Effect of neutrally buoyant particles on transitional pipe flow characteristics.

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Particulate flows play a variety of significant roles in nature and industry, whether it be flow in rivers or blood flowing in our bodies or in the chemical and biomedical industries. Thus it becomes important to study these types of flows.

Past studies on neutrally buoyant particles have been shown to affect the transitional flow characteristics. There is indeed a relationship between their size and flow stability in the transitional flow regime between laminar and fully developed turbulence in pipe flows.[1] Further studies were done to establish a universal scaling for onset of fluid turbulence based on particle size and concentration.This enabled the authors to predict the transitional behaviour of a range of particulate flows. However This scaling was based on relatively larger particle size and concentration, but mostly left aside low particle concentrations, and smaller particles.[2]. The mechanism by which transition is affected is largely unknown too, mostly because it has been not been possible to observe the trajectory of particles and the velocity field simulatneously.

With the aim of studying the effect of low concentration and small sized particles on the transitional behaviour of the fluid, a test rig was developed, with exactly that capability. The rig features a 12 m -long, 2 cm diameter pipe filled with a transparent working fluid driven through it by a motor fixed to a piston-cylinder arrangement. A local, transversal injection system was developed to introduce controlled perturbations in the system. To study the flow features, a laser and camera system designed to deliver simultaneous particle image velocimetry (PIV) and particle tracking velocimetry (PTV) measurements of the fluid's and particles' velocity fields. An additional setup of camera and laser was fitter further downstream towards the end of the pipe to study the fate of the introduced perturbation. The system was also coupled with a differential pressure transducer to study the pressure drop of the fluid along the pipe.

We found too that the transition to turbulence is affected by the particles even when their concentration is comparatively low. We found that varying particles concentration and size has either a stabilising or a destabilising effect on the Reynolds numbers characterising the different phases of the transition to turbulence. This particle- fluid interaction and its affect on the transitional behaviour of the fluid was studied extensively particularly concentrating on the appearance of turbulent flow features such as puffs and slugs, and the particles' behaviour within them. Discrepancies between particles and fluid's velocities were found to vary within the structures themselves, raising the question of how locally inhomogeneous momumentum transfer between the two phases may affect the evolution of puffs and slugs, and thereby the transition mechanism.

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[1]Matas et al ., *Phy. Review Letters* 90 (2003).

[2]Hogendoorn et al., *Phy. Review Fluids* 7 (2022).