Density Effect of Solidified Hydrogen Isotope Particles on Particle Image Velocimetry

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Introduction

The Particle Image Velocimetry (PIV) technique was first applied to He II research on vertical thermal counterflow experiments a few years ago. The unique features of this visualization technique show great potential to unveil the fluid dynamics aspects of He II flows, which can not be thoroughly investigated by temperature and pressure measurements. The slip velocity between the tracer particles and He II caused by the density difference between them may distort the measured flow velocity information. In the present research, we compare this effect by using solid hydrogen isotopes particles as tracers in He II horizontal channel flows.

Experimental Setup

The experiment is contained in liquid helium flow visualization facility (LHFVF). The facility has a horizontal bore 5 meter long, and 0.2 m in diameter for experimental insert, which is shielded by two thermal shields cooled by LHe and LN2 natural circulation loops respectively. The facility is capable to create precise fluid motion with a maximum volume displacement of one liter. The experimental channel is constructed of stainless steel with a 20 mm X 20 mm square cross-section and 3.5 m length. The mean forced flow velocity up to 0.2 m/s are achieved. The particle seeding port is at 0.17 m upstream of the center visualization port. A frequency doubled pulsed Nd:YAG laser and a CCD camera are aligned with the visualization port for PIV measurement.

Three different seeding gas mixtures, H2/He D2/He and H2-D2/He, are tested in this configuration. The gases are mixed and inject into the superfluid helium phase directly by using a novel seeding system developed in previous research [1]. The optimum seeding control parameters are obtained by trial and error. The results indicate that in narrow space very small Hydrogen isotope concentration (less than 1%) is preferred. The steady state forced flow profiles are measured within a Reynolds number range from 5X10^4 to 3X10^5.

Results and Discussion

The slip velocity measurements show that the particle size follows a certain statistical distribution, which has a peak around 4.3 microns and with 90+% of the particles being smaller than 10 microns. The slip velocity also shows shift around 0.6 mm/s downwards caused by laser heating. The measured horizontal velocity profiles are reasonably agreed with each other for all three different density particles. The measured velocity profiles in vicinity of the wall show reasonable agreement with the classical turbulent flow boundary layer as discovered in previous research [2]. This result verifies that the slip velocity effect is negligible in this case for solid hydrogen and solid deuterium particles.

Conclusion

The micron-size solid H2, D2 and H2-D2 tracer particles have been successfully generated by solidifying helium diluted seeding gas in He II during the experiments. The steady state forced flow results confirm the fidelity of the micron-size solid H2 and D2 particles for tracking He II flow.

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References