§11. Boiling Process in Quench of Superconducting Coil under Low-temperature Liquid

Tsuji, Y., Eikoku, Y., Ishida, K., Kato, D. (Nagoya Univ.), Iwamoto, A., Hamaguchi, S.

Small temperature fluctuations in saturated super fluid He II (at 1.9K) was measured by using the small thermistors operated by a lock-in amplifier. The experiments were performed in a rectangular channel (13×13×200 mm) in which the heater was set at the bottom. We found that the periodic temperature oscillation and the pulsive boiling sound appear. They are synchronizing and the oscillating frequencies strongly depend on the helium pressure and the heat flux. When the He pressure decreases, the oscillation frequency decreases. However, the decay rate is independent of the heat flux.

In the glass dewar, the rectangular duct (cross section is $A = 1.69[cm^2]$, length is $L = 20[cm]$) made of GFRP is set. The liquid He temperature is set at 1.9K. The heater is located at the bottom, which generates the thermal counter flow. We measure the temperature inside the duct by small thermistors at three locations. From the temperature gradient, the heat flux carried by the normal fluid is calculated, which is compared to the heater supplied power $q[W/cm^2]$. Small temperature fluctuations are measured by thermistors. We can observe cyclic sounds inside the dewar, which may be generated by the bubble generation due to the boiling. The sounds are recorded by microphone positioned on the top of glass dewar.

Particle image velocimetry (PIV) is a potential tool to measure the local velocity and it promises us to give a deep understanding of complex super fluid motions [1]. PIV is a standard technique in classical fluid researches. But its application to super fluid has just started, and there remain several problems. The most difficult one is the development of proper imaging particles that can be spread in homogeneous over the liquid and track the flow field. Liquid helium is a very low density fluid with small viscosity, and it exists in low temperature. These conditions prevent the conventional particle spreading techniques developed so far in classical fluid. On the successful application of tracer particles, there have been two challenges of PIV measurement in super fluid turbulence. One is the use of commercial (d~1μm) polystyrene microspheres and the other is the condensationand dispersion of solid hydrogen particulates from the gas phase. In the present study, we tried the former approach. From the PIV measurement we found the relation: $v[mm/s] = 50.6 \cdot q[w/cm^2]$ which is consistent with the normal fluid velocity calculated by the heater power.

Increasing the heat flux, we observed the film boiling phenomena in He II[2]. Although this phenomenon was found in 1960's, little is known among this research community. In the boiling process, the pressure above lambda pressure (5kPa) is a decisive factor which boiling mode appears. Above the lambda pressure, the film boiling is related with the co-existence of three phases, that is He II, He I and helium vapor. Below the lambda pressure, the film boiling should be accompanied with only two phases; He II and helium vapor. The boiling curve for He II may be different from that of ordinary fluid, but the detailed things are not clarified. In He II boiling, the detached vapor bubbles cannot be seen due to extremely large effective thermal conductivity, and the nucleate boiling is only observed in a transition state at the beginning of film boiling.

In Fig1, we visualized the boiling process inside the rectangular duct. It is made of acrylic resin for visualization. Using the CCD camera, the cyclic oscillation was recorded. The vapor height was measured and it was compared with the temperature fluctuation obtained by small thermistor attached on the wall and sound pressure as plotted in Fig.2.

Changing the heat flux, we investigate the temperature fluctuations. The oscillating frequency is affected by the heat flux. It becomes large for larger heater power. But it is found that the oscillating frequency is more strongly affected by helium pressure. In the film boiling there appears also a cyclic sound. The sound is associated with the bubble in the boiling. We measured the sound by microphone set up at the test section. Comparing with the visualized picture with sound signal, we found that the sound is generated just after the boiling and vapor is generated.

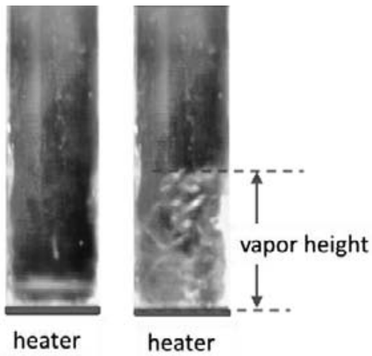

Figure1 Cyclic oscillation inside the rectangular duct in super fluid condition.

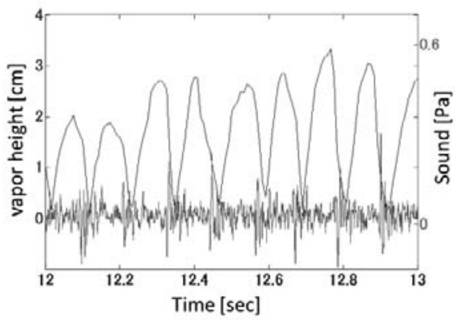

Figure 2 Vapor height and sound pressure in the cyclic oscillation.

[1] T.Xu and W.V.Sciver, PIV application in He II forced flow research, Teion Kogaku, vol.43,100-108, 2008
[2] S. Takada, Heat transfer mechanism of He II film boiling in a narrow channel, Ph.D thesis, Tsukuba Univ., 2009.