DIRECT NUMERICAL SIMULATIONS OF TURBULENT VISCOELASTIC JETS DESCRIBED BY THE FENE-P MODEL

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INTRODUCTION

Several spatial direct numerical simulations (DNS) of turbulent planar jets of dilute polymers, described by the finitely extensible non-linear elastic constitutive equation closed with the Peterlin approximation (FENE-P), are carried out in order to investigate and develop a theory for the far field of the viscoelastic jet. These are the first massive direct numerical simulations of these flows, and use the algorithm proposed by [1] to tackle with the complex numerical challenges posed by these heavy computations.

RESULTS

The data obtained from the DNSs covers the entire transitional region as well as the fully turbulent jets far-field up to 18 slot widths. The influence of rheological parameters of the fluid on the turbulent statistics of the jet are discussed, revealing considerable changes in comparison to the Newtonian case. In particular, the solvent maximum value of the centreline mean kinetic turbulent energy dissipation is reduced by a factor greater than 80% in the most dramatic case, clearly showing the influence of the polymers on the flow development. Significant changes are also found in the jets spreading and decay rates (Fig. 1g-h), as well as in the Reynolds stress (Fig. 1a-d) and mean velocity components.
A new theory based on order of magnitude considerations and on hypothesis regarding the self-similar behaviour of the mean flow is proposed and validated by the DNS data. The theory results in new analytical expressions for the jet spreading and decay rates and for the stream-wise evolution of the characteristic mean polymeric shear stress ($\sigma_c^{[p]}$), such as, $\delta \sim x$, $U_c \sim x^{-1/2}$, and $\sigma_c^{[p]} \sim x^{-3}$. The theoretical results display a good agreement with the DNSs results, are ilustrated in Fig. 1f-i.

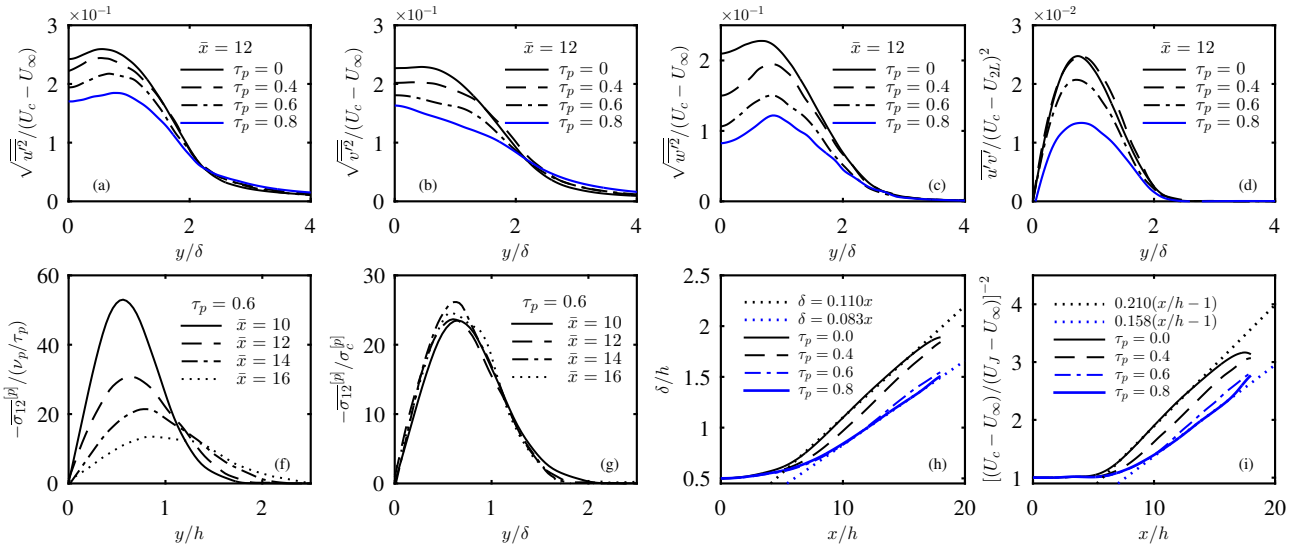

Figure 1. Results from direct numerical simulations of turbulent planar jets with polymer additives, for different relaxation times τ_p, ($\tau_p = 0$ corresponds to a Newtonian fluid): Profiles of Reynolds stresses components (a-d), polymeric shear stresses in natural (e) and similarity coordinates (f); jet half-width (g) and centreline mean velocity (h).

References

[1] T Vaithianathan, Ashish Robert, James G Brasseur, and Lance R Collins. An improved algorithm for simulating three-dimensional, viscoelastic turbulence. *Journal of Non-Newtonian Fluid Mechanics*, **140**(1-3):3–22, 2006.