A Haliselbon dumbbell model in turbulent flow diluted with polymers

Kiyosi Horiuti

Department of Mechano-Aerospace Engineering, Tokyo Institute of Technology, Japan

A new model for convection of polymers dispersed in turbulent flow is proposed. In the mesoscopic scale, the polymer chains are represented by the elastic dumbbells and their motion is pursued by Brownian dynamics, while the macroscopic motion of solvent fluid is determined by DNS. We develop a new dumbbell model in which commonly assumed constraint of affinity in the motion of the bead-spring configuration with the macroscopic fluid deformation is relaxed. Non-affinity is introduced by allowing slippage of the dumbbells as stretching of polymers progresses. When the affine (or contravariant) dumbbell is rotated to the non-affine (or covariant) direction, the slip parameter α is adjusted so that altered orientation is more precisely captured. Assessment is conducted by dispersing the dumbbells in homogeneous isotropic turbulence. In the proposed model, the elasto-inertial turbulence (EIT) which emerges in the elongated affine dumbbells (P.C. Valente *et al.* JFM 760, 2014) is eliminated by converting contravariant configuration to covariant configuration. Figure 1 shows the temporal variations in α and the length of the dumbbell connector vector, $|\boldsymbol{R}|^2$, along the trajectory of a single dumbbell. Colors of markers indicate the cosine angles which $\boldsymbol{R}$ makes with the eigenvector orthogonal to the vortex sheets at each instant. Initial value of α is 0. When the contravariant constraint $\alpha \equiv 0$ is removed, the dumbbell is transformed back and forth into between covariant and contravariant configurations. This alternate conversion is repeated quasi-periodically with lapse of temporal interval comparable to the relaxation time. Marked enhancement of drag reduction is achieved in comparison to the fully affine case. The largest elastic energy production is achieved in the highly stretched covariant configuration, whereas intermediate production is attained in the contravariant configuration with intermediate length. Contravariant and covariant configurations share the complementary roles in their elongation.

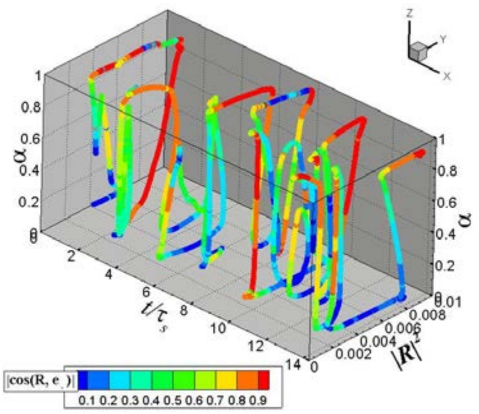

Figure 1. Profiles of α and the dumbbell length $|\boldsymbol{R}|^2$ are shown as a function of time normalized by the relaxation time τ_s taken along the trajectory of a single dumbbell. Color of the markers denotes the cosine angle which $\boldsymbol{R}$ makes with the direction orthogonal to vortex sheets.