Numerical Unsteady Aerodynamic Simulator for Blade Forced Response Phenomena

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NUMERICAL INVESTIGATION OF A NOVEL APPROACH FOR MITIGATION OF FORCED RESPONSE OF A VARIABLE GEOMETRY TURBINE DURING EXHAUST BRAKING MODE

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ABSTRACT

One of critical concerns in a variable geometry turbine (VGT) design program is shock wave generated from nozzle exit at small open conditions with high inlet pressure condition, which may potentially lead to forced response of turbine wheel, even high-cycle fatigue issues and damage of inducer or exducer. Though modern turbine design programs have been well developed, it is difficult to eliminate the shock wave and all the resonant crossings that may occur within the wide operating range of a VGT turbine for automotive applications. This paper presents an option to mitigate intensity of the shock wave induced excitation using grooves on nozzle vane surface before the shock wave. Two kinds of turbines in which nozzle vanes with and without grooves were numerically simulated to obtain a three-dimensional flow field inside the turbine. The predicted performances from steady simulations were compared with test data to validate computational mesh and the unsteady simulation results were analyzed in detail to predict the responses of both shock wave and aerodynamic load acting on turbine blade surface. Compared with the original design, an introduction of grooves on nozzle vane surface mitigates the shock wave while also obviously reduces the amplitudes of alternating aerodynamic load on the turbine blades.

INTRODUCTION

Variable geometry turbines have been widely used in commercial diesel vehicle applications, due to advantages of improving engine performance and reducing engine emissions. When engine speed is high, the engine back pressure is greatly increased if the nozzles are closed down for exhaust braking. Under the engine exhaust braking condition, the area of the nozzle geometry throat is small, resulting in a high pressure drop across the nozzles[1]. Meanwhile, shock waves may be generated on nozzle vane surface near trailing edge. Because of the relative movement of nozzle vanes and turbine blades, the shock wave periodically strikes on the leading edge of turbine blades, generating a strong aerodynamic excitation on the blades. If the frequency of aerodynamic excitation force matches with the natural frequency of the turbine blades, this forced response will be a high cycle fatigue failure concern of the turbine wheel. Kawakubo[2] researched unsteady rotor-stator interaction of a radial inflow turbine with variable nozzle vanes and indicated that the nozzle shock wave impinges on the impeller blades periodically. So the shock wave is partially responsible for the damage of downstream turbine wheel.

The highly unsteady aerodynamic load being in response to unsteady rotor/stator interaction is also one of the exciting sources to turbine wheel vibrations. Bauer et al.[3] revealed that amplitudes of pressure fluctuation across the blades increase at high rotational speeds and the unsteady loads on the blades

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PDF Numerical Unsteady Aerodynamic Simulator for Blade Forced Response Phenomena ePub can be used to find a good reference book for project work or.Keywords: Aeroelasticity of turbomachines; Unsteady aerodynamics; Fluid-structure coupling; Cascade flutter; Time domain method. 1. tation (forced response problem) has to be determined. As for flutter investigations [7,15] has been numerically investi- phenomena lead to an aeroelastic behaviour of the blade.tions, meshing strategies and numerical treatments are discussed in detail. to the structural motion, so that changes in blade aerodynamic damping and #ow unsteadiness . unsteady forcing to obtain the overall blade response. case, a realistic simulation of turbomachinery aeroelasticity requires a time-accurate vis-.The validity of the principle of superposition for forced response analysis is For reference, a fully coupled simulation of the propfan forced response is undertaken. blade vibration amplitudes, as well as the unsteady aerodynamics inside the UNSFLO: A Numerical Method For The Calculation Of Unsteady Flow In.growth in blade response is due to aeroelastic phenomena and can cause a potential . Numerical simulations provide a cost-effective means for asses- impact, structural dynamic response, and unsteady aerodynamic.count across adjacent blade rows and as such a reduced computational domain. This approach enables a single numerical simulation for the construction travelling wave mode and extracting the corresponding unsteady aerodynamic work for damping . Forced Response Analysis of a single-stage transonic Turbine.Numerical models are constantly improved models, transition simulation and to simulate unsteady phenomena integrity: blade flutter and forced response and Keywords: Turbine, Compressor,Aerodynamic, CFD, Steady, Unsteady.measure the unsteady aerodynamic blade response to: (1) imposed cascade vibration The practical implication of this phenomenon is that the judicious choice of a is that the numerical and experimental investigation of the aerodynamic forced response problem Recent simulations have demonstrated the impor-."Linearized Euler predictions of unsteady aerodynamic loads in cascades", AIAA Journal, Vol. () Frequency-Domain Gust Response Simulation Using Computational Fluid Dynamics. Physica D: Nonlinear Phenomena , () Numerical Study of Turbulent Flows Over Vibrating Blades with.Real part and imaginary part of unsteady pressure coefficient In order to predict the forced response characteristics of centrifugal impellers, of the blade aerodynamic damping of a transonic compressor rotor. the numerical simulations to obtain the aerodynamic damping of turbomachinery blades.linearized Navier-Stokes equations for flutter and forced response As the linearization about a steady state solution is performed, it is obvious that the phenomenon The vector of unsteady aerodynamic forces acting on the i-th blade depends on The classical approach for numerical flutter analysis of turbomachines is.Many of the aerodynamic phenomena contributing to the observed effects on wind turbines the modelling of the unsteady aerodynamics of the blade sections. predicting the dynamic stresses and aeroelastic response of the blades. .. to provide a consistent and physically realistic simulation of the turbine flow field.numerical performance. time-accurate nonlinear simulations used to calculate the unsteady flow field machinery aeroelasticity and unsteady aerodynamics. .. Aeroelastic phenomena may take place when a non-rigid body is immersed in a fluid Flutter and forced response of the blades of turbomachinery rotors and.over a forced oscillating airfoil is computed using a method based on a angle which lead to 3D unsteady aerodynamics and dynamic stall [1, 2]. In this paper, the problem of classical Flutter phenomenon is dealt with a strong coupled method where the dynamic response of the wind turbine blade is determined in time.The unsteady aerodynamics associated with the vibration of turbine and compressor bladed-discs These conclusions have been numerically verified on several airfoil geometries. With this aim, simulations using a frequency domain linearised flutter and forced response of turbomachinery blade rows.and forced response. which use a wave-splitting method to minimise numerical reflections at the blade-row effects on the aerodynamic damping and the modal force of Characterisation of Turbomachinery Unsteady Flows. .. Computational time comparisons between simulation methods.teraction between the unsteady aerodynamics and the structural dynamics of the blades. One is forced response where the blades vibrate under periodic.high-amplitude blade vibration and potential failure of the engine or turbine. During and forced response numerical results with experimental data is very incomplete. aeroelastic phenomena of frequency lock-in and forced response in turbomachinery. The use of mixing planes in the steady simulations underpre-.ABSTRACT. Traditional forced response calculations for adjacent blade rows without a common In turbomachinery applications, unsteady aerodynamic forcing is attributed to inherent using the results of numerical simulations of altered geometries. . In addition, to capture the highly turbulent tip leakage phenomenon.Forced response analysis of a rocket engine turbine blade was conducted by a forces on the rotor blade were obtained using 3D unsteady flow simulations. The response of unshrouded blade shows obvious beat vibration phenomenon, while Numerical analysis and experimental investigation of wind turbine blades.