§ 29. Study on Heat Transfer of Pressurized Superfluid Helium in a Flow Channel Using a Visualization Method

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1. Introduction

In the second phase of LHD project, the cooling of pressurized superfluid helium (He IIp) in a helical coil has been planned. For such a purpose, study of the heat transfer of pressurized helium in cooling flow channels has been required to examine the stability of the helical coil. The present work is aimed at understanding the heat transfer and boiling phenomena of He IIp in cooling flow channels qualitatively by direct observation using a visualization method and quantitatively by measurement using a highly-sensitive high-resolution sensor. In the first year of the project, a test section, the combination of a transparent heater, temperature and pressure sensor was devised and experiments using it were carried out.

2. Experimental set-up

In Fig. 1, a block diagram of the experimental set-up used in this work is shown. In the experiment, a transparent heater (25 mm x 25 mm) was heated by amplifying rectangular voltage waves with a high-speed power amplifier. Also, to make the measurements synchronized with the start time of heating, a trigger signal from a wave generator was used as the measuring start signal for a high-speed video camera and digital oscilloscope. The action of a boiling film formed on the heater surface was observed by a high-speed video camera, and the data measured by the superconductivity temperature sensor and pressure sensor set over the heater were shown by a digital oscilloscope. The experiment was made at several pressures from the subcool region of 101 kPa to the saturated region of 5.04 kPa. The experiment temperature was 1.9 K.

3. Experimental results

Fig. 2 shows the experimental results for He II at atmospheric pressure (P = 101 kPa). Fig. 2(a) shows an overview of the boiling film formed on the surface of the transparent heater, which took a quadrangular pyramidal structure. Also, it was found that the top of the structure fluctuated. Fig. 2(b) shows the pressure and temperature waves at the boiling state. For He IIp at the atmospheric pressure, the oscillation of the temperature and pressure were not detected at a significant level. Also, during heating, it was found that a stable temperature region was formed on the heater surface. On the other hand, in an experiment with He IIp at a pressure of 5.04 kPa, oscillation of the pressure and temperature was detected, and the temperature of the heater surface was lower than that for the experiment at atmospheric pressure. The fact shows that the heat transfer in the saturated region is raised compared with that at atmospheric pressure. Also, the amplitude of the oscillation of the pressure and temperature was reciprocal to the pressure. Thus, we consider that the reason why the oscillations of the pressure and temperature were not detected at atmospheric pressure is that the S/N ratio of the output signal of the sensor was lower than that at the pressure of the saturated region.

4. Summary

The study of the heat transfer in He IIp was carried out using a visualization method and a pressurized superfluid helium cryostat with an optical window. Using this experimental apparatus, we found that the measurements for the action of the boiling film formed on the transparent heater and for their pressure and temperature are possible. In the next few years, we plan to improve the S/N ratio of the sensor signal and to obtain experimental data on the heat transfer of the heater surface in more detail. We expect that we can get a new insight on the effect of the flow behavior in the He IIp cooling channels to the heat transfer.

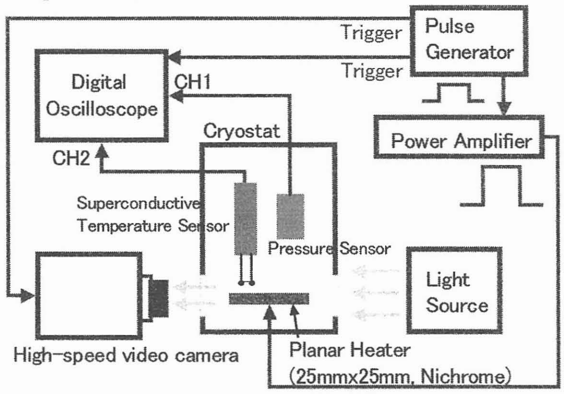

Fig. 1 Block diagram of the experimental set-up.

(a)

(b)

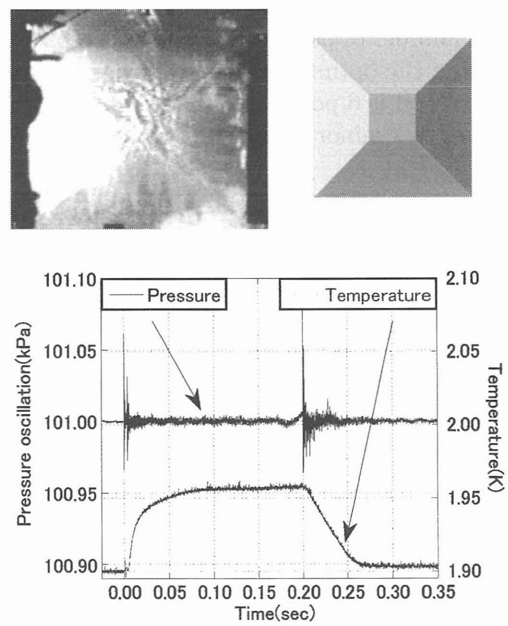

Fig. 2 Experimental results obtained from a test section at P= 101 kPa, T=1.9K, q=10 W/cm^2 and a heating time of 0.2s. (a) Left: a boiling film formed on the surface of the transparent heater, Right; a schematic illustlation of the film.(b) Pressure and temperature waves at the boiling.