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Experimental durability evaluation of coil springs - Influence of the test frequency under corrosion

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- **Motivation**
- **Test procedure**
- **Test evaluation**
  - Dry fatigue test - basic series
  - Dry fatigue test and corrosion fatigue tests
  - Dry fatigue test, corrosion fatigue tests and corrosion fatigue tests after pre-damage
  - Influence of the test frequency
  - Influence of Corrosion after pre-damage
- **Summery and outlook**

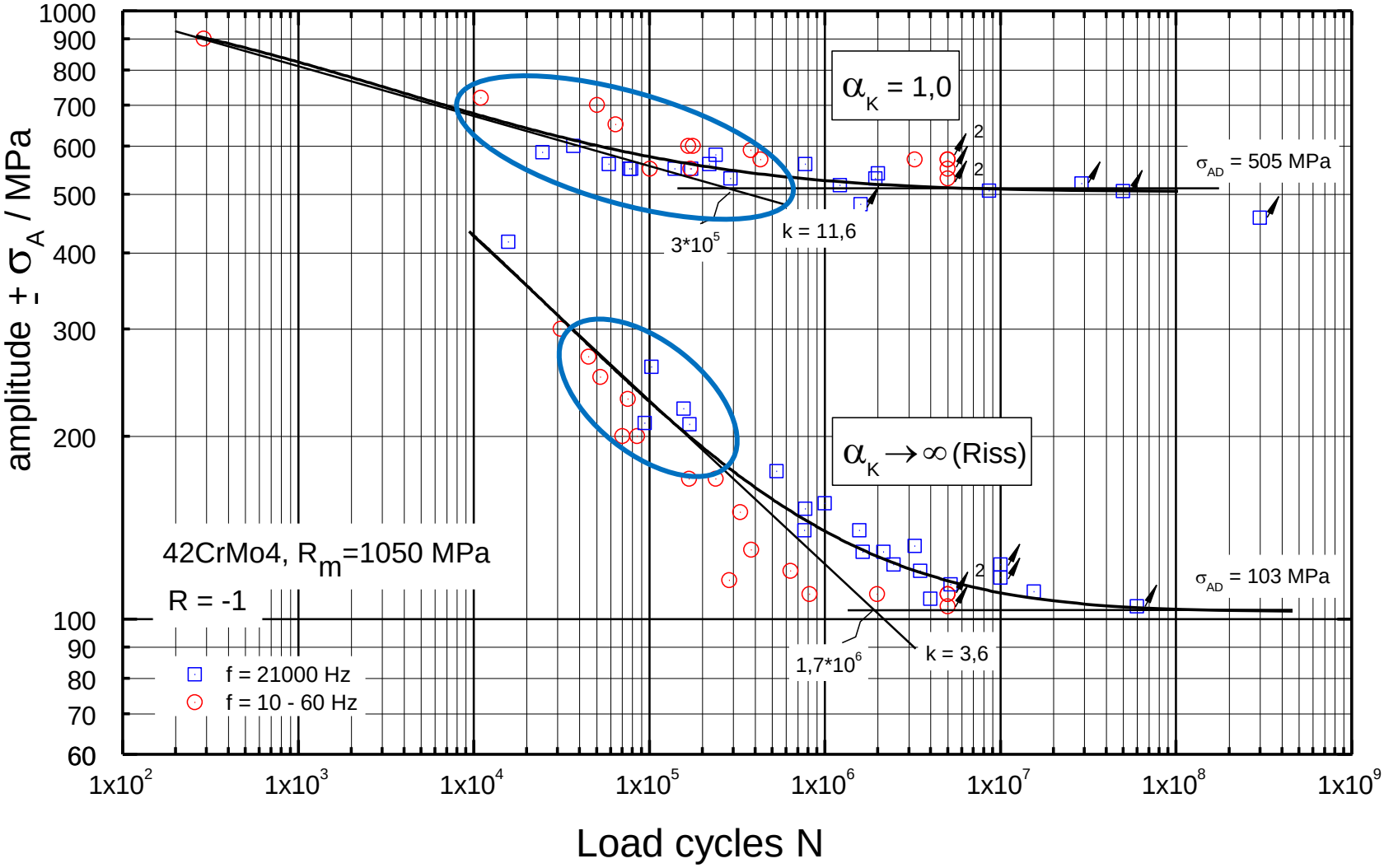
Motivation

- Due to various designs of spring testing machine used all over the world, the testing frequency varies considerably e.g. from 1,0 Hz to 8,0 Hz
- The test duration caused by the different machines leads to different duration of corrosion impact during the corrosion fatigue test
- Question is: What is the effect on fatigue life?
- Based on a lot of tests IABG has proposed a frequency correction of:

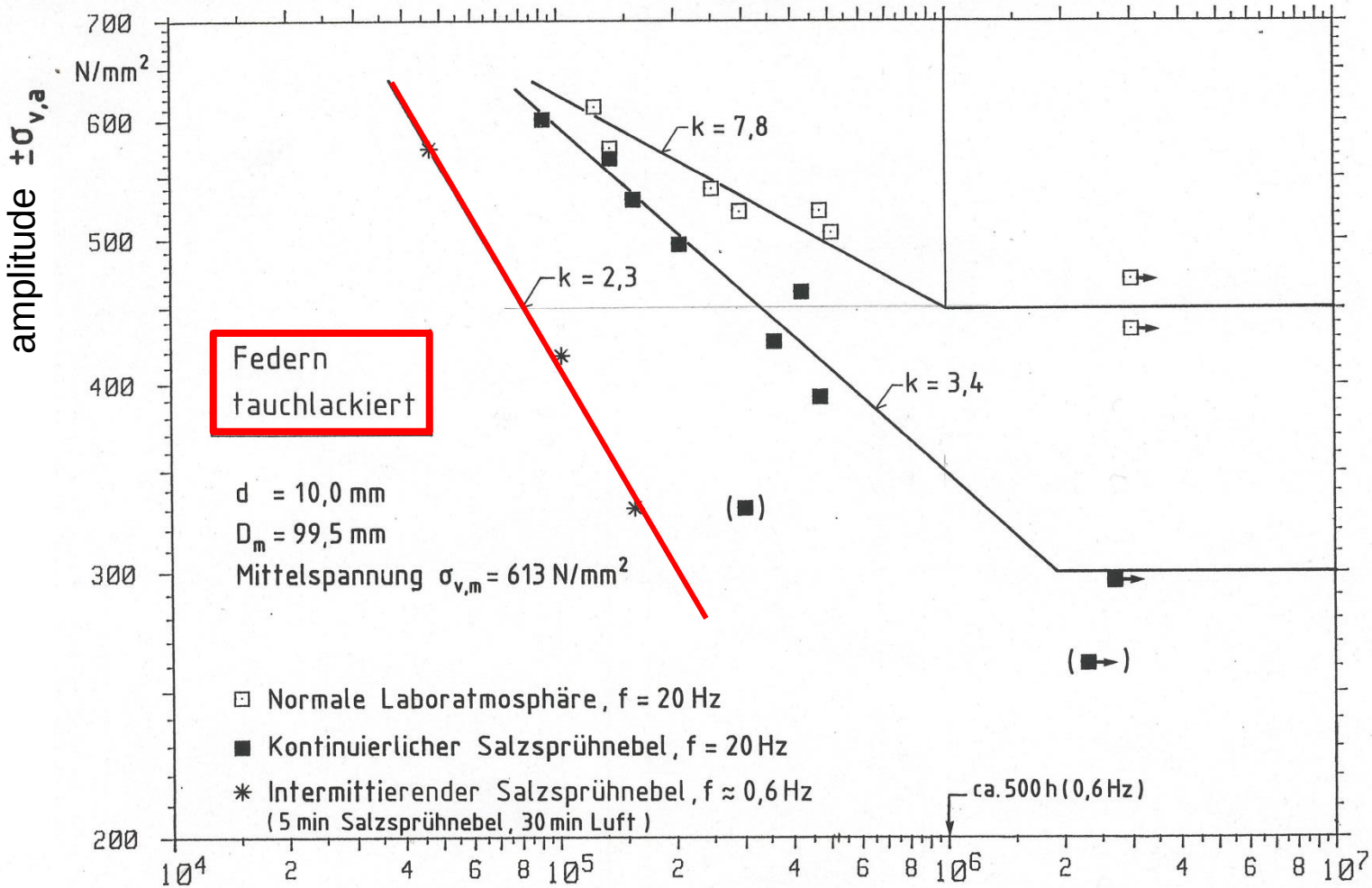
$$\frac{N_1}{N_2} = \left(\frac{f_1}{f_2}\right)^{\frac{1}{3}} \qquad \text{(Hück, 1995)}$$

- Thesis 1 – Is this is still valid?
- Thesis 2 - Has corrosion during fatigue tests a impact at all?

Motivation


amplitude ± σA / MPa
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
1x10^2
1x10^3
1x10^4
1x10^5
1x10^6
1x10^7
1x10^8
1x10^9
Load cycles N
αK = 1,0
σAD = 505 MPa
k = 11,6
3*10^5
αK → ∞ (Riss)
σAD = 103 MPa
k = 3,6
1,7*10^6
42CrMo4, Rm=1050 MPa
R = -1
f = 21000 Hz
f = 10 - 60 Hz

Motivation



Load cycles N

Test Procedure – Test Equipment

CSTM
Corrosion Spring Testing Machine (high frequency)

VTRC
Variable Test Rig for resilient Components (low frequency)

GISM
Grit Impact Simulation Machine

Corrosion Chamber

Test Procedure

Spring design

- Simple design with a wide range of stress variations

d = 14,25 mm
D_m = 85,0 mm
L_0 = 350 mm

- Use of original spring pads in order to avoid any influence of the load input

Test procedure

pre-damage

Pre-damage grit impact → 4 weeks – alternating climate test unloaded → Corrosion fatigue test, const. mean load, different frequ.

Pre-damage grit impact → 4 weeks – alternating climate test unloaded → Dry fatigue test, const. mean load

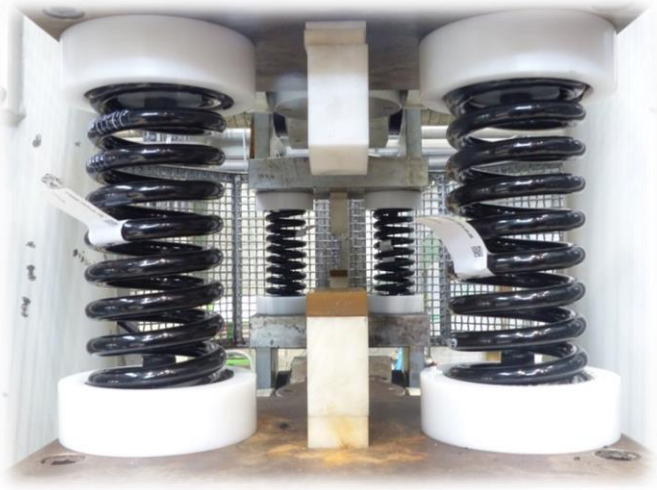
Dry fatigue test, const. mean load

Corrosion fatigue test, const. mean load, different frequ.

Test Procedure – Test-setup

1,5 Hz **4,1 Hz** **7,4 Hz**

Electro hydraulic **Resonance testing machine**



Grit Impact

- Gravel 5-6 mm
- 70 km/h
- Rotating spring
- Spring body

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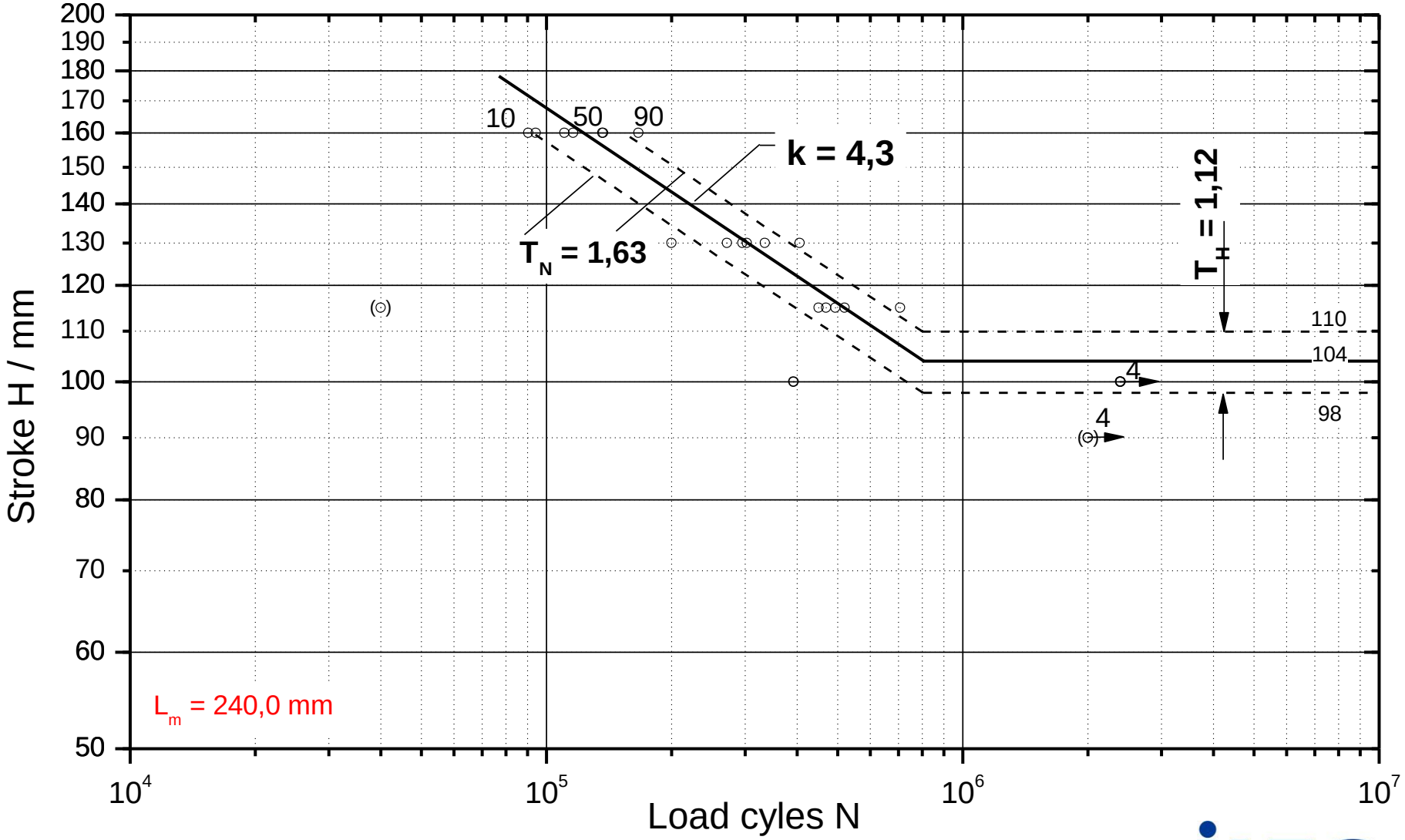
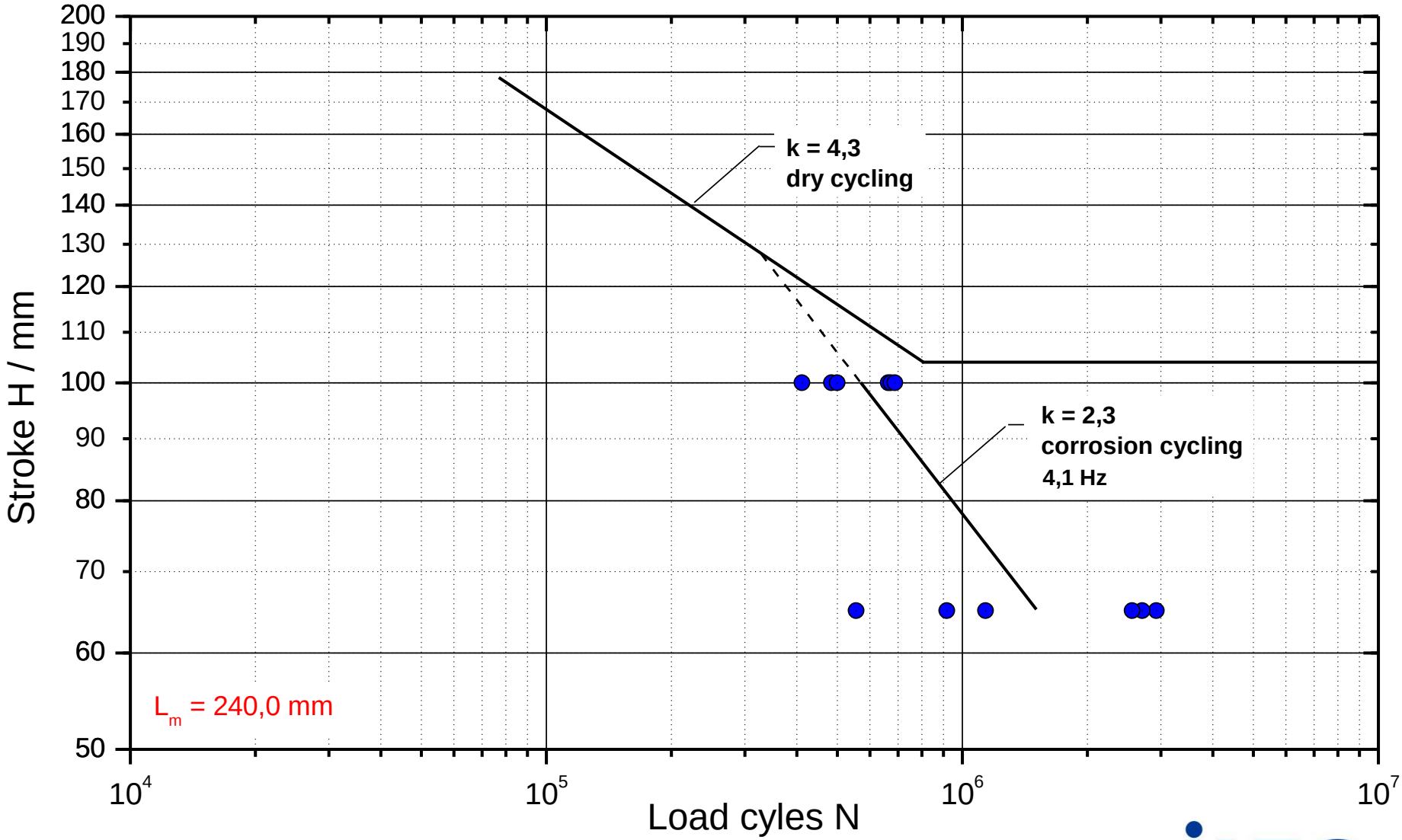
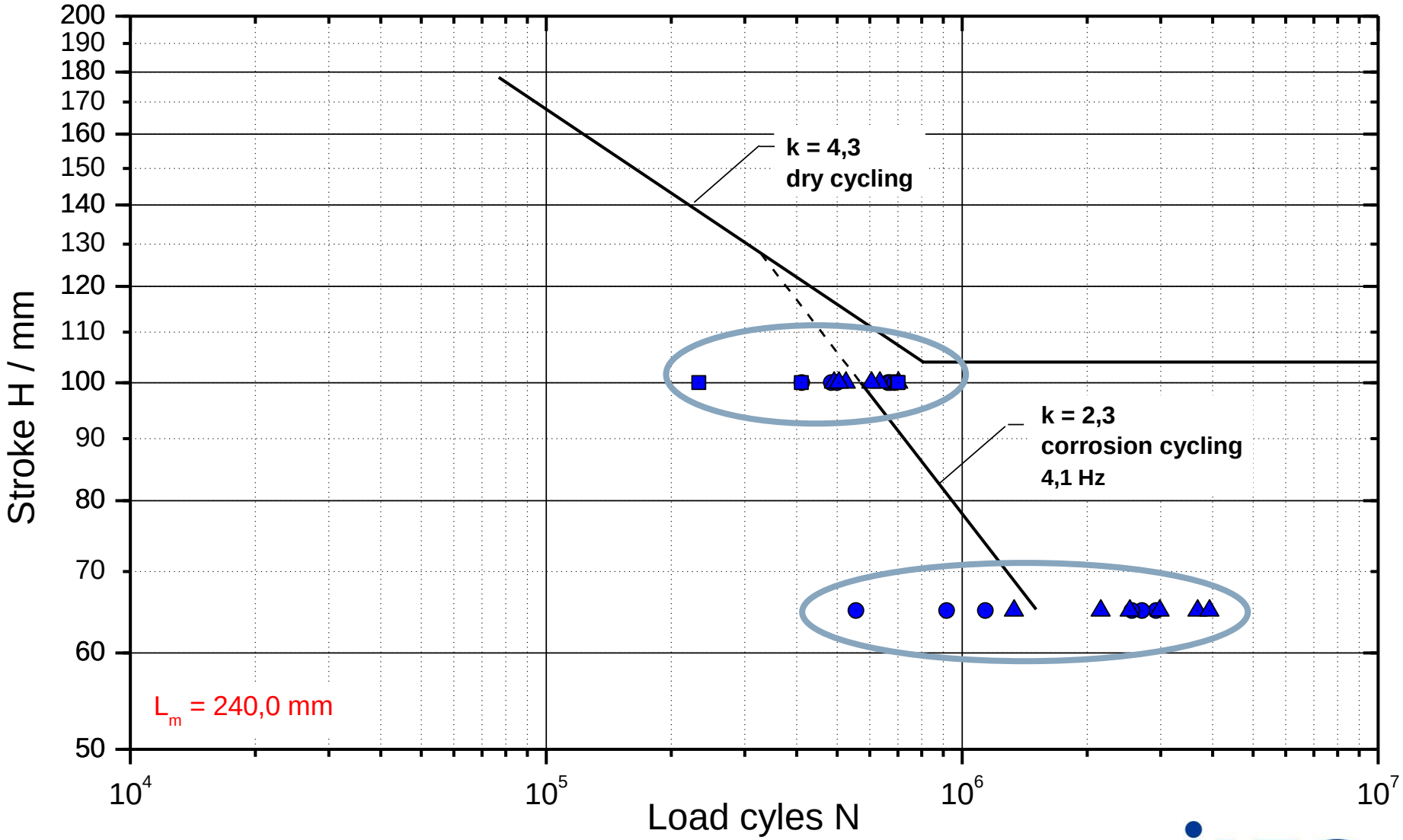
Life without corrosive environment - Basic Series



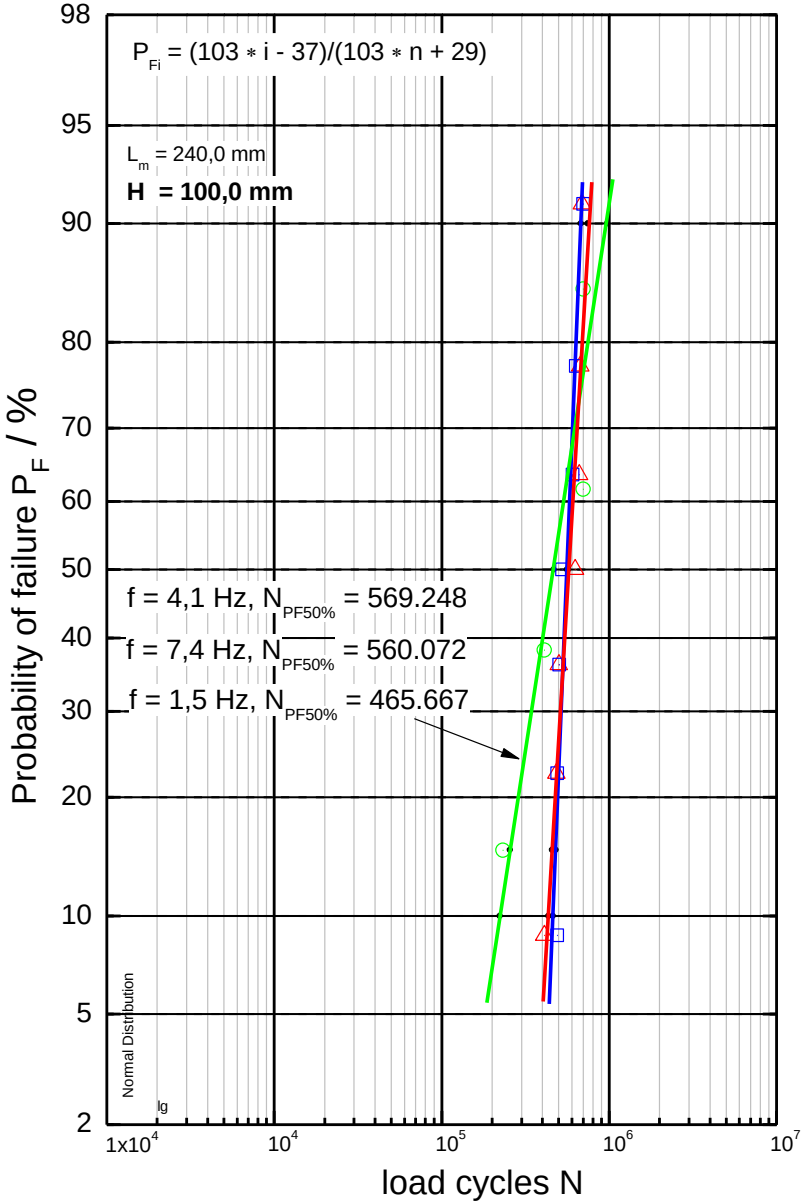
Influence of corrosion of undamaged springs

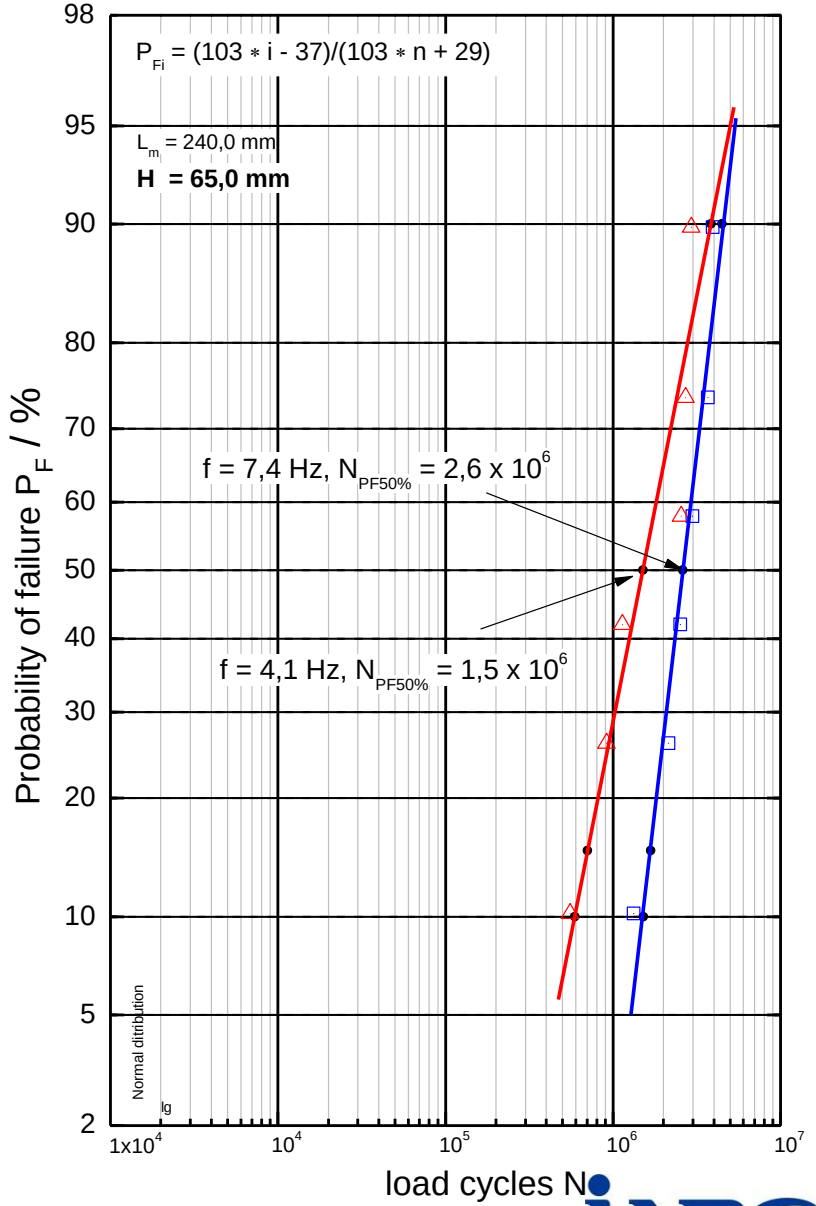


Influence of corrosion of undamaged springs

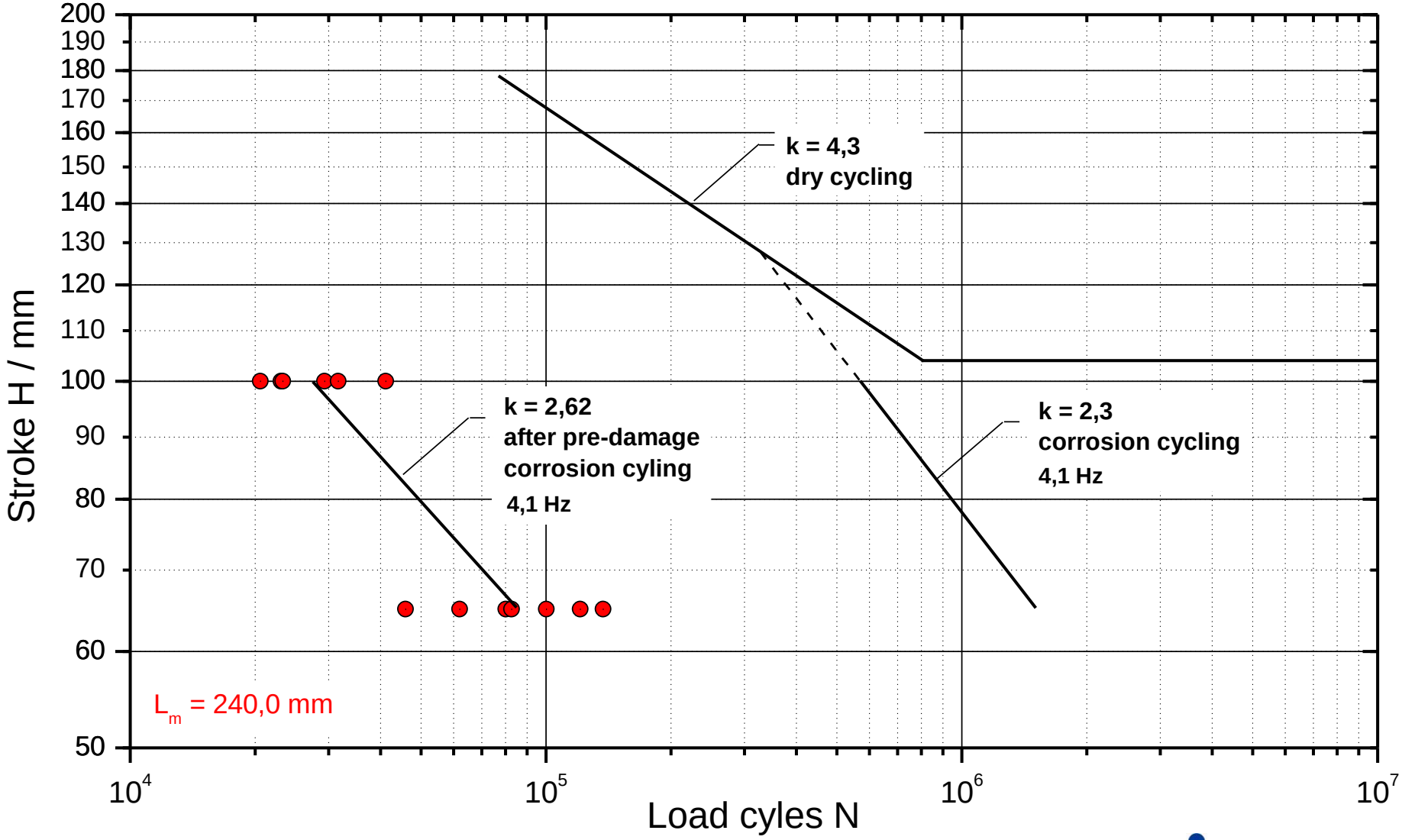


Life under corrosion at 3 different test frequencies





Basic Series + Corrosion fatigue + Corrosion fatigue after pre-damage



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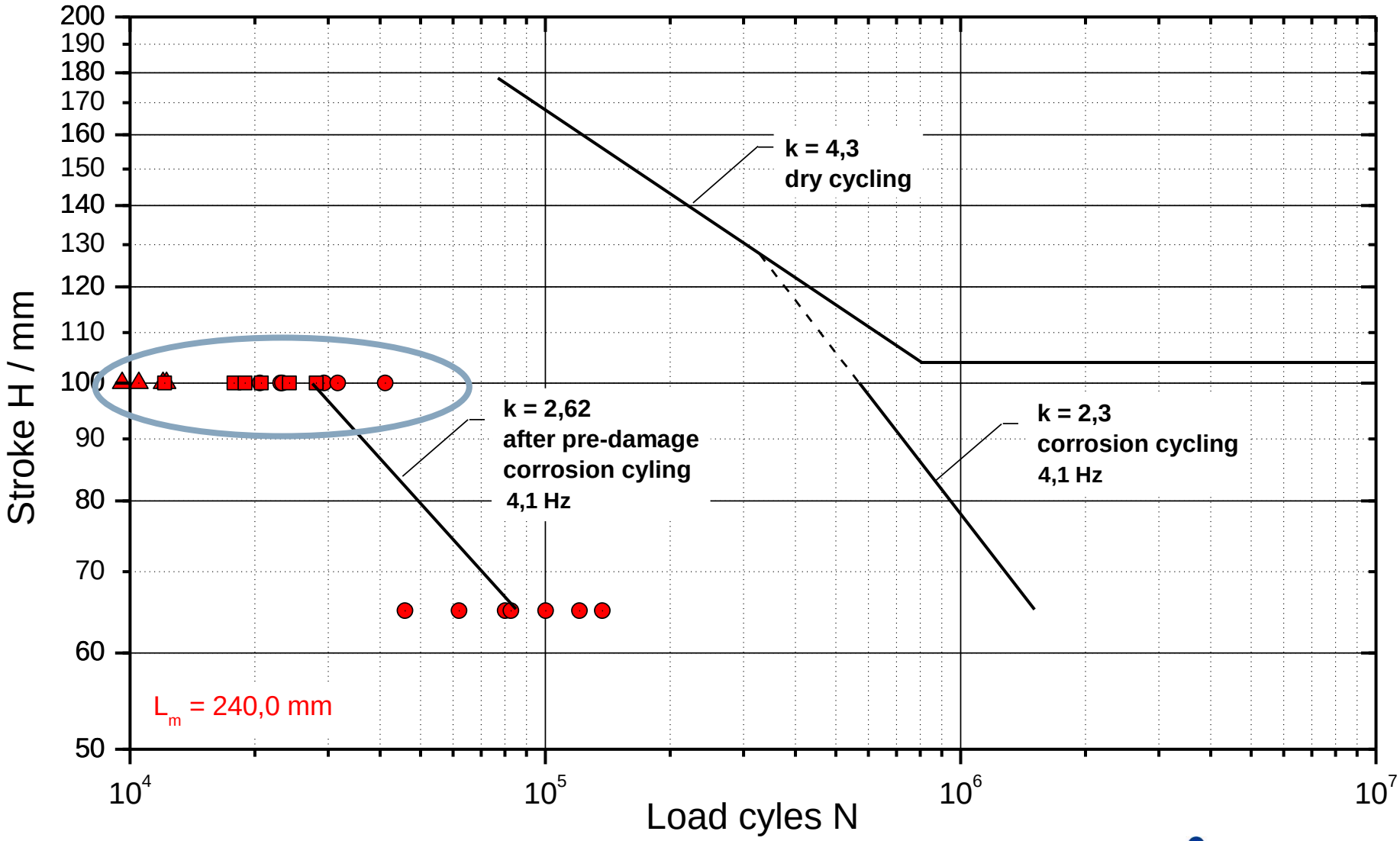
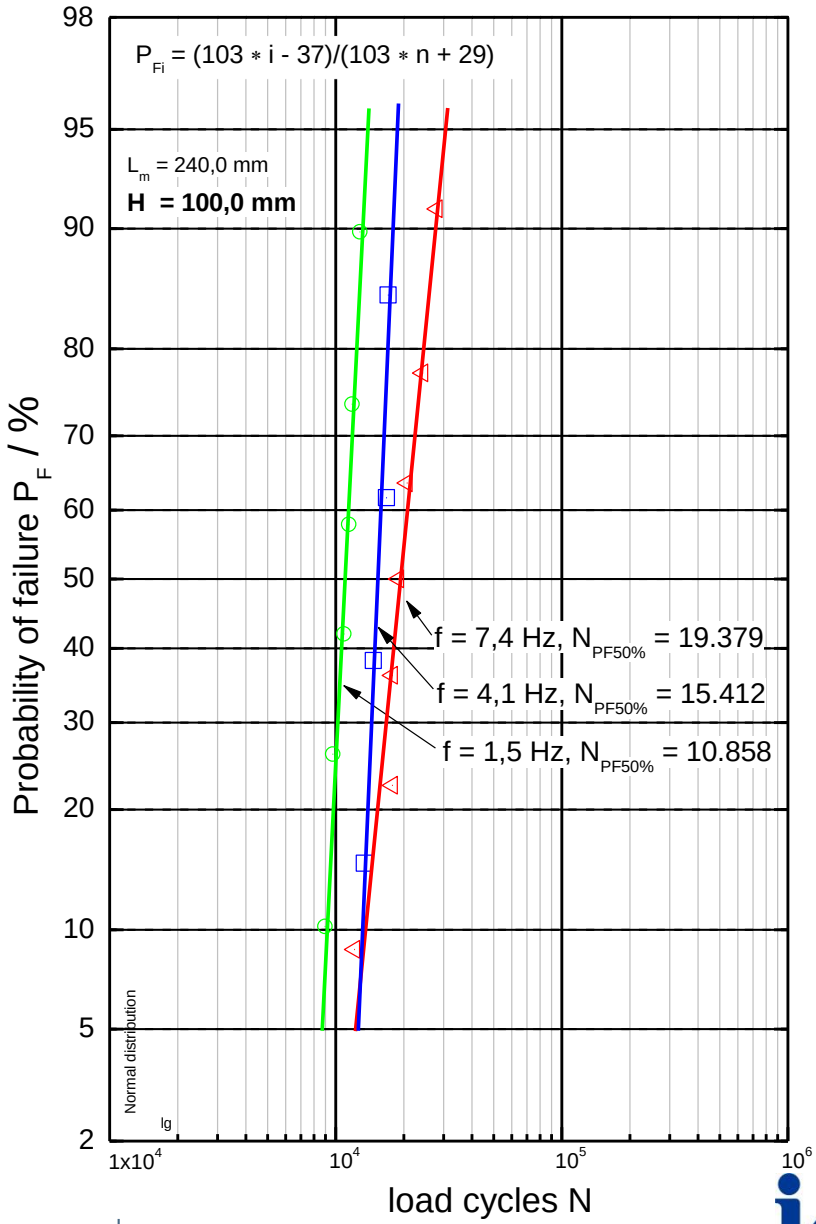
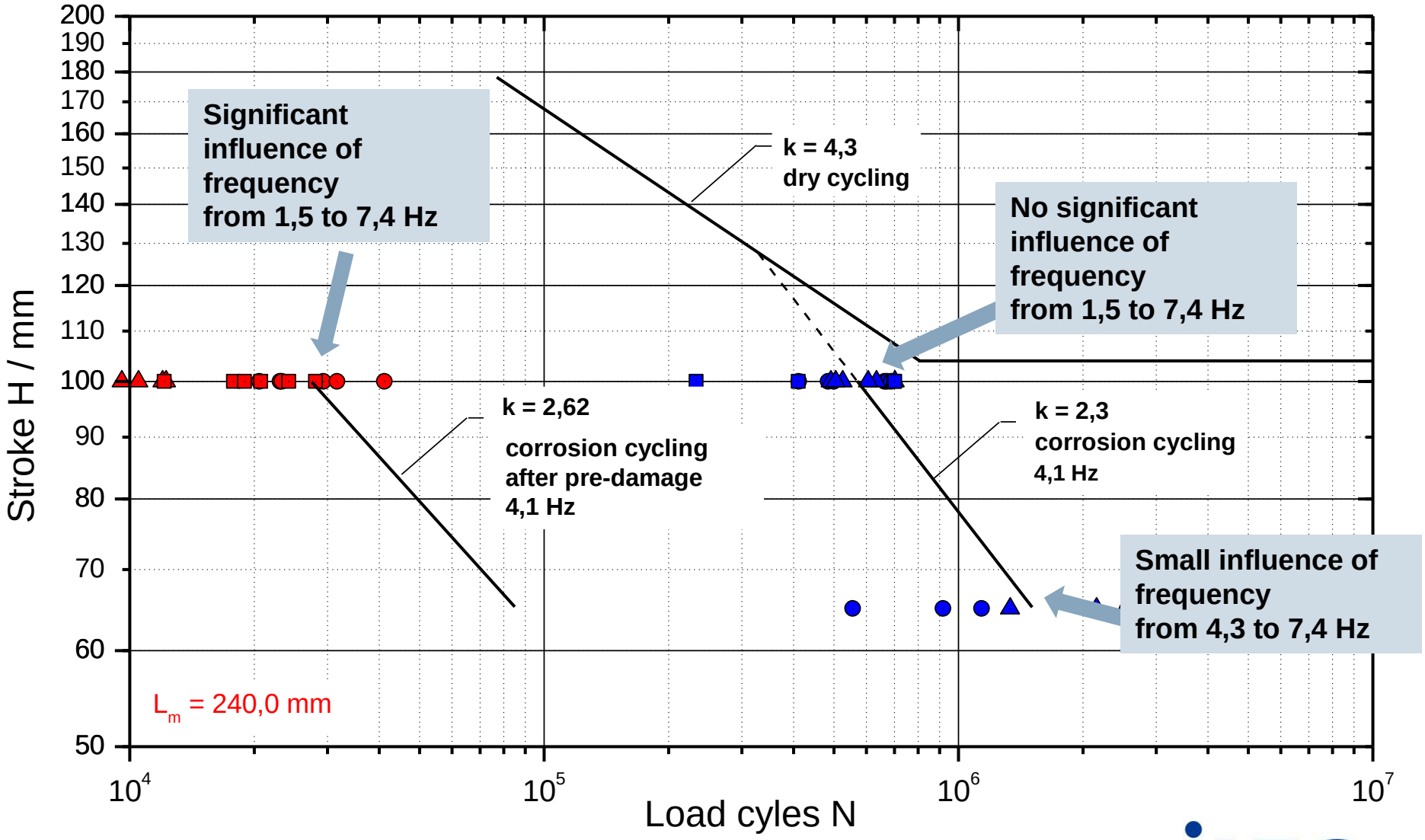


Life under corrosion after pre-damage at 3 different test frequencies



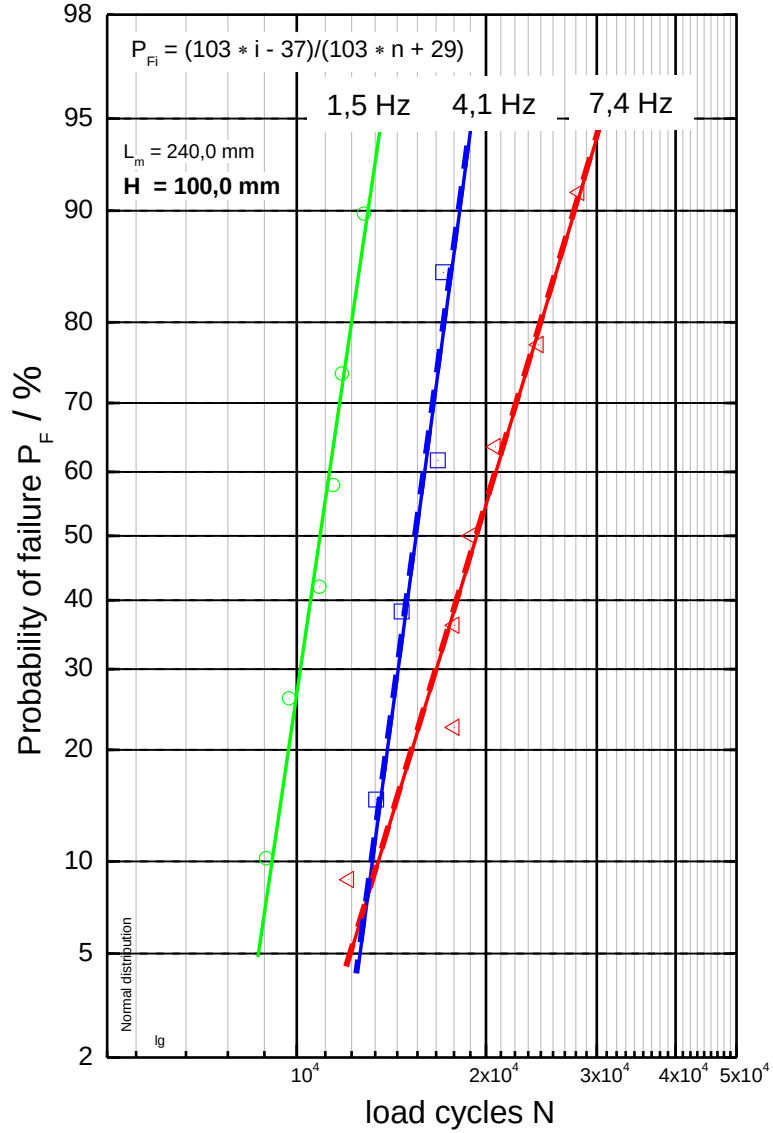
Influence of the test frequency



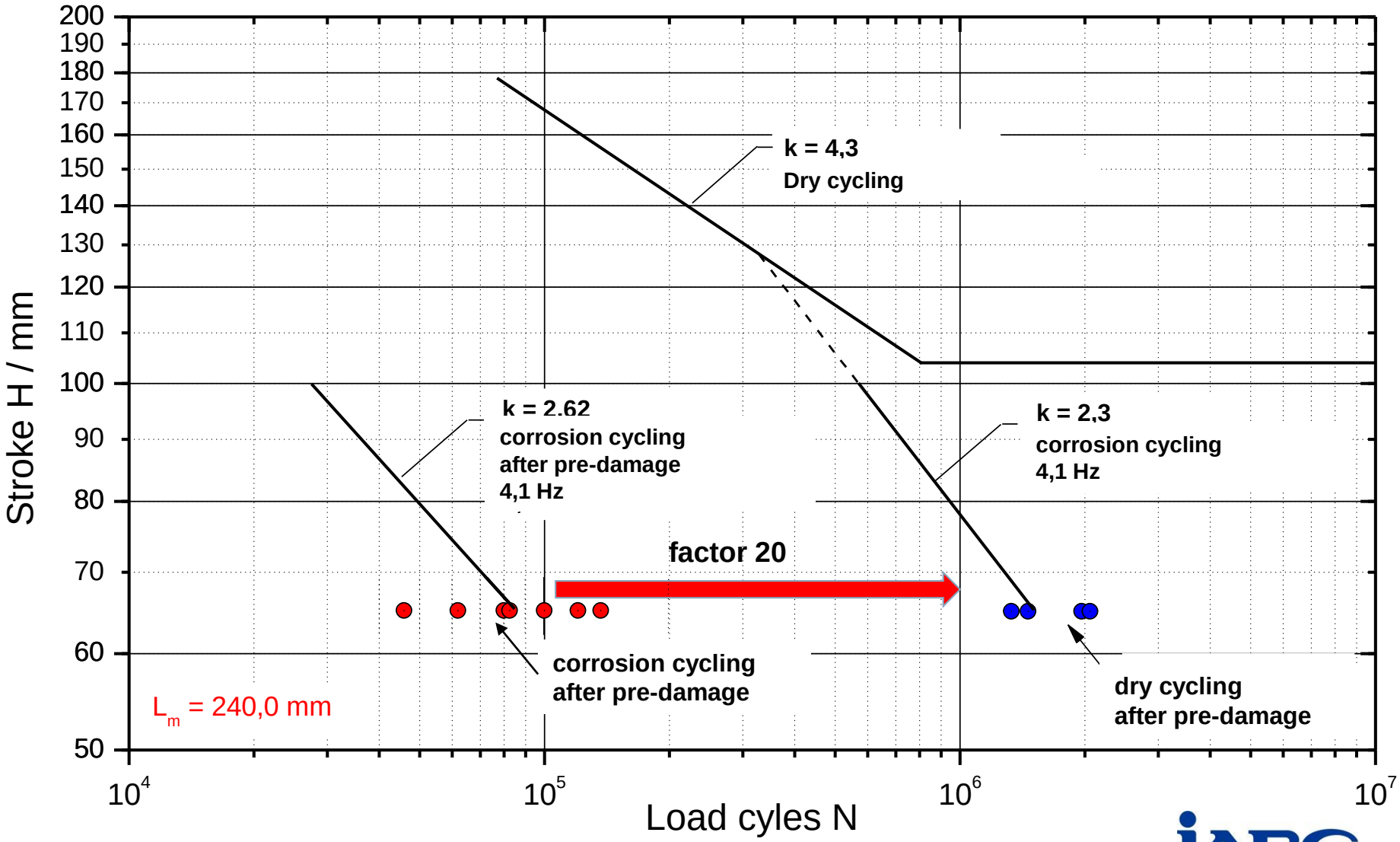
Test Evaluation – Corrosion fatigue after pre-damage at 3 different speed with frequency correction

Application of frequency correction proposed

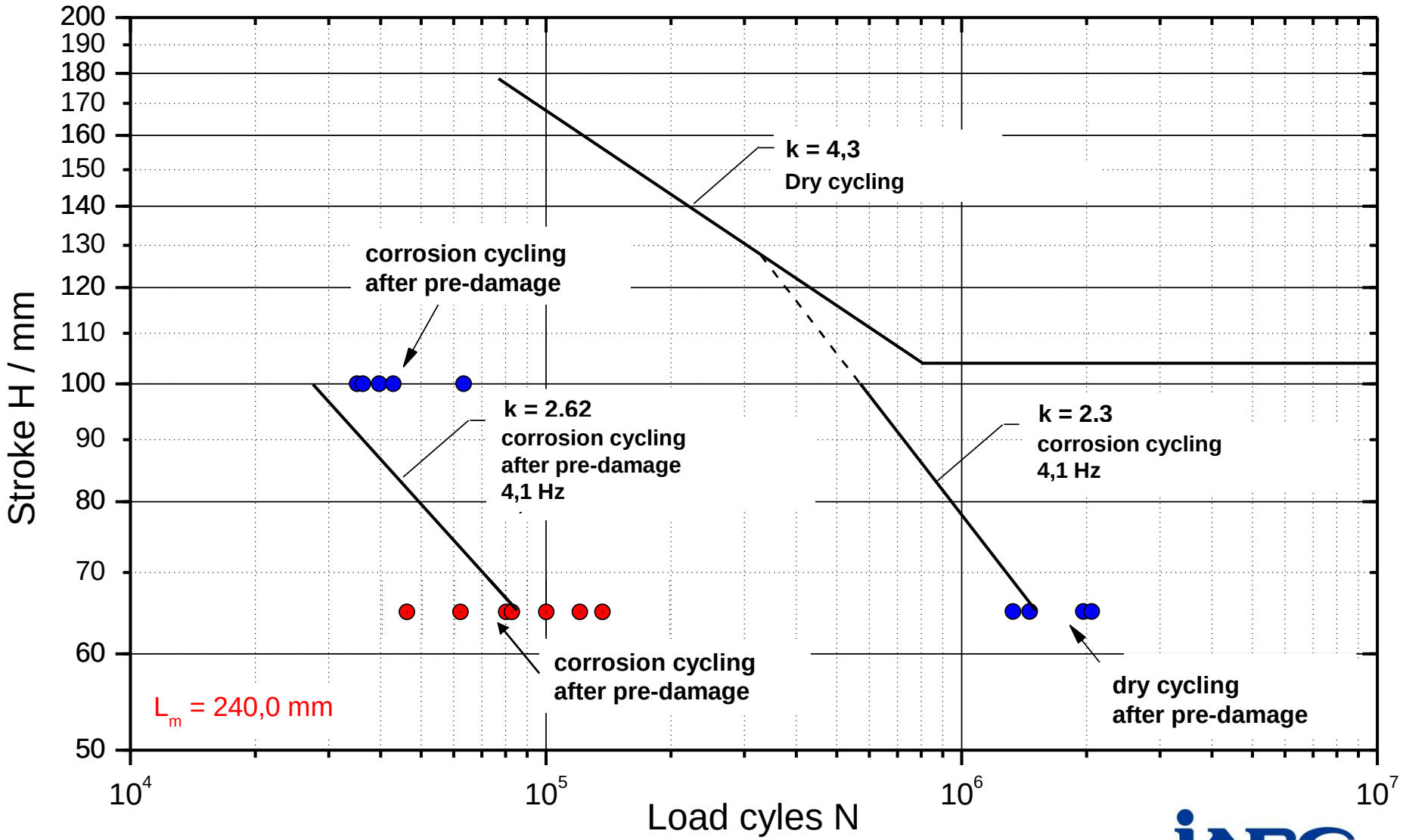
$$\frac{N_1}{N_2} = \left(\frac{f_1}{f_2}\right)^{\frac{1}{3}}$$



Basic Series + Corrosion fatigue + Fatigue test after pre-damage



Basic Series + Corrosion fatigue + Corrosion fatigue after pre-damage



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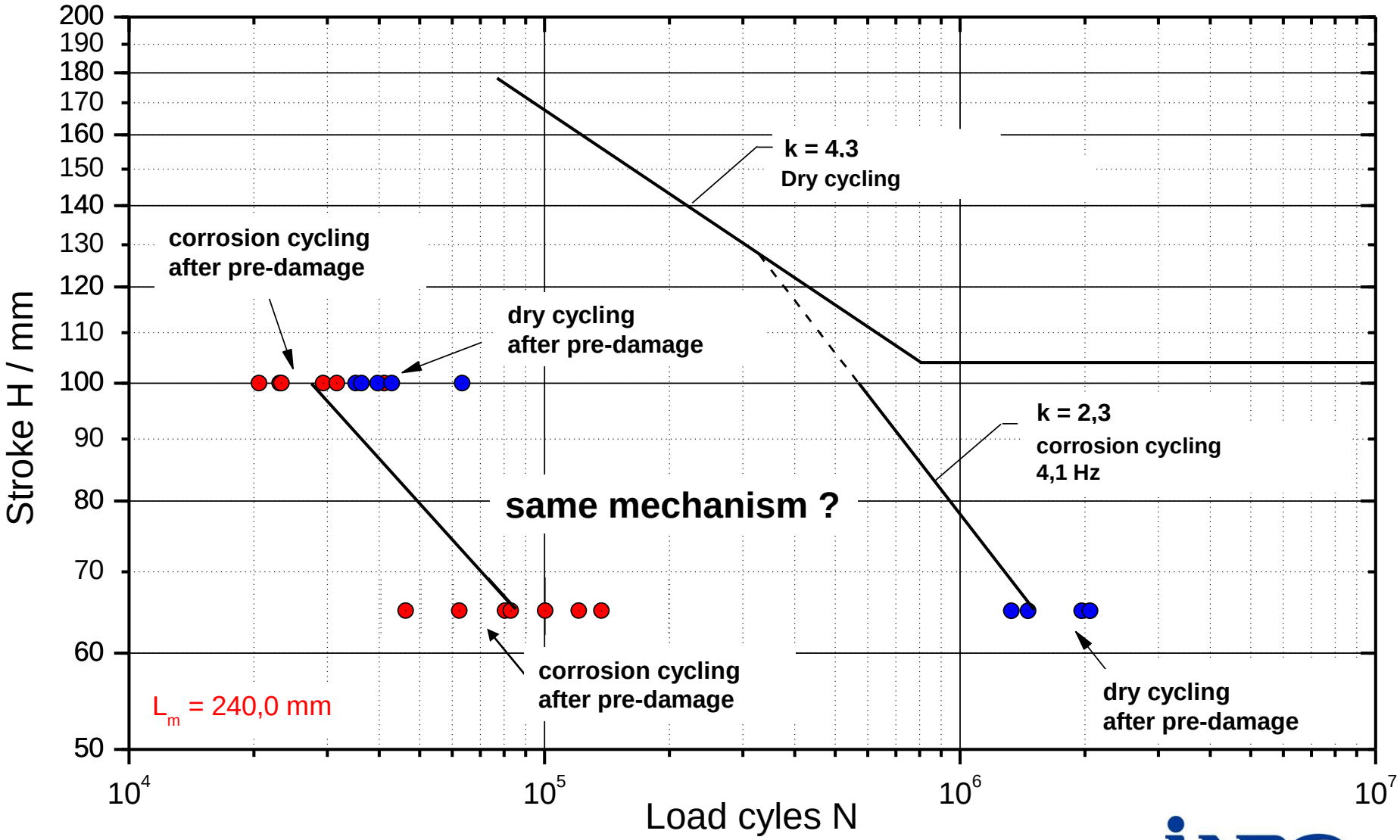
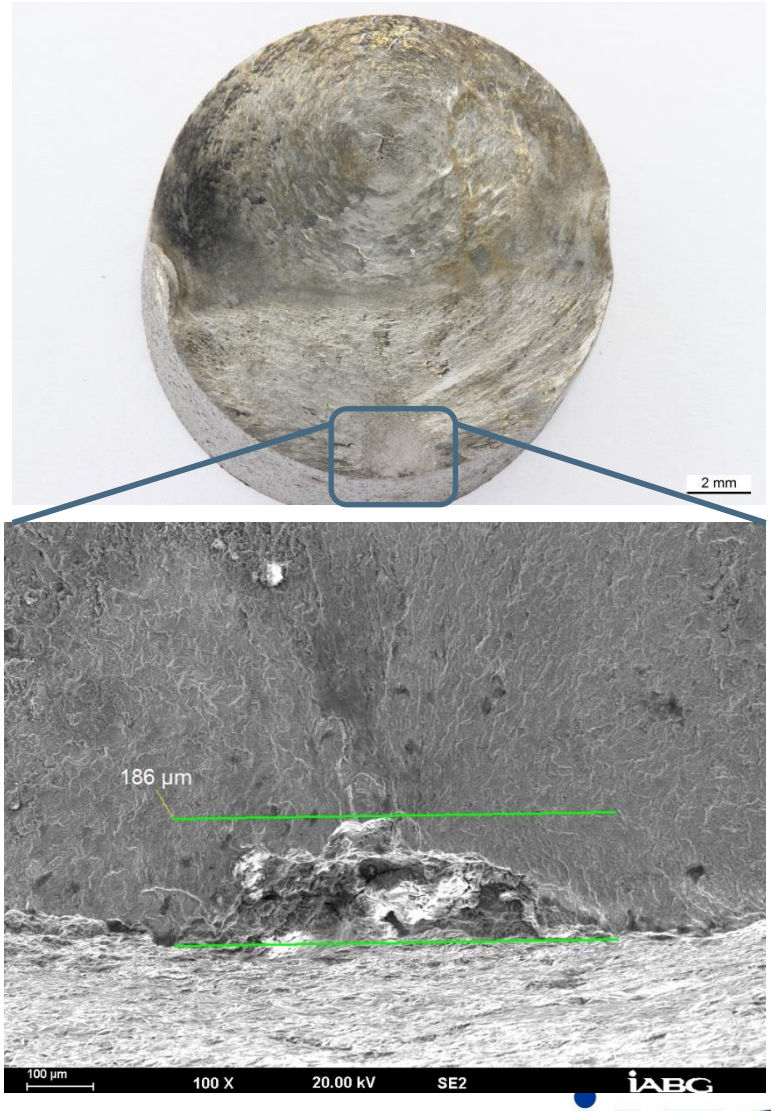


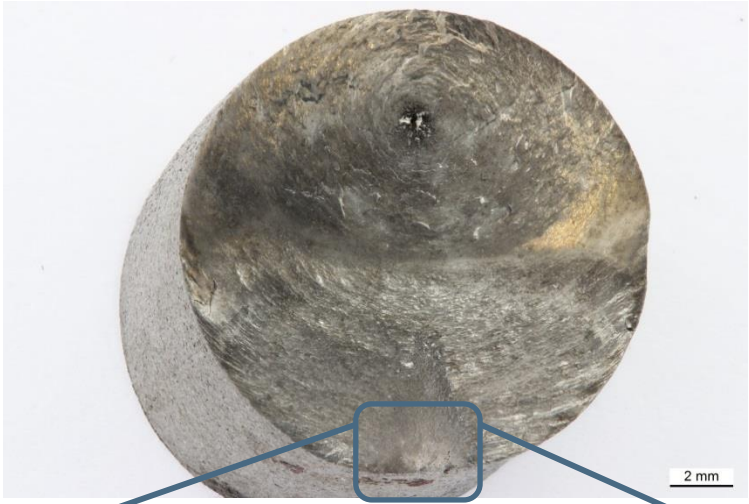
Fracture reason after pre-damage

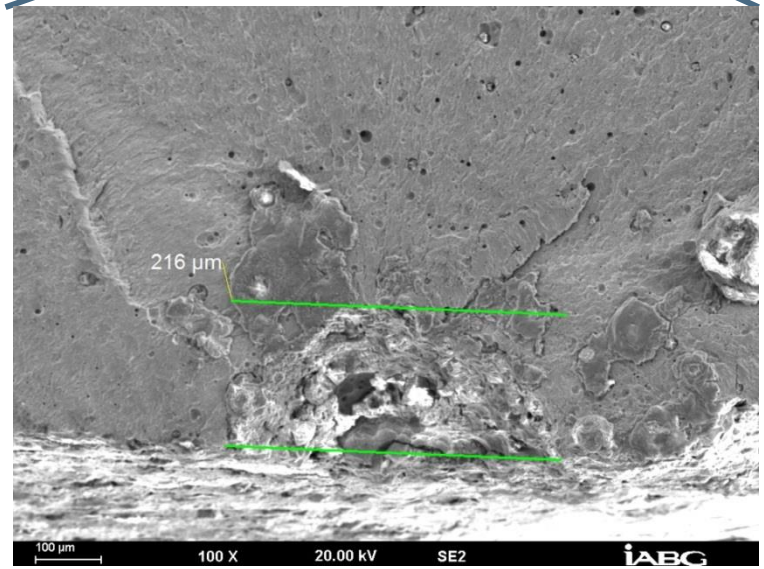
Fracture pattern after pre-damage and **corrosion** during fatigue test



Fracture reason after pre-damage

Fracture pattern after pre-damage and fatigue test





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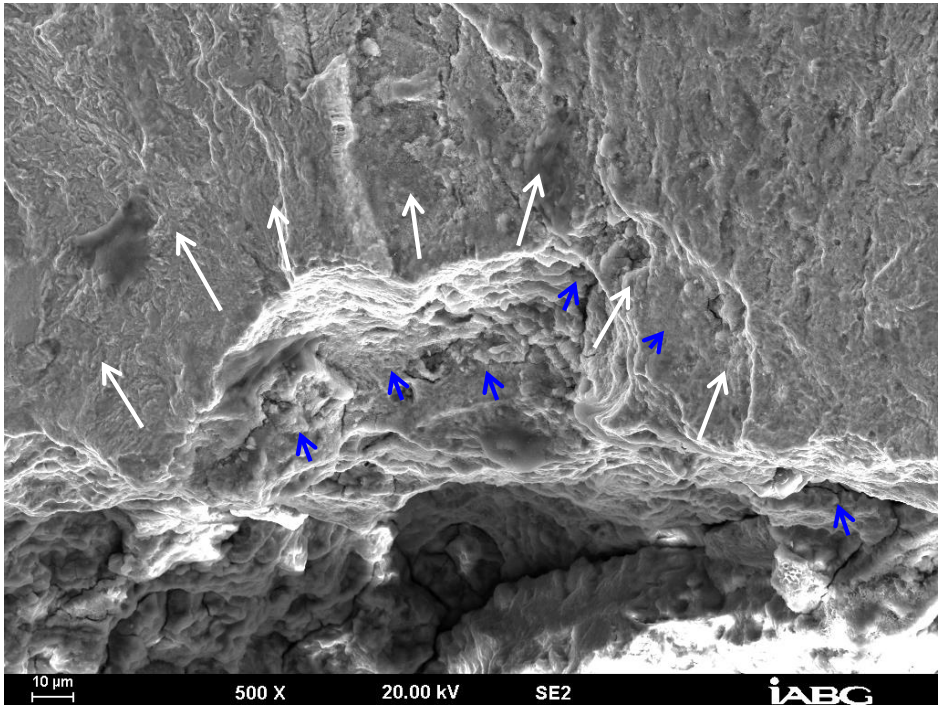
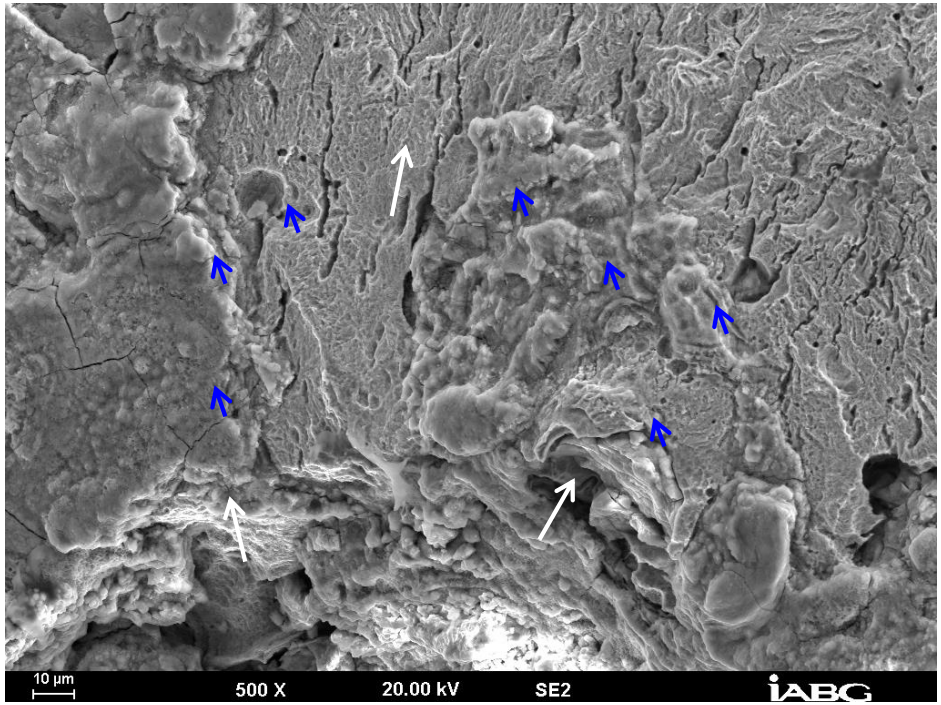


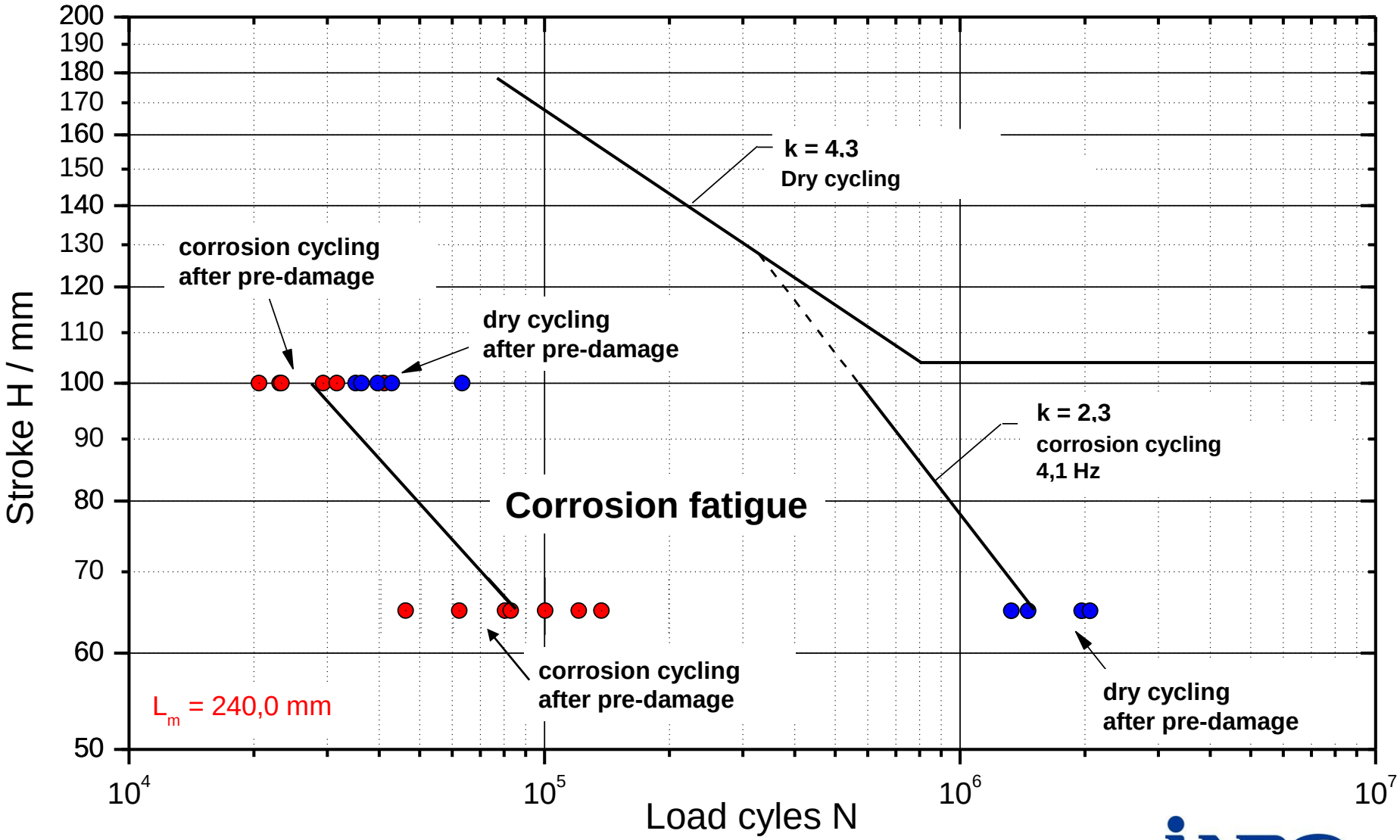
Fracture pattern after pre-damage and fatigue test



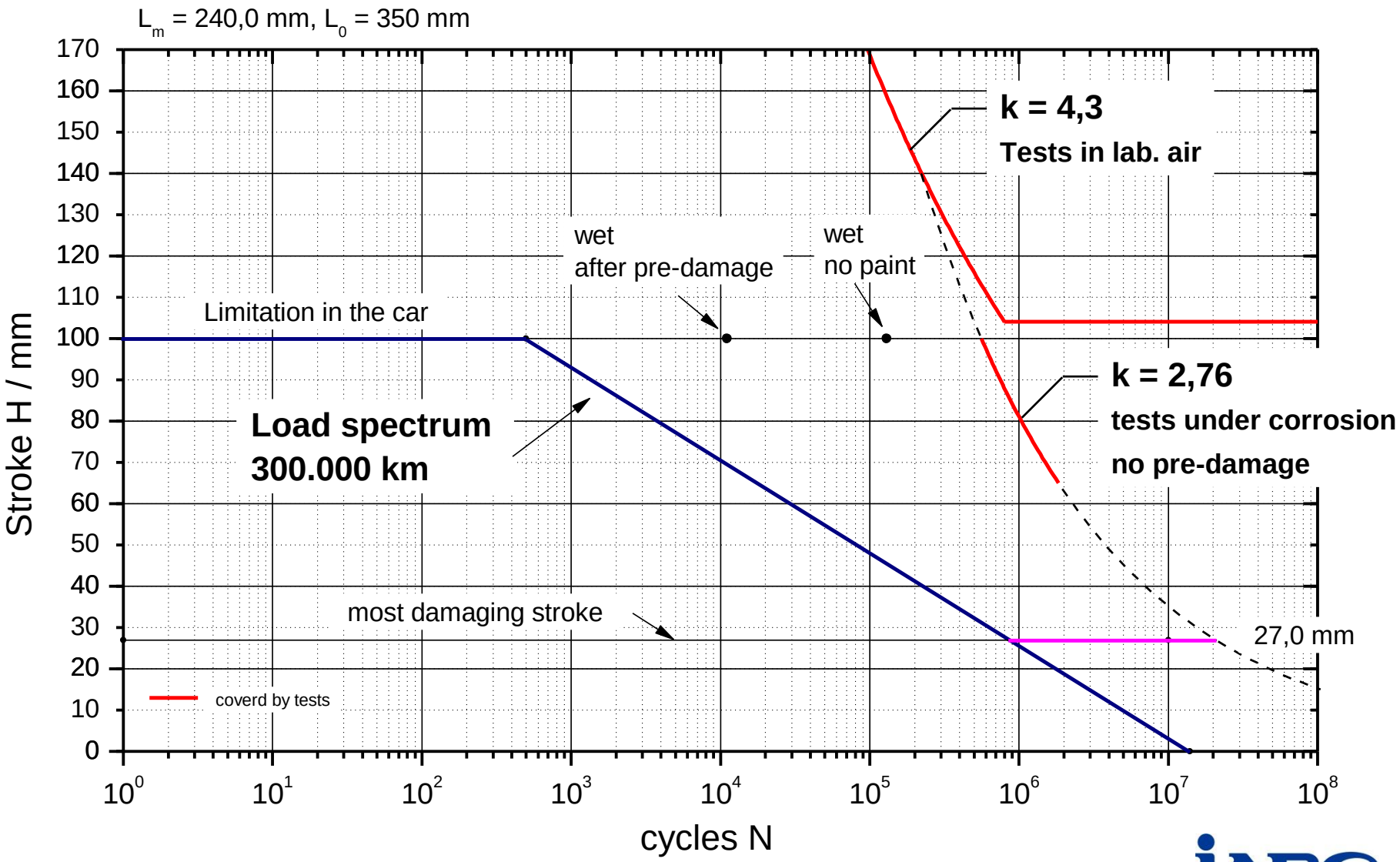
Corrosion fatigue in both cases

- Subsidiary cracks in z-direction, cross pattern
- Cracks are widely open and rough crack flanks
- Mechanical and corrosive effect evolve to a corrosion fatigue

Basic Series + Corrosion fatigue + Corrosion fatigue after pre-damage



Dimensioning Situation



Summary

- The influence of the test frequency is not significant at standard corrosion fatigue test
- The influence of the test frequency is just visible at the corrosion fatigue test after pre-damage and the proposed frequency correction factor is a good approximation

$$\frac{N_1}{N_2} = \left(\frac{f_1}{f_2}\right)^{\frac{1}{3}}$$

- Corrosion during fatigue test has an influence on the fatigue life
- The influence of corrosion increases at lower test levels
- At the test after pre-damage with and without corrosion the springs fail caused by corrosion fatigue

Outlook

- The influence of the surface protection chosen?
- What is the fatigue life of springs after pre-damage with and without corrosion?
- What are the main influencing factors to the frequency influence?

Your Contact

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