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FINAL REPORT Nr.5/2012(3-2014)

on THE ACCIDENT

of HELICOPTER MD 369E, REGISTRATION OH-HJR ON JULY 12, 2012 AT KASTIRE

The Aircraft Accident and Incident Investigation Bureau of the Republic of Latvia is a governmental, independent of all aviation authorities, organization established by law to investigate and determine the cause or probable cause of accidents and serious incidents that occurred in the civil aviation, as well if necessary for enhancing flight safety incidents.

The sole objective of the safety investigation in accordance with Annex 13 to the Convention on International Civil Aviation, the Regulation (EU) No.996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in Civil as well as Cabinet Regulation No.423 of May 31, 2011 “Procedures of Civil Aviation Accident and Incident investigation” is the prevention of future accidents and incidents. The Report shall contain, where appropriate, safety recommendations. Safety investigation is separate from any judicial or administrative proceedings and investigation Report is not deal with purpose to apportion blame or liability but only for purpose of the safety enhancement. The Report shall protect the anonymity of any individual involved in the accident or serious incident.

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THE ACCIDENT of HELICOPTER MD 369E, REGISTRATION OH-HJR

ON JULY 12, 2012 AT KASTIRE

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Abbreviations

CAA - Civil Aviation Authority; **PIC**- Pilot in Command;
ICAO - International Civil Aviation Organization;
NLR - National Aerospace Laboratory; **CPL** - Commercial Pilot Licence;

SIA - Safety Investigation Authority; **UTC** - Universal Time Coordinated;
SHP - Shaft Horse Power; **OGE-** Out of Ground Effect.

SYNOPSIS

Unless stated otherwise all times in this Report are UTC time

On July 12, 2012 a MD369E helicopter, registration OH-HJR incurred damage during a forced landing near Kastire (**N56.21.160; E26.86.220**), local community Rušona Riebiņi reagion, Latvia after an engine in-flight shutdown. The helicopter was being used to trim trees using saw apparatus that is suspended under the aircraft and connected to the cargo hook. According to pilot's information at morning on the day of the accident, the pilot made helicopter pre-flight check and everything operates normal. Pilot took off and flew to sawing place about 200 m from landing place. After approximately 35-40 minutes working he called by radio ground staff and informed that he goes to landing place. When he approached approximately 50 m from landing place at height about 40 m the pilot heard that engine noise reduced, helicopter begins to roll, turned 90 degrees to the left. The pilot tried to increase airspeed by pushing cyclic forward and collective down. After that for a very short moment helicopter did flare but at the next moment the machine descended and struck the ground heavily. The helicopter came to rest laying on its left side, breaking the forward and aft landing skid struts and left skid tube. The tail boom had separated from helicopter and the main rotor blades were separated from rotor and threw away from helicopter due to ground contact. The pilot, sole person on board, was not seriously injured. There was not fire. The helicopter was owned and being operated by company HeliPro Oy, Finland and was being used for tree trimming along power lines. Day visual meteorological conditions prevailed for the flight.

Picture 1 Accident site

Picture 2 Accident site

NOTIFICATION

At 10:15 local time on July 12, 2012 the Transport Accident and Incident Investigation Bureau (TAIIB) was informed by phone from representative of the "HeliPro Baltic" Ltd. about occurrence of the helicopter MD369E, registration OH-HJR, Finland.

General information of the serious incident

Operator	-	HeliPro Oy, Finland
Aircraft Type	-	MD Helicopter MD 500E (Model 369E)
Nationality	-	Finland
Registration	-	OH-HJR
Manufacturer	-	McDonnell Douglas Helicopter Co
Owner	-	HeliPro Oy, Finland
Year of manufacture	-	1991
Place of Accident	-	Kastire, Latvia;
Date and time	-	July 12, 2012, approximately at 6:45 UTC

Investigation

The Transport Accidents & Incidents Investigation Bureau (TAIIB) of the Republic of Latvia as State of Occurrence according to Annex 13, Section 5.1. instituted an investigation into the circumstances of the accident and start to conduct the investigation. The Notification of Accident according to Section 4.1 of Annex 13 was sent to the State of Registry and Operator (SIA of Finland), State of Manufacture (NTSB). SIA Finland appointed accredited representative (ACCREP) to assist instituted investigation.

1. Factual information

1.1. History of the flight

The helicopter was contracted and being used to trim trees using a saw apparatus that is suspended under the aircraft and connected to the cargo hook. The saw apparatus contains a remote control for operation which is resident within the cockpit such that the pilot can start and stop the saw and release the apparatus as required.

According to pilot's testimony on the morning of the occurrence at the day of the accident, the pilot completed his daily pre-flight inspections of the helicopter, everything operates normal so that the helicopter would be ready for performing sawing work.

Pilot took off and flew to sawing place about 200 m from landing place. After approximately 35 min working he called by radio ground staff and informed that he goes to landing place. When he approached approximately 50 m from landing place at height about 40 m he put out his head of helicopter to see the saw and noticed some yellow lights on the instrument panel but he not sure about that. After short time (2-5) sec pilot heard engine noise reducing, helicopter begins to roll, turned 90 degrees to the left. Pilot tried by pushing cyclic stick forward by creating differing amounts of lift at different points in the cycle and by collective lever changing the pitch angle of all the main rotor blades pitch down to get more airspeed but without success. He dropped the saw and helicopter collided with ground and felt to left side.

As the pilot was operating the saw during this time his attention would have been out the pilot door and below the aircraft. The pilot did not report a chip light or any other panel warnings before receiving the engine noise reducing.

1.2. Injuries to persons

None

1.2. Damage to aircraft

Inspection of the wreckage at the accident site revealed that the main-rotor head, the main-rotor blades, the tail rotor blades and the rotating and non-rotating flight control components for the main-rotor system and tail rotor system had suffered extensive damage

As result of technical inspections the following damaged parts of aircraft were found:

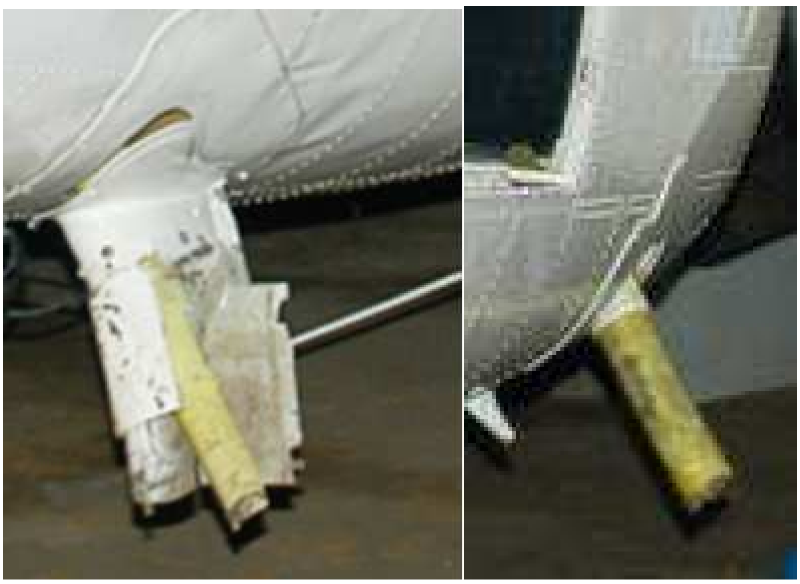


Figure 3

- left side landing skid front strut and rear strut broken;

Figure 4

- All blades of five bladed main rotor broken;

- tail boom broke in two - sinhronized elevator, vertical stabilizer and transmissions separated from tail boom, tail rotor drive shaft teared (**Figure 5**);

– one blade of two bladed tail rotor broke, other deformed (**Figure 6**);

– vertical stabilizer broke (**Figure 7**);
– different failed components were thrown from the helicopter;

Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

Figure 13

Figure 14. The dropped saw

Examination of the aircraft revealed that all damage observed on the fuselage, main rotor assembly, tail rotor and flight controls, resulted from the impact with the ground.

1.4. Other damage

NIL

1. 5. Personnel information

The flight crew certified and qualified for the flight in accordance with existing regulations

PIC	-male, age - 46,
Licence	- CPL(H) FI37848 issued 14.10.2008., -validity 31.10.2012., -ratings - NF(H); - AS350; - HU369/MD500N/600, valid until 31.10.2012; - R-44, valid until 30.06.2012.
Total flying experience	-2195 hrs

Flying experience on aircraft type MD 500 - 78 hrs;

Flaying hours in incident day - 40 min;

MD 500E last 3 month - 20 hrs;

With external load total - 1036 hrs;

With external load total last 3 month - 180 hrs;

1.6. AIRCRAFT INFORMATION

Aircraft type – The FAA model designation is Model 369E;
The FAA/ICAO aircraft type designator is H500;
The MDHI commercial designation is MD500E;
Manufacturer- McDonnell Douglas Helicopter Co;
Manufacturer's serial No – 0475E;
Model – Model 369E;
Name of owner- HeliPro Oy, Finland;
Registration No. OH-HJR;
The Certificate of Registration N02132, Date of issue on 02 July, 2010;
Certificate of Airworthiness No2132, Date of issue on 14 September, 2010;
Airworthiness Review Certificate, Date of first extension 13 September 2011,
Date of expiry 14 September 2012;
Year of manufacture – 1991;
MTOW - 1.361kg;
Total aircraft flying hours- 962hrs 40min;
Flight hrs (since last periodic inspection) –10hrs, 30 min;
Helicopter was registered in UK at 18.01. 92 and flights in UK by March 2010, flight hours 766.1;
Helicopter registered in Finland **01.07.2010**, flight hours **766.1**;

Engines Model – 250-C20R/2;
Engine Serial No- CAE-295354;
Engine sale date 11/30/90, shipped from AGT-GMS to MDHC, Engine time 0.0;
Engine installed on aircraft MD 500E, serial 0475E 03.08.91;
Manufacturer- Allison Division of General Motors Corporation;
When helicopter was transferred to Finland **engine 250-C20R/2, CAE-295354 found installed on helicopter, TSN of aircraft = with TSN of engine;**
Takeoff power rating - 450 SHP;
Engine total time-962hrs 40min (before accident);
Flight time (since last periodic inspection) –103hrs;

Maintenance activities

Records indicate the helicopter was serviced and maintained in accordance with existing directives. At the time of the accident, the engine and airframe had accumulated approximately 962 hours 40 min total time since new, and there were no outstanding maintenance issues with either. The last routine inspection was completed about 103 hours prior to the accident.
07. 09. 2010 100/300/600/1500/1750fh/12M/24M inspection at 766.1 hrs by Helitech Oy of Helsinki (work order 6317/10);

26.04.2011 FCU BR53193 23051989 installed at engine tsn 817801.5 unit TSO- no reason for removal/change (working order 6613/11);
27.04. 2011 replaced fuel nozzle with new (working order 6613/11), not shown reason for removal/change;
16.09. 2011 100h/12m annual inspection performed at 859.2 hrs by Helitech Oy (work order 6743/11);
07.11.2011 fuel nozzle replaced, installed s/n 2328 at 868,15hrs by Helitech Oy (work order 6788/11);
29.11.2011.starting problem trouble, fuel pump replaced, installed new, s/n AJK0018 at868.16hrs
27.01.2012. TO inspection performed at 894.1 fh, working order 6846/12;
19.04.2012. installed onboard cargo hook, 924.1fh, incorporate changes in helicopter weight and balance record, working order 6914/12;
19.04.2012 bleed valve replaced, installed s/n FF51384, not shown reason for removal/change;
06.07.2012. TO inspection performed at 952.15fh, working order 6988/12;

AD 96-19-01 Bearing Inspection and Exchange complied with.

1.7. Meteorological information

According to State Ltd "Latvian Environment, Geology and Meteorology Centre" Meteorological observation stations of Daugavpils (*55°56'03.05'' N; 026°39'33.18'' E)* and Rezekne (*56°32'40.96'' N; 027°16'50.34'' E)* weather conditions on July 12, 2012 from 8:00 to 11:00 were following:

Hour (Latvian summer time)	Hour average air temperature, °C		Hour max. air temperature, °C		Hour min. air temperature, °C		Hour average relative air humidity, %	
	Daugavpil	Rēzekn	Daugavpil	Rēzekn	Daugavpil	Rēzekn	Daugavpil	Rēzekn
08:00-09:00	18.0	17.1	19.0	17.2	17.3	17.0	81	81
09:00-10:00	19.6	17.7	20.3	18.6	19.1	17.2	78	81
10:00-11:00	21.2	18.7	21.7	19.3	20.3	18.4	70	77

Hour (Latvian summer time)	Hour average wind direction, rhumbs		Hour average wind speed, m/s		Hour average wind gusts m/s	
	Daugavpils	Rēzekne	Daugavpil	Rēzekne	Daugavpil	Rēzekne
08:00-	southeast	east	0.3	1.4	2.3	3.2
09:00-	southeast	east	1.4	1.9	3.5	3.9
10:00-	south	southeast	3.2	1.4	6.8	3.3

According to manual observation data in Daugavpils total quantity of clouds was 8octas (5 octas low level clouds, 3 oktas midlevel clouds, altitude of the cloud base above ground level (AGL) 950m, visibility 14km.

1.8. Aids to Navigation

NIL

1.9. Communications

The radio equipment functioned normally and had no relation with the cause of incident.

1.10. Aerodrome information

NIL

1.11. Flight recorders

NIL

1.12. Wreckage and impact information

The helicopter was recovered from the accident site to the hangar in the Riga International airport. Inspection revealed that the tail-rotor drive components remained intact. The tail rotor turned normally. When the engine was disconnected the main-rotor mast and main transmission were turned by hand.

1.13. Medical and pathological information

Accordingly to excerpt from medical card issued by Daugavpils Regional Hospital and person medical examination protocol the pilot had bruise of head and face scratches.

1.14. Fire

NIL

1.15. Survival aspects

NIL

1.16. Tests and research

1.16.1. Fuel analyze

Fuel without mechanical additives and water pollution (Testing Report No.67109)

1.16.3. Engine Model 250-C20R/2, S/N CAE 295354, oil analyze

Oil analyzes results according qualitative indices:

- Oil conforms to oil brand Mobil Jet Oil 254 standard requirements;
- Not diluted with fuel or coolant liquid;
- Water addition not stated;
- Viscosity 4-7%;
- Cu content 1ppm;
- Fe content 2ppm;
- Fe content before oil filter strainer 48ppm;
- Al content before oil filter strainer 11ppm.

1.16.4. Engine Model 250-C20R/2, S/N CAE 295354, oil filter inspection

Oil filter housing marking:
FACET LUBE FILTER,
P/N 1740001-C3,
REV A S/N 249
Use Element P/N 038088-08

Figure 15. Facet Scavenge Filter

Oil filter was disassembled for inspection.

Figure 16. Disassembled Scavenge oil filter

Oil filter rough element marking:

FACET,
FAA-PMA
038088-08, Non-cleanable

As a result of inspection on outer side of metallic filter it was stated metallic chips. The rough filter element was cut and was stated that on inside filtering material of fine element from oil intake side are metallic chips. At oil outlet side there were not metallic chips or mechanical additives.

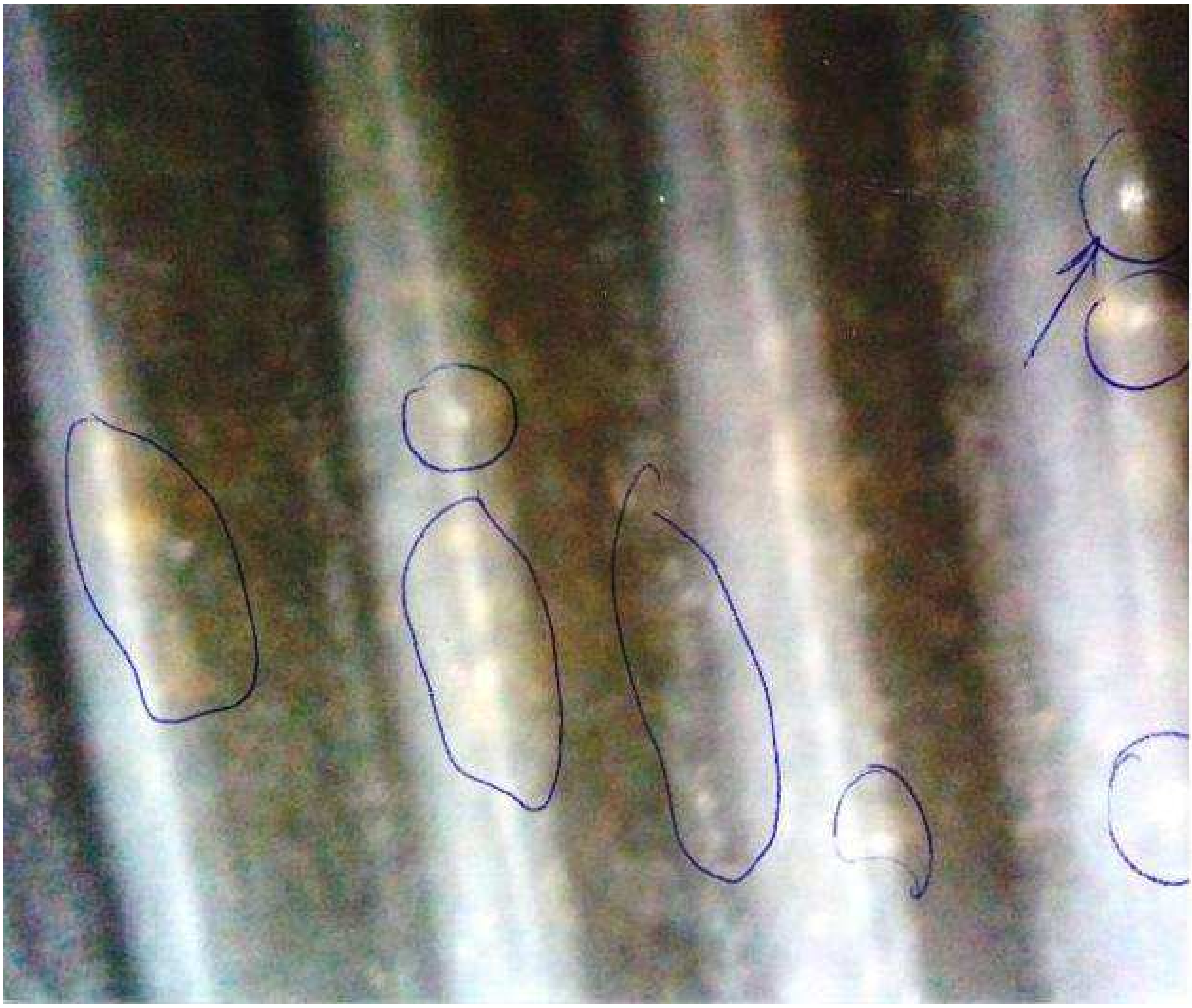


Figure 17. Metallic chips inside filtering material

As a result of inspection of Oil Filter and both filter elements it was stated:

- The engine oil has high content of metals –Fe and Al;
- On both filter elements (rough and fine) are metallic chips – ferromagnetic and nonmagnetic that could witness about engine bearings or other mechanical component failure;
- Oil filter not damaged and is in good working condition.

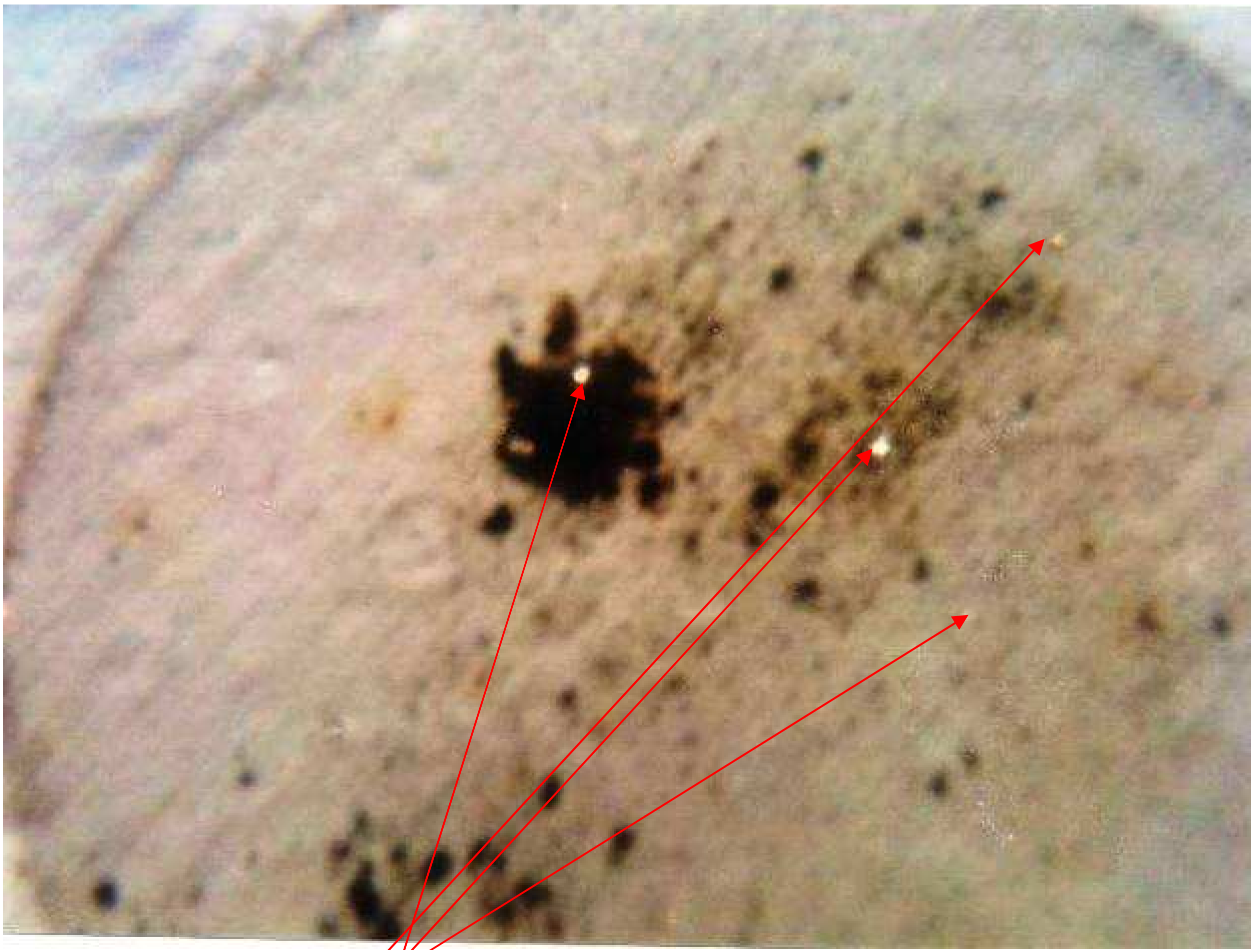


Figure 18. Microscope image of metallic chips

1.16.5. Engine 250-C20R/2 inspection after disassembling from helicopter

For further inspection with aim to reveal the possible engine damaged components the engine was removed from helicopter.

Figure 19. Removed engine

Figure 20 Removed engine on the stand for disassembling into sections

After removing from helicopter the engine was disassembled into modules:

- Combustion section;
- Turbine section;
- Accessory gearbox section;
- Compressor section.

Figure 21 Compressor section

In intake of compressor section were some debris noted as well as traces of oil leakage.

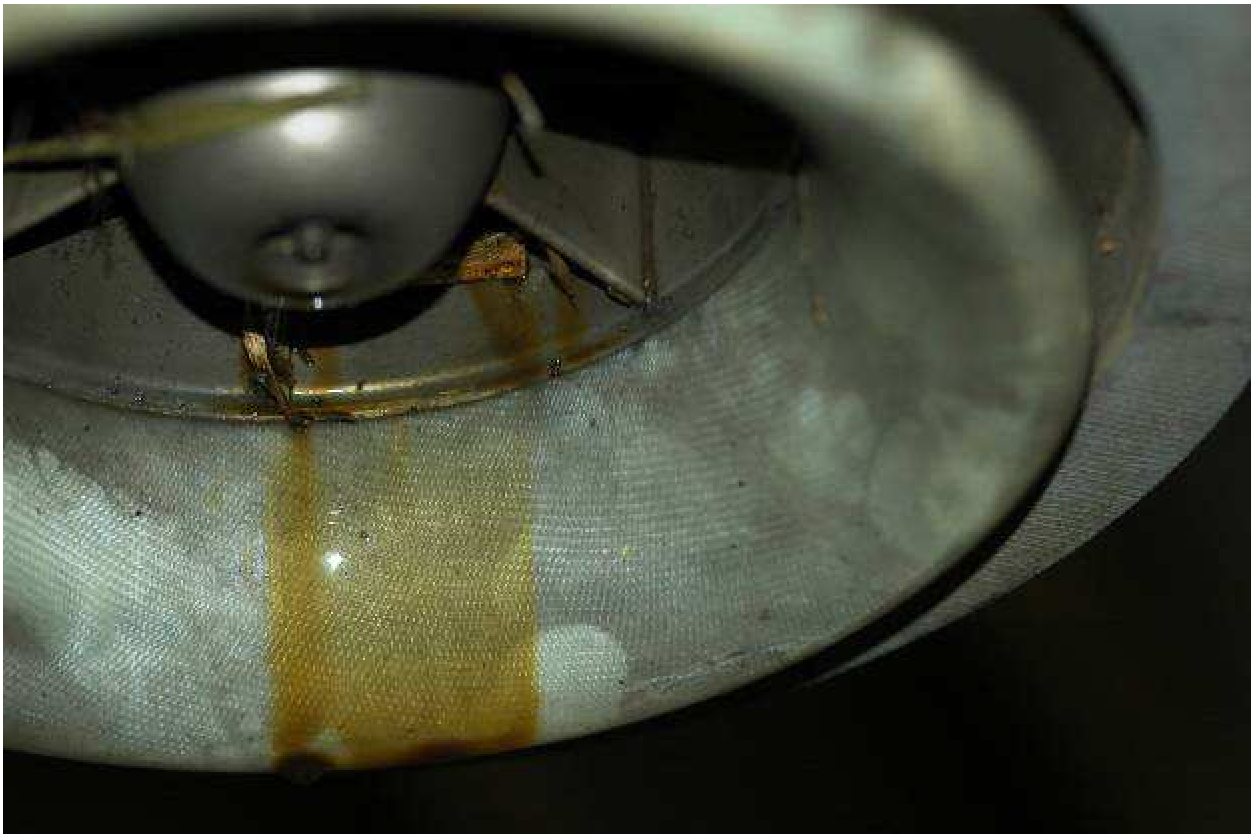


Figure 21. Traces of oil leakage

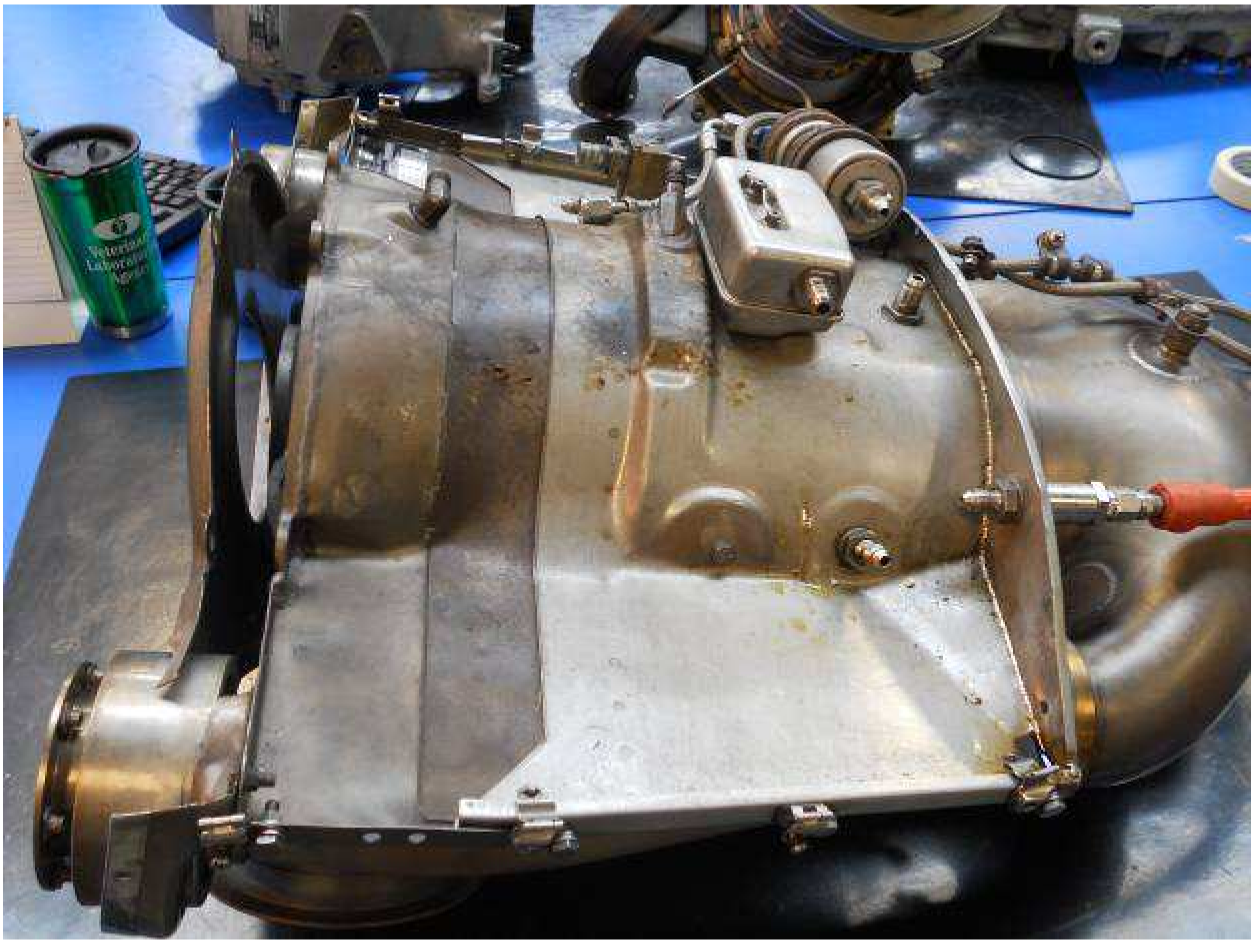


Figure 22. Turbine section

Figure 23. Accessory gearbox section (opened)

Figure 24. Combustion section

Figure 25. Pieces of metal in the poured oil from engine

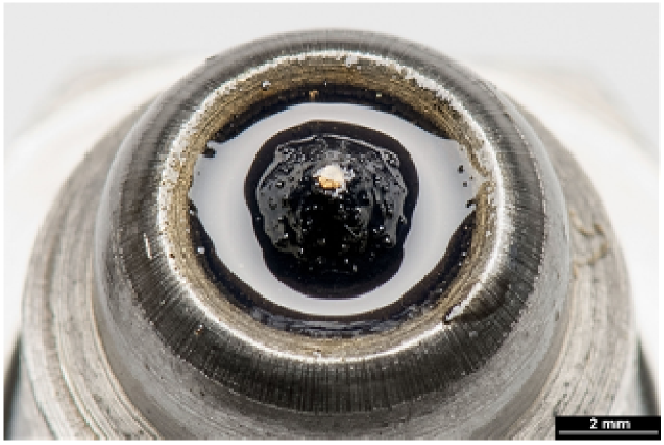


Figure 26. Oil with small amount of metallic chips on the Lower chip detector

Figure 27. Metallic chips on the upper chip detector

Figure 28. Instrument panel warnings

The warning and caution indication light on the instrument panel were checked by pressing button "Test warning and caution lights". All warning lights including "Engine chips" were lighting during checking.

After separating into modules and performing visual investigation of modules and chip detectors it was stated:

- upper metallic chip detector is full with metallic chips;
- it seems that the compressor gear gearwheel some teeth has signs of probable pitting, it was difficult to make any conclusion by visual inspection;
- on the compressor axle the cogwheel surface wear out (not visible cracks);
- the gear box bearings without visible defects and had free rotation without any noise;
- the compressor gear bearing in fastening place had lateral play (5-7mm);
- in the compressor inlet tract has some quantity of oil;
- pieces of metal in the poured oil from engine;
- the warning indication light "Engine chips" on the instrument panel was not damaged.

1.16.6. Engine 250-C20R/2 inspection after disassembling from helicopter

Taking into account the opened marks and indications of deficiencies and conclusions made after the on-site investigation and in the hangar after separating engine into modules, investigators had opinion that possible causes of engine fault (lost power) could be lack of the gearbox oiling due to contamination of the oil pump with metallic chips, damage of the compressor vibration damper, that causes leaking oil in the compressor inlet tract or damage of accessory gearbox section bearings. Therefore the compressor and accessory gearbox were sent to Air Transport Safety Institute laboratory (NLR) in Amsterdam for further investigation in the laboratory conditions in accordance with the Memorandum of Understanding between the Transport Accident and Investigation Bureau and NLR.

The proposed phases in the investigation process were following:

- Investigation and identification of the material of the chipping found in the oil, filters and gearbox;
- Determination of the source, or sources, of the chipping, based on manufacturer data;
- Macro-inspection of the gearbox and components that share the same oil system;
- Determining the most probable cause of failure of the engine;
- Discussing further steps in the investigation if necessary.

To identify of the material of the chipping found in the oil the metallic chips were analyzed with Scanning electron microscope (SEM) as well as Energy dispersive analysis of X-rays (EDX) of particles were performed. The chips from the Lower chip detector were not analyzed, because there were only a few very small particles.

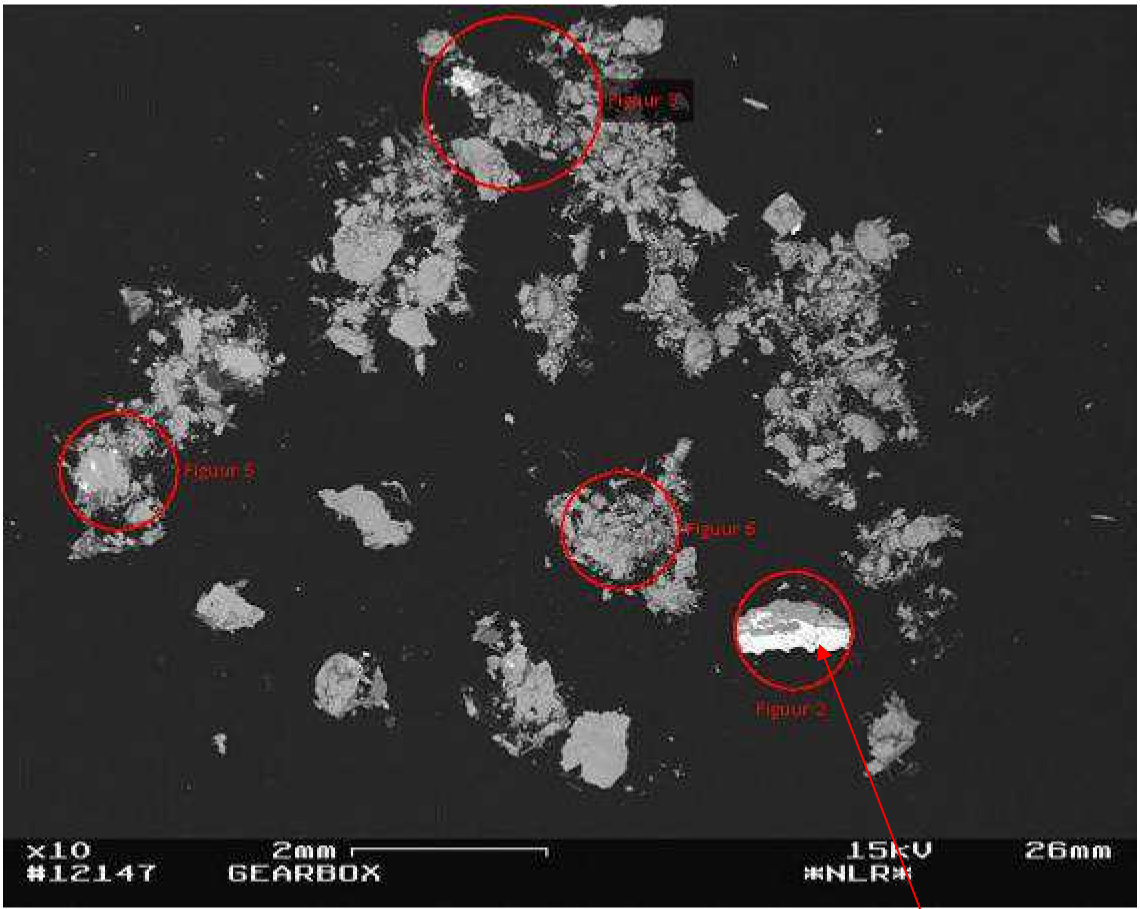


Figure29. Overview of the particles found on the Upper chip detector (after cleaning)

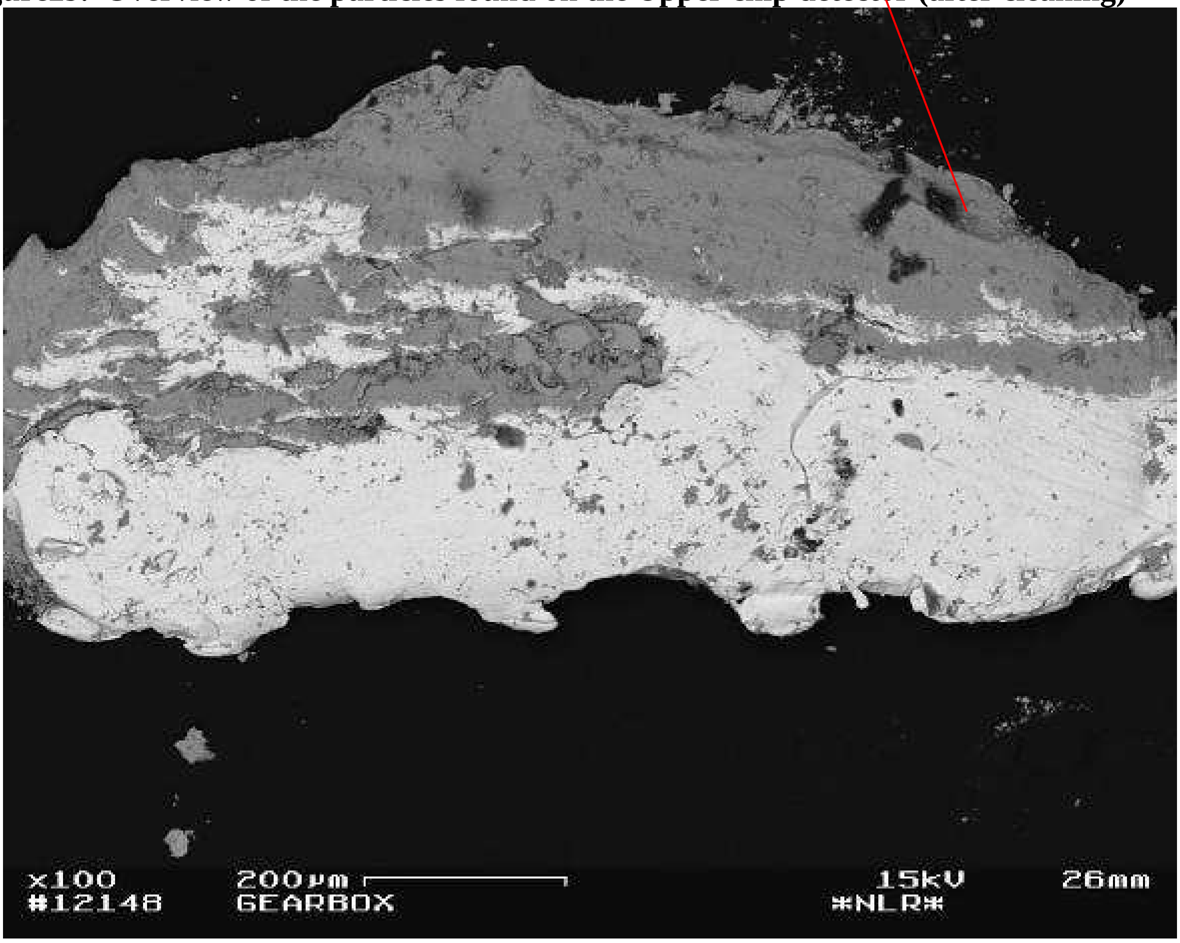


Figure 30. Image higher magnification. The white material is 100 % silver

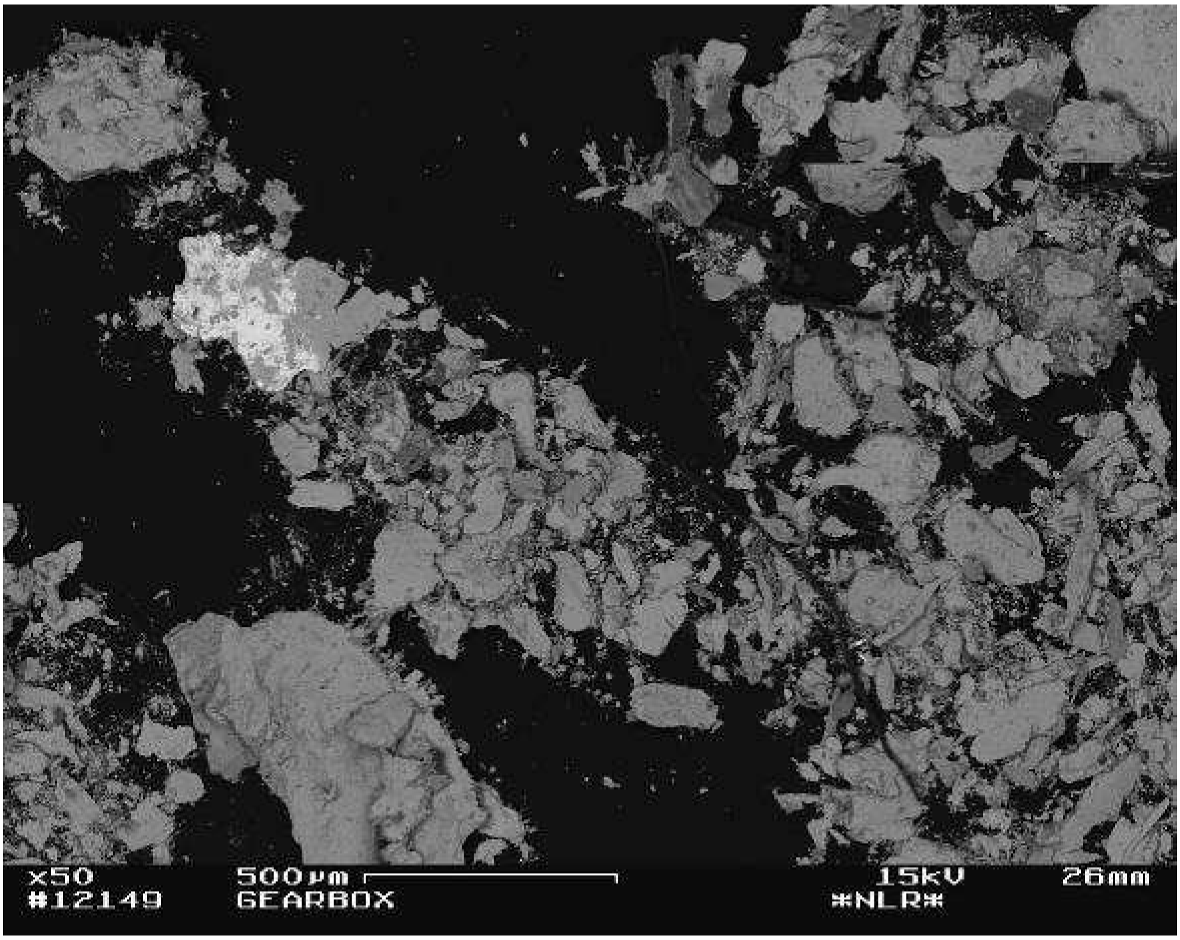


Figure 31. Higher magnification image

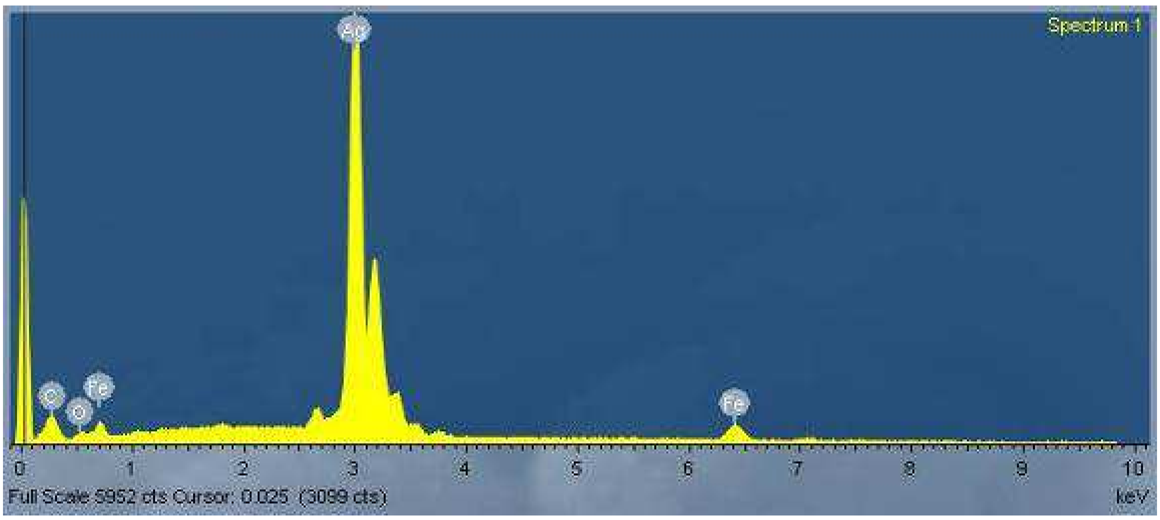


Figure 32 EDX analysis of the white appearing material in Fig. 10. Material mainly consists out of silver

Table 1 Main chemical composition (wt%) of the particles present on the Upper chip detector (EDX analysis)

Particle	V	Cr	Mn	Fe	Ni	Mo	Si
A	1.16	3.7		79.99		3.48	
B		1.07	0.66	77.09	1.58	0.93	0.2
C	0.52	2.84		86.31			

As shows Table 1 the particles that laboratory found in the Upper chip detector can be grouped into four different materials:

- particles with a composition similar to M50 (3.7Cr, 3.5Mo, 1.2V measured);
- particles with a composition similar to TBA-2e (1.1Cr, 1.6Ni, 0.93Mo and 0.66Mn measured);
- particles with a composition of 0.5V, 2.8Cr (+balance Fe);
- Pure Ag particles attached to Fe particles.

The silver, which is often used as a coating of the cage, and the bearing steels makes investigators believe that the failed component is a bearing, therefore there was necessary to know which bearings contain these alloys and Ag-coatings for more detailed expertise. Such information was only in the disposal of engine manufacturer Rolls-Royce. Taking into account that information about materials data were not in disposal of NLR laboratory but determination of the sources of the chipping was possible only based on manufacturer information, a decision was made to contact with engine Manufacturer Rolls-Royce for getting necessary data of materials. After discussing further possible investigation with Rolls-Royce, company offered assistance with the investigation, subsequent to work conducted at NLR and a decision was made to conduct the further investigation at H+S Aviation AMC in Portsmouth, England. Macro-inspection of the Accessory gearbox section and components that share the same oil system was performed in the NLR;

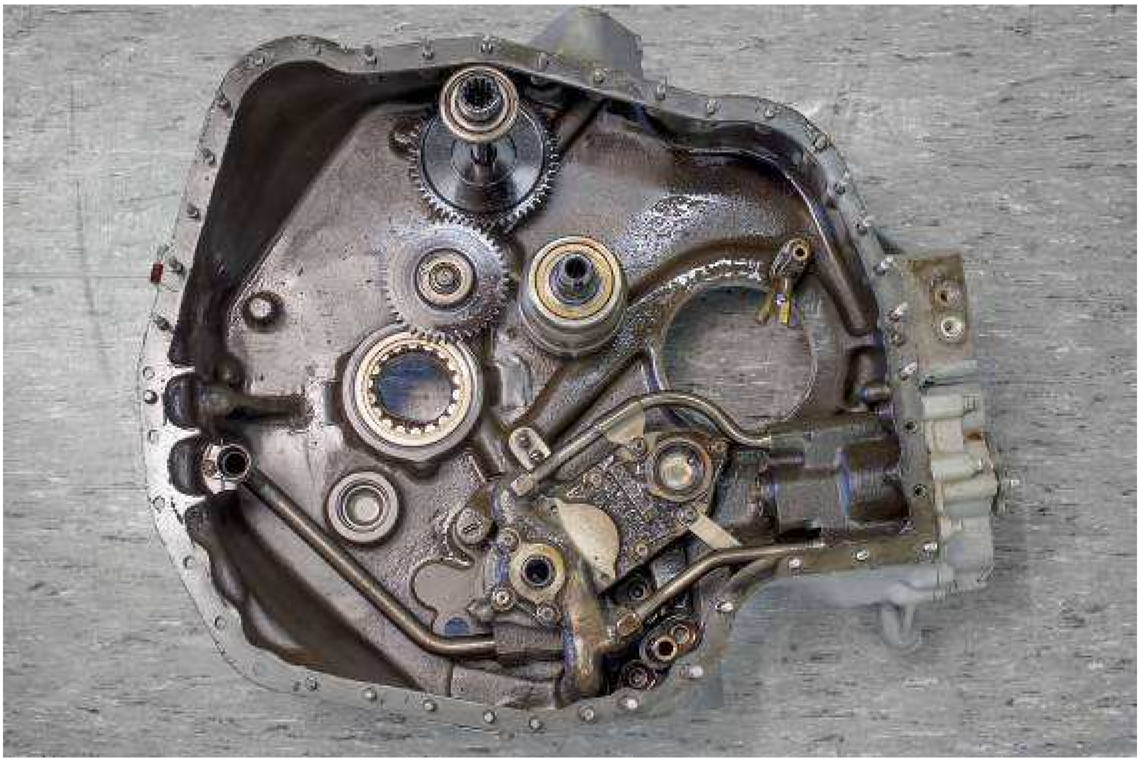


Figure 33A.

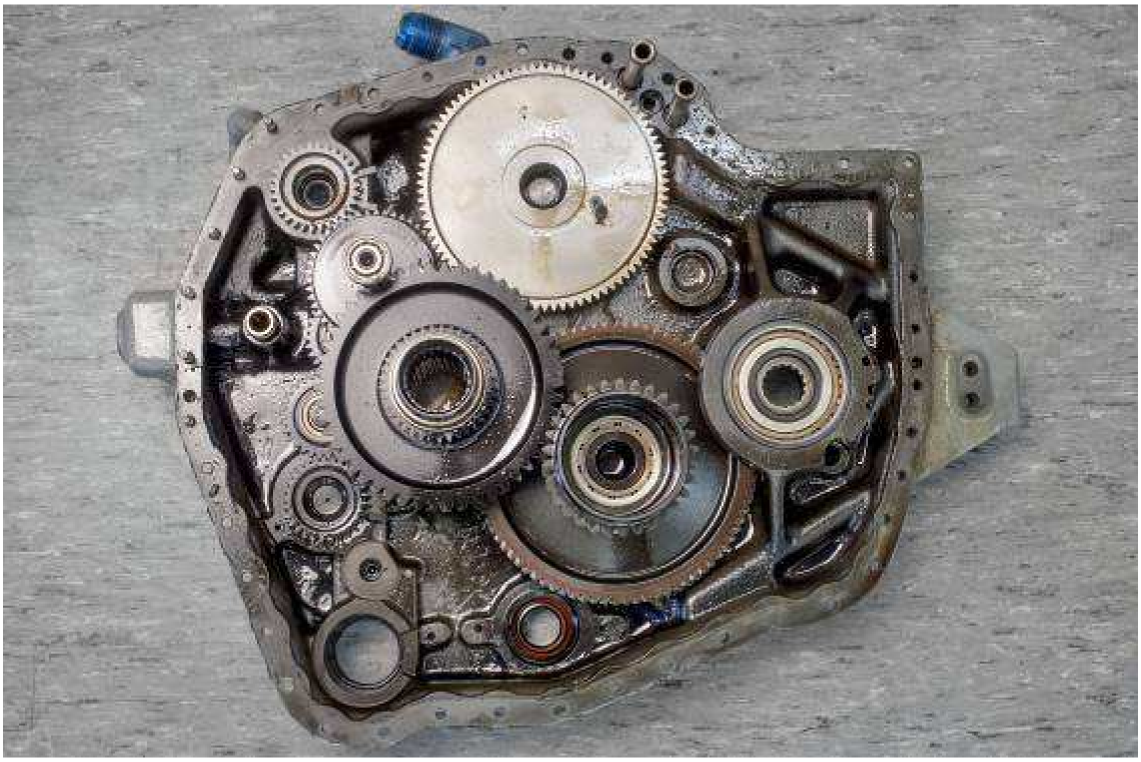


Figure 33B. Accessory gearbox section cogwheels

Turning the components of the gearbox does not give an audible sound of bearing problems. Also there was almost no resistance to turn the gears and therefore the bearings.

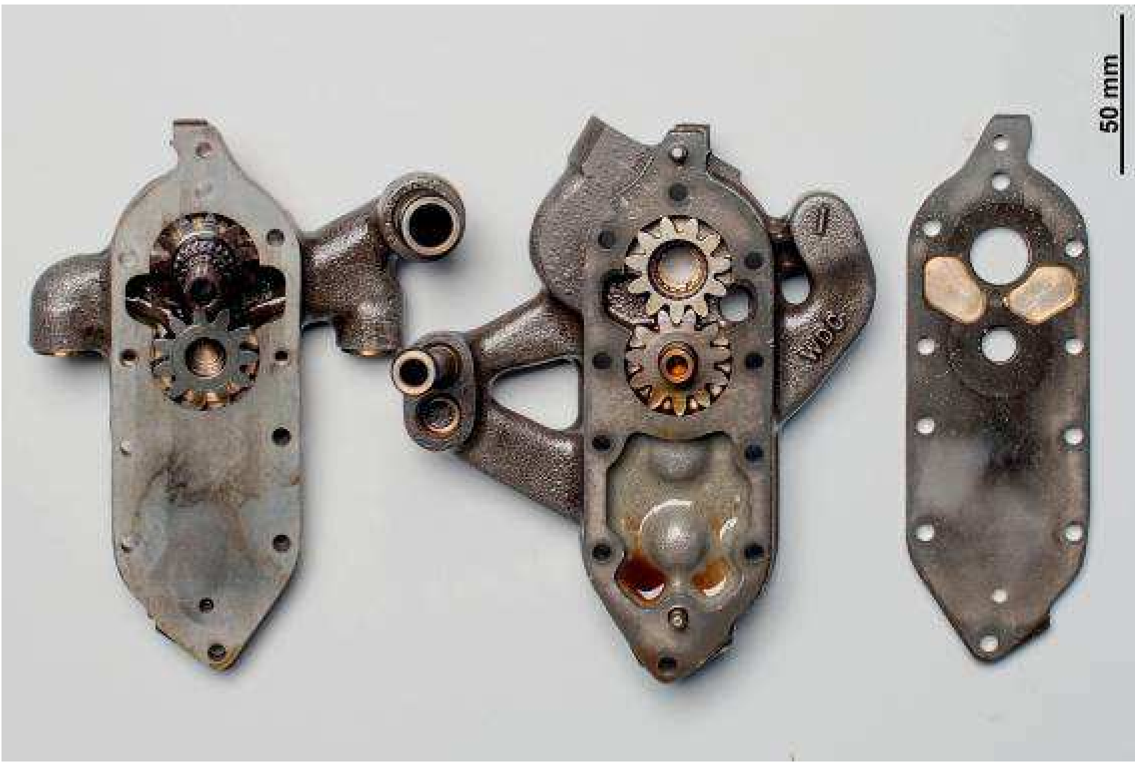


Figure 34. Gearbox oil pump (disassembled) and cogwheels

The gearbox oil pump was disassembled and there not found any metal particles or damage to the teeth of the cogwheels of the oil pump.

1.16.7. Engine 250-C20R/2 modules inspection at the H+S Aviation Ltd AMC

The investigation was conducted by Rolls-Royce engineers on 15/16 April 2013 with the TAAIB investigator in charge providing oversight.

The engine Model 250-C20R/2, S/N CAE-295354, **Compressor (CAC 15553; 23050833**) inspection and disassembling was carried out. As a result of inspection it was stated following:

- Rotation was checked, was found rubbing with quick rundown;
- Some debris noted in intake;
- When No1 scavenge and feed tubes were removed, oil residue found in both tubes;
- When No1 reducer was removed, oil residue found in reducer;
- A rig test of the No. 1 bearing pressure reducer was conducting referencing the oil flow requirements specified on the drawing. The drawing specified 0.6-1.0lb/min at 120 +/- 2 psi and 180 F +/- 5 degrees. The test included the pressure reducer and the No. 1 bearing oil supply line. The reducer flowed .76lb/min. A second test was conducted which confirmed repeatability;
- When front support was removed No1 bearing found damaged;(Figure)
- With all contents of the front support still intact (front housing, bearing outer race and carbon seal) an air supply was attached to the oil feed to check if clear. The air flow was good with no debris exiting the feed;
- No 2 bearing axial play was checked found to be 0.009” (limit max 0.014”);
- Shroud clearance was checked, found to be 0.0135”;
- Rotor total travel checked , found to be 0.0495”(limit minimum 0.030”);
- Compressor case blade tracks found to have heavy scoring due to blade contact as a result of the No1 bearing failure; (Figure)
- Front shroud found to have damage to coating, does not appear to be contact damage. (Figure)

Figure 35. Damaged No1 bearing.

The bearing was found during inspection was found that a three (3) roller wide section of the separator was fractured. The remaining section was intact but showed damage from roller contact inside the individual pockets (windows). The damage was predominately to the top and bottom of the pockets but was also noted to the sides. The majority of the rollers retained within the remaining section of separator show signs of size reduction, flattening and end wear.

Figure 36

Two (2) of the remaining three (3) rollers were found inside the housing as was a localized area of debris which was believed to be missing separator and/or roller material. This material was wiped with a clean paper towel and placed in a bag. The aft end (shoulder) of the bearing journal shows impact 360 degrees;

The **Gearbox (CAG 15459; 23035185)** of engine Model 250-C20R/2, S/N CAE-295354, had not major discrepancies noted during cursory visual. No further disassembly carried out.

The **Turbine (CAT 15354; 23038160) of** engine Model 250-C20R/2, S/N CAE-295354,

- Rotation was checked, both rotors found to rotate satisfactory;

- The first stage turbine nozzle shield and flow path shows heavy concentration of diffused material covering the shield OD as well as the pressure side of the first stage nozzle and downstream components; (Figure)

- Turbine disassembled to remove both rotors to view, further deposits found throughout the gas path;

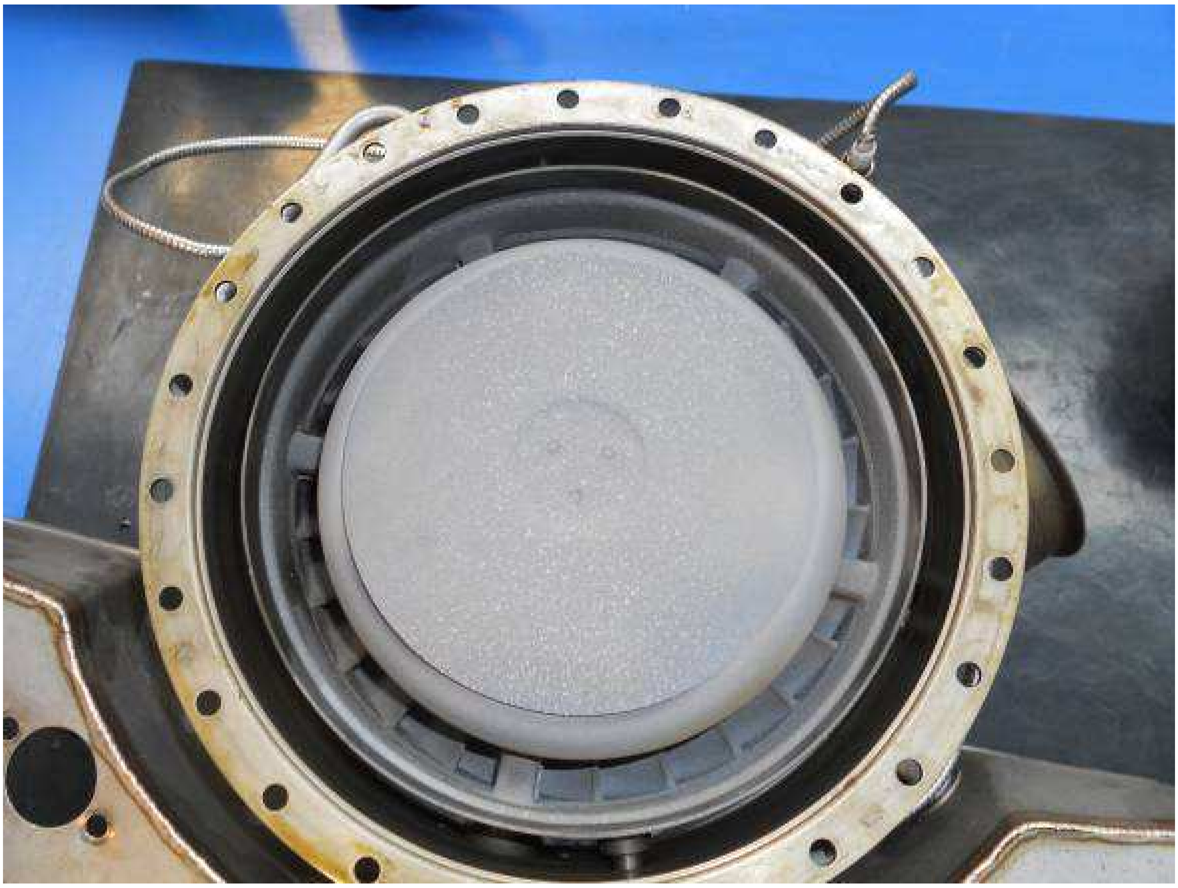


Figure 37 The first stage turbine nozzle shield and flow path shows heavy concentration of diffused material

Figure 38. Turbine 1st stg

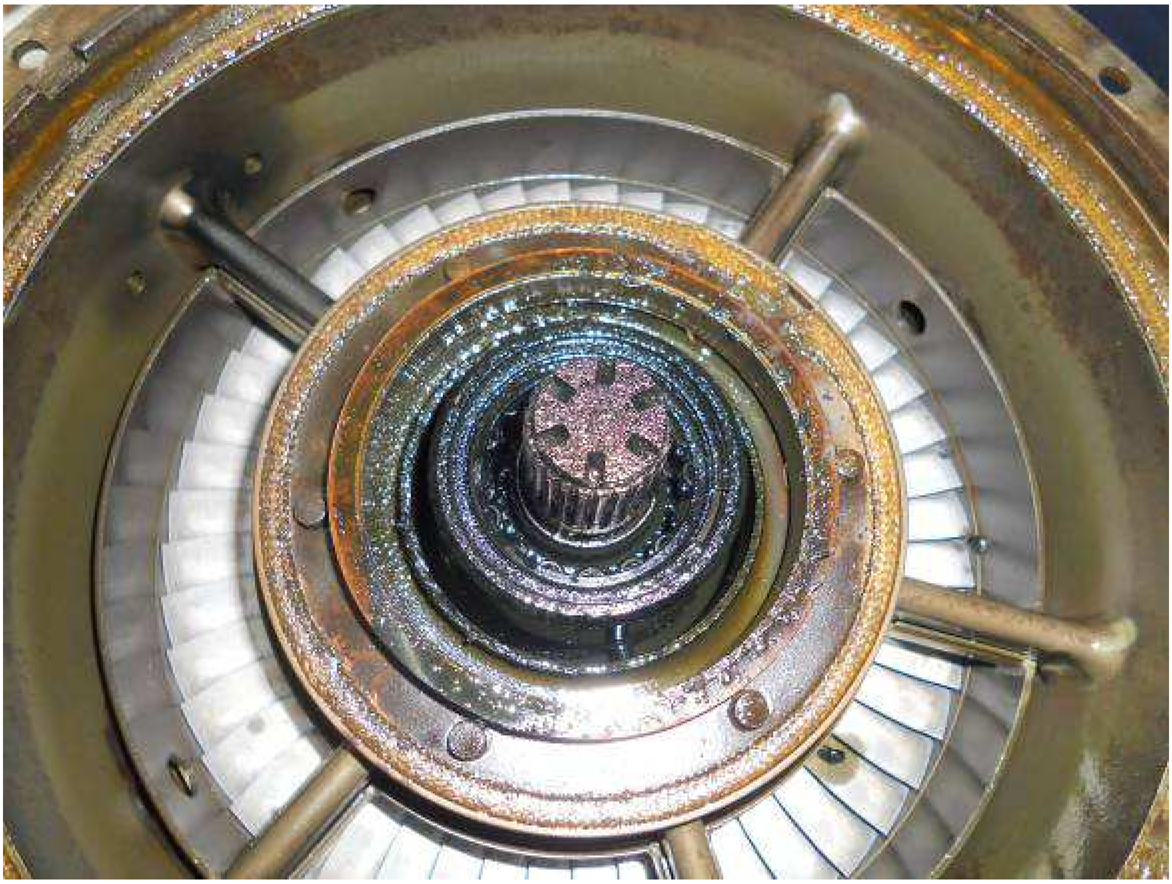


Figure 39. Heavy concentration of diffused material

Figure 40. Heavy concentration of diffused material

Figure 41 Front shroud damage to coating

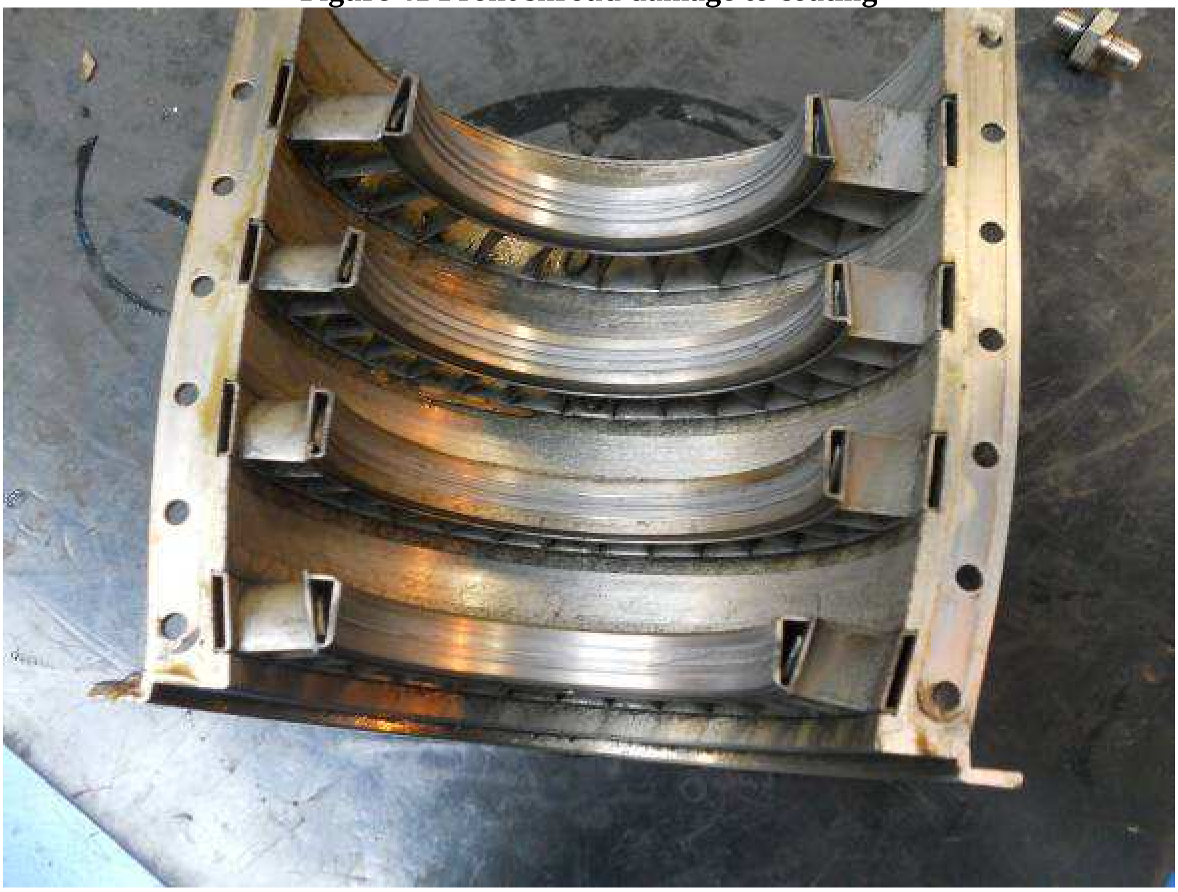


Figure 42 Compressor case blade tracks have heavy scoring due to blade contact

Figure 43. Blades tip rub on the stage 1 compressor wheel contact

The findings during inspection reflect the cause of occurred accident - the resulting loss of power due to the unsupported rotor having heavy contact with the compressor cases. The magnetic chip indication was from the breakup of the No1 bearing resulting in the case material passing through the engine and depositing on the first stage nozzle and gas rotor.

1.16.8. Engine 250-C20R/2 components metallurgical inspection

Because during inspection in the H+S Aviation the damage of the No. 1 bearing was revealed the compressor components were shipped to the Rolls-Royce Corporation Materials Laboratory in Indianapolis, Indiana, USA for detailed examination and analyses to find the cause of bearing No 1 damage.

Front Compressor Support Assembly; P/N: 23039752-C; S/N: 42207 inspection

Visual Examination

The condition of the front compressor support assembly documented in *Figures 44* and *45*. *Figure 45* shows witness marks on the aft flange indicating the orientation of the compressor case as it was installed. The radial witness marks are from the compressor case split lines. The support assembly was generally oily but exhibited no obvious damage or impact marks on the struts.

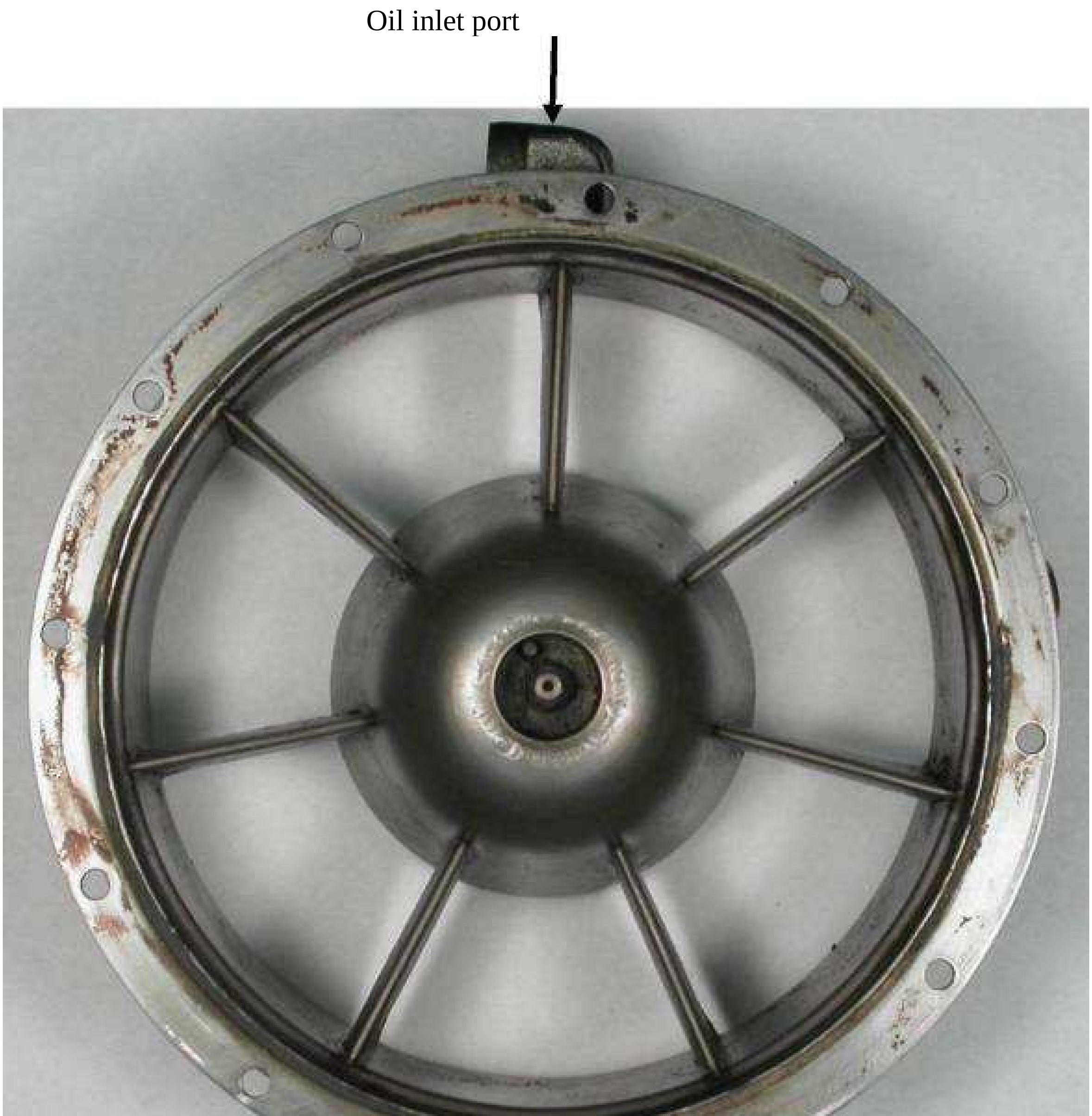

Oil inlet port

Figure 44. The front compressor support assembly viewed from the front side

Figure 45. The front compressor support assembly viewed from the aft side

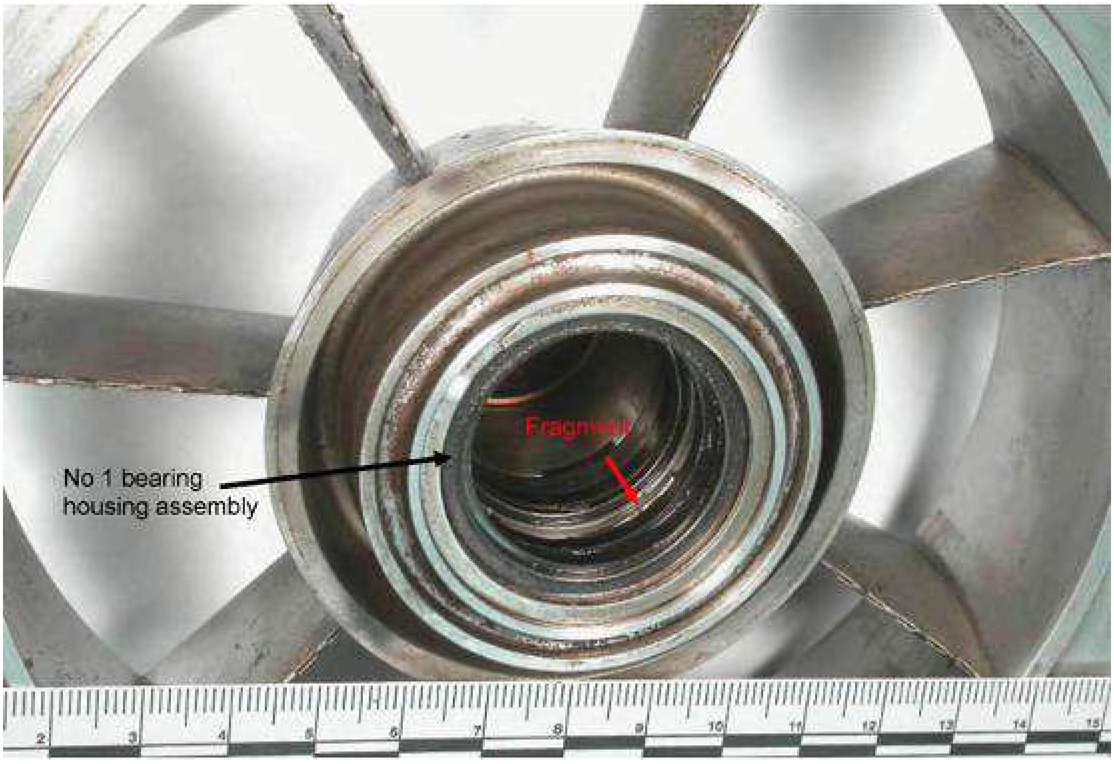


Figure 46. The aft side of the No1 bearing sump area

The No 1 bearing housing was still installed in the hub area, and bearing fragments and/or debris was noted within the housing as shown in *Figure 46.* Additional debris was noted between the bearing housing and the front support hub wall after the bearing housing was removed. *Figure 47* shows the debris fragment in the front support cavity

Figure 47. After the bearing housing assembly had been removed.

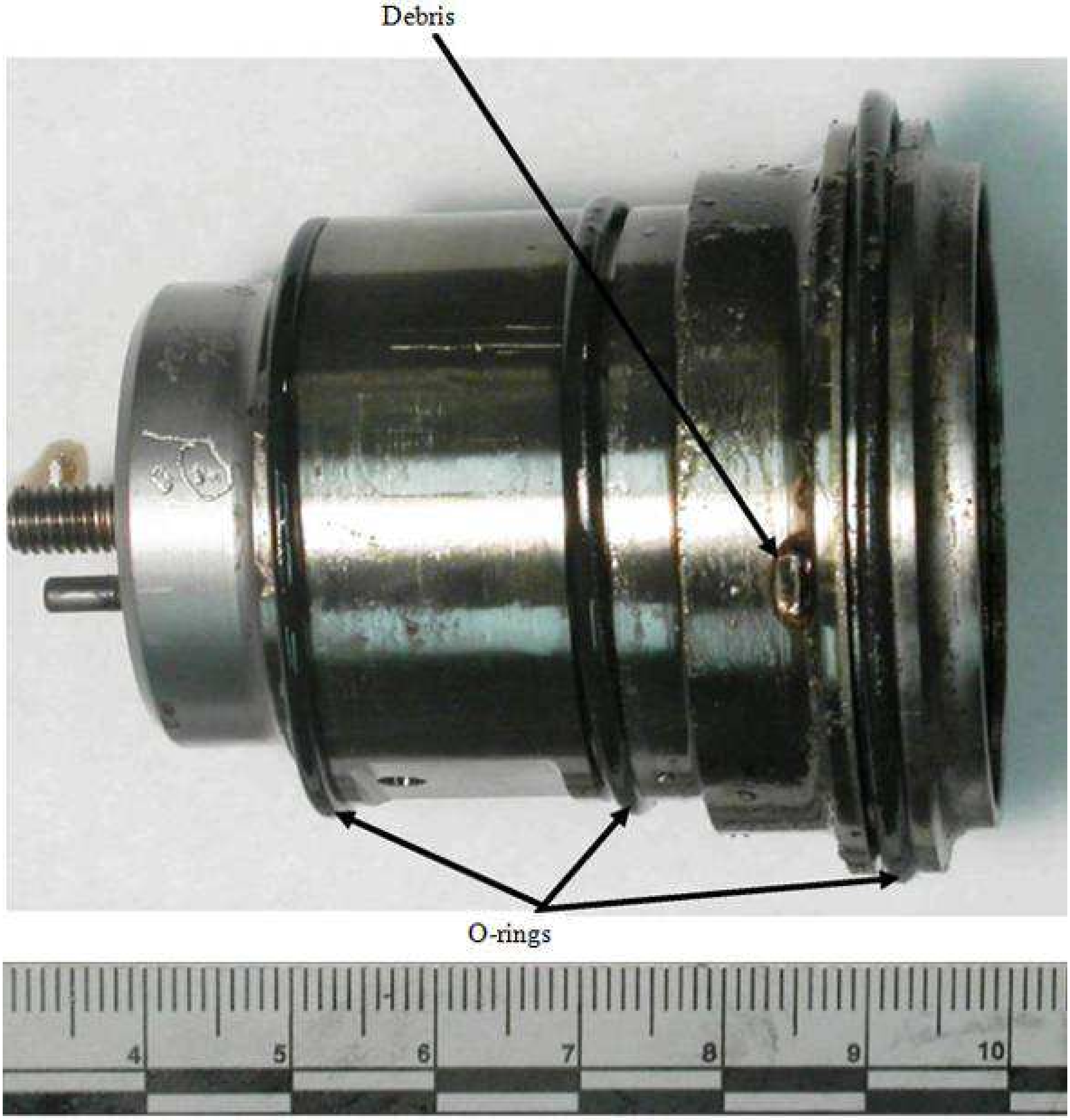


Figure 48. The outer surface of the bearing housing assembly with debris

Figure 48 shows the outer surface of the bearing housing assembly and the debris on its outer surface. The rubber O-rings were swelled and loose fitting.

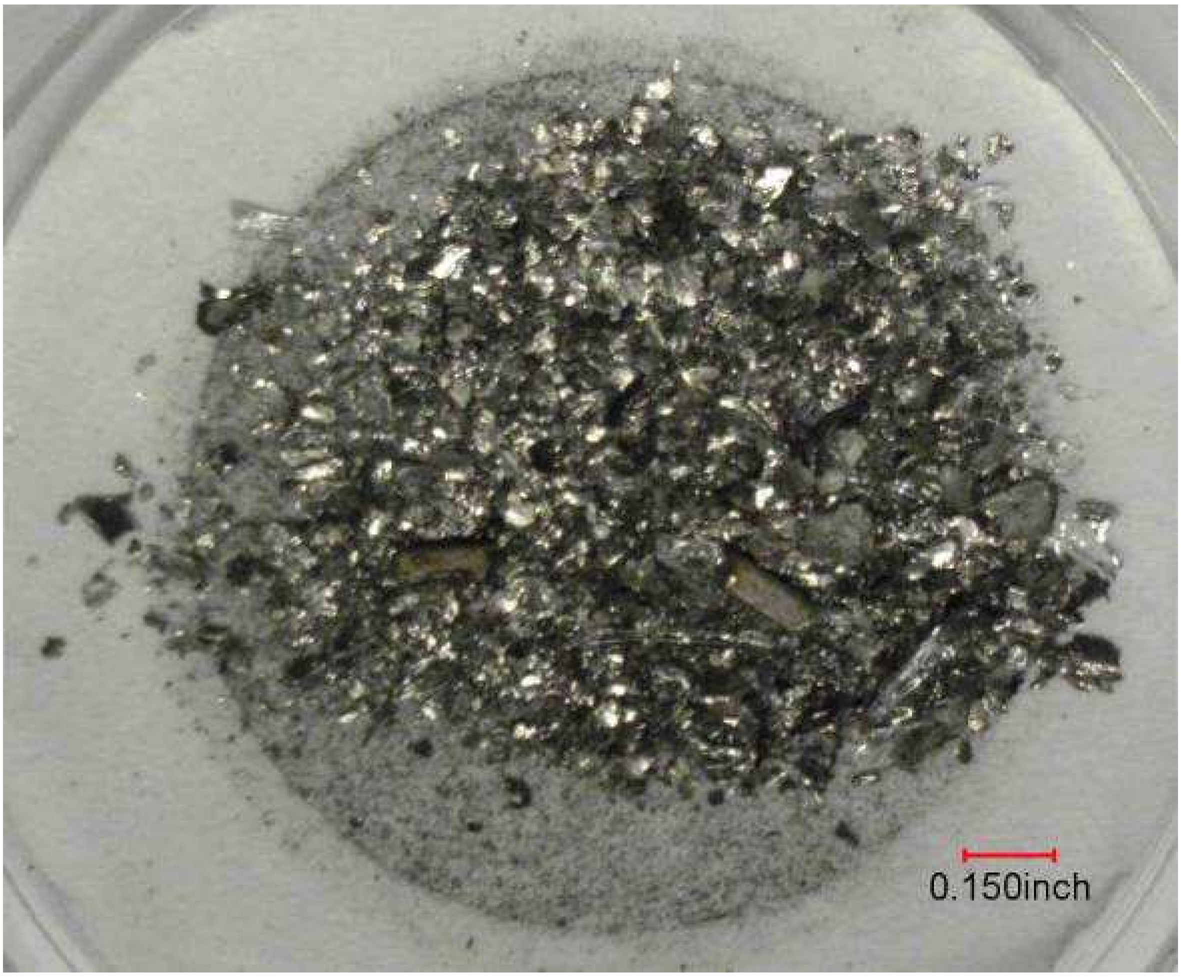


Figure 49. The debris flushed and collected from both the front compressor support and the bearing housing assembly.

Figure 49 shows the debris that was flushed and collected from both the front compressor support assembly and the bearing housing assembly. The bottom image reveals the larger fragment recovered from the bearing housing assembly sump area (see *Figure 46).* Several of these fragments were analyzed using the scanning electron microscope (SEM) x-ray dispersive analysis system revealing most of the fragments were consistent with an AMS6491 (M50) type material used in the outer ring, inner ring and rollers. Other fragments, including the fragment shown at the bottom of *Figure 49,* was consistent with an AMS6415 (4340) type material with silver plating which is consistent with the materials used in the No 1 bearing separator.

No.1 Bearing; P/N: 23009609; S/N: MP00888, inspection

Figure 50. The No.1 bearing (minus the outer race)

Figure 50 shows the components after they were cleaned to remove surface oil. The bearing outer ring was retained in the bearing housing and was photographed separately after it was removed from the housing and therefore is not included in this image.

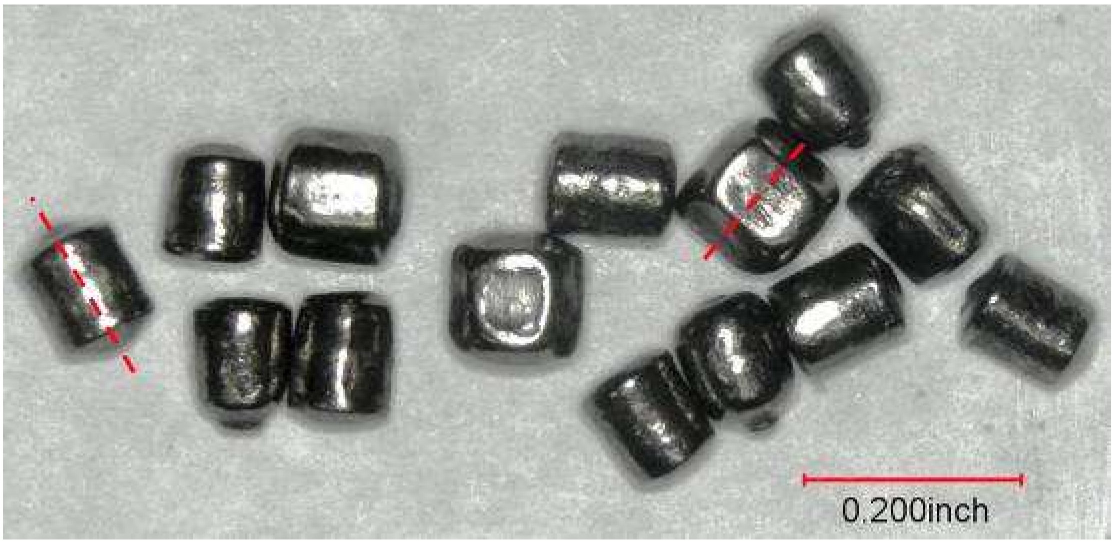
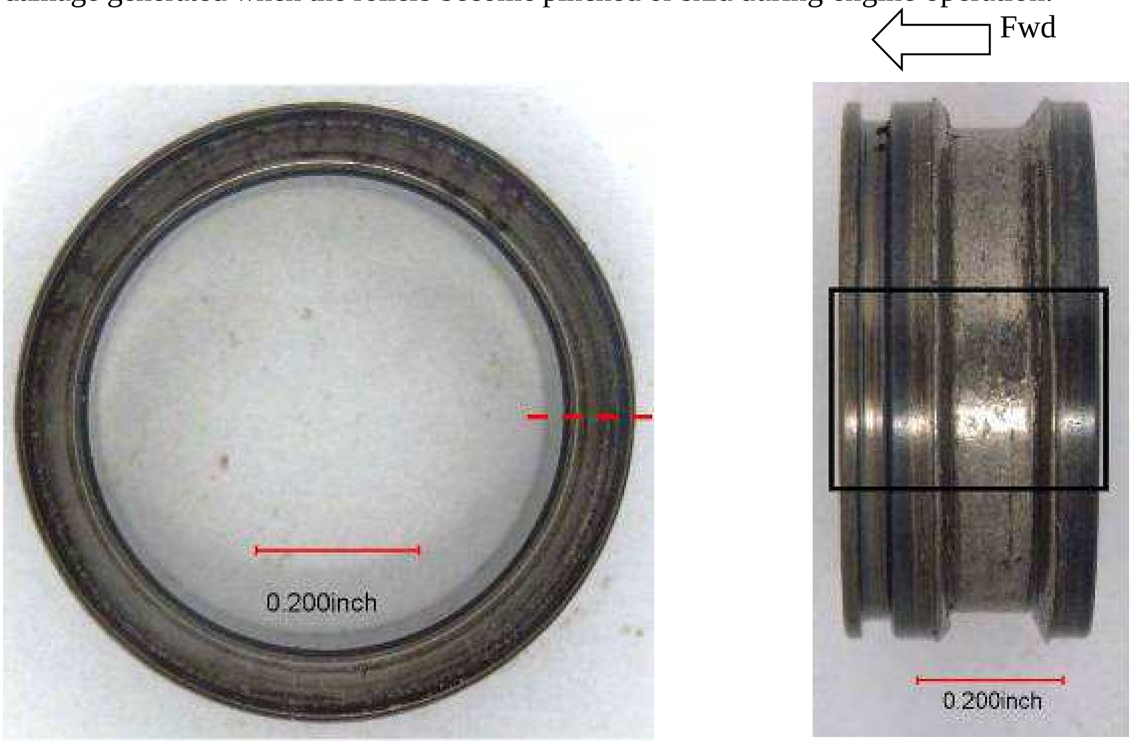


Figure 51. The variety of damage that the 14 (fourteen) rollers exhibited from the No1 bearing. The red dashed lines represent the planes for metallurgical sectioning

All fourteen (14) rollers were recovered and are shown in *Figure 51*. Many of the rollers contained flat spots, others exhibited bulging at the ends of the rollers, and some exhibited both conditions. Three rollers appeared larger than many of the other rollers, but roller diameter varied widely among all fourteen rollers.

Figure 52 The variety of damage that the 12 (twelve) of rollers exhibited from the No1 bearing. Two rollers had undergone metallurgical evaluation and were unavailable for the photograph.

Figure 52 shows twelve of the rollers lined up to illustrate the variations in size and damage. The other two rollers were sectioned for metallurgical analysis prior to recording this photograph. Detailed dimensional measurements of their diameters were deemed unreliable because of the flat spots on the circumference. The general condition of these rollers and the damage observed is consistent with damage generated when the rollers become pinched or skid during engine operation.



Inner ring aft face | Inner ring side view

Figure 53 Condition of the No.1 bearing inner ring. The black box represents the area shown in Figure 54. The red dashed line represents the plane for metallurgical sectioning.

Figure 53 shows the general condition of the No.1 bearing inner ring. The serial number on the aft side of the ring's face reads "SER MP00888". The right side image shows a general side view of the inner ring and highlights the area shown as a detailed view in *Figure 54.*

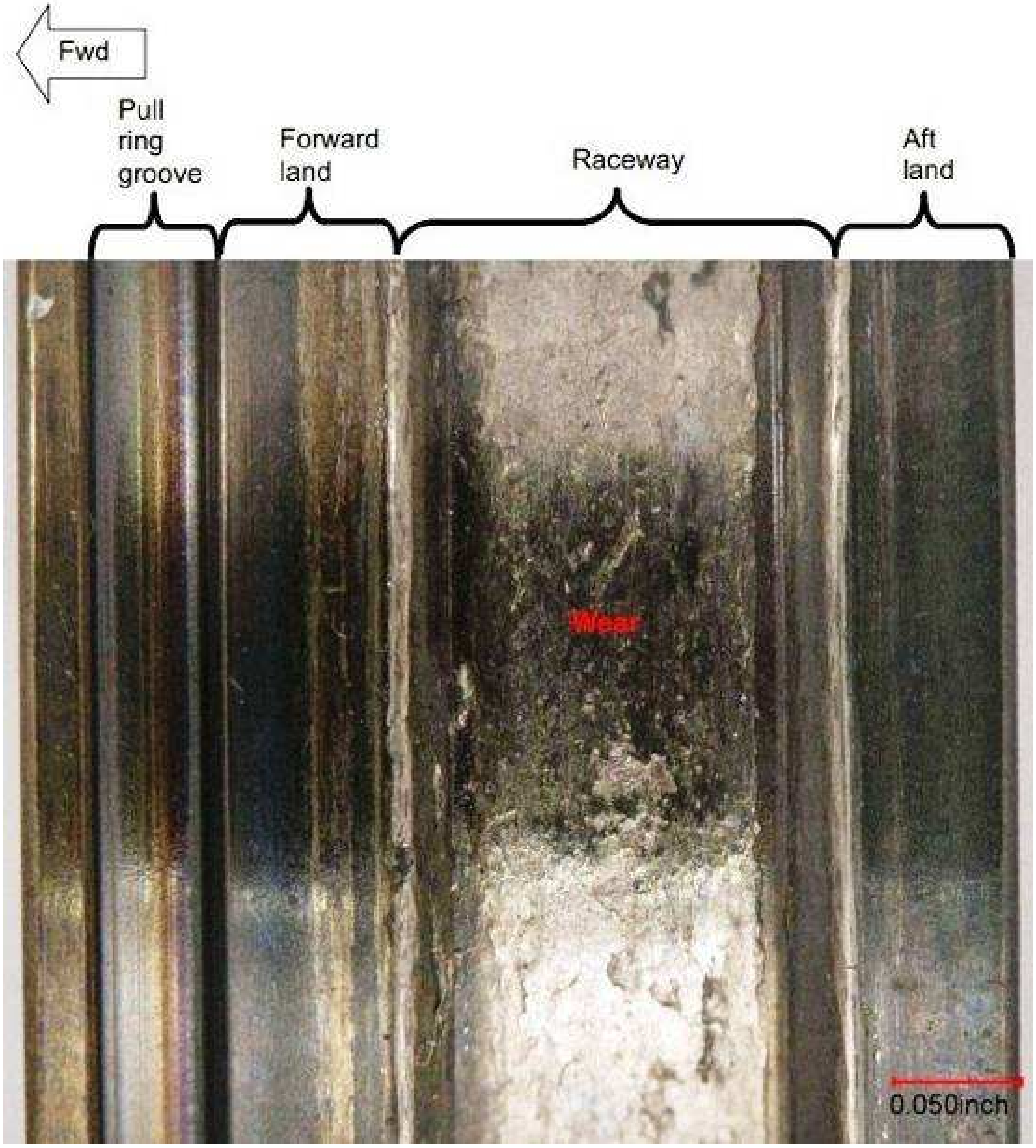


Figure 54. A localized portion of the No.1 bearings inner ring (see black box in Figure 53).

The raceway exhibited localized impact dents from rolling over debris and transferred or smeared material around the raceway circumference. The shoulders were also smeared and deformed outward resulting in an extruded or smeared material lip on the outer corners. The general condition of the raceway is consistent with damage generated during roller skidding during operation.

The bearing housing was sectioned and the No.1 bearing outer ring was extracted. *Figure 55* shows the general condition of the No.1 bearings outer ring after it was removed from the bearing housing.

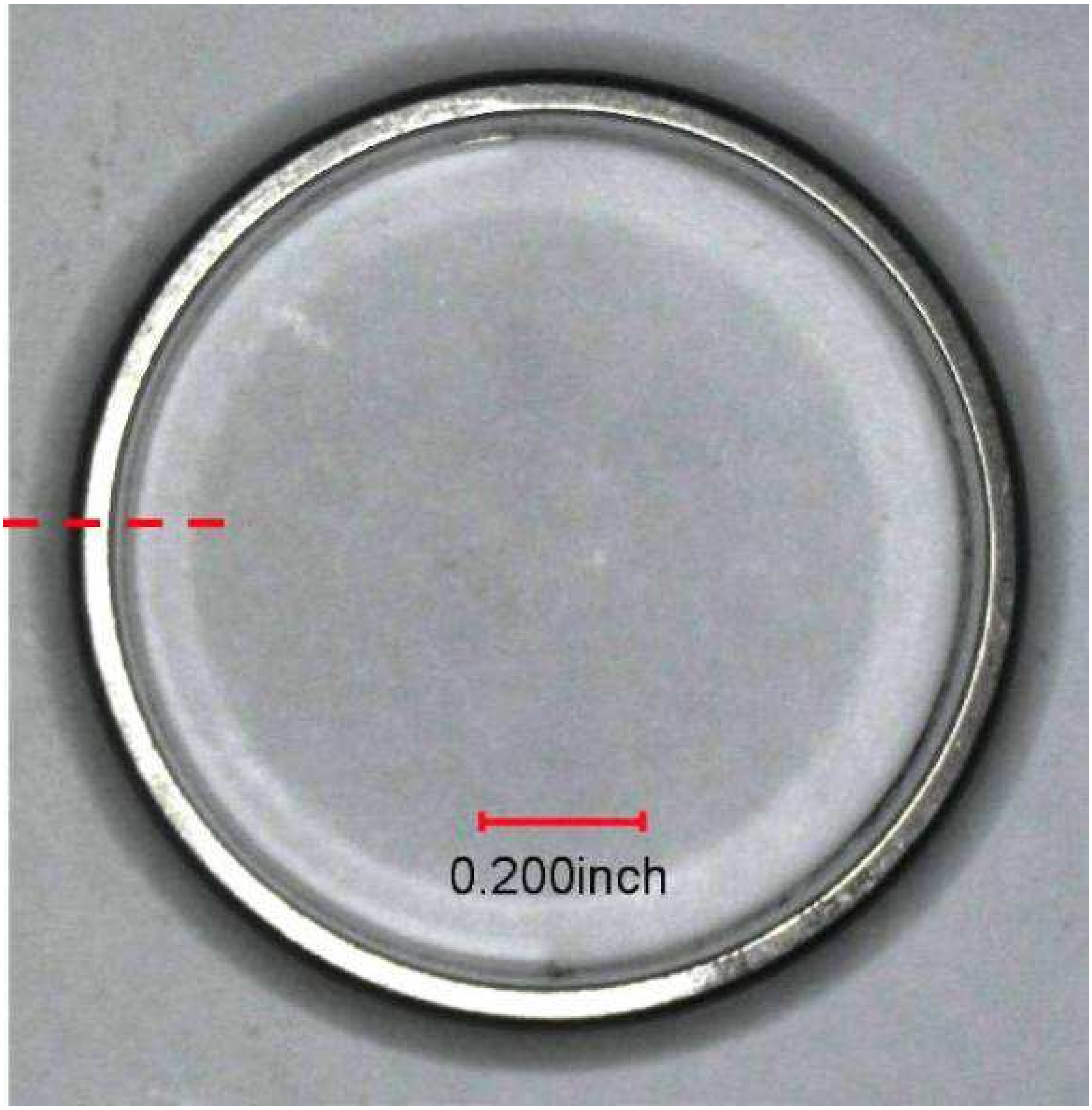


Figure 55. The general condition of the No.1 bearings outer ring after it was removed from the bearing housing. The red dashed line represents the plane for metallurgical sectioning.

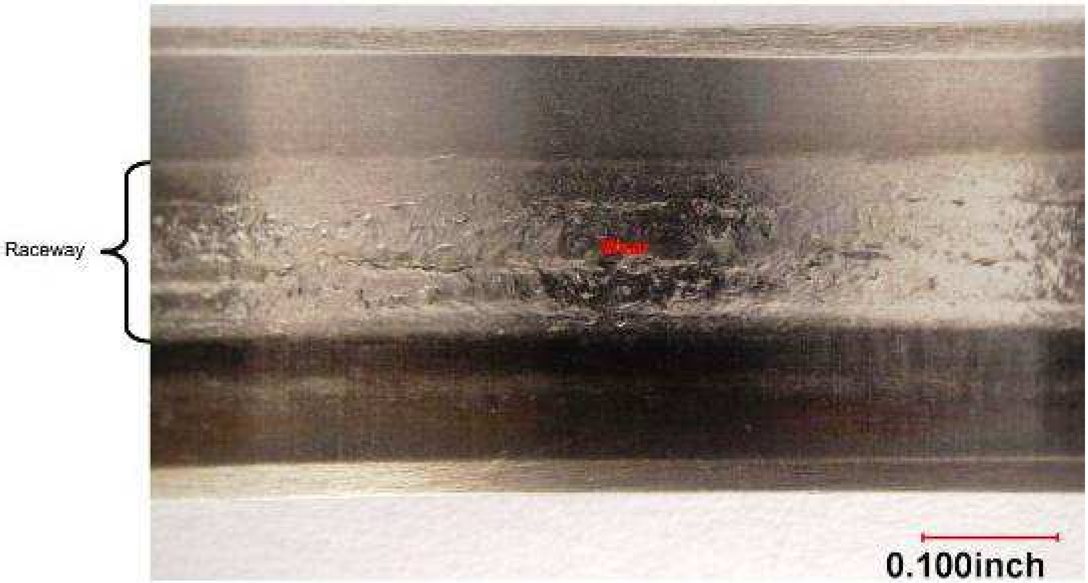


Figure 56. A detailed view of the outer raceway

Figure 56 shows a detailed view of the outer raceway. This surface appeared similar to the inner raceway and exhibited impact damage from rolling over debris and smearing. The aft side of the ring was slightly darker and heat tinted than the forward half.

*Figure 57*shows the general condition of the No. 1 bearings separator. The top image shows that the separator had fractured and two of the roller pockets were missing. The bottom image shows a view of the outer diameter of the separator. Significant wear and smearing was observed on the roller retention features and pocket web areas on the outer diameter of the separator as shown in the bottom image of *Figure 57*.

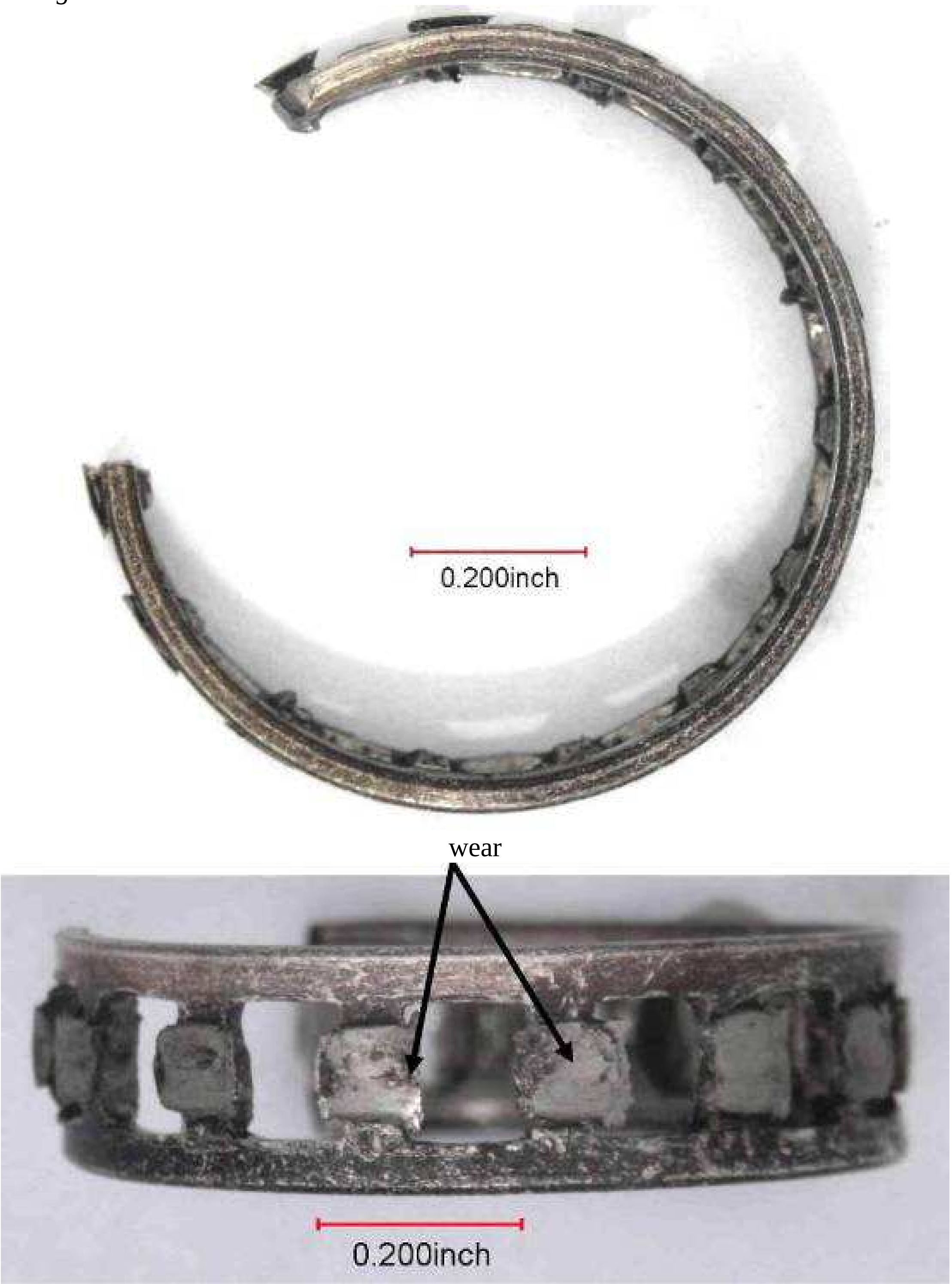


Figure 57. Condition of the No.1 bearing separator

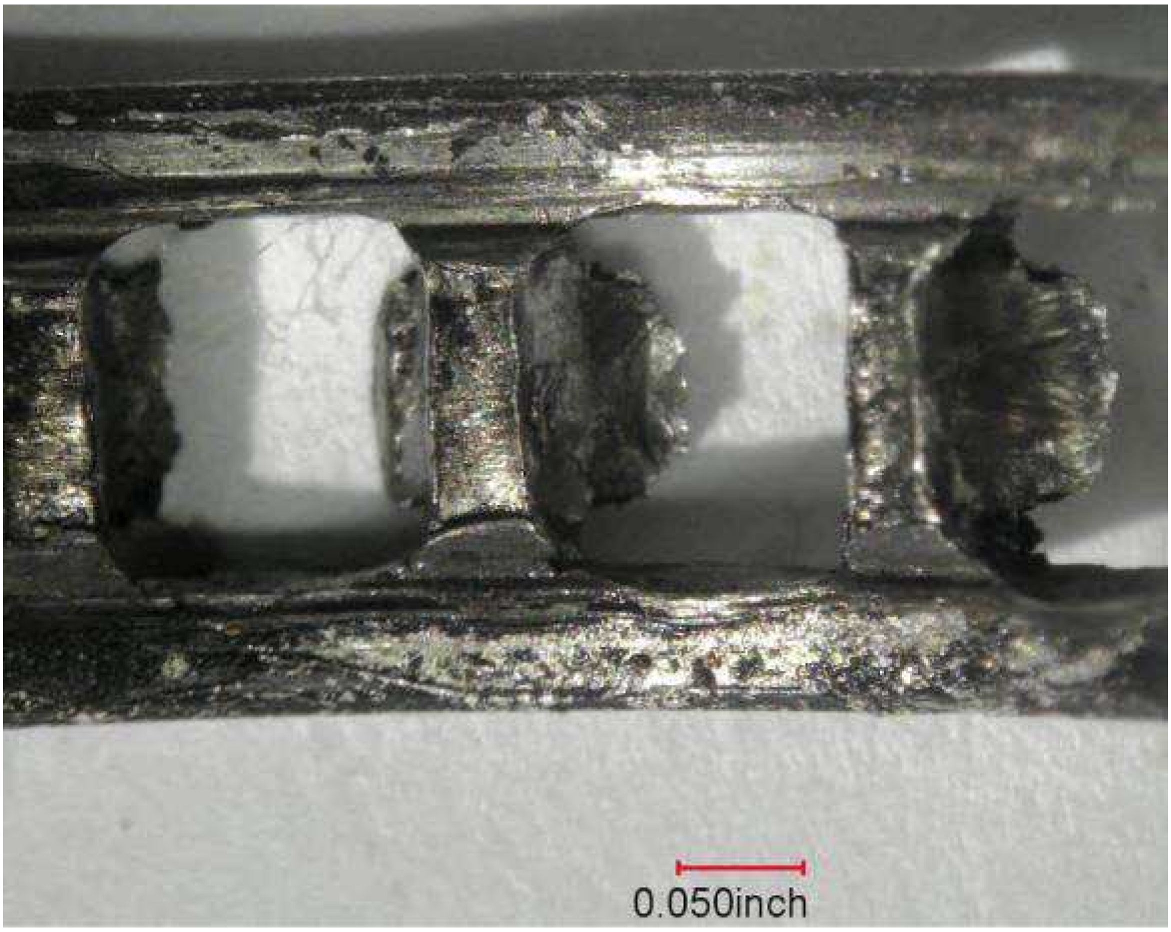


Figure 58. Wear deformation from the inner surface of the No. 1 bearing separator pockets.

Smearing and plastic deformation was also noted in the roller pockets and on the inner surface of the separator rails as shown in *Figure 58.* Detailed fractographic analysis was not conducted on this component as the fracture damage was considered secondary.

Metallographic Examination

The montage metallographic image of *Figure 59* shows a cross section of the No.1 bearing components (excluding the separator) arranged in a manner to simulate orientation during engine operation. The white areas indicate localized heat distress on each of the components; specifically throughout the roller, the inner raceway and the aft shoulder of the inner raceway, and the outer raceway.

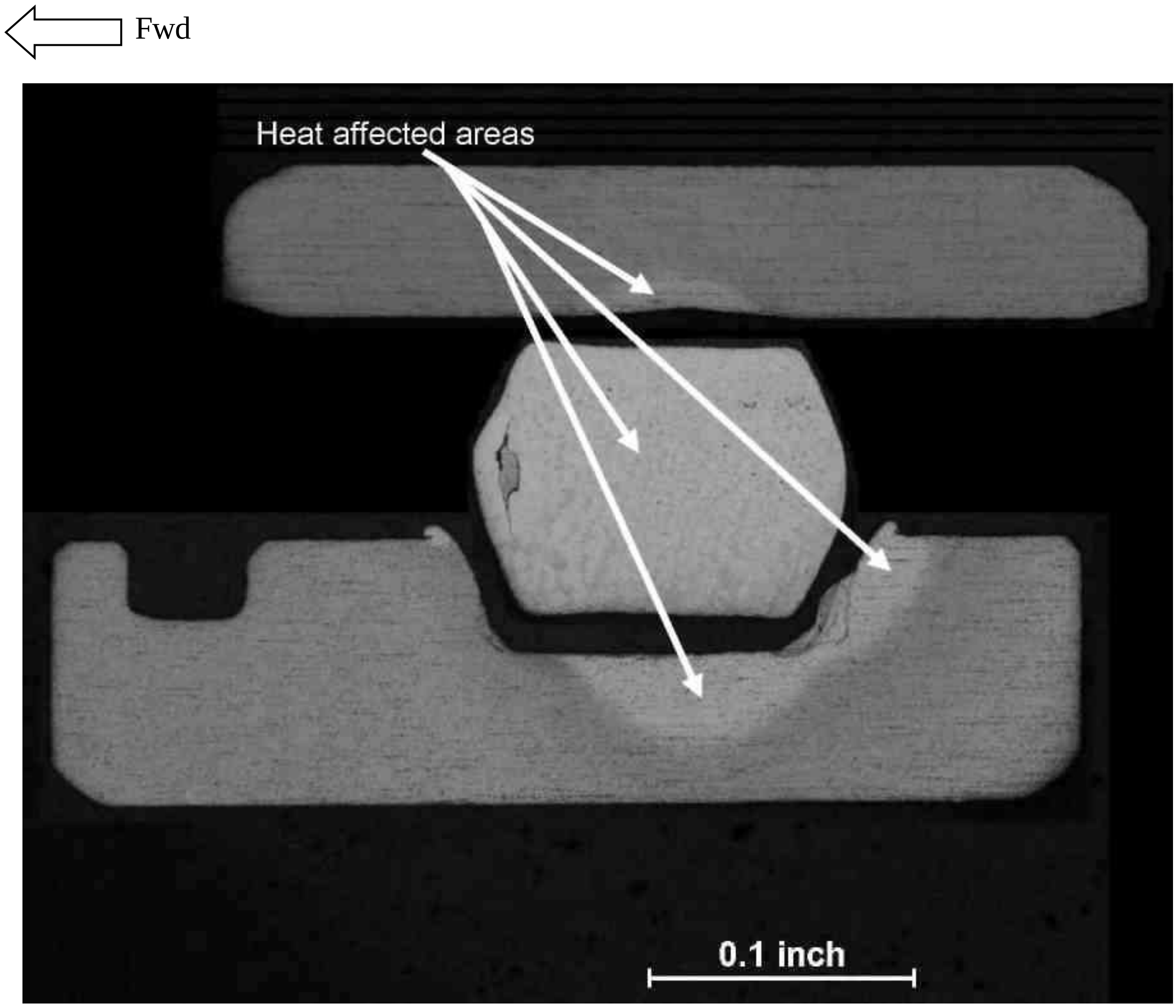


Figure 59 the montage metallographic image a cross section through the No.1 bearing with the separator excluded. Used etchant: Nital 5%

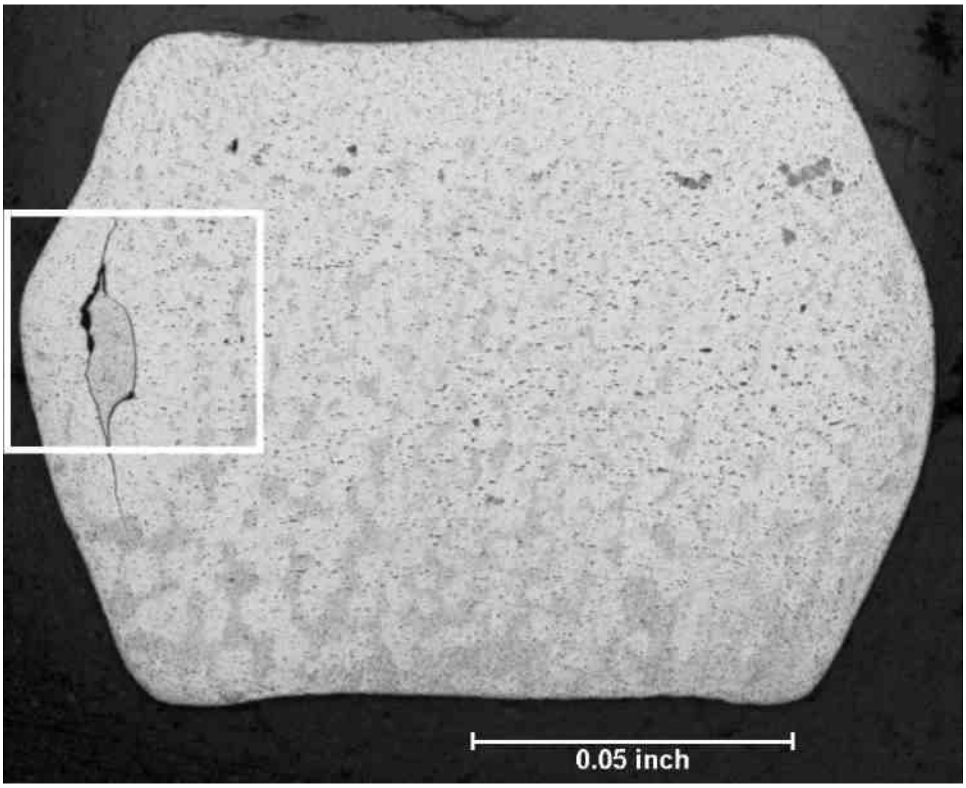


Figure 60A Magn=25X

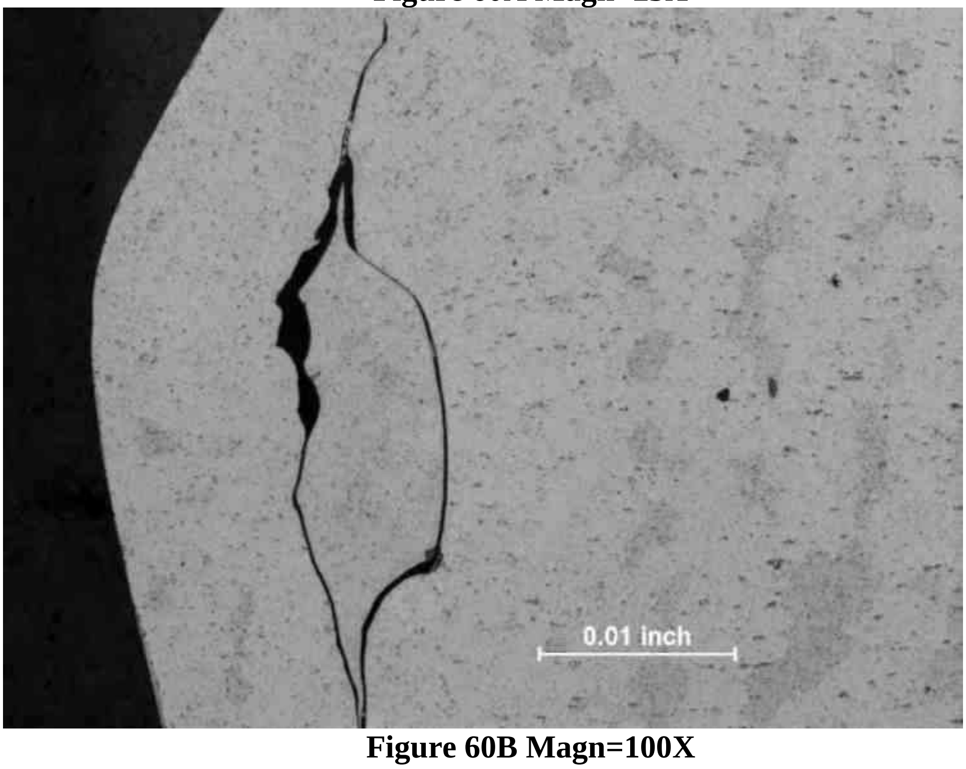


Figure 60B Magn=100X

The metallographic images above show a cross section through a roller from the No.1 bearing. Used etchant: Nital 5%

Figures 60A and 60B show a higher magnification view of a section through a representative roller from the No.1 bearing. The heat affected zone extended throughout the entire roller. The roller had a general barrel shaped appearance and was bowed outward at each of its ends. One end contained a subsurface crack at one end of the roller. The general condition of the roller is consistent with significant heat distress during operation.

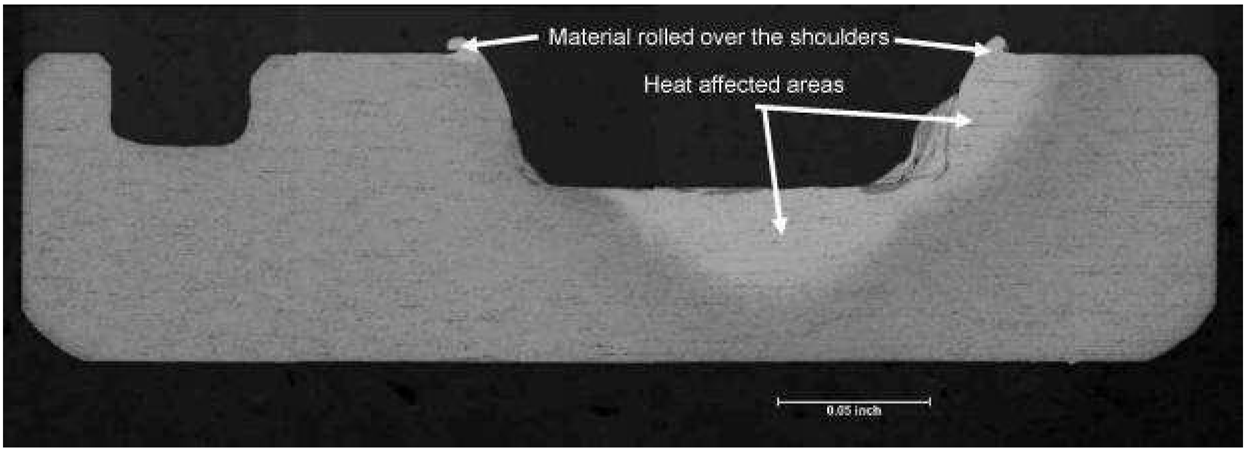


Figure 61 The montage metallographic image shows a cross section through the No.1 bearings inner ring. Used etchant: Nital 5%

The montage metallographic image of *Figure 61* shows a cross section through the No.1 bearing's inner ring and illustrate the heat distress and plastic deformation around the center and aft raceway areas. Also shown are plastic deformation and smearing damage along the forward and aft raceway shoulders where material has been extruded or rolled over the bearings raceway corner.

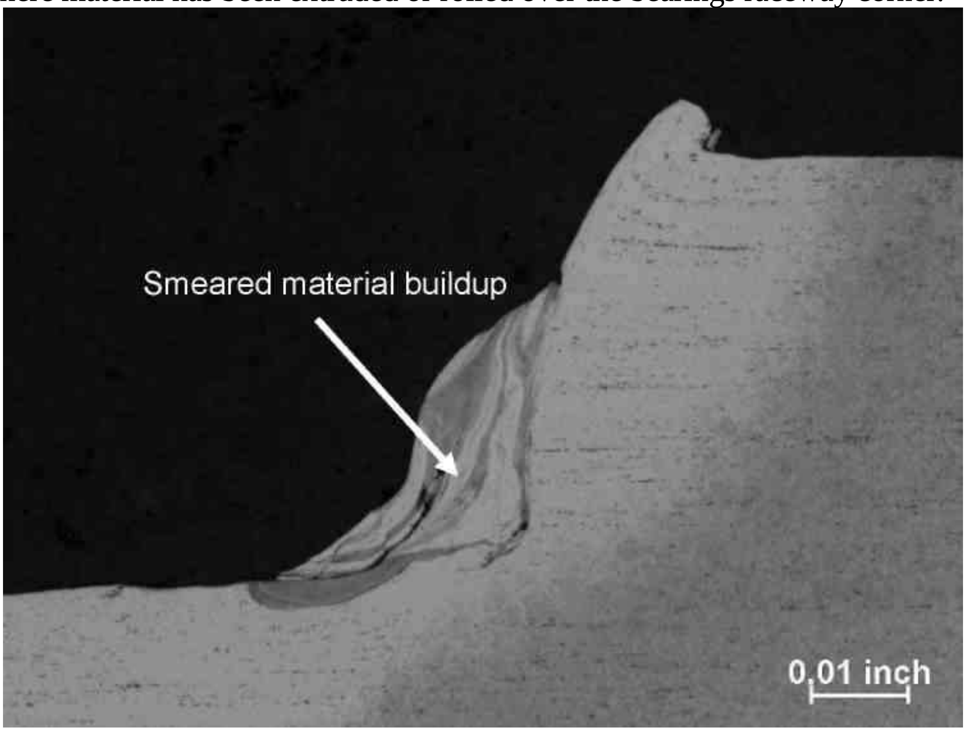


Figure 62 The metallographic image of a portion of the No.1 bearings inner ring. Used etchant: Nital 5%

Figure 62 contains a detailed view of the smeared material built up and thermal distress in the aft corner of the inner rings raceway.

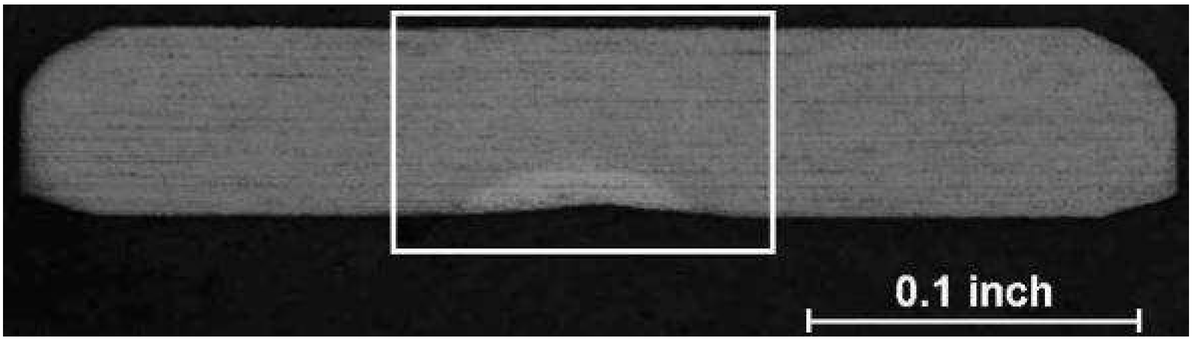


Figure 63. The metallographic image of a cross section through the No.1 bearings outer ring. The white box represents the area shown in *Figure 64.* Used etchant: Nital 5%

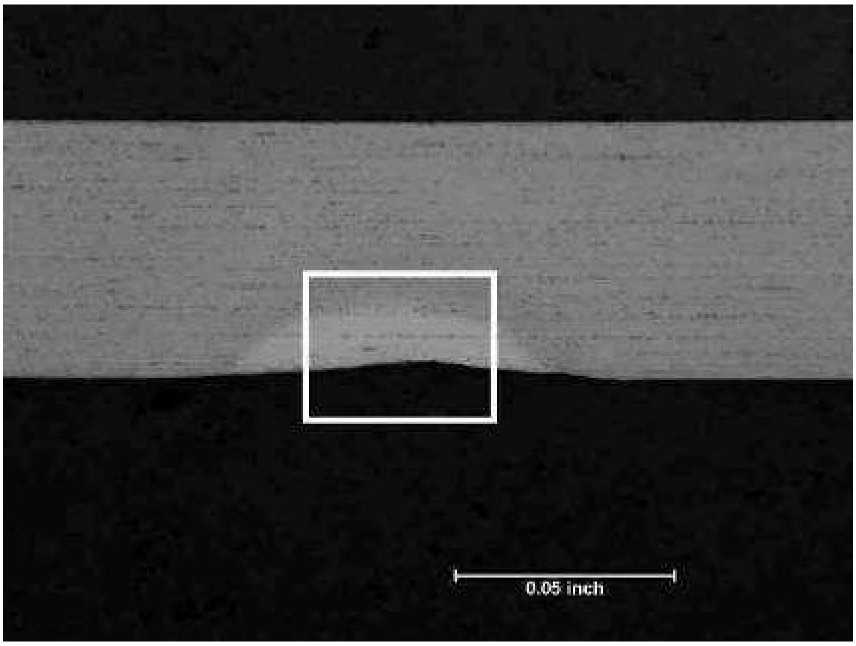
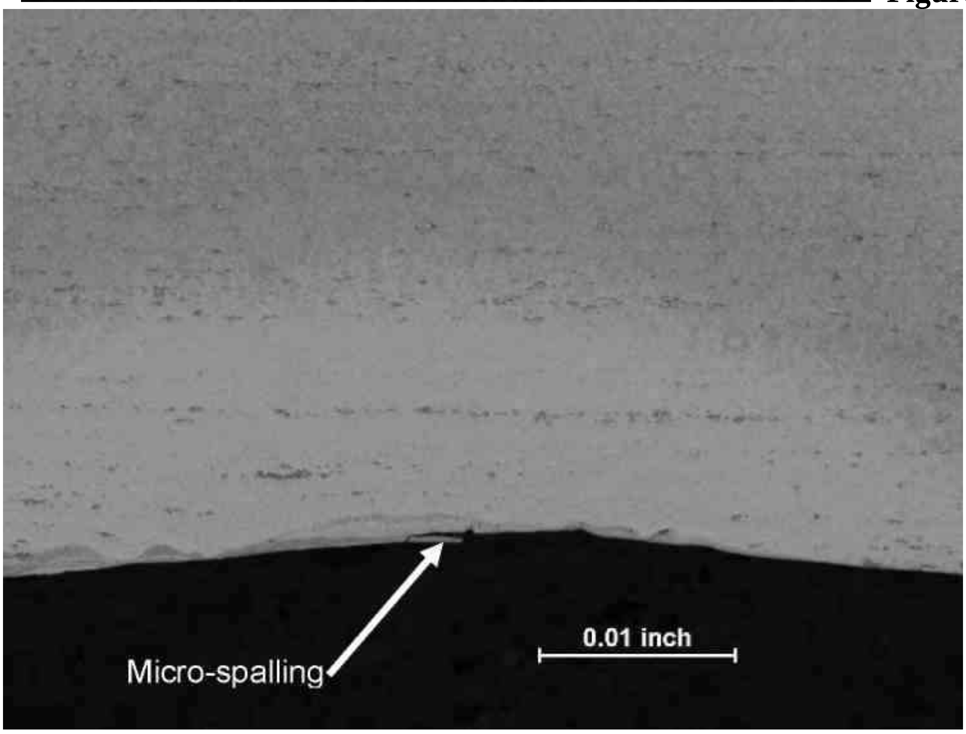


Figure 64A



Magn.=100X

Figure 64B The metallographic image of a cross section through the No.1 bearings outer ring. Used etchant: Nital 5%

Figures 63and 64A, 64B show a cross section through the outer ring and highlights the thermal distress along the raceway. The detailed views presented in *Figure 64* shows the heat affected zone was positioned along the center of the raceway and extended approximately 0.012 inch deep. Some micro spalling was also noted along the raceway surface. Detailed metallographic evaluations of the bearing separator were not conducted.

Hardness

The hardness of the inner ring measured on the cross section in an area unaffected by heat indicated an average hardness of 64.5 HRC (averaged value of 65.1, 65.0, 64.3, 64.3, 64.4 and 64 HRC measured and converted from Vickers). This value is slightly higher than the engineering drawing requirement of 61.0 to 64.0 HRC, but may have been affected by the general thermal distress evident in the bearing components.

The hardness of the outer ring on the cross section measured in an area unaffected by heat indicated an average hardness of 62.9 HRC (averaged value of 64.8, 61.4, 63.9, 63.2, 62.8 and 61.6 HRC measured and converted from Vickers) which met the engineering drawing requirement of 61.0 to 64.0 HRC.

The hardness of the rollers and the bearing separator were not evaluated as the observed thermal distress and damage deemed hardness measurements unreliable.

Chemistry

Semi-quantitative x-ray fluorescence (XRF) analysis determined that the outer ring, inner ring, and rollers were consistent with an AMS6491 (M50) type material as required by the engineering drawing. Semi-quantitative energy dispersive spectroscopy (EDS) analysis determined that the separator was silver plated AMS6415 (4340) type material as required by the engineering drawing.

Carbon Seal Runner; P/N: 23033440*; S/N: Undetermined, inspection

The general condition of the carbon seal runner is shown in *Figure 65.* The raceway exhibited a heat tint (bluish color) that encompasses approximately 180 degrees of the seal runner's circumference. There was a groove in the center between the contact areas of the two carbon elements and coke deposits along the aft portion of the runner, but no other obvious damage was noted. No metallurgical, hardness or chemical analyses were conducted on this component.

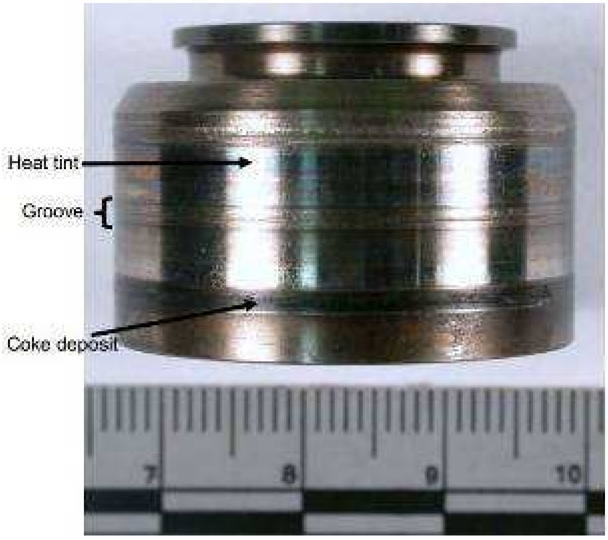


Figure 65 The images of two views approximately 180° apart showing the general condition of the carbon seal runner (Divisions = mm)

Stage 1 Compressor Wheel; P/N: 23032621; S/N: E7793

The condition of the stage 1 compressor wheel is shown in *Figures 66* and *67*. There was no obvious damage along the leading edges of the airfoils and no obvious sign of knife seal rub. Blade tip rub was evident around the entire circumference of the wheel and was consistent with damage noted along the blade path in the compressor case. *Figure 68* shows representative example of tip rub damage. No metallurgical, hardness or chemical analyses were conducted on this wheel.

Figure 66 The image of the leading edge surface of the stage 1 compressor wheel (Divisions=mm)

Figure 67 The image of the shows the trailing edge surface of the stage 1 compressor wheel (Divisions=mm)

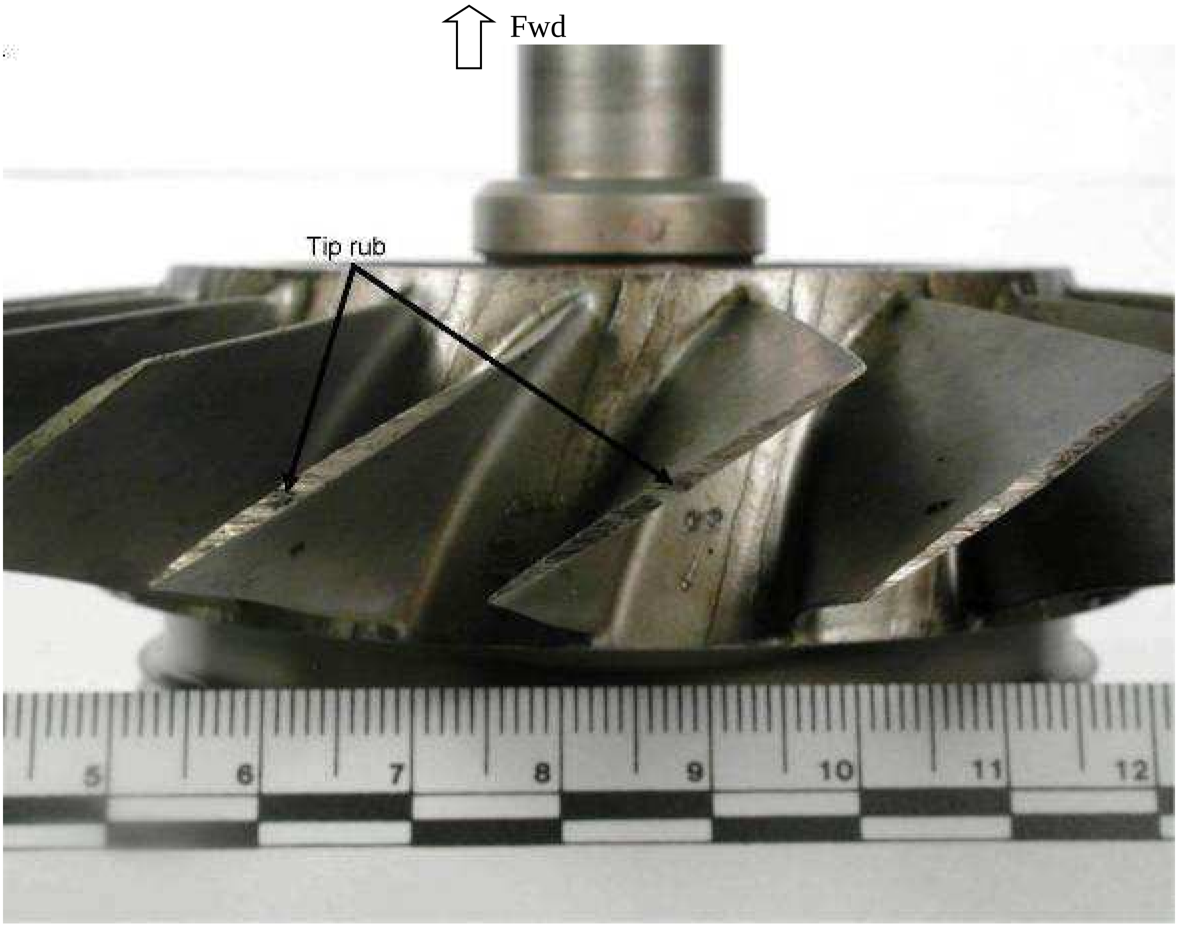


Figure 68.The image of a representative example of tip rub exhibited by the stage 1 compressor wheel. Divisions = mm

Stage 2 Compressor Wheel; P/N: 23032622; S/N: E11224

Figure 69. The image of the leading edge surface of the stage 2 compressor wheel (Divisions = mm)

Figure 70. The image of the trailing edge surface of the stage 2 compressor wheel (Divisions = mm)

The condition of the stage 2 compressor wheel is shown in *Figures 69* and *70.* There was no obvious damage along the leading edges of the airfoils and no obvious sign of knife seal rub.

Oil staining and/or coke deposits were evident along the inner surface of the aft spacer arm as shown in *Figure 71* and spanned an arc of approximately 180 degrees. Blade tip rub was evident around the entire circumference of the wheel and was consistent with damage noted along the blade path in the compressor case (discussed later in this report).

Figure 71. The image of the oil wetting within the aft inner diameter of the stage 2 compressor wheel. Divisions = mm

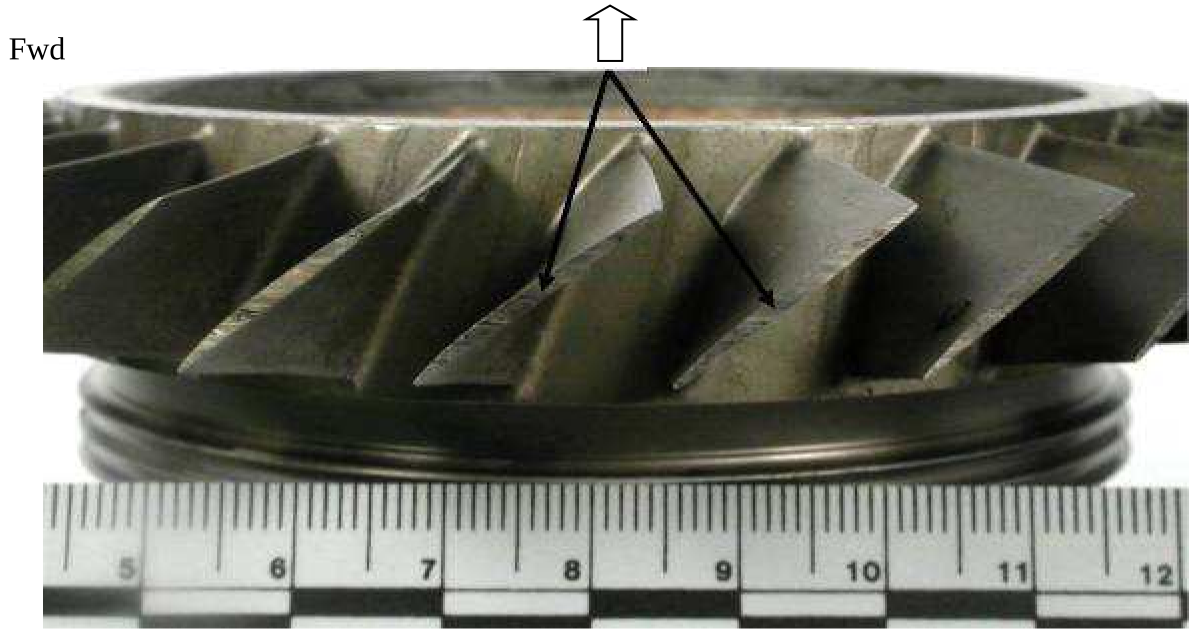


Figure 72. The image of a representative example of tip rub exhibited by the stage 2 compressor wheel. Divisions = mm

Figure 72 shows an image exhibiting a representative example of tip rub damage. No metallurgical, hardness or chemical analyses were conducted on this wheel.

Stage 3 Compressor Wheel; P/N: 23032623-A; S/N: KR20500

The as-received condition of the stage 3 compressor wheel is shown in *Figures 73* and *74.* There was no obvious damage along the leading edges of the airfoils and no obvious sign of knife seal rub.

Figure 73. The image of the leading edge surface of the stage 3 compressor wheel (Divisions = mm)

Figure 74. The image of the trailing edge surface of the stage 3 compressor wheel (Divisions = mm)

Oil staining and/or coke deposits similar to those noted on the stage 2 compressor wheel were evident along the inner surface of the aft spacer arm as shown in *Figure 75.* This condition spanned an arc of approximately 180 degrees. Blade tip rub was evident around the entire circumference of the wheel similar to that found in the first two compressor stages and was consistent with damage noted along the blade path in the compressor case.

Figure 75. The image of the oil wetting within the aft inner diameter of the stage 3 compressor wheel. (Divisions = mm)

Figure 76 shows an image exhibiting a representative example of tip rub damage. No metallurgical, hardness or chemical analyses were conducted on this wheel.

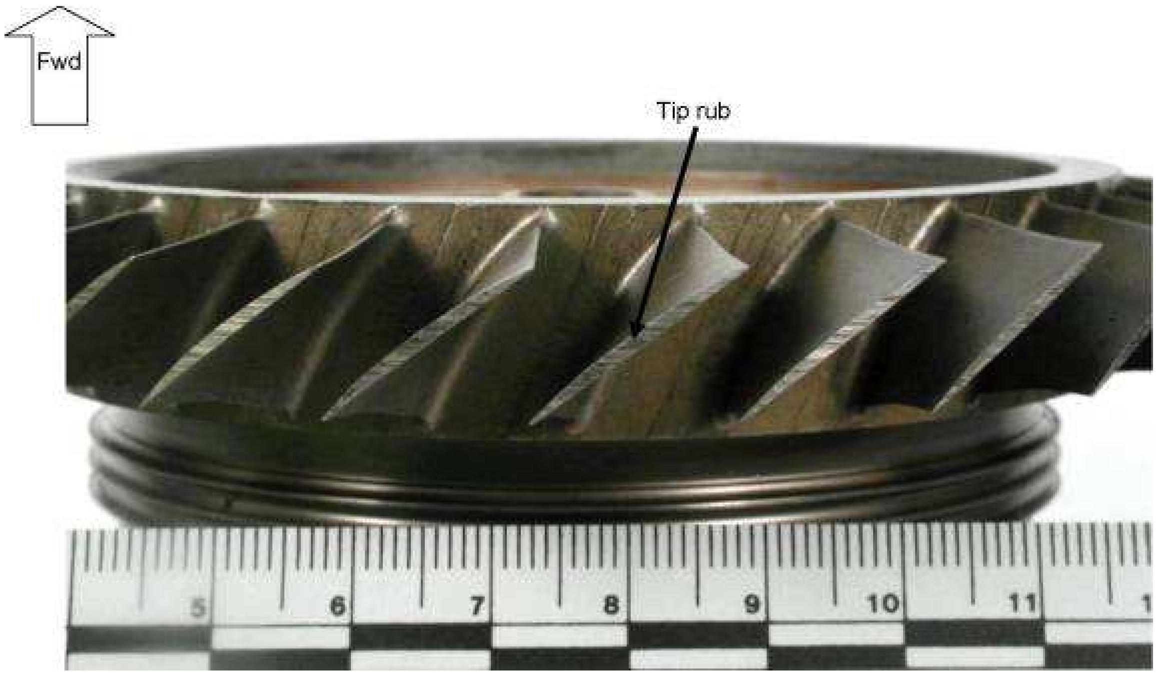


Figure 76. The image of a representative example of tip rub exhibited by the stage 3 compressor wheel. (Divisions = mm)

Stage 4 Compressor Wheel; P/N: 23032624-D; S/N: E66427

The condition of the stage 4 compressor wheel is shown in *Figures 77* and *78.* There was no obvious damage along the leading edges of the airfoils and no obvious sign of knife seal rub. Blade tip rub was evident around the entire circumference of the wheel as was noted in the previous compressor stages and was consistent with damage noted along the blade path in the compressor case.

Figure 77. The image of the leading edge surface of the stage 4 compressor wheel. Divisions = mm

Figure 78. The image of the leading edge surface of the stage 4 compressor wheel. Divisions = mm

Figure 79 shows an image exhibiting a representative example of tip rub damage. No metallurgical, hardness or chemical analyses were conducted on this wheel.

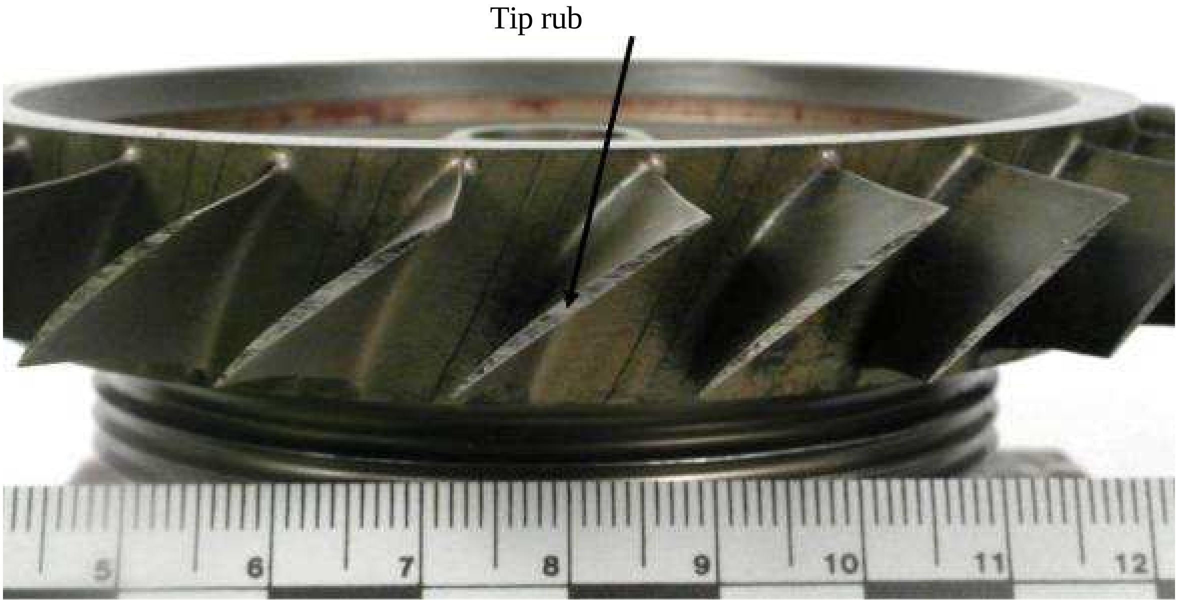


Figure 79. The image of a representative example of tip rub exhibited by the stage 4 compressor wheel. (Divisions = mm)

Impeller; P/N: 23032620-1; S/N: 25879

The condition of the compressor impeller wheel is shown in *Figures 80 and 81.* Blade tip rub was evident around the entire circumference. *Figure 82* shows an image exhibiting representative damage. No metallurgical, hardness or chemical analyses were conducted on this wheel.

Figure 80. The image of the condition of the impeller as viewed from the forward face.   Divisions = mm

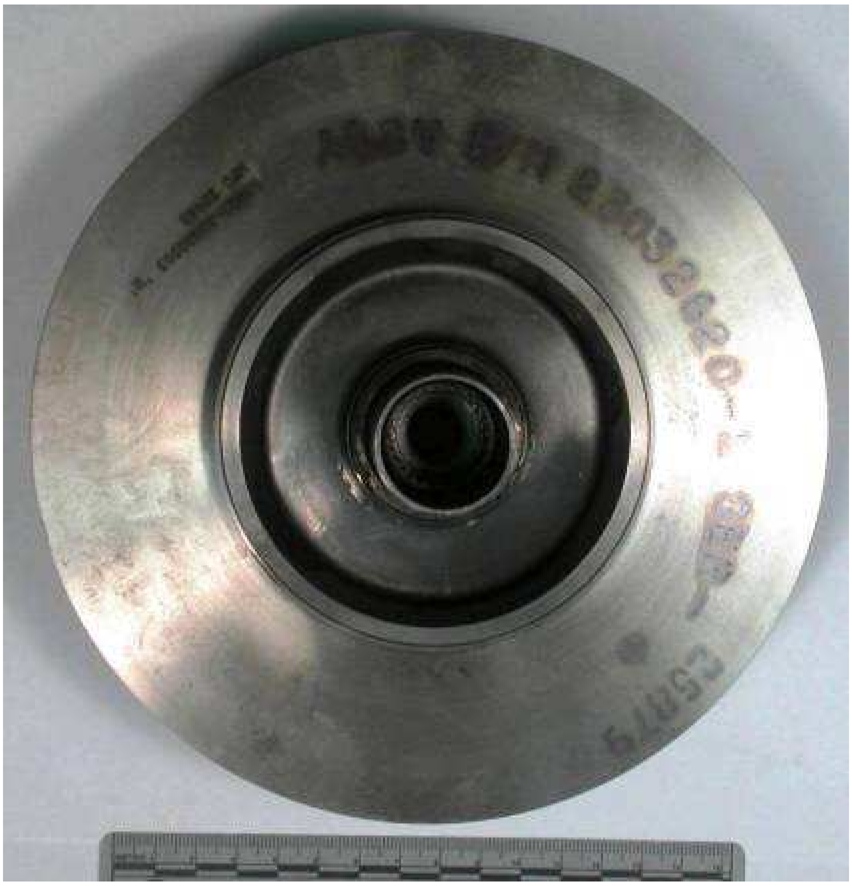


Figure 81. The image of the condition of the impeller as viewed from the aft face. (Divisions = mm)

Figure 82. The image of a representative example of tip rub on the impeller. (Divisions = mm)

Compressor Case Halves; P/N: 23032630-C; S/N: Set# 37004

The as-received condition of the compressor case halves are shown in *Figure 83 and 84.*

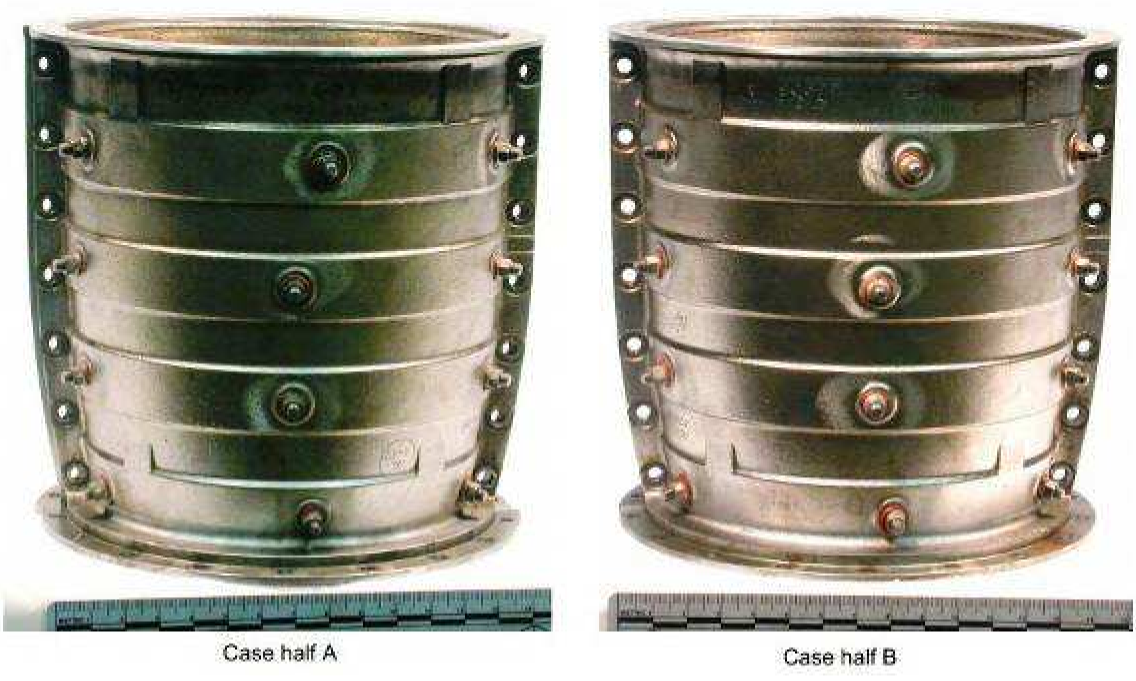


Figure 83. The image of the outer surfaces of the compressor case halves. (Divisions = mm)

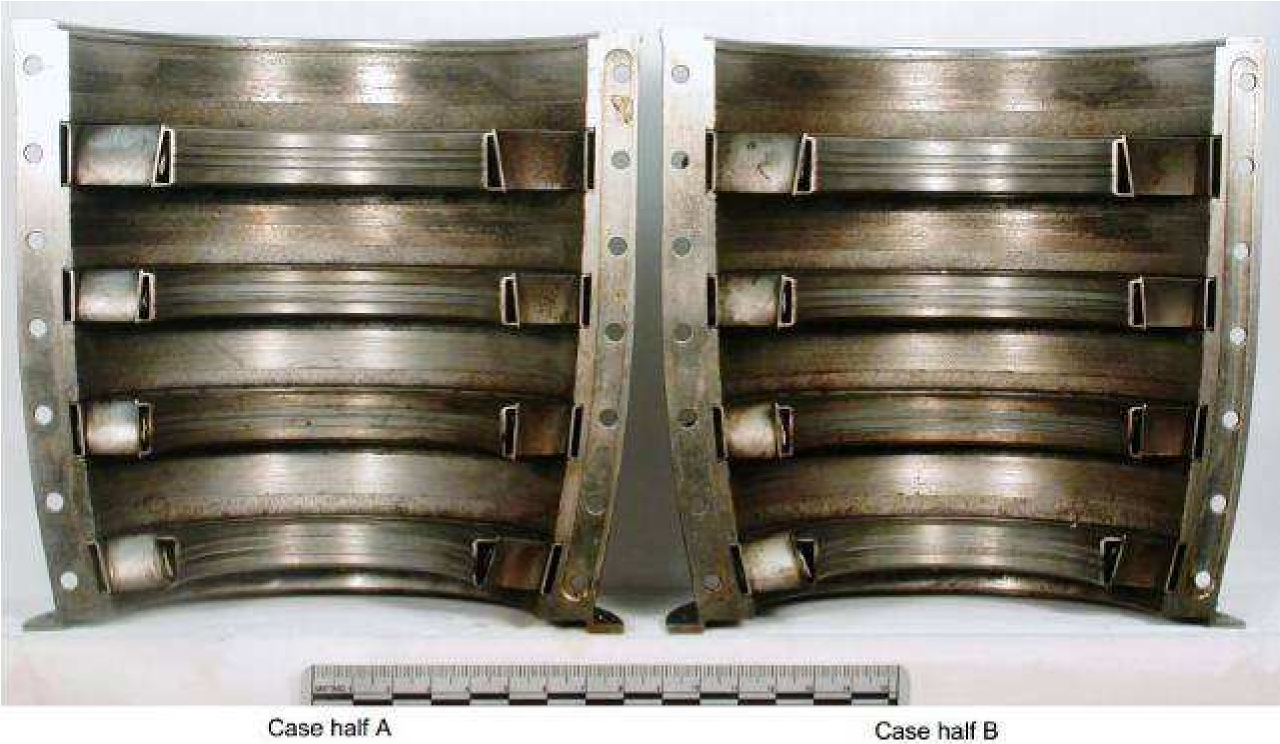


Figure 84. The image of the inner surfaces of the compressor case halves after light cleaning with soap and water. (Divisions = mm)

It was unable to distinguish which was the upper and lower units so for the purposes of identification they were labeled A and B. No obvious damage from heat distress was observed on the outer surface. *Figure 84* shows the inner surfaces after a light cleaning with soap and water to remove surface debris. Rub damage was evident along all four blade paths and was consistent with the tip rub damage noted on the compressor wheels. The groves in the stationary seals appeared fairly uniform with evidence to suggest axial shift of the compressor rotor assembly. There is no evidence of impact damage to any of the compressor vanes. No metallurgical, hardness or chemical analyses were conducted on this part.

Compressor Shroud; P/N: 23034646-B; S/N: GR21151, inspection

The condition of the impeller shroud is shown in *Figures 85* through *86*.

Figure 85. The image of the impeller shroud as viewed from an oblique view to the forward face. Divisions = mm

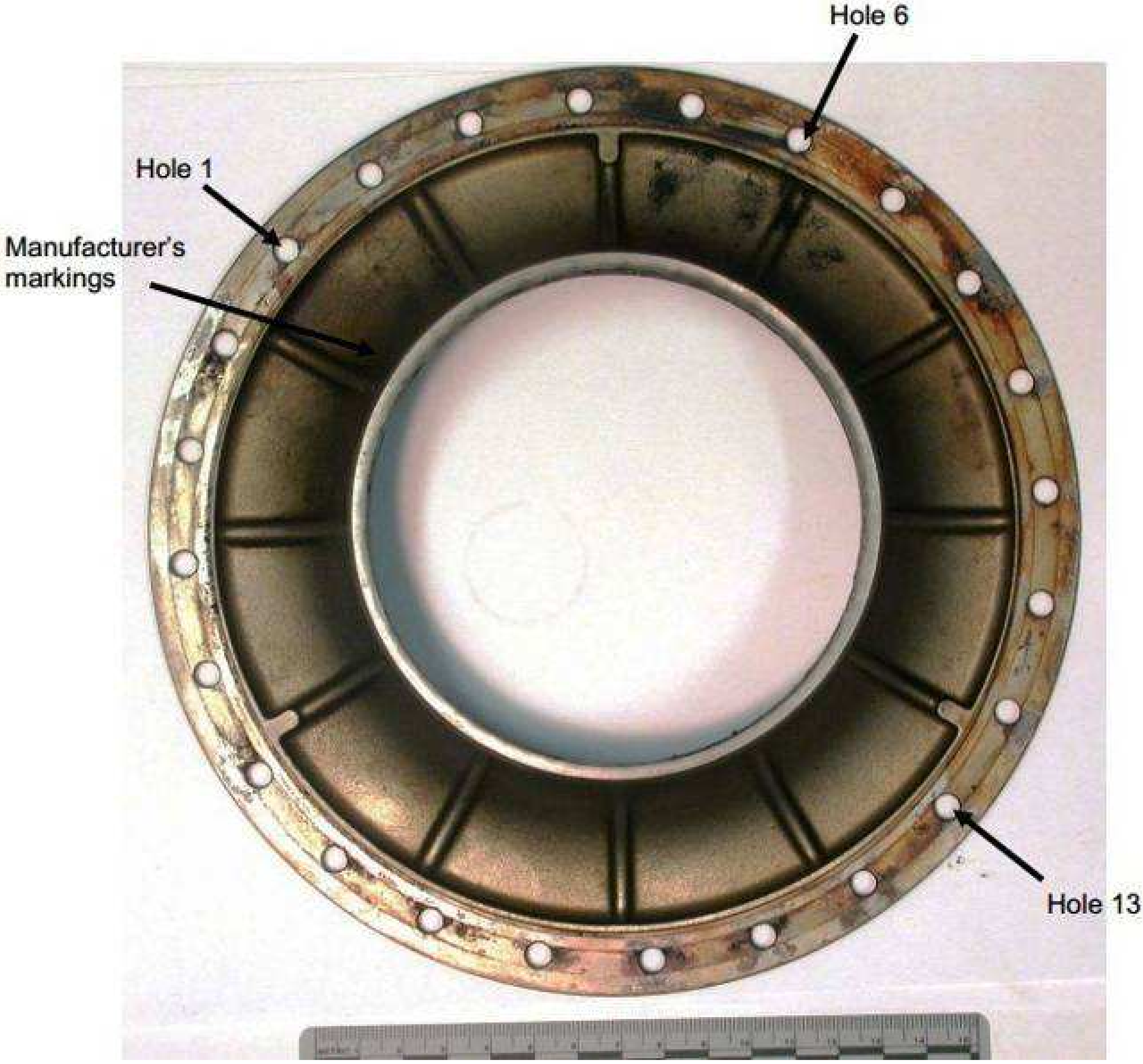


Figure 86. The image of the impeller shroud as viewed from the forward face. Divisions = mm

The forward surface was generally oil stained and dirty, but no obvious damage or heat distress was noted. Pitting was evident on the inner aft surface of the shroud as shown in *Figures 86* and *87*. No obvious patterns were noted, but the pitting appeared most severe near the forward portion of the shroud. A radial cross section was made through the shroud (see red dashed lines in *Figure 87)* and detailed views of the pitting damage is shown in *Figure 89A and 89B.*

Figure 87. The image of the impeller shroud from the aft face. The red dashed lines represent the plane of metallurgical sectioning. (Divisions = mm)

Figure 88. The image of a detailed view of the inner surface of the impeller shroud. (Divisions = mm)

The pitting damage was consistent with spalled areas of the coating applied to the shroud surface. The pitting appeared to be within the coating because no areas of the base metal were evident. Other areas appeared to be blistered, but not yet spalled off. This pitted area did not show evidence of heavy rub scars, but the blistered areas did appear to be rubbed.

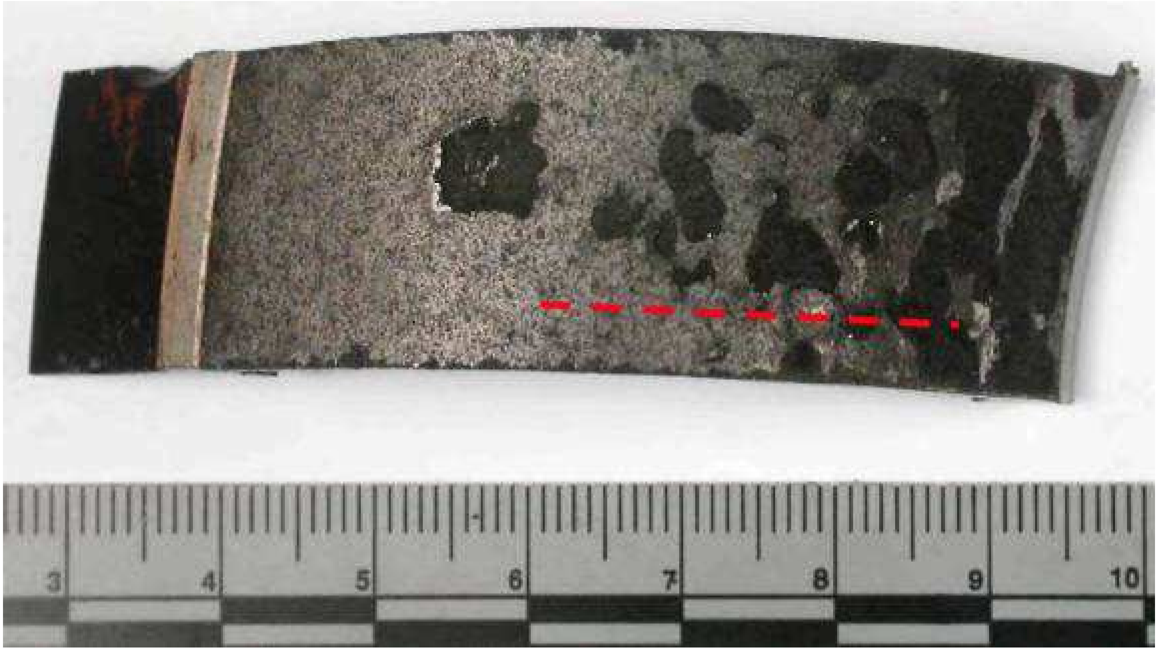


Figure 89 A

Figure 89 B. The image of a detailed view of the section removed from the impeller shroud. (see red dashed lines in *Figure 89A*). The red dashed line represents the plane for metallurgical sectioning. (Divisions = mm)

Metallographic Examination

The scanning electron microscope (SEM) images in *Figure 90* show a cross section through one of the blistered areas on the impeller shroud. The coating had delaminated and localized portions of the coating had liberated. Several areas of the coating exhibited different morphologies. Four of these areas of differing morphologies were analyzed by semi-quantitative dispersive spectroscopy (EDS) analysis to determine their compositions. The locations analyzed are marked on the bottom image of *Figure 90A and 90B.*

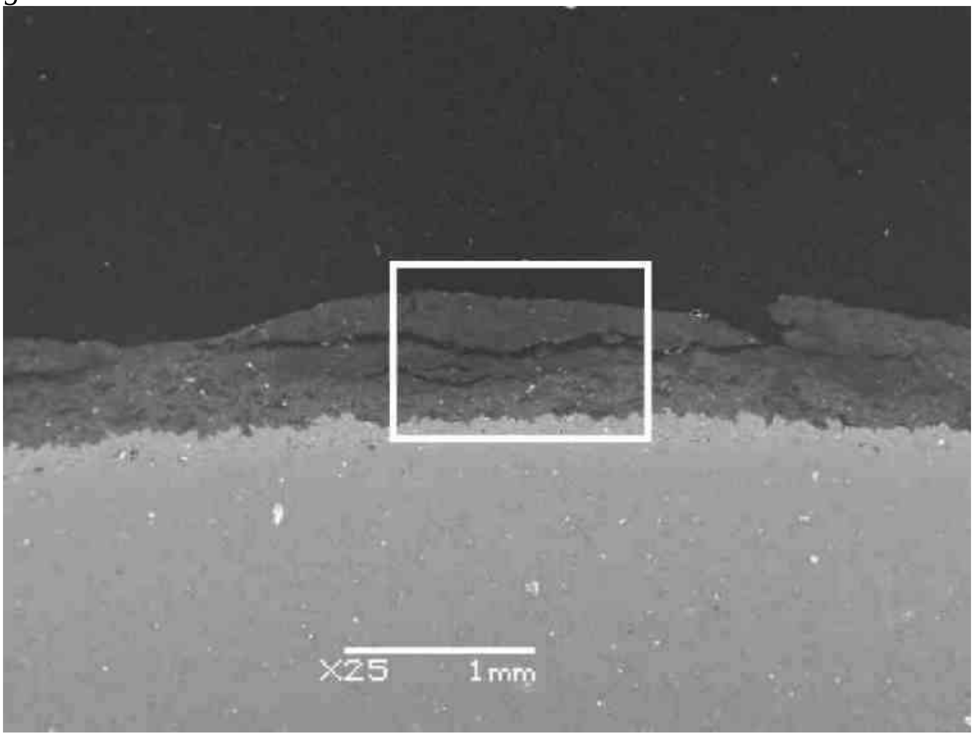


Figure 90A

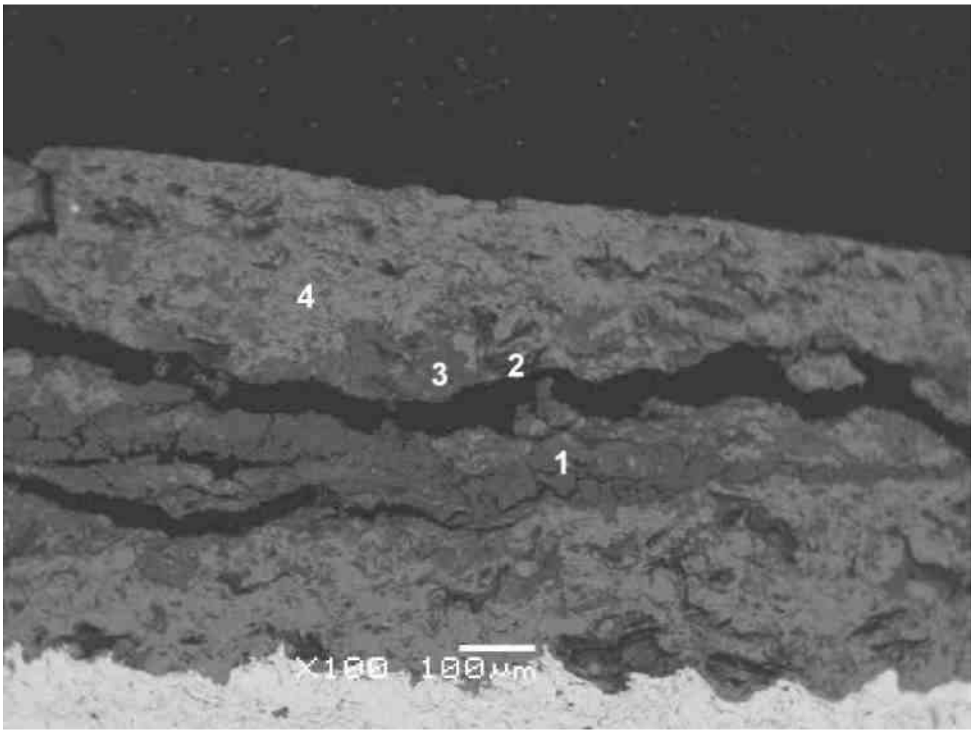
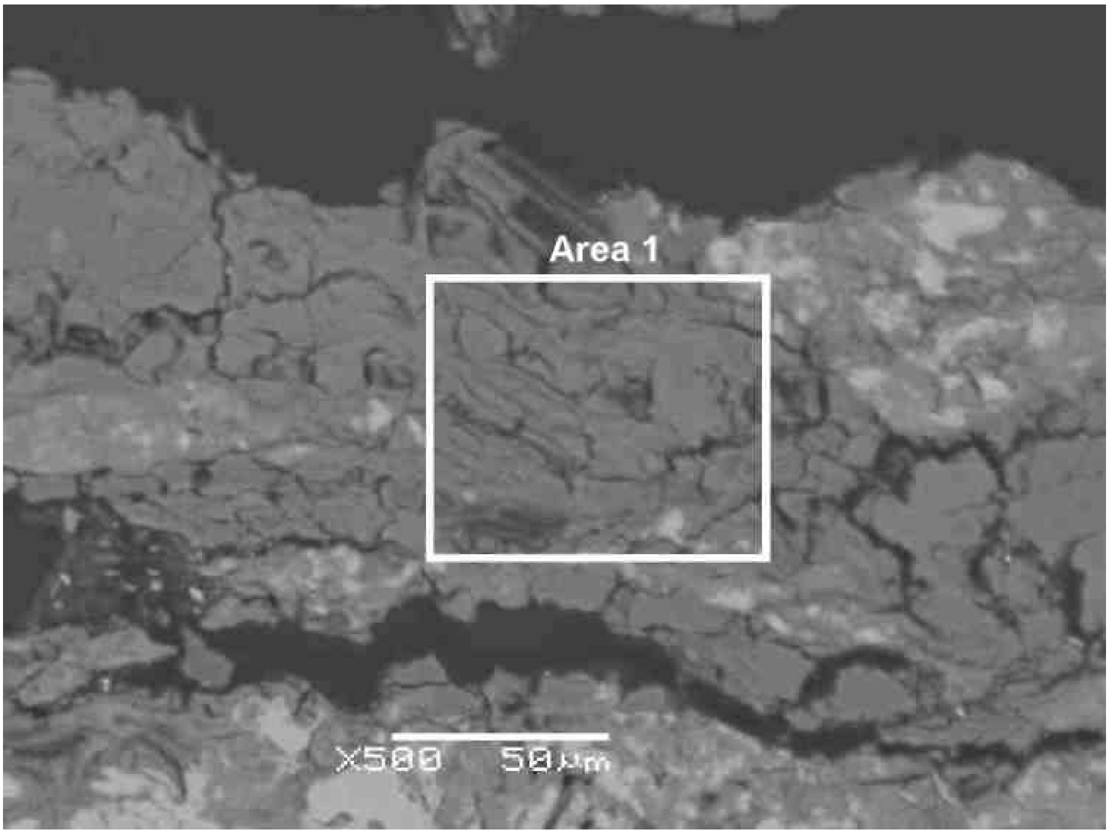


Figure 90B. The SEM images above show a portion of the cross section taken from the impeller shroud (see red dashed line in *Figure 46*).

The SEM image at the top of *Figure 91* shows a portion of the cross section of the impeller shroud and the area referred to as "area 1" and was prevalent along the crack. The resultant spectra at the bottom of the page revealed that it was primarily comprised of aluminum and oxygen with trace elements of carbon, sodium, silicon, sulfur and chlorine. This is consistent with aluminum oxides that are produced during the coating process, but are typically uniformly dispersed throughout the coating.



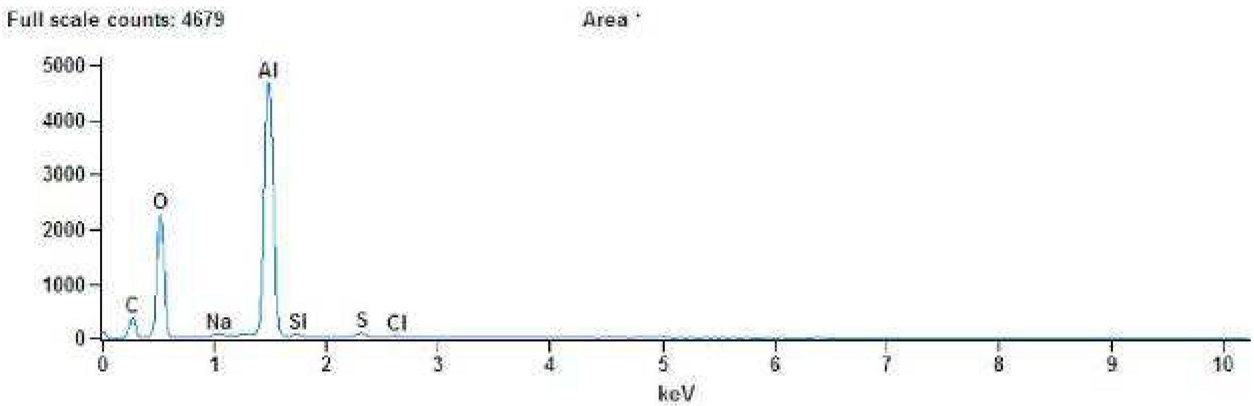
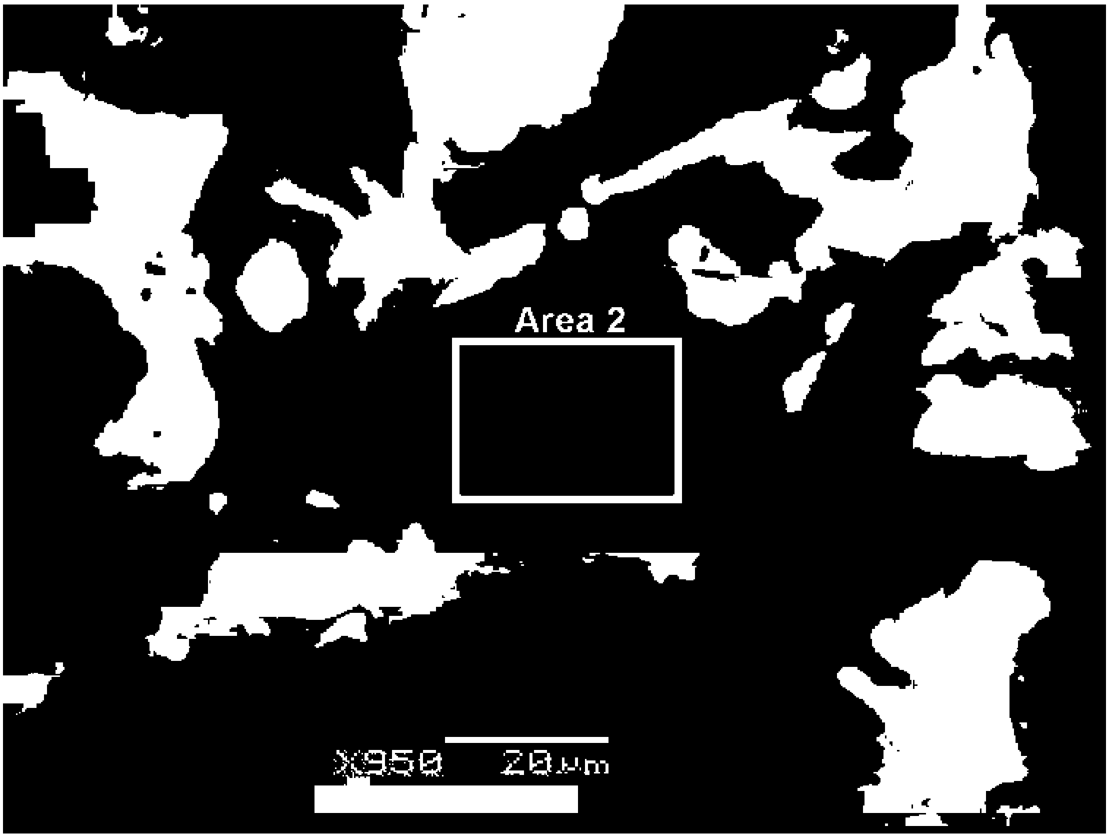


Figure 91. The SEM image at the top of the page shows area 1 that was analyzed by EDS and the resultant spectra is shown at the bottom of the page.



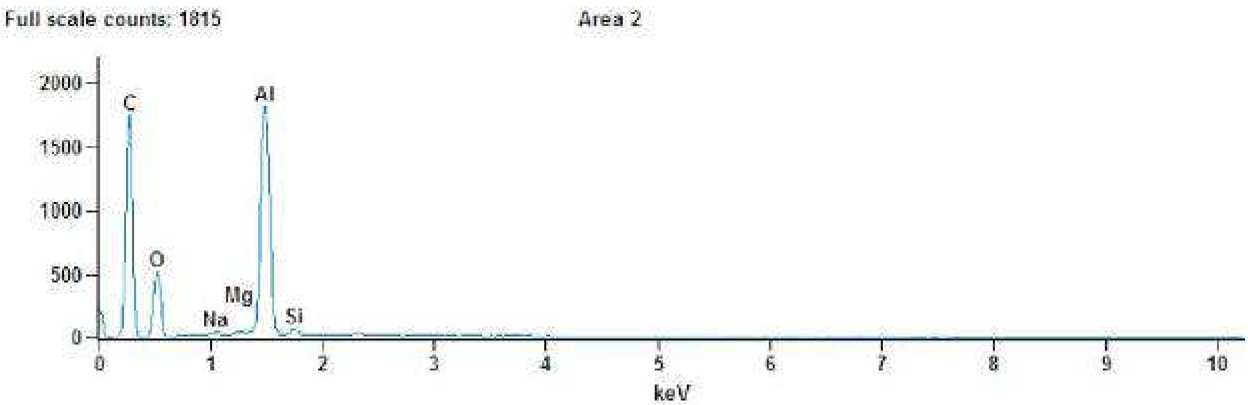
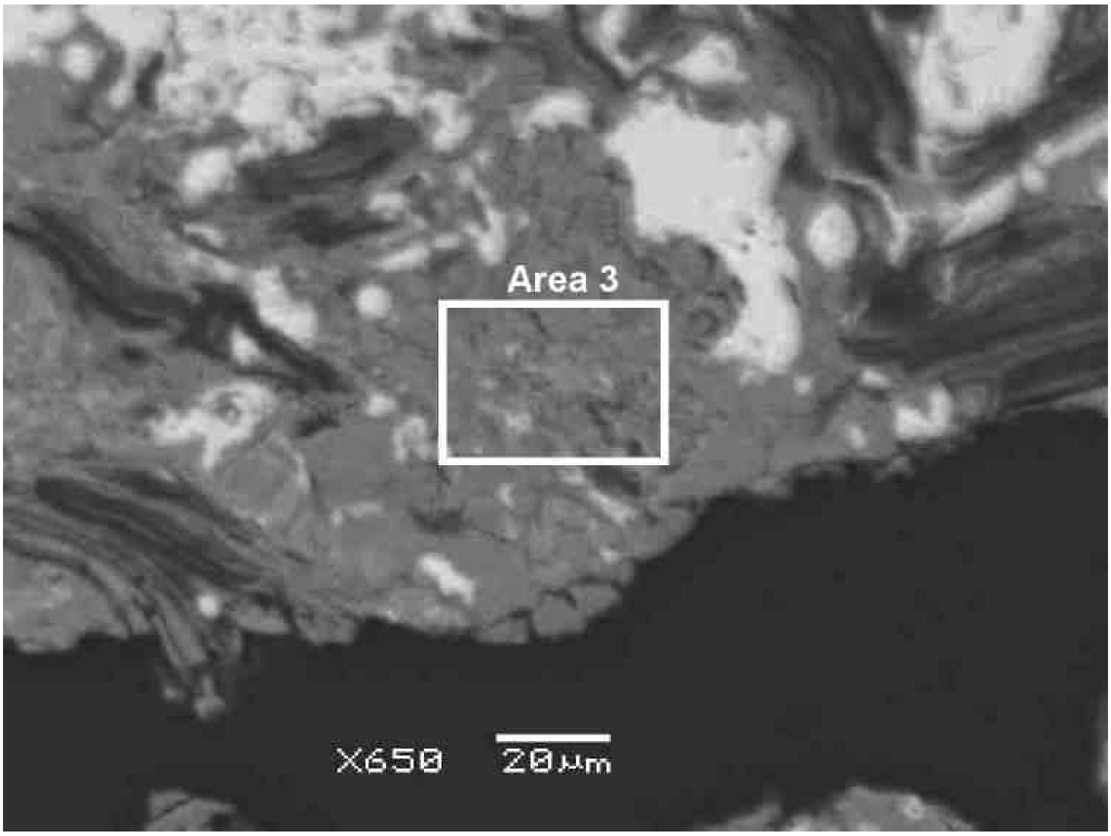


Figure 92 The SEM image at the top of the page shows area 2 that was analyzed by EDS and the resultant spectra is shown at the bottom of the page.

The SEM image at the top of *Figure 92* shows the area referred to as “area 2”. The resultant spectra at the bottom of the page reveal that it is primarily comprised of carbon, aluminum and oxygen with trace elements of sodium, magnesium and silicon. This area is consistent with the milled graphite particles that are intentionally included as part of the coating to improve the friability or abradability of the coating.



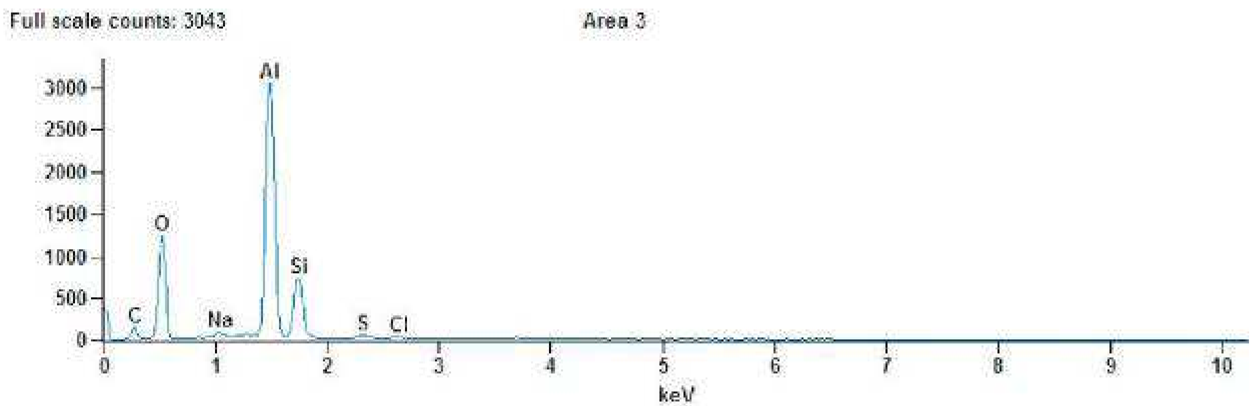
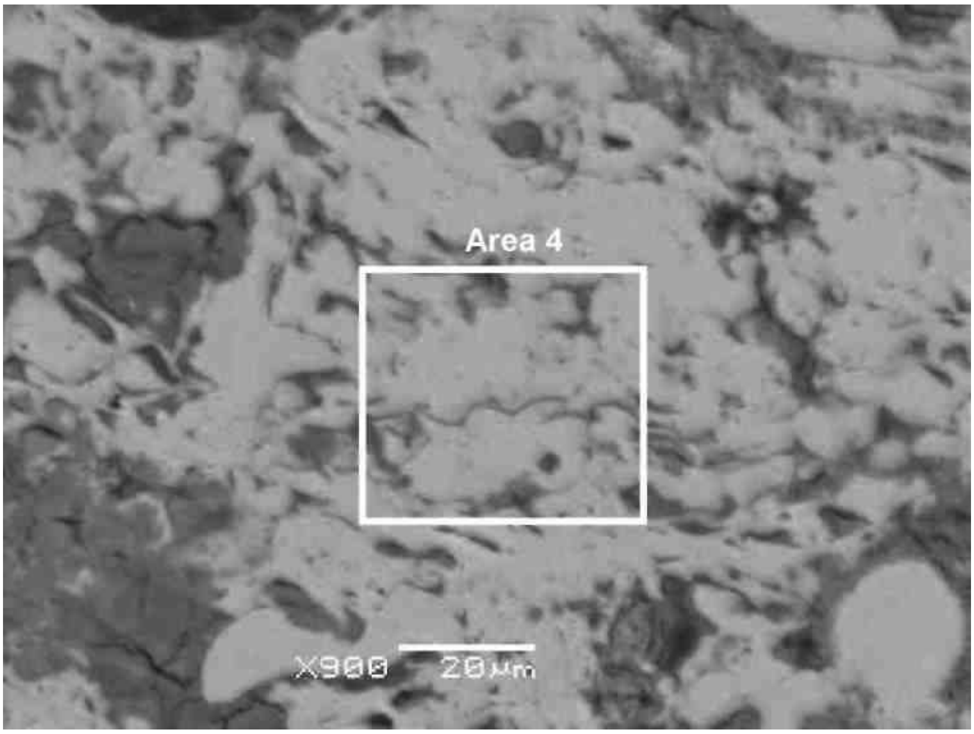


Figure 93. The SEM image at the top of the page shows area 3 that was analyzed by EDS and the resultant spectra is shown at the bottom of the page.

The SEM image at the top of *Figure 93* shows the area referred to as "area 3". The resultant spectra at the bottom of the page reveal that it is primarily comprised of aluminum, oxygen and silicon with trace amounts of carbon, sodium, sulfur and chlorine. These areas appear to be more uniformly dispersed throughout the coating, but were also evident along the crack.



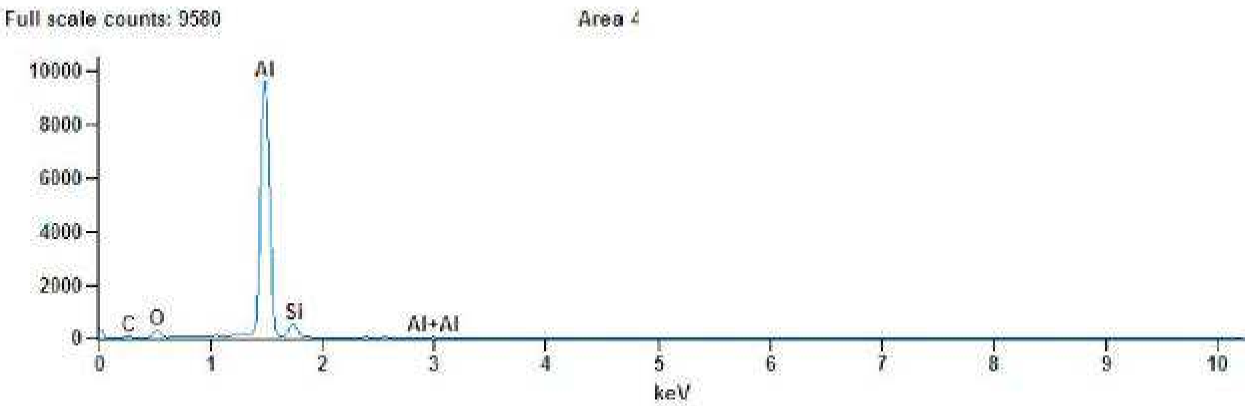


Figure 94 The SEM image at the top of the page shows area 4 that was analyzed by EDS and the resultant spectra is shown at the bottom of the page.

The SEM image at the top of *Figure 94* shows the area referred to as “area 4” and is representative of the aluminum portions of this coating system. The resultant spectra at the bottom of the page reveal that it is primarily comprised of aluminum with only trace amounts of carbon, oxygen and silicon.

The general condition of the impeller shroud appears to be deteriorated and may have caused a slight performance loss. However, the condition of this shroud was not believed to have contributed to the skidding damage observed in the No. 1 bearing. The specific cause for the damage to the shroud coating was beyond the scope of this investigation. Use or disclosure of this data is subject to the restriction on the first page of this document.

Compressor Tie Bolt; P/N: 23035136-A; S/N: 50500, inspection

Figure 95. Compressor tie bolt **Coke deposits**

The condition of the compressor tie bolt is shown in *Figure 95 and 96.* There was slight discoloration on the mute area and coke deposits on the aft end as shown in *Figure 97.* No metallurgical, hardness or chemical analyses were conducted on this component.

Figure 96. The image of the compressor tie bolt (top) and localized discoloration on the mute area (bottom), Divisions = mm.

Figure 97. The image of the coke deposits on the end of the compressor tie bolt. (Divisions – mm)

Compressor Rear Support and Diffuser; P/N: 23032626-A; S/N: GR20521 inspection

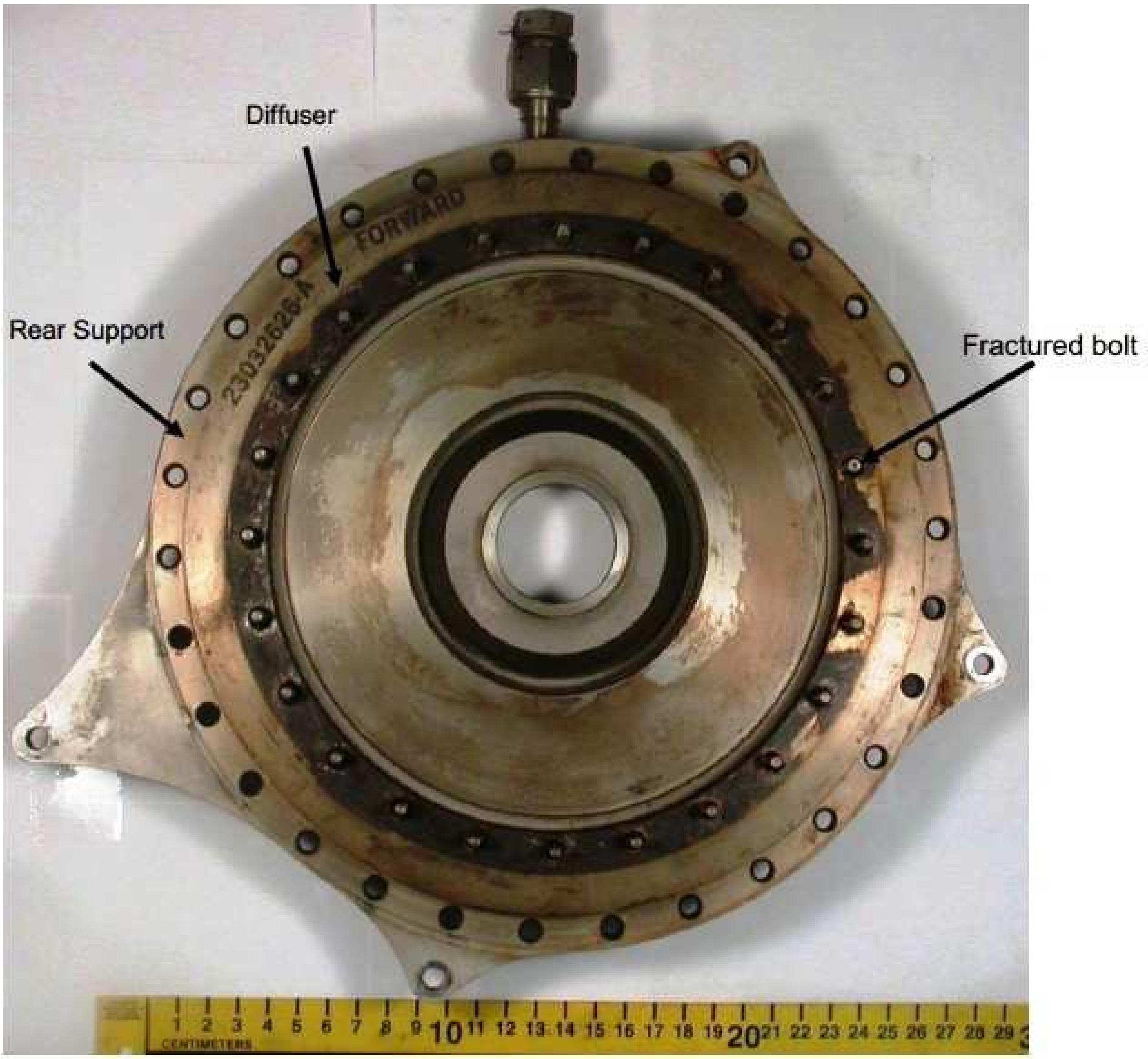


Figure 98 The image of the condition of the compressor rear support and diffuser as viewed from the forward face. Divisions=cm

The condition of the compressor rear support and diffuser assembly is shown in *Figures 98* and *99.* The general condition was dirty with local areas of oil staining and/or surface corrosion. One mounting bolt on the forward side had fractured. The fracture appeared bright and shiny and the macroscopic fracture features were consistent with overload indicating the bolt most likely fractured during disassembly. Detailed fractographic evaluations were not conducted. Both static seals exhibited uniform grooves. All but two of the nuts holding the diffuser assembly to the rear support had been removed.

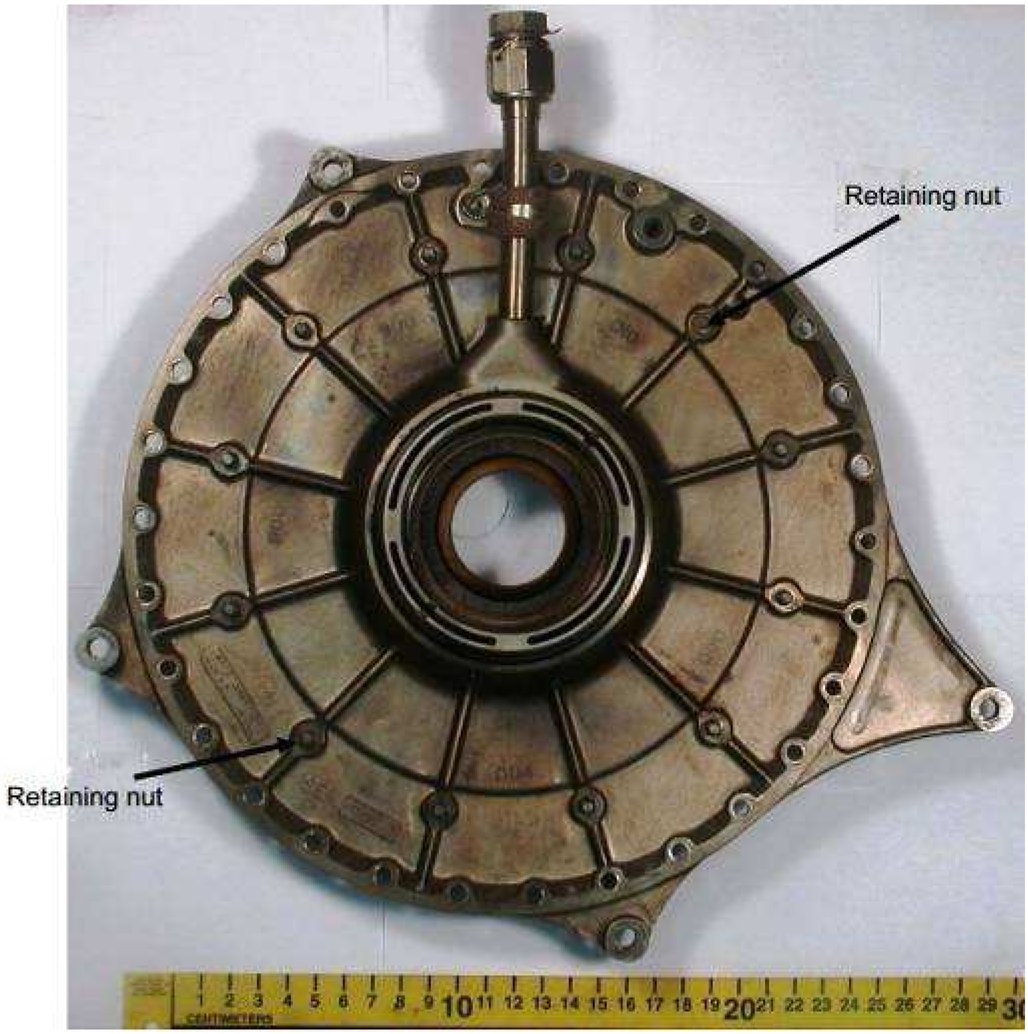


Figure 99 The image of the condition of the compressor rear support and diffuser as viewed from the aft face. Divisions=cm

The O-ring on the aft face was swollen and ill fitting as shown in *Figure 100.*

Figure 100 The image of the loose fitting O-ring on the compressor rear support and diffuser as viewed from the aft face

Bleed Manifold; P/N: 23035225-E; S/N: RE10758

The as-received condition of the bleed manifold is shown in *Figures 101* and *102.* No obvious damage was noted to this component but red colored RTV gasket type material was evident on the bolt ring and the triangular shaped ports. No metallurgical, hardness or chemical analyses were conducted.

Figure 101. The image of the condition of the bleed manifold as viewed from the forward face. Divisions = cm

Figure 102. The image of the condition of the bleed manifold as viewed from the aft face. Divisions = cm

Scroll Assembly; P/N: 23035248-E; S/N: MA34384

The as-received condition of the scroll is shown in *Figures 103* and *104.* The scroll surfaces were dark, but no obvious damage was noted on this component. No metallurgical, hardness or chemical analyses were conducted.

Figure 102. The image of the conditions of the scroll assembly from the forward face. Divisions = cm

Figure 102. The image of the conditions of the scroll assembly from the aft face. Divisions = cm

1.17. Organizational and management information

„HELIPRO OY" has its home base at Helsinki, Malmi Airport, Finland and is engaged in AERIAL WORK operations commenced by single engine helicopters.

According to Flight Work Permit No.213/40 issued by Traffic Safety Agency of FINLAND on 2009 the „HELIPRO OY" was authorized to perform 5 forms of flight operation, including Cutting works (Sahauslennot). Authorized aircraft is helicopters with take-off weight **3175 kg.**

The area of operation is mainly Finland; but includes also Sweden and Baltic States. All flights are conducted in accordance with Visual Flight Rules (VFR).

The operator has contracted a continuing airworthiness management (EASA PART-M) and maintenance activities (EASA PART-145) with company "HeliTech OY" Ltd CAMO organization (FI.MG.0023 and FI.145.0009)

Organizational structure of company HELIPRO OY is following:

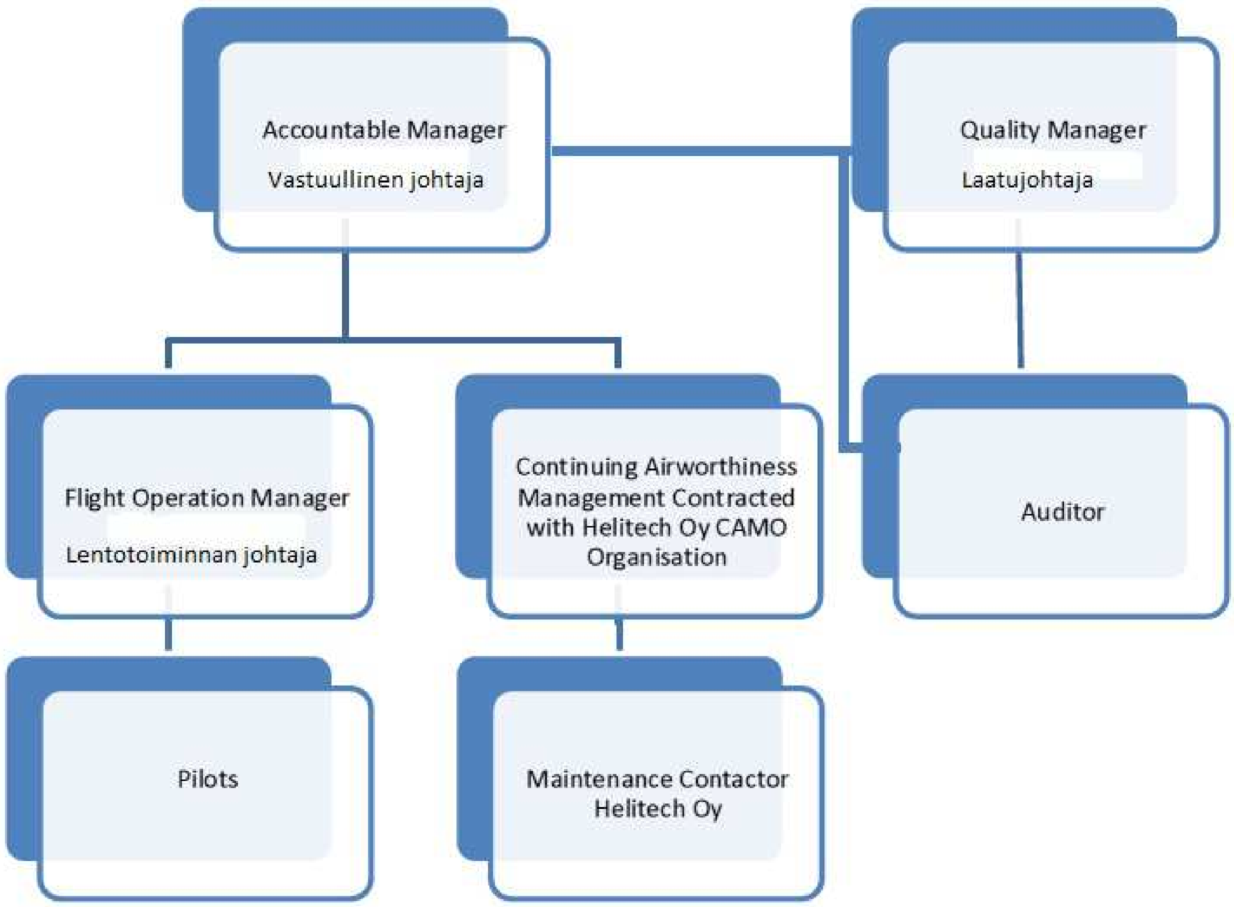


Figure 103. Organizational structure

The pilot of helicopter MD 369E, registration OH-HJR, company Accountable Manager and Quality Manager was the same person. The PIC of helicopter was approved as Accountable Manager and Quality Manager of Helipro OY by Traffic Safety Agency of FINLAND. According to Company Helipro OY Operations Manual for Aerial Work Operations issued on 15.09.2010 Revision 2 the Accountable Manager has the overall responsibility for ensuring that the QAP is implemented and maintained, and has the ultimate responsibility for sourcing the corrective action and ensuring that the corrective action has re-established compliance with the standard required by the Authority, and any additional requirements defined by operator.

The primary role of the Quality Manager is to verify that the standards required by the Authority, and any additional requirements defined by (operator), are being carried out under the supervision of the relevant Nominated Post holder.

- The Quality Manager is, on behalf of the Accountable Manager, responsible for ensuring that the QAP is properly established and maintained;
- The Quality Manager is responsible for that quality inspections are done within the proper timescale;
- The **Quality Manager function reports directly to the Accountable Manager**, and has access to all parts of the organization, including relevant part of any sub-contractors organization. The Quality Manager shall have relevant knowledge on quality assurance of quality systems, and **must be acceptable to the Authority**.

Taking into account abovementioned it follows, that Accountable Manager controls herself.

The Flight Operations Manager is responsible for the leading and controlling of flight operations in all.
According to the Item 5 QUALIFICATION REQUIREMENTS of Operations Manual for Aerial Work Operation:

- The flight crew shall be qualified on the helicopter type and have adequate knowledge of the type of work that is performed;
- The Flight Operations Manager shall assign a Commander for each flight or series of flights;
- The Flight Operations Manager defines qualification requirements;
- The Flight Operations Manager controls that **training needed for pilots for aerial work** flights is performed according to attachments 1, 2, 3 and 4.

The Flight Operations Manager will bring to the attention of the appropriate manager(s) any occurrences which indicate that HeliPro procedures may need revising in the interests of flight safety.

The Item 8.5.4.1. Description of chapter 8.5. Instructions for Aerial Work operations defines:

- External loads may only be slung from hooks installed on the helicopter for that purpose. These hooks shall have both electric and mechanical release mechanism;
- There are two types of external slung load flights: Slinging with line 15-20 m long and long lining which is slinging with a line over 30 m long, with a remote hook at the end. When long lining the vertical reference is maintained via looking out of the door or bubble window, and not through the front with the mirror.

The Item 8.5.4.3. “Sawing flight, System Configuration” of chapter 8.5. Instructions for Aerial Work operations defines:

- The helicopter is maintaining a power line **by sawing the branches off with an 2 m long external saw;**
- The helicopter is fitted with a 80 kg light external saw which together with the saw boom ex-tended approximately 30 m below it.

According to Item 8.5.4.4. Pilot Qualification the Pilot has to be accepted by the Flight Operations Manager to perform external slung load-flights. **Before taking Helipro Oy's internal training** pilot shall have following flight experience and training:

- External slung load basic course;
- **For sawing flights**: **500 fh** (pilot in command) and **20 fh** experience external slung load flights and 30 fh low flight experience (for example power line surveillance).

According to Item 8.5.4.5. Helicopter Qualification:

- During external Slung load flights the helicopters total weight shall be such that it as a minimum is able to hover OGE and in addition has at least 3 inches of mercury (R44 piston engine).

According to Item 8.5.4.11. Pilot, Air and Ground Crew Training

- **Pilot must be approved by Flight Operation Manager for this task;**
- **Before external slung load flights pilot is trained according to training program, attachment 4. Before operations air/ground crew has to be briefed/trained using training list, attachment 4. The Flight Operation Manager controls that training is performed before flights by using training document, attachment 4.**

According to the sections 2.1.1 and 2.1.2 of Attachment 4 before the commencement of cutting flights the pilot must be obtained the training, which includes both theoretical and flight training. Cutting flights training package contains 5 + 10 flight hours. The training must be kept training records, which are held on file for at least (3) three years of training ended.

1.18. Additional information

NIL

1.19. Useful or effective investigation techniques

Not applicable

2. Analysis

The occurrence aircraft engine (model Rolls-Royce 250-C20R/2**,** serial number CAE-295354) was manufactured by Allison Gas Turbine Division, a division of General Motors Corporation.

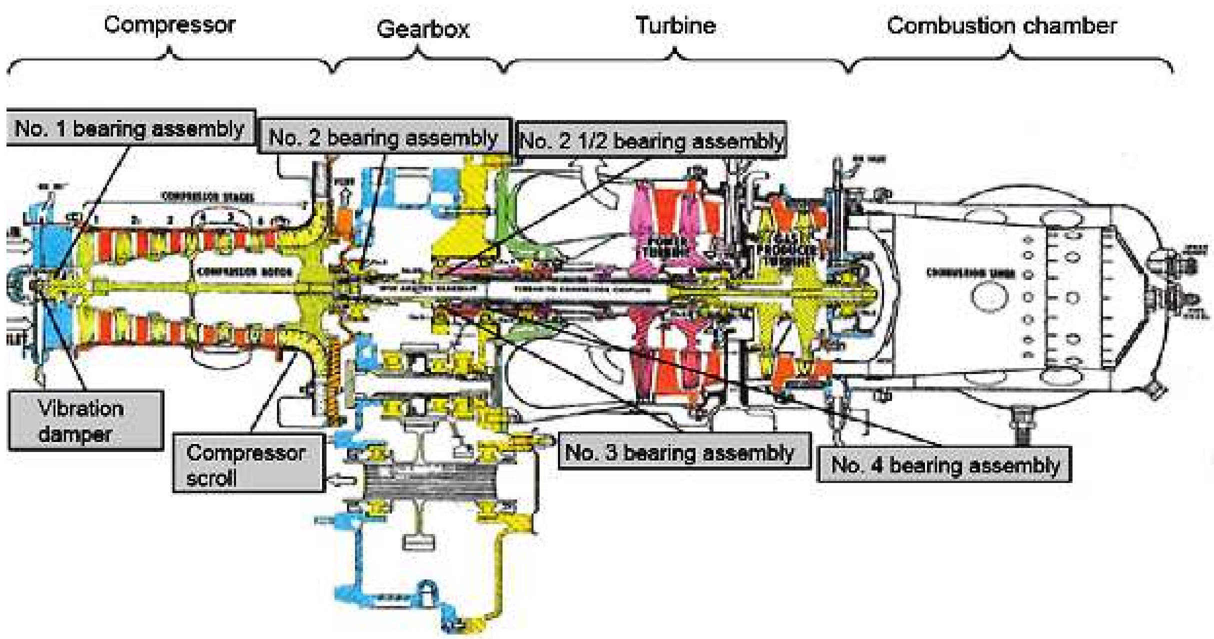


Figure 104. Rolls-Royce 250-C20R/2 engine schematic drawing

Rolls-Royce is the current holder of the type certificate issued by the Federal Aviation Administration (FAA) for this engine model.

The engine is a turboshaft modular-type engine and consists of a compressor, a gearbox, a turbine, and a combustion chamber (Figure 104). It is rated at 450 SHP (shaft horsepower), (340kW).

2.1. Compressor Design

The forward end of the compressor rotor is positioned radially by the No. 1 bearing, a small roller bearing supported inside a housing on a thin film of oil. This oil film damped installation allows a small amount of radial movement of the bearing within the housing to help reduce vibration. The aft end of the rotor is supported by the No. 2 bearing, a large ball bearing designed to take combined radial and axial (thrust) loads as well as accommodate small amounts of angular misalignment. Angular misalignment in the No. 2 bearing can occur in part because slight radial movement is allowed in the No. 1 bearing. The angular misalignment in the No. 2 bearing results in moment loads.

The No. 1 bearing consists of inner ring (also referred to as a race), 14 rollers, a roller separator (cage) and an outer ring (see Figures 50-55).

Each component of the bearing is manufactured to a nominal dimension which incorporates a specified allowance above or below that dimension.

2.2. No. 1 Bearing Examination results

The No. 1 bearing was taken to the Rolls-Royce Laboratory for further inspection. Analysis determined that the bearing component alloys and hardness values were within the manufacturer's specified ranges; no pre-existing deficiencies were found with the No.1 bearing materials. It was also determined that all of the metal particles found on the chip plugs matched the bearing material. The fragments recovered from the bearing housing assembly sump area and analyzed using the scanning electron microscope (SEM) x-ray dispersive analysis system revealed, that most of the fragments were consistent with an AMS6491 (M50) type material used in the outer ring, inner ring and rollers. Other fragments were consistent with an AMS6415 (4340) type material with silver plating which is consistent with the materials used in the No 1 bearing separator. Type of materials was as required by the engineering drawing. There was no indication of a reduced oil flow to the No. 1 bearing.

Many of the rollers contained flat spots, others exhibited bulging at the ends of the rollers, and some exhibited both conditions. Three rollers appeared larger than many of the other rollers, but roller diameter varied widely among all fourteen rollers.

The No.1 bearing inner ring raceway exhibited localized impact dents from rolling over debris and transferred or smeared material around the raceway circumference. The shoulders were also smeared and deformed outward resulting in an extruded or smeared material lip on the outer corners. The general condition of the raceway was consistent with damage generated during roller skidding during operation.

The No.1 bearing outer ring surface appeared similar to the inner raceway and exhibited impact damage from rolling over debris and smearing. The aft side of the ring was slightly darker and heat tinted than the forward half.

The bearing No1 separator had fractured and two of the roller pockets were missing. Significant wear and smearing was observed on the roller retention features and pocket web areas on the outer diameter of the separator. Smearing and plastic deformation was also noted in the roller pockets and on the inner surface of the separator rails.

The metallurgical examination of the No.1 bearing components revealed heat distress on each of the components, specifically throughout the rollers, the inner raceway and the aft shoulder of the inner raceway, and the outer raceway.

2.3. Compressor wheels examination results

2.3.1. Stage 1 Compressor wheel

There was no obvious damage along the leading edges of the airfoils and no obvious sign of knife seal rub. Blade tip rub was evident around the entire circumference of the wheel and was consistent with damage noted along the blade path in the compressor case.

2.3.2. Stage 2 Compressor wheel

The condition of the stage 2 compressor wheel had not obvious damage along the leading edges of the airfoils and no obvious sign of knife seal rub. Oil staining and/or coke deposits were evident along the inner surface of the aft spacer arm and spanned an arc of approximately 180 degrees. Blade tip rub was evident around the entire circumference of the wheel and was consistent with damage noted along the blade path in the compressor case.

2.3.3. Stage 3 Compressor wheel

There was no obvious damage along the leading edges of the airfoils and no obvious sign of knife seal rub. Oil staining and/or coke deposits were evident along the inner surface of the aft spacer arm. This condition spanned an arc of approximately 180 degrees. Blade tip rub was evident around the entire circumference of the wheel similar to that found in the No.1 and No.2 compressor stages and was consistent with damage noted along the blade path in the compressor case.

2.3.4. Stage 4 Compressor wheel

There was no obvious damage along the leading edges of the airfoils and no obvious sign of knife seal rub. Blade tip rub was evident around the entire circumference of the wheel as was noted in the previous compressor stages and was consistent with damage noted along the blade path in the compressor case.

2.3.5. Compressor impeller wheel

The compressor impeller wheel blade tip rub was evident around the entire circumference.

2.4. Compressor case examination results

On the outer surface no obvious damage from heat distress was observed. Rub damage was evident inside along all four blade paths and was consistent with the tip rub damage noted on the compressor wheels. The groves in the stationary seals appeared fairly uniform with evidence to suggest axial shift of the compressor rotor assembly. There was **no evidence of impact damage** to any of the compressor vanes.

2.5. Compressor shroud examination results

There was not noted obvious damage or heat distress. Pitting was evident on the inner aft surface of the shroud. No obvious patterns were noted, but the pitting appeared most severe near the forward portion of the shroud. The pitting damage was consistent with spalled areas of the coating applied to the shroud surface. The pitting appeared to be within the coating because no areas of the base metal were evident. Other areas appeared to be blistered, but not yet spalled off. This pitted area did not show evidence of heavy rub scars, but the blistered areas did appear to be rubbed.

2.6. The chip detection system

The helicopter is equipped with warning and caution indicators located at the top of the instrument panel, including Engine Chip Detector

Figure l05. Instrument panel

According to pilot's testimony there were not chip lights or abnormal instrument indications prior to the engine power loss. At that moment when the pilot heard engine noise reducing he was observing the saw through helicopter's window, therefore he can not to see caution indicator's indications. The pilot assured that during preflight check as well as during performing cutting work was not any abnormalities with engine operation as well as engine chip warning.

During investigation it was found on the chip plugs overdose of the metal particles matched the bearing outer ring, inner ring, rollers material and separator silver material. Such quantity of accumulated metallic debris could be enough for chip detectors to illuminate a cockpit warning light.

During investigation it was found that the chip detection system has been functional, therefore it is possible to conclude that during flight chip indication warning appeared, at least chip light to be forced flicker on.

In all likelihood during performing cutting work the pilot did not notice engine chip warning light and continued to work. According to Section III Emergency and Malfunction Procedures, Item 3-9 pilot must land as soon as possible in case on engine chip indicator comes on.

Investigation did not find evidence that there was the rapid failure of the bearing, but preceded by progressive wear, that generates metal debris for a period of time that was long enough to be detected either during routine maintenance chip detector and oil filter inspections, or during operation when the engine's magnetic chip detectors accumulate enough debris to illuminate a cockpit warning light. In either case, bearing wear is detected before damage is so extensive that it causes the engine to fail.

2.7. Bearings design and failure causes

Bearings can fail for a variety of reasons, including material defects, improper installation, inadequate or contaminated lubrication, and abnormal loading. Most impending bearing failures, however, are preceded by progressive wear that generates metal debris for a period of time that is long enough to be detected either during routine maintenance (chip detector and oil filter inspections) or during operation (**when the engine's magnetic chip detectors accumulate enough debris to illuminate a cockpit warning light**). In either case, bearing wear is detected before damage is so extensive that it causes the engine to fail.
Because the compressor rotor acts like a gyroscope, it resists changes in orientation during yaw and/or pitch maneuvers. As the bearing supporting the forward end of the compressor rotor (the No. 1 bearing) is oil film damped, it allows some radial movement of the compressor rotor.
Aircraft maneuvers induce a gyroscopic moment reaction across the No. 1 and No. 2 bearings, thus, the compressor rotor acts like a gyroscope and resists changing its position when the aircraft yaws or pitches.
Large roller excursions can result in high roller-to-raceway contact stress, spalling of the rollers and raceways, and cyclical loading of the cage leading to fatigue cracking. If the cage cracks, the loss of hoop continuity allows it to expand radially, thus resulting in interference with the guide land and restraining the rollers from rolling. If the excursions are large enough that the rollers run completely off the raceway, scoring and grooving of the rollers will occur. This results in roller skidding, overheating, metal generation and bearing failure.

3. Conclusion

3.1. Findings

- **The findings during inspection reflect the cause of occurred accident - due to the unsupported rotor having heavy contact with the compressor cases that resulting loss of engine power;**

- Because the loss of power occurred when the helicopter was on final approach to the landing area, at low airspeed and low height above uneven ground, it resulted in a hard landing;

- When the No. 1 bearing failed, the compressor rotor remain unsupported, occurred axial shift of the compressor rotor assembly, compressor wheels contacted the compressor cases;

- The condition of the No.1 Bearing was consistent with damage generated from roller skidding and/or increased loading from a loss of internal clearance within the bearing during engine operation. Thermal distress, smearing, and plastic deformation were evident in the bearing components;

- The microstructure on the outer and inner rings away from heat affected areas was consistent with an AMS 6491 (M50) type material as required by the engineering drawings;

- The chemistry of the outer ring, inner ring and rollers were consistent with an AMS6491 (M50) type material as required per the engineering drawing. The chemistry of the cage was consistent with silver plated AMS 6415 (SAE4340) type material as required per the engineering drawing;

- Localized pitting and blistering was evident on the compressor shroud coating. Although the coating appeared to be in a degraded condition, this did not appear to have contributed to the skidding damage noted on the No. 1 bearing;

- The magnetic chip indication was from the breakup of the No1 bearing resulting in the case material passing through the engine and depositing on the first stage nozzle and gas rotor;
- The investigation determined that a operator has contracted with continuing airworthiness management (EASA PART-M) and maintenance activities (EASA PART-145) company and the helicopter had been serviced and maintained in accordance with existing directives (including **FAA AD 96-19-01,** Rolls Royce. Bearing inspection and exchange) and was being operated within its approved limits;

- The chip detection system was found to have been functional and the bearing had been adequately lubricated;

- The parts that comprised the bearing were manufactured of the alloys and hardness specified by the manufacturer, and no pre-existing deficiencies in those parts were found;

- Company „HELIPRO OY" was authorized by authority - Traffic Safety Agency to perform Cutting works;

- The pilot of helicopter had position of company Accountable Manager and Quality Manager, therefore work executor, manager and quality supervisor was the same person;

- Authorized aircraft were helicopters with take-off weight **3175 kg;**

- Helicopters take-off weight did not exceed allowed take-of weight limit;

- The Flight Operations Manager shall assign a Commander for each flight or series of flights;
- Pilot had not had acceptance from the Flight Operations Manager to perform cutting work with used helicopter type;

- Before the commencement of cutting flights the pilot must be obtained the training, which includes both theoretical and flight training.

- According to Cutting flights training package contains 5 + 10 flight hours;

- The flight crew had qualified for flying on the helicopter type but **had not adequate knowledge, experience and training** for work that was performed with the turboshaft engine helicopter;
- According to Instructions for Aerial Work operations the helicopter maintaining a power line **by sawing the branches off was authorized to work with an 2 m long external saw;**
- Pilot did not use the saw according to authorized specifications of Instructions for Aerial Work operations;

3.2. Causes

3.2.1. Direct cause

The direct cause of the accident of Helicopter MD369E, registration OH-HJR was engine 250-C20R/2 failure – loss of power.

3.2.2. Root cause

The root cause of the accident of Helicopter MD369E, registration OH-HJR was bearing No.1 of compressor engine 250-C20R/2 failure, probably due to large roller excursions that results in high roller-to-raceway contact stress, spalling of the rollers and raceways, and cyclical loading of the cage leading to fatigue cracking.

3.2.3. Contributing cause

Loss of power when the helicopter was on final approach to the landing area, at low airspeed and low height above uneven ground.

4. Safety Recommendations

Recommendation - LV2014001

The Accident Investigation Board recommends to the company “Helipro OY” to establish independent Quality Management System.

Recommendation - LV2014002

The Accident Investigation Board recommends to aviation authority – the Traffic Safety Agency of Finland to perform audit of company “Helipro OY” Operations Manual for Aerial Work Operations, particularly to pay attention that the training should take into account the specific characteristics of the type of helicopter for cutting work as well as revise company quality management system.

Recommendation - LV2014003

The Accident Investigation Board recommends to company Rolls-Royce, taking into account the probability of another similar No. 1 bearing failure to consider opportunity to issue a Commercial Engine Bulletin (CEB) of reducing periodical inspection and exchanging interval.

May 05, 2014 Riga

Investigator in charge: Visvaldis Trubs

Director of Aircraft Accident
and Incident Investigation Bureau Ivars Alfreds Gaveika