Hawker Siddeley Aviation HS748 Series 2A, G-BPDA

AAIB Bulletin No: 7/99 Ref: EW/C98/2/3 Category: 1.1

Aircraft Type and Registration:	Hawker Siddeley Aviation HS748 Series 2A, G-BPDA
No & Type of Engines:	2 Rolls Royce Dart turboprop engines
Year of Manufacture:	1977
Date & Time (UTC):	9 February 1998 at 0230 hrs
Location:	Liverpool Airport
Type of Flight:	Public Transport - Cargo
Persons on Board:	Crew - 2 - Passengers - None
Injuries:	Crew - None - Passengers - Not applicable
Nature of Damage:	Nose landing gear wheel detached
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	4,700 hours (of which 2,000 were on type)
	Last 90 days - 95 hours
	Last 28 days - 30 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and component examination by AAIB and the manufacturer

History of the flight

The aircraft was on a night freight flight from Liverpool to Belfast with a cargo of newspapers. The take off was normal and the landing gear retracted apparently normally during the climb. On selecting the gear down for the landing at Belfast, the crew noted that the red 'In-Transit' annunciator light for the nose landing gear (NLG) was very slow to extinguish. However, the three green Landing Gear Locked Down light captions were obtained and the crew continued the approach to Runway 25, holding the NLG off the runway for as long as possible during the landing ground roll. After the NLG touched down, the feel of the aircraft led the crew to suspect a burst nose gear tyre. They informed ATC of this possibility after the landing and taxied slowly to the stand. On arrival the left nose wheel was found to be absent. It was subsequently located near the beginning of Runway 27 at Liverpool, indicating that it had departed from the aircraft shortly after the start of the take-off run.

Component description

The NLG has two wheels on a common axle. The axle assembly rotates with the wheels (*ie* a 'live' axle) and is carried on two taper roller bearings fitted in an axle housing mounted at the bottom of the NLG oleo (Figure 1.1). The assembly comprises a tubular axle approximately 19 inches long with an integral hub at the right end and a removable hub at the left end. The left hub is splined to the axle and retained axially by a castellated axle nut. The nut acts through an outboard bush to clamp the left hub against a shoulder on the axle, via a conical bush. Nut rotation on the axle after assembly is prevented by lock dowels retained by locking wire which locate in the castellations of the nut and pass through holes in the axle. The axle assembly is retained axially within the axle housing bearings by a bush bearing against the right hub flange and by a bearing adjustment nut screwed onto the left hub. This nut is prevented from rotating relative to the hub by a locking pin located in the hub. The nut has a castellated outer diameter and is adjusted by means of a hook spanner. The NLG manufacturer's Maintenance Manual requires the bearing adjustment nut to be adjusted to give 0.005 to 0.008 inch end float of the axle assembly relative to the axle housing.

The Manual specifies a special tubular spanner (PN MT1510) and a Torquemaster torquemeter for turning the axle nut, which is tubular with 8 castellations on the outer end; the required assembly torque is 275 to 300 lb feet. The Manual specifies that, before tightening the axle nut to clamp the axle assembly together during assembly, the bearing adjustment nut should be screwed fully onto the hub (*ie* maximum separation of the bearing adjustment nut from the bearing). Only after the axle nut has been torque tightened is the bearing adjustment nut to be screwed back to bear against the inner race of the right bearing and then adjusted to provide the specified end float (see under Landing gear history).

Component examination

The left hub assembly, the outboard bush and the axle nut were reportedly found with the left wheel, with the bearing adjustment nut attached. All parts were reportedly found correctly locked. These components were subsequently removed from the separated left wheel and were initially sent to the landing gear manufacturer for examination, together with the axle tube. The conical bush was not recovered. The components were subsequently examined by AAIB (Figure 2.1).

The examination revealed severe deformation of the mating end faces of the axle nut and the outboard bush, consistent with the effects of wear and plastic deformation due to repeated hammering contact between them. The left hub exhibited polishing and spalling damage to the surface normally in contact with the conical bush and appreciable wear of the splines. Additionally, the inner surface of the hub normally contacted by the outboard bush was severely corrosion pitted; the diametric clearance between the axle and the outboard bush was approximately 0.010 inch. The inboard end face of the bearing adjustment nut had suffered severe wear, of approximately 0.030 inch, apparently from abnormal contact with the left bearing inner race. The crests of most of the axle threads (Figure 2.2) and all of the axle nut threads had been worn away and this had apparently allowed the nut, and hence the left hub and wheel, to separate from the axle.

With the exception of the corrosion, the above damage to the recovered components was consistent with deformation and gross wear as a result of prolonged repetitive rubbing and/or hammering contact between the axle assembly components.

The axle nut and the bearing adjustment nut had also both suffered local damage to the edges of the castellation slots. This consisted of irregular local yielding of the material as a result of forcible impact in these areas (Figure 2.3), apparently due to use of incorrect tools and possibly consistent with the effects of attempts to rotate the nuts by striking the edges of the slots tangentially with a hard object. The damage, in some places locally severe, was present on both sides of all 8 slots of the axle nut, *ie* in both the tightening and slackening directions. In the case of the bearing adjustment nut, most of the 12 slot edges were affected, but the damage was predominately in the unscrewing direction, *ie* nut translation towards the bearing.

Landing gear history

At the time of the accident the NLG had accumulated 36,431 cycles since new. It had last been overhauled, by Dan Air Engineering, in 1992 and was installed on G-BPDA in November 1992. Maintenance records indicated that since installation the axle assembly had twice been adjusted, during the operator's line maintenance activities. A further un-recorded adjustment occurred shortly before the accident.

The first adjustment, in 1994, followed a series of reports in the Technical Log over a 5 week period of excessive NLG vibration, noise and/or shimmy during gear retraction after take-off and a report of aircraft steering problems. It was recorded as 'Axle end float adjusted'.

During 1995, 9 cases of aircraft directional control problems associated with NLG steering were recorded. Remedial action including re-rigging the steering system and changing components. In early 1996 the NLG axle assembly was again adjusted, after the operator found 'excessive end float'. This was followed by 3 cases of problems with the axle assembly left end cover or the associated bush during 1996 and 1997.

A report by the operator indicated that during a routine change of both nosewheels on 7 February 1998 a small amount of end-float in the axle assembly was noted. This was in excess of the allowable limit specified in the landing gear manufacturer's Component Maintenance Manual, and the axle nut was found to be loose. The operator noted that HS748 NLG axle nuts were occasionally found loose. As the correct torquemeter was not available and the tube spanner for the axle nut could not be found, the operator's line maintenance personnel tightened the nut with a hook spanner. The torque loading used was unknown but was judged to be less than the maximum value of 300 lb feet specified in the NLG manufacturer's Maintenance Manual. The axle assembly end-float was adjusted, reportedly in accordance with the NLG manufacturer's Component Maintenance Manual. Entries in G-BPDA's Technical Log showed that the nosewheels had been replaced but the work on the axle was not recorded. The accident occurred on the 5th flight after this work.

Relevant events were as follows:

EVENT	DATE	AIRCRAFTTIME SINCE NEW - hr	AIRCRAFTCYCLES SINCE NEW	AIRCRAFT CYCLES PRIOR TO ACCIDENT
Last NLG Overhaul and last recorded NLG Axle	4-9-	9,205	19,888	5,974

Assembly Installation	92			
Reports of NLG vibration, noise and/or shimmy during gear retraction after take-off	6-8-94 to 15-9-94	10,317 10,388	21,732 21,842	4,130 4,020
NLG Axle Assembly Adjustment	15-9-94	10,388	21,842	4,020
Reports of aircraft directional control problems associated with NLG steering	23-5-95 to 15-10-95	10,894 11,184	22,612 23,023	3,250 2,839
NLG Axle Assembly Adjustment	23-2-96	11,479	23,436	2,426
NLG Axle left cover rivets sheared	16-4-96	11,594	23,603	2,259
NLG Axle left cover bush missing	6-5-96	11,641	23,676	2,186
NLG Axle left cover bush sheared	4-10-97	12,778	25,412	450
NLG Axle Assembly Tighten & Adjustment	7-2-98	13,075	25,857	5
Accident	9-2-98	13,079	25,862	-
Embodiment of Dowty SB 32-100E (see Section 5)	15-5-98	13,283	26,145	-283

Following the accident a new axle nut was fitted to the axle during attempts to make the aircraft towable but it was found to be impossible to achieve the minimum specified torque loading. Since the accident the operator has acquired the correct axle nut spanner and torquemeter.

Background

Procedures for adjusting the NLG axle assembly or bearing adjustment nuts were not included in the Hawker Siddeley HS748 Aircraft Maintenance Manual (AMM) (748017 D.22) or the Dowty Rotol Ltd (subsequently Dowty Aerospace Landing Gear Ltd and Dowty Aerospace Gloucester Ltd) NLG Maintenance Manual (915M/1) on which the relevant part of the AMM was based. A procedure for assembling the axle assembly was given to operators in Dowty Rotol Ltd Service Letter A2, Issue 3, 24 May 1982. This noted: "Following an instance where axle nuts were found loose by an operator, this service letter is to inform operators that on re-assembly of the Nose Undercarriage axle, after repair or overhaul, the following procedure should be adopted and read in conjunction with assembly instructions in the Overhaul Manual." The summary specified the correct tools and the method for correctly torquing the axle nut and setting the bearing adjustment nut and included: 'Note: It is essential that the bearing adjusting nut is backed off prior to torque loading the axle nut.' The original issue of the Service Letter was not available.

Dowty Rotol Ltd Service Letter A11 of 4 July 1989 again 'informed operators' that 'the correct Tube Spanner and Torque Spanner must be used to torque tighten the Axle Nut'. It noted that "There have been a number of occurrences where the Axle Hub and Bush Sub-Assembly has been incorrectly assembled at overhaul. This has resulted in excessive Axle End Float due to fretting, and/or slackening of the Axle Nut [and] has resulted in the loss of the left hand nose wheel. The problem is attributed solely to Overhaul Agencies not complying with Maintenance procedures."

Dowty Aerospace Gloucester Ltd Service Bulletin 32-100E, issued on 21 May 1990 'informed operators of the need to carry out a once-only examination of the NLG for correct axle end float and axle nut integrity.' Compliance was categorised as 'Recommended', at 2,000 landings following the fitment of an overhauled nose gear or within 2,000 landings from receipt of the Bulletin for those aircraft with a nose gear having more than 2,000 landings since overhaul. It recommended that any axle assembly showing evidence of incorrect assembly or damage to the axle nut castellations should be removed for rectification by an overhaul/repair agency within 1,000 landings.

The correct procedure for torque tightening the axle assembly and adjusting the bearing adjustment nut was also contained in the Dowty Aerospace NLG Component Maintenance Manual 32-20-01, Section P (3), latest Issue at the time of the incident, Dec 1/93). This included: 'CAUTION: ENSURE THAT THE [BEARING ADJUSTMENT] NUT DOES NOT ABUT THE BEARING DURING TORQUE TIGHTENING OF THE AXLE NUT.' This manual is commonly referred to as the 'NLG Overhaul Manual'.

Maintenance scope

The operator was not a Joint Aviation Requirement (JAR) 145 approved maintenance organisation and all base maintenance was contracted to an organisation that was JAR 145 approved. However, the operator was required by the CAA to be responsible for the standard of all the maintenance conducted on its aircraft. Definition of this responsibility was included in the Air Operator's Certificate (AOC) granted to the operator by the CAA. Line maintenance was carried out by the operator under the auspices of the base maintainer's approval but no meaningful CAA definition of the scope of line maintenance was found. During discussions with the CAA, in the context of this investigation, some opinion suggested that line maintenance would normally be expected to be confined to those activities specified in the AMM and that the use of procedures given in Component Maintenance or Overhaul Manuals would not be considered appropriate. This was not explicitly specified in any way, but was considered to be normally accepted practice. However, this was later formally stated not to be the Authority's policy in differentiating between base and line maintenance. G-BPDA's operator and maintenance organisation considered that it was accepted practice for older aircraft designs, such as the HS748, where the aircraft manufacturer supplied the operator with a wide range of Component Maintenance and Overhaul Manuals as well as the AMM, for use of information from the Component Manuals as well as the AMM to be necessary for maintenance of the aircraft.

Joint Aviation Authority (JAA) Temporary Guidance Leaflet (TGL) No 6 provided the following definition: 'Line Maintenance is any maintenance that must be carried out before flight to ensure that the aircraft is fit for the intended flight. It may include:

- Trouble shooting.

- Defect rectification.

- Minor repairs and modifications which do not require extensive disassembly and can be accomplished by simple means.'

The CAA had implemented this TGL by means of CAA Airworthiness Notice No 14.

The NLG manufacturer considered that operators would normally not possess the axle nut special tool and that the procedures for axle assembly and adjustment given in their Maintenance Manual and Component Maintenance Manual would not be expected to be carried out during maintenance but were appropriate for undertaking by a NLG repair or overhaul agency.

No hangar was available to the operator and line maintenance was carried out in the open.

Discussion

Failure

The evidence indicated that the damage to the axle assembly components, indicative of repetitive hammering and fretting contact between them and responsible for the separation of the left wheel, had been due to operation with appreciable play existing between the components. It therefore appears that the left hub with its two bushes had either not been clamped to the axle at the time of installation, or that preload had been lost in service.

The landing gear manufacturer considered that the damage was typical of that resulting if the axle nut is tightened on assembly without the bearing adjustment nut having first been backed off sufficiently to maintain clearance between the bearing adjustment nut and the left bearing (Figure 1.2). Unless such clearance exists, tightening the axle nut will preload the left hub against the left bearing (via the bearing adjustment nut), rather than against the axle shoulder (via the conical bush). This will allow displacement of the hub and conical bush relative to the axle (Figure 1.3) with consequent hammering and fretting wear. The evidence indicated that this was the likely cause of the failure.

Maintenance

The point at which the axle assembly had probably been incorrectly torque tightened could not be established. It appeared likely that the end float and axle nut looseness discovered two days before the accident had been caused by excessive wear resulting from previous incorrect assembly. Although there was no record of axle nut disturbance following the 1992 NLG overhaul, no details of the operations carried out during the in-service adjustments were available, and the un-recorded tightening of the nut two days before the accident indicated that this could also have happened previously.

No evidence was found to indicate what maintenance investigation had been made into the cause of excessive NLG axle end float prior to adjusting the assembly on the three occasions that this was known to have occurred since NLG overhaul. On the last occasion it would be expected that the looseness of the axle nut, with no reported deficiency in the nut locking components, would have led the operator's line maintenance personnel to suspect a problem of some sort with the assembly and to have investigated, but this did not occur.

Instructions to ensure that the bearing adjustment nut is backed off fully before tightening the axle nut were given in the Component Maintenance Manual and emphasised to operators in a Service Letter first issued prior to 1982 and in a Service Bulletin issued in 1990. It was apparent that a number of similar cases of nosewheel detachment as a result of incorrect axle assembly had occurred, dating back at least 16 years prior to G-BPDA's accident, and probably earlier; the Service Bulletin that had resulted from the NLG manufacturer's experience of the service history of their equipment and aimed to prevent recurrence had been issued almost 8 years before the accident. The Service Bulletin had not been incorporated on G-BPDA prior to the accident, although recommended by the landing gear manufacturer, and there was no mandatory requirement for the operator to have done so as it had not been mandated by the CAA. This remains the case.

The appropriateness or otherwise of axle retorquing and adjustment as a line maintenance operation was unclear. It was apparently necessary normal practice for portions of the component manuals to be used during HS748 line maintenance. There did not appear to be any documentary definition of the CAA position, and these considerations were not addressed by the broad JAA definition given in TGL No 6. There would thus seem to be considerable scope for misunderstanding by the operator of the acceptability of their carrying out procedures that were outside the scope of the AMM. This was particularly the situation in this case where instructions for operators to follow the particular procedure, and to refer to the 'Overhaul Manual', had been given in a NLG manufacture's Service Letter. In order to remove the ambiguity that currently exists and to clarify the matter for maintenance organisations and operators it has been recommended that:-

Safety recommendations

Recommendation No 99-25

The CAA define limits for the scope of line and base maintenance operations and take measures aimed at ensuring that operators and maintainers are fully aware of these limits.