Learning Optimal Parametric Hydrodynamic Database for Vortex-Induced Crossflow Vibration Prediction of Both Freely-Mounted Rigid and Flexible Cylinders

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ABSTRACT

The Vortex-induced vibration (VIV) prediction of long flexible cylindrical structures relies on the accuracy of the hydrodynamic database constructed via rigid cylinder forced vibration experiments. However, to create a comprehensive hydrodynamic database with tens of input parameters including vibration amplitudes and frequencies and Reynolds number, surface roughness and so forth is technically challenging and virtually impossible due to the large number of experiments required. The current work presents an alternative approach to approximate the crossflow (CF) hydrodynamic coefficient database in a carefully chosen parameterized form. The learning of the parameters is posed as a constraint optimization, where the objective function is constructed based on the error between the experimental response and theoretical prediction assuming energy balance between fluid and structure. Such a method yields the optimal estimation of the CF parameters including vibration amplitudes and frequencies and Reynolds number, surface roughness and so forth, such as equipment aging and bio-fouling, inevitably alter the hydrodynamic coefficients, making long-term riser prediction and monitoring even more challenging.

The measured hydrodynamic coefficients are not only helpful in understanding the nature of the rigid cylinder free vibration but also serve as the fluid force database of several semi-empirical codes (Triantafyllou et al., 1999; Roveri et al., 2001; Larsen et al., 2001) for flexible riser response in the ocean current, assuming that the strip theory is valid (Han et al., 2018; Fan et al., 2019(1); Wang et al., 2021). However, to create a comprehensive hydrodynamic database with tens of input parameters including vibration amplitudes and frequencies as well as Reynolds number Re (Xu et al., 2013), surface roughness (Chang et al., 2011), riser configurations (Lin et al., 2020) and so forth is technically challenging and virtually impossible due to the large number of experiments required. Besides, during the lifetime of a riser in the field, long-term effects, such as equipment aging and bio-fouling, inevitably alter the hydrodynamic coefficients, making long-term riser prediction and monitoring even more challenging.

Therefore, the current work presents an alternative approach to approximate the crossflow (CF) hydrodynamic coefficient database in a carefully chosen parameterized form. The learning of the parameters is posed as a constraint optimization, where the objective function is constructed based on the error between the experimental response and theoretical prediction assuming energy balance between fluid and structure. Such a method yields the optimal estimation of the CF parametric hydrodynamic database and produces the VIV response prediction based on the updated hydrodynamic database. The method then was tested on a freely-mounted CF-only vibrating rigid cylinder in a moderate Re and a large-scale flexible cylinder test in the Norwegian Deepwater Program, and the result is shown to robustly and significantly reduce the error in predicting cylinder VIVs.