots confirmed the power loss, completed emergency procedures, that included shutting down the right engine, and returned to Kununurra Airport. There were no injuries to the flight crew or passenger and no damage to the aircraft.

The pilots reported that at the time of the power loss, the aircraft was configured with the landing gear retracted, flaps retracted and engine take-off power set. The aircraft was not equipped with an engine data logger or other type of on-board recording device.

Engine examination

Following the occurrence, the right engine was removed and sent to an authorised engine repair facility for examination under the supervision of the Australian Transport Safety Bureau (ATSB). The fuel control unit and other engine accessories were removed and reinstalled on a replacement engine. The fuel control unit subsequently operated without problem.

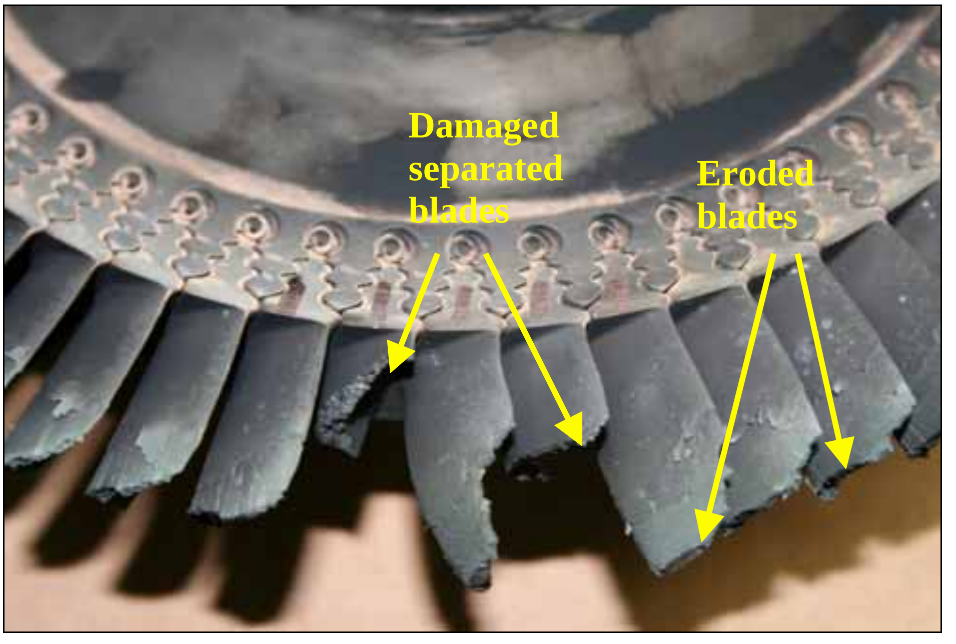
Disassembly, inspection and examination of the engine identified the following anomalies:

- non-ferrous material on the reduction gearbox chip detector plug making it ineffective in detecting metal contamination
- slight contact between the compressor and the inlet housing
- erosion of all compressor turbine (CT) blade tips
- two CT blades separated, one at the blade root and one halfway along the length of the blade
- heat damage to the CT blade surfaces
- impact damage and metal fusion/adhesion on the CT nozzle guide vanes
- impact damage of the power turbine blades
- damage of the inter-turbine temperature probes
- indications of high vibration damage to the compressor section.

1 The 24-hour clock is used in this report to describe the local time of day, Western Daylight-saving time (WDST), as particular events occurred. Western Daylight-Saving time was Coordinated Universal Time (UTC)+ 9 hours.

Examination of the compressor, fuel nozzles and engine bearings did not reveal any anomalies. The examination determined that a CT blade failure was the initiator of the damage, with secondary damage to the compressor section as a result of severe vibration following release of the two CT blades (Figure 1).

Figure 1: Compressor turbine disk and blades



Engine operation

The Pratt and Whitney Canada model PT6A-34 turbo prop engine was classed as a lightweight free turbine engine that essentially comprised two major rotating assemblies; the compressor turbine (CT) and the compressor, and the power turbine (PT) and the power turbine shaft[2].

The CT was driven by the gas flow that was deflected from the combustion section of the engine onto the turbine blades by the CT stator vane assembly. The CT disk comprised a 58-blade disk assembly rotating within a segmented shroud housing. The PT was rotated by the remaining energy in the downstream gas flow after it had exited the CT and had been deflected from the respective stator assembly.

Engine history

The serial number PCE 50916 right engine, was installed on 2 January 2004 with 10,303.3 hours time since new (TSN), zero hours time since overhaul (TSO), 12,743 cycles since new (CSN) and zero cycles since overhaul (CSO). On 4 July 2005, at 909.5 hours TSO, and 1,983 CSO, the power section was removed to repair exhaust duct damage. At the time of the occurrence, the engine had accumulated 11,729.6 hours TSN, 1,426.3 hours TSO, 15,819 CSN and 3,076 CSO.

2 The engine utilised two independent turbine sections; one driving the compressor in the gas generator section and the second (two-stage power turbine) driving the propeller shaft through a reduction gearbox.

Engine manufacturers calculate the serviceable lives of engine components based on testing in order to determine retirement times of the components. The retirement time of the CT disk and blades of the engine was 16,000 cycles as published by the engine manufacturer.

The maximum starting temperature for the engine was 1,090 ºC[3] and the maximum take-off temperature was 790 ºC. There were no documented engine logbook entries indicating that an over-temperature event of the engine had occurred[4].

Examination of the engine components

Compressor turbine blades

In order to establish the contributing factors leading to the engine failure, the CT disk and several other associated components were examined and analysed at the ATSB's laboratories. An initial examination of the CT disk revealed that in general, each blade within the assembly displayed significant distress. The damage pattern for each blade was observed to be reasonably consistent with blade tip portions having fractured from the main airfoil body (Figure 2).

Figure 2: The compressor turbine disk and blade assembly as-received by the ATSB[5]

Other significant damage included disruption to the diffusion bonded Sermaloy J coating on the airfoil surfaces of all blades within the CT disk. The aluminide coating damage was characterised by peeling and fracture of the outer layer away

3 Allowable for a maximum of 2 seconds. Starting temperatures of more than 850 degrees C required further inspection.

4 An over-temperature event would require additional inspections of the engine before further operation and these inspections would have to be entered in the engine logbook.

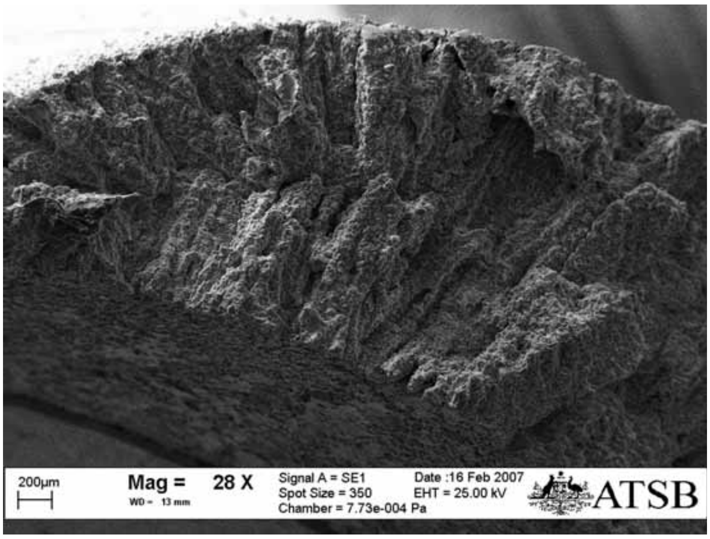
5 Blades labelled 1 to 5 were removed during the engine disassembly.

from the nickel alloy substrate. The coating loss was most severe toward the tip of each blade, with negligible damage observed at the platform or root end. No evidence of corrosive attack from sulphidation was observed on any of the blade airfoils (Figure 3).

Figure 3: The compressor turbine blades showing flaking of the blade coating and damage to the blade tips

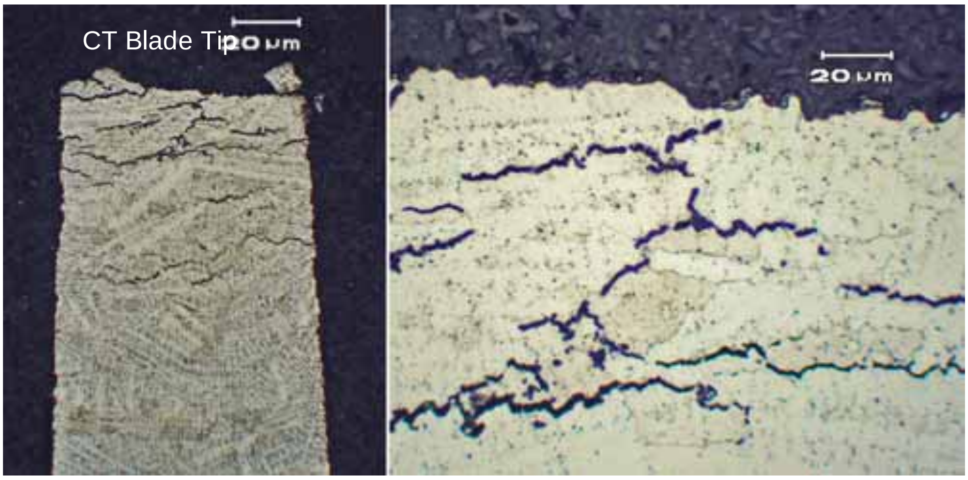
Low power magnified examination of the blade tip fracture surfaces from the CT blade assembly revealed no obvious evidence of fatigue or any other such form of progressive failure mechanism. When the fracture surfaces were examined at high magnification using a scanning electron microscope (SEM), a combination of intergranular features coupled with an accumulation of melted/resolidified nickel alloy were observed (Figure 4). Numerous secondary cracks intersecting the main fracture surface were also observed. No evidence of fatigue cracking was found during the SEM examination.

Figure 4: SEM image of the fracture surface from one of fractured CT blades showing intergranular features



In order to further quantify the failure mechanism of the CT blade assembly, a number of blades were longitudinally sectioned and then prepared using metallographic techniques. When the etched microstructure of the CT blades was examined, numerous intergranular cracks were observed within the microstructure of the CT blades. The cracks were concentrated in a parallel arrangement in close proximity toward the fractured tip of each blade. When viewed at high magnification, the cracks were identified to have initiated at the nickel alloy dendritic grain boundaries (Figure 5). These features indicated that the blades had been subjected to a 'high temperature creep' event, leading to stress rupture of the CT blade assembly.

Figure 5: Low and high magnification images showing the extensive intergranular cracking



Compressor turbine shroud

Examination of the compressor turbine shroud assembly revealed that a quantity of molten nickel alloy from the compressor turbine blades had deposited onto each of the shroud segments. The textured surface of the metallised nickel alloy layer also contained heavy rub marks where some of the compressor turbine blade tips had ground into the deposited nickel alloy.

Turbine blade creep and over-temperature operation

Turbine blade creep[6] is a damage mechanism that occurs to components exposed to extremely high operating temperatures. The conditions of temperature, stress, and time under which creep and stress-rupture failures occur depend on the metal or alloy, and on the service environment[7]. The inherent physical properties of nickel-base alloys lend their suitability for use in gas turbine components that are subjected to harsh environments at high temperatures such as those in a turbine engine assembly.

When a ductile material undergoes creep under stress at high temperatures, voids develop in the grain boundaries as the grains move relative to one another. Stress rupture fractures in ductile materials are inter-granular and are characterised by the inter-granular voids. These voids significantly reduce the service life of the material and the blades.

When engine operating temperatures exceed 1,205 ºC, the likelihood of incipient melting and high temperature stress rupture of the nickel-base alloy turbine components is increased.

Causes of over-temperature

Typical causes of over-temperature within a turbine engine included:

– anomalies of the fuel control

– anomalies of the fuel nozzles

– throttle mismanagement[8]

– anomalies of the engine trim

– loss of cooling air

– low starting power supply voltage

– compressor stall.

6 Slow plastic deformation under prolonged load, greatly accelerated by high temperatures.

7 ASM Handbook, Failure Analysis and Prevention, Volume 11, page 264.

8 An example of throttle mismanagement would be introducing fuel into the engine at low RPM values before air flow through the engine was sufficient for self-sustained operation.

2 ANALYSIS

The majority of the engine damage was confined to the compressor turbine (CT) section of the engine. When the CT blade tip fracture surfaces were examined, a combination of features associated with high temperature exposure and intergranular stress rupture were observed. In addition, the cast internal structure of the examined nickel-base alloy blades each contained a fine network of cracks that had developed at the blade tips. Intergranular crack growth of this type is strongly indicative of stress rupture from advanced creep.

As the investigation could not identify any anomalies of the fuel control, fuel nozzles, compressor or fuel control, the reason for the over-temperature and release of the CT blades was most likely extremely high engine operating temperatures.

The investigation could not determine when the engine had sustained the localised high temperature heating of the compressor turbine components.

3 FINDINGS

Contributing safety factor

- The aircraft’s right engine sustained localised high temperature heating of the compressor turbine components during operation, which contributed to the engine failure.