EXPERIMENTAL INVESTIGATION OF TAYLOR-COUETTE FLOW WITH RADIUS RATIO 0.1 TO 0.3

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Abstract Turbulent flow of a very wide Taylor Couette flow (radius ratio 0.1 up to 0.3) is the scope of the present work. Flow visualisation shows the existing coherent structures. Laser Doppler Velocimetry is used to analyse the local velocity behaviour and understand the flow in this geometry.

SCALING OF THE TORQUE IN TAYLOR COUETTE

Turbulent structures in concentric rotating Taylor-Couette flow (TC) and its dependency on different parameters form the scope of this investigation. Depending on the rotation rate of the cylinders, one is able to have super critical transition to turbulence or sub critical transition. Eckhardt et al. [1] pointed recent analogies between the Taylor-Couette flow, Rayleigh-Bénard flow as well as pipe flow. The analogies in Nusselt number scaling with Rayleigh Bénard has been already studied (c.f. [2]). Subcritical transition in Taylor-Couette flow is mainly investigated for narrow gaps (radius ratio of inner and outer cylinder $R_1/R_2 \rightarrow 1$), where the analogy to plane shear flows becomes more obvious [3]. In the present work we study the case where the inner cylinder vanishes (($R_1/R_2 \rightarrow 0$) experimentally. When the inner cylinder vanishes completely the flow remains as a solid body rotation. For the case of small cylinders rotating at different speed as the outer cylinder a shear comes into account and disturbes the solid body rotation. Doing this with a small radius ratio ($R_1/R_2 = 2/7$) for counter rotating cylinders one can observe small turbulent structures transfered to the outer cylinder. These turbulent structures than can grow to larger packages of turbulence or decay.

EXPERIMENTAL INVESTIGATION

In our investigation we use an experimental apparatus with a radius ratio of $R_1/R_2 = 0.3$ and 0.1. The inner cylinder (1) as well as outer one (2) rotate with angular velocities $\Omega_{1,2}$ in corotating ($\mu = \Omega_2/\Omega_1 > 0$) and counter rotating direction ($\mu < 0$). The end plates of the concentric cylinder gap are attached to the outer cylinder at an aspect ratio of $L/(R_2 - R_1) = 14$ and 11.1. We use water and silicone oil as working fluid with different kinematic viscosities, leading to shear Reynolds numbers $Re_S = 2R_1R_2(R_2 - R_1)/(R_2 + R_1)\nu$ in the range of $10^3 - 10^5$. The outer cylinder is made out of acrylic glass to enable optical access. An additional torque sensor measures the torque applied to the driven shaft. Flow visualisation by the use of Kaliroscope and blue dye is performed and turbulent states are identified by the captured images and videos. Processing the visualisation time series than can be used to determine the type of structures as well as the behaviour of growth and decay. In Figure 1 a turbulent spot for the case of counter rotating cylinders of $\eta = 0.3$ can be observed.

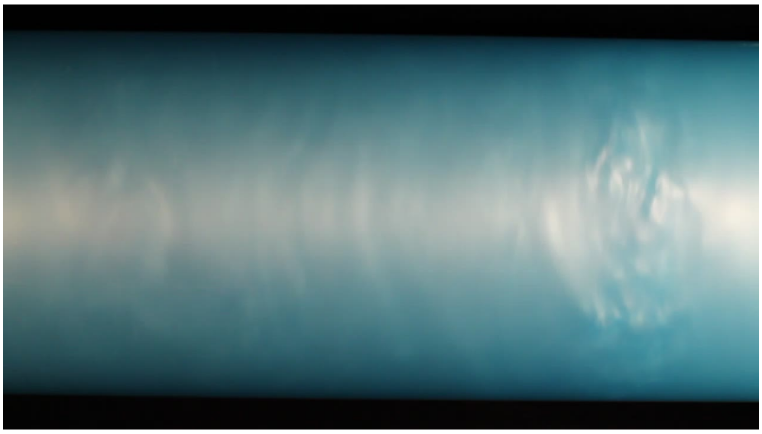

Figure 1. Turbulent spot for strong counter rotating wide gap Taylor-Couette flow ($\eta = 0.3$, $Re_S = 12,000$, $\mu = -0.4$)

An analysis of the flow behaviour leads to space-time plots such as Figure 2. Here different flows can be identified. For one case turbulent spots form randomly all over the measurement area and disappear later on. In the other case a huge turbulent structure is rising from laminar flow and decreasing afterwards. Laser Doppler Anemometry is used to measure

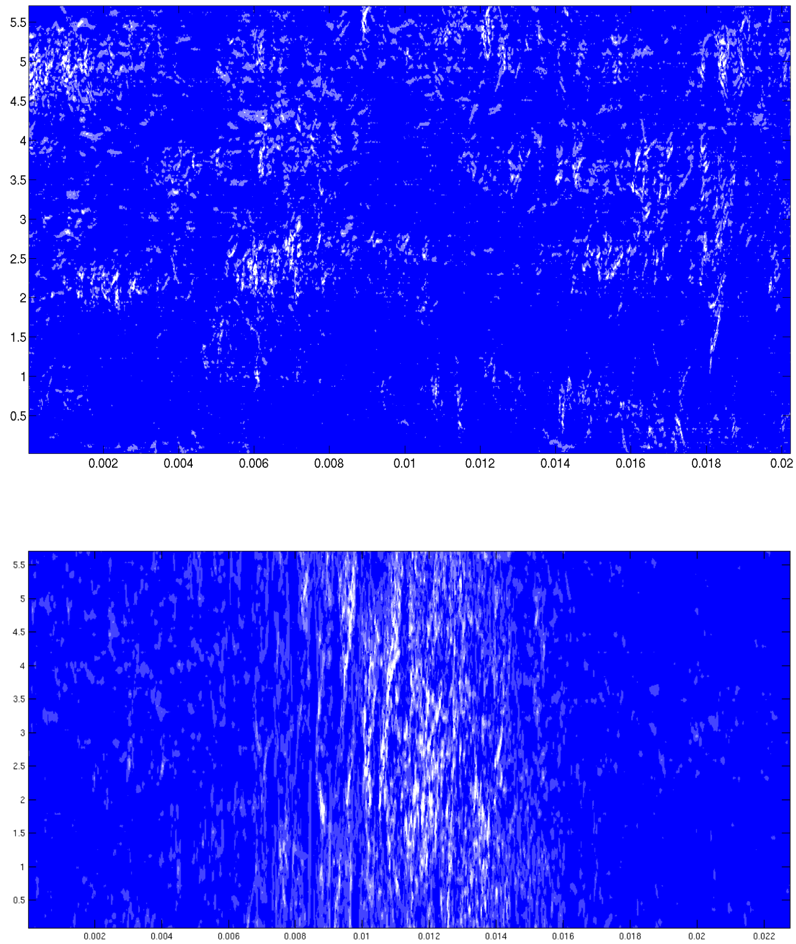

Figure 2. Temporal behaviour of the fluctuations observed for $\eta = 0.3, Re_S = 12,000$. Blue indicates laminar flow, white areas of turbulent fluctuations governed by the flow visualisation (compare Fig. 1. Top: $\mu = -0.4$, Bottom: $\mu = -0.5$.

azimuthal velocity at different positions. Radial profiles are given and the boundary layers at inner and outer cylinder are measured for different counter- and corotating cases.

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References

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