HELICOPTERS

Corrosion of steel and stainless steel - fatigue limit effects

Helicopter dynamic system components

N. Guillemot, J.M. Besson – rotor stress department

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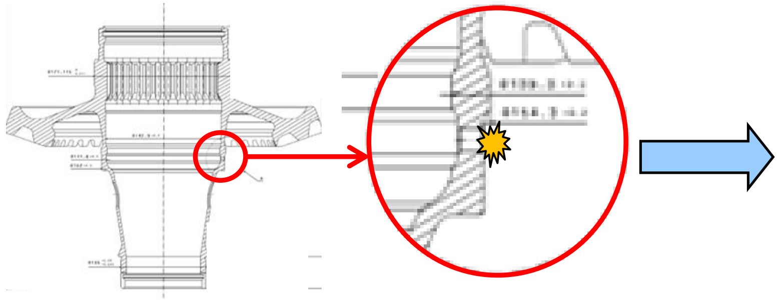
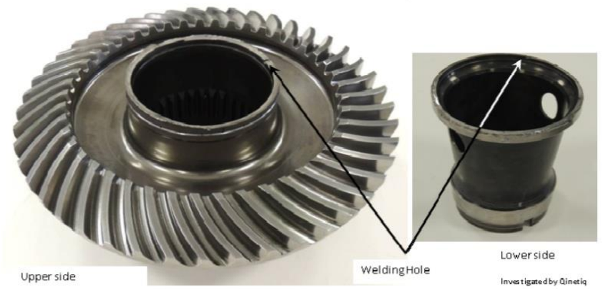
EC225 ditching: specific corrosion on 32CDV13 steel

- Vertical shaft of the Main Gear Box (MGB) ➔ such corrosion inside the MGB is unusual
- Crack initiation on a 60µm depth corrosion pit
- One of the main root causes is **corrosion**

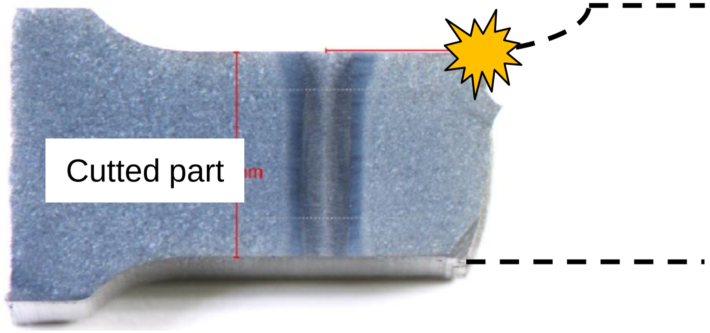
Part failure in two pieces



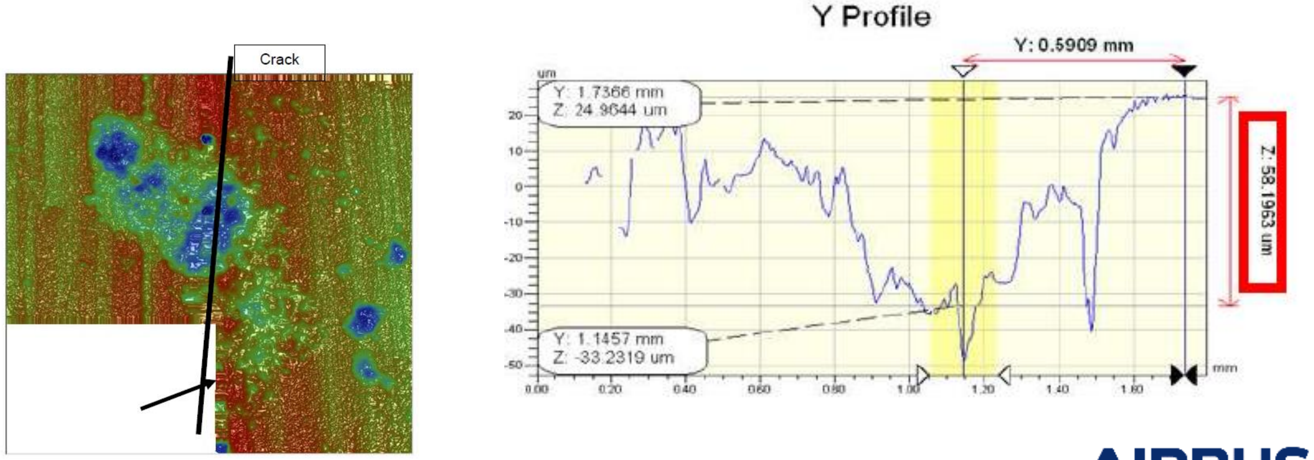


Failure in the shaft radius

(close to the welding joint)



3D measurement of failure areas



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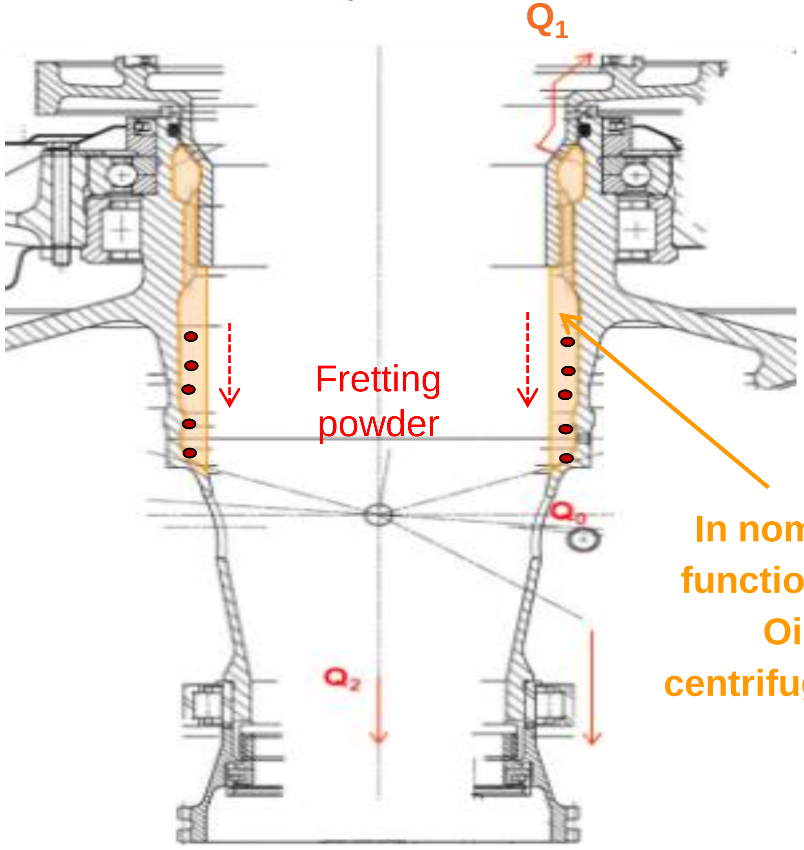
EC225 ditching: specific corrosion on 32CDV13 steel (2)

- Scenario details:

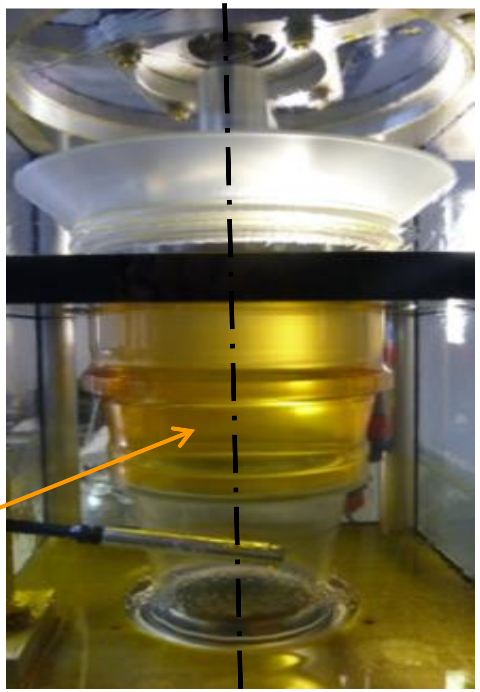
External temperature : 10°C



Internal temperature: 100°C

In nominal functioning: Oil centrifugation

Ω

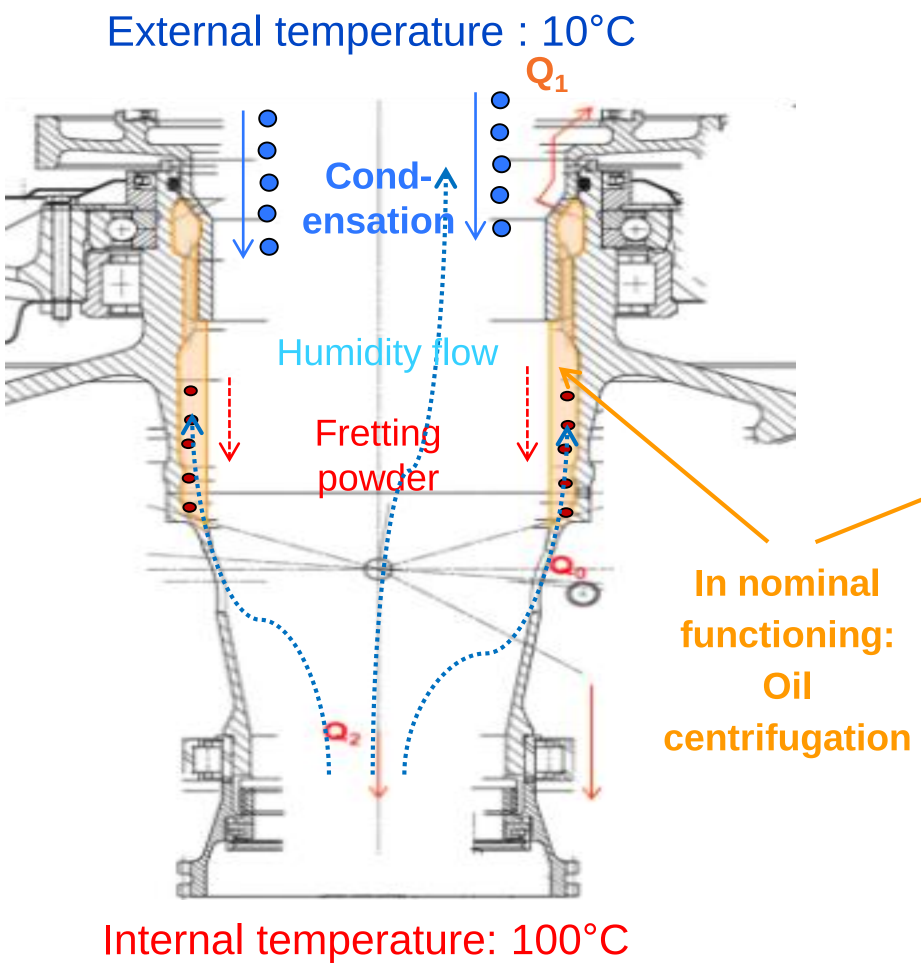


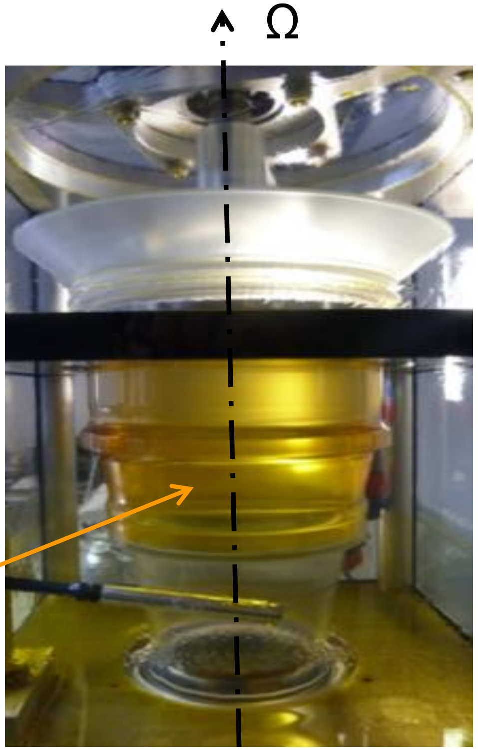
Sticked fretting powder

- During nominal functioning : « **swimming pool effect** » (oil centrifugation) in the inner diameter.
- **Fretting powder** created by the wear of splines and due to centrifugation

EC225 ditching: specific corrosion on 32CDV13 steel (2)

- Scenario details:



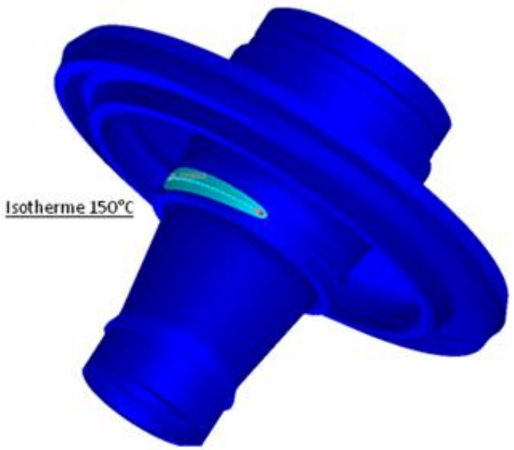


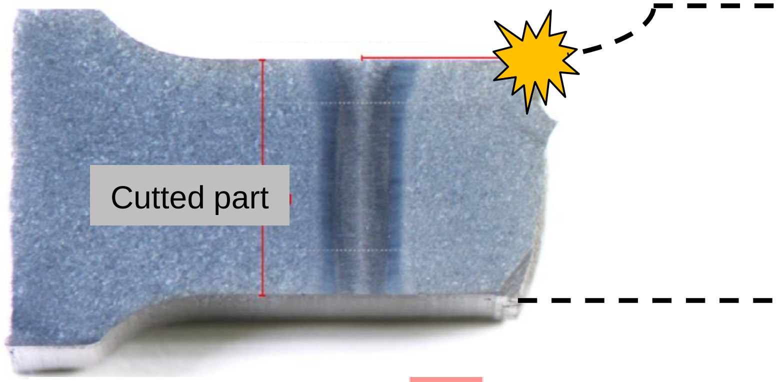
Sticked fretting powder

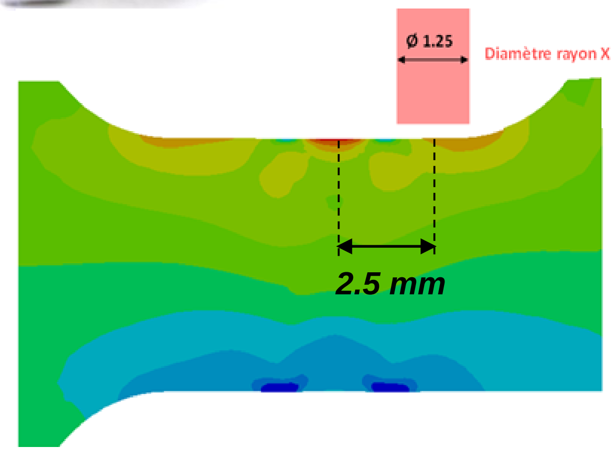
- During nominal functioning : « **swimming pool effect** » (oil centrifugation) in the inner diameter.
- **Fretting powder** created by the wear of splines and due to centrifugation
- Exchange with external air and **condensation** effect lead to humidity ingress inside the gearbox.
- Due to temperature gradient 100°C inside the MGB and 10°C outside in the main rotor shaft, an **humidity flow** is created. Then, a mixture of humidity and fretting powder could be trapped in the inner diameter.

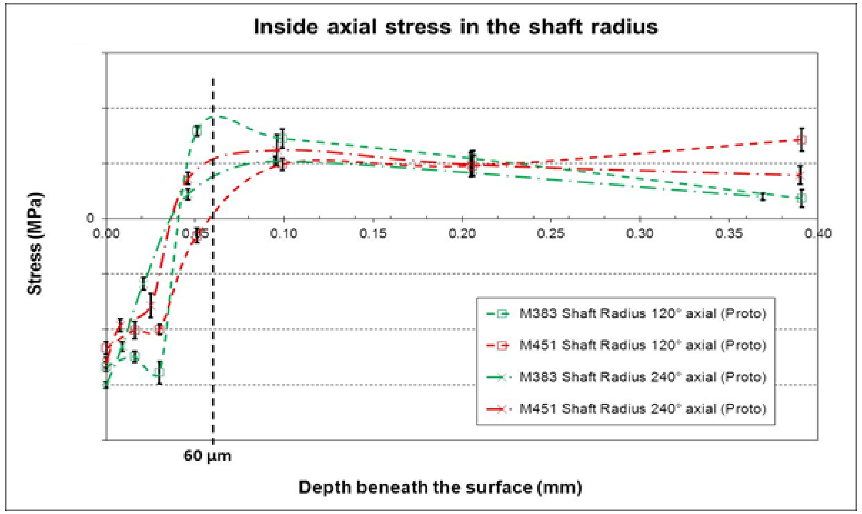
EC225 ditching: specific corrosion on 32CDV13 steel (3)

- Internal component of the Main Gear Box (MGB)
  Crack initiation on a 60µm depth corrosion pit
- Now, use of **welding modelling** in order to predict residual stress field ➔ Fatigue behaviour









EC130: some mast/hub bolts failure from severe corrosion

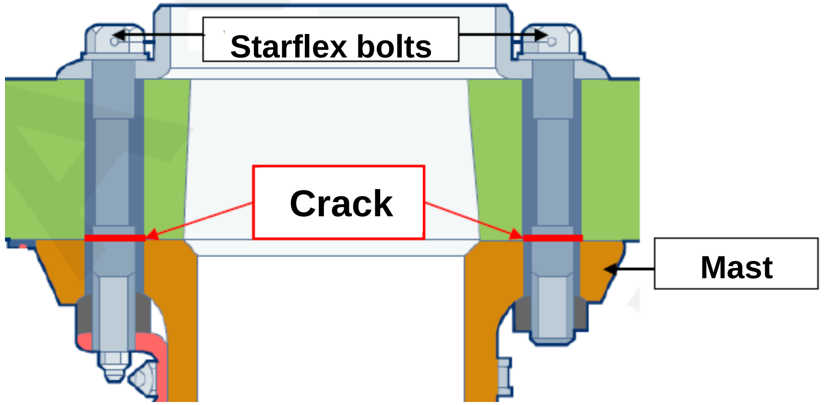
➢ Context

- ✓ Customer operating in hot and wet conditions
- ✓ **Some bolts were brocken (high strength steel) detected by maintenance routine**
- ✓ Fretting and severe corrosion marks
- ✓ Retex: Among 415 customers, 9% with light fretting or corrosion which remains much lower than these 2 incidents

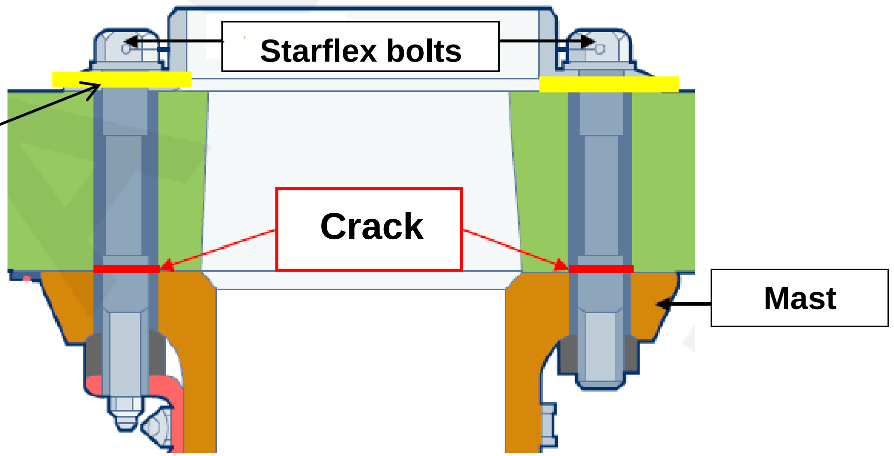
35NCD16 bolt without cadmium

➢ Background

- ✓ This assembly design exists since 1978 on more than 34 million of FH on Ecureuil fleet without any significant incident on this bolted assembly up to now

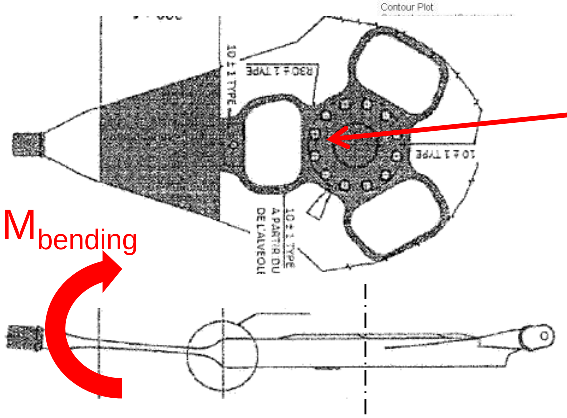


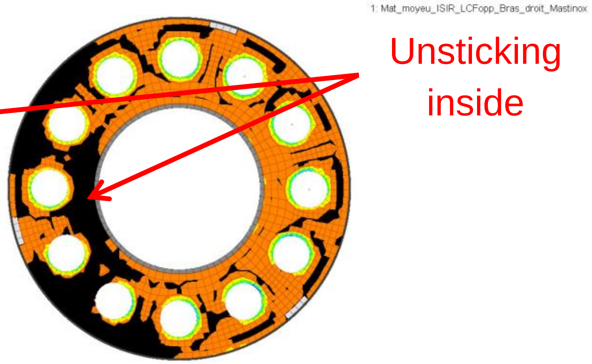
EC130 mast/hub bolts failure from severe corrosion



- Root cause:
  - ✓ Assembly with presence of interface products not according to maintenance documentation.
    - →1st case: on the plane surface (complete loss of torque)
    - → 2nd case: under screw head and in the threads

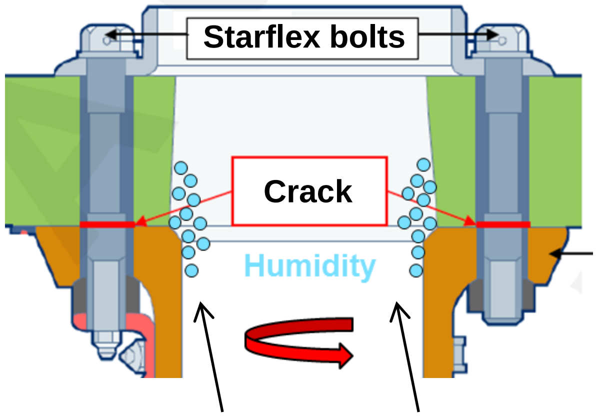
    Partial loss of tightening (> 30% according to torque tests)
  - ✓ Local unsticking between mast & hub (outside & inside)

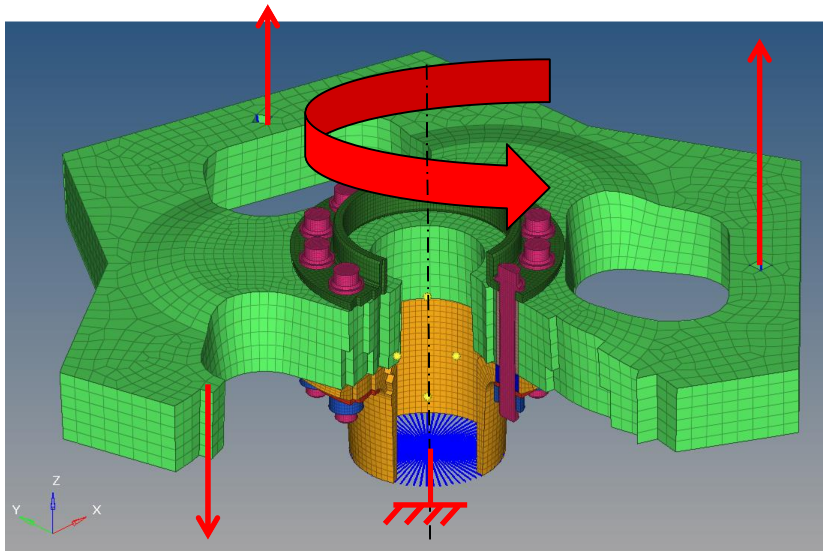


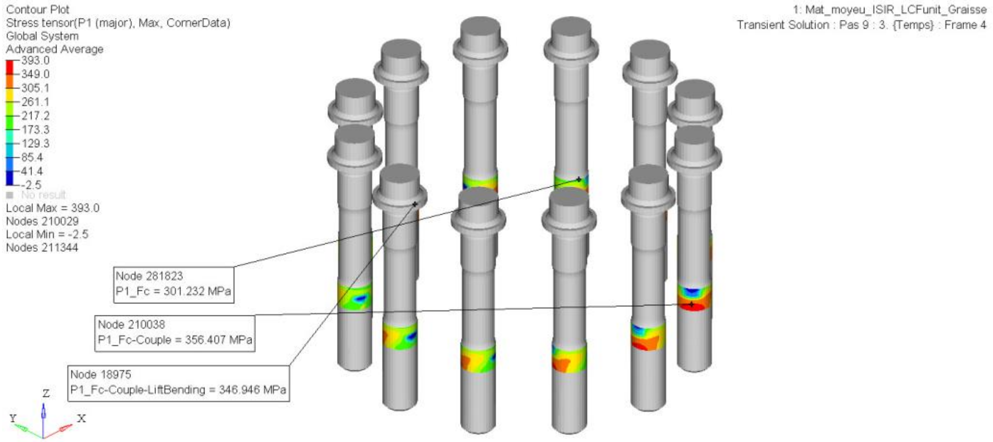


EC130 mast/hub bolts failure from severe corrosion

- Root cause:
  - ✓ Local unsticking between mast & hub (outside & particularly inside)
  - ✓ Humidity trapped at the interface hub/mast by centrifugal effect
  - ✓ Corrosion **with confinement** at the plane interface
  - ✓ Bolts failure







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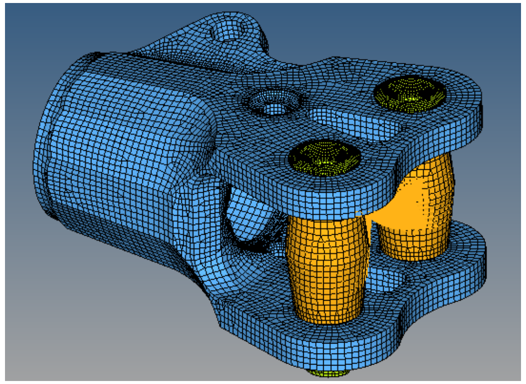
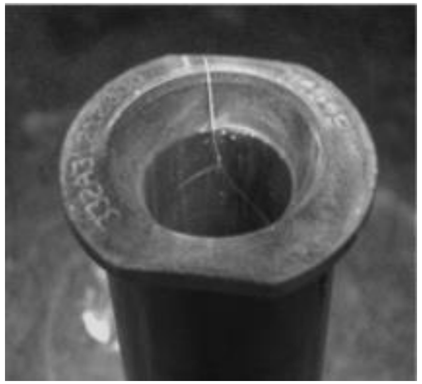
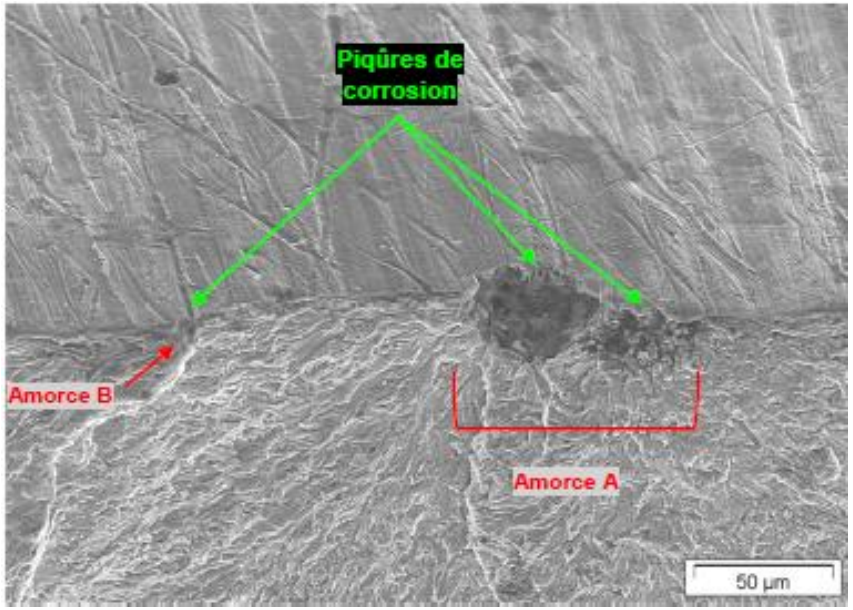
AS332 MK2 blade pin: stainless steel

- One of the main root cause is corrosion
  - ✓ Such corrosion pit is unusual for such stainless steel (MARVAL X12)
  - ✓ Other aggravating factors have influenced crack initiation.





50µm depth corrosion pit



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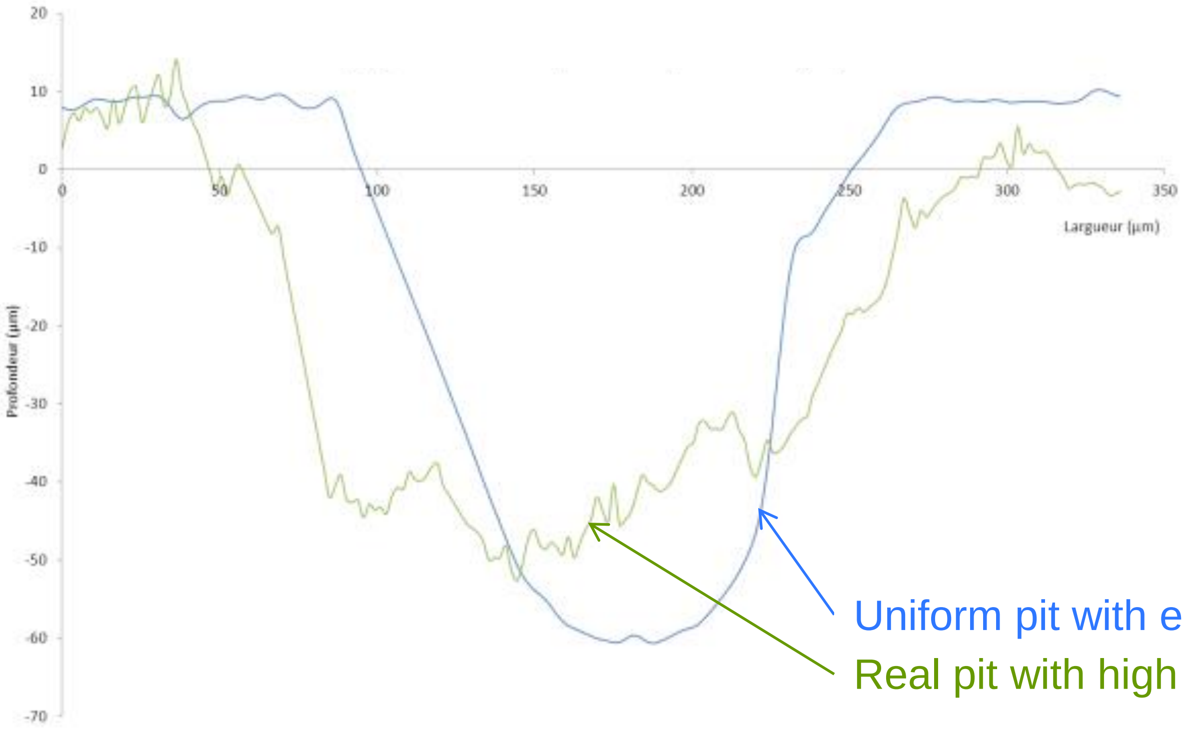
Corrosion testing method for high strength steel

- Standard salt spray process is not adapted : no corrosion pits creation (generalized corrosion)
- Tests with electrolytic polishing: not representative in terms of « local roughness »



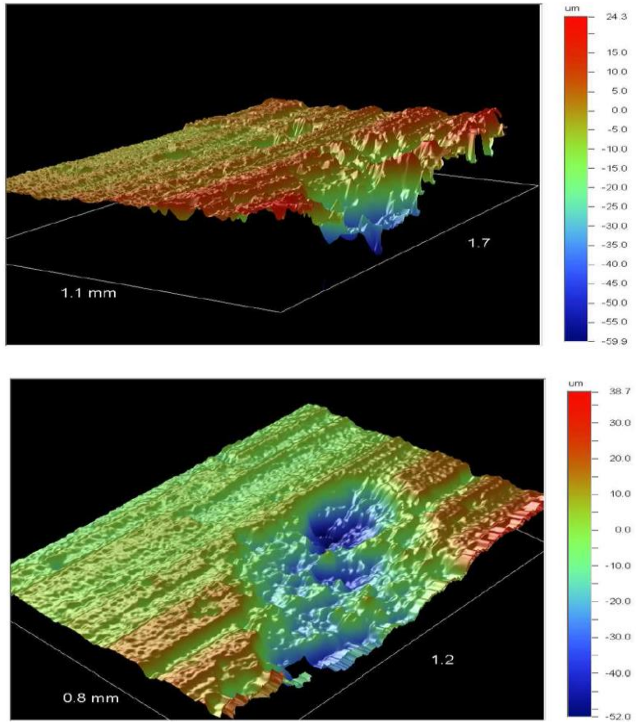
Uniform pit with eletro-polishing

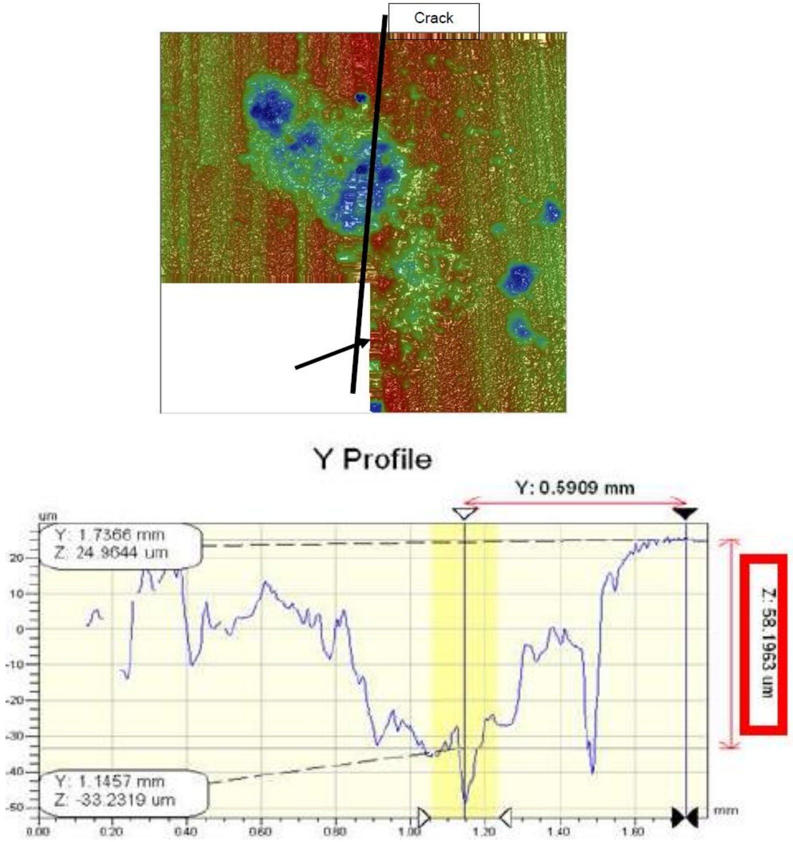
Real pit with high roughness

Pits generated with electrolytic polishing

Corrosion testing method for high strength steel (2)

- ➢ 3D roughness and morphology measurement





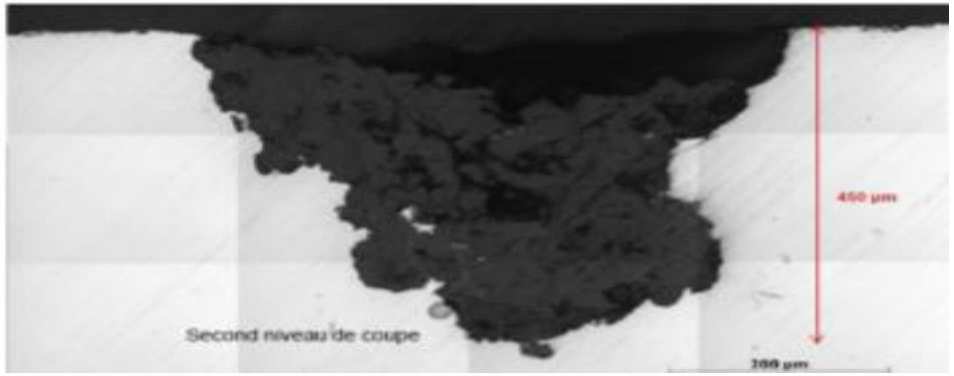
- ➢ A specific protocol has been developed in order to generate corrosion with appropriate roughness (accelerated test)

Corrosion testing method for stainless steels

- Standard salt spray process is not adapted : no corrosion creation
- Tests have been done with several methods: Retained method is based on successive acetic acid attacks

Corrosion on blade pin

Corrosion on specimen after acetic acid attacks



- Same corrosion morphologies between real parts and corroded specimen

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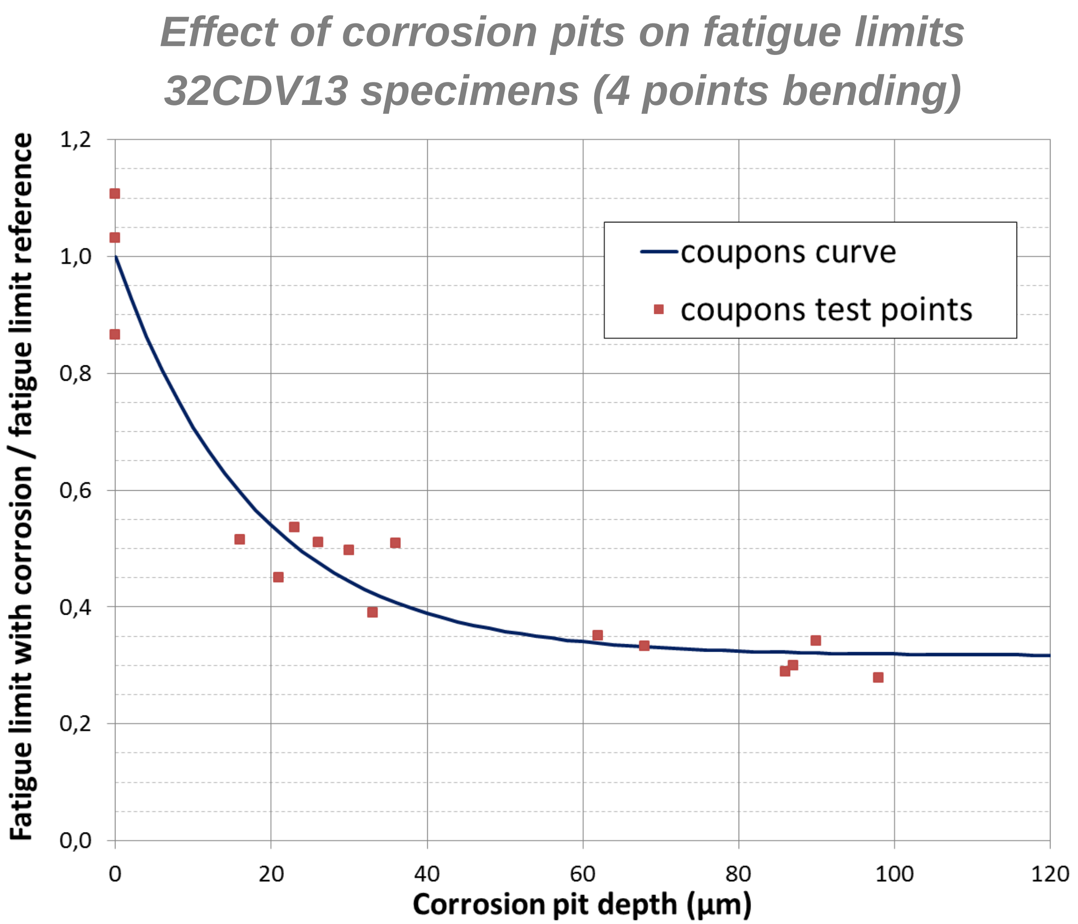
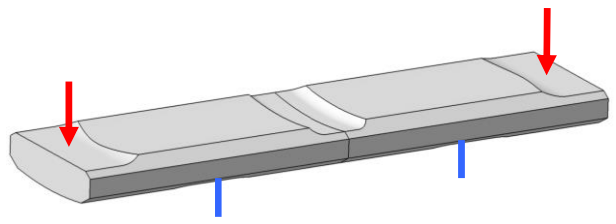
Fatigue results on specimens

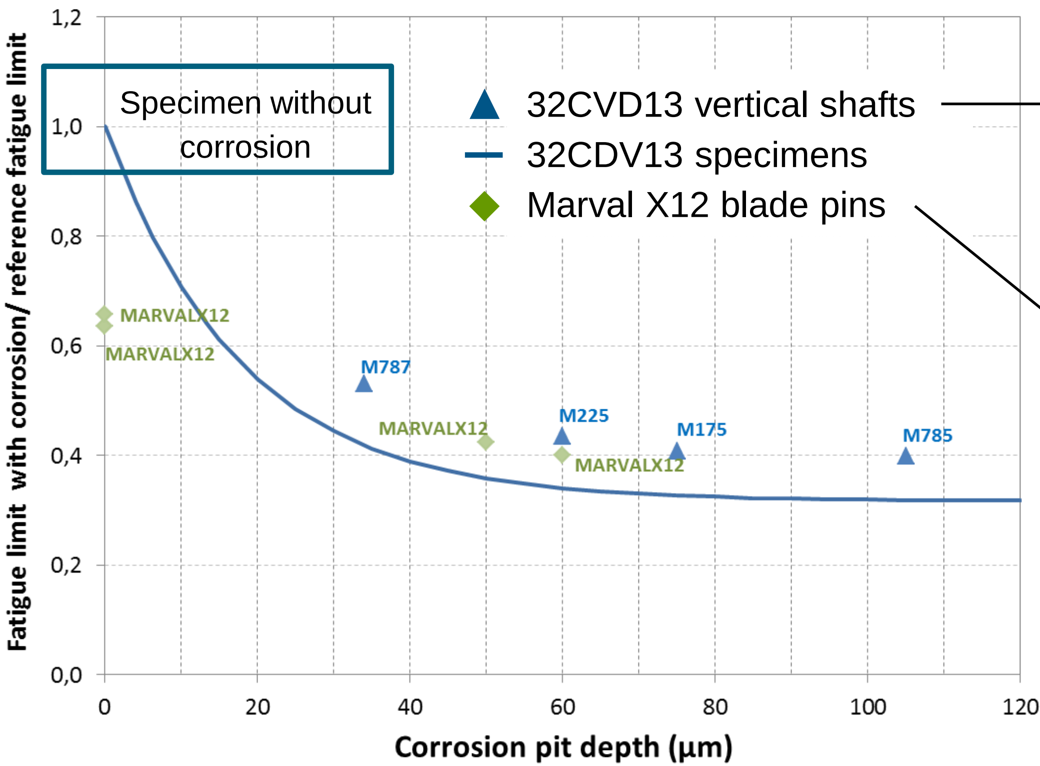


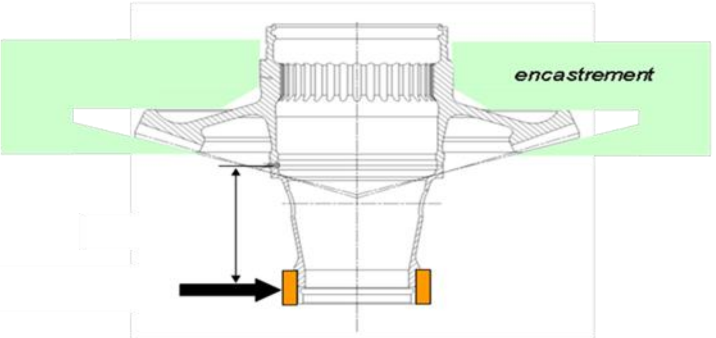


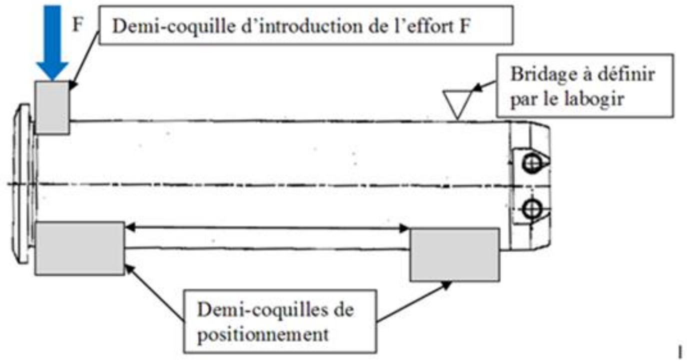
- ➢ Even with 20/30 µm depth, corrosion has an important impact on fatigue limit
- ➢ Asymptotic impact from 100µm depth

Fatigue results on full scale parts

Effect of corrosion pits on fatigue limits
Comparison between specimens and full scale components



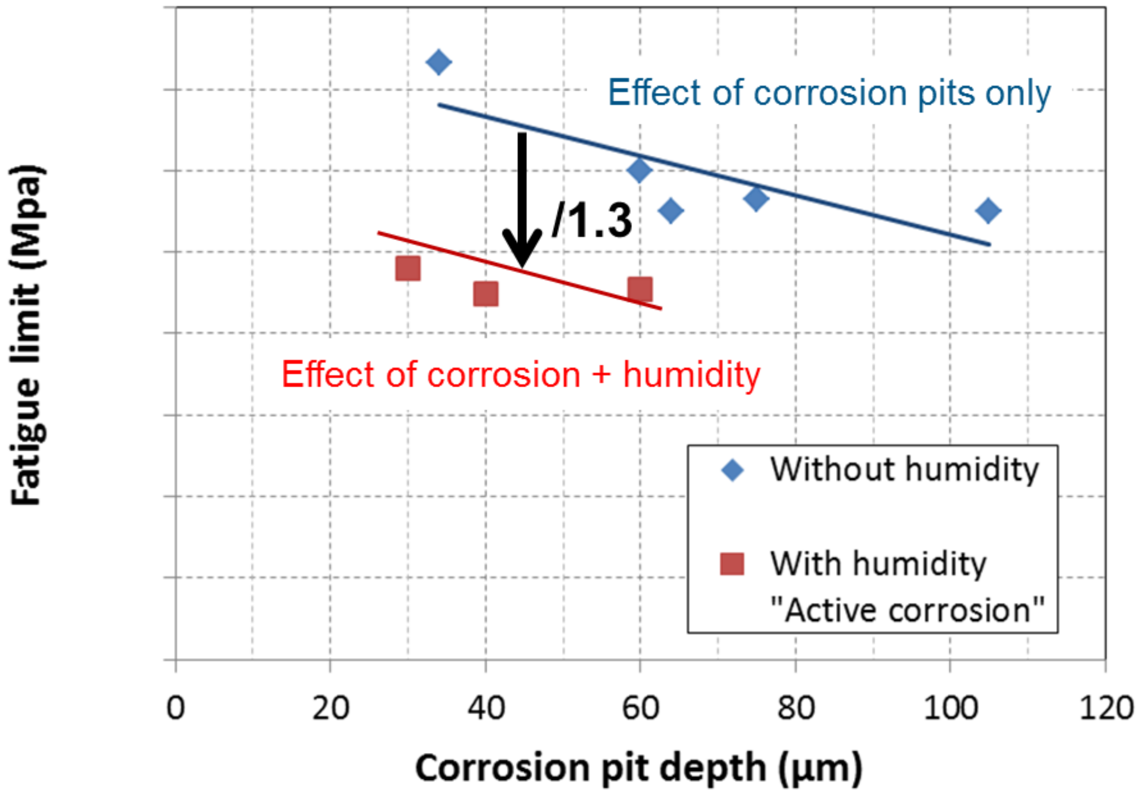


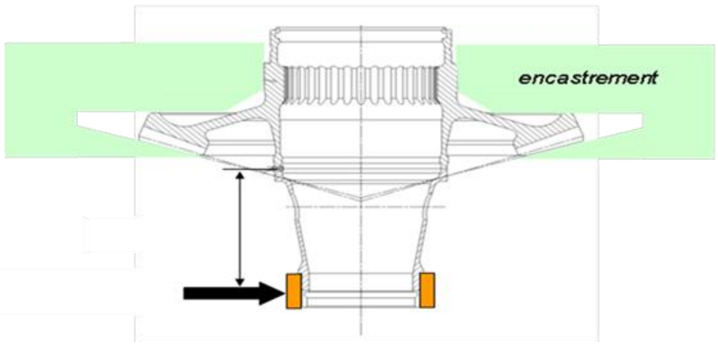


- Full scale component results and specimen results are consistent
- Full scale component behaviour lightly higher than specimen tests

Fatigue results on full scale parts

Effect of humidity & corrosion pits on fatigue limit





Fatigue test with humidity only
(without any aggressive products)
→ phenomenon called « active corrosion »

- In addition with corrosion pits, **HUMIDITY** generates an additional knockdown factor on fatigue limit
  ➔ Factor = 1,3 (less severe than fatigue corrosion)

Conclusions

➢ Airbus Helicopters fleet

- For the last 10 years, more critical corrosion cases have been discovered on dynamic components
  - Ageing of AH fleet (more than 93 millions of FH & 50 years)
  - More helicopters are flying today in severe climatic environments and usage conditions

➢ Design and stress issues: "safety first"

- A threat assessment is defined to check all possibilities of corrosion on external and internal parts taking into account surface integrity generated by manufacturing processes (welding, machining, …)
- Inspection intervals for Damage Tolerance are computed thanks to knockdown factor applied on fatigue limit and not on cycles.
- The fleet feedbacks allow to develop new design rules for corrosion damage tolerance

➢ Prospects

- Influence of humidity (« active corrosion ») must be better understood
- Better knowledge of hydrogen embrittlement phenomenon (Environment Assisted Cracking & fatigue corrosion)
- Research activities are going on and growing

Thank you