DeepStar – High Reynolds Number Results

Background

DEEPSTAR (www.deepstar.org) have made available high Reynolds (Re) number data for Vortex-Induced Vibration (VIV) benchmarking purposes. DEEPSTAR is a JIP consisting of the following operator companies:

- Anadarko
- BP
- Chevron Corporation
- ENI/Agip
- Kerr-McGee
- Marathon
- Petrobras
- Statoil
- Total

The high RE data comes from CTR 5402 and CTR 6402. The purpose of these CTRs was to assess the potential value of high RE data as a source of predicting the response of flexible marine risers. The work relating to CTR 5402 was conducted during 2001, and supplemental high RE data was acquired during 2003 and covered by CTR 6402.

Experimental Details

The high RE data was obtained by Oceanic Consulting Corporation at St. Johns, Newfoundland, Canada. The experiments were conducted in the IMD 200m wave/towing tank facility, and the specifications of which are provided below.

IMD Wave/Towing Tank Facility Specifications	
Length	200m
Width	12m
Still Water Depth	7m
Tow Carriage Speed	10m/s
Max. Wave Height (regular waves)	1m
Max. Sig. Wave Height (irregular waves)	0.5m
Range of Wavelengths at 7m Depth	0.5m – 40m
Max. Wind Speed: 1m from fans	11m/s
Max. Wind Speed: 5m from fans	5m/s
RE Range	$2\times10^5 – 1\times10^6$

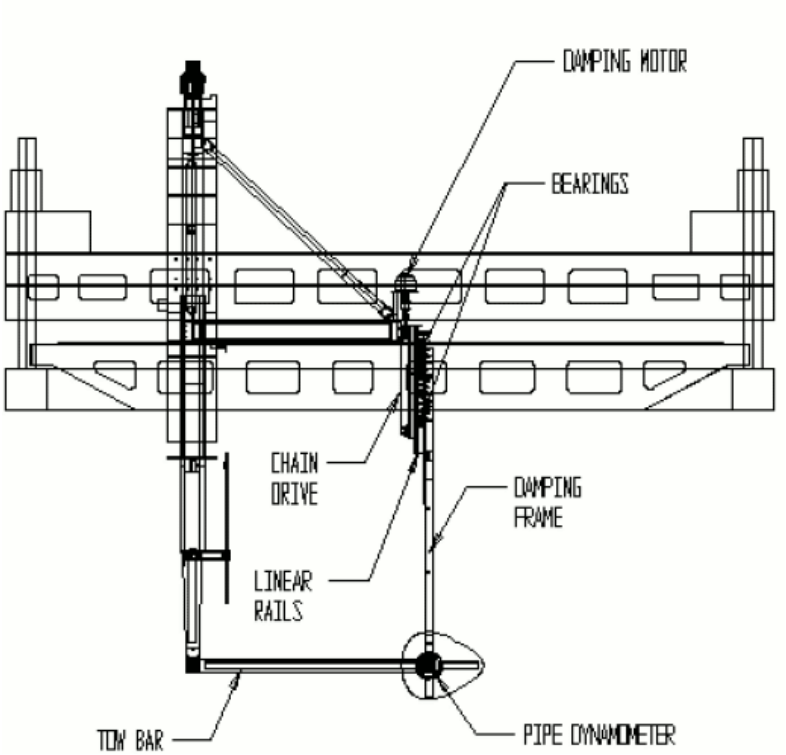
The experimental setup for the high RE tests are summarised in the table below.

Test Cylinder Characteristics	
Cylinder Length [L]	6m
Cylinder Diameter [D]	0.325m
Depth of Cylinder During Towing	2m below surface
Cylinder Surface: Rough	Ks/D = 0.0025
Cylinder Surface: Intermediate Rough	Ks/D = 0.0008
Cylinder Surface: Straked (Rough Jacket)	Ks/D = 0.0025
Strake Height	0.25 D
Strake Pitch	16 D
Cylinder Vibrating Mass [$M_{Vibrating}$]	817kg
Cylinder Displaced Mass [$M_{Displaced}$]	525kg
Mass Ratio = $M_{Vibrating}/M_{Displaced}$	1.56
Mass Ratio = $(\pi/4)$ $M_{Vibrating}/M_{Displaced}$	1.22

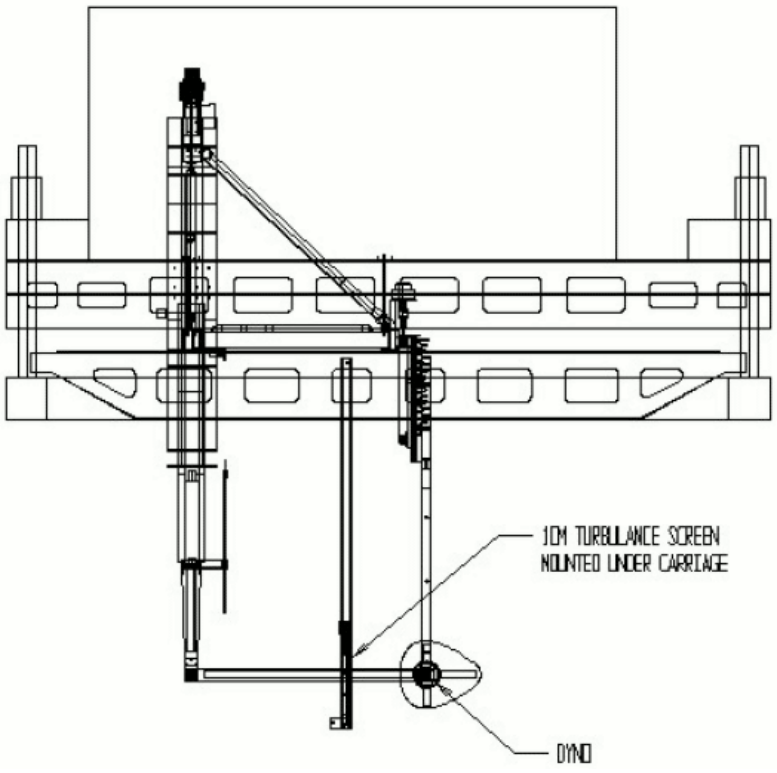
Two different modes of operations were tested:

- Free vibration mode
- Forced vibration mode

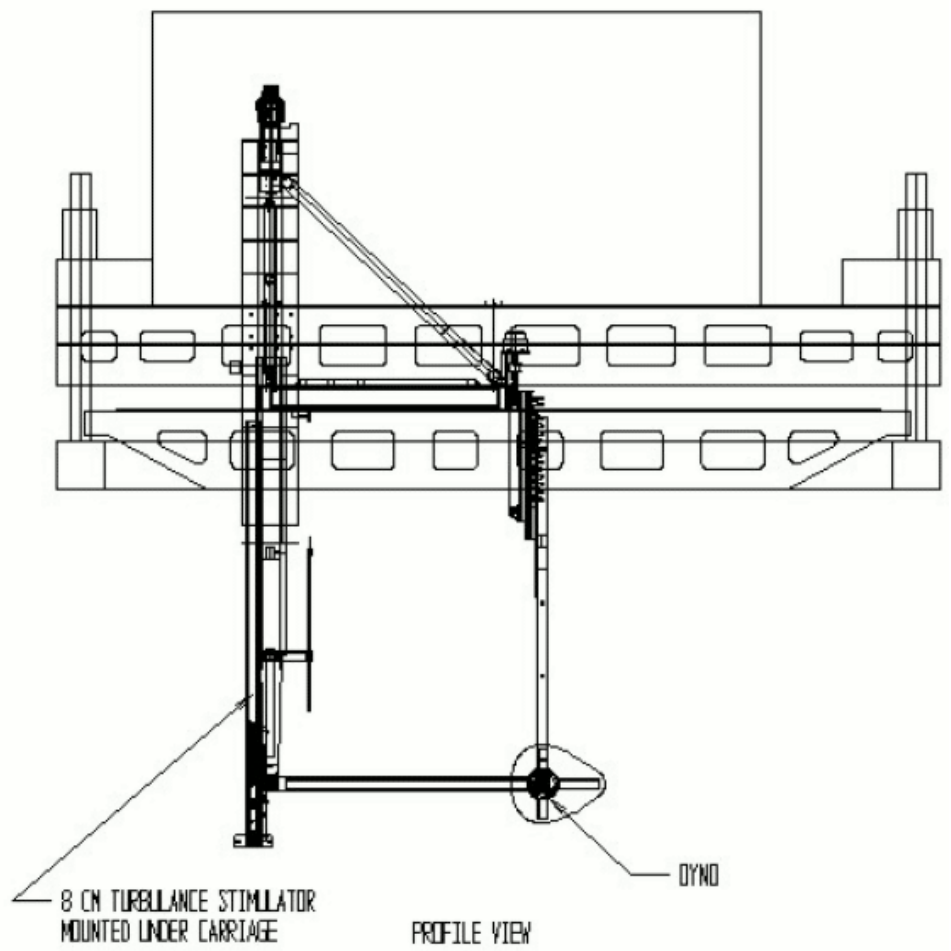
For the free vibration mode, the cylinder is mounted in between the ends of tow bars. The tow bars can be interchanged to allow the cylinder to oscillate in one or 2 degrees of freedom, namely the transverse and in-line directions. A schematic drawing of the towing frame and the cylinder (pipe dynamometer) is shown below.



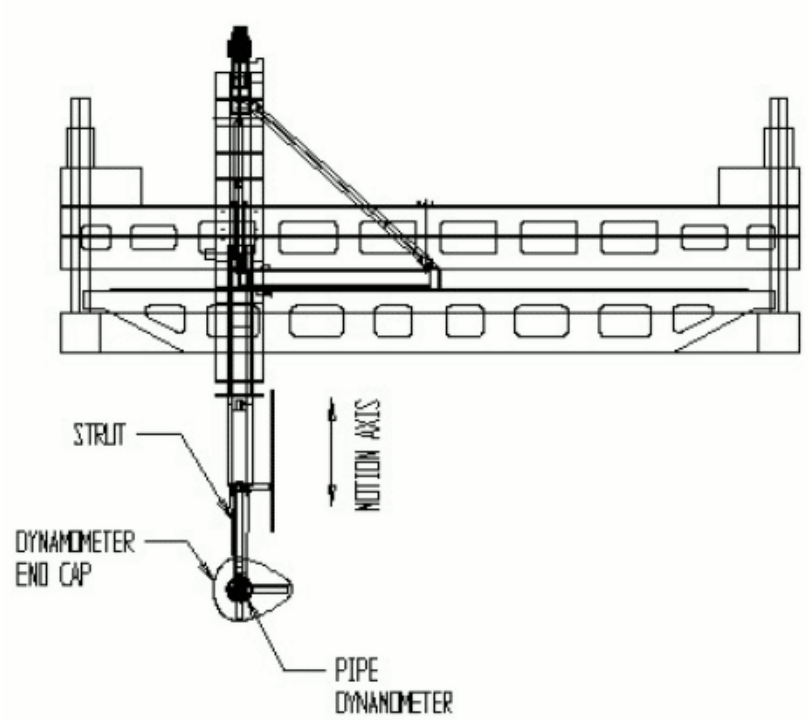
In the free vibration mode, turbulence screens were also used to assess the effects of turbulence on a smooth cylinder. Two different screens were used (fine and course). The position of the fine screen, relative to the smooth cylinder, is shown below.



The position of the course screen, relative to the smooth cylinder, is shown below.



In the forced vibration mode, the cylinder is placed directly between supporting struts and the tow bars were removed. The supporting struts are excited by an actuator, and mono-chromatic (single frequency excitation) and bi-chromatic (double frequency excitation) were applied to the cylinder. A schematic of the cylinder position operating in this mode is shown below.



Experimental Results

The data for high RE testing are divided into 2 key categories:

1. Detailed experimental results:
    - Clv against A/D: lift coefficient against vibration amplitude
    - Cm against A/D: added mass coefficient against vibration amplitude
    - Cd against A/D: drag coefficient against vibration amplitude
2. Summary experimental results:
    - A/D against Vrn: this data is based on Clv against A/D and taking Clv = 0.

Within each of the above categories, the following sub-categories are used:

- Cylinder surface type: Smooth, Almost Smooth, Intermediate Rough, Rough, Straked
- Vibration type: Free (1DOF and 2DOF), Forced (Monochromatic and Bi-chromatic)
- Turbulence screen (Smooth, Almost Smooth cylinders only): Fine grid (0.05m), Course grid (0.40m)

Data is presented in graphical format as well as tabular form.