SOME AERODYNAMIC INVESTIGATIONS OF CONFINED CO-AXIAL SWIRLING JETS

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SIDH NATH SINGH
Applied Mechanics Department

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Dedicated to my parents

CERTIFICATE

This is to certify that the thesis entitled "SOME AERODYNAMIC INVESTIGATIONS OF CONFINED COAXIAL SWIRLING JETS" by SIDH NATH SINGH has been prepared under our supervision in conformity with the rules and regulations of the Indian Institute of Technology, Delhi. We further certify that the thesis has attained a standard required for a Ph.D. degree of the Institute. The research report and results presented in the thesis have not been submitted, in part or full, to any university for any degree or diploma.

R.C. Malhotra

Dr. R.C. Malhotra
Professor
Dept. of Applied Mechanics
I.I.T. Delhi.

DPA

Dr. D.P. Agrawal
Assistant Professor
Dept. of Mechanical Engineering
I.I.T. Delhi.

AK Raghava

Dr. A.K. Raghava
Assistant Professor
Dept. of Applied Mechanics
I.I.T. Delhi.

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SIDH NATH SINGH

ABSTRACT

It is well established that the swirl has a marked effect on the behaviour of free jets (single or co-axial); the flow field, the jet growth, mass entrainment and jet mixing are all affected. Also increased intensity of the swirl gives rise to a recirculation zone at the central axis. However, the presence of a confinement may limit jet development because of the paucity of fluid being available for entrainment. The present study was undertaken to investigate flow development for swirling co-axial jets exhausting into a confined circular duct having a diameter greater than the outer diameter of the annular jet. The important geometrical and dynamical parameters responsible for the mixing of the jets in a confined space were identified through an exhaustive review of the reported literature. Thereafter, the present program was clearly established keeping in mind the gap in the knowledge of the phenomenon. The experimental programme consisted of measurements of the velocity distribution, the flow angle and the wall static pressure for different combinations of swirl in both the jets for : $U_o/U_i = 1.6$ fixed conditions. For this purpose, an experimental test rig with the possibility of fitting various vane type swirlers in both the inner and the outer jet was designed and fabricated. Several combinations of swirlers were also designed and fabricated to enable one to vary the swirl intensity in the two jets independently. In all 28 swirl combinations covering the condition of no swirl, co-and contra-swirls were investigated. For anoptimum contra swirl combination ($O = -45^{o}$, $I = -30^{o}$), eight set of experiments were conducted to investigate the effect of variation in the geometrical parameters on flow development. The velocity distribution was measured by traversing radially a calibrated 3-hole pressure probe at different axial locations along the length of the test section upto a point where the flow tended to become uniform. A tuft probe was also traversed for flow visualisation. The data was processed on an ICL 2960 computer and analysed to give the distribution of velocities, the centrifugal force, the angular momentum, etc. All the results have been presented graphically. The experimental results indicate that swirl imposed on the inner jet results in an increased mixing whereas swirl imposed on the outer jet enhances both the mixing and the rate of spread. For weak co-and contra swirl combinations, no marked effect was observed on the flow development. However, a strong contra-swirl results in improved mixing. A wall recirculation zone was found to occur for all cases investigated with its shape and siz **changing** depending on the swirl conditions in the jets. A central recirculation zone close to the jet exit plane was observed for conditions of strong swirl in the inner jet. Its formation and location in the test section was strongly influenced by the geometrical parameters such as the expansion shape, the expansion ratio, the test section length, etc.

The flow was theoretically predicted by numerically solving the elliptic form of the Navier Stokes equations. The existing Teach-T programme was successfully modified for predicting the cases of swirl in the co-axial jets. A stream-line curvature correction was incorporated in the computer program. The numerical predictions were compared with the experimental results and a good matching was observed for conditions of weak swirl.

The results of the present study are likely to find direct use in various practical applications including that for combustion chambers, thrust augmentors etc.

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