SERIOUS INCIDENT

Aircraft Type and Registration:	Leonardo AW189, G-MCGU
No & Type of Engines:	2 General Electric Co CT7-2E1 turboshaft engines
Year of Manufacture:	2014 (Serial no: 92007)
Date & Time (UTC):	4 March 2021 at 1036 hrs
Location:	3 nm south-east of Porthcawl, Wales
Type of Flight:	Emergency Services Operations
Persons on Board:	Crew - 4 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Collapsed heating duct, cabin air vent motors and auto transformer rectifier units ingested debris
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	45 years
Commander's Flying Experience:	4,507 hours (of which 595 were on type) Last 90 days - 77 hours Last 28 days - 24 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional enquiries by the AAIB

Synopsis

While returning from a SAR training sortie, shortly after selecting the cabin and cockpit heating ON, a heating duct failed causing fragments of duct insulation material to be discharged through the heating vents. The heating system was turned OFF but the subsequent presence of smoke, and a smell of burning, prompted an emergency landing. Several weeks later, a similar heating duct failure occurred on another of the operator's AW189 helicopters. The occupants of both helicopters suffered respiratory irritation.

The investigation determined that the heating ducts failed due to non-uniform adhesion at joints between rigid and flexible sections of duct. Interim safety action taken by the manufacturer includes the publication of a Service Bulletin to inspect and modify the installation of the heating duct. A further heating duct failure occurred on another AW189 following embodiment of the Service Bulletin and that event will be reported separately by the AAIB. At the time of publication of this report, the investigation into the recent duct failure is ongoing and the aircraft manufacturer is continuing to work with the duct manufacturer to achieve a permanent design solution.

History of the flight

Following completion of a SAR training sortie involving winching operations at Porthcawl, the helicopter transitioned into forward flight to return to its base at St Athan. The cabin and cockpit heating was selected ON and the vents opened. Approximately two minutes later, the flight crew observed light-green coloured foam debris in the cockpit, which primarily appeared to be coming from vents under the windscreen and from the adjustable vents on the left side of the cockpit. They selected the heating to OFF but subsequently detected a smell of burning and decided to land. They selected a field close to a road and completed the landing checks.

The flight crew made a PAN call to Cardiff Radar which was acknowledged. Approximately 30 – 45 seconds later, when the aircraft was approximately 100 ft agl, the smoke was seen coming from vents under the windscreen which the commander described as "whisps at first, followed by thicker grey smoke." The flight crew made a MAYDAY call to Cardiff Radar. The transmission was received but the flight crew did not hear the response due to the helicopter's low altitude.

The aircraft landed without further incident. The rear crew vacated the aircraft, all doors were opened for ventilation and the engines were shut down. The local RFFS, which had been notified by ATC, attended with the Police approximately 20 minutes after landing. The RFFS surveyed the aircraft with a thermal camera, which showed no signs of fire.

Company engineers subsequently attended the aircraft. Inspection of the aircraft and heating system revealed no additional findings. Following consultation with the company Engineering Manager, the heating system was isolated and the aircraft was ground run for 10 minutes, with no reoccurrence of the smoke. The aircraft then lifted into the hover for a further two minutes, to ensure that increased engine power did not cause the issue to reoccur, after which it was flown back to St Athan, landing seven minutes later. During the flight, the crew noted a slight smell of burnt material but there was no smoke. The rear crew returned to base by road.

Aircraft examination

Subsequent inspection by the operator's engineers showed that a heating duct in the right-hand rear area of the fuselage had collapsed and the external insulation was missing from a large section (Figure 1). The cockpit fans and two Auto-Transformer Rectifier Units (ATRUs) which have integral cooling fans and are mounted close to the failed duct, were found to have ingested duct insulation material. The duct failure occurred at 1,399 flight hours since new.

Subsequent event

On 17 April 2021 G-MCGT, another of the operator's AW 189s, experienced a heating duct failure (at 1,522 flight hours since new) when the heating was selected ON at the end of a SAR sortie. Inhalation of the resulting particles and debris was unavoidable and all crew members experienced respiratory irritation.

Figure 1

Collapsed heating duct on G-MCGU

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Aircraft information

The AW189 heating system mixes bleed-air from the engines, or the Auxiliary Power Unit (APU), with external ambient air. The heating duct takes the hot air from the engine deck down through the baggage compartment in the right rear fuselage and under the floor, where it is routed forward to supply the cockpit and cabin heating vents. The section of duct that failed runs close to the avionics rack. To accommodate a change in direction in the duct routing, this part of the duct is comprised of alternating flexible and rigid bend sections, bonded together using F6065, a two-part silicon pressure-sensitive adhesive (Figure 2).

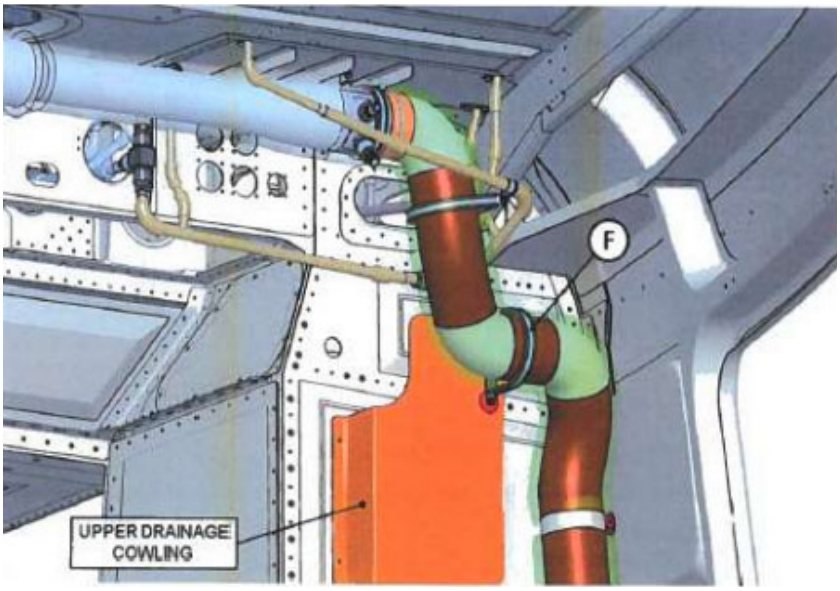

Figure 2

Heating duct on AW189 showing flexible sections in brown and rigid sections in green (Circle 'F' indicates a securing 'P-clamp')

Fleet inspection

Following the duct failure on G-MCGU, the operator issued a Technical Directive requiring a one-time inspection of the heating duct on all its AW189s within 50 flight hours. It included visual inspection of the external surface of the duct, inspection of cabin floor heating outlets and (depending on aircraft configuration) the cockpit fan inlet, for evidence of insulation fibres which might indicate a possible duct breakdown. The inspection also included operation of the heating system to check for any anomalies or unusual odour.

This inspection was performed on G-MCGT on 14 March 2021 with no findings, 31 flight hours before it experienced failure of the heating duct. The inspection had not required removal of the duct insulation material.

Previous events

Prior to the duct failure on G-MCGU, the operator had previously experienced heating duct failures on two other AW189s within its fleet. The first occurred on G-OENC, having accrued 1,077 flight hours on 26 October 2018 and the second on G-MCGN, having accrued 851 flight hours on 3 December 2019. Neither event resulted in a precautionary landing.

Component examination

The failed ducts from G-MCGU and G-MCGT were sent to the aircraft manufacturer's laboratory for examination. The manufacturer analysed the morphology of the bonding surfaces and compared those from the failed joints (highlighted by red ellipses in Figure 3) to those on the intact joints (blue ellipses). To facilitate the examination, the intact joints were manually separated by pulling the mating sections in opposite directions (denoted by black arrows).

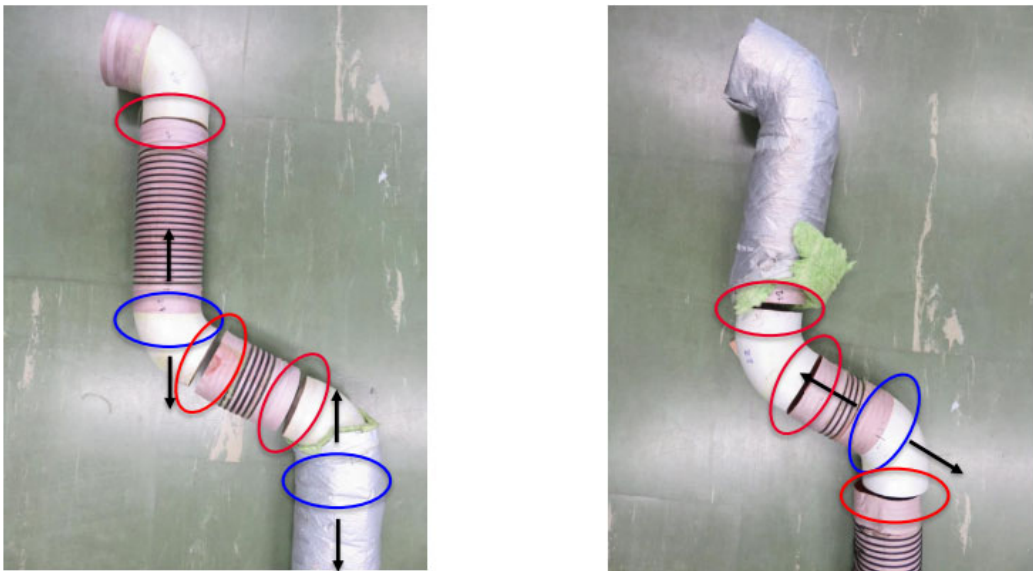

Figure 3

Failed heating ducts from G-MCGU (left) and G-MCGT (right)

On failed joints and those manually separated, adhesive was generally only present on the internal surfaces of the flexible sections. The only traces of adhesive present on the outer surfaces of the rigid bend sections appeared to be where adhesive had squeezed out from the joints during the assembly process.

In this design, the rigid bends are fabricated from composite fibre bundles arranged in a criss-cross pattern, impregnated with resin. It was noted that the rigid sections did not exhibit uniform smoothness across their entire surface; in some areas, voids were evident between the fibre bundles, while in others, resin had filled the voids (Figure 4).

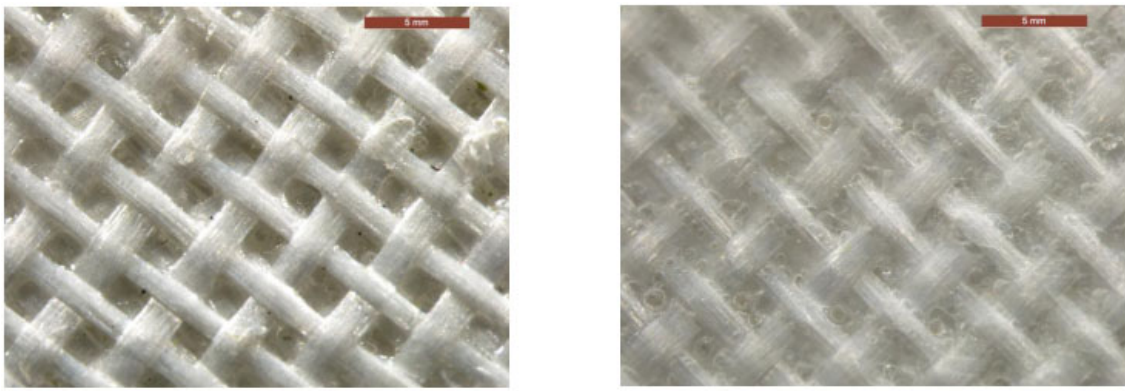

Figure 4

Surface of rigid bend sections, showing voids between fibre bundles

Several different characteristics were observed on the adhesive bonding surface, which had previously been in contact with the rigid sections:

- Some areas exhibited cubic-shaped reliefs in the adhesive (Figure 5), caused by penetration of the adhesive into the voids between the crossed fibre bundles that make up the surface of the rigid bend sections.
- Some areas exhibited well-defined imprints of the crossed fibre bundles, while others exhibited only slight imprints (Figure 6).
- Some areas exhibited small and large bubbles in the adhesive (Figure 7).

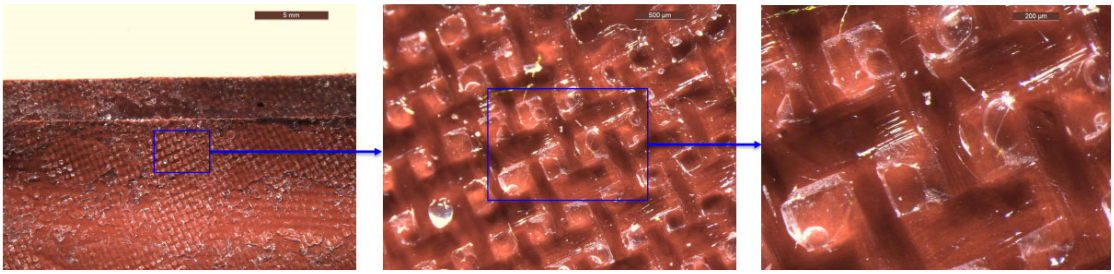

Figure 5

Cubic-shaped reliefs in adhesive, corresponding to cross-fibre bundles on rigid sections of duct

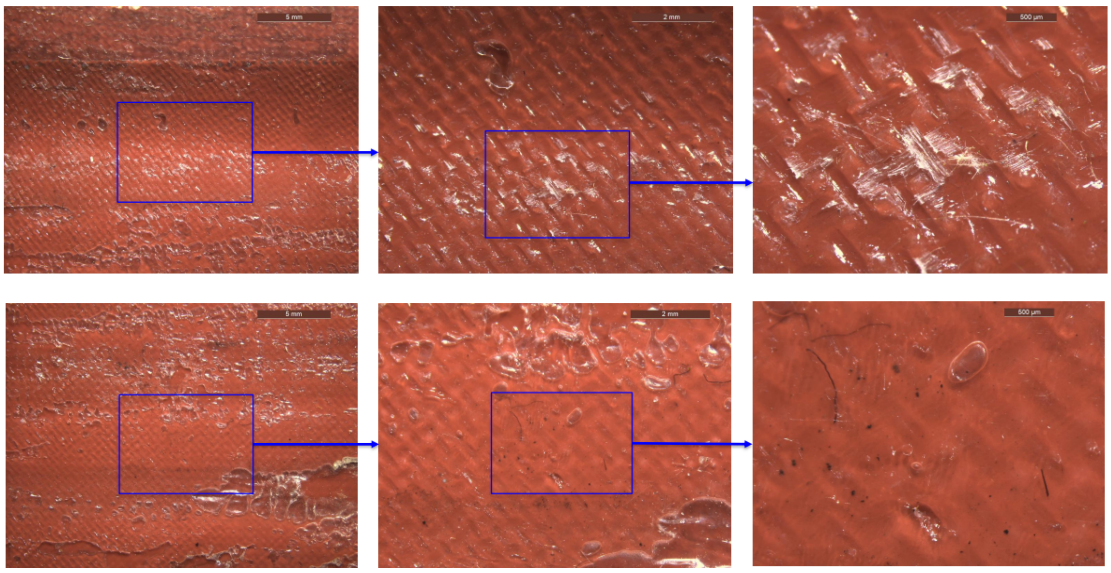

Figure 6

Areas of adhesive showing well-defined imprints from cross-fibre bundles (top row) and less well-defined imprints (bottom row)

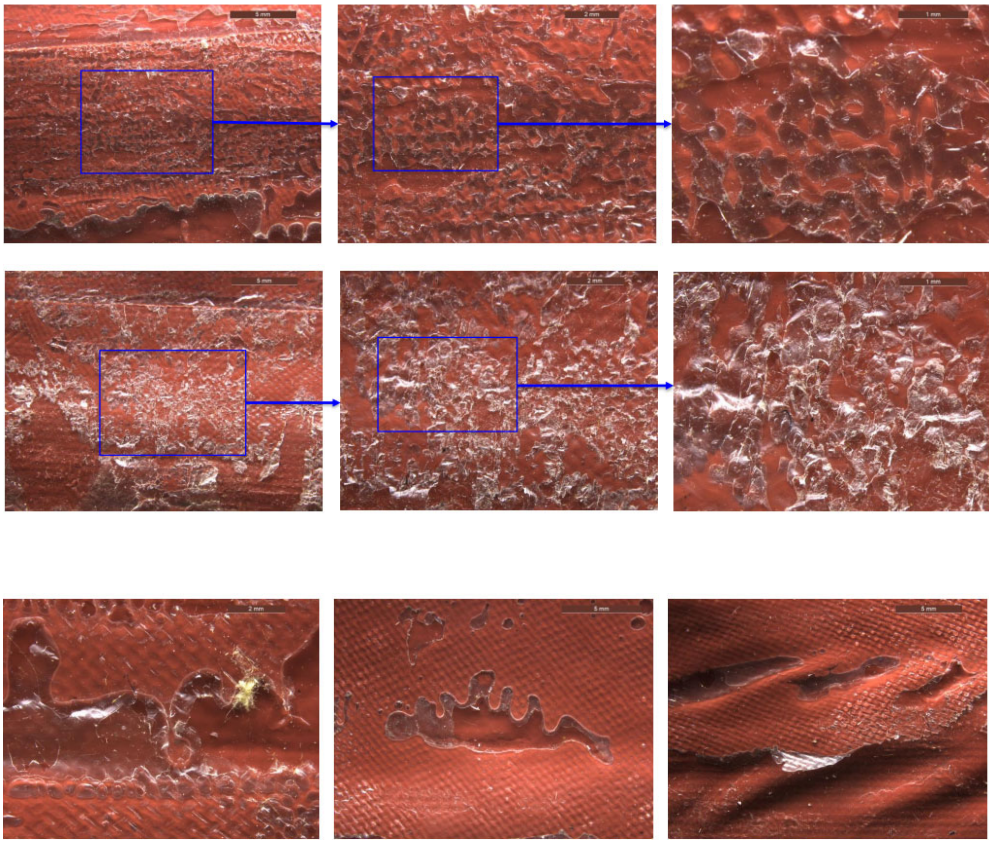

Figure 7

Areas of adhesive showing small intact bubbles (top row), small bubbles with broken film (middle row) and large bubbles (bottom row)

In general, on the intact joints the proportion of the bonding surface covered by cubic-shaped reliefs and well-defined fibre imprints was greater than the proportion which exhibited slight imprints and bubbles.

On the failed joints, the bonding surfaces showed an almost complete absence of cubic-shaped relief. A greater proportion of the surface exhibited areas of slight fibre imprints and bubbles than areas of well-defined fibre imprints.

The presence of cubic-shaped reliefs within the adhesive has a positive effect on the adhesion, as it indicates mechanical interlocking to the surface of the rigid bend sections. However, as the surface of the rigid bend sections was not uniform in respect of the presence of voids between the fibre bundles, this morphology could not be achieved across the entire bonding surface.

The manufacturer considered that the definition of imprints from the fibre bundles in the adhesive varied according to the local mating pressure between the sections. In some areas with well-defined imprints, a few fibre bundles from the rigid bend section had detached with the adhesive, when the joints separated. This suggested that the adhesion may have been effective in those areas and, in the areas with less well-defined imprints, the adhesion was likely to be weak.

The manufacturer considered that the presence of bubbles in the adhesive may have been caused by relative movement between the mating surfaces during the bonding operation prior to solidification of the sealant, due to a loss of the applied mating pressure. The bubbles were characterised by weak films of adhesive, which would originally have been in contact with the surface of the rigid bend sections. When the joints separated, these films either remained intact or broke, forming some dimples in the latter case.

The fact that only a thin film of adhesive would have been in contact with the surface of the rigid bend sections, in combination with the presence of bubbles, which represent discontinuities in the adhesive layer, would have reduced the effectiveness of the bond.

Risk assessment

The aircraft manufacturer assessed the potential safety effects of a hot air escape from a failed heating duct. The duct runs adjacent to an avionics rack and equipment in the immediate vicinity includes two radar altimeters, two GPS units and two ATRUs. For the radar altimeters and GPS units the identified failure modes relate to a potential loss of functionality. In each case, the effect of a complete loss of both units was categorised as having a severity rating of 'Major[1]'.

The ATRUs provide electrical heater power to the main and tail rotor blades as part of the aircraft's ice protection system. The manufacturer's System Safety Assessment for the AW189 full ice protection system (fitted to G-MCGU but not to G-MCGT) indicated that loss of one or both ATRUs could contribute to several functional failures. The most critical failure mode identified was an unannunciated loss of heating in the main rotor blade critical zones, which has a severity rating of 'Catastrophic[2]'.

Based on these two events, the manufacturer recalculated the functional failure probability for this failure to take account of the potential contribution of a hot air escape. The probability increased slightly from the certification figure of 1.711×10^{-10} to 1.827×10^{-10}, which is still below the safety target for a catastrophic failure condition of 1.00×10^{-9}.

Interim action

Following examination in the aircraft manufacturer's laboratory, the failed ducts were sent to the duct manufacturer for further examination to determine if there were improvements to the duct design or manufacturing which could be implemented as a long-term solution. The results of that examination were not known at the time of writing this report, however as an interim solution, Leonardo Helicopters published Service Bulletin (SB) 189-296 *'ATA 21 – Heating duct rear avionic bay inspection'* on 23 July 2021.

Footnote

1 'Major' failure conditions are defined as those which would reduce the capability of the rotorcraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew workload or in conditions impairing crew efficiency, physical distress to occupants, possibly including injuries or physical discomfort to the flight crew.

2 'Catastrophic' failure conditions are defined as those which would result in multiple fatalities to occupants, fatalities or incapacitation to the flight crew, or result in the loss of the rotorcraft.

The SB requires operators to perform a one-off inspection of the heating duct and to improve installation of the duct by repositioning an existing 'P-clamp' at one of the bonded joints (shown as item F in Figure 2) and introducing an additional fixing at another joint. The compliance instructions require that the SB is embodied within 400 flight hours or 12 months from date of publication, whichever occurs first.

Other information

Prior to publication of this report, the operator reported that on 10 October 2021, G-MCGM, another of it AW189s, experienced a heating duct failure prior to SB 189-296 having been embodied. The failed duct from G-MCGM was not examined as part of this investigation but given the similarities with the G-MCGU and G-MCGT duct failures, it is considered likely that the same failure mode was involved.

The operator reported a further AW189 heating duct failure on G-MCGV (S/N 92008) which occurred on 7 January 2022. SB 189-296 had been embodied on this aircraft on 30 October 2021 and the failure occurred 71 flying hours later. The failed duct has been sent to the duct manufacturer for examination to identify whether the same failure mode is involved. The examination will also inform ongoing efforts by the aircraft manufacturer and its suppliers to define a permanent design solution. The G-MCGV duct failure event will be reported separately by the AAIB.

Conclusion

The heating ducts on G-MCGU and G-MCGT failed due to non-uniform adhesion on the bonding surfaces between the rigid and flexible duct sections. This led to fragments of insulation material being discharged through the cabin in cockpit heating vents, causing respiratory irritation to the occupants and, in the case of G-MCGU, the presence of smoke which necessitated an emergency landing. The aircraft manufacturer published a Service Bulletin requiring inspection and modification of the duct as an interim solution, while it works with the duct manufacturer to achieve a permanent solution. A subsequent duct failure occurred on G-MCGV, which had the Service Bulletin embodied and this event will be reported separately by the AAIB.

Safety action

On 23 July 2021 the aircraft manufacturer published Service Bulletin 189-296, requiring operators to perform a one-off inspection of the heating duct and to modify the duct installation.