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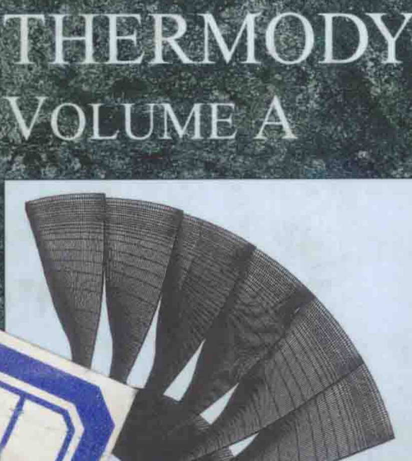
VOLUME A



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Turbomachinery – Volume A

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Contents – Volume 1

Turbine Aerodynamics

Design Methods

Transition and Turbulence

Blade–Row Interaction and Aeroelasticity

Erosion

Secondary Flows and Tip Clearance Flows

Additional Paper

Contents – Volume 2

Compressors

Rotating Stall and Instability

Calculation Methods

Steam Turbines

Condensation

Radial Compressors

Radial Machines

Heat Transfer and Cooling

Pumps and Hydraulic Turbines

Performance

Authors' Index

Turbine Aerodynamics

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Aerodynamic performance of two isolated turbine stators in transonic annular cascade flow

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ABSTRACT

The objectives of the present work are to investigate experimentally the steady aerodynamic characteristics of two isolated turbine stators and the development of the wakes at transonic flow conditions in an annular turbine facility. The steady three-dimensional flow field was measured at several axial downstream positions and three radial positions using a three-dimensional Laser-Two-Focus anemometer and a total pressure probe. Steady vane surface pressure distributions were recorded on the vane surfaces. A trailing edge shock propagating in the stator downstream flow field was found to have a significant influence on the velocity and turbulence intensity distribution. In the wake strong radial velocity components were obtained. Close to the trailing edge they are directed towards the hub, further downstream the flow is directed towards the tip.

At midspan the experimental vane surface data and wake flow data are compared with predictions from two different numerical models: Firstly a 2D/Q3D code solving the viscous terms only in the boundary layer region of the vanes (k-l turbulence model) and elsewhere the Euler equations, secondly a fully viscous 3D code using a Baldwin-Lomax type turbulence model. Fairly good agreement between numerical results and experimental data were achieved. Differences, which are mainly observed in the wake flow predictions, are assumed to be due to turbulence modeling and a possible grid resolution influence. Furthermore, three dimensional flow contributions were observed in the 3D predictions, especially in the wake region, which could partly lead to the differences between VOLSOL and UNSFLO results. Different trends for the 3D effects have been found in the experiments and for VOLSOL.

The data will serve as part of a database for further experimental and numerical investigations of stator-rotor interactions in a turbine configuration. It is assumed that the presented data describe key parameters determining the forced response of a downstream rotor blade row.

INTRODUCTION

The flow in turbine stators is complex, including three-dimensional secondary flow effects and wake induced flow disturbances. This leads to loss, noise, unsteady flow and rotor blade vibrations due to stator-rotor interactions. The origin, decay and interaction phenomena of stator wakes and shocks are essential for the prediction of the aerodynamical and structural performance of the following blade rows. Numerous publications have been presented on annular stator flows. Binder and Romey [1982] presented subsonic results. Vortices were identified to contribute strongly to losses and mixing of the wake with the core flow, even at positions far downstream of the trailing edge. Radial components of the flow velocity towards the hub were obtained especially in wake regions. Sieverding et al. [1983] came to similar conclusions, testing a turbine nozzle guide vane in a low-speed annular facility. Total pressure loss, flow angle and static pressure measurements revealed a radial migration of the passage vortices in the passage flow field and at the outlet towards the hub under the influence of the radial pressure gradient. Both experiments showed total pressure distributions in the wake close to the trailing edges resembling Gaussian curves in the pitchwise direction. A vane geometry almost identical to the present one, but with coolant ejection slots close to the trailing edges, was tested in transonic flow in a straight cascade by Colantuoni et al. [1995] and in an annular facility by Kapteijn [1995]. The wake was found to resemble Gaussian curves with separate standard deviations for pressure and suction side of the jet. A weak shock structure at the suction side trailing edge was found.
The pressure and velocity distributions, created by wakes and shock structures, affect the steady and unsteady loading and pressure excitation of downstream positioned rotor blades. These phenomena were studied numerically by several authors, eg. Korakianitis [1992], who used wake velocity deficit data from several experimental investigations as rotor inlet conditions. For his examined subsonic cases the computed unsteady rotor passage flow was found to be sensitive to the amplitudes of the potential flow interactions, but not to changes in the viscous wake amplitudes. Kielb and Chiang [1992] and Izsak and Chiang [1993] modeled velocity and pressure distributions downstream of a turbine stator as incoming flow distortions into a rotor row in their forced response analysis. They reported problems in modeling stator wakes due to lack of appropriate turbulence models and lack of high speed stator wake data for verification.

OBJECTIVES

The objectives of this investigation are to gain a better understanding of the aerodynamic effects of turbine stator induced disturbances on the downstream flow field. Experiments and computations were carried out with two isolated stator configurations in a transonic annular wind tunnel. The wake characteristics and its interaction with shocks downstream of the cascades were examined. The aim was to gain a detailed understanding of the wake flow with the perspective to study stator-rotor interactions, which is planned as future work.
It was of interest how accurate the wake flow can be predicted with different numerical tools, because this is expected to be essential for the foreseen unsteady stator-rotor interaction simulations. Therefore, two numerical methods, which differ in turbulence modeling and flow field solution strategy, were applied to predict the flow around and behind the stator.