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ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation AO-2008-032 Final

Flight Control System Event
19 km west of Camden, NSW – 8 May 2008

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608
Australia
1 800 020 616
+61 2 6247 4150 from overseas
www.atsb.gov.au

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Abstract

On 8 May 2008, the pilot of an American Champion Aircraft (ACA) 'Citabria', model 7GCBC (registered VH-MWY), was returning to Camden Aerodrome, NSW, after a local area flight, when the upper elevator control cable fractured. The pilot was able to maintain control of the aircraft's pitch attitude using wing flaps, and subsequently landed the aircraft safely, with only minor damage to the propeller.

Laboratory examination of the failed cable found the failure (and an adjacent area of significant damage) to have developed from the progressive fatigue cracking of individual cable wires in locations where the cable passed over guide sheaves. The examination also determined that the cable had not been manufactured to conform with the requirements of the accepted standard for aircraft control cables (MIL-DTL-83420).

From 2005, the aircraft manufacturer changed its internal procedures to require that only cable manufactured and certified to MIL-DTL-83420 be used for new aircraft production. Following the cable failure, the Civil Aviation Safety Authority (CASA) published an Airworthiness Bulletin (AWB), highlighting the issues associated with the use of non-MIL standard cables in aircraft control applications, and recommended that owners and maintainers of American Champion Aircraft ensure that periodic inspections are conducted with appropriate veracity.

FACTUAL INFORMATION

Summary of the event

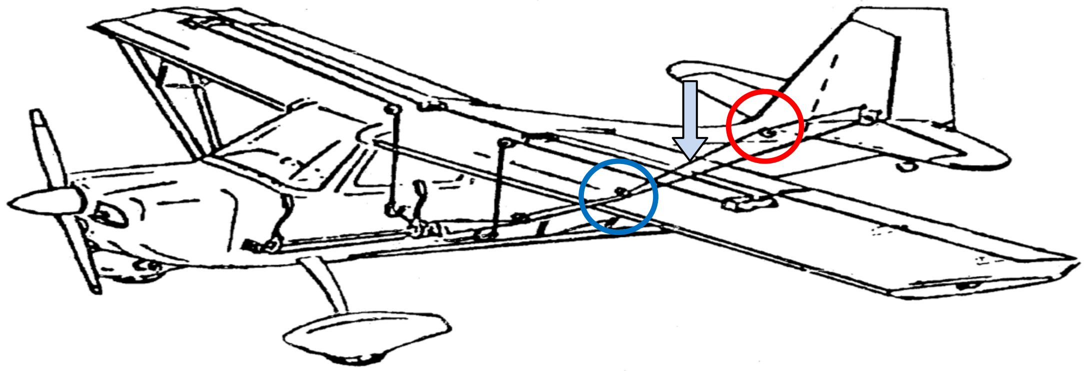
Around 16:30[1] Eastern Standard Time, on 8 May 2008, the pilot of an American Champion Aircraft, 'Citabria', model 7GCBC (registered VH-MWY), departed Camden aerodrome, NSW, for a local area flight including aerobatic manoeuvres. The pilot was accompanied by one passenger. At approximately 17:10, while returning to the aerodrome, and at an altitude of 3,000 ft, the pilot reported suddenly losing the ability to control the aircraft's elevators through the control column. By using the aircraft flaps to regulate the pitch attitude, the pilot was able to retain control of the aircraft and commence an approach to runway 06 at Camden. The pilot reported that the aircraft landed hard, striking and bending the propeller on the runway surface, before rolling off the right side of the runway onto the grass verge. Neither the pilot nor passenger sustained any injuries.

Engineering examination

During the initial examination of the aircraft, maintenance personnel found that the upper of the two elevator control cables (Elevator UP cable, part number 3-1072) had fractured at a location corresponding with its passage over a mounted guide sheave (pulley) located in the upper empennage area (Figure 1). Australian Transport Safety Bureau (ATSB) investigators who later attended and examined the aircraft, found the associated sheave (part number MS24566-3B) to

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.

Figure 1: Location of 'up' elevator control cable (arrowed), with failure at rear upper sheave (red circle) and damage at the central sheave (blue circle)



be in good condition and able to freely rotate without resistance. Further damage to the cable, in the form of localised strand fracture and fraying, was also found in a location associated with the cable run across the next sheave forward in the fuselage.

A sample of the elevator cable, including the fractured and damaged areas, was removed from the cable assembly and retained for ATSB laboratory examination.

Aircraft history

The aircraft (serial number 1347-2003) was manufactured by American Champion Aircraft Corporation (ACA) and issued an export certificate of airworthiness (No. E198553) on 20 October 2003. The aircraft was imported into Australia, where it was assembled, inspected and issued with an Australian registration (VH-MWY) and certificate of airworthiness.

At the time of the elevator cable failure on 8 May 2008, the aircraft had accrued a total operating time-in-service (TTIS) of 2,904.7 hours. A review of maintenance documentation for the entire aircraft life revealed no evidence of previous accident damage or reported problems with the elevator or other flight control systems.

The last scheduled maintenance inspection of the aircraft (a 100 hourly inspection) was conducted on 12 April 2008, at an aircraft TTIS of 2,827.6 hours.

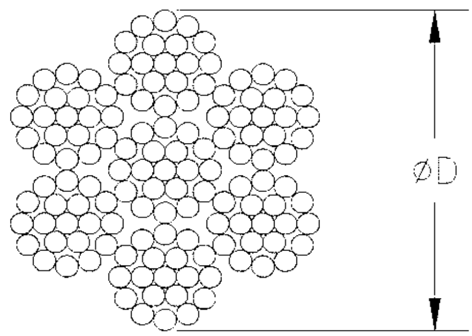
Technical examination

A 2.8 m length of elevator control cable, containing both fractured and damaged areas, underwent metallurgical examination in the ATSB's Canberra laboratories. In addition, a short length of a similar new cable was also received for examination and comparison against the sample removed from the aircraft. The exemplar cable was provided by the aircraft maintenance organisation and was removed from a spool of cable carrying the following identification:

7x19x1 8GL100 Type 1 Non-Jacketed
MIL-DTL-83420 Wire Rope Comp A
Zn-Coated C/Steel
Loos & Co Inc USA

All of the cable samples had been produced as conventional spiral-wound regular lay[2] wire rope, with seven strands of 19 wires each and a nominal 1/8" (3.175 mm) cable diameter (ØD, Figure 2).

Figure 2: 7x19 cable construction



Fracture and damage

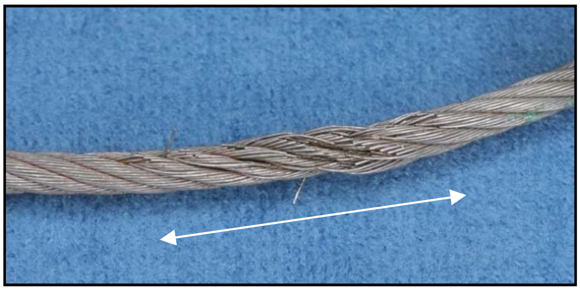
The elevator cable fracture occurred approximately 600 mm (24") from the interconnection with the elevator control horn. The failed area was characterised by fraying and separation of the strands and wires for a length of approximately 60 mm (2.4") from the point of failure (Figure 3).

2 Regular Lay - where the direction of the lay of the wires in each strand is opposite to the direction of the lay of the strands making up the rope.

Figure 3: Cable fracture and associated strand separation

Around 1.7 m (5.5') forward from the point of fracture was a second area of cable damage – presenting as a localised zone of individual wire breakage and separation from the associated strands (Figure 4).

Figure 4: Secondary elevator cable damage



Both areas of cable failure showed no observable gross corrosion, or other anomalous features.

At low magnifications under the stereomicroscope, the majority of wire failures from the fractured (Figure 5) and damaged areas (Figure 6) showed sharp, square-edged transverse fractures, with little or no evidence of necking[3] or plastic deformation typically associated with tensile overstress fractures.

Figure 5: Strand fractures – main failure

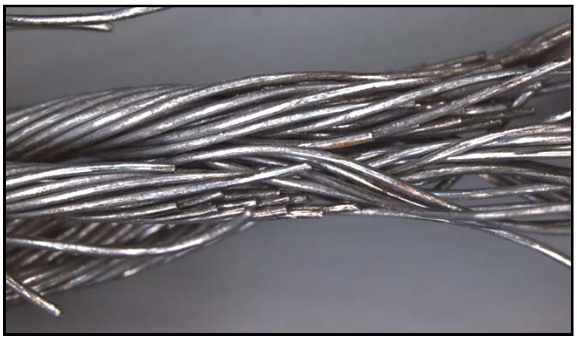
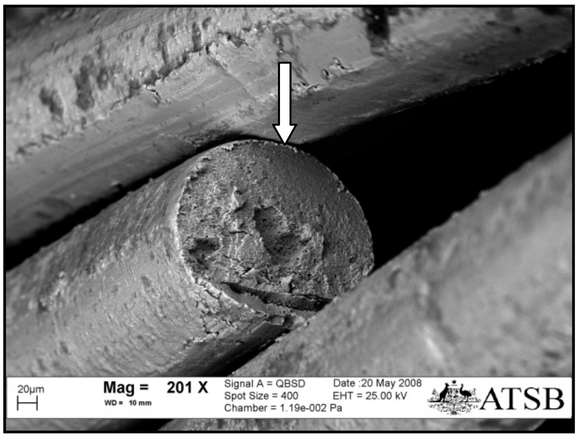


Figure 6: Wire fractures – damaged area

When examining several fractured strands under the scanning electron microscope (SEM), it was evident that the majority of failed wires displayed features typical of a fatigue cracking mechanism, with the crack origin areas associated with the contact surfaces between the wire and its immediate neighbour (Figure 7). Fatigue cracking extended part-way across the section, with the remainder presenting a more uneven, woody appearance associated with final tensile failure of the wire.

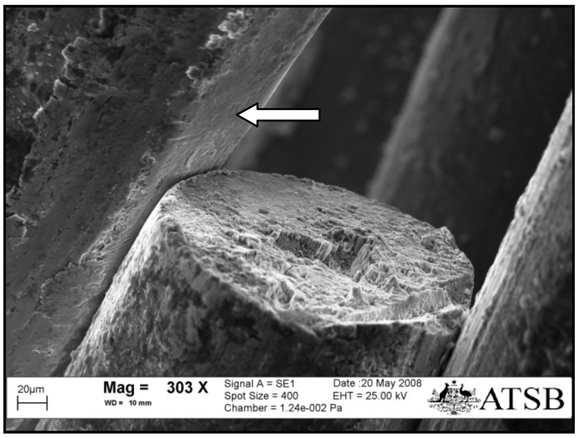
Figure 7: Wire fracture – fatigue area origin indicated at arrow



Many of the strand wires showed evidence of movement, fretting and wear of the contact surfaces and smearing of the surface metallic material (Figure 8).

3 A symmetric and localised reduction in section, typically associated with tensile overstress fractures of ductile materials.

Figure 8: Rubbed and worn wire surface (arrowed)



Cable structure

Metallographic sections were taken through both failed and exemplar cable samples and prepared to present a cross-sectional view. Optical measurements confirmed the individual wire diameters to fall within a 0.23 – 0.24 mm (0.0090 – 0.0094") range for both cables. Both cables showed a surface coating of a bright metallic material – verified as zinc using SEM x-ray spectrometry techniques. Comparing the coatings between cables, it was evident that the failed cable showed considerably less overall zinc mass – particularly within the void spaces between wires in each strand (Figures 9 and 10). Zinc is provided primarily for corrosion protection, but its low hardness and ductility also allow it to act as solid lubricant.

Yellow and red coloured, non-metallic filaments were noted within the void spaces between the core strand and the six outer strands of the exemplar cable. The failed cable from VH-MWY did not contain any coloured filaments within the internal structure.

Figure 9: Failed cable cross-section. Zinc coating evident as white material on the surfaces of each wire

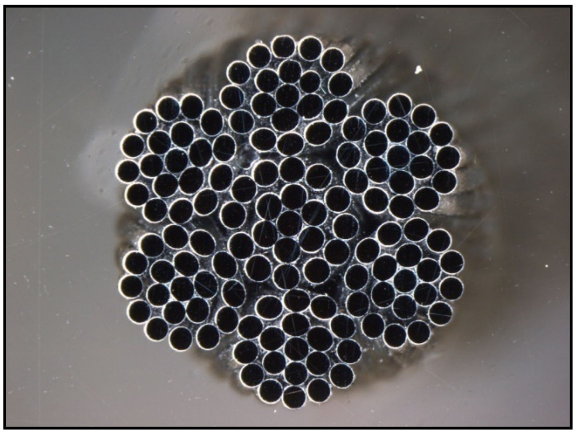
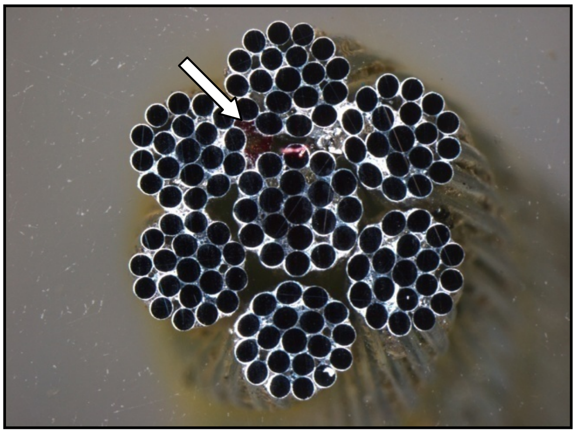


Figure 10: Exemplar cable cross section. Note the greater zinc mass between the strand wires and the red coloured filament (arrowed)



Micro-hardness tests conducted on the individual wires from each cable, returned results that were comparable, with the exemplar cable typically 30 - 40 hardness points (~6%) higher than the failed cable (Table 1).

Table 1: Cable wire hardness measurements

Location	Hardness ($HV_{0.5}$)
Failed cable – centre wires	563 – 606
Exemplar cable – centre wires	605 – 638
Failed cable – outer wires	543 – 586
Exemplar cable – outer wires	592 – 635

CABLE STANDARDS

Wire rope used as flight-critical aircraft control cable, is required to meet approved specifications (such as industry or military specifications, or Technical Standard Orders)[4]. US Military Specification MIL-DTL-83420 *Wire Rope, Flexible, for Aircraft Control* is the accepted standard for aircraft control cable – providing for jacketed and non-jacketed cable types in both zinc-coated carbon steel and stainless steel compositions.

Certification of cable to MIL-DTL-83420 requires that the product demonstrate compliance with a series of evaluative tests, including ductility, breaking strength and fatigue endurance. The standard also provides for the inclusion of coloured filaments within the cable structure (for identifying individual manufacturers), and an internal lubricant, to minimise friction between strands and wires.

Aircraft standards – control cables

In communications with the ATSB, the aircraft manufacturer indicated that until 2005, cable certified to MIL-DTL-83420 was not specifically required to be used for aircraft production. The manufacturer reported that a metallurgical evaluation had found the cable used did not contain the internal lubricants required by the MIL standard, but was otherwise compliant.

Aircraft standards - maintenance

Table III-1 of the manufacturer's service manual for Citabria model 7ECA, 7GCAA and 7GCBC aircraft, required that every 100, 500 and 1,000 hours of operation, the maintenance provider shall:

> 20. Check rudder, elevator and elevator trim cables, turnbuckles, guides and pulleys for security, wear and operation

ANALYSIS

Cable failure

The loss of elevator control reported by the pilot of VH-MWY during the flight on 8 May 2008, was a direct result of the fracture and separation of the upper elevator control cable (Part No. 3-1072) at a location approximately 600 mm from the elevator control horn connection.

The ATSB's examination of the elevator cable attributed the failure to the localised and progressive fatigue cracking and fracture of individual wires within the cable structure; progressively weakening the cable to a point where it failed in flight, as it was no longer able to sustain normal operating loads. A second area of wire damage found on the same cable was also confirmed to be the result of fatigue cracking.

The fatigue cracking and failure of the cable across guide sheaves is typical of the influence of cable construction and behaviour when stressed in a dynamic environment. As the cable rolls across a sheave, the individual strands and wires slide and move against each other. Frictional effects between wires can produce localised wear and surface damage if the cable lubrication and surface conditions do not provide adequate resistance. To compound the effect, increased cyclic and tensile stresses in the outer elements of the cable at the sheave, can provide ideal conditions for the initiation and growth of fatigue cracking. As the cable cracks and individual wires fracture, stress is transferred into the remaining strands and wires, accelerating the failure process.

Cable construction

The investigation found evidence that the failed elevator cable from VH-MWY had not been manufactured to the accepted standard for aircraft control cables (MIL-DTL-83420). Although comparable in general dimensions and material, the cable did not contain the manufacturer's colour indicator filaments within the strand windings, and it carried a visibly lower level of zinc coating over and amongst the strands and wires, when compared to a sample of known MIL-DTL-83420 cable.

Although the production and certification standards for the cabling used within VH-MWY were not known, it was considered likely that the cable used had not undergone the full fatigue endurance type tests as specified within MIL-DTL-83420.

4 US Federal Aviation Regulations Title 14, part 23, subpart D, §23.689 'Control Systems – Cable systems'.

Cable maintenance

The aircraft maintenance / service manual required that all control cables and associated fittings be inspected at 100-hourly intervals, as part of the aircraft's routine scheduled maintenance program. The last 100-hourly inspection had been conducted 27 days prior to the cable failure.

The fatigue cracking failure mechanism affecting the elevator control cable from VH-MWY was characterised by its progressive, developing nature. A finite period of operational time was required for such cracking to initiate and subsequently propagate to a point where final overstress failure could occur. While that time-frame was not specifically known for the case in question, it was considered very likely that the cracking was well advanced and thus able to be detected by visual or tactile methods during the routine inspection carried out 27 days prior to the failure event.

FINDINGS

Context

From the evidence available, the following findings are made with respect to the in-flight failure of an elevator control cable from an American Champion Aircraft 'Citabria', model 7GCBC (VH-MWY). The findings should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing Safety Factors

- Until 2005, the aircraft manufacturer did not specifically require that Citabria 7GCBC aircraft be produced using control cables manufactured and certified to MIL-DTL-83420 *[Safety Issue]*
- The model 7GCBC 'Citabria' aircraft, serial number 1347-2003, was manufactured using elevator control cables not certified to the requirements of the MIL-DTL-83420 specification for aircraft control cable. *[Safety Issue]*
- The control cable inspection regime used by maintenance personnel had not identified the developing cable fatigue damage, even though it was likely the cracking was well advanced and should have been detected during the last 100-hourly inspection. *[Safety Issue]*
- While the aircraft was in flight, the 'up-elevator' control cable, part number 3-1072, fractured from a pre-existing area of fatigue cracking of the individual cable strand wires.
- Control of the aircraft's elevator was lost as a result of the cable failure, depriving the pilot of the primary means to control the aircraft's pitch attitude.

SAFETY ACTION

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.

Depending on the level of risk of the safety issue, the extent of corrective action taken by the relevant organisation, or the desirability of directing a broad safety message to the aviation industry, the ATSB may issue safety recommendations or safety advisory notices as part of the final report.

American Champion Aircraft Corporation

No requirement to meet control cable MIL specifications prior to 2005

Safety Issue

Until 2005, the aircraft manufacturer did not specifically require that Citabria 7GCBC aircraft be produced using control cables manufactured and certified to MIL-DTL-83420

Aircraft manufactured using control cables not certified to MIL specification requirements

Safety Issue

The 'Citabria' model 7GCBC aircraft, serial number 1347-2003, was manufactured using elevator control cables not certified to the requirements of the MIL-DTL-83420 specification for aircraft control cable.

Action taken by American Champion Aircraft Corporation

From 2005, the aircraft manufacturer has specified that all control cable runs must be produced from cable certified to the requirements of MIL-DTL-83420.

Civil Aviation Safety Authority

Maintenance inspection regime inadequate

Safety Issue

The control cable inspection regime used by maintenance personnel had not identified the developing cable fatigue damage, even though it was likely the cracking was well advanced and should have been detected during the last 100-hourly inspection.

Action taken by the Civil Aviation Safety Authority

The Civil Aviation Safety Authority has published an Airworthiness Bulletin (AWB27-011) highlighting the circumstances surrounding the cable failure sustained by VH-MWY, and recommending:

- All flight control cables in American Champion Aircraft models are immediately inspected for damage.
- Operators consider replacing control cables that cannot be traced to MIL-DTL-83420 certification.
- Where required by aircraft maintenance documentation, flight control cables are periodically inspected in accordance with FAA AC 43-13-1B chapter 7, section 8, paragraph 7.149d, and the manufacturer's approved data.

Aircraft operator

Maintenance inspection regime inadequate

Safety Issue

The control cable inspection regime used by maintenance personnel had not identified the developing cable fatigue damage, even though it was likely the cracking was well advanced and should have been detected during the last 100-hourly inspection.

Action taken by the Aircraft operator

Following the occurrence, the aircraft operator arranged an immediate inspection of all other American Champion Citabria Aircraft in its fleet. Another aircraft was subsequently identified with deteriorating cables - those cables were replaced with cables certified to the MIL-DTL-83420 specification.

SOURCES AND SUBMISSIONS

Sources of Information

- E-mail communications between the Australian Transport Safety Bureau (ATSB), the US National Transportation Safety Board (NTSB) and American Champion Aircraft Corporation (ACA).
- Aircraft Maintenance Certification Logs (volumes 1 and 2) for VH-MWY.

References

- American Champion Aircraft Service Manual and Parts Manual, Citabria models 7ECA, 7GCAA & 7GCBC.
- US Electronic Code of Federal Regulations, Title 14, Part 25, Sub-part D, §25.603 *Materials*
- US Electronic Code of Federal Regulations, Title 14, Part 23, Sub-part D, §23.689 *Cable systems*
- US Department of Defence Specification MIL-DTL-83420 *General Specification For Flexible Wire Rope For Aircraft Control,* including detail specification sheet MIL-DTL-83420/1D
- US Department of Defence Qualified Products List of products qualified under detail specification MIL-DTL-83420

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 of this report was provided to:

- The aircraft owner & operator
- the aircraft maintenance organisation
- the aircraft pilot at the time of the occurrence
- the aircraft manufacturer
- the US National Transportation Safety Board (NTSB)
- the US Federal Aviation Administration (FAA)
- the Civil Aviation Safety Authority (CASA).

Submissions were received from the aircraft owner & operator, the maintenance organisation, the NTSB, and CASA. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.