Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A03C0068

FLIGHT CONTROL MALFUNCTION

GOVERNMENT OF CANADA
DEPARTMENT OF TRANSPORT
BEECH KING AIR C90A C–FGXU
DAUPHIN, MANITOBA 25 NM SW
13 MARCH 2003

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

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Summary

The crew of a Transport Canada Beech King Air C90A, registration C–FGXU, serial number LJ1140, departed Winnipeg, Manitoba, at 0940 central standard time[1] on a routine training flight to Prince Albert, Saskatchewan. The captain was the pilot flying and the co-pilot was the pilot non-flying. At approximately 1026, at flight level 220, the crew heard a loud bang accompanied by severe airframe vibration and a substantial pitch up in aircraft attitude. The captain disconnected the auto-pilot, reduced engine power, selected full nose-down trim, and applied forward pressure on the control column to regain control. As the airspeed reduced to below approximately 150 knots, the vibrations stopped. With limited elevator control remaining, the captain reduced engine power and established a descent while maintaining hard nose-down pressure on the control column to keep a constant level aircraft attitude. The co-pilot declared an emergency and requested a diversion to Dauphin, the nearest suitable airport for landing. At 15 000 feet, the captain elected to extend the landing gear to effect a more rapid descent and as a precaution to give more time to stabilize the aircraft in the event that lowering of the landing gear would affect airflow past the tail. Prior to landing, at approximately 200 feet above ground level, the crew detected another brief vibration followed by a sudden pitch down, requiring aggressive trim and elevator control inputs to control. The crew completed a flapless landing without further incident. After exiting the aircraft, the crew observed that the left elevator trim-tab pushrod had failed.

Ce rapport est également disponible en français.

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[1] All times are central standard time (Coordinated Universal Time minus 6 hours).

Other Factual Information

Transport Canada (TC) documentation indicated that the crew was certified and qualified to perform the flight crew duties they were assigned. Prior to departure, the pilot-in-command operated all of the flight-control trims through their full range of movement, and both crew members checked the elevator electric pitch trim functions in accordance with standard operating procedures. The elevator trim checks were normal; no binding or excess force was required for operation.

The elevator trim system incorporates a pushrod attached to the trim tab with a set of stainless steel bushings, an inner bushing rotating inside an outer bushing, at the attachment point. The last major inspection of the elevator trim system was accomplished during a phase 2 inspection of the aircraft on 21 October 2002, at an airframe time of 7901 hours. The elevator trim-tab free play was checked and found to be within the required manufacturer's specifications.

The elevator trim-tab pushrod attachment hardware was removed to facilitate the installation of new magna-fluxed hardware (MS 17825–4 castellated fibre locknuts and close tolerance AN 174–7 bolts). After removal of the hardware, it was noted that the steel inner bushing (p/n 90–524024–1) on the left trim-tab arm was seized within the steel outer bushing (p/n 90–610010–5). The inner bushing was removed and found to be corroded and rusted. Both mating faces of the inner and outer bushings were cleaned, and the bushings were lubricated and re-installed with the new attachment hardware. The elevator trim was run through its full operating range and was found to operate smoothly, with no signs of binding.

The occurrence happened approximately 150 flight hours after the inspection, at an airframe time of 8050 hours. An examination of the aircraft after the occurrence revealed that the left elevator trim-tab pushrod had failed at the threaded rod, flush with the surface of the jam nut, adjacent to the adjustable fork-end (see Photo 1). The fork-end was seized at a right angle to the trim-tab horn. The pushrod cutout in the elevator lower surface showed rub marks from the jamming of the fork-end in several locations in the cutout after the failure occurred. The torque on the attachment hardware was checked and found to be 90 inch-pounds. The manufacturer's recommended torque is 25 to 30 inch-pounds, with a provision to go as high as 50 inch-pounds to aid in aligning the slot in the castellated nut. It was reported that a torque wrench had been used during the installation of the castellated nut.

Photo 1. Failed left elevator trim-tab pushrod

The trim tab and attachment hardware was forwarded to the Transportation Safety Board of Canada (TSB) Engineering Branch for examination. Scanning electron microscope examination of the fracture face on the threaded rod showed fatigue originating in a thread root. The fatigue cracking had progressed to overstress rupture with no noticeable final overstress region, suggesting that the failure occurred under normal service loads when the crack reached critical size. Metallurgical testing of the pushrod showed that it met material specifications.

Examination of the inner faces of the trim pushrod clevis showed a worn recessed area and rub marks around the bore for the clevis/horn attachment bolt. Examination of the horn assembly showed that mechanical rubbing had removed the paint from the horn around the periphery of the outer bushing, consistent with contact between the sides of the horn and the trim pushrod clevis.

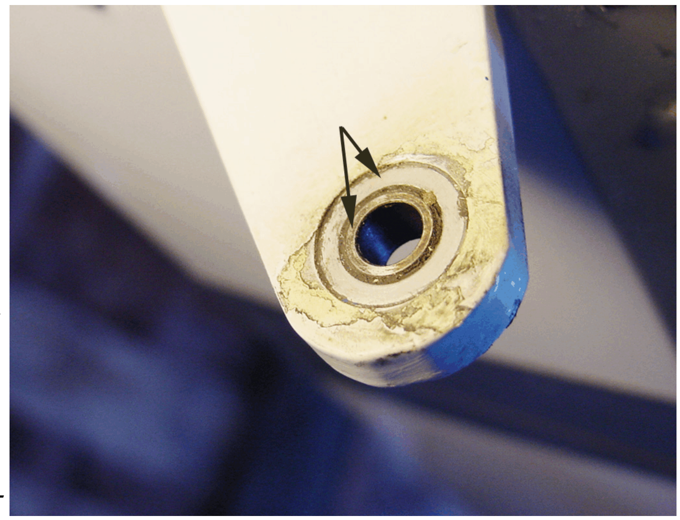

Photo 2. Inner and outer bushing arrangement

The drag torque required to rotate the castellated fibre locknut was measured at 3 inch-pounds. The relative position of the inner bushing was marked, the clevis re-installed on the horn with the original fasteners, and the assembly was torqued to the manufacturer's specification of 25 inch-pounds plus the 3 inch-pounds of drag torque, for a total installed torque to 28 inch-pounds. A force gauge was used to measure the rotational resistance of the clevis; the results averaged 18.1 pounds of force. Torque on the attachment bolt was then increased to 87 inch-pounds, plus the 3 inch-pounds of drag torque, for a total of 90 inch-pounds to match the as-installed assembly. Again, a force gauge was used to measure the force required to rotate the clevis; the results averaged 52.7 pounds of force. It was noted during the tests that the inner bushing remained fixed in the outer bushing and the clevis rotated about the inner bushing (see Photo 2). The clevis is designed to remain fixed to and rotate with the inner bushing.

The inner bushing was removed and a significant amount of non-uniform, circumferential galling[2] was observed extending around the entire circumference of the outer surface of the inner bushing. A dimensional check against the manufacturer's specifications showed that the inner bore of the outer bushing was undersized and non-cylindrical, while the diameter of the inner bushing was oversized, resulting in an interference-fit[3] between the two bushings and the non-uniform galling. The manufacturer's designed clearance range is between 0.0001 and 0.0016 inches; the measured clearance was between 0.0000 and -0.0013 inches.

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[2] Fretting or chafing of a mating surface by sliding contact with another surface or body.

[3] A fit between two parts in which the part being put into a hole is larger than the hole itself.

TC inspected two new inner bushings and one new outer bushing from stock that had been supplied by the aircraft manufacturer. A dimensional check of the bushings showed that they were non-cylindrical in nature (out-of-round) and outside of the manufacturer's dimensional specifications. The two inner bushings were between 0.0003 and 0.0004 inches oversized, the outer bushing was 0.0009 undersized and all three bushings were between 0.0006 and 0.0008 inches out-of-round. There are no out-of-round limits. The oval nature of the bushings, if aligned, would have resulted in an interference fit and would not have allowed the inner bushing to rotate.

The TSB Engineering Branch recently examined a failed trim-tab pushrod from a commercial operator's Beech King Air 90 aircraft after a similar occurrence on 05 June 2002. The failure mode was similar to the failure mode in this occurrence.

Analysis

The trim-tab/clevis assembly was inspected and serviced approximately 150 hours prior to the failure and, at that time, the inner bushing was found seized in the outer bushing and corroded. The seizing of the inner bushing likely initiated the wear observed on the inner faces of the clevis and may have initiated the fatigue cracking of the pushrod end if the rotational resistance of the clevis at that time was sufficient.

The elevator trim pushrod failed as the result of fatigue cracking of the threaded section of the rod end. The fatigue crack was initiated by the increased bending load generated from a progressively stiffening pushrod to trim-tab attachment. The original fit between the inner and outer bushings was less than ideal, with an interference fit occurring between these two parts at points around the interface. The non-cylindrical nature of the outer bushing inner bore is consistent with the non-cylindrical nature of a new bushing found in TC stores. However, it could also be indicative of manual reaming, some time after manufacture, to facilitate the insertion of the inner bushing. Reaming of the bushings without the associated drawings could lead to a risk of seizure if the dimensional and out-of-round limits are not strictly observed. TC, Aircraft Services indicates that the associated drawings for this practice are not readily available to aircraft maintenance engineers. Movement between the two ill-fitting bushings, aided by the higher-than-prescribed installation torque on the through bolt, likely produced the galling, which resulted in eventual seizure.

Because the bushing had seized, the trim pushrod had rotated about the inner face of the clevis and outer faces of the inner bushing. However, the through bolt was overtightened, which effectively eliminated rotation and increased the bending loads on the pushrod until it eventually failed in fatigue. This whole process was considered to have been progressive in nature: as assembly lubricant was displaced, fretting debris accumulated, galling/wear developed, and friction in the overall assembly increased. The steel-on-steel design of the elevator trim-tab bushings increases the risk of seizure if there is inadequate lubrication.

The following TSB Engineering Branch report was completed:

LP 028/2003 – Elevator Trim Tab Rod Failure.

Findings as to Causes and Contributing Factors

1. The elevator trim pushrod failed from fatigue cracking in the threaded section of the rod end. The fatigue crack was initiated by the increased bending load generated from a progressively stiffening pushrod to trim-tab attachment, resulting in limited elevator control.

2. The original fit between the inner and outer bushings was less than ideal, with an interference fit occurring between these two parts at points around the interface.

3. Movement between the two ill-fitting inner and outer bushings, aided by the higher than prescribed installation torque on the through bolt, likely produced the galling, which eventually resulted in seizure.

4. The elevator trim-tab pushrod attachment bolt was found to be tightened to a value higher than that prescribed by the manufacturer. As a result, when the inner bushing became seized, the pushrod clevis was not free to rotate.

Findings as to Risk

1. The design of the bushing arrangement is such that the close tolerance nature of the inner and outer bushing pair requires strict adherence to manufacturing tolerances, quality control, and optimal maintenance procedures.

2. The elevator trim-tab inner and outer bushings are both made from stainless steel, which increases the risk of seizure if there is inadequate lubrication.

3. Several new bushings obtained from the manufacturer did not meet the dimensional design specifications. Distribution of such bushings could result in the machining or reaming of bushings to facilitate installation. Reaming of the bushings without the associated drawings increases the risk of seizure if dimensional and out-of-round limits are not strictly observed.

Safety Action Taken

On 21 March 2003, TC issued a Service Difficulty Alert, AL–2003–03, recommending that operators of Raytheon/Beech 90 series aircraft disassemble and thoroughly inspect the elevator trim-tab hardware installation and ensure that the inner bushing rotates freely.

The manufacturer, Raytheon/Beech, has been made aware of the new, out-of-tolerance bushings held in stores by TC and is conducting a quality-control check of the bushings held in its stores.

Raytheon Aircraft Company has taken the following action concerning the elevator trim-tab bushings:

1. In April 2004, a Safety Communiqué was issued to alert operators to inspect for seized elevator trim-tab bushings. The communiqué describes two previous occurrences and reminds operators of the correct installation inspection and corrective action for seized bushings.

2. Bushings in the spares inventory were dimensionally inspected.

3. The following revisions were made to the Maintenance Manual on the installation procedures:

   – allow polishing for a proper fit;

   – inspect to ensure that only the inner bushing contacts the clevis after assembly; and

   – instructions to ream the outer bushing after installation are provided, as some distortion occurs during the installation of the bushing.

On 09 June 2004, the TSB sent Aviation Safety Advisory A040035 to the Minister of Transport, suggesting that TC may wish to liaise with the Federal Aviation Administration (FAA) in a follow-up to the manufacturer’s quality-control check, to ensure that no out-of-tolerance bushings remain in stores or in distribution.

On 09 June 2004, the TSB also sent Aviation Safety Advisory A040036 to the Minister of Transport, suggesting that TC may wish to liaise with the manufacturer and the FAA, to ensure that design and maintenance issues regarding the trim-tab bushings are adequately addressed.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 07 September 2004.