Research Proposal

Modeling and Prediction of Vortex-induced Vibrations of Multiple Interfering Bluff bodies

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When two flexibly mounted cylinders are tandem-arranged in the flow interference region, the upstream cylinder subjected to the free-stream flow can be excited into the vortex-induced vibrations (VIV) response, and the downstream cylinder immersed in the wake developed by the upstream cylinder can be excited into the wake-induced vibrations (WIV). VIV of an isolated elastically mounted cylinder have been thoroughly investigated over the last few decades. Its characteristics and mechanisms have been extensively reviewed in several literatures (Bearman, 1984; Williamson and Govardhan, 2004; Triantafyllou *et al*. 2016). Different from the excitation of VIV, wake-induced vibrations (WIV) occurs on a flexibly mounted cylinder placed within the wake flow developed by the other cylinder. As a consequence of the downstream body interfering with the vortices shedding from upstream body, a WIV response is characterized by a build-up of the oscillation amplitude persisting to high reduced velocity (Bokaina and Geoola, 1984; Hover and Triantafyllou, 2001; Assi *et al*. 2010). There are many practical engineering applications involving the structure in the configuration of two or more cylinders in close arrangement where VIV and WIV responses can be excited by the free-incoming flow and the wake interference simultaneously, such as arrays of risers system in the offshore platform, marine floating pipeline and crossflow heat exchanger. The combination of VIV and WIV increases the complexity of the dynamic response of such structures. To address the modeling and prediction of vortex-induced vibrations of multiple interfering bluff bodies, this proposal plans to start from the following two aspects in 12 months:

(A) Mapping the hydrodynamic properties of the cylinder free vibrations with the rigid cylinder forced combined-IL-and-CF vibrations.

For single cylinder VIVs, we can use the rigid cylinder forced vibration to map the hydrodynamic properties of the rigid and flexible cylinder free vibration accurately (Williamson and Govardhan, 2004; Fan *et al*. 2019). However, such a relationship is still unknown for the cylinder WIVs and calls for a further investigation.

(A.1) We intend to experimentally study the hydrodynamic forces of a rigid cylinder forced vibration in the wake of a stationary rigid cylinder with prescribed CF-only or combined-IL-and-CF motions and numerically compare with the corresponding rigid cylinder WIVs. (We have successfully developed a FSI numerical methodology based on discrete vortex method (DVM) for multiple rigid cylinders free vibrating in flow (Lin and Wang, 2019).)

(A.2) In order to assess the validity of the strip theory as the underlying assumption for all the semi-empirical prediction methods for flexible riser VIV in the offshore industry, we plan to compare the experimentally hydrodynamic coefficients from the rigid cylinder forced vibration with the numerically simulated fluid forces distribution along a flexible cylinder undergoing WIVs (we have successfully extended our DVM method to simulate multiple flexible cylinders vibrations (Lin et al. 2018)).

(B) Physics characterization of the wake interference between the two cylinders in tandem configuration and modeling criterion for multiple cylinders.

For a pair of static cylinders, previous studies (Zdravkovich, 1987; Zhou and Alam, 2016) have proposed detailed classifications of flow interference regime for different separations and incidence angles of the cylinders. However, there are few studies have been carried out on physical characterization of the wake interference between the two vibrating cylinders. Therefore, we plan to investigate two vibrating cylinders of a same diameter in a tandem configuration to address the following three questions as,

(B.1) whether and in what condition, the upstream cylinder vibration can be modeled as single cylinder VIVs (free from the interference from the downstream cylinder in the wake);

(B.2) whether and in what condition, the downstream cylinder vibration can be modeled as a cylinder WIVs in the wake of a stationary cylinder (the upstream cylinder motion is a weak effect).

(B.3) whether and in what condition, the hydrodynamic properties we learnt from the two cylinders in tandem configuration can be extended to model multiple (over three) cylinders vibration interference in the uniform inflow.

Selected References

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