BAC One Eleven 501EX, G-AWYR, 21 November 1997 at 1037 hrs

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Aircraft Type and Registration:	BAC One Eleven 501EX, G-AWYR
No & Type of Engines:	2 Rolls Royce Spey 512-14DW turbofan engines
Year of Manufacture:	1969
Date & Time (UTC):	21 November 1997 at 1037 hrs
Location:	Birmingham Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 6 - Passengers - 73
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Main landing gear tyre, wheelbrake hydraulic pipeline bracket and right inboard flap damaged
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	7,232 hours (of which 2,660 were on type)
	Last 90 days - 138 hours
	Last 28 days - 45 hours
Information Source:	AAIB Field Investigation

History of flight

The aircraft was taking off on Runway 15 at Birmingham Airport for Amsterdam with the First Officer as the handling pilot. The weather was good, with the wind from 150°M at 5 kt and with an ambient temperature of +6°C. The calculated take-off weight was 39,200 kg (86,420 lb) and the normal flap setting of 18° was used; the calculated V_1 and V_r for the conditions were coincident at 129 kt. As the aircraft was rotated for take off a loud bang was heard by the crew. All flight deck indications were normal and no handling abnormalities were experienced. The crew informed ATC of the event and requested a runway report while continuing the Standard Instrument Departure, retracting the landing gear and flaps with no abnormalities evident. ATC informed the crew that a report of rubber debris on the right side of the runway had been received from an arriving aircraft. The Cabin Purser was informed of a possible problem and that it might be necessary to return to Birmingham. Following a runway inspection, ATC informed the crew that extensive tyre debris had been found on the runway, on the right side. The Commander reviewed the situation and decided to return to Birmingham after burning off excess fuel.

A PAN call was made and ATC vectored the aircraft into a holding pattern and allocated it a discrete radio frequency. The First Officer remained the handling pilot while the Commander managed the situation. The crew checked that the relevant drills had been completed and formulated a plan for the landing and for actions after landing. They advised ATC of these, confirmed a radio frequency for direct communication with the Fire Service and briefed the cabin crew and passengers on the situation and on the possible need for an emergency evacuation after landing. At 1201 hrs a normal approach to Birmingham's Runway 15 was made, with the Commander taking over control for the landing. The aircraft was brought to a halt on the runway using reverse thrust and gentle wheel braking, with minimal braking applied to the suspect right landing gear wheels, and the engines were shutdown. Communications between the crew and the Fire Service were established during the ground roll and the crew was informed that the right outboard tyre (No 4) was damaged and smoking. On the basis of an assessment of the tyre condition by the Fire Service after the aircraft had come to rest, it was concluded that emergency evacuation was not necessary and the passengers and the cabin crew were disembarked using the airstairs and taken to the airport terminal.

Component description

Each main landing gear has two wheels on a common axis. The left wheel of the right landing gear is designated as No 3 and the right as No 4. Each wheel is fitted with a 40 x 12 (overall diameter x cross section width in inches) bias ply tyre with a ply rating of 20 (related to the maximum recommended load and pressure) and a speed rating of 200 mph. The tyre consists of a casing of bonded layers of rubberised nylon cord laid crossply around steel wire bead cords, sealed on the inside by an impermeable rubber inner lining and protected on the outside by a bonded-on rubber compound tread. The casing sidewalls incorporate a number of awl vents to vent the interior of the casing laminate material to atmosphere.

The aircraft manufacturer's Maintenance Manual recommended tyre inflation (normally with nitrogen) to a pressure dependant on the aircraft take-off weight but noted that 'normally tyres are maintained at the maximum design take-off weight pressure or at the maximum take-off weight pressure which suits the operator's particular operating conditions.' At the maximum take-off weight listed (99,650 lb) the recommended pressure was 171 psig with a tolerance of +10/-0 psig and this was the value used by the operator. A typical tyre/wheel combination has around 12 potential leak paths and the tyre manufacturer noted that an inflation pressure loss of up to 5% per day can be expected.

Tyre scheduled line maintenance consisted of a visual check of tyre condition during the flight crew's pre-flight external check plus visual inspection and pressure checks every 24 hours elapsed time. It was intended that a pressure check should be done as part of the Terminal Inspection, which was scheduled by the Maintenance Schedule every 48 hours, or recorded in the aircraft's Technical Log if a Terminal Inspection had not been carried out in the previous 24 hours. The check required tyre pressures to be checked not less than 1 hour after landing; the operator's procedure on finding a low pressure was as follows:

PERCENTAGE PRESSURE BELOW	REQUIRED ACTION

REQUIREMENT %	
< 5	Inflate to required pressure.
5-10	Inspect for cause of pressure loss and rectify. If no cause found and no record of previous low pressure in the Technical Log, inflate and record event. If repeated on consecutive checks reject tyre and wheel.
>10	Reject tyre and wheel, along with its partner on the same axis.

This generally corresponded to the tyre manufacturer's recommendations and to the Aircraft Maintenance Manual procedure for a Cold Tyre Pressure Check. Except in cases where a tyre pressure was more than 5% below the requirement the operator did not record the measured values.

The type of tyre that failed is retreadable a number of times, in line with normal practice. No firm limit is applied by the manufacturer to the allowable number of retreads, the suitability for retreading being determined by various inspections and checks before, during and after the rework process, including leakage checks and visual and shearography inspections. Shearography is a technique of holographic laser imaging of a tyre under stress aimed at revealing any unacceptable damage or anomalies present in the tyre casing. The manufacturer also monitored the condition of tyre types at various stages of their life by destructive testing and inspection of sample tyres returned from service. The operator had imposed a limit of 6 retreads on this type of tyre. It was generally accepted that experience had shown that the sensitivity of a tyre to abnormal operating conditions tends to increase with the overall operating life of the tyre casing, ie effectively to increase with the number of retread operations that the tyre had experienced.

Aircraft examination

Examination reportedly showed that the No 4 tyre had suffered major damage, including loss of its entire tread; a bracket securing hydraulic flexible brake lines to the right main landing gear leg had been damaged; the right inboard flap had sustained heavy impact damage and was markedly bowed back at its centre. The operation of the wheelbraking and flap systems had apparently not been significantly affected by the damage.

The casing of the failed tyre remained intact and fragments of the tread amounting to an estimated 95% of the total were recovered. Detailed investigation of the parts by the tyre manufacturer showed that the casing inner lining had suffered splits that were judged to have been caused by the propagation of cord break-up and ply separation within the casing material. It was assessed that the escape of nitrogen through the lining fractures into the casing laminate had been at a rate that had exceeded the capacity of the awl vents, thus causing pressurisation of the casing material and consequent complete tread separation from the casing. The manufacturer concluded that the initiating casing damage that had caused the lining fractures was not typical of that found during their retread inspection or sample condition monitoring and had been caused by accelerated fatigue of the casing fabric as a result of excessive deflection of the tyre. This would tend to cause excessive flexing of the ply cords together with a reduction in cord strength because of increased casing temperature generated by the flexing and could have been due to either overload or underinflation. No assessment could be made of the period over which this condition would need to have persisted to have caused the premature failure, or of the point in time in relation to the accident that it may have occurred. The manufacturer found no evidence of foreign object damage to the tyre likely to have caused a puncture of the inner lining and considered that any such damage should have been apparent, given that the casing was intact and most of the tread was recovered.

Damage to the tyre sidewall was consistent with the effects of contact with the brake line bracket mounted on the main landing gear leg.

Examination of the No 3 tyre showed a small degree of incipient damage, consistent with having been overloaded because of No 4 tyre deflation. The No 3 and No 4 wheels reportedly showed no signs of defect or appreciable damage; they were checked by fitting them with serviceable tyres, with no anomalies found.

Background

The No 4 tyre had been retreaded by the manufacturer for the sixth time in June 1997. The manufacturer's records indicated that it had been reworked in accordance with the relevant specifications and that inspections had not revealed any anomalies with the tyre. Both of the right main landing gear wheels and tyres had been installed on G-AWYR on 25 September 1997 at 55,870 Airframe Hours/47,822 Airframe Landings. The accident occurred 322 Hours/296 Landings later.

The inflation pressure of the failed tyre had reportedly last been checked during a Terminal Inspection of the aircraft at 0600 hrs on the morning of the accident and found to be within the required range; the pressure gauge used had received its last annual calibration less than 4 months earlier. No record was found to indicate that the tyre had operated in a significantly underinflated condition at any previous stage, and the operator's procedures should have resulted in rejection of the tyre had such a condition occurred.

Tyre manufacturers note that 'keeping aircraft tyres at their correct inflation pressure is the most important factor in any preventative maintenance programme' and that testing has shown the general characteristic of Figure 1 for the effect of underinflation on the number of test take-off cycles before failure of a typical aircraft tyre. It was also noted that an underinflated condition of one tyre on a landing gear with dual wheels on an axis would very probably not be detectable by visual checks, even in the case of relatively gross underinflation, because the fully inflated tyre would take the load and prevent abnormal flattening of the underinflated tyre. A system providing tyre pressure indication at the landing gear for use during external aircraft inspection, consisting of a small pressure gauge permanently fitted to each wheel, is available as an option on some aircraft, including the BAC 1-11 (manufacturer's Service Newsletter 32/67, issue 4 of 14 June 1979). It is likely that such a system would provide a simple, cheap and reliable means of ensuring adequate tyre pressure shortly before each take-off. Systems providing flight deck indication of tyre pressures are in use on some modern aircraft such as the Airbus A300-600, A310, A320 and A340 and on the Boeing 747-400.

Similar cases

Information from the CAA MOR Database suggested that there had been 34 other cases of tread shedding from BAC 1-11 main landing gear tyres between 1976 and the date of G-AWYR's incident, 20 of which had occurred during the take-off roll, frequently at high speed. Details were limited but indicated that the results had included flap damage in 27 cases, in some cases severe, and hydraulic system damage in 9 cases, including hydraulic system pressure loss in 4 cases. Nacelle and/or engine damage had occurred in 7 cases, including 2 cases of complete loss of power from one engine. In an additional possibly similar case, G-AWYR suffered further damage to hydraulic pipes and a flap fairing in January 1998, in Holland, when a tyre burst on landing.

Discussion

The evidence indicated that the No 4 tyre had suffered premature failure as the result of excessive deflection which could have been due to operating at some point while either underinflated or overloaded. The low level of No 3 tyre damage did not suggest that this tyre had operated while significantly underinflated and thus transferred excessive load to the No 4 tyre and it was therefore likely that the damage had resulted from underinflation of the No 4 tyre. How such a condition could have occurred could not be established as there was no record of significant underinflation having been found since the tyres had been installed and the evidence indicated that there had been no foreign object damage that could have punctured the tyre since the last check 4.5 hours before the accident.

No evidence was found to indicate that the failed tyre may have been defective when fitted after retreading, 296 landings before the accident. However, it was likely that the tyre, having had a relatively high life, with a relatively high number of retreads, would have had an increased sensitivity to abnormal operating conditions compared to a lower life tyre.

Safety recommendations

The evidence suggested that underinflated operation is particularly damaging to aircraft tyres and the most likely cause of tyre break-up. Clearly a significant amount of energy is present in the tread of a tyre rotating at high speed and tread separation has the potential for causing appreciable and hazardous aircraft damage. In this case the flap damage did not noticeably affect the operation of the aircraft but was potentially serious and severe damage to the brake systems and engines was possible. Potentially hazardous damage had occurred in previous similar cases, including extensive flap damage, hydraulic system loss and/or engine damage and two cases of sudden engine failure at a critical point in the take-off. Tyres are routinely examined as part of the flight crew's preflight checks but underinflation of a single tyre on a muti-wheel assembly is difficult if not impossible to detect. In order to reduce the possibility of underinflated operation it has been recommended that:

Safety recommendation 99-11

The CAA consider a requirement for the installation, on the wheels of UK registered aircraft where a potentially hazardous level of tyre underinflation can be undetectable by external visual inspection, of a device to provide ready indication of such a condition during routine pre-flight external inspection.

It has also been recommended that:

Safety recommendation 99-12

The CAA consider requiring the fitment on future aircraft types on the UK Register of a system to provide continuous flight deck indication of tyre pressures and/or warning of abnormal pressures.