

Scanning Electronic Microscopy for Helicopter applications



GNMEBA

9, 10 June 2022 – Aix-en-Provence

Gaël MONAVON – AIRBUS Helicopters

HELICOPTERS

AIRBUS

Agenda

Introduction

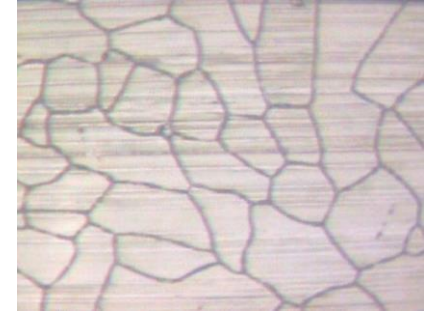
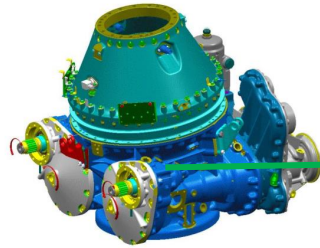
Different usages of SEM:

- 1) Material & Processes development
- 2) New Surface treatments
- 3) Paint analysis
- 4) Part certification
- 5) Particle analysis for In-Service monitoring

Conclusions

Introduction

Helicopter materials

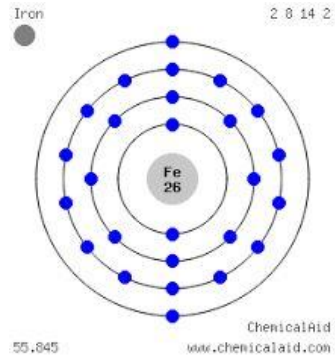


Grain size (scale: μm)

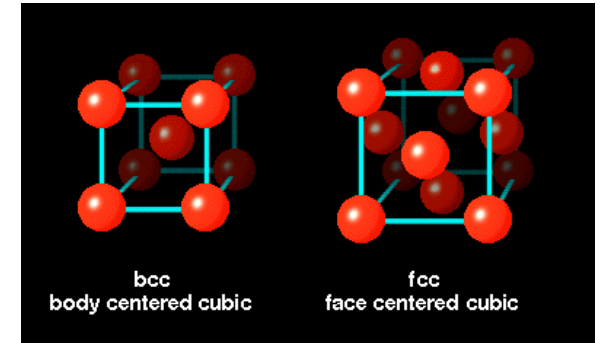
Periodic table of the elements

group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	H	He											B	C	N	O	F	Ne	
2	Li	Be											Al	Si	P	S	Cl	Ar	
3	Na	Mg											Zn	Ga	Ge	As	Se	Br	Kr
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Cobalt	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og	
lanthanoid series			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu			
actinoid series			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr			

*Numbering system adopted by the International Union of Pure and Applied Chemistry (IUPAC). © Encyclopædia Britannica, Inc.



Iron atom (scale: nm)



Ferrite

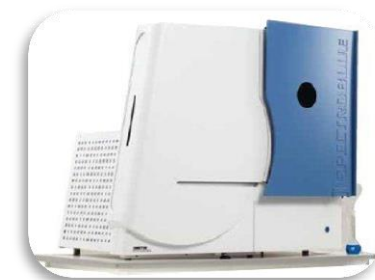
Austenite

Our helicopters are made of atoms !

... and sometimes devil is in the details

Introduction

Some equipments



Introduction

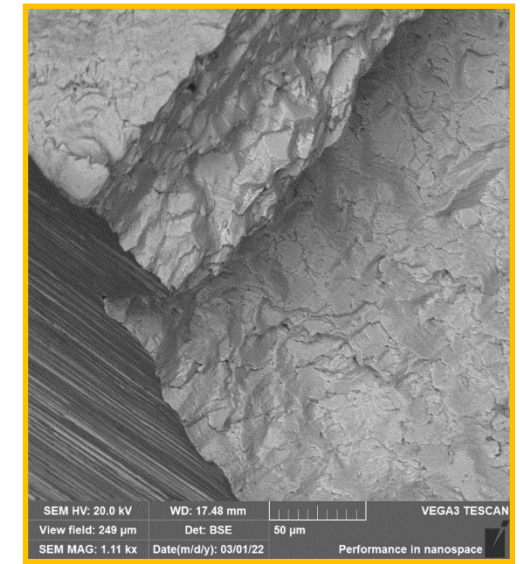
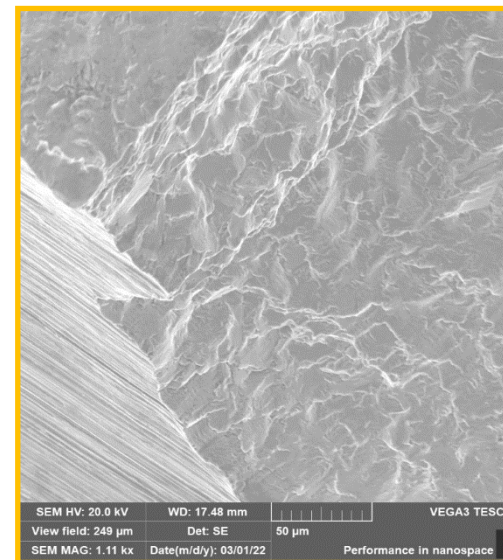
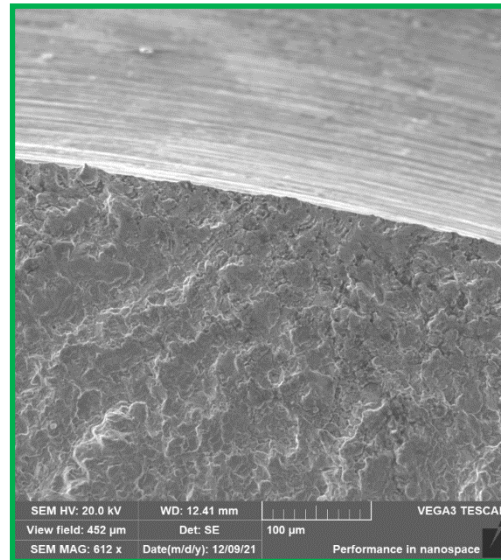
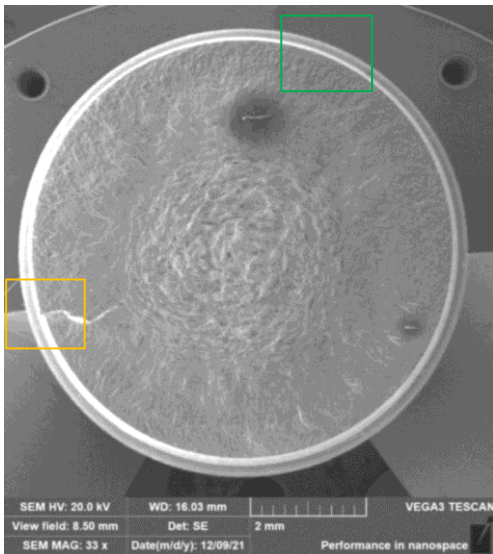
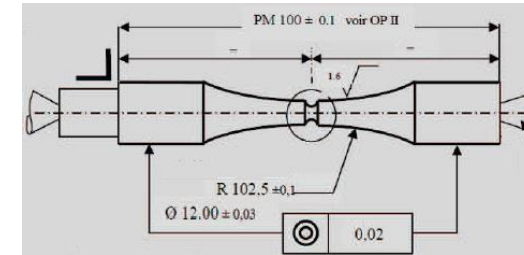
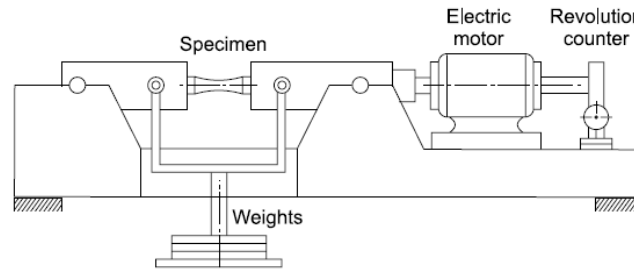
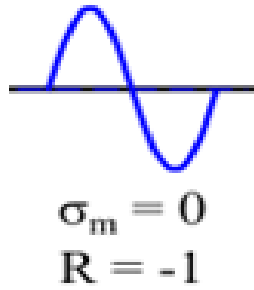
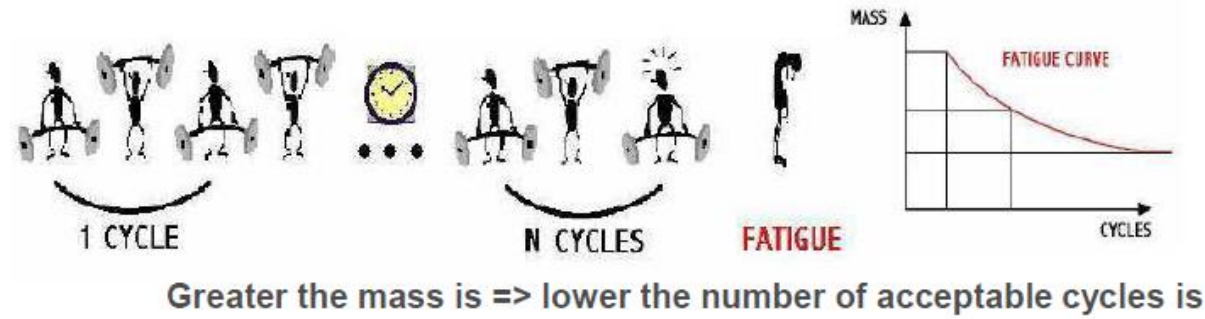
Focus on SEM

- Both technologies available (Tungsten and FEG)
- All equipments equipped with SE / BSE / EDX (EBSD available in other labs in Airbus Group)



1) Material & Processes development

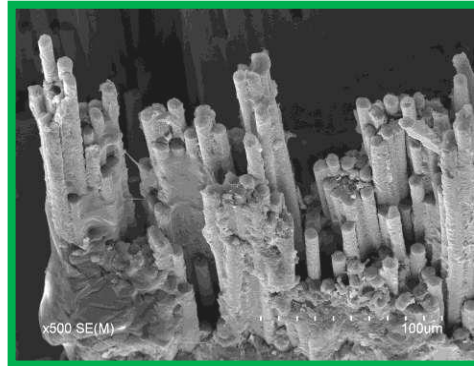
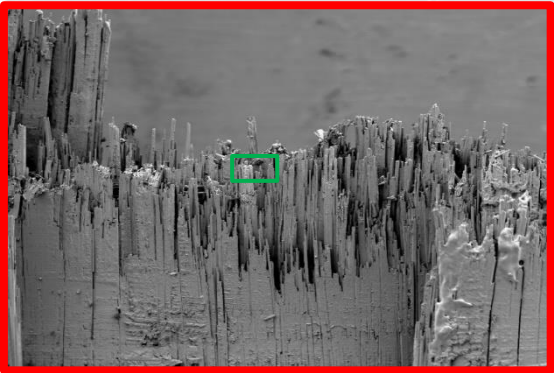
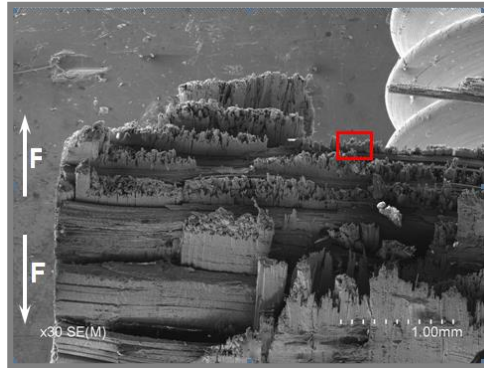
- Fractography after fatigue test for new M&P characterization



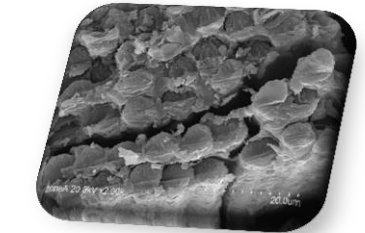
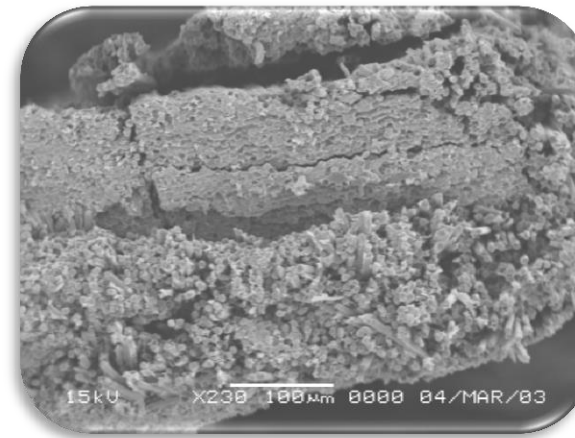
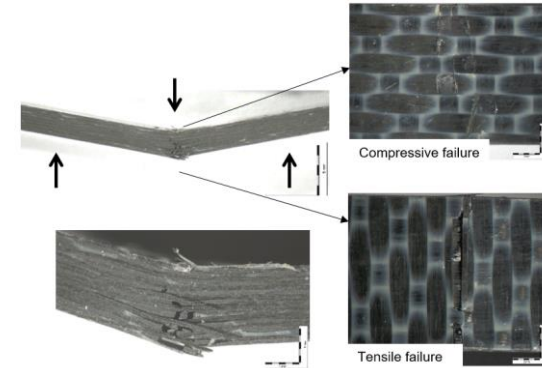
Validity of mechanical property is checked with SEM

1) Material & Processes development

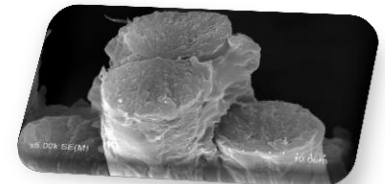
- Fractography after fatigue test for new M&P characterization



Static Tensile test



Compression



Tension

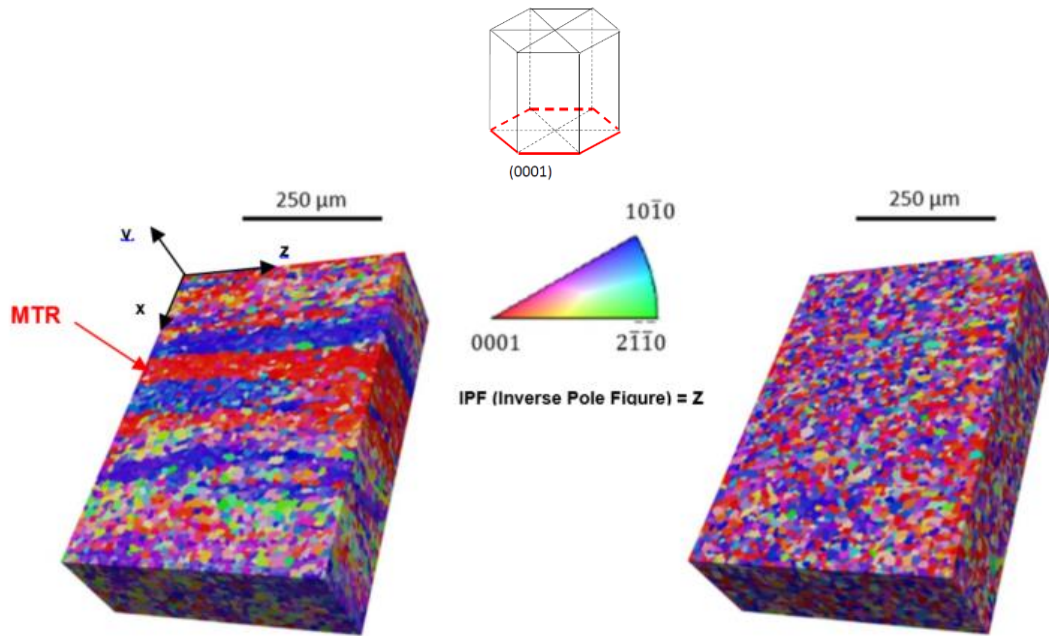
Static Bending test

Validity of mechanical property is checked with SEM

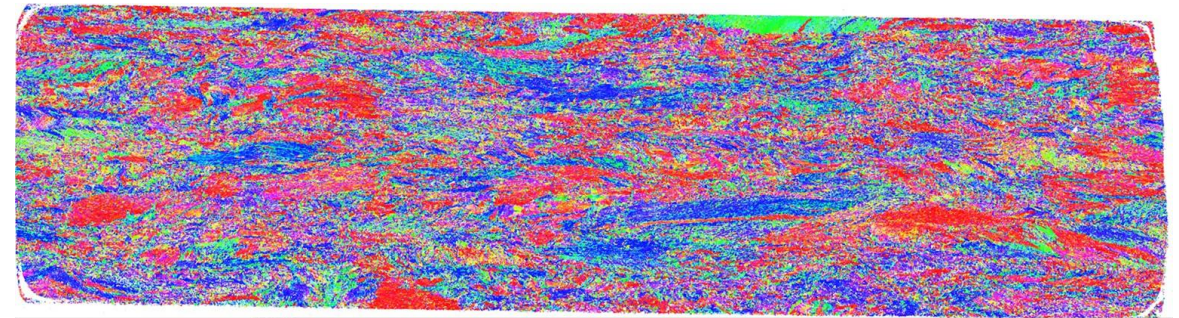
1) Material & Processes development

- Texture for M&P characterization: MTR's (Micro Texture Regions) or so called macrozones

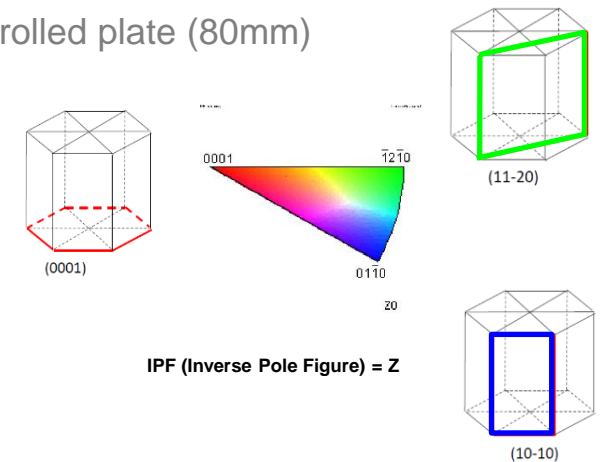
MTR's can be isolated/random, or more widespread depending on the thermomechanical history



Macrotexture is the same in both cases, same number of grains with red crystal orientation but in case 1 red grains are clustered in a MTR, whether in case 2 they are randomly distributed



Ti-64 cross rolled plate (80mm)



Microtexture is checked as it can impact mechanical characteristics

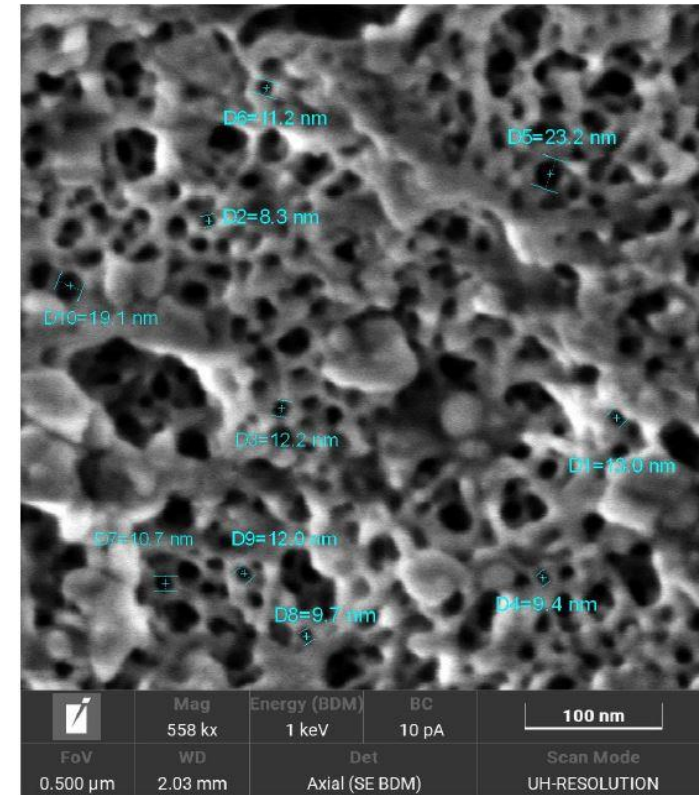
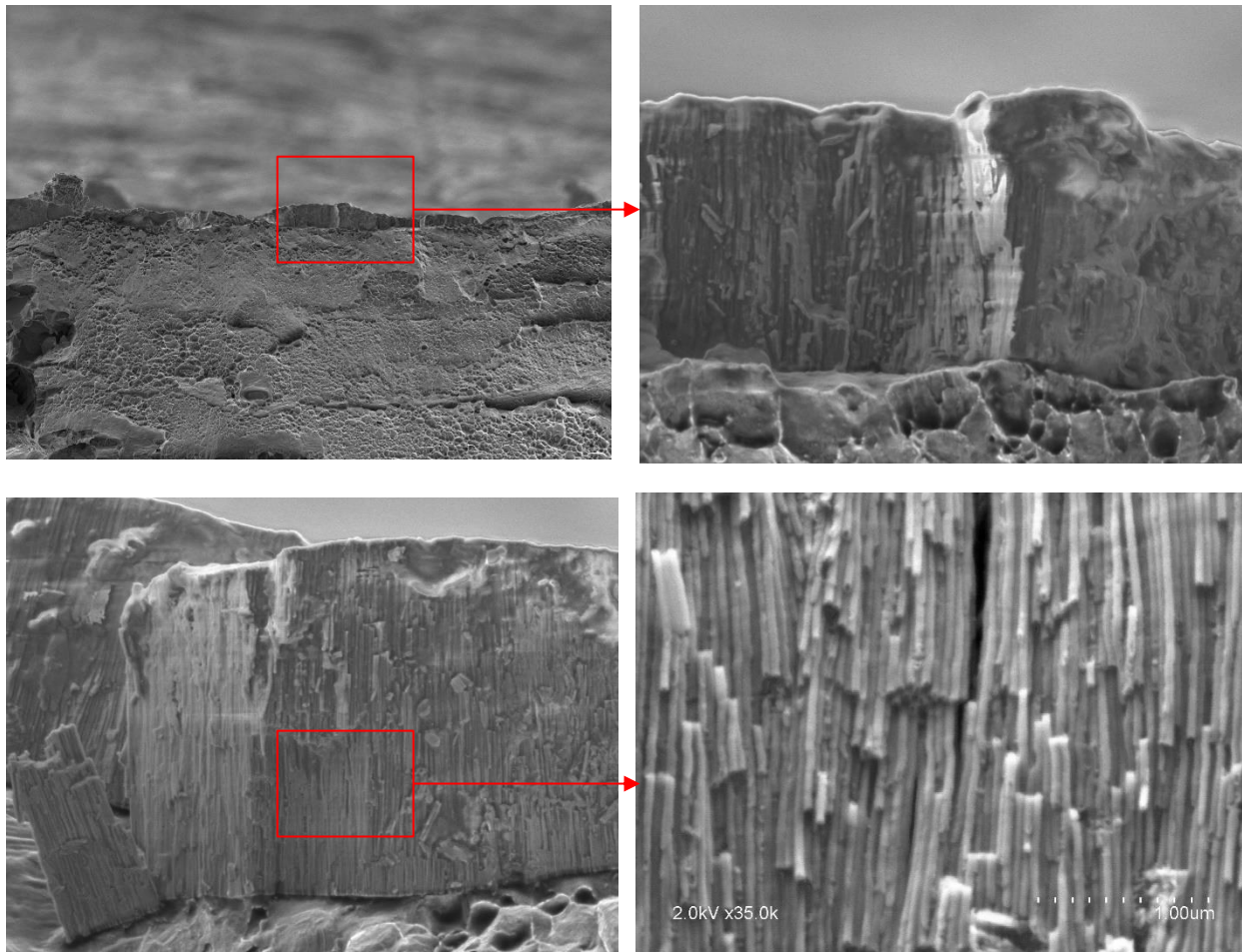
2) New surface treatments

Context: Reach regulation → new surface treatment processes to be developed and characterized

Hazmat TG	Materials	Current processes	Substitution processes
Hazmat 1	Steel	Cadmium electroplating + Chromic finishing CrVI	Zinc-Nickel + Finidip CrIII
			Cadmium electroplating + Finidip CrIII
			Cadmium electroplating + EcoTriNoCo
Hazmat 3	Al	CAA + Chromium sealing	TSA + Lanthane 613.3 + Hot water sealing
Hazmat 5	Al	Alodine 1200 + primer (P05)	Anaphoresis
		Alodine 1200	Chemical Conversion CrIII (CCC)
		Alodine 1200	Surtec + PACS
Hazmat 7	Mg	Mordancage	Permanganate Phosphate
		Chromium stripping	Hydrofluoric stripping
Hazmat 10	Al / Ti	Alcaline pH9 degreasing	Bonderite C8000 GL

2) New surface treatments

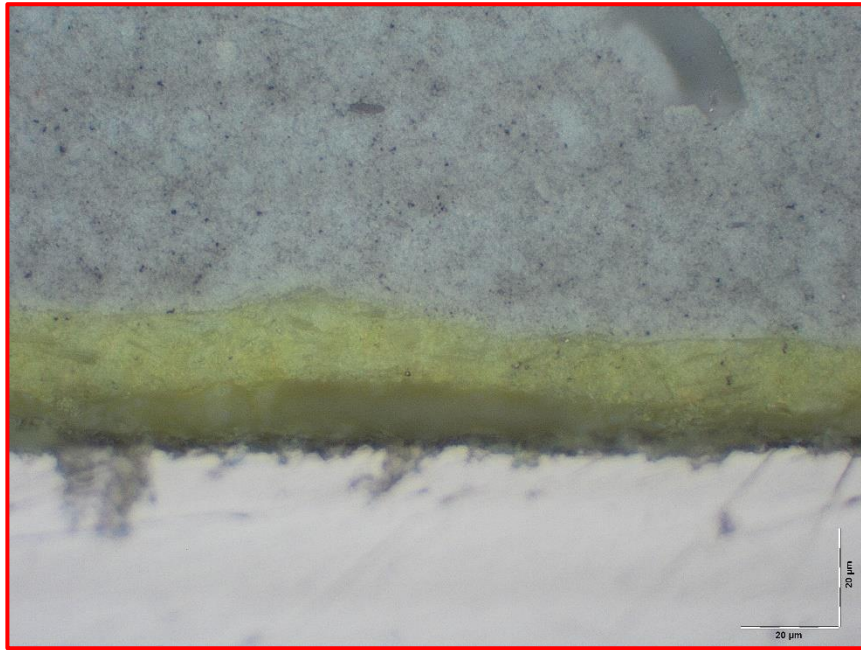
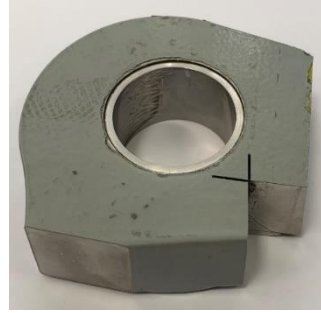
- Example of TSA on Aluminium alloy
- Many tests are requested to qualify a new surface treatment (adhesion, thickness, corrosion, fatigue, chemistry ...) and are of course linked to what can be observed with SEM



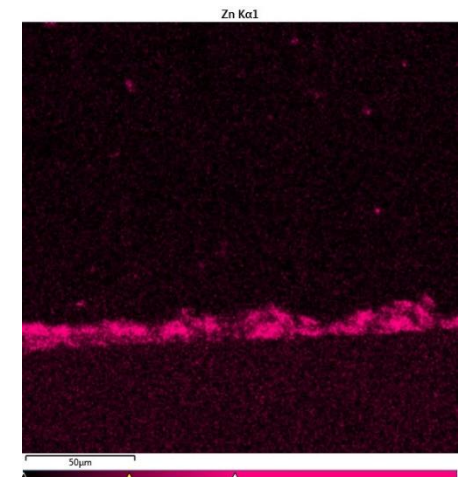
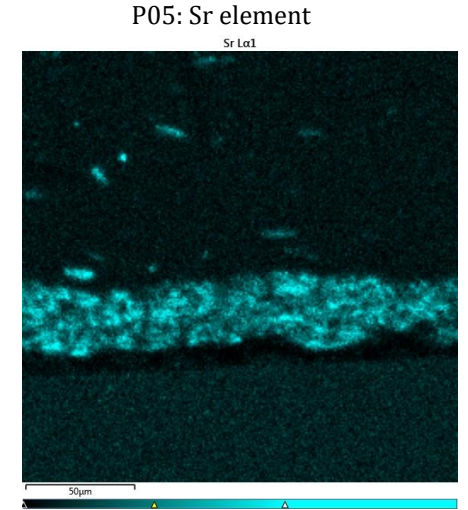
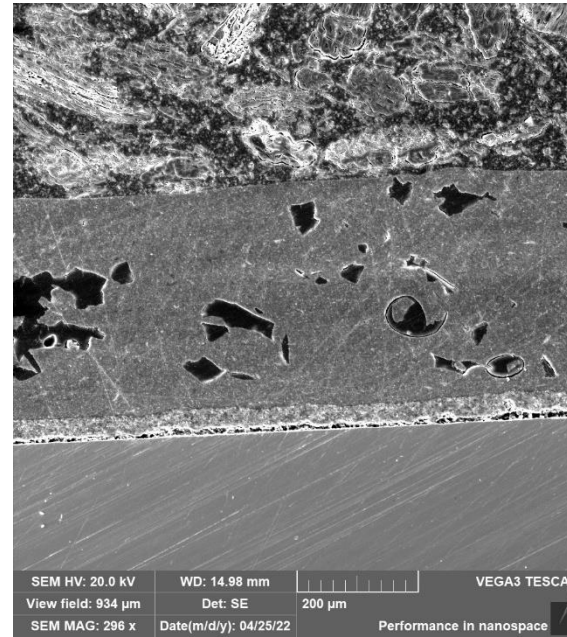
Top view (observation of pores)

3) Paint analysis

- Different paint layers (thickness and chemical composition)

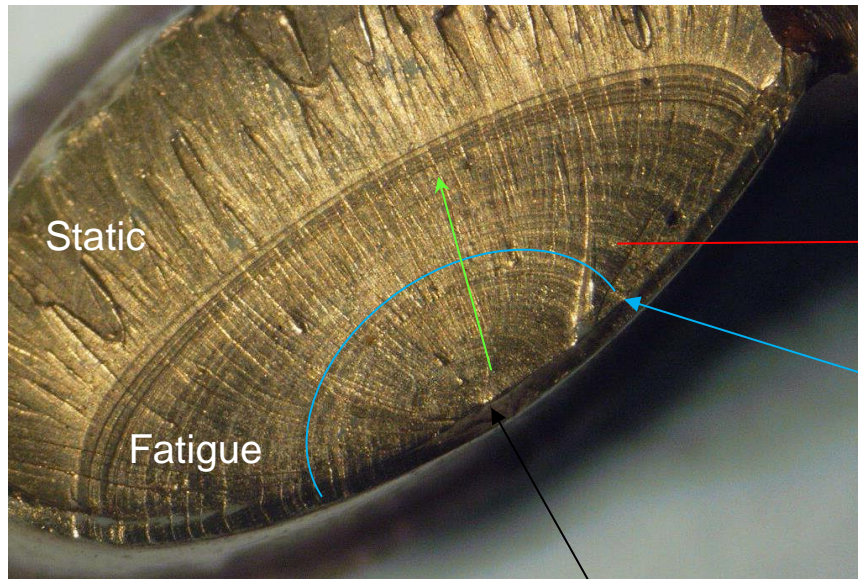


← P103
← P05
← P15
← Stainless steel



4) Part certification

- Many helicopter parts are certified via a fatigue test
- Failed part is then submitted to fractography:
 - Macro mark counting
 - Striation counting



Initiation point

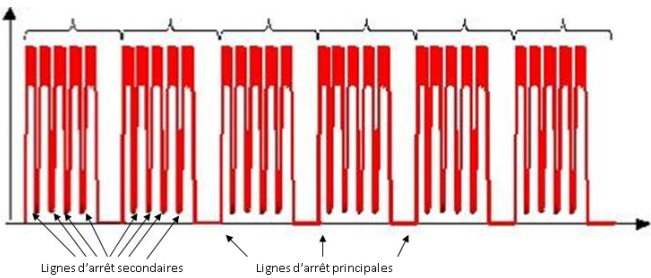
Propagation lines

Beach marks

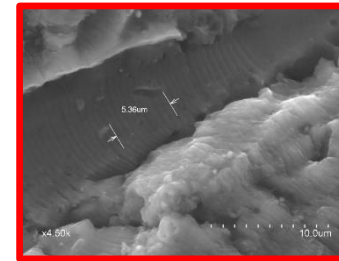
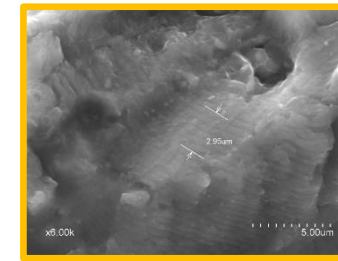
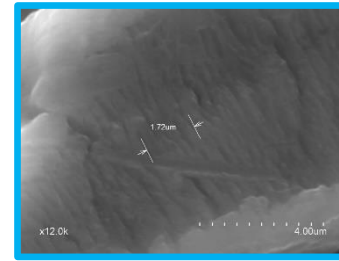
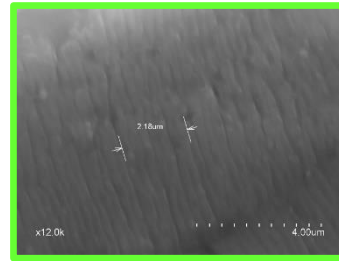
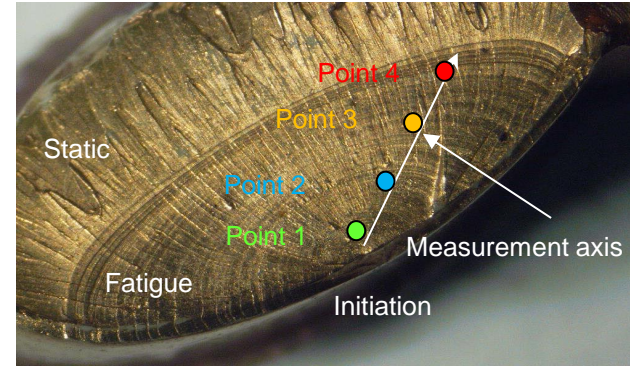


Striation observed at Scanning Electronic Microscope

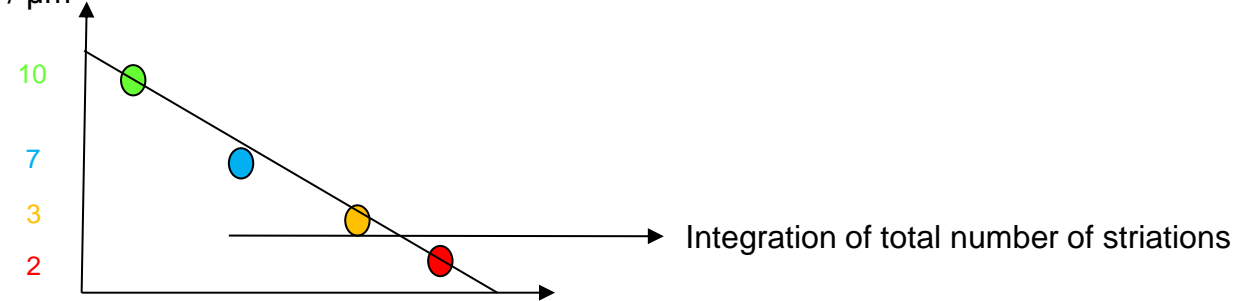
4) Part certification



Macro mark



Striation / μm

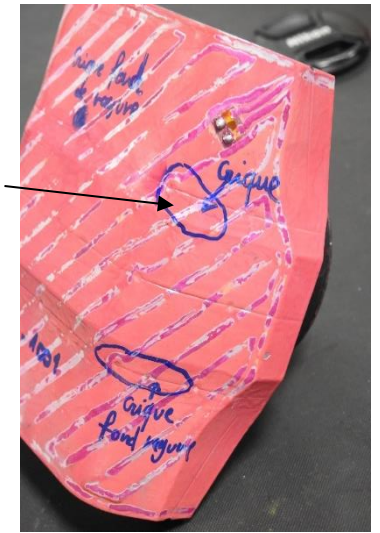


Striation

4) Part certification

Example of H160 Spherical bearing certification test (Damage tolerance)

Crack in fatigue test

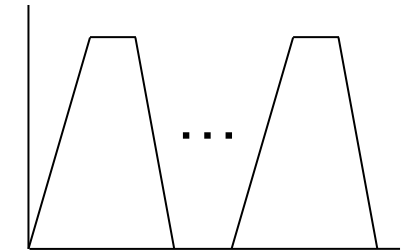


Phase	Number of blocks or cycles
A	50 blocks (LCF)
B	400 000 cycles (HCF)
C	40 blocks (LCF)
D	100 000 cycles (HCF)

LCF 1			
Charge (N ou N.m)	stat	dyn	phase
FC	125128	0	0
Fbdp	0	0	92
Faba	0	0	0
Fabf	0	0	-73
Mf	0	0	-45
Mt	0	0	-111

LCF2			
Charge	stat	dyn	phase
FC	246589	0	0
Fbdp	-2150	9397	92
Faba	-700	17080	0
Fabf	-700	17080	-73
Mf	-229	1657	-45
Mt	11	4205	-111

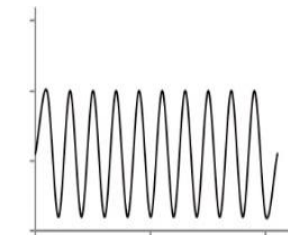
40 cycles LCF01->LCF02-> LCF01



LCF

Charge	stat	dyn	phase
FC	246510	0	0
Fbdp	-4440	9668	92
Faba	-5310	17089	0
Fabf	-5310	17089	-73
Mf	-500	1521	-45
Mt	730	4770	-111

Fin des 100 000 cycles de HCF (500 000 cycles total de HCF)

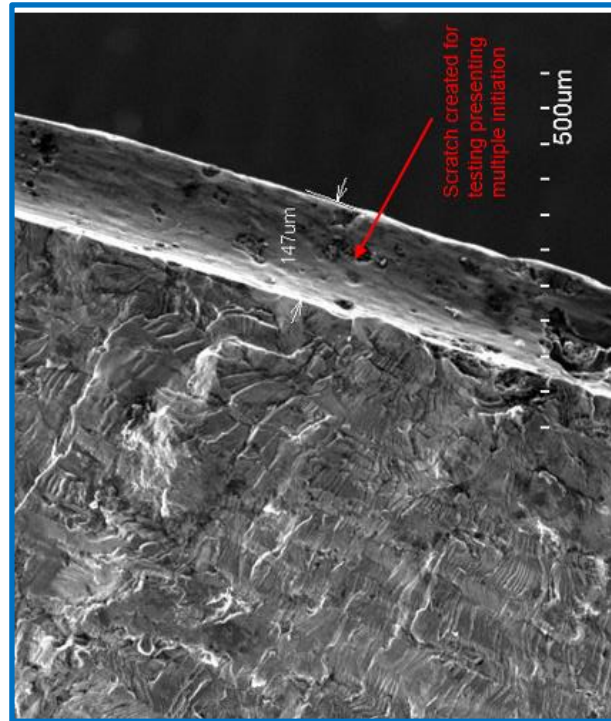
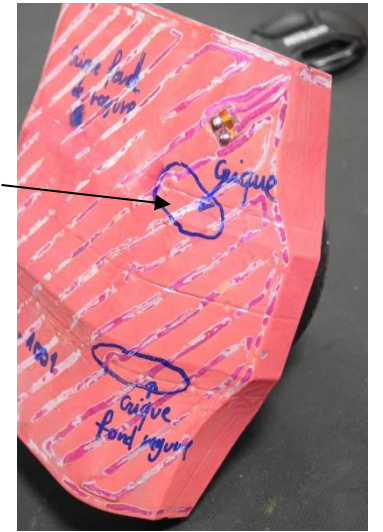


HCF

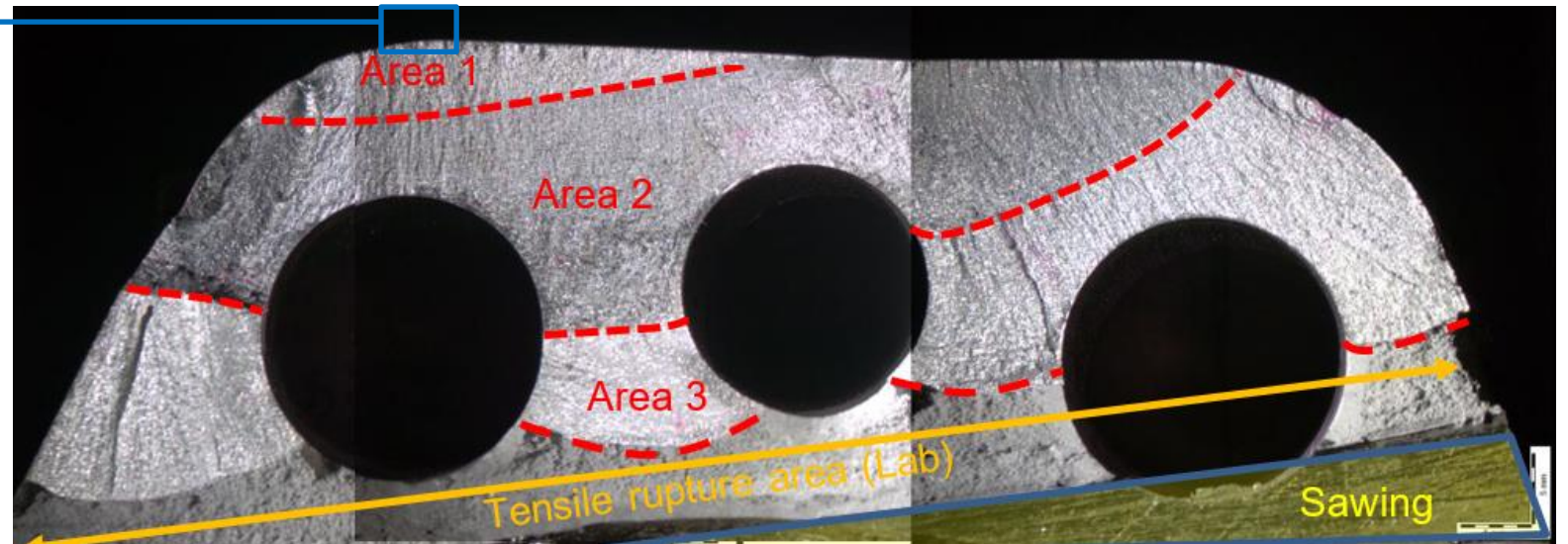
4) Part certification

Example of H160 Spherical bearing certification test (Damage tolerance)

Crack in fatigue test



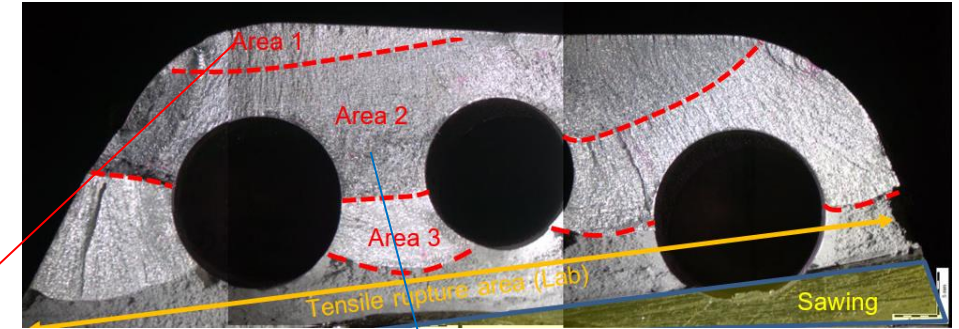
Scratch (150µm depth) Damage Tolerance test at initiation in area 1



3 areas of fatigue propagation (after crack opening)

4) Part certification

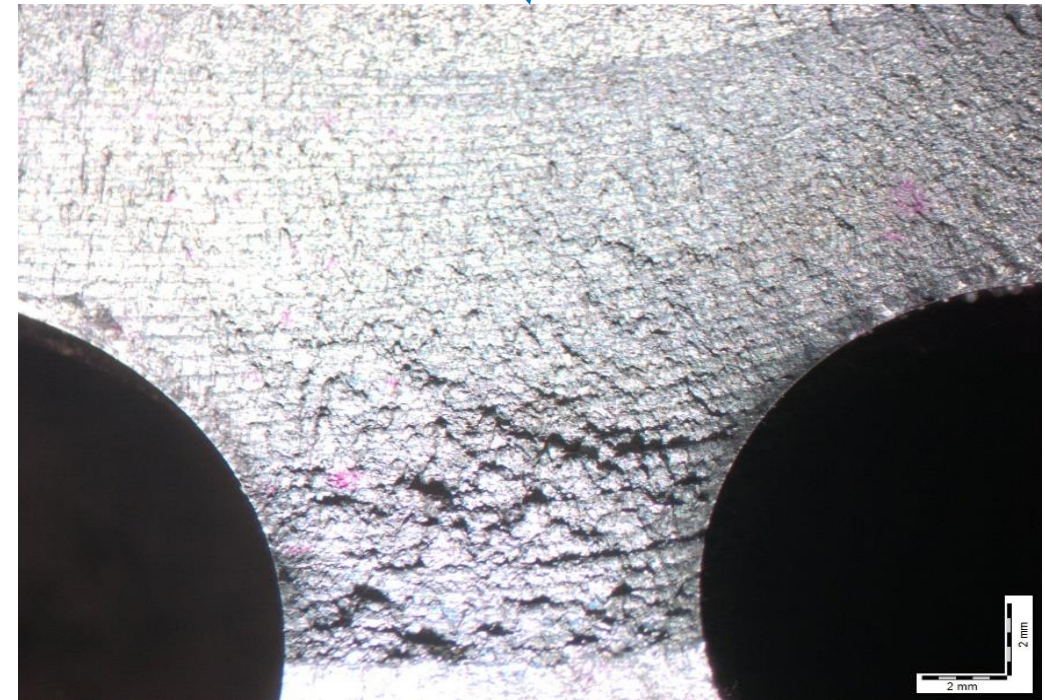
Example of H160 Spherical bearing certification test (Damage tolerance)



Rapport d'essai ETL2019-41171

POINTS MESURES			Distance	Densité (stries/μm)	Nombre de μm/strie (da/dn)	Cumul des stries direction	Cumul des stries total
	X (mm)	Y (mm)					
Amorçage	44,04	72,94	0,00 mm	30,00	0,03	0	0
Point 1	43,90	71,94	1,01 mm	29,50	0,03	30019	30019
Point 2	44,96	72,20	1,18 mm	29,80	0,03	35053	35053
Point 3	44,70	70,62	2,41 mm	28,56	0,04	70966	70966
Point 4	44,70	70,39	2,63 mm	25,26	0,04	76893	76893
Point 5	44,75	69,28	3,72 mm	20,29	0,05	101784	101784
Point 6	44,68	68,87	4,11 mm	14,31	0,07	108553	108553
Point 7							
Point 8							
Point 9							
Point 10							
Point 11							
Point 12							
Point 13							
Point 14							
Point 15							
Point 16							
Point 17							
Point 18							
Point 19							
Point 20							
Point F			4,52	14,31	0,07	114377	114377

Area 1: ~114 000 striations

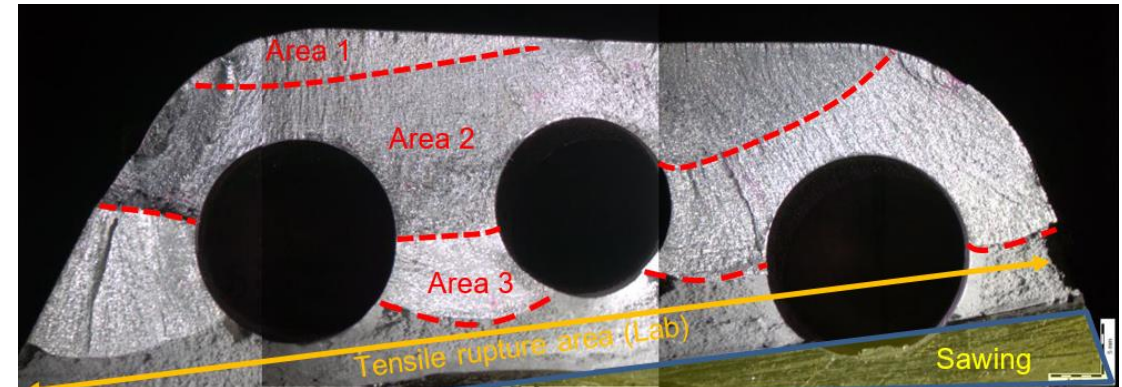


Area 2: 40 beach marks

4) Part certification

Example of H160 Spherical bearing certification test (Damage tolerance)

Phase	Number of blocks or cycles	
A	50 blocks (LCF)	
B	400 000 cycles (HCF)	
C	40 blocks (LCF)	Area 2
D	100 000 cycles (HCF)	Area 3



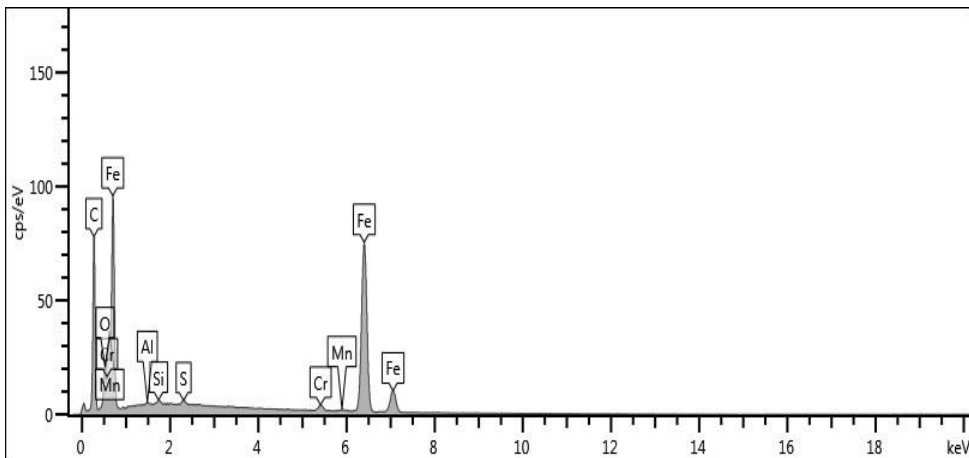
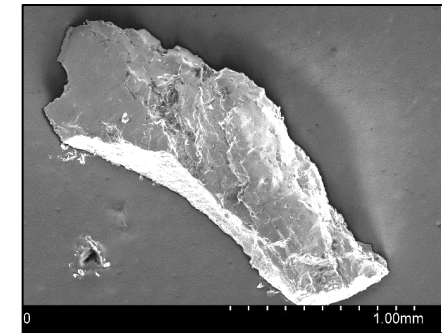
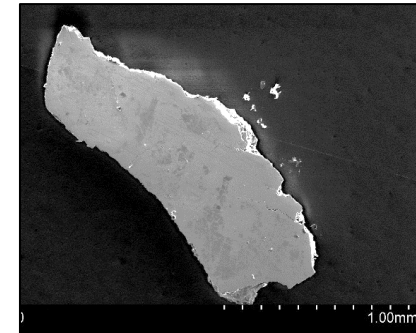
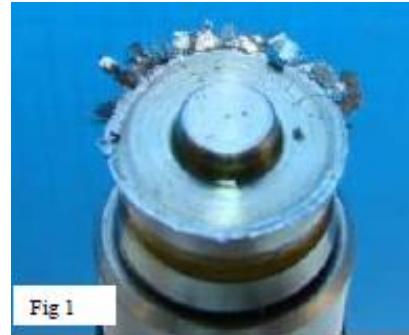
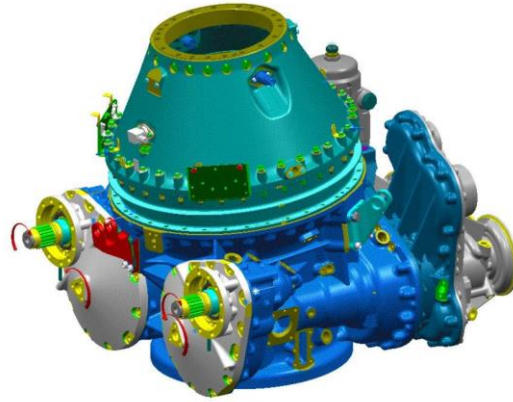
Step 1 - Identification of the block where the crack was initiated (e.g. Phase B)

Step 2 - Striations counting in the phase B (e.g. 114 000 striations)

$$400\ 000 - 114\ 000 = 286\ 000$$

Initiation occurred after 286 000 cycles

5) Particle Analysis for In-Service monitoring

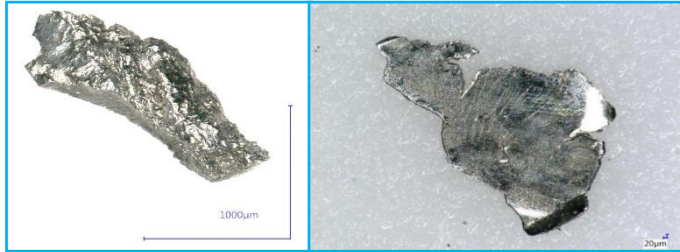


Alloy	C	Si	S	P	V	Cr	Mn	Ni	Mo	Fe
100C6	0,95 – 1,1	0,15 – 0,35	< 0,01	< 0,015	< 0,3	1,35 – 1,6	0,2 – 0,4	<0,4	<0,1	The rest

100C6 steel composition

5) Particle Analysis for In-Service monitoring

Always coupled with morphology analysis



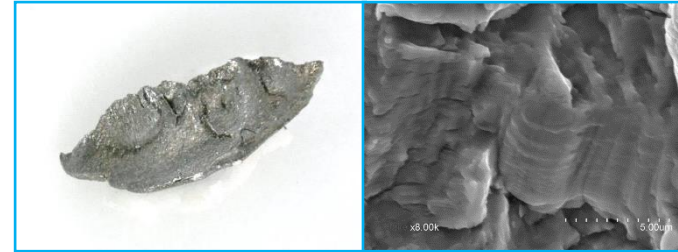
Scale / laminated scale

Result of superficial damage of bearings or gears.



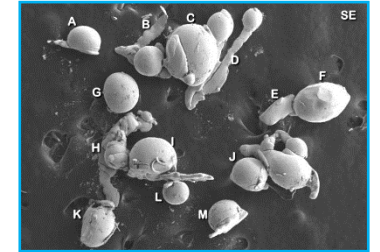
Metal flake

From broken bearing race or gear tooth.



Splinter

Small fragments from fatigue crack propagation.



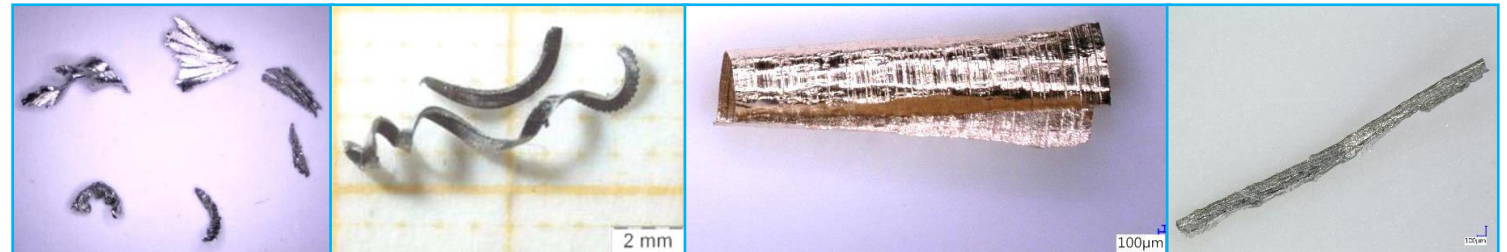
Welding residues

FOD



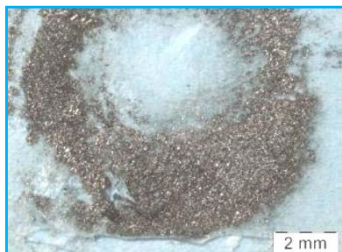
Lock wire / pin

FOD



Swarf

From machining, assembly, or result of a contact between two parts.



Abrasion / wear

Result of parts in contact in oil, can colour the lubricant.

Materials	Comments
16NCD13	Carburized steel, used for gears
18NC16	Carburized steel, used for gears
32CDV13	Nitrided steel, used for gears
E80DCV40 (M50)	Used for bearings
13DCNV40 (M50 NIL)	Used for bearings
100C6	Used for bearings

Commonly used materials for gears and bearings

Size	Particles surface
M	< 0.1 mm ²
L	0.1 mm ² ↔ 0.5 mm ²
XL	0.5 mm ² ↔ 1 mm ²
XXL	1 mm ² ↔ 1.5 mm ²
XXXL	1.5 mm ² ↔ 3 mm ²

Particles size classification

Conclusions:

- SEM largely used on helicopter parts:
 - During development phase and certification
 - During Manufacturing
 - In-service

- SEM used for different materials:
 - Metallic
 - Organic
 - Electronic

- SEM is a key equipment of our lab and Helicopter safety

- Expectations:
 - Better resolution required (better comprehension of M&P)
 - Increase chamber size
 - More automation
 - Automatic image recognition

- Thanks, Questions?

