UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING, SCIENCE & MATHEMATICS

SCHOOL OF ENGINEERING SCIENCES

Doctor of Philosophy

USE OF ACTUATOR DISC MODEL FOR MODELLING AXIAL COMPRESSOR DYNAMICS

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In the work described herein, simplified ways of modelling the flow in axial compressors were investigated. In general full mathematical simulations of multi-stage axial compressors are not efficient in terms of calculation time and resources needed. Therefore to deal with such problems simplified models are used to represent compressor dynamics. The actuator disc model (ADM) is one of these. It gives the possibility to calculate the pressure rise between the areas upstream and downstream of the blading in the compressor as a function of the axial velocity.

The first question addressed in the research was whether the accuracy of the classical ADM can be increased by adding so called internal degrees of freedom to it. The number of internal degrees of freedom needed for a significant increase of accuracy was estimated by comparing the response of a blade row to time-periodic excitations represented by an actuator disk with internal degrees of freedom and by the linearized Navier-Stokes equations. It was found that in the case of subsonic flow one internal degree of freedom can be considered as the most important, both for the design and off-design regimes. In the case of transonic flow in the off-design regime two internal degrees of freedom are more important than the rest. However, for the transonic design regime no internal degrees of freedom could be distinguished as being especially significant.

In the second part of the research a modified classical ADM was used for numerical simulation of rotating stall onset in a low-speed axial compressor. The model was modified by adding one degree of freedom describing a hysteresis loop in the compressor characteristic. Laboratory experiments show that there are two different stall inception patterns in low-speed axial compressors: one modal and one spike-like. It was demonstrated that with appropriate assumptions the ADM model with an incorporated hysteresis loop can describe both phenomena. Calculations also demonstrated that it is possible to find parameters of the model such that the results quantitatively fit the experimental data.