# ABSTRACT

The flow between the annular region of concentric rotating cylinders is referred to as Taylor-Couette flow. Applications of such annular flows are ubiquitous in high-speed electrical and turbo-machines, process industries, and astro and geophysical systems. An understanding of Taylor-Couette flow is important both from an industrial application point of view and also from the viewpoint of fundamental fluid dynamics. In high-speed electrical and turbo-machines, skin-friction drag a very critical parameter. The overall aim of this thesis is to explore the role of active control strategies in achieving sustained control of turbulence. Various control strategies, namely radial temperature gradient, opposition control, and axial oscillation of the inner cylinder have been investigated.

First simple rotating Taylor-Couette flows with radial temperature gradient are studied. In this study gravity and rotation axis are mutually orthogonal. An In-house finite-difference-based incompressible solver is used to perform three dimensional numerical simulations in cylindrical coordinates in a fixed frame of reference. The effect of increase in rotation rate ($1000 \leq \mathrm{Re} \leq 5000$) in tandem with thermal stratification ($0 \leq \mathrm{Ri} \leq 0.3$) is investigated. For neutrally buoyant cases, flow statistics and dynamics reveal that on increasing the rotation rate more intense turbulence is observed, as depicted in azimuthal velocity fluctuations and Reynolds shear stresses. Near-wall streaks form a herringbone-like pattern, and the streak spacing is uniform in the axial direction. On heating the outer wall of the cylinder, since buoyancy now acts in both radial and azimuthal directions, a complicated flow phenomenon is observed. For weak to moderate buoyancy, due to the interaction of inertial and thermal buoyancy forces, the near-wall streak spacing decreases. The streaks are observed throughout the axial domain. The spatial density of the vortical structure increases. Heating of the outer cylinder results in more intense streaks and coherent structures in the half-circumferential domain due to unstable stratification aiding turbulence, while in the other half-domain, stable stratification mitigates turbulence.

In counter-rotating Taylor-Couette flows, the effect of thermal stratification ($0 \leq$

Ri $\leq 0.4$) in tandem with an increase in rotational speed of the inner and the outer cylinder is investigated such that $Re_i = Re_o$ (ranges from 1000 to 5000). Large Taylor rolls are observed with scales much smaller than the gap width, unlike SRTC flows where Taylor rolls occupy full gap width. Vortical structures are observed near the inner and outer wall, while the core is almost vortex free. On heating, depending on the interaction of inertial and thermal buoyancy force, thermal stratification leads to suppression and enhancement of turbulence in respective halves, as observed in simple rotating Taylor-Couette flows.

In opposition control, various velocity control strategies are numerically investigated. The idea is to reduce skin friction by introducing blowing and suction near the walls. Wall-normal velocity control shows maximum drag reduction at $r^+ = 15$. The spatial skipping of points in azimuthal and axial directions, as well as temporal skipping, is performed for wall-normal velocity control in order to check its experimental realizability. A virtual wall is formed between the real wall and the detection plane inhibiting vertical transport of momentum for all the cases exhibiting drag reduction. A marked reduction in the spatial density of vortical structures is observed.

In axial oscillation of the inner cylinder, numerical simulation is performed for wide gap T-C flows. The maximum drag reduction occurs at an optimal oscillating period. The drag reduction is attributed to the formation of Stoke's layer, which affects the near-wall self-sustaining cycle. Further, the effect of oscillating amplitude is investigated for a fixed optimal oscillating period. A marked reduction in turbulent intensities, Reynolds stress and vortical structures is observed as amplitude increases. Beyond a threshold amplitude, transition to a new regime occurs leading to enhanced turbulence and an increase in skin-friction drag.