The SCR Wave-Rigid Body Rotation Model Maximum Amplitude Analysis Influenced by Z Direction Motion Based on Cable3D

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The SCR Wave-Rigid Body Rotation Model Maximum Amplitude Analysis Influenced by Z Direction Motion Based on Cable3D

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Abstract. Rigid body rotation(RBR) of steel catenary riser(SCR) is a problem which cannot be ignored in the caculation of transverse flow displacement and other velocity and acceleration. For the chapter, on basis of the RBR, wave force model, the large-deflection slender beam model(LDSB) and the suspension point's z direction motion, the influence of RBR on the transverse direction displacement of the SCR is explored. The results of analysis indicate that the structure is large affected by the wave and cross flow motion relative to RBR. With water depth augment, the maximum amplitude reduces from 10th to 200th.The displacement of RBR on the structure increases with the increase of vector S, and decreases with the diminution of vector S. At 140 nodes ,the effect is greatest There exists phase difference between rigid body oscillation and linear motion superposition the wave load, In working conditions 2 and 3, it is more significant. And the amplitude increased, offset or even decreased.

1. Introduction

The steel catenary riser is an important equipment for offshore production. Min Lou et.al [1] studied vibration suppression of risers. The marine risers with fairings through LES was researched by Jingyu Qu et.al [2]. Min Lou[3] make a study of VIV suppression of parallel risers. The steep S of flexible riser with influence of top angle, volume and mid water arch on the configurations was put forward by Dapeng Zhang et.al [4]. Jieying Sun[5] researched the risers and mooring system for S-spar consideration of heave damping plates. The lazy-wave unbonded flexible riser for layers's fatigue analysis was introduced by Tunan Fu et.al [6]. Zhiwen Wu et.al researched dynamic analysis riser under waves and vortex[7-8]. Vamshikrishna Domala and Raji Sharma [9] researched vortex-induced vibration response of riser.

In the actual platform-riser-mooring system, riser is connected with the platform through the flexible joint, and the platform-mooring system movement has an effect on the riser's response. Based on Cable3d-SCR model, the z-directional linear harmonic motion is added to the SCR model to study the influence of Z movement to the structure. By placing the rigid body swing as a load term superimposed on the structure equation, the comparison is made to the response of SCR between the oscillation of the rigid body and no the oscillation.

2. SCR LDSB and RBR Model

2.1 Caculation Vibration Theory[7][10]
The load gravity, hydrodynamic load, hydro static load, inertial and drag force and so on will be expressed in load q of SCR.

$$M\ddot{r} + Br^{(4)} - (\lambda r')' = q \tag{1}$$

M the quality matrix for SCR; B stiffness matrix for SCR; λ Lagrangian for SCR. q -the uniform force for SCR.

2.2 SCR Rigid Rotation System Model .
Under the action of wave, current and so on, there is a rotation taking the OB as the axis of rotation. As shown in figure 1.S is the rotation radius.

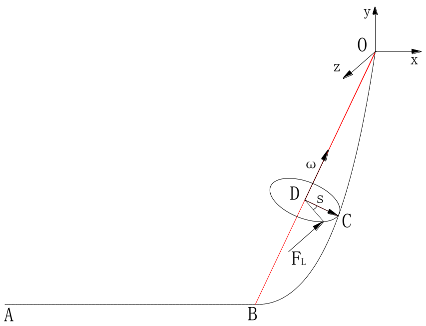

Figure 1. Rigid swing system

The riser's formula is got from the theorem[7][10],:

$$(m+m_a)s^2\ddot{a}_r + c_a s^2\dot{a}_r + mgc_1 s a_r = q_z\sqrt{s_1^2 + s_2^2} + q_x c_2 s_3 \tag{2}$$

m_a m - mass and its additions, α_r -angular displacement, q -environmental load, Other parameters are detailed in the literature[7][10].

After substituting formula (2) into formula (1), the equation (3) is got:

$$M\ddot{r} + Br^{(4)} + (m+m_a)\ddot{r}_r + c_a\dot{r}_r - (\lambda r')' = q \tag{3}$$

3. The SCR response of z linear harmonic motion.

The response of the SCR model in z direction is the main content of this paper. In this paper, the response of the Cable-SCR model is used to calculate the displacement. On the basis of applying wave load, the z direction motion, rigid body swing are superimposed on the SCR. Table 1 shows the linear parameters of conditions.

The response value of 10, 80, 140 and 200 are 2.53031m, 0.93382m, 0.55306 m and 0.38387m. After superimposed RBR, maximum amplitude of 10-200 are 2.52998m, 0.92835m, 0.54688m, 0.38299m. The response increase of the node 10-200 are -0.01%, -0.59%, -1.12% and -0.23%.It shows with the increase of the node, structure transverse response decrease gradually .After the superposition of RBR, the structural response is weakening.

As shown in figure 2-figure5 the response of each node of the structure decreases with the top movement amplitude reduce or the increase of the motion frequency as shown in table 2.

Table 1. The Top Load Response Parameters for Conditions [10]

Number.	A (m)	T (s)	f (Hz)	ω (Hz)
Con.1	3.0	10.80	0.093	0.581
Con.2	2.0	9.900	0.101	0.634
Con.3	1.0	9.000	0.111	0.698

Table 2. The Maximum Amplitude

Number.	Location	No RBR(m)	With RBR(m)	η (%)
Con.1	10th	2.53031	2.52998	-0.01%
Con.1	80th	0.93382	0.92835	-0.59%
Con.1	140th	0.55306	0.54688	-1.12%
Con.1	200th	0.38387	0.38299	-0.23%
Con.2	10th	1.76981	1.76936	-0.03%
Con.2	80th	0.74533	0.74471	-0.08%
Con.2	140th	0.45808	0.46017	0.46%
Con.2	200th	0.28692	0.28663	-0.10%
Con.3	10th	0.96836	0.96843	0.01%
Con.3	80th	0.51933	0.52159	0.44%
Con.3	140th	0.3507	0.35698	1.79%
Con.3	200th	0.24682	0.24670	-0.05%

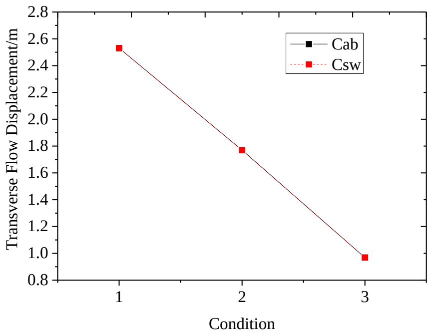

Figure 2. The amplitude of 10th varies with conditions.

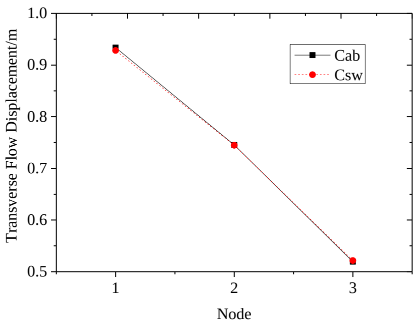

Figure 3. The amplitude of 80th varies with the conditions.

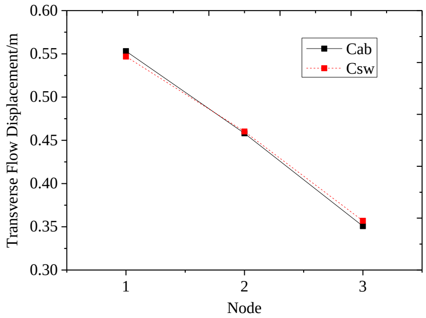

Figure 4. The amplitude of 140th varies with conditions.

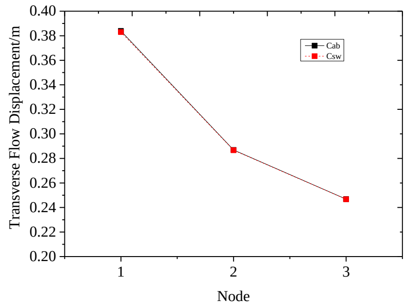

Figure 5. The amplitude of 200th varies with conditions.

3.1 Deep water linear Wave and SCR Interaction Model. [7]

If the floating platform or SCR moves with $\ddot{x}$ and $\dot{x}$, relative Morison motion formula:

$$f_H = \frac{1}{2} C_D \rho A (u_x - \dot{x}) |u_x - \dot{x}| + C_M \rho \frac{\pi D^2}{4} \frac{\partial u_X}{\partial t} - C_m \rho \frac{\pi D^2}{4} \ddot{x} \tag{4}$$

A -the projection areas, ρ - the sea water density, $\overline{V}_0$ -the drainage volume, C_m - the additional mass coefficient, C_M -the mass coefficient, C_D -the drag force coefficient.

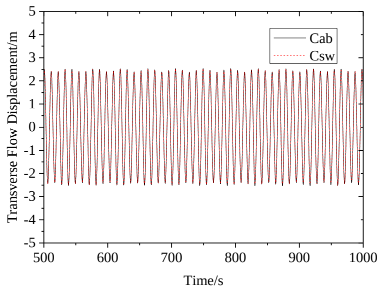

Figure 6. The 10th variation amplitude

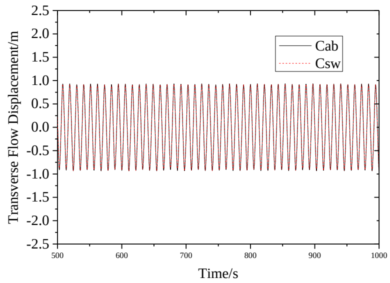

Figure 7. The 80th variation amplitude

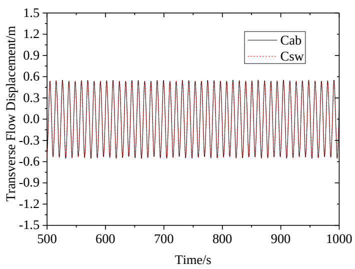

Figure 8. The 140th variation amplitude

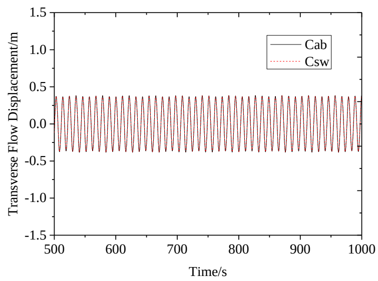

Figure 9. The 200th variation amplitude

4. Conclusion

The RBR of SCR is an important problem for cross-flow response relative to VIV. In this article, the maximum amplitude for the Cable-SCR model used to calculate is studied, as formula 1- formula 3. By placing the RBR model and wave model as a load term superimposed on the SCR equation, the maximum amplitude of the RBR is in comparison with the response of SCR no the oscillation, as figure 2- figure 5 and figure 6- figure 9.It shows with the node number increases, structural cross-flow response decrease gradually from 10th to 200th, as table 2. After the superposition of RBR, the increased structural maximum amplitude is weakening. And the change is the alike between maximum amplitude and the rotation radius vector S, From 10th to 140th, it gradually increased and then decreased to 200th.

The superposition or offset is on behalf of phase difference between the waves, the linear motion and rigid body rotation, as table 2.

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