BAe 146-300, G-BSNS

AAIB Bulletin No: 7/2000 Ref: EW/G99/07/21 Category: 1.1

Aircraft Type and Registration:	BAe 146-300, G-BSNS
No & Type of Engines:	4 Lycoming ALF 502-R5 turbofan engines
Year of Manufacture:	1990
Date & Time (UTC):	13 July 1999 at 1718 hrs
Location:	Stansted Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 5 - Passengers - 103
Injuries:	Crew - None - Passengers - None
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	7,064 hours (of which 3,958 were on type)
	Last 90 days - 97 hours
	Last 28 days - 30 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and investigation by the aircraft manufacturer

In flight incident

During a flight from Stansted to Edinburgh and as the aircraft was in a gentle climbing right turn passing through Flight Level (FL) 120 onto a radar heading, it suddenly yawed violently to the right. Coincident with this yaw and the accompanying roll to the right the yaw damper disengaged, immediately followed by autopilot disengagement. The aircraft continued to roll to the right until the commander managed to arrest the roll at a reported 50° bank angle. After the commander had regained level flight, the aircraft handled normally with the yaw damper and autopilot disconnected. The lateral disturbance had been sufficient to cause a cabin trolley in the aisle to tip against one of the seats, and for the meal trays to slide off the passenger tables. The commander decided to return to Stansted and used gentle bank angles throughout the remainder of the flight until the aircraft landed normally.

Operator's investigation

The subsequent investigative work conducted by the operator placed particular emphasis on the yaw damper system and autopilot, both of which were tested satisfactorily. The aileron control circuit cable tensions and the left spoiler deployment angles were found to be outside limits, and these were adjusted accordingly. Finally, the left spoiler actuator was found to be leaking, and this was also replaced. Following a satisfactory flight test, the aircraft was returned to service on 17 July.

Flight data recorder information assessment

Since the above work had not been considered to have identified the cause of the incident, the aircraft manufacturer conducted an analysis of the Flight Data Recorder (FDR) data. This showed that the aircraft had been passing 10,500 feet at an indicated airspeed of 275 kt, with the yaw damper and autopilot engaged, when a 20° right turn was selected (from 300° to 320°) following which the aircraft achieved a 28° bank angle to the right. At this point, a 1.5° rudder 'step input' to the left occurred, resulting in immediate yaw damper disconnect, together with a lateral acceleration of about 0.1g. The autopilot initially remained engaged, applying corrective aileron to achieve the selected heading. (Note: the autopilot does not operate the rudder). Approximately 6 seconds after the yaw damper disconnected the autopilot also disconnected, probably due to roll rate exceedance. The pilot then applied a succession of aileron and rudder inputs over approximately 30 seconds, during which lateral accelerations of more than 0.2g were recorded. There followed two short autopilot re-engagements before the aircraft was manually flown back to Stansted. A plot of the relevant FDR data is shown at Figure 1.

Yaw damper system description

The purpose of a yaw damper system is to prevent Dutch roll and to provide turn co-ordination. The BAe 146 has two yaw damper channels, the central component of each being a yaw computer signalling individual yaw damper actuators. Each actuator has a maximum ±2° rudder authority, the output of each being mechanically summed in the fin downstream of the rudder pedal and trim input points, such that the total yaw damper rudder authority is ±4°. A comparator at the summation point continuously monitors the two channels. If a difference of 1.5° or more occurs, the comparator immediately applies the yaw damper brake and isolates both channels.

Each yaw computer receives dedicated sensor inputs from a yaw rate gyro, a lateral accelerometer and a vertical reference unit (VRU). The latter contains a gyroscope, with the primary output driving its associated attitude direction indicator (ADI). Thus VRU No 1 drives ADI No 1 (ie the commander's ADI) and VRU No 2 drives ADI No 2. Secondary outputs are also generated within each VRU which are buffered by isolating amplifiers (and hence cannot be fed back into the primary signal). The secondary output of VRU No 1 provides roll attitude signals to the No 1 yaw damper computer, the autopilot and the FDR. The secondary output of VRU No 2 is fed to the No 2 yaw damper computer only.

Subsequent investigation by the aircraft manufacturer

The VRUs in this type of aircraft are derivatives of those used on other aircraft such as the Boeing 737-100/200 series. According to British Aerospace, worn gyro bearings in these VRUs have been known to cause pitch and roll computational errors in manoeuvring flight. Accordingly, both VRUs were returned to the component manufacturers for inspection and test. VRU No 1 was found to have worn rotor (gyro) bearings and VRU No 2 showed signs of fluid contamination on the secondary output circuit board. Since the FDR roll attitude data appeared normal, this indicated that the secondary output roll attitude signals generated by VRU No 1 had been satisfactory. It was therefore concluded that VRU No 2 had been the source of incorrect secondary output roll attitude signals to the No 2 yaw damper computer, which induced the 'step input' to the rudder and consequent yaw damper disconnect.

The FDR data was used to compare the response of the aircraft manufacturer's design simulator against that of the aircraft. A rudder step input of 1.5° was applied to the simulator under identical circumstances to those experienced by the aircraft. A good correlation between simulator and aircraft bank angle, heading change, pitch attitude, lateral and normal 'g' was achieved.

The manufacturer also commented that, following the yaw damper disconnect, the observed application of aileron and rudder would have tended to temporarily aggravate the Dutch roll, since the inputs appeared more than the minimum required to regain level flight. However, optimum crew reaction to yaw damper failure is difficult to achieve in practice since related simulator training provides poor representation of Dutch roll affects because of the inability of simulators to accurately replicate lateral accelerations.

Safety action by the aircraft manufacturer

The aircraft manufacturer has experienced previous instances of fluid contamination of VRUs. Although the contaminant was not identified in this case, the VRUs are installed in the avionics bay which is located below the forward galley and toilet. A protective membrane is installed above the avionics bay, however if this becomes damaged, or a leak occurs in the galley or toilet drains, it is possible that fluids can leak into the avionics bay.

Service Bulletin, SB 25-236-01143A Revision 2, of 31 March 1993, details the installation of a protective splash cover on the VRUs. This modification had not been embodied on this aircraft prior to this incident, but it has subsequently been incorporated. In addition, as a result of this incident the aircraft manufacturer issued Service Information Letter SIL 25/23 in January 2000, reminding operators of the availability of this Service Bulletin.