BAe 146-RJ100, G-BZAT

AAIB Bulletin No: 7/2003	Ref: EW/C2003/02/01	Category: 1.1
Aircraft Type and Registration:	BAe 146-RJ100, G-BZAT	
No & Type of Engines:	4 Lycoming LF507-1F turbojet engines	
Year of Manufacture:	1997	
Date & Time (UTC):	10 February 2003 at 0840 hrs	
Location:	Birmingham Airport	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 5	Passengers - 94
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Left nose wheel detached	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	30 years	
Commander's Flying Experience:	3,500 hours (of which 2,600 were on type)	
	Last 90 days - 135 hours	
	Last 28 days - 45 hours	
Information Source:	AAIB Field Investigation	

Synopsis

Apart from a slight nose wheel shimmy during takeoff, the crew noticed nothing unusual during a flight from Glasgow to Birmingham Airport. However, after they had parked at the stand, it was apparent that the left nose wheel was missing and this was subsequently found adjacent to the runway at Birmingham. Examination of the aircraft revealed that an abutment ring (spacer) was incorrectly installed on the subject nose landing gear axle, and that this had precluded the correct locking action of two bolts designed to secure the wheel retaining nut. Three safety recommendations are made as a result of this event.

History of Flight

The crew were operating their second and final sector on a split-duty nightstop, returning from Glasgow to Birmingham. They arrived at the aircraft in good time for their 0650 hrs departure and the Captain, as handling pilot, carried out the pre-flight external checks. He noticed nothing unusual and the aircraft was prepared for departure.

During takeoff, at about the point of rotation, a slight nose wheel shimmy was felt by both pilots sufficient for them to comment on but not to cause any alarm. They continued the flight without incident and due to reduced visibility at Birmingham decided to carry out a CAT IIIB autoland. The aircraft was configured early to prepare for the approach to Runway 15 and the landing gear was lowered at about 7 nm on finals. The autoland was normal and after clearing the runway the crew

taxied the short distance to their stand. On parking, the dispatcher pointed excitedly at their nose wheel and shortly afterwards an engineer informed them that one of the two nose wheels was missing.

Flight Recorders

The 30 minute CVR had recorded over the period of the takeoff from Glasgow, subsequent landing at Birmingham and taxi to stand. The recording of the events after this provided no useful information to the investigation.

The solid state FDR had retained data from the previous 37 sectors, including four Glasgow to Birmingham flights. In comparison with the previous three departures from Glasgow on the same runway, data recorded during the incident takeoff showed no anomalies. Additionally, no unusual behaviour was evident in the data recorded during the landing at Birmingham.

Nose Wheel Installation

The Nose Landing Gear (NLG) has two independent wheels, positioned either side of the noseleg, Figure 1, and these are each located on the axle by means of an inboard spacer, referred to as an 'abutment ring' and an outboard spacer. The abutment ring inner diameter is chamfered on one side and this allows it to abut directly against a flange at the inboard end of the axle and not foul a blend radius between the axle and the inboard flange of the axle. The nosewheel is secured by a wheel retaining nut, which is torque tightened to 25 ft lbf and, in order to secure this nut, two special locking bolts are screwed in to a flange on its outboard side. The ends of these bolts locate into slots in the axle, and any movement of the wheel retaining nut is prevented by the location of the bolts within the slots. The two locking bolts are then wire-locked together.

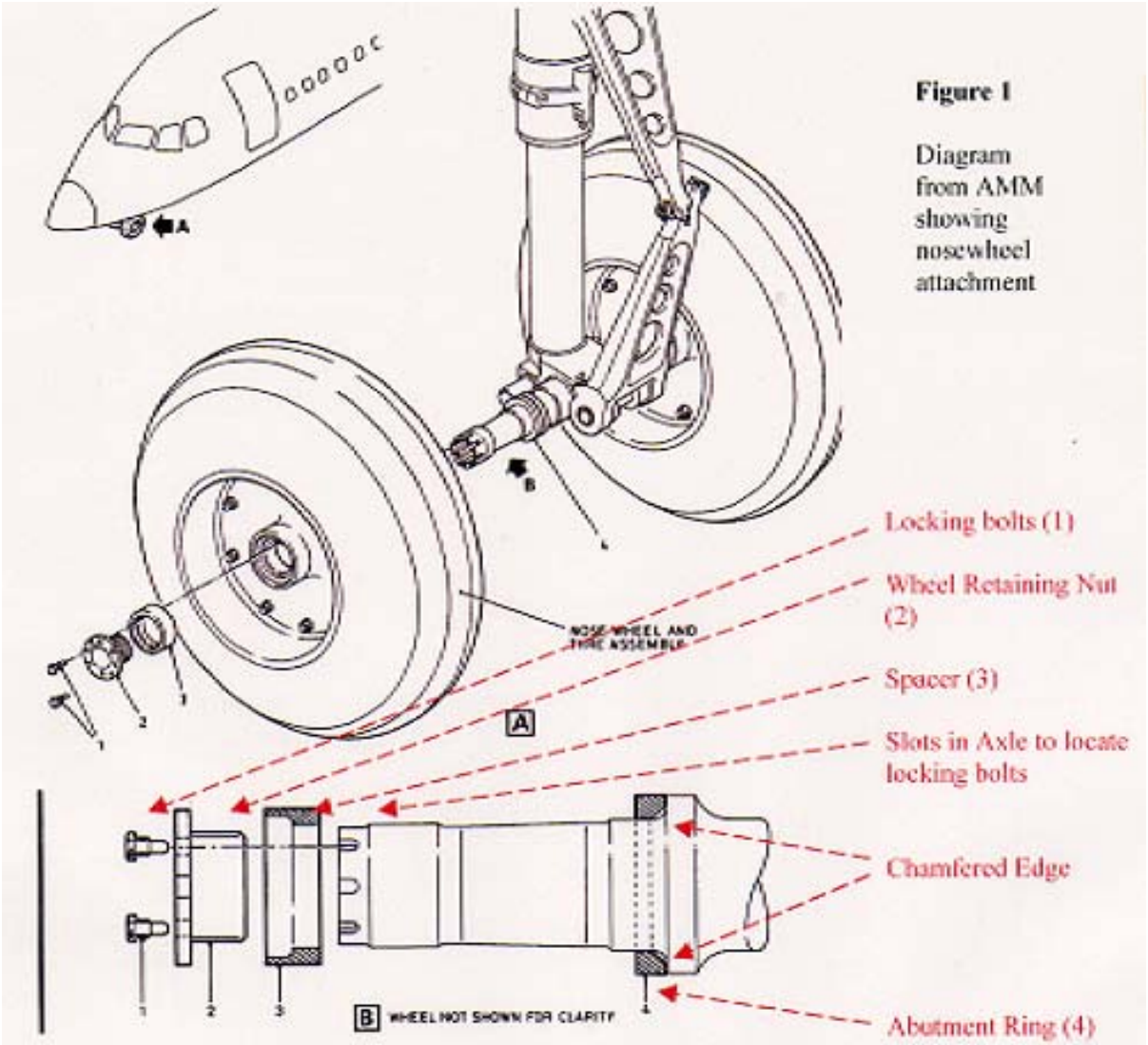

Figure 1

Diagram from AMM showing nosewheel attachment

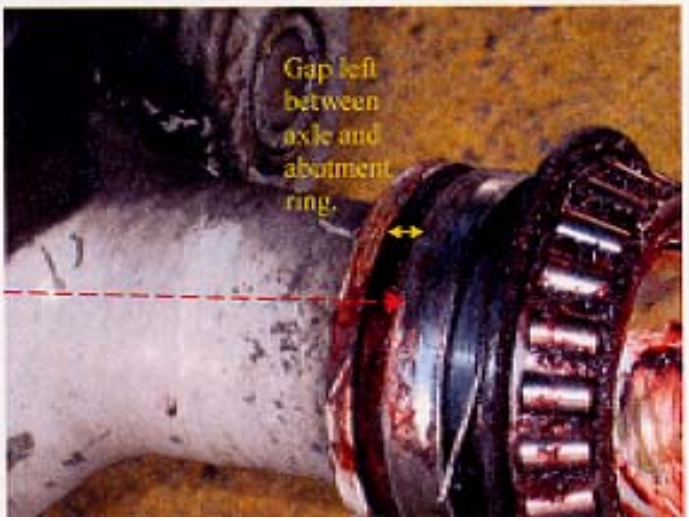

Figure 2

Nosewheel axle 'as found' with abutment ring fitted incorrectly

Aircraft examination

The NLG was found with only the right wheel attached. On the left axle, the inboard wheel bearing and the abutment ring were present. The abutment ring, however, was found to have been fitted with the chamfered edge facing outboard. With no chamfer on the inboard face to accommodate the blend radius on the axle, a gap was present between the abutment ring and the inboard flange of the axle. With such a gap present, it is possible to fit and torque-load the wheel retaining nut, but the nut locking bolts are then not long enough to engage with the slots in the axle. Thus, since the subject wheel was fitted, the wheel retaining nut would not have been locked. The normal rotation of the left wheel is such that, over a period of time, frictional forces through the wheel bearing would tend to unscrew the wheel retaining nut completely, and allow the wheel to migrate off the axle. The missing left nose wheel was subsequently located on the grass approximately 150 m to the right side of Runway 15 at Birmingham Airport but the wheel retaining nut, locking bolts and outboard spacer were not found, despite searches at both Glasgow and Birmingham Airports.

Maintenance Instructions

The following are extracts from the Aircraft Maintenance Manual (AMM) describing the removal and installation of the nosewheel and tyre.

AMM 32-42-17 401- WHEEL AND TYRE - NOSE - REMOVAL/INSTALLATION BAe146 - EFFECTIVITY: On aircraft ALL - DATE: Sep 15/02 - BAE SYSTEMS

B. Remove nose wheel and tyre

(1) Support weight of aircraft with nose wheels clear of ground (Ref.AMM 07-00-00, page block 1).

(2) Reduce tyre pressure to 20% of unloaded inflation pressure (Ref.AMM 12-10-32, page block 1) using tyre inflation adapter.

(3) Cut and remove lockwire and remove wheel nut locking bolts (1).

(4) Remove wheel retaining nut (2) using nose wheel nut spanner. Remove spacer (3).

(5) Carefully remove wheel.

C. Install nose wheel and tyre

WARNING: DO NOT USE AN AXLE WHICH HAS BEEN SUBJECT TO CADMIUM MELTING. THIS CAN CAUSE THE AXLE TO BECOME BRITTLE

CAUTION: DO NOT INSTALL WHEEL TO A DAMAGED AXLE AS THIS CAN DAMAGE THE WHEEL.

(1) Clean grease and dirt from axle shaft using a lint-free cloth.

(2) Make certain painted surfaces of axle show no signs of burning, blackening, charring, blistering, discolouration or melting of cadmium plating.

NOTE: Cadmium melting appears as spots of dull grey metal deposit and the metal around the deposit will appear bare.

(3) Make certain machined surfaces of axle are smooth and show no signs of damage or discolouration.

(4) Apply a thin layer of grease.....

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(6) Make certain abutment ring (4) is in position, with chamfered side facing inboard, and carefully assemble wheel onto axle.

CAUTION: MAKE CERTAIN SPACER (3) IS INSTALLED ON THE AXLE WITH THE REBATED SIDE FACING OUTBOARD.

(7) Install spacer (3) and wheel retaining nut (2). Hand tighten nut.

(8) Using nose wheel nut spanner and torque spanner, torque tighten wheel nut to 75 lbf.ft. (10.168 mdaN), while manually rotating wheel.

(9) Unscrew wheel nut until wheel rotates freely.

(10) Torque tighten wheel nut to 25 lbf.ft. (3.389 mdaN) while manually rotating wheel.

CAUTION: MAKE CERTAIN LOCKING BOLT HOLES ARE CORRECTLY ALIGNED WITH SLOTS IN AXLE BEFORE ATTEMPTING TO INSTALL BOLTS (1).

(11) If necessary, increase wheel nut torque to align locking holes with slots in axle. Install locking bolts (1) finger tight and make certain bolts engage slots in axle.

(12) Tighten locking bolts (1) using spanner and wire-lock together.

(13) Inflate tyre to correct pressure (Ref.AMM 12-10-32, page block 1).

(14) Lower aircraft and remove support equipment (Ref.AMM 07-00-00, page block 1).

(15) Inflate tyre to correct pressure for a loaded tyre (Ref.AMM 12-10-32, page block 1).

Maintenance History

Both nosewheels were changed overnight on the 4 February 2003 and the task was performed outdoors with the aircraft on the ramp. Two licensed engineers and a technician were responsible for the double nosewheel change, with one of the engineers performing the change of the left nosewheel. The engineer concerned had only performed this task once since completing his initial course on the RJ aircraft last year, and he reported that he referred to the AMM whilst changing the wheel. His recollection of the task was that the abutment ring had remained on the axle when he removed the left wheel and, therefore, he had no need to check the orientation of the abutment ring. His conclusion subsequent to the incident was that the abutment ring was fitted incorrectly prior to his changing of the wheel. Since this nosewheel change on the 4 February 2003, the aircraft had completed 32 landings; the previous nosewheel change was performed on 2 January 2003. Subsequent to this event, the operator checked their RJ100 fleet and no other abutment ring spacers were found fitted incorrectly.

Previous Incidents

The abutment ring is known to have been been incorrectly fitted to 146/RJ aircraft on two previous occasions. The first was in September 1994, when the left nosewheel detached on landing, and this had been changed two days prior to the incident. As a result, the manufacturer amended the AMM to describe the task more explicitly and included a diagram showing the axle assembly. The new AMM text and illustrations were published in March 1995.

The second incident occurred in July 1997 when the left nosewheel detached on takeoff. The aircraft subsequently diverted and, having circled to burn excess fuel, landed safely. The nosewheel had been changed two days prior to the incident. As a result of this event, the operator painted red both the area

of the chamfered face of the abutment ring and the area on the axle to be covered by the spacer, ie, if red paint is visible then the abutment ring is incorrectly fitted. A warning placard to this effect was also placed on the NLG strut. The operator also issued a newsletter highlighting the need to comply with AMM instructions and operating procedures.

Human Error in Aircraft Maintenance

Various studies carried out into human factors in maintenance have attempted to quantify the probability of human error. For example, Ostrom, in a paper titled '*Structured Human Error Analysis for Airplane Maintenance and Design*'[1], presents figures on maintenance error probability, for one generation of military transport aircraft, taken from a major aircraft manufacturer. This study indicates that there are small, but significant probabilities, of maintenance personnel, for example, ignoring a warning/caution/note, of improperly removing/replacing/installing/cleaning/lubricating as part of a step and of skipping a step in a procedure. In this incident any of these errors could result in the incorrect assembly of the nosewheel installation.

Analysis

The wheel detached due to the incorrect assembly of the abutment ring on the axle. The design of abutment ring allows it to be fitted the wrong way round and, in this circumstance, the locking bolts do not perform their locking function of the wheel retaining nut. The locking bolts can still be fitted and wire locked without it being apparent that they are not located into the slots in the axle and are, therefore, free to move with the wheel retaining nut. The incorrect assembly of the right nosewheel may not result in its detachment since the direction of rotation of the right wheel will tends to tighten the wheel retaining nut. In the two previous incidents the left nosewheels both detached two days following the nosewheel changes.

Based upon only these three known instances of incorrect assembly that have been reported over the life of the BAe 146/RJ fleet, it would appear that the various studies of human error in aircraft maintenance, which suggest that there is a probability of error in such a relatively simple task, are correct, but that the actual probability of error in carrying out this task is very small. However, despite the heightened awareness of this problem that may be brought about by additional cautions, placards and training, the opportunity remains for the abutment ring to be fitted incorrectly. Ideally, the design of such components should ensure that they can only be fitted in the correct orientation. The following recommendation is therefore made:

Safety Recommendation 2003-30

It is recommended that the Civil Aviation Authority, in conjunction with the NLG and airframe manufacturers, review the design of the NLG nose wheel installation on the BAe 146/RJ aircraft with a view to precluding the possibility of incorrect assembly of the wheel abutment ring.

After the first incident there was a change to the AMM, in March 1995, to include an illustration to show the location of the spacers on the axle NLG assembly. The text made reference to the abutment ring but a '*caution*' in the text was only included for the outboard spacer and not the inboard abutment ring. As the possibility for the incorrect assembly of the abutment ring could be easily and quickly highlighted by the addition of a specific '*caution*' in the AMM, the following safety recommendation is made:

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[1] Structured Human Error Analysis for Airplane Maintenance and Design, L Ostram et al, published October 1997, Idaho National Engineering and Environmental Laboratory, INEEL/EXT-97-01093

Safety Recommendation 2003-31

It is recommended that BAE Systems review the AMM procedures for the removal and installation of the nose wheel of the BAe 146/Avro RJ series aircraft to include a specific caution with respect to the fitment of the nose wheel abutment ring located at the inboard end of the NLG axle.

The engineer in this incident had only carried out this task on one previous occasion and the nosewheel change took place in far from ideal conditions, ie, outside, late at night (at approximately 0300 hrs), during cold weather with snow around, and during the third night of a four day shift period. Under these circumstances it is possible that engineers may not generally refer directly to the AMM but may rely on familiarity and experience of the task.

To minimise the immediate risk of this incident being repeated, the operator has introduced a Technical Instruction No 146-32-02 which highlights the correct assembly of the abutment ring. This topic will also be included in the aircraft type and recurrent training courses. It is therefore recommended that:

Safety Recommendation 2003-32

BAE Systems should ensure that the introduction of an awareness programme to highlight the possibility of incorrect assembly of the nose wheel abutment ring to the NLG axle is instigated, and include this awareness as an item in the aircraft type and recurrent training courses.