Fatigue testing of 5-1/2 FHMOD Pin-Box drill collar tubular connections with in-plane resonant test rig

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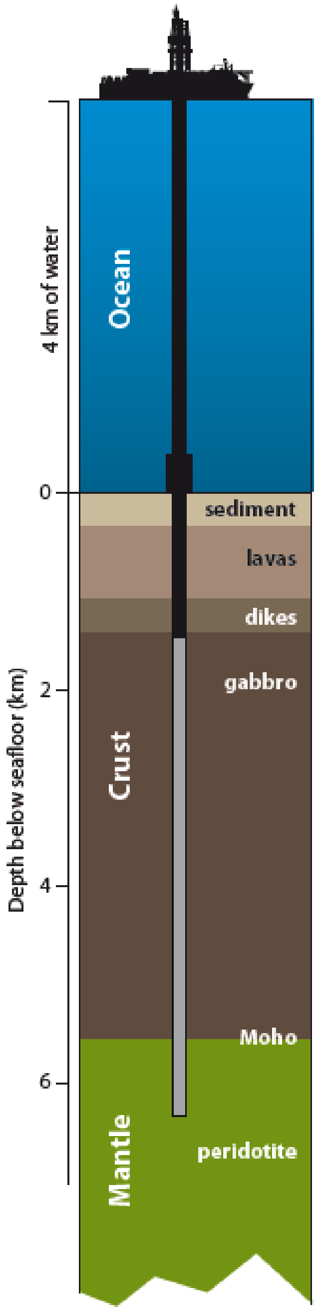
(c) *Japan Agency for Marine-earth Science and Technology, JAMSTEC*

JAMSTEC (Japan Agency for Marine-earth Science and Technology)



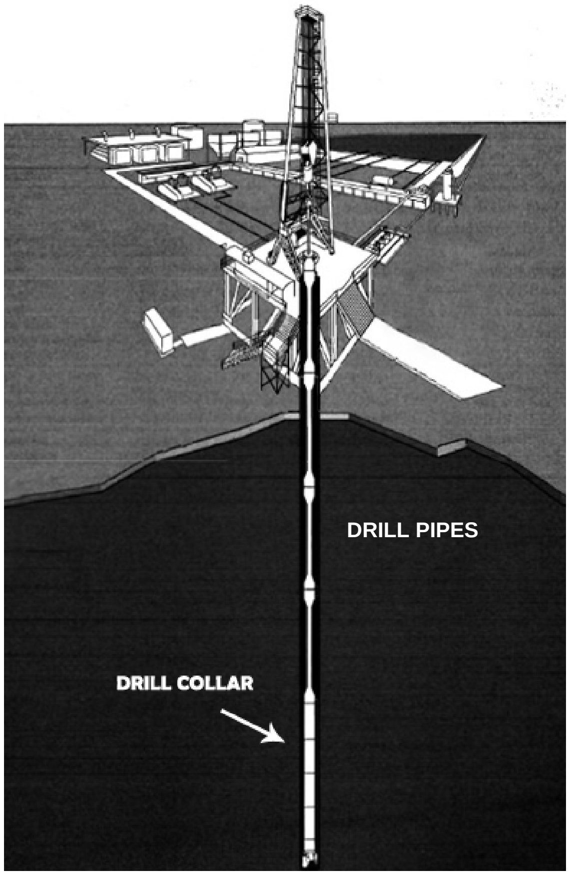
CHIKYU Vessel (Chikyu -> "pianeta Terra")

IODP
INTERNATIONAL OCEAN DISCOVERY PROGRAM

Deep Sea Scientific Drilling:

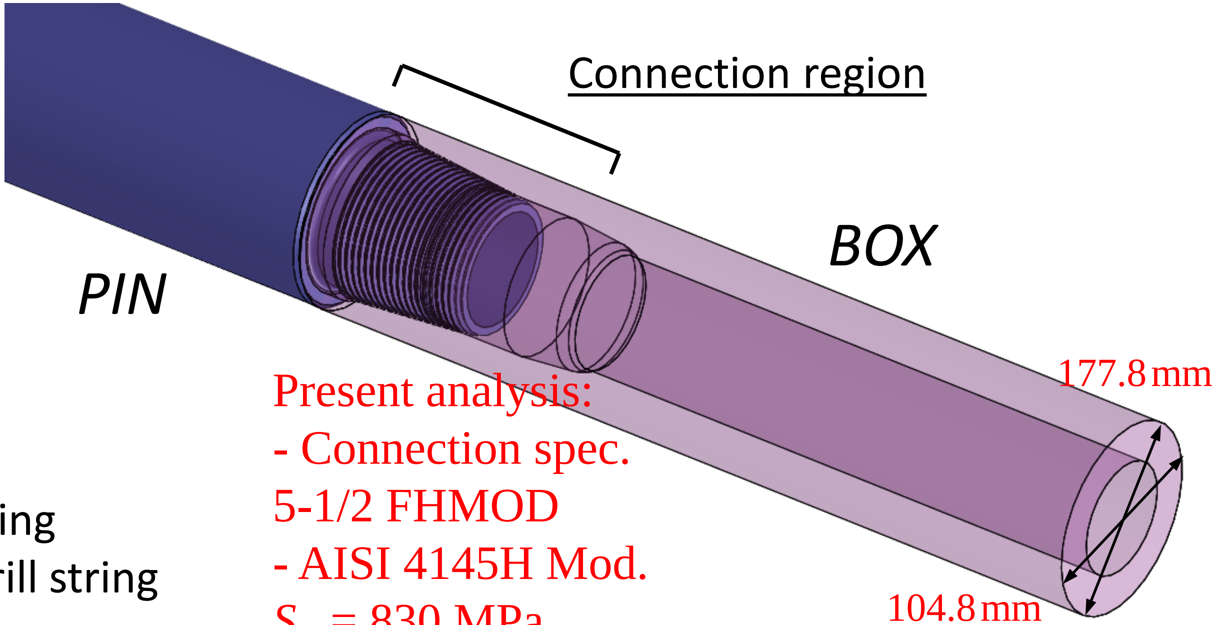
- Climate and Ocean Change
- Biosphere Frontiers
- Earth Connections
- Earth in Motion (*earthquakes and tsunami*)
- Education and Outreach

Intro: Drill Collar connection to be tested



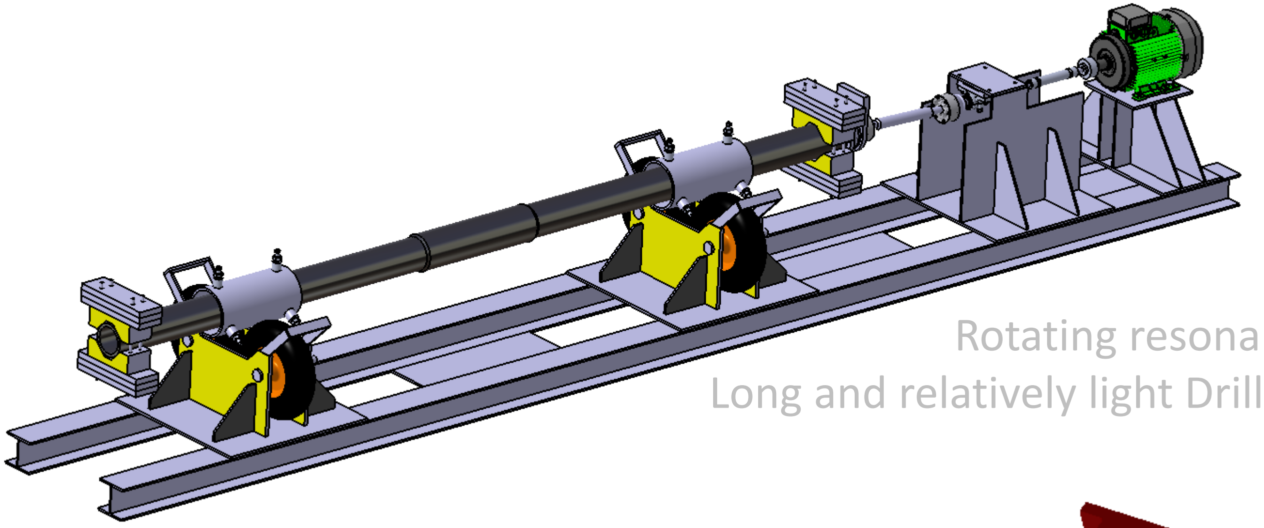
Drill Pipes at Top of the drill string
Drill Collars at Bottom of the drill string

Drill Collars:
- Large thickness pipe sections
- Uniform section from end-to-end



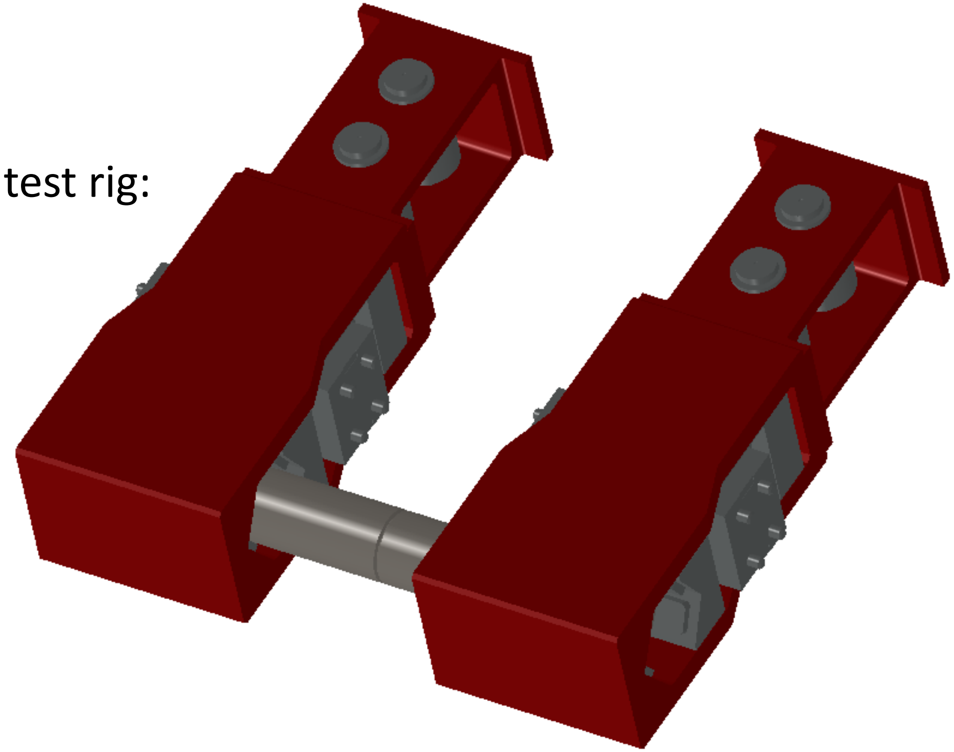
Present analysis:
- Connection spec. 5-1/2 FHMOD
- AISI 4145H Mod.
S_Y = 830 MPa
S_U = 1030 MPa

Intro: Resonant test rigs at University of Pisa, Mechanical department

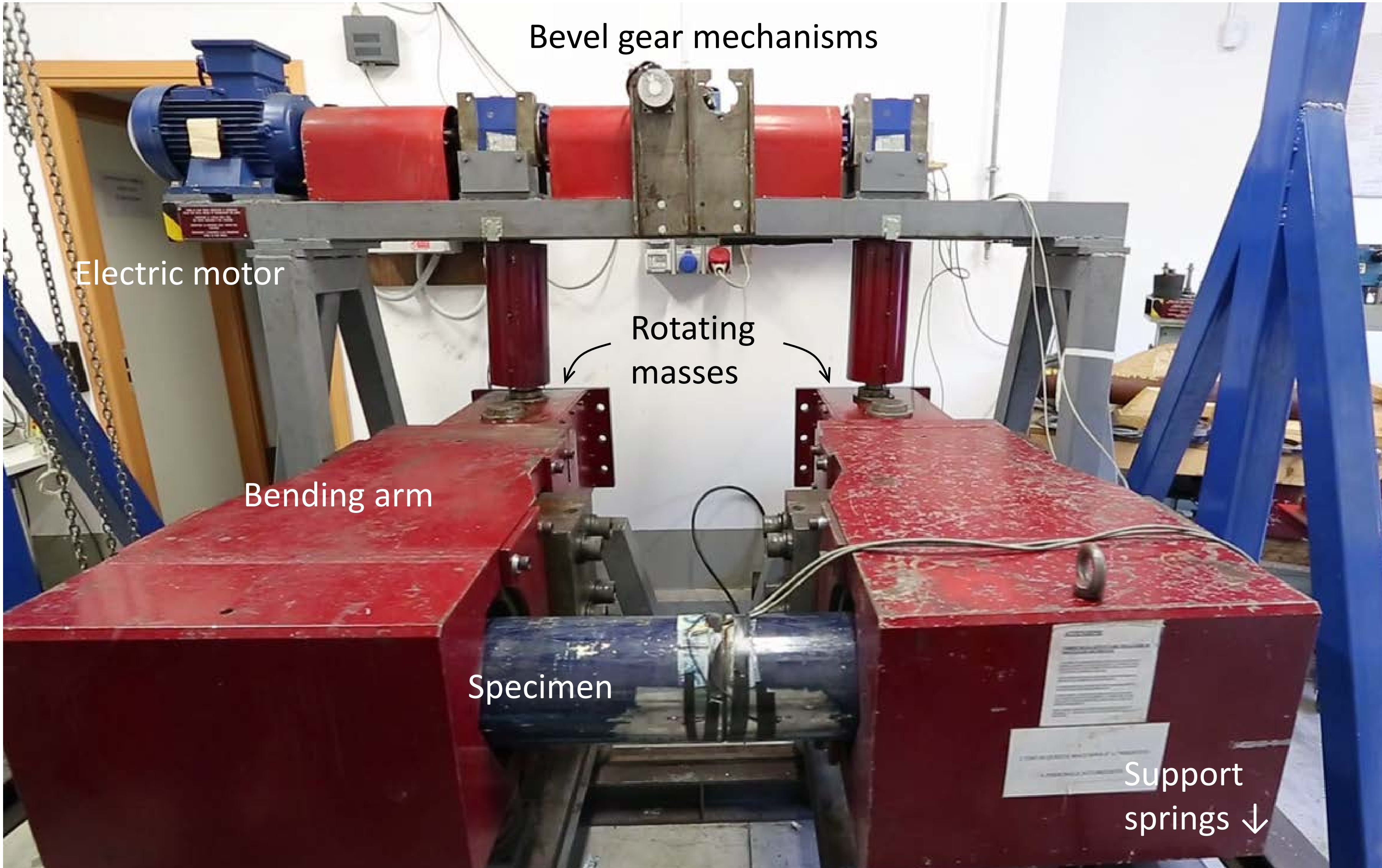


Rotating resonant fatigue test rig:
Long and relatively light Drill Pipe connections

In-plane resonant fatigue test rig:
Short and heavy section
Drill Collar connections

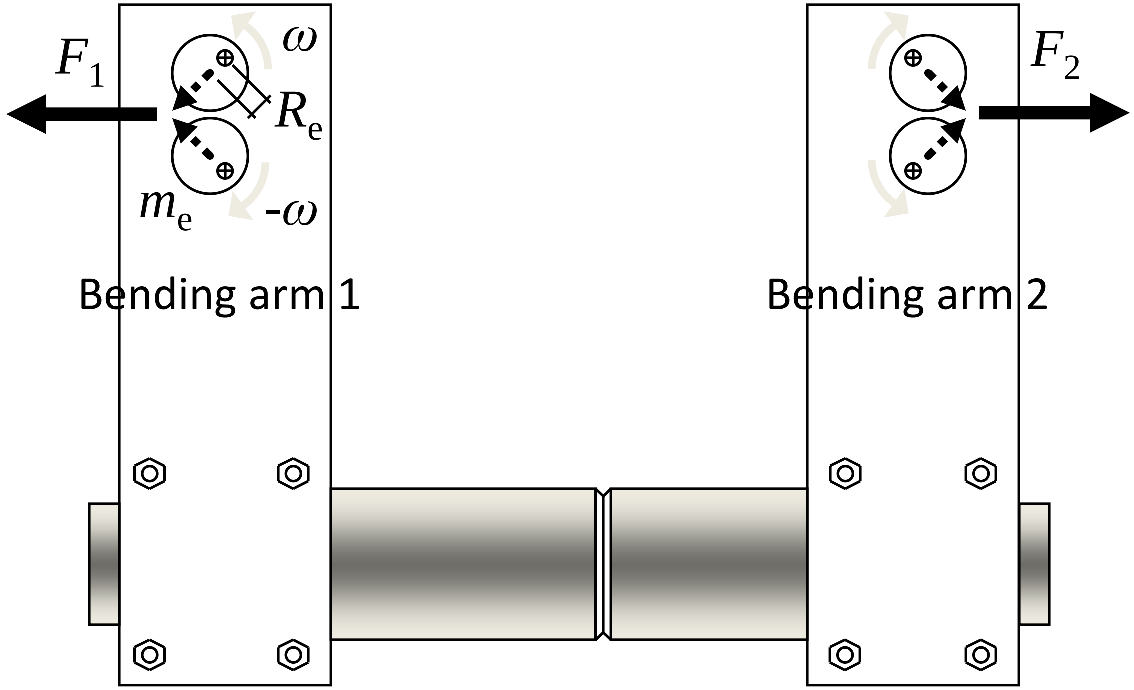


Hardware of the bench



In-plane resonant fatigue test rig

How it works



L. Bertini, M. Beghini, C. Santus, A. Baryshnikov, Resonant test rigs for fatigue full scale testing of oil drill string connections. International Journal of Fatigue. Vol. 30 (6), pp. 978-988, 2008

In-plane resonant fatigue test rig

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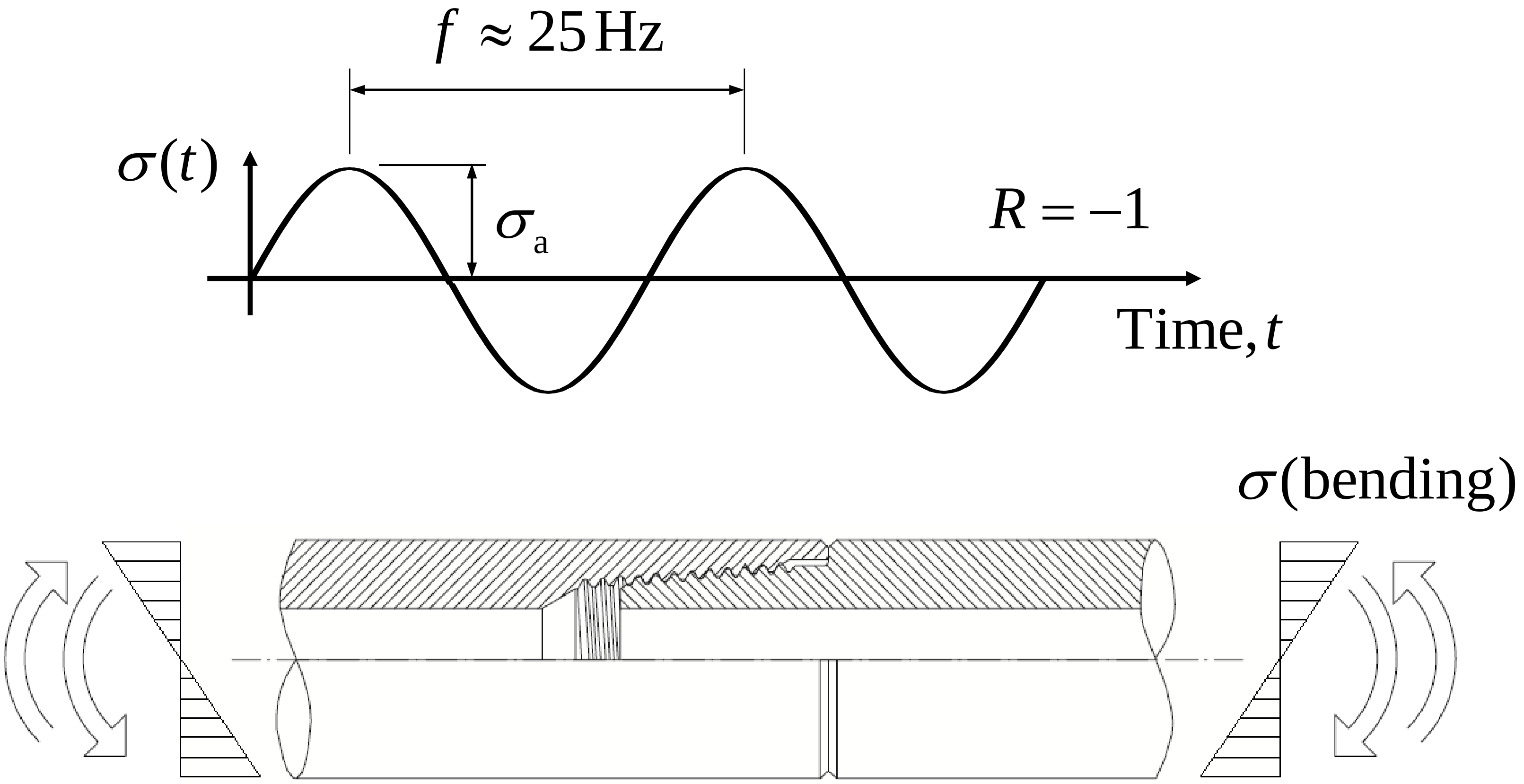

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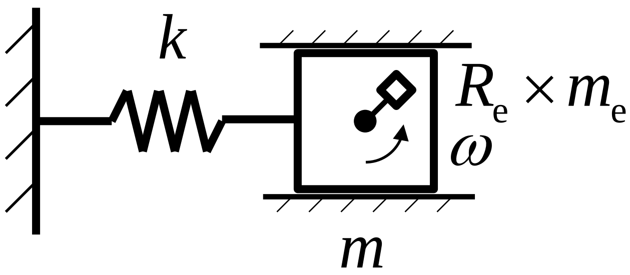
In-plane resonant fatigue test rig

How it works

In-plane resonant fatigue test rig

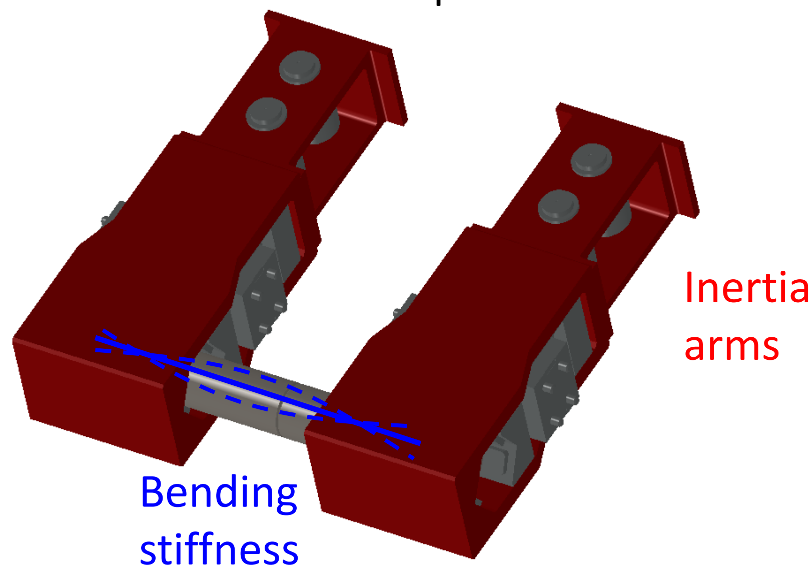
Resonance modeling

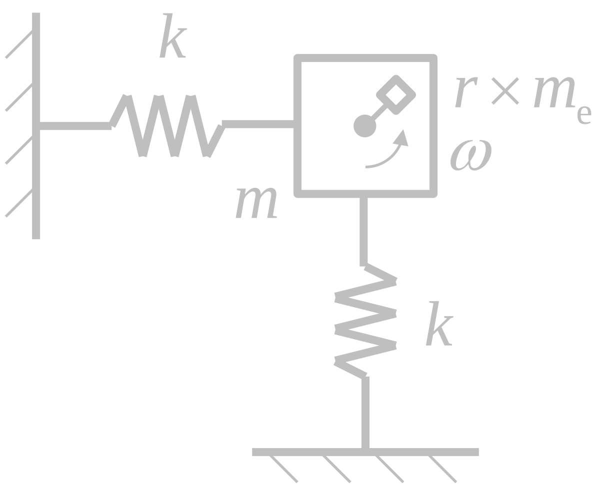
1 DOF dynamic model



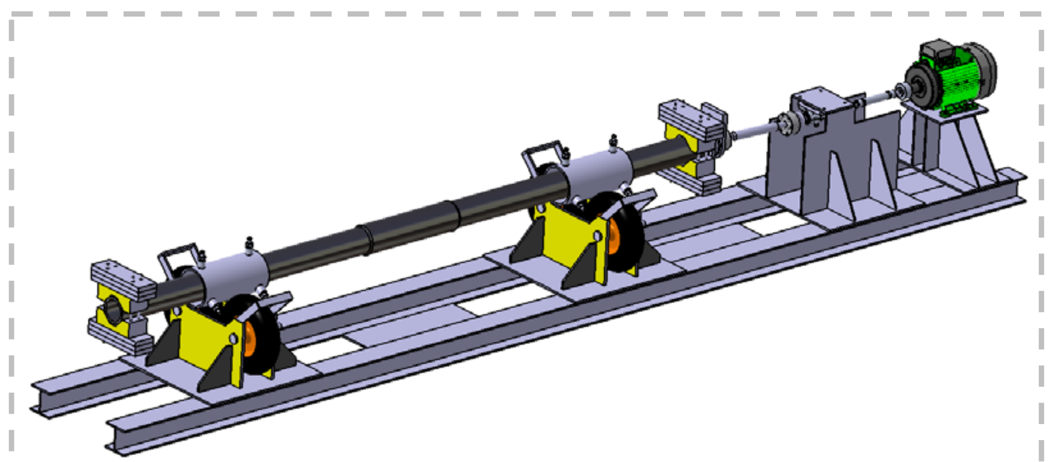
$$\omega_n = \sqrt{\frac{k}{m}}, \text{Resonance:} \omega \to \omega_n$$

In-plane resonant bench





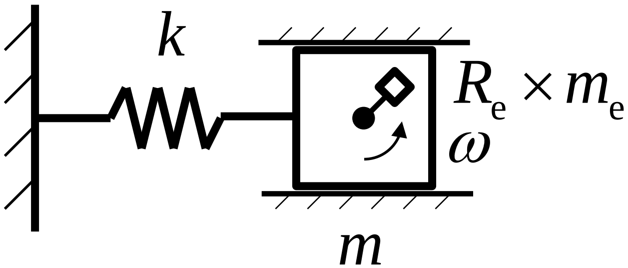
Rotating resonant bench



In-plane resonant fatigue test rig

Resonance modeling

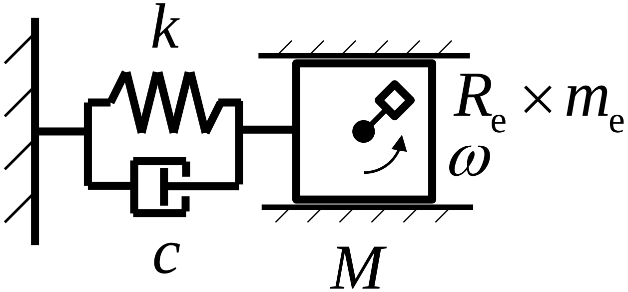
Basic dynamic model, no dumping



$$\Omega = \omega / \omega_n$$

$$\sigma_a \propto r\, m_e \frac{\Omega^2}{|1-\Omega^2|}$$

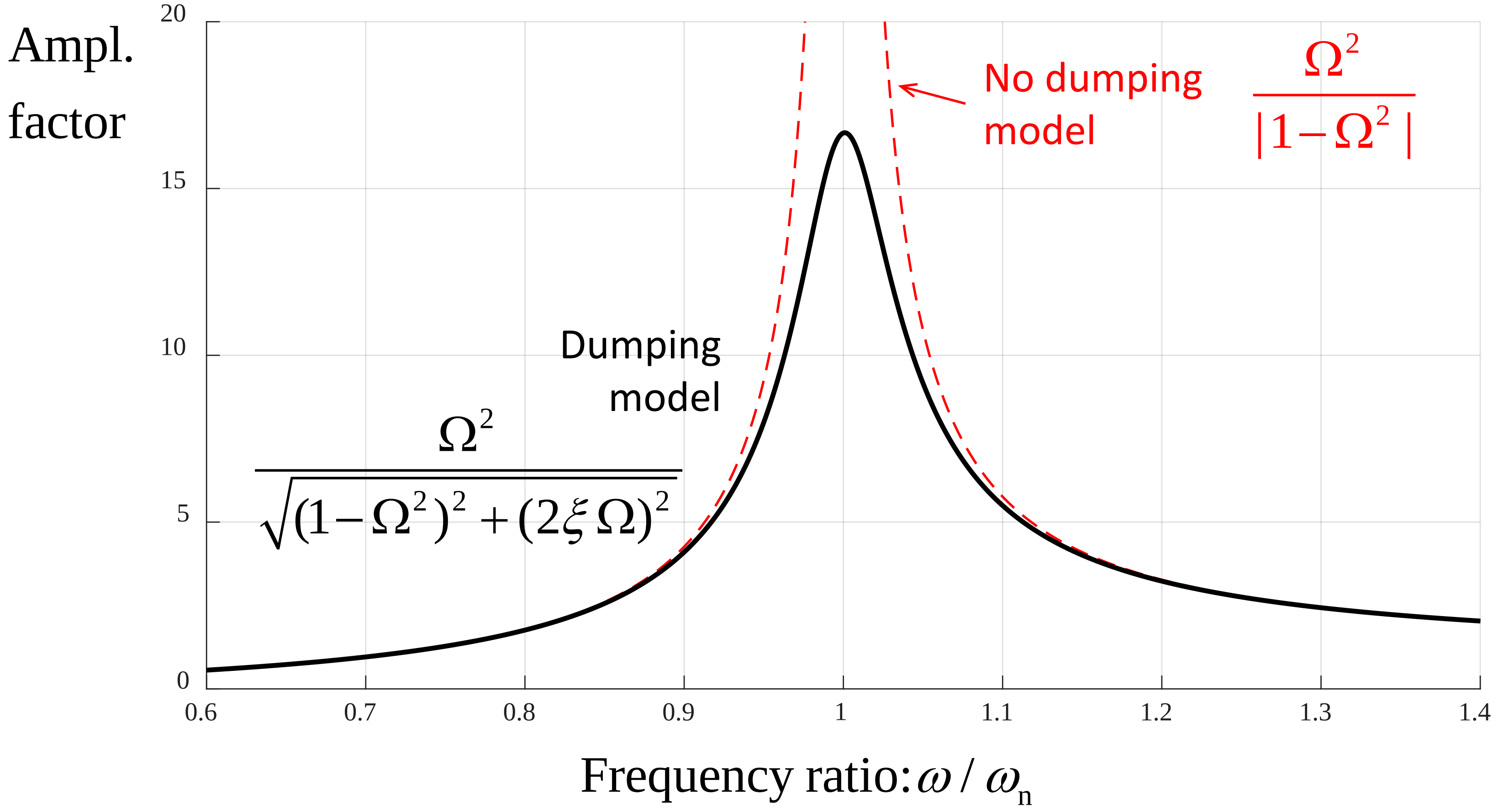
Dynamic model with dumping



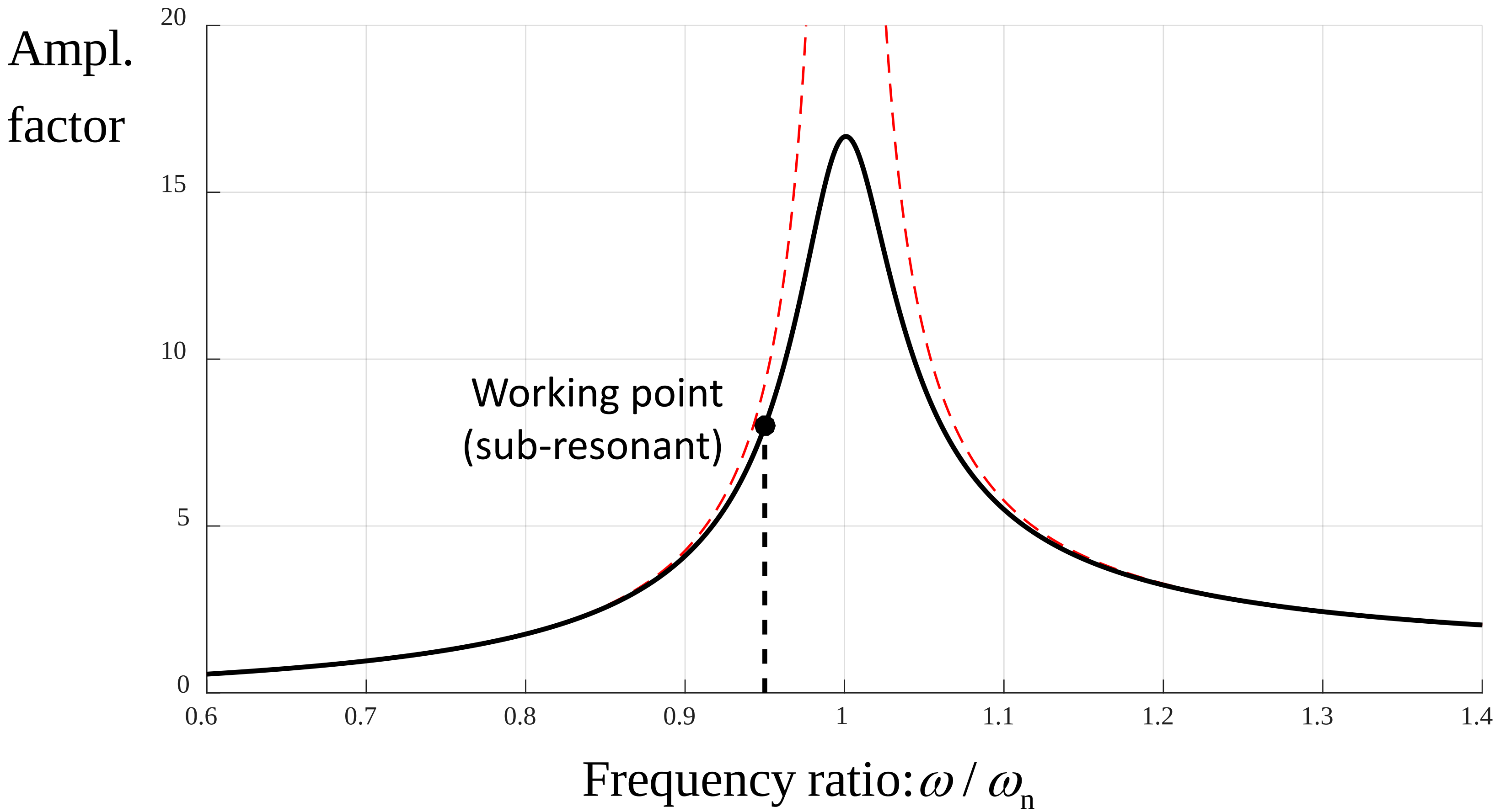
$$\xi = \frac{c}{2\sqrt{k\, m}}$$

$$\sigma_a \propto r\, m_e \frac{\Omega^2}{\sqrt{(1-\Omega^2)^2 + (2\xi\,\Omega)^2}}$$

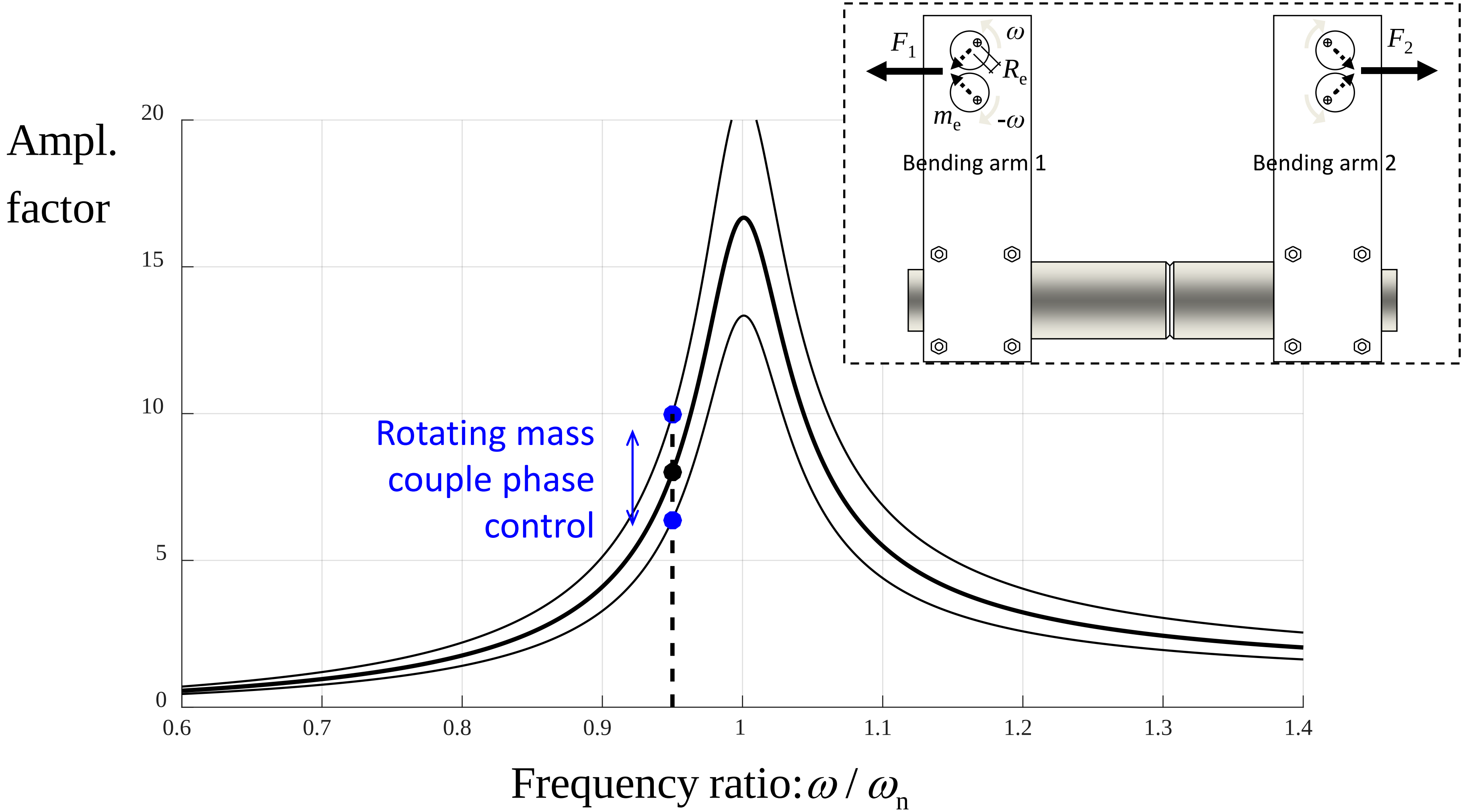
Resonance modeling



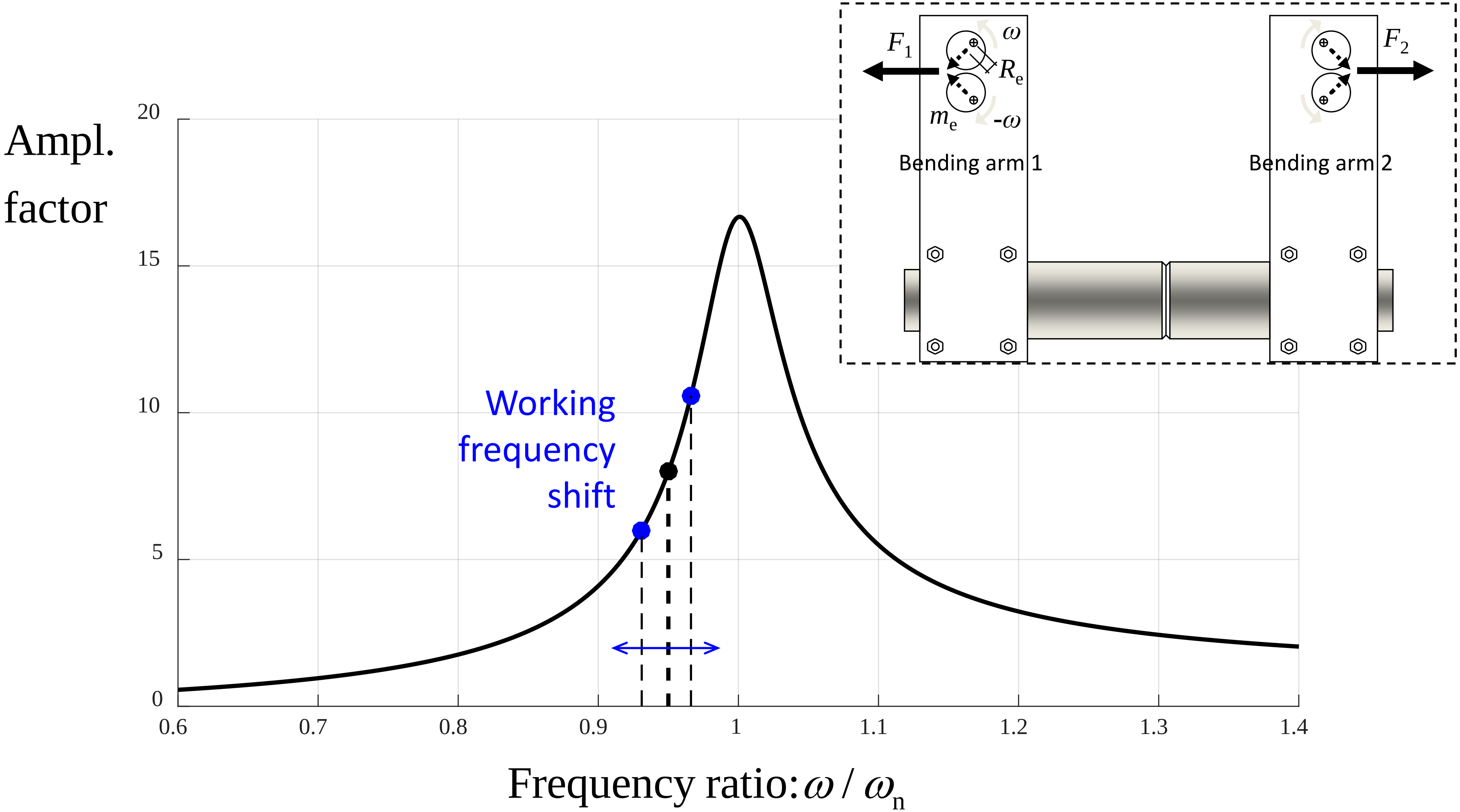
Resonance modeling



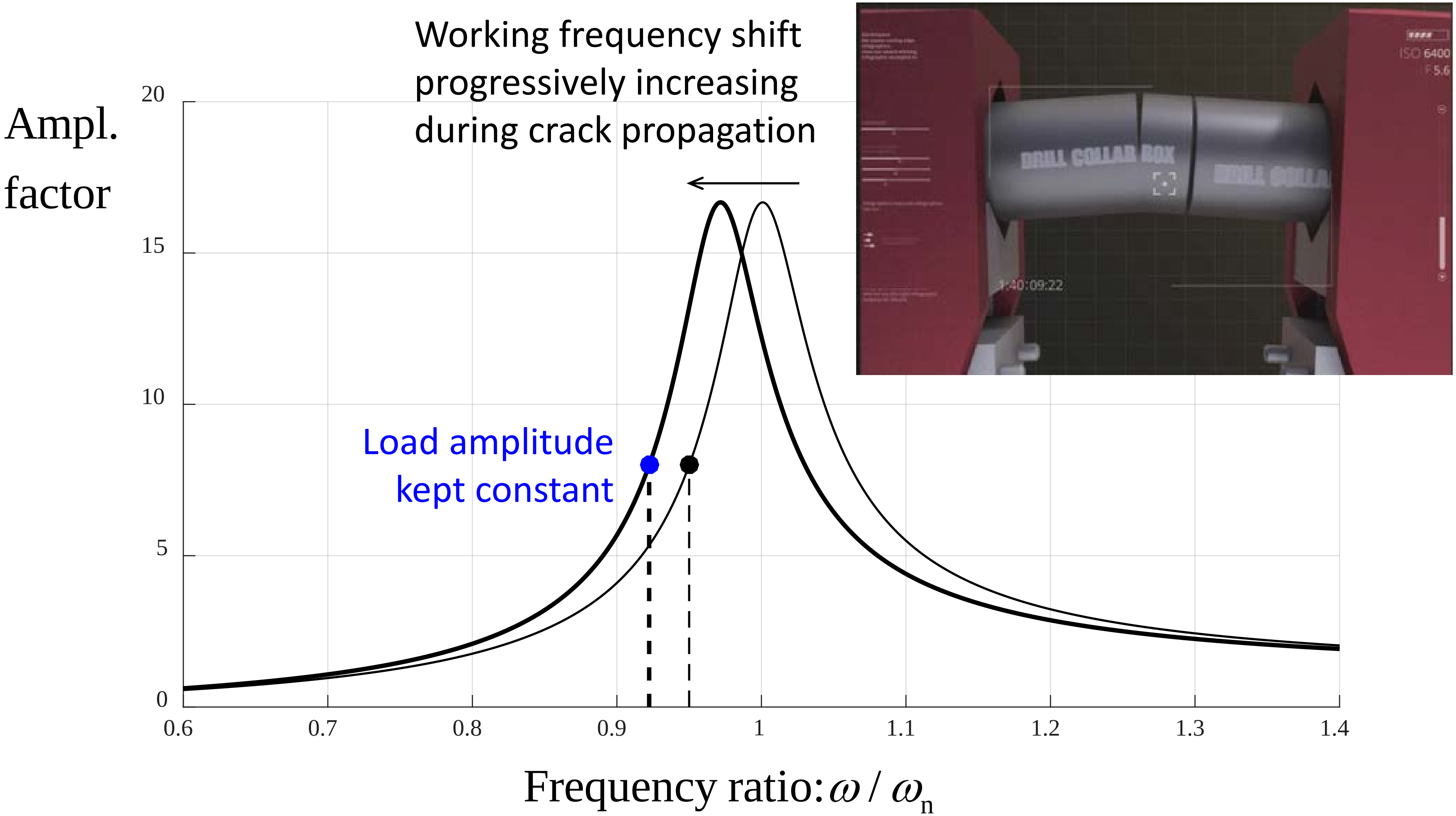
Resonance load control 1: mass phase shift



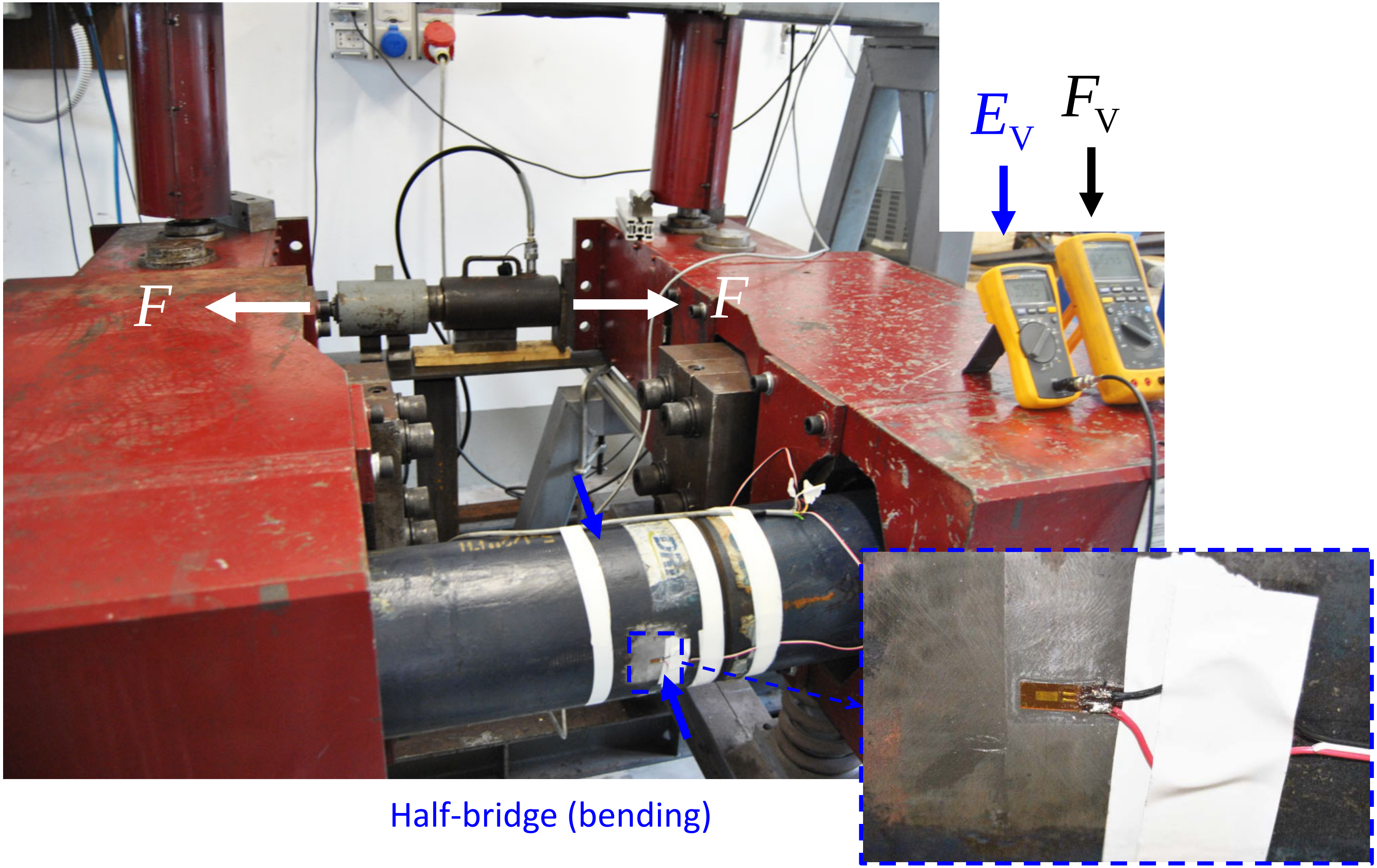
Resonance load control 2: working frequency control (inverter) - Ok



Resonance load control with frequency during crack propagation

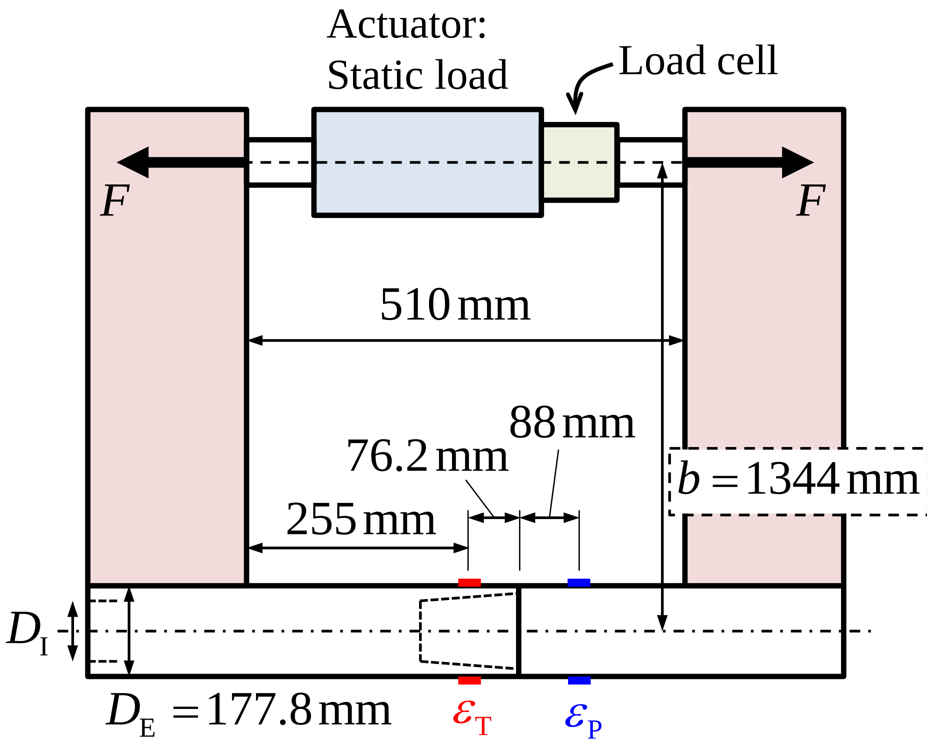


Load controlled with strain-gages – (Static) calibration recommended



Half-bridge (bending)

Strain-gage calibration



$$F = F_V \, K$$

$$W = \frac{\pi}{4} \frac{D_E^2 - D_I^2}{D_E}$$

$$\sigma = \frac{F\,b}{W}$$

$$\varepsilon = \frac{\sigma}{E}$$

1st step

Verification:

$$\varepsilon_{T(P)} = \frac{4}{n_B} \frac{E_{V,T(P)}}{V_B \, G \, k_{SG}}$$

>10% difference Tread (T)

<5% difference Pin (P)

2nd step

Calibration:

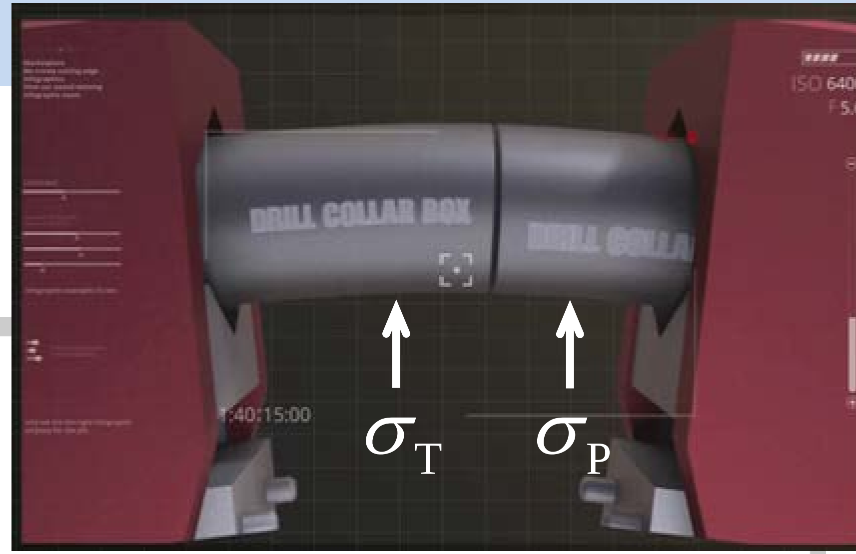
Stress to voltage ratio

$$C_{T(P)} = \frac{\sigma}{E_{V,T(P)}}$$

Monitoring during test running

Initial strain gage signal (no crack)

Control panel



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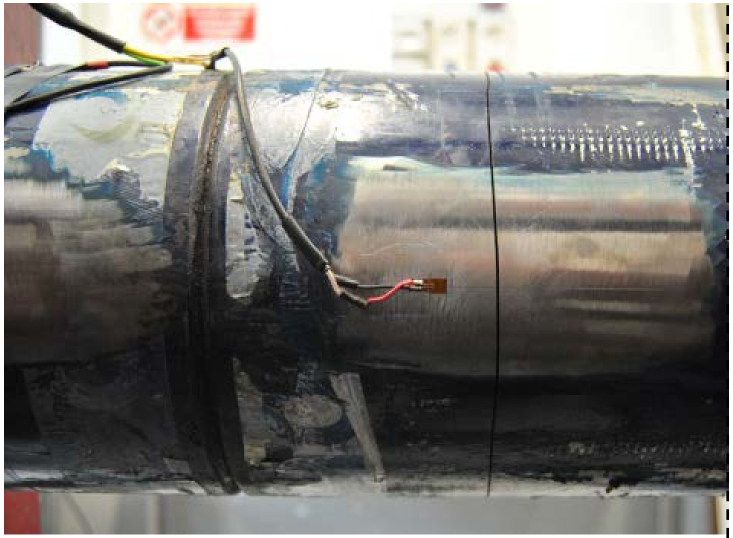
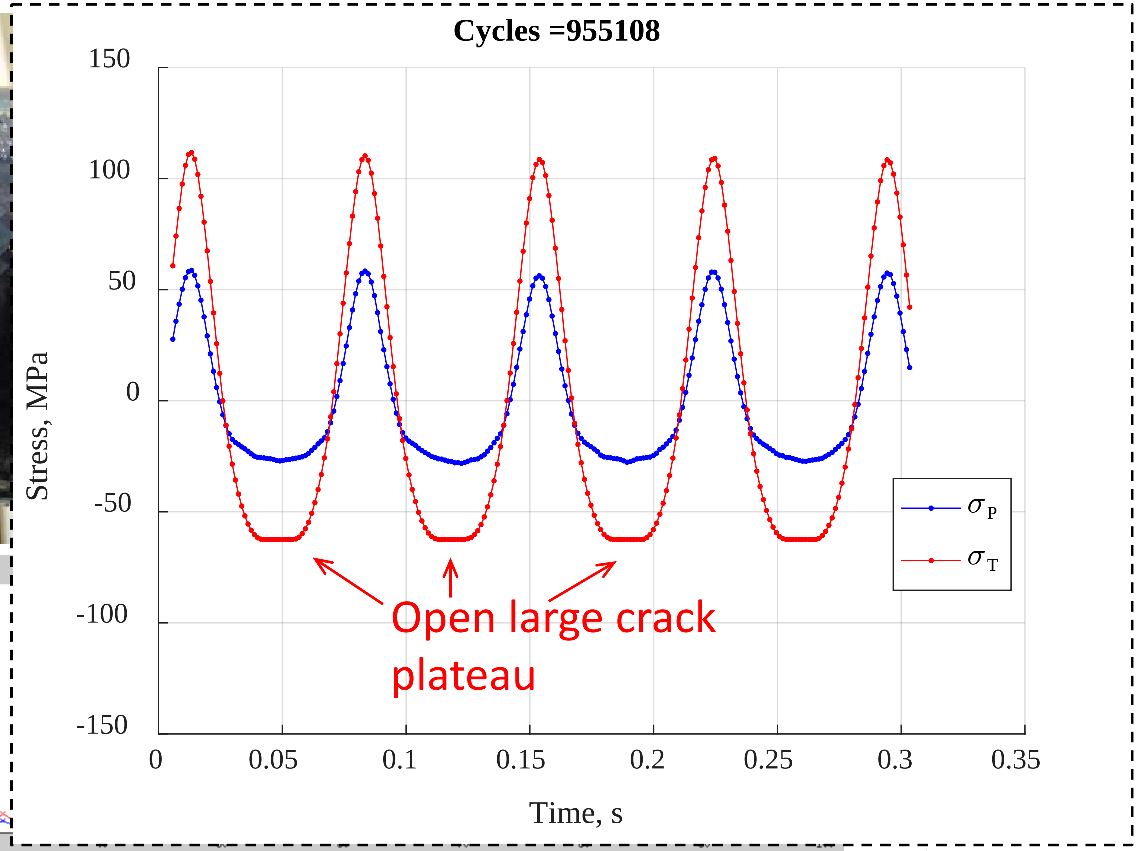
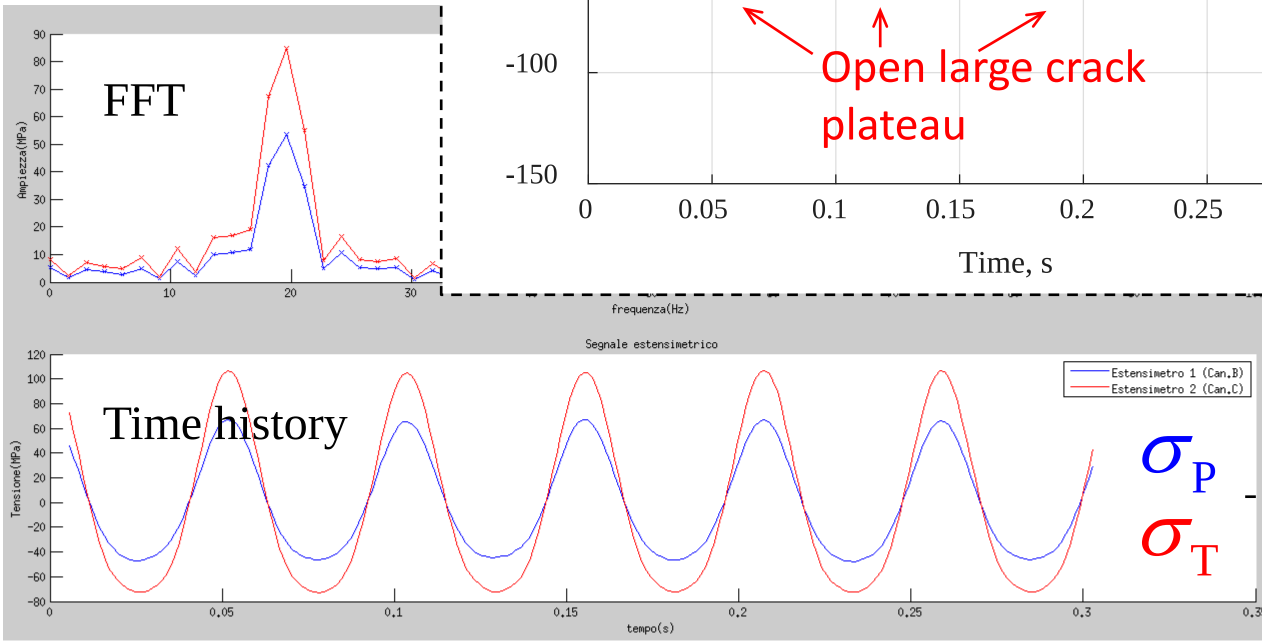






σ_P

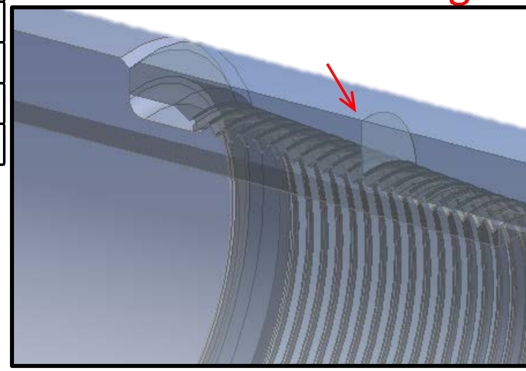
σ_T

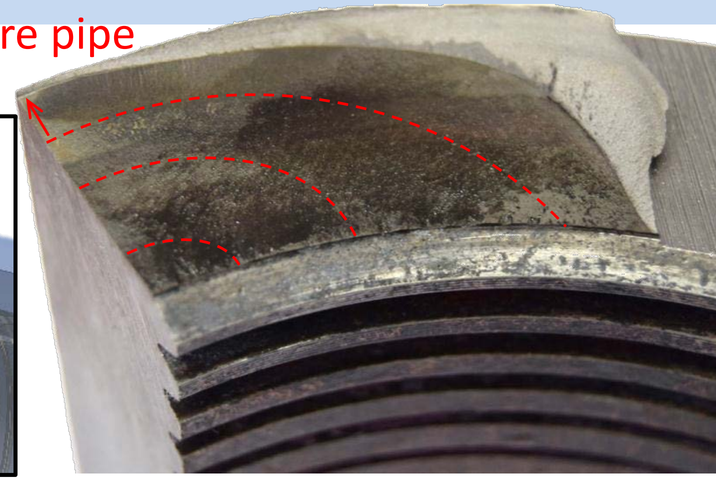
Crack initiation/ failure

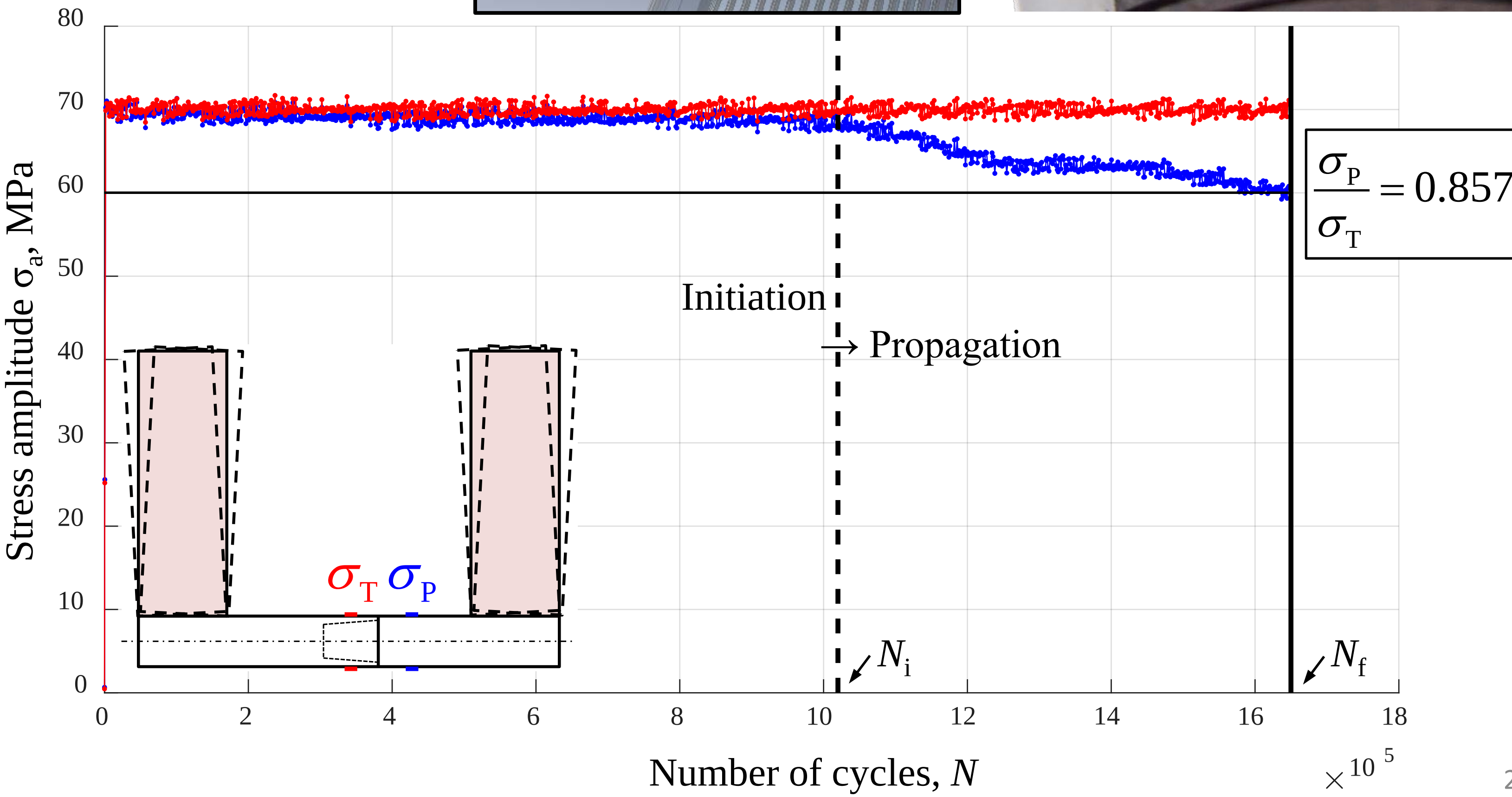
Maximum crack size before pipe leakage

	N_n	N_f	sigma_a, MPa
1	7.80E+05	1.09E+06	90
2	3.10E+05	4.90E+05	90
3	4.50E+05	6.40E+05	90
➔ 4	1.02E+06	1.65E+06	70

Test interruption after previous test experience







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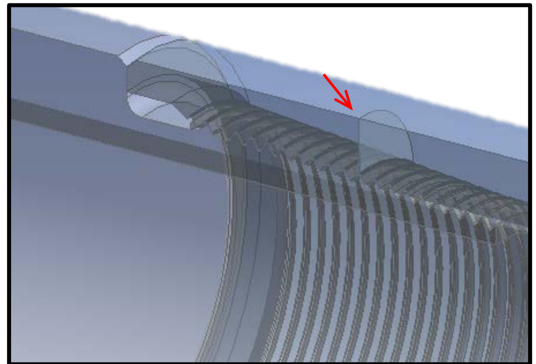
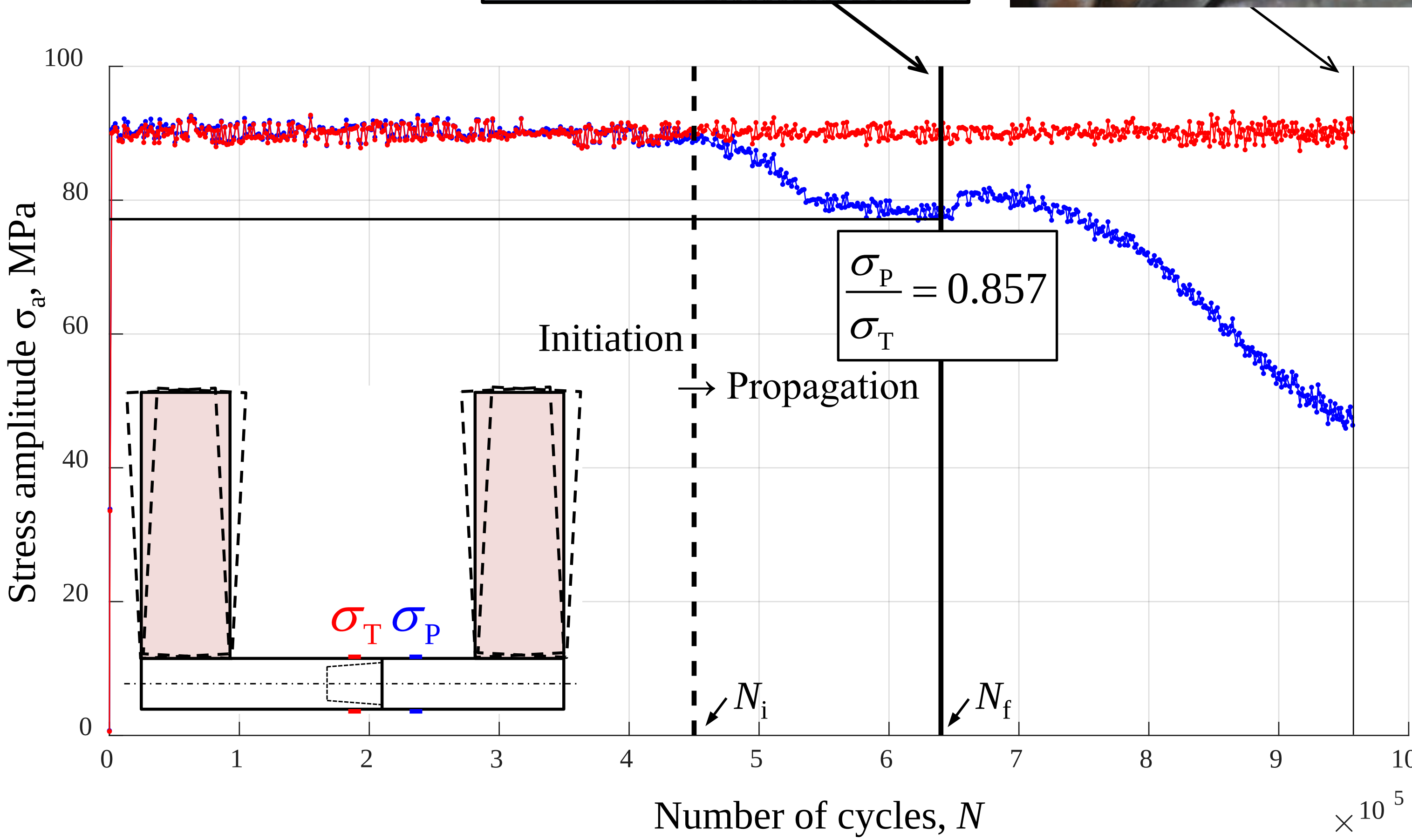
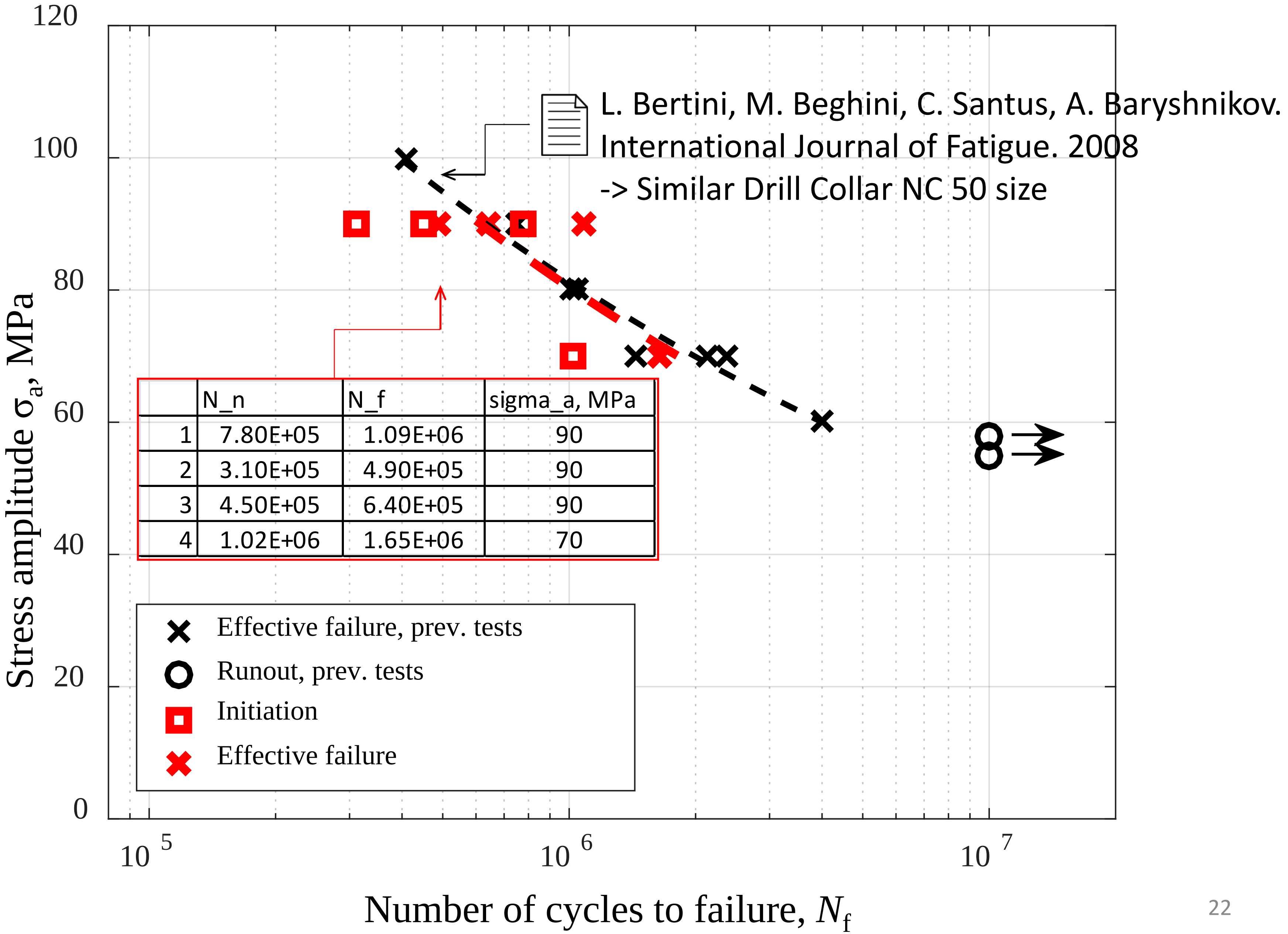




Test results *S-N* plot, comparison with similar DC data



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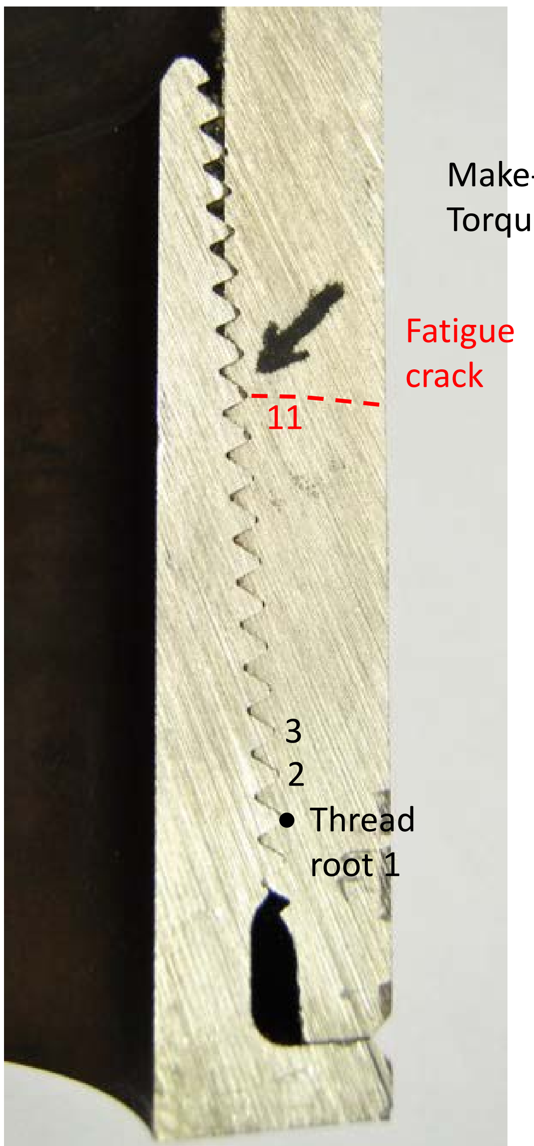
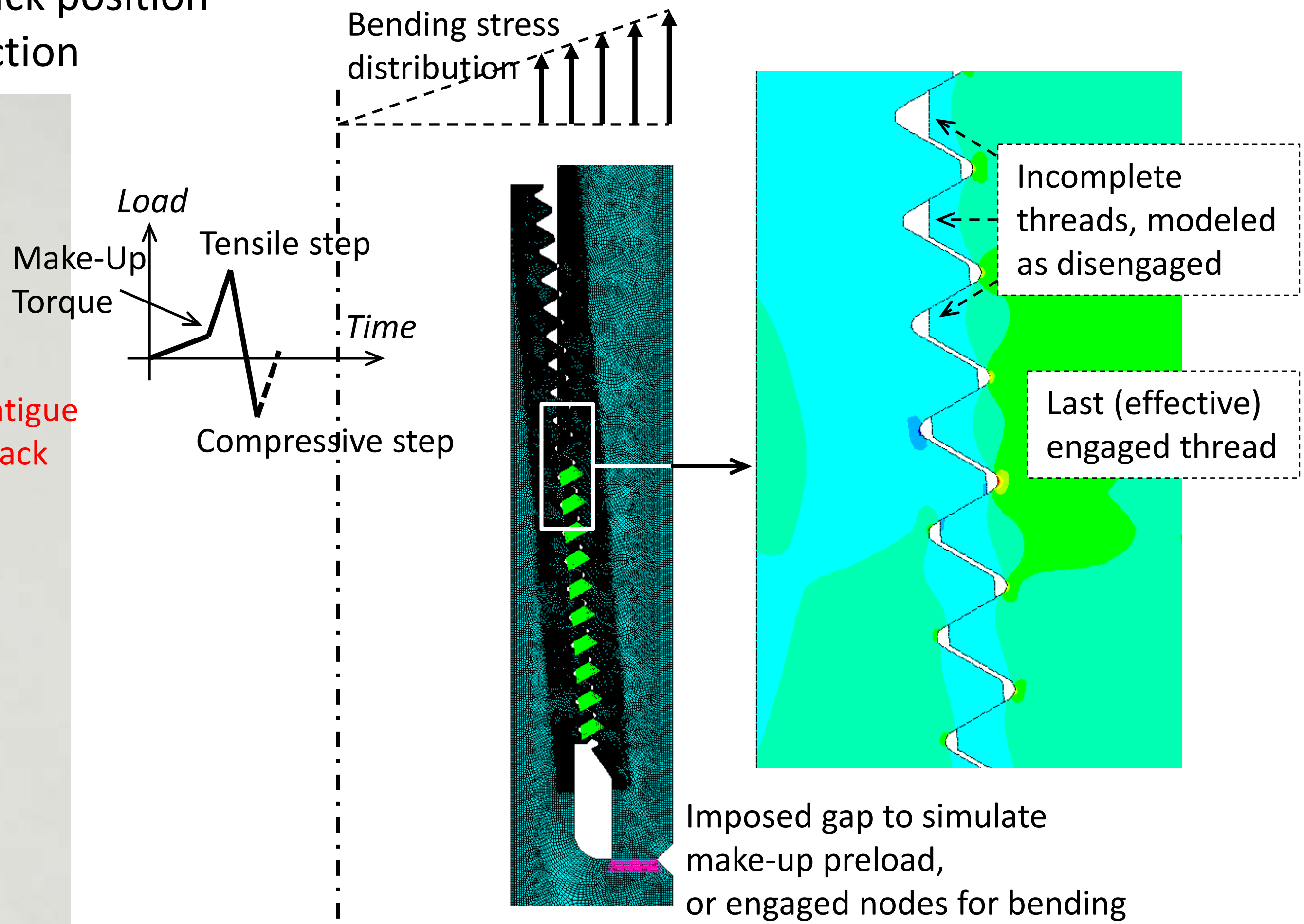
FE analysis for prediction of the crack thread root position

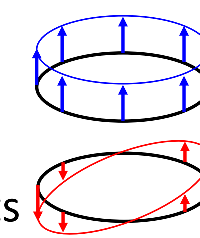
Evidence of fatigue crack position
Test 4, longitudinal section



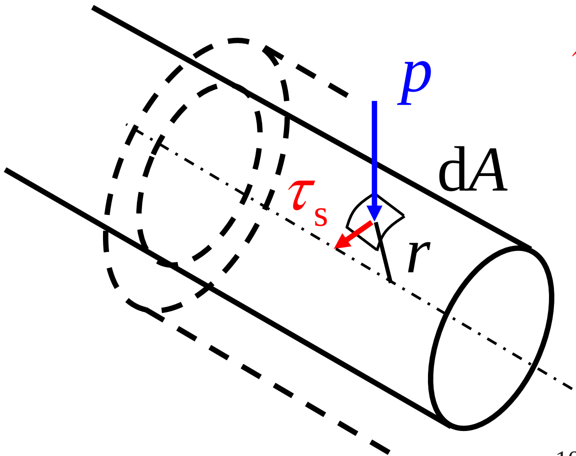


Time 1 Preload (Make-Up): Plane25,
Harmonic 0 – Axisymmetric model

Time 2,3 Bending load superimposed: Plane,
Harmonic 1, different closed contacts

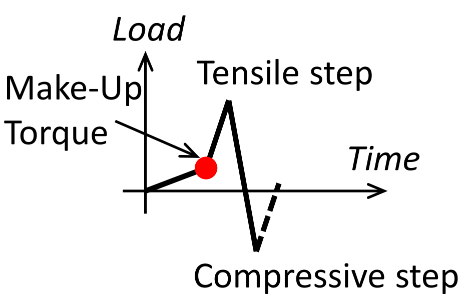


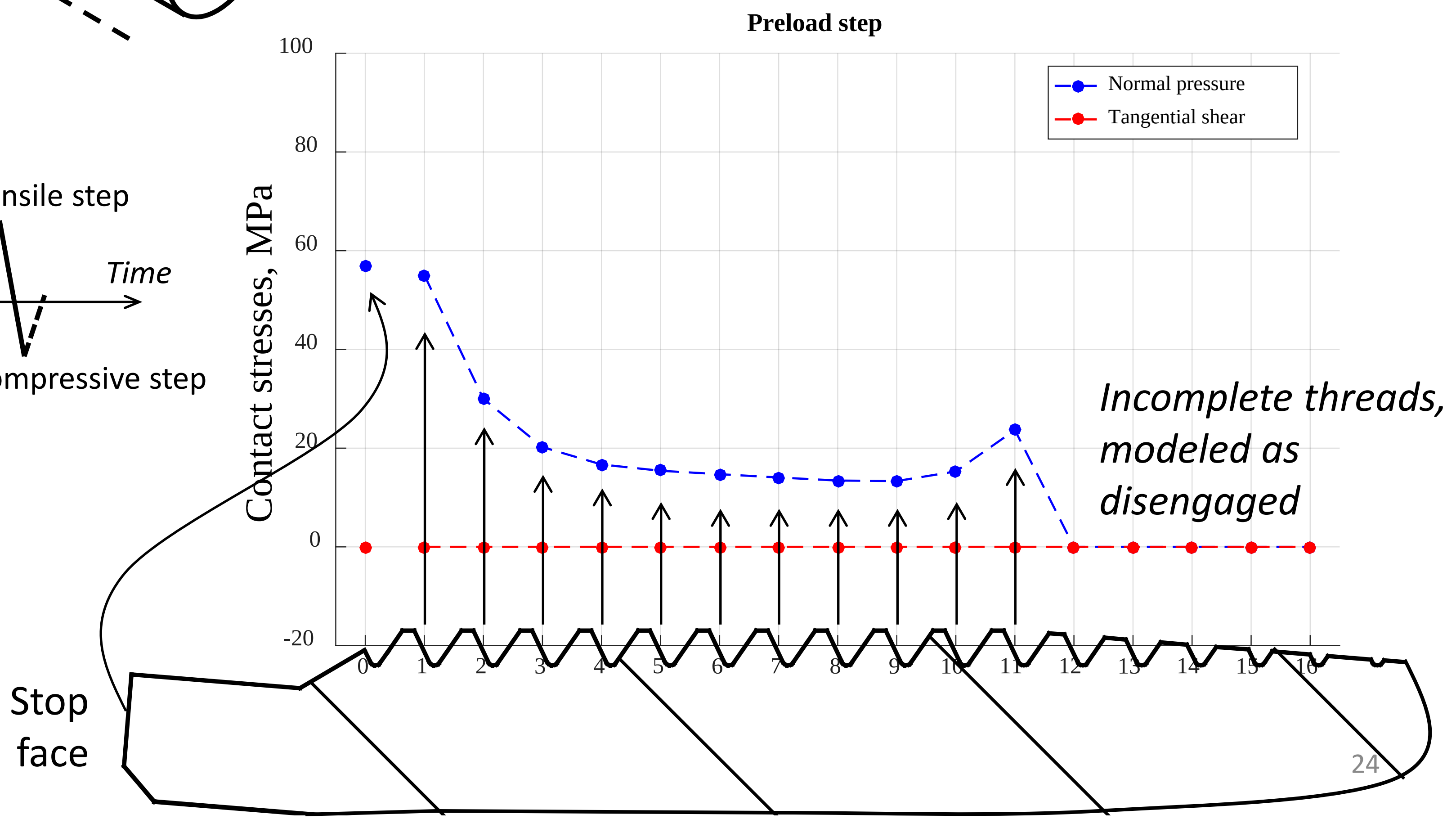
FE analysis for prediction of the crack thread root position



$$\tau_s = f\ p \rightarrow \text{Make-Up torque / stop face interference}$$

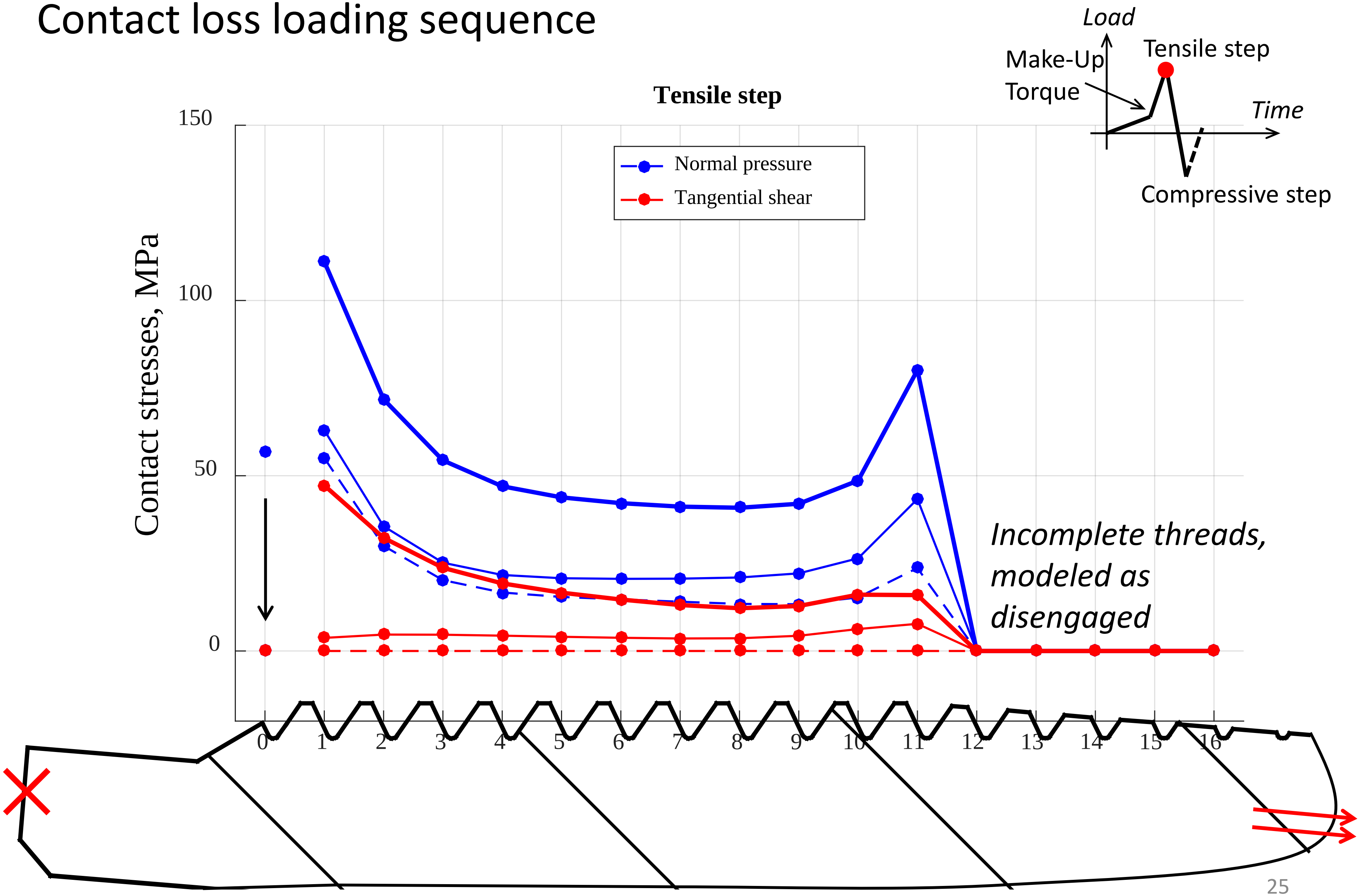
C. Santus, L. Bertini, M. Beghini, A. Merlo, A. Baryshnikov. International Journal of Pressure Vessels and Piping. 2009





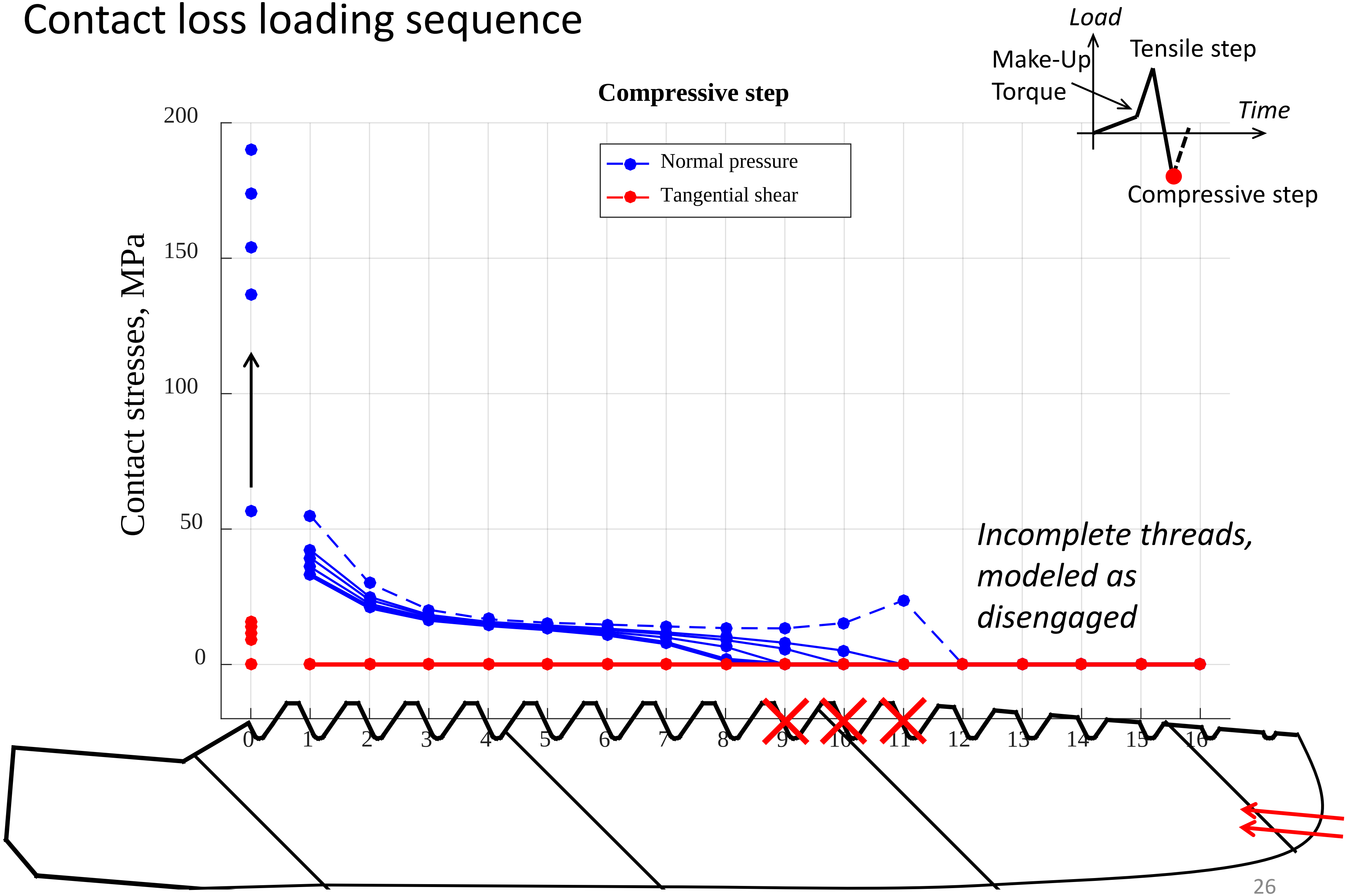
FE analysis for prediction of the crack thread root position

Contact loss loading sequence



FE analysis for prediction of the crack thread root position

Contact loss loading sequence



FE analysis for prediction of the crack thread root position

Goodman prediction of thread root fatigue crack position

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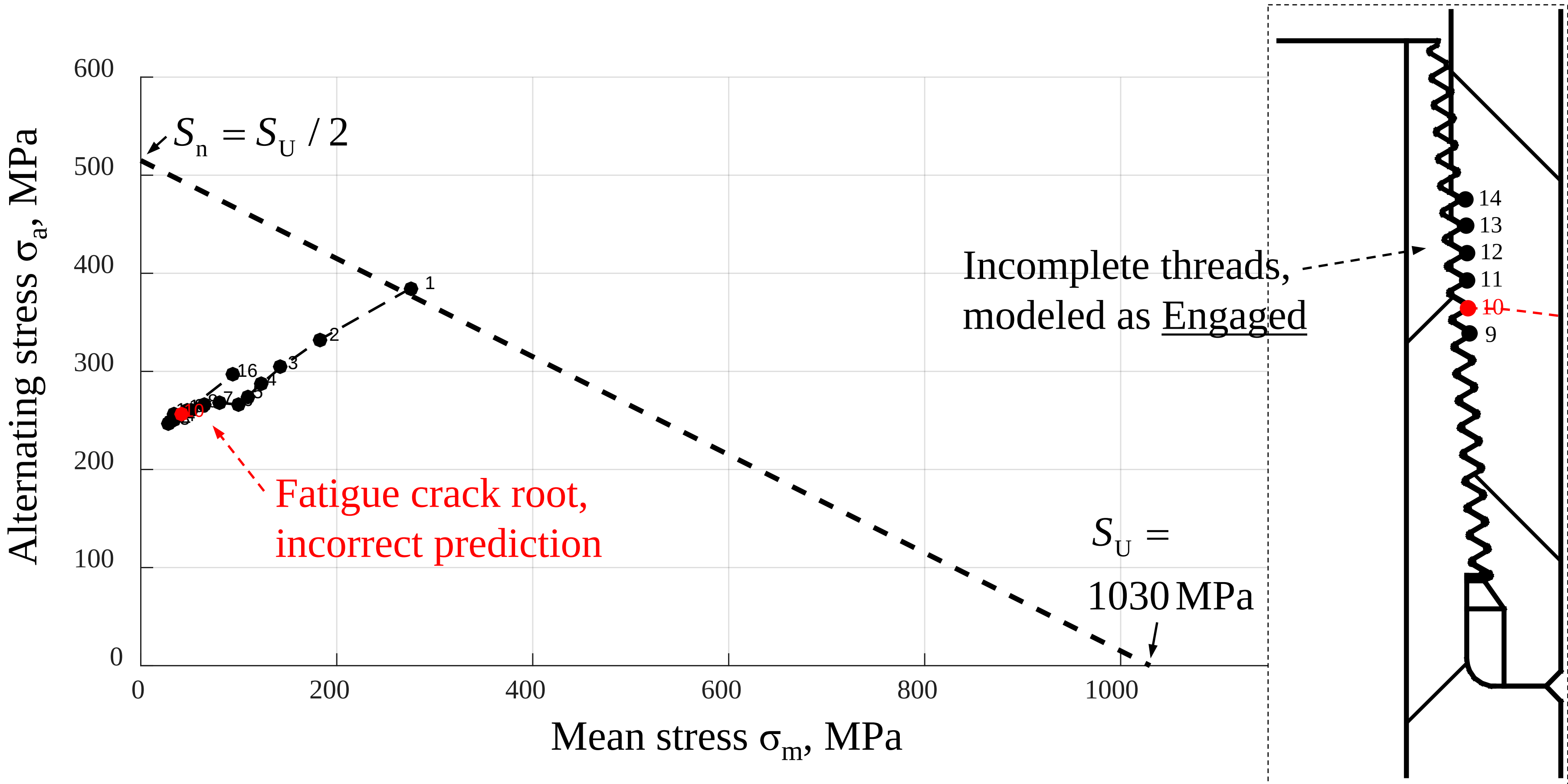

FE analysis for prediction of the crack thread root position

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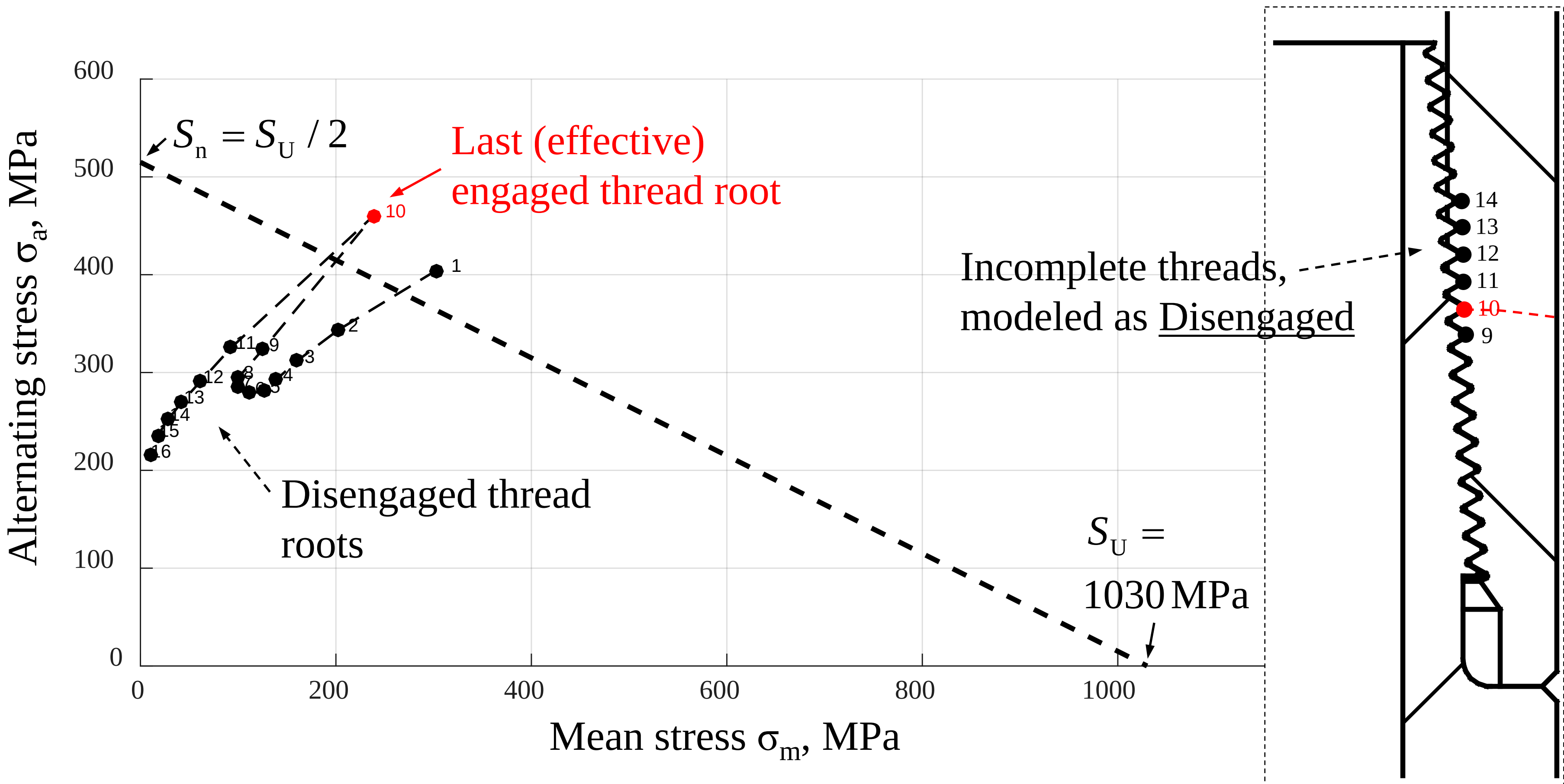

Final remarks

Conclusions

Resonant bench used for Drill Collars 5-1/2 FHMOD connection

Very similar strength as previous Drill Collar NC 50 connection

Incomplete threads need to be disengaged in FE simulation for correct fatigue crack thread root

Future work (UniPi – JAMSTEC)

Similar Drill Collar connection (different manufacturer) with improved strength

Several tests on Drill Pipes with the *Rotating* resonant test rig