FLOW INVESTIGATIONS IN CURVED DIFFUSERS

BY

BIRESWAR MAJUMDAR

A THESIS SUBMITTED
IN FULFILLMENT OF THE REQUIREMENT FOR
THE DEGREE OF
DOCTOR OF PHILOSOPHY

DEPARTMENT OF APPLIED MECHANICS
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
INDIA

SEPTEMBER, 1994

CERTIFICATE

This is to certify that the thesis entitled **FLOW INVESTIGATIONS IN CURVED DIFFUSERS** being submitted by **Bireswar Majumdar** is report of bonafide research work carried out by him under my supervision. This thesis has been prepared in conformity with the rules and regulations of the Indian Institute of Technology, Delhi. I further certify that the thesis has attained a standard required for a Ph.D. degree of the Institute. The research reported and results presented in the thesis have not been submitted, in part or full, to any University for any degree or diploma.

Dr. S.N. Singh
Associate Professor
Department of Applied Mechanics
I.I.T. Delhi

ACKNOWLEDGEMENTS

It is a great pleasure for me to record my deep sense of gratitude and appreciation to Dr. S.N. Singh, the thesis supervisor for his valuable guidance, keen interest, encouragement and friendly discussions during the course of this work.

I am also grateful to Prof. D.P. Agrawal, Department of Mechanical Engineering (Presently, Joint Educational Adviser (Technical), Ministry of Human Resource Development) for his assistance, discussions and continuous encouragement at various stages of this work.

The author gratefully acknowledges the assistance and valuable suggestions provided by Dr. Srinivas V. Veeravalli, Assistant Professor, Applied Mechanics Department and Dr. Ratan Mohan during this study.

The assistance of the staff of Gas Dynamics Laboratory, especially Mr. T.R. Bhogal, Mr. Harbhajan Singh and Mr. Sambhu Prasad for their skillful work during fabrication and experimentation is acknowledged. Thanks are also due to Mr. Sita Ram, Fluid Mechanics Laboratory and staff member of the Applied Mechanics Department Workshop.

The author extends his sincere thanks to Regional Engineering College, Durgapur and Ministry of Education, Govt. of India for providing financial assistance under the Quality Improvement Program.

Author has no words to express his gratitude to his wife Susmita and daughter Basupurna for their immense patience, understanding and sacrifice through out the period of this work. The continuous encouragement from author's parents and elder brother Mr. Ratneswar Majumdar made it possible to complete his Doctoral Research Work at I.I.T., Delhi.

Finally, the author thanks his friends Dr. Jayanta Dutta (Lecturer, I.I.T., Kharagpur), Mr. Ashim Jana and Mr. Apurba Dey for their help at different stages of this work.

Bireswar Majumdar

Bireswar Majumdar

ABSTRACT

It is well known that the flow development in a diffuser depends on several geometrical and dynamical parameters and hence influence its performance. The effect of curvature on the flow through curved constant area ducts is well documented in literature. The presence of curvature in diffusers complicates the flow development in them due to simultaneous turning and diffusion of the flow. Reported literature on curved diffusers is scanty and the investigations are restricted to 90° or part turn diffusers, C-shape diffusers and S-diffusers. The present study was undertaken to investigate the effect of curvature on the flow development within curved diffusers. The important geometrical and dynamical parameters responsible for these types of flows were identified through an exhaustive review of the literature which also established the need and scope of the present research program.

The experimental program consisted of two parts -- (i) detail measurements in two-dimensional (AS = 6.0) small area ratio (AR=2.0) curved diffusers to study the effect of center line contour shape (namely 90°, U-(180°) and S-(90°/90°) turn) on the flow development, keeping AS, L/W_1 and inlet flow conditions fixed. and (ii) Similar measurements in a large area ratio (AR = 3.4) curved diffuser with low aspect ratio (AS = 0.685) for an elliptical center line shape with 90° turn to study the effect of the deflector plates, installed at inlet, in improving the flow development and hence the performance of this diffuser. To achieve the above objectives, two experimental test rigs have been designed

and fabricated. The velocity distribution and the turbulence intensity distribution have been measured using calibrated 3-hole pressure probes and hot-wire anemometer respectively at different axial locations between the parallel walls. Wall pressure distribution and static and total pressure variation across the various measuring sections have also been recorded. A tuft probe was traversed for flow visualization. The data has been processed on a PC AT-386 computer and analyzed to give the distribution of mean velocities, static and total pressures, transverse velocities, flow angles, turbulence intensities, etc. in the diffuser.

The experimental results, in general, indicate the generation of secondary motions within these diffusers due to imbalance of centrifugal force and radial pressure gradient. Generation of more number of vortical motions in the later portion of the diffusers are seen between the parallel walls for small area ratio diffusers occupying the total width and the number o vortical motions are more for S-diffuser compared to 90°- and U-diffusers. The study also shows best performance for 90°-diffuser while the uniform flow distribution is observed at the exit for S-diffuser. For large area ratio curved diffuser the vortical motions are between the curved walls occupying the half depth. The effectiveness of the deflector plates in improving the performance of large area ratio curved diffuser has also been established.

A computer program based on finite volume technique, using k-ε turbulence model has been adopted and modified to predict the flow in 2-D geometries. Numerical predictions obtained from this program have been compared with the experimental results of small area ratio curved diffusers and good matching was obtained till the flow behaved as 2-D. The developed program has also been used for parametric study on 2-D 90° curved diffusers, varying center line shape and length and area ratio. The parametric study has been able to identify the effect of these parameters on the performance of the curved diffusers.

CONTENTS