Group Discussion 2
Vortex Induced Vibrations

Session Chairman: Dr. Carl Trygve Stansberg

1. PRESENTATIONS

1.1 By Dr. Carl Trygve Stansberg, Norwegian Marine Technology Research Institute, Norway, on Recent VIV research at MARINTEK/NTNU

Marine Technology Centre in Trondheim, Norway:

Key VIV Work at MARINTEK and NTNU.

- Model tests in laboratory and large-scale (fjord) testing,
- Analysis of experiment data (small-, large- and full scale tests),
- Development of VIV prediction tools,
- Consultant work,
- Research at the Centre of Excellence on Ship and Ocean Structures,
- Model tests in laboratory and large-scale (fjord) testing,
- Analysis of experiment data (small-, large- and full scale tests),
- Development of VIV prediction tools:
  - VIVANA (Semi-empirical force model prediction tool),
  - SIMVIV (Simplified response model prediction tool),
  - CFD-code,
- Consultant work on:
  - Marine risers,
  - Deepwater umbilicals,
  - Free spanning pipelines,
- Research at the Centre of Excellence on Ship and Ocean Structures (CeSOS), NTNU:
  - 3 PhD students on VIV on pipelines, one post doc. (CFD; PIV a.o.).

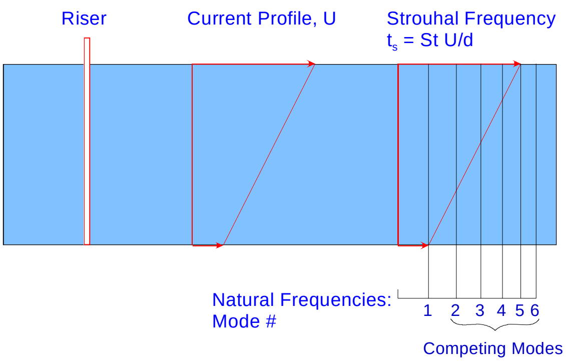
History of Projects:

- 1983, High Re VIV tests in cav. Tunnel for Oil company,
- 1993, Skarnsund project for JIP,
- 1996, Rotating rig VIV riser tests for NTNU/MT,
- 1997, Hanøytangen project for Norsk Hydro,
- 1997, Dr.ing thesis, Vikestad for NTNU,
- 1997, VIV test staggered buoyancy for Shear7/JIP,
- 1998, Clashing criteria and VIV for NDP,
- 1998, VIV on Statfjord SCR for Statoil,
- 1999, Rotating rig VIV riser test in directional current for Statoil/NH,
- 1999, Analysis full-scale drilling riser VIV experiment for NDP,

- 1999, VIV in current and floater motions for NDP,
- 1999, Clashing energy and VIV for NDP,
- 2000, VIV suppression devices for Norsk Hydro,
- 2000, VIV suppression of drilling riser for NAVIS,
- 2000, Lift coefficients of straked risers for NTNU,
- 2001, VIV of pipelines, very long free spans for Norsk Hydro,
- 2001, Riser VIV tests using fibre optics for Norsk Hydro,
- 2001, VIV on SCR in current at different angles for STRIDE ph.4 / 2H Eng.,
- 2002, 2-D riser bundle tests for US engineering comp.,
- 2003, VIV suppression test in rotating rig for ExxonMobil URC,
- 2003, Ormen Lange free span pipe VIV model tests, phase 3 for Norsk Hydro,
- 2003, Dual riser clashing tests for NDP,
- 2003, High mode VIV model tests for NDP,
- 2004, Faired 3D riser VIV test, effectiveness and instability for NDP,
- 2004, Galloping 2D tests for Statoil,
- 2005, Parametric 2D tests of strakes for NDP,
- 2005, Ormen Lange umbilical free span VIV tests for Norsk Hydro.

A Key Problem:

Unknown Interactions for Long Risers in Shear Flow



Higher Velocity: Higher modes excited and competing between modes, difficult to predict response.

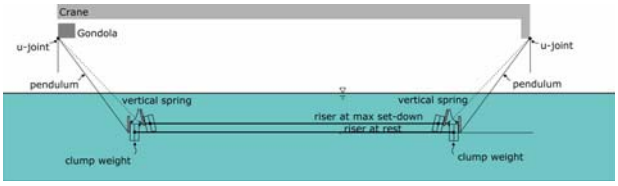


Figure 1.1- NDP High Mode VIV Test in 50m x 80m Ocean Basin.

Figure 1.2- The MARINTEK Ocean Basin (50m x 80m x 10m).

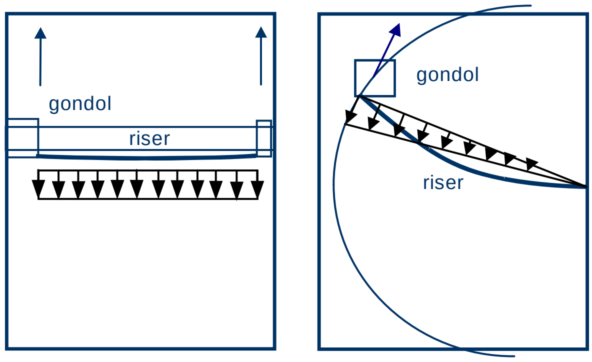


Figure 1.3- NDP High Mode VIV Test in Ocean Basin, test set-up for uniform and sheared flow.

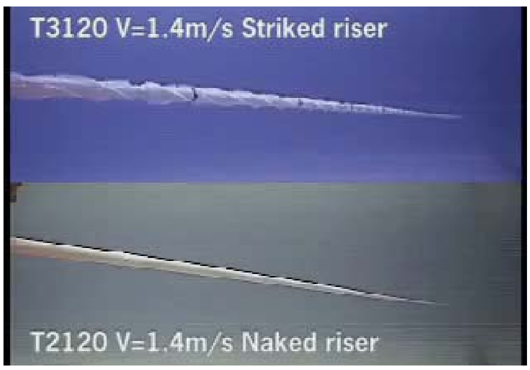


Figure 1.4- Straked riser and naked riser tests.

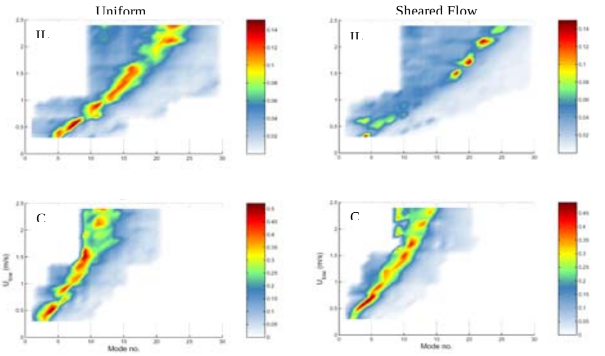


Figure 1.5- Example of results, modal weight vs. tow speed.

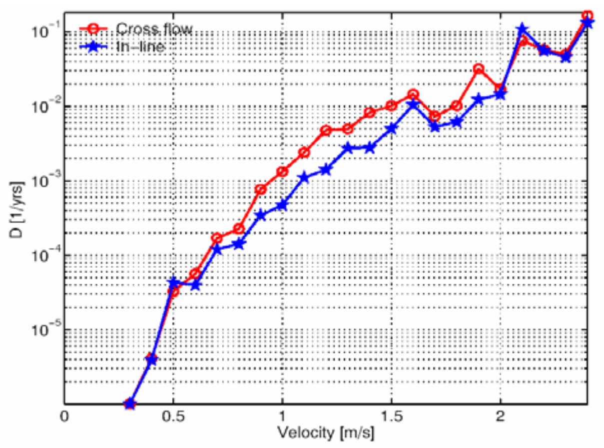


Figure 1.6- Crossflow (CF) and Inline (IL) fatigue vs. tow speed for bare riser in uniform flow.

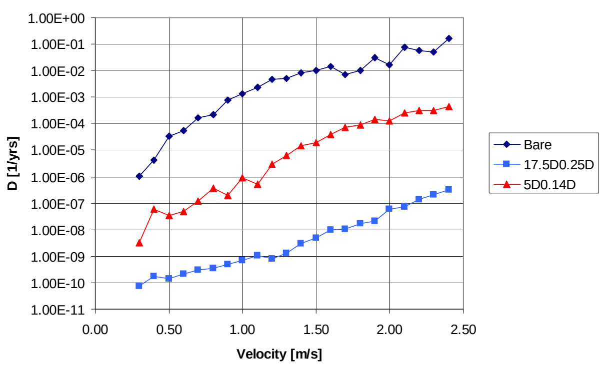


Figure 1.7- Max. fatigue damage vs. tow speed (bare and straked risers).

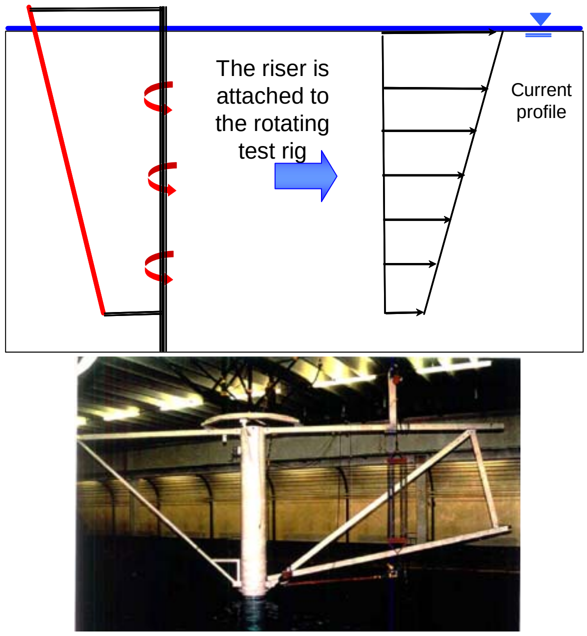
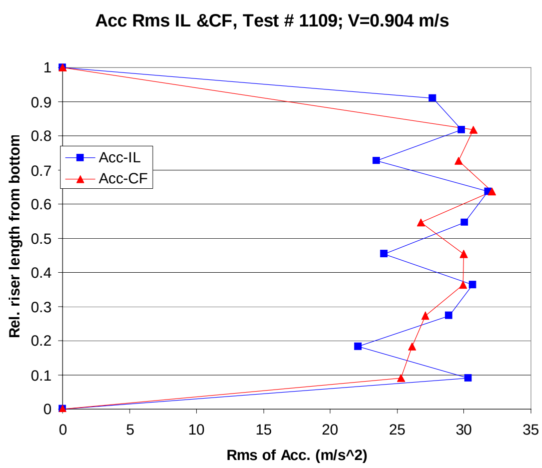


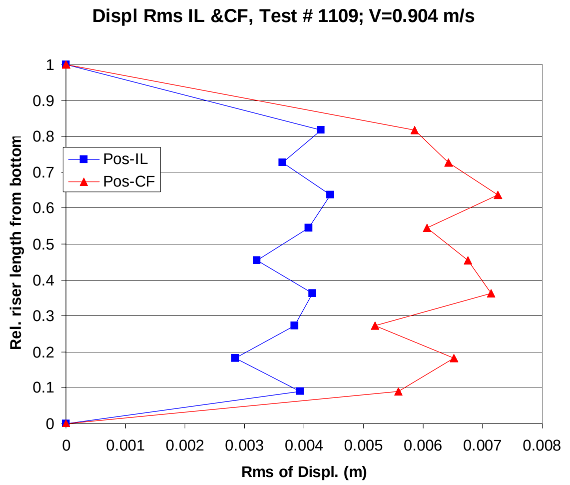
Figure 1.8- Set-up Rotating Rig experiment in towing tank.

Rotating rig riser model and instrumentation:

- Type: rubber hose with intersection of aluminium for housing accelerometers,
- Length: 9.6 – 13.1 m,
- Outer diameter: 0.023 m,
- Weight in air: 5.327 N/m,
- Pretension (at lower end): about 690 N,
- Instrumentation: 10 pair of accelerometers, 3 component force transducers in both ends, set-down, velocity.

Examples of results, 2D uniform current test:





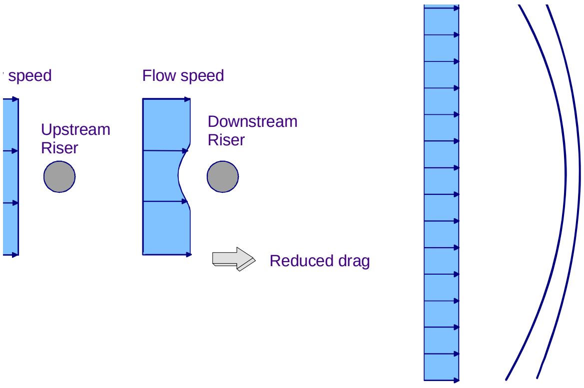


Figure 1.9- NDP Riser Clashing Tests - principles. Towing of “vertical” risers, constant current profile and equal velocity scaling.

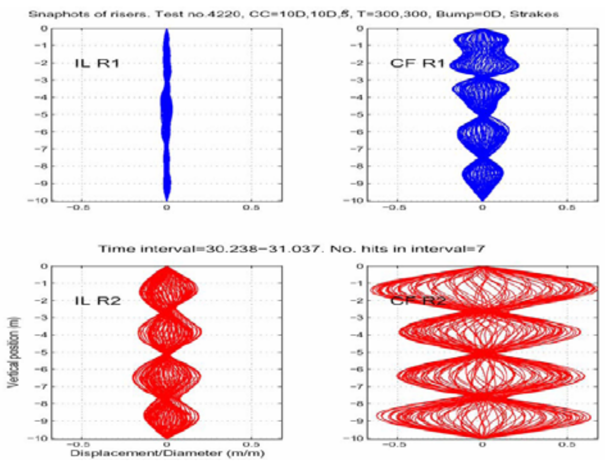
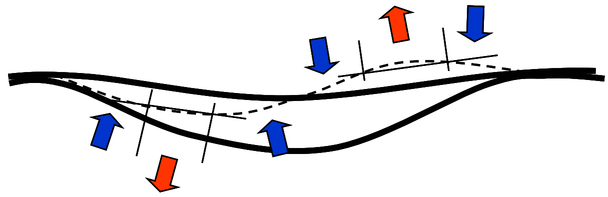


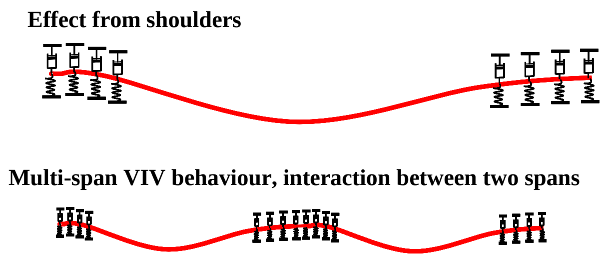
Figure 1.10- Test results, snapshots of risers.

Ormen Lange VIV on Free Spans:

- Model testing of single and multispan pipe,
- Analysis of results,
- VIVANA extensions (CF) and studies.



Ormen Lange Free Spanning Pipe Project: Combining VIV Model Tests and VIVANA Calculations.



Visualization of flow around circular cylinders using Particle Imaging Velocimetry (PIV):

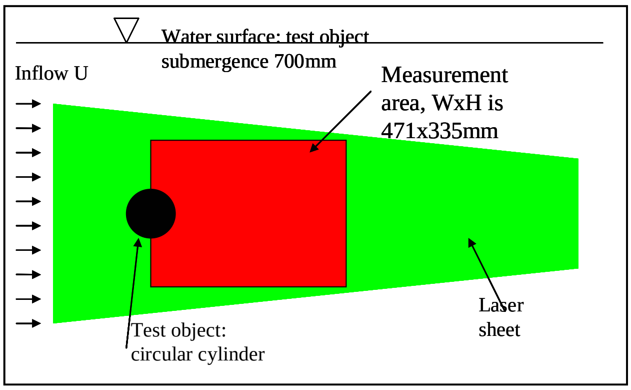


Figure 1.11- Side view of test setup.

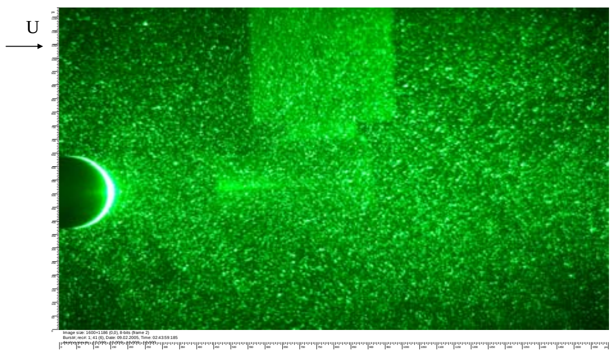


Figure 1.12- Typical picture of seeding particles in the fluid.

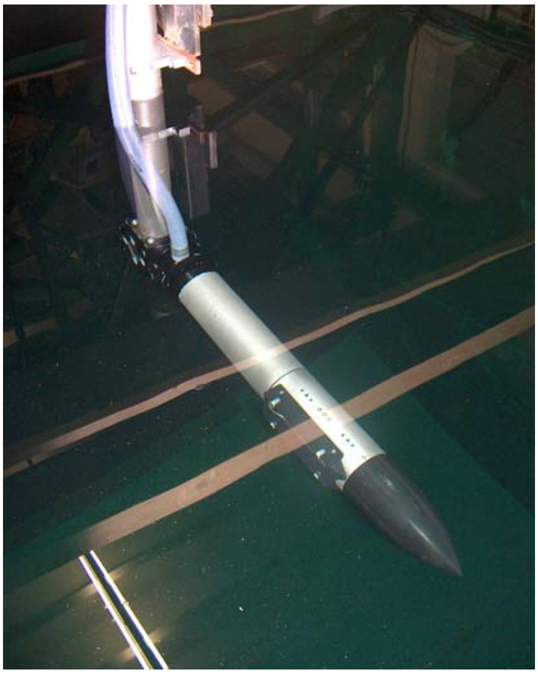


Figure 1.13- Probe following the object during towing.

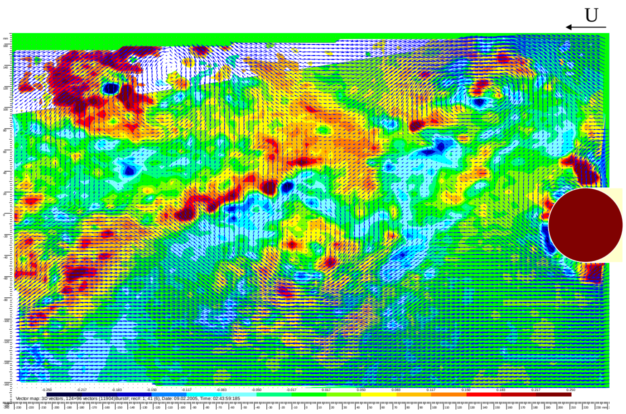


Figure 1.14- 3D velocity vector plot.

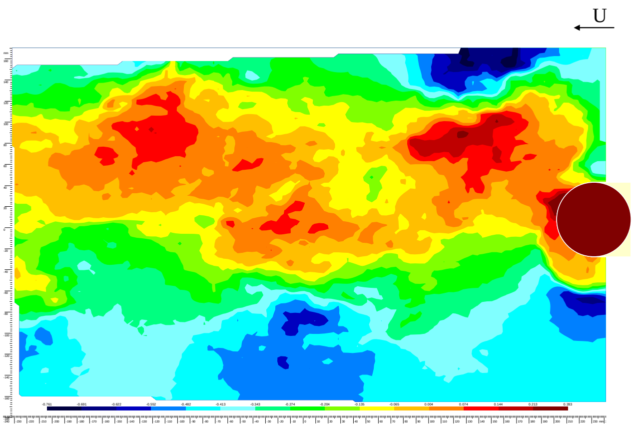


Figure 1.15- Velocity component inline with towing, U.

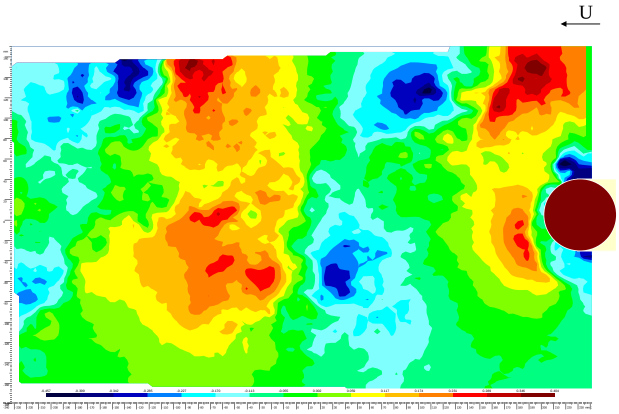


Figure 1.16- Crossflow velocity component, V.

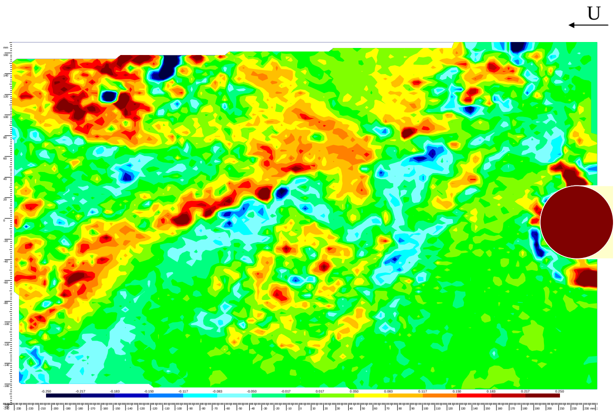


Figure 1.17- Velocity component along the cylinder, W.

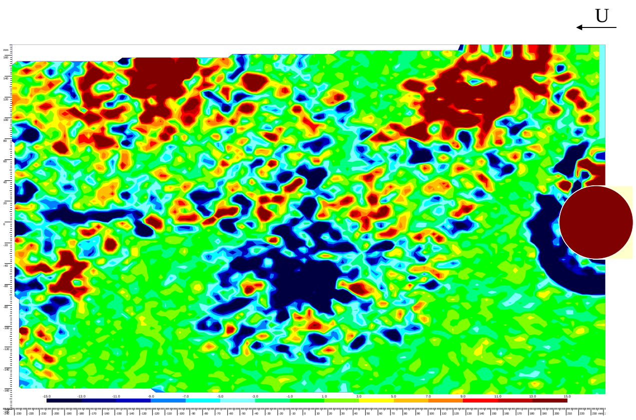


Figure 1.18- Vorticity.

Summary.

- High-mode VIV experiments,
- Riser interaction,
- Free spans,
- Particle Imaging Velocimetry experiments.

1.2 By Dr. Jaap de Wilde, Maritime Research Institute Netherlands, The Netherlands, on Vortex Induced Vibrations

VIV has received much attention by the industry in the last decade. A large number of research and test campaigns has been carried out.

- What have we learned from this and what is the next step?
- What are the industry needs?
- How can we address the issues with model tests or other methods?

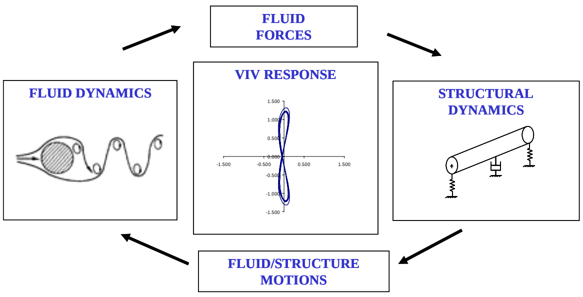


Figure 1.19- VIV is complex problem.

MARIN VIV Work.

- Older work in eighties (Jaap van der Vegt),
- Renewed interest in late nineties by deepwater developments,
- VIVARRAY JIP (Triantafyllou, MIT),
- High Reynolds VIV apparatus (Jaap de Wilde),
- SPAR VIM (Radboud van Dijk).

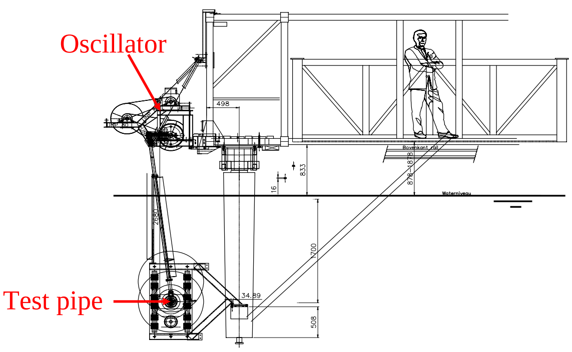


Figure 1.20- High Re test apparatus.

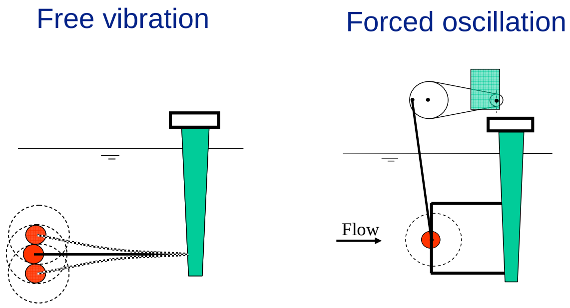


Figure 1.21- Free vibration and forced oscillation.

Figure 1.22- Oscillator.

Figure 1.23- Divers.

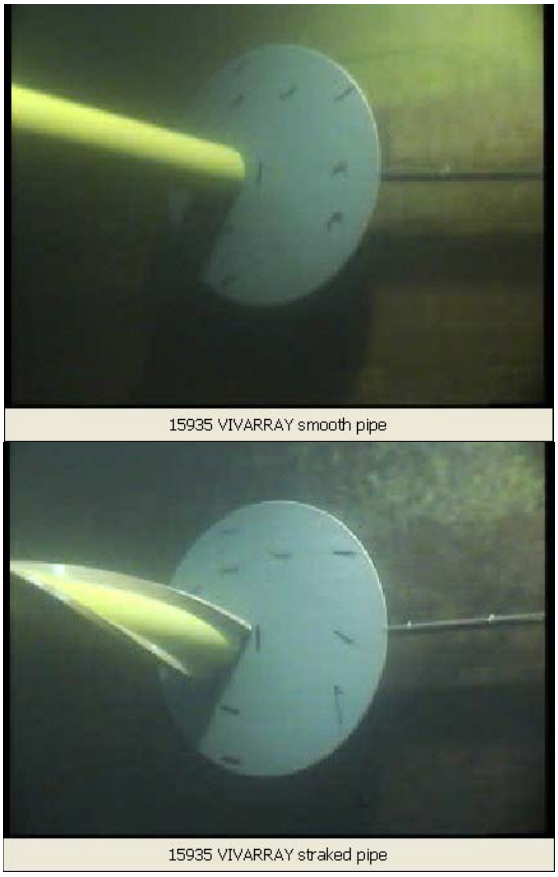


Figure 1.24- Bare pipe and pipe with strakes.

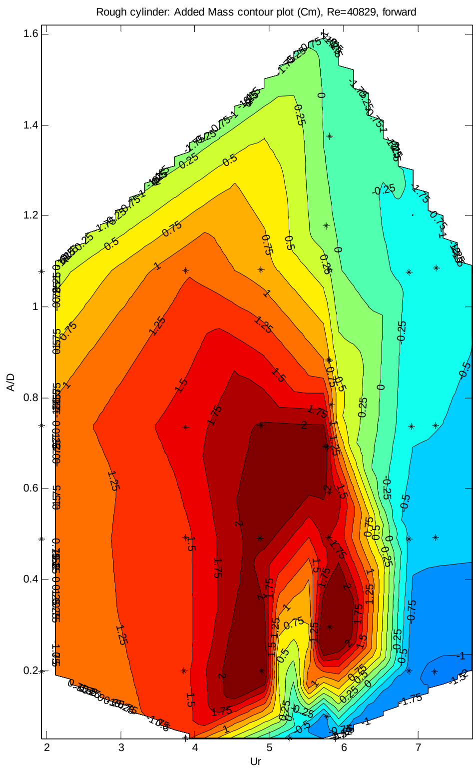


Figure 1.25- Added mass (Cm).

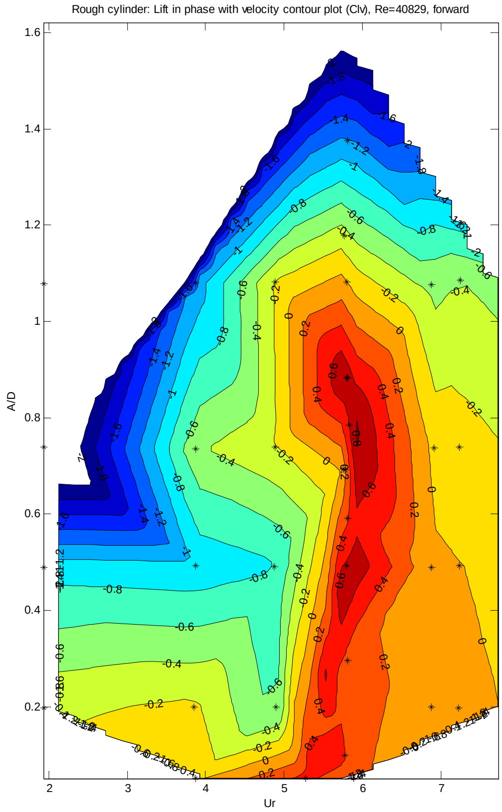


Figure 1.26- Dynamic lift (Clv).

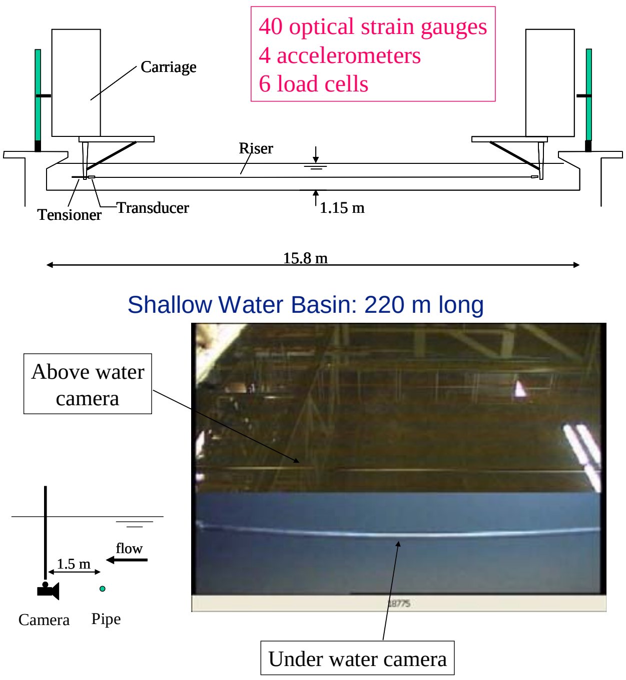


Figure 1.27- Experiment with 12.6 m long pipe

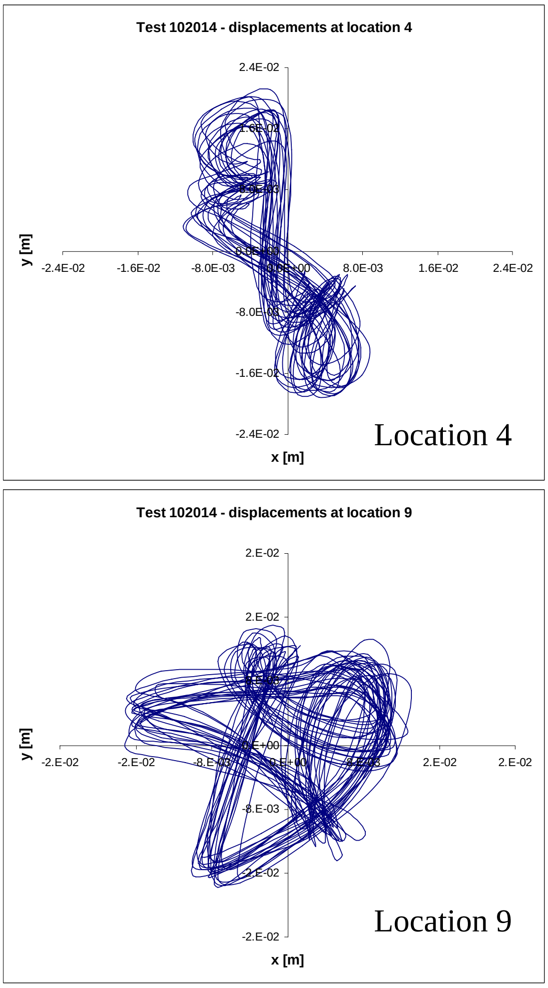
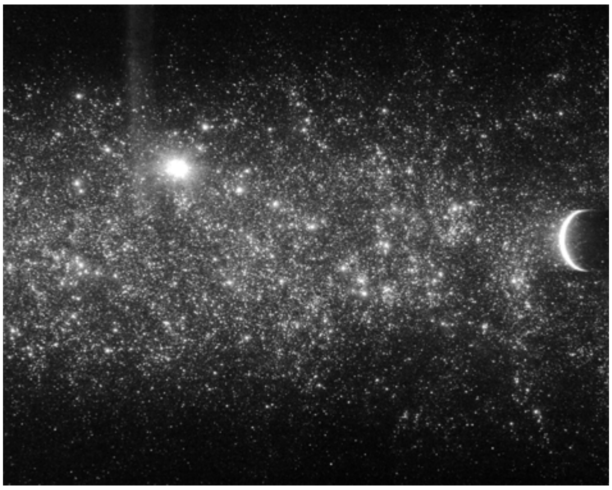


Figure 1.28- Motions test 102014 from FBGs.



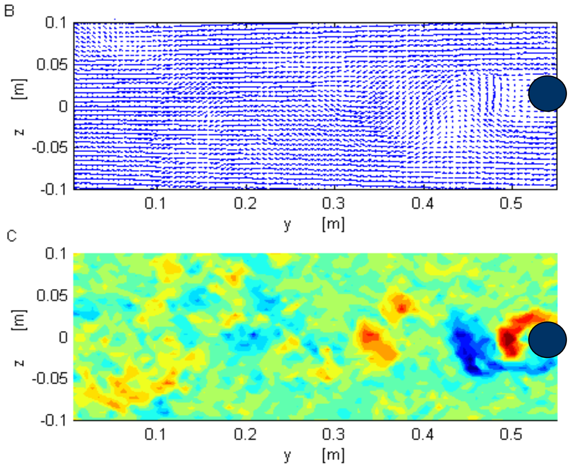


Figure 1.29- PIV 50 mm cylinder (experiments 2000).

Spar VIV Test Set-up.

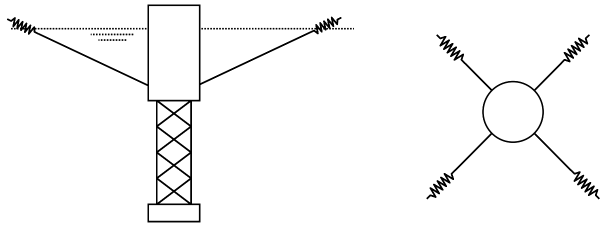


Figure 1.30- 4 line mooring with linear springs.

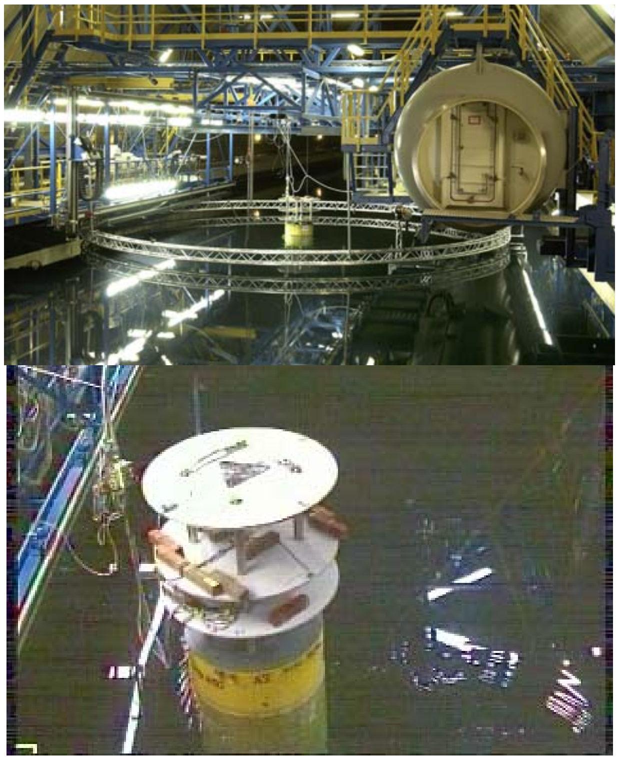


Figure 1.31- Spar Tests.

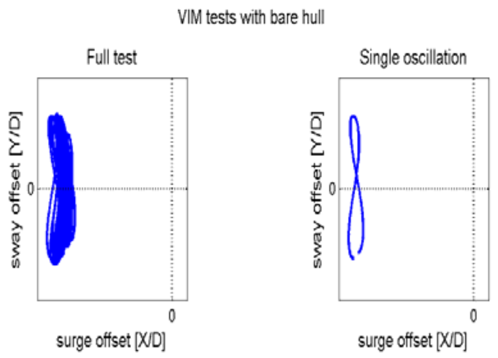


Figure 1.32- VIM tests with bare hull.

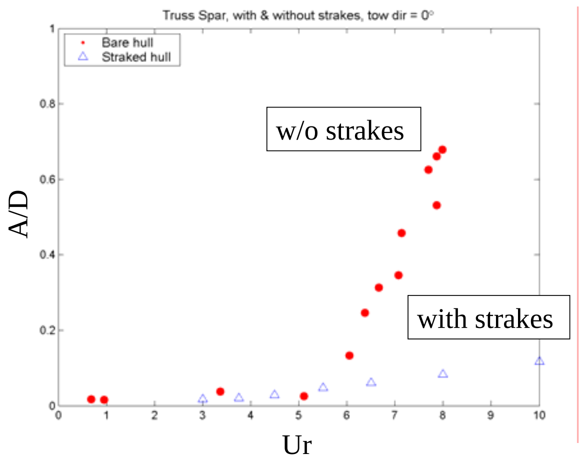
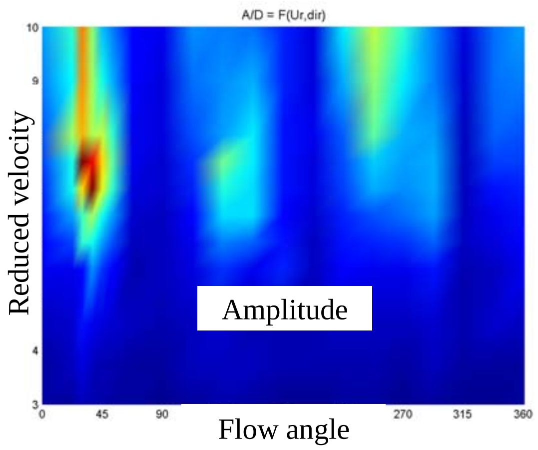
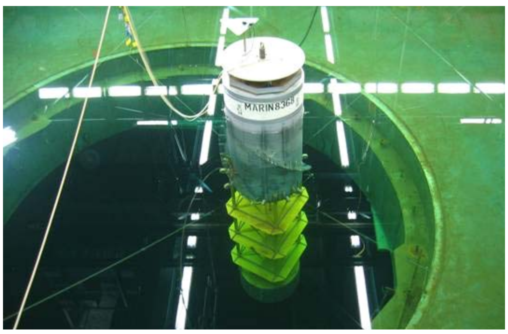


Figure 1.33- Truss spar, with and without strakes.





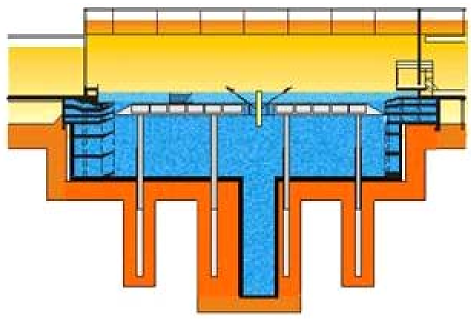


Figure 1.34- Truss Spar in waves and current.

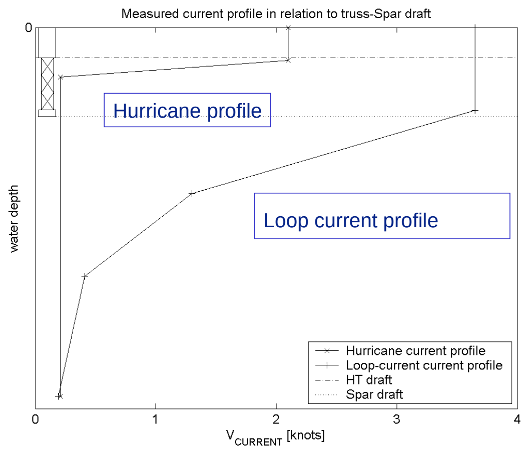


Figure 1.35- Measured current profile.

<u>Outstanding VIV Research Topics.</u>

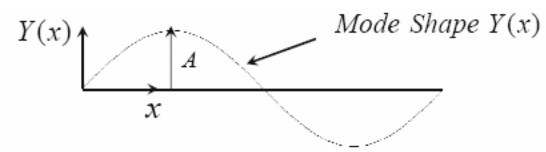
- Scale effects,
- Surface roughness and turbulence,
- High mode response of long risers,
- Riser-riser VIV interaction,
- Implementation of knowledge in codes, software and test procedures,
- Miscellaneous VIV (galloping, bundles, jumpers, Calm buoys, semi's, TLPs, etc.).

MARIN plans:

- Further development High Reynolds apparatus,
- Further development SPAR VIM model tests,
- PIV (MARIN-Sirenha, 2005),
- CFD (University Twente),
- Fully instrumented long catenary model riser (PhD thesis),
- Development VIV prediction tool together with Delft University (PhD thesis).

1.3 By Dr. John Shanks, RiserTec Ltd, United Kingdom, on Power Balance Methods for VIV Assessments

Basic Power Balance Approach.



X-flow velocity:

$$\dot{y}(x,t) = \omega A Y(x) \sin \omega t$$

Lift force:

$$p(x,t) = \frac{1}{2} \rho D V^2 C_L \sin \omega t \times Sign[Y(x)]$$

Power-in:

$$\Pi^{IN} = \int_{Lin} p(x,t) \dot{y}(x,t) dx$$

Lift curve:

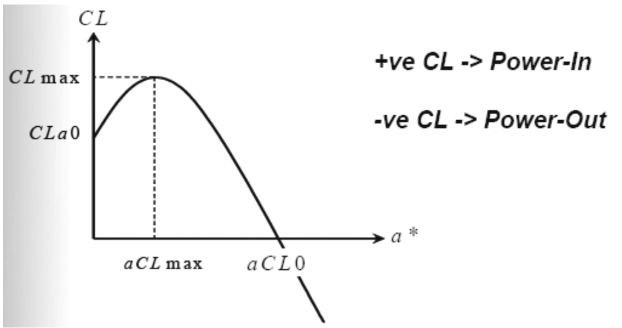


Figure 1.36- Self limiting process.

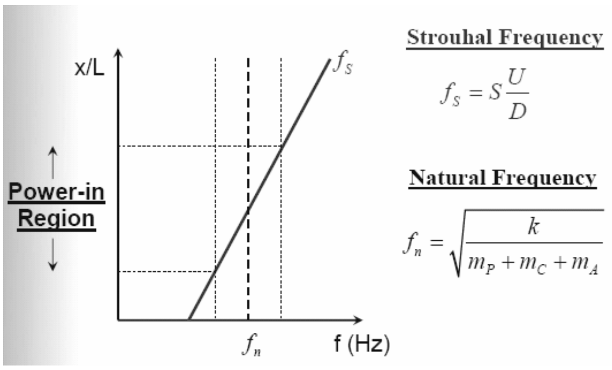
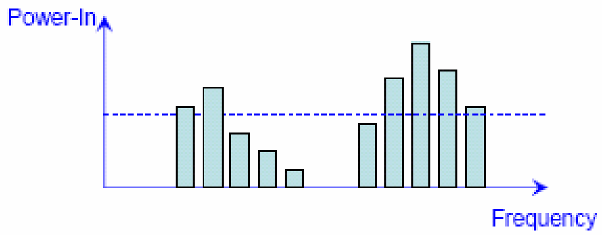
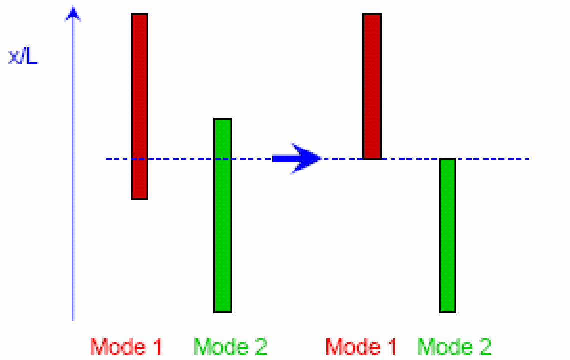


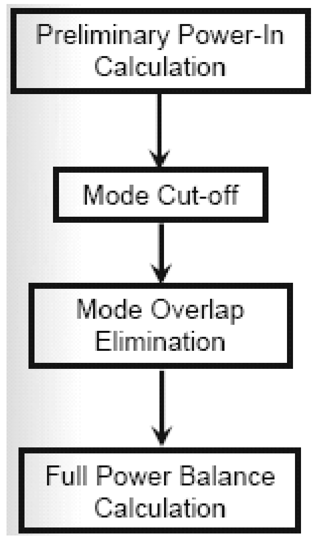
Figure 1.37- Power in region.

Multi-mode response:

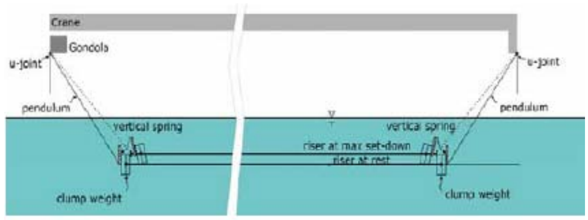


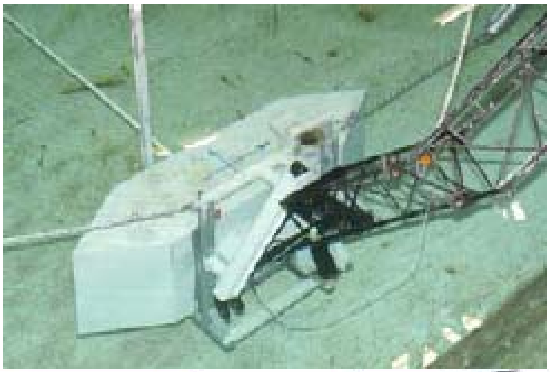


Basic Shear7 flow chart:



NDP High Mode Tests.





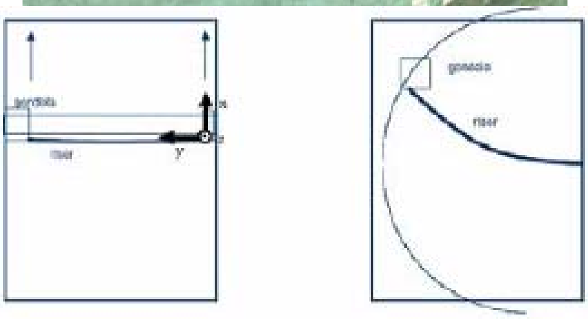


Figure 1.38- Small-scale VIV strakes.

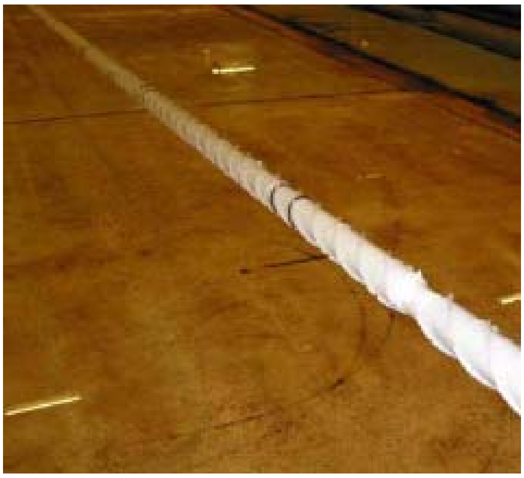
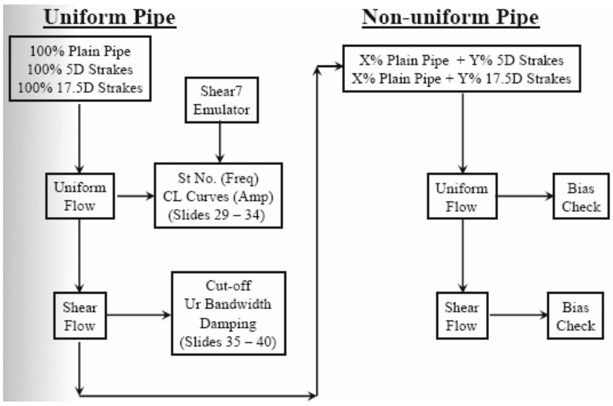


Figure 1.39- VIV strakes fitted to test riser.

NDP high mode test program:

- 38m long x 27mm OD fibre glass pipe,
- 5 kN nominal tensions,
- Uniform and triangular current profiles,
- Current speeds 0.3, 0.4 to 2.4 m/s (22 cases),
- Plain pipe plus short and long pitch strakes,
- 50, 75, 90 and 100% strake cover,
- Over 300 cases.

Shear7 calibration flow chart:



Shear7 calibration results:

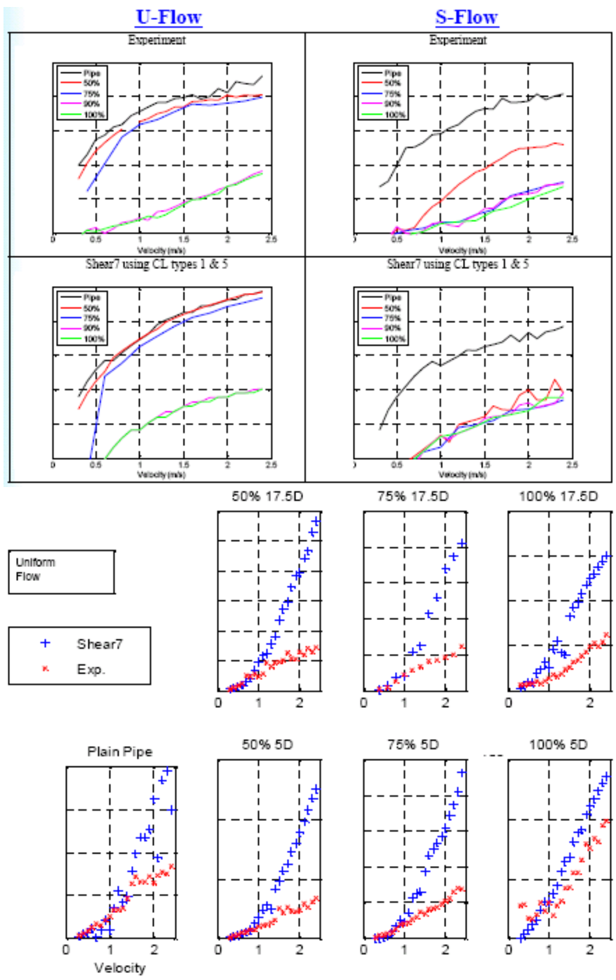
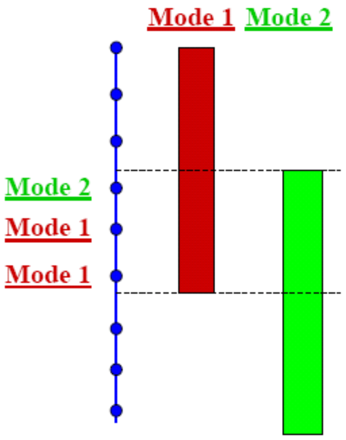
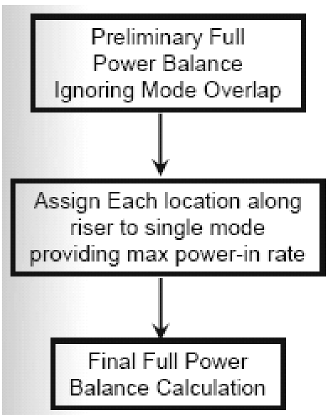


Figure 1.40- Shear7 calibration results.

Maximum power method:



Basic RTVIV flow chart:



VIV of Pipeline Spools.

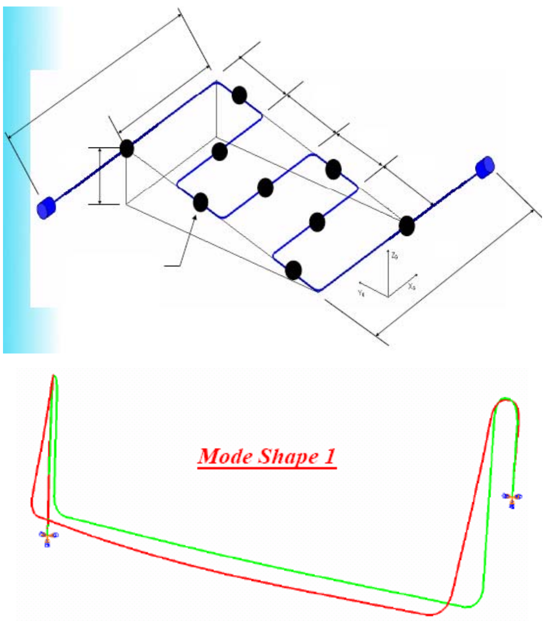
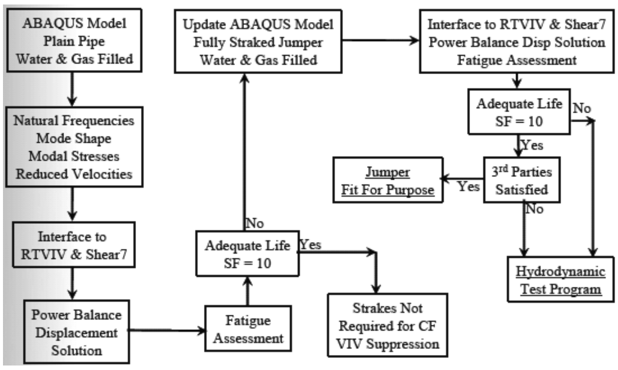


Figure 1.41- Vertical Configuration.

3D ABAQUS model gives displacements and stresses for unit amplitude displacement.

Analysis Procedure:



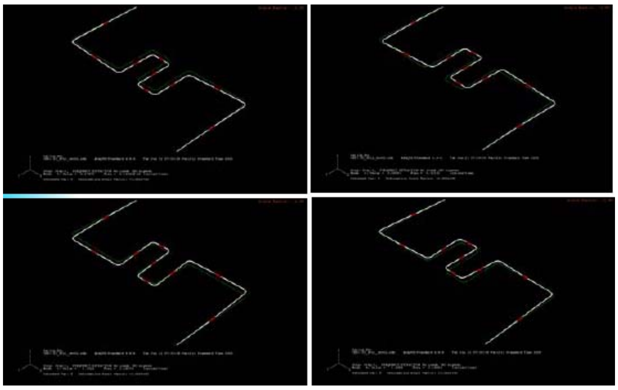


Figure 1.42- Mode shapes - datum position.

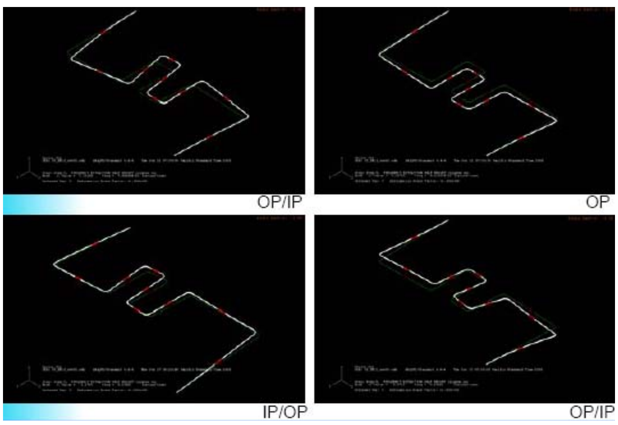
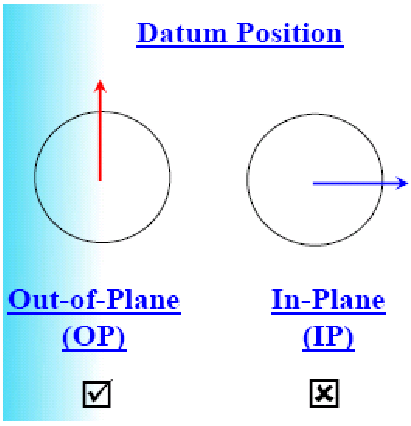
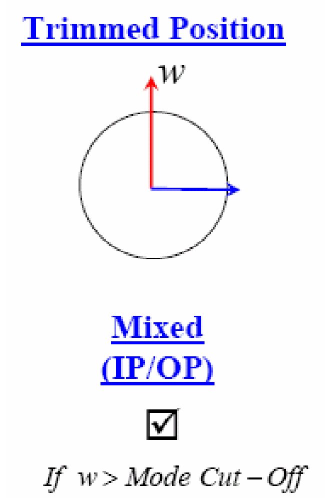


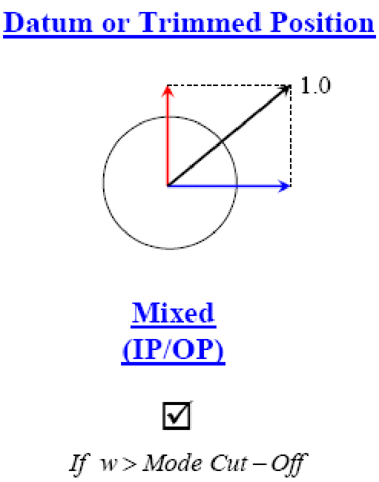
Figure 1.43- Mode shapes - trimmed conf.

Vertical method:

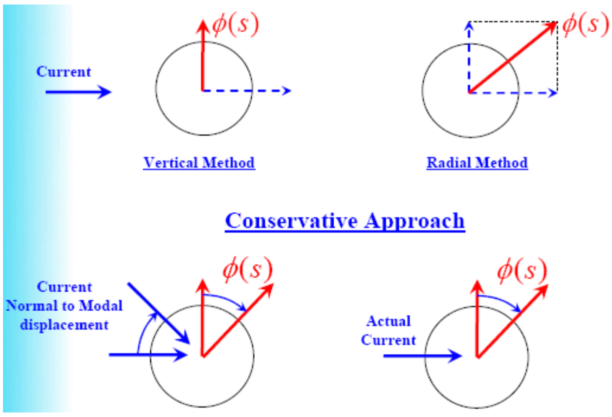




Radial method:



Vertical v radial methods:



Summary Fatigue Results.

Cover	Configuration	Method	Life
Unstraked	Datum Trimmed	Vertical Vertical	1.00 0.04
Straked	Datum Trimmed Trimmed	Vertical Vertical Radial	1600 10 2400

Conclusions.

- Power Balance Methods provide useful design tool,
- Ongoing development needed to improve continuity,
- Max power and radial methods look promising for complex spool geometries,
- Further high quality high mode tests needed,
- Calibration against CFD also potentially useful;