INCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash 8, G-JEDR
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2003
Date & Time (UTC):	3 March 2011 at 1255 hrs
Location:	Exeter Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 39
Injuries:	Crew - None Passengers - None
Nature of Damage:	Right main landing gear inboard wheel detached
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	6,778 hours (of which 3,417 were on type) Last 90 days - 103 hours Last 28 days - 24 hours
Information Source:	AAIB Field Investigation

Synopsis

After takeoff from Exeter Airport, as the landing gear was retracted, the inboard wheel of the right main landing gear separated from its axle and fell to the ground within the airport boundary. The crew entered a holding pattern to the east of the airport and carried out the 'Alternate Landing Gear Extension' procedure. The aircraft returned to Exeter where it landed safely. The investigation found that the wheel's outer bearing had seized. This was most likely as a result of the bearing cage and cup having come into contact due to excessive movement of the cage, probably due to wear. This caused the bearing to fail catastrophically. Consequential damage had allowed the wheel to detach. Safety actions have been taken with the intention of preventing a recurrence.

History of the flight

The aircraft was on the final sector of a four sector rotation which had commenced at Newcastle Airport at 0705 hrs that morning. The commander had performed the pre-flight inspection, which included a visual examination of the right landing gear. Nothing unusual was noted.

During the takeoff from Runway 08 at Exeter a single "ding" audio signal activated between 80 kt and V_1/V_R. The co-pilot checked for any indications on the relevant instruments but there were none and he reported "spurious, continue". The takeoff was continued and the landing gear was selected up once a positive rate of climb was established.

A number of passengers seated on the right side of the aircraft noticed sparks emanating from the right inboard wheel area during the takeoff roll and saw the right inboard wheel fall from the aircraft as the landing gear retracted. They did not inform the cabin crew at this point. The flight crew were advised by ATC shortly after takeoff that the aircraft may have lost a wheel. The climb was continued to FL030 and a right turn was made to join the hold at the Exeter NDB. The FMS was programmed to fly the hold and the autopilot was engaged.

The commander contacted the Senior Cabin Crew Member (SCCM) on the interphone to inform her of the situation and asked her to inspect the right landing gear area. The passengers informed the SCCM of the loss of the wheel and she could see that the gear was retracted and the landing gear doors were closed, but parts of the landing gear mechanism were protruding. She reported her observations to the commander. The co-pilot then spoke with a company engineer who was a passenger on the flight and confirmed for himself the SCCM's observations.

The flight crew reviewed the 'Landing Gear Malfunction' and 'Emergency Landing' sections of the Abnormal and Emergency Checklist and agreed that the landing gear should be extended using the 'Alternate Landing Gear Extension' procedure. On actioning this, the left main and nose landing gear indicated down and locked but the right landing gear did not indicate any movement. The company engineer advised the flight crew that the right landing gear had not lowered. Following a discussion with the engineer, the pilots prepared to use the landing gear manual lowering procedure but the right landing gear then lowered and indicated it was down and locked. This was visually confirmed from the cabin by the engineer and the co-pilot.

The commander transmitted a MAYDAY which was acknowledged by ATC and the emergency transponder code of '7700' was set. The pilots reviewed the 'Emergency Landing' procedure and discussed their options. They agreed that although the landing gear had lowered and indicated locked down, there was a possibility that the right outboard wheel may detach in the air or on landing and they should also be prepared for the right landing gear to collapse on touchdown. They considered shutting down the right engine for the approach and landing but agreed to keep it operating in order to reduce the asymmetric effects of selecting the propeller to disc or reverse.

The commander gave the Nature, Intentions, Timings and Special instructions (NITS) briefing to the SCCM, who then briefed the other cabin crew member. The passengers were then individually briefed. Following the commander's instructions, they also moved passengers on the right side away from the propeller area, distributing them evenly forward and aft.

The co-pilot contacted the operator's Chief Pilot by radio to discuss the most appropriate landing procedure. It was decided that they would use a left-wing-down technique ensuring that the left mainwheels touched down on the runway first, then lowering the remaining right mainwheel onto the runway as gently as possible. The flaps would be set at 35° and the touchdown would be at or just below the V_{REF} of 112 kt calculated for their landing weight of 24,000 kg. No wheel braking would be used during the landing roll.

The approach was flown manually with the co-pilot calling out check altitudes, airspeed and rate of descent. At 1,000 ft on the radio altimeter the passengers were instructed to adopt the brace position.

The aircraft touched down on the left mainwheels at or about V_{REF} and the right mainwheel was lowered onto the runway. The aircraft then veered to the left and the commander had to apply significant amounts of right rudder in order to regain the centreline. The pilots had briefed not to use the toe brakes during the landing roll and as the aircraft slowed to a walking pace the commander made a gentle application of the emergency brake, bringing the aircraft to a stop and the parking brake was set. Once the AFRS was in position, the commander instructed the SCCM to disembark the passengers; this was carried out through the front left door. The co-pilot and the SCCM used the public address system to make announcements before the aircraft electrical systems were isolated. The SCCM had briefed a number of Able Bodied Persons (ABPs) to ensure the safe containment of the passengers following the disembarkation. The passengers were taken to the terminal in buses.

Flight recorders

The aircraft was fitted with a flight data recorder (FDR) and a cockpit voice recorder (CVR) and these were downloaded by the AAIB. Given the nature of the incident, the FDR data was of limited use to the investigation. The CVR recordings confirmed the crew's description of events following the incident and for the landing but the event was overwritten with later recordings from when the aircraft was on the ground at Exeter Airport.

The CVR had a two-hour recording duration of which the last 40 minutes were when the aircraft was on the ground with electrical power on. The loss of the event on the CVR occurred despite the operator having made efforts to preserve the recordings. The first action on the part of the operator was to ask the crew (via the radio) to pull the circuit breakers (CBs) as soon as they landed. The crew asked for the "coordinates" of the CBs as they were unsure where they were but this information was not relayed back to them. Once on the ground, the crew's primary concern was to shut down the aircraft and ensure that all passengers and crew were safely disembarked. As the commander disembarked he asked an aircraft engineer, who was about to board the aircraft, to pull the CBs. This was not done and when the engineer then turned the aircraft's electrics on, the CVR started to record again until the aircraft was shut down 40 minutes later.

Initial examination

The detached main wheel and bearing debris found on the runway were recovered for AAIB inspection. Initial examination of the aircraft revealed that the wheel nut was still in position on the axle with its locking devices correctly installed. The brake unit was loose on the axle and had sustained damage to the heat pack, Figure 1. The wheel nut and brake unit were then removed from the axle along with the remains of the failed wheel bearings. The axle had light scoring to its bearing surfaces and there was minor flailing damage to components close to the brake unit.

Figure 1

Wheel axle as found

The right main landing gear inboard door showed evidence of contact with the rotating wheel assembly and its rear hinge attachment had been torn away from the door. The door remained attached to the aircraft by the other hinge and operating linkage, Figure 2. The nacelle above the door was slightly damaged by the door.

Figure 2

Inboard main gear door showing detached hinge

General arrangement of wheel bearings

Each mainwheel is fitted with a pair of taper roller bearings arranged with their smaller rolling diameter towards the centre of the wheel. Figure 3 shows the general arrangement of the mainwheel, brake unit and bearings.

Each wheel bearing consists of a cup located in the wheel and an inner cone, roller and cage assembly which locates on the axle, Figure 4. The bore of the outer bearing cone is of a slightly smaller diameter than the inner bearing to prevent misassembly. The rollers and cups are common to both bearings. The bearings are lubricated on installation with specified high quality grease.

Figure 4

New wheel bearing cone assembly showing rollers located in the cage

The correct wheel installation process involves tightening the wheel nut to a specific torque loading to seat the bearings initially before backing off the nut and then tightening it to a lower in-service torque loading. The wheel must be rotated by hand throughout the process to ensure the correct pre-loading of the bearings is achieved.

Detailed examination of failed parts

The remains of the wheel bearings and the wheel were examined with representatives of the bearing manufacturer, the wheel manufacturer and the operator present. There was evidence of sufficient grease of the correct type. The seven recovered rollers, Figure 5, were examined and these showed there was minimal heat generation and the roller bodies and spherical thrust large end showed minimal wear or distress prior to the incident. As these rollers were found on the runway, it cannot be certain which bearing these came from as the same part number roller is used in both bearings.

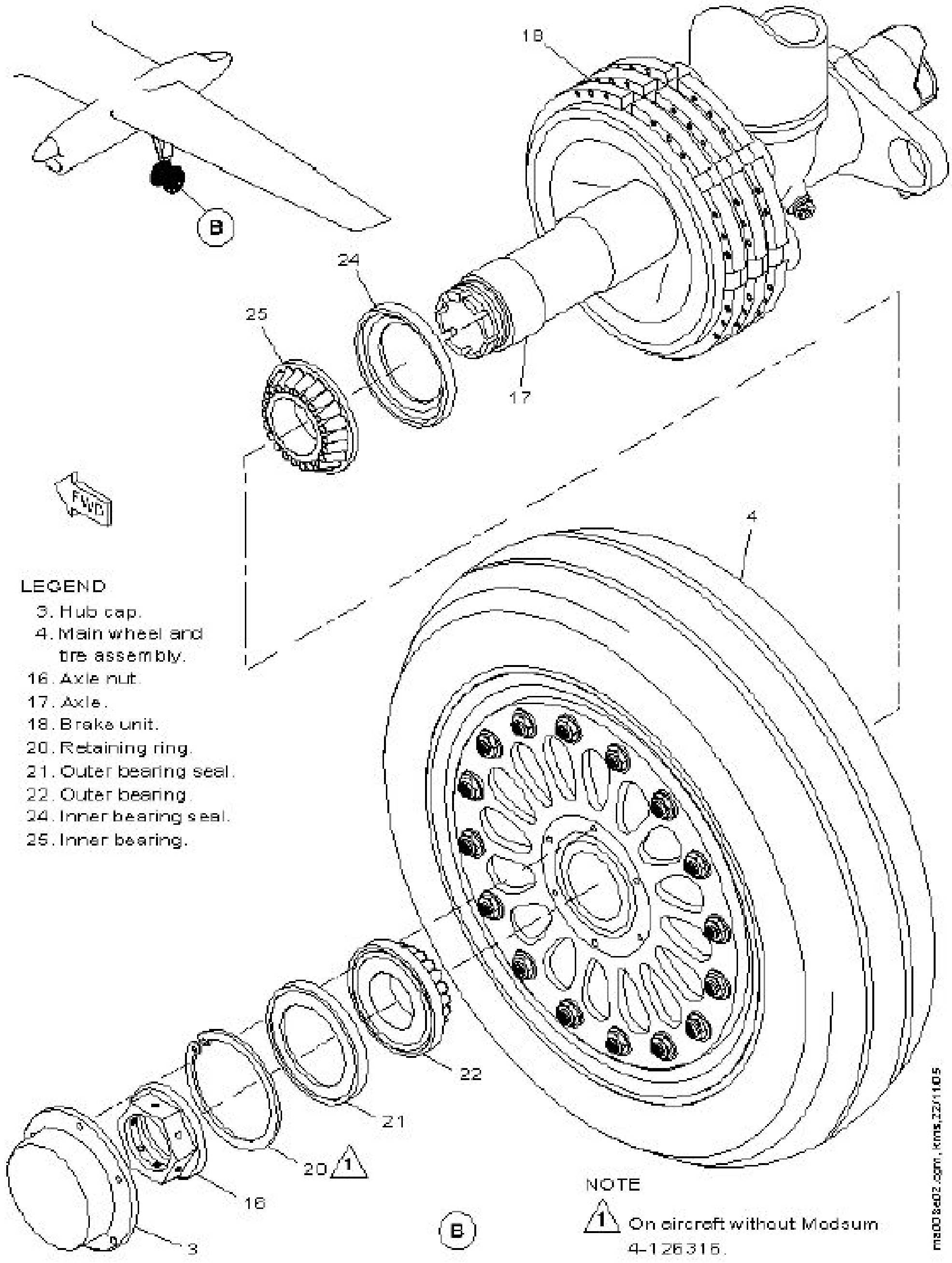

Fig. 402-2

Figure 3

General arrangement of the mainwheel and bearings

Figure 5

Recovered bearing rollers showing signs of mechanical rather than heat damage

Both inboard and outboard bearings had suffered significant damage. The outboard bearing (closest to the wheel nut) showed that it had failed first and its cone thrust rib had been pushed flat by the forces of the failure, Figure 6, allowing the wheel to detach. The outboard bearing appeared to have suffered a cage trapping episode, where the cage became trapped between the rotating cup and the rollers, instantaneously locking the bearing and causing catastrophic failure. The inboard bearing suffered consequential, low temperature damage as the spinning wheel became unsupported by the severely damaged outboard bearing.

Figure 6

Outer bearing cone, showing deformed thrust rib

Inspection of other similar bearings

Two other wheel bearings from a mainwheel that had been recently removed from an aircraft for overhaul were examined. Both bearings were found to have cage clearance, due to cage wear, that made them unserviceable. One bearing showed evidence that the cage had just started to make contact with the cup raceway.

Two new bearings were taken from stores and examined; both showed near maximum allowable new manufacture cage clearance.

Wheel and bearing history

The last inspection of the inner and outer wheel bearings was in the operator's workshops in October 2010, when the wheel assembly was removed from service to allow a tyre change to be completed. The wheel assembly was refitted to the aircraft and had completed 570 landings before the bearing failure. The outer bearing was first fitted in June 2009 and the inner bearing in 2006.

In-service history of this wheel bearing design

These part number bearings are known by their manufacturer to be sensitive to increasing cage clearance. Proper inspection techniques are highlighted in their publication, 'Aircraft Landing Wheel Bearing Maintenance Manual', and in their training courses which emphasise the need to check for evidence of cage wear and cage-to-cup contact. The same part number bearings have been used extensively in other aircraft types over a long period of time without any significant in-service issues. There have been a limited number of other bearing failures on this aircraft type, but these have been attributed to either incorrect installation or the use of inappropriate grease.

Potential causes of the failure

The bearing manufacturer advised that the typical causes of a bearing cage becoming trapped in an aircraft wheel application are, listed roughly in order of probability in this instance:

- Loose or worn cage bearing returned to service
- Inadequate flying nut torque, incorrectly applied nut torque or loss of nut torque
- Heavy landings or rough terrain inducing radial shock-loads and cage wear
- Contamination or loss of bearing grease causing cage wear
- Excessive wheel shimmy due to worn linkages
- Brake judder or vibration causing cage wear

There was insufficient evidence to determine which, if any, of these potential causes initiated the failure.

Safety actions

Engineering

As a result of this event, several safety actions were initiated with the intention of preventing a recurrence.

The bearing manufacturer's representative has reiterated to its quality and production departments the need for the cage on these part number bearings to be 'close' to the low end of the manufacturing tolerance to ensure the maximum possible cage-to-cup clearance exists from new.

The wheel manufacturer has reviewed the bearing inspection section of the Component Maintenance Manual for the wheel to ensure that all the inspections recommended by the bearing manufacturer are included. They have also recommended to the aircraft manufacturer that the roller bearing and cage assembly is replaced at each tyre change.

The aircraft manufacturer has considered the wheel manufacturer's recommendation and notes that some operators already replace their wheel bearings on this basis. It also considers that proper bearing inspection and maintenance practices will ensure satisfactory bearing performance and they intend to reiterate these practices to their operators.

The operator, as a result of its internal investigation, is intending to take the following actions:

1. All engineers involved in the repair and overhaul of wheels and their associated wheel bearings will receive the bearing manufacturer's inspection requirements and techniques training.
2. The bearing manufacturer's Aircraft Landing Wheel Bearing Maintenance Manual will be available in their wheel and brake workshop as a reference document for the inspection process.
3. All new bearings received from suppliers will be fully inspected.

The operator is also considering the introduction of a fixed operating life for these bearings rather than the 'on-condition' basis used at present.

Operations

The operator has reminded flight crews of the need to pull the CVR/FDR circuit breakers following an incident to prevent the loss of data.

Analysis of operational issues

The commander, when performing the pre-flight inspection of the right main landing gear, had not noticed any abnormalities and given the nature of the bearing failure, it is unlikely that any would have been visible.

After ATC had notified them of the loss of the wheel, the crew took up a holding pattern at the Exeter NDB. This gave them a safe environment in which to analyse the problem. Having an engineer onboard, licensed on the aircraft type, was beneficial and his knowledge was used to good advantage.

The flight crew's incremental approach to solving the problem and effective Crew Resource Management (CRM) contributed to a safe outcome.

Conclusions

It is most likely that the outer wheel bearing suffered a trapped cage which caused it to fail catastrophically. Consequential damage deformed the outer bearing cone, allowing the inboard wheel of the right main landing gear to detach from its axle during landing gear retraction. It was not possible to determine the cause of the trapped cage.