Embraer EMB-145EP, G-RJXA

AAIB Bulletin No: 5/2002	**Ref: EW/C2001/09/01**	**Category: 1.1**
INCIDENT		
Aircraft Type and Registration:	Embraer EMB-145EP, G-RJXA	
No & Type of Engines:	2 Allison AE3007A turbofan engines	
Year of Manufacture:	1999	
Date & Time (UTC):	6 September 2001 at 0542 hrs	
Location:	Near Glasgow Airport	
Type of Flight:	Scheduled Public Transport	
Persons on Board:	Crew - 4	Passengers - 23
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Melted starter turbine blades, melted vent panel on underside of engine nacelle plus scorching to electrical and mechanical engine components	
Commander's Licence:	Airline Transport Pilots Licence	
Commander's Age:	34 years	
Commander's Flying Experience:	4,450 hours (of which 123 were on type)	
	Last 90 days - 123 hours	
	Last 28 days - 47 hours	
Information Source:	AAIB Field Investigation	

History of flight

The crew and aircraft were assigned to operate an 0545 hrs scheduled flight from Glasgow to Manchester. The weather was fine with a light wind from the west, good visibility, air temperature 12°C and QNH 1016 HPa. In accordance with company standard procedures, the commander started the engines using bleed air from the APU. Engine start is automatically controlled by the appropriate FADEC (Full Authority Digital Engine Control unit). Having selected the engine start selector to START momentarily and then to RUN, the pilots are required only to monitor the engine indications on the EICAS (Engine Indicating and Crew Alerting System) screen in the centre of the instrument panel. All of the engine indications were normal during both starts and the

subsequent taxiing for a departure from Runway 23. On the runway the commander handed control to the co-pilot for take off. Both engines achieved the required N1 during the take-off ground roll and the after take-off checks were completed without incident. Climb thrust rating and a target speed of 220 KIAS were selected for the New Galloway 1H Standard Instrument Departure climbing to 6,000 feet. About 105 seconds after the application of ALT T/O-1 thrust (an alternative take-off thrust setting that is less than maximum thrust) whilst climbing through 2,500 feet the fire warning tone sounded and the Master Warning caption illuminated. At the time the co-pilot was hand-flying the aircraft whilst the commander was transmitting a routine message to ATC. The co-pilot announced, "Engine Fire No 1", retained control of the aircraft and took over responsibility for radio communication whilst the commander carried out the vital actions. The commander confirmed the warning before operating the left engine fire handle and discharging the first fire extinguisher shot. The fire warning indication ceased almost as soon as the shot was discharged. At about the same time, the co-pilot acknowledged ATC instructions to turn left onto 150° and to climb to FL 110. The aircraft was in VMC conditions and so he accepted the turn but asked for an amended clearance to stop the climb at 6,000 feet which was granted.

The commander summoned the senior flight attendant to the flight deck and briefed her for the rapid return to Glasgow. At the end of that briefing the co-pilot declared an emergency using the MAYDAY prefix asking for radar vectors for a return to the airport and he informed the controller that they would need time to complete checks. The two pilots then reviewed their actions against the QRH drill for engine fire and began preparing and briefing for a single-engined ILS approach to Runway 23. Meanwhile the cabin crew prepared the cabin. Since there were no passengers seated beside the over-wing exits, they re-located two company staff to seats beside those exits and briefed them on their use. The flight attendants were unable to see much of the left engine from the cabin windows but neither attendant had heard or seen any abnormality at the rear of the cabin.

On handover from Scottish Centre to Glasgow radar, the pilots were invited to state at what range they wished to intercept the ILS centreline. They opted for 10 nm finals which they later extended to 12 nm to give themselves more time to complete their preparations. The commander briefed the passengers using the cabin public address system and advised them that after a normal landing, the aircraft would be met and inspected by the emergency services before it could be taxied to the Terminal. At 17 track miles from touchdown the commander took control from the co-pilot and engaged the autopilot whilst the co-pilot swiftly reviewed their actions thus far. Next the co-pilot contacted the company operations room to advise them that they were returning. With all the preparations for landing completed, the co-pilot monitored the flight instruments whilst the commander flew the approach with the autopilot disengaged. The runway was visible from about 10 nm finals and an uneventful flaps 22 landing ensued. After confirmation from the fire service on 121.6 MHz that there were no signs of fire, the commander taxied the aircraft back to the Terminal where the passengers disembarked normally.

Description of air turbine start system

The pneumatic engine starting system utilises an Air Turbine Starter (ATS) mounted on the rear of the engine accessory gearbox. Air can be supplied from the APU, a ground air supply or from the other engine via the cross bleed. During engine start, the electrically operated Start Control valve (SCV) is opened, under FADEC control, thus allowing air to the ATS. The pneumatic energy is converted to driving torque, which rotates the gas generator part of the engine. When N2 reaches 56.4% the FADEC signals the SCV to close (in fact it is spring-loaded to the closed position). An amber caution message on the EICAS screen indicates the open status of the SCV above 53% N2 and this will remain on if the valve fails to close.

The ATS consists of an axial turbine driving an 8.4:1 ratio planetary reduction gear assembly, the output shaft of which is waisted so that it will shear in the event of a mechanical jam, see Figure 1 *(jpg 168kb)*. The unit has an integral, 350 cc capacity oil reservoir. After the air has passed through the turbine, it is discharged via an annular exhaust in the casing into the engine compartment. When the engine is self-sustaining and the SCV has closed, a sprag clutch in the ATS gearbox allows it to disengage, thus preventing it from being back-driven by the engine. Apart from the EICAS indication of SCV operation, there is no instrumentation of the ATS and no warning on the flight deck that it is being back-driven by the engine. In fact, this part of the powerplant indication system is similar to those on other modern jet aircraft, and complies with JAR 25.1305(c)(4).

Examination of aircraft

The only external sign of damage was on a vent panel on the underside of the nacelle. The vent was in close proximity to the ATS exhaust and the honeycomb material in the panel had burned away. Inside the engine compartment, some of the components close to the ATS were scorched in appearance, with some minor heat damage to the carbon fibre bypass duct. A cable loom associated with the FADEC also appeared scorched, although this had not been severe enough to melt the cable insulation.

The ATS casing was blackened and had been subjected to heat sufficiently intense to melt the adhesive that had attached the data plate. The latter had fallen off and was not recovered. A metal grill covered the annular exhaust in the casing and visible behind it were the solidified molten remains of the turbine blades.

The SCV had a mechanical position indicator on its casing and this showed the valve to be in the closed position. When electrical power was applied to the system and the FADEC was selected to a maintenance mode, it was possible to check and confirm the correct EICAS indication by using a spanner to physically hold the valve open against its spring pressure. This test eliminated the possibility of the SCV failing to close after engine start without the crew receiving an appropriate warning. During the subsequent removal of the engine accessories, it was confirmed that the butterfly was securely attached to the valve spindle. It was thus concluded that neither the SCV nor the indicating system had contributed to the incident.

The ATS was removed from the engine by undoing the QAD (Quick Attach/Disconnect); essentially this was a V-shaped band that clamped the ATS mounting flange to the associated pad on the engine accessory gearbox. It was observed that the output shaft had not sheared and that it could not be rotated by hand. Removal of the oil filler plug revealed only a sticky black residue in the reservoir, and it was surmised that the bulk of the oil had been consumed in the fire. In support of this, when the turbine cover was subsequently removed, it was found that the internal casing had fractured, allowing oil through to the turbine area, the exhaust of which had been sprayed with aluminium alloy from the melting blades. The magnetic plug in the gear section of the ATS was heavily contaminated with metallic debris.

The specialised tooling necessary to disassemble the ATS in an appropriate manner was not available in the UK. Accordingly, it was shipped to the manufacturer's facility in Phoenix, USA for a strip examination. This particular component was fitted to the aircraft at build and had achieved 3,985 flying hours and 4,372 cycles, more than any other in the operator's Embraer fleet.

ATS history

The same type of ATS is fitted to Embraer 135/145, Cessna Citation X and Saab 2000 aircraft. The ATS manufacturer has reported eight occurrences since January 2000 involving the unit and/or its interface with the engine, the common theme being the failure of the ATS to disengage after engine start. Three of these 'back drive events' have resulted in fires. No incidents were recorded involving Citation X aircraft; it is possible that this reflects the lower utilisation of corporate aircraft.

In June 2000, Embraer issued Service Bulletin (SB) 145-80-0001, which introduced a shorter ATS output shaft. This was necessary due to a misquoted dimension between the ATS and engine manufacturers during the design process, resulting in the shaft being slightly too long. The interference so caused was judged to impose axial loads on the shaft that in turn had a detrimental effect on the ATS planetary gear system. Embraer also issued SB145-80-0004 in May 2001; this introduced a plug within the hollow shear section of the engine gearbox end of the shaft, thus preventing the loss of engine oil in the event of a shear. After issue, both Service Bulletins were incorporated on new-build aircraft. On 13 July 2001, the Brazilian Airworthiness Authority issued NPRM (Notice of Proposed Rule-Making) AD (Airworthiness Directive) 2001-145-02, which conferred mandatory status on SB 145-80-0004. This NPRM procedure is a copy of the FAA (Federal Aviation Administration) system, which allows industry to comment on the airworthiness authority's proposals. At the time of the incident to G-RJXA, the NPRM process was incomplete and so SB 145-80-0004 had not yet been mandated by the UK CAA.

The ATS removed from G-RJXA was pre-SB 145-80-0001, although the operator's Modification Committee had already decided to embody the latest ATS version (P/N 3505910-5) across its fleet.

Examination of the ATS

A report of the strip examination conducted at the manufacturer's facility in Phoenix was forwarded to the operator and to the AAIB. The proceedings had been observed by an official from the local FAA office and he had concurred with the findings.

It was concluded that the failure occurred when the overrun bearings within the clutch seized as a result of operation with excessive axial load. The latter arose from shaft interference; evidence of this was apparent in the form of witness marks on the output shaft. This was in line with previous, similar failures on units fitted with pre-SB 145-80-0001 shafts. The high speed of the back drive produced high temperatures within the starter, causing failure of one or more rotating components, including the turbine seal. The high temperature caused vaporisation of the oil in the starter, with the vapour then being forced out of the exhaust vent and the turbine seal. Ignition of the vapour would have occurred when the temperature of the starter external case became sufficiently high.

Related issues

A search of the CAA's Mandatory Occurrence Report (MOR) database, dating back to January 1976, revealed 72 incidents (in addition to those detailed above) involving failures or malfunctions during the engine start process on Public Transport Category aircraft. Most of these were not relevant to the subject investigation. Of the remainder, about 18 involved starter failures, with about 6 of these possibly being related to start valve malfunctions. As with any database, the lack of detail made comparison difficult; however, it was apparent that the ATS fitted to Embraer 135/145 was experiencing a relatively high rate of defects. Whilst an improvement may be anticipated following the embodiment of SB 145-80-0004, some of the failures occurred to post-

modification output shafts. The ATS manufacturer stated that; "To minimise the catastrophic failures and associated collateral damage due to back drive events, [the manufacturer] is pursuing an output shaft design that incorporates a decoupler".

Cockpit voice recorder

When the CVR was replayed following the incident, it was found that the area microphone had not been working. A loose wire was subsequently found to this unit, which was located in close proximity to the windscreen. It was concluded that it had become disconnected during a windscreen change that had been carried out approximately two weeks prior to the incident. The Aircraft Maintenance Manual (AMM) did not require a CVR function test following a windscreen change. However, pending a revision to the AMM, the operator has instigated such a test following a windscreen change.

Summary

The engine fire indications were genuine and well handled by the entire crew. The Air Turbine Starter (ATS) had failed when the overrun bearings within the clutch seized as a result of operation with excessive axial load. The heat generated was sufficient to vaporise and ignite the ATS lubricating oil. The ATS fitted to G-RJXA was of a standard no longer fitted to production aircraft. At the time of the incident, the aircraft operator had already decided to replace any older standard ATS within its fleet and the modification will be mandated by the UK CAA. Consequently, no AAIB recommendations were made.