Full dynamics of red blood cells in a shear flow

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Red blood cells (RBCs) are unique highly deformable non-spherical capsules. Their rheological behavior is complex due to their specific mechanical properties. While their internal medium is a simple Newtonian fluid, their membrane combines high viscosity, incompressibility, bending modulus and coupling with the 2D elastic cell cytoskeleton. In addition, the interplay between membrane elasticity and biconcave cell shape generates a cell shape memory. Recently, we have revisited the dynamics of RBCs in steady and oscillating shear flows. We experimentally showed and theoretically described new important features for the tanktreading motion: swinging, intermittency, chaos, induced by the interplay between cytoskeleton elasticity and shape memory. Our work generated many numerical simulations, which displayed significant differences with experiments. We present here a complete set of experiments describing the full dynamics of RBCs in a moderate shear flow. We show that upon increasing the shear rate the stable motion of RBCs progressively changes (evolution of the cell orbit in the flow) from tumbling to a rolling motion in the shear plane. Cytoskeleton elasticity is responsible for this motion (stiffened cells always tumble). We reveal a new spinning-precessing motion at the transition to tanktreading. Conversely, upon decreasing the shear rate the transition tanktreading to tumbling-rolling occurs via a transient intermittent regime. The transition between the two motion shows a strong hysteresis. Finally we show that RBCs never deform much and remain biconcave, even during tanktreading, contrarily to predictions of numerical simulations. We interpret this result in terms of moderate shape memory and strong bending modulus.