Embraer EMB-145EP, G-EMBD

AAIB Bulletin No: 9/2004	Ref: EW/C2003/11/02	Category: 1.1
INCIDENT		
Aircraft Type and Registration:	Embraer EMB-145EP, G-EMBD	
No & Type of Engines:	2 Allison AE3007/A1/1 turbofan engines	
Year of Manufacture:	1998	
Date & Time (UTC):	15 November 2003 at 1350 hrs	
Location:	Venice Airport, Italy	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 4	Passengers - 39
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Separation of tyre tread from left inboard mainwheel	
Commander's Licence:	Air Transport Pilot's Licence	
Commander's Age:	40 years	
Commander's Flying Experience:	8,220 hours (of which 3,045 were on type)	
	Last 90 days - 159 hours	
	Last 28 days - 68 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During takeoff at Venice, the left inboard main wheel tyre (number 2) shed its tyre tread. The tread had failed as a result of overstress in the sidewall of the tyre leading to a break up of the tyre casing plies. Air penetrated through the failure in the inner wall of the tyre and then permeated through the casing leading to the tread package lifting from the carcass. The overstress was attributed to the tyre running under inflated due to an air leak from the overpressure valve. The leak was due to corrosion on the over pressure valve seat from a poor anodised layer during manufacture and a degraded O-ring seal. Four safety recommendations are made which address approved maintenance procedures for Embraer 145 mainwheels.

History of the flight

The aircraft had been prepared for a flight to Manchester from Venice. During the take-off ground roll, as the aircraft reached rotation speed the flight crew felt a sudden but moderate vibration. At that stage the commander was committed to the takeoff and since all the aircraft's systems indications appeared normal in the cockpit, he decided to continue the flight. Venice ATC were contacted and requested to carry out a runway inspection, which revealed tyre debris on the departure runway.

Because there were no indications of other problems with the aircraft the commander continued the flight to Manchester. On approach to Manchester, the crew declared an emergency and then carried out an uneventful landing on Runway 24L.

An engineering inspection revealed that the left inboard mainwheel tyre (number 2) had shed its tread and deflated. In addition, tyre debris had severed the wiring from the weight on wheels switch located at the bottom of the left main landing gear.

Both the number 2 wheel and its companion wheel, left outboard (number 1), were removed and sent to the tyre manufacturer for further examination together with the tyre debris recovered at Venice.

Wheel and tyre description

Detailed descriptions of the Embraer 145 wheel and tyre characteristics may be found within the AAIB report into the incident involving G-EMBL (EW/C2003/11/03) contained in this Bulletin.

Tyre examination

Before the number 2 wheel assembly was sent to the operator's wheel repairers, the tyre manufacturer visually examined both the number 1 and number 2 tyres whilst still on their wheels. The failed number 2 tyre was then removed from its wheel assembly and returned to the tyre manufacturer for a further detailed examination.

Since it was fitted to G-EMBD the failed number 2 tyre, which was on its second retread (R2), had completed 107.5 hours and 68 landings. The tread had separated around half of the tyre circumference down to the carcass and inter-tread fabric layers. The tread failure had occurred at the original tread to case interface and not at the retread layer. The recovered tread remains showed that the tyre was about 15% worn with evidence of overheating. The inner liner had a fracture extending diagonally from the bead, across the carcass and down the opposite side wall. Underneath this fracture the casing showed signs of break up of the plies but no signs of foreign object damage. Destructive examination of the tyre confirmed that the casing break-up was localised and in the tyre's mid plies at the interface with the bead apex and bead filler.

The tyre manufacturer concluded that the casing break up was both advanced and severe for a carcass at the R2 level. The casing break-up had progressed into multiple separations of the casing plies. Pressure then fed through the inner liner failure, causing pressurisation of the carcass, which the tyre awl vents were unable to relieve, leading to the tread lifting and finally stripping from the carcass. The manufacturer concluded that the casing break-up was due to over deflection of the tyre sidewall which is normally associated with either tyre under inflation or tyre overloading.

The companion number 1 tyre was a new tyre at fit and showed approximately 20% wear with heavy abrasion on the tread shoulder; this was indicative of overloading. The tyre manufacturer concluded that this was most probably because of the increase in load caused by deflation of the number 2 tyre.

Wheel assembly examination

Examination of the wheel assemblies took place at the wheel overhaul agency for the aircraft operator. The number 1 tyre was pressurised to 177 psi and immersed in a water tank which revealed a leak from one of the three fuse plugs.

The severity of the damage to the number 2 tyre prevented any pressure testing of the original fitting. Consequently, the damaged tyre was removed and a new tyre was installed on the reconstructed number 2 wheel assembly. The tyre was then pressurised to 177 psi and immersed in a water bath which revealed an extensive air leak from the overpressure valve. The overpressure valve was not loose in its fitting but when it was removed, there was debris on its O-ring seal and a blackened area on the valve seat on the wheel assembly.

Number 2 Wheel Assembly Metallurgy

A metallurgist examined the overpressure valve, O-ring seal and the wheel half containing the valve seat. Whilst sampling the darkened substance on the valve seat, it was discovered that this substance appeared to be filling a cavity. Examination of the cavity showed that it was the product of a penetrative corrosion process. The protective anodising layer around the unaffected area of the valve seat had a normal appearance but this layer thinned dramatically on approaching the cavity. In addition, the threaded hole did not have a fully formed anodised layer.

The metallurgist concluded that the debris on the O-ring was aluminium corrosion product pulled from an area above the first thread of the valve fitting. Examination of the O-ring showed that this had lost its elastic properties when compared to a new O-ring seal.

O-ring lubricant

The lubrication that was used on the O-ring on the overpressure valve during assembly by the wheel repairer was 'Molycote 111'. The O-ring seal was made from silicone rubber and, according to the datasheet for this lubricant, it is not compatible with silicone rubber. The datasheet quotes:

> *'These specific Dow Corning compounds should not be applied: To O-rings or other components made of silicone rubber because they can deteriorate the silicone rubber...'*

Number 2 wheel history

Since its manufacture in 1998, the wheel had completed 5,426 hours and 4,283 landings on aircraft. The wheel's removal history showed 10 workshop visits with only one overhaul of the wheel, in September 2000, during its fifth workshop visit. This overhaul was also the last time the over pressure valve was disturbed, to facilitate the replacement of the O-ring seal, some 2,921 landings and 3,291 hours prior to the incident.

A 'worn to limits' or damaged tyre caused the previous nine removals of the wheel assembly prior to the incident. No repairs or damage of the overpressure valve seat area of the wheel were reported on the records during these workshop visits.

Wheel manufacturing process

The wheel assembly is constructed from a forging of 2014 T6 aluminium alloy. Following the machining of the forging and prior to the application of a protective sulphuric acid anodised coating, the wheel is prepared by washing and rinsing to remove any contaminants. Once the anodising process is complete, it is 100% visually inspected and the anodised layer is tested for thickness on a flat portion of the wheel. Following the anodising process, the wheel is primed and painted before being stored.

Before 2001, the manufacturer manually washed and rinsed new wheel assemblies prior to the anodising process. After 2001, new wheels have been subjected to several machine washes and rinses to remove any contaminants before entering an automated anodising process.

Component Maintenance Manual (CMM)

The CMM for the wheel assembly contains information on the work required at each workshop visit. The section entitled 'CHECK' details the required inspections on the wheel, depending on the tyre change number at the workshop visit. The first part of this check, entitled '1. TIRE CHANGE EXAMINATION', contains a list of required inspections at every tyre change. Paragraph 1.A of Part 1 quotes:

'Visually examine each wheel half assembly (145,190) for corrosion and damage. Examine for a loose valve stem (55), over inflation plug (95), insert screws (150) and balance weight nuts (170,200). Tighten to the necessary torque (refer to page 801).'1

This visual inspection is the first inspection of the wheel assembly. However, it does not require the removal of either the over inflation valve or the inflation valve, or other ancillary hardware.

Later under paragraph 1.I the CMM then quotes:

'Visually examine the over inflation plug (95) for damage. Replace each damaged plug. Replace preformed packing2 (105) at each tire change. Replace preformed packings (100) if damaged.'

The inference from this paragraph is that the over inflation plug has to be removed to be inspected for damage. In addition, this step does not contain a reference to inspect the over inflation valve seat area on the wheel assembly.

With regard to the replacement of the O-ring seals, or preformed packings, the CMM contains several references requiring the replacement of all of these at every tyre change. However, 'CHECK' Paragraph 1.H ambiguously quotes:

'Visually examine the preformed packings (105,140) and the grommet (60) for cracks, gouges, cuts, and circumference that is too large. Discard a defective preformed packing or grommet. Satisfactory preformed packings and grommets must have a slight stretch to install.

NOTE: It is recommended to replace all the preformed packings and the grommet at each tyre change and wheel assembly overhaul'

When the wheel is assembled, the CMM instructions entitled 'ASSEMBLY' should be followed. This quotes under paragraph 1. GENERAL INSTRUCTIONS:

'Apply a thin layer of (Dow corning 55, Dow corning 33, Dow corning 4, or equivalent) to preformed packings (105,115,140)...'

Molycote 111, used by the wheel repairers that carried out work on the number 2 wheel assembly, is an equivalent to Dow Corning 4. The reference 105 is from the illustrated parts list and related to the O-ring seal used on the over inflation valve.

The data sheets for Dow Corning 55, 33 and 4 all caution against its use on silicone rubber.

Maintenance

The aircraft's technical log was reviewed from when the failed number 2 wheel and tyre were installed on 1 November 2003 up until the date of the incident. During this period, specific tyre pressures had not been recorded in the technical log and there were no records of tyre pressure problems.

The aircraft operator requires that the tyre pressures should be checked during the 'INTERMEDIATE CHECK', which is accomplished once every 48 hours. When completed, an authorised engineer signs a specific box on the relevant technical log page; the last recorded intermediate check was completed on the 14 November 2003 at 0100 hrs (36 hrs 50 minutes before the failure).

On 9 September 2003, the intermediate check procedure was amended by the operator to issue 5. This amendment added a requirement to record adjusted tyre pressures in the technical log.

---

[1] The numbers in brackets refer to items shown on the Illustrated Parts List

[2] In this context the phrase 'preformed packing' is an alternative description for an O-ring seal

Analysis

From the examination of the tyre, it was clear that the tread failure occurred as a result of overstress. The most likely reason was that the tyre had run whilst under inflated. This had allowed the side walls of the tyre to become stressed leading to the failure of the casing plies, and subsequent penetration of the inner liner, allowing the remaining air pressure to permeate through the plies and lift off the tread package. The tread had then separated at the point of take-off rotation which is when the tyre would have been under its greatest centrifugal force. Fortunately, secondary damage to the aircraft was limited to the wiring at the base of the main landing gear. However, because the Embraer 145 has rear mounted engines, it is feasible that rubber debris could have been ingested by an engine at a critical stage of the takeoff, thereby compounding the seriousness of the incident.

The under inflation of the number 2 tyre was probably caused by an extensive leakage of air from the overpressure valve. The leak rate was sufficient that during the intervening 37 hours since the last pressure check, the tyre pressure may have decayed to a level that critically over stressed the tyre sidewall during the subsequent taxi and take-off flight phases.

It is also possible that the leak had caused the tyre to run under-inflated on previous flights, progressively reducing the structural strength in the tyre's sidewall prior to the incident flight. The reason for the leakage was corrosion of the over inflation valve seat caused by the absence of an adequate protective anodising layer in that area. The failure of the anodising may have been due to a contaminant being present during the application of the layer at manufacture, as the preparation process at the time was a manual wash and rinse. Recent automation of the cleaning process has significantly reduced the risk of recurrence.

It was also discovered that the O-ring seal for the overpressure valve had been in place for a long time, having only been disturbed once during the wheel's lifetime. The seal had degraded, possibly due to the use of an incompatible lubricant and its length of time fitted to the wheel. These factors may have allowed moisture to penetrate past the seal and facilitate the corrosion of the aluminium.

The CMM requires an inspection of the wheel assembly at every tyre change. However the inspection is carried out whilst the valves are still fitted, thus preventing a full inspection of the entire wheel, and in particular the corroded area on the affected wheel. The only opportunity for an inspection of the affected area would be during inspection of the valve and replacement of its O-ring seal but the CMM does not require an inspection of the valve seat area.

On the defective number 2 wheel assembly, the over inflation valve was only removed once; this was during an overhaul and the O-ring seal was replaced at that time. This would have been the only occasion that the valve seat could have been visually inspected; it is not known if the corrosion was present at that time.

The work carried out on the number 2 wheel was in variance to the CMM which required the replacement of the O-ring seals and inspection of the overpressure valve at every tyre change. Discussion with overhaul organisations involved revealed that it was standard practice to disturb the over inflation valve only at overhaul which was every 5th tyre change. This variance may have been attributable to an ambiguity in the CMM. Although there are several references to replacing the O-ring seals, the note in CHECK paragraph 1.H states that replacement is recommended whereas paragraph 1.I requires replacement at every tyre change.

Had the over inflation valve been removed and its O-ring seal replaced at each tyre change, it is possible that the corrosion would have been noticed and the wheel assembly scrapped. Therefore, it was recommended that:

Safety Recommendation 2004-23

Goodrich Aircraft Wheels and Brakes Division should amend the Embraer 145 Wheel Component Maintenance Manual to require visual inspection of the inflation and over-inflation valve seat areas at every tyre change.

Safety Recommendation 2004-24

Goodrich Aircraft Wheels and Brakes Division should review the Embraer 145 Wheel Component Maintenance Manual to clarify the requirement to replace the preformed packings (O-ring seals) at each tyre change.

Safety Recommendation 2004-25

Goodrich Aircraft Wheels and Brakes Division should review the use of Dow Corning 33, 55, 4 and Molycote 111 on the silicone rubber preformed packages, determine whether degradation occurs and if so, specify only compatible lubricants.

Safety Recommendation 2004-26

Goodrich Aircraft Wheels and Brakes Division should notify all wheel repair stations of amendments to its Embraer 145 Wheel Component Maintenance Manual arising from these recommendations.