Lockheed L1011 Tristar, 9Y-THA, 25 November 1998

AAIB Bulletin No: 4/2000 Ref: EW/C98/11/3 Category: 1.1

Aircraft Type and Registration:	Lockheed L1011 Tristar, 9Y-THA
No & Type of Engines:	3 Rolls Royce RB-211 turbofan engines
Year of Manufacture:	1980
Date & Time (UTC):	25 November 1998 at 1302 hrs
Location:	Runway 27L, London Heathrow Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 11 - Passengers - 215
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Right nosewheel stub axle broken
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	N/A
Commander's Flying Experience:	N/A
Information Source:	AAIB Field Investigation

The aircraft was operating a scheduled passenger flight from London Heathrow to Antigua. The crew reported for duty one hour before the scheduled departure time of 1210 hrs, having arrived in the UK some 72 hours previously. The aircraft pushed back from gate R36 onto the inner taxiway at 1240 hrs. It then taxied via block 47I to the holding point (right side) for departure from Runway 27L. Having received line-up clearance, the aircraft entered the runway at 1302 hrs.

As the commander was about to make the right turn to align the aircraft with the centreline, the crew felt a 'thud' as though the aircraft had run over an object on the runway. The commander considered that this was probably a tyre failure as the nosewheel steering then felt somewhat heavier than usual. A following aircraft at the holding point called on the Tower frequency to report that there was a problem with the L-1011's nosewheel. The commander stopped the aircraft in its current position on the runway threshold and applied the parking brake. The APU was started in order to give electrical power and air conditioning and the three engines were shutdown. The passengers remained seated and were calm. The crew then waited for ground assistance.

The Heathrow Tower controller declared an Aircraft Ground Incident and the emergency services were rapidly in attendance. Ground equipment was brought to the aircraft in order that the passengers could disembark normally onto waiting coaches.

Prior to departure, there were no significant deferred defect entries in the aircraft's Technical Log. The flight engineer had performed the pre-flight external inspection but reported seeing nothing unusual at that stage.

The runway continued in use for departures using a reduced take-off distance from an intersection. The aircraft was defuelled in situ to reduce the weight and then towed off the runway under the supervision of a contracted salvage and recovery manager, the full length of the runway being available for use again by 1900 hrs.

The right nosewheel had separated from the nose landing gear through a failure of its axle. The nose landing gear piston assembly, including the left axle and the stub of the broken right axle was removed from the aircraft and returned to Lockheed Martin for examination. The detached axle portion was retained by the AAIB and taken for metallurgical examination to DERA, Farnborough.

The axle had failed from multi-origin cracking which was distributed around the bottom half of its circumference. Approximately 80 initiation sites were counted. Crack development in the steel (under chrome plating) had begun in an intergrannular mode to a maximum depth of 0.014 inch. Areas of transgrannular cracking (fatigue) had then developed to a maximum penetration of 0.270 inch near bottom dead centre which was the focus of the final rupture. The initial intergrannular phase was consistent with being the result of a stress corrosion or hydrogen embrittlement process. The fatigue had developed as a result of the stress concentration created by this initial cracking. A metallographic section showed two other intergrannular cracks parallel to the main fracture with associated cracks through the chrome. There were also numerous cracks in the chrome layer some of which penetrated through its full thickness. Such cracks would create a stress concentration in the steel surface and expose it to oxidising or corrosive agents. The fracture surface had a brown or purple discoloration to a maximum depth of 0.046 inch. The discoloured area covered the intergrannular cracking and some of the initial development of fatigue.

The axle is manufactured from 4340 steel and analysis showed that the material of the failed axle conformed to specification. The axle stub is chrome plated and is covered by an interference fit steel sleeve on which the wheel bearings are located. The fracture plane was within the chromed area and 0.22 inch inboard of the end of the fitted, or contact, part of the sleeve. It was also enclosed by the sleeve's outward flared end which abuts a circumferential flange on the axle stub and, therefore, the cracked surface is not directly accessible for inspection on an assembled component.

DERA analysis of the stained area on the fracture surface identified no corrosive agents and all of the fracture surface showed evidence of carbonaceous deposit (probably post fracture contamination) and iron oxide. It was considered that the discoloration was due to an enhanced thickness of the oxide layer which would be typical of a free steel surface being exposed to a high temperature i.e. overheating after the cracking had begun to develop. The aircraft manufacturer attributed the discoloration to one or more of the heat treatment (baking) cycles that the component would have been subjected to at its last overhaul. This placed the initiation and early development of the cracking during the nose landing gear's first overhaul life.

The nose landing gear on 9Y-THA had accummulated 51,938 flight hours since new and 25,879 flight hours and 7871 flight cycles since being installed in July 1990 following overhaul. Full records of the last overhaul were not available as the overhaul agency was under a national legal obligation to keep such records for only 7 years. The overhauler stated that the chrome plating would not have been stripped from the axle but the axle would have been inspected by the magnetic particle technique.

In July 1984 a similar axle failure had been experienced on a Tristar turning to line up for departure from London Heathrow to the Middle East. The crew did not realise that a nosewheel had been lost and they completed a normal flight and landing at Bahrain. The nose landing gear is designed to take all certification loads on one wheel and axle to allow for the burst tyre case, assuming the remaining axle to be undamaged. The manufacturer's assessment of that failure was that the axle stub had been damaged during a manufacturing grinding process. Using an etching technique (Reference: " A New Inspection Process for Detecting Abusive Grinding Damage in Hard Chromium Plated Parts", by R.W.Messler and R.R.Miller, Grumman Aerospace Corporation, presented at the 1974 Airlines Plating Forum.), the manufacturer detected a pattern of cracking on the chrome surface which is considered to be indicative of grinding damage. Fine surface cracking is normal in hard chrome but abusive grinding can produce coarser cracking through the full depth of the chrome producing a network of surface cracks which is colloquially known as 'mud-cracking' or 'chicken wire' cracking. The metallurgical report also stated that the grinding process had produced cracks in the underlying steel from which stress corrosion cracking had developed. The turning manoeuvre during which the final rupture had occurred was recognised as a high load case, comparable to touchdown, which could be expected to cause rupture in a cracked axle. No in-situ inspection technique was available for this location on the axle and it was considered that the failure was no more significant in safety terms than a burst tyre. It was recommended that a magnetic particle inspection of the subject area be carried out at overhaul.

In the case of 9Y-THA, DERA's metallurgical examination of the axle did not reveal any of the changes in crystal structure of the steel which normally result from overheating during grinding but the manufacturer did detect a "mud-cracking" pattern in the chrome adjacent to the fracture using the etching technique.

The intact left axle was also examined. The sleeve was removed and the stub was subjected to some non-destructive inspection. Fluorescent magnetic particle inspection (FMPI) disclosed no evidence of cracking. High frequency eddy current showed indications of cracking around the lower half of the circumference which was judged to be shallow and perhaps restricted to the chrome layer. The etching technique revealed the 'mud-crack' pattern over a distance of 0.25 inch of the inboard end of the chrome ie covering the area which was fractured on the right stub. The chrome was chemically stripped, FMPI again applied and no cracks were detected. However, when the stub was sectioned at the six o'clock position four cracks were found, the deepest being 0.032 inch. From the metallographic section these appeared to be intergrannular and therefore consistent with stress corrosion (or hydrogen embrittlement) with no evidence of fatigue development.

Lockheed Martin considered the non-destructive testing techniques which were available and decided that there was none which, in practical terms, could be used in the field to inspect the failure location in the axle. The company has decided that the only way to ensure that any potential damage is reliably detected is to remove the axle's sleeve and chrome coating at overhaul and perform an inspection using ultra sensitive fluorescent penetrant inspection. Lockheed Martin is currently making a temporary revision to the Component Maintenance Manual and anticipates completion of this in March 2000. A permanent revision will be incorporated in the Overhaul Manual by June 2000.