Investigation of Quantum Flows of 4He by Visualization and Second Sound Attenuation

L. Skrbek[a], S. Babuin[b], D. Duda[a], M. J. Jackson[a], M. La Mantia[a], M. Rotter[a], J. Šebek[b], D. Schmoranzer[a], and E. Varga[a]

[a]Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, 121 16 Prague, Czech Republic
[b]Institute of Physics ASCR, v.v.i., Na Slovance, 182 21 Prague, Czech Republic

We report recent experimental investigations of quantum turbulence (QT), using the superfluid ^{4}He in the two-fluid regime ($T \geq 1.2$ K) as a working fluid. We discuss our visualization studies of the Lagrangian dynamics of solid deuterium particles of micron size, focusing on the crossover from quantum to classical behavior of turbulence generated in thermal counterflow. The dynamics of particles of size $d \approx \ell/10$ is studied at length scales $\ell_{\rm exp}$ straddling the average distance ℓ between quantized vortices. The normalized probability distribution (PDF) of the particle velocity changes from the power-law shape typical of QT at scales $\ell_{\rm exp} < \ell$, to the nearly Gaussian form typical of classical turbulent flows at $\ell_{\rm exp} > \ell$. Additionally, the normalized PDF of the particle acceleration at $\ell_{\rm exp} < \ell$, appears consistent with a previously unreported law that predicts a roll-off exponent for the PDF tails. We further report an experimental study of the steady-state and decay of QT generated by a forced flow in a 7 mm wide square duct, with and without silver sinter superleaks and/or obstructing grid (0.5 mm mesh size and 0.1 mm tines). Steady-state flows with a mean velocity of up to 1 m/s are produced by a low temperature bellows, the density of quantized vortex lines is deduced from the attenuation of second sound. We discuss steady state pure superflow, forced pipe superflow, forced grid turbulence and their temporal decays in terms of vortex line density across 4 decades over 200 seconds, containing a robust classical-like power law dependence of the form $t^{-3/2}$. We acknowledge the support of GAČR P203/11/0442.

Section: VT - Vortices and turbulence

Keywords: turbulence, ^{4}He, thermal counterflow, flow visualization

INVITED PAPER