VIBRATORY STRESS ANALYSIS AND FATIGUE LIFE ESTIMATION OF TURBINE BLADE

By

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to my parents

CERTIFICATE

This is to certify that the thesis entitled 'VIBRATORY STRESS ANALYSIS AND FATIGUE LIFE ESTIMATION OF TURBINE BLADE' by Nalinaksh S. Vyas has been prepared under our supervision in conformity with the rules and regulations of the Indian Institute of Technology, Delhi. We further certify that the thesis has attained a standard required for a Ph.D. degree of the Institute. The results contained in this thesis have not been submitted, in part or full, to any other university for any degree or diploma.

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ABSTRACT

Analysis of vibratory stress behaviour of a turbine blade has been attempted through theoretical and experimental models. Reissner's dynamic functional in conjunction with Ritz process has been employed to set up the eigenvalue problem for a practical case of a tapered, twisted, asymmetric aerofoil cross-section blade mounted on a rotating disc at a stagger angle. Taking experimentally generated nozzle excitation data in Fourier form and viscous damping, the problem of forced vibration is formulated. Modal analysis technique is used to obtain the decoupled equations of motion. Experimentally generated modal damping data is employed in obtaining the blade response in terms of displacements and moments. Blade stresses, obtained using Strength of Materials formulae, are analysed as functions of rotor speed, blade geometry, vibrational modes and nozzle excitation.

An experimental rig has been set-up to conduct investigations on rotating turbine blades. Nozzle excitation is simulated by use of electromagnets. The excitation is distributed over the blade length. Strain-gauge technique is employed for measurement of blade strains. Investigations are also carried out on blade damping. Damping data is generated for different blade vibratory modes as function of rotor speed and strain amplitude. Blade strains are obtained for different harmonics of nozzle excitation at various rotor speeds. Comparisons are made between the theoretical and experimental stress harmonics.

A theoretical analysis of the transient response of blade during step-up and step-down operations of a turbomachine is made. Initially the response of a stationary plane cantilever beam to a force with variable excitation frequency is obtained using Duhamel's integral. The analysis is extended to the case of an actual turbine blade rotating with constant angular acceleration, to obtain resonant stress levels.

On the basis of the stress analysis done and using known fatigue theories,a fatigue life estimation procedure is outlined. Numerical examples worked out for the test blade under laboratory conditions of operation are presented.

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