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HEMORHEOLOGY USING TWO FOCI FLUORESCENCE CORRELATION SPECTROSCOPY

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ABSTRACT

In classical rheological measurements of blood, such as with a cone-plate rheometer, it is assumed that the velocity profile is linear across the width of the rheometer gap. However, the validity of this assumption is questioned as measurements of blood flow in microfluidic devices have shown heterogeneous distribution of red blood cells (RBCs) and shear have a considerable effect on the local hemodynamics. Local measurement of velocity fields through dense suspensions, however, is notoriously difficult to measure using conventional optical techniques primarily due to the loss of tracer signal with increasing RBC volume fraction, also known as the hematocrit (HT). To overcome this limitation and to re-explore the velocity profile in rotational rheometers, we first propose the use of two-foci fluorescence correlation spectroscopy (2f-FCS) in measuring velocity profiles in dense RBC suspensions up to 40% HT flowing in rectangular glass capillary microchannels.

To accomplish velocity measurements using 2f-FCS, two spatially separated laser foci are created and observed with optical fibers, which then transmit fluorescence signals to two separate avalanche photodiodes. This setup allows for the independent measurement of fluorescence fluctuations as low concentration fluorescent beads are transported from the upstream to the downstream foci. The cross-correlation of the fluorescence fluctuations results in a peak lag time that reflects the transit of fluorescent particles between foci. Knowing the focal distance and lag time enables calculation of local speed at a given height in the microfluidic device.

Velocity profile across the microfluidic device is achievable for both transparent fluids and dense suspensions of RBC of at least 40% HT. Non-aggregated RBCs at 40% HT exhibited parabolic velocity profile characteristics of Newtonian fluid. In contrast, a plug flow is observed for aggregated RBCs at 40% HT which are characteristic of shear-thinning fluids. It is known that blood exhibits shear thinning behavior which is primarily due to RBC aggregability and secondly by RBC deformation. However, interestingly, the velocity of the non-aggregated RBC does not exhibit the same shear thinning behavior observed in bulk rheological measurements for mean shear rates between 3-30 s^{-1}. To confirm the validity of the velocity measurement using 2f-FCS a secondary flow condition is verified which is a constant flow condition. It is found that in the range of 10 - 40% HT the velocity profile conforms with theoretical results.

2f-FCS proves to be a valuable tool in re-exploring the measurement of local velocity fields of dense suspensions.