Nonlinear wave loads on fixed offshore turbines; II – ringing

LES in marine hydrodynamics and offshore wind power, part II, Lyngby, 24-26 August 2011

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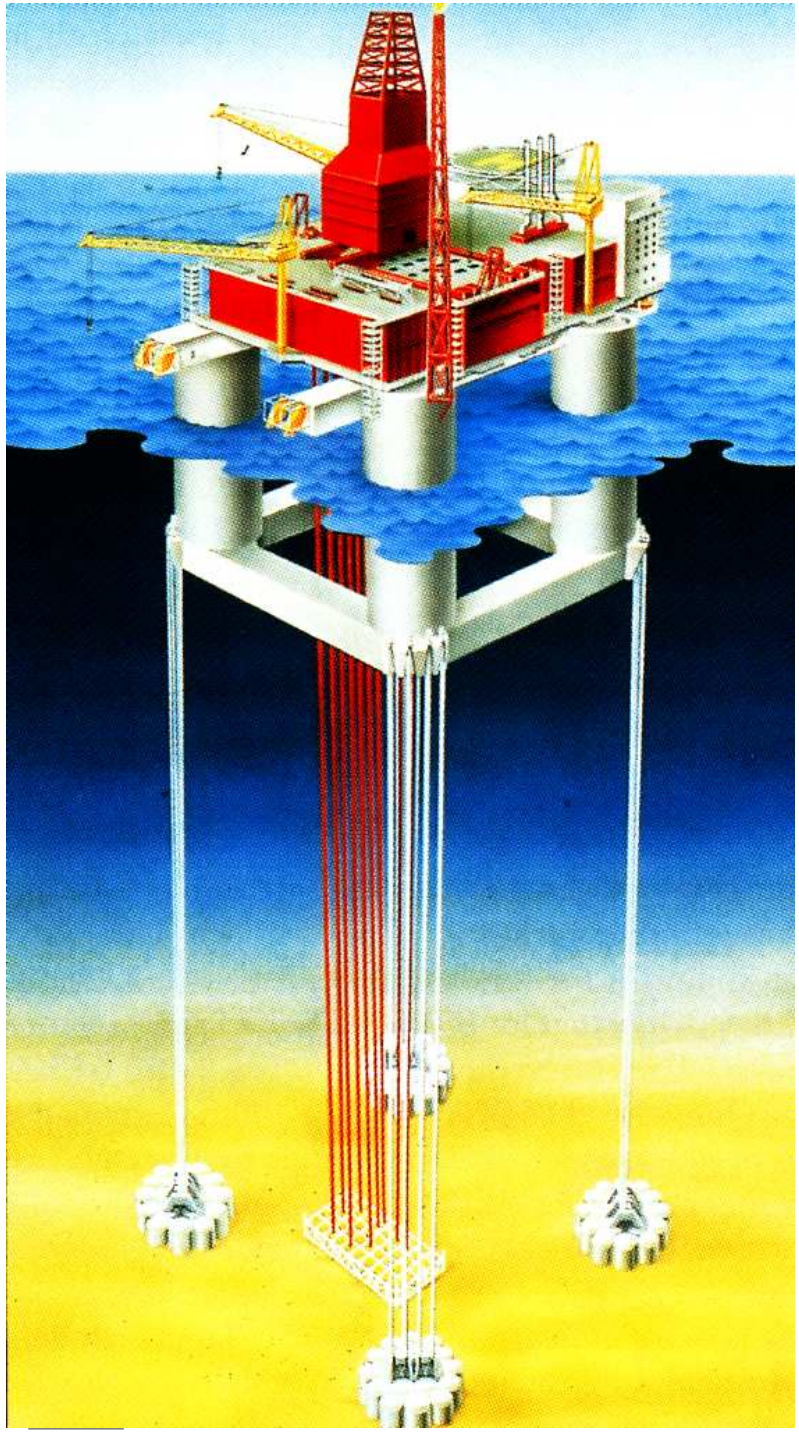
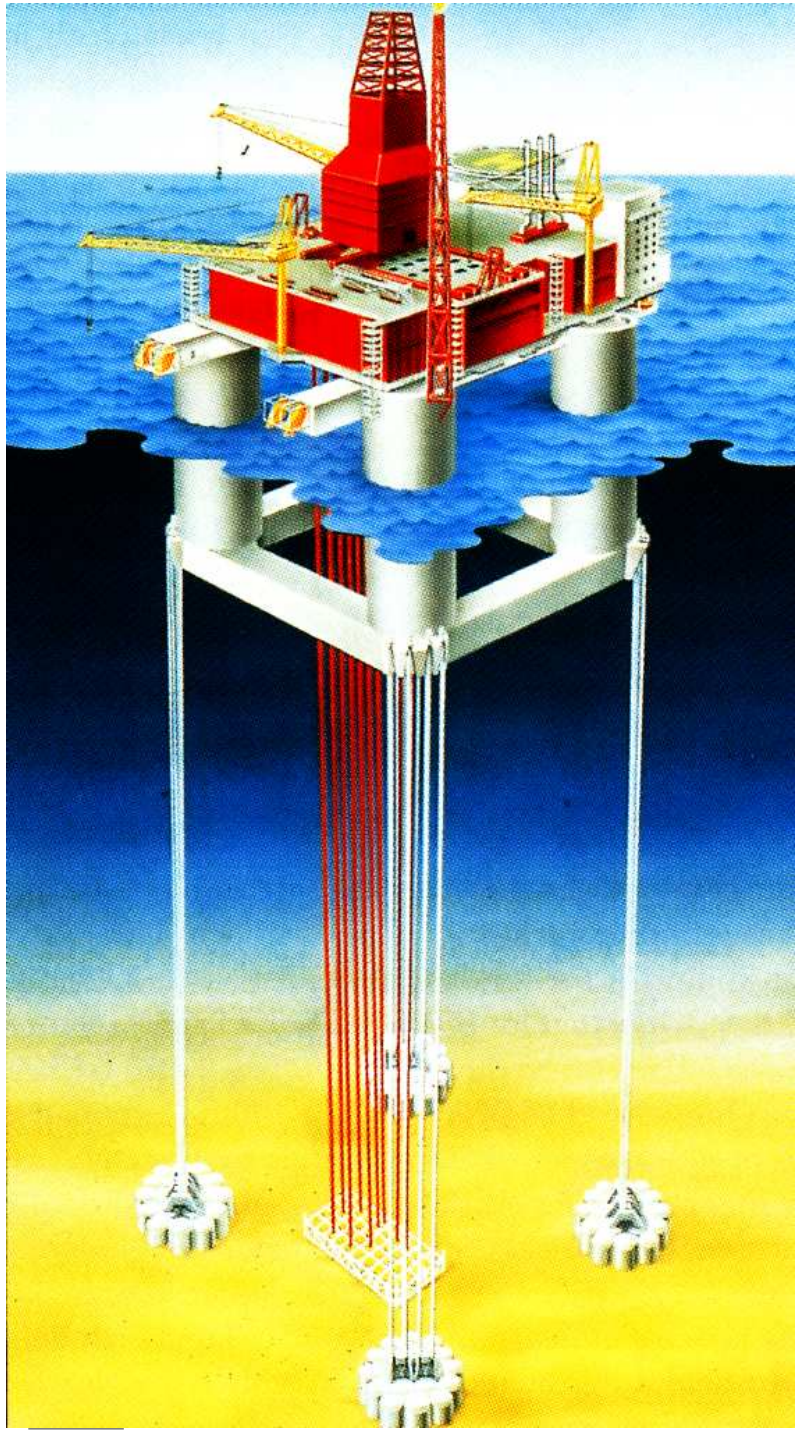
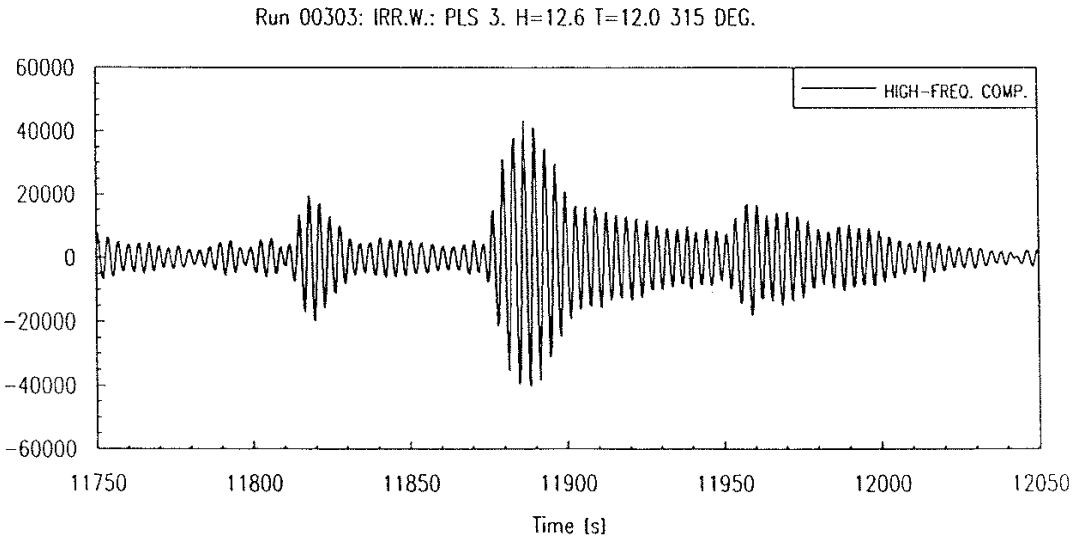
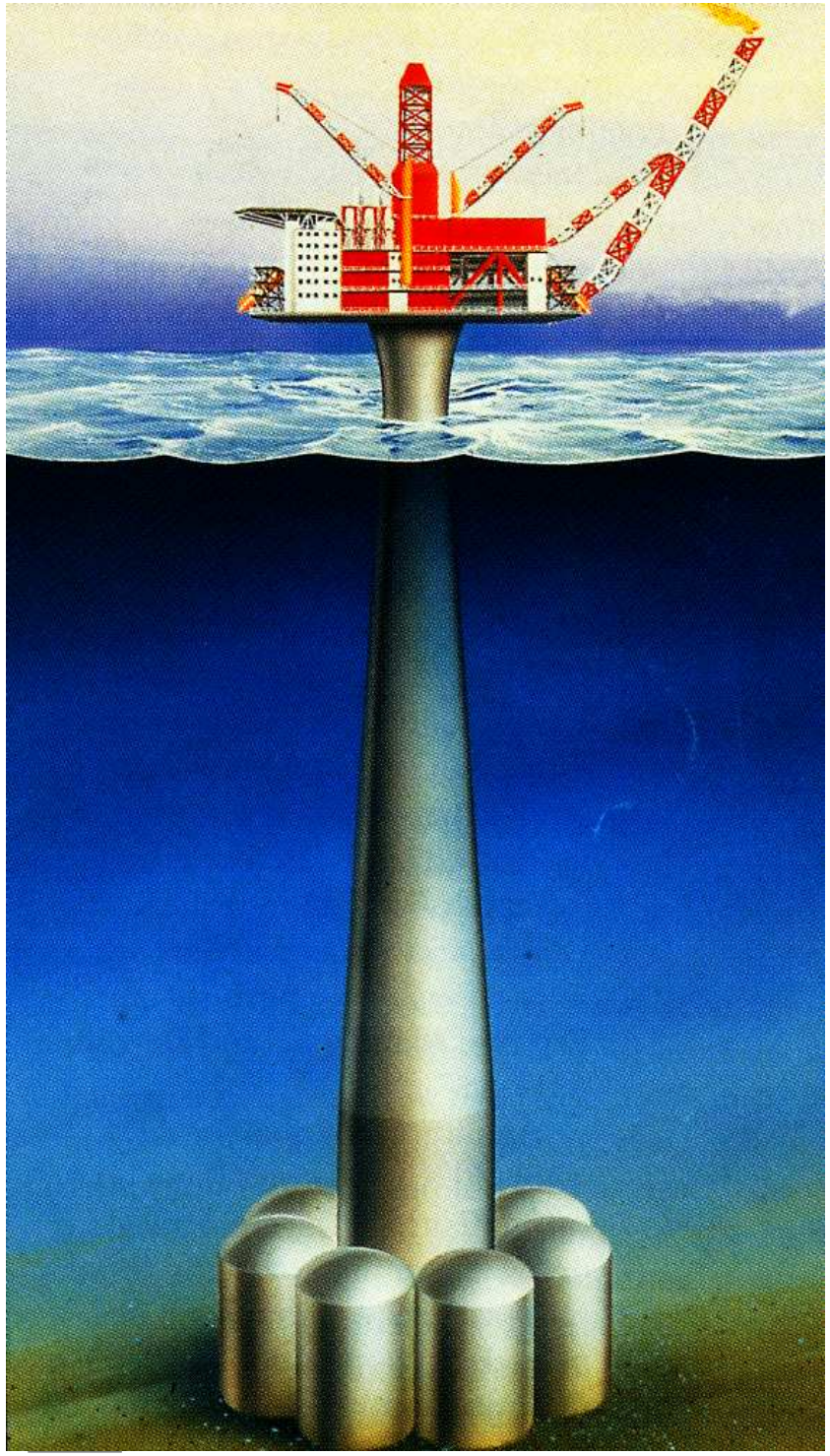


Heidrun platform

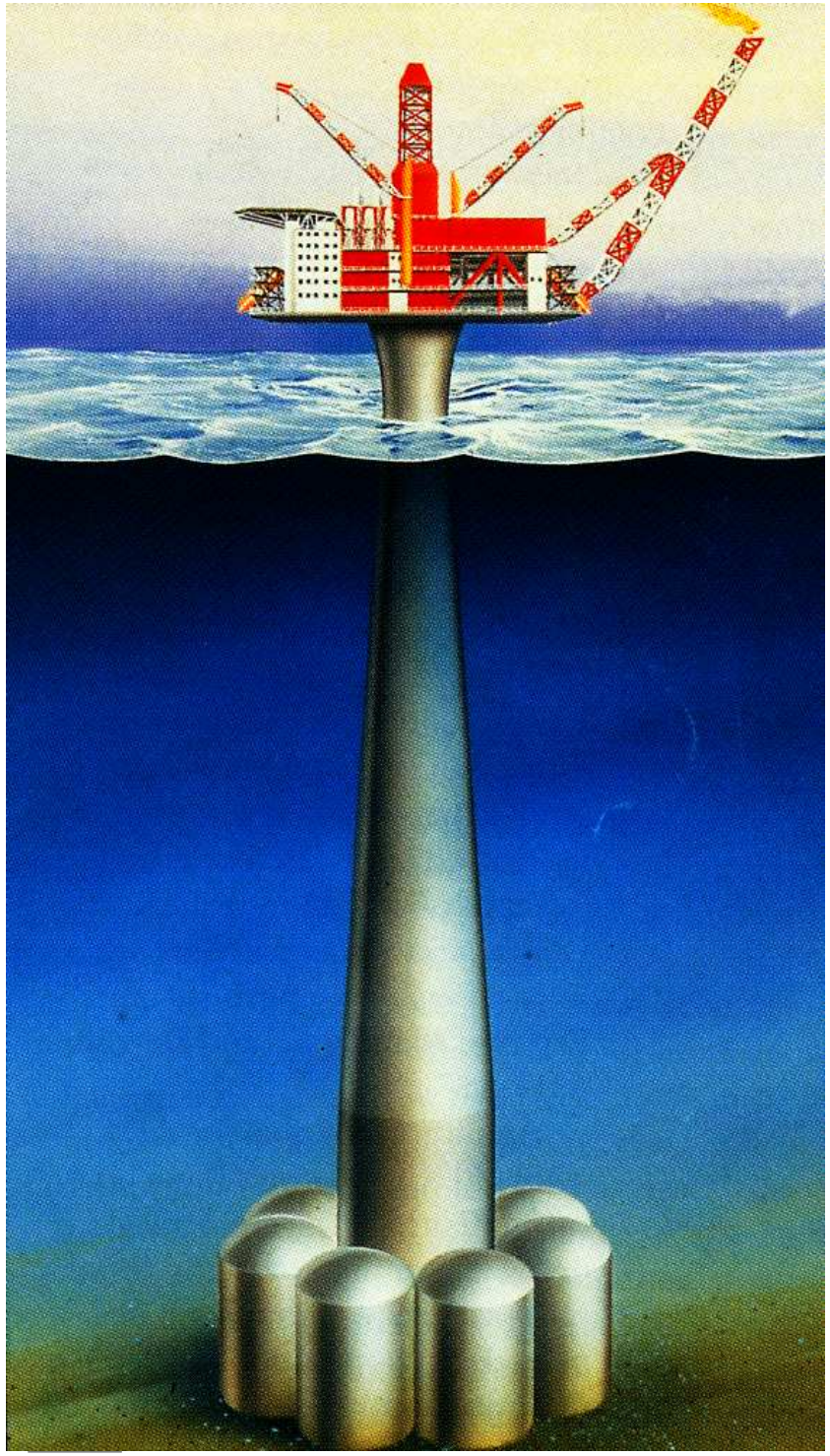


Heidrun platform

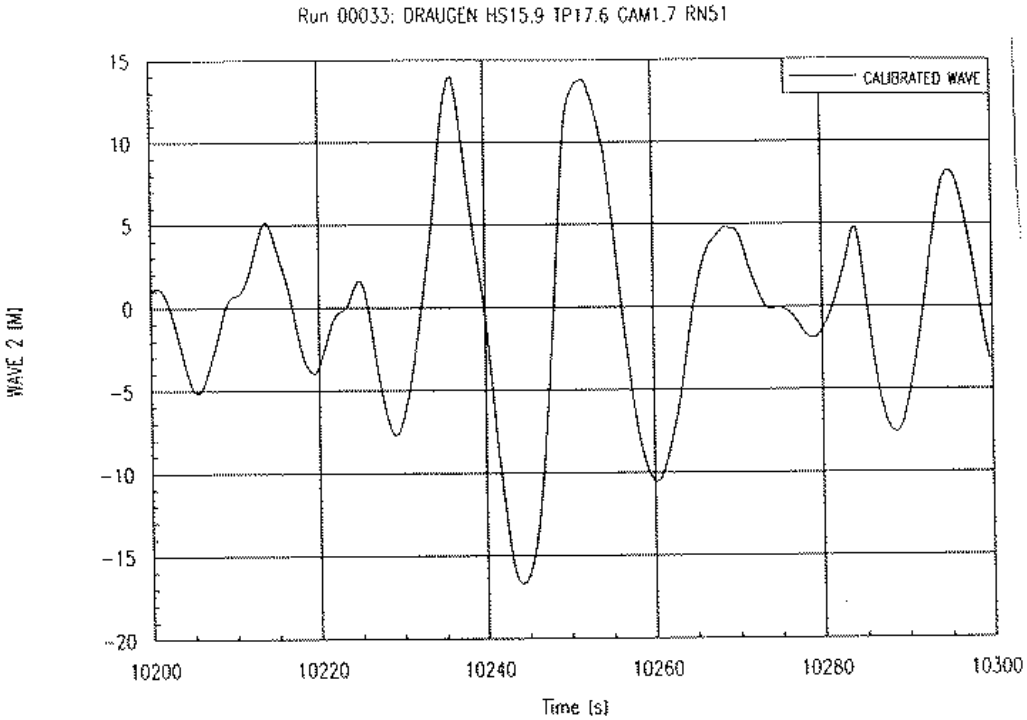


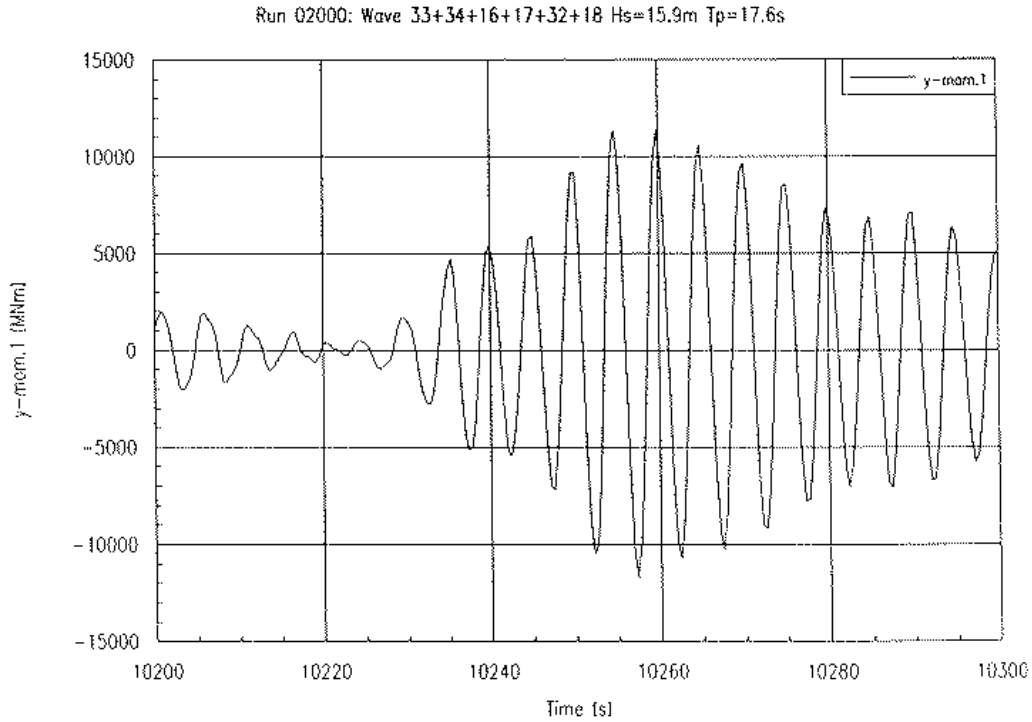


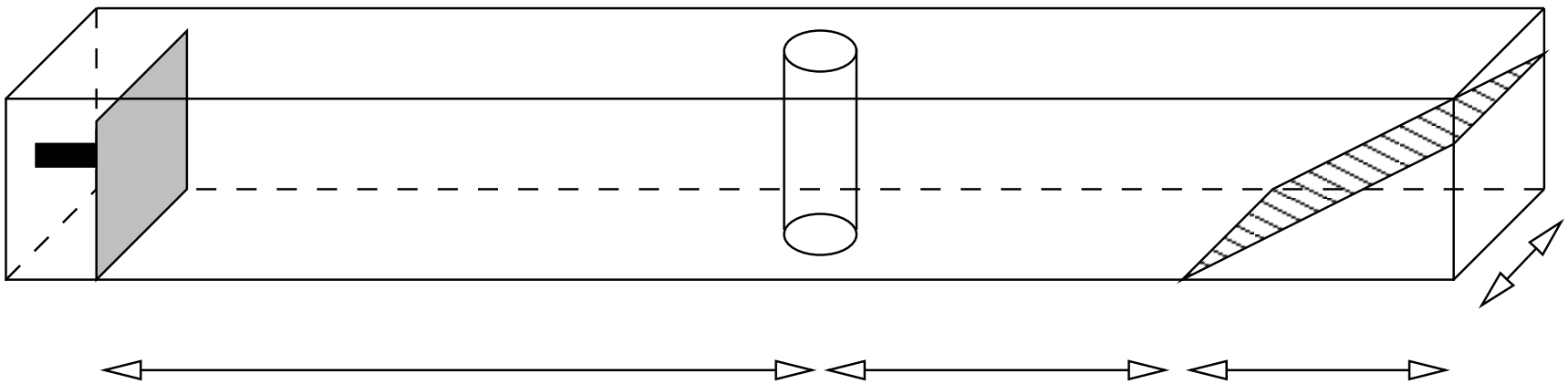
Draugen platform



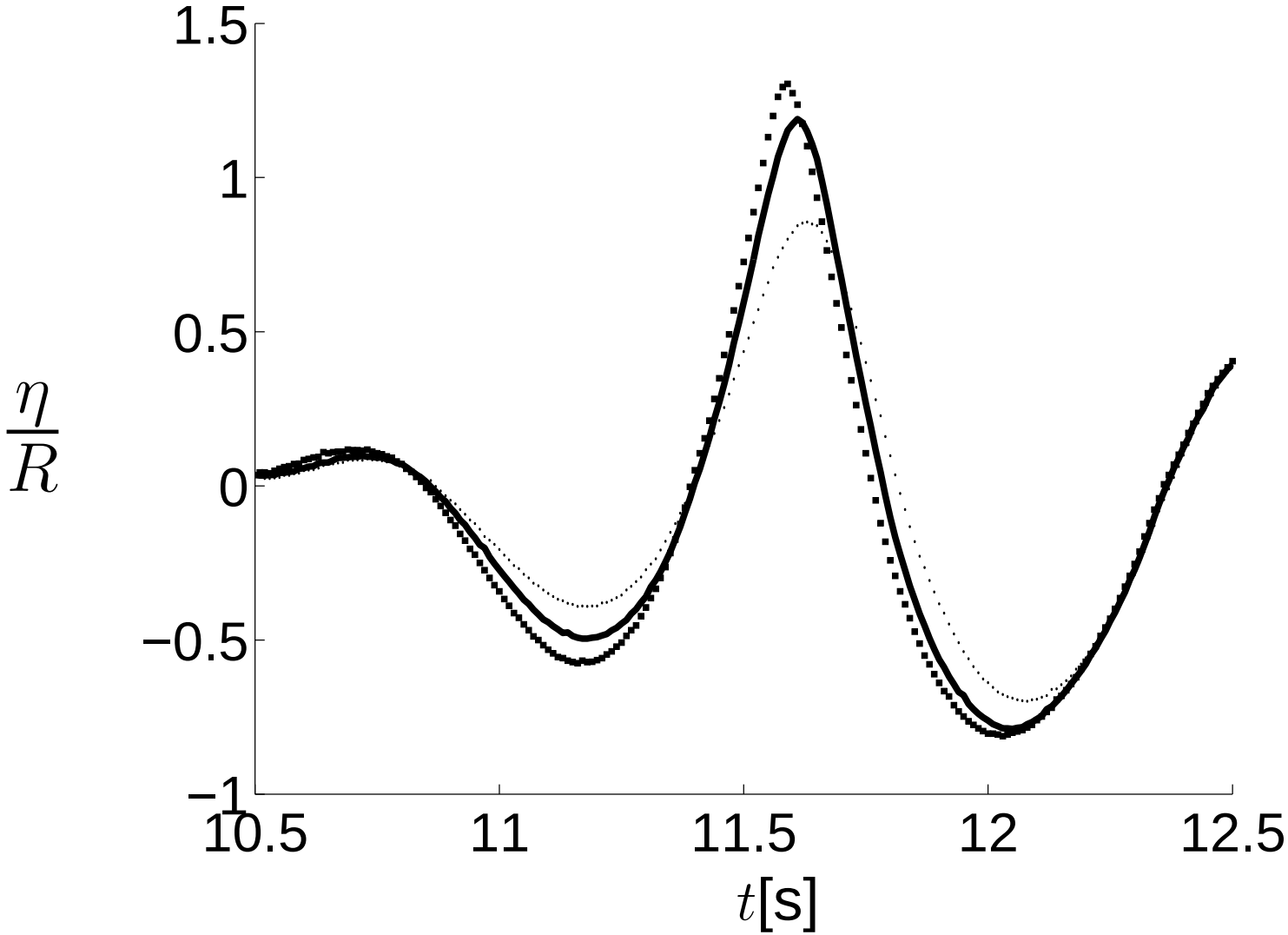
Draugen platform



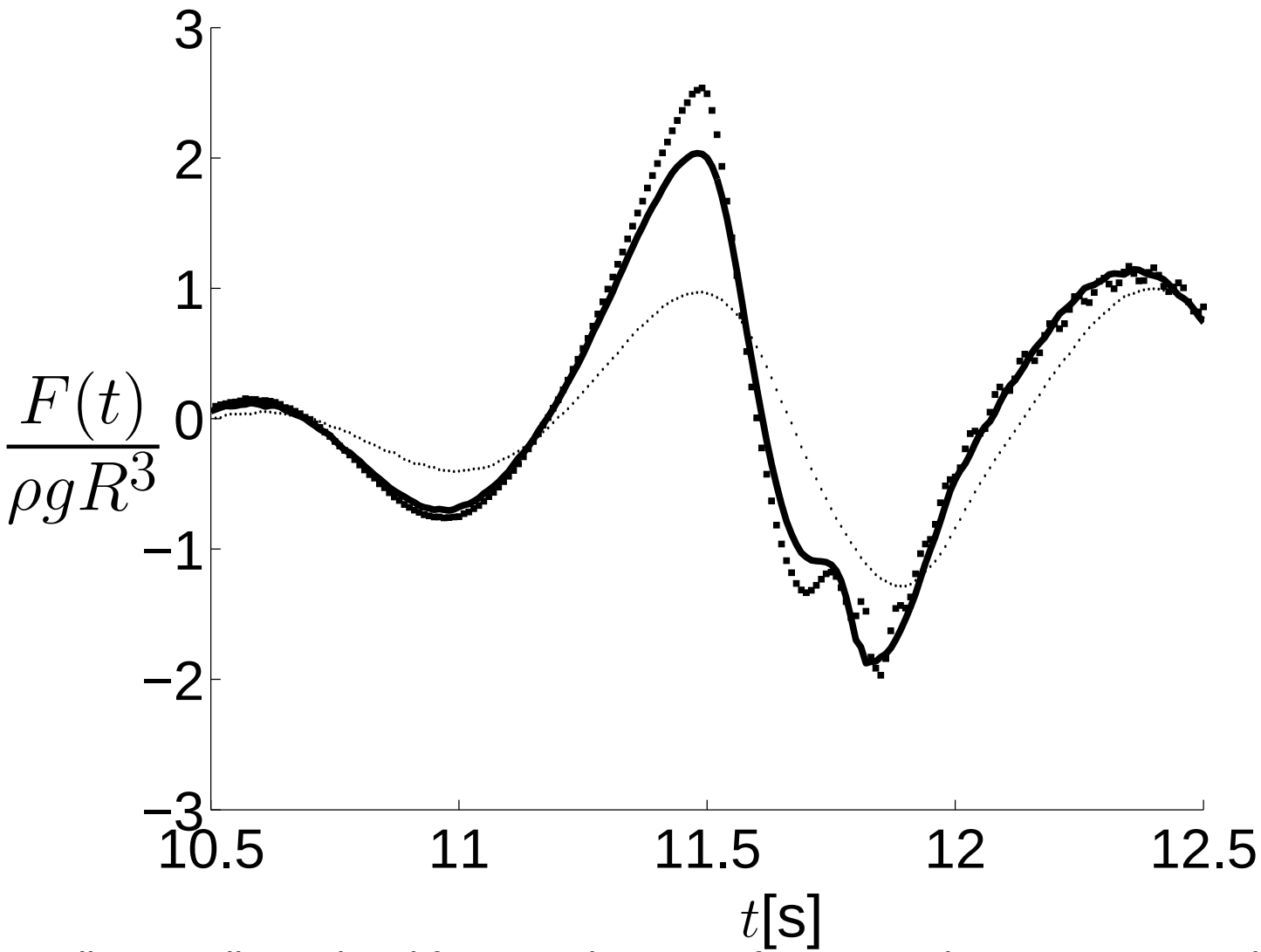




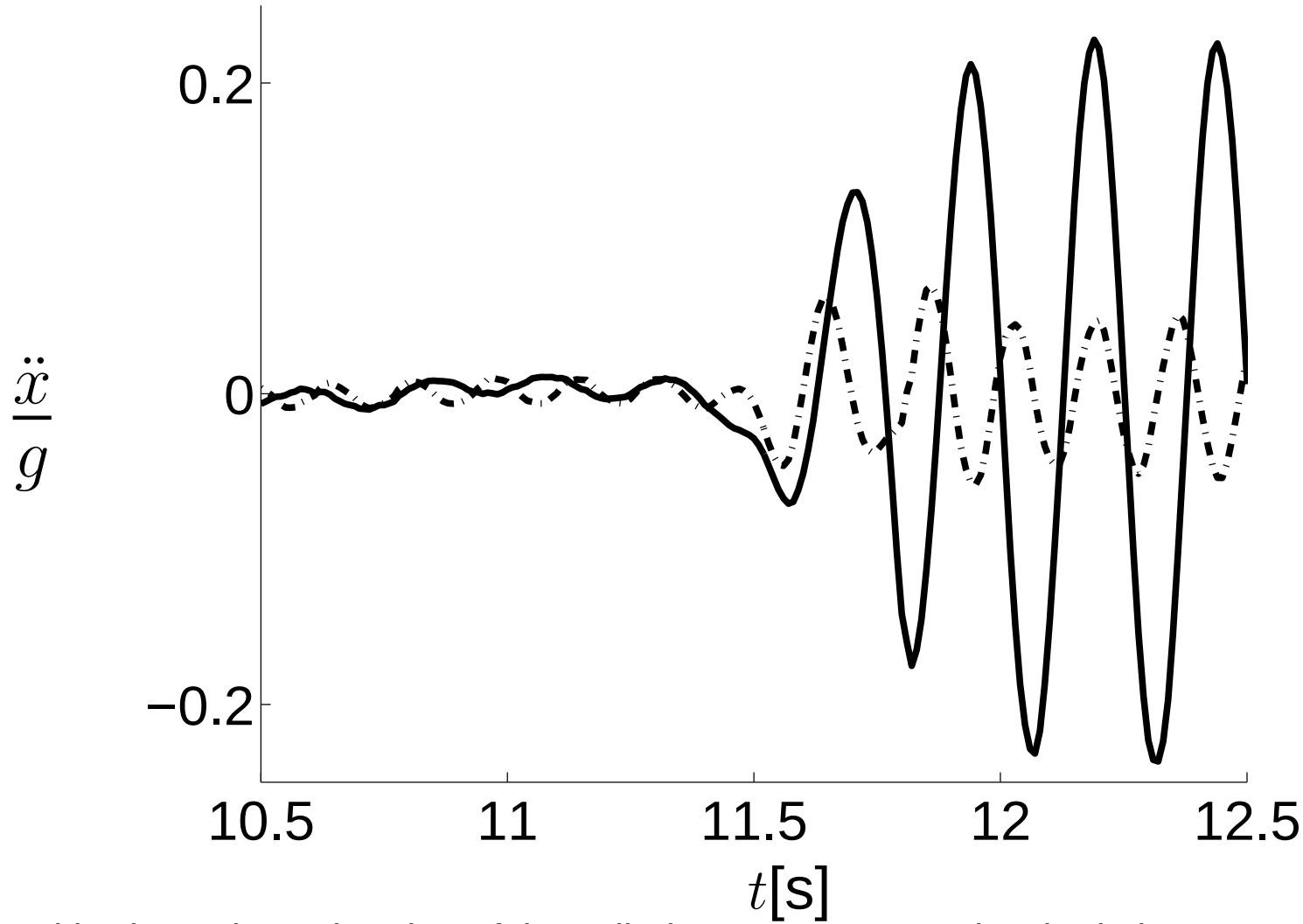
Wave tank experiments in focusing waves and irregular waves



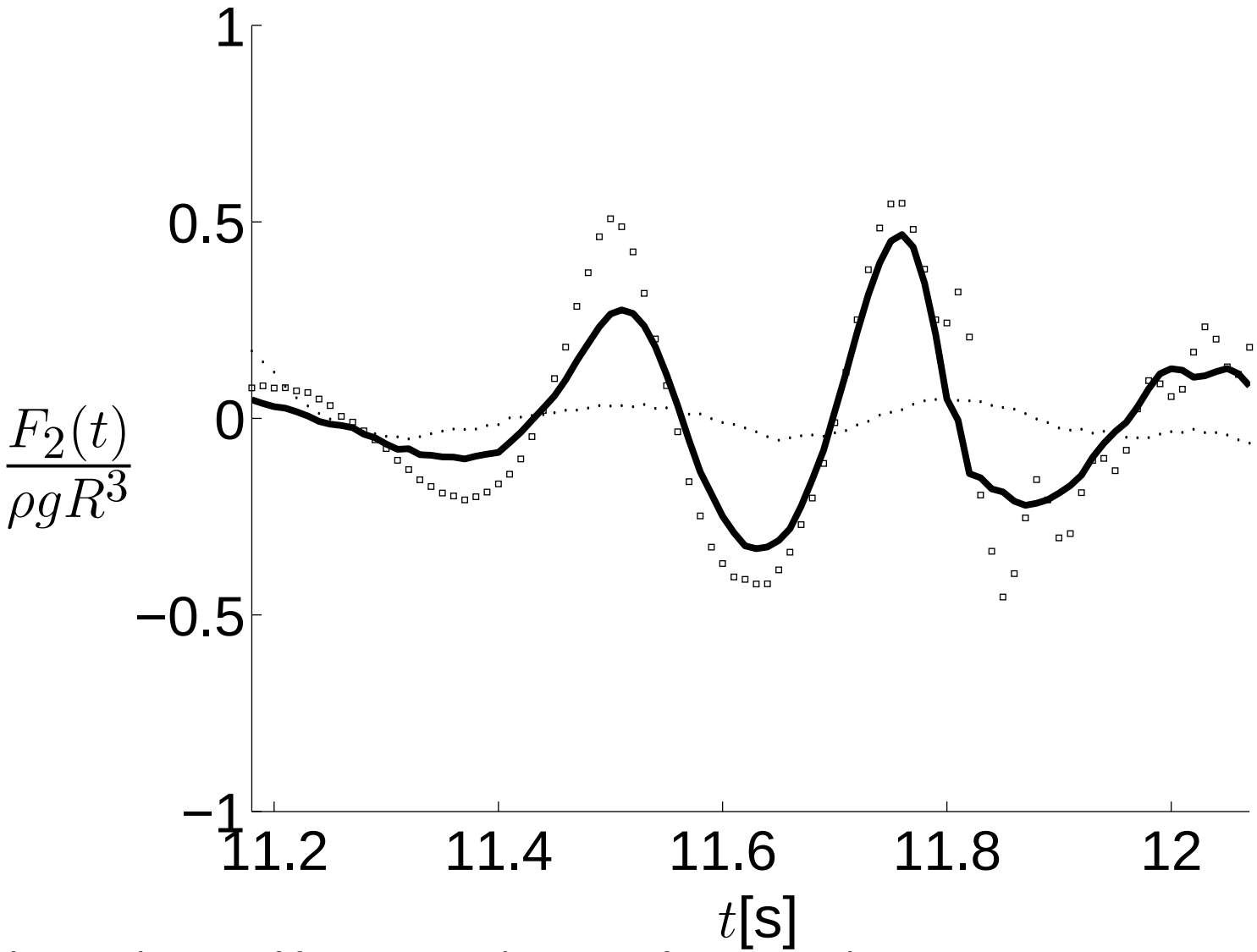
Wave elevation at the cylinder position; $k\eta_m$=0.23 (....), 0.33 (—-), 0.37 (- - -); Grue&Huseby'02



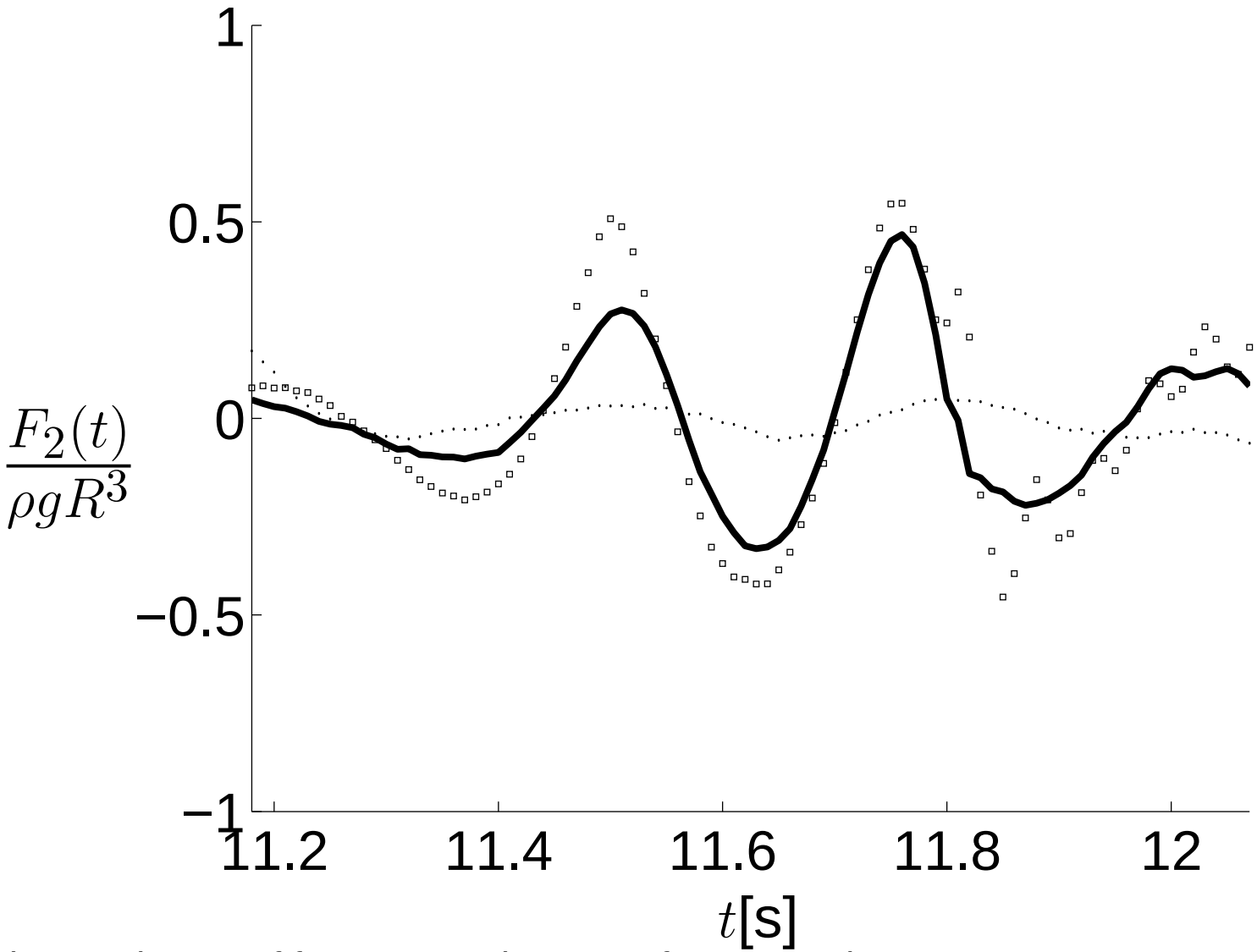
Corresponding nondimensional force on the upper force transducer; Grue&Huseby'02



Simulated horizontal acceleration of the cylinder at mean water level relative to g. $k\eta_m$=0.33. $\sigma/\omega = 4$ (solid line), $\sigma/\omega = 6$ (dash-dotted line). kR=0.27–28. $R = 5.95$ cm; Grue&Huseby'02



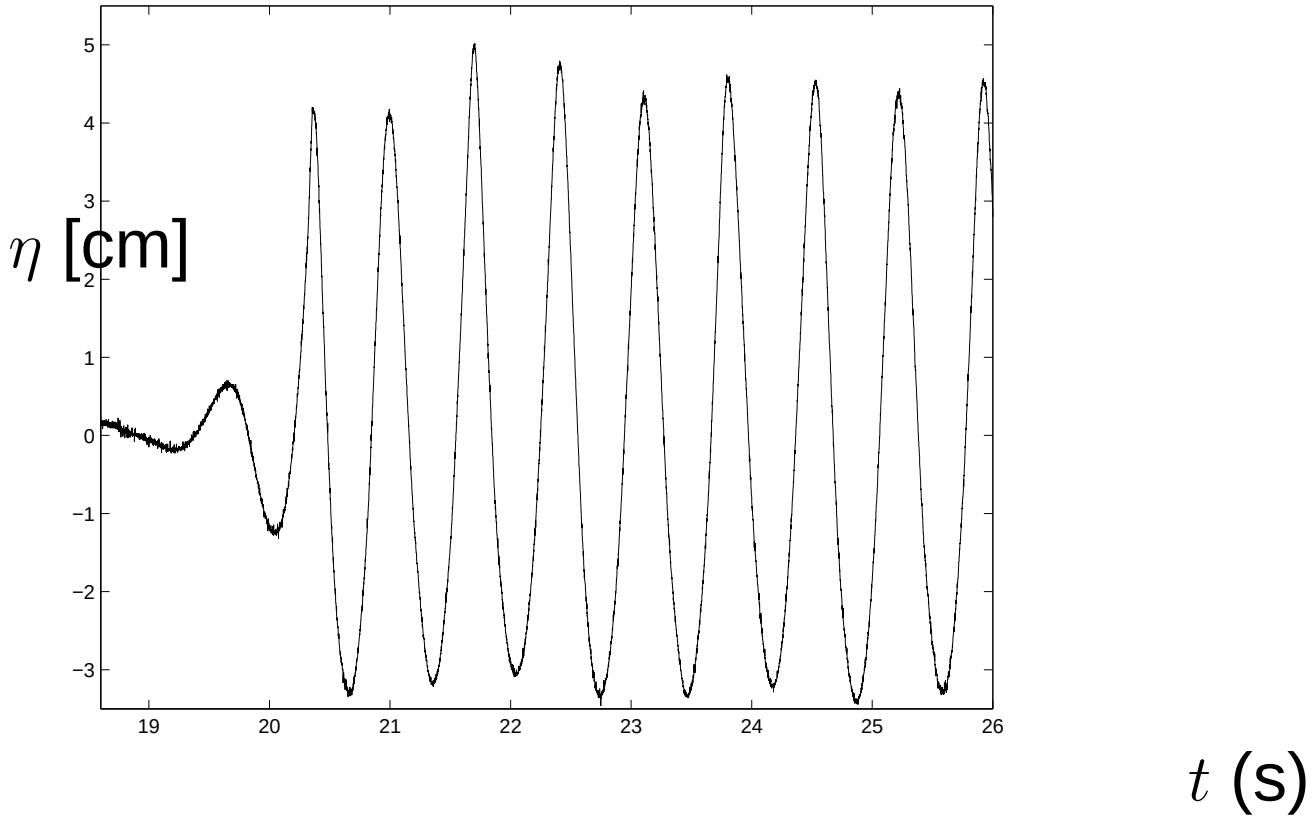
Higher harmonic part of force F_2 on the upper force transducer.
$k\eta_m$=0.23 (thin dots), 0.33 (solid line), 0.37 (small squares).



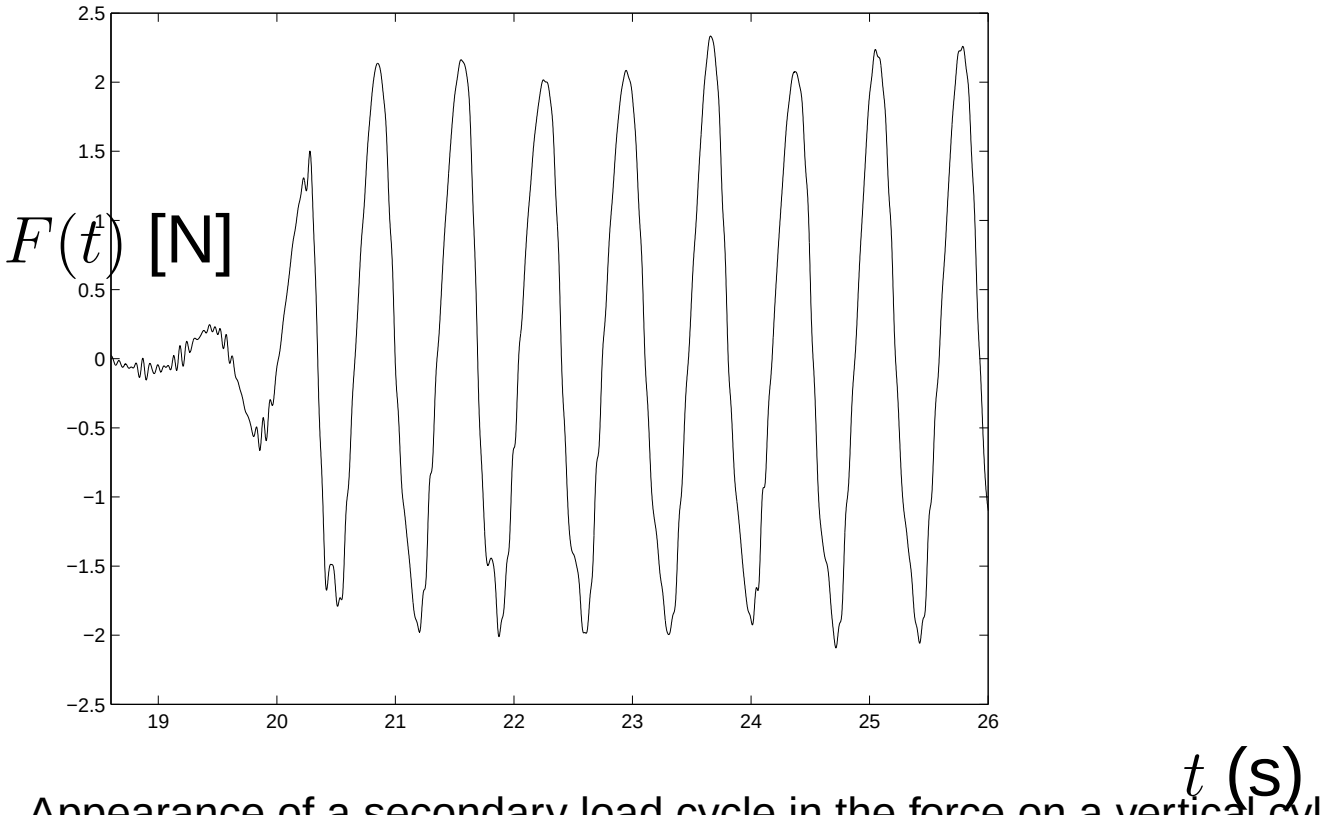
Higher harmonic part of force F_2 on the upper force transducer.

Note: peak to peak higher harmonic force is about 0.8; FNV gave $|F_3|/\rho g A^3 = 2\pi(kR)^2 \sim 0.57$

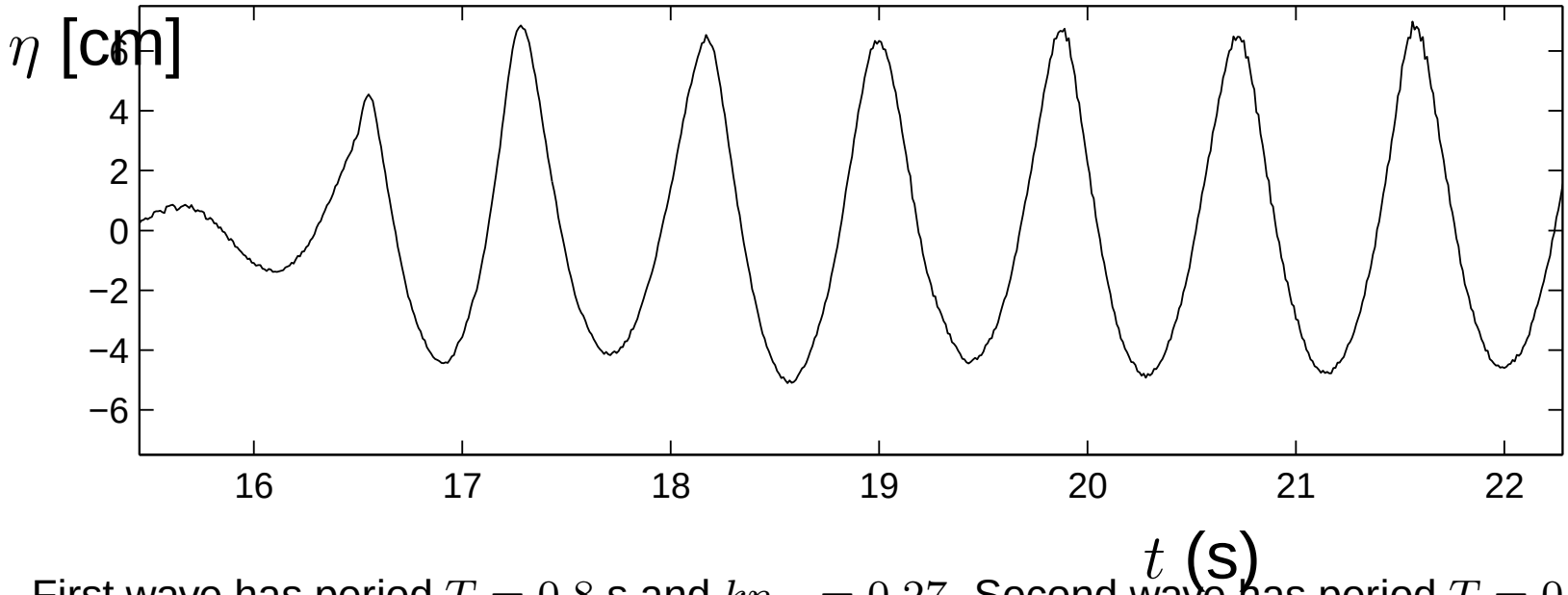
for $kR \sim kA$, which is the case here.



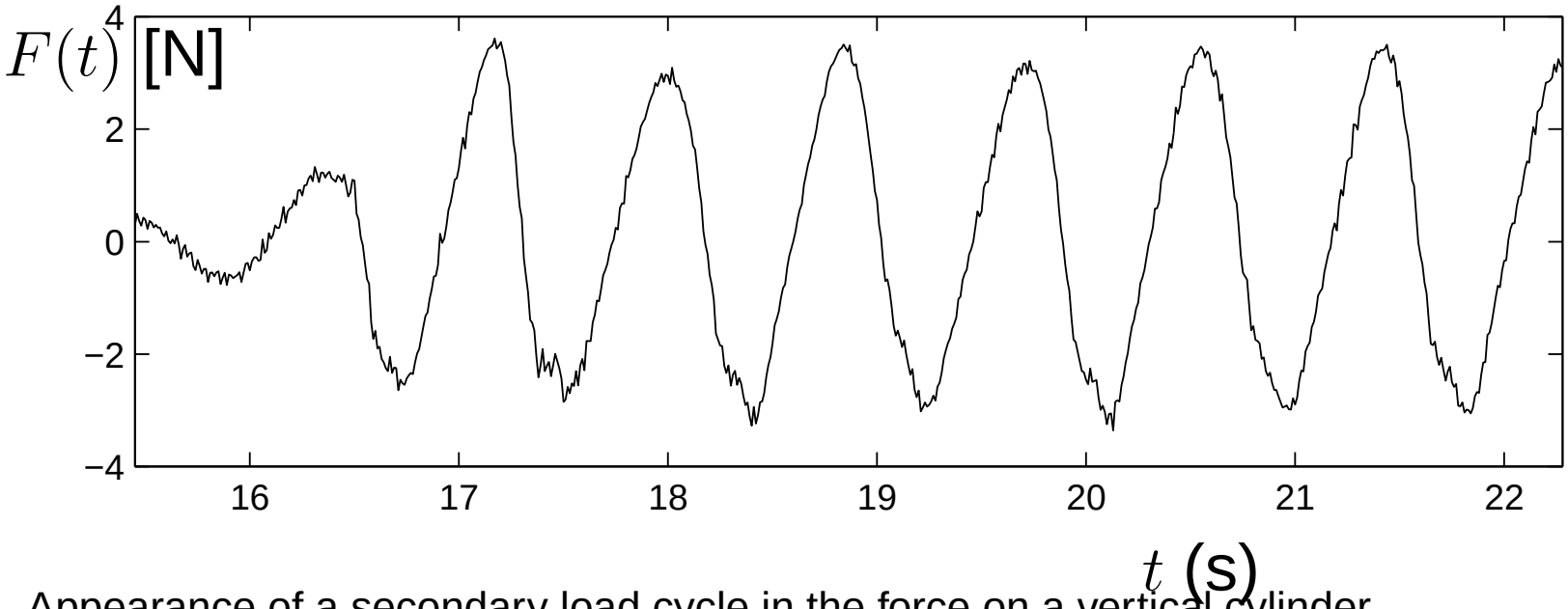
First wave has period $T = 0.62$ s and $k\eta_m = 0.38$. Second wave has period $T = 0.69$ s and $k\eta_m = 0.32$. Periodic part has period $T = 0.7$ s and $k\eta_m = 0.34$.



Appearance of a secondary load cycle in the force on a vertical cylinder.

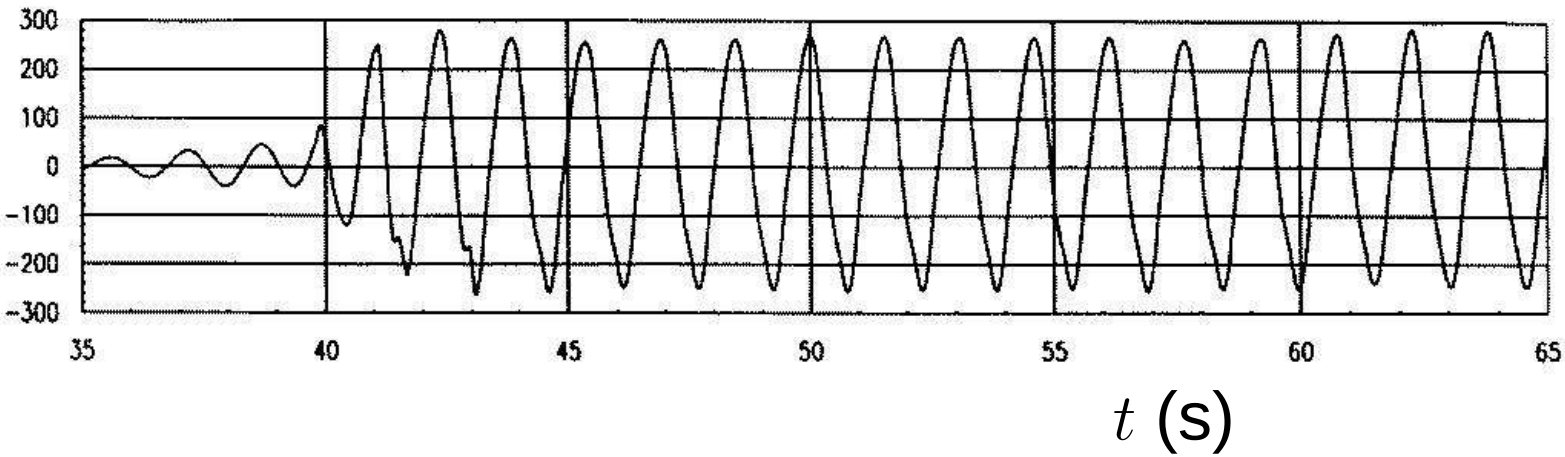


First wave has period $T = 0.8$ s and $k\eta_m = 0.27$. Second wave has period $T = 0.79$ s and $k\eta_m = 0.38$. Periodic part has period $T = 0.86$ s and $k\eta_m = 0.34$.

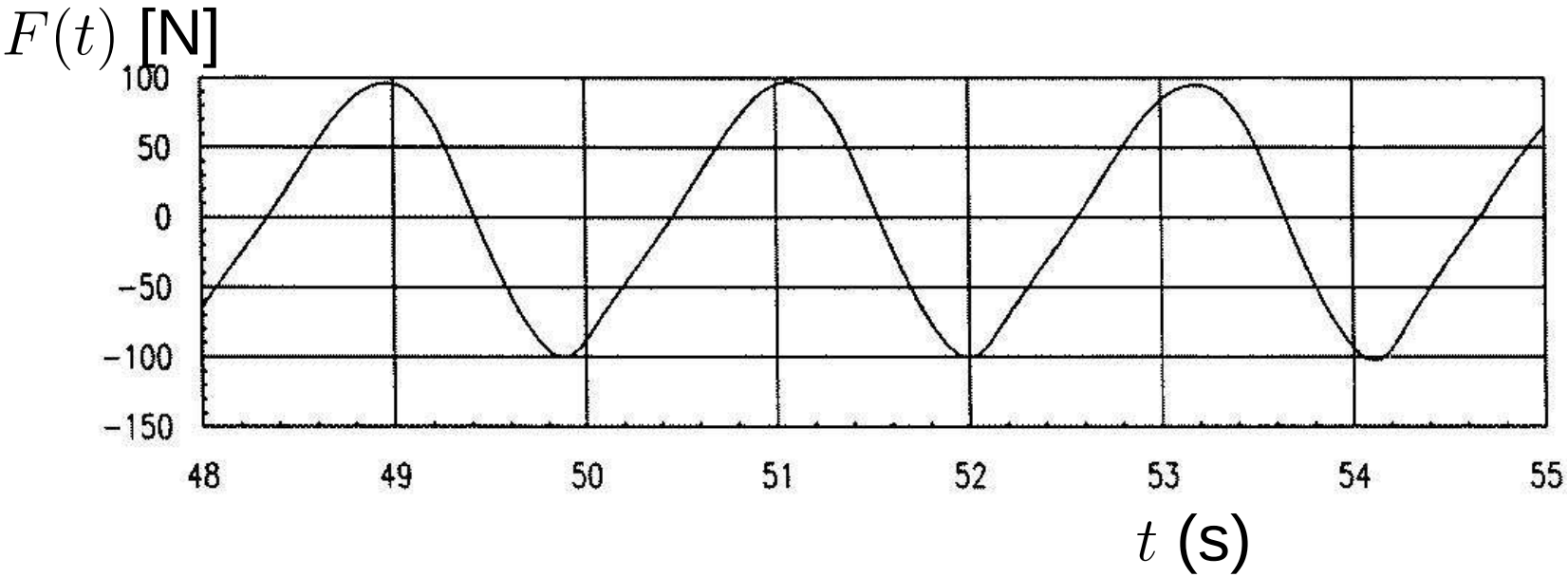


Appearance of a secondary load cycle in the force on a vertical cylinder.
Cylinder radius 3 cm.

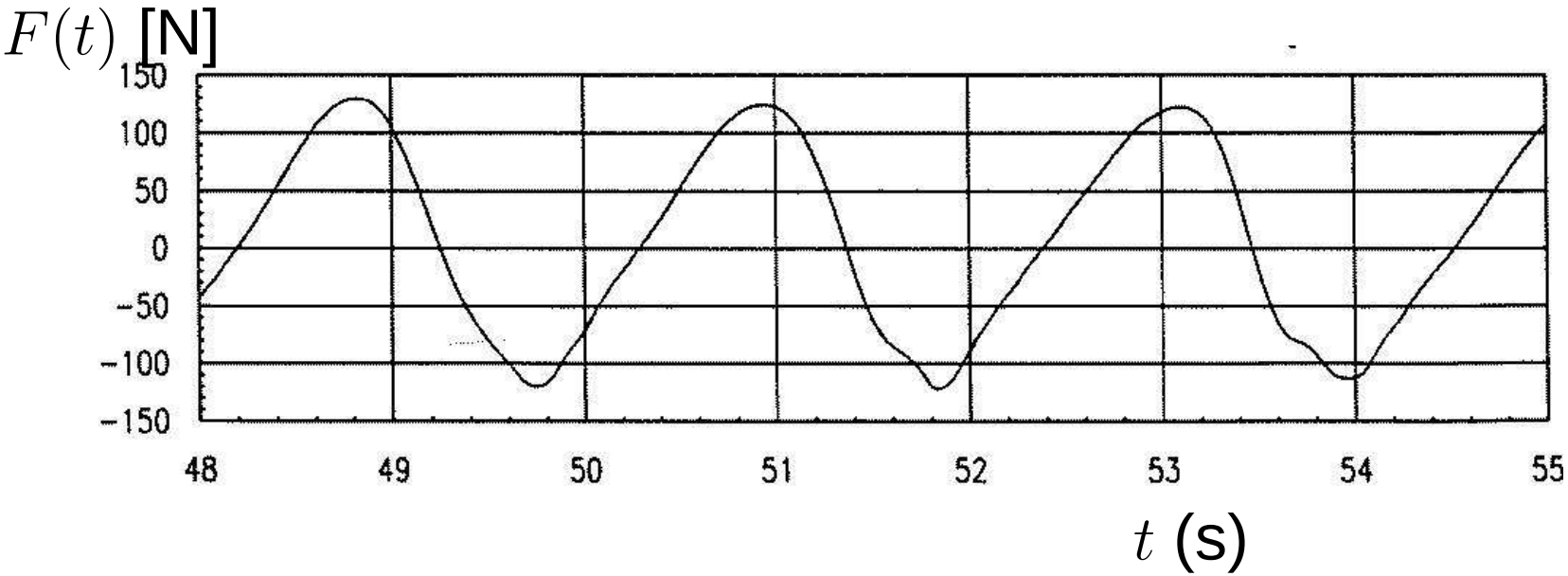
$F(t)$ [N]



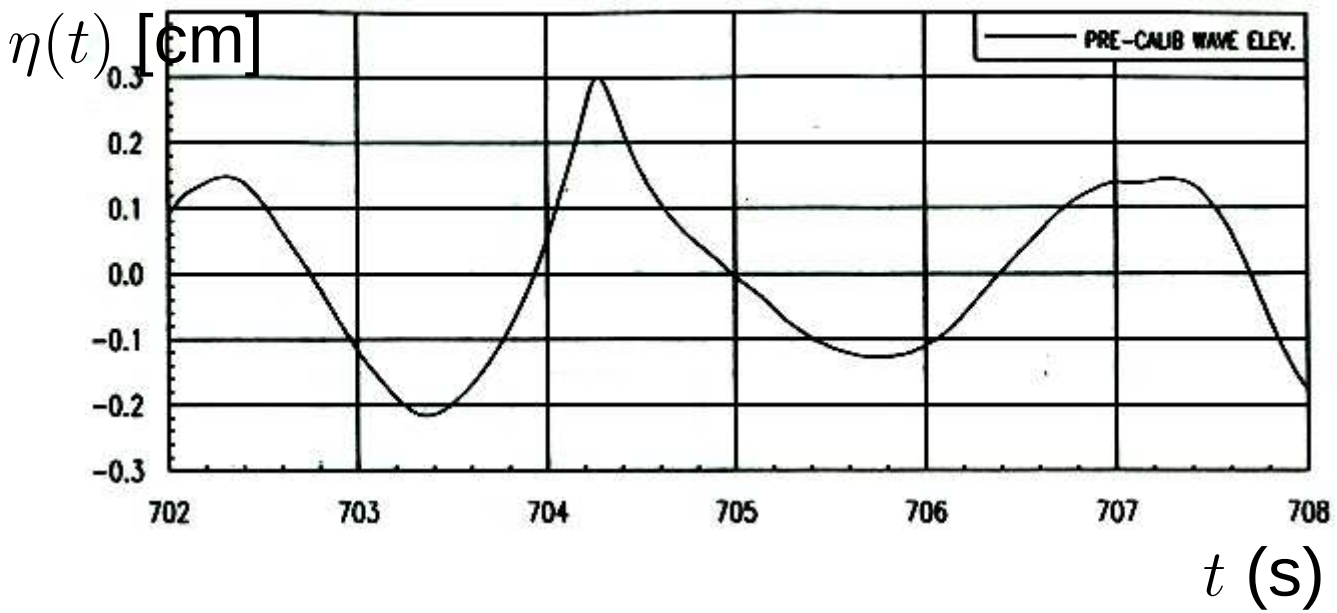
Force history in wave trains. Periodic waves with $(\omega^2 H/2g, \omega^2 R/g)$ equal $(0.32, 0.28)$



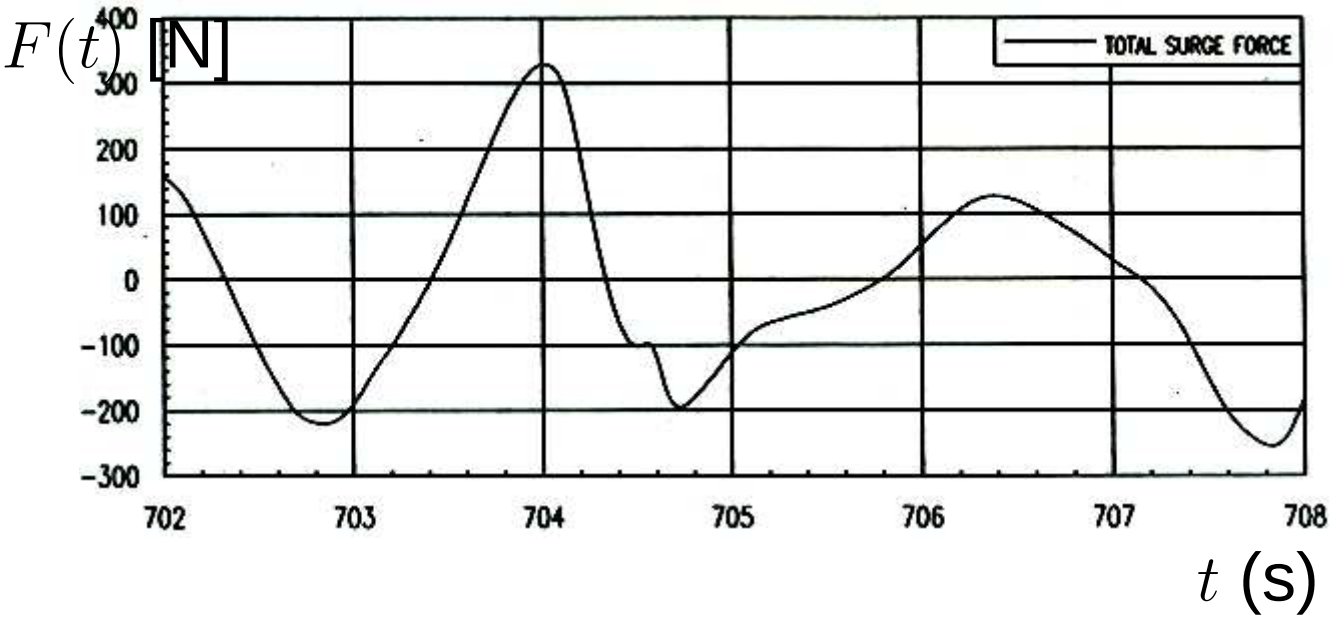
Force history in wave trains. Periodic waves with $(\omega^2 H/2g, \omega^2 R/g)$ equal $(0.20, 0.15)$



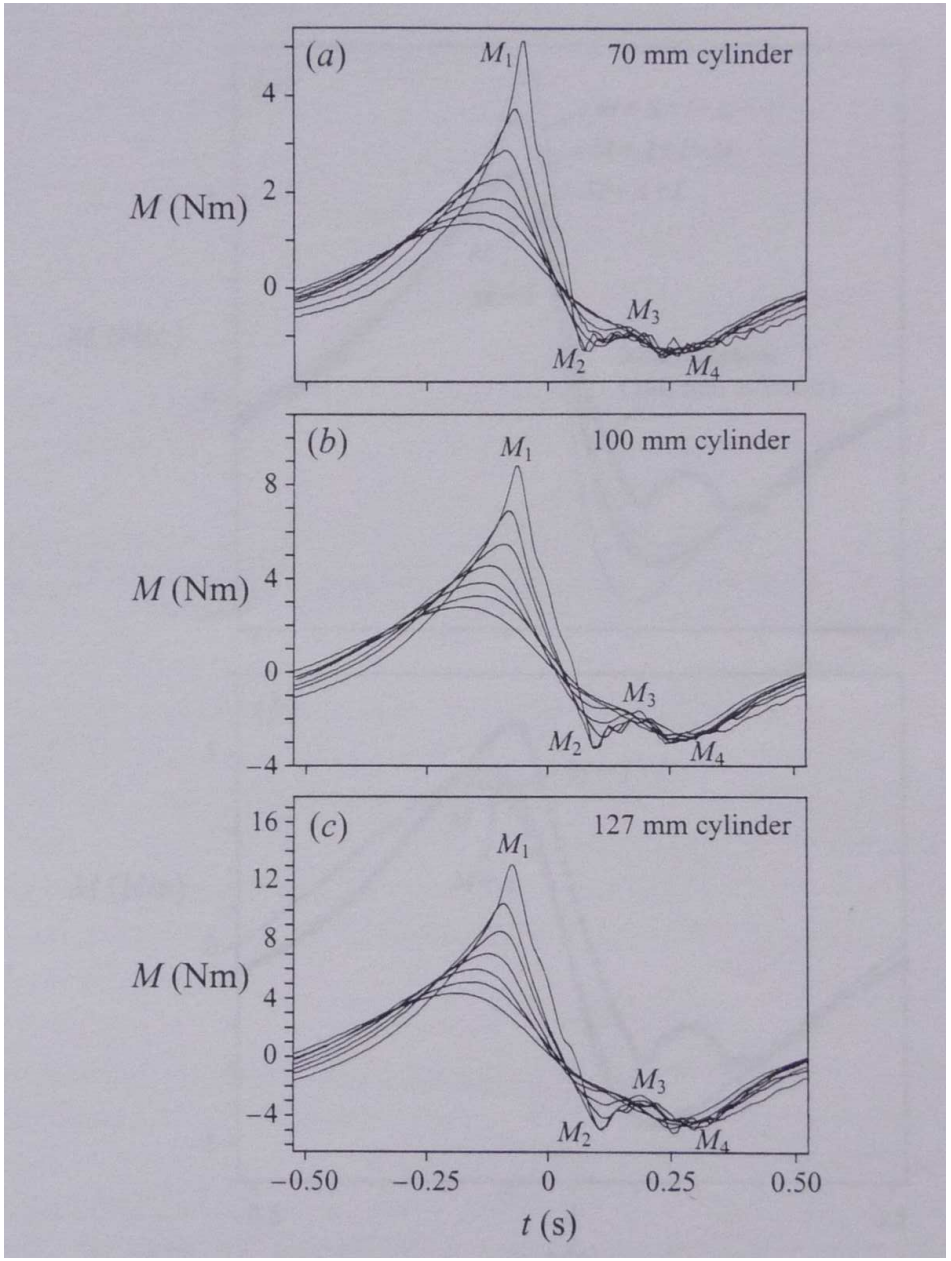
Force history in wave trains. Periodic waves with $(\omega^2 H/2g, \omega^2 R/g)$ equal $(0.24, 0.15)$.



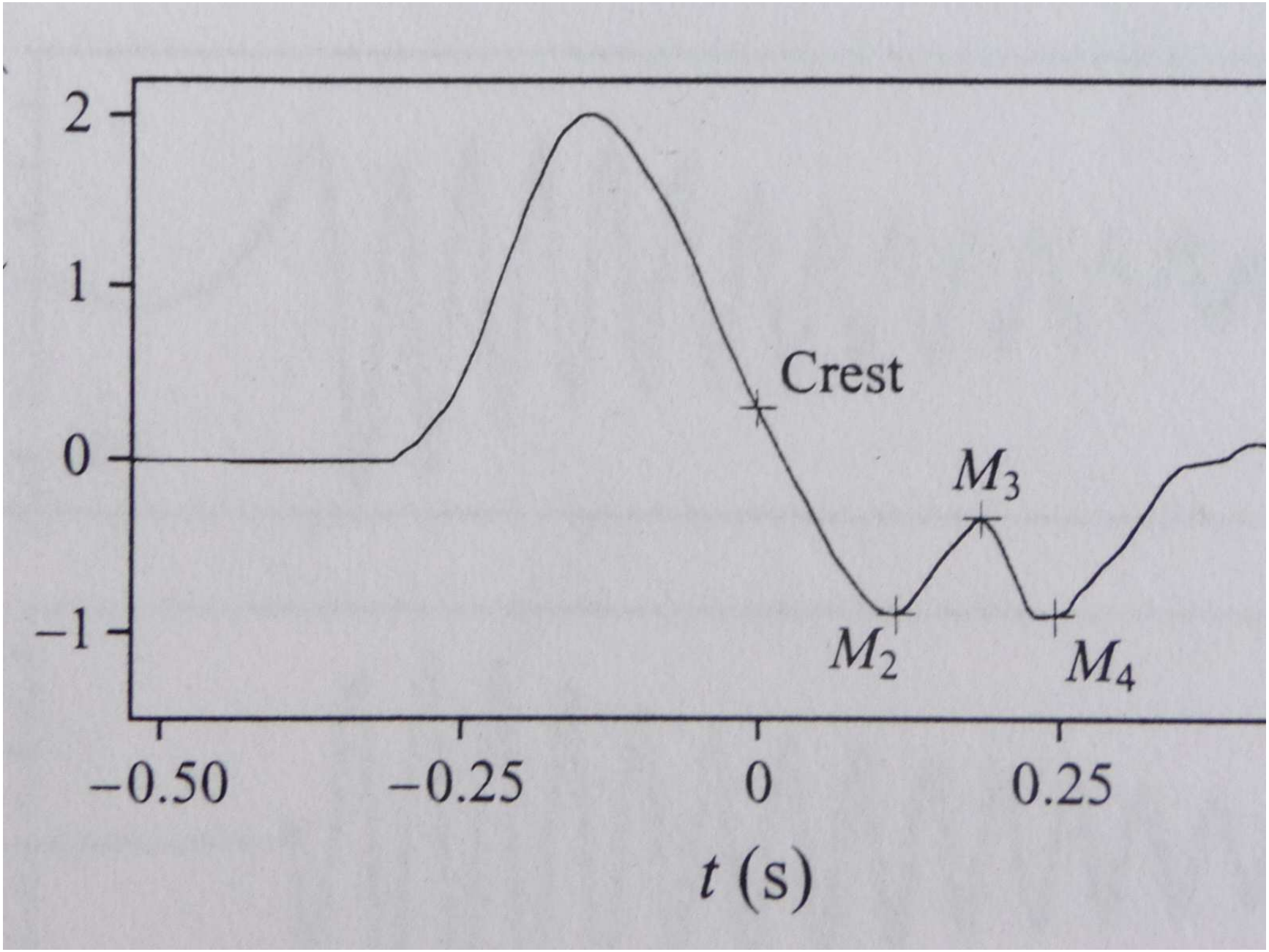
Irregular waves with elevation with $(k\eta_m, kR) = (0.20, 0.11)$.



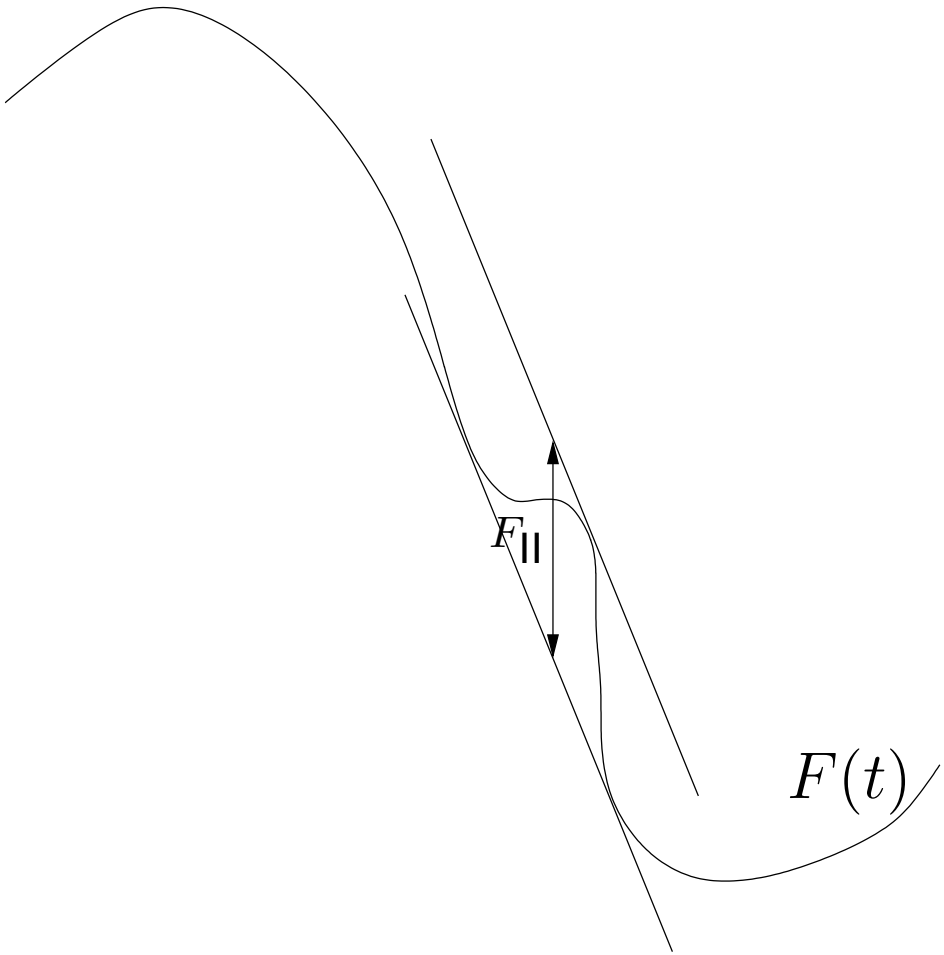
Irregular waves with elevation with $(k\eta_m, kR) = (0.20, 0.11)$.



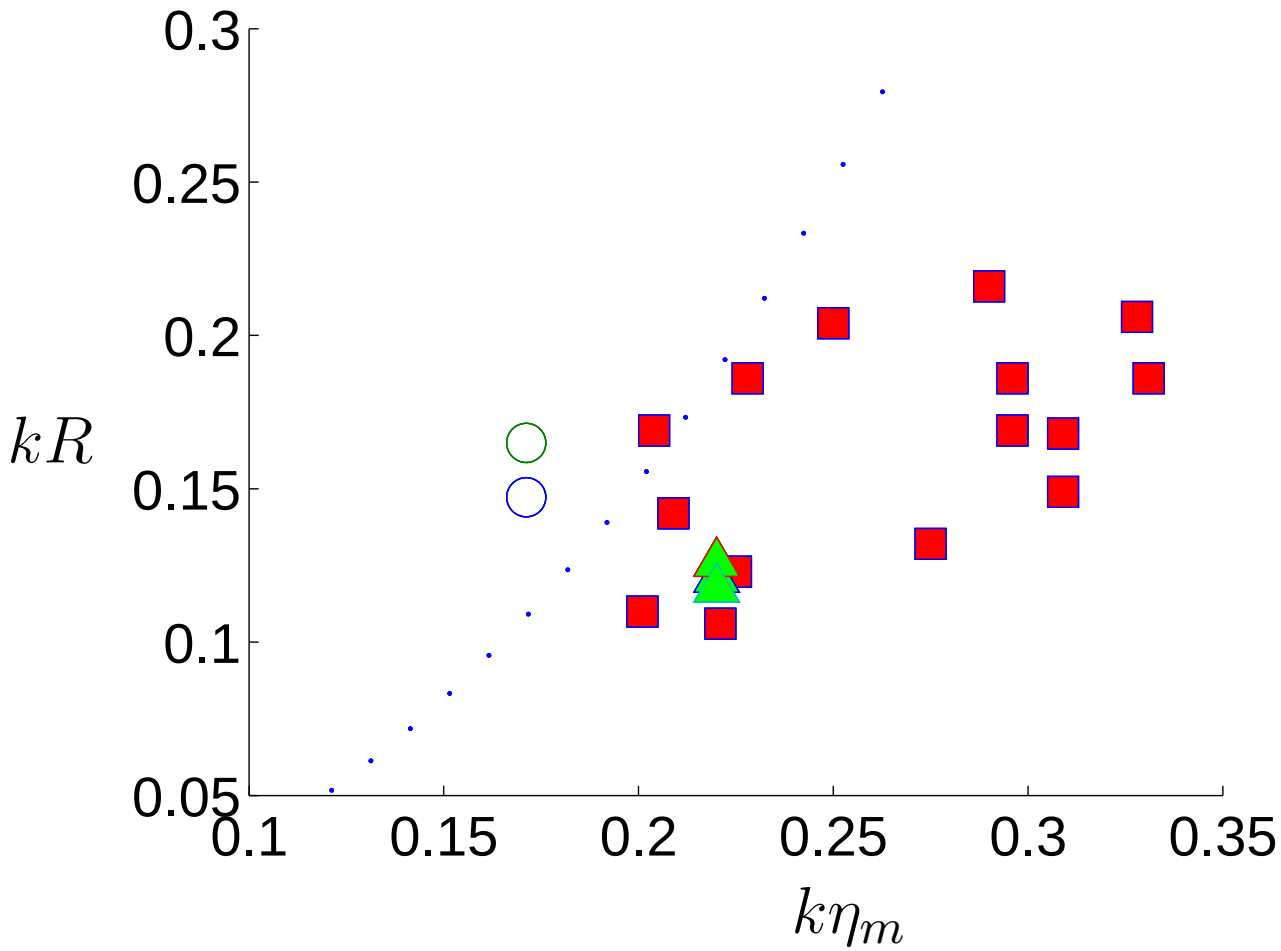
Chaplin, Rainey & Yemm, JFM 350 (1997)



Chaplin, Rainey & Yemm, JFM 350 (1997)



Definition of the magnitude of the secondary force oscillation, F_{II}. $F_{\text{p-p}}$ denotes the peak to peak force of the event.



Model experiments for the Draugen platform. Occurrence of secondary load cycle (red). Observed ringing (green). No ringing (open circles). Dotted line indicates $u_{max}/\sqrt{g2R} = 0.4$.

These experiments (Saga Petroleum) showed a secondary load cycle, after the wave crest had passed the column, like for other observations, but with lower kA and kR. It had

- local frequency 3-4 ω

- $F_{II}/F_{p-p} \sim 0.06 - 0.10$.

- note that in FNV $|F_3/F_1| = (kA)^2 \sim 0.04$ for $kA \sim 0.2$, which is lower than in the 'Saga'-observations.

- the 2ndary load cycle occurs for $k\eta_m \sim kA$ down to 0.2 and for $u_{max}/\sqrt{g2R} > 0.4$ (Grue&Huseby, 2002).

- the strong higher harmonic force may be important for fixed offshore wind turbines.

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