Some Aspects of Experimental Investigations of FIV in a Hydrodynamic Tunnel for Naval Applications

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Flow Induced Vibration is a relevant topic that needs to be analyzed in naval applications to ensure acoustic discretion and structural resistance. Although large improvements have been performed regarding modeling and computation in the past decades, academic experiments are still required for FIV physical analysis and the validation of numerical computations. The paper presents experimental methods and results of academic FIV studies related to naval applications performed in the hydrodynamic tunnel at the French Naval Academy. The experiments aim to analyze FIV on naval structures as lifting surfaces at various flow conditions including transition, turbulent boundary layer, vortex shedding and cavitating flow as well ([1],[2],[3],[4]). The instantaneous wall-pressure has to be considered as the exciting field of the structure in a FIV problem. Figure 1 shows a transient time series of the wall-pressure coefficient measured close to the leading edge on the suction side of an hydrofoil experiencing a pitching motion at a relative low angular velocity. As shown as the angle of incidence increases the instantaneous pressure decreases exhibiting several features. This is related to different boundary layer regimes existing on the foil surface and passing over the wall-pressure transducer. At a first stage, the pressure decreases with no significant fluctuations that can be related to a laminar boundary layer. Then sudden strong wall-pressure fluctuations occur whereas the wall-pressure coefficient exhibits an inflexion behavior revealing a transitional boundary layer. Then the pressure coefficient decreases again with a net increase of the pressure fluctuations due to turbulent boundary layer. Finally strong low frequency wall-pressure fluctuations occur as the results of boundary layer detachment and vortex shedding. This shows that a structure can be submitted to various instantaneous flow loadings with different spectral components depending on the boundary layer regimes that can coexist on the structure. FIV depends on the degree of coupling between the wall-pressure spectral content and the structural modal response. An example of FIV observed in the tunnel is illustrated on Figure 1 showing the vibration level of a relative thick rectangular plate versus the Reynolds number and the frequency. As shown as the flow velocity increases a strong increase of the vibration level is recorded as the vortex shedding frequency coincides with a structural mode frequency. FIV experimental analysis required the development of advanced experimental devices to analyze both the flow and the structure response. At the Naval Academy, the structural response is analyzed through stresses, strains and vibration measurements. Local strains can be obtained from integrated strain gauges embedded in the structure. The vibration modal response is measured by means of mono-point laser or

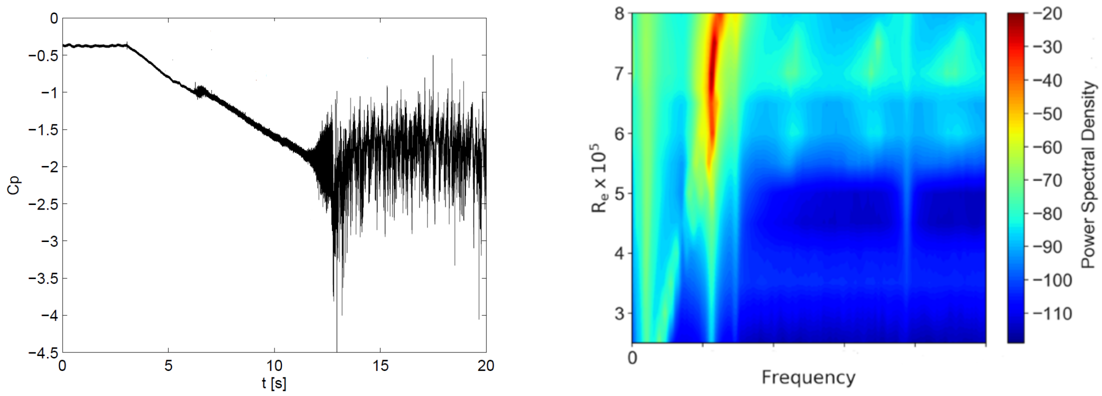

Figure 1: Left; Experimental transient time series of the wall pressure coefficient close to the leading edge on the suction side of a hydrofoil undergoing a pitching transient motion. Right; Experimental vibration level of a rectangular plate versus frequency and Reynolds number.

scanning laser vibrometers in order to identify the operating modal response. The global deformation shape of the structure can be obtain from a specific distance laser measurement device. Regarding the fluid, flow dynamics is examined through advanced technics based on Particle Image Velocity measurements and Proper Orthogonal Decomposition. Hydrodynamics forces are measured using a multi-component hydrodynamic balance. High speed cameras can be used in order to analyze the structural and flow dynamics in some cases. The paper presents FIV experiments and several physical results are reported. This provides an experimental data base for FIV physical analysis and that should be very beneficial to validate FIV simulations on academic cases for naval applications particularly.

References

[1] J. B. Leroux, O. Coutier-Delgosha, and J. A. Astolfi, "A joint experimental and numerical study of mechanisms associated to instability of partial cavitation on two-dimensional hydrofoil.," *Physics of Fluids*, vol. 5, pp. 52–101, 2005.

[2] A. Ducoin, F. Deniset, J. A. Astolfi, and J.-F. Sigrist, "Numerical and experimental investigation of hydrodynamic characteristics of deformable hydrofoils.," *Journal of Ship Research*, vol. 53, pp. 214–226, 2009.

[3] A. Ducoin, J. A. Astolfi, and M. L. Gobert, "An experimental study of boundary layer transition induced vibrations on a hydrofoil.," *Journal of Fluids and Structures*, vol. 32, pp. 37–51, 2012.

[4] A. Lelong, P. Guiffant, and J. A. Astolfi, "An experimental analysis of the structural response of flexible lightweight hydrofoils in cavitating flow.," *ASME. J. Fluids Eng*, vol. 140(2), p. 9 pages, 2017.