Finite-Span Effect on Vortex-Induced Vibration Simulations

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Abstract

The effects of using periodic boundary conditions when simulating vortex induced vibration (VIV) on a finite-span model are explored. When spanwise coherence is smaller than the simulated span, the peak VIV amplitude is under-predicted due to spreading of energy in frequencies around the Strouhal number.

Keywords: Vortex-Induced Vibration, Detached Eddy Simulations, spanwise coherence

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1. Introduction

Vortex-induced vibrations (VIV) are commonly observed in bridge decks, cables, power conductors, risers in oil rigs, etc. The Karman vortex shedding in the wake of the cylinder produces periodic forcing on the cylinder. In certain conditions the vortex-shedding frequency synchronizes ("lock-in") with the natural frequency of the system which results in high-amplitude oscillations (VIV) limited by the system damping. Experimental investigations of VIV are typically performed with finite-span cylinders with aspect ratios greater than 10 to minimize "end effects" (*cite*), where end-effect refers to the three-dimensional flow that results due to the finiteness of the model. End plates have been used in experiments, which reduce but not completely eliminate the end effect as horse-shoe vortices develop at the intersection of the cable and the end plates.

This problem is avoided in simulations by using periodic boundaries in the span direction. While the periodic boundaries imply an infinitely-long cylinder, the finite size of the computational domain in the span direction imposes a periodicity in the flow which may not exist in reality. If spanwise variations occur in the problem and the length scale of these variations is larger than the simulated span, then the flow simulations with spanwise periodicity will likely yield incorrect results. For stochastic (turbulent) flows, this length scale can be measured using two-point correlation; in particular, spanwise coherence is used.

In this paper, we present detached eddy simualtion (DES) results of four models of a circular cylinder experiencing VIV. The aspect ratio of these models are, $L/D = 1,\ 2,\ 5,$ and 10. Spanwise coherence is analyzed and it is observed that while the coherence is high around the vortex-shedding frequency (f_v),

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when
the reduced frequency, $k = fD/V_\infty$ matches the Strouhal number, $f_v D/V_\infty$
Introduction of VIV, review
Aspect ratio of cylinder, history
Motivation for this paper

Figure 1 presents a lift coherence contour for a $20 \times D$ static cylinder. As the figure shown, the cylinder is not corelated for the most frequency when it is long enough, exact for $St \sim 0.2$. In here, the peak frequency ($St \sim 0.2$) is the Kármán vortex shedding frequency. It is well known that the amplitude of rigit cylinder will significant increase if the natural frequency is close to the vortex shedding frequency.

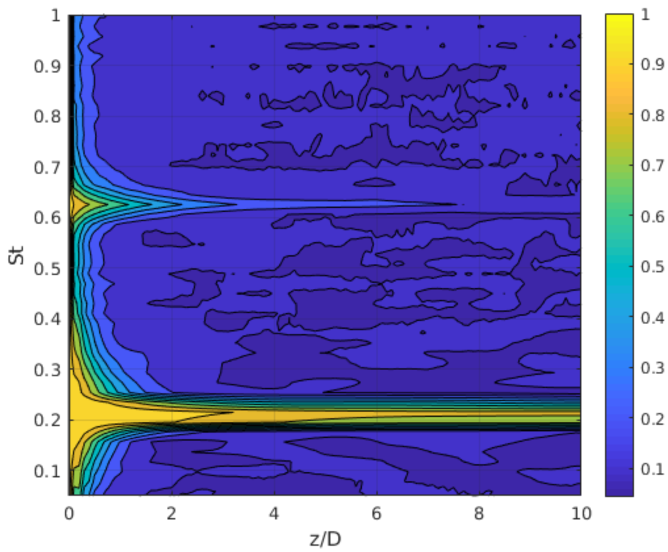


Figure 1: Lift coherence for static cylinder

change Z to L/D

2. Computational Methodology

add A schematic of the setup for the vortex-induced vibration(VIV) simulations As Figur 2 shown, an elastically-mounted cylinder with different aspect ratio is used in the simulations. The flow is considering as the incompressible flow since similar experiments were carried out in water runnel(ref).

numerical method, mesh

In order to study the aspect ratio of the circular cylinder, four different aspect ratios ($L/D = 1, 2, 5,$ and 10) have been chosen and simulated at reduced velocity $V_{R,n} = 2, 3, 4, 5, 5.9, 7, 8$. The averaged peak amplitude results are shown in

3. Numerical Results and Verification

Figure 3 compared the predicted non-dimensional mean amplitude for $10 \times D$ cylinder with the experiment (see e.g., Ref. [1]). Overall, the predicted amplitudes agree well with

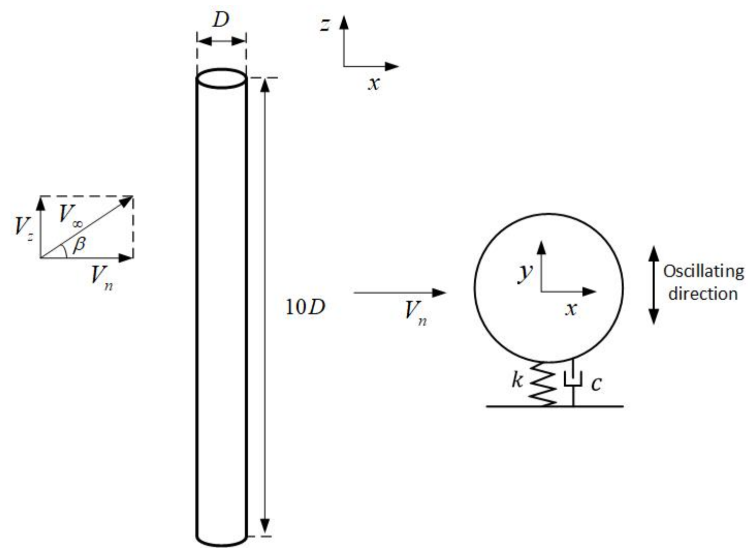


Figure 2: A schematic of the simulated setup for VIV simulations.

the experiment. Four branches can be identified on the experiment : initial excitation, upper branch, lower branch and desynchronization. All four branches are observed on the simulations. Therefore, the simulated method is able to simulate vortex induced vibration.

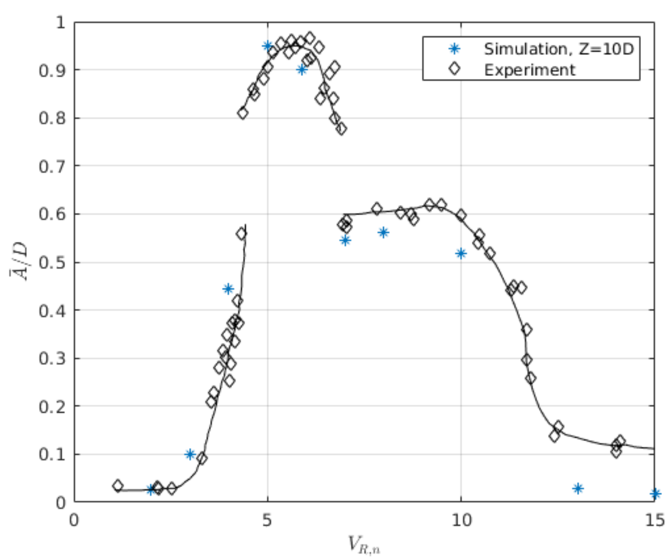


Figure 3: Comparison of predicted and experimental non-dimensional mean amplitude A/D for various reduced velocities $V_{R,n}$

Figure 5 and 6 present force coefficients coherence for different spans cylinders ($Z = 1D, 2D, 5D$, and $10D$). For longer cylinders ($Z = 5D$ and $10D$) are only correlated to the peak vortex shedding frequency and its harmonics. However, the shorter cylinders ($Z = 1D$ and $2D$) have more wider coherence for more frequencies??

Figure 7 shows ... different peak value, wider, lower psd smaller L/D.

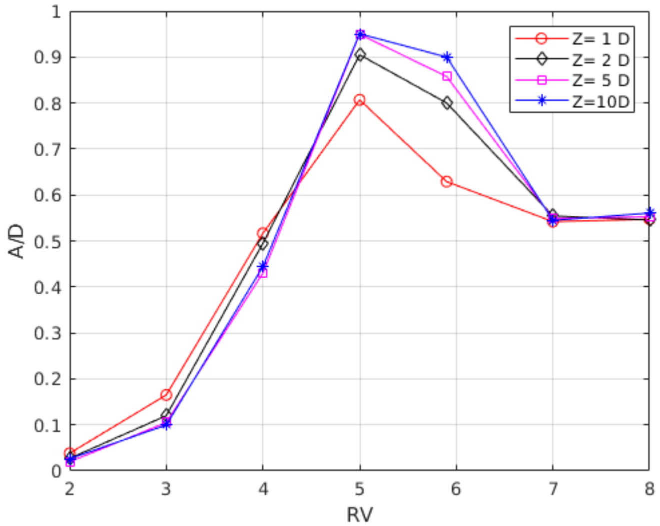
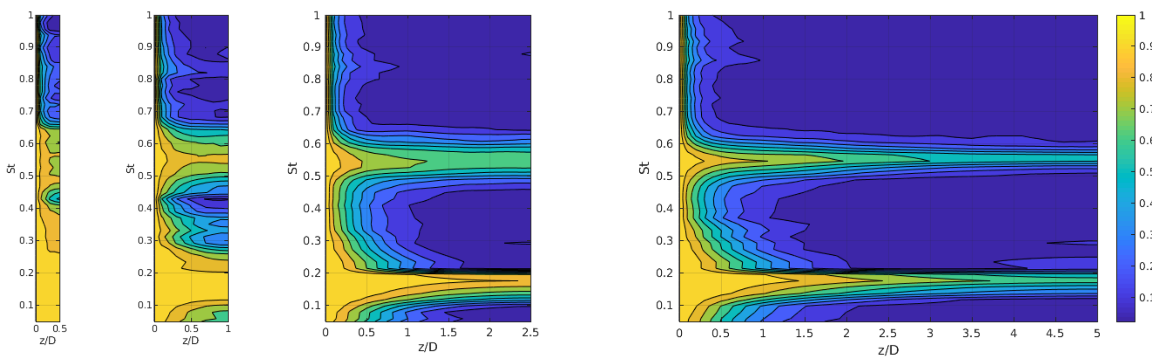
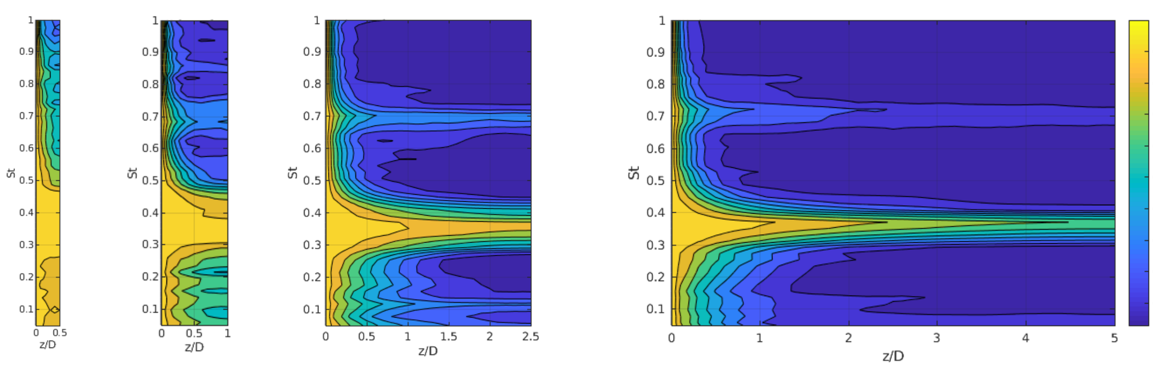


Figure 4: Comparison of predicted non-dimensional mean amplitude A/D for various reduced velocities $V_{R,n}$ for different span lengths



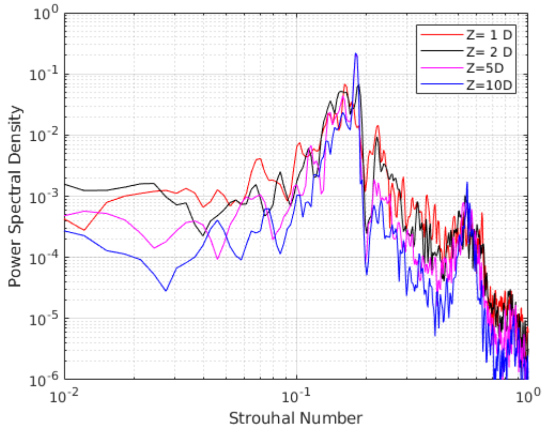
(a) $Z = 1D$ (b) $Z = 2D$ (c) $Z = 5D$ (d) $Z = 10D$

Figure 5: Lift coherence for various aspect ratio at $V_{R,n} = 5$

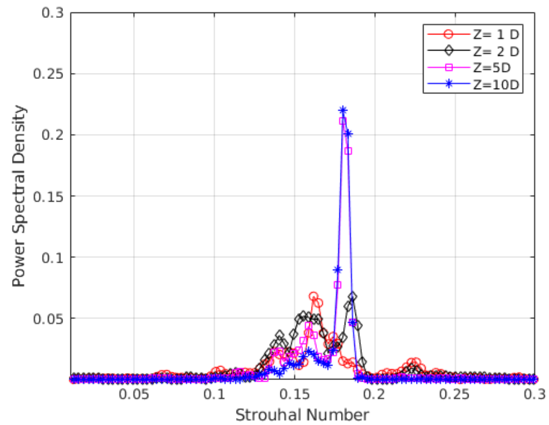


(a) $Z = 1D$ (b) $Z = 2D$ (c) $Z = 5D$ (d) $Z = 10D$

Figure 6: Drag coherence for various aspect ratio at $V_{R,n} = 5$



(a) Power spectral densities of C_l



(b) Zoom-in

Figure 7: Comparison of predicted power spectral densities (PSDs) of C_l for various frequencies at $V_{R,n} = 5$.

4. Conclusion

5. References

References

[1] Khalak, A., Williamson, C., 1997. Fluid forces and dynamics of a hydroelastic structure with very low mass and damping. Journal of Fluids and Structures 11, 973–982.