THE TURBULENT/NON-TURBULENT INTERFACE LAYER IN A VISCOELASTIC FLUID

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Abstract: Many flows are characterised by the coexistence of turbulent (T) and irrotational (or non-turbulent - NT) flow regions *e.g.* wakes, where the two flow regions are separated by a very sharp interface layer: the turbulent/non-turbulent interface (TNTI)[1]. When very long chains of molecules (polymers) are dissolved into a Newtonian solvent the resulting medium exhibits complex viscoelastic properties that substantially affect the flow, and present substantial less entrainment than Newtonian fluids[2]. However, several of the mechanisms governing the enstrophy near the TNTI layer need clarification, particularly the role of new viscoelastic terms and their impact on classical quantities, where virtually no experimental data or numerical simulations have been reported. In the present work new massive DNS of viscoelastic fluids are carried out to analyse the enstrophy dynamics within the TNTI layer. The DNS used the finitely extensible elastic model with the Peterlin closure (FENE-p) is used to compute the polymer stresses. One Newtonian and 4 viscoelastic simulations have been carried out, where the maximum relaxation time of the polymer molecules is equal to $\tau_p = [0.025, 0.05, 0.100, 0.200]\ s$. To the author's knowledge these are the biggest DNS carried out so far for the FENE-p fluid. Figure 1 (left and center) shows iso-surfaces of

Figure 1: Top view of the irrotational boundary (IB) observed through iso-surfaces of vorticity magnitude for a Newtonian fluid (left) and viscoelastic fluid with $\tau_p = 0.200$s (center); Conditional enstrophy budgets for viscoelastic fluid with $\tau_p = 0.200$s (right).

vorticity magnitude corresponding to the irrotational boundary (IB) that constitutes the outer border of the TNTI layer separating T from NT fluid, for a Newtonian and a viscoelastic fluid. It is clear that the typical roughness associated with this interface is substantially altered for viscoelastic fluids, compared to the Newtonian case, where the IB is much more convoluted, and suggests that a substantial increase of the integral scale exists in these cases. Figure 1 right shows the conditional enstrophy budgets of the fourth viscoelastic fluid. While for a Newtonian fluid the enstrophy production is roughly balanced by the enstrophy dissipation, in the viscoelastic case a new term arises - viscoelastic production - that can increase or decrease the enstrophy within the T region. This in turn affects the mechanism of generation of enstrophy in the TNTI layer, which modifies the entrainment rate characteristics of the flow, the details of which, will be discussed in the presentation.

References

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