



N911MK – Serious Incident Investigation

SafranHE Examinations Summary

(SafranHE ref. RIs 2017/013)

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N911MK (SafranHE ref.: RIs 2017/013) – **SafranHE Examinations Summary**

▪ **Background**

Date of event : 26 Jan. 2017

Location : Sioux Falls, USA

Operation : EMS

Aircraft : EC145 s/n 9218, registration N911MK

Engines : Arriel 1E2 s/n 47068 (LH) and 47069 (RH), TSN 6198hrs, TSO 2603hrs (Module 3)

▪ **Circumstances reported to SafranHE**

10 minutes into the flight, the pilot noticed a #2 twist grip light which illuminated momentarily, then extinguished. Shortly thereafter, he noticed a CAD caution light which also illuminated for a second and then extinguished. He then heard a strange noise from the #2 engine, but noted that all engine parameters were normal. He elected at this time to abort the flight and return to the Sioux Falls airport. In the turn back to the airport, he noticed a glow in his night vision goggles and at about the same time, the #2 fire light illuminated. He subsequently blew both fire bottles and secured the #2 engine and proceeded with a single-engine approach and landing at the Sioux Falls airport with no further issue. After landing, it was apparent that there was a large amount of oil on the engine deck and down the side of the aircraft.

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▪ Heat / fire examination

- Heat/fire damage limited to rear end of RH engine.
- Soot analysis confirmed an oil based fire.
- Stains of liquid splatter in lower part of engine.
- Heat/fire marks on lower part of hot section of RH engine.

→ Potential ignition sources



RH engine compartment condition after the event

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▪ Components sent to SafranHE for examination – Main findings RH engine

- Significant coking in rear bearing casing.
- Scavenge line : blocked with coke at Magnetic Plug level. Significant coking in tube. No metallic debris.
→ **Scavenge line's clogging with coke (no metal) led to oil overflowing from rear bearing casing**
- Corrosion of the rear bearing's flexible cage associated with dispersion with its surface treatment. Cases of cage corrosion are very rare and not systematically associated with bearing failure.
- Rear bearing operated satisfactorily until its final moments of operation when it seized up in an excess of oil following the clogging of the scavenge line and until the pilot shut-down the engine.
- Evidences of Gas Generator's spool (labyrinth lips and blade tips lightly worn) operating with seized bearing. Differences between engines' parameters reported by pilot only after the engine shut-down.
→ **Engine parameters normal until shut-down by pilot**

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▪ **Components sent to SafranHE for examination – Main findings RH engine**

- No significant signs of oil in internal cavities.
- No evidences of oil exiting from rear bearing casing's support arms and through holes for oil pipes or T45 probes.
- No evidences of fire through or around the holes for oil pipes or T45 probes.
 - **N911MK is different from previous 2 known cases of fire under cowlings where the fire appeared to be caused by oil or hot air loaded with oil escaping through the holes designed for the oil pipes and T4 probes**
- All oil pipes and ducts were found in place, tightened, not broken and not cracked.
- No oil exiting from chaffing mark on oil pipe at front of the engine.
- Oil escaped from the rear bearing casing into the main air path and from there into the engine exhaust (no escape from the main air path to under the cowlings).
- Oil also escaped from the rear bearing casing into the vent line.
- Metallic vent pipe contained metallic debris, liquid oil and coke residues. No significant coking in tube & in metallic pipe.
 - **No evidence of oil escaping outside the engine other than in the exhaust and in the rear bearing casing's vent line**

AHD components initially sent to and examined by SafranHE before sending them to AHD upon their request :

- Elastomer vent line found slit open in two positions. Openings were from inside going out. Contained metallic debris, liquid oil and coke residues. No significant coking.
- Vent line's 3-way union blocked with coke. Coke found hard and compacted in orifice. No metallic debris.

INVESTIGATION REPORT	Preliminary ☐ Final ☒
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Accident ☐
Incident ☒

Reference	TEA_Rls2017-013-1_v2	Commercial File	N/A
Accident / Incident report	Rls2017/013	Preliminary Information report A(I)	N/A

Data					
Date of occurrence		Occurrence place		Operator	
2 Feb. 2017		Sioux Falls, South Dakota, USA		AVERA McKENNAN	
Aircraft type		S/N		Registration	
EC145		9218		N911MK	
Engine type		S/N		TSN	TSO
ARRIEL 1E2		47069		6198 hrs	2603 hrs
Accessories					
Designation, P/N		S/N	Work performed	TSN	TSO
Bearing P/N: 9609000562		unreadable	Examination	2603 hrs	N/A

Circumstances reported to SAFRAN HELICOPTER ENGINES

After flying for 10 minutes, the pilot noticed that the "TWIST GRIP" light had illuminated momentarily, then, shortly after, that another light had illuminated on the CAD for one second. Then, he heard an unusual noise coming from the right-hand engine and observed that the engine parameters were normal. He decided to abort the mission and to return to base. While he was turning back, he noticed that the "FIRE" light had illuminated for the right-hand engine. He triggered off both extinguishers, shut down the engine and completed the flight in single engine mode.

On the ground, the inspection revealed the presence of fire marks on the right-hand engine and on the aircraft. Some oil was also found on the engine compartment deck and on the right-hand side of the aircraft.

Conclusion

This document reviewed the outcome of the Gas Generator rear bearing's examination.

The bearing operated satisfactorily until its final moments of operation in an excess of oil following the clogging of the scavenge line and until the pilot shut-down the engine.

The bearing seized up with rollers, cage and outer ring locked together. The rollers were then flattened due to the friction with the rotating inner ring. The latter was also worn and ultimately broke into fragments during the engine shut-down phase when it was still rotating and mounted on its shaft.

VALIDATION		APPROVAL	
DATE	Validated by D2S/TEA	DATE	Approved by D2S/TEA
11 July 2018		11 July 2018	

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1 BACKGROUND

1.1 INTRODUCTION

The Arriel 1E2 engine s/n 47069 was fitted to EC145 aircraft s/n 9218, registration N911MK at the time of the serious incident on February 2nd, 2017.

The engine was sent back to Safran Helicopter Engines factory in Dallas, Texas, for examination. During the tear-down, it was found that the Gas Generator rear bearing was deteriorated. The bearing was subsequently examined by the Safran Helicopter Engines laboratory located in Bordes, France.

The purpose of this document is to report the Gas Generator rear bearing's examination findings and subsequent discussion.

1.2 INSTALLATION

The bearing is located at the rear of the Gas Generator spool (in blue on schematic below). The spool is also guided by two ball bearings at the front in the compressor area.

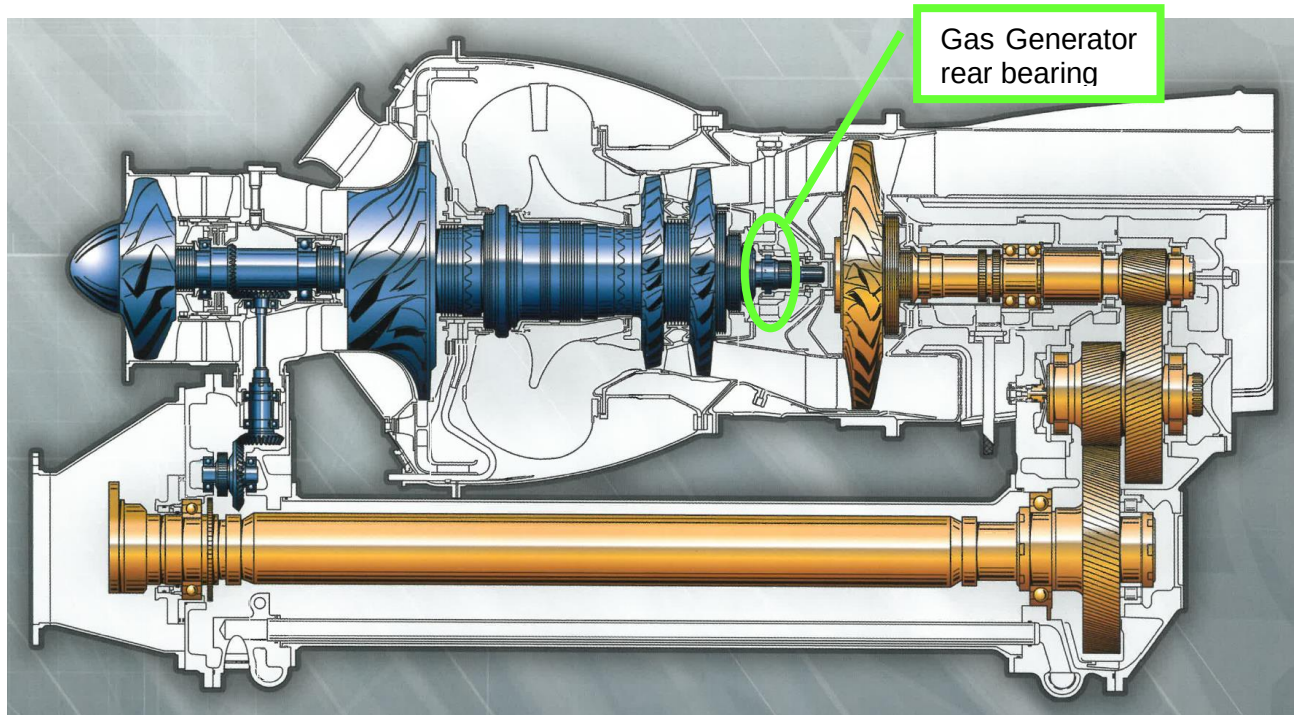


Fig. 1 : ARRIEL 1 Engine General Schematic

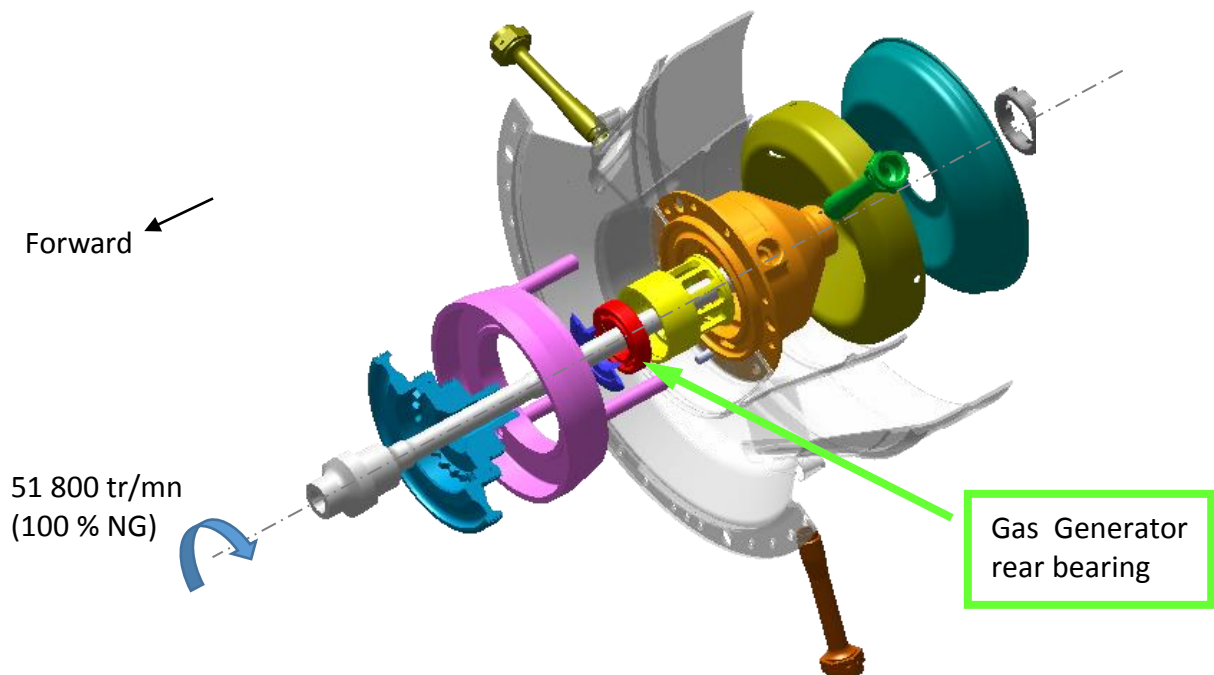


Fig 2 : split view of rear bearing assembly

2 ENGINE HISTORY

Recent maintenance:

Date	TSN	TSO (Mo3)	Task	Done by	Remarks
26 Jan. 2017	6198	2603	Event		
27 Dec. 2016	6146	2551	Periodic check (EMM) 400 hr - Inspect oil filter - Inspect rear bearing's Elect. Mag Plug	Operator	No record available of inspection result
14 Dec. 2016	6114	2519	Oil analysis (SOAP)	Operator	No record available of analysis
22. Oct 2016	5988	2393	Periodic check (EMM) 800 hr - Oil system drain - Inspect strainer of rear bearing's Elect. Mag Plug 1200 hr - Remove and clean oil scavenge tube	Operator	No record available of inspection result
25 Jul. 2016	5815	2220	Periodic check (EMM) 600 hr Permeability check rear bearing ass'y	Operator	No record of permeability test result No trend analysis possible
23 Jun. 2016	5739	2144	Periodic check (EMM) 400 hr - Inspect oil filter - Inspect rear bearing's Elect. Mag Plug	Operator	No record available of inspection result
21 May 2016	5637	2042	- Oil system rinse - Permeability check rear bearing ass'y	Operator	Checks done because oil tank's sight glass was cloudy and dark. Permeability test result: 100 ml No trend analysis reported.

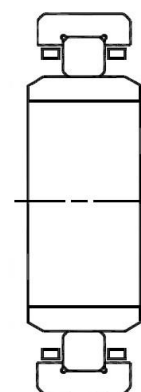
3 BEARING DEFINITION

Description of equipment	P/N	S/N	Manufacturer's marking
Roller bearing	9609000562	unreadable	6905 M176

- Supplier : SKF
- Radial clearance : 0.03 to 0.04 mm
- Rollers' axial clearance : 0.01 to 0.02 mm

Materials :

- Outer ring 80DCV40 (M50)
- Rollers 80DCV40 (M50)
- Inner ring 80DCV40 (M50)
- Separating cage 40NCD7



4 EXAMINATION

4.1 VISUAL EXAMINATION

4.1.1 Bearing



The bearing as received was totally blocked and could not rotate.

All the rollers, cage and outer ring were stuck together.

All the bearing's rollers were flattened and did not protrude from the separating cage any more. The outline of their shape could be guessed on the inner surface of the separating cage.

4.1.2 Separating cage



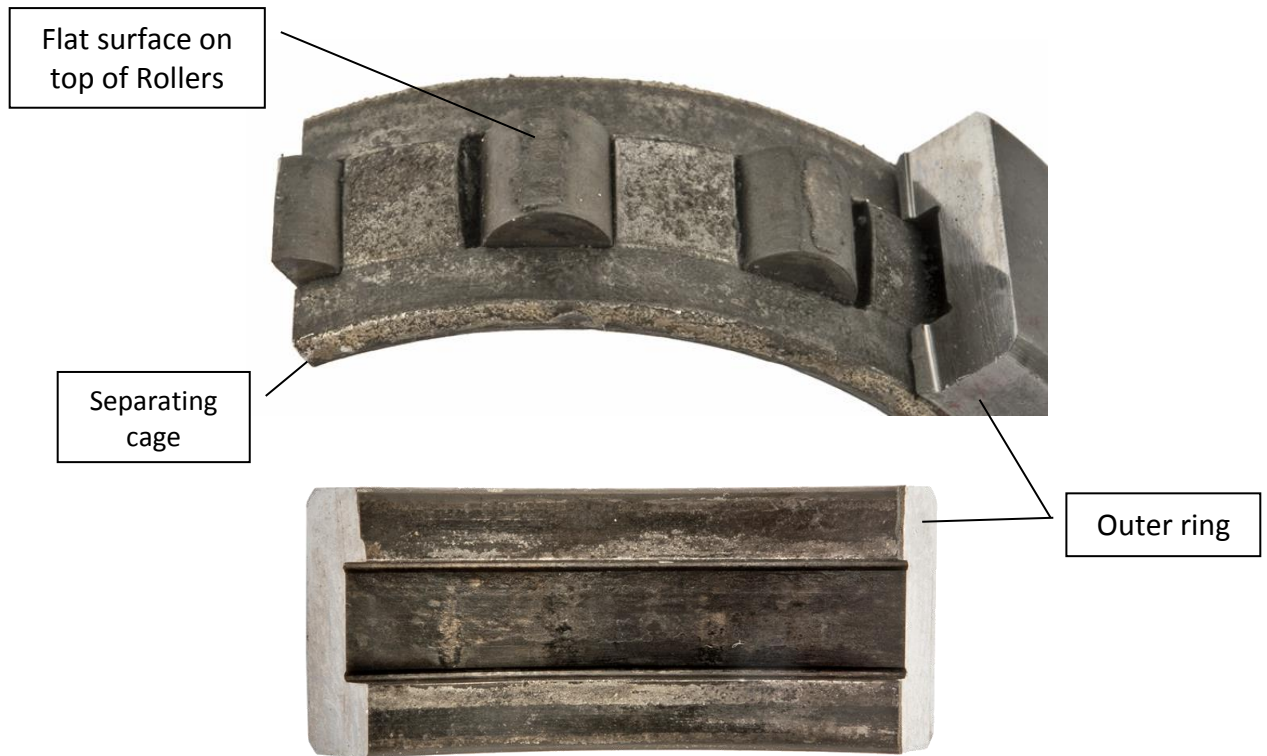
The separating cage and the flattened rollers showed circular scoring marks consistent with rubbing against the rotating inner race. It also exhibited numerous impact marks and indentations consistent with contacts with debris during the rubbing with the rollers and the rubbing and rupture into several fragments of the inner race.

4.1.3 Outer ring

The outer ring showed no indication of movement (rotation or displacement) against its support and was externally in good condition.



A section of the outer ring was cut-off to reveal the concealed part of the rollers and also to reveal the race's surface (see following page).



Once removed, the rollers appeared to have retained their cylindrical shape except for a flat surface where it came in contact with the race in the outer ring. The separating cage showed light circular scoring. Similarly, the race in the outer ring showed light circular scoring whilst retaining its shape. The small extent of the flat surfaces on the rollers and the light scoring on the separating cage and on the race of the outer ring indicate that once the rollers stopped rotating with respect to the separating cage, they initially skidded on both the inner and outer rings until the elevation of temperature produced by the friction led to expansion of the rollers and then their blockage against the flanks of the outer race.

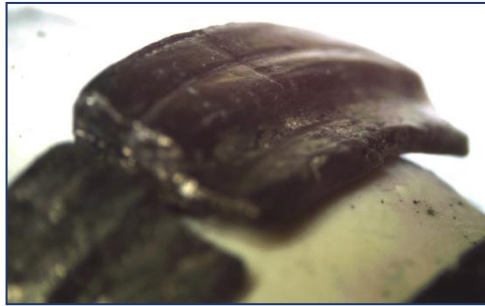
4.1.4 Inner ring

The inner ring was broken into fragments, several of which could be recuperated.

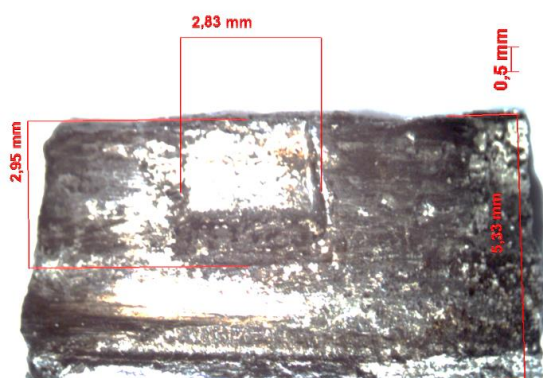


The fragments exhibited traces of rotational scoring and metal ripping at the race's surface indicative of friction under a significant radial load.

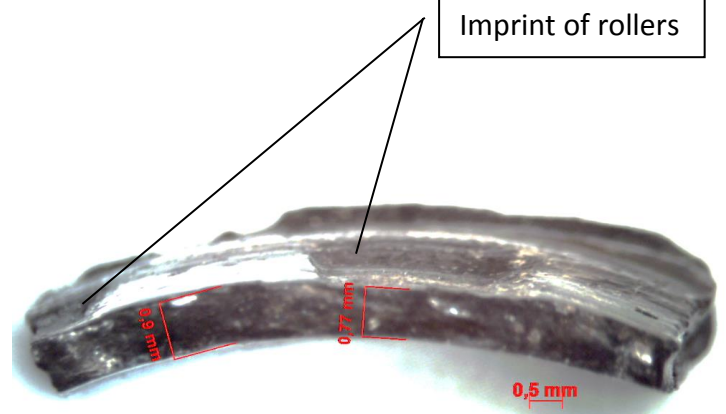
Several fragments showed rectangular imprints left by the flattening rollers. These imprints indicate that a significant sudden radial load was applied to the inner ring whilst it was still on the shaft. The fragments had blunted and rounded edges due to contacts with surrounding parts or debris after the rupture of the ring.



Imprint of roller



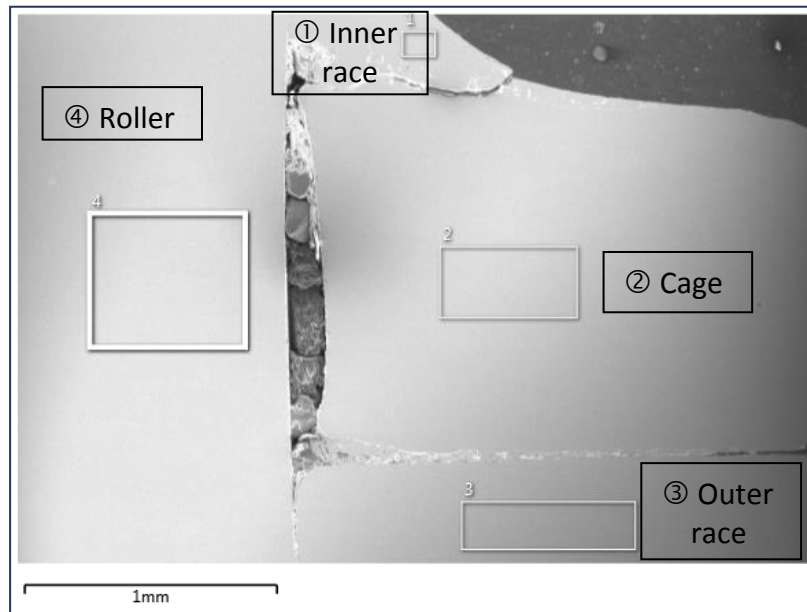
Imprint of rollers



4.2 CHEMICAL COMPOSITION

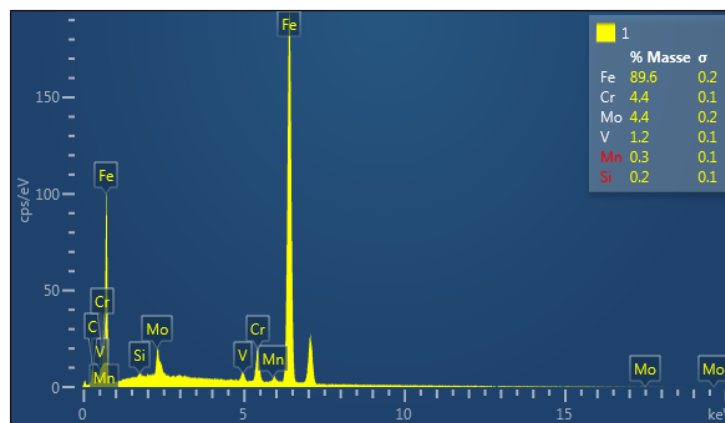
A section of the bearing assembly was cut off, wrapped in resin and polished so it could be examined.

The sample's components were analysed for their chemical compositions with the Energy Dispersive Spectroscopy (EDS) method.

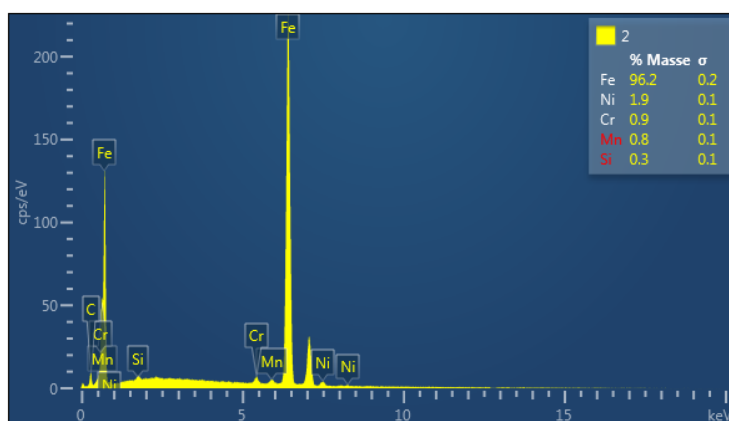


Close-up on bearing's section

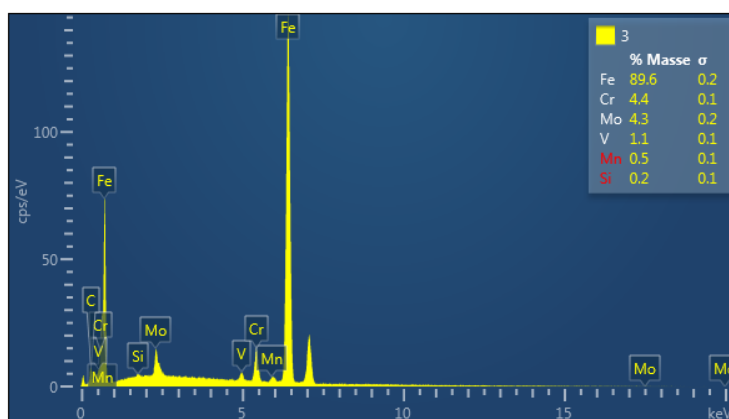
Spectrum analyses :



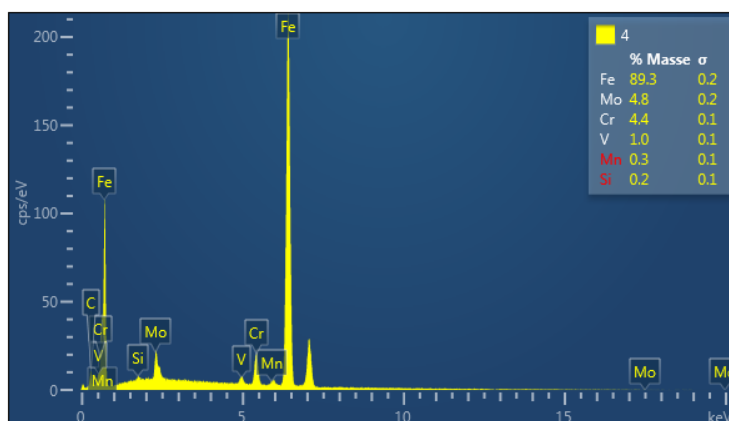
Zone 1 – Inner race



Zone 2 – Separating cage



Zone 3 – Outer race



Zone 4 – Roller

Results :

Zone 1 – Inner race	.	.	.	80DCV40 (M50)	→	Conform
Zone 2 – Separating cage	.	.	.	40NVD7	→	Conform
Zone 3 – Outer race	.	.	.	80DCV40 (M50)	→	Conform
Zone 4 – Roller	.	.	.	80DCV40 (M50)	→	Conform

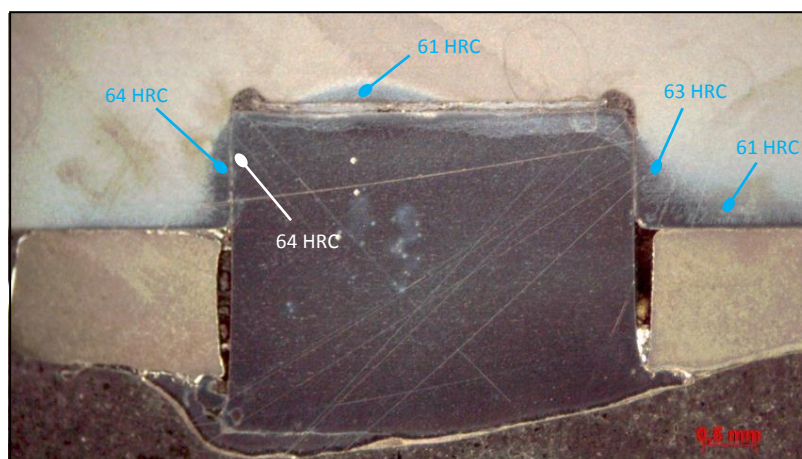
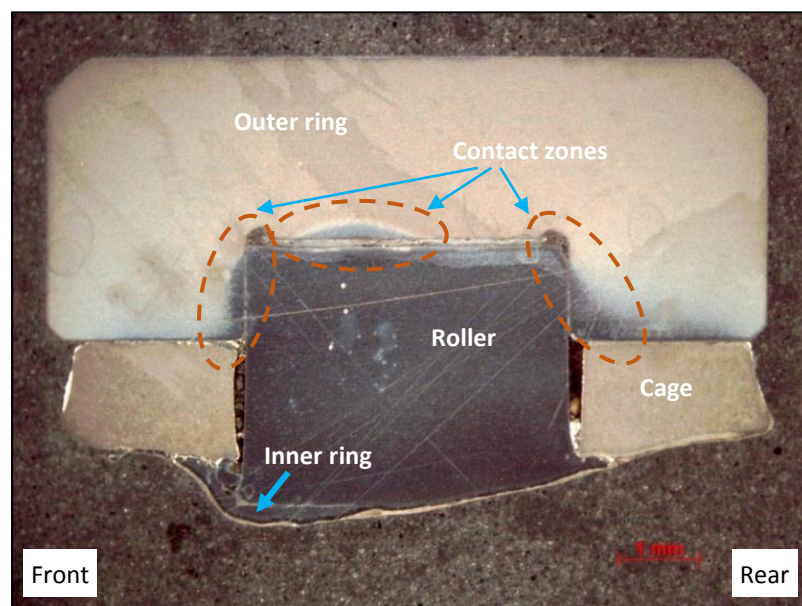
4.3 NITAL ETCHING

The polished bearing section underwent a “NITAL” chemical etching treatment. This treatment produces colorations of varying hues depending on the temperatures to which the components were exposed. The comparison is only valid for the inner ring, the rollers and the outer ring as they are made of the same alloy.

The NITAL etching revealed a different hue for the roller when compared with the outer ring. This is consistent with the hardness measurements (see next §).

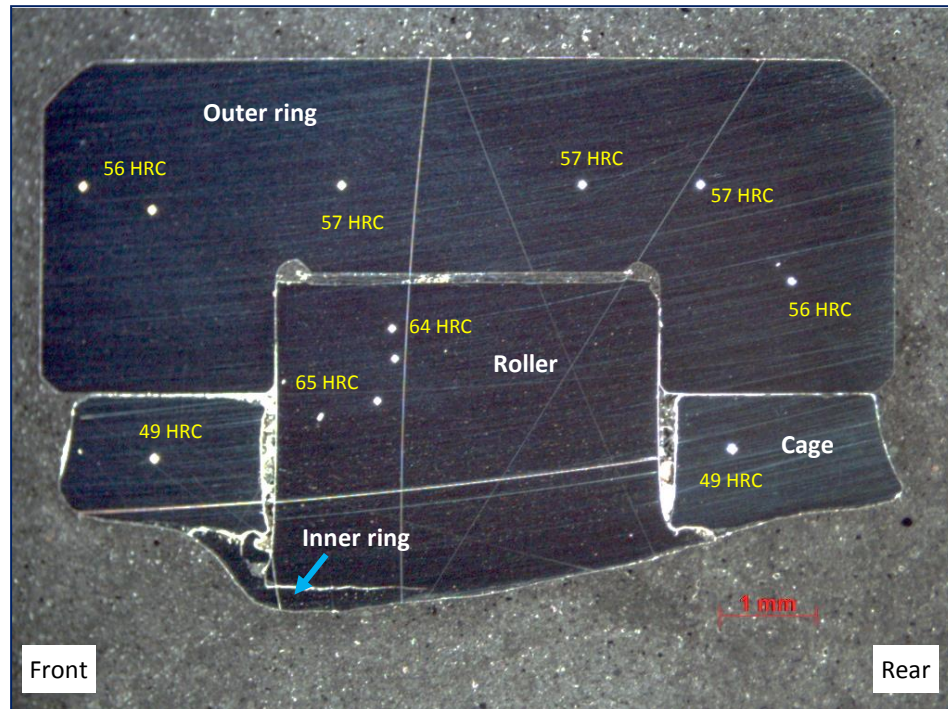
It also revealed heat transfer zones where the rollers came in contact with the outer ring. When the rollers seized up, their temperature increased due to the friction with the rotating inner race and they expanded and came in contact with the outer ring (at the bottom of the race and against its inner walls) thus locking them in place with respect to the outer ring. The heat produced by the friction of the inner ring on the rollers was then transferred to the outer ring by conduction.

The different colorations indicate a metallurgical transformation of the materials under influence of the rising temperature coming from the friction of the rotating inner ring on the rollers.



4.4 HARDNESS MEASUREMENTS

The polished section was used to measure the hardness levels in different areas. The size of the inner ring fragments did not allow to take measurements on them.



Results :

	<u>Measurements</u>	<u>Specification</u>	<u>Status</u>
Inner ring . . .	could not check	61 – 64 HRC	could not check
Separating cage . . .	49 HRC	25 – 33 HRC	Not conform
Outer ring . . .	56 – 57 HRC	61 – 64 HRC	Not conform
	61 – 64 HRC (at contact zones, see § 4.3 on previous page)		
Roller	64 – 65 HRC	61 – 64 HRC	Not conform

The outer ring, the inner ring and the rollers are made of the same 80DVC40 (M50) alloy. Under rising temperature conditions, the hardness for this alloy initially drops. If the temperature keeps increasing, then the hardness increases again and can exceed the original hardness. In this instance, the rollers rubbed against the inner race and they lost material. The hardness measurements give a consistent information as they indicate that the temperature experienced by the rollers was higher than that experienced by the outer ring (except at the zones of contact where the hardness levels are similar). This information is also consistent with the NITAL etching checks (see § 4.3).

The cut section showed that some of the inner ring's material transferred to and adhered to the roller.

4.5 SUMMARY OF FINDINGS

The examination of the bearing showed that its deterioration was due to seizure with rollers, cage and outer ring locked together. The cross section revealed that the rollers were not damaged prior to the seizing and that the rollers' and the outer ring's race profiles were nominal. The outer ring showed no indication of movement against its support and was externally in good condition. All the bearing's rollers were flattened due to rubbing with the rotating inner ring. The inner ring ultimately broke into fragments when it was subjected to a significant sudden radial load whilst still on the shaft. The material analysis confirmed that they were conform.

5 DISCUSSION

[REDACTED] the conditions of operation of the bearing and possible contributors to its deterioration could be reviewed :

- **Excessive loading**

The rotary components of the Gas Generator showed some light rubbing marks that were evenly distributed around their peripheries (blade tips and labyrinth lips) and without signs of operation under excessive unbalance.

The bearing's inner ring showed indications of friction followed by rupture under sudden significant radial loading as that ring was still rotating and still fitted on the shaft. Such a sudden overload can be explained when the engine shut down and went through resonance modes as it slowed down (as all engines do during shut-down).
- **Mishandling of engine (shocks, fall,...)**

Unlikely as the engine was installed 2603hrs before the event.
- **Material discrepancy**

Materials checked and found correct.
- **Internal discrepancy**

The bearing showed damage limiting the extent of the examination.

However, its examination did not reveal any discrepancies within the parts that were analysed. Moreover, the engine was operated for 2603hrs since its last disassembly.
- **Dimensions out of tolerances**

The bearing showed damage preventing dimensional checks.

However, the engine was operated for 2603hrs since last disassembly.
- **Improper assembly**

There were no signs of movement of the bearing in the support cage and the cross sections showed the proper shape of the rollers and outer race. Moreover, the engine was operated for 2603hrs since last disassembly. It is considered that the assembly was performed correctly.

- **Misalignment (between rings)**
Same as above
- **Lack/insufficient lubrication**
The investigation revealed that oil had overflowed from the bearing chamber. During the sequence of events, the pilot checked and found all engine parameters in the proper range. In particular, he did not mention any loss or drop of oil pressure.
There is no information though about possible flights with one engine deliberately shut-down (windmilling).
- **Excessive oil temperature**
The pilot checked and found all parameters in the proper range. In particular, he did not mention any excessive oil temperature.
- **Excess of oil in chamber**
The investigation revealed that oil had overflowed from the bearing chamber once the scavenge line was clogged. The bearing is designed to operate in an oil mist and not in an oil bath. The presence of liquid in the bearing chamber will provoke a resistance to the movement of the rollers.
Prior to the clogging of the scavenge line, the bearing was still in satisfactory condition as no metallic debris were found in the scavenge line's strainer / magnetic plug assembly.
The pilot did not report any change in engine parameters until he activated the fire push-button which in turn led to the activation of the fuel shut-off valve and to the engine shut-down.
Therefore, the bearing operated satisfactorily until its final moments of operation in an excess of oil following the scavenge line's clogging and until the pilot shut-down the engine.
- **Pollution of oil system**
The bearing showed damage limiting the extent of the examination.
All metallic components found in debris were indigenous to the rear bearing assembly and oil.
- **Oil quality**
The oil exhibited low levels of additives. Although unfavorable, it does not by itself explain the deterioration of the bearing.

As mentioned in the documents listed above, this event is the only known case (excluding cases where operational and/or maintenance issues were identified) where a Gas Generator rear bearing deterioration happened following the blockage of the scavenge line with coked oil over the 2000 to mid-2017 period representing 22 million flight hours with Arriel 1 engines.

6 CONCLUSION

The bearing operated satisfactorily until its final moments of operation in an excess of oil following the clogging of the scavenge line and until the pilot shut-down the engine.

The bearing seized up with rollers, cage and outer ring locked together. The rollers were then flattened due to the friction with the rotating inner ring. The latter was also worn and ultimately broke into fragments during the engine shut-down phase when it was still rotating and mounted on its shaft.