PIV MEASUREMENTS OF HE II COUNTERFLOW AROUND A CYLINDER

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Introduction

The two-fluid model describes He II as if it consists of two interpenetrating fluid components, the viscous normal fluid and the inviscid superfluid. The normal fluid component contains the thermal excitations while the superfluid component carries no entropy. A heat current in He II is carried by the entropy containing normal fluid, which flows at a velocity given by the relation, $v_n = q/\rho sT$, with q being the applied heat flux, ρ being the total fluid density and s the specific entropy. A special case is that of the bulk fluid at rest with the normal fluid flow balanced with flow of the superfluid component such that the superfluid velocity v_s is counterflowing to the normal fluid. Here we report the first Particle Image Velocimetry (PIV) experiments that visualize thermal counterflow around a cylinder immersed in He II.

Experimental

In the PIV technique, one seeds the He II with micron sized particles and tracks their motion to obtain a full field map of the flow. In thermal counterflow, we have previously shown that the particle mainly tracks the normal fluid flow, but may also be affected by the turbulent superfluid component [1]. In our recent study [2], we placed a 6.35 mm OD transparent circular cylinder in a one dimensional rectangular channel, which is 200 mm long and 38.9×19.5 mm^2 in cross section. The channel is immersed in a constant temperature He II bath with the top end open to the bath while the lower end is closed by a thin film heater. The front wall has a 45×20 mm^2 optical window for imaging the particles with a CCD camera. The cylinder is located inside the channel spanning the full width and orthogonal to the flow.

Results and Discussion

Figure 1 contains an example of the observed counterflow field around the cylinder. These are representative data which actually fluctuate in time and are therefore only typical. They were acquired at 2.03 K and for a heat flux of 7.2 kW/m^2 directed upward, which corresponds to v_n = 23 mm/s. Clearly seen are turbulent structures both in front of and behind the cylinder. However, a more subtle effect is the tendency for the large vortices downstream of the cylinders to cling more closely to the channel walls than do those upstream of the cylinder. Although we have no theoretical explanation for these structures, it is speculated that the large vortices downstream of the cylinder are the result of some form of flow separation occurring in the turbulent superfluid component. However, since the normal fluid component interacts more strongly with the suspended particles [2], it is possible that the transverse velocity component of v_n as it flows around the cylinder could push these vortices toward the channel walls. Further work is required to confirm this suggestion.

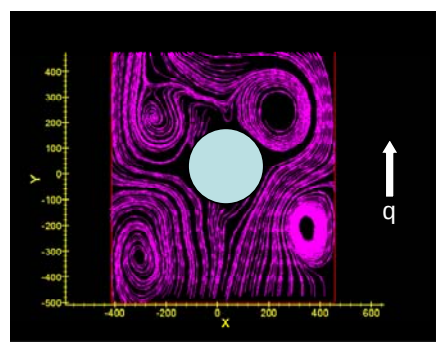

FIGURE 1. Turbulent structures generated by thermal counterflow around a 6.35 mm OD cylinder. T = 2.03 K and q = 7.2 kW/m^2 of channel cross section, which corresponds to normal fluid velocity of v_n = 23 mm/s.

References

[1] Zhang, T. and Van Sciver, S.W., J. Low Temp. Phys., **138**, 865-870 (2005).
[2] Zhang, T. and Van Sciver, S.W., Nature Physics, **1**, 36-38 (2005).