Numerical Solution of Nonlinear Aeroelastic Problems Using Linearized Approach and Finite Element Approximations

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Abstract

The mathematical modelling of fluid-structure interaction (FSI) problems is important in various applications as aeroelastic tools used to investigate the aircraft safety. The classical aeroelastic approach based on the asymptotic aeroelasticity is fast, efficient and reliable, and this is why it is still very popular in the technical practice. The critical velocity can be determined, but in general the asymptotic stability does not guarantee the safety. Even if the system is aeroelastically stable, an external excitation can cause the transient growth and consequently the structural failure. In this case the use of computational methods is an alternative, which can provide an additional information.

The mathematical modelling of FSI problems in general is much more complicated as viscous possibly turbulent flow needs to be modelled. Moreover, the flow field interacts with the nonlinear behavior of the elastic structure and due to the vibrating structure the time changes of the flow domain has to be taken into account. Last, the coupled fluid-structure system for the fluid flow and for the oscillating structure needs to be solved simultaneously using a coupled strategy at any time instant. All this together makes the high fidelity aeroelastic models still very demanding to be solved efficiently and thus its direct use in industry is rather rare.

This paper is interested in solution of two-dimensional aeroelastic problems. The classical approach of linearized aerodynamical forces is used to determine the aeroelastic instability and the aeroelastic response in terms of frequency and damping coefficient. This approach is compared to the coupled fluid-structure model solved with the aid of finite element method used for approximation of the incompressible Navier-Stokes equations. The finite element approximations are coupled to the non-linear motion equations of a flexibly supported airfoil, the cases of two and three degrees of freedom are considered. Both methods are first compared for the case of small displacement, where the linearized approach can be well adopted. The influence of nonlinearities for the case of post-critical regime is tested and the numerical results are discussed.

References

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