Explaining the flow of elastic liquids

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The talk will review what has been learnt from many recent studies about explaining in general terms why elastic liquids behave unexpectedly compared with elastic solids and viscous liquids. Four anomalous behaviours will be discussed:

- (i) the formation of large vortices upstream of a constriction, along with an associated large pressure drop;
- (ii) the long wake downstream of a sphere (at low Reynolds numbers), along with an associated increase in drag;
- (iii) the long time for capillary forces to squeeze a liquid filament;
- (iv) the wide variation in apparent extensional viscosity of the international standard fluid M1 when measured in different apparatuses.

Many features can be explained and understood using the simplest constitutive equation, that of an Oldroyd-B fluid. The behaviour of this fluid has been examined in all possible limits (various weak flows, strong flows, and large elastic stresses), producing the important ideas of relaxation and tension in streamlines. The model fluid has however some undesirable properties, (a negative viscosity under certain conditions) which can be regularised by requiring a finite extensibility of the underlying microstructure, the FENE modification. This modification enables the remaining details in the four anomalous behaviours to be explained. The FENE model brings two new properties

- a high extensional viscosity, which produces the increases in drag,
- and an anisotropy, which produces the long upstream vortex.

These properties lead to the development of two new theoretical approaches

- a elastic boundary layer theory,
- and a `wine glass' model of the flow into a constriction.