Breakup of inertial aggregates in homogeneous and isotropic turbulence

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The breakup of solid object dispersed in laminar and turbulent flows is a complex phenomenon, involving the simultaneous action of body forces, hydrodynamic interactions and colloidal forces. Here, we consider a dilute suspension of point-like, inertial particles dispersed in $3D$ isotropic and homogeneous turbulence. The evolution of both heavy and light particles is analysed by varying the particle Stokes number $St \in [0; 4.1]$ and the fluid-to-particle density ratio $\beta \in [0; 3]$. We numerically solve the flow and inertial particle dynamics at the Reynolds number $Re_\lambda \simeq 200$. We study the fragmentation process under two different scenarios, namely of brittle and ductile breakup. In the first one[1], aggregates breakup whenever the local instantaneous total stress - resulting from joint action of the turbulent shear σ_ϵ and the drag σ_{St}- exceeds a critical value. Regardless of the values of (St, β), we find that shear stresses similarly impact the breakup of inertial aggregates, and dictate the breakup rate of weak aggregates (Fig.1). When the density ratio is different from unity or inertia is very strong, drag stresses become dominant and cause the breakup of the most resistant aggregregate. In the second scenario[2], aggregates accumulate energy, and their breakup occurs when the energy transferred to the aggregate by the flow exceeds a critical value. For neutrally buoyant aggregates, we contrast predictions of ductile *versus* brittle breakup. Turbulent rare fluctuations are crucial for the breakup of brittle aggregates, while they become less relevant for ductile aggregates. In the limit of highly ductile aggregates, the breakup rate is dictated by the mean properties of the flow. We propose a simple model to capture this behaviour[3].

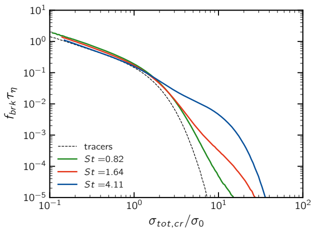

Figure 1: Breakup rate of neutrally buoyant aggregates ($\beta = 1$), of variable inertia, as a function of the critical total hydrodynamics stress $\sigma_{tot} = \sigma_\epsilon + \sigma_{St}$ experienced by the aggregate. The x- and y-axis are normalized by the Kolmogorov time scale of the flow τ_η and the average shear stress σ_0 of tracers, respectively.

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[1] Frungieri *et al.*, https://arxiv.org/abs/2211.03431 (2022)
[2] Frungieri *et al.*, https://arxiv.org/abs/2302.11350 (2023)
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