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Evaluating flow-induced damping by solving a perturbation flutter problem

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Abstract

Flow-induced damping and flutter share a similar mechanical origin related to the energy exchange between a structure and the fluid flowing over it [1]. Whereas the flutter of flags, plates, and filaments has been studied extensively in the fundamental fluid-structure interaction literature, flow-induced damping received less attention, yet it is of considerable interest for the design of hydraulic turbines. Flow-added damping must be known to accurately predict the response amplitude of a turbine runner excited by rotor-stator interaction. The amplitude response will dictate the life of the component under fatigue loading.

In this conference talk, we present a monolithic approach to solve a fluid-structure interaction perturbation problem by the finite element method (FEM). We implemented in FreeFEM++ the formulation of the perturbation problem of a fluid passing over a flexible flat plate in two-dimensional flow, similar to that studied by Guo and Païdoussis [2]. The structure is modelled by the linearized elasticity equations, and the fluid is modelled as a perturbation solution to the linearized incompressible Navier-Stokes equations for an inviscid "plug" mean flow. This hybrid approach combining a viscous perturbation flow with an inviscid mean flow ensures that circulation effects are captured and that high Reynolds number problems can be tackled. The fluid and structure equations are coupled by the kinematic and dynamic boundary conditions at the fluid-structure interface. The monolithic approach allows us to solve all equations simultaneously, which is particularly useful for the study of flow-induced damping and flutter.

The method is fast, solving for the complex eigenvalues of the flat plate in two-dimensional flow in seconds. We thus reproduce the results of Ref. [2] with an FEM approach that can be extended to more complex geometries and flow conditions, opening the way for calculations on hydro turbines.

Keywords-component

Hydraulic turbines; Flow-induced damping; Flutter; Fluid-structure interaction; Finite element method.

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