AVIATION OCCURRENCE REPORT

LOSS OF CONTROL

GOVERNMENT OF CANADA
DEPARTMENT OF TRANSPORT
AIRCRAFT SERVICES DIRECTORATE
BEECHCRAFT KING AIR A90 C-FCGE
NORTH BAY, ONTARIO
18 MARCH 1997

REPORT NUMBER A97O0043

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Government of Canada
Department of Transport
Aircraft Services Directorate
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Summary

C-FCGE, a Beechcraft King Air A90, was on a training flight in level cruise at 11 500 feet above sea level (asl) in the vicinity of North Bay, Ontario, when the crew experienced a vibration in their aircraft and an uncommanded turn to the right. The decision was made to divert to North Bay. During the descent, a severe vibration developed and control of the aircraft was briefly lost. After this severe vibration ceased and control was regained the aircraft required significant left rudder to maintain co-ordinated flight. An uneventful landing was completed. No injuries occurred.

Other Factual Information

The Beechcraft King Air owned by the Government of Canada and operated by Transport Canada's Aircraft Services Directorate at Ottawa, Ontario, was being flown by a crew of two on a routine training flight. There were no other persons on board the aircraft. After an uneventful first leg the crew landed in North Bay, Ontario at 1800 eastern standard time (EST)[1], refuelled, carried out normal pre-flight inspections and departed 45 minutes later for another training flight with Ottawa as the planned destination after a round-robin routing. After approximately one hour of flight, while in level cruise at 11 500 feet asl, the crew experienced a slight vibration and a shallow uncommanded right turn. The aircraft was returned to level flight, the autopilot was selected off and a cockpit check was completed when another uncommanded but steeper turn to the right developed. The aircraft was once again returned to level flight and, as the vibration was continuing, a decision was made to land in North Bay due to its close proximity.

During the descent, at approximately 8 500 feet asl, a severe vibration developed which violently shook the aircraft and rapidly moved the rudder and ailerons causing the hands and feet of the pilot flying to be displaced from the control wheel and rudder pedals. After approximately 30 to 45 seconds, the vibration stopped and control was regained. The descent was then continued at 140 knots, as the aircraft seemed controllable at this speed. However, to maintain coordinated flight, the crew had to hold approximately 2/3 left rudder. The remainder of the descent, approach and landing were uneventful and the aircraft landed safely. No injuries occurred.

A maintenance recovery team was dispatched and examined the aircraft. They determined that the hardware connecting the rudder trim actuator push/pull rod to the rudder trim horn was missing. After replacement of the missing hardware and a free play check, the aircraft was ferried to Ottawa. The aircraft was returned to service after a severe turbulence check and non-destructive testing (NDT) of fittings in the empennage and wings.

The rudder trim is set by turning a wheel in the cockpit. This movement is converted into a fore and aft motion of the push/pull rod. The rod, attached by a clevis and bolt to a horn on the starboard side of the rudder trim tab, displaces the tab either to the left or right. This causes the rudder to be moved in the opposite direction thereby trimming out the control forces necessary to maintain co-ordinated flight. (See Figure 1)

The hardware attaching the push/pull actuating rod to the rudder trim horn was last replaced when the aircraft was painted during the period 25 January 1995 to 10 March 1995. Since then, the last maintenance completed in this area was the rudder trim tab free play check on 24 January 1997. Part of this check calls for a visual inspection of the trim tab actuating system and directs that any inconsistencies be rectified prior to the free play check. No problems were detected and the component passed the check. As a result, the attaching hardware was not disturbed during the process. The aircraft flew a total of 59 hours between the free play check and the occurrence.

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[1] All times are EST (Coordinated Universal Time minus 5 hours) unless otherwise noted.

The Beechcraft 90, A90, and B90 Series Illustrated Parts Catalogue (IPC Fig 54, page 3, Index #42) specifies that the attachment hardware used to connect the rudder trim actuator include an AN173 bolt (no length specified), two AN320-3 castellated nuts and two AN380-2-2 cotter pins.

The aircraft operator also uses Beechcraft 100 aircraft in a similar role. The Beechcraft 90 and 100 are alike in

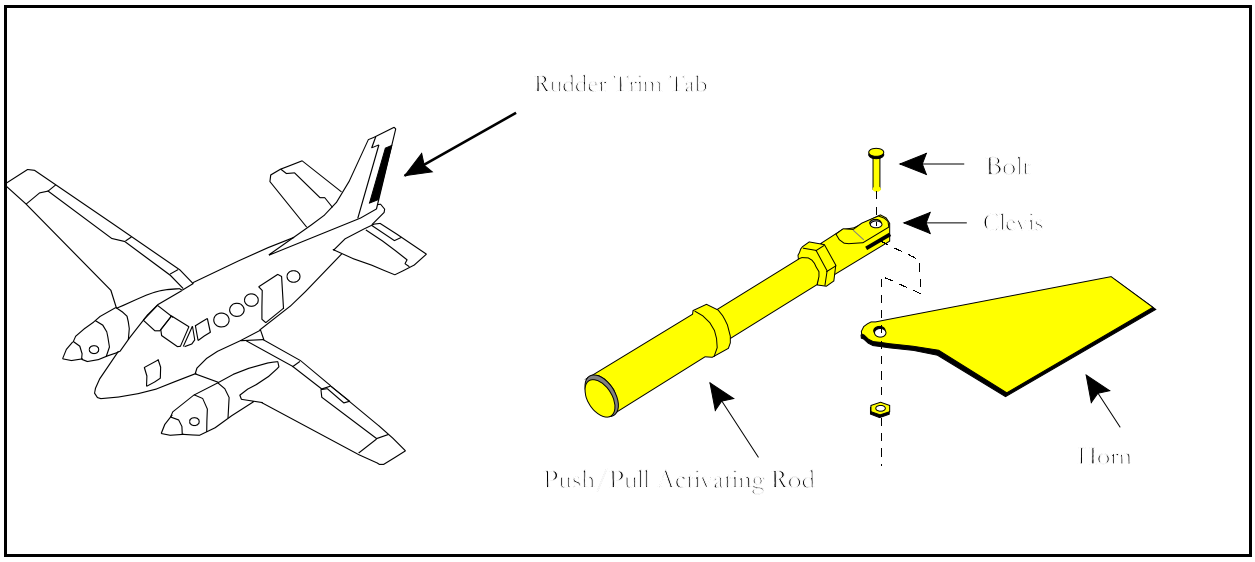

Figure 1 Rudder Trim Tab Location and Parts

many respects including the rudder trim tab and actuator. The IPC for the Beechcraft 100 specifies an AN173-5 bolt in this assembly along with one AN960-10L washer, one AN320-3 castellated nut and one MS24665-132 cotter pin (IPC 27-21-01, page 3, Index #3).

Inspection of other Beechcraft A90 aircraft used by the operator revealed that the rudder trim actuator is typically attached to the horn using an AN173-5 bolt, washers of varying thickness and number (to ensure the correct orientation of the cotter pin hole in the bottom of the bolt with the indentations in the nut), one AN320-3 castellated nut and one cotter pin.

Analysis

Securing Hardware

The bolt and associated hardware securing the push/pull actuating arm to the rudder trim tab horn was missing after the occurrence. There are several possibilities as to why the bolt failed to remain secure. Possibilities are - it was not there on take-off, it fell out at some point, or it broke during flight. The first hypothesis is not likely, as the crew would have noticed this during pre-flight inspections or in flight prior to the occurrence.

In order for the bolt to fall out during flight the cotter pin would have to either been missing prior to or broken during the flight, the nut would have to back off and the bolt would have to move upwards against gravity. The cotter pin was present during the previous free play check and, as there is no force on the pin, it is unlikely that it would subsequently break. Installations of this assembly were inspected on the operator's other King Air aircraft and it was noted that the bolt threads were painted. This would decrease the likelihood of the nut backing off even if the cotter pin were missing. Furthermore, the bolt is held in place by a bushing in the trim tab horn. The fit between the bushing and the bolt is quite tight. This ensures that the rudder trim will pass the free play check which demands a tolerance of only 0.021 inches.

The third hypothesis, that the bolt broke in flight, is the most likely scenario. The fracture would not have been due to overload stresses because there was no evidence of deformation on the clevis or trim tab horn. However if there were cyclic loads of sufficient magnitude present, the bolt could have failed in fatigue without damaging the surrounding components.

As the shank of the AN173–5 bolt does not extend all the way through the lower arm of the clevis, a fatigue crack could have developed at the threads due to a stress concentration as a result of the shear load. The shank of the bolt, however, is thicker than the threads and therefore prevents them from coming in contact with the clevis and bearing any load.

The bolt may have been manufactured from sub-standard material or not been an aircraft quality part. As the bolt was not recovered, it was not possible to examine it. Several samples of attaching hardware from the parts bin in the operator's supply section (bolts, washers, castellated nuts and cotter pins) were examined to confirm conformance with respective specifications. Most met the specifications, however, one was found to be non-conforming and many showed evidence of previous use notwithstanding the operator's policy that only new parts are used when assemblies like this are replaced. It is possible, that a sub-standard part either similar in appearance to the correct part or purposely manufactured to a lower standard and supplied as an aircraft quality part, was mistakenly installed after the aircraft was painted by the operator two years previously.

The bushing was recovered from the aircraft by pressing it out of the horn. It was compared to another bushing from the operator's supply section. The original was 0.002 inches in diameter smaller and had a rougher finish than the new bushing. It was noted that it was difficult to insert an AN173 diameter bolt into it. The normal practice when completing this assembly is to try several bolts in the fitting and use the one that gives the tightest fit. Given the close tolerances required for this fitting and a bushing that had a slightly smaller inside diameter, the possibility exists that a technician might have used a non-conforming bolt in this installation if it resulted in the tightest fit.

In summary the attaching hardware securing the rudder trim tab to the actuator did not remain secure. The reasons for this could not be conclusively determined.

Vibration and Loss of Control

The initial indication of difficulty during this occurrence was a slight vibration and an uncommanded turn to the right. The vibration may have been a result of a trim tab "buzz" due to play in the tab. The amount of free play allowable in this mechanism is quite small (0.021 inches). As a result any wear on the bolt would have a significant impact. If wear on the bolt progressed sufficiently to allow vibrations or "buzz" to commence, the bolt could fail quickly. Fatigue fractures of aircraft bolts have been known to occur in cyclic load situations in a matter of hours after installation[2]. The turn to the right could have resulted from a slight rudder trim tab displacement as the bolt was wearing and the fitting was becoming looser.

The second event that occurred was a severe vibration and loss of control. Examination of the rudder trim system determined that when disconnected, the push/pull actuating rod is free to rotate and/or move slightly in the vertical or horizontal plane. If the push/pull actuating rod moved slightly up or down the trim tab would be completely free to move. As a result there is a possibility that tab flutter could occur at airspeeds well below Vne. If this occurred the result would be large oscillatory displacement of the rudder. According to the AGARD aerodynamics textbook "a number of accidents and near accidents have occurred from flight failures in control linkages of tab systems."[3] The large control deflections and loss of control experienced by

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[2] Canadian Forces QETE Report D000397(QI-RM) 23 December 1997.

[3] AGARD Manual of Aeroelasticity Part V, Chapter 3, "Flutter of Control Surfaces and Tabs"

the flight crew could have resulted from rudder tab flutter. The source of excitation, which started the flutter condition, is unknown but a change in airspeed, altitude and/or aircraft attitude probably was the cause of the severe vibrations stopping. Fortunately, the flight conditions that initiated the rudder tab flutter were not present for the remainder of the flight.

When the crew finally regained control of the aircraft they noted that 2/3 rudder was required to maintain co-ordinated flight. If the push/pull actuating rod moves slightly up or down and inward toward the aircraft body, the arms of the clevis can end-butt against the horn (see Figure 2) and force the tab to the left. If this occurred, the rudder would be displaced to the right requiring left rudder input to maintain co-ordinated flight. Tests on another King Air showed that when the rod is in this position the trim tab would be displaced approximately half its maximum deflection if the trim tab control started in the neutral position. The air stream would be sufficient to hold the tab horn firmly against the clevis unless another buzz was introduced. These tests also showed that this was a fairly stable position for the clevis that would not shift with control inputs or minor vibration.

Illustrated Parts Catalogue

The description of the attaching hardware for the rudder trim tab actuator in the IPC for the King Air 90 is confusing when compared to the IPC for the King Air 100. In the former the length of the bolt (IPC Fig. 54, page 3, part 54-42) is not defined (i.e. should be AN173-5 or -6) and, immediately following this entry, the IPC lists two castellated nuts and two cotter pins which appear to be part of this assembly. The extra nut and pin are actually used to secure the bolt (part 54-40) that attaches the front of the actuator to the aircraft. As well, the build-up description does not call for any washers, which are necessary to ensure the hole for the cotter pin in the bolt is within the indentations of the nut to allow the pin to seat properly. The IPC for the King Air 100, on the other hand, lists these parts in a more logical manner with each assembly (bolt and securing hardware) listed separately. Beechcraft acknowledged this inconsistency and is amending the IPC to correct this deficiency. Standard industry practices, as used by the aircraft operator's technicians, would call for the use of washers in the attachment for the King Air 90.

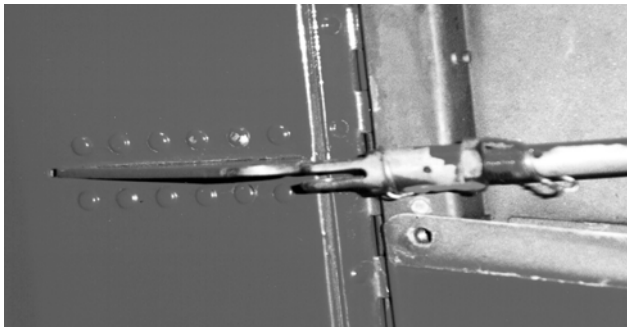

Figure 2 Clevis against the horn

The Canadian Air Regulations (CAR) prohibit the substitution of parts listed in the manufacturers IPC unless accompanied by approved data acceptable to the Minister[4]. A technician referring to the IPC for guidance on how to attach the rudder trim tab actuating arm to the horn would be faced with an obvious error in the parts list. According to the CARs, an operator faced with this dilemma must identify the problem to the manufacturer and then wait for him to amend the IPC or issue data acceptable to the Minister to substitute the specified parts for a more logical assembly. This delay could result in an unacceptable grounding of an otherwise serviceable aircraft. Previously an operator could refer to a substitution guide or similar document and install an equivalent part identified therein in cases such as this. With the onset of the CARs, this is no longer possible.

Before the enactment of the CARs the operator handled this discrepancy by either referring to the IPC description in the King Air 100 manual for guidance on how to complete this assembly or using the identical build-up that had previously been installed.

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[4] CAR 571.13 and Airworthiness Manual 571.13, including information notes.

Findings

1. The attaching hardware securing the rudder trim tab to the actuator did not remain secure. The reasons for this could not be conclusively determined.
2. Tests of a sampling of attaching hardware from the operator's supply system revealed one bolt which did not conform to the AN173 specifications and several that showed evidence of prior usage.
3. A minor vibration and uncommanded right turn developed, which the crew was able to control. Later a severe vibration developed, which resulted in the crew losing control of the aircraft, but the vibration stopped when the parameters that sustained it changed as the aircraft descended. Left rudder was then required to maintain co-ordinated flight.
4. The King Air 90 IPC does not identify the length of the bolt to use to connect the actuator to the horn. As well the description of the assembly is confusing and not consistent with how the King Air 100 IPC describes the assembly. The assembly normally used was an AN173-5 bolt, two washers, an AN320-3 castellated nut and a cotter pin.
5. The Canadian Aviation Regulations do not permit the substitution of parts listed in the manufacturer's IPC unless accompanied by approved data acceptable to the Minister of Transport.

Causes and Contributing Factors

The bolt securing the rudder trim actuator to the rudder trim tab horn became detached for reasons that could not be conclusively determined. The rudder trim tab was then free to either oscillate or be held to the left by the disconnected trim tab actuating arm.

Lack of detail and an inconsistent and confusing description of the parts required for the attachment of the actuating arm to the trim tab in the Illustrated Parts Catalogue as well as the possibility that a non-conforming bolt was used when the fitting was last installed may have also contributed to the bolt not remaining secure.

Safety Action

Action Taken

Immediately after the occurrence, the operator inspected the rest of their fleet to ensure the condition and conformity of the Rudder Trim Tab attachment hardware.

Action Required

TSB liaise with Transport Canada to have Beechcraft review and revise the IPCs of the Beechcraft 90, A90 and B90 aircraft to reflect the correct AN hardware for the rudder trim tab to rudder trim actuator attachment.

TSB liaise with Transport Canada to have CAR 571.13 revised to make it more realistic and operationally feasible for operators.

Initiatives currently underway throughout the aviation community to identify and eradicate non-conforming parts be continued. While this occurrence cannot be positively identified as being due to this problem, it is a possible scenario that cannot be eliminated. Education of aviation personnel, through this and similar occurrences where problems associated with these parts are revealed, should continue.

Department of Transport - Aircraft Services Directorate institute procedures to ensure that all parts issued from their supply section conform to the specifications required in appropriate publications.

ADDENDUM

The following actions have been taken by the TSB and Transport Canada in addressing the Safety Actions Required, as in the public report:

1. Transport Canada has written the Federal Aviation Administration recommending that Raytheon Beech be contacted to have the Aircraft Maintenance Manual amended to include complete assembly instructions and illustration.

2. Transport Canada does not recognize the Illustrated Parts Catalogue as an authoritative document for the purposes of assembly, only for the identification of appropriate parts. Therefore, Transport Canada does not agree that CAR 571.13 should be revised.

3. Transport Canada, Aircraft Services Directorate, has verified that all parts in their parts supply section conform to the required specifications and are in the appropriate bins. This activity is on-going.

   All warehouse and procurement staff and aircraft maintenance engineers (AME) in the Aircraft Services Directorate have received training on bogus parts to increase awareness on this issue.

   The Aircraft Services Directorate Maintenance Control Manual was amended to enhance parts control procedures.