



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

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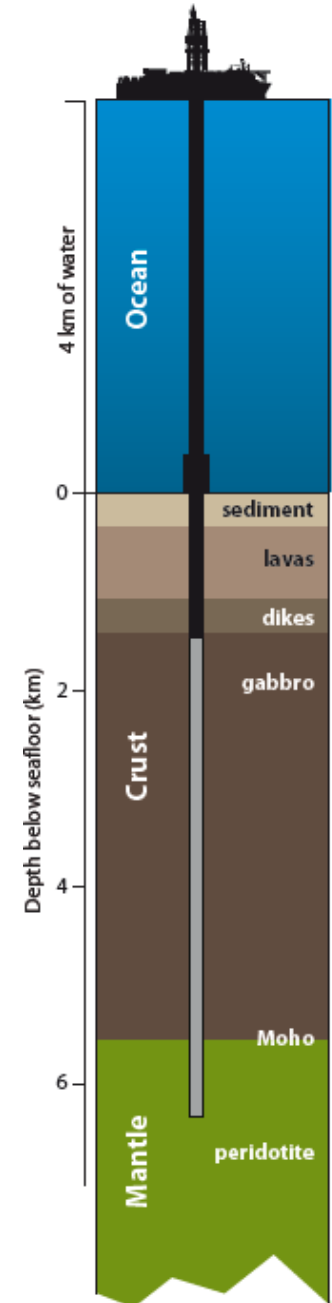
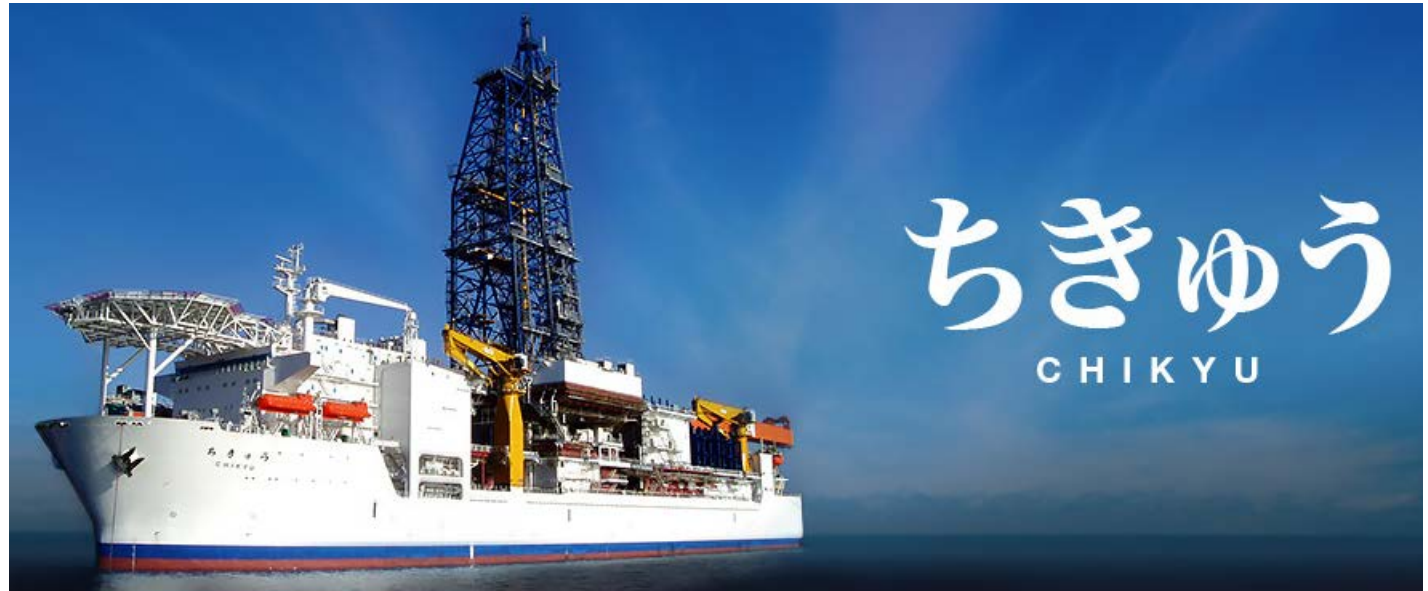


(a) University of Pisa, DICl Department

(b) ACTA Srl

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

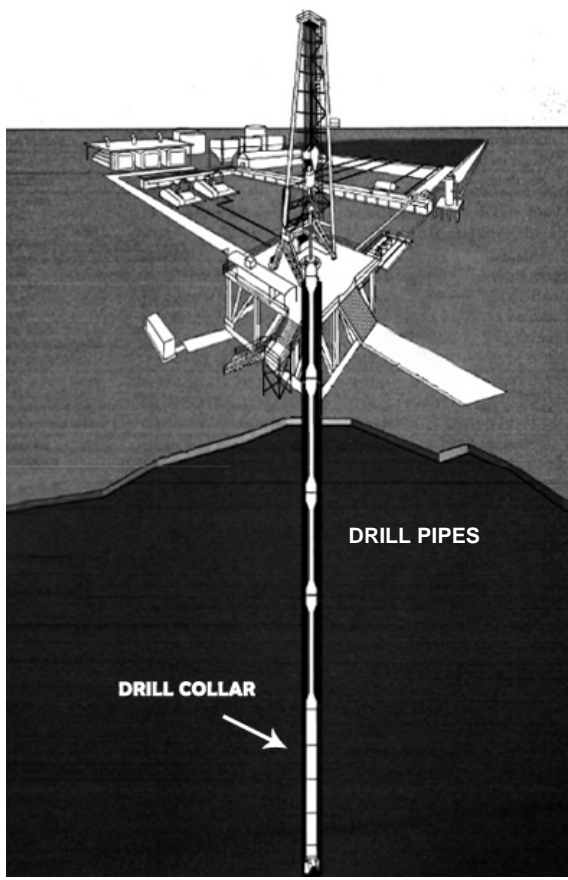
CHIKYU Vessel (Chikyu -> "pianeta Terra")



Deep Sea Scientific Drilling:

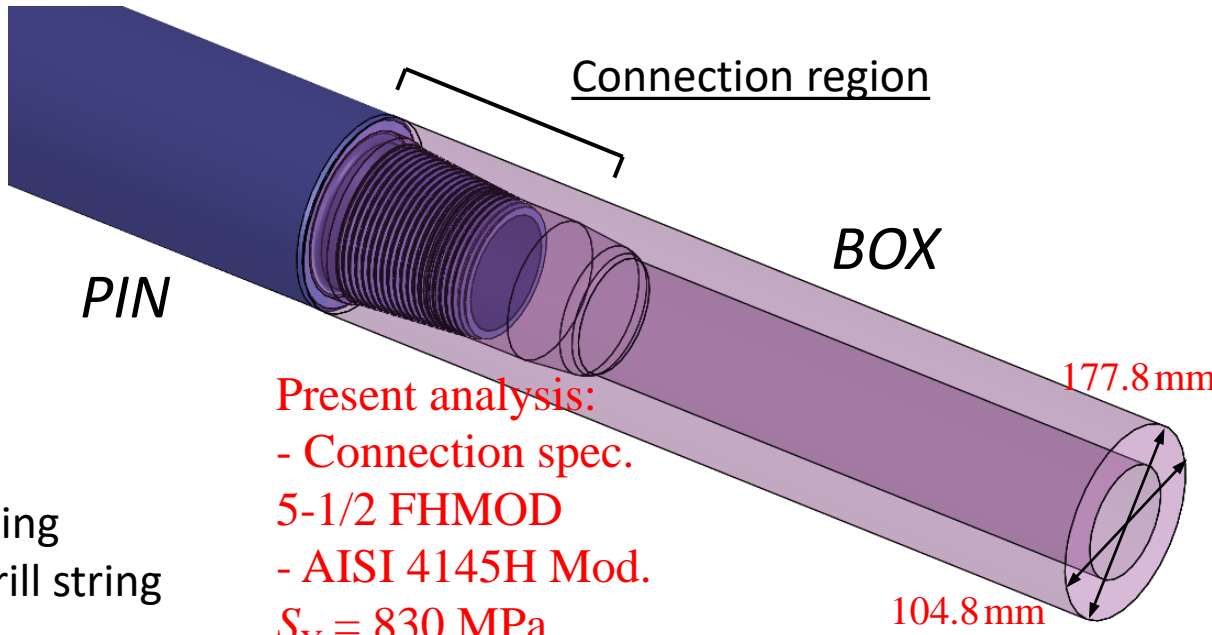
- Climate and Ocean Change
- Biosphere Frontiers
- Earth Connections
- Earth in Motion (*earthquakes and tsunamis*)
- Education and Outreach

Intro: Drill Collar connection to be tested



Drill Collars:

- Large thickness pipe sections
- Uniform section from end-to-end

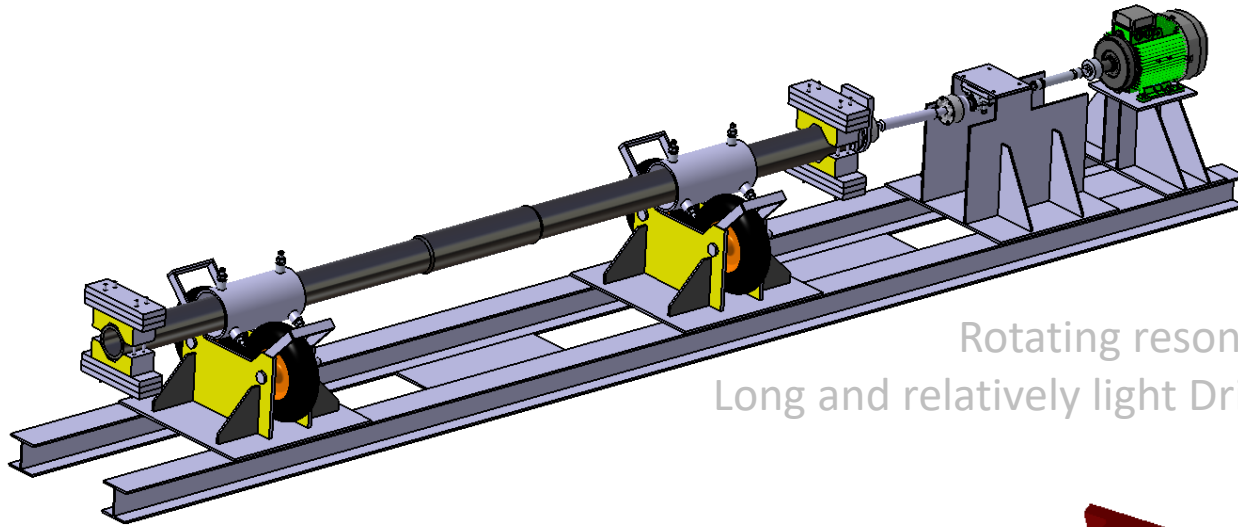


Present analysis:

- Connection spec. 5-1/2 FHMOD
- AISI 4145H Mod.
- $S_Y = 830 \text{ MPa}$
- $S_U = 1030 \text{ MPa}$

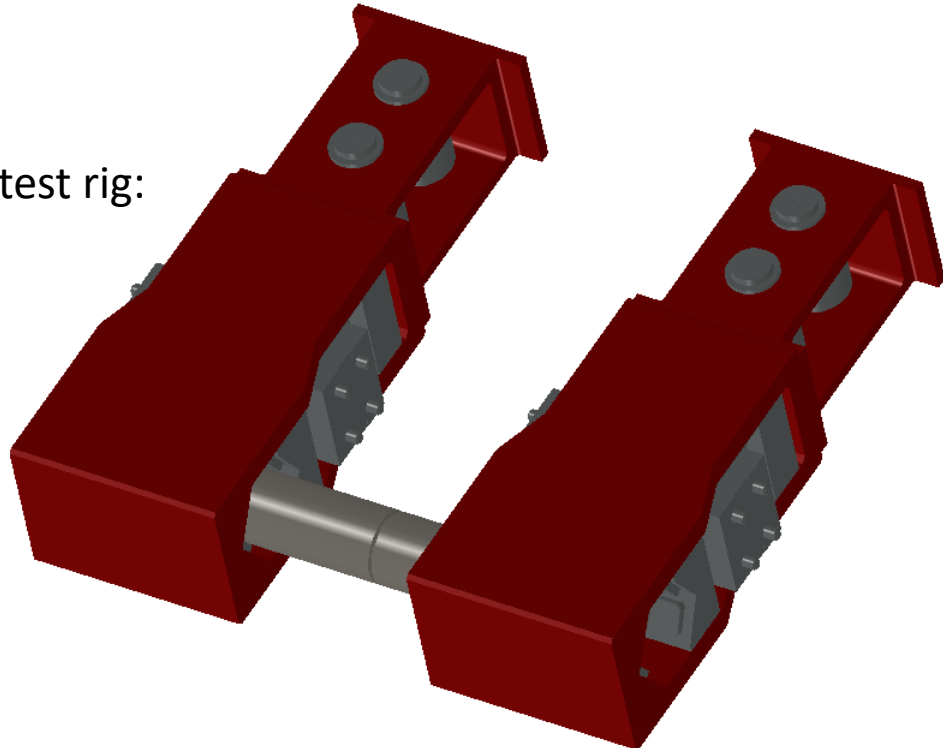
Drill Pipes at Top of the drill string
Drill Collars at Bottom of the drill string

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



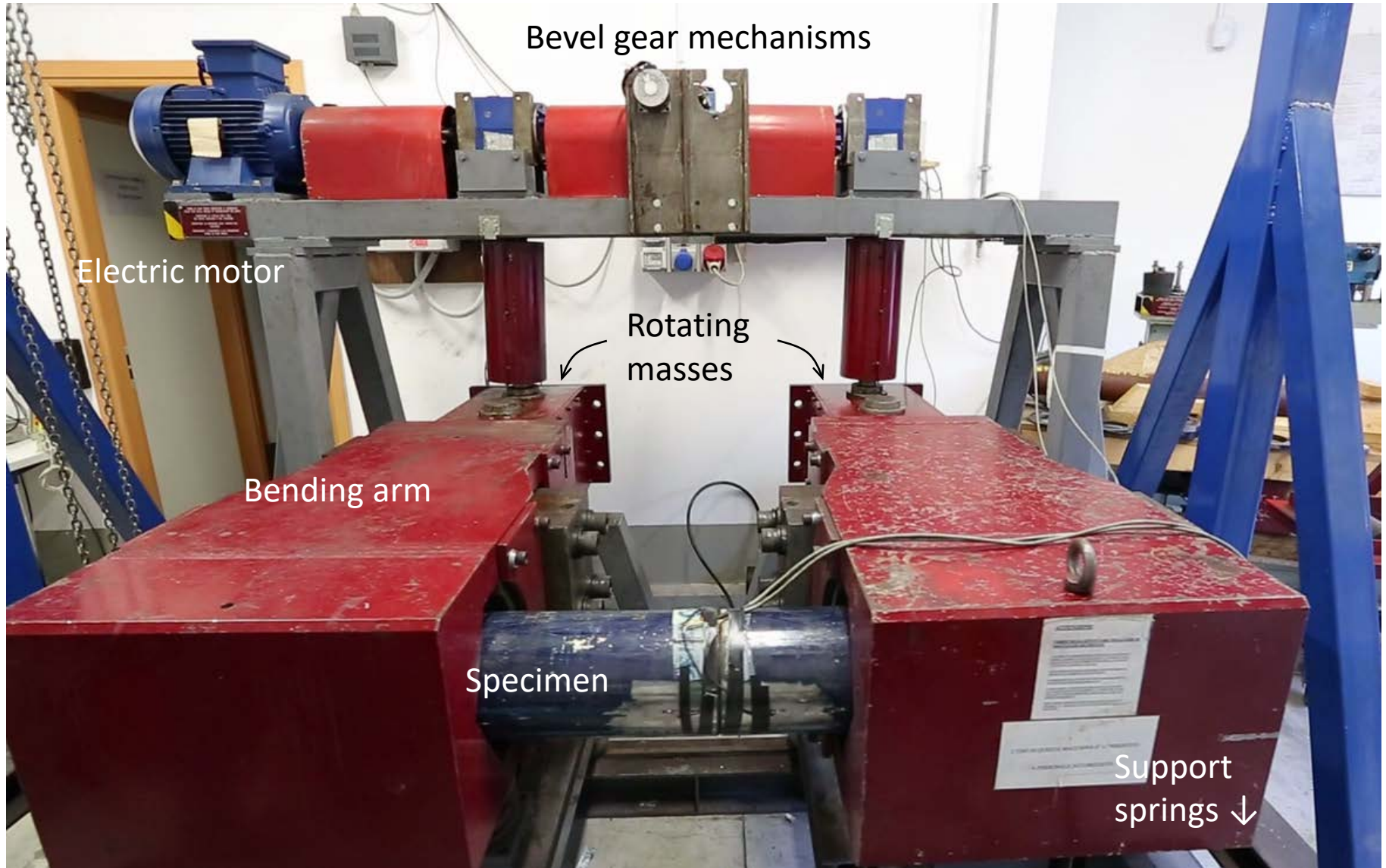
Rotating resonant fatigue test rig:
Long and relatively light Drill Pipe connections

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

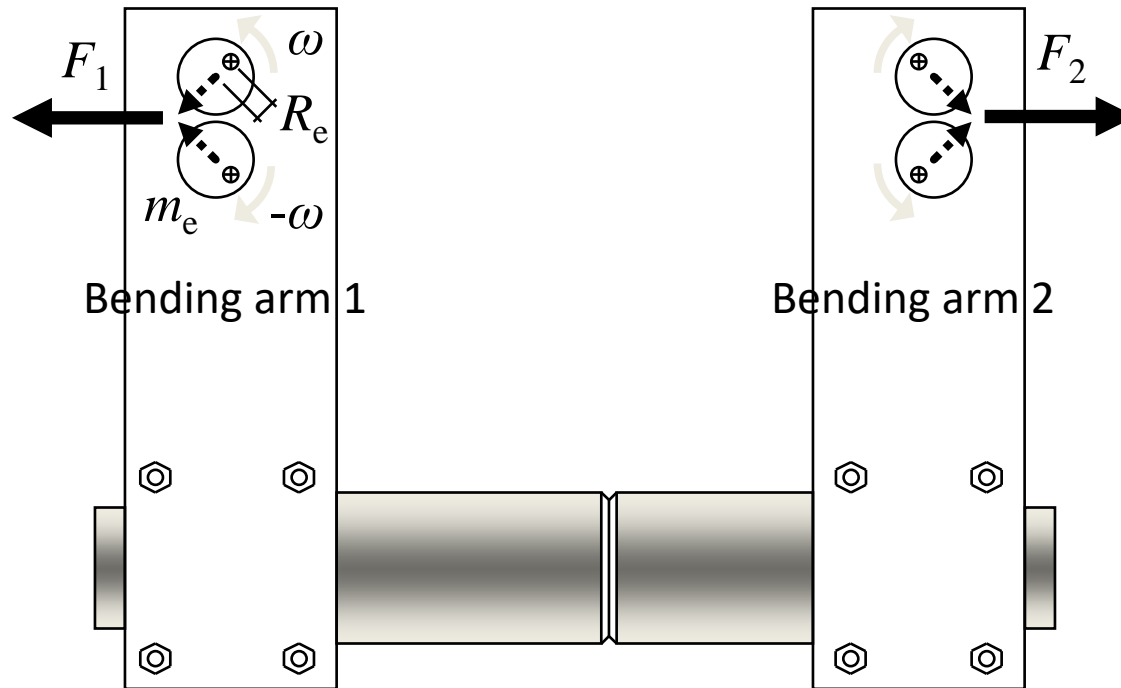


In-plane resonant fatigue test rig

Hardware of the bench



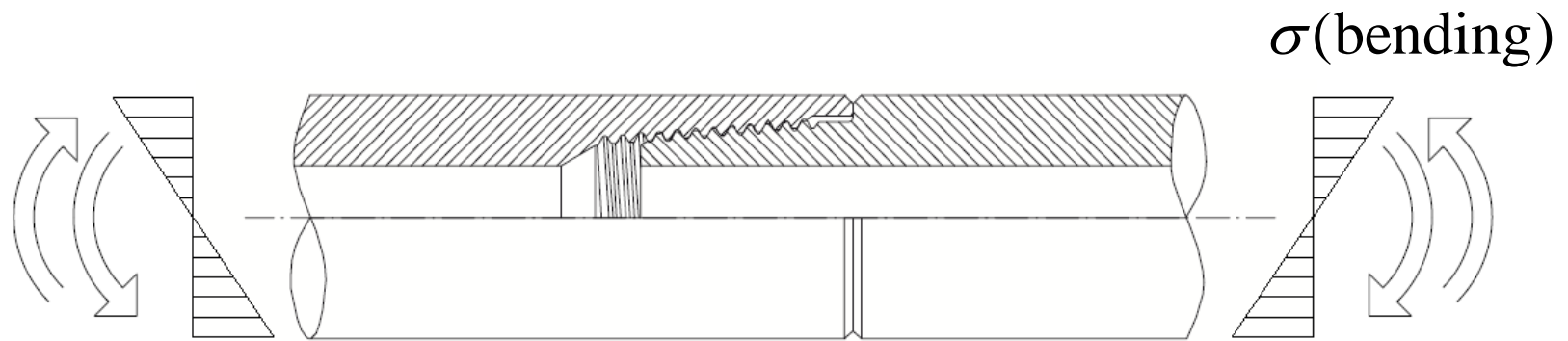
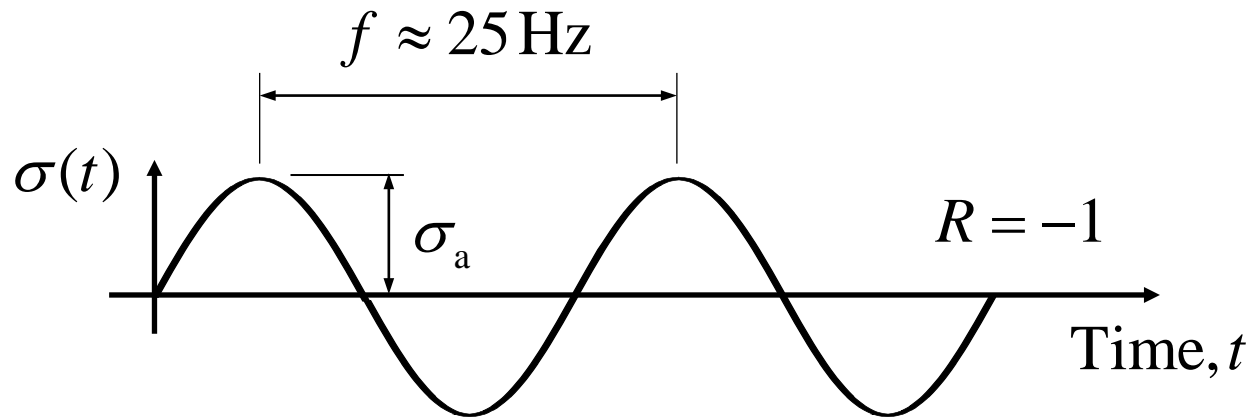
How it works



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

How it works

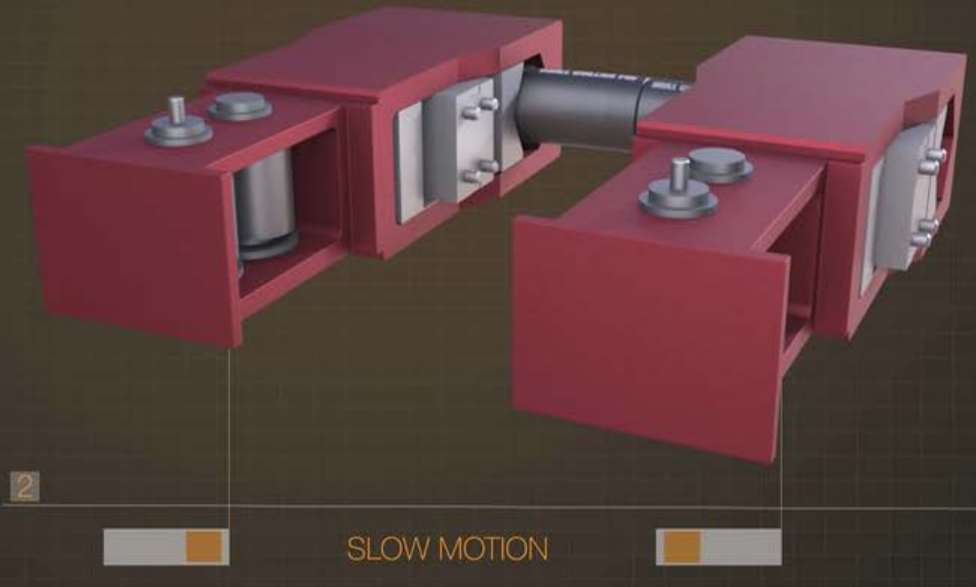
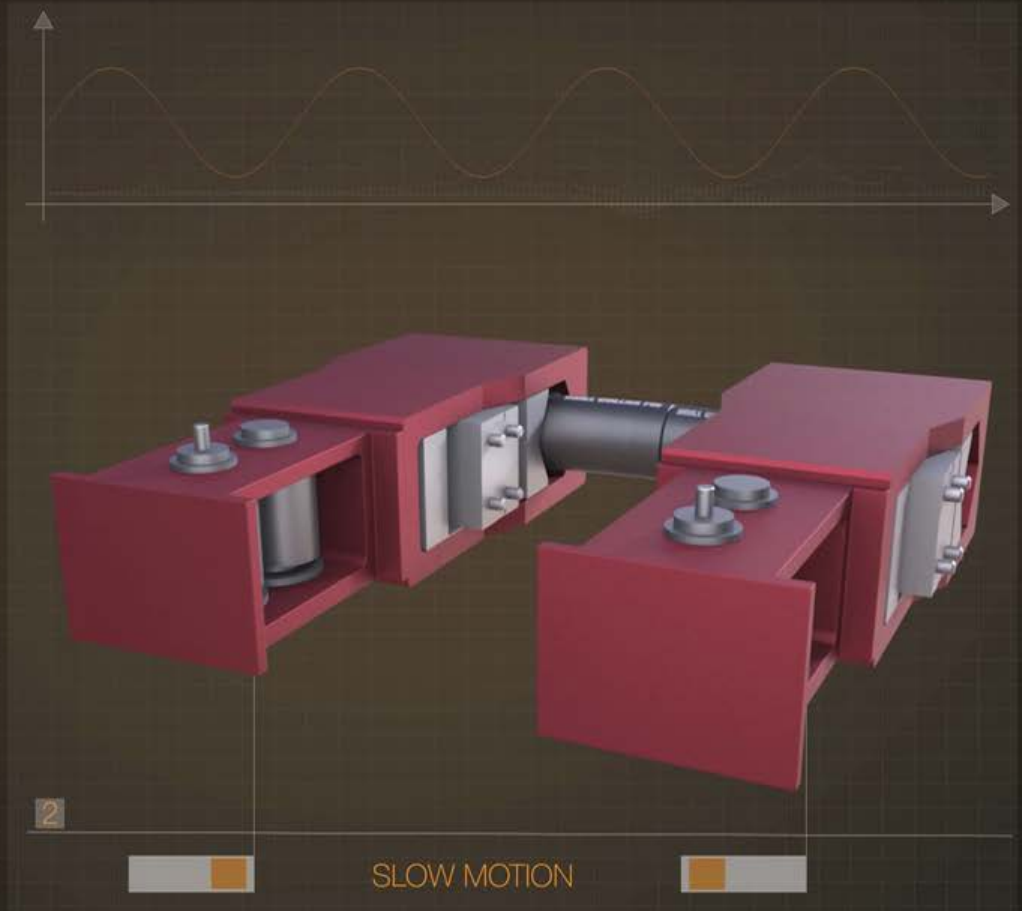


L. Bertini, M. Beghini, C. Santus, A. Baryshnikov, Resonant test rigs for fatigue full scale testing of oil drill string connections. International Journal of Fatigue. Vol. 30 (6), pp. 978-988, 2008

How it works

Bending load control 2

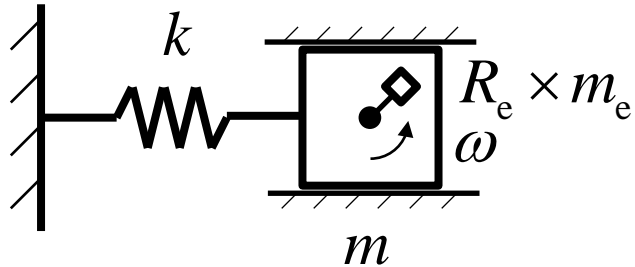
While it is maximum when the two couples of rotating masses are OUT-phase.



In-plane resonant fatigue test rig

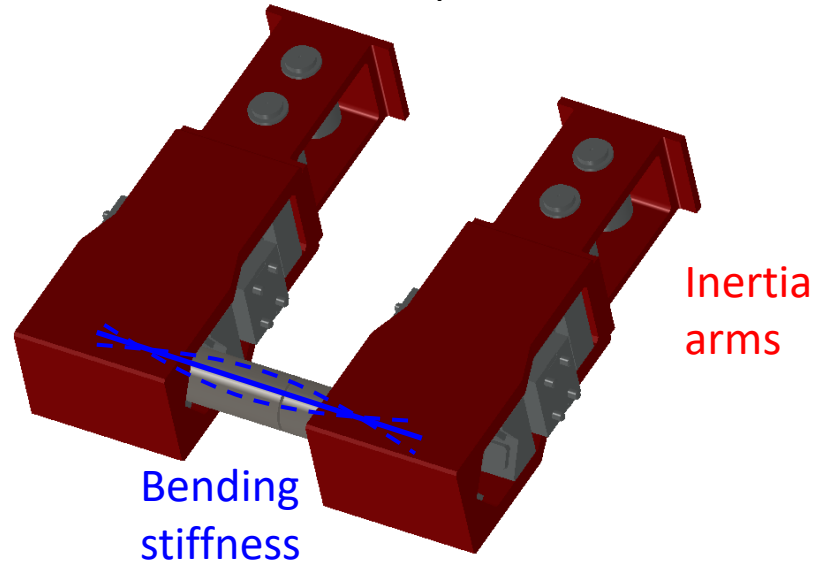
Resonance modeling

1 DOF dynamic model

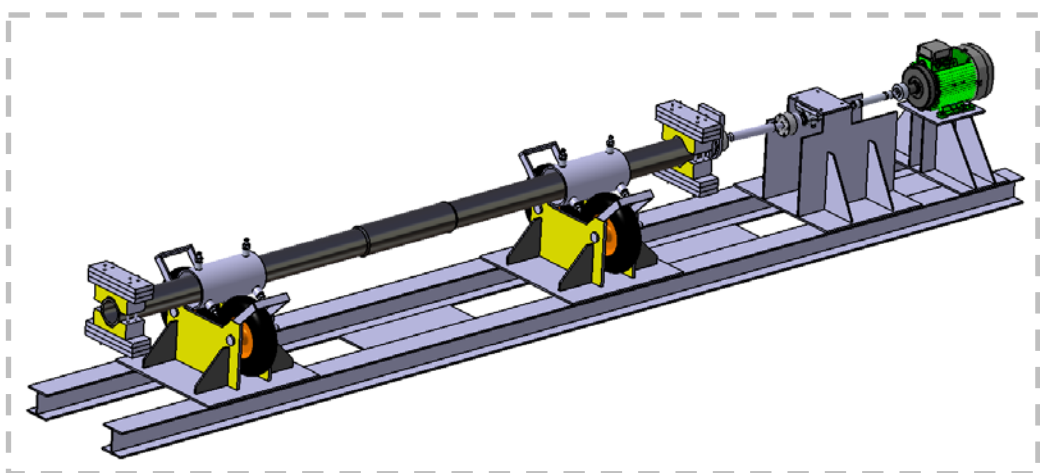
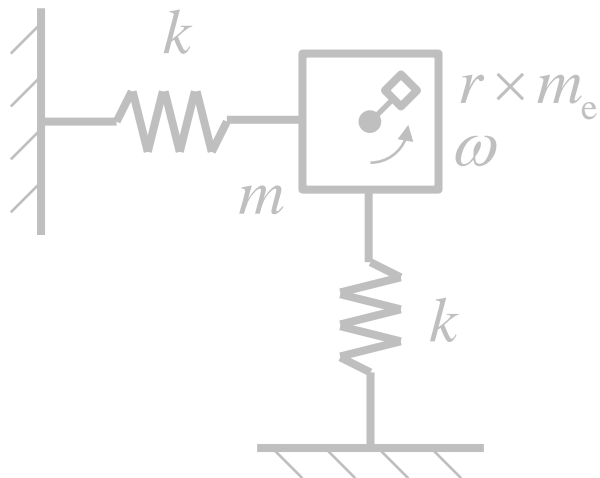


$$\omega_n = \sqrt{\frac{k}{m}}, \text{ Resonance: } \omega \rightarrow \omega_n$$

In-plane resonant bench

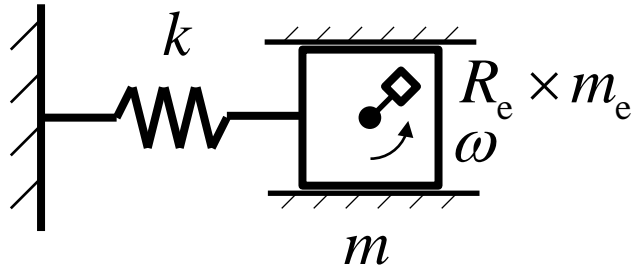


Rotating resonant bench



Resonance modeling

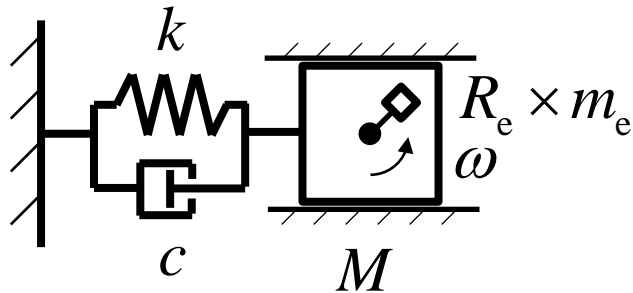
Basic dynamic model, no dumping



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

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

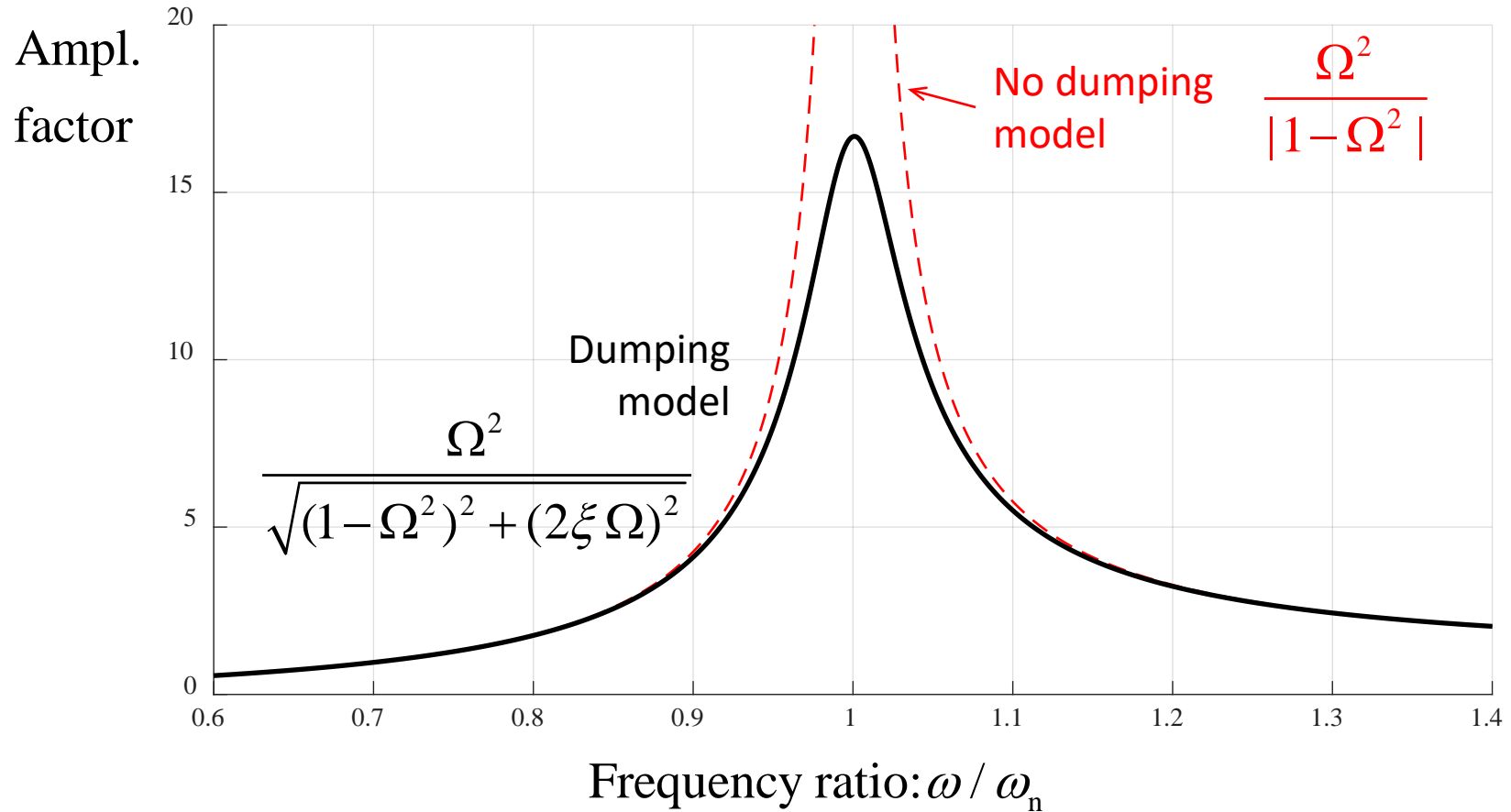
Dynamic model with dumping



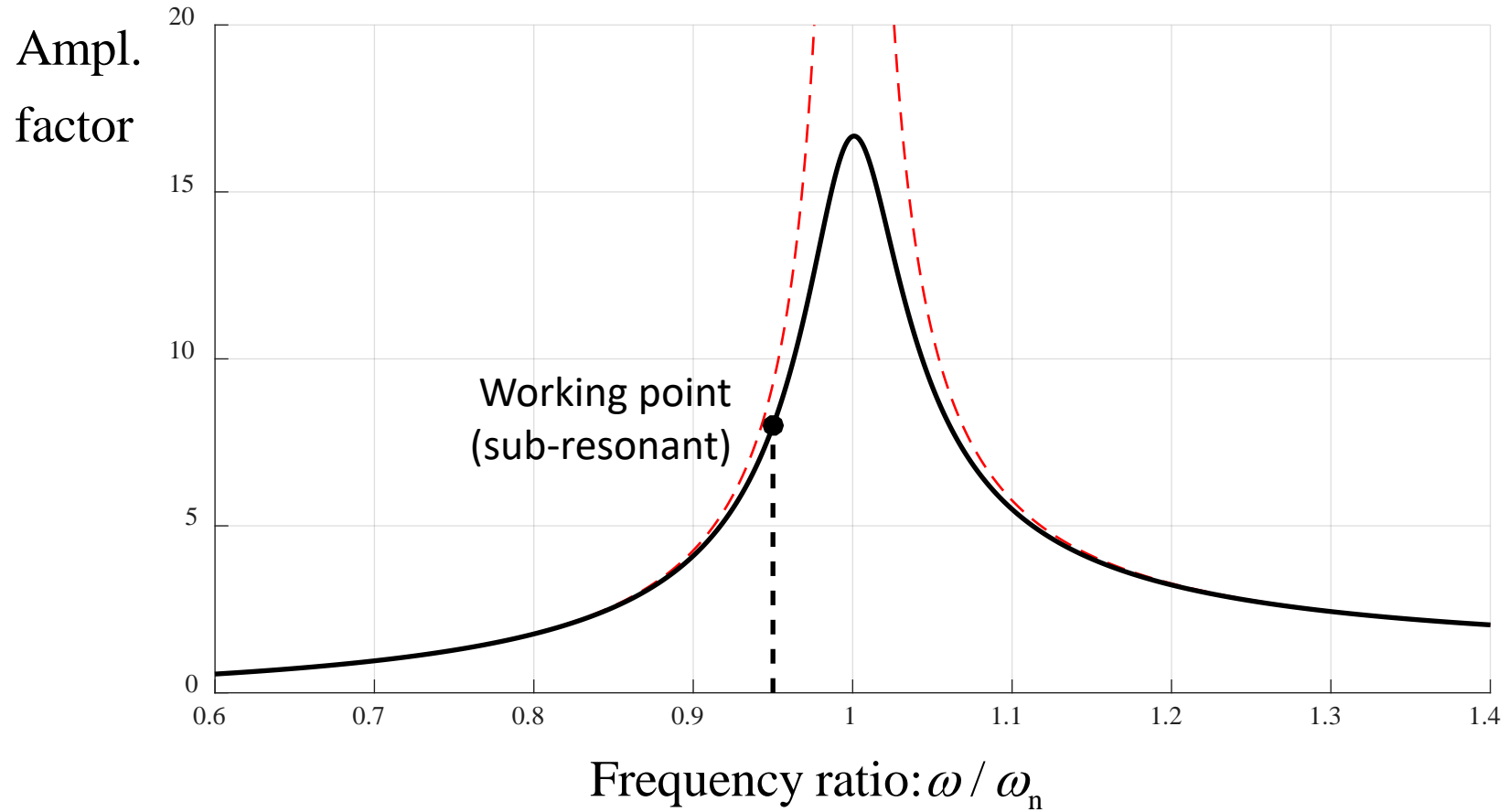
$$\xi = \frac{c}{2\sqrt{k m}}$$

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

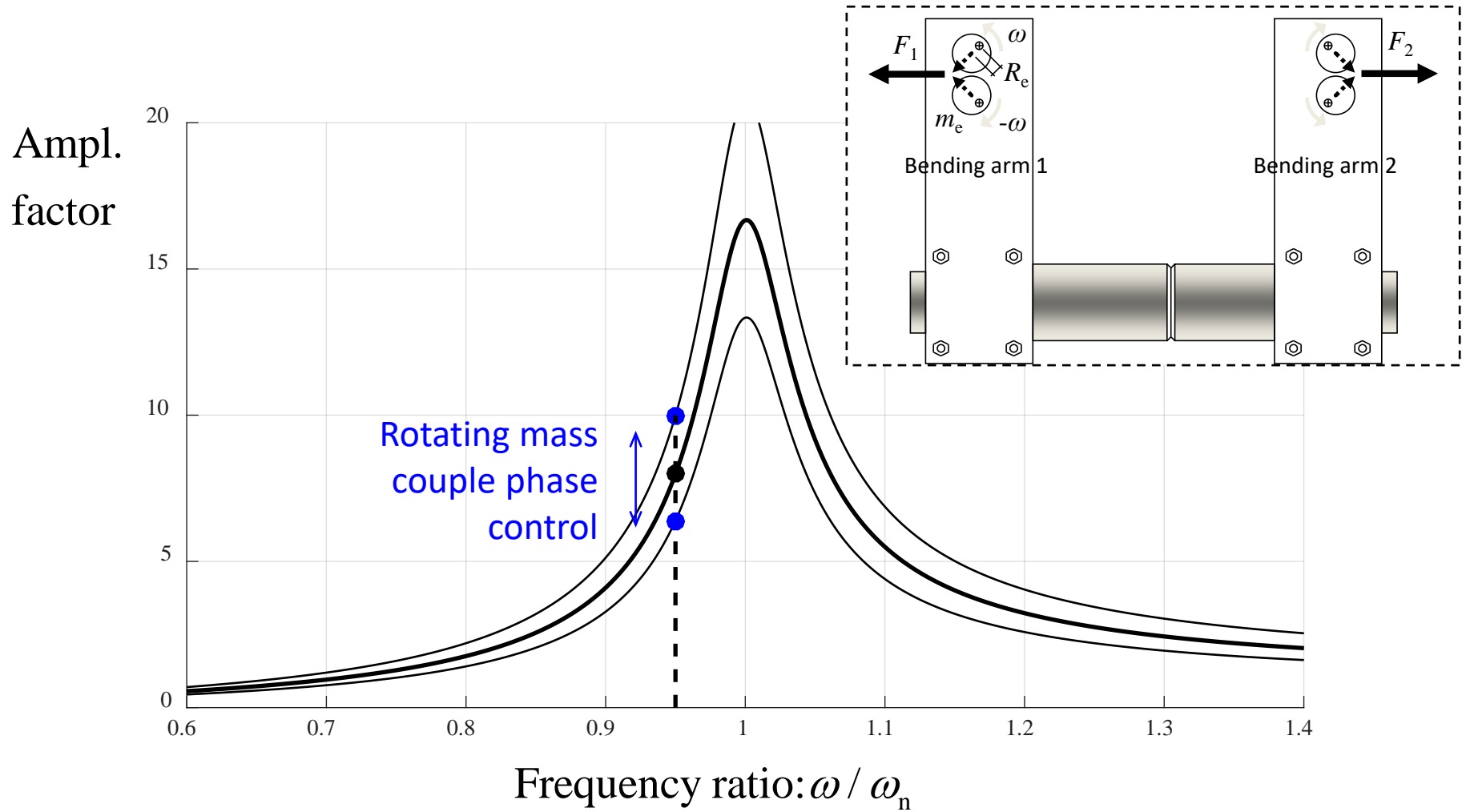
Resonance modeling



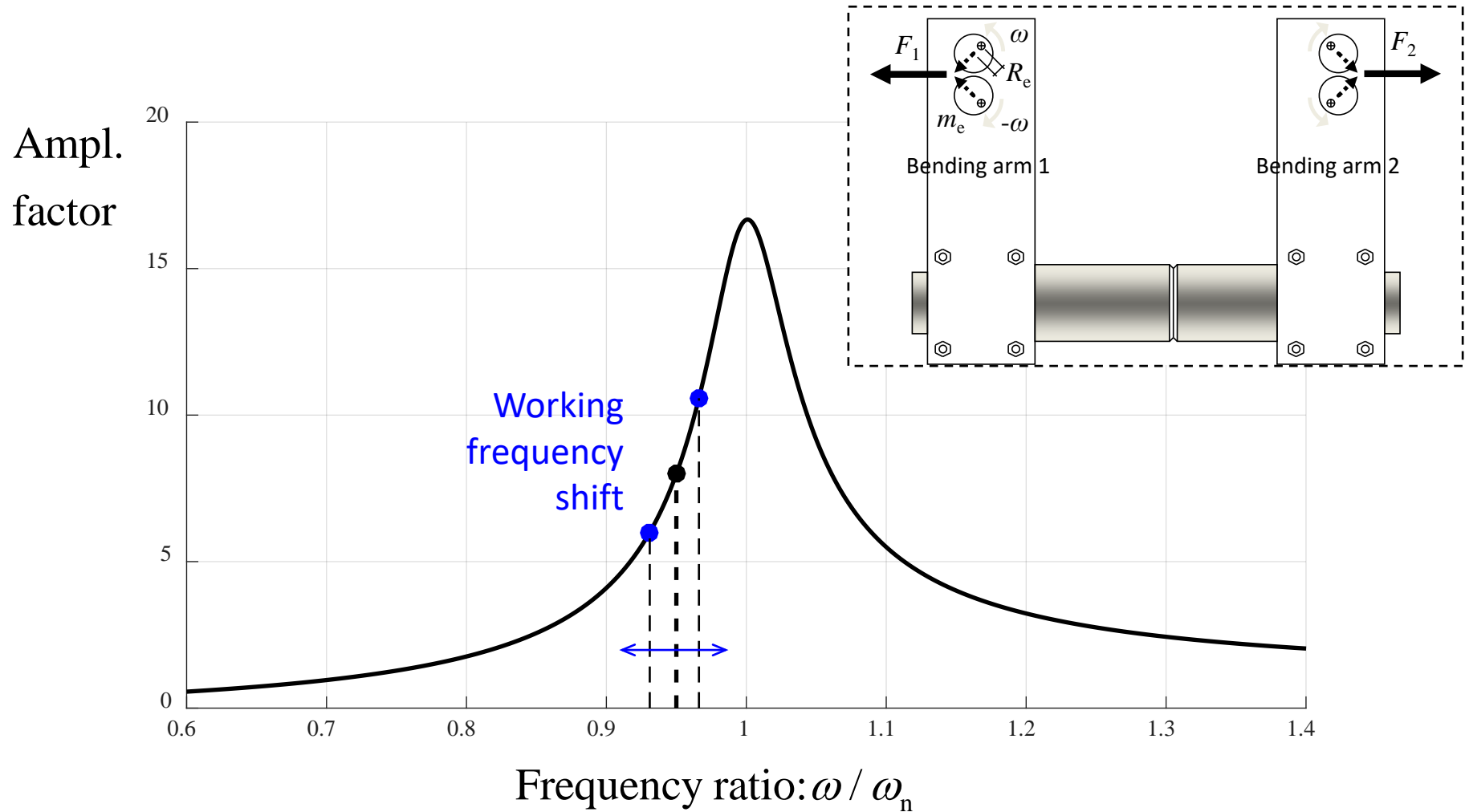
Resonance modeling



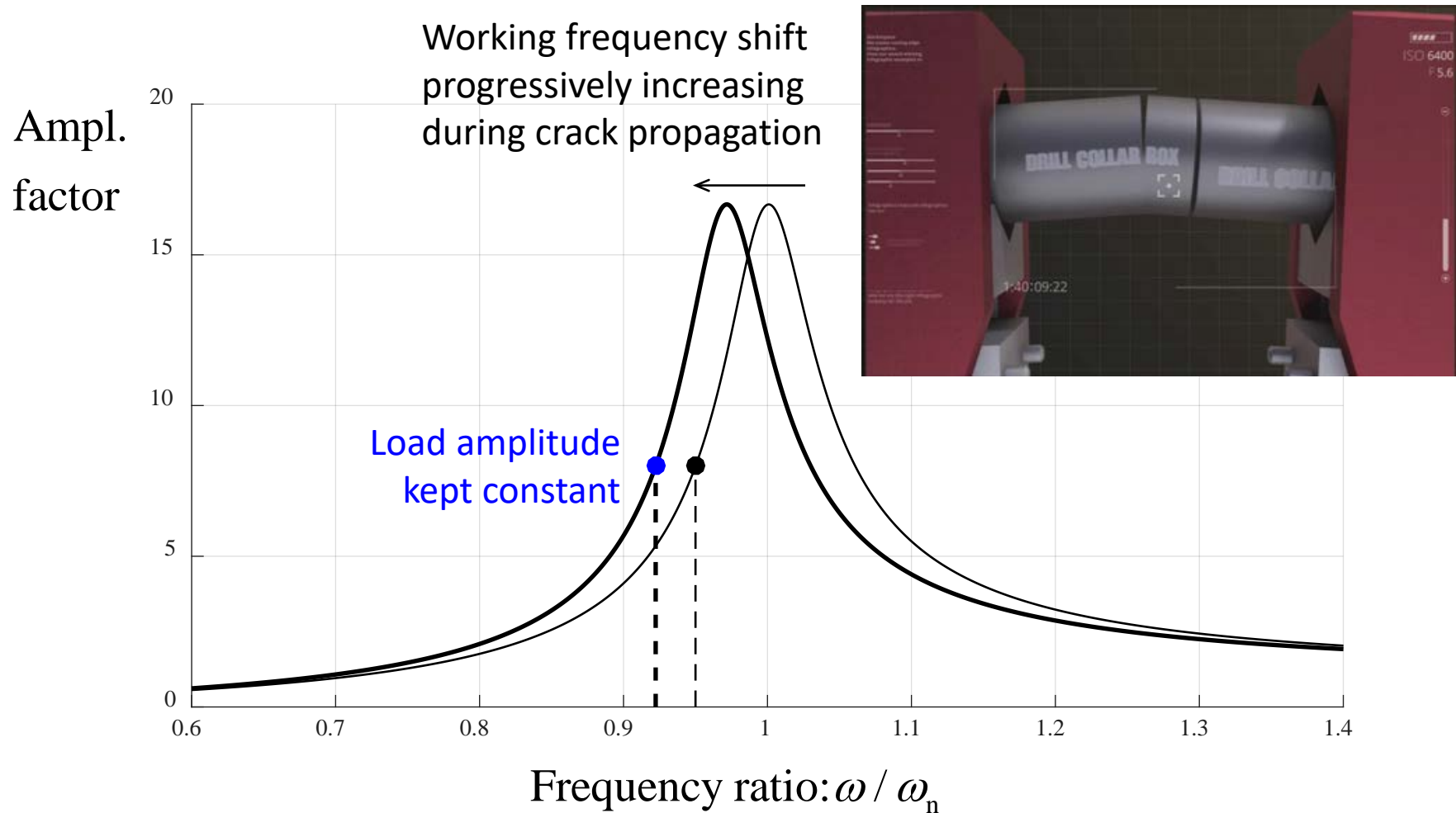
Resonance load control 1: mass phase shift



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

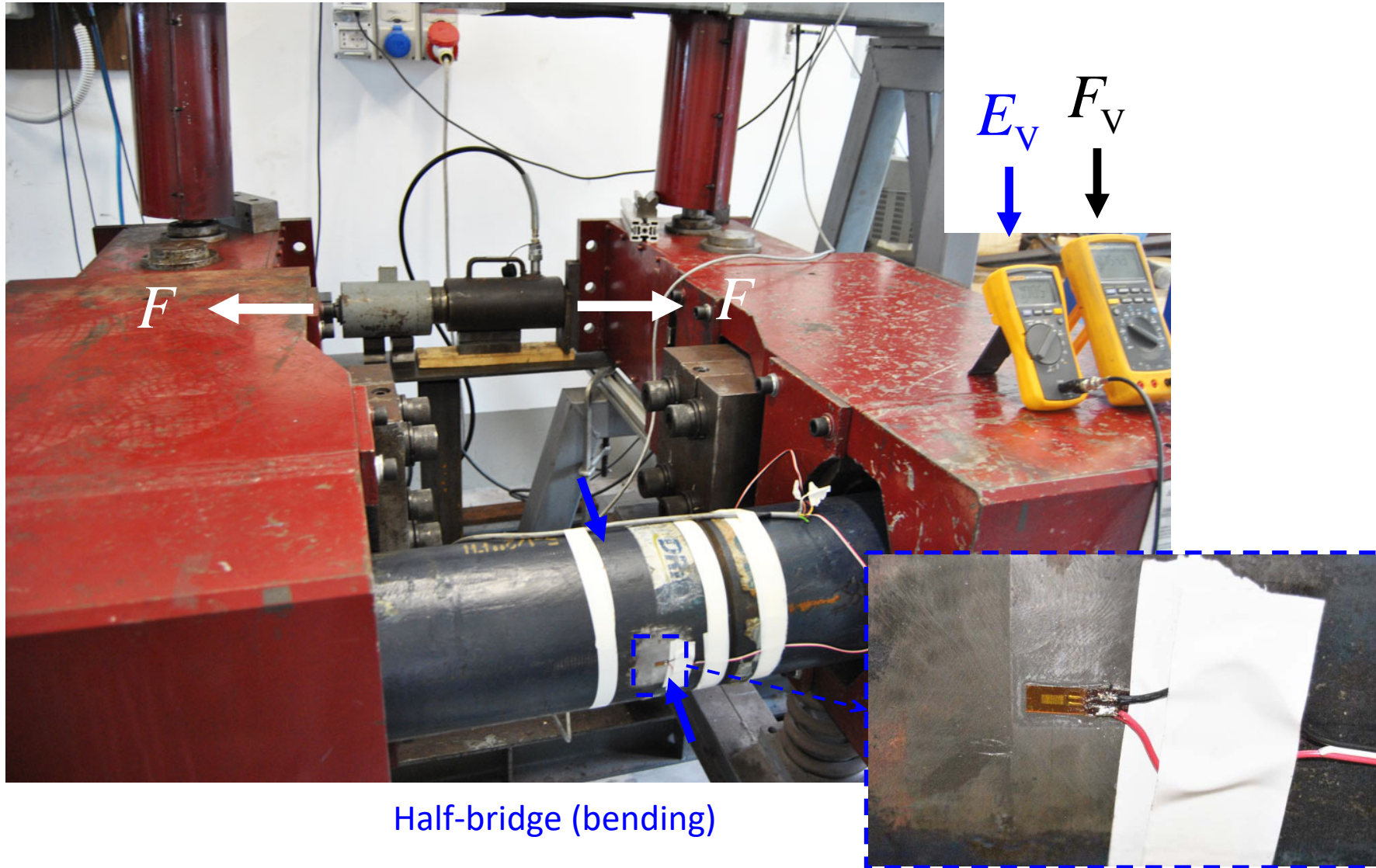


Resonance load control with frequency during crack propagation

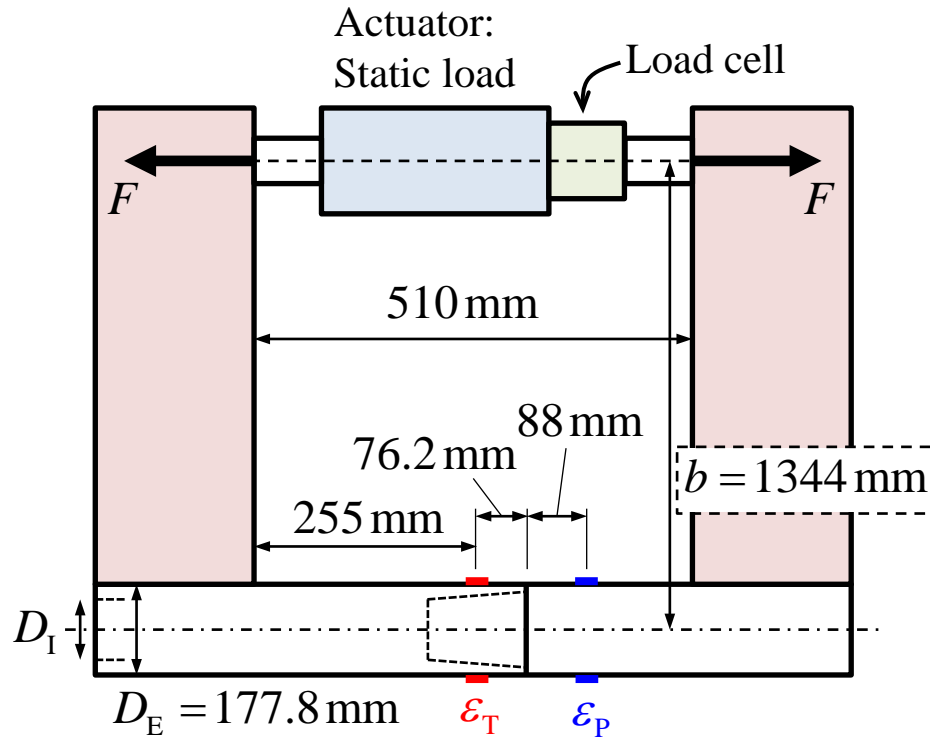


Strain-gage calibration

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



Strain-gage calibration



$$F = F_V K$$

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

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

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

Verification:

1st step

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

>10% difference Tread (T)

<5% difference Pin (P)

2nd step

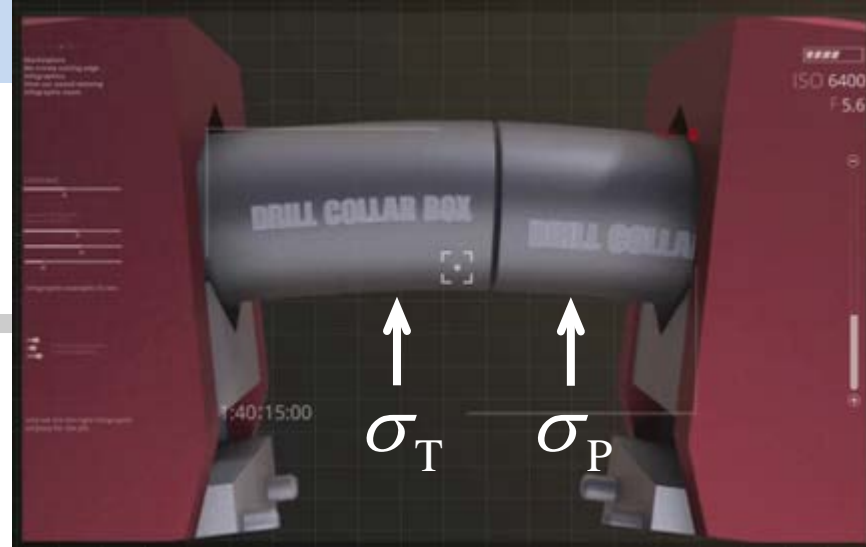
Calibration:

Stress to voltage ratio

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

Monitoring during test running

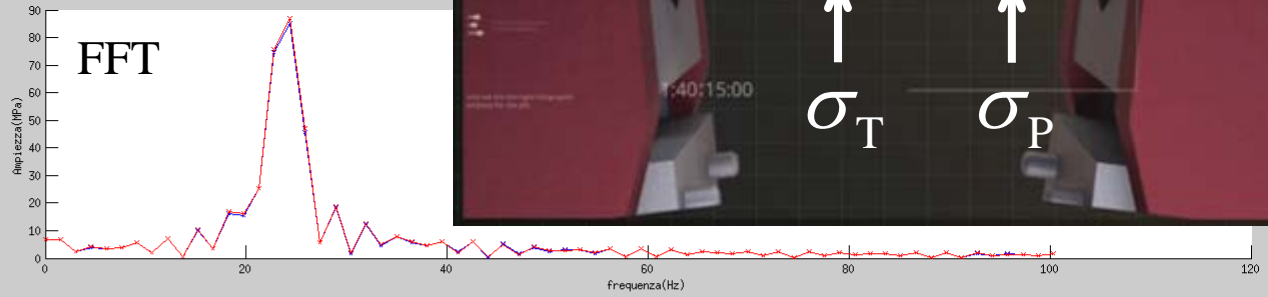
Initial strain gage signal (no crack)



Control panel

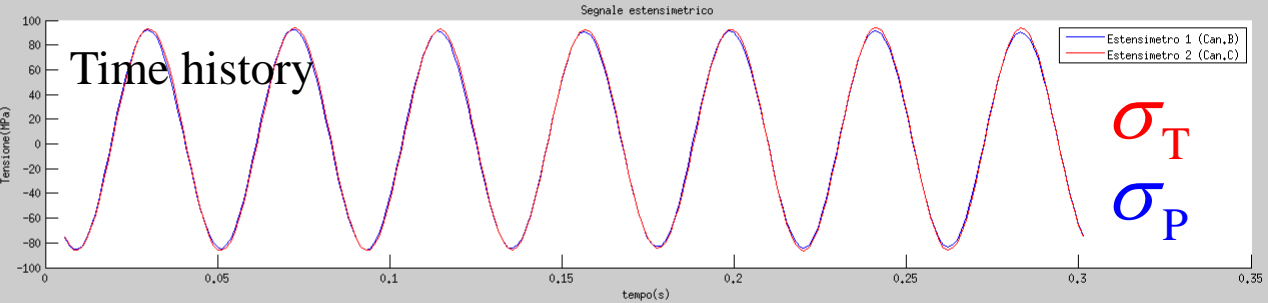
Controlli

Cont. Manuale	Cont. Automatico	Tarature banco
Motore passo	0	<input type="range"/>
Motore eccitazione	97.1%	<input type="range"/>
Attiva controllo	Parametri controllo	
Tensione inseguita	90	



Comunicazione/Acquisizione

Comunicazione (on)	Osservazione (on)	...
Intervallo acquisizione(s)	1	
Reg. tensione(s)	60	
Campioni/acquisizione(n)	240	
Reg. campionamento(s)	600	
Impostazioni comunicazione	ip: 151.114.180.143 porta: 80	



Campione in prova

Emergenza

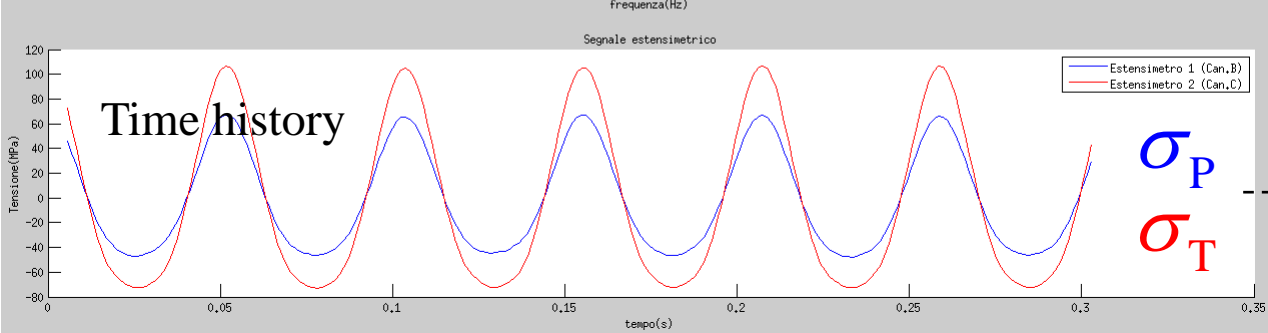
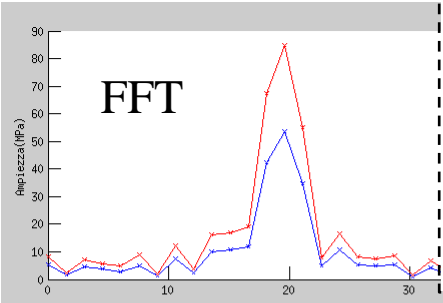
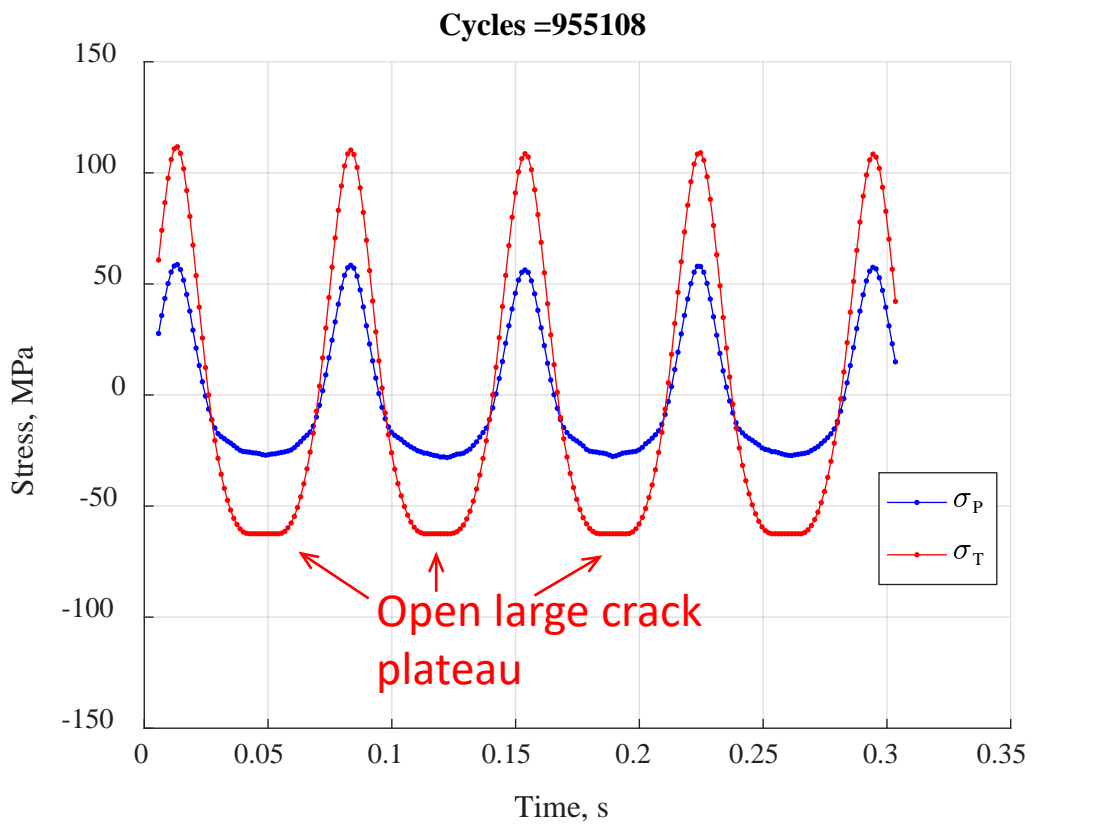
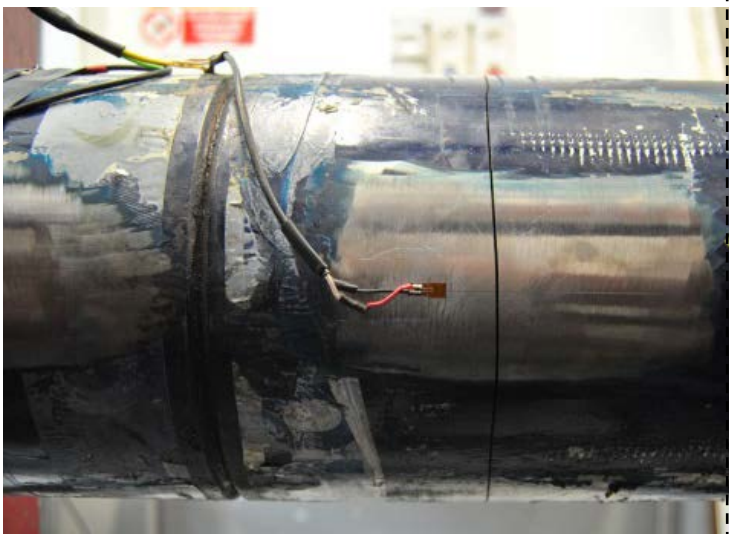
Stato macchina/Contatori

Cicili/sec	24.3	Hz	Conferma file	prova_T2.txt	File...
Tensione (picco-picco)/2	E1:89.1 - E2:90.3	MPa	Conferma cartella	/home/accime/Dropbox/Avviamento banc	Dir...
Tensione media	E1:3.2565, E2:3.3217	MPa	Impostazioni prova	Gestione dati	Reset contatori prova
Tempo totale prova	1167	sec	In prova...	Pausa prova	Ferma prova
Numero cicli effettuati	24573	ad	Vedi storia di carico		
Angolo sfasamento masse	0	deg			

effettuato salvataggio campionamento su file: prova_T2.txt

Monitoring during test running

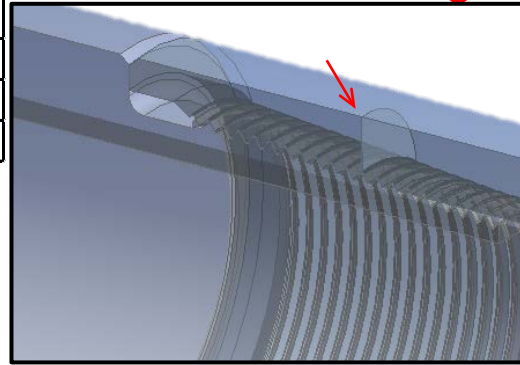
Initial strain gage signal (no crack)



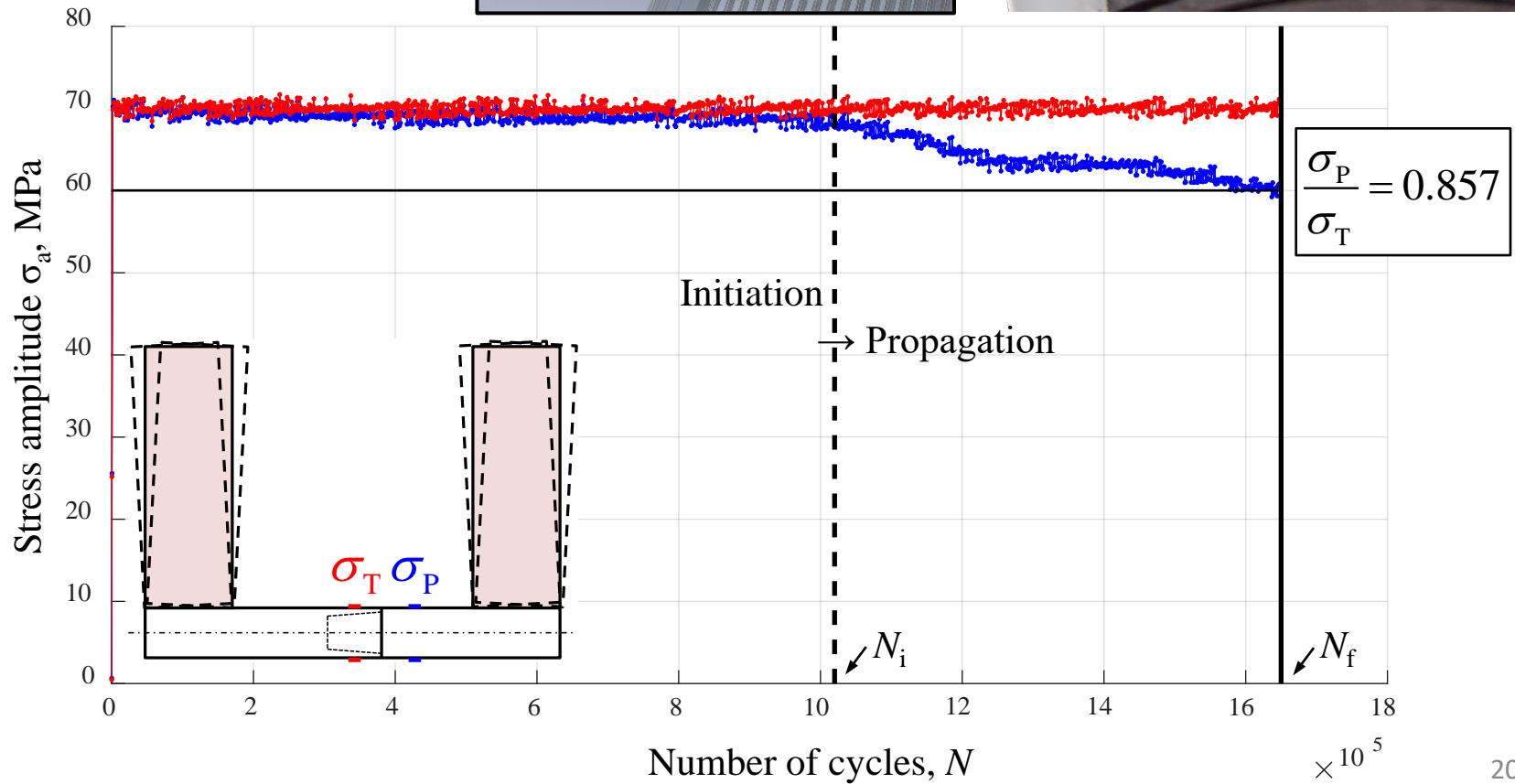
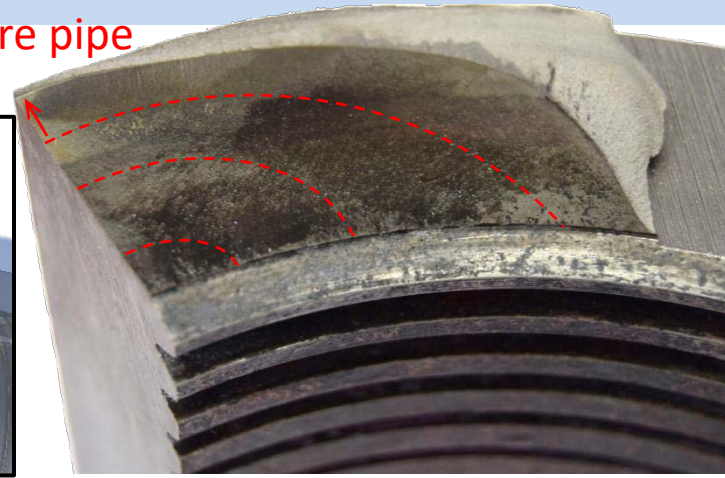
Crack initiation/ failure

	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

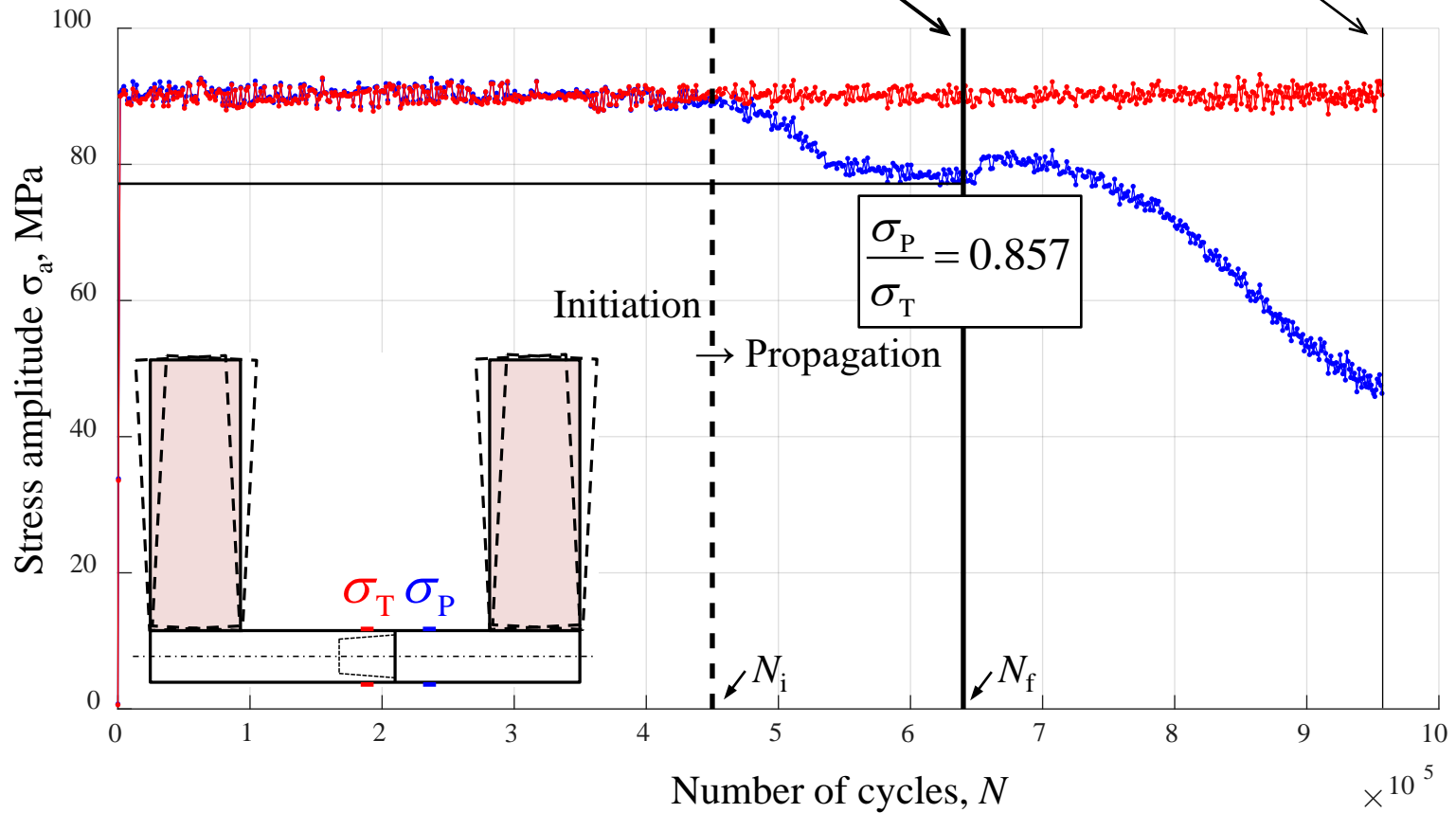
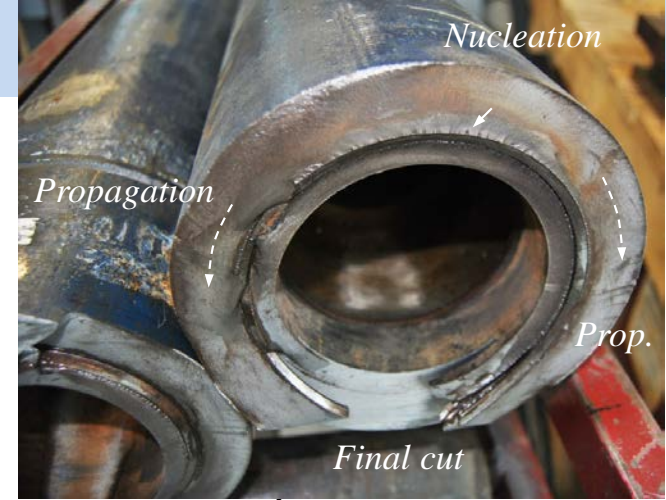
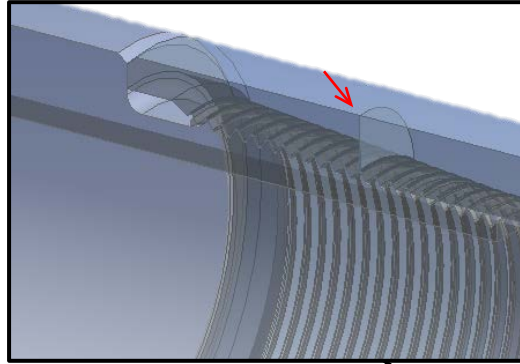


Maximum crack size before pipe leakage

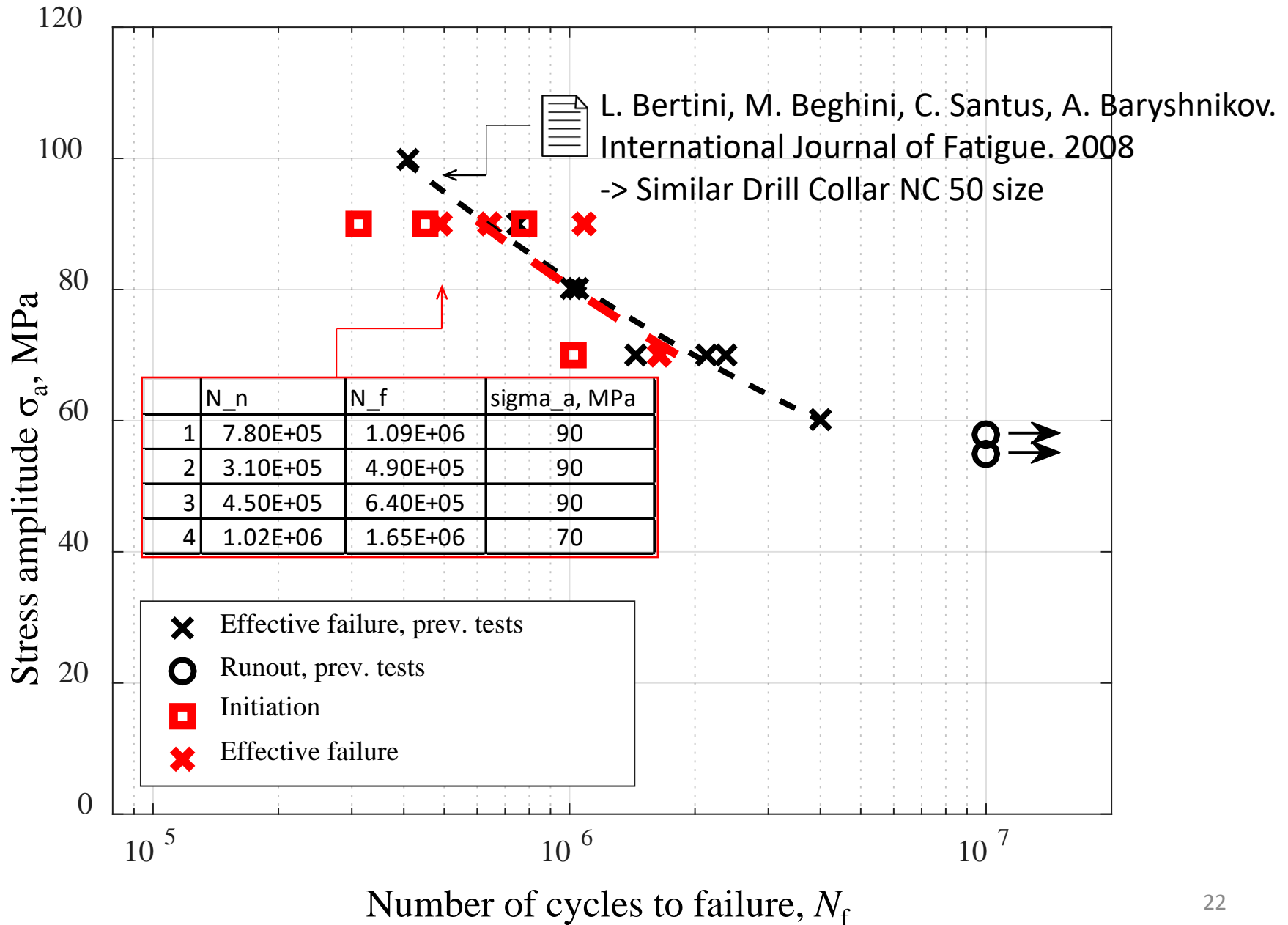


Crack initiation/ failure

	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

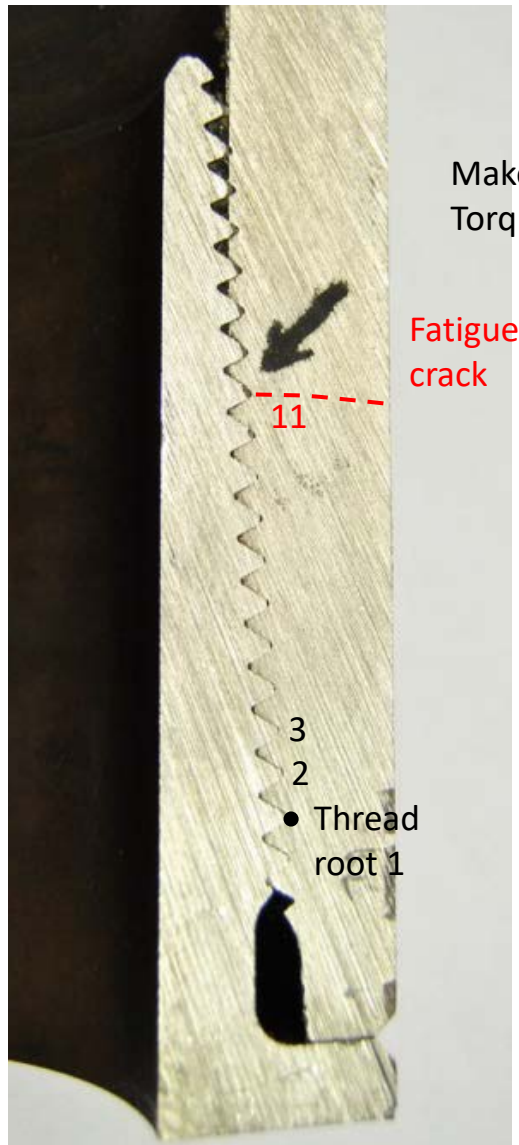


Test results S-N plot, comparison with similar DC data

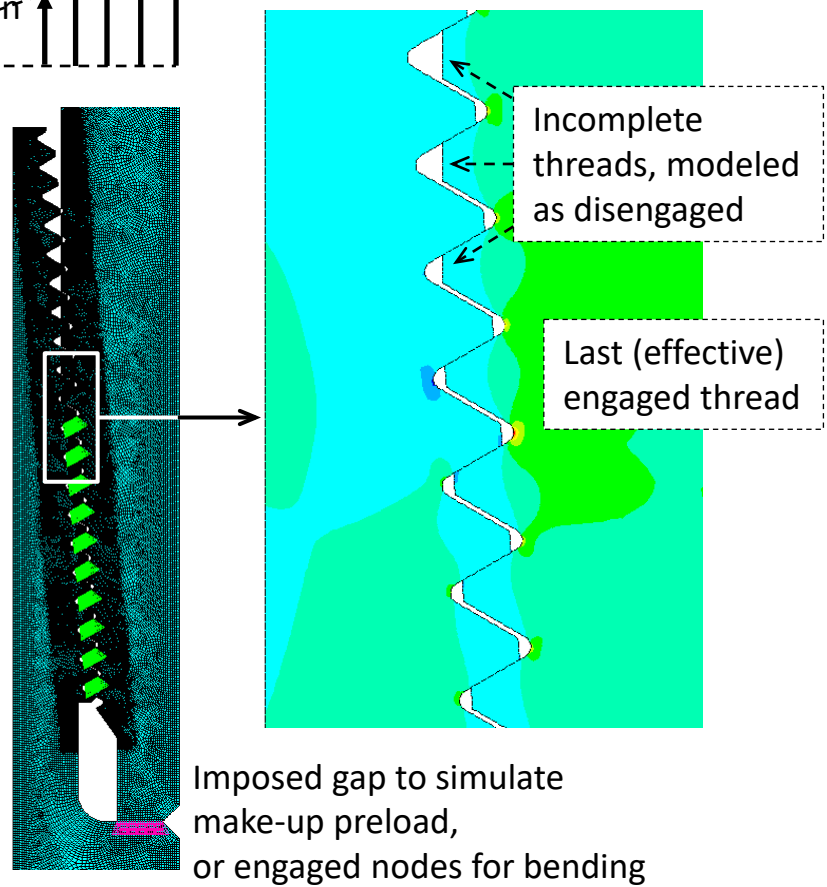
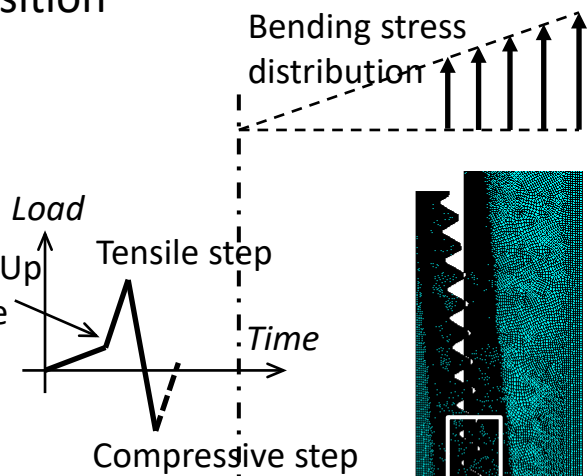


FE analysis for prediction of the crack thread root position

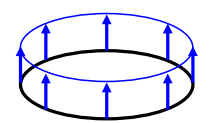
Evidence of fatigue crack position
 Test 4, longitudinal section



Fatigue crack



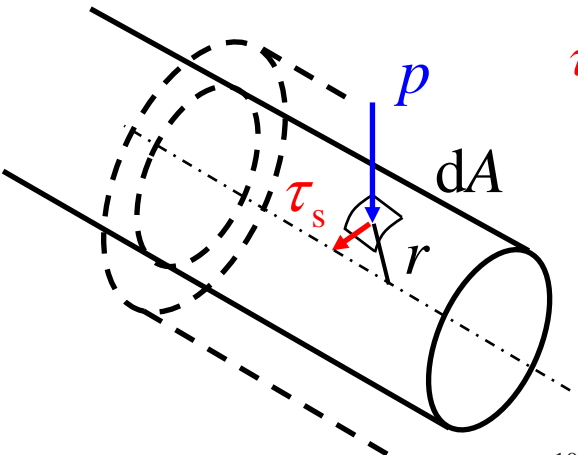
Time 1 Preload (Make-Up): Plane25,
 Harmonic 0 – Axisymmetric model



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



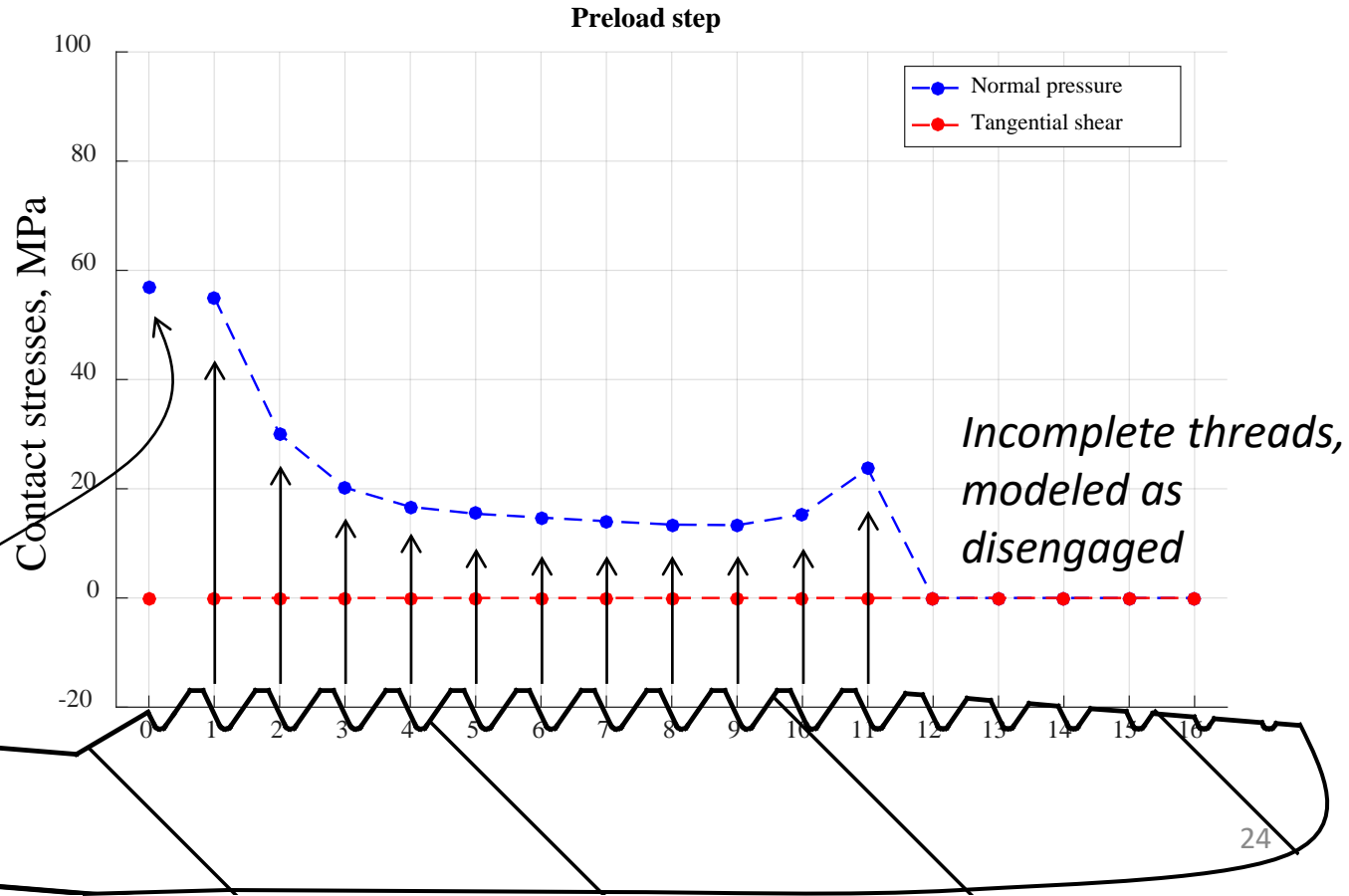
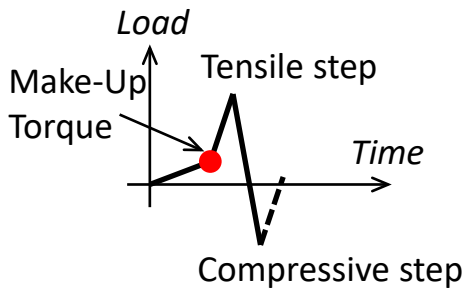
FE analysis for prediction of the crack thread root position



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



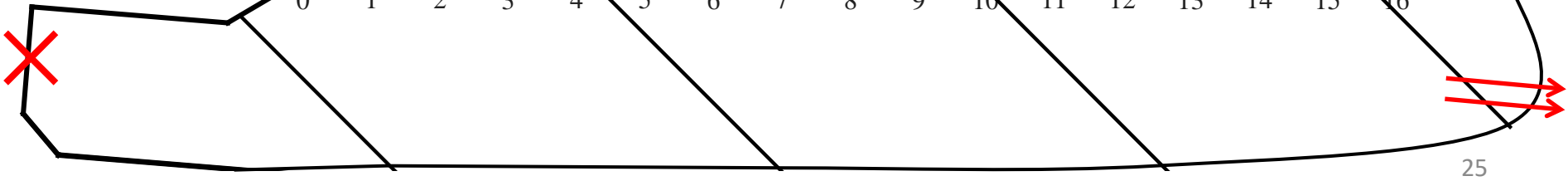
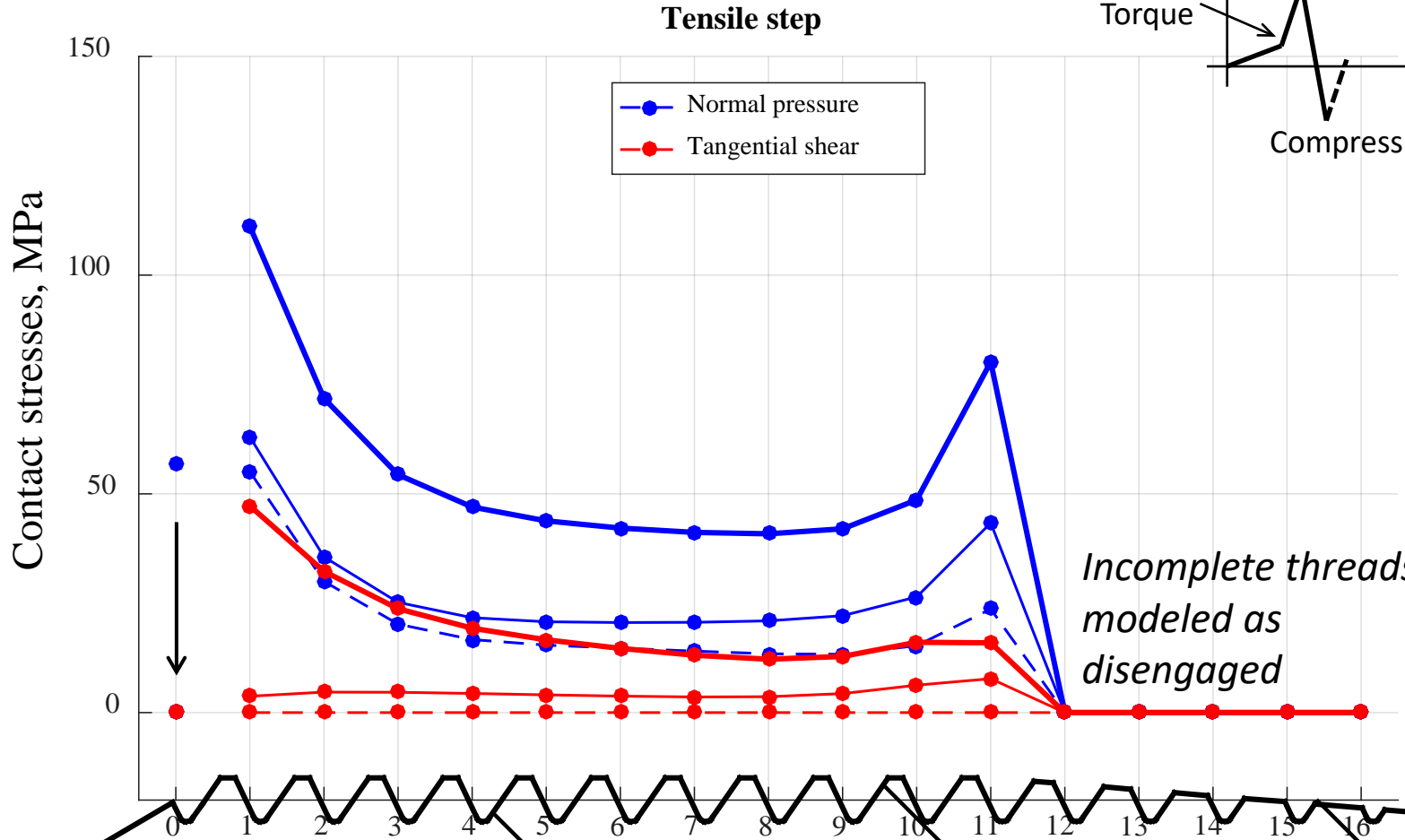
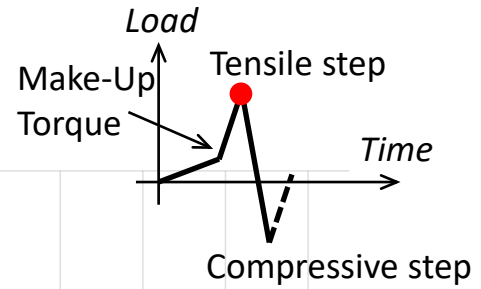
C. Santus, L. Bertini, M. Beghini, A. Merlo, A. Baryshnikov. International Journal of Pressure Vessels and Piping. 2009



Stop face

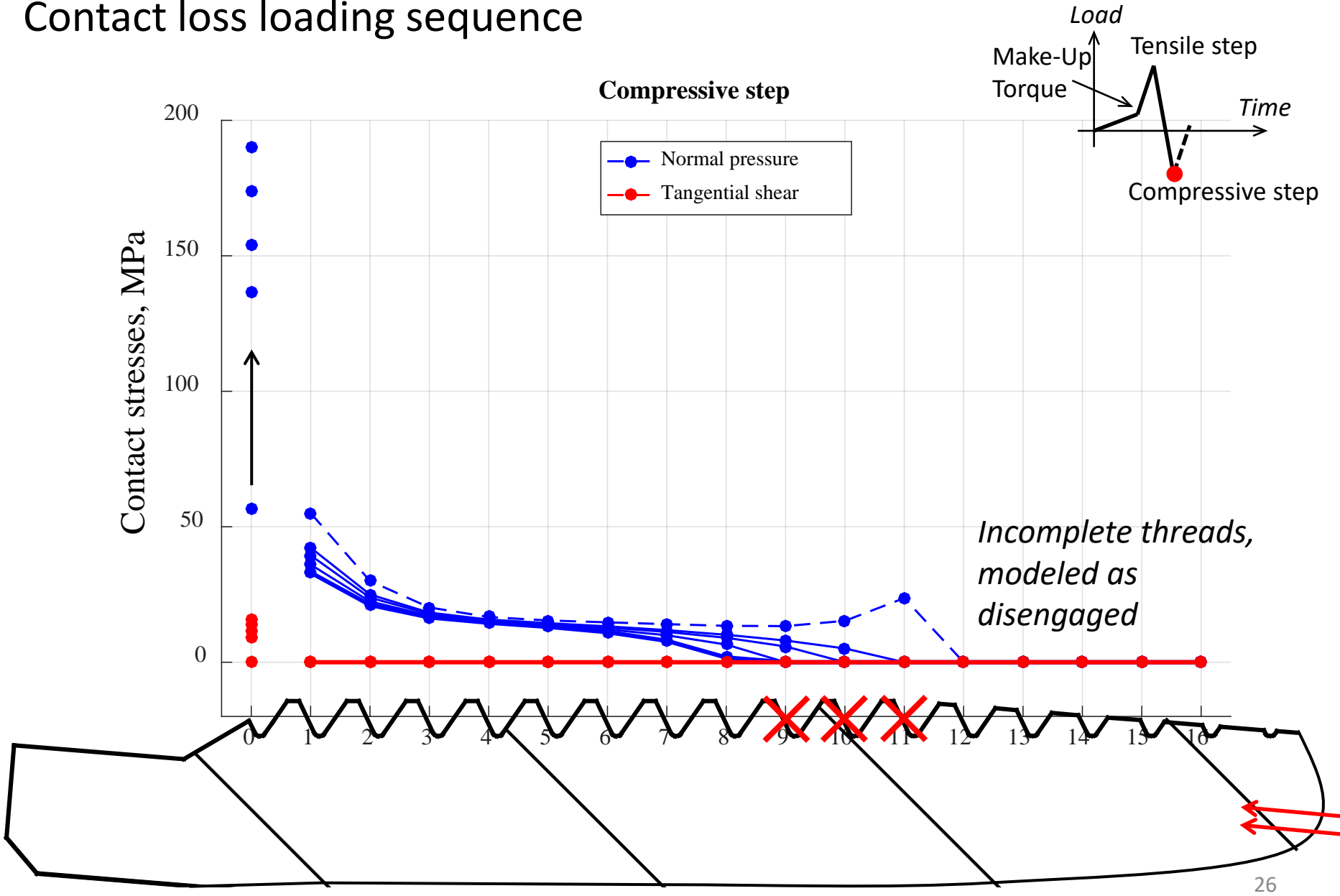
FE analysis for prediction of the crack thread root position

Contact loss loading sequence



FE analysis for prediction of the crack thread root position

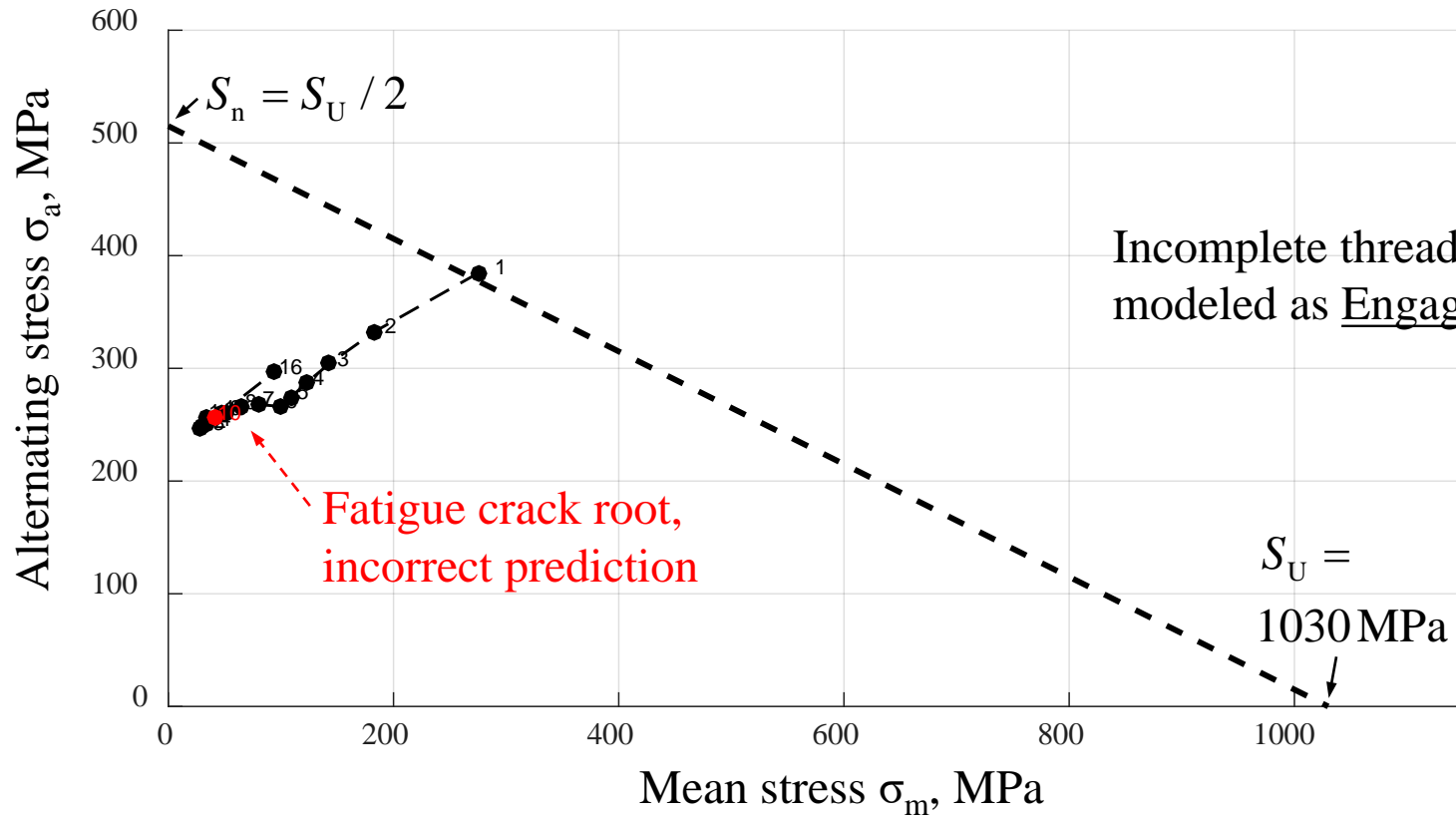
Contact loss loading sequence



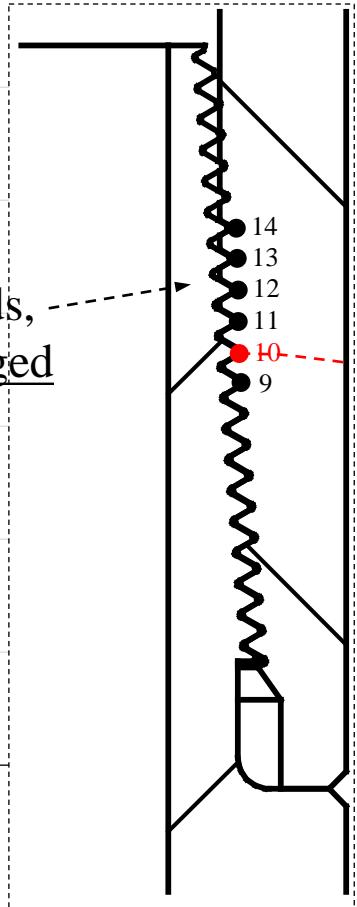
FE analysis for prediction of the crack thread root position

Goodman prediction of thread root fatigue crack position

	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



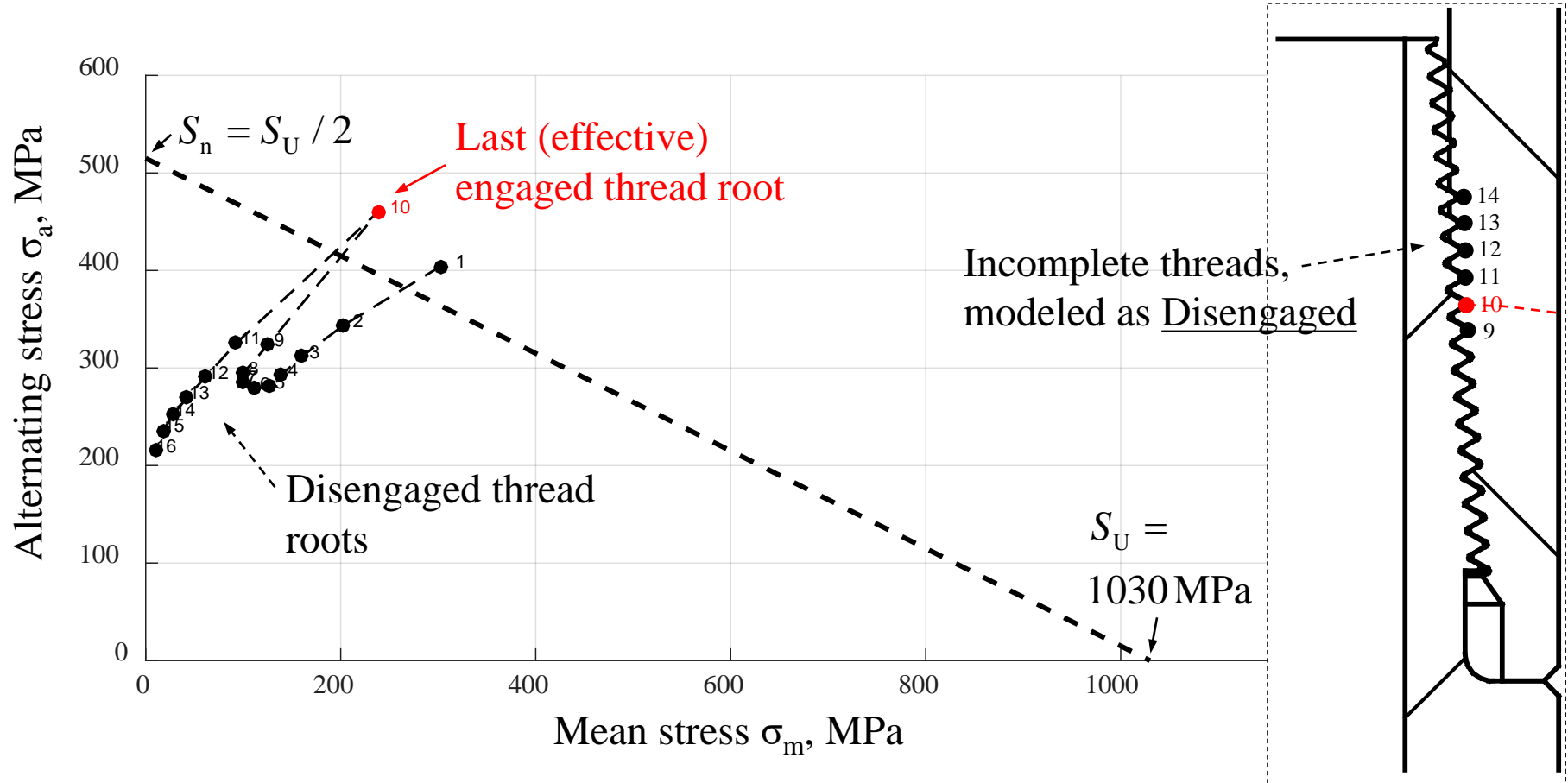
Incomplete threads, modeled as Engaged



FE analysis for prediction of the crack thread root position

Goodman prediction of thread root fatigue crack position

	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



Conclusions

Resonant bench used for Drill Collars 5-1/2 FHM0D 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