Self-organized co-rotating dust vortices in complex plasmas

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Self-organized co-rotating vortices are observed in many complex driven-dissipative flow systems in nature, such as the vortices behind aircraft wings, and the leapfrogging smoke rings, among others. Similar structural transition from single vortex into co-rotating vortices has been also recovered in many of laboratory dusty plasma experiments, for which the physical mechanisms are yet to be fully understood. This motivates us to analyze the vortex dynamics using the dust clouds confined in an azimuthally symmetric torus embedded within a bounded background plasma, as a prototype for various driven-dissipative systems. Using a 2D hydrodynamic formulation and its numerical solutions, we demonstrate that the steady vortex structure in the low Reynolds number (R_e) regimes is mainly determined by the geometry of the bounded domain, whereas in the high R_e or nonlinear regimes, the flow structure starts to have additional dependence on the dynamic regime. As a consequence, circulating flows become rounder in shape when convection dominates diffusion, and such a transition is controlled by a parameter say μ, the kinematic viscosity of the flow. Thus, the nonlinear vortex structure at very high R_e regime is characterized by the critical transition through a parameter μ^* and the emergence of self-organized co-rotating circular vortices of the similar sizes surrounded by shear layers filled with weak flows that enable the smooth matching to the external boundary. The size and number of the co-rotating vortices depend on aspect ratio of the bounded plasma domain. The nonlinear solutions can be used to interpret the structural transition and the conditions of self-organized co-rotating vortices in various dusty plasma experiments as well as many other relevant complex driven-dissipative natural systems.

Reference:-

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