Chapter I

MODELLING OF ROTATING STALL CELLS

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Abstract

The main purpose was to find a method, which predicts based on the single stage characteristics of a multistage compressor, the position of the rotating stall line. Restricted to the big stall phenomenon, the mass flow rate of the stalled compressor and the delivered pressure rise were to determine.

A literature survey shows that rotating stall is investigated very extensively. In spite of the large amount of studies that were done in that field the physical reasons of the phenomenon are still unknown. A brief review of the different approaches is given.

To determine the pressure rise and the stage loading during stall in a multistage compressor, a numerical analysis was carried out. For this purpose a model is introduced that divided the compressor into two kinds of elements : the stages that will be replaced by actuator discs and the vaneless space consisting of the inlet and outlet duct as well as the space between two successive actuator discs. To describe the non-uniform flow field during stall it is assumed that the distorted flow consists of a steady mean flow with superimposed large perturbations. The first is known from design-programs and will be used for the input data of the actuator discs. The latter were required to be three-dimensional in pressure, temperature and velocity. To obtain the pressure rise and the flow coefficient for the overall system, it was necessary to determine the propagation of the perturbation quantities through the compressor by solving the basic fluid dynamic equations. When stating the momentum equation it was not possible to find a mathematical model for the complex structure of the distortion because here, opposed to the small perturbation assumption, no linearization of the equations is allowed. Because of these difficulties it was not possible to calculate the stalled compressor characteristic. Another more analytical approach was made.

The derivation of this model is based on experimental results taken in the rotating stall region in a single and multistage compressor. In the experiments carried out at the VKI and in Cambridge the principal structure of the stalled flow was observed. From general features, a model was derived, which represents the stalled flow as a superposition of a clean and distorted flow part. The model represents a normal cut through compressor, with axis and the blade height over circumferential extent. The basis is the set of the axial velocity isolines. The stall cell is represented by the reserved, zero and small through-flow and the transients to the clean flow. Restricted to one big stall cell and based on this division of the stalled flow it was then possible to derive a general relation to the stage characteristic : the clean flow and the small through-flow are similar to the parallel compressor theory on the given steady performance curve. To be modelled remains the pressure rise and flow coefficient delivered by the reserved flow. The first is obtained by