TORQUE MEASUREMENTS IN A WIDE GAP TAYLOR-COUETTE FLOW

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Abstract In the present work we investigate turbulent differentially rotating Taylor-Couette flow. In a wide gap experiment we measure the torque effecting on the inner cylinder wall for a wide range of angular velocities of both cylinders. The dependency on shear Reynolds number is reported. We find a maximum in torque for counter rotating cylinders and compare our experimental results with numerical investigations.

SCALING OF THE TORQUE IN TAYLOR COUETTE

In this work turbulent structures in concentric rotating Taylor-Couette flow (TC) and its dependency on different parameters are investigated. Depending on the rotation rate of the cylinders, one is able to create huge amount of different flow cases and coherent structures inside the annulus. Eckhardt et al. [2, 3] defined a transverse u_z flux J_{u_z} for pipe flow, a heat flux J_θ for Rayleigh-Bénard and angular motion flux $J_\omega = r^3(< u_r\omega >_{A,t} -\nu\partial_r < \omega >_{A,t})$, where $< ... >_{A,t}$ denotes a spacial temporal average over a cylindrical surface of height L at radius r, for Taylor-Couette flow, which has a similar analytical form. Analytically, J_ω has to be independent of all radii ($\partial_r J_\omega = 0$). So it is of great interest to quantify the angular motion flux J_ω as a parameter for the flow. At the wall the J_ω corresponds to the torque that the fluid works on the cylinders: Thus the dimensionless torque $G = T/(2\pi L\rho\nu^2) = \nu^{-2}J_\omega$ can be used to quantify the angular motion flux J_ω. Different present studies were performed to measure the torque in Taylor-Couette flows with narrow gaps ([4, 6, 7]) and for a wide but short gap ([1]). Measuring this dimensionless torque in terms of the laminar torque G_{lam} in a wide gap Taylor-Couette geometry is the purpose of this work.

EXPERIMENTAL INVESTIGATION

In our investigation we use an experimental apparatus with a radius ratio of $R_1/R_2 = 0.5$ (cf Fig. 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 can be rotated separately at an aspect ratio of $L/(R_2 - R_1) = 20$. We use 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 $10^3 - 10^6$. The outer cylinder is made out of glass to enable optical measurements. The inner cylinder is devided into three sections (Fig. 1). The middle section is used for measuring the torque T the fluid interacts on the rotating cylinder wall. The outer parts reduce the influence of the top and bottom end plates. The results of the torque measurements are shown in Fig. 2 for different constant shear Reynolds numbers. The torque has a peak at a slight counter rotatin of about $\mu_max = -0.2$ for all investigated shear Reynolds numbers [5]. The comparison with numerical calculations by H. Brauckmann show a very good agreement. In the present paper we discuss the behavior of the torque signal with different flow states.

Laser Doppler Anemometry is used to measure 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. In a second apparatus we are able to perform radial-azimuthal velocity measurements and compare these to the experiment with torque measurements.

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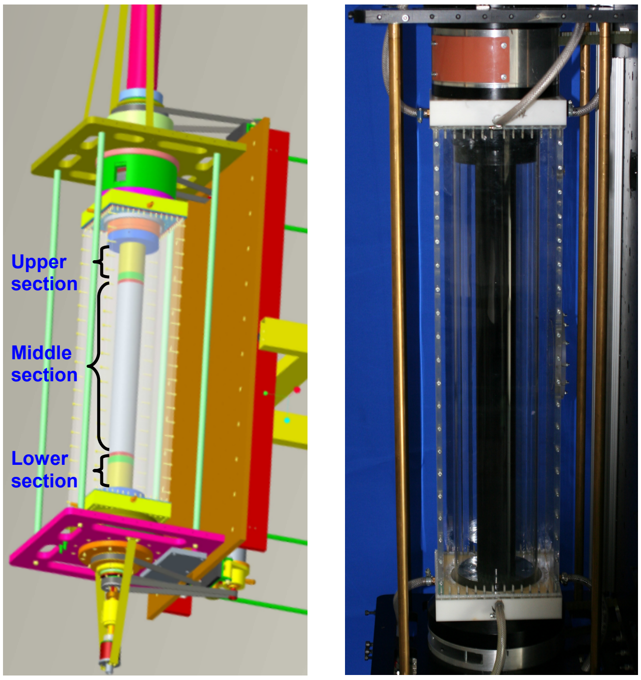

Figure 1. Drawing and image of the Taylor-Couette system, $R_1 = 35mm, R_2 = 70mm, \eta = 0.5, \Gamma = 20$ with surrounding water bath. The inner cylinder is separated into three sections. The middle section measures the torque. The upper and lower sections are pivoted inside the end plates.

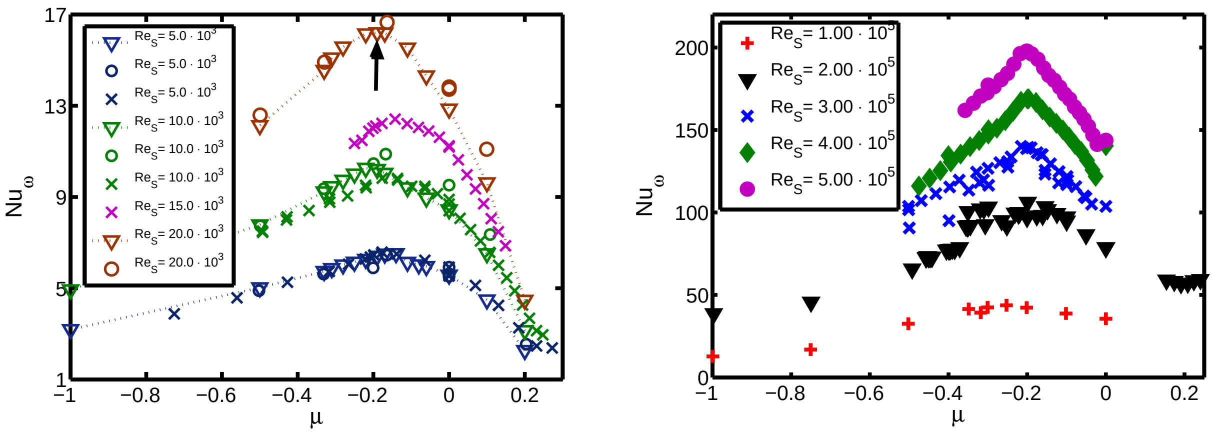

Figure 2. The dependency of the quasi-Nusselt number $\mathrm{Nu}_\omega = G/G_{lam}$ on the ratio of rotation rates μ for constant shear Reynolds numbers. Left: Measurements and numerical calculations for $\mathrm{Re}_S/10^4 = 0.5, 1, 1.5, 2$. The circles represent experimental torque data for silicone oil $\nu = 8.41 \times 10^{-6} m^2/s$, the crosses represent measurements for $\nu = 22.81 \times 10^{-6} m^2/s$ compared with direct numerical simulations (triangles). Dotted lines serve as a guide to the eye, the black arrow indicates the maximum at $\mu = -0.2$. Right: Measurements at constant shear Reynolds numbers $\mathrm{Re}_S/10^5 = 1.00, 2.00, 3.00, 4.00, 5.00$ using a silicone oil of $\nu = 0.65 \times 10^{-6} m^2/s$.