Universität Stuttgart

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Master Thesis

Topic:	**Simulation of airfoil flutter vibrations without and with impact absorbers**
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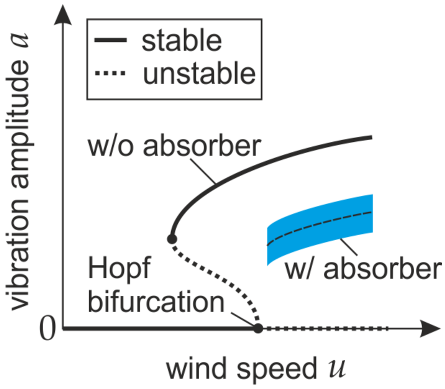
Background



The aero-elastic behavior of a simple airfoil was recently studied experimentally in a wind tunnel. The airfoil had a uniform cross section area (NACA 0010-65) and was suspended elastically such that it was able to undergo pitch and plunge motion. Two configurations were analyzed, one without and one with impact absorbers. As illustrated schematically in the diagram, the static equilibrium (rest position, a=0) loses stability at a critical wind speed giving rise to vibrations (Hopf bifurcation). In the configuration without absorber, Limit Cycle Oscillations (periodic vibrations) occur already for wind speeds lower than the critical one. More specifically, the stable static equilibrium co-exists with the Limit Cycle Oscillation down to the indicated turning point. In the configuration without absorbers, the saturation of the growing vibrations is attributed to nonlinear aerodynamic forces associated, in particular, with flow separation. In the configuration with absorbers, the impacts transfer energy from the low-frequency pitch-plunge mode to high-frequency elastic modes of the airfoil, so that the vibration energy is dissipated more efficiently on faster time scales. Thus, the post-critical vibration level is significantly reduced. While the vibrations are strictly periodic in the case without absorbers, the discontinuous mechanical nonlinearity (unilateral contacts) in the case of impacting absorbers leads to strongly modulated, non-periodic vibrations, as illustrated by the shaded region in the figure.

Research goal

The objective is to simulate the aero-elastic behavior of the elastically suspended airfoil without and with impact absorbers, and compare with the available measurements.

Approach

The elastically suspended airfoil is described in terms of a subset of normal modes of vibration. The natural frequencies are updated and the structural damping is specified based on the results available from modal testing. The impact absorbers are modeled as point masses, subjected to gravity, and the contact with the airfoil is described using Hertzian contact theory. The flow is modeled as two-dimensional, using the arbitrary Lagrange Eulerian form of the Navier-Stokes equations. Efficient high-order discontinuous Galerkin spectral element method is utilized to solve the governing equations. The radial basis function method is used to update the position of the fluid mesh. First, numerical forward time step integration is used to simulate the fluid-structure interaction. A coupling with different time steps for structure and fluid simulation can be used for better efficiency. The wind speed is both successively increased and decreased in order to obtain the whole branch of stable Limit Cycle Oscillations in the case without absorbers. Then Harmonic Balance is used in conjunction with predictor-corrector path continuation in order to resolve also the unstable branch of Limit Cycle Oscillations between Hopf bifurcation and turning point.