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Self-similar breakup of polymeric threads as described by the Oldroyd-B model

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When a drop of fluid containing long, flexible polymers breaks up, it forms threads of almost constant thickness, whose size decreases exponentially in time. Using an Oldroyd-B fluid as a model, we show that the thread profile, rescaled by the thread thickness, converges to a similarity solution. Using the correspondence between viscoelastic fluids and non-linear elasticity, we derive similarity equations for the full three-dimensional axisymmetric flow field in the limit that the viscosity of the solvent fluid can be neglected. A conservation law balancing pressure and elastic energy permits to calculate the thread thickness exactly. The explicit form of the velocity and stress fields can be deduced from a solution of the similarity equations. Results are validated by detailed comparison with numerical simulations.