Spatio-temporal measurements of velocity gradient by Diffusing-Wave Spectroscopy

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The velocity gradient is the key quantity of many hydrodynamic phenomena (boundary layers, dissipative structures, drags etc...). Here we report the first spatially and temporally resolved measurements of the velocity gradient in a Taylor-Couette flow both in the laminar regime and in the unstable regime (transition to turbulence). The measurements are performed using a dynamic light scattering technique called Diffusing-Wave Spectroscopy (DWS) [1,2], which takes advantage of the diffusive nature of the multiply scattered light in a turbid colloidal suspension.

In a DWS measurement, the time autocorrelation of the intensity $g^{(2)}(t) = \langle I(t_0)I(t_0+t)\rangle/\langle I(t_0)\rangle^2$ is measured and decays because of the phase shift of light in time at each scattering event [3,4]. This decay is due on the one hand to the Brownian motion of particles and on the other hand to the fluid motion and more precisely to the velocity gradient in the flow, which can therefore be deduced. In addition to what Bicout and Maret have already done in a Taylor-Couette flow [5], we have obtained a time-evolving map of the velocity gradient, which shows the Taylor-Couette instability, including Taylor vortices. The possibility of detecting mechanical defects with DWS is also presented, with a setup where the inner cylinder presents a small defect. This work is the first step of the study of quasi-local velocity gradients and dissipation in some complex flows.

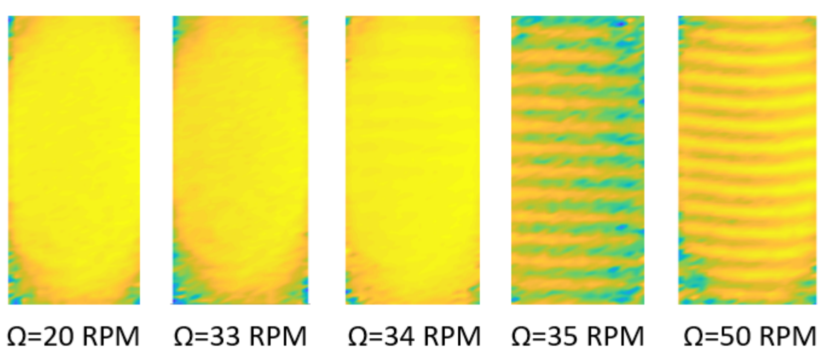

Figure 1. Color map of the velocity gradient measured by DWS on the surface of the Taylor-Couette cell. For each map, blue corresponds to the lowest values of the velocity gradient while red corresponds to the highest values. In our setup, the threshold is at $\Omega = 34$ RPM, where we can start to distinguish the Taylor vortices.

References

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