STUDIES ON NON-CIRCULAR STEPPED EJECTOR DIFFUSERS

by

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Dedicated to

My Parents, My Teachers

and

My Wife, Cherry

CERTIFICATE

This is to certify that the thesis entitled "**Studies on Non-circular Stepped Ejector Diffusers**" being submitted by **Parminder Singh**, is a report of bonafide research work carried out by him under our supervision. The thesis has been prepared in conformity with the rules and regulations of the Indian Institute of Technology, Delhi, New Delhi. We 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, or any part thereof, have not been submitted, in part or full to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

The performance of an air ejector diffuser employed downstream of a turbine for cooling of the exhaust gas depends upon extent of entrainment of ambient air through the annular opening slots, its effective utilization for cooling and the static pressure recovery. The effect of forced secondary injection in diffusers to improve the quality of discharge in terms of exit velocity profile and pressure recovery is well documented in literature. The provision of natural entrainment of ambient fluid and its effective utilization for cooling in addition to achieving maximum pressure recovery makes the study interlinked problem involving diffuser as well as ejector flow characteristics. Systematic study of Literature on diffusers, methods of boundary layer control and ejectors has highlighted the geometrical and dynamical parameters which affect the performance of air ejector diffusers. Direct reported studies on ejector diffusers are scanty and the investigations are generally, restricted to circular cross section. Literature on noncircular diffusers is virtually not available in spite of their aerospace applications. The present study has been undertaken to investigate the effect of various geometrical parameters like slot height, slot thickness, extent of overlap and slot inclination on the performance of ejector diffuser employed in military helicopters after a careful review of the literature. The present work has been divided into three phases:

i) **Experimental Study**: Two ejector diffuser configurations have been fabricated and tested to carryout experimental investigations with each configuration having provision for entrainment of ambient air through five annular openings (slots) along the length. One of the configurations has uniform slot opening of 10 mm

with overall area ratio of 9.0. The other configuration has uniform slot opening of 20mm and area ratio of 25. Diffuser inlet cross section for both configurations has been fixed as 50 mm x 50 mm and both have the same length of 1.012 m. Based on the reported literature and experimental setup constraints, experiments have been carried out at Reynolds numbers of approximately $2x10^5$, $2.5x10^5$and $3x10^5$ for configuration with area ratio 9 and at $3x10^5$ for the second configuration after establishing Reynolds number effect on the first diffuser using air as the fluid medium. The velocity distribution has been measured using a calibrated 3-Hole pressure probe at different sections along the length of the diffusers. Wall static pressures along the diffuser lengths have also been measured by providing wall pressure taps. The experimental results have been used to determine the effect of area ratio and Reynolds number on the diffuser performance apart from generating data for validating the CFD code. Over the range of Reynolds numbers investigated, no significant effect of Reynolds number on the performance of the diffuser has been observed. For diffuser with area ratio of 25, no secondary air entrainment was observed beyond third slot opening.

ii) **Validation of the CFD Code:** The validation of the CFD code "FLUENT" has been carried out in three steps. In the first step, the computational results were compared with the experimental data of Kwong and Dowling [15] on a conical diffuser with secondary air injection. In the second step, numerical simulations were validated against the present experimental data obtained on two ejector-diffuser configurations at Reynolds numbers of approximately $2x\ 10^5$, $2.5x10^5$ and 3×10^5 for the 10 mm slot configuration and at Reynolds number of $3\ x10^5$

for 20 mm slot configuration. In the third step, validation for temperature field has been done against the experimental results reported by Ferri and Mahrer [49] for slot cooling at high subsonic flows.

iii) **Parametric Investigations:** The parametric investigations have been carried out to analyze the effect of various geometrical parameters of the diffuser on the performance of air ejector diffuser using the validated CFD code.

a. *Effect of Overlap*: The effect of overlap has been studied by varying the overlap from 0mm to 20 mm in intervals of 5mm for the five slot openings of 10mm each. The study has shown that there is no significant effect of the overlap on the performance of the air ejector diffuser.

b. *Effect of number of slots*: Attempt has been made to optimize the number of slots. In this study the number of slot openings has been varied from 4 to 10 for fixed overall area ratio of 9 and fixed length of 1.012 m of the ejector diffuser. Although improvement in the static pressure recovery is seen as the number of slots is increased, total entrainment in the diffuser is found to be same for all the cases.

c. *Effect of Wall Thickness*: To establish the effect of wall thickness (interface height), the number of slot openings was fixed at 4 with the overall diffuser area ratio of 9 and length of 1.012 m. The wall thickness of the diffuser sub-sections was varied from 0 to 5.5 mm to investigate its effect on the diffuser performance. This study has shown that there is a significant increase in the static pressure recovery with increase in wall thickness. Whereas, the total entrainment of the secondary air in the diffuser decreases with increase in the wall thickness.

d. *Effect of slot orientation*: For this part of the investigation, the slot openings have been inclined at angles of 15, 30 and 45 degrees to study the effect of slot orientation on entrainment and pressure rise. This study was again performed on a diffuser with four slot openings for a diffuser of overall length of 1.012 m and area ratio of 9.0. The study has shown that the static pressure recovery improves with increase in the slot inclination with reduction in the cumulative mass entrainment.

e. *Cooling effect*: Optimized configurations obtained from the above studies have been used to establish the cooling effect of the entrained air on the hot exhaust gases. It has been observed that the diffuser with more of number of smaller sized slots results in better cooling across the exit plane as a result of highest secondary air entrainment. Static pressure recovery in the diffuser also improves with more number of smaller slots.

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