

Analysis

The pilot and two crewmembers were conducting a night helicopter air ambulance flight. While en route, the No. 2 engine twist grip caution light illuminated. The pilot checked the instruments and did not notice anything anomalous. The twist grip light disappeared then reappeared and flickered a few more times. All parameters were in the proper range. Shortly after, he heard a "winding down sound," then "~~heard~~ a hissing sound" and ~~detected~~ "the smell of exhaust in the cabin." He responded by turning off the cabin heat then lowered the collective and diverted toward an airport. During the turn, the No. 2 engine FIRE light illuminated, and he noticed an orange glow from the back-right side of the helicopter. He pressed the No. 2 engine emergency off switch, noticed that the FLI needles split, and continued with one engine inoperative. Subsequently the No. 1 fire bottle ~~light illuminated, which was becoming active~~, indicated ~~ing~~ there was a fire in the engine compartment, so he activated the bottle. Then the No. 2 fire bottle ~~light illuminated became active~~, which indicated ~~ing~~ that the fire had not yet been extinguished, so he ~~active~~ ~~discharged~~ the second fire bottle. The FIRE light extinguished, and he continued the flight and made a running emergency landing at the diversion airport.

A post-incident examination of the helicopter and inspection of both engines was completed. The No. 2 engine deck area was thermally damaged from an oil fire. The No. 2 engine exhibited significant internal coke buildup with blockages noted in the rear bearing scavenge line and the airframe's vent line 3-way union. The blocked scavenge line allowed the oil to escape the rear bearing chamber, which resulted in oil in the engine's main air path, in the rear bearing vent line, and onto the engine deck. A failure of the rear bearing occurred due to ~~a lack of excessive~~ oil lubrication in the rear bearing chamber. The No. 2 engine gas generator rear bearing was found severely damaged and seized; the seizure of the bearing was due to the bearing operating in excess oil.

The No. 1 engine rear bearing assembly also exhibited significant coke buildup in similar locations but continued to operate normally during the incident. The bearing was found covered with coke, but otherwise in good condition. The 3-way union was partially blocked with coke.

The operator would have benefitted in using a high thermal stability oil. The engine maintenance performed by ~~the~~ operator was lacking proper recording and was not completed exactly as prescribed in the engine maintenance manual. If performed properly, the rear bearing strainer maintenance check, the permeability test, and permeability trend analysis could have helped the operator recognize the impending clogging of the rear bearing scavenge line.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be:

The gas generator rear bearing oil scavenge line blocked with coke, which resulted in ~~oil overflow and~~ a failed rear bearing due to ~~a lack of an excess of~~ oil lubrication. Contributing to the incident was the operator not completely performing the maintenance items and not utilizing an oil for higher temperatures.

Factual

History of Flight

On January 26, 2017, about 2145 central standard time, a Eurocopter Deutschland GMBH MBB-BK 117 C-2 helicopter, N911MK, sustained minor damage when it experienced an inflight engine fire and made an emergency landing at Joe Foss Field Airport (FSD), Sioux Falls, South Dakota. The airline transport pilot and two crewmembers were not injured. The helicopter was operated as a Title 14 *Code of Federal Regulations* Part 135 air ambulance flight.

In his post-incident statement, the pilot reported that while conducting a night helicopter air ambulance flight en route, the No. 2 engine twist grip caution light illuminated. He checked that the throttle was in flight mode, and then checked the first limit indicator (FLI) and tachometer, which were both indicating normally. The twist grip light disappeared then reappeared and flickered a few more times. He stated that the engine instrumentation was indicating in the proper range. Seconds later the caution advisory display (CAD) illuminated with ENG PA DIS (engine parameter discrepancy) cautions on both engines; both of the FLI needles were married and all parameters were in the proper ranges. Shortly after the ENG PA DIS lights illuminated he heard a "winding down sound," and then, "[heard](#) a hissing sound" and [detected](#) "the smell of exhaust in the cabin." He responded by turning off the cabin heat, lowering the collective, and turning toward FSD. During the turn, the No. 2 engine FIRE light illuminated. The airspeed was above 100 knots when he noticed an orange glow from the back right side of the helicopter. He continued to slow below 100 knots to meet the requirements for one engine inoperative (OEI) flight procedures. Once below 100 knots, he broke and raised the red plastic switch guard and pressed the emergency off switch (EMER OFF SW). Subsequently the FLI needles split and the ACTIVE and BOT 1 lights illuminated, so he pressed the BOT 1 push button. The BOT 2 light illuminated and since the FIRE light was still illuminated, he pressed the BOT 2 push button. About two seconds after pressing the BOT 2 push button, the FIRE light extinguished. He then completed all of the emergency checklist items for an engine fire. During the fire emergency, the No. 1 engine FLI never exceeded 10.5 and the mast moment indication did not increase into the yellow region. He noted that the helicopter had descended about 300 ft. Since the FIRE light was extinguished, he continued the flight in order to make an emergency landing at FSD. The pilot kept the helicopter at 500 ft while en route. About 13 nm southwest of FSD, the pilot radioed the tower controller and declared an emergency and was cleared to land on runway 3. He executed a low approach with a running landing and stopped on the runway in less than 100 ft.

Aircraft and Owner/Operator Information

Maintenance Information

On December 27, 2016, a 400-hour periodic check was performed by the operator at 6,146 hours engine time since new (TSN), and 2,551 hours engine time since overhaul (TSO) on the engine's module 3. During the check they inspected the oil filter and the rear bearing's magnetic plug. There was no record of the inspection results.

On December 14, 2016, a spectrometric oil analysis program (SOAP) was performed by the operator at 6,114 hours engine TSN, and 2,519 hours engine TSO on the engine's module 3. There was no record of the analysis results.

On October 22, 2016, an 800-hour and a 1,200-hour periodic check were performed by the operator at 5,988 hours engine TSN, and 2,393 hours engine TSO on the engine's module 3. During the 800-hour check they drained the oil system and inspected the rear bearing's magnetic plug strainer (TU208).

During the 1200-hour check they removed and cleaned the oil scavenge tube. There was no record of either inspection results.

On July 25, 2016, a 600-hour periodic check was performed by the operator at 5,815 hours engine TSN, and 2,220 hours engine TSO on the engine's module 3. During the check, conducted a rear bearing assembly permeability test was conducted. There was no record of the permeability test results or a trend analysis.

On June 23, 2016, a 400-hour periodic check was performed by the operator at 5,739 hours engine TSN, and 2,144 hours engine TSO on the engine's module 3. During the check they inspected the oil filter and the rear bearing's magnetic plug. There was no record of the inspection results.

On May 21, 2016, the oil level sight gauge was replaced by the operator at 5,637 hours engine TSN, and 2,042 hours engine TSO on the engine's module 3. The operator reported that the gauge was cloudy and dark and needed to be replaced. They also rinsed the oil system and conducted a rear bearing assembly permeability test; 100 milliliters of oil were collected during the test. A trend analysis was not completed.

The most recent gas generator rear bearing scavenge oil flow rate (permeability) check was performed 383 flight hours (FH) before the incident. The result of this test and the amount of oil collected was not recorded. The last rear bearing scavenge oil tube and in-line strainer maintenance was performed 209 FH before the incident. The lubrication system was serviced, the oil filter replaced, and engine oil change was last completed 51 FH prior to the incident. The rear bearing scavenge magnetic plug was inspected 12 FH prior to the incident. Oil change intervals during this period averaged 168 FH.

An oil system rinse and a permeability check were completed at 5,637 hours engine TSN. These tasks were unscheduled and were performed because of clouding of the oil tank's sight glass.

Prior to and during the incident the operator was using Mobile Jet II oil, which was acceptable per the engine maintenance manual (EMM). After the incident they switched to a high thermal stability Eastman 2197 turbo oil, per the oil options in the EMM. The high thermal stability oils provide better performance especially when stopping the engine quickly.

Wreckage and Impact Information

The pilot landed the helicopter along the centerline of runway 3 at FSD, with a running landing distance of less than 100 ft. The helicopter did not sustain any additional damage during the landing.

A post-incident examination of the helicopter revealed fire damage limited to the aft outboard section of the No. 2 engine deck and the aft section of the engine compartment and cowling. The engine cowling, the central wall, and upper heat shield sustained thermal damage. Local blistering to the engine deck paint and oil splatter on the deck floor was were observed. There was no evidence of a pool fire. The lower part of the engine was covered in oil residue with some thermal damage evident (Figure 1).



Figure 1. Engine deck thermal damage and oil residue

The No. 2 engine oil tank was 1 to 1.5 quarts low. The right side of the fuselage was streaked with oil and oil was noted on the tailboom. The engine's vent line and all oil lines were checked and found tight, not broken, and not cracked. The elastomer vent tube was still attached to the engine's vent line and to the 3-way union deck fitting.

The engines were removed and sent to the manufacturer's facility for a tear down and detailed examination under the supervision of the NTSB.

The No. 2 engine displayed a light coat of soot aft of the combustor section and engine oil was observed on the bottom of the engine. There was light thermal damage to hose and harness insulation and attachment hardware along the lower right side and bottom of the engine. No other external discrepancies were noted. The gas generator rotor was seized. The end of the MO3 (high pressure gas generator module) rear bearing chip detector was coated with a black substance. No significant ferrous material was observed. The gas generator rear bearing oil scavenge pipe was clear at the rear bearing casing's exit and heavily contaminated with oily carbon material at the rear bearing strainer end. The rear bearing strainer housing union was obstructed by coke. The rear bearing scavenge strainer and magnetic chip detector housing were full of coke particles. The inner surfaces of the rear bearing casing were coated with oily soot and there wasere a large amount of loose carbon chunks and particles. Fragments of inner race were found inside. Soot marks showed that oil escaped from the rear bearing casing into the engine's main air path. There were no indications of fire in the rear bearing casing and adjacent parts. The rear bearing casing's support arms and the intermediate cavities around the rear bearing casing were clear of oil and showed no signs of internal fire. Oil also escaped from the rear bearing casing into the metallic vent line. The running surface for the small-diameter labyrinth on the piston shaft forward end was deeply grooved. The rear bearing was displaced on the turbine bolt. The retaining ring circlet was broken into two parts which were found during disassembly and each part did

not show significant damage. A small amount of oil was present at the bearing. The bearing inner race was fragmented. The bearing color and texture were consistent with adhesion and subsequent seizure damage. The roller assembly exhibited significant rotational scoring with only a small amount of material remaining. The scored surface was battered. There were carbon deposits on the inner surfaces of the bearing support assembly cage outer race and vibration dampeners. All of the cage dampeners were corrosion damaged and some were missing material. The bearing's lubrication hole was clear. The cage bolt had carbon deposits inboard of the lock feature. There was gouging on the inside consistent with contact with the turbine bolt. There were black deposits on the tip of the rear bearing chip detector. The oil scavenge pipe between the rear bearing housing and the in-line strainer/chip detector contained an oily black substance. The rear bearing strainer housing union where the rear bearing scavenge line attaches was partially obstructed by oily soot/coke. The rear bearing chip detector housing and strainer were obstructed by coke. The gas generator rear bearing chip detector was operationally tested using an engine installed on a test cell. Ultimately, the test indicated that the engine chip detector was operational and that the black debris on the detector tip impeded the detector function, until it was cleaned and retested.

No. 2 engine 3-way union (deck fitting)

There were outward opening, axially-oriented holes at two locations in the airframe elastomer tube that connected the engine vent pipe to the 3-way union deck fitting. A section of another elastomer drain tube, part of an airframe collector drain line, was lying on the engine deck. It was separated and melted at both ends. The outside surface of the tubes was heat damaged, but the insides appeared smooth. Oil and shiny debris ~~was~~were observed inside the tubes with no obvious evidence of coke. The 3-way union deck fitting was clogged with coke and no metallic debris observed.

The No.1 engine was on the incident helicopter and did not experience any malfunctions during the incident. The engine was inspected in order to compare it to the No. 2 engine and identify any potential similarities. There was no evidence of fire, component failure, or uncontainment. The aft end of the engine was uniformly coated with soot near the exhaust. The engine external pneumatic and fuel piping showed no obvious damage. The No. 1 engine inspection revealed that the rear bearing chamber contained a significant amount of coke. All orifices on the casing exhibited coke. The 3-way union was partially blocked with coke. The rear bearing was mostly covered in coke but was undamaged and able to be rotated. There was hard carbon/coking adhering to the inside surface of the rear bearing housing oil supply tube. There was hard carbon/coking adhering to the inside surface of the rear bearing housing oil scavenge tube. The inside surface of the rear bearing housing vent tube contained a small amount of carbon/coking. The rear bearing support assembly was intact with no visible damage. The inner surfaces of the support assembly were coated with coking. Carbon/coking was adhered to the inside surface of the passages that receive the oil supply, oil vent, and oil scavenge tubes. The turbine shaft was intact and exhibited circular scoring on the end of the shaft adjacent to the rear bearing cage. The turbine retention nut external splines exhibited coking. The piston shaft labyrinth seal closest to the rear bearing was covered in coking. The engine oil return chip detector, the rear bearing chip detector, and rear bearing strainer were found clean and clear of contaminants.

No. 1 engine 3-way union (deck fitting)

The rear bearing vent line and union were circumferentially lined with carbon residue/coking. The 3-way union was partially blocked with coke.

Additional Information

According to the engine manufacturer, the return of experience data (not including the incident engine) showed that from 2000 to 2017 there were 16 cases of rear bearing coking on Arriel 1 engines in over 22 million flight hours. Only 2 of these events involved an Arriel 1E2 engine on the same model helicopter. None of the previous 16 cases led to a bearing deterioration or failure.

For reference in this report the term "coke" is considered the solid residue created when oil undergoes severe oxidative and thermal breakdown at engine temperatures in excess of the prescribed range. The higher the temperature, the harder, blacker and more brittle the coke/deposit residue. Coking performance of oils varies based on formulation and the engine environmental conditions. Coking occurs because the temperature and the oil residue time are higher than the oil stability limitations. Operational factors can influence coke formation and build up, including inadequate operational and maintenance procedures, i.e. record of permeability checks, trend analysis, strainer checks, **and** improper engine stabilization time before shutdown, ~~promote coke build up~~. Obstructions to flow or directional changes cause reduction in flow rate and increases in oil residence time. High post-shutdown temperatures due to conducted or convected heat increase deposition in low-drainage areas. Low clearance scavenge ports increase the likelihood of blockage due to shedding. Prolonged aircraft inactivity enables moisture absorption of coke deposits, which typically shed after startup. However, the EMM gives instructions about engine storage conditions. Unprotected reactive metals in the oil system, such as lead, cadmium or magnesium, can increase deposits (reaction between oil and metals). Low-alloy iron and copper can stimulate coke formation by catalysis. Positive washing of system surfaces by high liquid oil flow reduces residence time. Increased airflow in high-temperature metal contact zones reduces the amount of coke deposits formed by promoting oil volatilization. Other methods to reduce coking emphasized by the engine manufacturer are, choosing the most appropriate oil for the type of operation, ensuring oil quality, abiding by the EMM instructions and by proper engine stabilization time before shutdown.

After Incident Actions

As a result of this investigation the following items were published:

- FAA Special Airworthiness Information Bulletin SW-18-04 – Engine Oil Drainage System
- Safran Helicopter Engines released "Service Letter SL 1642/96/Arriel/25 version 3 – Subject: Excessive oil coking in the gas generator rear bearing housing" 2/16/2018
- Arriel 1 – Unscheduled inspections – Task : 05-50-00-200-801. Released to operators 30 March 2018. Added reference to the task "Treatment of an engine after clogging of the rear bearing air vent"
- Airbus issued "Information Notice No. 3213-I-71 – Airframe mounted engine vent lines" 2/22/2018