TURBULENT DRAG REDUCTION WITH FLEXIBLE AND RIGID POLYMER SOLUTIONS: FROM LOW TO MAXIMUM DRAG REDUCTION

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ABSTRACT

We present an experimental study of turbulent drag reduction with flexible and rigid polymer solutions in a 2:1 aspect ratio rectangular channel. The experiments are carried out at low drag reduction (LDR, $\%DR < 40$), high drag reduction (HDR, $\%DR > 40$) and maximum drag reduction (MDR, where the velocity profile U^+ roughly matches Virk's asymptote), with partially hydrolyzed polyacrylamide as a flexible polymer, and xanthan gum as a rigid polymer[1]. The rheology of the polymer solutions is characterized with a Malvern Kinexus Ultra+ Rheometer. We measure velocity profiles, streamwise and wall-normal Reynolds stresses and power spectra of streamwise velocity fluctuations with a Laser Doppler Anemometry (LDA) setup.

Our results[2] show similar effects of both polymeric additives on the velocity and Reynolds stress profiles, provided that the Reynolds numbers and $\%DR$ are also similar. At both HDR and MDR, the power spectral densities of streamwise velocity fluctuations of both XG and HPAM flows show a power-law decay near -3 instead of $-5/3$ in the inertial range. This slope was recently interpreted as evidence of elasto-inertial turbulence (EIT) in polymer jets[3]. At concentrations near 100 ppm, we observe that flexible polymer solutions are more effective at reducing drag, while XG can only reach MDR at very high concentrations. Therefore, we hypothesize that the formation of polymer aggregates with high concentrations contributes to increase viscoelasticity and $\%DR$ in rigid polymer solutions.

REFERENCES

1. Pereira A. S., Andrade R. M., Soares E. J., Drag reduction induced by flexible and rigid molecules in a turbulent flow into a rotating cylindrical double gap device: Comparison between Poly (ethylene oxide), Polyacrylamide, and Xanthan Gum, *J. Non-Newtonian Fluid Mech.*, **202**, 72–87, 2013.

2. Mitishita R. S., Elfring G. J., Statistics and spectral analysis of turbulent duct flows with flexible and rigid polymer solutions, *J. Non-Newtonian Fluid Mech.*, **311**, 104952, 2023.

3. Yamani S., Keshavarz B., Raj Y., Zaki T. A., McKinley G. H., Bischofberger I., Spectral universality of elastoinertial turbulence, *Phys. Rev Lett*, **127**, 074501, 2021.