STALLING BEHAVIOUR OF A CONTRA-ROTATING AXIAL COMPRESSOR STAGE

by

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CERTIFICATE

This is to certify that the thesis entitled, "STALLING BEHAVIOUR OF A CONTRA-ROTATING AXIAL COMPRESSOR STAGE" being submitted by Mr. Yashpal Jain to the Indian Institute of Technology, Delhi, for the award of the degree of "Doctor of Philosophy" in Mechanical Engineering is a record of the candidate's own bonafide research work carried out by him. Mr. Jain has fulfilled the requirements for the submission of this thesis.

The results contained in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.

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ABSTRACT

An axial compressor is a vital component in an aircraft gas turbine power plant/engine. Such a compressor suffers from the problem of aerodynamic instabities, viz; rotating stall and surge if operated under off-design conditions of speeds and flows; thus restricting the useful operating range of an engine. The increase in the useful operating range, by improvement of stall/surge margin in an aero compressor is a matter of important consideration for further developments of fuel efficient aero-engines. The use of contra-rotation of two-adjacent rotors is being considered as one of the possible solutions for a significant improvement in fuel consumption. Understanding of the off-design performance of a contra-rotating axial compressor stage is therefore considered necessary. The review of the existing literature reveals that there is little knowledge about the performance and stalling behaviour of a contra-rotating axial compressor stage. The work reported in this thesis which is mainly experimental, concentrates on the study of some aspects of performance and stalling behaviour of a contra-rotating axial compressor stage.

Experimental investigation reported in this thesis was carried out on a test compressor having a hub-tip ratio of 0.667 suited to study the effect of various parameters

such as the speed ratio of the two contra-rotors, rotor staggers, pitch-chord ratios, and axial spacing between the two rotors. Steady state instruments such as, total pressure probe, yaw probe and wall static pressure tapping etc. were used during the course of experimentation for the measurement of flow rate through the compressor and pressure rise across the rotors. To monitor the on-set of rotating stall and also to determine stall properties fast response dynamic sensors such as hotwire anemometers and pressure transducers in conjunction with on-line real time frequency spectrum analyser were used.

From the results of tests carried out in the present investigation it has been revealed that a contra-rotating axial compressor stage provides much higher pressure rise and through flow and enhanced stall free operating range as compared to rotor-stator stage. It has also been found that operating parameters, such as speed ratio of two rotors, and design parameters such as stagger-settings of blade rows, pitch-chord ratios of two rotors and axial-spacing between the two rotors have a marked influence on the performance and stalling behaviour of the first rotor as well as the contra-stage. Furthermore, it is revealed that under certain operating conditions, such as second rotor running faster than the first rotor, it is possible to suppress rotating stall to a very low flow coefficient. Conventional rotor-stator stages donot provide such a stable operation of the stage. The above advantages of contra-rotation assume a greater significance in the context of the possible application of contra-rotation in the next generation "turbofan" engines.

Based on the experiemental observation that the stall onset and stall propagation speed both vary with the speed ratio of two rotors in contra-rotation, an analytical treatment of stalling of contra-rotating axial compressor stage is presented which follows the Moore's linearised approach. Predictions of stall propagation speed are made using this treatment and the results are compared with the experiments.

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