HYDRO ELASTIC BEHAVIOR OF VIBRATING BLADES

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ABSTRACT

Fluid structure interactions play an increasingly significant role in turbo machinery. While the behavior of vibrating airfoil has motivated numerous experimental and numerical works, very few studies have been devoted to the case of a hydrofoil. This paper presents an investigation of the hydro elastic behavior of vibrating blades which is of strong interest for hydraulic machinery applications. Indeed, rotor-stator interactions in pump-turbine induce pressure fluctuations resulting from the interaction of the rotating parts and the stationary parts of the machine, see [1, 2]. This phenomenon can lead to blade cracking, vibrations of the guide vane or resonance in the distributor channels. The prediction of the fluid structure coupling in pump-turbine is thus a challenging task. As a representative case study for vibrating blade in hydraulics machines, a NACA 0009 oscillating hydrofoil is considered. Two types of motions are investigated: forced and free oscillations. In the former case, the time history of the hydrofoil incidence angle is forced by a sinusoidal law. For the free motion case, the hydrofoil is attached to a flexible structure featuring a given stiffness and damping. The profile is departing at rest from an incidence angle and freely oscillates. Results from experiments, carried out in the EPFL high-speed cavitation tunnel, and unsteady numerical simulations, performed with ANSYS CFX, are presented.

Numerical simulations are first validated: grid and time step independence are tested and a good agreement with experiments is found. The numerical results are then analyzed to model the hydrodynamic load acting on the oscillating hydrofoil. Added moment of inertia, fluid damping and fluid stiffness coefficients as well are introduced in the model. The forced motion is first considered. Frequency domain investigations enable to identify the model coefficients. The influence of the motion amplitude, the frequency and the upstream velocity are investigated. The added moment of inertia is found to be a constant as assumed by the potential flow analysis. With an appropriate normalization, the fluid damping and the fluid stiffness coefficients could be only expressed as a function of the reduced frequency. Behavior laws are found and two regimes can be identified. From a threshold value of the reduced frequency, the two layers of vorticity developing in the wake of the profile crossed and the wake rolls up into discrete concentration of vorticity. The development of those vortices can lead to thrust-generation modifying the hydrodynamic load on the hydrofoil.

The model is then assessed for a simple case of a 1-degree-of-freedom model: the free motion. Four under-damped systems are considered. On one hand, the free motion of the hydrofoil is simulated with ANSYS CFX. On the other hand, the motion is predicted with the model proposed in the paper. The resulting time history of the incidence angle is then compared. Numerical simulation and model prediction show good agreements in terms of frequency and dimensionless damping. According to this result, the hydrodynamic action of surrounding flow on a vibrating blade can be correctly predicted with this model.

1. Nicolet C., Ruchonnet N., and Avellan F. *One-Dimensional modeling of Rotor Stator Interaction in Francis Pump-Turbine*. in *23rd IAHR Symposium*. 2006. Yokohama.
2. Zobeiri A., Kueny J.L., Fahrat M., and Avellan F. *Pump-Turbine Rotor-Stator Interactions in Generating Mode: Pressure Fluctuation in Distributor Channel*. in *23rd IAHR Symposium*. 2006. Yokohama.