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Modelling and Simulation of Aero-Elastic Vibrations Using System Dynamic Approach

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Abstract : Flutter as a phenomenon of flow-induced and self-excited vibration has to be recognized considering its harmful effect on the structure especially in a stage of aircraft design. This phenomenon is also important for a wind energy harvester based on the fluttering surface due to its effective operational velocity range. This multi-physics occurrence can be presented by two governing equations in both fluid and structure simultaneously in respecting certain boundary conditions on the surface of the body. In this work, the equations are resolved separately by two distinct solvers, one-time step of each domain. The modelling and simulation of this flow-structure interaction in ANSYS show the effectiveness of this loosely coupled method in representing flutter phenomenon however the process is time-consuming for design purposes. Therefore, another technique using the same weak coupled aero-structure is proposed by using system dynamics approach. In this technique, the aerodynamic forces were calculated using singularity function for a range of frequencies and certain natural mode shapes are transformed into time domain by employing an approximation model of fraction rational function in Laplace variable. The representation of structure in a multi-degree-of-freedom coupled with a transfer function of aerodynamic forces can then be simulated in time domain on a block-diagram platform such as Simulink MATLAB. The dynamic response of flutter at certain velocity can be evaluated with another established flutter calculation in frequency domain k-method. In this method, a parameter of artificial structural damping is inserted in the equation of motion to assure the energy balance of flow and vibrating structure. The simulation in time domain is particularly interested as it enables to apply the structural non-linear factors accurately. Experimental tests on a fluttering airfoil in the wind tunnel are also conducted to validate the method.

Keywords : flutter, flow-induced vibration, flow-structure interaction, non-linear structure
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