UNSTEADY BLADE FORCES IN A TURBOMACHINE

BY

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CERTIFICATE

We are satisfied that the thesis presented by Sri V.V.RAMANA RAO is worthy of consideration for the award of the degree of Doctor of Philosophy and is a record of the original bonafide research work carried out by him under our guidance and supervision and that the results contained in it have not been submitted in part or full to any other University or Institute for award of any degree/diploma.

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ABSTRACT

An attempt is made to evaluate the unsteady aerodynamic forces in a turbomachine stage analytically and verify them by an analogy. The quantitative assessment of these unsteady forces which arise due to potential and wake interactions in a turbomachine stage is of utmost importance, since these forces lead to dangerous vibrations which may cause in-service failures of the machine.

The interaction model considered for theoretical investigations consists of a turbomachine stage with an upstream and downstream blade rows. The blade rows are considered as two-dimensional infinite cascades. The aerodynamic quantities of interest are unsteady lift and unsteady moment on a particular blade. Flow is assumed to be inviscid, except that the viscous wakes behind upstream blades are considered as regions of velocity defect. Successive approximation scheme is used in that while calculating the unsteady quantities at a particular blade, the entire unsteady effect on the circulation of any blade is taken to be small compared to the steady circulation carried by the blade. The flow is assumed to be compressible and subsonic. The analysis is made for a general camber airfoil having incidence to the flow. The effects of interactions were ultimately brought in the forms of upwash and downwash distributions over the

blades, and from these upwash and downwash components the unsteady lifts and moments due to various interactions are obtained through the application of basic isolated airfoil theories. A computer program is developed which calculates the unsteady lifts and moments due to the above interactions, for a general camber airfoil. Computations have been made over a wide range of geometric parameters and Mach number.

The theory developed for the determination of unsteady forces has been substantiated by experimentation through the use of hydraulic analogy which utilizes the fact that the governing equations for a two-dimensional isentropic compressible gas flow are similar to the equations for a free surface incompressible water flow. A modified analogy which is suitable for simulating real gas flows on water table is used to simulate a simple flat plate stage on a rotating water table. As a first step in this direction, the validity of hydraulic analogy and in particular that of modified analogy has been established by considering compressible gas flow through an axisymmetric rocket nozzle. Isentropic, both subsonic and supersonic, and flows with shocks in the divergent section of the nozzle have been studied analytically and are simulated on the water table. From these studies, it is shown that, within the experimental errors, the modified analogy can be effectively used for the study of two-dimensional isentropic flow of gases, and flows with weak shocks. The experimental results obtained from the simulation of flat plate stage on rotating water table, through thus established modified analogy are compared with the computed results obtained for the stage geometry under consideration.

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