Avro 146-RJ85, D-AVRO

AAIB Bulletin No: 3/2003	**Ref: EW/G2001/10/08**	**Category: 1.1**
INCIDENT		
Aircraft Type and Registration:	Avro 146-RJ85, D-AVRO	
No & Type of Engines:	4 Lycoming LF507-1 turbofan engines	
Year of Manufacture:	1994	
Date & Time (UTC):	15 October 2001 at 1820 hrs	
Location:	North of London City Airport	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 5	Passengers - 65
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilots Licence	
Commander's Age:	45 years	
Commander's Flying Experience:	10,000 hours (of which 4,300 were on type)	
	Last 90 days - 142 hours	
	Last 28 days - 53 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further inquiries by the AAIB.	

At 1800 hrs, the aircraft commenced its taxi for departure from London City Airport for a scheduled flight to Frankfurt. During taxi, the commander reported that a YD (Yaw Damper) FAIL light illuminated. He consulted the aircrafts Minimum Equipment List (MEL) which noted that the aircraft could be dispatched with the yaw damper inoperative, provided that the Indicated Air Speed (IAS) was restricted to a maximum of 240 kt.

After takeoff, while in level flight at 3,000 feet, the aircraft was completing its first right turn when the crew noticed a yawing and rolling tendency to the right. The first officer, who was the handling pilot, disconnected the autopilot and reported to the commander that he was having difficulty in maintaining heading. The commander took control and found the same problem. He noted that the

rudder pedals appeared to be restricted in movement to the left. Left aileron was required to maintain a wings-level attitude, such that the aircraft was flying with left sideslip. The commander reported that he made one attempt to use the rudder trim, but there was no apparent improvement in the sideslip condition.

The crew declared an emergency with ATC and requested radar vectoring towards the nearest airport. They were given radar vectors towards London Stansted Airport and, after briefing the cabin crew on the situation, made an uneventful ILS approach to land on Runway 23.

The commander reported that, while on short finals at about 300 feet, the rudder restriction seemed to disappear, although there was still some yawing and rolling tendency present.

Description of the Yaw Control System

The aircraft is equipped with a conventional, hydraulically powered, rudder system. It is fitted with a single Yaw Damper (YD) system, intended to provide turn coordination and to suppress any tendency for the aircraft to Dutch Roll. In the case of D-AVRO, YD authority was limited to ?2.9° of rudder movement, which was approximately 10% of the total available rudder deflection. The YD system can be switched ON or OFF by the crew. If a YD failure is detected internally, the system is inhibited by the automatic application of the YD actuator brake, but the use of rudder pedals and rudder trim are unaffected.

A component, referred to as the Q-pot, senses pitot-static pressure and progressively restricts the maximum available rudder travel as airspeed increases. It is effectively a stepped cam device which, as it extends with increasing airspeed, moves between two claws linked to the rudder pedals (see Figure 1 *(jpg 70kb)*). At higher speeds, the larger diameters of the cam steps progressively restrict the amount of movement of the claws and thus restrict the rudder pedal travel.

Engineering actions

After landing, the aircraft was inspected by a maintenance contractor at London Stansted Airport.

It was noted that the rudder was deflected about 2° to 3° to the right, with the trim set to neutral and hydraulic power applied. The Digital Flight Guidance System (DFGC) was interrogated for possible fault indications. It was found to contain a fault message, logged at 1811 hrs on 15 October 2001, which indicated that a Yaw Damper failure had been detected, due to a disparity in synchronisation, on the ground at zero airspeed and altitude.

A YD serviceability test was carried out, which resulted at first in a FAIL, but a second test was PASSED. It was noted that, after the latter, the rudder had returned to neutral. It was concluded that the YD actuator servo had an intermittent fault, so it was replaced.

The YD actuator servo was sent to the manufacturer for testing and repair. Their report indicated that, although the unit met functionality requirements, there was a build-up of Carbon from the worn motor brushes. This was causing a short to earth of the motor and tachometer outputs, which could signal application of the Yaw Damper servo brake. Information from the airline and the YD manufacturer suggested that this condition was a common phenomenon. The YD actuator servo is currently an on condition item. As such, it is not required to undergo periodic inspection or overhaul. The AAIB therefore makes the Safety Recommendation shown at the end of this report.

During inspection of the aircraft systems, it was also noted that the Q-pot was out of adjustment. The engineers report did not note to what extent but, after adjustment to be within the Maintenance Manual tolerances, the aircraft was released to service and performed normally.

Analysis

Unfortunately, the operator had not made arrangements to download the Flight Data Recorder (FDR) data before the aircraft was returned to service, so no data was available for this investigation. This deprived the investigation of conclusive evidence as to the sequence of events. However, the following scenario, commencing with the YD failure on the ground, accords with the available evidence.

YD failures detected by the aircraft system will effectively lock the YD actuator, and hence the rudder position, at the offset angle adopted at the moment of failure. This could be anywhere in the range ?2.9°, as yaw damper activity is frequently excited by lateral accelerations during taxying. The effect of any rudder offset would have become more pronounced as speed increased during flight and a yaw/roll couple would have been experienced, with a tendency for the aircraft to roll in the direction of the residual rudder deflection. The autopilot, which does not have an input to the rudder system, would have compensated for the uncommanded roll by application of opposite aileron, which would have resulted in flight with crossed controls and the aircraft sideslipping.

After disconnection of the autopilot, the crew tried to correct the sideslip/rolling tendency by application of left rudder but found the pedals blocked and the rudder trim apparently ineffective.

The mis-rigged Q-pot was probably responsible for the apparent restriction in the rudder pedal movement, if it is assumed that the cam was too deeply inserted in the claws (Figure 1). Such a condition would result in a restricted rudder pedal movement, which would be equivalent to the restriction applicable at a significantly higher airspeed than the aircrafts actual airspeed at the time. This would also explain why the restriction cleared during the final stages of the approach to London Stansted, as the speed was reduced and also why it had not been apparent during the pre-flight rudder control check.

The fact that rudder pedal inputs are seldom required at higher airspeeds, except in the case of an engine failure, implies that such a mis-rigged Q-pot could remain undetected for some period of time.

The crews reference to the MEL during taxi was in accordance with the operators standard procedures at the discretion of the commander. The MEL indicated that dispatch with the Yaw Damper system inoperative was permissible, provided that the Yaw Damper master switch was selected OFF and the indicated airspeed was limited to a maximum of 240 kt. Autopilot and autothrottle would remain available for use under such circumstances.

The manufacturer has indicated that it will review the advice to crews contained in the Manufacturers Master MEL, and the QRH, with regard to Yaw Damper failures, noting the possible requirement for the application of rudder trim after takeoff.

Safety Recommendation 2003-16

It is recommended that BAe Systems consider introducing either a periodic inspection regime or a specific time between overhaul period on all Yaw Damper Actuator servo motors fitted to BAe146/Avro RJ series aircraft.