ACCIDENT

Aircraft Type and Registration:	BAe.ATP, G-MANH
No & Type of Engines:	2 Pratt & Whitney Canada PW126 turboprop engines
Year of Manufacture:	1989
Date & Time (UTC):	9 April 2011 at 0147 hrs
Location:	Cardiff Airport
Type of Flight:	Commercial Air Transport (Cargo)
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Both right main landing gear tyres, gear leg components, hydraulic pipes and flap/nacelle fairings damaged
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	56
Commander's Flying Experience:	10,138 hours (of which 1,379 were on type) Last 90 days - 85 hours Last 28 days - 28 hours
Information Source:	AAIB Field Investigation

Synopsis

During an otherwise normal landing at Cardiff, a failure in the right landing gear freed the axle to oscillate about a vertical axis, leading to severe damage and deflation of both tyres. The original failure was the result of the corrosion induced weakening of a threaded attachment. Consequent overload fracture of another component appears to have taken place before the Cardiff landing. The landing gear manufacturer is introducing a new Service Bulletin to address the deterioration of the corroded and failed area in service and amending the build procedure to obviate the possibility of surface damage during component assembly creating an origin for a corrosion process. A further problem noted during the fleet inspection following the original event has been addressed in the final Service Bulletin.

History of the flight

The aircraft was on a night cargo flight from East Midlands Airport to Cardiff. The flight was routine with the co-pilot as the Pilot Flying (PF). The surface wind at Cardiff was from 060° at 9 kt and Runway 12 was in use. In accordance with the company standard operating procedures, shortly after touchdown the PF selected full reverse thrust with the commander intending to take control at 60 kt. As the aircraft decelerated through about 80 kt the crew noticed an abnormal, lateral vibration that appeared to be increasing. The commander took control and stopped the aircraft on the runway, suspecting a burst tyre. The crew informed ATC and shut down the engines using normal procedures. Inspection of the landing gear and runway by the crew and the Airport Fire and Rescue

Service (AFRS) revealed damage to and deflation of both tyres on the right main landing gear along with airframe damage. Two metal components were recovered from the runway. Approximately four hours later the aircraft was then unloaded and towed clear of the runway.

Subsequent examination

The aircraft was first viewed by the AAIB whilst parked on Taxiway D, adjacent to Runway 12. At the time of this first examination, it was noted that temporary installation of an apex pin in the torque link assembly of the right landing gear had taken place. This was reported to have been carried out after absence of the original pin was observed following the landing event.

Initial AAIB examination of the tyres revealed circular cutting of the sidewalls on the inner face of each, including tearing of the carcass structure through the sidewalls and across the treads. Some damage to the upper torque link was also visible.

Metallic items and considerable quantities of tyre debris were recovered from the runway during a series of inspections carried out shortly after the incident. The metallic items were identified as the apex pin and the castellated nut which secures the former component in position. The locations from which the pin and nut were reportedly recovered were in the region of the touch down zone. Subsequent runway examination in that area revealed unusual markings, to the right of the centreline. Although not definitely attributable to this aircraft, they were consistent with the likely effect of oscillating motion of a double wheeled axle in a horizontal plane. This appeared to have resulted in a mixed rotation and translational motion of the wheels with consequent tyre skidding. The unusual runway marks were in the region of the concentration of the normal linear rubber markings caused by typical landing tyre contact.

Main landing gear design

The main landing gear leg of the ATP has conventional torque links attaching the sliding tube (sometimes known as the sliding member) and axle assembly, together with the wheels and brakes, to the upper section (main fitting) of the leg. The link system constrains the axle against rotating in the horizontal plane.

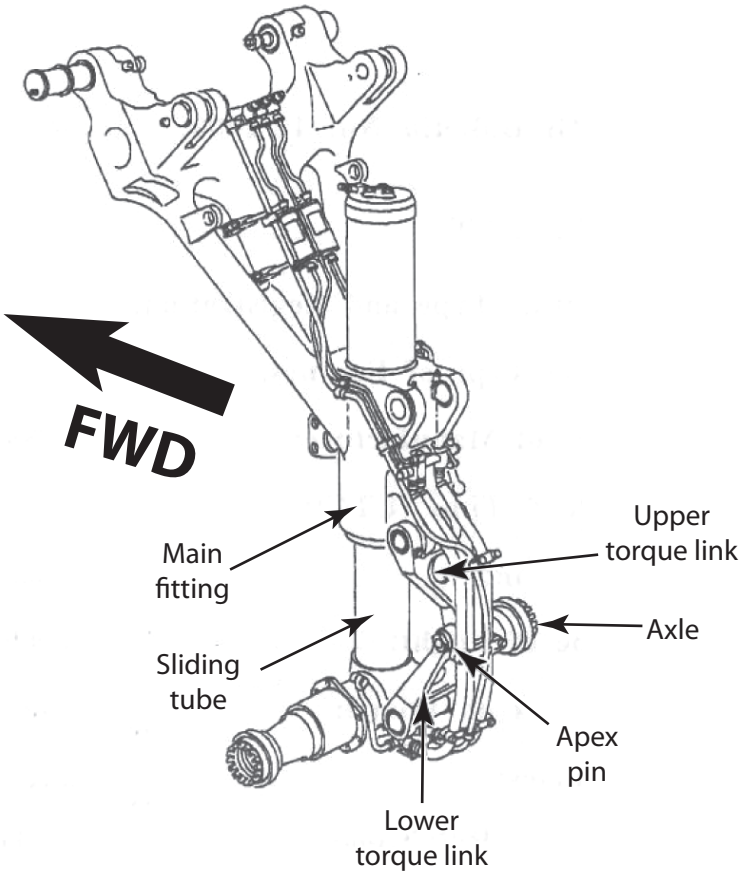

Figure 1

General view of leg with wheels and brakes removed

The upper torque link is pivoted on the aft face of the main fitting, whilst the lower link is similarly pivoted from the aft face of the axle/sliding tube assembly. The aft ends of each link incorporate an offset lug. The offsets enable an apex pin to pass horizontally through both lugs. Each link, when viewed from vertically above, is approximately triangular in profile and incorporates a pair of broadly spaced lugs at its forward end, with aligned horizontal axes and forming two apexes of each triangular component. The links are each pivoted via these lugs on corresponding fixed attachment lugs also having in-line horizontal axes. One pair of fixed lugs is mounted on the main fitting and carries the upper torque link whilst a further pair is on the sliding tube/axle assembly carrying the lower link. This pivot arrangement thus renders each link attachment rigid in a horizontal plane but permits angular movement in a vertical plane and hence controlled extension and compression of the sliding tube in the main fitting.

The lugs at the aft end of each link have bushed horizontal bores. The apex pin attaching the aft lugs together is secured in position by a large castellated nut screwed onto a threaded end portion of the pin. The pin also passes through a bracket and a washer fitted between the lugs and a shim positioned beyond the lug of the upper link directly secured by the castellated nut. (The bracket locates flexible hydraulic pipes routing to and from the brake units.) The castellated nut is prevented from rotating on the pin threads by a small diameter threaded locking bolt passing through the castellations and through one of two bores in the pin. These are orientated at 90º to the pin axis and 90º to one another. The shim thickness is varied to enable the backlash of the installed apex pin to be controlled on assembly, since the axial position of the castellated nut on the threads of the apex pin is dictated by the presence of the locking bolt and can only be varied in discrete steps corresponding to approximately $^{1}/_{12}$ of a

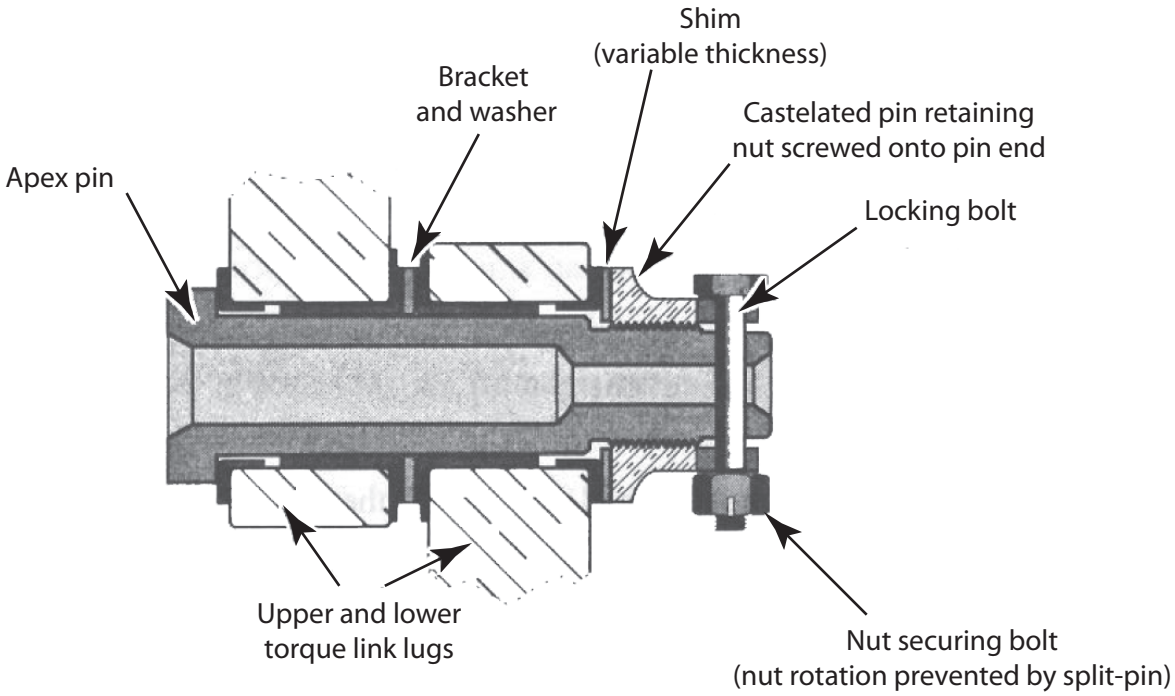

Figure 2

Section through apex pin, torque link lugs, castellated nut and locking bolt

rotation. The locking bolt itself is secured by a small castellated nut screwed onto its threaded end having a split pin to prevent relative rotation.

The apex pin has a plain head termination at the opposite end to the threaded portion, enabling it to be secured, by a special tool, against rotation during assembly and maintenance operations. The mid portion is chromium plated and ground to enable a close fit to be achieved within corresponding bushes in the two torque link aft lugs. The aft lugs of the torque links incorporate grease nipples to lubricate the contact surfaces between the lug bushes and the apex pin. The pin and the nut are totally cadmium plated (with the exception of the chromium plated bearing sections of the pin).

Activity at accident site

Following AAIB examination, the aircraft was jacked and the wheels removed. It was then equipped with slave wheels and tyres before being towed to a hangar where the landing gear leg was replaced. The removed unit was forwarded to the leg manufacturer for detailed examination. The apex pin and nut were both retained by the AAIB for further investigation.

Initial examination showed that the chromium plated bearing surface of the shank of the apex pin was in good condition indicating correct fit and adequate lubrication. The locking bolt was largely destroyed, only the centre portion surviving, remaining within one of the bores in the apex pin. Neither the hexagonal head of the locking bolt nor the threaded portion at its opposite end, the small securing nut, and the split pin, were recovered during the runway inspections.

Detailed examination

The external threads on the pin and corresponding internal threads in the castellated nut were found to be extensively corroded. Those thread forms on the pin closest to the chromium plated bearing region still retained approximately the correct major diameters whilst those over most of the remaining length were significantly reduced in that diameter. The minor diameters of the thread forms within the nut had been altered to be of larger than standard diameters. Two deep internal axially orientated grooves through the threads were evident at diametrically opposite locations in the bore of the nut. The crests of the thread forms on the pin and within the nut showed evidence of relative axial movement. Examination of the fractured ends of the surviving mid portion of the locking bolt revealed that the fracture faces were of irregular conical /spherical shape.

History of the landing gear leg

The landing gear leg was last overhauled by Messier Services UK Repair and Overhaul Company in 2004. It was installed in the right-hand position on G-MANH on 12 May 2004 by an operator of the type during a post-lease check. This was carried out at that operator's Ronaldsway, Isle of Man (IOM) base. It appears that the aircraft remained parked at that location until 20 August 2004. It was then flown to Bucharest, Romania, for conversion from passenger to freight configuration. It was not flown again until 19 January 2006.

Previous experience

Broadly similar failures were reported on corresponding components of two ATP aircraft in 1999. In both cases repeat axial loadings appeared to have caused progressive damage to the flanks of the threads on both the pin and the nut until thread damage permitted loss of engagement and allowed the castellated nut to be driven axially along the pin.

In the previous two incidents, however, no thread

corrosion was reported. Following those events a mandated Service Bulletin (SB) was drawn up by the aircraft manufacturer to instruct aircraft level activity and referred to a SB issued by the landing-gear manufacturer. This required dismantling of the torque link assembly for initial inspection after which periodic assessment of the end float of the nut/pin assembly is required and, where appropriate, dismantling of the joint and measurement of the threads. No similar failures have been reported in the eleven years since the imposition of the SB.

Other information

The present operator of the type in the UK reports that it rotates the fleet in such a way that utilisation is consistent and no aircraft has disproportionate downtimes or excessive calendar times between lubrication of the torque link bearings.

The pins are predominantly cadmium plated and the ground bearing surfaces are chromium plated, thus providing overall corrosion protection. The nuts are also cadmium plated. However, a number of dissimilar materials co-exist in close proximity once the torque links and pin are fully assembled. Under normal circumstances operation of the aircraft causes angular movement of the links and rotary relative movement of the pin within the links. This serves to spread lubricant and coat surfaces, supplying a degree of additional surface protection not present if any faces are not coated. Lubricant exiting from the bearing areas generally coats the exposed threads. There is no known history of significant corrosion of the pin and nut combination in normal operation.

Analysis

The condition of the internal thread forms in the castellated nut and the external threads on the pin were consistent with corrosion having removed material from the flanks of the thread forms in the nut and on the pin. This combination had apparently reduced the depth of mutual engagement to the point where the threaded joint was unable to carry its design axial load. The destruction of the locking bolt, the presence of internal axial grooves created within the nut (apparently by the fractured end faces of the locking bolt) and damage to the crests of the engaging thread forms, were all features consistent with axial separation of the castellated nut from the pin.

It was clear that axial loading had failed the corrosion weakened thread engagement. This had initially transferred the end load, applied via the lugs to the castellated nut, from their design support medium - the threaded joint between the pin and castellated nut - to the locking bolt (normally intended purely to prevent rotation of the castellated nut on the pin).

The nature of the visible damage to the ends of the surviving mid section of the locking bolt (being approximately conical / spherical in shape) was consistent with a sequence of discrete double shear loads being applied with different angular orientations by the castellated nut, after failure of its thread engagement, on the pin. This in turn was consistent with the bolt rotating in its bore in the pin between a series of shear load applications.

The failure of the weakened joint between the castellated nut and apex pin was thus the result of a sequence of loads applied to the nut through the torque links. These are presumed to have been caused by oscillating angular movement of the axle in a horizontal plane. Such repeat loading and failure was consistent with the effects of shimmy applied to a weakened nut/pin joint also having reduced angular restraint on motion of the axle in the horizontal plane. Once complete failure of the lock bolt had occurred, the nut was no

longer effectively restrained axially on the apex pin. The deteriorated state of the two engaging thread forms enabled the apex pin to continue translating to the end of the apex pin under oscillating load from the torque link lugs. Once the nut separated from the pin, the latter was free to fall out of the lugs of the torque links, allowing complete freedom of the axle to oscillate in a horizontal plane.

The location at which the apex pin and castellated nut were found on the runway indicates that final failure occurred almost immediately after touchdown. This, coupled with the failure to find any of the separated parts of the locking bolt, its nut and the split pin anywhere on the Cardiff runway, suggests that initial failure of the pin and castellated nut thread engagement occurred during previous operations on the ground elsewhere.

Significance of service history

The component history record shows that a newly overhauled landing gear unit was fitted in the right position on G-MANH in May 2004, at Ronaldsway IOM. The aircraft remained parked there for over 3 months. The proximity of Ronaldsway to the sea causes a saline atmosphere to prevail. It is possible that the saline atmosphere, combined with some surface damage to engaging threads sustained on assembly and the proximity of dissimilar metals once assembled, allowed corrosion to initiate during the three months idleness at Ronaldsway. During this period without relative movement of the pin within the bushes, comprehensive distribution of lubricant would not have taken place. The pin would thus have been more vulnerable to initiation of corrosion if some damage to the plating had occurred when the threaded joint was assembled during overhaul.

The aircraft subsequently carried out a single flight to a conversion centre near Bucharest where it spent a total time of approximately 18 months idle whilst under conversion and in storage.

Summary of failure sequence

From the evidence it has been deduced that the sequence of failure was as follows:

(1) The initial parts of the failure process occurred during ground operation prior to arrival at Cardiff.

(2) Corrosion damage to engaging thread forms progressively reduced the strength of the joint between the castellated nut and the apex pin on the right landing gear.

(3) During ground operation, the castellated nut was loaded by horizontal forces in the torque link lugs which exceeded the strength of the weakened threaded joint such that the threads disengaged and the nut was forced to move axially along the threaded portion of the apex pin.

(4) Axial movement of the nut permitted the base radii of the castellations within the nut to come into contact with the shank of the locking bolt.

(5) Reduced angular restraint of the axle as a result of axial migration of the castellated nut along the apex pin allowed directional oscillation or ‘shimmy’ of the axle to occur. This produced ‘hammer blows’ on the shank of the locking bolt.

(6) Repeated impacts between the base radii of the castellations within the nut and the shank of the locking bolt resulted in progressive

distortion and double shear failure of the latter and continuing translation of the castellated nut along the apex pin. Axial grooving of the thread forms within the nut was created by the fractured ends of the mid portion of the locking bolt being drawn through the nut.

(7) Final separation of the castellated nut from the apex pin permitted the latter to migrate from the lugs and the sliding tube/axle assembly to rotate (or steer) about the tube axis, leading to high lateral loadings being applied to the tyre treads and the upper torque link cutting into the sidewalls of the tyres. The tyres sustained severe damage and deflated.

No previous instances of corrosion in the apex pin / nut combination have been reported to or recorded by the aircraft or landing gear manufacturers. The reason for the corrosion on this occasion, contrasting with its apparent absence on others, could not be determined. Unusual features of the operating life and storage location of the aircraft immediately after installation of the landing gear unit, however, may have contributed to an initial corrosion mechanism leading to long term deterioration.

Subsequent action

The landing gear manufacturer is replacing the existing SB with a new one to require regular removal of the nut from the pin to check for end float of the threads thereby avoiding the presence of corrosion from preventing float and thereby masking any deterioration of the thread form. It further requires an inspection of apex pin and nut threads for corrosion and replacement of both components if any is present. The likelihood that some surface damage was inflicted on the thread forms of the pin and/or the nut during assembly of the unit on G-MANH is to be addressed by introducing a jointing compound on the thread forms during future assembly operations. The unit assembly drawings are to be amended by the landing-gear manufacturer to reflect this modified procedure. The locking bolt, nut and split pin are to be discarded at each inspection and replaced with new items.

The landing gear manufacturers new SB is being reviewed by the aircraft manufacturer to enable its own SB to incorporate the controlling actions instructed by the landing gear manufacturer's SB. The aircraft manufacturer intends recommending to EASA that their revised SB be considered for Airworthiness Directive (AD) action.

Further event

During a fleet inspection carried out as a result of the failure, a fractured locking bolt was found on an apex pin on another aircraft. The castellated nut remained correctly screwed onto the apex pin. Examination of the fracture face of the bolt indicated a fatigue mechanism as the cause of the failure. A requirement to replace the locking bolt and nut with new items during re-assembly following implementation of the inspection action was therefore incorporated in the SB as described above.