Pitch control problems, BAe 146-200, G-JEAX, December 12, 2002

Micro-summary: **This BAe 146-200 experienced pitch control difficulties on climb.**

Event Date: **2002-12-12 at 1309 UTC**

Investigative Body: **Aircraft Accident Investigation Board (AAIB), Great Britain**

Investigative Body's Web Site: **http://www.aaib.dft.gov/uk/**

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S1/2003 - BAe 146-200, G-JEAX

AAIB Bulletin No: S1/2003	**Ref: EW/G2002/12/02**	**Category: 1.1**
Aircraft Type and Registration:	BAe 146-200, G-JEAX	
No & Type of Engines:	4 Lycoming ALF502R-5 turbofan engines	
Year of Manufacture:	1989	
Date & Time (UTC):	12 December 2002 at 1309 hrs	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 5	Passengers - 36
Injuries:	Crew - 2 Serious	Passengers - 1 Minor
	1 Minor	
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	37 years	
Commander's Flying Experience:	5,728 hours (of which 2,778 were on type)	
	Last 90 days - 51 hours	
	Last 28 days - 43 hours	
Information Source:	AAIB Field Investigation	

History of the flight

The aircraft had been parked overnight on the apron at Belfast City Airport. At 0200 hrs it was anti-iced with undiluted Type II+ fluid in preparation for a departure to Birmingham at 0655 hrs. At 0555 hrs the crew reported at Belfast City for a four sector duty, shuttling between Belfast and Birmingham.

The first three sectors proceeded without incident and the aircraft arrived at Birmingham, for the second time, at 1145 hrs. The synoptic situation at 1200 hrs showed high pressure centred over Norway with a light south-easterly flow over the route between Birmingham and Belfast. Frontal systems affected the southern half of the UK producing a mixture of rain and snow over the Midlands. This precipitation was falling from multiple layers of cloud, which had a base at about 1,000 feet. The UK Low Level Forecast for the route warned of severe icing in freezing rain and moderate icing in cloud.

The aircraft remained on stand at Birmingham for 55 minutes. During this time a mixture of rain, sleet and snow fell. The commander and co-pilot discussed the need to de-ice the aircraft, but decided that the snow was not settling on the airframe and that it would not be necessary. The aircraft pushed back off stand at 1240 hrs. During the full and free check of the controls, prior to takeoff, the control column was held fully back for about 25 seconds to allow any excess water to drain from the elevator. This was in accordance with standard operating procedures.

The aircraft took off at 1252 hrs and followed the Whitegate 3E Standard Instrument Departure. The commander flew the aircraft manually until it had reached approximately 3,000 feet, when he engaged

the autopilot. ATC instructions enabled the crew to maintain a continuous climb. The crew activated the aircraft's anti-ice systems as appropriate but were not aware of any significant accumulations of ice during the flight. The aircraft cleared the tops of the clouds at about 18,000 feet.

During the climb, the flight crew noticed that the aircraft was oscillating in pitch more than was customary. Minor pitch oscillations with the autopilot engaged are not an unusual feature of the aircraft type but the oscillations were unusually pronounced on this sector. The autopilot remained engaged for significant portions of the climb but the level-off at FL 240 was flown manually. Shortly after establishing level flight, the autopilot was re-engaged but the aircraft began to oscillate in pitch and diverge from its assigned flight level. The commander disengaged the autopilot and was immediately aware of a strong pitch-up tendency. He applied an increasing forward pressure on the control column and supplemented this with electric elevator trim in the nose-down sense. At FL 242 the aircraft was reported to have pitched down at a marked rate. Having pitched to below the straight and level attitude, the commander then tried to counter this with a progressive rearwards force on the controls. He described the feel of the control forces as very heavy but did not regard the controls as jammed. Unable to arrest the aircraft's rate of descent, the commander instructed the co-pilot to assist him on the control column. They both pulled back with considerable force. The control column suddenly moved aft, the aircraft pitched up and the flight crew felt a violent shudder through the whole airframe that lasted for two or three seconds. After this, the crew stated that the control forces returned to normal and they were able to level the aircraft at FL 240.

During the pitching manoeuvres, two of the three cabin crew had fallen in the cabin aisle. One of them had sustained a broken leg and the other had a suspected sprained ankle. This latter injury was subsequently diagnosed as a fracture. The third cabin attendant and a passenger, who were both seated, had suffered minor head injuries. Two doctors, who were among the passengers, attended the cabin attendant with the broken leg.

The crew transmitted a PAN call, requesting gentle turns and a continuous shallow descent. Control of the aircraft was handed to the co-pilot while the commander managed the aftermath of the event. At 10 nm on final approach to Belfast City Airport the commander resumed control of the aircraft. The landing on Runway 04 was completed without further incident and the aircraft was met by the Emergency Services.

From the time that the crew felt the control forces return to normal at FL 240 the aircraft had been flown manually. Both pilots described the control forces and aircraft response as normal for the remainder of the flight.

Flight Recorders

Cockpit Voice Recorder

The aircraft was fitted with an A100 Cockpit Voice Recorder (CVR) which recorded the commander's, co-pilot's and cockpit area microphones on a continuous 30 minute loop when electrical power was applied. Unfortunately, the incident had been over-written by the time the aircraft had been shut down at Belfast. It was noted that there was a significant 400Hz breakthrough on the area microphone channel, which rendered the output difficult to decipher.

Flight Data Recorder

The aircraft was fitted with a Plessey 1584 Flight Data Recorder (FDR) which recorded about 60 parameters on a 25 hour continuous loop. All of the data was recovered from the FDR, although there were data dropouts throughout the recording. Nevertheless, it was possible to extract all the relevant parameters at the time of the incident.

Information extracted from the Flight Data Recorder

A time history of relevant parameters during the climb to FL 240 is shown in Figure 1. From Fig 1 it can be seen that, with the autopilot engaged, the elevator trim started to provide inputs to the pitch control system on a 12 to 15 second cycle at about FL 90. The elevators appeared to respond correctly to the applied trim, and the aircraft also responded in the conventional sense, describing a 'phugoid' motion also of period 12 to 15 seconds. The Total Air Temperature (TAT) at which the trim started to operate was about +1°C which equates to an Outside Air Temperature (OAT) of about minus 8° C. The cyclic trim inputs appeared to occur in those climb phases where the autopilot was engaged, but not when the autopilot was disengaged.

A time history of the manoeuvres which caused the accident is shown in Figure 2 The data show that a nose-down trim input was made about two seconds after the autopilot was disconnected, and that the aircraft responded by decreasing the pitch attitude, accompanied by a decrease in the vertical acceleration to about 0.4g. This indicates that the elevators responded in the correct sense to the elevator trim, which in turn indicates that the elevators were free to move. It can also be seen that the elevators moved rapidly to about 7° in the aircraft nose-up sense about 10.5 seconds after the autopilot was disengaged. The aircraft appears to have responded to the elevator movement by increasing the pitch attitude, and by the normal acceleration increasing to a maximum value of about + 3g. Subsequently the aircraft described an oscillatory motion in pitch, with a period of about 1.5 seconds. Straight and level flight was restored about 22 seconds after the autopilot was disengaged. The aircraft was flown manually for the remainder of the sector and the elevator trim remained at the position selected when the autopilot was disengaged for several minutes before it was altered by the pilots.

Elevator control system

The BAe 146 elevator control system is comprised of two independent mechanical circuits which use a series of cables, rods and levers to operate the left and right elevators via servo tabs. The control columns (and hence the left and right elevator circuits) are interconnected through a breakout mechanism, which allows control of one elevator to be retained in the event of a jam in the other elevator circuit. The mechanical inputs to the servo tabs are transmitted through torsion bars which prevent overstressing, by allowing the tabs to blow back if the load on the torsion bar reaches a set value. When the input force reaches this value, the torsion bar contacts its stops and the control column then moves the elevator directly.

The autopilot controls the aircraft in pitch via the pitch servomotor, which is connected to the input linkages to the left hand elevator servo tab. The servomotor operates the right hand elevator servo tab by back-driving the right hand elevator circuit via the interconnected control columns and the left elevator circuit.

Automatic pitch trimming is provided whenever the autopilot is engaged, to relieve any steady load being held by the pitch servomotor and to ensure that the pitch axis of the aircraft is in trim when the autopilot is disengaged. The autotrim servomotor signals are derived from the pitch servomotor control voltages. In the event of the trim servomotor failing to trim when required, or trimming in the wrong direction, monitoring systems will illuminate an amber 'EL TRIM' legend on the pilots' instrument panel to annunciate a trim malfunction.

Preliminary engineering examination

The aircraft was inspected by the AAIB at Belfast City Airport on the morning after the incident. A visual inspection of the elevator control runs did not highlight any defects and no evidence was found of any foreign objects having interfered with the control system. Functional checks of the elevators and autopilot system on the ground were normal.

A number of previous incidents of pitch control problems on servo tab controlled aircraft were attributed to the accumulation of de-icing fluid residues in the gaps between the servo tabs and the elevators, which can subsequently freeze in flight causing the elevators to become very stiff or jam.

On inspecting the elevators, drops of de-icing fluid were found on various components, including the left-hand elevator trim jack and the right hand elevator gust damper. A thin layer of dried de-icing fluid residue was found in the gaps between the elevators and the servo tabs. When sprayed with a water mist, the residues re-hydrated to form a very thin layer of gel. The refractive index of the gel was measured to be 1.377, which corresponds approximately to that of a 75% Type II de-icing fluid mixture, which should theoretically freeze at around minus 21 ?C. A sample of the residue was placed in a freezer at minus 18 ?C for 30 minutes, after which it had not frozen. Given the very small quantities of residue found and its low freezing point, it is not immediately clear what effect, if any, the residues might have had. Given the weather conditions at the time, the elevator control difficulties might have been caused by natural icing.

During examination of the elevators, it was noted that the bearings in the rod ends which attach to the servo tabs did not show any external evidence of grease. These are sealed and are not designed to be re-greased, relying on the integrity of the grease seals to ensure grease retention. On removal, the bearings were found to be very stiff in operation. The grease seals were in good condition, but on disassembly the bearings were found to contain a dried, almost powdery residue which provided no lubrication properties and the bearing cage was completely devoid of grease. This raises concerns that moisture ingress into the bearing cage void could cause the bearing to seize as the moisture freezes in flight. It is believed that these bearings had been on the aircraft since it was built.

Further work

The AAIB and representatives from the aircraft manufacturer jointly assessed the recorded flight data. Initial analysis of this data showed symptoms of increased stiffness in the elevator servo tabs, possibly due to freezing of the tabs to the elevators' trailing edges.

At this time, there is insufficient evidence to reach specific conclusions on the cause of the stiffness but the investigation will examine the possibility of natural airframe icing, the effects of de-icing fluid residues and the implications of component failures within the pitch control system.

The applicability and suitability of the advice available to flight crew for recognising and dealing with autopilot pitch oscillations, abnormal pitch control forces and ineffective pitch controls will also be examined. The aircraft manufacturer has agreed to provide advice to pilots as matter of priority.