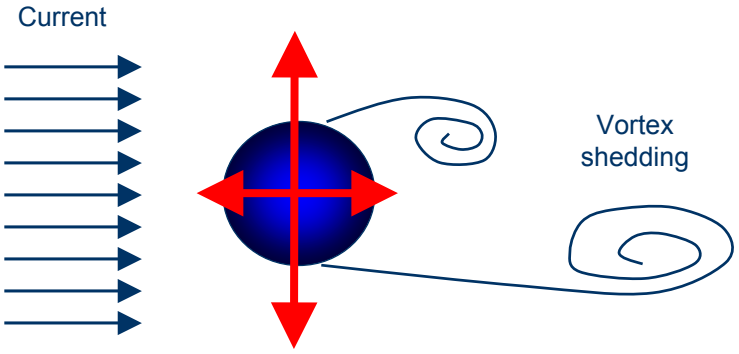
Vortex Induced Vibrations



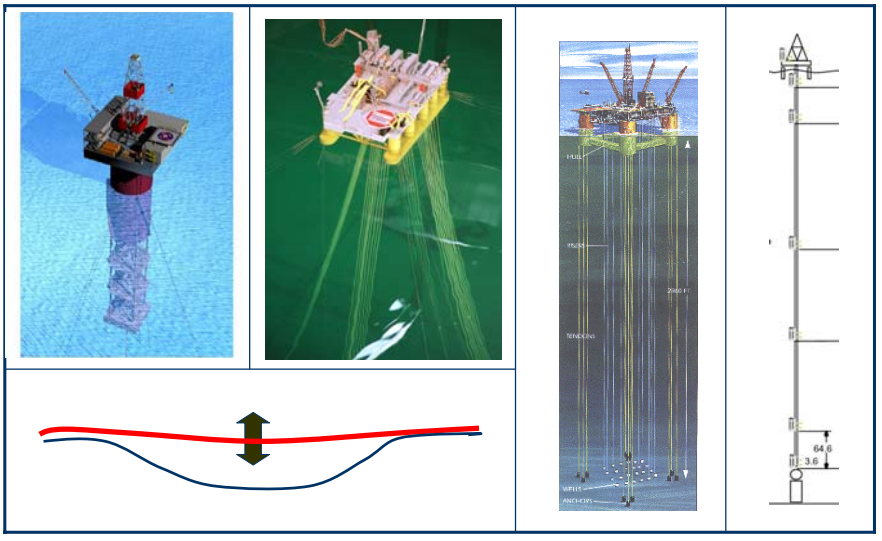
The cylinder starts to oscillate

f_{st} = St U/D, St ≅ 0.15 – 0.3

SPAR with D=30 m, U=1.5 m/s, f_{St} ≅ 0.01 Hz (T_{St}=100 s)

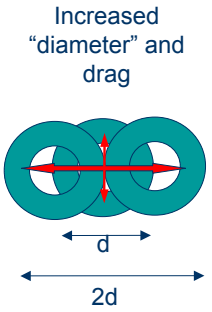
Riser with D=0.30 m, U=1.5 m/s, f_{St} ≅ 1 Hz

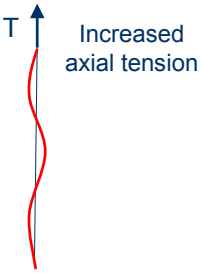
VIV problem areas



More specifically…

- Risers:
  - Reduced fatigue life
  - Increased axial tension
  - Increased extreme loads
  - Increased drag
- SPAR:
  - Increased global motions
  - Increased drag (Off-set)
  - Increased mooring line tensions (ULS &FLS)





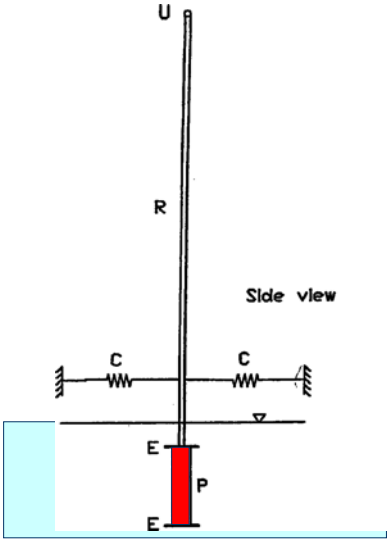
Key VIV Work at MARINTEK and NTNU,

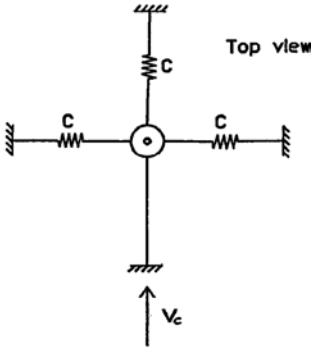
- Model tests in laboratory and large-scale (fjord) testing
- Analysis of experimental data (small-, large- & full scale test results) NDP
- Development of VIV prediction tools
  - VIVANA (Semi-empirical force model prediction tool)
  - SIMVIV (Simplified motion model prediction tool)
  - CFD-code
- Consultant work on
  - Marine risers
  - Deepwater umbilicals
  - Free spanning pipelines

Typical VIV tests

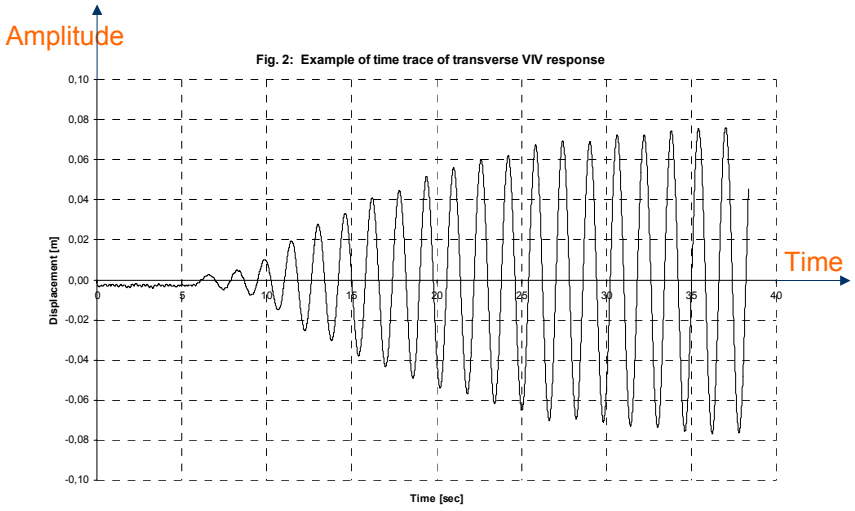
- 2-D Tests (L/D = 10-25)
  - To determine hydrodynamic coefficients
  - To study effect of VIV suppression devices
  - To study in-line vs cross-flow oscillations
- 3-D Pipe Tests (L/D =50-150)
  - To study multimode oscillations of free spanning pipelines in uniform current
- 3-D Tests (L/D > 300)
  - To study multimode oscillations in uniform and sheared current

Set-up for 2-D test

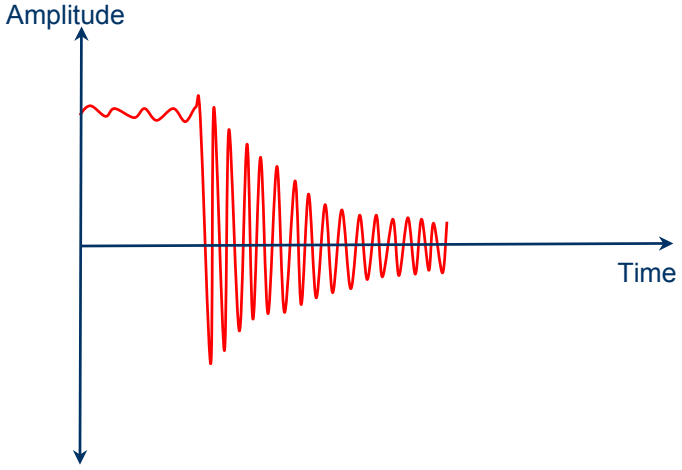




Cross-flow VIV response

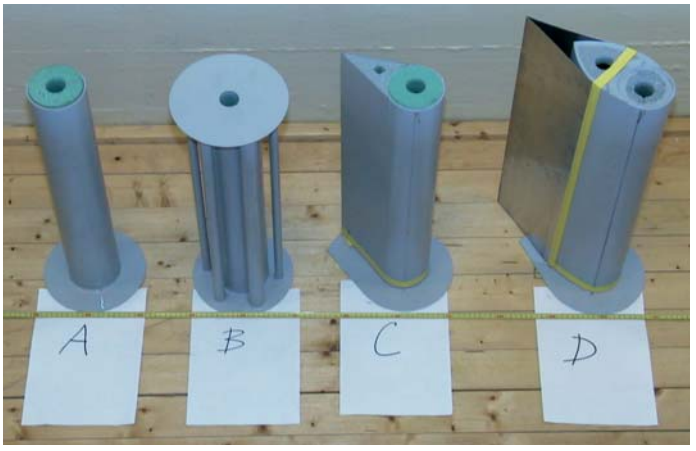


Cross-flow response w/ strakes

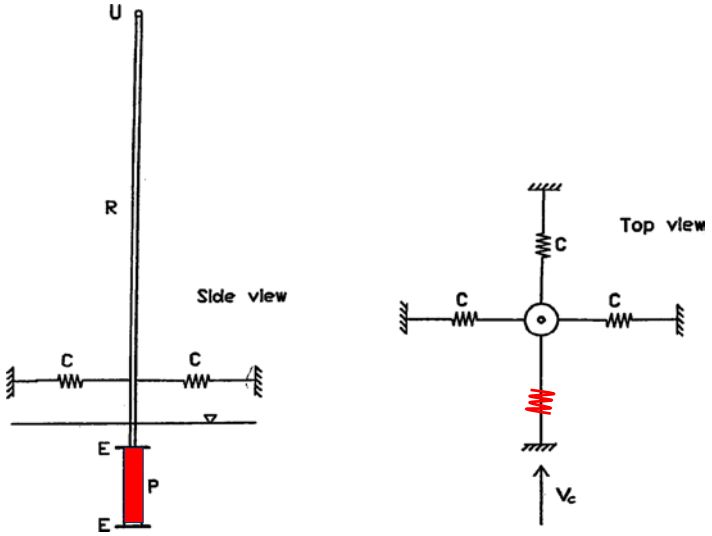


Models of various VIV suppression devices

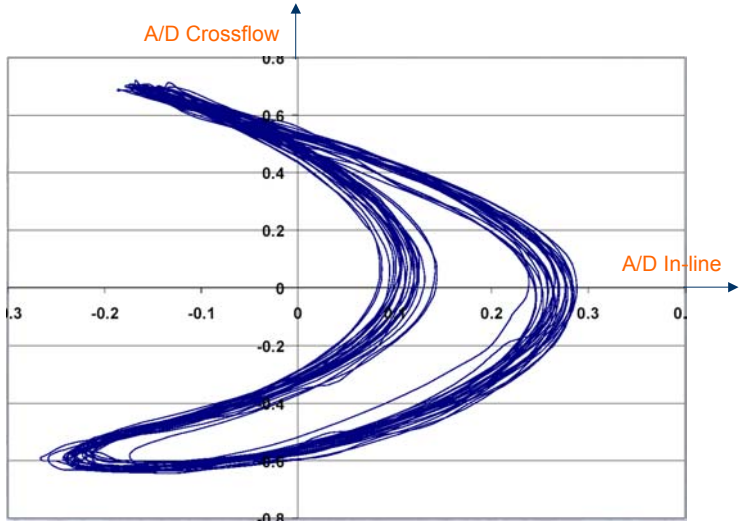
Various VIV suppression designs



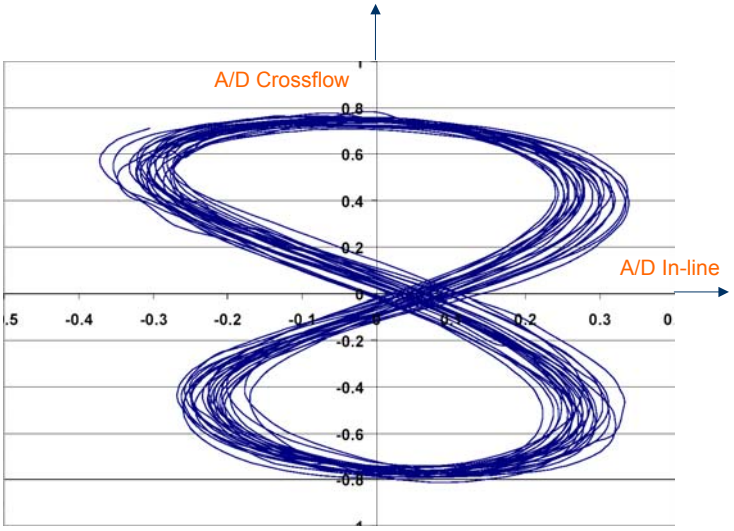
Inline vs. cross-flow VIV – Test set-up



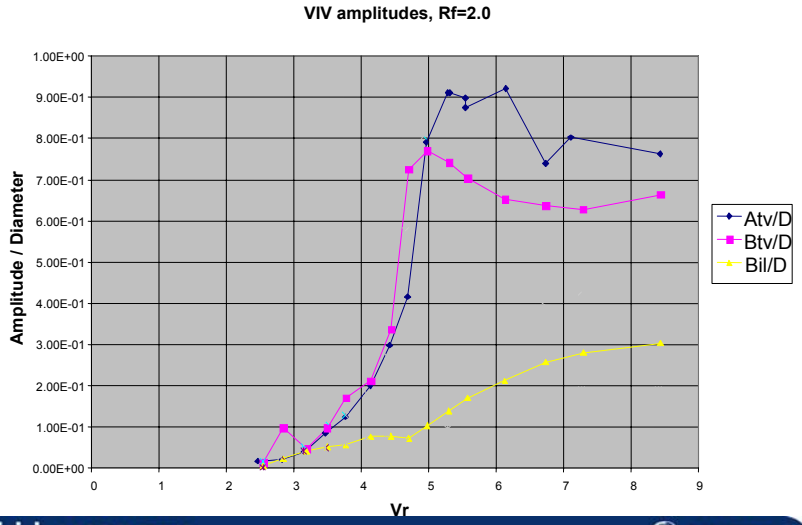
In-line and cross-flow oscillations - out of phase



In-line and cross-flow oscillations - in phase



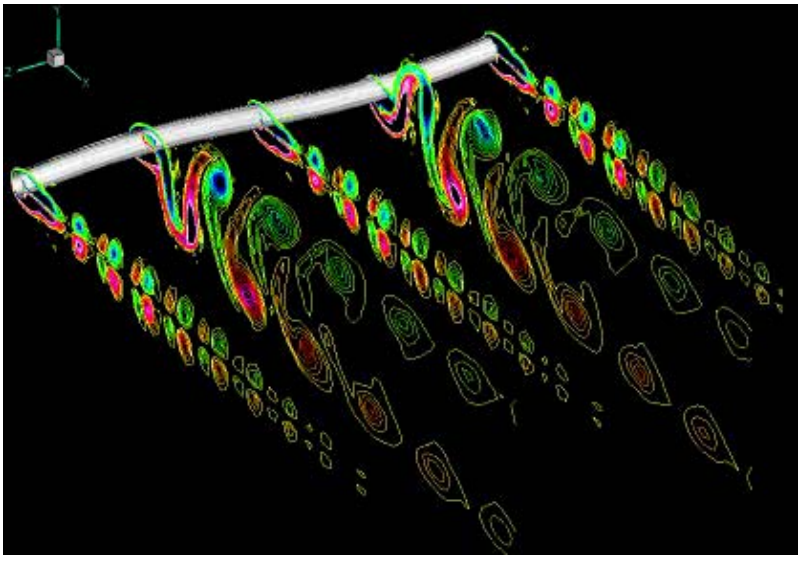
Cross-flow and in-line VIV amplitude



Experimental VIV projects at MARINTEK

Year	Project	Client
1983	High Re VIV tests in cav. tunnel	Oil comp.
1993	Skarnsund project	JIP
1996	Rotating rig VIV riser tests	NTNU/MT
1997	Hanøytangen project	Norsk Hydro
1997	Dr.ing thesis, Vikestad	NTNU
1997	VIV test staggered buoyancy	Shear7/JIP
1998	Clashing criteria and VIV	NDP
1998	VIV on Statfjord SCR	Statoil
1999	Rotating rig VIV riser test in directional current	Statoil/NH
1999	Analysis full-scale drilling riser VIV experiment	NDP
1999	VIV in current and floater motions	NDP
1999	Clashing energy and VIV	NDP
2000	VIV suppression devices	Norsk Hydro
2000	VIV suppression of drilling riser	NAVIS
2000	Lift coefficients of straked risers	NTNU
2001	VIV of pipelines, very long free spans	Norsk Hydro
2001	Riser VIV tests using fibre optics	Norsk Hydro
2001	VIV on SCR in current at different angles	STRIDE ph.4 / 2H Eng.
2002	2-D riser bundle tests	US engineering comp.

Multi-mode VIV with vortex shedding



Eigen frequency of a submerged beam with pinned ends

$$f_B = \frac{\pi}{2} n^2 \sqrt{\frac{EI}{mL^4}}$$

Eigen frequency of a submerged truss with constant tension

$$f_T = \frac{n}{2} \sqrt{\frac{T}{mL^2}}$$

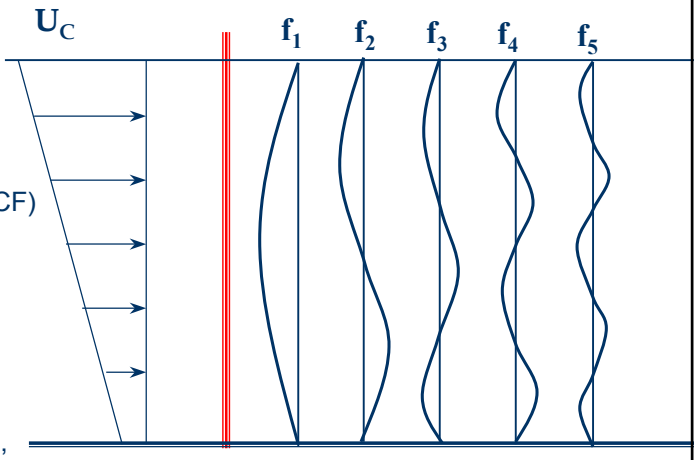
Combination of stiffness

$$f = \sqrt{f_B{}^2 + f_T{}^2}$$

L = length
T = tension
m= mass (incl. added mass) pr. length

E = Young's modulus
I = Area moment of inertial
n = mode number

Multimode VIV in sheared current



Strouhal Frequency (CF)

f_S=St Uc / D

Riser:

L= 2000m, D= 0.25 m,

Uc = 2 m/s → $f_S = f_{50}$ i.e. 50th mode

Uc = 1 m/s → $f_S = f_{525}$ i.e. 25th mode