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Aeroelastic Stability Analysis in Turbomachinery Using Reduced Order Aeroelastic Model Tool

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Abstract : In the present day fan blade of aero engine, turboprop propellers, gas turbine or steam turbine low-pressure blades are getting bigger, lighter and thus, become more flexible. Therefore, flutter, forced blade response and vibration related failure of the high aspect ratio blade are of main concern for the designers, thus need to be address properly in order to achieve successful component design. At the preliminary design stage large number of design iteration is need to achieve the utter free safe design. Most of the numerical method used for aeroelastic analysis is based on field-based methods such as finite difference method, finite element method, finite volume method or coupled. These numerical schemes are used to solve the coupled fluid Flow-Structural equation based on full Naiver-Stokes (NS) along with structural mechanics' equations. These type of schemes provides very accurate results if modeled properly, however, they are computationally very expensive and need large computing recourse along with good personal expertise. Therefore, it is not the first choice for aeroelastic analysis during preliminary design phase. A reduced order aeroelastic model (ROAM) with acceptable accuracy and fast execution is more demanded at this stage. Similar ROAM are being used by other researchers for aeroelastic and force response analysis of turbomachinery. In the present paper new medium fidelity ROAM is successfully developed and implemented in numerical tool to simulated the aeroelastic stability phenomena in turbomachinery and well as flexible wings. In the present, a hybrid flow solver based on 3D viscous-inviscid coupled 3D panel method (PM) and 3d discrete vortex particle method (DVM) is developed, viscous parameters are estimated using boundary layer(BL) approach. This method can simulate flow separation and is a good compromise between accuracy and speed compared to CFD. In the second phase of the research work, the flow solver (PM) will be coupled with ROM non-linear beam element method (BEM) based FEM structural solver (with multibody capabilities) to perform the complete aeroelastic simulation of a steam turbine bladed disk, propellers, fan blades, aircraft wing etc. The partitioned based coupling approach is used for fluid-structure interaction (FSI). The numerical results are compared with experimental data for different test cases and for the blade cascade test case, experimental data is obtained from in-house lab experiments at IT CAS. Furthermore, the results from the new aeroelastic model will be compared with classical CFD-CSD based aeroelastic models. The proposed methodology for the aeroelastic stability analysis of gas turbine or steam turbine blades, or propellers or fan blades will provide researchers and engineers a fast, cost-effective and efficient tool for aeroelastic (classical flutter) analysis for different design at preliminary design stage where large numbers of design iteration are required in short time frame.

Keywords : aeroelasticity, beam element method (BEM), discrete vortex particle method (DVM), classical flutter, fluid-structure interaction (FSI), panel method, reduce order aeroelastic model (ROAM), turbomachinery, viscous-inviscid coupling
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