AAIB Bulletin No: 2/2005 **Ref: EW/G2004/09/07** **Category: 1.1**

Aircraft Type and Registration:	Boeing 737-33A, 9H-ADH
No & Type of Engines:	2 CFM56-3C1 Turbofan engines
Year of Manufacture:	1998
Date & Time (UTC):	1 September 2004 at 1836 hrs
Location:	Glasgow Airport, Scotland
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 5 Passengers - 138
Injuries:	Crew - None Passengers - None
Nature of Damage:	Burst tyre. Flaps, left main landing gear sidestay and hydraulic control lines damaged
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	7,000 hours (of which 5,000 were on type) Last 90 days - 187 hours Last 28 days - 60 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent enquiries by the AAIB.

Synopsis

During the takeoff from Glasgow Airport, the left inboard (No 2) tyre shed its tread. This led to the loss of the A system hydraulic contents, failure of the landing gear to retract and failure of the left main landing gear (MLG) green 'down and locked' light to illuminate in the cockpit. After holding for three hours to burn off fuel, the aircraft landed safely. The tyre failure was most probably due to fatigue in the sidewall. The tyre was at its sixth retread and close to its wear limit and may have reached its ultimate fatigue life prematurely for an undetermined reason; the retread limit for this tyre was R-6. The operator has since put in place several safety actions to prevent recurrence. No recommendations are made in this report.

History of flight

The intention of the flight was to fly from Glasgow to Malta. Preparations for the flight had been carried out with no identified problems and the aircraft taxied uneventfully to Runway 23. The takeoff, flown by the commander, appeared to the crew to be normal but, in the first stages of the climb out, the first officer (FO) noticed that the A system hydraulic quantity was rapidly reducing. At the same time the commander requested the landing gear to be raised. On selecting the gear lever to UP; the landing gear failed to retract, the three red gear unsafe warning lights for each landing gear illuminated, two green gear 'down and locked' lights also illuminated (the left MLG light was not illuminated) and the HYD master caution light also came on. The commander levelled the aircraft at 3,000 feet and informed ATC that they had a technical problem which needed to be observed. ATC offered an immediate return to Glasgow, which was declined by the crew.

Some five seconds after takeoff the ground movement controller at Glasgow noticed a white stream emanating from the underside of the aircraft and informed the tower. This information was passed to the crew of 9H-ADH, who then confirmed that they had lost their A hydraulic system. They calculated that they would have been overweight for an immediate landing and so they decided to hold in the vicinity to burn off fuel.

Following three aircraft movements on the runway, the crew aboard a recently landed Boeing 757 notice tyre debris on the runway. ATC were informed and the runway was then closed for an inspection, which indeed revealed tyre debris. This was cleared and the runway subsequently reopened.

During this time the crew of 9H-ADH tried to establish the condition of the left MLG, as there was no green down and locked indication. Using a 'gear viewer' in the cabin floor, they confirmed that the gear appeared to be down, but were unable to see the wheel and tyre. So that they could fully understand the situation, the crew requested a fly past of the tower at Glasgow, with an engineer available on the ground to visually assess the landing gear. During the flypast, the engineer was able to establish that the left inboard main wheel (No 2) tyre was either missing or damaged and that the left MLG was down. The aircraft then re-entered the holding pattern to burn off more fuel to reduce its weight in preparation for landing.

Some three hours later the aircraft landed safely at Glasgow.

Aircraft Examination

A subsequent examination of 9H-ADH revealed that the No 2 tyre had shed its tread, deflated and had become detached from the rim of the wheel. Tyre debris had been flung upward and rearward,

becoming lodged against the left rear spar close to aileron and spoiler control cables; debris was also found wrapped around the left MLG actuator. Hydraulic lines feeding the MLG transfer unit, which is supplied by A hydraulic system, were damaged and this allowed the leakage of hydraulic fluid. It also led to a subsequent failure of the No 1 engine hydraulic engine driven pump (EDP). Structurally, the left inboard trailing edge flap, mid flap and fore flap also suffered damage from the debris. There was also evidence of tyre debris striking the fuselage above the wing and the lower surface of the left horizontal stabiliser.

The left MLG side stay lock link had been hit by debris, causing it to bend to the extent that the ground lock pin could not be inserted. This also meant that the gear down and locked safety proximity sensor, mounted on the lock link, was out of proximity, preventing the illumination of the left MLG green down and locked light in the cockpit.

Tyre History

The tyre was a H40 x 14.5 x 19 with a 24 ply rating, which was manufactured in 2000. It had been retreaded on the 5 February 2004 with its sixth retread (R-6), which would have been its last retread as the limit is R-6. The shoulder to shoulder Shearography, following the retread, did not show any anomalies. The tyre was fitted to 9H-ADH on the 22 July 2004 and had completed 230 cycles prior to the accident.

The operator carries out tyre pressure checks every 24 hours and, in the days leading up to the accident, the values recorded were all within 5% of the required tyre pressure. The aircraft manufacturer defines the tyre pressures in the maintenance manual (MM) and states:

> *'a) if the measured tire pressure is below the necessary pressure by no more than 5%, inflate the tire to the necessary pressure.'*

Tyre Examination

The aircraft operator sent the tyre to the aircraft manufacturer for a detailed examination. The tyre had suffered a full shoulder to shoulder tread loss with the separation occurring at the outermost fabric layer. From the limited amount of retrieved tread pieces, this examination showed that the tyre was close to its fully worn condition. There were two ruptures to the sidewall of the tyre and severe damage had occurred to the inner liner. This was considered to be consistent with a tyre running with little or no tyre pressure. From the splits in the inner liner and sidewall of the tyre, it was evident that the nylon cords of several plys were broken. The damage was considered to be due to fatigue of the sidewall.

There were no signs of damage from foreign objects or evidence of cuts. Additionally there were no signs of manufacturing defects.

The conclusion of the manufacturer's examination was that the probable cause of the tyre tread loss was fatigue in the nylon cords of the lower sidewall. This allowed the tyre inner liner to split, air to then pressurise the carcass, which then led to the rupture of the sidewall and tyre deflation. It was not possible to ascertain if the tread loss occurred prior to or following the loss of pressure in the tyre.

The wheel assembly was tested with a new tyre installed, and this did not show any signs of leakage. The companion wheel and tyre (No 1) was also removed and tested, again with no signs of tyre pressure leakage, but it did exhibit signs of damage consistent with running overloaded, an expected condition brought about due to the failure of the No 2 tyre.

Discussion

The loss of the tyre tread on 9H-ADH was assessed as being due to fatigue of the sidewall of the tyre. Every tyre has an ultimate fatigue life, which is determined by the type of operation and the maintenance of the tyre during its life. Fatigue life is reduced by a tyre which is run under-inflated or run over-loaded at any time in the past, tyre damage or by having a lower natural tolerance due to manufacturing imperfections. Unfortunately, the only way to determine the fatigue life is to destructively test the tyre and carry out tensile tests of sections of the tyre. So that a tyre never reaches its fatigue life in service, a retread limit is set on the tyre which should never be exceeded. The retread limit is determined through destructive testing of sample tyres at various lives, and a determination made as to whether the tyre type would survive another retread level or not. In this case, the tyres used on 9H-ADH had a retread limit of R-6; the tyre that failed was at this retread level. The failed tyre was also close to its wear limit, meaning that it would soon have been removed and scrapped. Therefore, the tyre had probably reached its ultimate fatigue limit at an earlier age than predicted by the sample testing on other tyres.

When a tyre is retreaded it is subjected to a Non Destructive Test (NDT) inspection called Shearography; this is designed to identify any abnormalities not only with the retread but also with the carcass itself. The problem with this type of inspection is that it will not identify an impending fatigue failure; it can only show a problem once it has occurred. Therefore, it is difficult to predict from Shearography whether a tyre will survive the operational cycle before its next retread. The best chance of detecting a problem is to carry out a full bead to bead Shearography, which should also detect any problems with the tyre sidewall. However, in most cases only a shoulder to shoulder Shearography check is carried out to examine the area which has been subjected to the retread. This was the case with the failed tyre.

From the indications received by the crew in the cockpit shortly after takeoff, the tyre lost its tread at rotation, the point where the tyre would have been under greatest stress. The loss of the A hydraulic system was directly attributable to tyre tread debris damaging the hydraulic lines to the left MLG transfer unit. The landing gear is retracted using pressure from the A hydraulic system and, with the loss of the hydraulic contents, the gear would not have been able to retract when commanded. The failure of the green 'down and locked' indication on the left MLG was, again, attributable to damage from the tread debris. The left side stay lock link, which carries the proximity sensor for the cockpit light, had been distorted, moving the sensor out of proximity with its target, even though the gear was down and in the locked position. The most concerning aspect of the tread failure was the piece of debris which had become lodged near to the control cables for the spoilers and ailerons on the left wing. This had the potential to result in a control restriction during a critical phase of flight.

Actions taken by the operator

Since this accident the operator has put in place various measures to prevent a recurrence, these include:

1. A new retread limit of R-3 on all tyres fitted to Boeing 737-300 aircraft.
2. Full bead to bead Shearography to be carried out following a retread, as opposed to the previous shoulder to shoulder Shearography.
3. A maintenance instruction was issued to clarify the correct tyre pressures for every aircraft in the operator's fleet and engineers were briefed on the importance of tyre pressure management.
4. Any tyres manufactured in 2000, or with a retread of level 4 and above, have been removed from service.
5. For flights from Malta, takeoffs to be carried out with flaps 5 only.
6. Flight crews briefed on vigilance of the tyre condition during the pre-flight inspection.

In consideration of the above, and the fact that the aircraft manufacturer is aware of the damage caused to 9H-ADH as a result of this tyre failure (loss of the A hydraulic system and the potential for tyre debris to cause a control restriction), it was not considered necessary to make any safety recommendations.