Modal Interactions of Inclined Marine Riser under Vortex Induced Vibrations

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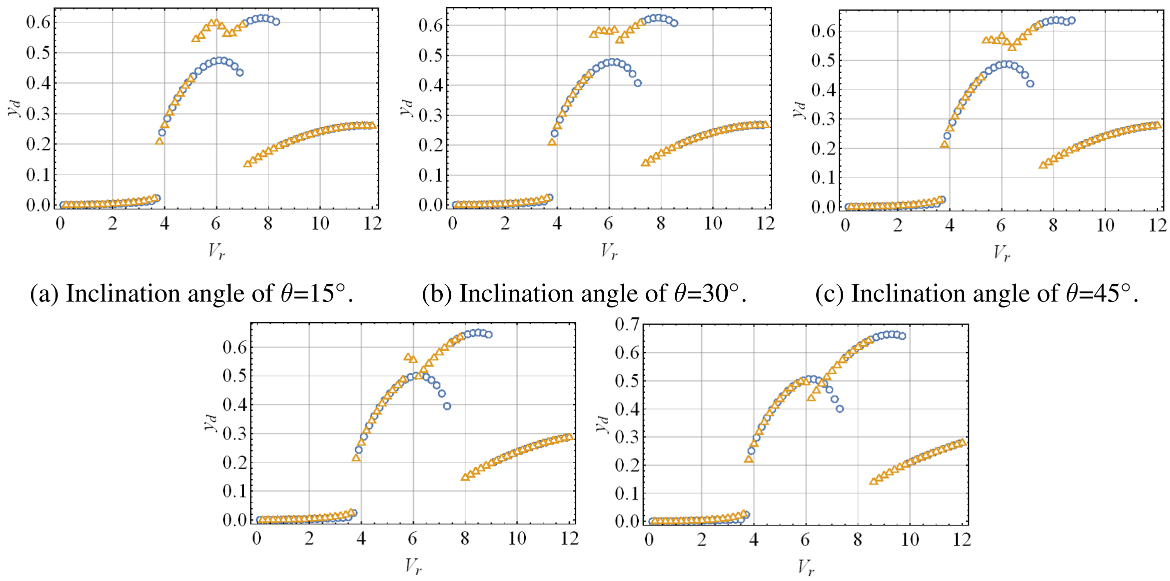
Abstract. In this work, we numerically study the response of an inclined marine riser excited by cross-flow vortex induced vibration forces under uniform currents. The effects of configuration angle, static deflection and nonlinear geometric stretching are considered causing the natural frequencies to be closely spaced. The response of the riser reveals that the structure can undergo 1:1 modal transition between the first two vibration modes during the lock-in phenomenon.

Introduction

The response of marine risers undergoing vortex-induced vibration is very rich in containing multimodal interactions with nonlinear features arising from fluid-structure coupling [1] based on the vortex shedding forces or induced by structural geometric effects [2]. Due to the complexity of analysis, in this work, a simplified riser beam model with nonlinear geometry is used to numerically analyze the cross-flow vibration of the structure when coupled with a Van Der Pol oscillator model [3] governing the vortex-induced vibration forces. A multi-mode reduced order model is utilized for the numerical results.

Results and Discussion

Following the mathematical model, we solve the static solution based on given parameters of configuration angle θ, applied tension T and the self-weight of the riser σ. Then, the dynamics of the riser around the equilibrium configuration is studied by sweeping the reduced velocity V_r, i.e. the vortex shedding frequency, and analyzing the response of the structure y_d. The results are depicted in Fig. 1.



(a) Inclination angle of θ=15°. (b) Inclination angle of θ=30°. (c) Inclination angle of θ=45°.

(d) Inclination angle of θ=60°. (e) Inclination angle of θ=75°.

Figure 1: Response of the inclined riser yd versus the reduced velocity V_r at T=2σ , x = 0.3 for different configuration angles. (○) Forward sweep. (△) Backward sweep.

The response of the structure shows the evolution of an intermediate band between the first and second modes response attributed to the 1:1 internal resonance, exciting both modes. This feature gets weaker when the influence of the static deflection and geometric effects are reduced by increasing the configuration angle and vanishes when the configuration angle is 75°. To conclude, we studied the VIV response of the inclined riser considering nonlinear geometrical effects. The complex dynamics involved are due to the presence of interacting resonances that require further investigations.

References

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