Ripple Spring Wedge Ageing

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Sommaire

1. Slot Wedge Basics

2. Ripple Spring Case Study

3. Take Away

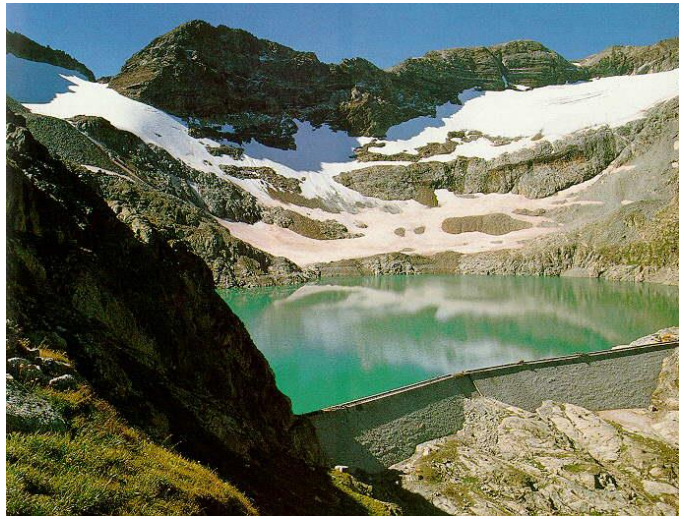
EDF data for the hydro fleet

EDF is the largest hydroelectricity producer in European Union (after Norway, not part of EEC)

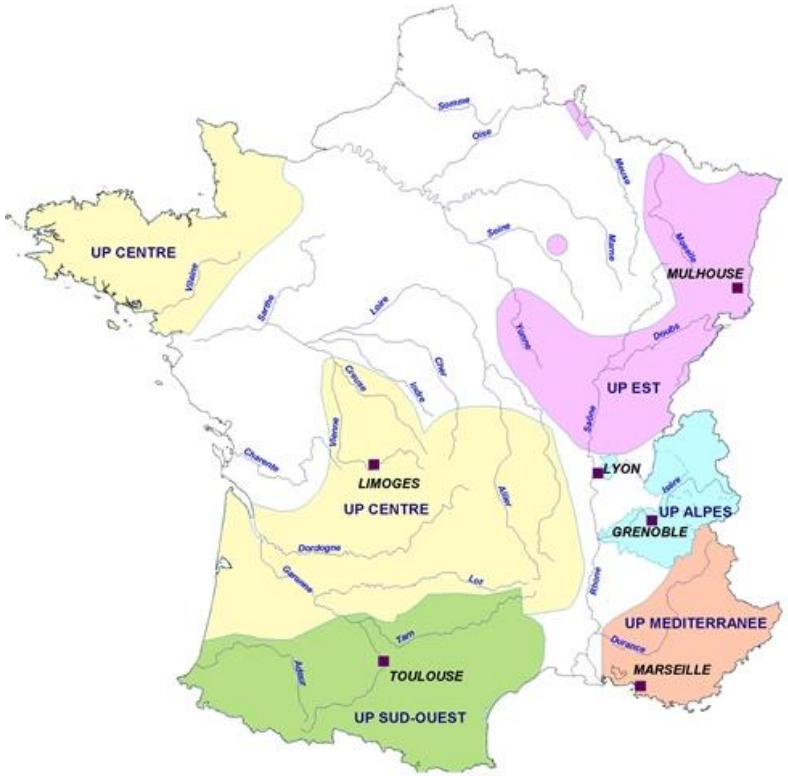
21% of EDF installed power; <10% of the energy production

1134 hydro units in 439 power plants

5000MW of PSP



Highest head (Portillon) = 1418 m



Largest PSP (Grand Maison : 1800MW

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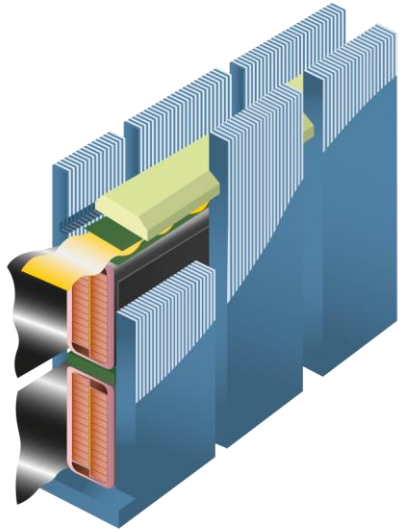
Slot Wedge Basics

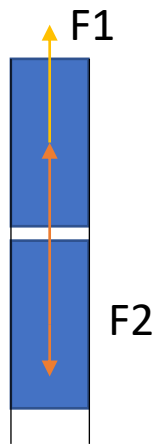
Forces in stator slots

End of Life Criteria

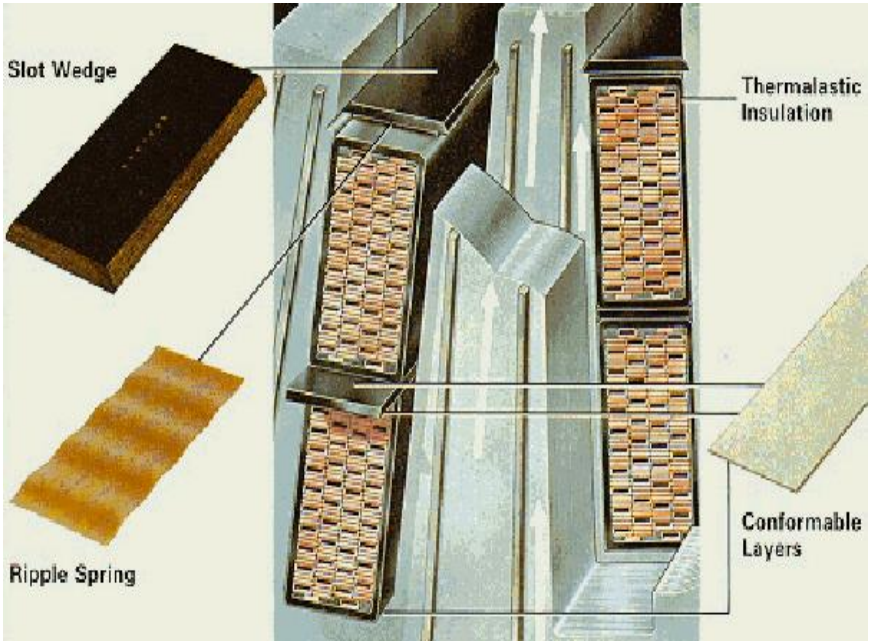
Various wedging technologies

Slot wedge : What is the purpose

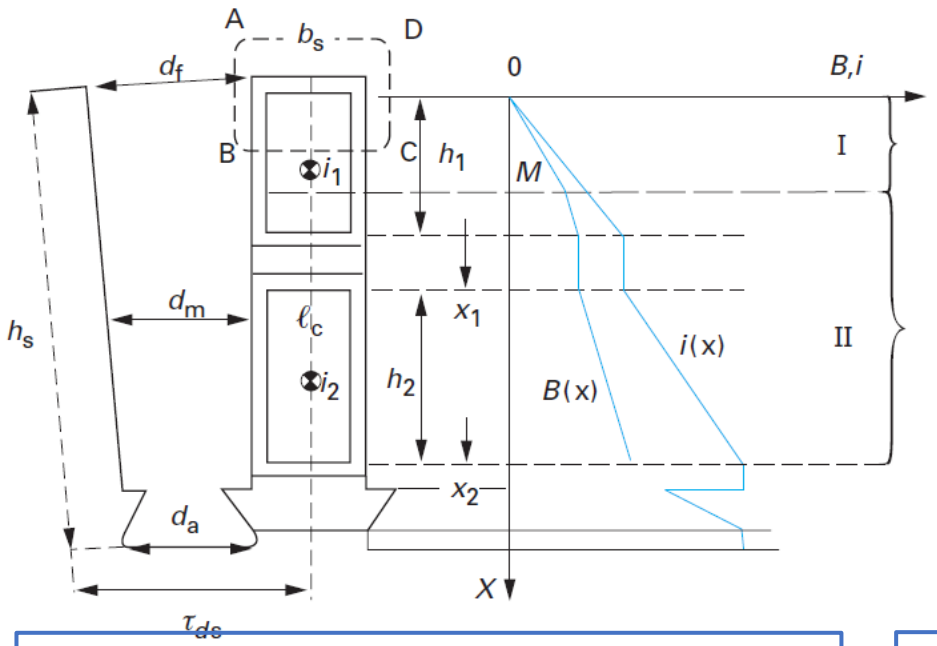


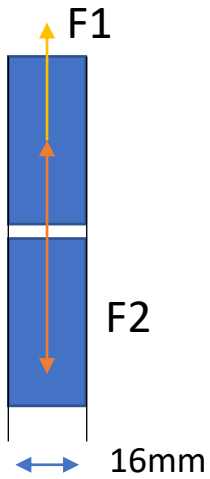


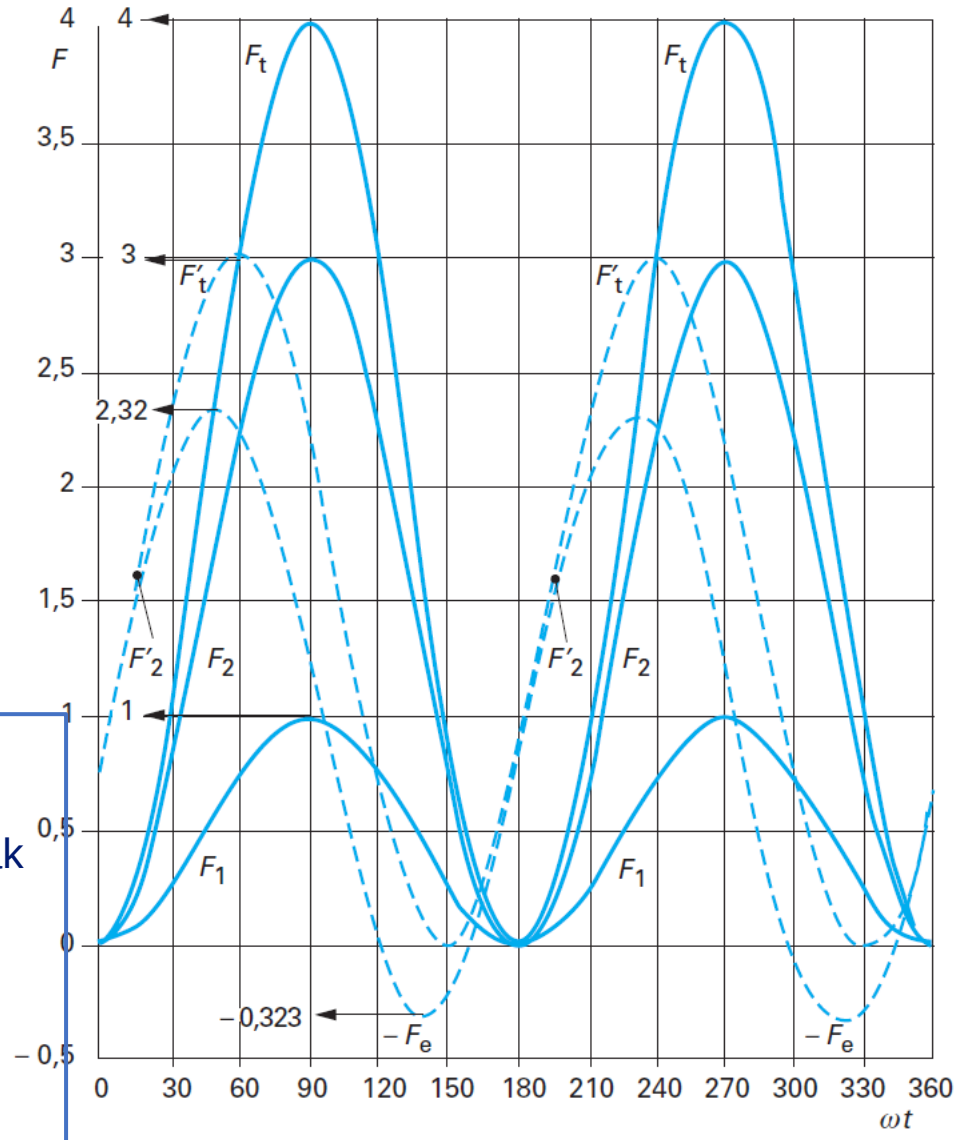
- Stator windings, located in slots
  - 2 bars per slots : current inter action
- Radial wedge
  - Also lateral wedge
- Slot wedge prevents stator bar radial movement
  - Current $\wedge$ Magnetic field = Force
- In case of same phases in a slot :
  - no outward force
- In case of different phases in a slot :
  - pulsating force inward and outward
    - Must withstand short circuit forces



Slot wedge purpose : some numbers







Oscillating force on wedge at 2f
(100 or 120Hz)

In slots with same phases:
No force on wedge
Force to slot bottom : 4 (μ_0/bs) I² sin²(ωt)

In slots with different phases :
Force on slot = 0,323 (μ_0/bs) I² sin²(ωt)

Case of a stator 50MVA; 2550A

Slot same phase : 0,128MPa peak towards slot bottom

Different phases : 0,01MPa towards the slot wedge

Short circuit case 5 I : 0,5MPa towards slot wedge

Ripple spring force

Ripple Spring :

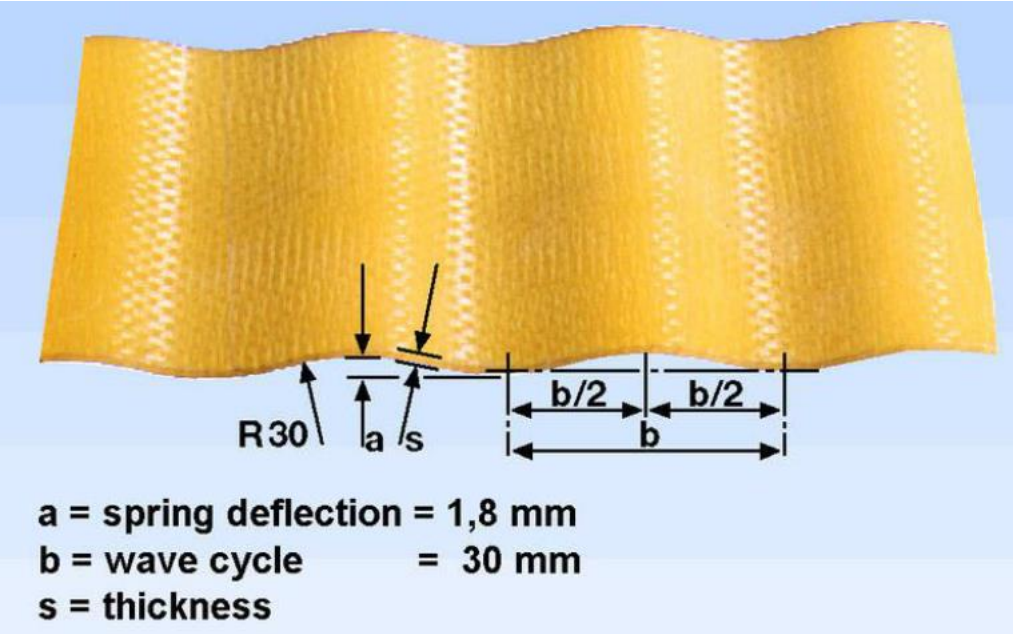
Glass fiber roving,
baked with class F resin

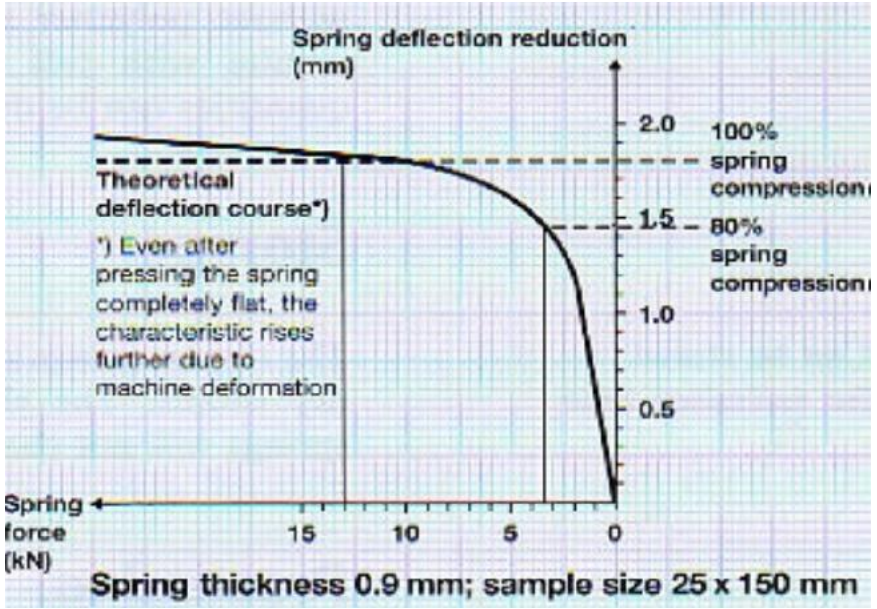
Manufacture KREMPEL (most reknown)

2 thicknesses :

0,8 (Hydro) or 0,9mm (turbo)

At 80% compression :
0,8mm spring => pressure ~0,6MPa
0,9mm spring => pressure ~0,9MPa

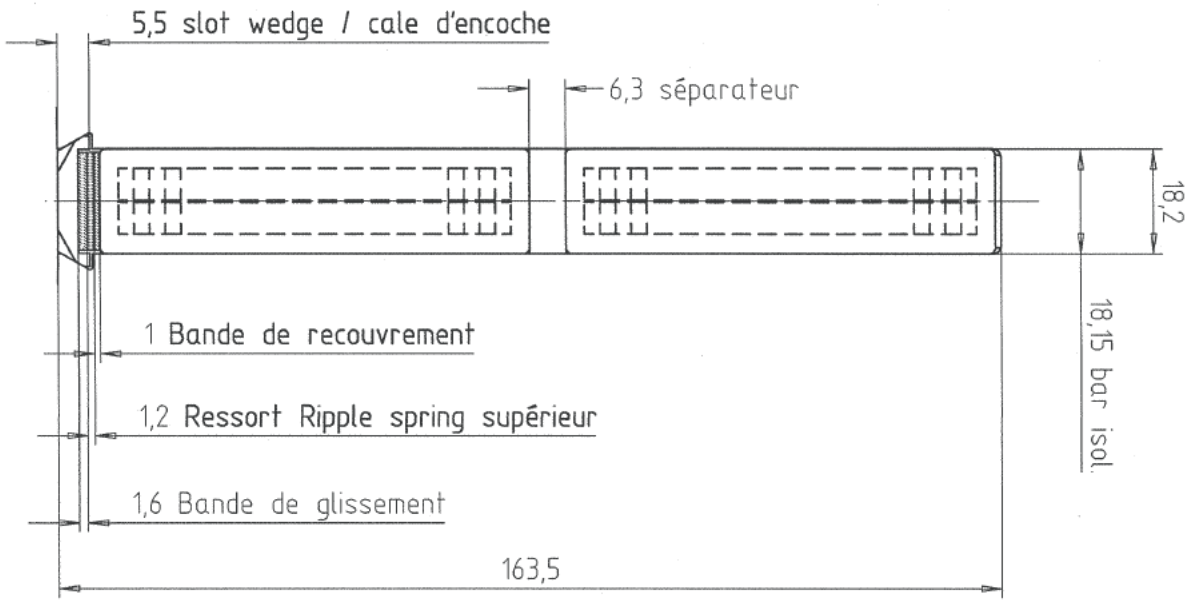




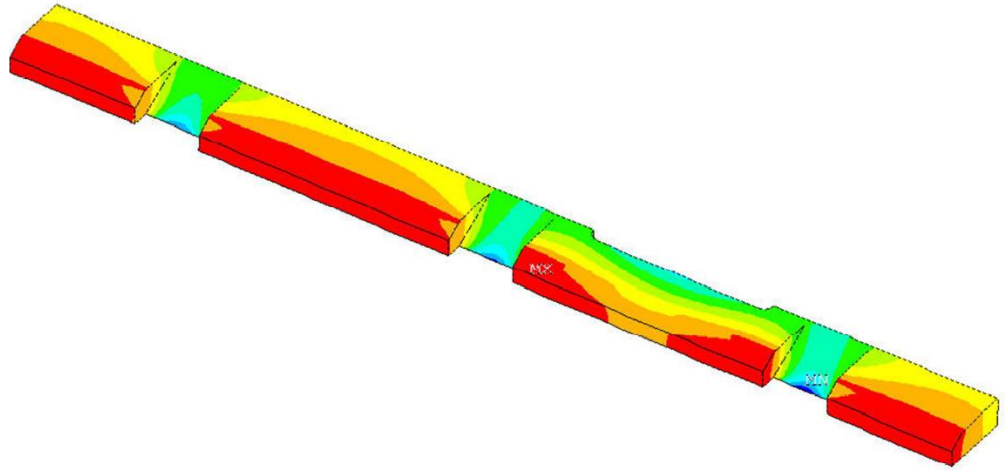
Loose Wedge Criteria

Slot wedge is submitted to rather low stress compared to material properties

Sufficient slot wedge under rated condition can be achieved with only few wedges :
50% of wedges above 20% compression is enough

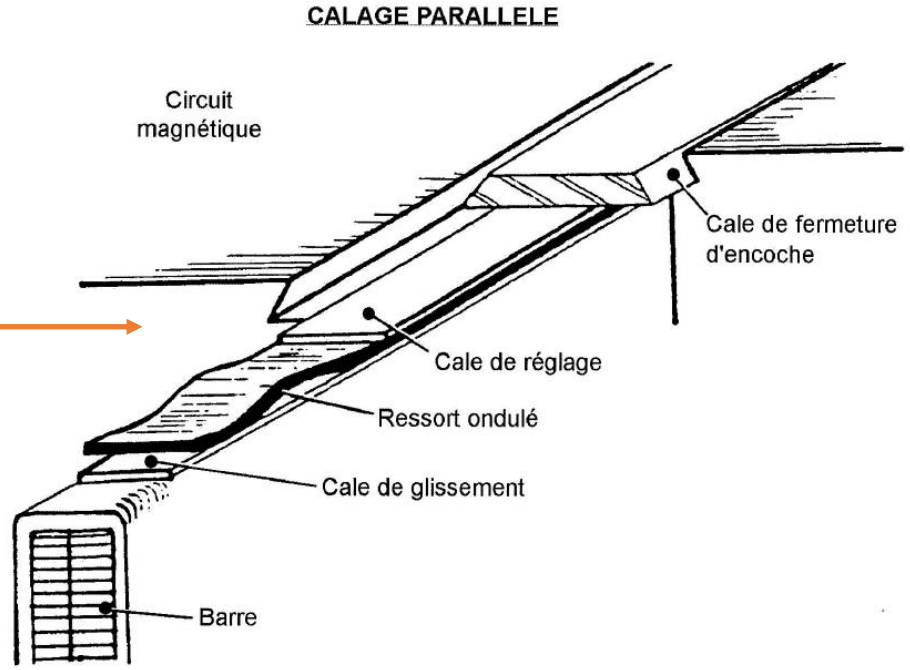


Wedge withstand to be designed under short circuit condition
In many cases for Hydro :
5 to 6mm thickness is enough
In case of SC, RS may go flat ; this is no issue

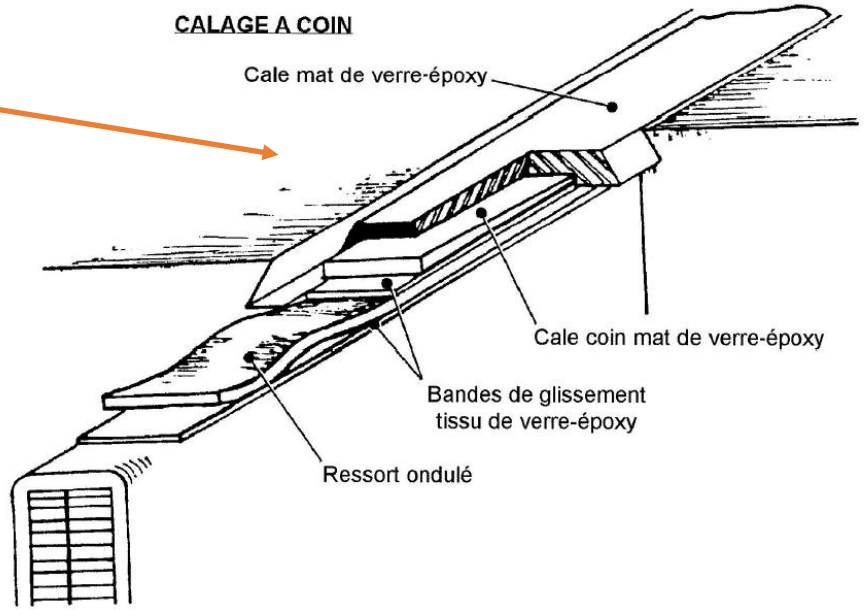


Various technologies

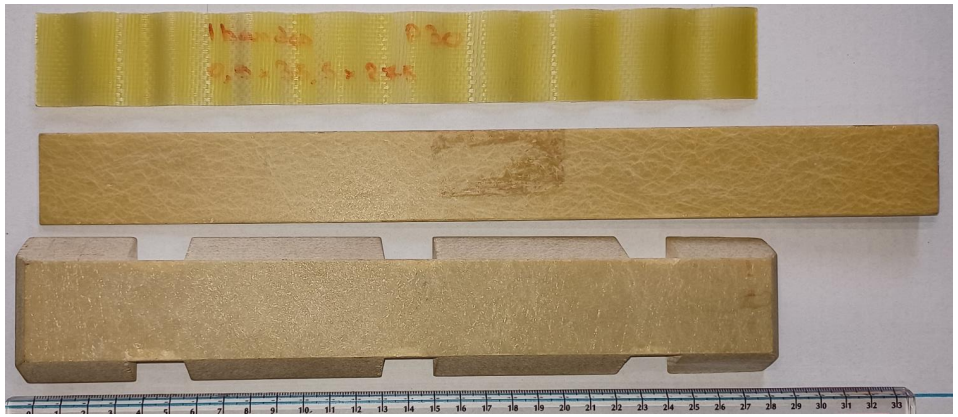
Flat or parallel wedge : large friction force on spring, requires greasing to avoid spring damage



Tappered wedge : Spring compression is achieved by conic wedge insertion; quite precise achievement



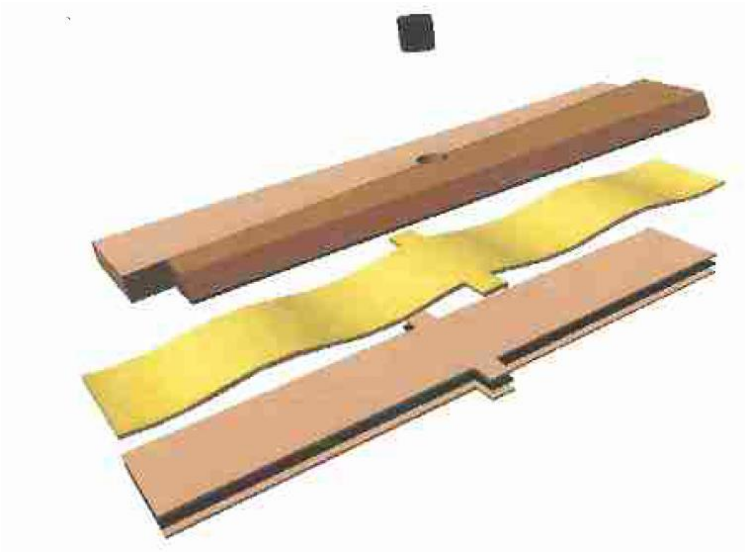
Continuous/Non continuous



RS wedge technology

Continuous :
Slot is wedged 100% of its length

Non continuous :
~50% of slot length is wedged
Example with bias wedge self locking



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Ripple Spring case

Ripple Spring failure cases

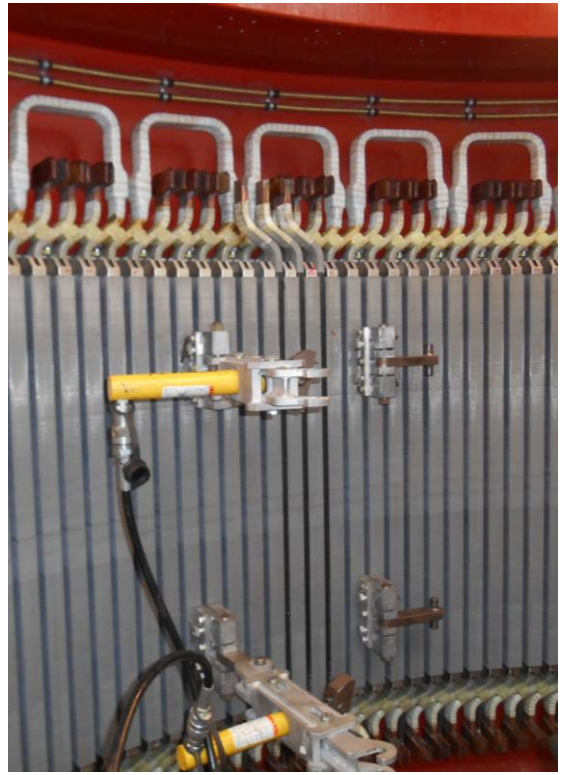
Analysis of aged material

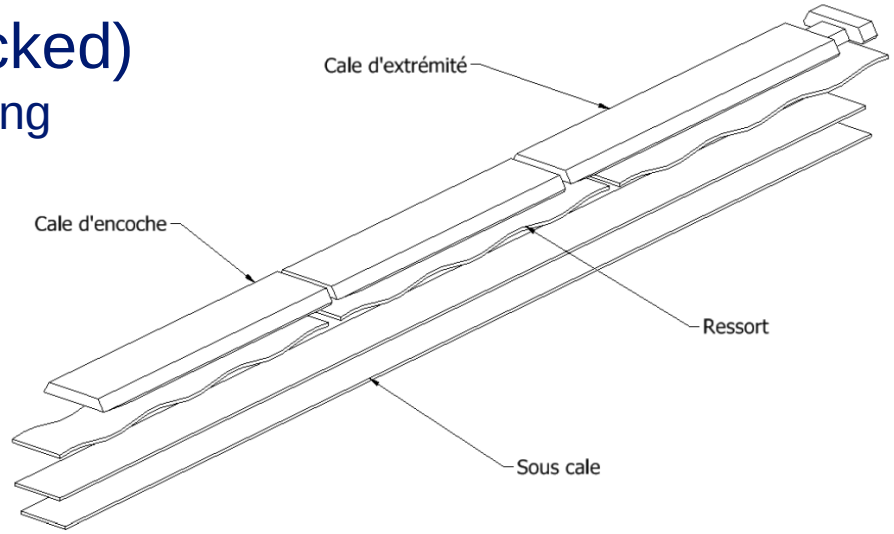
Site testing

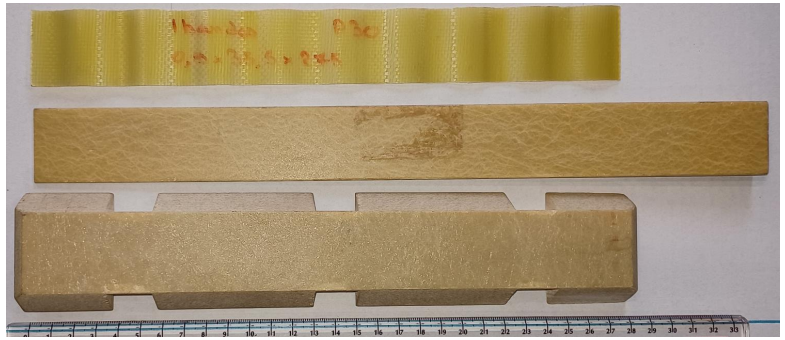
RS wedge failure cases

RS wedging fails when pressure in slot is released
This may occur in case of

- Slot content shrinking :
  - No bar pressing during mounting
- RS wave breaking (cracked)
  - No Greasing during mounting
- RS material softening
  - RS material ageing
  - Stator over heating

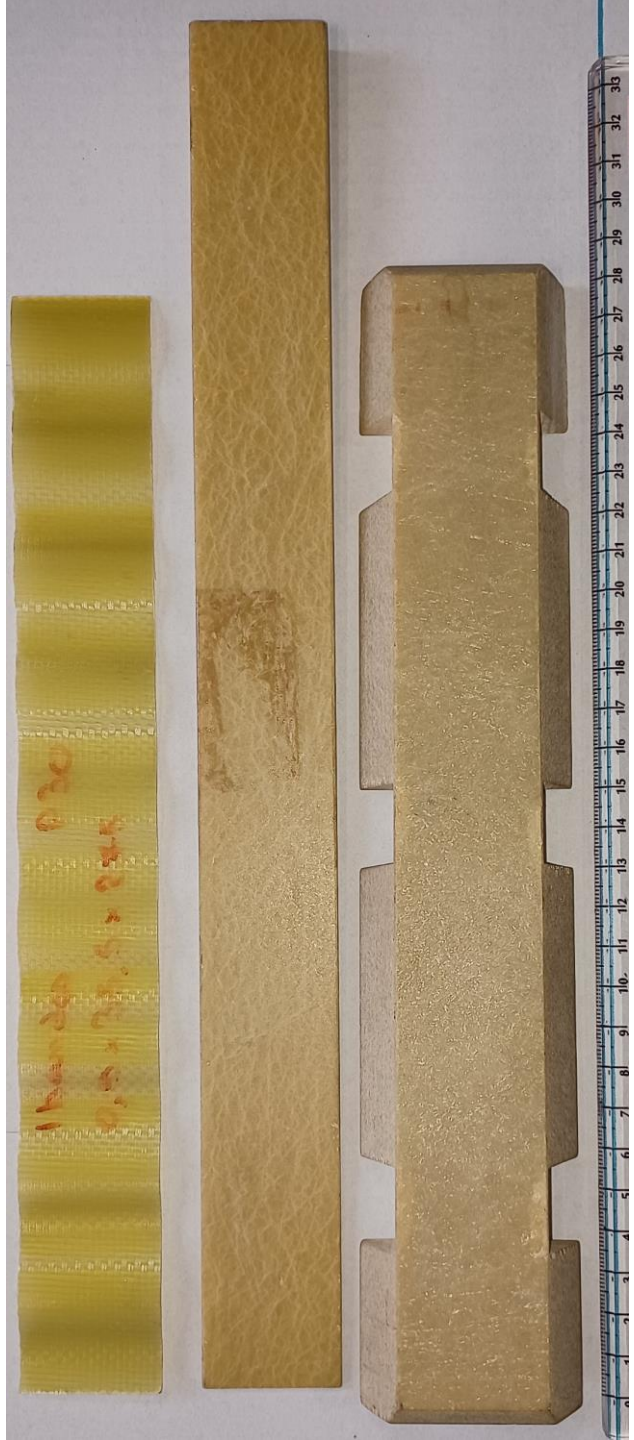






1. Ajoutez un titre sur une ligne

Entrez votre texte

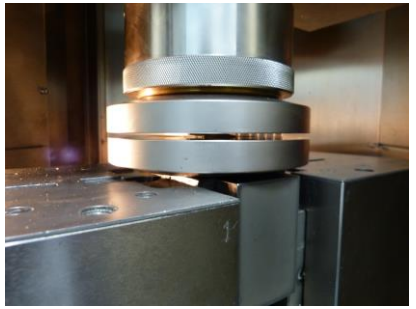


Analysis of aged RS

RS taken from hydro units after 30 years of service

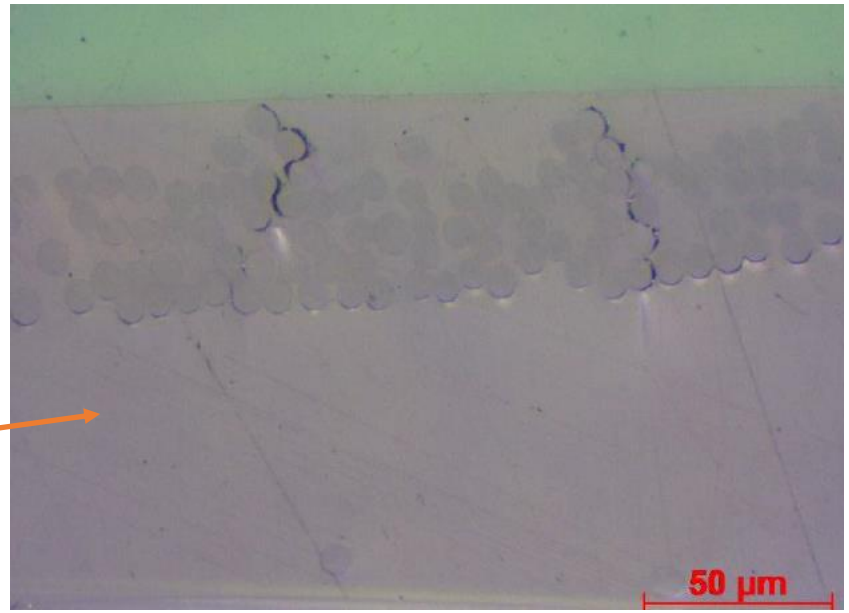
150MVA; PSP type

Large number of start stop cycles



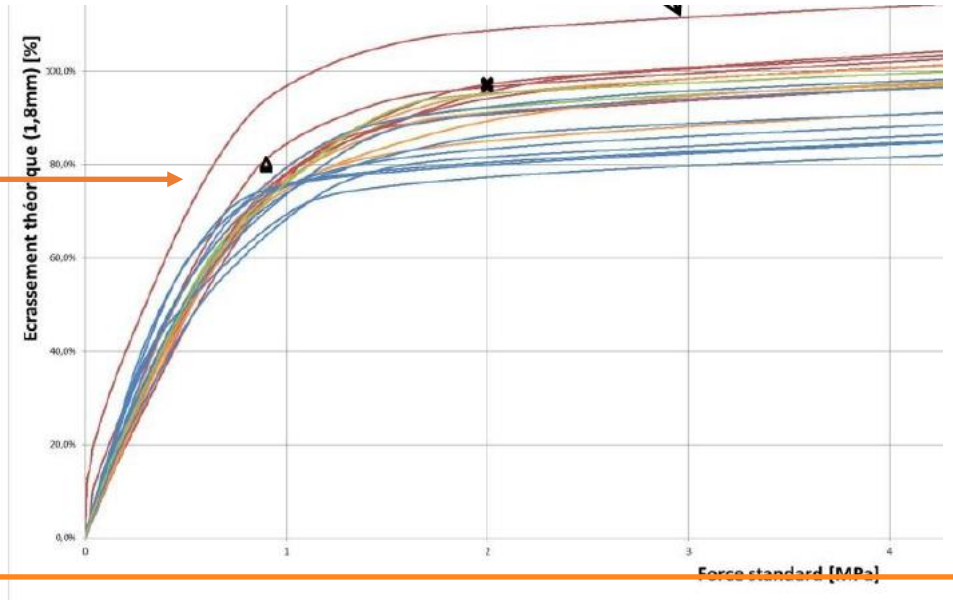
Springs were forensic measured

Microscope magnification



Some surface cracks founds

Pressure/compression curve



Compared to new ones

Fiber analysis

Analysis of aged RS

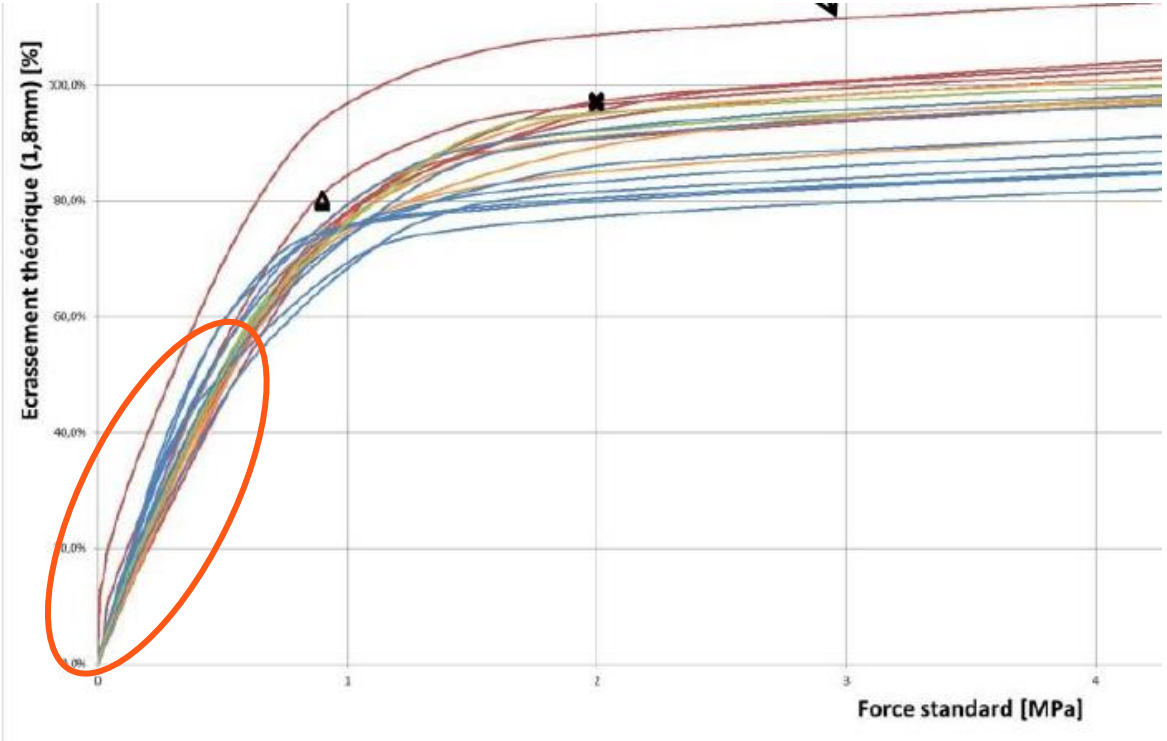
After 30 years, remaining RS compression in stator slots : 5% to 50%

All aged springs show homogeneous mechanical

RS are still compliant with new RS requirement

RS as a component is extremely resilient to mechanical and thermal stresses
It can survive for decades

Providing initial mounting, RS wedge expected to last ~40 years



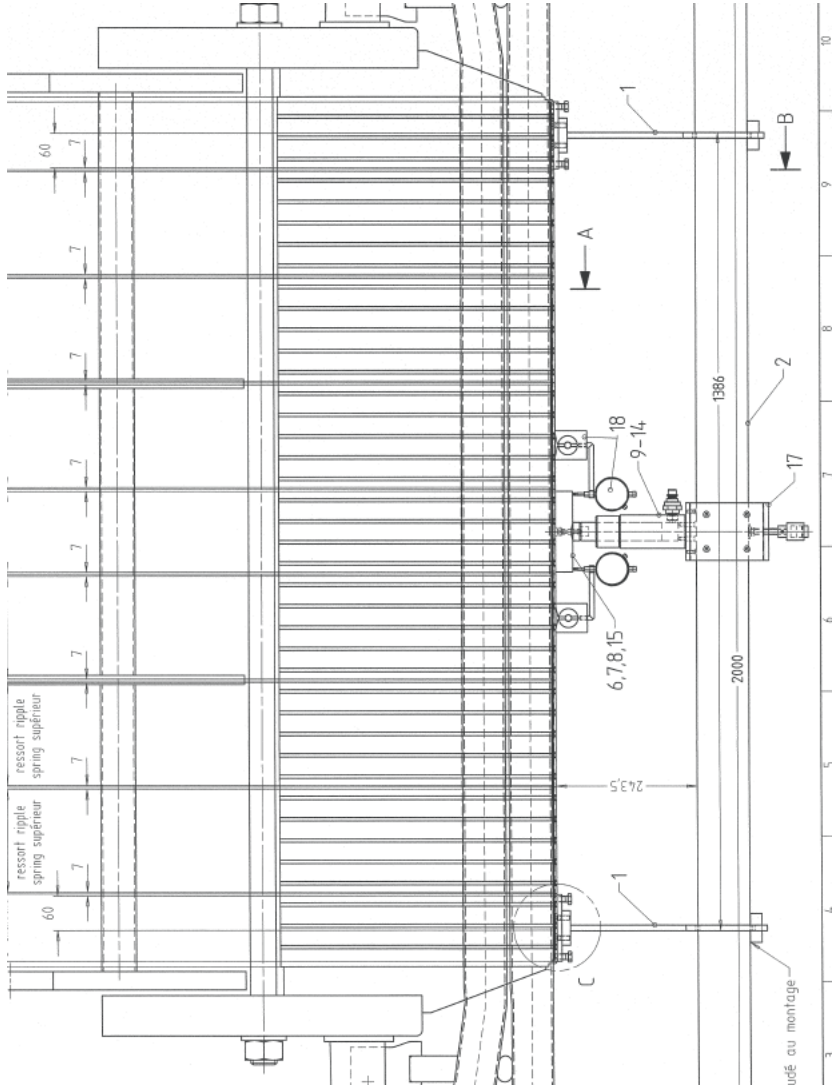
RS wedge check technique

Tapping is not so relevant for RS

Wave measurement with opening in wedge

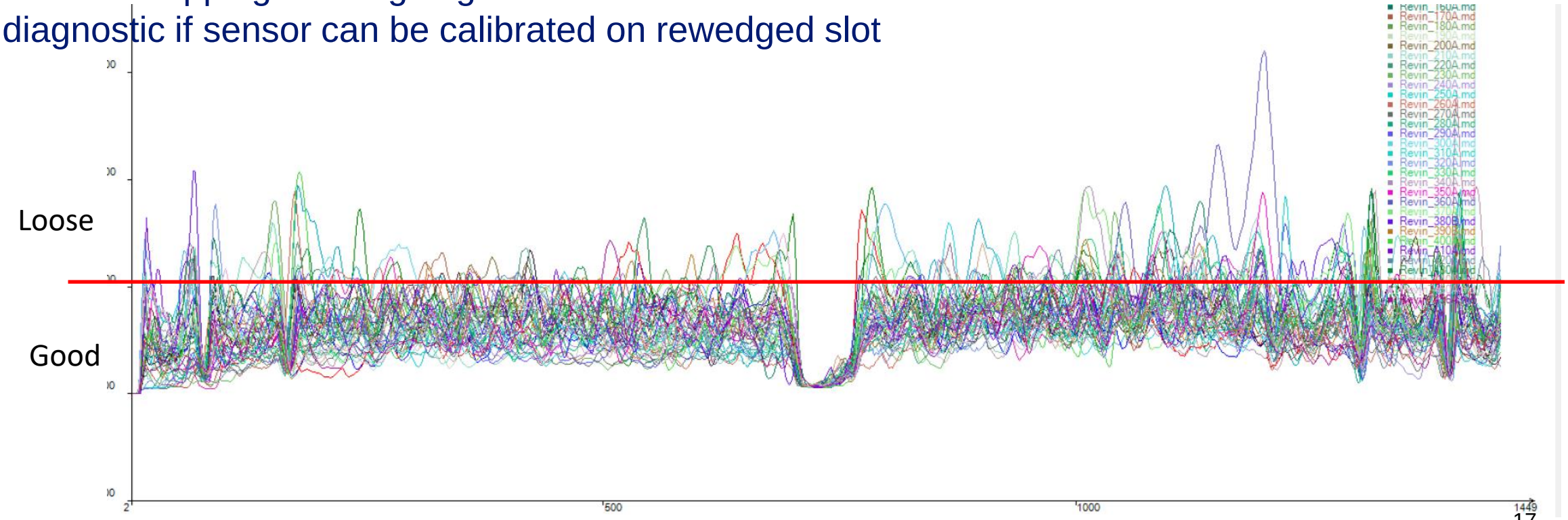
Pressure/displacement : with jack

« Wood pecker » system
Eg : Diris device



RS wedge check case of a 200MVA generator motor

Checked with Diris device
Robotic inspection
Rotor in situ
Wedge hammering with frequency sweep
Wedge response analysis
Provides a full mapping of wedge tightness
Better diagnostic if sensor can be calibrated on rewedged slot



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Conclusion

Key Take Aways

Ripple Spring Life Expectancy

RS material life > 40 years in service

RS life is not the limiting factor for a RS wedge

BUT **Initial installation is prime importance and key to long lasting stator wedge**

- Initial Compression : 75 to 80% to accomodate for future shrinking of slot material
- Press stator bars towards bottom of slots to cancel all existing slot gaps
- Dry out wedges (in case of large slots, turbo generators) to avoid in situ shrinking of material
- Use grease in case of wide slots (turbo generators mostly) to avoid wave breaking
- All the above to be checked in the winder procedure/method statement

Thank you