Melting of a finite-size Lagrangian sphere in homogeneous turbulence

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We seek to characterize the melting of a single finite-size sphere that is free to rotate and translate, immersed in homogeneous isotropic turbulent flow—a so called Lagrangian melting problem (figure 1). This is investigated through a set of interface-resolved direct numerical simulations varying the Taylor Reynolds number, Re_λ, and initial sphere size, characterized by the Stokes number Stk, adopting a recently-proposed immersed boundary method[1]. The principal question we seek to answer is: how does the volume evolution (i.e. the melting) of an initially-spherical solid depend on the turbulent mixing and initial size, characterized by Re_λ, Stk, respectively? When the immersed solid remains fixed and is restricted from any rotational or translational motion, we show how an energy-cascade argument adopting classical laminar boundary-layer scalings for rigid, stationary walls can adequately describe the heat-transfer, and hence the volume evolution. This prediction fails when Lagrangian melting is considered, owing to the relative motion that is introduced between the solid and liquid phase which weakens the analogy with canonical rigid-wall setups. In the spirit of literature surrounding finite-size particle-laden turbulence[2 3], we show that proper parameterization of this relative motion, given by the slip velocity, and appropriate choice for a solid-motion timescale form the necessary ingredients in predicting melting in tandem with Lagrangian motion.

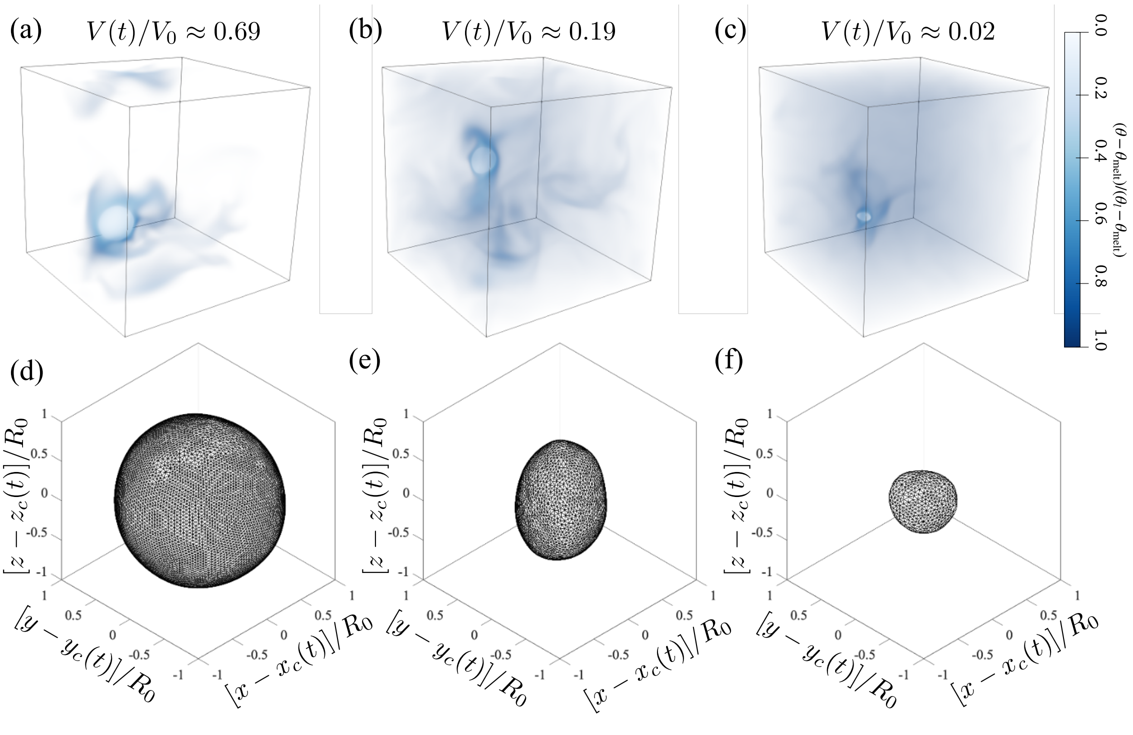

Figure 1: Melting of a Lagrangian sphere with initial radius $R_0 = 0.1L$ in homogeneous isotropic turbulence at Taylor Reynolds number $Re_\lambda \approx 50$ where L is the domain size. (a–c) Volume contours of instantaneous temperature with increasing melt duration from left to right (characterized by the object volume normalized on the initial volume $V(t)/V_0$). (d–f) Zoomed views of the solid geometry corresponding to the snapshots in (a–c).

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[1]Zhong et al., *Journal of Computational Physics* (in press)
[2]Bellani & Variano, *New Journal of Physics* **14**, 125009 (2012)
[3]Xu & Bodenschatz, *Physica D: Nonlinear Phenomena* **237**, 2095–2100 (2008)