AIRCRAFT ACCIDENT REPORT 3/84

Accidents Investigation Branch

Department of Transport

Report on the accident to Cessna 404 Titan G-OEMA over the North Sea on 3 April 1983

LONDON
HER MAJESTY'S STATIONERY OFFICE

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Department of Transport
Accidents Investigation Branch
Royal Aircraft Establishment
Farnborough
Hants GU14 6TD

18 July 1984

The Rt Honourable Nicholas Ridley MP
Secretary of State for Transport

Sir,

I have the honour to submit the report by Mr C C Allen, an Inspector of Accidents, on the circumstances of the accident to Cessna 404 Titan G–OEMA which occurred over the North Sea on 3 April 1983.

I have the honour to be
Sir
Your obedient Servant

G C Wilkinson
Chief Inspector of Accidents

Contents

Accidents Investigation Branch

Aircraft Accident Report No: 3/84 (EW/C820)

Operator		Banline Aviation Ltd
Aircraft:	*Type:*	Cessna 404 Titan
	Model:	Ambassador
	Nationality:	British
	Registration:	G–OEMA
Place of Accident:		Over the North Sea, 55 nautical miles east of Clacton VHF Omni-directional Range (VOR) Latitude: 51°30′ North Longitude: 002° 35′ East
Date and time:		3 April 1983 at 2149 hrs All times in this report are GMT

Synopsis

The accident was notified to the Department of Trade Duty Officer at 0346 hrs on 4 April 1983. The investigation was commenced that morning.

Whilst cruising over the North Sea at night with the autopilot engaged, the aircraft suddenly rolled to the right and the commander found that the aileron controls had jammed. He subsequently regained lateral control and declared an emergency. The aircraft was then diverted to Manston aerodrome where a safe landing was carried out.

Subsequent investigation showed that the right aileron outboard hinge bolt and bracket had failed, allowing the right aileron to jam in the wing structure.

The report concludes that the accident was caused by the failure in fatigue of the right aileron outer hinge bolt, as a result of which control of the aircraft was seriously impaired. The fatigue failure was initiated by thread damage probably caused by over-torquing of the associated nut. Contributory factors were the restricted access to, and the design of, the aileron hinge assembly.

1. Factual Information

1.1 History of the flight

The aircraft was returning to East Midlands Airport on a charter flight from Munich, with a pilot and seven passengers on board. Having departed from Munich at 1922 hrs, the flight proceeded normally until after the aircraft had crossed the Belgian coast and the commander had established radio-telephony (RTF) contact with London Control (Air Traffic Control – ATC) at 2146 hrs. The aircraft was then flying towards Clacton VOR on airway Blue 29 (B29) at Flight Level (FL) 80, with the autopilot and altitude lock engaged. The weather in the area was good, although it was a dark night.

At approximately 2149 hrs, without warning, the aircraft rolled to the right. The commander endeavoured to regain level flight by overpowering the autopilot but, having no success, disconnected it. He then found that the control wheel was deflected laterally some thirty degrees to the right and that the aileron control circuit was jammed; he therefore rolled the aircraft level by use of left rudder and the application of additional power on the right engine. After regaining control, he tripped the three circuit breakers associated with the autopilot, but this did not lead to any improvement in lateral control. He therefore examined the exterior of the aircraft as far as possible, with the aid of a torch, and discovered that the outer section of the right aileron had become detached. The outboard end of the aileron was protruding approximately ten degrees above the top surface of the wing, and the inboard section was jammed into the underside of the wing structure adjacent to the flap.

The commander then selected the Emergency Code A7700 on the aircraft's radar transponder and at 2154 hrs reported to London Control that he would 'HAVE TO DECLARE A MAYDAY' as he had a problem with the right aileron. This was acknowledged by London Control who suggested that the nearest available aerodrome was Southend. At 2158 hrs London Control informed the commander that Manston was open and prepared to accept the aircraft. The commander decided to divert to Manston, was given a radar vector and was told that helicopters had been scrambled to intercept his aircraft.

At 2205 hrs control was handed over to Manston Radar, who then vectored the aircraft, by means of small heading changes, onto the extended centreline of runway 29, at a position 14 nautical miles (nm) from touch-down. The Search and Rescue (SAR) helicopter from Manston was by this time positioned 6 nm north-west of the aircraft. The approach was continued with the assistance of Manston's Precision Approach Radar, and the aircraft landed safely at 2220 hrs.

The commander afterwards stated that, throughout the approach, he had maintained lateral and directional control by use of differential power and rudder. The wing flaps were not extended, due to the unknown effect of the displaced aileron on the airflow over the wing.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	–	–	–
Non fatal	–	–	–
Minor/none	1	7	

1.3 Damage to aircraft

The aircraft was substantially damaged.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Commander: Male, aged 37 years

Licence:	Airline Transport Pilot's Licence with a Class 1 medical certificate renewed on 11 June 1982. (A licence renewal medical is permissible every 12 months while the commander exercises only the Commercial privileges of his licence, and is below the age of 40 years.)
Most recent Certificate of Test:	21 January 1983
Most recent Certificate of Test, Cessna 404 aircraft:	6 December 1982
Ratings:	Groups A and B, endorsed for Cessna 400 series aircraft, and Piper PA 23, 28, 31 and 32. Instrument rating renewed 13 February 1983.
Flying experience:	3230 hours, of which 900 hours were on type.

1.5.2 Commander's Flying Duty Period (FDP):

The commander had flown earlier on the day of the accident from East Midlands Airport to Munich. His recorded on and off duty times were 0530 hrs and 0925 hrs respectively. After a rest period of 9 hours and 35 minutes, the commander resumed his duties at 1900 hrs and, after landing, recorded an off duty time of 2235 hrs at Manston. Employing a split duty extension of FDP technique and his discretionary powers, the commander's allowable FDP amounted to 16 hours 48 minutes. The recorded FDP was 17 hours 05 minutes.

It is understood that the CAA has subsequently reminded the operator concerned of the relevant provisions of their Air Operator's Certificate.

1.6 Aircraft information

1.6.1 General

Manufacturer:	Cessna Aircraft Company, USA
Aircraft type:	C404 Titan
Date of Manufacture:	1977
Constructor's No:	404–0102
Engines:	2 Continental GTS10–520–M
Registered Owner:	Kilby Brothers (Property) Ltd
Certificate of Airworthiness: (C of A)	Transport Category (passenger) valid until 14 December 1983
Certificate of Maintenance:	Valid until 11 April 1983 or 100 aircraft hours, whichever occurs the sooner
Total airframe hours:	1065 hours
Flying hours since last check:	23 hours 30 minutes
Maximum weight authorised:	8,400 lb (3,814 kg)
Maximum landing weight:	8,100 lb (3,677 kg)
Take-off weight:	8,061 lb (3,660 kg)
Estimated accident weight:	7,300 lb (3,314 kg)
Estimated landing weight:	7,250 lb (3,292 kg)
Calculated landing weight (original destination):	7,176 lb (3,258 kg)
Centre of Gravity Limits (gear extended):	
(a) Aft Limit:	179.08 inches aft of reference datum (30.00% MAC) at 8,400 pounds or less.
(b) Forward Limit:	170.31 inches aft of reference datum (16.32% MAC) at 8,400 pounds or less and 165.62 inches aft of reference datum (9.00% MAC) at 6,100 pounds or less, with straight line variation between these points.

Accident centre of gravity:	170.00 inches aft of reference datum (15.83% MAC) at 7,300 lb, and within the centre of gravity envelope.
Type of fuel:	Avgas 100 LL
Total aileron movement:	+ 25° – 15°
Total control column handwheel movement:	± 90°

1.6.2 *Detailed maintenance history*

This aircraft had been operated within Europe since its construction in 1977 until April 1980, when it suffered an accident whilst on the ground. It stood idle until August 1981, when it was ferried to Bremen, German Federal Republic, for repair. Subsequently, little or no flying was carried out until November 1982, when the aircraft was serviced and given a Dutch C of A for export to the United Kingdom.

On arrival in this country the aircraft was taken directly to Cranfield where it underwent another inspection on 14 December 1982, to ensure that it complied with the special conditions necessary for the issue of a United Kingdom C of A. During the period January to March 1983, the aircraft was used at irregular intervals, standing idle for several periods of up to eleven days.

The last occasion upon which the aileron system was maintained has been identified as occurring during a 200 hrs inspection carried out in November 1982 at Bremen, when both ailerons were removed in order to replace the aileron control cables. On this occasion, all four hinge bolts and their respective nuts were replaced. The maintenance organisation concerned states that these nuts were tightened to the correct torque value, utilising a special home-made torque wrench adaptor. The aircraft's total flight time was then 995.30 hours.

1.6.3 Throughout the Cessna Service Manual for this aircraft the following references, only, are made to the visual inspection of the ailerons and hinges:

'D. Flight Controls (Chapter 5)

(4) Aileron – Inspect skins for cracks and loose rivets, bellcrank quadrant, stop bolts and jam nuts for proper safety, pulleys for condition, security, operation and travel; inspect hinge for condition, cracks and security.'

A more detailed description of the hinge inspection is laid down on page 10 of paragraph 2–30:

> 'Visually inspect the ailerons skins for cracks and loose rivets, hinges, hinge bolts, hinge bearers, hinge attach fastenings and bonding jumpers for security. Visually inspect the aileron hinge bolts for proper safety of nuts.'

The above inspections are recommended to be carried out at 200 hour intervals. There was no requirement for any periodic removal of aileron surfaces.

The reported damage occasioned during the ground accident on 27 April 1980 affected only the engines and propellers, with no reference being made to wing or aileron damage.

1.7 Meteorological information

The accident happened at night. The weather in the area was generally fine, with 3 oktas of cirrostratus at 25,000 feet. At 8,000 feet, the wind was from 250° true, at 15-20 knots (kt), and the air temperature minus 13°C.

The Manston weather transmitted to the aircraft at 2206 hrs was wind from 205° magnetic at 5 kt, visibility 22 km, cloud 1 okta at 4,000 feet, and the corrected mean sea level pressure setting was 1006 millibars.

1.8 Aids to navigation

Not applicable.

1.9 Communications

At 2146 hrs, the commander made his initial RTF contact with London Control, and acknowledged his onward clearance. At 2154 hrs he transmitted 'LONDON THIS IS GOLF OSCAR ECHO MIKE ALPHA'. As there was no reply, he again transmitted 'LONDON GOLF OSCAR ECHO MIKE ALPHA' and London Control invited him to 'GO AHEAD'. The commander then reported 'I'M AFRAID I'M GOING TO HAVE TO DECLARE A MAYDAY. I GOT A PROBLEM WITH AN ELEVATOR AILERON, IT'S ALMOST OFF THE STARBOARD WING'.

London Control vectored the aircraft until it was within range of Manston's radar coverage and, at 2205 hrs, the commander was requested to change RTF frequency to 126.35 MHz, Manston Approach. Throughout, communications were normal.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

None were required and none were fitted.

1.12 Examination of the aircraft

1.12.1 Initial on-site examination (see Appendix 1)

The aircraft was examined at RAF Manston on the morning following the accident. The aircraft was undamaged, apart from the partially detached right aileron and the wing structure at the inboard end of the aileron housing. Each aileron has two hinge assemblies; it was evident that the right aileron had become detached from its outboard hinge bracket and pivoted upwards about the inboard hinge. The inboard section of the aileron was seen to be jammed into the wing structure, thus fixing the aileron at a dihedral angle of 10° to the plane of the wing, with the outboard end displaced 5° rearwards. The left aileron was found deflected downwards some 8°. The trim tab on the left aileron was also deflected downwards a further 5° from the chord of the aileron.

The control handwheels were found to be rotated 30° to the right, and jammed; the aileron circuit was completely immobilised.

1.12.2 *Aileron hinge construction (see Appendix 2)*

The aileron hinges on Cessna the 404 and 441 models are similar; each consists of a self-aligning sealed ballrace mounted in a ½ inch thick shaped alloy plate. This plate is in turn fixed to the wing structure, so that the rotational axis of the bearing is parallel to the span axis of the wing rear spar. This forms the 'eye' end of the hinge joint. An aluminium alloy bracket, with two protruding triangular lugs, is attached to the leading edge spar of the aileron at a position opposite, and in line with, the hinge bearing. This is the 'forked' section of the hinge joint. A ¼ inch diameter hole in each lug allows a bolt to pass through the lug, the hinge bearing, and then the opposite lug. At the date of the accident the manufacturer's maintenance manual specified that the ¼ inch diameter bolt should have one .064 inch thick washer placed under its head and that, after the bolt has been inserted through the aligned holes, a similar washer should be placed under a castellated stiff-nut screwed on to the bolt threads. A cotter pin would then be inserted through the nut castellations and a pre-drilled hole in the bolt, in order to effect a double lock of the stiff-nut. The recommended torque value quoted in the maintenance manual is 30-40 lb ins, with a maximum of 48 lb ins allowable in order to facilitate the insertion of the cotter pin.

The investigation showed that the specified bolt (NAS 464 P4-12) is of a length which, if two .064 inch washers are inserted as recommended, it is not possible to insert the cotter pin. A number of maintenance organisations approached during this investigation stated that they use one .032 inch thick washer, only, under the nut, a method which only just allows the full diameter of the cotter pin hole in the hinge bolt to be uncovered. In spite of this modified method of assembly, subsequently approved by the manufacturer in Service Information Letter ME 83-25 the tips of the hinge lugs are still deflected inwards towards the hinge bearing as the stiff-nut is tightened. This nut is designated as a shear nut and, with the insertion of a nylon locking insert, approximately two turns, only, of the thread are available to engage in the bolt thread.

The aileron is located laterally by the resultant of the sideways forces on the hinge lugs, as neither hinge assembly acts as a master hinge.

1.12.3 *Detailed examination of the damaged area*

On removal of the damaged aileron, full and free movement of the aileron controls was obtained, the left aileron achieving its required deflection of plus 25° to minus 15°. The outboard lug of the right outer aileron hinge bracket had broken away approximately one third of the way up from its base, and was not recovered. The right inboard aileron-mounted hinge bracket had suffered some distortion, and skin damage was apparent on the upper and lower wing shrouds.

The three remaining aileron hinge joints were dismantled and inspected, and in each case the assembly consisted of an appropriate bolt, castellated nut, cotter pin, and one .032 inch thick washer positioned under the nut. It was also noted that the aileron hinge bracket lugs were deflected by the tightened nut and bolt towards each face of the hinge bearing. When the nut was removed, the lugs resumed their manufactured position at 90° to the backplate. A significant clearance was then observed between the inside face of the lug and the exterior face of the hinge bearing inner race.

When the damaged aileron was removed, the tail end of a ¼ inch diameter bolt, complete with castellated nut and cotter pin, was recovered from inside the aileron leading edge cavity inboard of the hinge location. A ¾ inch diameter hole is positioned in the aileron leading edge ribs, adjacent to the hinge assembly.

Initial examination of the bolt tail indicated that it had failed approximately eight thread turns from the end, and had failed in single bending fatigue. Since there was no sign of any significant corrosion, it was apparent that the failure was a recent event and that the recovered bolt tail was in all probability a component part of the failed bolt assembly. It was noticed that the associated cotter pin was not fully aligned with a nut castellation, and was distorted (see Appendix 3).

The intact lug of the failed outboard hinge assembly exhibited signs of damage on the inner face, and witness marking on the exterior face. The damaged inner face involved deep metal smearing around the aft segment of the hole but no damage was visible to its bore or outer circumferential edge. The witness marks on the exterior face indicated that a washer of undetermined thickness had been inserted between the nut and lug. The region of heaviest contact of the washer to the lug was around that part of the circumference closest to the lug root. The pressure face of the stiff-nut also exhibited signs that loading had been concentrated on one half of its circumference.

All four hinge bearings on G–OEMA were examined and found to be dry, with signs of corrosion within the bearings. In addition, there was evidence of some side and radial play, together with one case of rotational stiffness. The right outboard bearing, however, was relatively free to rotate and possessed minimal side play. There was no evidence to suggest that it had seized.

1.12.4 *Metallurgical examination of the damaged parts*

A metallurgical examination of the remaining thread end of the aileron hinge bolt and associated nut, together with the damaged lug, was carried out by the Royal Aircraft Establishment at Farnborough. Their report concluded that:

> "Failure of the bolt occurred by fatigue in plain bending. Damage to the thread in the region of fatigue crack initiation is believed to have been produced before the bolt fractured but the cause is not apparent from examination of the available parts. There is no evidence that the failure had been influenced by manufacturing defects, and the material strength is not in question. Staining on the fracture surface suggests that there may have been two separate periods of growth with a period of corrosion in between. Fatigue failure of one lug on the associated attachment bracket appears to have occurred as a consequence of the bolt failure."

It was also determined that this fatigue failure had progressed from the inner face towards the outer lug face.

The report established that the crack growth involved a high number of cycles, but pointed out that determination of time to failure was dependent on the source of the stresses involved in growing the crack.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

There was no fire.

1.15 Survival aspects

After the partial aileron detachment, the aircraft remained intact and controllable, albeit with difficulty. After regaining control, the commander briefed the passengers to don their lifejackets and to prepare for a possible landing on water. He also ensured that a passenger, familiar with the main door operating mechanism, occupied a seat adjacent to that door.

No dinghy was carried, nor was there a requirement to do so.

The aerodrome emergency services at Manston were alerted and were in attendance throughout the approach and landing of G–OEMA.

An SAR helicopter was scrambled from RAF Manston at 2158 hrs and reported airborne at 2210 hrs. It was then vectored by Manston Radar to an area close to G–OEMA's flight path; after the aircraft had landed safely at 2222 hrs, the helicopter returned to Manston, landing at 2224 hrs.

1.16 Tests and research

1.16.1 Over-torque tests

During the course of the investigation, it became apparent that difficulty is often experienced in tightening the subject hinge bolt due to restricted access; in fact, it proved virtually impossible to use a conventional torque measuring spanner for the purpose. As there was no evidence of a pre-existing material defect in the area of the failed bolt thread, the possibility was therefore considered that a degree of overtorquing may have precipitated the failure. To this end, a number of new nuts and bolts were assembled in turn into a new hinge bracket, employing spacers to simulate the hinge bearing, and a .032 inch thick washer was inserted under the nut pressure face, in each case.

The assemblies were variously tightened, each to a different dry torque value, ranging from 48 lb ins, the maximum allowable in the manufacturer's service manual, to 79 lb ins, the approximate value at which the thread strips. The tests indicated that thread deformation may occur at a value as low as 54 lb ins. This figure is only 12½% higher than the maximum permitted, and represents approximately 1/6 of a turn of a nut. As the damage to the thread flank and crown of the failed bolt in the region adjacent to the fatigue origin was characterised by a loss of material, a direct comparison with the damage to the 54 lb ins test bolt could not be made. However, a close correlation could be made between the slightly deformed unloaded faces of each thread form (see Appendix 4).

1.16.2 Loading considerations leading to aileron vibration measurements

Static bending loads would be present in the bolt as a result of the deflection of the compressed lugs reacting against the nearest half circumference of the bolt head and nut. However, for a fatigue crack to propagate, a cyclic loading mechanism must be present; therefore consideration was given to ways in which bending loads could be cyclicly applied to the nut and bolt assembly.

There was no evidence of a seizure of the hinge bolt and bearing which might have induced non-axial cyclic loading on the bolt as a function of normal aileron movement; accordingly, this possibility was discounted.

The hinge bolt is typically a close fit in the bore of the hinge bearing. Thus, although offset shear loads are present and are fed through the hinge lugs and out through the hinge bearings, they are considered to be relatively small in comparison with those generated by lateral vibration of the aileron.

Accordingly, lateral stiffness measurements were made on both an inboard and an outboard hinge bracket assembly. These suggested that for small deflections, the combined mounting stiffness of the aileron was such that a natural frequency of lateral vibration of the order of 40 Hz may be expected, based upon simple undamped vibration theory. Predominant vibrations generated by the type of engines fitted to G–OEMA and quoted by the manufacturer, are the first and half order of the engine rotation speed. At 2400 rpm, for example, this equates to 40 Hz and 20 Hz. At a typical cruise rpm value of 1800, the corresponding figures would be 30 Hz and 15 Hz.

In order to investigate the general area of lateral vibration levels that may be induced across the outboard aileron hinge by engine operation, measurements were made on G–OEMA whilst on the ground, using two accelerometers and a simple instrumentation system. The recording system used in the test did not establish any one basic frequency of vibration (the vibration waveform recorded in each case being characteristic of many coincident different frequencies and amplitudes of vibration), but it did indicate that some lateral vibration occurs across this joint at all engine rpm values and that the level of this vibration generally increases at higher engine speeds.

1.17 Additional information

1.17.1 Following the accident, the CAA issued a letter (No 550) to operators of Cessna 404 aircraft, dated 22 April 1983, including brief details of the failure and recommending revised interim procedures for the installation of the aileron hinges.

1.17.2 Other Cessna 400 Series hinge failure

One other known instance of a hinge failure, which occurred in the USA to the starboard outer aileron hinge of a Cessna 404, has been identified. This was discovered during an inspection carried out as a result of Cessna Service Information Letter ME 83-25. In this case one lug of the hinge bracket had failed completely and the other, which was partially cracked, failed as the aileron was removed. Initial examination of the fracture surfaces by Cessna has revealed regions of fatigue to be present, with both failures starting in the region aft of the ¼ inch diameter hole, close to the points of hardest contact of the bolt head and washer. The hinge bolt had not failed.

1.18 New investigation techniques

None

2. Analysis

2.1 General

The lives of all eight persons on board the Cessna were placed in jeopardy when the aircraft's right aileron became partially detached and then jammed. The pilot exhibited a considerable degree of skill and airmanship in regaining control and subsequently executing a successful approach and landing at night.

It must be remarked that the pilot's achieved Flying Duty Period exceeded the permissible value by a small amount, but this had no bearing on the course of the accident. In the circumstances it seems appropriate that, apart from reminding the operator of the provisions of his Air Operator's Certificate, the CAA proposes to take no further action.

Although, again, not relevant to the outcome, it is worth noting that, after the emergency arose, the pilot made two initial RTF calls using routine RTF phraseology before managing to attract the attention of London ATC. A standard Distress Call and Message would probably have elicited a more immediate response.

However, these minor points must not be allowed to detract from the fact that, overall, the emergency was dealt with in a very skilled and professional manner by the commander.

2.2 The aileron hinge bolt failure

It was clear from the examination of the aircraft shortly after the accident that the sequence of events which led to the jamming of the right aileron had been initiated by the failure of the aileron outer hinge bolt. The subsequent detailed metallurgical examination determined that the bolt had suffered a fatigue failure in plain bending, the crack origin being at the base of a damaged area of thread form. There was no evidence of weakness in the bolt material or of any defect in manufacture; there were, however, signs of thread distortion on the recovered part of the bolt tail end. The distortion was similar to that produced on a number of new, production, bolts during over-torque tests carried out after the accident, apart from differences in the profile of the loaded face of the thread form. However, it is probable that these differences were due to the effects on the failed bolt thread of in-flight loading during the course of the 70 hours' flying time in G–OEMA since the bolt was first inserted.

The maintenance organisation involved in the most recent hinge bolt change has stated that new nuts and bolts were fitted on that occasion. It would seem therefore, that the slight corrosion which had apparently occurred between two phases of crack growth must be attributable to a period of aircraft inactivity, possibly associated with wet or damp conditions; it is noted that the aircraft was standing idle for several such periods in early 1983, shortly before the accident.

The maintenance organisation has also stated that the subject nuts were tightened to the correct torque value. However, in view of the fact that

(i) new aileron hinge bolts and nuts were reported to have been fitted

(ii) there is no evidence that any further maintenance was undertaken on the hinge bolts up to the time of the accident

(iii) access to the aileron hinge bolt is restricted to the extent that the use of a conventional torque-measuring spanner is difficult, if not impossible,

the balance of the evidence suggests that the distortion of the thread on the subject bolt probably occurred as a result of a small degree of inadvertent overtorquing during this most recent bolt change.

When considering the failure sequence, the plane of failure on the bolt at a cross-section close to the plane of the nut pressure face is significant; this is because the plane of the nut pressure face would be expected to be the most likely site of failure under those conditions, it being here that the greatest number of adverse factors with respect to fatigue resistance are in operation, as explained below.

(i) Axial shear loading, applied, as in this case, to a bolt thread by a nut, is most intense in the plane close to the nut pressure face

(ii) stress concentrations always exist at the trough of a thread form, however uniform the loading throughout the nut

(iii) a thread root bending moment will be present which will exercise its maximum effect in this area

(iv) If the external loading applied to the nut is non-axial, then the bending moment induced in the bolt can only be applied through its surface region, i.e. the threaded area, where the adverse factors for direct loading already exist.

Assuming that the non-axial loading mentioned above had been applied in an oscillatory manner, then a means existed of cyclicly varying the stress in a region of the bolt threads that was already locally highly stressed.

As regards the origins of any such oscillatory loads, the presence of relatively high frequency lateral aileron vibrations was confirmed by the post-accident tests and is consistent with the metallurgists' findings that the crack growth involved a high number of cycles. Normal aerodynamic loading from control surface movements may have been a contributory factor.

In summary, it is concluded that a degree of over-torquing of the nut most probably induced a local region of higher than anticipated stress in the bolt threads which, together with the non-axial loading inherent in the hinge design and lateral vibration of the aileron, was sufficient to initiate a fatigue crack.

2.3 The subsequent hinge failure

Inspection of the remaining, serviceable, aileron hinge bracket lugs on G–OEMA shortly after the accident showed them to be retained in a state of inwards deflection by their respective nut and bolt assemblies. The likelihood must be that, when the subject bolt failed, the action of the deflected lugs in resuming their upright positions projected the bolt tail through the ¾ inch diameter hole in the aileron leading edge rib. The initial failure of the bolt was followed by the fatigue failure of the hinge bracket as a result of the re-distribution of loads throughout the hinge; by then only one lug was carrying the entire hinge load. The head of the bolt, together with the broken section of this lug, evidently fell away in flight.

Consideration was given to the possibility that the initial failure had occurred at the outboard lug, thereby precipitating the hinge bolt failure. This hypothesis infers that, following the outboard lug failure, but before bolt failure, relative motion occurred between the inner race and inner face of the inboard lug, in such a manner as to produce the asymetric damage around the hole. For such damage to occur, the bolt would have had to adopt a rocking action in the lug hole, leaving commensurate deformation of the hole. However, no such deformation was detected; moreover, the direction of fatigue crack propagation in the outboard lug was inconsistent with this failure sequence.

2.4 Remedial measures

During the course of the investigation it became clear that the manufacturer's instructions regarding the insertion of a relatively thick, .064 inch, washer under the head of each aileron bolt and nut, repectively, had been found in service experience to be impracticable when using the specified bolt. For instance, all the hinges on G–OEMA had been assembled with one, thinner .032 inch washer under each nut, and subsequent inquiries have shown this to be common practice amongst operators of Cessna 404 and 441 series aircraft.

It is also clear that, although the design of the hinge assembly is robust, it does contain elements that could contribute to crack propagation. For example, deflection of the hinge lugs imparts non-axial loads to the bolt through the nut. The provision of a longer hinge bolt, together with shims between the inside faces of the hinge lugs and the hinge bearing would prevent this lateral deflection of the lugs and thus the inducement of non-axial loading.

The associated nut, as presently in use, is a shear nut and, as such, will apply relatively low axial loads in comparison to the bolt's ultimate strength. In order to allow for a wider variation of torque levels, the substitution of a tension nut on a longer hinge bolt is desirable.

The manufacturer's recommended external visual inspection of the bolt and hinge is required every 200 hours and places emphasis on the security of the nut. Although the bolt failure occurred within the recommended 200 hour inspection period and there is apparently no record of a similar occurrence on other aircraft, inspection would not have revealed the thread damage which probably initiated the crack propagation.

3. Conclusions

(a) *Findings*

(i) The commander was properly licensed and sufficiently experienced to undertake the flight.

(ii) The commander slightly exceeded his maximum permissible flight duty time; however, this had no bearing on the accident.

(iii) The aircraft was properly certificated and, with the exception of the aileron hinge assemblies, was maintained in accordance with the manufacturer's recommendations.

(iv) The right aileron outer hinge bolt failed in fatigue, causing a fatigue failure of an associated lug.

(v) Lateral control of the aircraft was seriously impaired when the affected aileron pivoted and then jammed against the wing structure.

(vi) Initiation of the fatigue failure was most probably caused by a degree of overtorquing of the associated nut at the time that the bolt was last changed, coupled with non-axial loading, inherent in the hinge design, and lateral vibration of the aileron.

(vii) The commander displayed commendable skill and airmanship in regaining control of the aircraft and in carrying out a safe landing.

(viii) The manufacturer's service manual recommended a method of aileron hinge assembly, incorporating two washers, which was impracticable with the specified length of bolt.

(b) *Cause*

The accident was caused by the failure in fatigue of the right aileron outer hinge bolt, as a result of which control of the aircraft was seriously impaired. The fatigue failure was initiated by thread damage probably caused by overtorquing of the associated nut. Contributory factors were the restricted access to, and the design of, the aileron hinge assembly.

4. Safety Recommendations

It is recommended that, on Cessna 404 and 441 model aircraft:

4.1 All aileron hinge installations incorporate shims so that, when the aileron is assembled to the wing, lateral deflection of the hinge lugs is precluded.

4.2 A tension nut be used in conjunction with an appropriately longer hinge bolt for providing the clamping force across the hinge, and to allow for a greater variability in the levels of torque applied to the nut.

4.3 Consideration be given to replacing the aileron hinge bolts and nuts at periodic intervals.

C C Allen
Inspector of Accidents
Accidents Investigation Branch
Department of Transport

July 1984

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