

Resonant bench for fatigue testing of steel drill pipe connections

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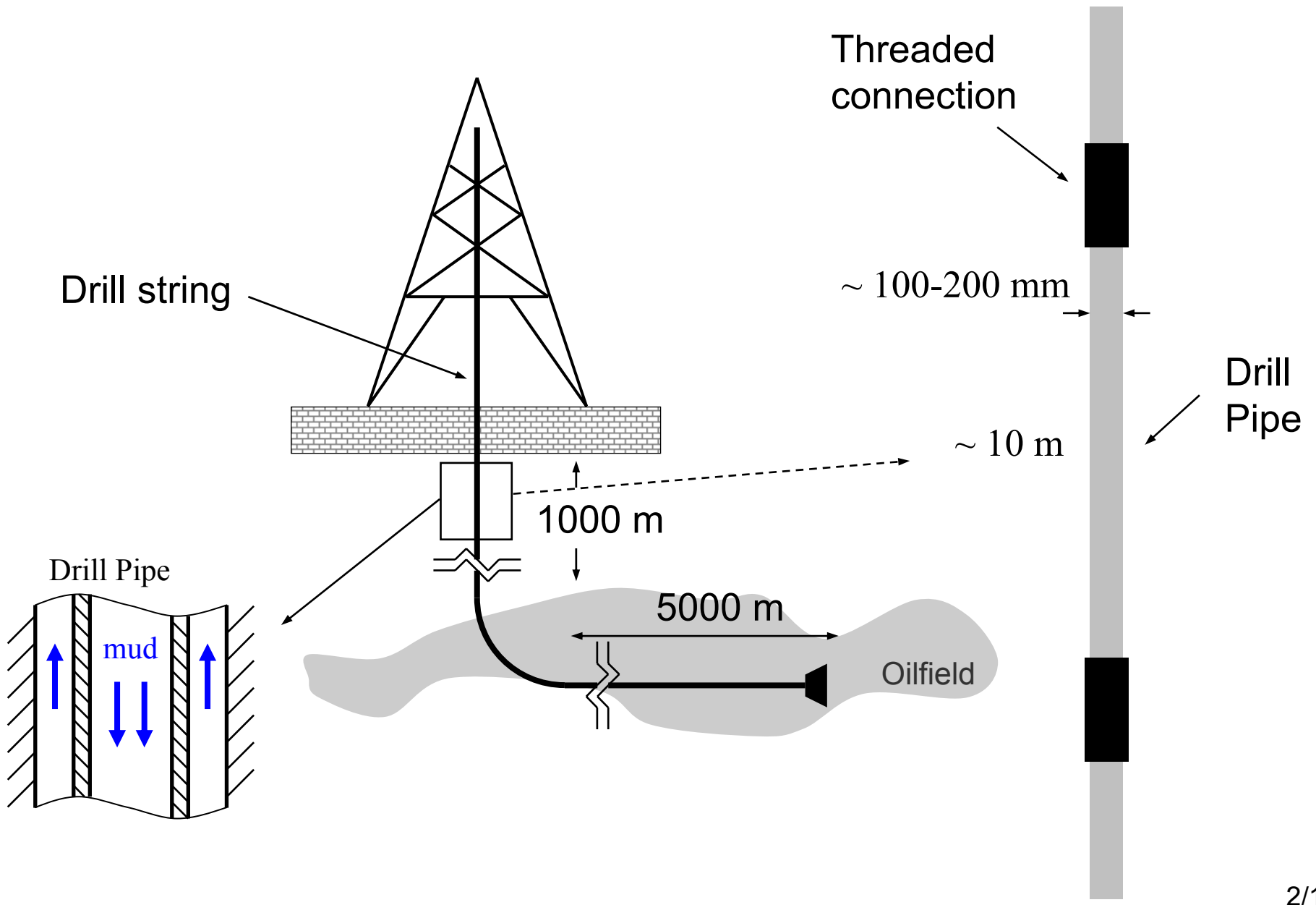
VAM Drilling

TOTAL

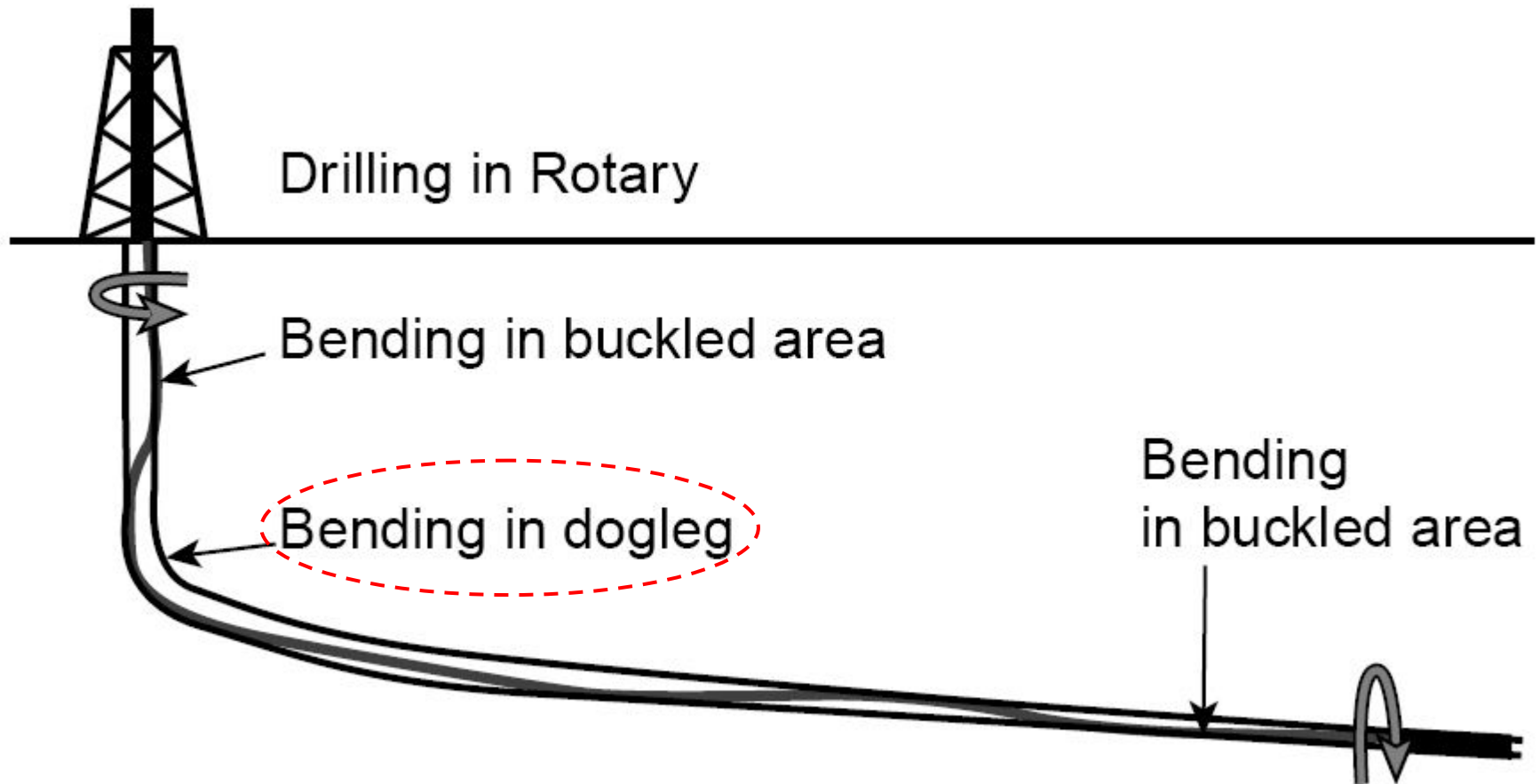
GDF SUEZ



Drill string / Drill pipes



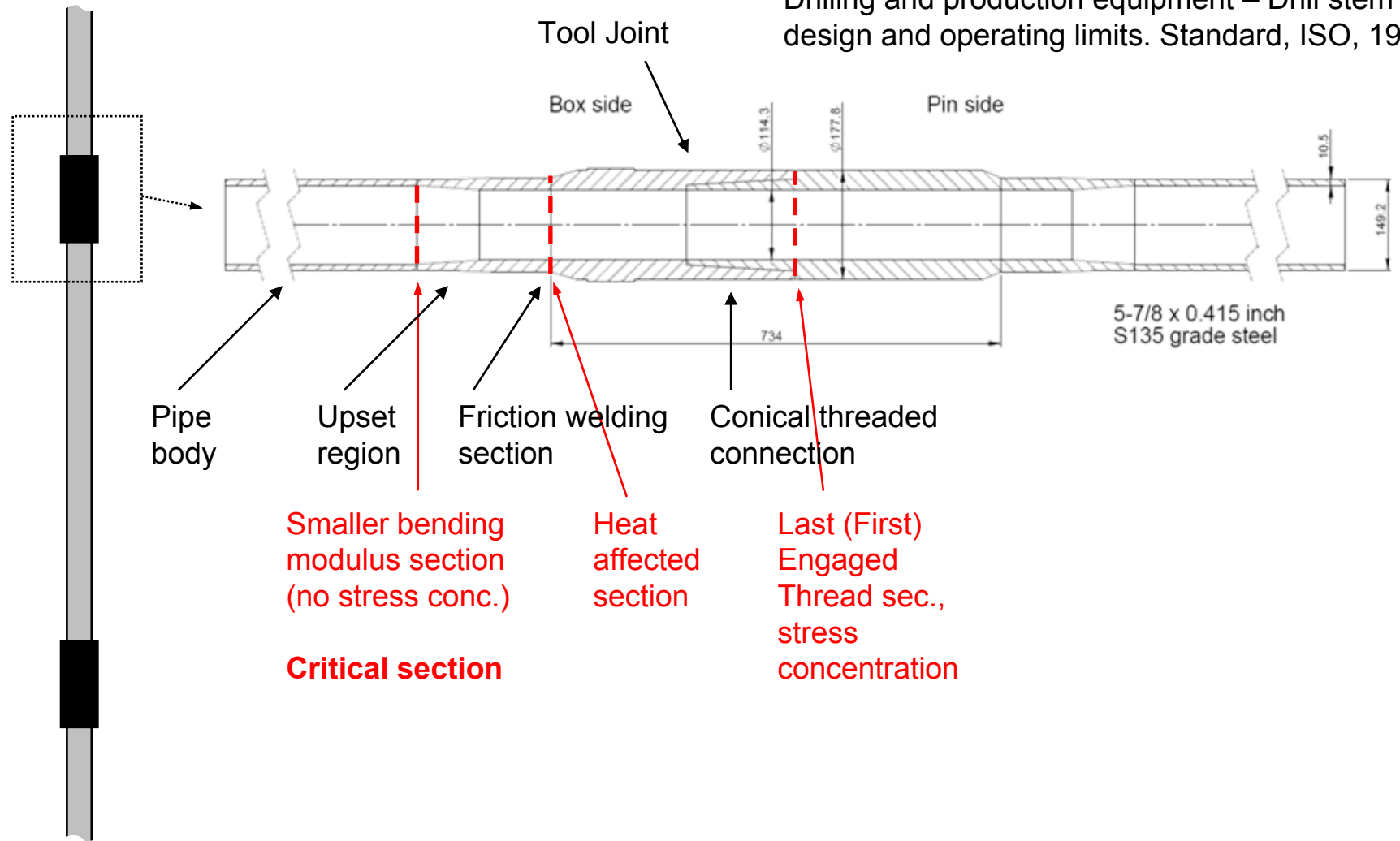
Deviated/horizontal oil well drilling



[*] O. Vaisberg, O. Vincké, G. Perrin, J.P. Sarda, J.B. Faÿ. Fatigue of Drillstring: State of Art. Oil and Gas Science and Technology – Revue de l'Institut Français du Petrole, 57(1):7–37, 2002

Drill pipe, steel

ISO 10407. Petroleum and natural gas industries
 Drilling and production equipment – Drill stem
 design and operating limits. Standard, ISO, 1993



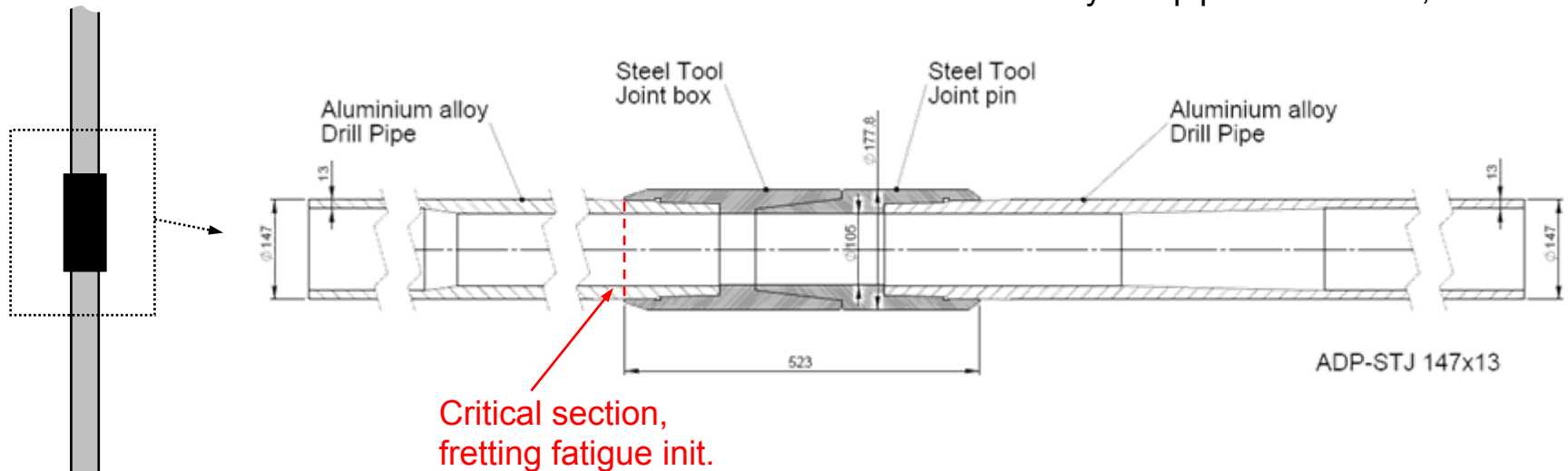
Smaller bending modulus section (no stress conc.)
Critical section

Heat affected section

Last (First) Engaged Thread sec., stress concentration

Drill pipe, ADP-STJ

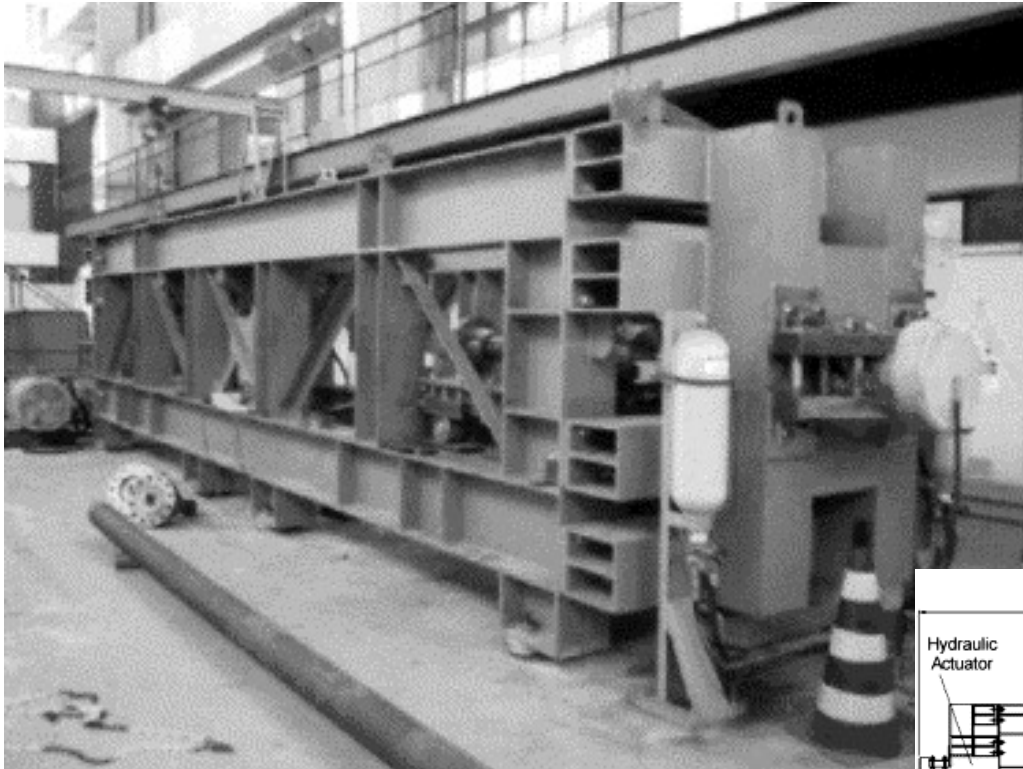
ISO 15546. Petroleum and natural gas industries
Aluminum alloy drill pipe. 2nd edition, 2007



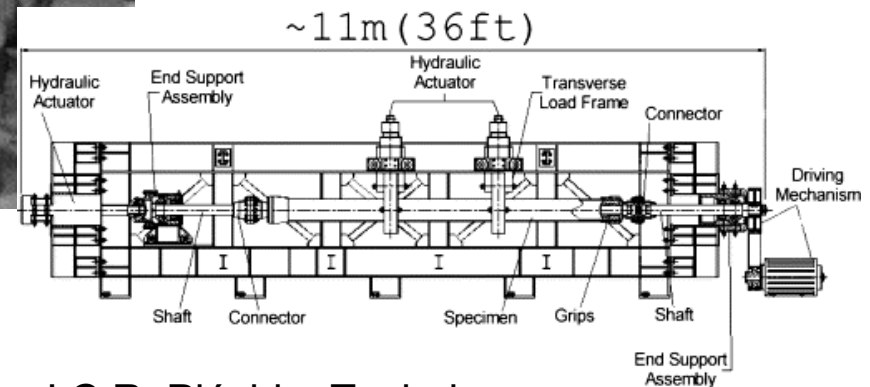
[*] L. Bertini, M. Beghini, C. Santus, A. Baryshnikov. Resonant test rigs for fatigue full scale testing of oil drill string connections. *International Journal of Fatigue*, 30(6):978–988, 2008.

[*] C. Santus. Fretting fatigue of aluminum alloy in contact with steel in oil drill pipe connections, modelling to interpret test results. *International Journal of Fatigue*, 30(4):677–688, 2008.

Drill pipe, full scale fatigue testing

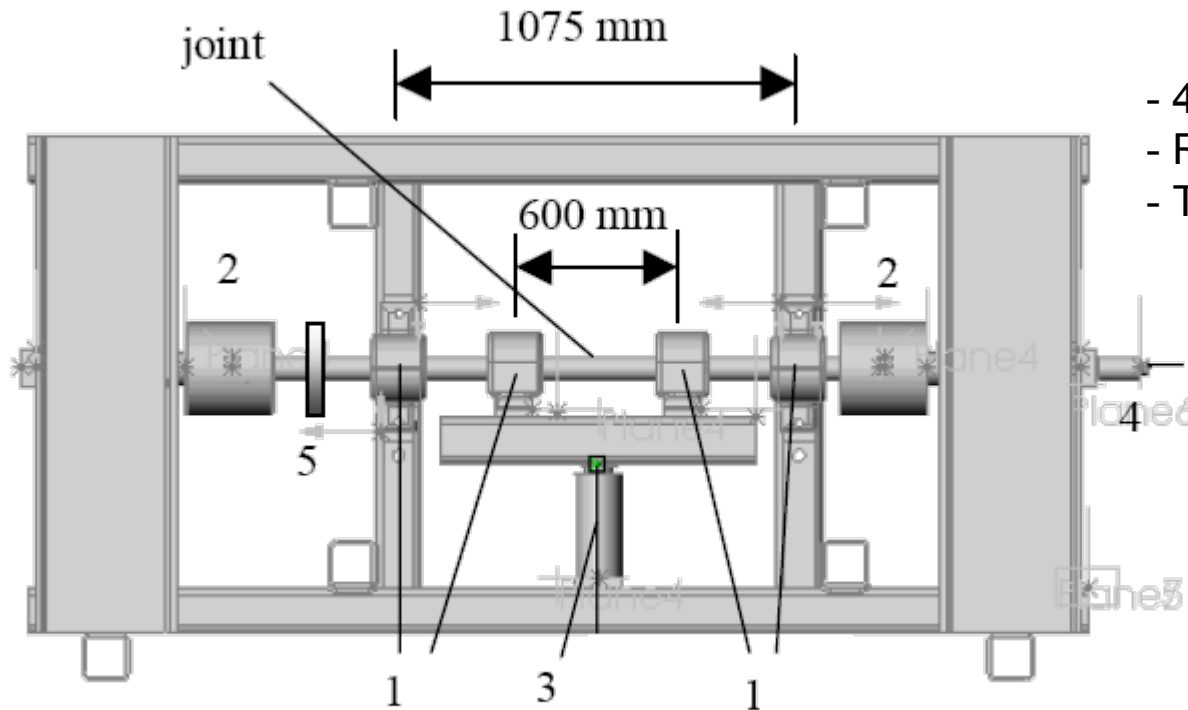


- 4 point bending scheme,
- Rotating pipe,
- Test frequency range: 5-15 Hz.



[*] G.F. Miscow, P.E.V. DeMiranda, T.A. Netto, J.C.R. Plácido. Techniques to characterize fatigue behaviour of full size drill pipes and small scale samples. International Journal of Fatigue, 26(6):575–584, 2004

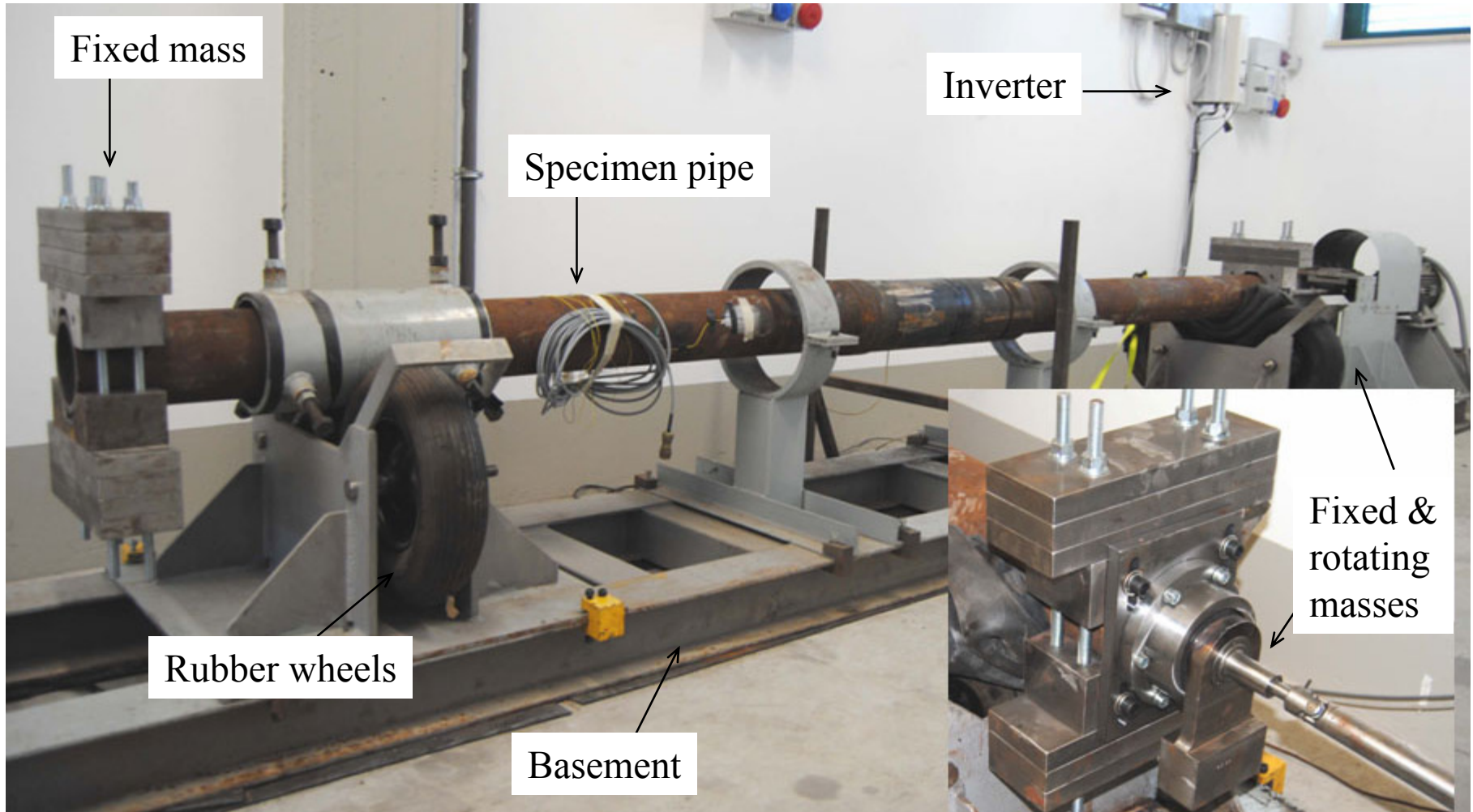
Drill pipe, full scale fatigue testing



- 4 point bending scheme,
- Rotating pipe,
- Test frequency: 17 Hz.

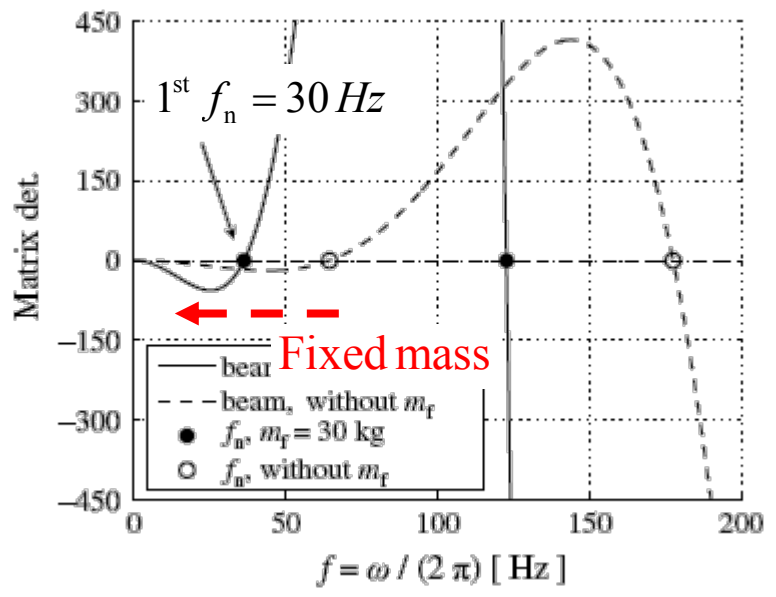
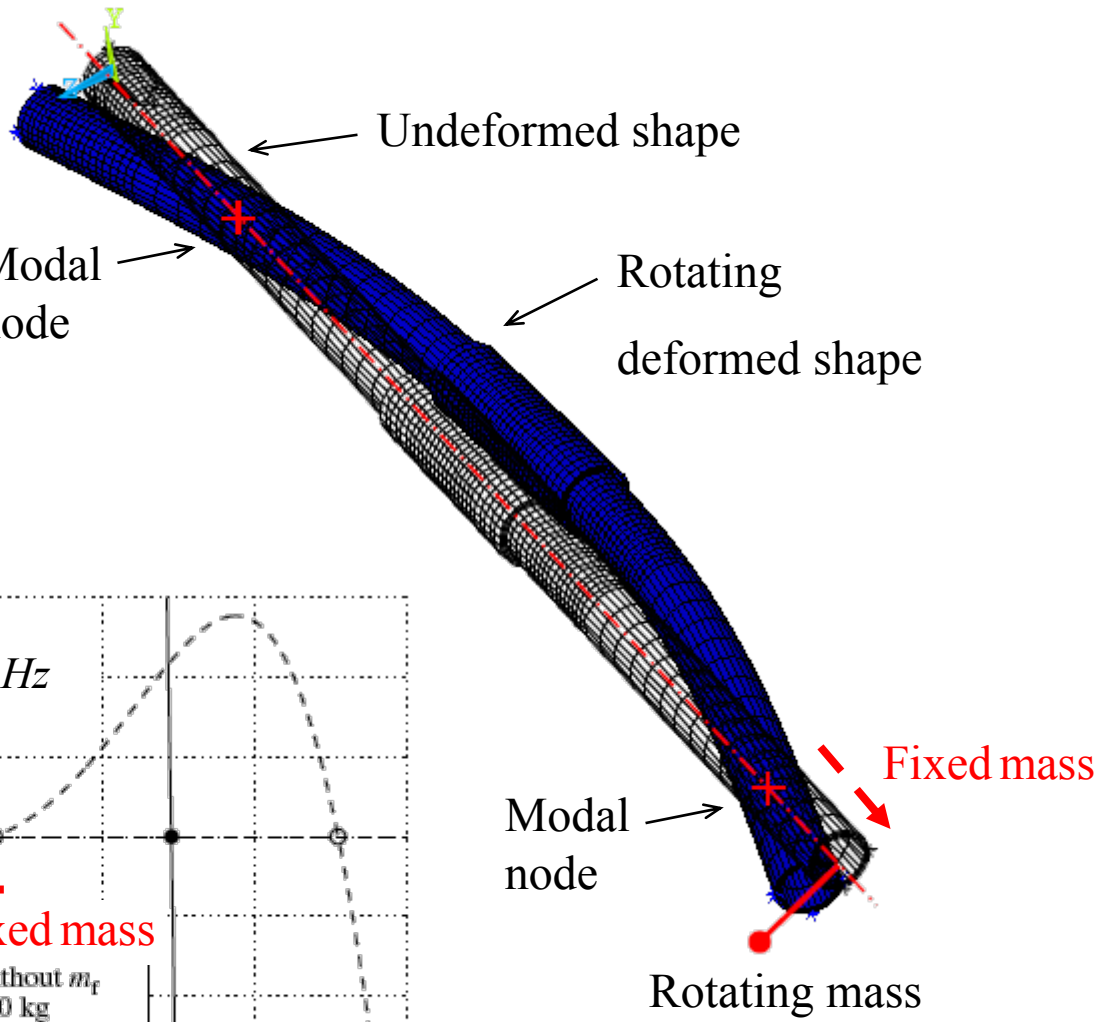
[*] M. Veidt, A. Berezovski. Design and application of a drill pipe fatigue test facility. Proceedings of the Structural Integrity and Fracture International Conference. Brisbane, Australia, 2004.

Steel drill pipe rotating fatigue resonant bench



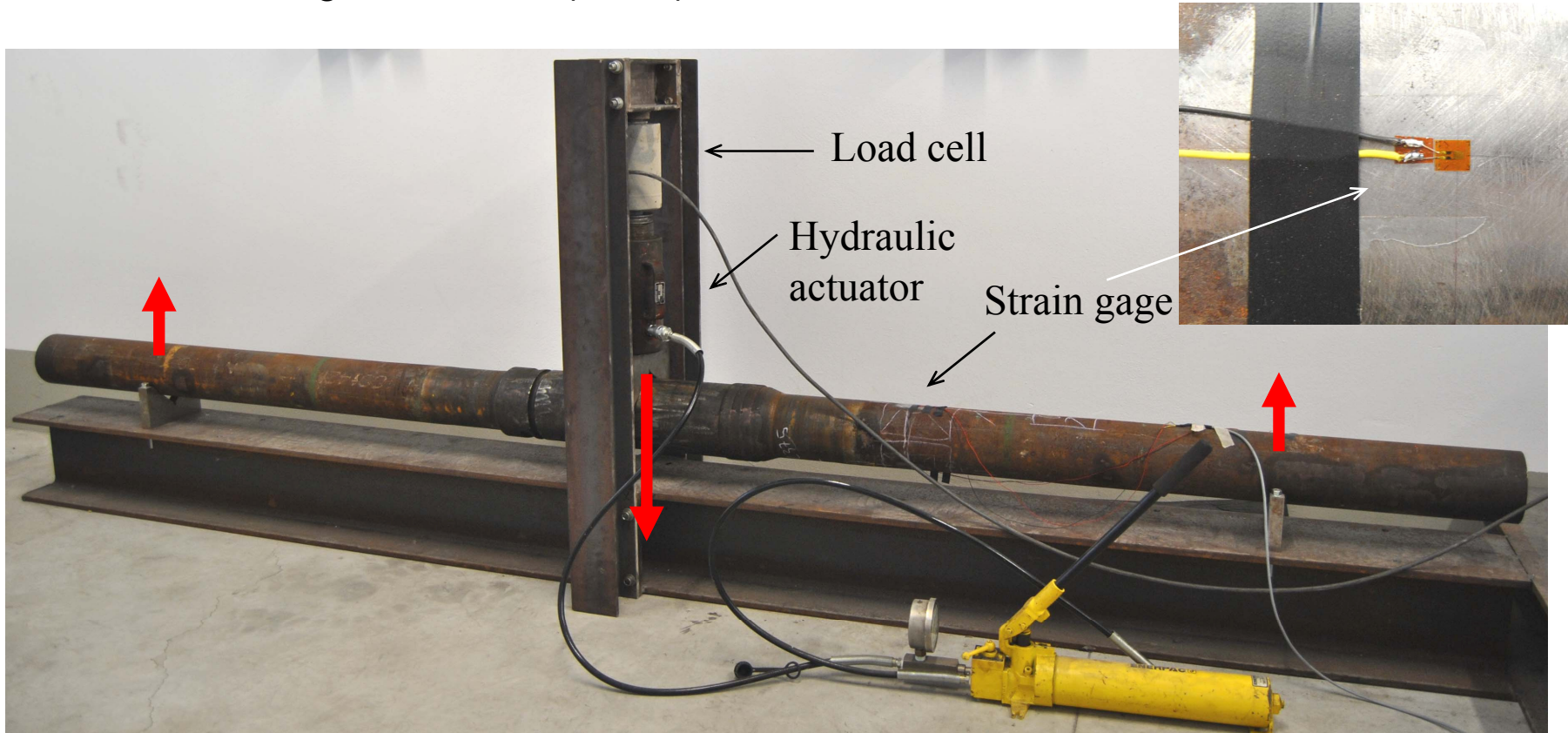
- Light frame,
- Test frequency: 30 Hz.

Frequency and vibrational mode control

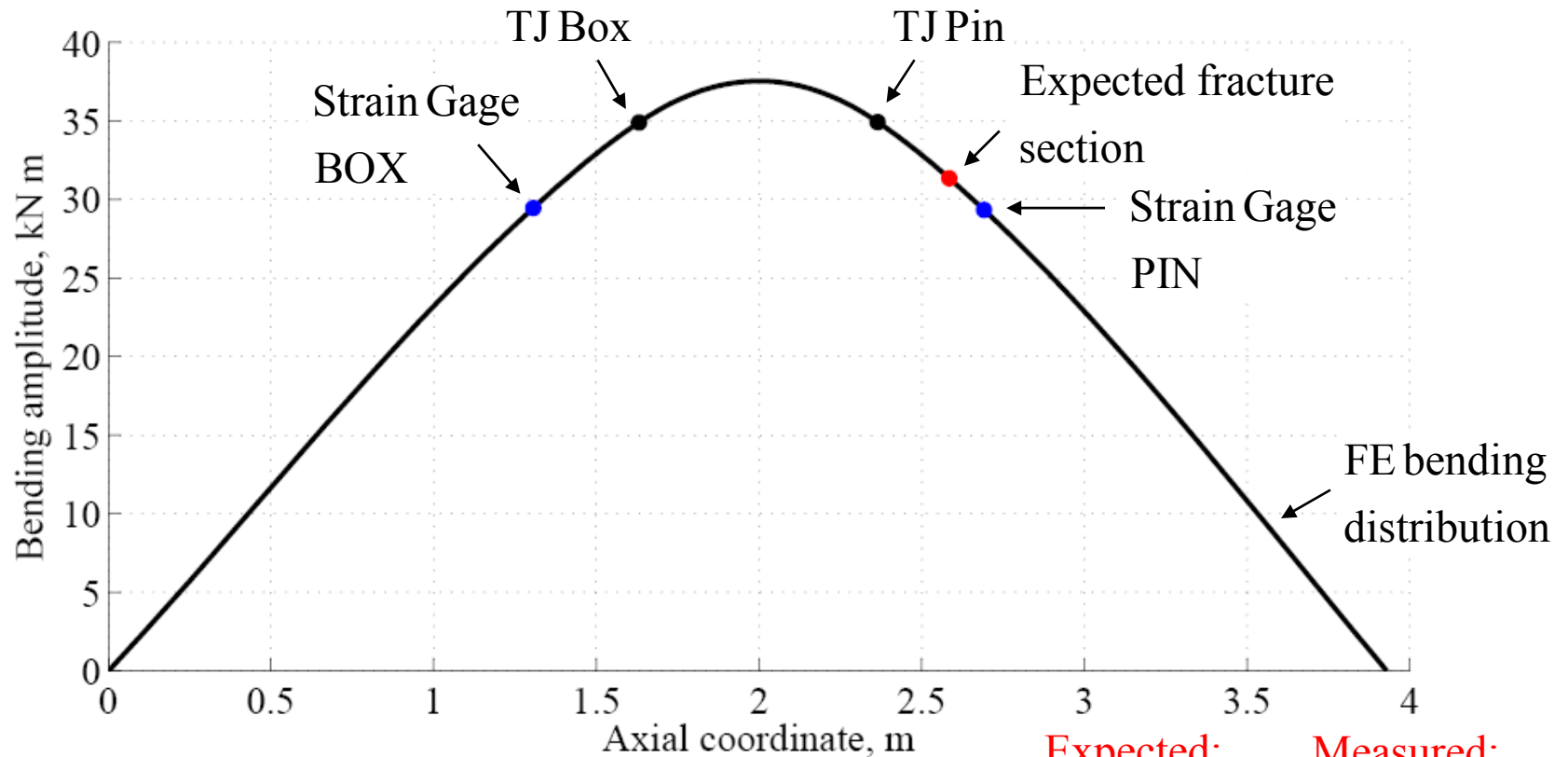


Test load control

Preliminary bending verification (static)



Test load control – Strain Gage



Measured:

$\sigma_a = 178 \text{ MPa}$

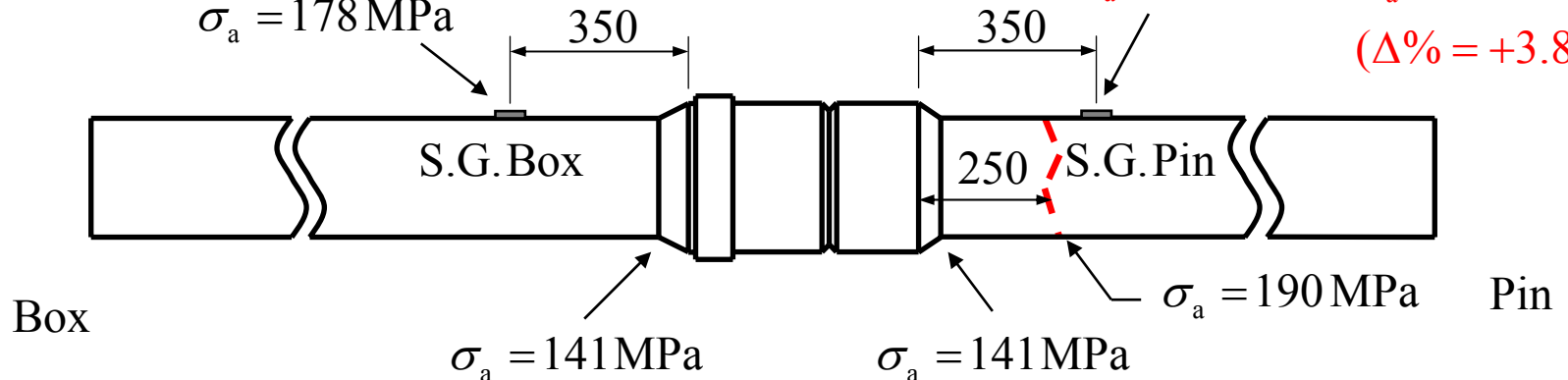
Expected:

$\sigma_a = 178 \text{ MPa}$

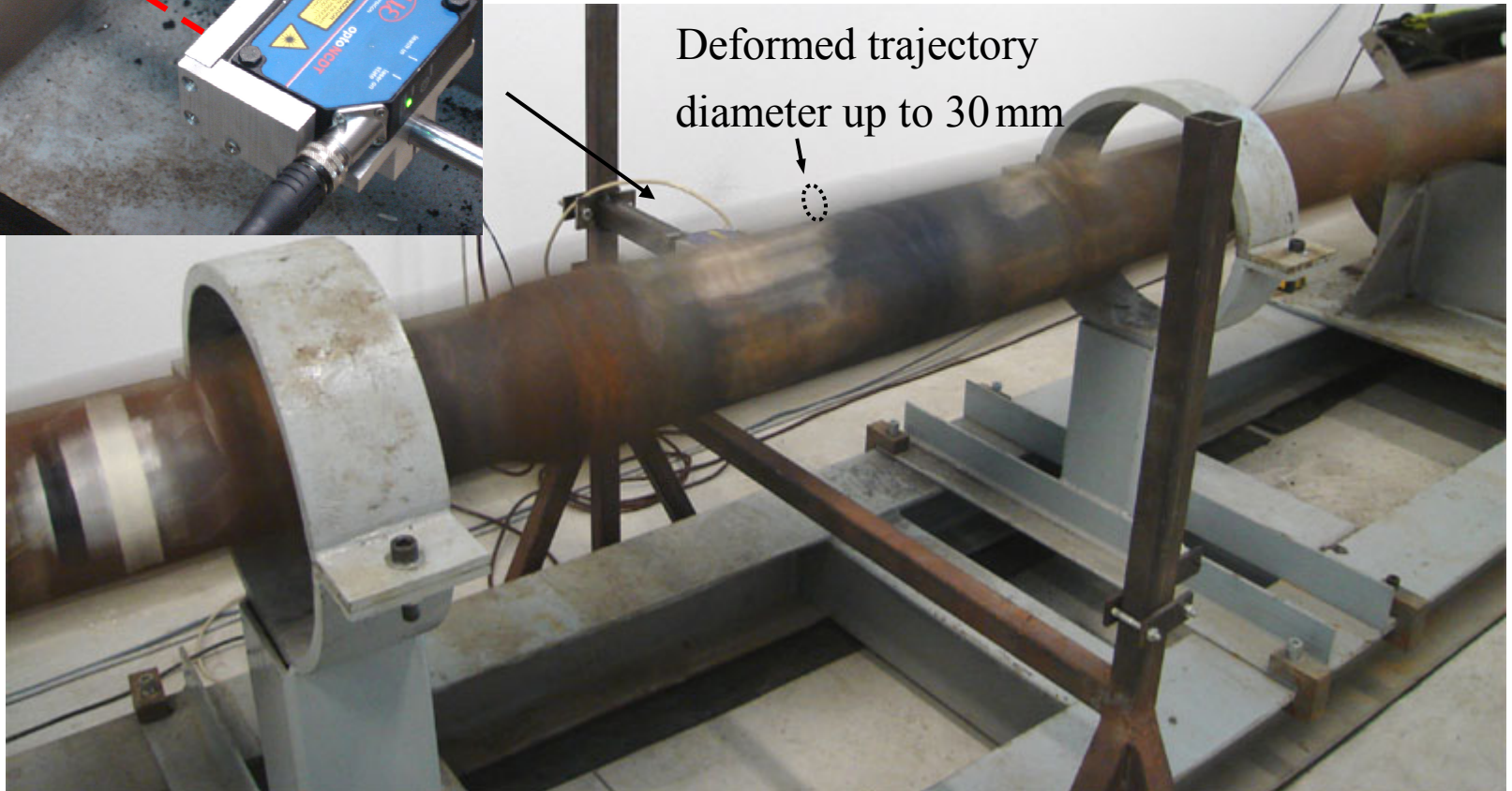
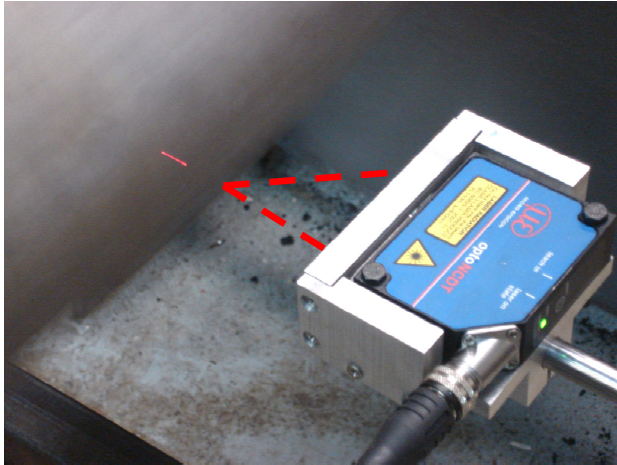
Measured:

$\sigma_a = 185 \text{ MPa}$

($\Delta\% = +3.8\%$)

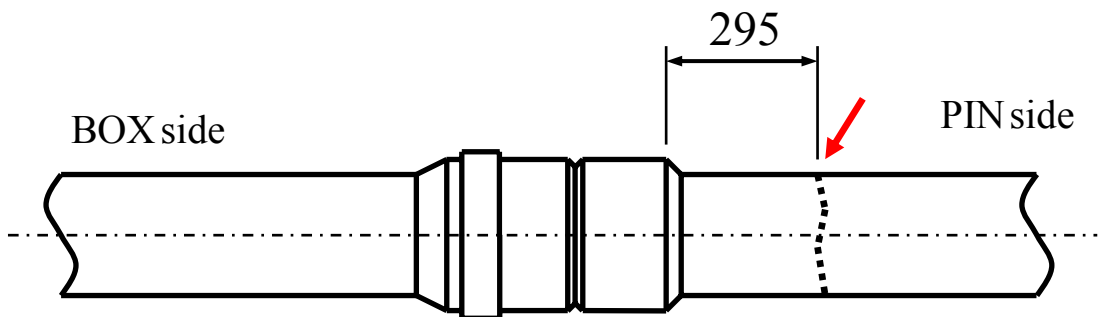
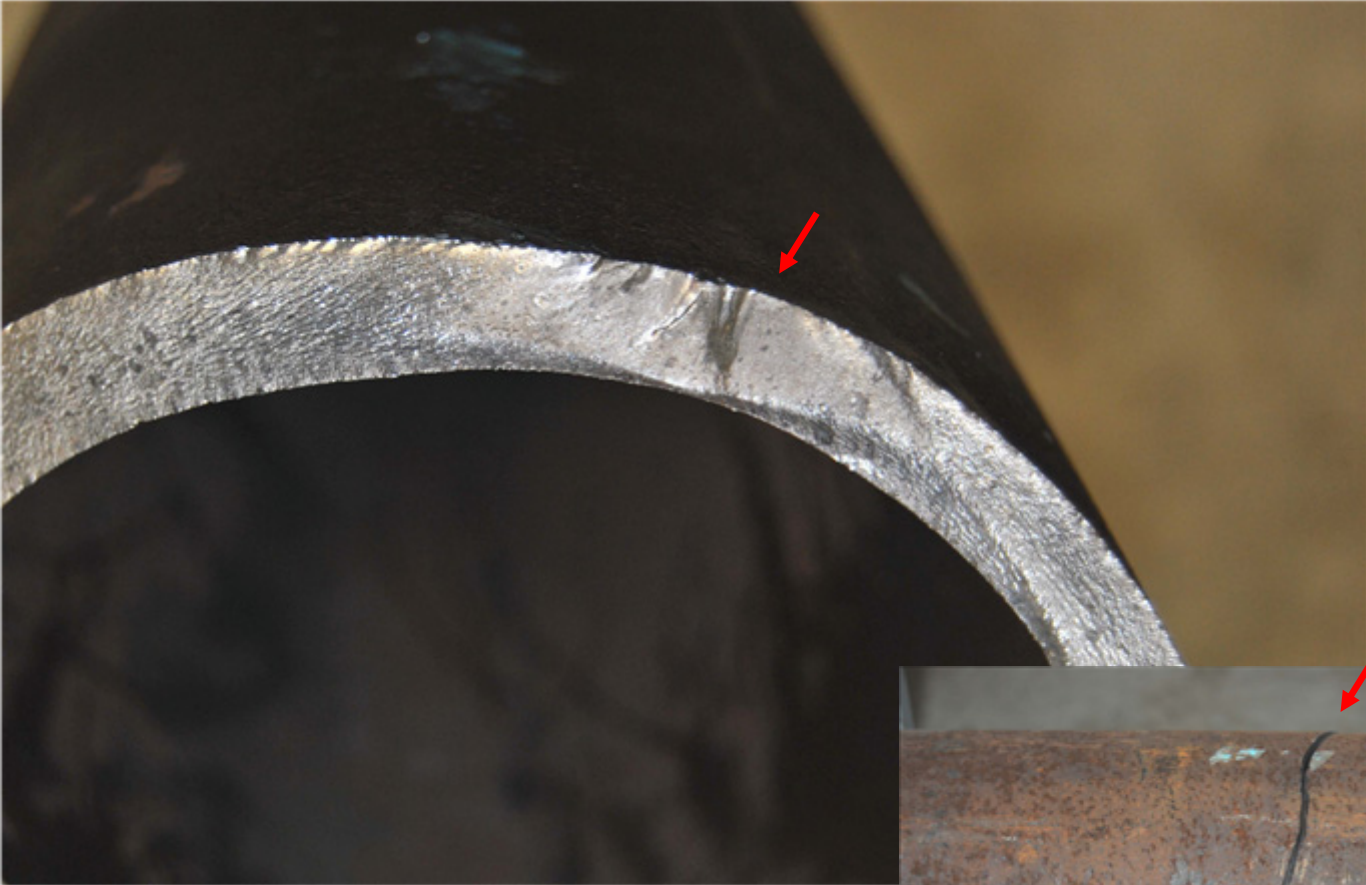


Test load control – Laser



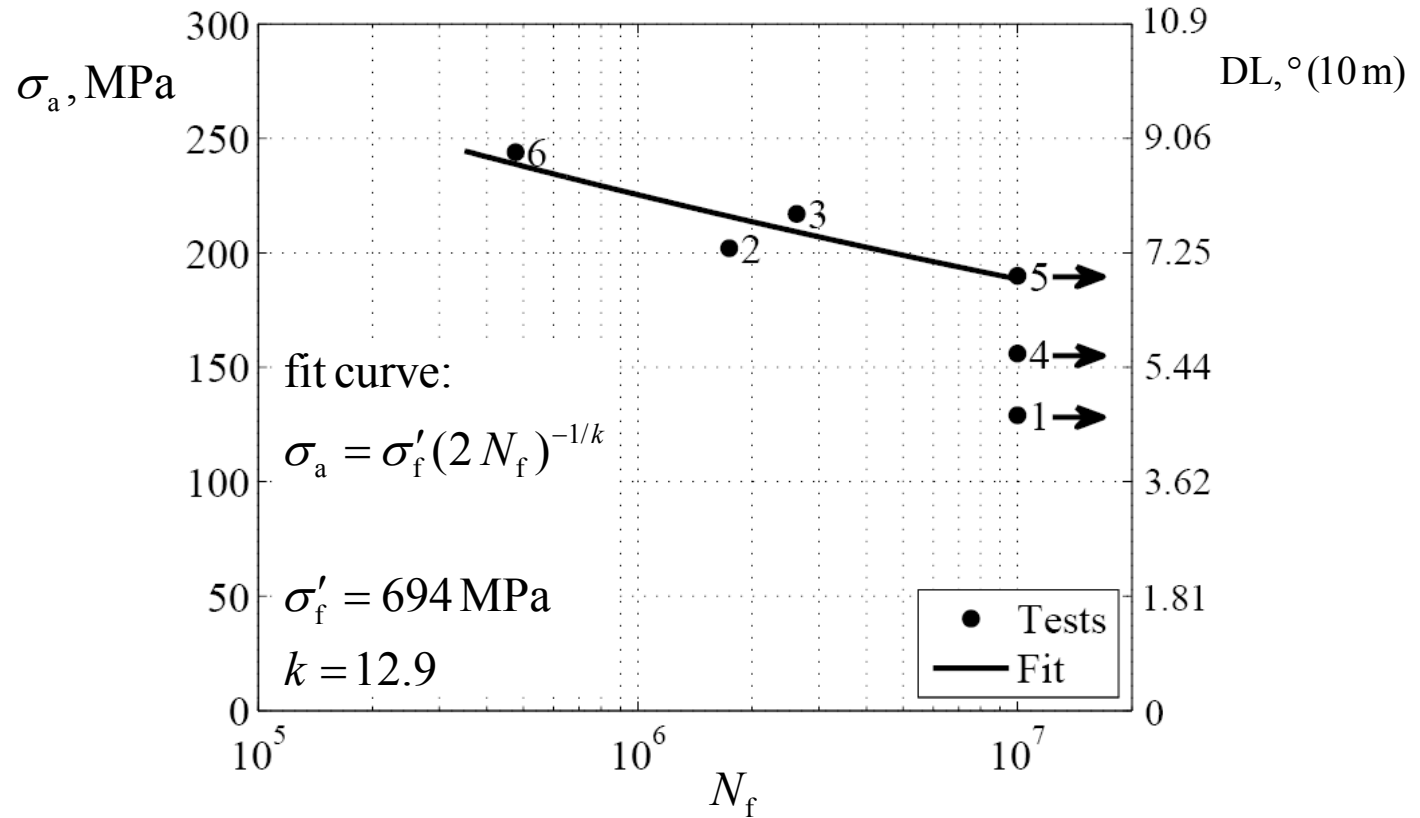
Laser displacement measure & control

Fatigue fracture



Test results

5-7/8x0.45"
S135 grade



Test n.	σ_a , MPa	R_C , m	DL, °(10m)	DL, °(100 ft)	N_f
1	129±7	123±6	4.66±0.22	14.2±0.66	run out
2	202±10	78±4	7.35±0.36	22.4±1.09	1.742×10 ⁶
3	217±11	73±4	7.85±0.41	23.9±1.24	2.621×10 ⁶
4	156±8	101±5	5.67±0.27	17.3±0.82	run out
5	190±10	83±4	6.90±0.32	21.0±0.97	run out
6	244±12	65±3	8.81±0.39	26.9±1.19	477×10 ³

Dog-Leg severity angle

$$\frac{1}{R_c} = \frac{2}{D_o} \frac{\sigma_a}{E}$$

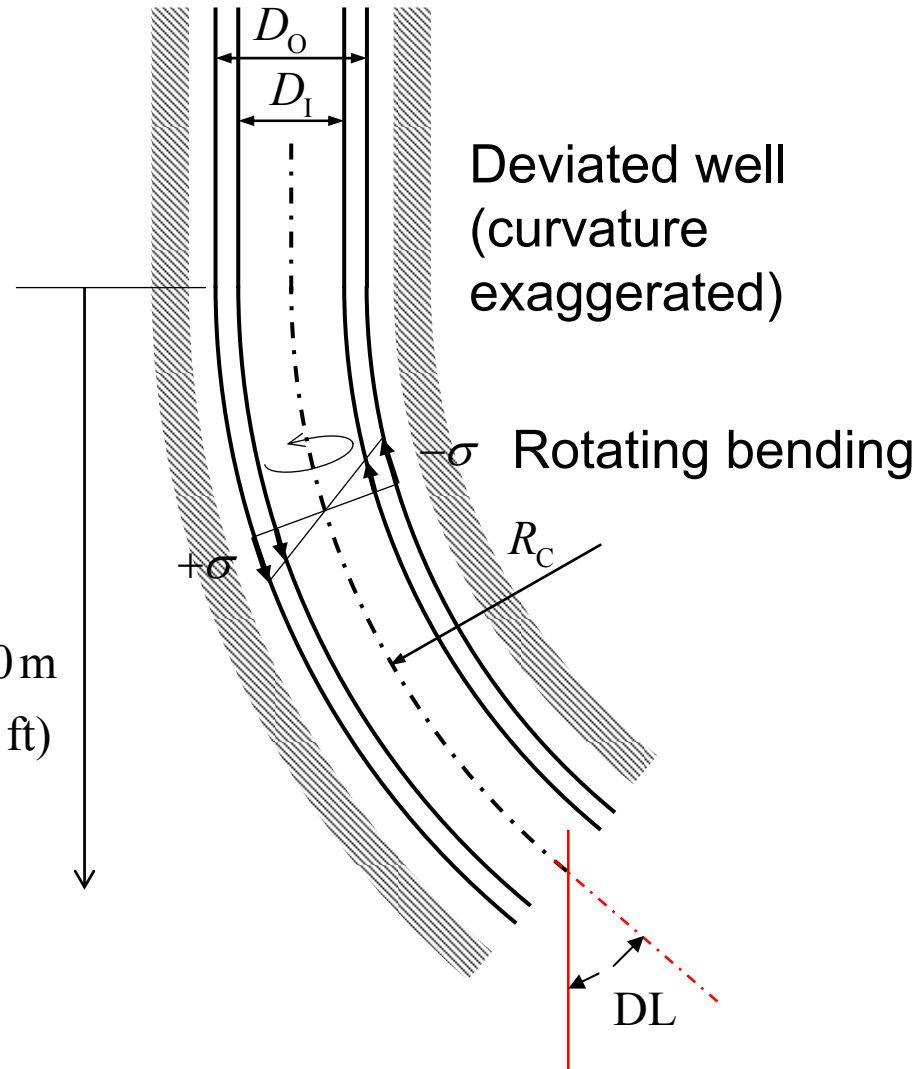
$$DL = \frac{H}{R_c} \frac{180}{\pi}$$

$$DL = H \frac{180}{\pi} \frac{2}{D_o} \frac{\sigma_a}{E}$$

DL [°], H = 10 m, D_o [m],
σ_a, E [MPa]

H = 10 m
(= 100 ft)

$$\sigma_a \leftrightarrow \frac{1}{R_c} \leftrightarrow DL (H = 10 \text{ m})$$



Dog-Leg severity, axial load effect

$$DL = H \frac{180}{\pi} \frac{2}{D_o} \frac{\sigma_a}{E} \frac{\tanh(KL)}{KL},$$

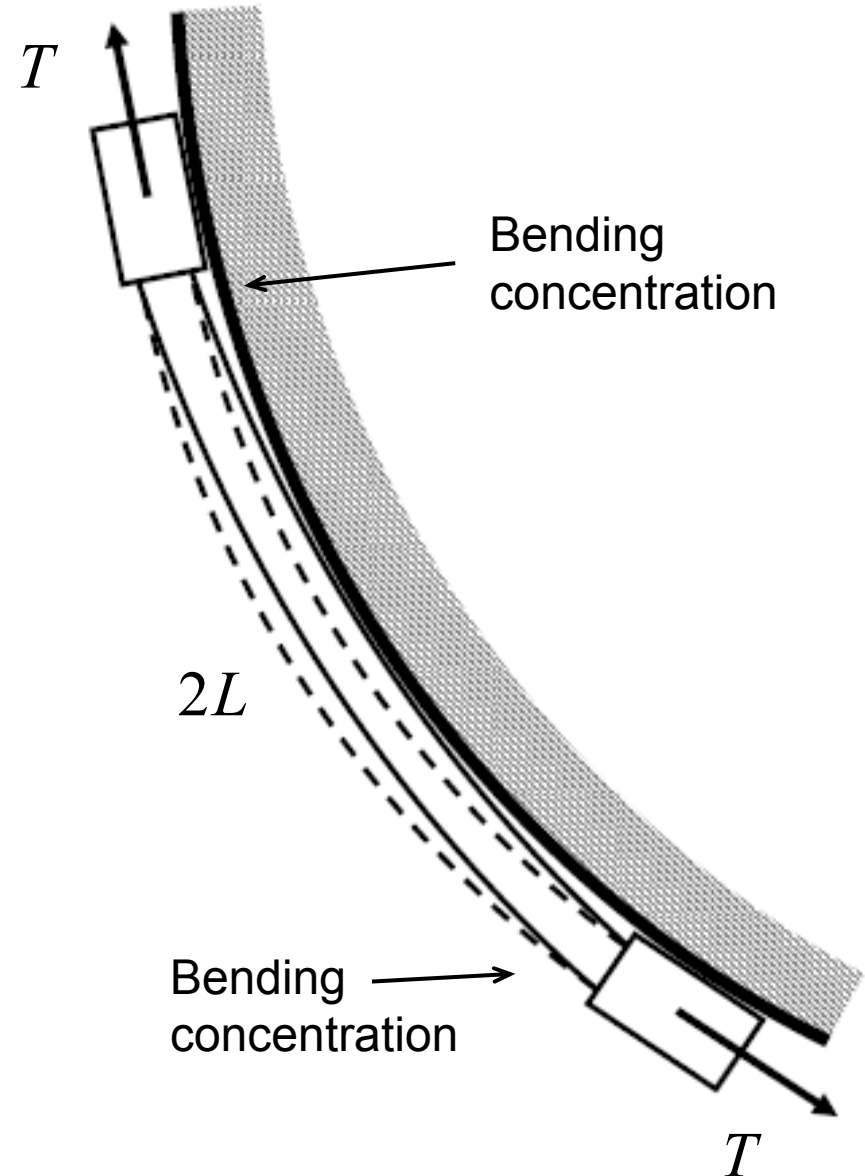
$$KL = \sqrt{\frac{T}{EI}},$$

$$I = \frac{\pi}{64} (D_o^4 - D_i^4)$$

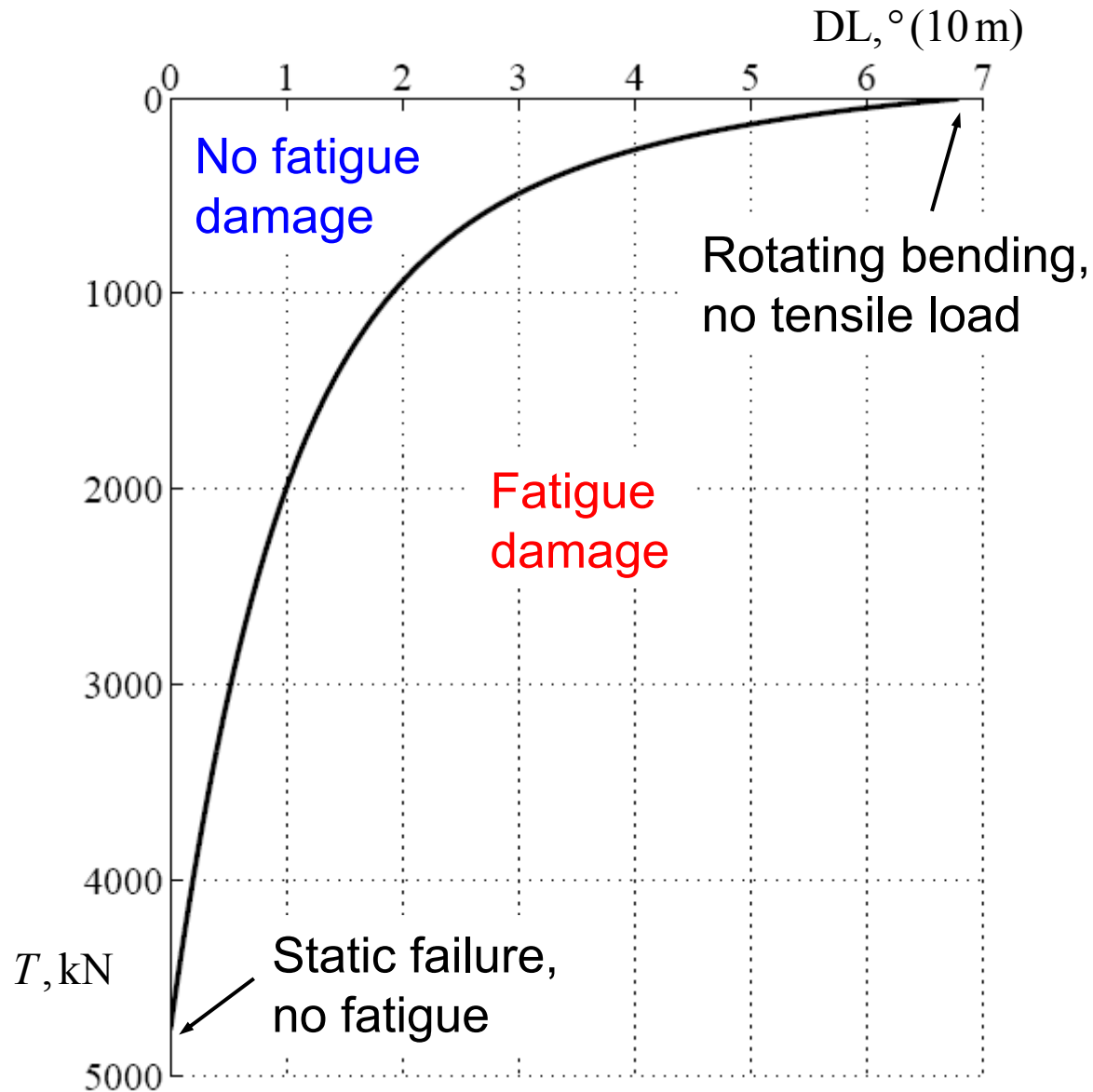
$$\sigma_m = \frac{T}{A},$$

$$A = \frac{\pi}{4} (D_o^2 - D_i^2)$$

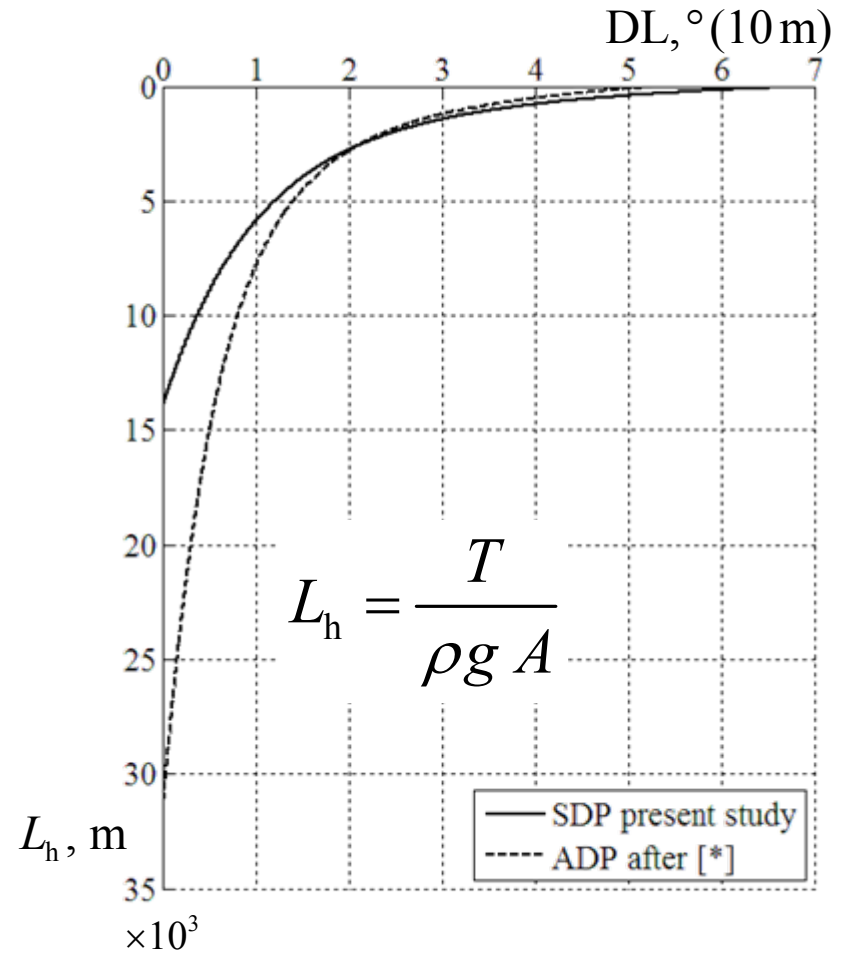
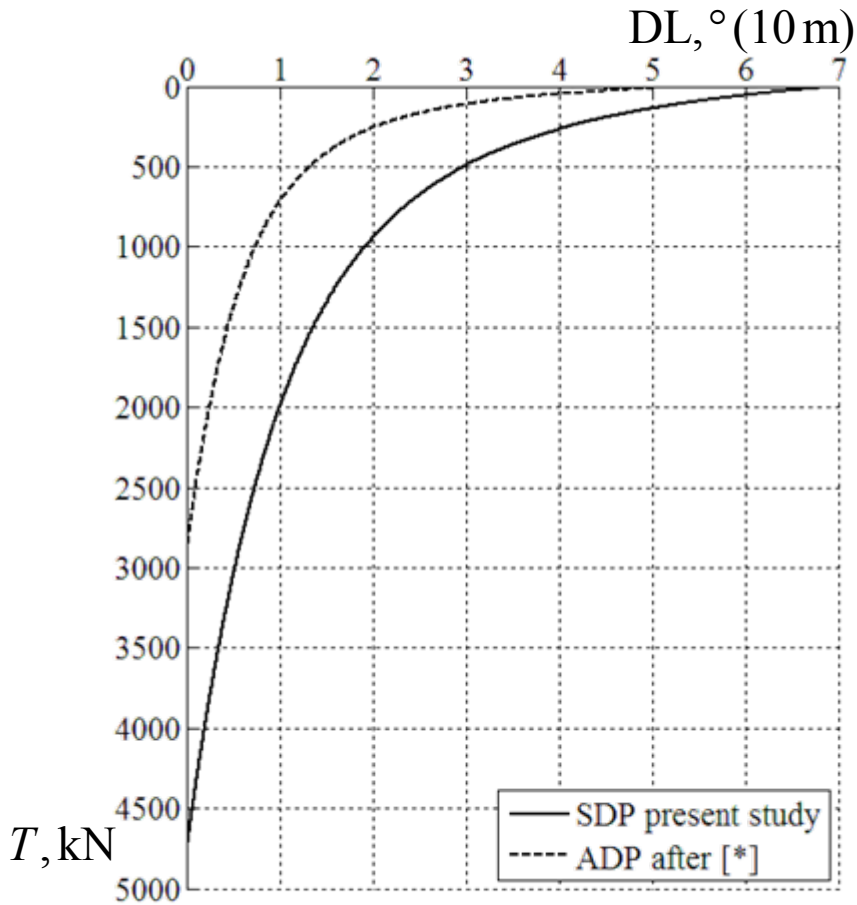
$$\sigma_{a,\max} = S_n \left(1 - \frac{\sigma_m}{S} \right) \text{ (Goodman)}$$



Dog-Leg severity vs. axial load graph



Connection strength comparisons



[*] 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, 30(6):978–988, 2008.

Conclusions

- Resonant test rig for Steel Drill Pipe *full scale* fatigue:
 - light frame of the testing machine
 - high frequency testing.
- Steel drill pipe fatigue fracture away from the connection region.
- Fatigue limit 5-7/8x0.45” S135 grade: $\sigma_a = 190$ MPa, DLS = 6.9° (H = 10 m).
- Comparison graphs:
 - dog-leg severity / axial load,
 - dog-leg severity / hung length.