Embraer EMB -145, G-EMBP, 2 March 2001 at 1745 hrs

AAIB Bulletin No: 8/2002	**Ref: EW/C2001/3/2**	**Category: 1.1**
Aircraft Type and Registration:	Embraer EMB -145, G-EMBP	
No & Type of Engines:	2 Allison AE3007/A1/1 turbojet engines	
Year of Manufacture:	2000	
Date & Time (UTC):	2 March 2001 at 1745 hrs	
Location:	Runway 24 at Edinburgh Airport	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 4	Passengers - 41
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Fracture of nose landing gear axle	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	41 years	
Commander's Flying Experience:	6,800 hours (of which 1,460 hours were on type)	
	Last 90 days - 172 hours	
	Last 28 days - 63 hours	
Information Source:	AAIB Field Investigation	

History of flight

The crew was rostered for four sectors to operate between Edinburgh and Paris, Charles de Gaulle Airport. There were no unserviceabilities in the Technical Log and the previous commander informed the oncoming commander that the aircraft appeared fully serviceable. The aircraft flew on the first sector, with the first officer as the handling pilot, and landed on Runway 09 at Paris without incident. The runway was dry, the surface wind was 130°/10 to 17 kt. The commander described the landing as good.

At the end of the next sector, the commander, as handling pilot, established the aircraft on a visual approach for Runway 24 at Edinburgh. The weather was CAVOK with a surface wind of 130°/06 kt and the runway was dry. By 1,200 feet agl, the crew had fully established the aircraft for landing with an approach speed of 136 kt IAS (Vref had been calculated as 131 kt). Touchdown was made on the main landing gear and the commander gently lowered the nose gear to the runway. As the nose gear touched the runway, both pilots were aware of an "audible high speed noise". The commander considered that it was possibly a burst tyre even though there was no vibration. The

noise decreased as the ground speed reduced. The commander brought the aircraft to a halt on the runway and the first officer informed ATC asking for the AFS to visually check the aircraft for a suspected burst tyre. When the AFS arrived, the fire chief established communication with the commander on 121.6 MHz and informed him that the left nose wheel appeared to be more deflated than the right. The commander decided to ask for a company engineer to check the tyre and the first officer transmitted this request to ATC. As they waited for the engineer, the crew shut down both engines. When the engineer arrived, he established communication with the commander on intercom and assessed the situation. He then asked the commander to taxi the aircraft forward about 10 feet so that he could listen for the reported noise. The commander started the right engine, released the parking brake and, with ATC approval, slowly increased engine power. The aircraft started to move and as it did so it turned to the left. The commander stopped the aircraft and realised that the electric hydraulic pumps were still off (following the engine shutdown). Once he had reselected the pumps 'ON', he again slowly increased power. As the aircraft started to move, there was a loud 'bang' and the aircraft moved to the left. The engineer informed the commander that the left nosewheel had fallen off. ATC was informed and the passengers deplaned normally before the aircraft was towed clear of the runway.

The commander subsequently confirmed that there had been no unusual indications associated with the landing gear and no nosewheel 'shimmy'. The runway was declared closed by ATC at 1742 hrs and an inspection revealed no FOD on the runway apart from debris associated with the nosewheel. The runway was declared open at 1832 hrs

DFDR information

The cockpit voice recorder (CVR) and the flight data recorder (FDR) were removed from the aircraft and replayed. The CVR recording was consistent with an uneventful flight and landing. A number of anomalies were identified in the recorded FDR data. As a consequence the FDR data was considered unreliable and not used in the investigation.

The recording anomalies were reported to the operator and flight data recordings from other Embraer 145 aircraft were examined. All the recordings exhibited the same anomalies. Recommendations concerning the recording anomalies are published in AAIB Bulletin 5/2002.

Component Description

The aircraft has a conventional tricycle landing gear. On the nose landing gear, twin wheels are carried on a fixed, hollow axle mounted at the base of a sliding tube forming the lower part of the oleo (Figure 1 (jpg 65kb)). Each wheel is supported on two taper roller bearings, the inner races of which register on chromed portions of the axle. With the original design standard each bearing was protected on its outer (or thrust) side by an elastomeric seal, and a water deflector disc was fitted inboard of the inboard seal (Configuration A). A subsequent modification added a water deflector for the outboard bearing as well. A further modification substituted an integrated seal / water deflector (Configuration C) on the thrust side of each bearing. The bearings and seal / deflectors are referred to here as Nos 1-4, from left to right.

The wheel / bearing assembly is retained by a castellated wheel nut screwed onto the end of the axle, torqued to 150-350 lb.in and secured by a lock bolt passing through one of three pairs of holes drilled in the shaft, at 60° intervals. The bolt is secured by a nut retained by a split pin. The outer ends of the wheel nut and the axle are normally flush.

Background

The Nose Landing Gear (NLG) is designed and manufactured for the aircraft manufacturer by Liebherr Aerospace Undenberg of Germany, with the wheels supplied by BF Goodrich of USA.

A BF Goodrich Service Bulletin (SB) (3-1551-32-2, issued on 16 February 2000, revised 10 May 2000) introduced the Configuration C integrated seal / water deflector for NLG wheel bearings. The reason for the SB was stated as *'Some rejections of nose wheel bearings have been reported during tyre changes. Analysis of rejected bearings showed that the damage was caused by moisture contamination'*. The SB noted that wheels from Serial No (SN) 1058 had the revised seals incorporated at manufacture. It suggested compliance for pre-SN 1058 wheels 'at a tyre change or wheel overhaul', but noted that *'if desired, current seal assemblies, P/N 68-1157, and water deflector shields, P/N 72-290, that are in serviceable condition can continue to be installed.*' The SB had been incorporated on G-EMBP at aircraft build and the correct configuration therefore included an integrated seal/deflector on the thrust side of each wheel bearing (Figure 2).

Embraer Service Newsletter (SNL) 145-32-0016, issued on 31 March 2000 and amended on 24 July 2000, was *'To inform all EMB-145 operators about the results of investigations carried out on some reported nose wheel bearing problems reported to EMBRAER, and to present a new integrated bearing grease seal / water deflector shield.'* It included a reprint of SB 3-1551-32-2.

Embraer SB 145-32-0067, issued on 27 December 2000, (Liebherr SB 1170C-32-04) specified a non-repetitive inspection procedure for the nose wheel axle. The reason was stated as *'The wheel axle is susceptible to scratching damage and overheating caused by sticking and seized wheel bearings. In the event that this damage occurs, the effective strength of the wheel axle may be reduced.'* Compliance was recommended within 600 flight cycles.

Aircraft History

The aircraft had accumulated 994 flight cycles since new at the time of the accident. The nose landing gear had not been replaced in this period. Both NLG wheels / tyres had been replaced at the operator's line maintenance facility at Edinburgh 8.48 flying hours / 6 landings prior to the accident because of tyre wear. The wheels fitted had been overhauled by a contractor and were reportedly supplied with bearings and Type C seal / deflectors taped in place. The mechanic who fitted the wheels could not recall the details of the procedure used. Furthermore, he did not consider that Aircraft Maintenance Manual or Service Bulletin instructions had caused confusion.

Aircraft Examination

Examination showed that the NLG axle had suffered a complete fracture at the centre of the chromed seat area for Bearing 2 (left inner bearing), on a plane perpendicular to its axis, detaching the left wheel from the aircraft. Adjacent to the fracture the axle showed signs of severe 'over temperature', with paint in the axle bore blistered and blackened. Specialist metallurgical examination showed that the temperature in the area of the failure had probably exceeded 800°C, the microstructure had been modified and the hardness had increased from around 550 HV10 to 600-650 HV10. Cracking of the chromium plating and secondary cracking into the axle was apparent. Failure of the axle had initiated with intergrannular fracture at the lower outside surface at several closely spaced positions and had propagated around the hollow section in both directions to

the top, apparently in a fast fracture mechanism. Analysis of a sample remote from the overheated region confirmed that the axle material conformed to the required specification (35NCD16).

The NLG wheel nut was found in place, secured with the lock bolt, with its outer end proud of the end of the axle by 1.5 mm. All four NLG wheel bearings (Timken PN 13889 and PN 13830) were in accordance with the BF Goodrich Component Maintenance Manual (32-49-04, 31 Aug 2000). Nos 3 & 4 bearings and seals were removed without AAIB personnel present and their installed location could not be ascertained; they are here referred to as Bearings X and Y, with associated Seals / Deflectors X and Y.

Inspection revealed that double seals had been installed on the thrust side of three of the four bearings, Nos 1, 2 and Y. In each case the remains of a Type A seal was found located next to the bearing, with a Type C seal / deflector located outside of the Type A seal.

Bearing 1 was intact, but with dulling, scoring and pitting of the rolling surfaces. The grease around the bearing was black and contained appreciable quantities of grit. The adjacent Type A seal had suffered deformation of its lip, radially inwards, consistent with the effect of abnormal loads applied by the Type C seal / deflector behind it. The lip had been partially machined and chipped, apparently by contact with rotating parts of the bearing.

Bearing 2 exhibited severe distress, with severe wear of the outer race and gross rotational wear of the inner race, which had seized onto the axle. All of the recovered rollers (21 out of 24) had sizeable longitudinal flats worn into them and the thrust face worn into a hemispherical shape. The bearing cage had fractured and partially broken up. All of the recovered components of the bearing showed signs of overtemperature. Grease deposits found around the bearing were dry and powdery, black in appearance and with appreciable grit content.

Bearing X, which had been assembled with a single Type C seal / deflector, remained in good condition, with red coloured grease containing little grit. The condition of Bearing Y and its grease and associated seals was similar to that at the Bearing 1 position.

Discussion

The evidence clearly indicated that the NLG axle had failed as a result of severe overheating, which had been generated by Bearing 2 having operated in a grossly deteriorated condition. Local embrittlement and cracking had led to rapid fracturing of the axle, probably under normal loading. There had been previous cases of wheel bearing deterioration and axle 'over temperature' on EMB-145 nose landing gears, attributed to dirt and water ingress into the bearings. In this case the double seals incorrectly fitted at three of the bearing positions had caused distortion and abnormal wear of the seals and severe degradation of the standard of bearing sealing. This would have allowed worn seal material accompanied by external dirt and water to enter the No 2 Bearing and it was possible that this had caused the bearing deterioration that led to the accident. Alternatively the incorrect assembly could have resulted, through in service use, in reduced bearing pre-load and unloading of the inboard bearing cone resulting in roller skewing and subsequent bearing lock-up.

The detailed causes of the incorrect installation could not be determined. There had clearly been confusion over the different standards of seal / deflector configuration that may have been brought about by the fact that 'wheel assembly' part numbers had not been changed to reflect the introduction of the wheel assembly modification. This could have been resolved by reference to the BF Goodrich Service Bulletin 3-1551-32-2, introducing the updated seal / deflectors, that stated in

para D, that *'the new seal assembly will replace the current inner and outer wheel half seal assemblies, PN 68-1157, and the water deflector shield, PN 72-290 (currently used only on the inboard side of the wheel assembly)*'.

The SB was however generally clear, and included a figure showing the parts layout. Furthermore, the note in the SB stating that 'if desired, current seal assemblies, P/N 68-1157, and water deflector shields, P/N 72-290, that are in serviceable condition can continue to be installed' did not seem to have been a factor in this case.

Operator's post accident actions

Following the accident the operator inspected the nose landing gear axles on its EMB-145 aircraft for damage. There was subsequently an inspection for the correct installation of wheel bearing seal / deflectors. No discrepancies were found. The operator also issued an Alert Quality Assurance Notice and applied decals to the nose landing gear doors aimed at raising awareness of the different seal / deflector standards for the nosewheel as described in the Aircraft Maintenance Manual. The operator subsequently specified fitment of only the latest standard of seal/deflector when nosewheels were replaced.

Manufacturer's post accident action

On 9 March 2001, immediately following the accident, the manufacturer released a Field Report (No GST-0773/01) to all EMB-145 operators re-emphasising that NLG bearing inspections should be carried out in accordance with the BF Goodrich Component Maintenance Manual (CMM) 32-49-04. This document brought to the attention of operators and maintenance organisations the need to adhere strictly to the inspection criteria and recommended that maintenance personnel pay attention to the contents of Service News Letter 145-32-0016 Revision 1. It did not however mention the fact that incorrect assembly was the cause of the bearing failure.

On 12 December 2001, BF Goodrich issued a revision to CMM (32-49-04) to provide specific continued maintenance procedures and incorporated the newer standard integrated seal/water deflector part numbers in the illustrated parts list. The use of the abbreviation 'Opt' however in the Illustrated Parts List listing ('27 72-290.....Shield, Water Deflector (Opt to item 30A)') could still lead to confusion as it could be taken to mean either that 'Item 27' is an alternative or an addition ('optional extra') to 'Item 30A'.

On 22 February and 28 May 2002, Embraer revised the Aircraft Maintenance Manual (AMM) chapter 32-49-05, with two changes both specifically highlighting the proper assembly of the two different bearing/seal configurations. The mention of 'WATER DEFLECTOR' in section 3-J of the document however appears inconsistent with the caution in Section 1-J and not does reflect the post modification standard which uses two seal/water deflector shields. It is however clarified in Section 3-J(3) but it is considered that the wording could still create a misunderstanding.

In addition the Service Bulletin 3-15551-32-2 Revision 1 issued 10 May 2000 incorporated within Service News letter 145-32-0016 Revision 1 issued 24 July 2000 has not been amended to remove the ambiguous statement regarding the continued use of the 'current seal assemblies and water deflector shields'.

It the light of the above the following recommendation is made:

Recommendation No 2002-09

It is recommended that Embraer and BF Goodrich again review and revise relevant maintenance documentation, relating to the nose landing gear wheel bearings on Embraer EMB-145 aircraft, to remove any ambiguity in the procedures for installing older seals and water deflectors and the newer standard integrated seal / deflectors.