Embraer EMB-145EU, G-EMBL

AAIB Bulletin No: 9/2004	Ref: EW/C2003/11/03	Category: 1.1
INCIDENT		
Aircraft Type and Registration:	Embraer EMB-145EU, G-EMBL	
No & Type of Engines:	2 Allison AE 3007/A1/1 turbofan engines	
Year of Manufacture:	1999	
Date & Time (UTC):	18 November 2003 at 2025 hrs	
Location:	Birmingham Airport, Birmingham	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 4	Passengers - 43
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Separation of tyre tread from the left inboard mainwheel plus damage to trailing edge of left flap	
Commander's Licence:	Air Transport Pilot's Licence	
Commander's Age:	47 years	
Commander's Flying Experience:	3,800 hours (of which 1,200 were on type)	
	Last 90 days - 85 hours	
	Last 28 days - 10 hours	
Information Source:	AAIB Field Investigation	

Synopsis

During takeoff at Birmingham, the left inboard main wheel tyre (number 2) shed its 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, which may have been as a result of leakage from the wheel fuse plugs. Four safety recommendations regarding the maintenance of Embraer 145 wheels and tyres are made.

History of the flight

The intended flight was from Birmingham to Dusseldorf in Germany. The takeoff was normal except for the requirement of a more positive rate of rotation than normal. Following this and as the aircraft accelerated, the commander felt a vibration through the control column. At the same time, a passenger noted that as the gear retracted the wings waggled slightly to the right followed by a loud banging noise from the bottom of the aircraft, which worsened as the aircraft's airspeed increased. He had also noted that during the taxi from the stand at Birmingham there was a 'roughness' felt through the aircraft that had continued until takeoff.

The cabin staff subsequently notified the commander of the noise evident around rows 15 and 16, and that this had been present since takeoff. All the aircraft's systems indications appeared normal in the cockpit, so the commander slowed the aircraft to 210 KIAS, levelled off at FL90 and then requested a return to Birmingham. During the approach to Birmingham the commander declared a PAN and prepared the aircraft for an emergency landing. The aircraft landed on Runway 33, at a weight close to the maximum landing weight, with the airfield fire service in attendance. With no fire or damage evident, they escorted the aircraft to the stand. When on the stand, ground staff informed the commander that the left inboard main wheel (number 2) tyre had shed its tread.

The detached tyre tread had flailed around as it departed the tyre and pieces of tread became trapped between the main gear and its side stay. The main gear also exhibited signs of contact from the tyre tread as it shed. There was also damage to the flap because of the tread striking the trailing edge of the composite panel as it departed the tyre. In addition to losing its tread, the number 2 tyre had deflated and it had a large split in its sidewall.

The number 2 wheel and tyre and its companion, the left outboard main wheel and tyre (number 1), were then removed for further investigation. In addition, several small pieces of tyre tread were recovered from the side of the runway.

Flight Recorders

The aircraft was equipped with a 25 hour duration flight data recorder (FDR) and a 2 hour duration cockpit voice recorder (CVR); both retained information from the entire flight.

The AAIB have previously reported anomalies and made recommendations regarding the Embraer 145 FDR system to Centro Technico Aerospacial (CTA) of Brazil. AAIB safety recommendations 2002-01,-02,-03 and -04 refer to deficiencies with parameters recorded at rates higher than once per second. The manufacturer has responded to these recommendations by issuing SB145-31-0042 dated 23 September 2003 which details appropriate modifications. The operator is implementing the SB on its fleet but it was determined that the modification was not installed at the time of the incident.

The push back was uneventful. During taxi a series of rhythmic noises were recorded on the CVR. Analysis showed the origin to be the aircraft wheels as they passed over taxi lights.

The commander was the handling pilot for takeoff. The airspeed at rotation was 154 kt on a magnetic heading of 330 degrees with Flap 9 selected. Two minutes after takeoff, at FL40 with undercarriage and flaps retracted; the commander commented "A BIT OF ELEVATOR FLUTTER THERE, JUST A LITTLE BIT". Half a minute later a member of the cabin crew contacted the commander and commented "THERE'S A REALLY FUNNY NOISE COMING FROM THE BACK OF THE CABIN. IT SOUNDS LIKE ITS COMING FROM UNDERNEATH. WHEN WE TOOK OFF IT STARTED MAKING IT THEN". The first officer commented that he could feel it in the back of his seat and the commander confirmed that he too could feel it. The cabin crew again contacted the commander and commented "I HAVE BEEN DOWN TO THE BACK TO LISTEN MYSELF, IT IS QUITE A LOUD KNOCKING NOISE .... IT SEEMS LIKE IT IS COMING FROM UNDERNEATH THE AIRCRAFT".

Four and a half minutes after takeoff the crew requested a return to Birmingham Airport and the commander advised the passengers they intended to return to Birmingham Airport due to aircraft vibration. The crew made a PAN call and advised ATC of the problem.

Whilst reporting that the cabin was secure for landing, the cabin crew advised that the knocking had become louder. The commander was the handling pilot for the approach and landing; no handling difficulties were reported and the absence of any elevator "flutter" was noted. The aircraft was configured for landing with Flap 45 selected. The airspeed at touchdown was 129 kt with a normal acceleration peak value of 1.277g.

After touchdown, during a 34 second period the average brake pressure recorded by the DFDR was 900 psi for Brake No 1 and 830 psi for Brake No 3, which is consistent with an application of brakes during that time. Five minutes fifty seconds after touchdown there was a brake overheat warning. The average brake pressures for the previous 19 landings were 270 psi for Brake No 1 and 290 psi for Brake No 3. The crew later commented that the aircraft may have been on the limit for an overweight landing and that this may have contributed to the brake overheat warning.

After landing a member of the cabin crew reported to the commander that "THE KNOCKING STOPPED WHEN THE LANDING GEAR WENT DOWN". Four minutes after touchdown ATC reported that a lump of rubber had been found on the runway. The taxi to stand and engine shutdowns were uneventful.

Wheel and tyre description

The main wheel assembly used on the Embraer 145 consists of two halves of forged aluminium alloy. The two wheel halves are joined with tie bolts and retain the tubeless tyre in place on the inner rims of each half. An inflation valve, used to inflate the tyre, and an over-inflation valve, to relieve when the tyre pressure reaches a prescribed level, are fitted to the outer wheel half.

Three equally spaced thermal relief or fuse plugs are installed around the centre of the wheel assembly. These relieve the tyre pressure when the temperature of the wheel reaches a specified level, normally because of very heavy braking from a high energy stop. The fuse plugs consist of a eutectic fuse material[1] installed in a drilling through the cylindrical fuse body. The outer edge of the fuse plug contains a groove for an O-ring, which provides an air tight seal with the wheel assembly. Using a wooden dowel, to prevent damage to the eutectic, the fuse plugs are push fitted into their fitting on the pressure side of the wheel. The plug then sits on a recess, which contains a hole to allow the air from the tyre to escape to atmosphere when the plug relieves. When the wheel temperature increases to a predetermined level, the eutectic melts, breaking its bond with the fuse body and the air pressure from the tyre pushes the eutectic out of the plug leaving a hole for the release of tyre pressure.

The size of the mainwheel tyres fitted to G-EMBL are 30 x 9.5-14, and consist of a 16 ply rated cross-ply tubeless tyre with a speed rating of 210 mph (182 kt). The tyre casing is made of a series of plies of cord coated with a rubber compound, forming a 'fabric', installed around metal beads with each layer laid at a different angle to obtain the bias or cross-ply. The beads hold the tyre to the wheel rims and are made of high tensile wire; above each bead runs a rubber apex piece. At the interface between the tread and tyre casing are layers of nylon fabric known as the inter-tread fabric. These layers provide protection for the casing plies and tyre stability at high speeds. The tread is a rubber compound applied above the inter-tread fabric. The inner liner is an impervious rubber compound applied to the tyre's inner face to prevent leakage of gas and moisture ingress into the casing. Awl vents in the tyre sidewall allow excess air inside the casing to be vented to atmosphere.

Retread levels

The number of retreads applied to a tyre is different for every tyre and its type of operation. A tyre tread will usually wear long before the ultimate fatigue life of the tyre casing is achieved so to maximise its use, retreads are applied. The principal limiting factor for re-treading a tyre is fatigue. The process of determining a retread level (the number of permitted retreads) is one of testing in-service tyres for the level of degradation during a certain operation. A sampling of tyres that are beyond 80% worn are subjected to NDT (Non Destructive Testing) and then destructively tested to determine the current structural integrity of the tyre. A judgement is then made as to whether the tyre will survive an escalation in the retread level.

[1] A metallic compound resembling solder which melts at a specific temperature

When establishing a retread level, it is assumed that the tyre has been operated in accordance with the Aircraft Maintenance Manual (AMM) and at the correct pressure. This gives a high level of confidence that following a retread, the tyre structure will outlast the tread wear. A tyre which has run under-inflated or in an overloaded condition will reduce the fatigue life, leading to potential casing failure sooner than predicted.

At the time of the incident, the tyres fitted to the operator's Embraer 145 were limited to retread level 3. However the tyre manufacturer was investigating an escalation to retread level 4 and one tyre had been retreaded to this level, but this subsequently failed in service (see below).

Tyre inspections

When a tyre re-treader receives a tyre, they carry out a visual examination and other checks on its serviceability and previous history. This is to identify the physical condition of the tyre. One area of particular concern is evidence of the tyre running under-inflated; and is usually identified by creases in the inner liner or excess shoulder wear. A tyre that has run under-inflated is immediately scrapped, due to the increased stresses imposed on the tyre structure. Once cleared through the initial inspections a retread is applied, with visual inspections carried out throughout the process.

Following a retread operation, the tyre has NDT carried out known as Shearography. The machine used by the tyre manufacturer, and utilised on the failed tyre from G-EMBL, is relatively new but based on an established concept and uses a digital image scan of the retread, and in some cases the sidewall. The machine can identify any areas of total adhesion failure in the plies under the tread. Shearography, however, will not identify a weakness or impending fatigue failure of the casing plies, as the machine is limited to detection of a total loss of adhesion.

Wheels and tyres history

Number 1 wheel assembly

The number 1 wheel assembly had completed 6,929 flight hours and 6,423 landings since its manufacture. During that time, the wheel had visited a workshop 15 times, all for tyre changes. The wheel records showed that despite the workshop visits, the fuse plugs and the O-rings had been replaced only once. They were replaced during the previous overhaul in September 2002, 1,421 hours and 1,209 landings prior to the incident. Since the overhaul, the wheel has been in the workshop on two occasions, both for tyre changes, but with no disturbance of the fuse plugs.

Number 2 wheel and tyre assembly

At the time of the incident the number 2 failed tyre was at retread level 3 and had been fitted to the aircraft for 115 flight hours and 108 landings. The tyre's work records showed that the previous retreads were satisfactory with no recorded anomalies. Moreover, there was no evidence to suggest that the tyre had run under-inflated at a previous retread level.

The number 2 wheel assembly had completed 3,039 hours and 2,721 landings in service with five workshop visits for tyre changes. The wheel had been overhauled once and it was during this workshop visit that the fuse plugs were disturbed and the O-ring seals replaced. Between the overhaul and the incident, the wheel had completed 476 flight hours and 391 landings, with just one workshop visit for a tyre change during that period.

Tyre Examination

The tyre manufacturer carried out a detailed inspection of the numbers 1 and 2 wheel and tyre assemblies, before the wheel assemblies were sent to the operator's wheel repairer. The number 2 tyre was subsequently removed from its wheel and sent back to the tyre manufacturer to enable the manufacturer to complete its own investigation. The AAIB supervised all of this activity.

Number 1 tyre

The companion number 1 tyre had about 20% tread wear and showed heavy abrasion to the shoulder ribs of the tread. This was indicative of overloading and considered a result of the deflation of the number 2 tyre, with the aircraft load transferring onto the number 1 tyre during landing.

Number 2 tyre

The number 2 tyre had a fully separated tread, which had occurred at the original interface with the tyre carcass and not in the retread area. The recovered tread accounted for less than 15% of the tyre, but measurements of this tread showed around 20% wear with some scuffing and abrasion to the remains of the shoulder ribs.

Further examination of the tyre, once removed from the wheel assembly, revealed large fractures to the inner liner. Two of these were localised fractures, but one fracture extended diagonally from an area immediately above the bead filler to the upper shoulder area. The inner liner, however, did not show signs of the tyre running for prolonged periods at reduced pressure or with the tyre deflated. Areas of wear on the exposed carcass were determined to be related to concave depression, either from landing or from braking, and were related to the tyre being deflated or nearly so on landing.

A section of the tyre showed the internal structure had suffered from a localised casing break-up within the plies, which originated at the bead apex and bead filler. The casing break-up had caused multiple ply separation in the tyre and a fracture in the inner liner. The air pressure in the tyre had then progressed through this inner liner fracture and pressurised the tyre carcass. The awl vents within the tyre were unable to cope with this pressure, leading to the lifting of the tyre tread from the carcass and the shedding under rotational load at takeoff.

The tyre manufacture concluded that the casing break-up was due to over deflection of the tyre sidewall, normally associated with the tyre running under-inflated or being overloaded.

Wheel assembly examination

The examination of the complete wheel and tyre assemblies took place at the operator's wheel repairer, under AAIB supervision. The number 1 companion wheel and tyre assembly was still intact so this was pressurised to 177 psi and immersed in a water bath to check for leaks. This revealed a large leak from one of the three fuse plugs. The assembly was then tested for a static leak rate of tyre pressure over time, accomplished both by the tyre manufacturer and then later by the wheel manufacturer. The tyre manufacturer results showed that over 24 hours, the tyre pressure reduced by 12 psi (6.7%), followed by a continual loss of 5 psi (3%) over subsequent 24 hour periods. The wheel manufacturer carried out a more detailed test of the leak rate using an immersion bath, but over a shorter period of 18 hours; this showed a pressure loss of 6 psi (3.4%). The wheel manufacturer concluded that it was unlikely that the pressure loss would have been more than 5% in 24 hours. However, the recorded tyre pressure was less than 97.5% after 12 hours. During this test a second fuse plug exhibited a slower, but visible leak.

The damaged number 2 tyre had to be removed from the wheel and a new tyre fitted before an immersion test at 177 psi could be carried out. This revealed leaks from all three fuse plugs, with no other areas of leakage. Following removal of the fuse plugs from the wheel assembly, the wheel manufacturer carried out a detailed inspection for the cause of the leaks.

In addition, the companion wheel to a failed number 2 wheel/tyre from G-EMBD (EW/C2003/11/02), which also exhibited a leaking fuse plug, was inspected by the wheel manufacturer. A static leak test, from an initial tyre pressure of 177 psi, showed a recorded pressure of 170.5 psi which was a drop of

6.5 psi (3.6%) after 18 hours. The tyre pressure was also less than 97.5% of the original pressure after 12 hours.

Fuse Plug Examination

Under AAIB supervision the wheel manufacturer examined the three leaking fuse plugs removed from the number 2 wheel (G-EMBL) assembly. The initial examination of the O-ring seals around each of the plugs showed these to be in a satisfactory condition with no signs of distress or degradation. Testing the fuse plugs for leaks using a special rig that enables the identification of the leak path showed that only one of the three plugs was leaking and that the leak originated from the eutectic. The wheel manufacturer described this as being due to damage to the eutectic that had broken the bond between the eutectic and the body of the fuse plug. Inspection of the wheel assembly did not reveal any abnormalities.

The fuse plugs from the number 1 (G-EMBL) companion wheel were similarly examined. Again the O-ring seals were satisfactory and measurement of the wheel assembly for dimensional accuracy showed this to be within the design limits. Visual examination of the fuse plugs indicated that the two leaking plugs had signs of partial melting of the eutectic. Rig testing showed leaks from the eutectic on the two leaking plugs; the third plug did not show any leaks. The wheel manufacturer stated that the eutectic had partially melted due to excess heat from the brakes during the high energy braking during the landing after the failure of the number 2 tyre. This had affected the bond between the eutectic and body of the fuse plug.

Examination of the remaining fuse plug from the companion wheel removed from G-EMBD revealed damage to the eutectic in the form of a circular imprint. This damage had caused the bond between the eutectic and fuse body and allowed the leak to occur.

Discussion with wheel repairers revealed that about 5% of wheels received in the workshop for repair or tyre changes had leaking fuse plugs.

Wheel assembly Component Maintenance Manual (CMM)

The CMM for the wheel assembly contains information on the work required at each workshop visit. The inspections are contained under the section entitled 'CHECK', which details the required inspections on the wheel, depending on the tyre change number for the workshop visit. The first section '1. TIRE CHANGE EXAMINATION' contains a list of required inspections at each tyre change. Paragraph 1.J then continues with an inspection requirement for the fuse plugs, or thermal relief plugs as they are referred to in the CMM. This quotes:

'J. Visually inspect the thermal relief plugs (110) for damage. Examine each thermal relief plug for a bulge or indentation at the fuse in the center. Replace each thermal relief plug that shows a bulge or indentation. Replace preformed packing[2] (115) at each tire change.'[3]

Therefore, at each tyre change, which is effectively every workshop visit, the CMM had a requirement to remove the fuse plugs, inspect and then refit them with a new O-ring seal.

Following re-assembly of the wheel assembly, the CMM calls for a leak test. This static test requires the assembly to be pressurised to the tyre operating pressure followed by measurement of the tyre pressure after three hours. If the tyre pressure after three hours is less than 95% of the original pressure, an investigation for the leak is carried out. A tyre pressure not less than 95% requires the tyre to be re-inflated and stored for 12 hours. If after, 12 hours, the tyre pressure is not less than 97.5% of the original pressure, the tyre is accepted and released for aircraft service. If the pressure is

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

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

less than 97.5% then a further 12 hour test is required. If the tyre pressure then drops below 97.5% again, an inspection and repair of the wheel and tyre is required.

Aircraft Manufacturer Information

The aircraft manufacturer has produced, over the years, several communications on the issue of tyre pressure management for the Embraer 145. The AMM and Ramp Maintenance Manual (RMM), used by operators, contain information about checking tyre pressures. Both manuals then quote limits for additional action if the tyre is found in an under-inflated state. These limits and actions are:

'Table 302 - Cold Pressure Setting

COLD TIRE SERVICE PRESSURE (%)	*RECOMMENDED ACTION*
100% to 105% of minimum service pressure	*None - Normal cold tire operating range*
95% to 100% of minimum service pressure	*Inflate to specified service pressure again*
90% to 95% of minimum service pressure	*Inspect tire/wheel assembly for cause of pressure loss. Inflate again and write in logbook. Remove tire/wheel assembly if pressure loss is higher than 5% and occurs again in 24 hours [1]*
80% to 90% of minimum service pressure	*Remove tire/wheel assembly from aircraft*
80% or less	*Remove tire/wheel assembly and adjacent tire/wheel assembly from aircraft*
Blown fuse plug	*Discard tire. If the plug blows while in service (rolling), scrap also axle mate*

[1] The tire removed because of low inflation pressure must be examined by an authorized retreader to make sure that the casing did not have internal degradation. If it did, discard the tire.'

The aircraft manufacturer's maintenance schedule requires the checking of tyre pressures once every 48 hours. However a published service newsletter, SNL 145-32-0002 dated 30 April 2002, quotes:

'1. [Embraer] Strongly recommend that tires be pressure checked and serviced every 24 hours, at least 3 hours after the last landing of the day. Refer to AMM Part II Chapter 32-49-01 and Chapter 32-49-04. The clarifications listed below also apply:

Owing to their particular operating conditions (extreme heat and cold; and under extreme load and speed), aircraft tires are made of a high percentage of natural rubber. Natural rubber is porous, which leads to a daily loss ranging from 1 to 5% of the tire air.

All aircraft tire manufacturers recommend air pressure checks and service every 24 hours.

The benefits of the 24-hour check include:

- *problem-free service, without concern for safety;*
- *extended tread life;*
- *less premature removals on account of step wear, groove cracking, and undercutting;*
- *worn tires that can be retreaded.'*

Maintenance

The failed tyre had been fitted to G-EMBL on 5 October 2003. The aircraft then underwent routine maintenance from 11 October 2003 until 7 November 2003 so the technical log entries between

7 November 2003 and the 18 November 2003 were reviewed. This revealed that there were no records of any tyre pressures, nor were there any entries of problems with the tyres.

The operator requires that the tyre pressures should be checked during the 'INTERMEDIATE CHECK', which is accomplished at least 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 16 November 2003 at 24:00 hours. The incident occurred at about 20:25 hours on 18 November 2003 and in the elapsed 44 hours, the aircraft flew 14 flight sectors.

On 9 September 2003, the operator amended the intermediate check, raising it to issue five. This amendment added the requirement to record adjusted tyre pressures in the technical log. Prior to 9 September 2003, the check did not require any recording of tyre pressures. G-EMBL's technical log, reviewed the day following the incident, contained a copy of the intermediate check. This was to the previously issued version identified as number 4 dated 18 October 2002 which did not require the tyre pressures to be recorded.

Communication

When an operator finds a tyre in a state that requires it to be changed, the whole wheel assembly has to be removed and sent to a specialist wheel repairer to have the tyre removed from the wheel. Following removal of the tyre, the wheel repairer then sends it to the relevant tyre re-treader for rework. During this investigation, it became evident that the paperwork sent to the tyre re-treader, did not contain the reason for the removal of the tyre from the aircraft. The paperwork would simply request a tyre retread, regardless of the state of the tyre. In some cases, the tyre re-treader has found a chalk mark added to the side wall of the tyre indicating a removal reason or a course of action such as 'SCRAP', but in most cases this cannot be verified by the paperwork.

Previous occurrences

Detailed below are other occurrences of tyre failure that have occurred on Embraer 145 aircraft, prior to the event on G-EMBL. These failures were not all associated with the same operator or the same tyre manufacturer as G-EMBL.

G-EMBD on 15 November 2003 (EW/C2003/11/02) - See the separate report contained in this Bulletin.

G-ERJG, Oslo on 5 June 2003

During the departure from Oslo, at the point of rotation there were vibrations similar to a rough runway surface. A passenger reported seeing debris on the right side of the aircraft, and another reporting this debris had been ingested by the right engine. All the aircraft system parameters were normal but a visual inspection of the engine by the crew revealed a possible ingestion of a foreign object. ATC then reported that they had recovered rubber debris from the runway. The crew declared a PAN and returned to OSLO. On landing, it was evident that the right hand main landing gear tyre had burst shedding its tread and deflating. The tyre investigation report concluded that the failure was as a result of casing break-up and inner liner fracture which then caused the shedding of the tyre tread. The tyre subsequently burst during the landing. The likely cause, although not conclusive, was that the tyre had been running under-inflated. The tyre was at retread level 4 and was the only Embraer 145 tyre at this level. The tyre manufacturer immediately stopped all retread operations beyond retread level 3, but would carry out investigations into the retread escalation program with a view to reintroducing retread level 4.

Frankfurt, Germany on 28 July 2003

The aircraft was due to operate a flight to Skopje, Macedonia, this required a long taxi to the assigned take-off runway. During the take-off roll, there was an indication of hot brakes in the cockpit and after a short distance the crew noticed a vibration and continuous bumping. The takeoff was rejected at a speed of 80 kt, and the aircraft stopped on the runway. Subsequent investigation revealed both left main landing gear tyres had failed. The tyre manufacturer concluded that both tyres had been severely overloaded, possibly as a result of one or both of the tyres running under-inflated.

Oporto, Portugal on 4 August 1997

During take off from Bilbao, Spain, at rotation, the crew felt a vibration in the cockpit. They elected to keep the landing gear extended and assessed the situation. There were no abnormal indications in the cockpit so they decided to continue to Oporto. On approach, they declared an emergency and the landing was uneventful. The crew later discovered that both the left main landing gear tyres had shed their tread. Subsequent inspections of the tyres revealed excess shoulder wear and cracking in the grooves of the remaining tyre tread. This evidence led to the conclusion that the tyres had been under-inflated and that the number one tyre had failed on take off at Bilbao and the number two tyre had then failed on landing at Oporto. This event led to the initial publication of SNL 145-32-02 mentioned previously.

Munich, Germany on 16 November 2001

During this night time departure and at rotation, the crew reported hearing a bang and seeing flashes. The landing gear was left extended and the crew contacted ATC who confirmed the flashes were sparks from the landing gear and that tyre debris had been found on the runway. Following a return to Munich and an uneventful landing, the crew discovered both left main landing gear tyres had burst and had caused secondary damage to the wheel and brake assemblies. The tyre manufacturer concluded that both tyres had been overloaded due to being under-inflated for a long period of time causing premature carcass fatigue.

Analysis

The examination of the tyre and the wheel assembly revealed that the most likely cause of the tyre failure was due to overstress in the tyre carcass, which may have been a result of the tyre running under-inflated. The tyre had failed during the take-off rotation when it was heavily loaded, with the resulting damage limited to the flap and the tyre itself. However, the outcome could have been more serious if pieces of tread had been ingested into an engine at this critical phase of flight. The noise heard by the passengers after takeoff was probably a piece of tread, trapped by the closed landing gear doors, flapping in the airflow and banging against the underside of the fuselage. As the aircraft accelerated, the noise in the cabin worsened with an increase in the level of vibration felt by the flight crew due to the increased flapping of the trapped rubber. The extension of the landing gear on approach released the trapped tread, and stopped both the noise and the vibration felt in the aircraft.

Further investigation revealed that the wheel assemblies had exhibited a leak path in the area of the fuse plugs. Detailed examination showed that in some cases the leaks were due to lack of adhesion between the eutectic fuse material and the body of the fuse plug. Whether this was a cause of the loss of tyre pressure or whether it was because of heat dissipated in the wheel following the resulting high energy braking and heavy weight landing could not be established. Indeed two of the leaking fuse plugs exhibited signs of partial melting which could have been a sign of the heat soaking, as indicated on the FDR by a brake overheat warning after landing.

Discussion with wheel repairers revealed that leaking fuse plugs were a common occurrence on wheel assemblies received for routine tyre changes. This would indicate that there may be a pre-existing problem with the fuse plugs and that this problem may be related to a breakdown of the bond between the eutectic material and the fuse plug body. The problem may be caused by heat soaking during normal service, general wear and tear, or the operational usage pattern of the aircraft. When a wheel repairer finds a fuse plug leaking, the normal course of action is to replace the plug and O-ring seal and discard the defective plug without further investigation. This practice makes it difficult to detect if there is a problem with the plugs and exposes the need for investigation by the wheel manufacturer into the underlying reasons for leaking fuse plugs.

Therefore, it was recommended that:

Safety Recommendation 2004-27

Goodrich Aircraft Wheels and Brakes Division should carry out research into the possible causes of the fuse plug leakage and consider action to reduce the risk of leaking fuse plugs.

The CMM for the wheel assembly is ambiguous in its statements on the replacement of the fuse plug O-ring seals. It requires the replacement of the O-ring seals at every tyre change but then countermands this requirement with a 'recommendation' to replace the seals at each tyre change. From the workshop records for the affected wheel assembly and others, the normal practice has been to replace the O-ring seals at each overhaul. This can occur as infrequently as the 6th tyre change. If this were the case then the fuse plugs would only be inspected at every 6th tyre change whereas the CMM requires replacement of the O-ring seal and inspection of the fuse plugs at each tyre change. Inspection at every tyre change could reduce the risk of a leaking fuse plug in service.

The report concerning the tyre failure on G-EMBD contained Safety Recommendation 2004-24 which recommended that the Wheel Component Maintenance Manual should be amended to clarify the requirement to replace preformed packings (O-ring seals) at each tyre change. Consequently, no additional safety recommendation regarding the replacement of fuse plug O-ring seals is made.

Tyre pressure monitoring

Tyre pressure loss due to leaking fuse plugs could have been identified by in-service monitoring and recording of tyre pressures but the technical log for G-EMBL had no entries relating to the tyre pressures after 7 November 2003. The omission may have been due to the older and incorrect version of the intermediate check being inserted in the technical log since this version did not contain the requirement to record any uplift of tyre pressure. At the time of the incident the operator carried out checks of the tyre pressures during the intermediate check, once every 48 hours as defined by the aircraft manufacturer, the last of which was some 44 hours before the failure. It is entirely possible that the tyre pressure on the failed tyre may have decayed to a critical level during that time, especially with the amount of loading the tyres received over that time. Static testing of the tyres showed that a leaking fuse plug can decay the tyre pressure by over 2.5% in 12 hours, albeit with the leak rate reducing exponentially as the tyre deflated (leakage less than 5% over 24 hours). With this in mind a fully loaded tyre may leak at a greater rate, making the possibility of an under-inflated tyre, due to leaking fuse plugs, more likely.

In its document SNL 145-32-0002 the aircraft manufacturer strongly recommends the checking of the tyre pressure once every 24 hours. With a tyre pressure test every 24 hours, it is more likely that an under-inflated tyre will be identified before it causes a failure However, if the tyre pressure trends were monitored, the increased frequency of pressure checks could be more effective, for if a tyre requires re-inflating on several occasions, although the pressure is still within the 95%-100% band, this could be an indication of a leak that if ignored has the potential to become worse. The logical action would be to remove the wheel assembly and investigate the cause of this 'slow' leak.

Therefore, it was recommended that:

Safety Recommendation 2004-28

EMBRAER (Empresa Brasileira de Aeronautica SA) should amend the maintenance schedule for the EMB-145 and similar models, to require that:

a. Tyre pressures are checked every 24 hours.

b. The as-found and re-inflation tyre pressures are recorded in the technical log for monitoring purposes.

During the investigation, a distinct lack of communication between the wheel repairers and the tyre re-treaders was evident with the reason for removal of a tyre from an aircraft not being communicated to the tyre re-treader.

At present, there is no way of identifying the onset of fatigue within the tyre carcass unless there has been a loss of adhesion within the plies which would be indicated during the Shearography NDT. Moreover, if there are no visible exterior signs of carcass damage, unless the operator informs the tyre re-treader that the tyre has been removed because of running under-inflated, the re-treader will not know that the tyre's fatigue life has been compromised. This lack of communication may result in a retread tyre failing prematurely through fatigue and at a critical stage of flight. It is for this reason that any tyre which has run under-inflated is scrapped. Therefore, it is vitally important that a tyre's operating history is made known to the tyre re-treader, including the reason for its removal.

Therefore, it was recommended that:

Safety Recommendation 2004-29

The European Aviation Safety Agency should require all wheel repair stations conforming to JARs (Joint Airworthiness Requirements) to inform the tyre re-treader of the reason for removal of the tyre from the aircraft and indicate if there has been any suspicion of the tyre running under-inflated.

Safety Recommendation 2004-30

The US Federal Aviation Administration should require all wheel repair stations conforming to FARs (Federal Airworthiness Requirements) to inform the tyre re-treader of the reason for removal of the tyre from the aircraft and indicate if there has been any suspicion of the tyre running under-inflated.

Safety actions taken since this incident

Since this incident, there have been several activities by the wheel manufacturer and the operator. The operator introduced arrangements for mainwheel daily tyre pressure checks on 19 November 2003 and a specific recording form to be used in conjunction with this new procedure followed two days later. The operator has also communicated the importance of following the AMM instructions to all stations that carry out the tyre pressure checks on its EMB-145 aircraft.

There was concern that tyres may have operated under-inflated and then subsequently been retreaded due to the lack of communication between the operator, wheel repairer and the tyre retreader. Consequently, all tyres belonging to the operator, which had been retreaded prior to the introduction of tyre pressure checks every 24 hours, are being replaced on an attrition basis. The operator has also placed a Company limit of two on the maximum number of retreads.

Since the operator introduced these actions, there have been five other in service tyre failures, which are still being investigated by the operator, two of which were:

G-EMBE 26 Jan 2004. The tyre was found deflated on stand with a large split in the sidewall. The subsequent tyre investigation revealed a possible fatigue failure, but there were no signs of the tyre being run under-inflated. One fuse plug was found leaking in the wheel assembly.

G-EMBH 5 Feb 2004. The right outboard main wheel tyre (number 4) had a large amount of tread missing when it arrived on stand. The tyre was at retread level 1, but had been fitted to the aircraft for 923 landings, which is significantly more than normal.

The 24 hour tyre pressure checking has already revealed several tyres that have been found under-inflated to the extent that they require removal to prevent failure in service. The operator, wheel repairer, tyre re-treader and the wheel manufacturer are investigating these events to identify if there is a common trend.

The aircraft operator's wheel repairer accepted Safety Recommendation 2004-29 and introduced a form to pass tyre removal information to the retreading agency. Moreover, the repairer now replaces each fuse plug and the other O-ring seals at each tyre change. They have also undertaken to monitor each wheel assembly for signs of leaking fuse plugs and are assisting the wheel manufacturer in investigating the reason for the leaks. To provide a better understanding of the reasons behind the leaking fuse plugs the wheel manufacturer has now provided drawings in the CMM for a fuse plug test set. This will enable repair stations to check where the leak for the fuse plug originates and provide more information to the wheel manufacturer on the possible causes of the leaks.