BULK STATISTICS OF STABLE AND DECAYING TAYLOR-COUETTE TURBULENCE

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Abstract In this talk we focus on the velocity fluctuations in highly turbulent Taylor-Couette flow for the case of stable flow (constant rotation) and for decaying flow. Turbulent flows are generally characterized by the range of scales of their fluctuations, and a statistical description of the flow is often done by calculating the correlations of velocity fluctuations. These correlations are found to behave like power-laws over a range of scales, and their exponents characterize a certain geometry of flow. Many systems have been investigated carefully: Pipe-flow, Von Kármán flow, Rayleigh Bénard convection, *et cetera*. There are, however, few reports [3, 4] quantifying the turbulent properties in Taylor-Couette flow.

In the presented work [2] we measure the longitudinal structure functions using laser Doppler anemometry, which is a non-intrusive technique and is able to measure the components of the velocity, and thus ideal for obtaining structure functions and the local velocity. We present the statistics of the turbulent velocity fluctuations for counter rotation for varying $a = -\omega_o/\omega_i$.

INTRODUCTION

We used the Twente Turbulent Taylor-Couette facility (T^{3}C) [5], which was filled with water and actively cooled to keep the temperature constant. The T^{3}C has an inner cylinder with an outer radius of $\rho_i = 200$ mm and a transparent outer cylinder with inner radius $\rho_o = 279$ mm, giving a radius ratio of $\eta = 0.716$. The cylinders have a height of $L = 927$ mm, resulting in an aspect ratio of $\Gamma = L/(\rho_o - \rho_i) = 11.7$. We measured the azimuthal velocity using laser Doppler anemometry (LDA). The advantage of this technique is that it allows for a non-intrusive measurement of a velocity component. For the case of counter-rotation the mean flow direction is not always in a single direction, and using, *e.g.* a hot-film probe or a pitot tube to measure the local velocity would result in measuring the *speed* in the wake of the probe. The laser beams go through the outer cylinder and are focused in the middle of the gap ($2\rho = \rho_i + \rho_o$) at mid-height ($z = L/2$), and lie in the θ–r plane. We fix our Taylor number to Ta $= 1.49 \times 10^{12}$ and measure 5×10^6 data points for each a. We calculate the probability density function ($\mathcal{F}$), see figure 1.

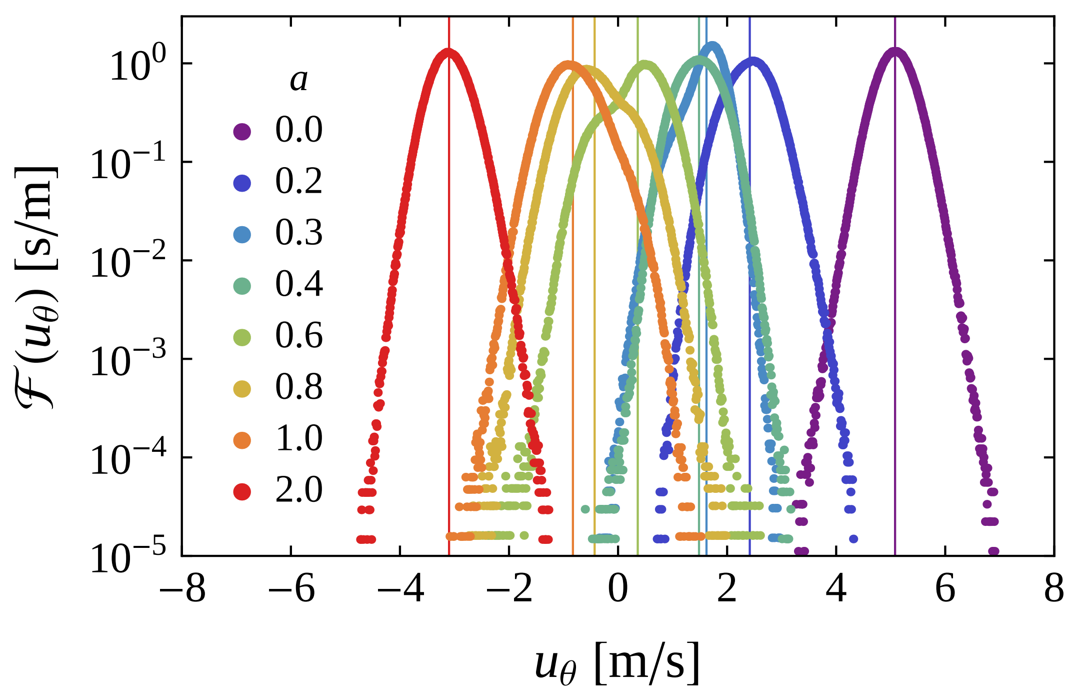

Figure 1. Probability density functions of the azimuthal velocity [$\mathcal{F}(u_\theta)$] measured at mid-height and mid-gap for varying $a = -\omega_o/\omega_i$. The means of the velocities are indicated by grid lines with their respective color. See ref. [2].

RESULTS

Though the PDFs describes the range of values expected for the flow, it does not contain any information about the dynamics; how does it vary in time? We therefore have to calculate the velocity increments ($\Delta_r u_\theta = u_\theta(t) - u_\theta(t - r/U)$) as a function of r, where r is the distance (Taylor's hypothesis) between the points (times) where u_θ is acquired. From that we calculate the moments and their respective scaling

$$D_p^* = \langle |\Delta_r u_\theta|^p \rangle \propto (D_3^*)^{\zeta_p^*} \tag{1}$$

using extended self-similarity (ESS) [1]. The resulting scaling exponents ζ_p^* are shown in table. 1, along with a comparison with those from Lewis and Swinney [3].

a	0	0_{LS}	0.2	0.3	0.4	0.6	0.8	1	2
p									
1	0.37	0.37	0.37	0.37	0.39	0.37	0.37	0.37	0.37
2	0.70	0.70	0.71	0.71	0.72	0.70	0.71	0.70	0.70
3^*	1	1	1	1	1	1	1	1	1
4	1.27	1.27	1.27	1.26	1.25	1.26	1.26	1.27	1.28
5	1.51	1.50	1.51	1.50	1.49	1.53	1.51	1.53	1.53
6	1.71	1.72	1.73	1.71	1.70	1.69	1.71	1.78	1.77

Table 1. ESS scaling exponents ζ_p^*, for different a. 0_{LS} are the data from Lewis and Swinney [3], for which $a = 0$ and Re $= 5.4 \times 10^5$. See ref. [2].

SUMMARY AND OUTLOOK

Our results show the scaling exponents of the extended self-similarity (ESS, [1]) structure functions do not depend on the rotation control parameter a in the linearly unstable regime, suggesting a universal scaling behavior for Taylor-Couette turbulence. In addition we provide the first results on decay turbulence in the Taylor-Couette geometry, we show that the decay is neither described by a power-law nor by exponential decay.

References

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