Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation –AO-2008-001
Final

Elevator balance tab failure
Port Moresby, PNG
31 December 2007
VH-OZX
Boeing Company 737-229

Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Occurrence Investigation

AO-2008-001

Final

Elevator balance tab failure
Port Moresby, PNG
31 December 2007
VH-OZX
Boeing Company 737-229

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: 62 Northbourne Ave, Canberra City, Australian Capital Territory
Telephone: 1800 020 616; from overseas + 61 2 6257 4150
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
AO-2008-001	23 June 2009	18	978-1-921602-70-2

Publication title

Elevator balance tab failure –Port Moresby, PNG – 31 Dec 2007 – VH-OZX, Boeing 737-229

Prepared by

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

Reference No.

INFRA-08543

Acknowledgements

Figures 1 and 6 courtesy of the aircraft operator.

Abstract

After departing Port Moresby, Papua New Guinea, at 0406 Universal time, coordinated on 31 December 2007, the flight crew of a Boeing 737-229 aircraft, registered VH-OZX, operating a scheduled flight from Port Moresby to Brisbane, experienced severe vibration through the aircraft's airframe, resulting in the crew declaring a MAYDAY and returning to Port Moresby.

A subsequent examination found a section of the right elevator balance tab had detached and was missing. Examination of the remaining sections of the balance tab revealed that two attachment screws from one of the elevator balance tab hinge blocks had unwound, which led to the tab failure.

The investigation found that airframe vibration had been reported by the flight crew the day prior to the accident. On that occasion, a level I - General Inspection of the aircraft was conducted by a licensed aircraft maintenance engineer after the aircraft landed, with no defects found.

The aircraft manufacturer was aware that other operators had experienced in-flight vibration as a result of excessive wear in the elevator balance tab hinge and control linkages, and had issued a number of service bulletins (SBs) to address the issues. These SBs included SB737-55A1070, which directed operators to carry out detailed inspection of the elevator balance tabs, including checks for free-play, control rod wear and loose hinge screws.

As a result of this accident, the aircraft operator implemented a 'fleet campaign directive' requiring the immediate accomplishment of SB 737-55A1070 on all of its aircraft.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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

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.

FACTUAL INFORMATION

History of the flight

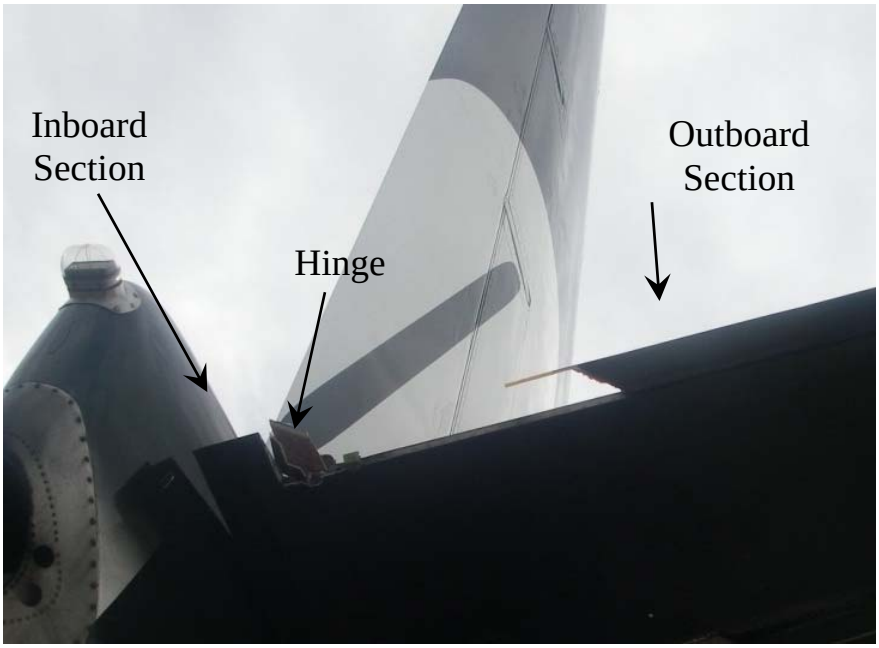
At 0406 Universal time, coordinated[1] on 31 December 2007, a Boeing 737-229 aircraft, registered VH-OZX, departed Port Moresby, Papua New Guinea on a scheduled passenger flight to Brisbane, Qld. The flight crew reported that, passing through 7,000 ft above mean sea level (AMSL) on climb, they felt a vibration through the airframe.

The flight crew reported the vibration was slight initially, however, no abnormal instrument indications were observed. At approximately 15,000 ft, after a progressive increase in intensity, the vibration became so severe that control of the aircraft became difficult. The flight crew then broadcast a MAYDAY[2] and initiated an immediate return to Port Moresby. As the engine thrust was reduced and the aircraft commenced descent, an increase in vibration was again experienced and the crew requested emergency services for the aircraft's arrival.

At approximately 4,500 ft, the vibration ceased, the crew configured the aircraft for the approach and an uneventful, overweight landing was conducted. There were no reported injuries.

A subsequent examination of the aircraft found that a section of the right elevator balance tab had detached and was missing from the aircraft (Figure 1).

Figure 1: Right elevator balance tab section detached



1 The 24-hour clock is used in this report to describe the time of day as particular events occurred. As the incident took place external to Australia; Universal time, coordinated (UTC), previously Greenwich Mean Time, has been used.

2 MAYDAY – The international distress signal.

Personnel information

The pilot in command (PIC) had approximately 9,500 hrs flying experience, with 3,500 hrs on the aircraft type.

The copilot had approximately 2,400 hrs flying experience, with 570 hrs on type. The copilot was also a former licensed aircraft maintenance engineer (LAME) endorsed on the Boeing 737 aircraft.

Flight crew actions

The copilot was the handling pilot for the flight. Following the departure from Port Moresby, he reported making a left turn and initial climb to 3,000 ft, before being cleared by air traffic control to flight level (FL) 330. The weather was reported as scattered cloud at 1,500 ft and 2,500 ft, light showers of rain with visibility greater than 10 km, and the wind was from the west at 15 kts.

After experiencing the severe vibration at approximately 15,000 ft, the crew elected to declare a MAYDAY and return to Port Moresby. The copilot requested that an on-board LAME come to the flight deck. The LAME advised the flight crew that he heard a crack in the tail section of the aircraft and suspected that the horizontal stabiliser screw jack may have failed. The PIC had taken control of the aircraft by this time and reduced speed, but it had no effect on the level of vibration. The crew reported that the vibration was such that it was difficult to read the aircraft's instruments.

Given the nature of the problem and the possibility of a failure of the horizontal stabiliser screw jack, the crew elected to conduct an overweight landing at approximately 48,000 kg (the maximum landing weight was 46,720 kg).

As the non-normal checklists did not cover this type of failure, the flight crew conducted a flap 30 landing, which was the standard landing flap setting.

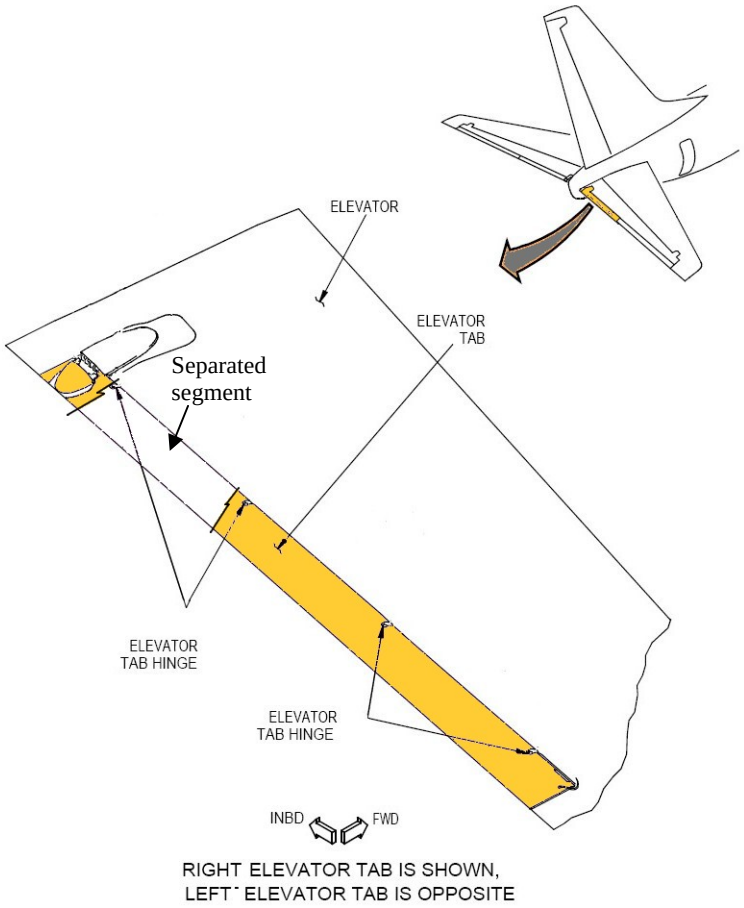
Elevator balance tab

The elevators fitted to the aircraft were operated by two identical power units supplied from the aircraft's two hydraulic systems. Each elevator contained a balance tab (Figure 2), which was locked in the faired[3] position during normal (powered) operation, but was unlocked to reduce control forces when operated in manual mode if there was a failure of the aircraft's hydraulic systems.

The elevator balance tab was constructed of a honeycomb core (glass/phenolic), an aluminium leading edge and fibreglass skins. The tab was actuated from the inboard end and fixed to the elevator at four evenly spaced hinge points.

3 Faired – In a neutral position, not protruding into the airflow

Figure 2: Elevator balance tab



* Adapted from Boeing service bulletin SB-737-55A1707-03.

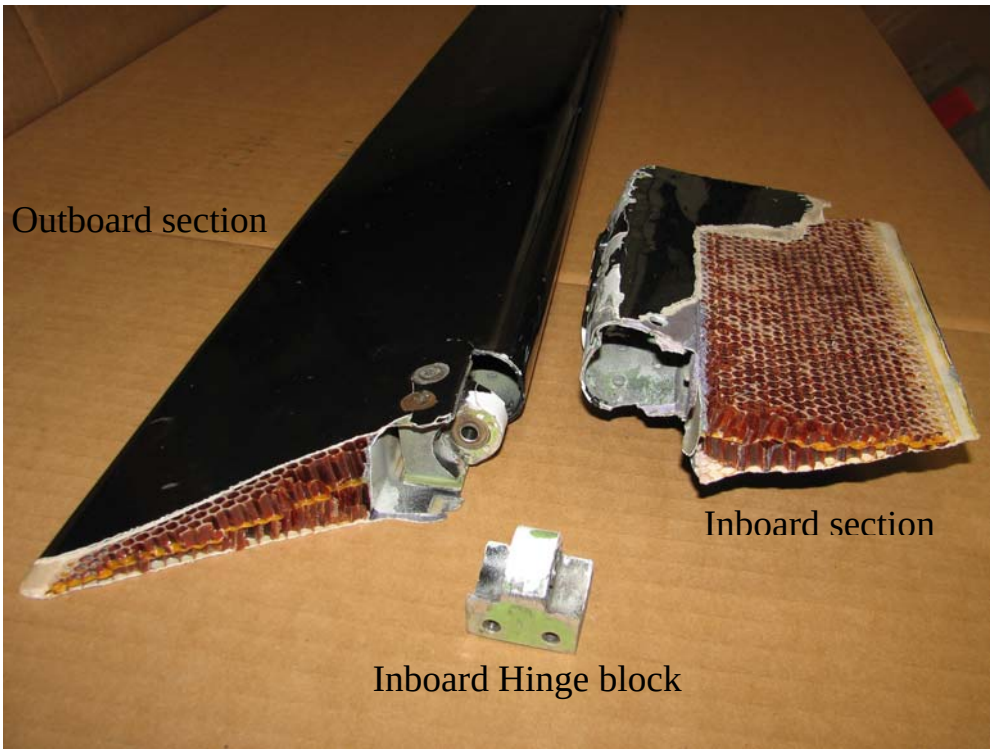
Failed right elevator balance tab

An examination of the right elevator balance tab found that it had failed, with the entire section between the inboard hinge and adjacent hinge fitting separating from the aircraft. The remaining sections of the balance tab were removed and sent to the Australian Transport Safety Bureau (ATSB) for examination (Figure 3).

Examination of failed balance tab

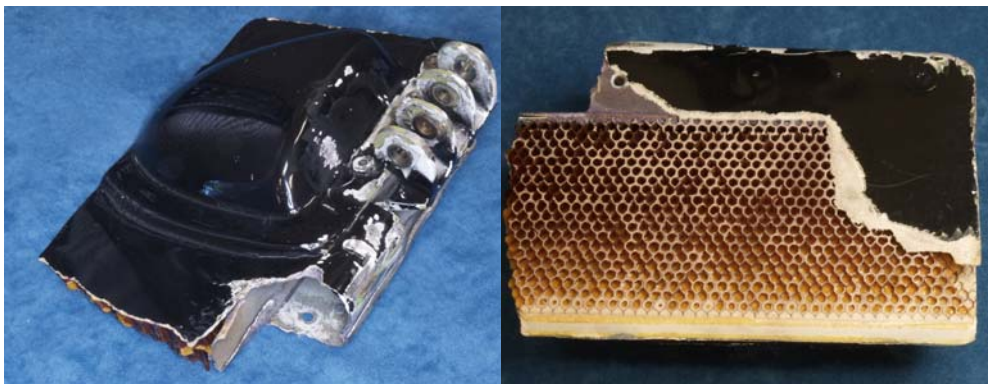
The ATSB examination of the recovered parts of the failed balance tab found that the upper skin of the outboard balance tab section was intact to the edge of the fracture, with the lower skin having peeled away slightly from the honeycomb core. The skin around the hinge cut-out, adjacent to the missing section, showed a crack extending from the corner of the cut-out.

Figure 3: Sections of elevator balance tab



The fracture of the inboard balance tab section extended through a cut-out in the leading edge for the location of the inboard hinge fitting. The fibreglass skin was intact up to the edge of the fracture on the upper surface, but the majority of the skin had separated from the lower surface (Figure 4).

Figure 4: Inboard tab section



Upper surface Lower surface

The adhesive between the skin and honeycomb core had remained bonded to most of the core surface. However, in some areas, the adhesive had separated from the honeycomb cell walls, indicative of an adhesive failure[4]. The adhesive appeared to be uniform across the core surface, with no evidence of un-bonded regions visible. Microscopic examination of the adhesive surface revealed an impression of the

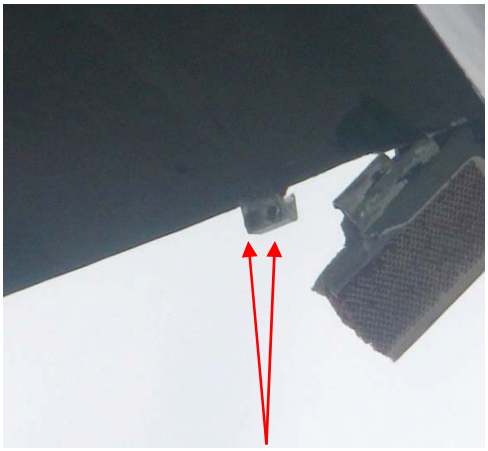
4 An adhesive failure refers to a failure where the bond between the adhesive and the substrate fails, whereas a cohesive failure refers to a fracture occurring in the bulk of the adhesive.

fibreglass weave, which was also indicative of a predominantly adhesive failure (Figure 5).

Figure 5: Fibreglass weave pattern in adhesive

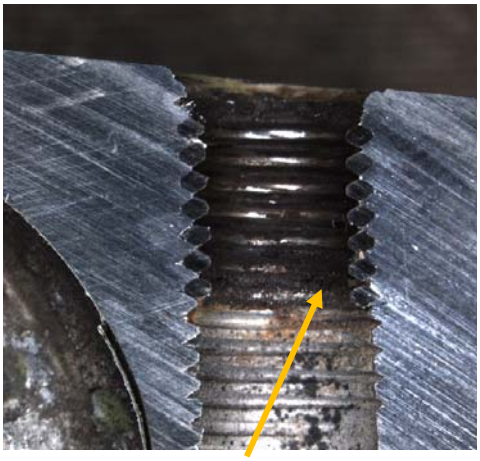
The inboard hinge fitting appeared to have separated from the inboard tab section adjacent to the fracture through the honeycomb. Two screws were engaged in the underside (Figure 6), but the corresponding screws from the upper side were missing. It was reported that these screws were not present when the hinge was removed from the aircraft. An examination of the sectioned hinge and thread insert found the thread insert to be in good condition (Figure 7).

Figure 6: Inboard hinge fitting



Screws on lower surface visible

Figure 7: Inboard hinge sectioned



Thread insert

Previous flights

During a flight from Brisbane to Noumea, New Caledonia on 30 December 2007, the copilot noticed a slight vibration of the airframe towards the rear of the aircraft. The vibration was also felt by one of the cabin crew and an on-board LAME who identified it as being predominant at the rear galley area. Although the flight crew did not enter the vibration into the aircraft's log book, a post flight walk-around inspection of the aircraft was carried out by the LAME with no defects found.

During the return flight to Brisbane, the copilot again noticed the vibration and made an entry in the aircraft's log book for 'unusual vibration through aircraft particularly at rear galley station...'. After that flight, another LAME carried out a level I - General Inspection, in accordance with the Aircraft Maintenance Manual, section 05-51-281-201, *Airframe vibration (conditional inspection) maintenance practices.* No defects were found during that inspection and the aircraft was released back into service.

On the following flight, from Brisbane to Port Moresby on 31 December 2007, the same copilot and cabin crew from the previous day were again operating the aircraft. That flight also carried the LAME who had conducted the inspection the night before in Brisbane. During that flight, the copilot again felt a low-level, intermittent, vibration. He mentioned this to the PIC, who confirmed feeling a slight vibration on occasion, but not all the time. After landing in Port Moresby, the copilot looked around the aircraft, but did not see anything untoward, so no further entries into the aircraft's log book were made.

Aircraft manufacturer

The aircraft manufacturer was aware that a number of operators had experienced in-flight vibration as a result of excessive wear in the elevator balance tab hinge and control linkages. In several occurrences, the vibration resulted in a portion of the elevator balance tab separating from the aircraft. In January 2000, the manufacturer released Boeing Service Bulletin (SB) SB737-55A1070 (with revisions dated May 2001, April 2006 and July 2006). The SB directed operators to carry out detailed inspection of the elevator balance tabs, including checks for free-play, control rod wear and loose hinge screws. The SB was mandated for compliance by the US Federal Aviation Administration (FAA), who issued Airworthiness Directive (AD) 2006-12-23. On 3 August 2006, the Civil Aviation Safety Authority (CASA) issued Airworthiness Directive (AD) AD/B737/175. In addition, the following ADs and SBs relating to the Boeing 737 elevators and/or tab system had also been issued:

- 6 December 2000 - CASA AD/737/127, Boeing SB737-27A1205. Relating to elevator balance tab rod attachment nut inspection.
- 31 August 2006 - CASA AD/737/292, Boeing SB737-55A1078. Related to wear and cracking of the elevator web and tab hinge components.
- 25 December 2007 - CASA AD/737/308, Boeing SB737-27A1266. Relating to elevator balance tab control rod assembly inspection.

Aircraft maintenance history

A review of the aircraft's maintenance history showed that it had completed a total of 62,594 hours and 43,575 cycles at the time of the accident. The right elevator balance tab had been installed on the aircraft at 60,233 hours and 42,361 cycles.

A review of the aircraft's records showed that the inspection requirements of the elevator AD's had been complied with. The 'elevator balance tab hinge inspection' requirement of AD/B737/175 was last complied with at 61,260 hours, which was 1,334 hours prior to the accident. The inspection frequency requirement for that AD was for the inspection to be conducted every 2,000 hours.

Airframe vibration inspection requirements

The Aircraft Maintenance Manual, Chapter 05-51-281-201 *Airframe vibration (conditional inspection) maintenance practices*, described the inspection procedure to be followed after reported airframe vibration. The procedure was divided into sub-parts. Part 2 - *Conditional Inspection*, classified the inspection requirements into aircraft configuration (trailing edge flaps up/down) and areas of the aircraft where the vibration was felt/noticed. Part 5 - *Airframe Vibration*, provided a troubleshooting guide broken down into the following two levels of inspection and testing:

> Level I: General Inspection – Performed on Ground – Initial report may not specify vibration type or location.
>
> (1) Level I checks might be used during a sensory check of the airplane after the first flight squawk.
>
> Level II: Inspections and tests – Initial report may specify vibration type and/or location, or flight condition – Inspections and tests require removal of panels, taking measurements, performing ground tests, etc.
>
> (2) Level II checks are more in-depth and require more time to perform.

In both the Part 2 inspection and Part 5 - level II inspection, where the rear fuselage was identified as the area of vibration, an inspection of the elevator balance tab and tab hinge was required.

The LAME who carried out the inspection at Brisbane reported that, on being notified of the airframe vibration, he spoke to the flight crew, who advised him that the vibration was low level. As he had extensive Boeing 737 maintenance experience, and was quite familiar with this specific aircraft, which had no previous reports of vibration, he elected to conduct a level I: General Inspection, of the aircraft. During that inspection, the security of the aircraft's access panels and hatches were checked, including the auxiliary power unit access door and a visual inspection of the flight control surfaces was conducted from the ground.

The aircraft's livery incorporated a black tailplane. The height of the elevator above ground was approximately 5 m. In addition, the elevator balance tabs normally remained faired with the elevator, preventing a clear view of the upper hinge screws from the ground.

Flight recorders

The aircraft was fitted with a digital flight data recorder (DFDR) and cockpit voice recorder (CVR). Both recorders were removed from the aircraft and sent to the ATSB for replay and analysis.

Replay of the CVR indicated that it contained approximately 32 minutes of conversations relating to the post-accident operation of the aircraft on the ground, indicating that the audio recorded during the accident had been overwritten by the continued operation of the CVR after the aircraft had landed.

The DFDR contained a digital data steam from a flight data acquisition unit for a minimum period of 25 hours. That recording medium was extracted and data relating to the accident flight was recovered. The quality of the recovered data provided a general overview of the flight path of the aircraft and confirmed the flight crew reports relating to the flight.

ANALYSIS

On 31 December 2007, shortly after takeoff from Port Moresby, the flight crew of a Boeing 737-229 aircraft, registered VH-OZX, reported an increasing vibration through the airframe that was the result of the failure of the right elevator balance tab.

The aircraft manufacturer was aware that excessive play in the elevator balance tab control linkages or loose hinge fittings could lead to vibration and subsequent failure of the tabs. A number of service bulletins (SB) and airworthiness directives (AD) were introduced to minimise such events. The aircraft maintenance manual also called for specific inspection of the elevator and balance tabs when vibration was identified at the rear of the aircraft.

A review of the aircraft's maintenance history showed that all relevant AD's and SB's had been complied with by the aircraft's operator.

Subsequent examination of the elevator balance tab sections showed that the fracture origins were associated with the leading edge of the hinge cut-outs. Despite the predominantly adhesive failure between the skin and the honeycomb core, there was no evidence of poor adhesive coverage or indication that the bond had failed prematurely. Therefore, it is probable that the initial failure was at the elevator balance tab hinge points.

Two upper hinge screws were missing from the inboard hinge block when the remaining elevator tab sections were removed from the aircraft. The inboard hinge block thread inserts were found to be in good condition and showed no evidence of the attaching screws being removed by force. As a result, the most likely scenario for the elevator balance tab failure was that, at some point during operation, the upper tab hinge screws had loosened and 'backed out' of the hinge block. The liberation of the upper hinge screws led to structural weakness and cracking of the elevator tab upper skin at the hinge cut-outs in the tab leading edge. That resulted in the vibration experienced and subsequent failure of the elevator balance tab.

The initial detection of vibration was not recorded in the aircraft's log book. Therefore, the licensed aircraft maintenance engineer (LAME) at Brisbane performed a level I - General Inspection of the aircraft, based on his experience of the Boeing 737, his knowledge of this specific aircraft and his understanding that this was the first incidence of vibration in the aircraft. However, that action did not take into consideration that the vibration had been identified as being to the rear of the aircraft, which required an inspection of the elevators and balance tabs. It also did not resolve the issue that no defects were identified during the level I – General Inspection to explain the reported vibration.

As vibration had been experienced on previous flights, there had been a period of time from the initial unwinding of the inboard hinge fitting upper screws, to the cracking and final separation of the tab section. It is probable that, had a detailed inspection of the elevator balance tab linkages and hinges been conducted, the issues with the inboard hinge block, and the loosening upper screws may have been observed and rectified.

FINDINGS

From the evidence available, the following findings are made with respect to the elevator balance tab failure involving VH-OZX, Boeing 737-229 on 31 December 2007, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The inboard hinge fitting, upper screws loosened and separated during service, resulting in vibration and failure of the right elevator balance tab.
- The level I - General Inspection, carried out on the aircraft, did not identify a breakdown of the elevator balance tab integrity.

Other findings

- The aircraft operator had complied with all applicable service bulletin and airworthiness directive inspection requirements for the elevator and balance tab.

SAFETY ACTIONS

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Operator

Elevator balance tab inspection

Although not identified as a safety issue, as a result of the accident, the operator implemented a ‘fleet campaign directive’ requiring the immediate accomplishment of service bulletin (SB) SB737-55A1070 Revision 3 on all of its aircraft.

APPENDIX A: SOURCES AND SUBMISSIONS

Sources of information

The sources of information for the investigation included the:

- flight crew of VH-OZX
- aircraft maintenance engineer
- aircraft operator
- aircraft manufacturer.

Submissions

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

A draft report was sent to the:

- aircraft operator
- flight crew of VH-OZX
- aircraft maintenance engineer
- aircraft manufacturer
- Civil Aviation Safety Authority (CASA)
- US National Transportation Safety Board (NTSB).

Submissions were received from the aircraft maintenance engineer and the copilot. The submissions were reviewed and, where considered appropriate, the text of the report has been amended accordingly.