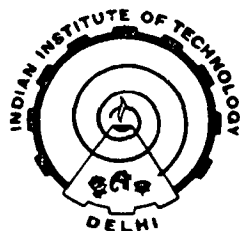


STUDY OF AERODYNAMIC PERFORMANCE OF A CONTRA-ROTATING AXIAL COMPRESSOR STAGE

by
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Thesis submitted
in fulfilment of the requirement for
the degree of
DOCTOR OF PHILOSOPHY



Department of Applied Mechanics
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
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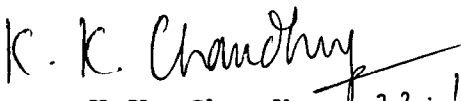
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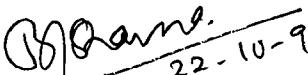
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CERTIFICATE

This is to certify that the thesis entitled "A Study of Aerodynamic performance of a Contra-Rotating Axial Compressor Stage" being submitted by Mr Devendra Singh Pundhir to the Indian Institute of Technology, Delhi, for the award of the degree of "Doctor of Philosophy" is a bonafide record of candidate's own research work carried out by him under our guidance and supervision. In our opinion, the thesis has reached the standards fulfilling the requirements of all the regulations relating to the degree.

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


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(D.S. PUNDHIR)

ABSTRACT

Axial flow compressors have played a vital role in the development of high thrust, efficient propulsion systems both of civil as well as military aircrafts. Over the years there has been a steady increase in stage loading which has led to increase in pressure rise per stage resulting into a reduction in the number of stages required to produce a high pressure ratio axial flow compressor. This demand for the development of high pressure ratio axial compressors has demanded a close scrutiny of the off-design problems such as rotating stall and surge.

The occurrence of rotating stall and surge restricts the useful operating range of a compressor as significant deterioration in performance is encountered once rotating stall is manifested. The improvement in useful operating range of an axial compressor has therefore been a matter of great interest for the last two decades. The present work is aimed at examining the aerodynamic performance of a contra-rotating axial compressor stage so as to be able to assess its suitability for providing significant improvement in design and off-design performance of a compressor or a bypass fan stage.

The experimental investigation in the present work is carried out using a test compressor housing a pair of contra-rotating rotors having a hub-tip ratio of 0.667 and a tip diameter of 486 mm. Three sets of bladings are used in the present investigation, namely untwisted C-4 aerofoils for both the rotors, twisted blades for a rotor-stator stage

and twisted blades for a rotor-rotor contra-stage. The contra-rotation of a pair of rotors has been provided by two separate d.c. motors each controlled by a thyrister unit. The speed ratio of the two rotors could therefore be fixed at any desired value. The contra-stage with untwisted blades provides nearly axial discharge when operated at a speed ratio of 0.66. The rotor-stator stage as well as the rotor-rotor contra-stage using twisted blades (as above) are both designed to produce the same design point performance and achieve swirl free (axial) discharge.

The main objective of the experimental study is to study the aerodynamics as well as aeroacoustic performance of a contra-rotating compressor stage and compare it with a rotor-stator stage with a view to illustrate the performance improvement obtainable using a contra-stage.

Tests have been carried out at different speed combinations of the two rotors. Further, three axial gaps between the two rotors have been examined to illustrate the trade-off between the aerodynamic and aeroacoustic performance as the axial gap is increased. Detailed flow structure measurements have been carried out using a pitot-yaw probe at three axial locations in the test compressor to illustrate the aerodynamic performance of a rotor-stator and rotor-rotor stage. The variation of relative total head loss across the blade span is obtained from these measurements for the two rotors. The efficiency of the rotor as well as of the stage is also estimated from the experimental results.

Sound pressure level measurements and spectrum analysis of sound signals have been carried out. The measurements of SPL are obtained both for the far field as well as in-duct location for various operating conditions for both the rotor-stator and rotor-rotor (contra) stage. These measurements illustrated the propagation of aerodynamic noise from a contra-stage.

The study also includes the effects of a symmetric distortion screen on the performance of a contra-stage. The effects of casing treatment on stall margin and efficiency of a contra-stage are also examined for three different casing treatments.

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CERTIFICATE

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