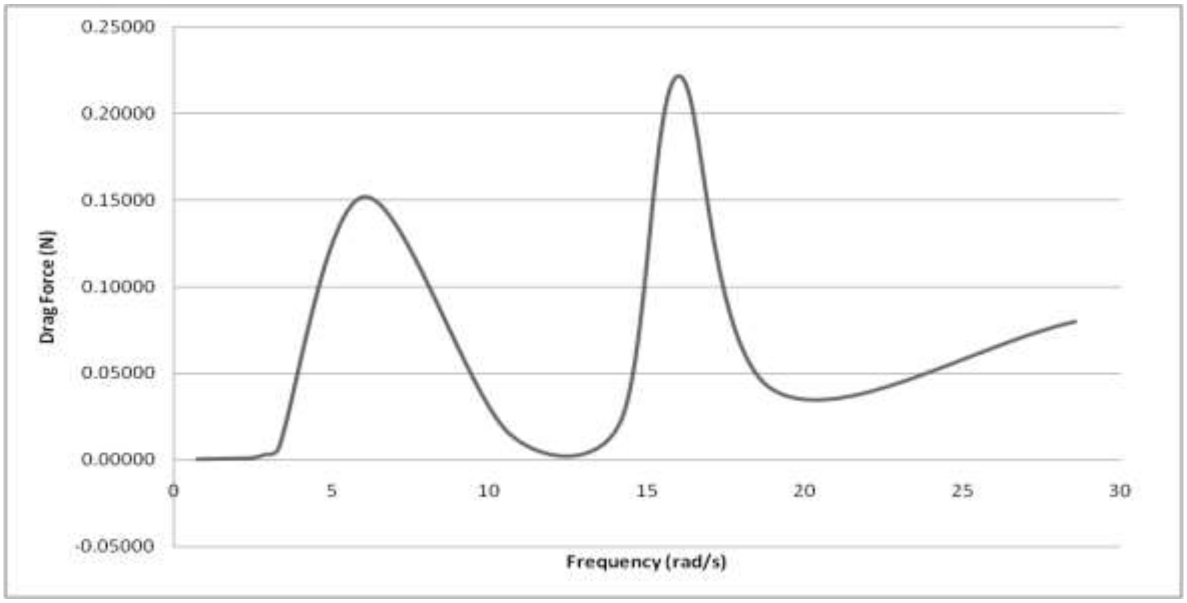

Fig.7(b). Frequency – Force Spectrum for Drag force.

Table 4 : Frequencies corresponding to Peak Lift and Drag forces in the spectrum.

Sl No.	Peak Lift Force (N)	Frequency corresponding to peak lift (rad/s)	Peak Drag force (N)	Frequency corresponding to peak drag (rad/s)
1	0.0012	2.44	0.15	6.04
2	0.027	6.04	0.23	15.98
3	0.12	28.57		

6. VIBRATION RESPONSE ANALYSIS.

3D Structural analysis of the riser to predict vibration response characteristics has been performed in ANSYS Workbench 15. Lift and Drag forces obtained from the 3D hydrodynamic analysis have been provided as input to the structural solver to obtain the riser response. Riser has been modeled as a hollow cylinder with thickness 0.0025 m. Number of 6 noded tetrahedral mesh elements have been chosen to be 66158. Top end has been modeled fixed in the x and y directions and the bottom end with motion in x, y and z direction arrested.

6.1. VIBRATION RESPONSE AT NATURAL FREQUENCIES.

Modal analysis for the riser with seven degrees of freedom has been performed to obtain the natural frequencies of the system. The first three modes of vibration and the corresponding natural frequencies of the riser in air has been obtained as 2.99, 9.7, and 20.23 rad/s respectively. Natural frequencies of the riser in water have been obtained solving Eqn. (8), considering added mass m_a = 0.16 kg. and spring constant k = 17.73 N-m/rad. The first three natural frequencies of the riser in water has been obtained as 2.88 rad/s, 7.16 rad/s, and 9.41 rad/s respectively.

$$\frac{1}{\omega_{nwater}^2} = \frac{1}{\omega_{nair}^2} + \frac{m_a}{k} \tag{8}$$

Drag and lift force, corresponding to the identified natural frequencies of the riser has been obtained from the plotted frequency – force spectrum. Loads corresponding to first three natural frequencies are given in table 5. Amplitude of variation of drag force has been much less compared to lift and hence it has been considered as a constant load acting in the flow direction on the riser. Lift force has been considered as periodically varying force acting in the cross flow direction as given in Eqn.(9). in structural solver.

$$F(t) = F_0 \times \cos(\omega_v \times t) \tag{9}$$

For all the identified natural frequencies, structural analysis has been performed to obtain vibration response characteristics. Figures 8(a), 8(b) and 8(c) shows the trajectories of the riser for a duration of 5 seconds.

Table 5 : Lift and Drag forces corresponding to natural frequencies of the riser in water.

Modes	Natural Frequencies (ω_n) rad/s	Lift Force corresponding to ω_n (N)	Drag Force corresponding to ω_n (N)
1	2.88	0.057	0.053
2	7.16	0.39	0.544
3	9.41	1.28	0.96

6.2. VIBRATION RESPONSE AT PEAK LOAD FREQUENCIES.

From the frequency – force spectrum, obtained in 2D hydrodynamic analysis, flow situations corresponding to peak loads on the riser has been identified. Structural analysis has been performed to obtain the vibration response of the riser during peak loads. Figures 9(a), 9(b) and 9(c) shows the trajectory of the riser during peak loads.

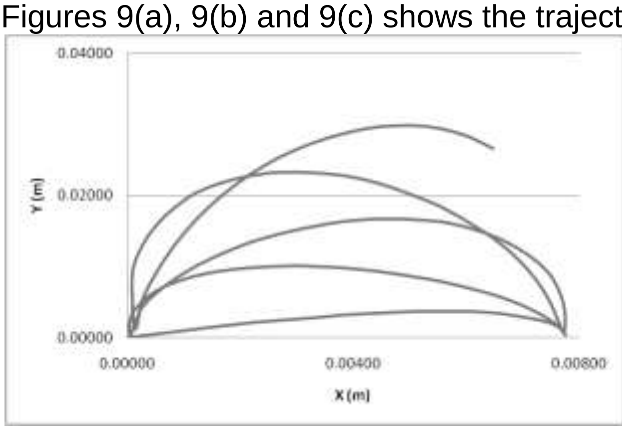

Fig.8(a).

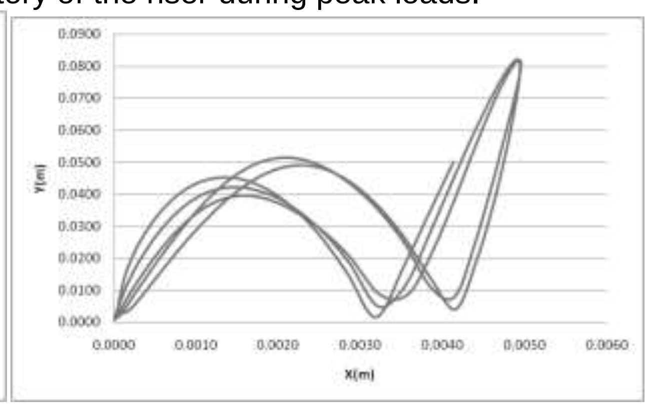

Fig. 8(b)

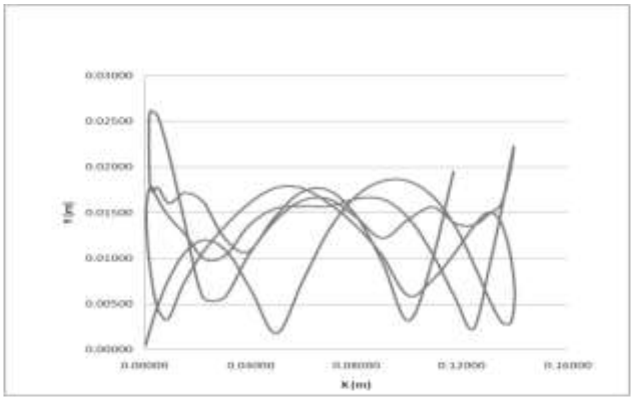

Fig. 8(c).

Fig 8(a). Trajectory of riser at first natural frequency excitation. Fig. 8(b). Trajectory of riser at second natural frequency excitation. Fig. 8(c). Trajectory of riser at third natural frequency excitation. Y – Total displacement in y direction, X – Total displacement in x direction.

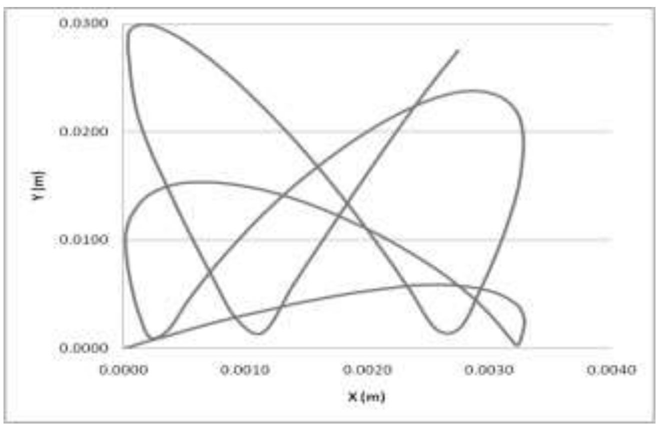

Fig. 9(a).

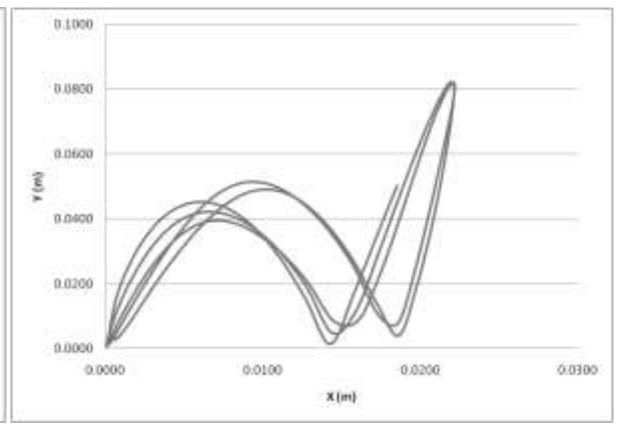

Fig. 9(b).

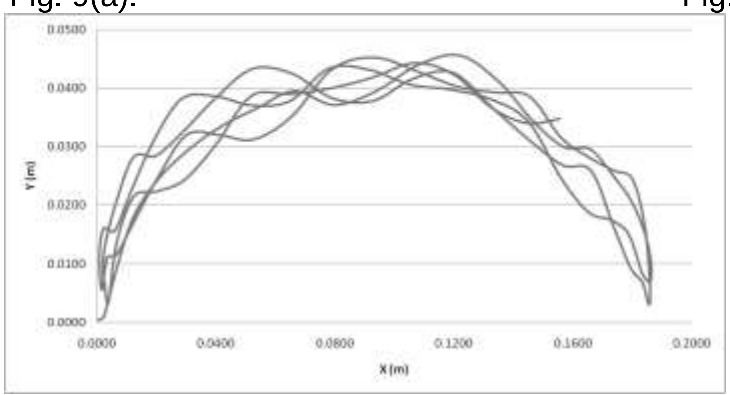

Fig. 9(a). Trajectory of the riser at first peak load frequency, 2.88 rad/s. Fig. 9(b). Trajectory of the riser at second peak load frequency, 6.04 rad/s. Fig. 9(c). Trajectory of the riser at third peak load frequency, 15.98 rad/s.

7. RESULTS AND DISCUSSIONS.

Figure 8(a) shows that the trajectory of the riser excited at first natural frequency is ‘C’ shaped one and lock in is not predicted at this point. For the second natural frequency the trajectory gives a clear ‘8’ figure pattern indicating lock in of the riser. Trajectory corresponding to the third natural frequency gives a more complicated branched ‘8’ figure pattern showing possible lock in.

Lock in has been observed at frequency 2.44 rad/s, instead of the first natural frequency of riser, 2.88 rad/s. Phenomenon may be attributed as a result of phase lag. Analysis for frequency at second peak load, 6.04 rad/s also shows a clear eight figure pattern as the riser trajectory.

At this frequency, both lift and drag forces are at peak values. The third peak load analysis gives again a ‘C’ trajectory, which shows no lock in. The frequency corresponding to this load, 15.98 rad/s is far beyond the natural frequency range of the riser. Hence the probability of lock in is also scarce.

Vortex shedding pattern at different locations of the riser, under sheared flow conditions has been found to be different. Efficacy of extending 2D flow simulations to 3D, to obtain force input for structural analysis has been successfully verified. Frequency – Force spectrum has been plotted for Reynolds number ranging from 250 to 2×10^4. Lock in was observed near first natural frequency at 2.44 rad/s indicating a phase lag. Lock in was clearly observed at all peak load frequencies of the spectrum within the range of risers natural frequency.

8. CONCLUSIONS.

The present work is an attempt towards the use of CFD based numerical studies in VIV prediction. The following conclusions can be drawn from the work carried out.

1. CFD is successful in prediction of vortices and this is evident from the subsequent bench mark structural behaviour. Use of commercial code can be justified as, the objectives are much beyond coding.
2. A reasonably accurate prediction of vortices is obtained from 2D studies. 2D simulations are resorted to neglecting the span wise flow pattern due to computational limitations.
3. Structural solver based on FEM has yielded the typical lock in patterns as described in 3D.
4. Fluid damping has been not accounted here, on the consideration of which better results can be obtained.
5. The shear flow vortex shedding in 3D can be decomposed into different layers and study can be extended using 2D simulations and structural analysis
6. On the whole this work contributes in providing with a force – frequency spectrum and bringing to light the fact that loci in occurs not only at natural frequencies but also at peak load frequencies of vortex shedding.

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