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**STUDIES ON THE FLOW CHARACTERISTICS OF HEATED  
COAXIAL AND MULTICOAXIAL JETS**

by

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*Dedicated to*  
*My Parents, My Supervisors*  
*and*  
*My Wife, Richa*

# C E R T I F I C A T E

This is to certify that the thesis entitled “**STUDIES ON THE FLOW CHARACTERISTICS OF HEATED COAXIAL AND MULTICOAXIAL JETS**” being submitted by **Vivek Kumar Patel** is a report of bonafide research work carried out by him under our supervision. This thesis has been prepared in conformity with the rules and regulations of Indian Institute of Technology Delhi, New Delhi, India. 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

Gas turbine is used as a prime-mover in many industrial appliances like aircraft, marine land based power plants, automotives etc. The combustor is an integral part of a gas turbine. Fuel efficiency and low pollutant emission are the basic need of twenty first century gas turbine technology. Mixing of jets in a combustor is a very complex process and a challenging research area. A coaxial jet type combustor consists of a central jet and an annular jet. The central jet is normally used to supply fuel and the annular jet is used to supply air. Multicoaxial jets are derived from the coaxial jets by introducing additional annular jet. The efficient mixing of jets and other techniques to create the reverse flow on the centerline is very important for the flame stability. Generating strong shear layers between jets and central recirculation zone (CRZ) in the near flow field is one of the successful techniques for stability of the flame. The focus of the present study is on these techniques to understand the mixing phenomena and flow characteristics of coaxial and multicoaxial jets in combustors.

The present work has been carried out in three phases, viz. experimental study, validation of CFD code and computational study. The focus of experimental study is to generate quality data in the form of measurements of velocity components, temperature and wall static pressure at different axial location of the test section for non-swirling/swirling and non-heated/heated multicoaxial jets in a non-expanded and expanded confinement. Vane type swirlers with vane angles of  $\pm 30^\circ$  and  $\pm 45^\circ$  are used for the swirling flow studies. In the second phase, the validation of CFD code has been done against the experimental results of Vu and Gouldin (1982) for coaxial jets and against present experiments for multicoaxial jets. In the last phase, parametric investigation has been done for the coaxial and multicoaxial jets by using validated

commercial CFD code. In this phase, first the effect of blockage and its location on the mixing of swirling coaxial jets (with and without heated jet) have been studied. After that, the effect of various swirl combinations for multicoaxial jets have been investigated to arrive at the optimum swirl combination. With the optimum swirl combination, effect of temperature variation in the jets has been studied to select the suitable temperature and appropriate jet for heating. After getting the optimum heated swirling jets combination, it has been used to find out the effect of blockage and its location on the mixing of multicoaxial jets for the optimum combination.

From the study it is observed that the coaxial jets are highly influenced by blockage and its locations and there is an optimum value of blockage and its location for a swirl combustor model. For the present case 10% blockage at  $x/R_i=10$  gives the best acceptable flow features and there is no further significant effect on mixing and the size of central recirculation zone (CRZ). The experimental study of multicoaxial jets confirms that, heat addition in the annular jet-1 helps in the formation of CRZ only for swirling flow cases, while, for the non-swirling cases it blows-off the CRZ and has an adverse effect on mixing of jets. Predictions for multicoaxial jets show that the swirl in central jet and annular jet-1 improve flow mixing and creates a CRZ which is strongly dependent on the upstream parameters. Swirl in annular jet-2 reduces the size of wall recirculation zone for an expanding confinement. Providing larger confinement for the same swirl combination results in enhancement of the CRZ and  $\pm 45^\circ$  swirl in all the jets with heated annular jet-1 is found to be the best possible combination for mixing and flow stability. Effect of blockage on multicoaxial jets shows similar effects as seen for coaxial jets and it confirms that the 10% blockage at  $x/R_i=10$  is the optimum combination of coaxial and multicoaxial jets for the present geometry.

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