Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation – AO-2008-046
Final

Airframe event
Orange aerodrome, NSW
6 July 2008
SAAB SF340B VH-ZLC

Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Occurrence Investigation
AO-2008-046

Final

Airframe event
Orange aerodrome, NSW
6 July 2008
SAAB SF340B VH-ZLC

Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office location: 62 Northborne 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 v.

CONTENTS

DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
AO-2008-046	25 June 2009	23	978-1-921602-60-3

Publication title

Airframe event , Orange aerodrome, NSW 6 July 2008 SAAB SF340B VH-ZLC

Prepared by

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

Reference No.

INFRA-08492

Acknowledgements

Regional Express Airlines, Meggitt Aircraft Braking Systems, The Timken Company.

Abstract

On 6 July 2008 at 1345 Eastern Standard Time, a SAAB 340B aircraft, registered VH-ZLC, departed the terminal at Orange aerodrome for a scheduled flight to Sydney. At the point of rotation during takeoff, the right outboard wheel was observed to have detached from the aircraft. The crew elected to continue the flight to Sydney where the aircraft landed without further incident.

Examination of the components found that the right outboard wheel detachment occurred as a result of the failure of the outboard wheel bearing. It was possible that the failure was related to a lubrication or setting (installation) issue, however this could not be positively determined due to the degree of damage sustained by the bearing components.

As a result of this occurrence, the aircraft operator undertook a thorough internal safety investigation and implemented a range of safety actions, including a review of wheel bearing maintenance procedures, and an audit of main wheel axle nut torques across the fleet.

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

On 6 July 2008 at 1345 Eastern Standard Time[1], a SAAB 340B aircraft, registered VH-ZLC and operating as flight ZL177, departed the terminal at Orange aerodrome towards runway 29 for a scheduled flight to Sydney. On board were three flight crew and 31 passengers, including a first officer and flight attendant travelling as passengers. The pilot in command (PIC) had approximately 13,000 hrs flying experience with 6,000 hrs on the aircraft type. The first officer (FO) had approximately 750 hrs on type.

Flight ZL177 was the third flight for VH-ZLC on 6 July. After the previous flight, the FO conducted a post-flight inspection and final external checks as per the Flight Crew Operations Manual which involved, among other things, visual inspections of the tyres and gear assemblies. The FO reported that he did not notice anything unusual.

A flight instructor and student in a Jabiru aircraft on the taxiway adjacent to runway 29, witnessed the take-off roll of VH-ZLC. Just after the point of rotation, the flight instructor and student reported observing the right, outboard wheel drop from the main landing gear (MLG) of ZLC and roll along the runway. The instructor made a radio call to inform the crew. The crew acknowledged the call and continued with the takeoff and departure procedures and, once complete, re-established communication with the Jabiru to verify the message. The loss of the wheel was also confirmed by the operator's airport agent at Orange.

The crew elected to continue to Sydney where the attendance of local emergency services was requested. The PIC communicated the situation to the flight attendant and suggested that normal cabin service be continued until further notice. The crew also consulted the Quick Reference Handbook (QRH) for abnormal or emergency checklists appropriate to the situation, but none were found.

The PIC made an announcement to the passengers, explaining the situation and advised that even though a normal landing was expected, they should assume the brace position when advised. Passengers were informed that the emergency landing was precautionary as the aircraft was capable of landing safely with only one of the right main wheels.

Sydney Air Traffic Control advised the crew that they could expect to be landing on runway 34R. However the crew requested runway 07 due to the prevailing wind conditions, which allowed the pilot to touch down initially on the left main gear.

The landing gear was lowered approximately 25 nm out from Sydney and was inspected by the passenger-first officer from a main cabin window (Figure 1). It was reported to the crew that the wheel was missing but no further damage was evident.

---

[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. At the time of the event Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours.

One orbit at navigation point Glenfield was conducted and the cabin was fully prepared for landing. Approximately 30 seconds prior to landing the passengers were instructed to brace as they had earlier been informed to expect.

The aircraft conducted a 35° flap landing on runway 07 in Sydney. The PIC held the right main gear off until speed reached approximately 80 kts and slowed the aircraft without the use of braking or reverse-thrust.

The passengers were taken for assessment and de-briefing and were also offered counselling. It was subsequently reported by the operator that although some passengers were visibly upset during the flight, a few passengers had misconstrued the briefing by the pilot as a false alarm or joke and that this may have been attributed to the terminology used in reference to a 'precautionary' landing, and the reassurance that a normal landing was expected.

The Australian Transport Safety Bureau (ATSB) subsequently inspected the aircraft's landing gear assembly and the detached wheel that was located in a field approximately 1 km from the point the aircraft became airborne at Orange aerodrome.

Figure 1: Right landing gear as observed from cabin. Location of the missing outboard wheel is arrowed.

Component history

The wheel assembly (part number: 5010488-2, serial number: Nov 07 – 3696), including bearings, was delivered new to the operator and added to the component maintenance record in December 2007. The wheel was fitted to the aircraft on 30 June 2008 and had completed 761 flight cycles since new. Four tyres had been successively fitted to the wheel and the wheel was due for an overhaul at the next tyre change. The previous tyre was changed at 725 cycles.

The licensed aircraft maintenance engineer (LAME) who fitted the wheel had 10 years experience with the aircraft operator, as well as thorough knowledge of the aircraft maintenance manual (AMM) requirements and extensive experience in performing wheel changes.

AMM procedures for the removal and installation of main wheels required the use of a torque wrench with 10-200 lbf.in[2] or 1-15 Nm and 2-30 Nm range. The procedure required an initial torque of 140 lbf.in (15.81 Nm) to be applied to the nut. The nut was then loosened and the final torque of 70 lbf.in (7.9 Nm) applied. The torque wrench used in the installation had scale of 0 - 100 lbf.ft (135 Nm), equivalent to 1200 lbf.in. The final torque of 70 lbf.in therefore represented approximately 6% of the full scale which was generally considered outside the useable accurate range for a torque wrench. The aircraft operator conducted a check of all wheels in the fleet and found the wheel nut on 26 of 148 wheels was outside acceptable torque limits. Those wheels were removed and the bearings cleaned and inspected with no defects identified.

The original grease used by the operator for bearing lubrication had been discontinued and a replacement product used for a few months, but due to performance concerns, was replaced with a third type. However, there were no reports of bearing issues during that time. All of the grease products were approved for use by the component maintenance manual (CMM).

The remains of the right outboard wheel bearing rollers, cones, cages and seals were removed from the landing gear assembly. These items were examined together with the detached wheel, at the ATSB facilities.

Wheel bearing installation (setting) procedure

The bearing manufacturer recommended that the setting of wheel bearings be carried out in three stages:

- Application of a seating torque to the wheel nut;
- removal (loosening) of all torque from the nut; and
- application of the final torque.

Manual rotation of the wheel was required during each of the nut tightening and loosening stages. Specifically, rotation during the loosening stage ensures the removal of any retained load from the seating torque that could otherwise result in an unacceptably high, final bearing pre-load.

---

2 One inch-pound force (lbf.in) is the torque created by one pound force acting at a perpendicular distance of one inch from a pivot point.

The wheel installation procedure in the AMM included the three defined stages for bearing setting and specified concurrent wheel rotation during the nut tightening stages, but did not specify wheel rotation during the nut-loosening stage.

Examination of components

Main landing gear (right)

Figure 2 shows the right landing gear. The wheel nut was bolted and lock-wired in place, retaining the remains of the bearing cones, cages and seals. Removal of these components revealed minor damage to the axle from contact with the wheel assembly. There appeared to be no damage to brake lines or surrounding components.

A significant amount of grease and metal debris was observed at the back of the brake assembly. Several bearing rollers were found embedded in the grease. The brake assembly also exhibited marks consistent with wheel contact, including evidence of abrasion on the inside of the brake hub.

Figure 2: Right main landing gear

Wheel (right outboard)

The wheel was recovered with the tyre inflated and the hub cap lock-wired in place. There was evidence of grease splatter on the surface of the wheel from underneath the hub cap (Figure 3).

Deep gouging was present on the outside of the hub, consistent with heavy contact against the brake assembly (Figure 4). The inside wall of the wheel hub and hub cap was coated with a thin layer of grease and metal debris. The wheel hub was also scored in the areas around the outboard bearing cup as a result of the bearing breakdown.

Both inboard and outboard bearing cups were present in the wheel hub. The outboard bearing seal and retaining clip were located under the hub cap.

Figure 3: Right outboard wheel, as recovered

Figure 4: Wheel hub damage

Wheel bearings

The wheel assembly included an inboard and outboard tapered roller bearing, installed as illustrated in Figure 5. The bearings consisted of a cup (outer race), cone (inner race), cage, and rolling elements (Figure 6).

The inboard and outboard cone assemblies were not intact (Figures 7 and 8). Both cones showed evidence of impact damage on the cone ribs that was likely caused by bearing breakdown and contact with liberated rolling elements. The inboard cone also showed impact marks on the rolling surface which were secondary to the bearing failure. The outboard bearing cone exhibited extreme metal smearing and heat discolouration.

Both bearing cups were present in the wheel hub, with the outboard cup exhibiting metal smearing and damage associated with heavy wear. The inboard cup was in reasonable condition with the surface showing light scoring and secondary contact damage with the cone assembly. The outboard cup showed evidence of metal smearing.

The inboard cage was found to be extensively damaged and the outboard cage destroyed. Four rolling elements were recovered from inside the brake assembly. It could not be determined if they originated from the inboard or outboard bearing. The rollers were rounded on one end and showed some impact damage and mild scoring on the rolling surface.

All of the bearing seals and retaining clips were accounted for. The outboard bearing cone seal was mostly destroyed, which probably occurred during the breakdown sequence.

Figure 5: Wheel cross section with inner and outer bearings highlighted

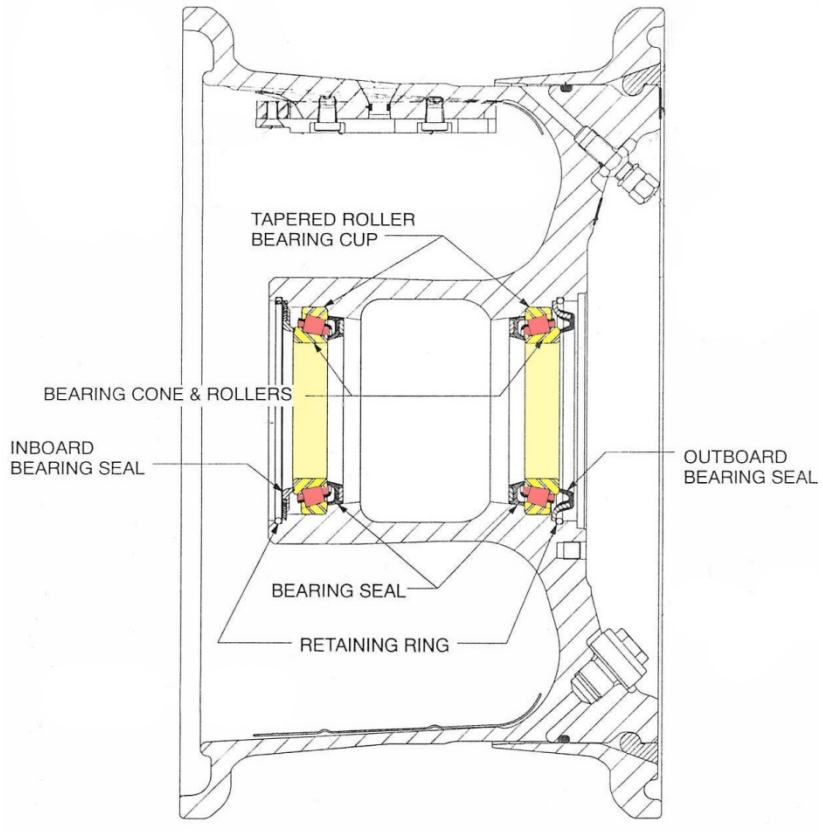

Figure 6: Example bearing

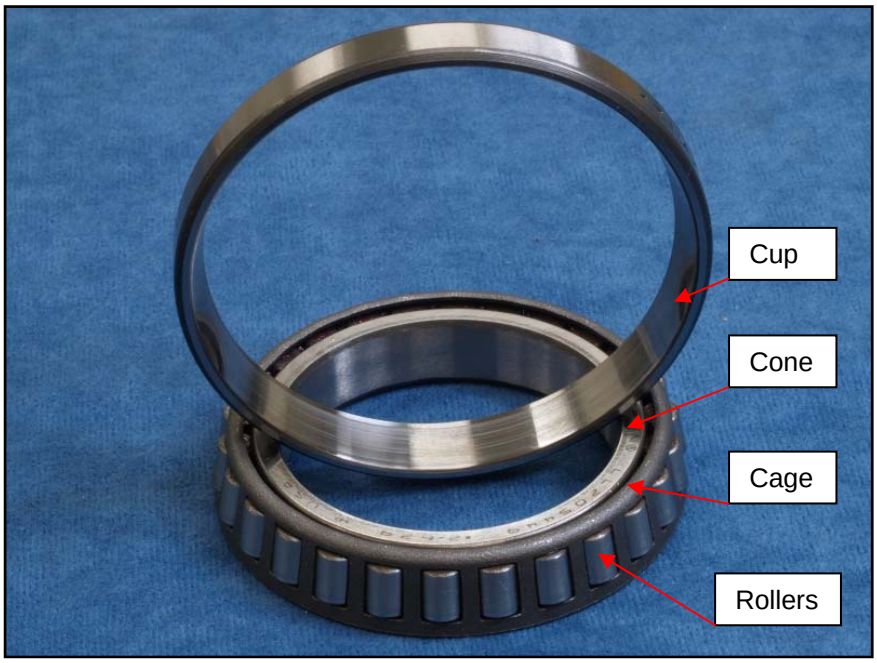

Figure 7: Inboard bearing cone and cup

Figure 8: Outboard bearing cone and cup

On-board recorded information

VH-ZLC was fitted with a flight data recorder (FDR) and a cockpit voice recorder (CVR) as required by Australian regulations.

The FDR was a Honeywell solid state flight data recorder, part number 980-4700-003 serial number SSFDR-07700. The FDR was forwarded to the ATSB for download and analysis.

The recovered data included a landing and 45 complete sectors; about 50 hours 37 minutes of aircraft operation. Analysis revealed that the recovered data provided a general overview of the flight path of the aircraft and allowed confirmation of the flight crew report.

Aircraft type history and certification

The aircraft manufacturer was aware of eight events since 2003 where the main wheel had detached from the landing gear leg and axle assembly. In all cases, the aircraft had landed safely. With respect to safety considerations when operating the aircraft with one wheel missing, the manufacturer indicated that the aircraft type was certified to Federal Aircraft Regulation (FAR) 25.511 for asymmetrical loads on multiple wheel units. In particular, sections (c) and (d) read as follows:

> (c) *Deflated tires.* The effect of deflated tires on the structure must be considered with respect to the loading conditions specified in paragraphs (d) through (f) of this section, taking into account the physical arrangement of the gear components. In addition—
>
> (1) The deflation of any one tire for each multiple wheel landing gear unit, and the deflation of any two critical tires for each landing gear unit using four or more wheels per unit, must be considered; and
>
> (2) The ground reactions must be applied to the wheels with inflated tires except that, for multiple-wheel gear units with more than one shock strut, a rational distribution of the ground reactions between the deflated and inflated tires, accounting for the differences in shock strut extensions resulting from a deflated tire, may be used.
>
> (d) *Landing conditions.* For one and for two deflated tires, the applied load to each gear unit is assumed to be 60 percent and 50 percent, respectively, of the limit load applied to each gear for each of the prescribed landing conditions. However, for the drift landing condition of §25.485, 100 percent of the vertical load must be applied.

It was considered that landing with one MLG wheel missing corresponded to landing with one deflated tyre. The manufacturer also indicated that landing loads would rarely be as high as 60% of the design loads and therefore, a normal landing would be expected.

The manufacturer advised that there had previously been a problem with a loose spacer behind the wheel nut, however, that issue was addressed in service bulletin 340-32-067 where the wheel nut and spacer were integrated into a single part. The integrated wheel nut was installed on the subject aircraft at the time the wheel detached.

ANALYSIS

The detachment of VH-ZLC's right main, outboard wheel during takeoff on 6 July 2008, was as a result of the failure of the outboard wheel bearing, which allowed the wheel unit to move axially outward to a point where it was no longer restrained by the landing gear axle.

The wheel had completed 725 flight cycles prior to the last tyre change, at which point the bearing cups and bearings were checked and re-lubricated. The bearing subsequently failed within 6 days and a further 36 cycles of being fitted to the aircraft. This suggested that a material or manufacturing defect was probably not a factor in this event. Some other common factors relating to bearing failure include improper installation (setting), lubrication, damaged bearing cages, or contamination by foreign material. To the degree possible, these factors were considered by the investigation. However, analysis of bearing damage typically involves detailed examination of the wear surfaces of the races and/or rolling elements, which was not possible in the case of the outboard bearing. The inboard bearing races, while in better condition, showed no evidence of any specific failure mechanism.

Bearing failure may be related to a setting issue if too much axle nut pre-load had been applied, if the pre-load inadvertently reduced in service, or if the bearing was misaligned. Incorrect bearing setting may also result from not adequately rotating the wheel during each stage of the setting procedure. It could not be ascertained if the subject wheel was also outside the torque limits, because there was no torque on the wheel nut once the wheel had detached. The use of the torque wrench with the incorrect scale, outside the calibrated range, may have increased the risk of incorrect torque being applied. The wheel build-up process was also reviewed by the aircraft operator and found that it would not be possible to install the bearing retaining clip and hence the wheel, if the bearings were installed incorrectly.

It was not possible to determine the adequacy of lubrication or presence of contaminants from the grease present in the wheel hub, hub cap and brake assembly. The lubricant type was not considered an issue as the bearing failure was an isolated event. However, it was recommended by the bearing manufacturer that the same grease be used on the bearings and the axle, as the mixing of incompatible grease products could result in a lubricant that no longer performs to original specifications.

FINDINGS

Context

From the evidence available, the following findings were made with respect to the main landing gear wheel detachment from SAAB SF340B, registered VH-ZLC, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The detachment of the right outboard wheel occurred as a result of the breakdown of the outboard wheel bearing. The mechanism for bearing failure could not be established.

Other safety factors

- The torque wrench used for fitment of the wheels was used outside of its calibrated torque range and may have contributed to incorrect torque application. *[Safety Issue]*

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.

Aircraft operator

As a result of this occurrence, the aircraft operator undertook a thorough internal safety investigation and implemented a range of safety actions, including but not limited to:

- An audit of the state of torque in the MLG wheel nuts across the entire fleet.
- A review of maintenance procedures with associated supervisors and engineers. Sample audits have also been conducted on wheel installation technique.
- Eleven wheels from the same batch were located and quarantined pending the investigation outcome. Two of the wheels were returned to the manufacturer for inspection. No bearing issues were identified.

Torque wrench unsuitable for task

Safety issue

The torque wrench used for fitment of the wheels was used outside of its calibrated torque range and may have contributed to incorrect torque application to the wheel nut.

Action taken by aircraft operator

The torque wrench used in the fitment of the wheel was considered unsuitable for the task and was replaced. The wheel nut sockets of all torque wrenches were modified to only fit tools suitable for the task.

APPENDIX A: SOURCES AND SUBMISSIONS

Sources of information

- Regional Express Airlines
- Meggitt Aircraft Braking Systems
- The Timken Company

Submissions

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 of this report was provided to Regional Express Airlines, The Civil Aviation Safety Authority, The Timken Company, Saab AB, and the Swedish Accident Investigation Board (SHK).

Submissions were received from Regional Express Airlines and The Timken Company. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.