The Emergence of a Hexagonal Pattern in Shear-Thickening Suspension under Orbital Shaking

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Abstract : Dense particle suspensions composed of mixtures of particles and fluid are omnipresent in natural phenomena and in industrial processes. Dense particle suspension under shear may lose its uniform state to large local density and stress fluctuations which challenge the mean-field description of the suspension system. However, it still remains largely debated and far from fully understood of the internal mechanism. Here, a dynamics of a non-Brownian suspension is explored under horizontal swirling excitations, where high-density patches appear when the excitation frequency is increased beyond a threshold. These density patches are self-assembled into a hexagonal pattern across the system with further increases in frequency. This phenomenon is underlined by the spontaneous growth of density waves (instabilities) along the flow direction, and the motion of these density waves preserves the circular path and the frequency of the oscillation. To investigate the origin of the phenomena, the constitutive relationship calibrated by independent rheological measurements is implemented into a simplified two-phase flow model. And the critical instability frequency in theory calculation matches the experimental measurements quantitatively without free parameters. By further analyzing the model, the instability is found to be closely related to the discontinuous shear thickening transition of the suspension. In addition, the long-standing density waves degenerate into random fluctuations when replacing the free surface with rigid confinement. It indicates that the shear-thickened state is intrinsically heterogeneous, and the boundary conditions are crucial for the development of local disturbance.

Keywords : dense suspension, instability, self-organization, density wave
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