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TURBULENT DRAG REDUCTION BY ADDITIVES

Abstract

The addition of a minute amount of polymer or surfactant additive to a turbulent fluid flow can result in a large reduction in the frictional drag in pipes and channels. Over the past decades numerous studies have been carried out on drag reducing additives (DRA). DRA have been successfully applied for potential benefits in various industrial processes, including oil well operations, heating and cooling water circuits, marine and biomedical systems. The use of additives to enhance flow in petroleum pipelines has received the greatest attention due to its great commercial success in reducing cost and energy consumption. Despite there having been a large amount of experiments in addition to both theoretical and simulation approaches, the nature of the drag reduction phenomenon is incompletely understood and remains a subject of debate. The aim of this thesis is to develop an understanding of the role of drag reducing agents and to explain the nature of the drag reduction mechanism. This could have an impact on the design of efficient pumping systems, the design of drag-reducing agents that are more stable over time, and the modelling of mixing processes that could be an important consideration in designing practical systems.

TURBULENT DRAG REDUCTION BY RIGID POLYMERS

Abstract

Polymer drag reduction has found applications in many fields, primarily in pipe-flows, but also in marine and biomedical applications. The phenomenon of polymer drag reduction has shown that the drag reduction effect is achieved, using a minute amount of polymer in a turbulent fluid flow which results in a large reduction in the frictional drag in pipes and channels. Although the phenomenon of the drag reduction has been known for almost half a century, its precise mechanism is not fully understood and still continues to be a fascinating challenge. In recent theories of drag reduction in wall turbulence, it was assumed that the presence of the polymer leads to an effective viscosity that increases linearly with the distance from the wall. Such a linear viscosity profile reduces the Reynolds stress (i.e. the momentum flux to the wall) which in turn leads to drag reduction. In this work, the turbulent drag reduction characteristics of the rod-like polysaccharide xanthan gum were investigated to understand the mechanism of the interaction of rigid polymers with turbulence using a horizontal closed-loop system. The use of rigid polymers leads to a shear thinning viscosity without any elastic effect, allowing to directly assess the effect of viscosity on drag reduction.

Keywords: Drag reduction, turbulent flow, xanthan gum polymer.

HIGH REYNOLDS NUMBER TURBULENCE IN COMPLEX FLUIDS

Abstract

Turbulence in fluids is ubiquitous in natural and industrial settings. It has been known for a long time now that some properties of turbulence, at least of macroscopic scale, can be influenced by the addition of a minute amount of large molecules such as polymers, fibers or surfactants. Despite the large interest in such modifications and their possible use for drag reduction in pipes, nature of turbulence is still unclear. Recent work has shown modifications of the energy density spectrum and the second order structure function at scales near the dissipative range and beyond raising additional questions as to how such modifications may occur and what their role may be. We have reexamined here the issue of modification of the structure of turbulence, using a dilute surfactant solution as complex fluid. This fluid has the particular property of shear thickening when driven at shear rates above a certain threshold. The rhelogical properties of this complex fluid are therefore very different from the often used polymer solutions which generally show shear thinning behavior. For comparison we also carried out experiments using a polymer solution. Through study of spectral properties and the structure function scalings, an important difference arises with respect to the reference case, water. The surfactant solution shows strong intermittency at small scales, which we believe to be due to the formation of the small gel parcels in the fluid. The large scales are on the other hand free of intermittency. While this transition is observed in the structure function scalings, no sign of this transition is seen in the power spectrum of velocity fluctuations which shows single scaling range. In fact, another complex fluid, a polymer solution, shows very similar phenomenology as the water case, we speculate that the fine tuning of fluid properties my shed new light on how intermittency occurs in fluid turbulence.

Keywords: Polymer, surfactant, rheology, turbulence.