ACCIDENT

Aircraft Type and Registration:	EC225 LP Super Puma, G-REDW
No & Type of Engines:	2 Turbomeca Makila 2A1 turboshaft engines
Year of Manufacture:	2009 (Serial no: 2734)
Date & Time (UTC):	10 May 2012 at 1114 hrs
Location:	20 nm east of Aberdeen
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 12
Injuries:	Crew - None Passengers - 2 (Minor)
Nature of Damage:	Damage to be assessed following salt water immersion
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	To be advised
Commander's Flying Experience:	To be advised
Information Source:	AAIB Field Investigation

This Special Bulletin details the progress made in identifying the failure mechanism that caused the 360° circumferential crack, in the bevel gear vertical shaft in the helicopter's main gearbox, which was identified in the early stages of the investigation and published in AAIB Special Bulletin 2/2012 in May 2012. It also details progress on the investigation into the indicated failure of the main gearbox emergency lubrication system.

History of the flight

The helicopter was on a scheduled flight from Aberdeen Airport to the Maersk Resilient platform, in the North Sea, 150 nm east of Aberdeen. On board were two flight crew and twelve passengers. The helicopter was in the cruise at 3,000 ft with the autopilot engaged and at an approximate speed of 143 KIAS. Thirty-four nm east of Aberdeen Airport, the crew were presented with indications of low pressure in both the main gearbox (MGB) main and standby oil lubrication systems. This was followed by a chip indication on the Vehicle Monitoring System (VMS), and the MGB oil temperature starting to increase.

The commander assumed control of the helicopter, reduced speed towards 80 KIAS, turned back towards the coast and initiated a descent. The crew activated the emergency lubrication system and during the descent the MGB EMLUB[1] caption illuminated on the Central Warning Panel (CWP), for which the associated procedure is to land immediately. The commander briefed the passengers and carried out a controlled ditching. The total flight time was 27 minutes.

The helicopter remained upright, supported by the emergency flotation gear. After the engines were shut down and the rotors were stopped, the crew and passengers evacuated the helicopter into one of the life rafts via the starboard cabin door. Six of the occupants were rescued from the life raft by a search and rescue helicopter, eight were transferred to a RNLI lifeboat.

Aircraft information

General information

The EC225 LP is a twin-engine, medium-sized helicopter developed from the Eurocopter AS332 L2 and L1 variants of the Super Puma. G-REDW was operated by two pilots and equipped with 19 passenger seats in the main cabin. It was also equipped with an emergency flotation system, a life raft fitted in each sponson and a deployable crash position indicator (CPI).

The MGB transmits power from the engines to the main rotor. The power from the engines is transmitted to the bevel gear through the combiner wheel and bevel gear pinion. The majority of this power is then transmitted upwards into the epicyclical reduction gear module. Two pinion gears, mounted at the bottom of the bevel gear vertical shaft, drive the main and standby oil pumps. The power train through the gearbox is illustrated at Figure 1.

The bevel gear vertical shaft consists of the bevel gear and a vertical shaft that are joined together by an electron beam weld: electron beam welding is also used to join the bevel pinion to the combiner wheel shaft. To ensure the integrity of these shafts, the disrupted material at the end of the weld is removed by drilling and reaming a 4.2 mm diameter hole; a countersink (chamfer) is also formed at each end of the hole. A PTFE plug is fitted in this hole to control the flow of oil within the vertical shaft.

MGB certification requirements

The EC225 LP was certified against the Joint Aviation Regulations (JAR) 29, which includes the requirement for the helicopter to continue safe flight, at prescribed torque and main rotor speeds, for at least 30 minutes following the loss of the MGB lubrication system. This is achieved on the EC225 LP by the use of a back-up lubrication system that uses a mixture of glycol and water (Hydrosafe 620) to cool and lubricate the MGB. This system is also known as the emergency lubrication system.

Main gearbox

The MGB fitted to the EC225 LP is of a similar design to the gearbox fitted to the AS332 L2, but has a greater torque capability. However, there are two significant differences to the MGB on the EC225 LP. The conical housing has been stiffened and the base material of the bevel gear vertical shaft has been changed from 16NCD13

Footnote

[1] The MGB EMLUB caption indicates loss of emergency MGB lubrication.

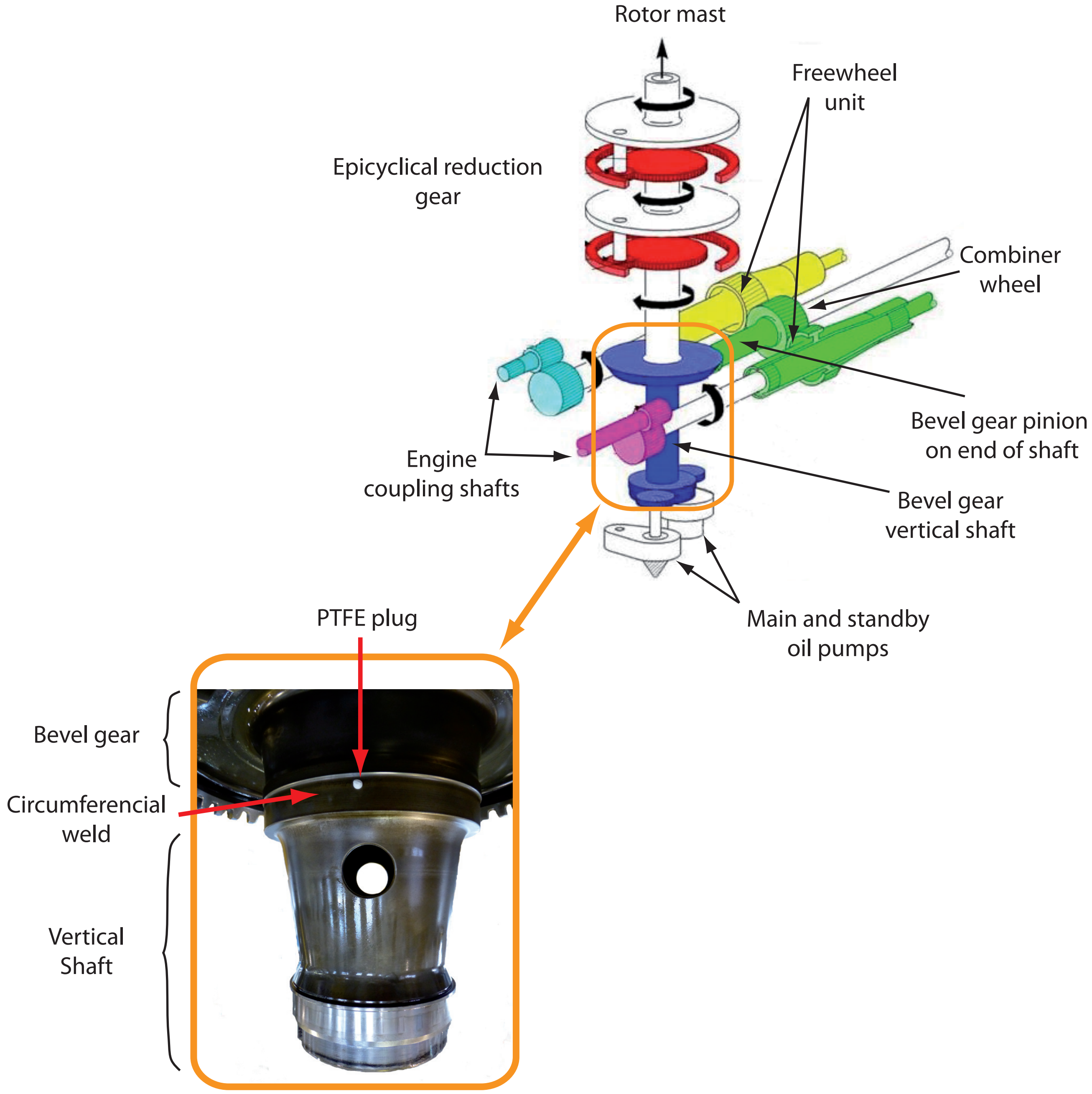

Figure 1

MGB power train

carburized steel alloy to 32CDV13 nitrided steel alloy. The 16NCD13 shaft (part number 331A323115) is no longer manufactured and the 32CDV13 shaft (part number 332A325101) is the replacement part for the MGB fitted to AS332 L1 and L2 helicopters. Approximately 732 of the 32CDV13 steel alloy shafts have been manufactured.

MGB lubrication

The MGB lubrication system includes two mechanically operated oil pumps and a crew-activated emergency lubrication system. The emergency lubrication system comprises: a bleed air supply from the left engine, a Hydrosafe 620 supply, a series of small pipes around and inside the main gearbox to deliver the Hydrosafe 620 spray, and a control and monitoring system on a Printed Circuit Board (PCB).

When the system is activated, an electro-valve (P2.4 valve) opens and bleed air from the left engine enters the system. At the same time, Hydrosafe 620 is pumped from a reservoir into the system. There are two similar sensors that monitor the pressure in both the Hydrosafe 620 and bleed-air lines; these sensors are mounted on the MGB. The MGB EMLUB caption will illuminate if low pressure is detected in either the Hydrosafe 620 or the bleed air lines, or there is an erroneous signal. This warning is inhibited for approximately 30 seconds after the system is activated, to allow the system to reach a steady state.

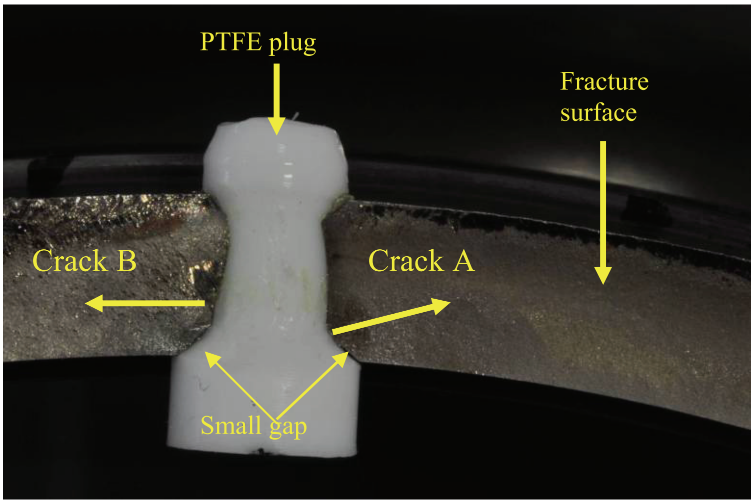

Figure 2

4.2 mm diameter hole in the weld

Engineering investigation

Overview

The MGB was fitted to G-REDW on 18 March 2012, following overhaul at the helicopter manufacturer's facility, where a new bevel gear vertical shaft (serial number M385) was fitted. This shaft failed in flight after approximately 167 flying hours.

A strip examination of the MGB established that the bevel gear vertical drive shaft had failed across the 4.2 mm diameter hole in the area where the two parts of the shaft are welded together. As a consequence of this failure, the lower part of the shaft moved downwards damaging the outer race retainer of the lower roller bearing and causing the pinion to disengage partially from the oil pump drive gears. This damaged the teeth on the oil pump drive gears and generated sufficient debris to activate the sump magnetic chip detector. At this stage, the lower part of the shaft was no longer being driven. During the examination, glycol was found throughout the gearbox casing and on all the gears and bearings. There was no visual evidence of heat distress or damage to any of the other components in the MGB.

Initial results of a dimensional survey of the MGB indicated that all the dimensions were within the design tolerances. Further work continues to establish the dimensions and concentricity of the bevel gear vertical drive shaft.

Examination of the shaft fracture surface

Examination of the fracture surface on both parts of the bevel gear vertical shaft revealed the presence of three cracks, identified as 'A', 'B' and 'C' (see Figure 2). Cracks 'A' and 'B' started from the 4.2 mm diameter hole in the weld and there was evidence of beachmarks and striations along both cracks, which are indicators of a fatigue failure. Crack 'A' was 336 mm long[2] and extended for approximately 250° around the circumference of the shaft. This crack appeared to have initiated from a small corrosion pit, approximately 60 µm

Footnote

[2] The length of the cracks was measured along the outer surface of the shaft.

deep, on the inner countersink. Crack 'B' was 106 mm long and extended for approximately 80° around the circumference. This crack appeared to have initiated at a small defect in the internal surface of the hole. Crack 'C' was 42 mm long and extended for approximately 30° around the circumference. One end of this crack joined Crack 'A' and the other end ran under Crack 'B'. While there were striations on the surface of Crack 'C', there was no evidence of any beachmarks.

In total, approximately 99% of the fracture surface on the bevel gear vertical shaft had failed in fatigue and 1% of the surface had failed in overload.

Examination of the 4.2 mm diameter hole

The diameter of the 4.2 mm hole was within the design specification. However, there was evidence of tooling marks and, what appeared to be, a spiral scratch that ran along the length of the hole. The geometry of the inner and outer countersinks was found to be outside the design specifications and there were a number of 'scoops' in the inner countersink (see Figure 3). There were patches of very small corrosion pits around the inner countersink, in the area where there is a gap (crevice) between the PTFE plug and the countersink. These corrosion pits were only initially detected using a scanning electron microscope.

The fracture surface was across the 4.2 mm diameter hole. The roughness of the surface of the hole on the lower section of the shaft, averaged over its length, was measured as 1.695 µm, using a Talysurf profile meter with an ISO-2CR filter. However, one end of the hole was much rougher than the other, with the average roughness measurements being 2.50 µm and 0.29 µm, respectively. The deepest feature was of the order of 60 to 70 µm. The roughness of the surface of the hole on the upper section of the shaft, averaged over its length, was measured as being between 0.92 µm and 1.48 µm.

Following the accident, 18 bevel gear vertical shafts, between serial numbers M308 and M559, were examined by the manufacturer. There was some variability in the geometry of the countersinks on the 4.2 mm diameter holes and a number were found to be outside the design tolerance. There was also evidence of tooling marks in the bore of a number of these holes.

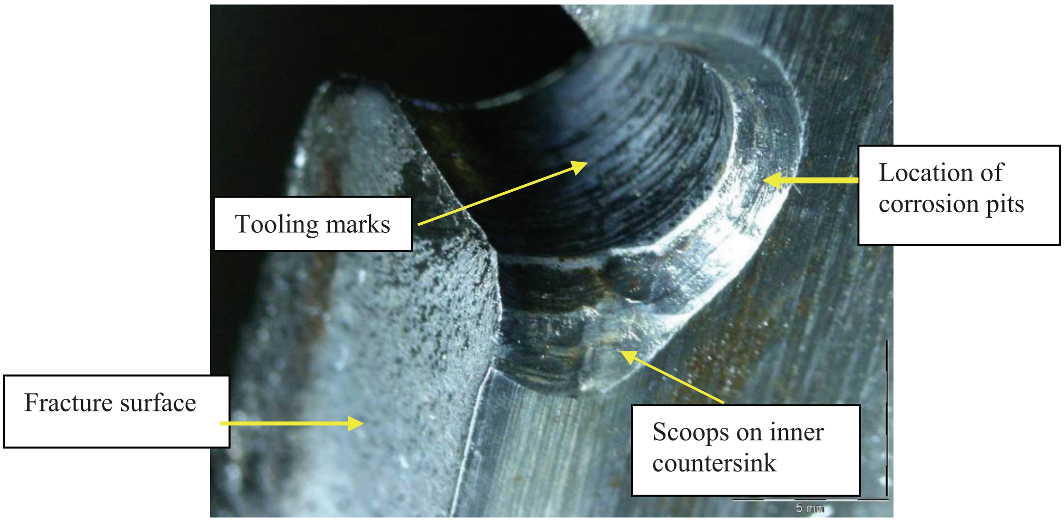

Figure 3

Condition of the 4.2 mm hole and countersink

Manufacturing change to the 4.2 mm diameter hole

The initial design was for a 100°±1° countersink (chamfer) at both ends of the 4.2 mm diameter hole. As a result of a production change in September 2009, to standardize production tooling, the angle of the countersink was changed to the same as that on the bevel pinion (90°±1°). The manufacturer assessed the effect on the stress in the region of the countersink as negligible. The first shaft manufactured following this change was serial number M330, on 14 June 2010. No change was made to the PTFE plug which is only used on the bevel gear vertical shaft.

It was established that when the PTFE plug is fitted in the hole, with a 90°±1° countersink, a small annular gap (approximately 0.37 mm x 0.05 mm in cross-section) can remain between the plug and the side of the countersink (see Figure 2).

Manufacturing dimensional inspection

A dimensional inspection is undertaken at the end of the manufacturing process to ensure that the component meets the design specification. The bevel gear vertical drive shaft is classed as 'Pièce Critique' (critical item) and an inspection document 332A32510100-DI926 lists the design features and specifies the percentage of components that need to be inspected accurately. This document calls for 10% of the countersinks in the 4.2 mm hole to be checked using a replicast[3] and shadow board. In addition, a visual inspection is carried out on all the holes and countersinks, using a torch and mirror.

The dimensional inspection also calls for the average roughness (Ra) of the hole to be measured, to ensure that it is less than 1.6 µm. However, when shaft serial number M385 was manufactured there was no acceptance criterion for surface scratches. Since the accident, the manufacturer has introduced acceptance criteria for scratches of a maximum depth of 5 µm.

Fatigue testing

As a result of this accident, 'single part' and dynamic fatigue tests have been undertaken on other bevel gear vertical shafts. In the 'single part' tests the shaft was subjected to a bending load in order to determine the fatigue properties across the weld. During one of these tests a crack initiated and propagated from the 4.2 mm diameter hole after it had been deliberately corroded under laboratory conditions prior to the test.

In the dynamic tests an instrumented shaft was run in an EC225 LP MGB in order to determine the in-service stress levels in the shaft and weld. The results of these tests are still being analysed.

Emergency lubrication system

This was the first occasion that the emergency lubrication system has been operated in-service.

Glycol was found throughout the main gearbox during the strip inspection, and there was no evidence of thermal damage. The amount of fluid remaining in the Hydrosafe 620 reservoir was also consistent with the pump operating normally. However, 32 seconds after the crew activated the emergency lubrication system, the MGB EMLUB caption illuminated.

The investigation of the emergency lubrication system has focused on the control and monitoring of this system. Nothing significant has been found during the test and inspection of the PCB (which controls and monitors this system), the two pressure sensors (air and glycol), the pipes and the relevant wiring. After the

Footnote

[3] A replicast is a replica of the feature made from a rubber compound.

accident, the P2.4 valve was found to be slightly open when it should have sprung closed; however, this does not readily explain why the MGB EMLUB caption came on. Further investigative work is planned.

The emergency lubrication system investigation has been broadened to include an assessment of component reliability and the certification process. There is some preliminary evidence that the in-service reliability of some of the components of this system is lower than that assumed in the System Safety Assessment for certification. The work in this area is ongoing.

Health and usage monitoring system (HUMS)

A review of the HUMS data showed no indication of any significant rising vibration trends until approximately six flying hours prior to the start of the accident flight. Prior to this period, the vibration levels on indicators associated with the bevel gear vertical shaft were below the mean level established from data collected from 23 other EC225 LP helicopters.

During the last six flying hours, which covered the two flights prior to the accident flight, the trend for indicator MOD 45, which monitors the meshing frequency of the bevel gear, and MOD 70 which monitors the meshing frequency of the oil pump wheels, increased. An amber[4] alert was generated for MOD 45 following the last flight on 9 May 2012, and for both indicators following the first flight on 10 May 2012. The operator's engineers followed the fault diagnosis chart in the Aircraft Maintenance Manual (AMM), Chapter 45.11.08.211. The washer on the accelerometer for these parameters was replaced following the first amber alert on 9 May 2012, and the MGB magnetic chip detectors were checked, and found to be free of debris, following the alerts on the 10 May 2012. Thirty six other indicators were checked and no significant trends were detected. In accordance with the guidance in the AMM, the aircraft was placed on 10 hourly close monitoring and released for flight.

Following the accident, the helicopter manufacturer analyzed the data for indicators MOD 45 and MOD 70 and reduced the vibration level required to generate an amber alert. Red alert thresholds have also been introduced for both these indicators[5].

Further work

The AAIB is continuing to work with the European Aviation Safety Agency (EASA), the Bureau d'Enquetes et d'Analyses pour la Securitie de l'Aviation Civile (BEA), representing the State of Manufacture of the helicopter, and Eurocopter, the helicopter manufacturer. The UK Civil Aviation Authority and the aircraft operator are also providing assistance to the AAIB.

The investigation will continue to review the results from the fatigue tests, with other data and evidence, to establish the mechanism that caused the initiation and propagation of the fatigue cracks in the bevel gear vertical shaft. It will also review the manufacturing process, dimensional inspections and quality system.

Further testing of components in the emergency lubrication system will be carried out, together with analysis of in-service data. The operational and survival aspects of the event will also continue to be investigated.

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Footnote

[4] An amber alert requires the operator to determine if a maintenance action is required, whereas a red alert requires a maintenance action to be carried out before the helicopter is allowed to fly again.

Footnote

[5] Eurocopter Service Bulletin No 45-001.