# STUDIES ON THE FLOW CHARACTERISTICS OF A STEPPED CONICAL DIFFUER WITH PASSIVE SUCTION

by

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*Dedicated to*

***Ma, Baba,***
***My Teachers***
*and*
***Sonali***

# CERTIFICATE

This is to certify that the thesis entitled "**Studies on the Flow Characteristics of a Stepped Conical Diffuser with Passive Suction**" being submitted by **SAIBAL SEN** is report of bonafide research work carried by him under our supervision. This 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 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

Stepped Conical Diffuser fall in the category of augmented diffusers and finds use in aerothermal, wall cooling and other applications involving the entrainment of the surrounding fluid. The aerothermal applications involving pressure recovery, mixing & cooling of engine exhausts have military applications and the detailed investigations conducted in these areas by leading R&D organizations are of sensitive and confidential nature and are not reported in open literature. The flow and performance characteristics of these diffusers are very complicated due to the combined effects of geometric and flow parameters. These diffusers have their significance on account of their wall cooling, boundary layer control, mass entrainment & flow mixing within the diffuser.

Based on the literature review, it is observed that detailed investigations are needed to explore the performance of the diffuser, which is strongly influenced by the entrainment, condition and development of the flow and the mixing of jet with the entrained fluid within the diffuser. The whole investigation programme was carried out in two phases: the experimental investigation and the computational investigation. The experimental investigation was carried out for two stepped conical diffusers having an AR of about 10 and divergence angles of $8^0$ and $12^0$ respectively. Both the diffusers were fabricated with commercial grade PVC / Perspex pipe sections.

The primary objective was to obtain data for validating the commercial CFD code 'FLUENT'. The second phase comprised of the parametric investigation for evaluating the effect of the geometrical parameters on the performance of the diffuser.

Experiments were carried out at three different inlet Reynolds numbers of $1.5x10^5$, $2.0x10^5$ and $2.5x10^5$ without swirl for the $8^0$ test diffuser and at one Reynolds number ($2.5x10^5$) without swirl for the $12^0$ test diffuser. The Mach number varied between 0.15 to 0.23 and the flow considered as incompressible. Velocity, total pressure distribution and wall static pressure are measured along the length of the diffuser using a three-hole pitot probe & wall pressure taps. The performance characteristics of the diffuser (i.e., mass entrainment & pressure recovery coefficient) have been evaluated for the different inlet conditions.

These experimental results were then used to validate the results obtained from computational analysis using commercial code 'FLUENT'. The CFD results obtained using the κ-ω SST model match quite reasonably with the experimental results. Based on the validation results 'FLUENT' has been utilized for undertaking the detailed parametric investigations.

Parametric investigation of the stepped conical diffuser under passive suction has been carried out through the variation of geometric parameters (i.e., divergence angle, slot overlap, interface height, inlet area ratio, standoff distance, length of first section and slot configuration) for prediction of performance parameters of the diffuser (i.e., pressure recovery coefficient

and mass entrainment) using computational methods. The influence of flow dynamic parameters namely the inlet Reynolds number and swirl has also been investigated. The study concluded that the pressure recovery increases with decrease in divergence angle, increase in interface height, slot angle and swirl. The mass entrainment increased with decreasing divergence angle, increase in interface height and decrease in swirl. The effect of length of overlap was observed to be insignificant. The study shows that the performance of the diffuser is practically independent of the inlet Reynolds number in the studied range.

The present investigation gives considerable insight on the flow field inside the stepped conical diffuser under passive suction. The investigation reveals that the geometric parameters namely the divergence angle and interface height affect the entrainment performance significantly. The inlet area ratio defined as the ratio of the diameters of diffuser inlet to nozzle exit and the standoff distance which is defined as the axial distance between the nozzle exit and the diffuser inlet have a strong influence on the initial entrainment and mixing of the mainflow with the entrained flow while the length of the first section influences mixing. Among the dynamic flow parameters investigated the Reynolds number has insignificant effect on the mass entrainment and pressure recovery characteristics while the increase in inlet swirl significantly reduces the entrainment into the diffuser.

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