Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A01P0282

INPUT FREEWHEEL UNIT FAILURE

DWAYNE AIR 2000, LTD.
EUROCOPTER SA315B LAMA C-GXYM
SAWTOOTH MOUNTAIN, BRITISH COLUMBIA
08 NOVEMBER 2001

Canada

Aviation Investigation Report

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Dwayne Air 2000, Ltd.
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Summary

The Eurocopter Lama SA315B, C-GXYM, serial number 2634, was engaged in heli-logging operations on the slopes of Sawtooth Mountain, near Buhl Creek, British Columbia, using a 150-foot longline. While lifting a load of logs, the pilot experienced difficulties and released the load from the lower hook on the longline. A mechanical screeching sound was heard. The helicopter gained some altitude momentarily but quickly descended and struck the steep, 45-degree slope below. The helicopter was destroyed at impact, and the pilot was fatally injured. The fuel tank ruptured, but no fire occurred.

Ce rapport est également disponible en français.

Other Factual Information

The helicopter was operating at 5900 feet above sea level. The weather at the time of the accident was reported as clear skies with no wind, and the temperature was about 5°C. The density altitude was just over 6000 feet. A light layer of snow covered the ground.

On the day of the accident, the helicopter had been operating for about 3.5 hours and was into the third logging cycle.[1] In this particular heli-logging operation, a logging cycle consisted of 20 to 30 turns.[2] Aircraft maintenance engineers on site reported that they had refuelled the helicopter twice that morning, and they estimated that the accident occurred about 15 minutes before the next refuelling stop. Before going for fuel, the pilot would normally call ahead to the log-landing area to request that they prepare choker cables to be delivered to the hillside by the helicopter; he had not yet radioed his intention to pick up the chokers from the landing area.

Fuel samples were gathered from the airframe fuel filter, the refuelling truck, and the portable refuelling equipment at the helicopter staging area. No contamination was found.

Section 4 (Performance) of the Transport Canada-approved rotorcraft flight manual (RFM) contains a speed-altitude graph outlining the in-flight parameters where pilots should avoid continuous operation (see Figure 1). The accident helicopter was used for repetitive heavy-lift (RHL) operations at about 165 feet above ground level and was being operated at a height and airspeed combination that had not been demonstrated to permit a successful emergency landing in the event of an engine power loss.

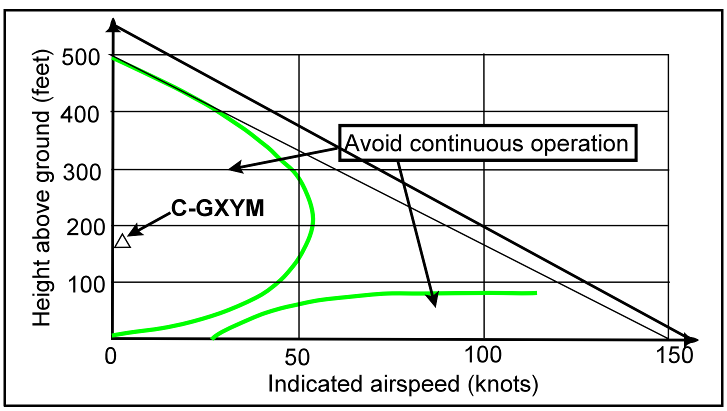

Figure 1. Speed-altitude graph (Eurocopter)

The Eurocopter Lama helicopter is a derivative of the Aerospatiale Alouette II and Alouette III helicopters and flew for the first time in March 1969. The accident helicopter, C-GXYM, was manufactured in 1976 and had accumulated a total of about 9525 flight hours. The engine was a Turbomeca Artouste III B1 (serial number 781) and had accumulated about 6040 total hours in service since new and 2817 hours since overhaul.

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1 A "logging cycle" is the time between refuelling operations and, in this case, was usually planned for an endurance of 60 to 75 minutes, with 90 US gallons of fuel.

2 A "turn" refers to the two-way flight of the helicopter, usually up and down a hill, to pick up and deliver a load to the log-landing area.

The wreckage was confined to a small area and was recovered. The engine attachments were found broken, and the engine was resting on top of the airframe. It was reported that the engine was operating after impact and subsequently shut down. The fuel tank was ruptured at impact, and investigators noted a strong smell of fuel beneath the wreckage at the accident site.

The leading edges of the main-rotor blades were not significantly damaged. Two of the three blades had each fractured near the blade root and bent down and aft. A two-inch branch had punctured the third blade near the tip. The longline remained attached to the aircraft cargo hook and extended back up the hillside in line with the released load and the helicopter wreckage.

During the examination of the accident helicopter, it was discovered that the input freewheel unit (IFWU) was missing. The IFWU is designed to allow the helicopter to enter autorotation in case of engine power loss or loss of drive to the main transmission. A search party commissioned by the TSB and provided by the operator found the IFWU by using metal detectors during a 100 person-hour search. The IFWU was found about 40 feet left of and 10 feet forward of the main wreckage.

Upon inspection of the retrieved IFWU, investigators noted that the identification data plate was missing. It probably detached during the accident sequence. Markings on the painted surface suggest that at some time the data plate had been glued and attached to the ring or driven head section of the IFWU. Eurocopter engineering drawings locate the data plate on the smaller diameter shaft or hub, on the engine side near the IFWU ring seal. Two similar IFWUs were examined for comparison after this accident: the method of application and placement of the identification data were not consistent. Furthermore, major subcomponent parts, such as the hub (driving shaft with ramps), do not have visible identification data, such as a serial number. The hub may be reused at overhaul of the IFWU.

Eurocopter does not attribute a service life limit or cycle limitation for the IFWU. Identification for this component takes the form of data plates or stickers that can become detached and lost. To ensure traceability, Canadian Aviation Regulations require permanent marking of identification information on life-limited components.[3] If an identification tag for a component becomes detached and lost, the component will remain airworthy as long as it is serviceable, remains installed in the aircraft, and has historical records to support the component's installation.

Subcomponent parts of the IFWU may be returned to service during an overhaul, creating an assembly with a mix of new and older parts. This new assembly maintains the same serial number and becomes, in effect, an "on-condition" or "time-continued" component.[4] Time-continued components may satisfy overhaul criteria but have subcomponent parts that have accrued time in service and cycles in operation that may jeopardize their future life expectancy

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3 Canadian Aviation Regulation 201.05(1) and (2).

4 "On-condition" or "time-continued" components satisfy overhaul criteria but are an amalgamation of new and used parts. This definition is not intended to contradict any authorized manual, Canadian Aviation Regulation, or Transport Canada-authorized publication.

or maintenance schedule. These components may not be capable of operating to their mandated time between overhaul (TBO) again. An IFWU's TBO is 1800 hours; however, an inspection must be performed at 800 hours.

The accident helicopter was routinely maintained and inspected at the operator's hangar facility in DeWinton, Alberta, from November 2 to 5. At the time of the accident, the helicopter had flown about 16 hours since its scheduled inspection was completed. A review of the technical records revealed no reported incidents or deficiencies that could be related to this accident.

After an examination of the engine and components, the engine was run up in an approved engine test cell facility. The engine produced full power, and vibration levels were assessed as acceptable. In general, post-accident examination and analyses have shown that turbine engines suffering in-flight failure exhibit severe damage from the impact forces. These examinations and analyses normally reveal damage attributable to high vibration levels resulting from bearing damage. The centrifugal clutch assembly that couples the engine to the main-rotor transmission was disassembled and examined; it was unremarkable.

The IFWU and drive shaft assembly was disassembled and examined at the TSB regional wreckage examination facility. It had accumulated 1090 hours since overhaul and 1015 hours since installation on C-GXYM. There were indications that the IFWU had malfunctioned. The cage that retains and locates the rollers was found broken in several places, and the rollers themselves showed indications of skidding. The cage/retainer, which is not normally subjected to loading forces, exhibited heavy wear. This wear occurs when the IFWU is allowed to freewheel during normal operations; the freewheeling causes the two rotating shafts of the IFWU to alternately disengage and engage under various in-flight load conditions. The two Nadella needles that join the two parts of the bushing set were found fractured; this damage allowed the cage to be slightly misaligned and lowered the spring tension. Damage to the tangs of the outer bushing indicated violent disengagement ("spit-out") where the rollers are ejected from the wedge (pinch angle) formed between the ramp of the hub shaft and the ring.

Using a scanning electron microscope, chemical analysis, and hardness testing,[5] the IFWU was analyzed further and the component material was evaluated for conformity with the manufacturer's specifications. Eurocopter provided expertise during the examination and produced a report.[6] The Eurocopter accident investigation group also had investigated previous similar accidents and had produced functional, dimensional, and application investigative reports.[7] The IFWU showed signs of distress related to repeated high loading. A large number of loading cycles[8] related to the RHL external load operation will accelerate the removal of material (wear) from the load-bearing surfaces by the processes of spalling (surface contact fatigue) and abrasive wear. The materials of the load-bearing surfaces are deformed during loading cycles

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5 Waldron and Co., Report No. 01-313.

6 Eurocopter, Examination Report No. STSA147/02.

7 Eurocopter, Investigative Report Nos. 2891, dated 06-04-1992; 2126/92, dated 30-07-1992; and 430/93, dated 29-01-1993.

8 The Eurocopter maintenance manual only considers cycles in a particular case for main-rotor blades (metal type) and defines a cycle as one landing, whether the rotor is subsequently stopped or not. For sling operation, one cycle means one load-carrying operation.

and fatigue over time. RHL external load operations create varying loads in flight that impose fluctuating pressures on the load-bearing contact surfaces. The helicopter remote hook was equipped with a gas shock to minimize impact forces transferred to the airframe by sudden jerks imposed on the longline.

After the examination of the accident IFWU, the operator removed the IFWU (serial number C-560) from another Lama helicopter (C-GZXX) operating in similar heli-logging conditions. This IFWU had accumulated about 1114 hours since overhaul and 837 hours since it was last inspected after a main-rotor blade strike incident. An examination of this IFWU revealed that, although it had not malfunctioned, it exhibited wear that exceeded the overhaul rejection criteria and that was similar to the wear found on the accident IFWU.

A third IFWU (serial number 3-C1622) provided by a different operator was also examined. This IFWU had accumulated 1495 hours since overhaul and had not been inspected in accordance with the Eurocopter 800-hour inspection requirement. It had also been subjected to RHL external load operations. The freewheel shaft was measured: the wear on the ramps exceeded the tolerance.

Lama helicopter components are not subjected to cycle count, except for the metal main-rotor blades and some component parts of the engine. Eurocopter assumes an average of six load cycles per hour for the metal blades used in sling operations. Helicopters engaged in RHL external load operations may experience as many as 30 cycles per hour and sometimes more.

Some helicopter manufacturers assume an average number of six cycles per hour when designing aircraft components and determining a maintenance schedule. The airworthiness limitations section in the Eurocopter maintenance manual states, “If the average flying time between two landings is less than ten minutes, apply to the manufacturer for special instructions.” The TBO for the Lama’s IFWU is not based on the number of operating cycles. Eurocopter considers time-in-service the only parameter for TBO.

The IFWU and the drive shaft assembly are lubricated by the main transmission oil system through a metered orifice in a goose-neck-type injector that directs oil through the centre of the drive shaft to lubricate the driving gears at both ends of the drive shaft and the IFWU internal subcomponent parts. The IFWU rotates at about 6000 rpm during normal engine operation. The lubricating oil is centrifuged, and much of the contaminants introduced or generated within the unit are trapped. This design does not constitute a closed circuit, because the oil drips back to the transmission, and it does not provide for the flushing of generated wear debris. Eurocopter incorporated several modifications to this system and reverted back to the jet-type injection of lubricating oil. The most recent revision incorporated a larger orifice at the oil jet. The Eurocopter Lama RFM lists acceptable oils for the main and tail gearbox lubrication; one of these comes under specification MIL.L.2105. Information provided by the operator indicates that the oil used—a Shell Spirax HD, described as a “heavy duty automotive gear” oil—conformed with US specification MIL.L.2105D.

Eurocopter reported having examined a distressed IFWU from an African operator and determining that the lubricating oil was contaminated and that the internal parts were excessively worn. Eurocopter also examined another IFWU malfunction in a Lama accident in Italy in October 1991. As a result of these accidents, Eurocopter issued service bulletin SB 05-31 on 19 August 1993, requiring an inspection of the IFWU every 800 hours to check for wear and contamination until the 1800-hour scheduled overhaul. This inspection was later incorporated in the maintenance manual in Section 5.20 as a separate component inspection, distinct from the T2 (800-hour) airframe inspections. A caution note accompanied the inspection procedures, alerting operators of the requirement to perform this inspection in accordance with Work Card No. 40-13-603. To accomplish this inspection, the IFWU is disassembled. Field technicians are required to ascertain the wear on the subcomponent moving parts at that time. Eurocopter does not issue overhaul criteria to field operators, reserving this function for overhaul-trained and certified personnel. The work card instructs field technicians to send the IFWU to an approved overhaul facility if wear is detected. Eurocopter and approved repair and overhaul representatives stated that about 80% of hubs returned for the 800-hour inspection or overhaul are removed from service because they fail to meet tolerances. A review of the technical records for the accident helicopter revealed that this inspection had not been carried out on the IFWU.

The accident helicopter was equipped with composite main-rotor blades, part number LOM L3160-100, manufactured in the US by Rotor Trends LLP (Limited Liabilities Partnership). Heli-logging operations require fast turnarounds: to make the operation economically viable, the helicopter must perform a specified number of turns for each logging cycle. In heli-logging, rapid descent and flare may cause the main rotor to accelerate, and the IFWU may disengage (or freewheel) and then re-engage. Although the composite main-rotor blades are more aerodynamically efficient than the original Eurocopter metal blades, both sets of blades can enter autorotation. The degree to which this occurs is dependent on flight profile, pitch angle, density altitude, and aircraft gross weight. In this flight profile (rapid descent and flare), the main rotor may freewheel, but not necessarily. Even a small application of collective pitch during rapid descents will keep the IFWU engaged. Many heli-logging operators mandate a minimum collective pitch angle or torque setting during rapid descent in their standard operating procedures to prevent freewheeling. The RFM makes no provision or consideration for this specific mode of operation where the pilot may not attempt to enter autorotation but the IFWU nevertheless is forced to disengage due to aerodynamic forces that propel the main rotor faster than it is driven. This disengagement may not be readily detectable or indicated by a “needle-split” on the engine and the main-rotor tachometer.

The helicopter manufacturer, Eurocopter France, has not certificated the use of composite blades on the Lama helicopter. The composite blades, however, were approved for use on the Lama by the US Federal Aviation Administration and Transport Canada in accordance with supplemental type certificate No. SH778GL and supplemental type authority No. SH92-13, respectively. In 1986, the French certification authority (the *Direction Générale de l’Aviation Civile*) in a reciprocal agreement with participating States, authorized the installation and the use of these blades in France. The RFM supplement, which provides the pilot with particular information concerning the composite blades, had not been incorporated into the TC-approved RFM. The supplement reminds the operator that the weight and power limitations set forth in the RFM are still applicable and that the operator is responsible to ensure that these limitations are observed. The supplement also requires that a specific placard be installed near the collective pitch indicator dial computer on the instrument panel. This placard is to remind the pilot that composite blades are installed and to add 190 pounds to the dial computer to establish correct pitch setting in conjunction with a pop-up chart on top of the centre console. The placard was not installed on the accident helicopter.

The Lama helicopter is not equipped with a torque gauge or indicator. The pitch indicator shows the angle of attack of the main-rotor blades (as demanded by the pilot through the collective control lever), not the transmission torque. The pilot can manually set the collective pitch dial computer at any time to take into account the outside air temperature, the weight of the helicopter, and the pitch setting required to hover, as determined during a power check. Furthermore, in consultation with the aircraft's pop-up charts, the collective pitch dial computer determines the appropriate maximum pitch setting so as to limit the power applied to the airframe components.

The helicopter was equipped with an Onboard Weighing Systems load cell, load meter, and data recorder to inform the pilot of the weights being lifted and to provide the operator with a record of the loads. The load cell system was reported to function erratically for several days before the accident. No data could be extracted from the unit after the crash.

In general terms, when heli-logging in the Lama, the pilot focuses outside the helicopter to position it above the load to be picked up and, to some degree, relies on the load metre to determine an acceptable load that could be lifted by the helicopter. The Lama is capable of exceeding the structural limitations of the power train drive components and the weight limitations of the cargo hook system.

Analysis

The wreckage exhibits damage patterns consistent with severe impact with the terrain. The main-rotor blades show damage characteristic of a helicopter rotor system turning at low-rotor rpm and striking the terrain. Furthermore, the damage and distress to the IFWU show that the unit had malfunctioned: the damage is not characteristic of impact damage. It is concluded, therefore, that the main rotor was not being driven at impact.

The helicopter was hovering in calm air about 165 feet above ground level, at a density altitude of more than 6000 feet. Out-of-ground-effect manoeuvring at this density altitude at high gross weight places a large torque loading on the main-rotor transmission and driving components. At this high power setting and blade pitch angle, the loss of drive resulted in rapid decay of the main-rotor rpm, and the proximity to the ground left little room for recovery. The pilot could not regain the rpm and was unable to prevent the helicopter from descending rapidly when the lift being generated by the rotor blades was no longer sufficient to sustain flight. Jettisoning the load lightened the helicopter, allowing it to climb momentarily; it then continued to descend and struck the terrain.

It was assessed that the fuel remaining at impact was sufficient for 15 minutes of flight before requiring refuelling. The engine was running on the ground after impact. Because the engine was capable of producing full power during the test cell examination, vibration levels were acceptable, and the engine was operating on the ground after impact, it is concluded that the engine did not lose power during flight.

The IFWU showed signs of distress related to the RHL external load type of operation, which imposed a high number of loading cycles, in the order of 30 per hour. This high cycle rate accelerated the wear on the load-bearing surfaces resulting from spalling and abrasive wear. The scheduled TBO for the Lama's IFWU is not based on the number of operating cycles. Eurocopter considers time-in-service the sole parameter for determining TBO. The IFWU was subjected to a high number of loading cycles and contamination; accordingly, the IFWU, with only 1090 hours since overhaul, malfunctioned before its TBO.

A review of the technical records for the accident helicopter revealed that the 800-hour inspection of the IFWU was not accomplished; therefore knowledge of its structural integrity was compromised. Compliance with this inspection may reduce the risk of failure by affording an opportunity to identify anomalies and consequently return the IFWU to a Eurocopter-approved repair facility for overhaul and to clean the unit of contamination before return to service.

During the freewheeling condition and repeated cyclic loading of the IFWU, the debris generated by the wear processes acted as an abrasive, causing accelerated wear of the cage/retainer, ramps, ring, and rollers. This metal debris was trapped within the assembly because of its design, contaminating the IFWU.

Rapid descent and flare may cause the main rotor to accelerate, and the IFWU may disengage (or freewheel) and then re-engage. Although the composite main-rotor blades are more aerodynamically efficient than the original Eurocopter metal blades, both sets of blades can enter autorotation. The degree to which this occurs depends on flight profile, pitch angle, density altitude, and aircraft gross weight. The manner in which the helicopter was being operated is believed to have contributed to freewheeling. The IFWU would have been subjected to more frequent and severe re-engagements, accelerating the wear.

The approved RFM supplement for the composite main-rotor blades supplemental type certificate was not incorporated in the accident helicopter’s RFM. Further, the pitch indicator gauge was not placarded in accordance with this approved supplement. The operator may not have respected the limitation associated with the LOM blade installation. This situation may have contributed to overloading the IFWU.

Findings as to Causes and Contributing Factors

1. The input freewheel unit (IFWU) and drive shaft assembly failed. Consequently, the engine could not drive the transmission and the main-rotor blades. The combination of the loss of drive and the operating flight regime resulted in the main-rotor rpm decaying so rapidly that the pilot was unable to control the loss of rotor rpm and could not prevent the helicopter from descending and striking the terrain.

2. The IFWU failed because of the wear on the internal parts caused by the repeated heavy lift operations and because of the contamination suspended and trapped in the lubricating oil between the unit’s rotating parts.

3. The operator did not perform the 800-hour inspection of the IFWU assembly required by the Eurocopter maintenance manual. As a result, the contamination and excessive wear of the freewheel internal parts were not detected.

4. To arrive at the time between overhauls, operators do not calculate and account for the number of cycles experienced in operation. Eurocopter assigns a total time-in-service to the IFWU, and the same time-in-service applies regardless of the operation type. The IFWU was subjected to a high number of loading cycles and contamination, reached its design limit before 1800 hours in service, and subsequently malfunctioned.

5. The manner in which the helicopter was operated allowed freewheeling to occur during rapid descents, contributing to accelerated wear of the subcomponent parts through disengagements and successive re-engagements.

Findings as to Risk

1. Helicopters engaged in repetitive heavy-lift (RHL) external load operations frequently experience as many as 30 cycles per hour and sometimes more. The helicopter manufacturer assumed an average of six cycles per hour when designing aircraft components for the Lama and, in this RHL external load environment, underestimated maintenance schedules.

2. The operator may not have respected the limitation associated with the LOM blade installation because the approved rotorcraft flight manual supplement for the composite main-rotor blades supplemental type certificate was not incorporated in the accident helicopter's flight manual and the pitch indicator gauge was not placarded in accordance with the approved supplement. This situation may have contributed to overloading the IFWU.

3. Eurocopter allows the reuse and mixing of subcomponent parts during repair or at overhaul. Time-continued or on-condition components have subcomponent parts that may satisfy overhaul criteria but that have accrued time in service and cycles in operation that may jeopardize their future life expectancy or maintenance schedule.

4. The helicopter was operated repeatedly in a hover about 165 feet above ground level, placing the helicopter in the "Avoid Continuous Operation" section of the speed altitude envelope chart. In this area of the chart, an emergency landing is unlikely in the event of an engine power loss.

Other Findings

1. Eurocopter does not attribute a service life limit to the IFWU. Identification for this component takes the form of data plates or stickers that can become detached.

Safety Action Taken

After the examination of the second input freewheel unit (IFWU) (serial number C-560), the operator reduced the component inspection interval to 400 hours. However, this inspection is distinct and separate from the airframe inspections because the IFWU may be installed on different helicopters with various inspection deadlines. This new inspection schedule has not been adopted by all operators of the 315B Lama helicopter.

Eurocopter issued AS [sic, SA] 315B TELEX Letter No. 55 (dated 13 February 2002) to remind Lama operators of the maintenance manual's 800-hour inspection requirement for the IFWU.

On 19 February 2002, the TSB issued Aviation Safety Advisory A020007-1, "Loss of drive - Eurocopter Lama, Input Freewheel Unit" to Transport Canada. The advisory stated that Transport Canada may wish to take action to ensure that the Eurocopter Lama is operated, inspected, and overhauled in a manner that takes into account the adverse effects on the IFWU of repetitive heavy-lift operations. Transport Canada published an article entitled “Freewheel Units” in *Vortex*, issue 2/2002. The article is applicable to all helicopter operators because all helicopters have a mechanism to automatically disengage the dead engine from the transmission. Transport Canada may undertake further action on this issue.

This report concludes the TSB’s investigation into this occurrence. Consequently, the Board authorized the release of this report on 21 May 2003.