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Aeroelastic Stability of Suspension Bridges using CFD

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Extended abstract

In recent years large span suspension bridges with very thin and slender profiles have been built without proportional increasing torsional and bending stiffness. As a consequence large deformations at the mid-span can occur with risk of aeroelastic instability and structural failure. Analysis of aeroelastic stability also named flutter stability is mostly based on semi-empirical engineering models, where model specific parameters, the so-called flutter derivatives, need calibration from wind tunnel tests or numerical methods. Several papers have been written about calibration of flutter derivatives using CFD models and the aeroelastic stability boundary has been successfully determined when comparing two-dimensional flow situations using wind tunnel test data and CFD methods for the flow solution and two-degrees-of-freedom structural models in translation perpendicular to the flow direction and rotation around the span axis of the bridge section. These models assume that the main contributing modal modes of the bridge are the first bending mode and the first torsional mode. The present work focuses on numerical evaluation of the flutter instability using an arbitrary number of modes describing the structural deformation. Furthermore, flutter derivatives are evaluated by CFD models using forced motion of a bridge section in a two-dimensional virtual wind tunnel. The parameter region of critical values is shown to be outside measured values. It is shown that a rough extrapolation of the measured values may lead to erroneous results and CFD simulations may be used for extrapolation into the critical region.

In a numerical example the Great Belt Link of Denmark is used with a mid-span of 1624m and outer span of 535m and pylons with a height of 250m. Numerical two-dimensional aerodynamic analyses have been performed on a bridge deck section for identifying the flutter derivatives.

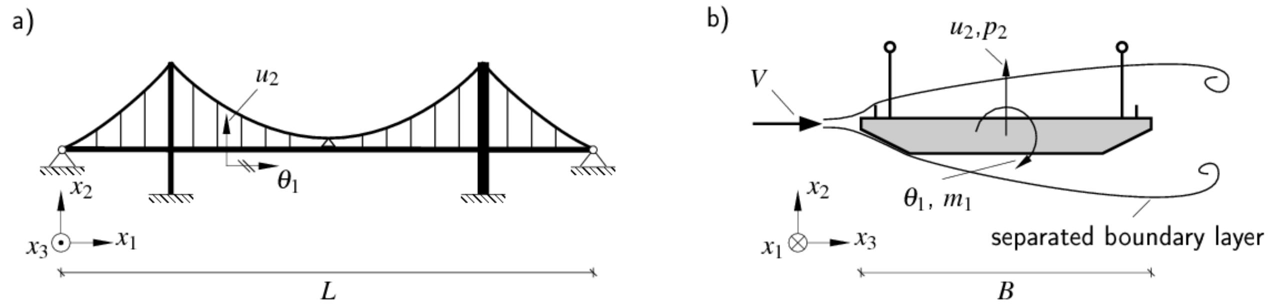

Fig. 1 Definition of notation. a) Principle structural setup of a suspension bridge. b) Cross section of bridge deck.

The grid around the profile is illustrated in Fig. 2a and the velocity vector field results from a steady simulation is visualized in Fig. 2b.

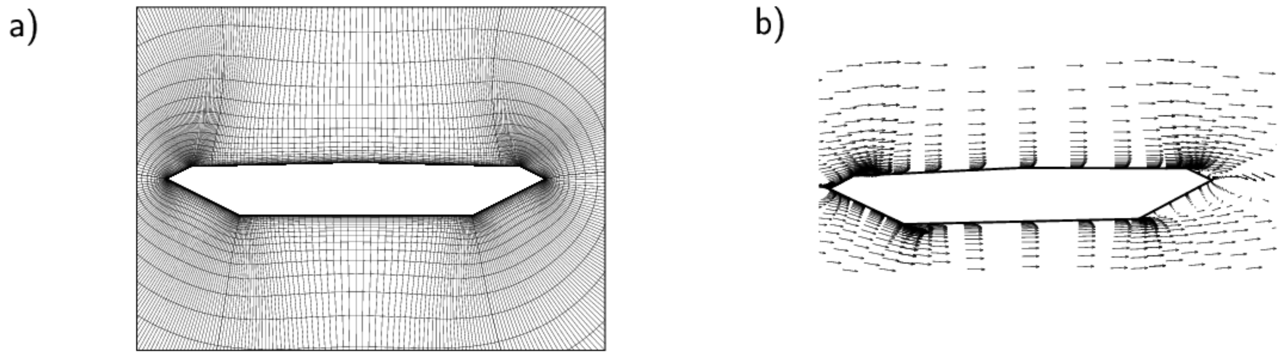

Fig. 3 a) Fine mesh around the bridge section. b) Velocity field visualization.

In Fig. 2 the numerical evaluated flutter derivatives are compared with wind tunnel test data. As seen, the qualitative and quantitative variations are captured by the numerical analyses. However, at large values for $\frac{2\pi V}{\omega B}$ the numerical solution deviates from the extrapolations. CFD results are easily obtained in the entire region and may be used for extrapolating measured flutter derivatives.

Finally, the critical flutter velocity and frequency are determined for different number of modes included in the analysis and using an extrapolation from the measured data and numerical evaluated flutter derivatives, respectively. It is concluded that the flutter analysis is very sensitive to the correct evaluation of flutter derivatives and a rough extrapolation may result in erroneous results.

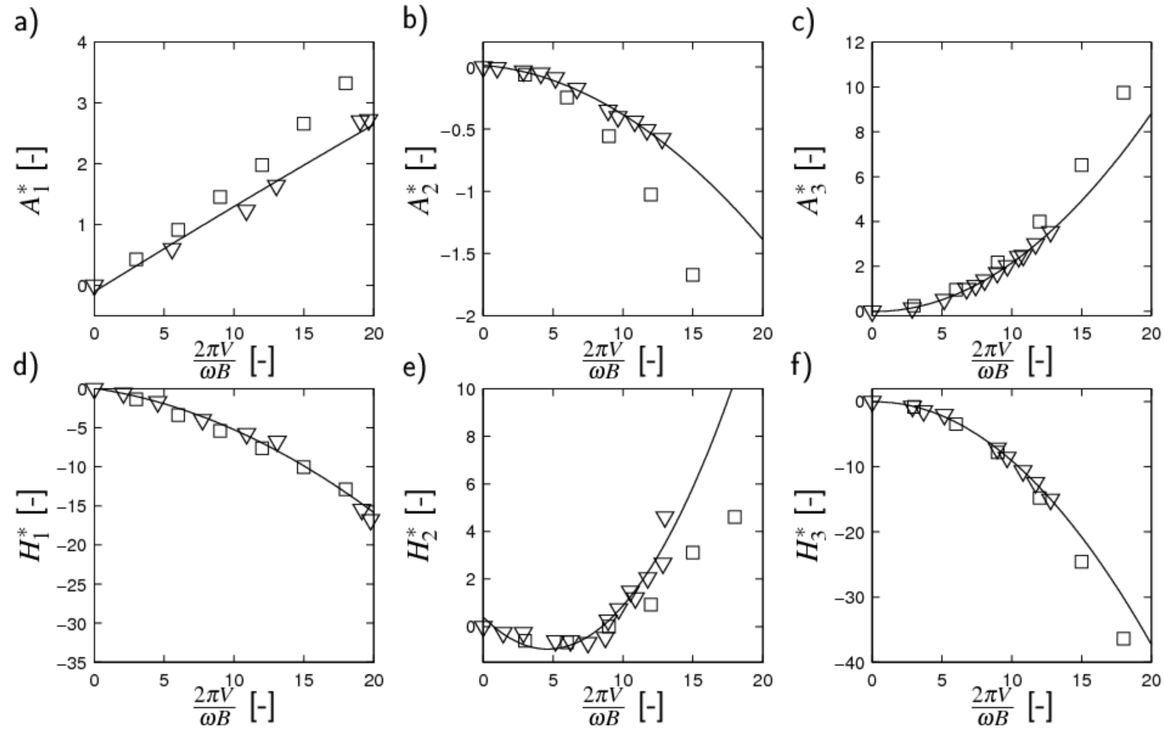

Fig. 3 Flutter derivatives. (∇) *Wind tunnel test results from Reinhold et al.* (□) *CFD results. (——) Least square fit to Reinhold test data using 3rd degree polynomiums.*