Aviation Safety Investigation Report 200401353

British Aerospace PLC 3201
16 April 2004

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Investigations commenced on or before 30 June 2003, including the publication of reports as a result of those investigations, are authorised by the CEO of the Bureau in accordance with Part 2A of the Air Navigation Act 1920.

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NOTE: All air safety occurrences reported to the ATSB are categorised and recorded. For a detailed explanation on Category definitions please refer to the ATSB website at www.atsb.gov.au.

Occurrence Numbe 200401353 **Occurrence Type:** Serious Incident
Location: «Location»
Date: 16 April 2004 **Time:** 9:05 CST
Highest Injury Leve Nil
Injuries:

	Fatal	Serious	Minor	None
Crew	0	0	0	2
Ground	0	0	0	
Passenger	0	0	0	19
Total	**0**	**0**	**0**	**21**

Aircraft Details: British Aerospace PLC 3201
Registration: VH-OAE
Serial Number:
Operation Type: Air Transport Low Capacity
Damage Level: Minor
Departure Point: Melbourne Vic.
Departure Time:
Destination: Mount Gambier SA

Approved for Release: 20 January 2006

FACTUAL INFORMATION

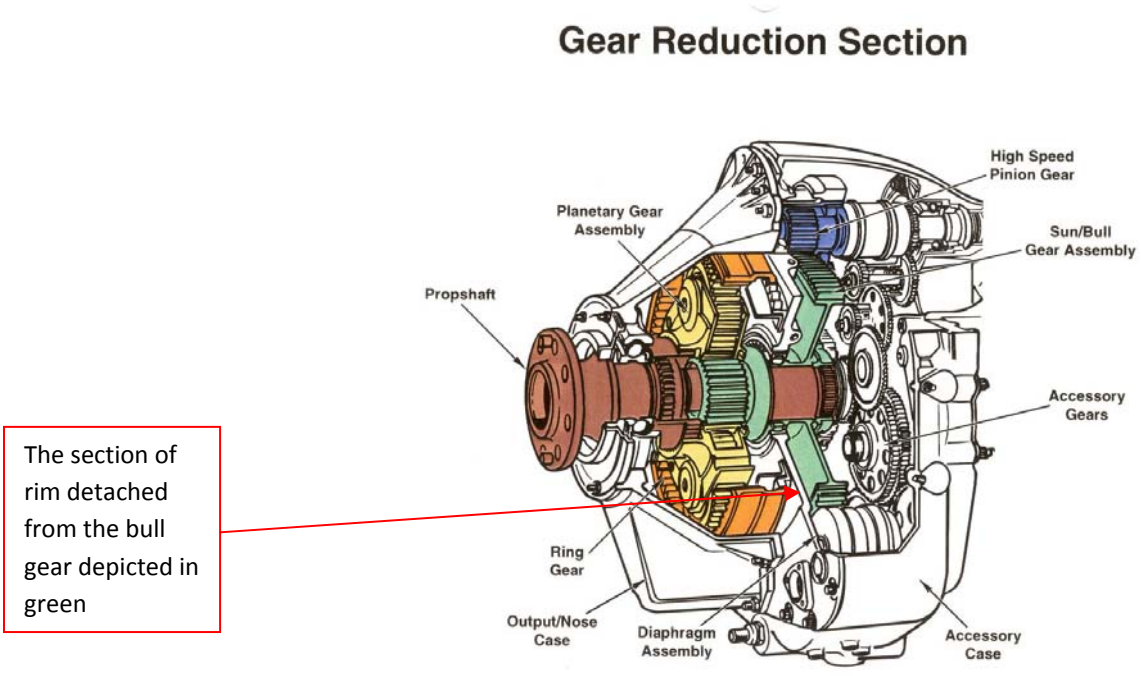
At 1100 Central Standard Time on 16 April 2004, a British Aerospace Plc, J32, Jetstream aircraft registered VH-OAE, with 2 pilots and 19 passengers on board, was on descent, during a scheduled passenger flight from Melbourne, Victoria to Mount Gambier, South Australia. As the aircraft passed through flight level (FL) 140, approximately 37 NM from Mt Gambier, the crew reported hearing a bang from the right engine. Simultaneously, the aircraft yawed to the right and they heard something impact the right side of the fuselage. Some smoke was evident in the cockpit.

A check of the aircraft's engine instruments confirmed a problem with the right engine and the crew shut down the engine and feathered the right propeller in accordance with the operator's quick reference handbook drills. The crew then advised air traffic control of the situation and continued for a landing at Mount Gambier Airport.

An inspection of the aircraft by the operator revealed that there had been an uncontained failure of the propeller reduction gearbox on the right TPE 331-12UHR-702H turboprop engine, serial number P66338C. There was also evidence of impact damage on the right side of the fuselage, below the co-pilot's side window area. That impact had not breached the aircraft's pressure hull.

An examination of the engine, supervised by the Australian Transport Safety Bureau (ATSB), found that a section of the spur gear teeth from the outer rim of the reduction gearbox bull gear, had detached during engine operation (See Figure 1). Spur gear teeth are radial, uniformly spaced around the gear's outer periphery and parallel to the shaft axis[1]. The detached section of gear had penetrated the diaphragm housing (intermediate gearbox housing) and the gearbox accessory case, before exiting the engine through the compressor air intake.

Figure 1: Cutaway diagram of TPE 331 reduction gearbox



[1] ASM International, Materials Information Society Handbook, Volume II.

The hole in the accessory case had allowed engine oil to escape and flow over the engine cowling, with metallic debris and oil entering the engine's compressor intake. Once inside the compressor, the oil was able to enter the aircraft's compressor bleed air system that supplied the aircraft's air conditioning and pressurisation air. There was also significant associated damage to the diaphragm housing, the high speed pinion and compressor/turbine main shaft, with metallisation[2] observed on the turbine and exhaust sections.

An ATSB Technical Analysis report (Appendix A), on the mode of failure of the bull gear, part number 3108295-1, found that the gear had failed as a result of a mechanism known to the manufacturer. The report indicated that the progressive propagation of high cycle fatigue cracking within the gear web and rim transition region, had caused a section of the gear rim to separate from the gear.

The engine manufacturer had introduced several changes to the bull gear design to address 'reliability and reparability issues' that had occurred in the TPE 331 engine type. Among those were changes in gear relief, gear tooth roots had been ground and shot peened to improve fatigue life, the gear rim inside diameter was shot peened to increase fatigue resistance and a coating was added to the gear web to dampen gear vibrations. The engine manufacturer reported that despite those actions some of the re-worked and coated gears had a higher failure rate than non-reworked gears.

The engine manufacturer also investigated TPE 331 engine diaphragm housings, in which gears had failed, to ascertain if distortion of the housing could cause bull gear to pinion gear misalignment. Several problems were identified with those housings that may have contributed to the gear failures. These included bull gear to pinion gear centreline growth and misalignment, growth between diaphragm to gearbox alignment pins and out-of-round bearing bores.

In October 2001, the engine manufacturer issued Service Bulletin (SB) A72-2087[3] in response to 16 in-service bull gear rim separations and 13 high speed pinion torque shaft failures. Four of those failures resulted in gearbox debris being ejected from the engine. One failure resulted in the penetration of the right side of an aircraft's pressure hull by a gear fragment. The bulletin indicated that high tooth loading on the bull gear to high speed pinion mesh, bull gear tooth profile, and distortion of the intermediate gearbox housings, had resulted in abnormal wear and subsequent failure of the assemblies.

Service Bulletin A72-2087 required replacement of the bull gear and high speed pinion with new, zero-time components, at intervals not to exceed 3,600 hours in service. It also required the inspection and the rework/overhaul of some gearbox components such as the diaphragm housing, plus a more stringent periodic inspection of specified gearbox components to ensure an optimum operating

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[2] Metal pulverised by the compressor becomes molten or burned in the combustion chamber and flows rearward, attaching to the turbine and exhaust assemblies (US Department of the Air Force.(1987). *Safety Investigative Techniques* (AF Pamphlet 127-1, Volume II). Washington DC: Author).

[3] Honeywell Alert Service Bulletin – TPE 331-A72-2087, ENGINE – REDUCTION GEAR AND SHAFT SECTION – Replace Gearshaft (Sun and Bull Gear) Assembly, Part No. 3107037-9/10, 3107122-1, 3107162-1, or 3108222-1, or 3108294-1 with Part No. 3108294-1, issued October 2001 and revised 16 November 2001.

environment for the bull gear. At the time of failure, the bull gear assembly in this engine had accrued 1,199.55 hours and 1,523 cycles since installation. The engine had accrued a total of 10,755.7 hours and 12,295 cycles since new.

In Australia, the Civil Aviation Safety Authority (CASA) issued Airworthiness Directive (AD) AD/TPE 331/57 to require compliance with SB A72-2087. That AD became effective on 31 October 2001. Amendment 1 to that AD was issued in January 2002. The AD actions had been incorporated into the occurrence engine at the manufacturer's German maintenance facility on 20 December 2002.

Information received from the engine manufacturer following this occurrence, indicated that there had been three bull gear failures in post SB A72-2087 engines. One of those failures was the subject of a UK Air Accidents Investigation Branch (AAIB) investigation, published in AAIB Bulletin number 7/2005. Information from the AAIB on that failure indicated that the bull gear had failed in a similar manner to the gear in this occurrence.

The engine manufacturer reported that a spectrometric oil and filter analysis program (SOAP)[4] was used to monitor an engine's in-service condition and to reduce the possibility of a premature mechanical failure. That program monitored the type and quantity of the deposits in the engine oil and oil filters over a specified period. A trending feature within that program could highlight an engine with a rapidly increasing filter 'weight' and indicate that further maintenance action was required. A high filter weight quantity of Carbon Steel in a sample could indicate a problem with the bull gear assembly. In November 2000, the engine manufacturer issued Alert Service Bulletin TPE 331-A79-0034[5] that changed the SOAP interval periodicity to a fixed 100+/- 20 engine hours to minimise variability. On 25 January 2001, CASA issued AD/TPE 331/55 that required Australian compliance with that Alert SB.

The operator had complied with the engine manufacturer's and CASA's SOAP requirements, forwarding samples to the manufacturer's approved venue for testing. The operator reported that they had become concerned about a SOAP report for the occurrence engine that had been received on 3 February 2004. That report, although still within the manufacturer's 'normal sample' guidelines, had a significantly higher filter weight result than had been previously noted for the engine. When queried, the manufacturer confirmed the results of the sample and indicated that a higher reading may be seen following an engine oil change. The engine oil had been changed 101 engine hours prior to that sample being taken. In the subsequent SOAP sample taken 60 engine hours later, on 24 February 2004, the filter weight had returned to a similar level to that of the pre-3 February 2004 samples. The final sample taken prior to the occurrence, on 1 April 2004, was higher than usual and all of the samples had traces of carbon steel.

[4] Service Information Letter – P331-97 - THE HONEYWELL SPECTROMETRIC OIL AND FILTER ANALYSIS PROGRAM FOR ALL TPE 331 ENGINES EXCEPT -14GR/HR ENGINES; Revision 10, Apr 5/02.

[5] Honeywell Alert Service Bulletin – TPE 331-A79-0034 - OIL DISTRIBUTION – DECREASED TIME INTERVAL BETWEEN SPECTROMETRIC OIL (AND FILTER) ANALYSIS PROGRAM (SOAP) SAMPLING; Revision 4, Apr 5/02.

ANALYSIS

The investigation determined that the bull gear failed as a result of a previously known high cycle fatigue cracking mechanism.

The Civil Aviation Safety Authority Airworthiness Directive (AD) requiring compliance with the manufacturer's Service Bulletin (SB) A72-2087 had been completed on the engine. However, the bull gear failed at less than half of the manufacturer's projected component life.

The diaphragm housing had been extensively damaged following the release of the section of the bull gear rim. That damage had prevented the investigation determining the housing's pre-failure condition and whether its condition had contributed to the failure.

At the time of the failure, the spectrometric oil and filter analysis program (SOAP) analysis had been carried out and assessed in accordance with the manufacturer's procedures. While the filter weight increases noted in the engine on 3 February 2004 and 1 April 2004 were within the manufacturer's 'normal sample' range, the above average filter weight, coupled with the traces of carbon steel may have been an indicator of the impending bull gear failure.

The crew handled the engine failure appropriately in accordance with the operator's procedures. The report of smoke in the cabin of the aircraft during the failure was consistent with the ingestion of engine oil into the compressor assembly immediately following the uncontained failure.

SAFETY ACTION

Following this and the other recent post SB A72-2087 bull gear failures, the following safety actions have been taken:

Engine Manufacturer

The manufacturer has re-assessed the SOAP procedures in Alert SB TPE 331-A79-0034 and has provided additional training to their team reviewing that data, to ensure that the guidelines are properly understood and more conservatively applied.

In August 2004, the manufacturer released Alert SB, SB TPE 331-A72-2114[6]. That SB was a warning to operators and stated:

> WARNING: FAILURE TO COMPLY WITH THIS SERVICE BULLETIN COULD RESULT IN DISTRESS OF THE BULL GEAR, THE HIGH SPEED PINION TORQUE SHAFT, OR THE HIGH SPEED PINION COUPLER. IF LEFT UNCORRECTED, THIS DISTRESS COULD RESULT IN EITHER ENGINE SURGE OR OVERSPEED, OR COULD RESULT IN AN IN-FLIGHT SHUTDOWN. ADDITIONALLY, FRAGMENTS OF THE BULL GEAR COULD EXIT THE GEARBOX AND BE STRUCK BY THE PROPELLER. ON RIGHT HAND ENGINE INSTALLATIONS, THESE FRAGMENTS MAY BE REDIRECTED AGAINST THE AIRCRAFT FUSELAGE WITH SUFFICIENT FORCE TO CAUSE FUSELAGE PENETRATION AND COULD RESULT IN SERIOUS INJURY OR DEATH TO PERSONNEL AND POSSIBLE LOSS OF THE AIRCRAFT.

The SB provided the authorisation and instructions for the rework and or replacement of the Intermediate Housing and Gear (Diaphragm) Assembly part number 3102593-7, with assembly part numbers 3102593-12 or 3107191-4. Those housings contain newly designed helical pinion and bull gears, pinion gear bearings, torque shaft assembly and lubrication components. Helical gear teeth lie along a helix at an angle to the shaft. [7] The SB also stressed that priority be given to incorporation of the bulletin on an engine positioned on the right of an aircraft, due to the possibility of gearbox debris striking the fuselage in the event of a failure.

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[6] Honeywell Service Bulletin – TPE 331-A72-2114 – ENGINE – REDUCTION GEAR AND SHAFT SECTION – REPLACE GEARSHAFT (SUN AND BULL GEAR) ASSEMBLY, PART NO. 3107037-9/-10, 3107122-1, 3107162-1, 3108222-1, OR 3108294-1 WITH PART NO. 3108384-1, issued 20 Aug 04.

[7] ASM International, Materials Information Society Handbook, Volume II.

Civil Aviation Safety Authority

In December 2004, CASA issued Airworthiness Directive (AD) AD/TPE 331/62[8]. That AD superseded AD/TPE 331/55 Amdt 3, 57 Amdt 1 and 58 Amdt 2. The CASA AD/TPE 331/62 incorporated the requirements of SB TPE331-A79-0034, SB TPE 331-A72-2087 and the associated Rework SB's, with the requirements of SB TPE 331-A72-2114.

The background statement for the AD indicated, in part:

> This directive provides an alternative to mandatory requirements by approving the use of the manufacturer's referenced service bulletins as an alternative to both compliance times given and the requirement to replace certain parts with other parts for certain model engines. The fitment of the new designed parts will provide terminating action for the repetitive inspections detailed in this Directive.

Operator

As a result of an internal investigation into this occurrence, that involved contact with other operators in Europe and the United States who have experienced similar failures, the operator instigated a seating allocation limitation in their Jetstream aircraft. That limitation was highlighted to crews by a safety memorandum and by a company standardisation directive, dated 1 December 2004.

The memorandum stated the following:

> In response to a recent service bulletin from Honeywell, seats [in] Row 1 on BAe32 [Jetstream] aircraft are only to be occupied under the following circumstances:
>
> - Where the number of passengers is 16 or more and the seat is required for a passenger.
> - Where there is an operational requirement for operational personnel to occupy a seat in Row 1 such as training and checking or auditing.
> - Where directed by the captain (such as a surveillance flight by a CASA Safety Auditor).
>
> This measure will further reduce the risks associated with potential bull gear failure on the TPE 331 [engined] aircraft.

[8] AD/TPE 331/62 has been amended to AD/TPE 331/62 Amdt 1, effective from 4 August 2005. This amendment includes provision for an alternative means of compliance for TPE 331 engines fitted to CASA 212 aeroplanes. There has been no other change to the AD. At the time of drafting the original AD the [engine] manufacturer had not provided CASA with documents detailing the AMOC [Alternative Means of Compliance].