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AAIB
Air Accidents Investigation Branch

AAIB Bulletin S5/2014 *SPECIAL*

ACCIDENT

Aircraft Type and Registration:	BAE Systems Jetstream 31, G-GAVA
No & Type of Engines:	2 Garrett Airesearch TPE331-10UGR-516H turboprop engines
Year of Manufacture:	1987 (Serial no: 785)
Location:	Doncaster Sheffield Airport, Yorkshire
Date & Time (UTC):	15 August 2014 at 1836 hrs
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Left main landing gear, left propeller, fuselage and wing
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	54 years
Commander's Flying Experience:	8,740 hours (of which 3,263 were on type) Last 90 days - 147 hours Last 24 hours - 6 hours
Information Source:	AAIB Field Investigation

The investigation

The Air Accidents Investigation Branch was notified of the accident at 1840 hrs on Friday 15 August 2014. An investigation was commenced under the provisions of EU Regulation 996/2010 and the Civil Aviation (Investigation of Air Accidents and Incidents) Regulations 1996; the operator, aircraft manufacturer, UK Civil Aviation Authority (CAA) and the European Aviation Safety Authority (EASA) are participating. This Special Bulletin is published to provide details of the initial facts and discussion surrounding the accident;

it includes information gathered from witness statements, the cockpit voice and flight data recorders, and a preliminary inspection of the aircraft and the accident site. The investigation is ongoing and a final report will be published in due course.

Synopsis

The aircraft's left main landing gear failed shortly after it landed on Runway 20 at Doncaster Sheffield Airport. The left main landing gear detached from its mounts and the aircraft slid along the runway on its remaining landing gear, left wingtip and luggage pannier before veering off the runway and coming to rest on the adjacent grass. The single passenger and the flight crew vacated the aircraft without injury. Preliminary findings indicate that the failure was initiated as a result of stress corrosion cracking in the forward yoke pintle at the top of the left landing gear leg. Further analysis is required to determine the precise details of the failure, however, the preliminary findings are of significance because the same aircraft, operating under a different registration, was involved in a similar accident in 2012[1] during which the right main landing gear failed. The subsequent investigation identified intergranular corrosion / stress corrosion cracking of the forward yoke pintle at the top of the main landing gear leg as the cause of that failure.

Two Safety Recommendations are made.

History of the flight

G-GAVA took off from Belfast City Airport at 1745 hrs operating a scheduled air service to Doncaster Sheffield Airport with one passenger and a crew of two pilots on board. The commander was the Pilot Flying (PF) and the co-pilot was the Pilot Monitoring (PM).

The departure, cruise and approach to Doncaster Sheffield Airport were uneventful. The 1820 hrs ATIS for the airport stated that the wind was from 260º at 5 kt, varying between 220º and 280º. Visibility was greater than 10 km, there were few clouds at 3,000 ft aal, the temperature was 17ºC and the QNH was 1,019 hPa. Although Runway 02 was the active runway, the crew requested radar vectors for a visual final approach to Runway 20, a request which was approved by ATC. The loadsheet recorded that the aircraft's mass at landing was expected to be 5,059 kg which required a target threshold indicated airspeed (IAS) of 101 kt.

The aircraft touched down at 1836 hrs with an IAS of 102 kt and a peak normal acceleration of 1.3 g, and the commander moved the power levers aft to GROUND IDLE followed by REVERSE. As the aircraft decelerated, the commander moved the power levers forward to GROUND IDLE and asked the co-pilot to move the rpm levers to TAXI. At an IAS of 65 kt, eight seconds after touchdown, the left wing dropped suddenly, the aircraft began to yaw to the left and the commander was unable to maintain directional control with either the rudder or the nosewheel steering tiller. The aircraft ran off the left side of the runway and stopped on the grass having turned through approximately 90º. The left landing gear had collapsed and the aircraft had come to a halt resting on its belly, right landing gear and left wing (Figure 1).

Footnote

[1] G-CCPW at Isle of Man Airport on 8 March 2012, report EW/C2012/03/03, published in AAIB Bulletin 10/2012.

Figure 1
The aircraft as it came to rest

The commander pulled both FEATHER levers, to ensure that both engines were shut down, and switched the electrics master switch to EMERGENCY OFF. The co-pilot transmitted "TOWER…… [CALLSIGN]" and the controller replied "[CALLSIGN] COPIED, EMERGENCY SERVICES ON THEIR WAY". The commander instructed the co-pilot to evacuate the aircraft. The co-pilot entered the main cabin where he found that the passenger appeared to be uninjured. The co-pilot considered evacuating the aircraft through the emergency exit on the starboard side of the cabin but judged that the main exit on the port side at the rear of the cabin would be the best option. The cabin door released normally but would not open completely because the sill of the doorway was at ground level (Figure 1). Nevertheless, all occupants were able to evacuate the aircraft through the main exit.

Recorded information

The aircraft was fitted with a Cockpit Voice Recorder (CVR) and Flight Data Recorder (FDR); both recorders captured the landing at Doncaster Sheffield Airport. The FDR only recorded five parameters which were pressure altitude, heading, airspeed, normal acceleration and a VHF transmission discrete. Additionally, a Terrain Awareness and Warning System (TAWS) was installed in the aircraft, recording 30 separate parameters including aircraft rate of descent, radio altitude and pressure altitude at a higher sampling rate than the FDR. This data is currently being decoded by the TAWS manufacturer.

A review of the previous 82 landings recorded on the FDR has not identified any of concern but it was noted that a peak normal acceleration of 1.72g was recorded during the eighteenth landing prior to the accident. However, this was within the landing gear limit load defined for a touchdown which is a rate of descent of 10 ft/sec at a maximum landing weight of 14,900 lb (6,758 kg).

Runway marks and debris

The aircraft left a number of marks on the runway starting approximately 370 m from the start of the runway threshold markings. The first marks were made by the top of the left landing gear cylinder, after it had folded under the wing, followed immediately by the left engine propeller striking the runway surface.

Aircraft damage

The left landing gear had broken away from its trunnions as a result of the failure of the forward yoke pintle housing; two sections of the pintle housing stayed attached to the pintle spigot (Figure 2). However, the landing gear remained attached to the aircraft by the radius arm (retraction jack) and hydraulic pipelines.

The blades on the left engine propeller had been badly damaged. The left aileron balance horn separated from the aircraft after it left the runway, becoming lodged in the soft ground. The left wingtip had sustained abrasion damage, resulting in a fuel leak from this area. The baggage pannier and anti-collision beacon on the underside of the fuselage also sustained considerable abrasion damage.

Landing gear

The Jetstream 31 main landing gear cylinder is manufactured from DTD 5094 aluminium alloy, which is known to be susceptible to stress corrosion cracking (SCC). In particular, SCC in the forward yoke pintle can be caused by the front face of the pintle housing rotating against the spigot bearing during extension and retraction of the landing gear. The resulting abrasion causes degradation of the protective surface treatment on the pintle housing, which can allow corrosion pits to form and ultimately lead to cracking. The Jetstream 32 main landing gear cylinder and later versions of the Jetstream 31 main landing gear cylinder are manufactured from L161 alloy and are not as susceptible to SCC.

Figure 2

Left main landing gear yoke forward pintle

The landing gear is attached to the airframe by trunnions that fit into steel spigots that are bolted to the inside of the yoke pintles. The upper surfaces of the pintles are machined flat to introduce a weak link that, in the event of the landing gear being subjected to a force outside of its design limits, will fail without damaging the fuel tanks. During the accident, the forward yoke pintle failed along this machined flat (Figure 3).

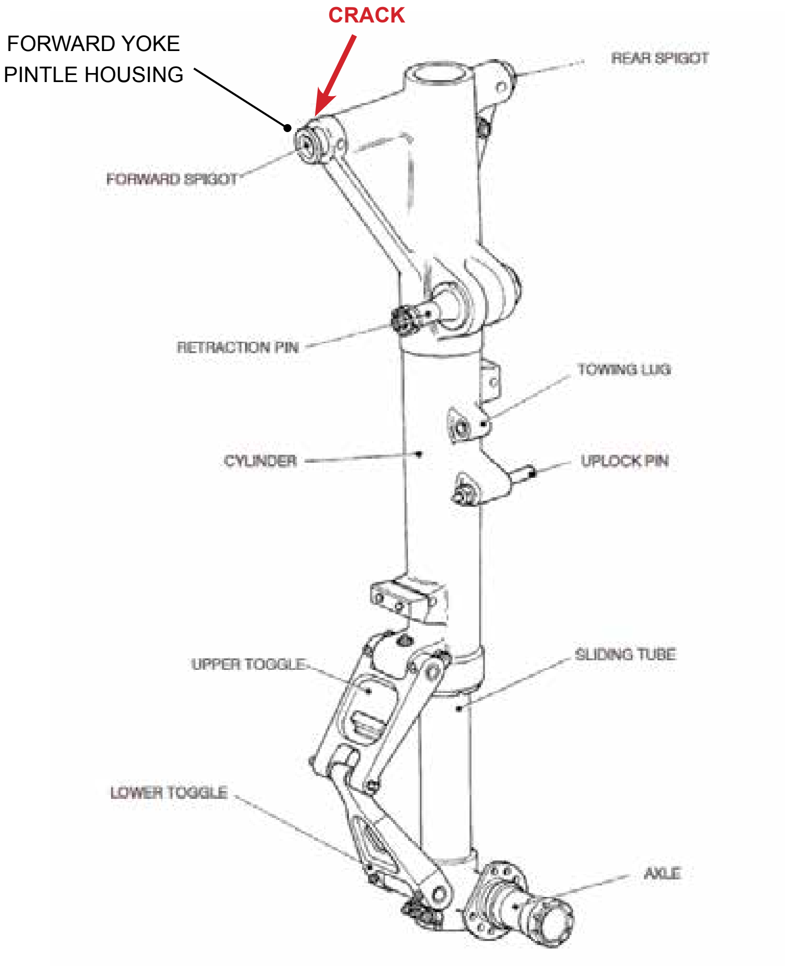

Figure 3

Jetstream 31 main landing gear leg

Previous occurrences

On 8 March 2012, the same aircraft, albeit operating under the registration G-CCPW, suffered a failure to its right main landing gear as it landed at Isle of Man Airport. The subsequent investigation identified intergranular corrosion / stress corrosion cracking of the forward yoke pintle at the top of the main landing gear cylinder as the cause of the failure. The issue of SCC in this area of the Jetstream 31 main landing gear cylinder had previously been identified in 1985 and the AAIB Report into the G-CCPW accident documents the history of the issue. At the time of the G-CCPW accident UK CAA Airworthiness Directive (AD) G-003-01-86 and Mandatory Service Bulletin (SB) 32-A-JA851226, Revision 4 were in force, to require regular high-frequency eddy current and visual inspections of this area. The eddy current inspection was required to be performed every 1,200 cycles or one calendar year, whichever occurred sooner; the visual inspection was required every 300 cycles or three calendar months.

The G-CCPW investigation determined that the existing eddy current and visual inspections had not detected the presence of cracks before failure occurred. In particular, the report raised concerns about the limitations of the eddy current technique in detecting cracks caused by SCC in the forward yoke pintle housing, due to edge effects, minimum detectable crack length and sensitivity of the technique in the presence of corrosion. As a result the investigation made the following Safety Recommendation:

Safety Recommendation 2012-008

It is recommended that the European Aviation Safety Agency review the effectiveness of Airworthiness Directive G-003-01-86 in identifying cracks in the yoke pintle housing on landing gears fitted to Jetstream 31 aircraft.

Safety actions arising from previous occurrences

On 19 June 2013 EASA responded to Safety Recommendation 2012-008 as follows:

'EASA, together with the Type Certificate Holder, is reviewing the effectiveness of the Airworthiness Directive G-003-01-86, and hence the service bulletin, in identifying cracks in the yoke pintle housing. It is agreed that the current service bulletin is not adequate and it is under the process of revision. A revised service bulletin will be produced which will be mandated by an Airworthiness Directive.'

SB 32-A-JA851226 was subsequently revised and Revision 6 was published on 18 December 2013, and was mandated by EASA AD 2013-0208, which superseded AD G-003-01-86. The changes to SB 32-A-JA851226 included revised access instructions, revised instructions for re-protecting the landing gear yoke pintle following the eddy current inspections and various administrative updates. There were no changes to the high-frequency eddy current technique, equipment or inspection intervals.

Following the G-CCPW accident, the aircraft manufacturer decided to place increased emphasis on 'prevention' rather than 'detection' of stress corrosion cracking and so published modification service bulletin SB 32-JM7862, dated May 2013, to introduce a new design solution. This requires installation of a 'special washer' to protect the forward face of the yoke pintle housing from rubbing against the spigot bearing during retraction and extension of the landing gear, and thus prevent initiation of stress corrosion cracking. SB 32-JM7862 requires the washer to be attached to the forward and top faces of the yoke pintle housing using an anaerobically curing, low adhesion, liquid gasket. The washer has a preformed 90º rectangular tab at the top, which is designed to fit against the machined flat on top of the yoke pintle housing, to prevent rotation of the washer. To accommodate the thickness of the washer, a new spigot bearing with reduced flange thickness was also introduced. Although not affected by stress corrosion cracking, this SB is also applicable to Jetstream 31 landing gear made from L161 and Jetstream 32 landing gear. SB 32-JM7862 was mandated by EASA AD 2013-0206.

On 3 December 2013 EASA issued an updated response to Safety Recommendation 2012-008 as follows:

> *'EASA, together with the Type Certificate (TC) holder, has reviewed the effectiveness of the airworthiness Directive G-003-01-86. A new design solution and a new inspection regime have been introduced which have been mandated by EASA AD 2013-0206 and EASA AD 2013-0208, respectively. Furthermore, a new inspection has been introduced in the Component Maintenance Manual of the Main Landing Gear.'*

The new inspection referenced in EASA's updated response relates to an inspection introduced to detection corrosion in the yoke pintle bore. Corrosion in this area was a finding of the G-CCPW investigation, although it was not directly related to the failure of the landing gear. Nonetheless this warranted safety action and was the subject of a separate AAIB Safety Recommendation[2].

Subsequently, in April 2014, the aircraft manufacturer became aware of an integration issue on some aircraft during embodiment of SB 32-JM7862 that caused the bearing locking pins in the spigot bearing cap to protrude from the (reduced thickness) bearing flange and foul on the special washer. Consequently, Revision 2 of SB 32-JM7862 was issued on 13 June 2014, with an instruction to rotate the spigot bearing cap by 180º so that the bearing locking pins did not foul against the washer. The compliance instructions for aircraft which already had Revision 1 of SB 32-JM7862 embodied, were to reverse the orientation of the spigot bearing cap *'at the next convenient maintenance input (e.g. when the aircraft is jacked)'*.

Metallurgy

Preliminary metallurgical examination of the fracture faces on G-GAVA's left landing gear has established that the failure initiated at the top outer edge of the forward yoke pintle and that the crack propagated axially along the top of the pintle, before final overload failure occurred. The presence of corrosion has been identified at the crack initiation site. The forward face of the yoke pintle housing exhibits rotational wear marks and corrosion pitting. There is also evidence of rotational wear marks on both the forward and aft faces of the special washer; further work is required to fully understand the origin of these marks. There was no visual evidence of the presence of gasket material on either of the mating faces of the washer or pintle housing although some gasket material was present on the top machined flat of the housing. Additionally the fracture faces exhibit considerable similarities to those from the G-CCPW accident. This provides strong evidence that the crack initiated due to stress corrosion cracking.

Footnote

2 AAIB Safety Recommendation 2012-024.

Maintenance history

The Jetstream 31 landing gears are required to be overhauled every 10,000 cycles or six calendar years and both main landing gears had last been overhauled in December 2012 and fitted to G-GAVA later that month[3]. At the time of the accident they had accumulated 955 cycles. The last eddy current inspection was carried out on both landing gear legs on 10 December 2013, 803 cycles prior to the accident, with nil findings. During the same maintenance input, SB-32-JM-7862 Revision 1 was embodied to install the protective washer on the forward face of the landing gear yoke pintle of both landing gear legs.

The technical records indicate that while conducting a detailed visual inspection of the landing gear during a subsequent maintenance input in March 2014, the protective washers on both landing gears were observed to have rotated out of position; the documented rectification action was *'MLG reinstalled in accordance with SB 32-JM7862 with protective washer'*. During examination of the aircraft after the accident, the special washer on the left landing gear was observed to be in the correct position, although the rectangular tab was not lying flush over the machined flat of the yoke pintle. Instead it was bent up at a slight angle. There was a fresh gouge in the yoke pintle housing near the edge of the special washer tab, which may have been caused by debris during the landing gear collapse. It was therefore not possible to determine whether the special washer tab was displaced prior to the accident, or as a result of the accident sequence. The special washer on the right landing gear had rotated out of position, by about 15º inboard.

The most recent visual inspection was performed on 30 June 2014, 226 cycles before the accident; no defects were noted. The operator also advised the investigation that they had no reports of the aircraft having sustained a hard or heavy landing.

Discussion

The ground marks on the runway from the failed landing gear and the left engine propeller, together with FDR data and audio analysis of the CVR indicate that the left main gear failed eight seconds after touchdown.

While the aircraft's rate of descent rate prior to landing is yet to be confirmed from the TAWS download, the aircraft weight was considerably below the maximum permissible landing weight and there is currently no evidence to suggest that the landing parameters were outside of the design specification for the landing gear. As such the landing gear should not have failed.

Metallurgical analysis has determined that a crack initiated at the top edge of the forward yoke pintle and propagated axially along the top of the pintle housing, ultimately resulting in an overload failure of the pintle yoke. Further analysis is required to understand the specific characteristics of the failure and how long the crack took to grow to failure. However, there is sufficient evidence to indicate that the failure was precipitated by stress corrosion cracking

Footnote

3 The left main landing gear on G-GAVA was a different unit to that which was installed at the time of the G-CCPW accident.

in the forward yoke pintle. Given the similarities of the failure to that which occurred on G-CCPW, it is evident that the inspections of and the modifications to the left main landing gear of G-GAVA were not effective in preventing this accident.

Rotational wear is evident on the mating faces of the forward yoke pintle and the special washer. Further work is being undertaken to determine the origin of this wear and also whether rotational wear on the forward face of the special washer may be related to fouling of the bearing locking pins. There is no visual evidence of gasket material on the mating faces of the yoke pintle and the special washer; however, it is not yet known whether the gasket material was omitted during installation or had been forced out by the rotating washer. Gasket material is evident on the machined flat of the yoke pintle housing, however this area would be expected to be cleaned to facilitate the regular visual inspections in this area.

Due to the known limitations of the eddy current inspection technique, following the G-CCPW accident the aircraft manufacturer decided to place increased emphasis on 'prevention' rather than 'detection' of stress corrosion cracking in the landing gear yoke pintle. They introduced the modification to install a protective washer on the forward face of the yoke pintle. The investigation determined that it is possible for the special washer to migrate / rotate out of position, which could cause it to abrade on the forward face of the landing gear yoke pintle. Prior to this accident, the aircraft manufacturer was unaware that the washer could rotate out of position and had not been made aware of the previous finding of migration of the special washers on G-GAVA. They also noted that SB 32-JM7862 contains instructions only for initial installation of the special washer and not for subsequent reinstallation in the event of a defect being identified. While the investigation has not yet determined whether the rotation of the washer is due to an installation issue (failure or absence of an effective gasket seal) or an integration issue (fouling of the washer on the bearing locking pins), any rotation would not only negate the protective effect of the washer, but may actively degrade the surface protection on the forward face of the yoke pintle housing. For aircraft with DTD 5094 landing gear with Revision 1 of SB 32-JM7862 embodied, the next opportunity to remove the landing gear and thus determine whether the special washer has caused wear on the forward face of the yoke pintle housing, may not arise until the next annual eddy current inspection. The following Safety Recommendation is therefore made:

Safety Recommendation 2014-038

It is recommended that the European Aviation Safety Agency take action to assure the continued airworthiness of those BAE Systems Jetstream 31 main landing gear legs that are manufactured from DTD 5094 aluminium alloy and have SB 32-JM7862 embodied.

Following publication of Safety Recommendation 2012-008, EASA determined that SB-32-A-JA851226 was inadequate, however, despite the subsequent revision to the SB and the publication of EASA AD 2013-0208, no substantive changes have been made to the NDT technique, equipment or inspection intervals nor to the intermediate visual inspections.

It is therefore evident that these actions did not result in increasing the effectiveness of the established inspection regime for detecting the presence of cracks in the landing gear forward yoke pintle housing. As embodiment of SB 32-JM7862 in this case may not have achieved the intended level of protection of the forward yoke pintle, an effective inspection regime for early detection of cracks is imperative. The following Safety Recommendation is therefore made:

Safety Recommendation 2014-039

It is recommended that the European Aviation Safety Agency take action to mandate an effective inspection regime for the Jetstream 31 that will detect cracking and prevent failure of the yoke pintle of main landing gear legs manufactured from DTD 5094 aluminium alloy.

Further work

The investigation is ongoing and this Special Bulletin is based on preliminary information which is subject to change. In particular, further detailed metallurgical examination of the left main landing gear is ongoing to characterise the exact nature of the failure. A comparative examination of the right main landing gear, which was subject to the same overhaul and recent component history, will also be undertaken. The investigation will also consider the maintenance history of the failed landing gear in more detail. The AAIB will publish additional Safety Recommendations if further safety action is required.

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