DATA SUMMARY

LOCATION

Date and time	**Wednesday, 17 August 2005; 19:45 local time**
Site	**Lobios (Ourense)**

AIRCRAFT

Registration	**LV-ALN**
Type and model	**EUROCOPTER AS 350 B3 "Ecureuil"**
Operator	**Helicopters A.R., S. A.**

Engines

Type and model	**TURBOMECA ARRIEL 2B**
Number	**1**

CREW

Pilot in command

Age	**42 years**
Licence	**Commercial Pilot Helicopter**
Total flight hours	**6,200 h**
Flight hours on the type	**200 h**

INJURIES

	Fatal	Serious	Minor/None
Crew			**1**
Passengers			
Third persons			

DAMAGE

Aircraft	**Major**
Third parties	**None**

FLIGHT DATA

Operation	**Aerial work – Commercial – Fire fighting**
Phase of flight	**Loading water in the bambi bucket**

REPORT

Date of approval	**30 January 2008**

1. FACTUAL INFORMATION

1.1. History of the flight

On 17 August 2005 at 12:46, helicopter LV-ALN took off from the base at Toen (Ourense) en route to a fire that had been declared in the area of Emtrimo. It returned to base to refuel at 14:40 and took off again at 15:40 to resume firefighting operations.

Later, at 17:40, it landed at the base in Sures to refuel, taking off at 18:30 to proceed once more to the area of the fire with 371 liters of fuel in its tank.

After 1 hour and 15 minutes in the air, the pilot initiated an approach to the reservoir of Lindoso, near Lantemil, to take on water. He reduced his descent and translational speed to an indicated airspeed of between 25 and 30 kt. Visibility was good, with a light wind of 0 to 10 kt.

It was then that the pilot noticed the engine chip indicator flashing, so he aborted the approach and pulled back on the collective, which actuated the low rotor RPM warning horn. The nose of the helicopter started turning to the left just as the pilot felt a loss of lift. He proceeded to a nearby field to land and released the contents of the water tank.

Photograph 1. Condition of the helicopter after the event

The tail and right skids contacted the ground first. One of the main rotor blades sheared off part of the tail cone and the helicopter turned over on its left side. There was no fire following the impact.

After shutting off the ignition, fuel and battery, the pilot was able to exit the helicopter by sliding out the top. He made his way through the rough until he reached a spot near the reservoir that was clear of the danger.

The aircraft suffered significant damage to its fuselage, landing gear and dynamic components, namely the main and tail rotors and transmissions.

The crash site, situated uphill from the reservoir, was steep and difficult to reach, with a slope of some 40°, covered by thickets of considerable height and a surface made irregular by the rocky terrain.

1.2. Personnel information

The 42-year-old pilot had 6,200 flying hours, a commercial helicopter pilot license valid until 30 April 2006 and authorization from Spain's Civil Aviation Authority to conduct forestry operations.

The operator's mechanics charged with maintaining the helicopter were properly licensed and qualified.

1.3. Aircraft information

1.3.1. *Aircraft history*

The helicopter, a Eurocopter AS 350-B3, serial number 3652, was manufactured in December of 2002.

Until December of 2003 the aircraft had been in the Chilean registry under registration CL-PPA, where it totaled 238.7 flying hours. The M01 module in its Arriel 2B engine had to be replaced at the 75.8 hour mark. It was eventually repaired and reinstalled.

In December of 2003, following a change in its registration to CL-CLZ, it was registered in Argentina as LV-ALN in the name of its current operator, Helicopters A.R., S. A.

At the end of June, 2005, with 703.7 flying hours, it was transferred to Spain under a wet lease agreement with Spanish operator Coyotair to aid in its forest firefighting

campaign. It remained in the areas of San Martin de Valdeiglesias and Morata de Tajuña in the province of Madrid until 14 August 2005, at which time it was relocated to the base of Toen, in Ourense, with 753.5 flying hours.

1.3.2. *Maintenance records*

1.3.2.1. Airframe

Total flying hours at the time of the accident: 771.9

The maintenance records show that all scheduled checks had been performed. There were no entries made in aircraft or flight logs concerning the appearance of engine chip warnings in the engine's oil system.

1.3.2.2. Engine

The Arriel 2B engine, serial number 22349, was manufactured and placed into service in December of 2002.

Early in its operational life, it was necessary to replace the M01 module, serial number 834, at the 75.8 operating hour mark due to a power supply problem. Another module, serial number 754, was installed in its place on 4 April 2003. Once the original module was repaired it was reinstalled on 13 August 2003 with 134.4 operating hours on the helicopter.

From the 134.4 operating-hour mark until the 771.9 hour mark, when the accident took place, there is no record in the engine logs of any main engine components being replaced or repaired.

At the 704 operating-hour mark, coinciding with its arrival in Spain and prior to starting the firefighting campaign, two manufacturer modifications, TU-122 and TU-100, were implemented. The modifications consisted of replacing the engine's drive shaft and coupling housing, which affected modules M01 and M05.

The engine's maintenance records indicated the completion of the scheduled maintenance. There were no entries concerning the appearance of particles in the engine chip detectors. A maintenance work order dated 7 August 2005, with 741.9 flying hours on the aircraft, had the following note: "Oil samples taken following the appearance of particles in the M01 chip detector." Another work

order dated 15 August 2005, with 759.5 flying hours, stated: "Particles in Magnetic Plug M01."

The following table lists all relevant information on the findings, incidents and actions related to the engine oil system following the implementation of the aforementioned modifications, TU-122 and TU-100:

Date	Total hours	Indication/Fault	Correction/Action	Observations
30-06-05	704	Arrival of helicopter to Spain.	TU-122 and TU-100 implemented.	Drive shaft and coupling housing replaced.
Unknown		Very fine powder in the Magnetic Plug of Module M01.	Continued operating	Helicopter AR does not have the powder analyzed.
07-08-05	741.9	Engine chip warning illuminates and particles found in the magnetic plug of Module M01. 15-hr inspection performed and oil sample taken.	Particles and oil sent to laboratory for analysis.	Oil analyzed but not the particles since some laboratory facilities were out of service. Sent to the manufacturer's laboratory after the accident.
11-08-05		25- and 50-hr inspections.		
14-08-05	753.5	Ferry flight to Toen base in Orense province.	Oil filter, oil and gaskets replaced.	Filter sent to Turbomeca on 31-08-05 following the accident.
15-08-05	759.5	Engine chip warning light illuminates and particles found in the magnetic plug of Module M01.		Particle sent to Turbomeca on 31-08-05 following the accident.
17-08-05	771.9	Engine chip warning light illuminates.	Driven bevel gear fractures.	Engine stoppage in flight.

In summary, on two occasions, 7 and 15 August, both the engine chip warning and the actual presence of particles in the magnetic plug of Module M01 were noted with the aircraft at 741.9 and 759.5 flying hours, respectively. This was indicative of the degradation of some component in Module M01. A very fine powder had appeared previously in this same module, but it was considered unimportant and did not result in any action even though it was the first such indication of any degradation.

An analysis of the particles in the manufacturer's laboratory was carried out following the accident. This analysis revealed no degradation in the gears or shafts, but rather that the chips came from the drive gear thrust bearing.

1.3.3. *Description and operation of the Turbomeca Arriel 2B engine*

The engine is a dual shaft gas generator free turbine engine equipped with a FADEC (Full Authority Digital Engine Control) consisting of five modules:

- Module M01 Power transmission shaft and accessory gearbox
- Module M02 Axial compressor
- Module M03 Centrifugal compressor, combustion chamber and gas generator turbine
- Module M04 Free turbine
- Module M05 Reduction gearbox

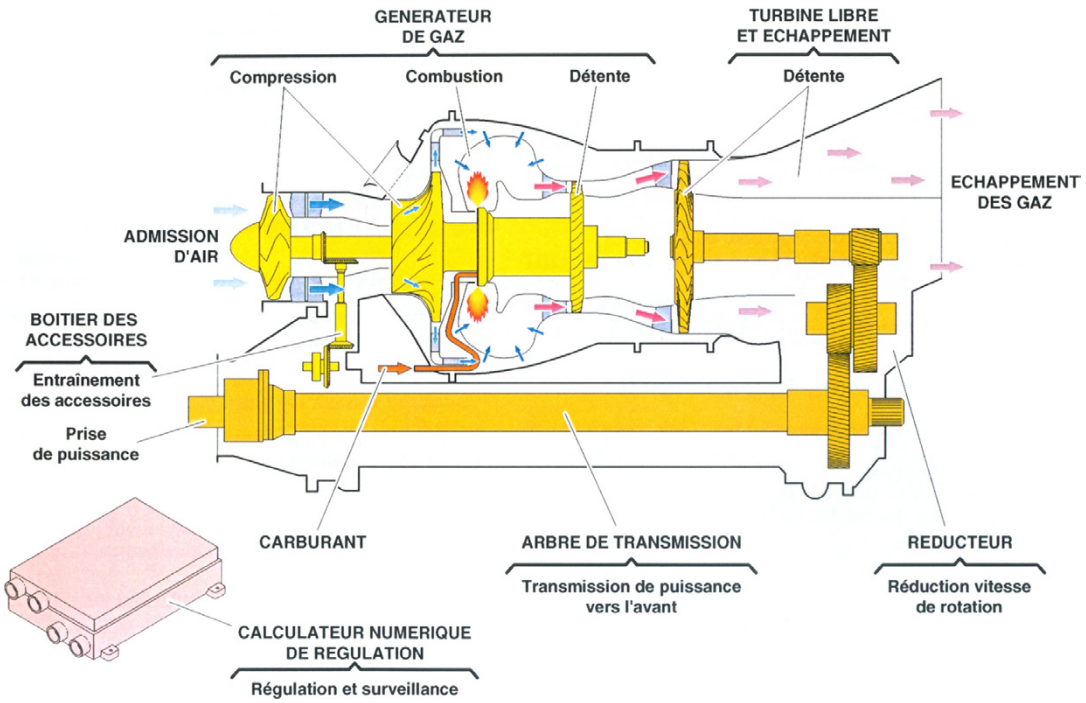


Figure 1. General diagram of the Arriel 2B engine

The engine is started by means of the starter-generator which, powered by an external energy source or by the onboard battery, and connected to the accessory box, initiates the movement of the box's gear assembly and the gas generator shaft via the accessory box's input shaft.

Once the engine is running, the accessory box input shaft transmits the motion of the gas generator shaft to the components connected to the box: fuel pumps, DC generator, oil pumps, alternator and phonic wheel.

The following figure shows the coupling of the gas generator shaft and the accessory box in greater detail.

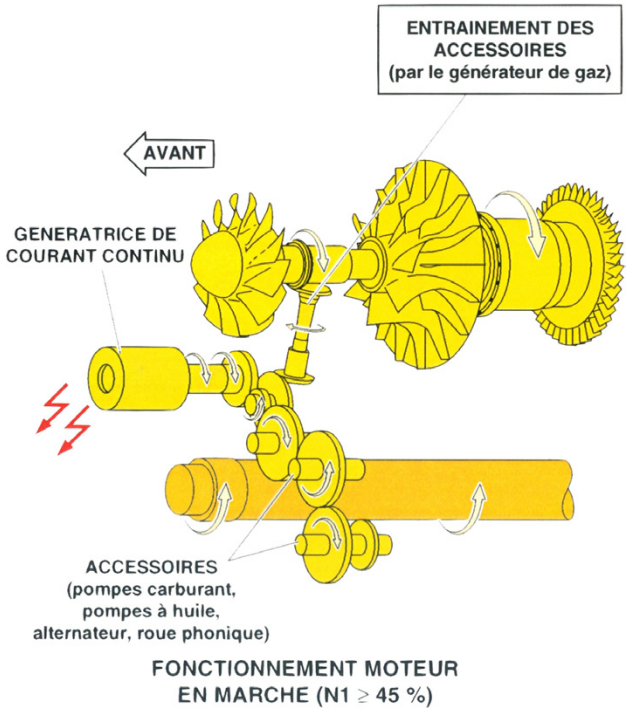


Figure 2. Operation of the engine accesory box (Module M01)

1.3.4. *Flight and maintenance procedures*

1.3.4.1. Flight Manual procedures

Section 3 of the Flight Manual, Emergency Procedures, states that if the amber "Engine Chip" light on the central warning panel illuminates, the pilot must land as soon as possible. The aircraft is expressly forbidden from taking off again until the instructions in the manufacturer's Maintenance Manual have been carried out.

1.3.4.2. Maintenance procedures

The manufacturer's Maintenance Manual, in its chapter on "Particles in the oil system," indicates:

a) The components where the particles can be found:

1. Mechanical magnetic plugs
2. Electrical magnetic plugs
3. Filter element in the oil system
4. Filter screen

b) The method for obtaining oil and particle samples, with instructions to send them for analysis to a specialized and approved laboratory should a visual inspection of the particles be inconclusive.
c) An outline of the actions to take (Decision Table) depending on the type of particles found.

The particles are identified according to the component where they were trapped (filter, screen or magnetic plugs) and to their nature and appearance:

- Rubber, paint, threads, paste or gaskets
- Sand, plant deposits
- Carbon
- Metallic, non-magnetic
- Magnetic, dark
- Magnetic, shiny

In this case the particles were metallic, shiny and magnetic, having been found in the magnetic plug of Module 01. With these data, the actions required by the maintenance manual are to replace modules M01 and M02 before flying the helicopter again, without having to wait for the results from the oil analysis.

1.4. Wreckage and impact information

Two of the main rotor blades were undamaged, and the third had the tip broken off by the impact with the tail cone, which indicates that upon reaching the ground, the rotor was turning at very low RPMs. The indications from the tail rotor blades, which only exhibited bent blade tips, were consistent with this conclusion.

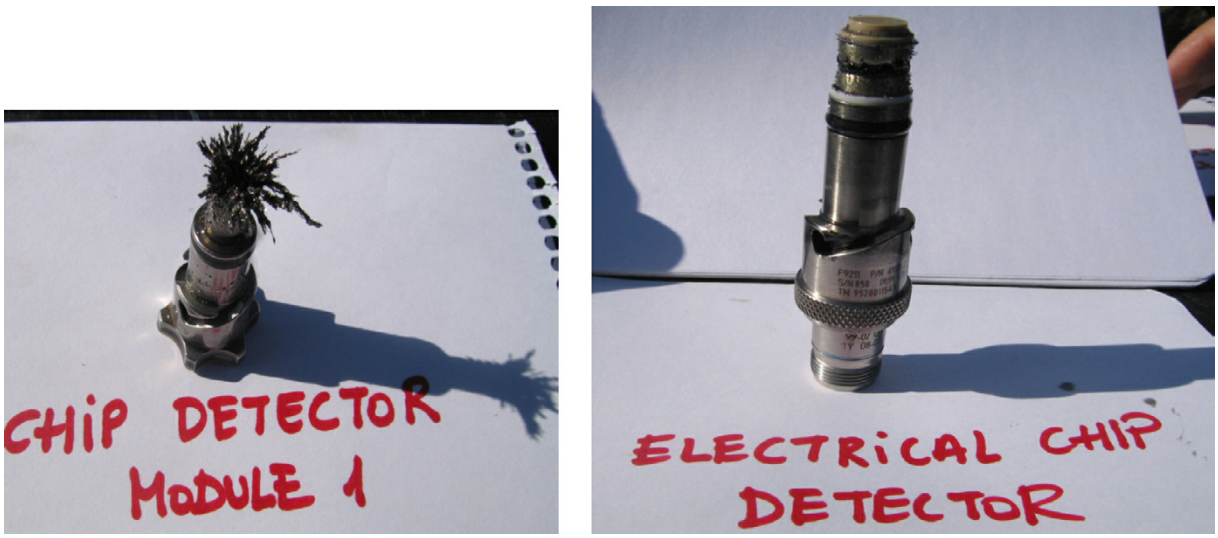
Inside the engine, the shaft of the gas generator rotated freely and neither the free turbine nor the drive shaft were jammed, transmitting motion to the helicopter's main gear box.

The VEMD (Vehicle and Engine Multifunction Display) indicated essentially zero revolutions on the engine's power and gas turbines, as well as a fault in the FADEC (Full Authority Digital Engine Control).

1.5. Tests and research

1.5.1. *Disassembly and visual inspection of the engine*

Once the shrubs were cleared from around the helicopter, the engine was removed from the fuselage. The damage was limited to two impact marks, one on the gas exhaust nozzle and the other on the drive shaft protection tube for Module 01.



Photograph 2. Particles in the chip detectors

The inspection revealed a large quantity of particles obstructing the magnetic plug in Module 01 and only a few particles in the electrical magnetic plug.

The shaft of the compressor-gas turbine assembly was noted to rotate freely, but without transmitting the motion to the accessory box, thus indicative of a connection or continuity problem between the engine shaft and the accessory box.

1.5.2. *Detailed analysis of the engine*

The engine was sent to the manufacturer's facilities for a detailed inspection and analysis.

Upon opening the engine, it was discovered that the driven bevel gear in Module M01 (see Figure 3), which transmits power from the gas generator to the accessory box, was broken and that its counterpart, the 23-tooth accessory drive bevel gear thrust, was damaged. In addition, the drive gear upper thrust bearing was heavily damaged (see Figure 3). Material was flaking off the shaft, which exhibited excessive

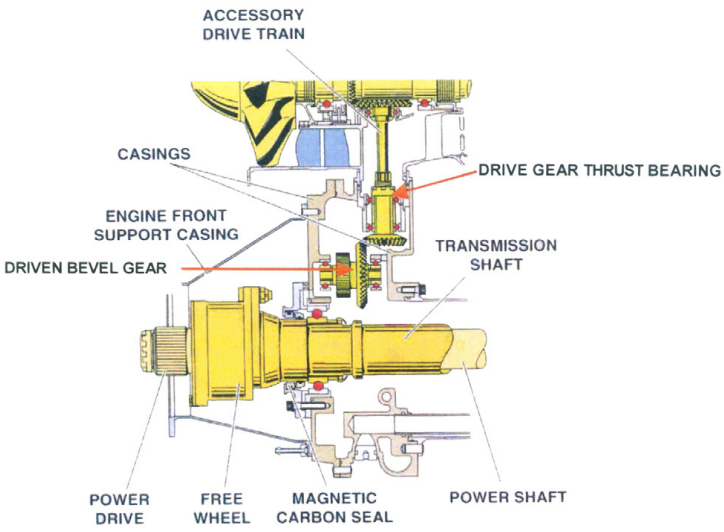


Figure 3. Detail of module 01

axial clearance, much greater than expected. The decoupling between the gas generator and the accessory box interrupted the operation of the fuel pump, and thus to the in-flight stoppage of the engine.

The breakage of the ring gear on the 41-tooth driven bevel gear resulted from the fatigue that started and propagated radially from the edge and base of the gear, on the side with the smaller diameter. The main cause of this fracture was rooted in the degradation of the drive gear upper thrust bearing, which allowed for a gradual increase in axial motion, producing a shift of the contact area between the teeth of the gears which resulted in a secondary bending moment between them. This cyclic overload in the gears' contact area initiated cracks in the base of the teeth. The cracks propagated toward the edges until the gear failed completely.

As stated in Section 1.4.2, subsequent to the accident, the manufacturer's laboratory analyzed and identified the particles collected from the magnetic plug of Module M01 at the 741.9, 753.5 and 759.5 flight hours. All the particles were metallic, magnetic and shiny and matched the material used to manufacture the bearings. No metallic particles from the gears were found. This indicates that all the particles found in the oil in the days leading up to the accident were generated by the degradation of the aforementioned bearing, there being no signs of wear or damage to any gear.

1.5.3. *History of faults in this type of engine*

As for prior faults in this type of engine, the manufacturer was aware of cases of Module 01 bevel gear rupture in Arriel 1 engines, all of them before the 100 operation hours and all involving a faulty installation. Consequently, a modification to the installation procedure was issued, identified as TU302 on Arriel 1 and TU61 on Arriel 2, and training was carried out at authorized centers.

In 2003 an Arriel 2, also with few operating hours, suffered a very similar bevel gear rupture as a consequence of an incorrectly installed washer.

This accident was the second occurrence in an Arriel 2 and differs from the rest in the engine operating time, which in this case exceeded 700 hours. These engines have a 3,000-hour potential operating time before overhaul.

Additionally, the manufacturer noted that they have produced 6,700 units of the various Arriel engine versions with a combined operating time of over 20 million hours.

1.6. Organizational and management information

The helicopter was flying during the summer forest firefighting season under a wet lease agreement in which the operator, Helicopters A.R., was charged with maintaining the

aircraft under the supervision/assurance of the leasing company, Coyotair, according to the terms established in the Resolution of 27 May 2003 of the DGAC (BOE 139) concerning the use by Spanish companies of aircraft registered abroad for forest firefighting operations. This Resolution establishes the conditions for temporarily leased aircraft, either wet or dry, as well as the technical requirements that must be met before the approval is granted. Article 4, Section 2 b) of the Resolution states that "aircraft operation must be assured from both an operational and maintenance standpoint." In order to fulfill with this requirement, the leasing company must control and supervise the operator´s operational and maintenance systems.

After the initial finding of metallic particles in the magnetic plug on 7 August, the operator's executive management unsuccessfully tried to obtain technical assistance from representatives of the manufacturer regarding the possible need to change out module M1. Due to personnel unavailability owing to vacation time, it was not until 15 August that it was possible to establish a contact between the operator and the manufacturer to inform the latter of the problem and to address it appropriately.

Over the course of the investigation into this event, it was noted that technical decisions involving the helicopter's operational and maintenance issues were made at the operator's executive management level.

2. ANALYSIS

2.1. Engine failure mechanism and background

The cause of the in-flight engine stoppage became obvious upon opening the engine, specifically Module M01, and observing the breakage of the 41-tooth driven bevel gear and its damaged counterpart, the 23-tooth accessory drive bevel gear thrust, which led to a decoupling of the gas generator and the accessory box, thus rendering the fuel pump inoperable. This was consistent with the events surrounding the accident. This evidence confirmed that the engine chip warnings, which could have resulted in decisive actions being taken, were a precursor to the engine failure.

The damage and fracture of the gears resulted from the massive degradation of the drive gear thrust bearing, which allowed for increased axial movement. A subsequent laboratory analysis of the particles collected in the engine oil after the initial warnings in the days prior to the accident confirmed that the process started with the degradation of the bearing.

The bearing degradation took place as a result of the application of a strong axial load, possibly due to an installation defect or to some abnormality in the operation of the component. The information gathered from the engine analysis, however, did not allow for a definitive conclusion in this regard.

- No misadjustments were detected which could be assumed as the result of non-conformities during the gears assembly.
- There were no signs of wear in the grooves of the accessory drive bevel gear thrust's 23 teeth.
- The other bearings that make up the assembly were in good condition and appeared to be adequately lubricated.

The most probable hypotheses to account for this type of damage are as follows:

- Shocks to the bearing during assembly.
- Contamination of the bearing during first hours of operation.
- Early fatigue of the bearing under normal operating conditions.

It was not possible to determine if any of these circumstances played a role in this case. The manufacturer is aware of other failures which bear a certain resemblance to that of this accident, but all involved fractures of the drive gear thrust bearing within the first 100 hours of engine operation resulting from faulty installations, and which the manufacturer believed to have addressed by way of design modifications which had been implemented in the accident engine. The same engine had required the replacement and repair of the M01 module due to a power supply fault very early in its life, after 75.8 operating hours. That may have been indicative of deficiencies in the assembly. Given the facts in this case, however, the over 600 hours that elapsed after that module was installed in the engine until it failed make it that much more difficult to identify a problem with an incorrect assembly. Even so, the facts reveal that this type of failure can lead to an almost immediate engine stoppage (in under 5 seconds), requiring an emergency landing. The uncertainty in the cause of the bearing failure and the consequences involved highlight the need to take appropriate measures to prevent a repeat or similar occurrence in another engine of this type. Such measures should be initiated by the manufacturer and should involve a review of design factors that could potentially be implicated in the fault. A safety recommendation is issued in this regard.

2.2. Operating and maintenance conditions under which the helicopter was flying

The condition of the particles collected by the magnetic plug of Module 01 following the in-flight warnings appeared before the accident on 7 and 15 August would have required the interruption of helicopter operations in accordance with the requirements of the Flight and Maintenance Manuals. The bright magnetic metallic particles could have been identified without the need for a detailed laboratory analysis.

The actions taken by the operator, sending the oil and particle samples to a laboratory for analysis, requesting off-site technical support from the manufacturer, changing the

oil and filters and periodically checking for the presence of particles, were not conservative enough to avoid the accident. It does not appear that a prior assessment was made by qualified personnel of the type of particles found in the oil before said decisions were taken.

While it appears that the helicopter was correctly maintained, the lack of technical log records (flight, aircraft and engine records) concerning the appearance of chip warnings in the engine's oil system calls into question the existence of proper mechanisms within the operator's structure for maintaining the aircraft's airworthiness.

Photograph 3. Metalic chips collected the 07-08-2005

The operator's ability to confront technical problems without qualified technical personnel on the one hand, and the leasing company's ability to control the operator's maintenance system on the other, are therefore doubtful. All of these deficiencies require the need to issue safety recommendations to be address to the appropriate aviation authority so as to improve the practices at both the operating and the leasing companies.

3. CONCLUSION

3.1. Findings

1. The operation was being carried under the terms of a wet lease agreement in which the operator, Helicopters A.R., was responsible for operating and maintaining the aircraft under the supervision/assurances of the leasing company, Coyotair, according to the conditions established in the Resolution of 27 May 2003 of the DGAC of Spain.
2. The crew and maintenance personnel held valid licenses.
3. Aircraft and engine log books appeared to be in order, but did not reflect the two chip detector warnings or the particles that had collected in the magnetic plugs.
4. The fine metal powder being previously found, the two engine chip warnings and the two occasions on which particles appeared in the magnetic plugs were indicative of the degradation of the affected bearing in Module 01.
5. The procedures in the manufacturer's maintenance manual were not adhered to following the appearance of these anomalies during operation.

3.2. Causes

The cause of the accident was the in-flight failure of the engine due to the breakage of a gear in the module connecting the drive shaft to the accessory box.

Prior to the fault, two warnings had been received on the engine detection system which were not handled in accordance with the provisions specified in the manufacturer's flight and maintenance manuals.

4. SAFETY RECOMMENDATIONS

REC 02/08. Given the inaction when confronted with the two engine chip detector warnings and in evaluating the particles collected, as specified in the manufacturer's maintenance manual, as well as the lack of records in the aircraft's logs, is recommended to the Civil Aviation Authority of the Republic of Argentina to reevaluate the technical and operational ability of the company Helicopters AR.

REC 03/08. Considering the leasing company's deficiencies in the control and oversight of maintenance on the part of the aircraft operator, is recommended to the Civil Aviation Authority of Spain (DGAC) to review the system put in place by the company Coyotair to assure control over the maintenance of its temporarily leased aircraft.

REC 04/08. Given the unknown origins of the degradation of the bearing which caused the malfunction, and keeping in mind that the most probable hypotheses in this regard are the following:

a) Shocks to the bearing during assembly;
b) Contamination of the bearing during the first hours of operation and,
c) Early fatigue of the bearing under normal operating conditions,

It is recommended to the engine manufacturer, Turbomeca, to review the need to modify the design, manufacture or assembly instructions of the drive gear thrust bearing assembly to the accessory box of the Arriel 2B engine.

The Bureau d´Enquêtes et d´Analyses pour la Sécurité de l´Aviation Civile (BEA) of France disagree with this safety recommendation because in their opinion this engine failure mode is not an airworthiness issue but it is only a reliability issue, since there is a detection and warning system allowing the pilot to take the appropriate action.