OSCILLATORY EXTENSIONAL RHEOMETRY WITH ULTRA-DILUTE POLYMER SOLUTIONS AND LOW VOLUME BIOFLUID SAMPLES

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The Cross-slot Oscillatory Flow Extensional Rheometer (COFER) [1] is a stagnation point flow device that uses piezo-driven micropumps to oscillate fluid within the cross, allowing measurements of flow-induced birefringence and excess pressure drop to be made on small samples of fluids, relative to standard continuous flow-through experiments. The original intended application of the COFER was to measure the extensional rheological properties of small volumes of biofluid samples, such as synovial fluid biopsies. Synovial fluid extensional properties are vital for the protection of the knee joints under compressive loads, and may provide a marker for the early detection of osteoarthritis, since the functional hyaluronic acid macromolecules in the diseased fluid become degraded. However, the COFER as described in [1] still required significantly larger volumes of fluid (~ 40 mL) than typically available. Recent advances in the design of the instrument have significantly improved its performance in various respects (e.g. [2]). Improvements to the optical line mean that the device is now capable of measuring the opto-extensional response of truly ultra-dilute polymer solutions with $c/c^* < O(10^{-2})$, in the concentration range used in turbulent drag reduction and enhanced oil recovery applications. The addition of a convenient injection point close to the cross, combined with the use of a micro-scale geometry, has also resulted in a considerable reduction in the required volume of test fluid to ~ $O(\mu L)$, providing the opportunity to test a range of exotic or scarce fluids, which were previously inaccessible to study in the device. The capabilities of the COFER will be showcased using a range of non-Newtonian fluids including dilute and ultra-dilute polystyrene solutions, hyaluronic acid solutions, and human saliva. The potential for further development of the device and for further in-depth studies of biological fluids will be discussed.

[1] J.A. Odell and S.P. Carrington (2006) Extensional flow oscillatory rheometry, Journal of non-Newtonian Fluid Mechanics 137: 110-120

[2] S.J. Haward (2010) Buckling instabilities in dilute polymer solution elastic strands, Rheologica Acta 49: 1219-1225