§19. Boiling Heat Transfer in Forced Convection Flow of Liquid Nitrogen in Narrow Channels

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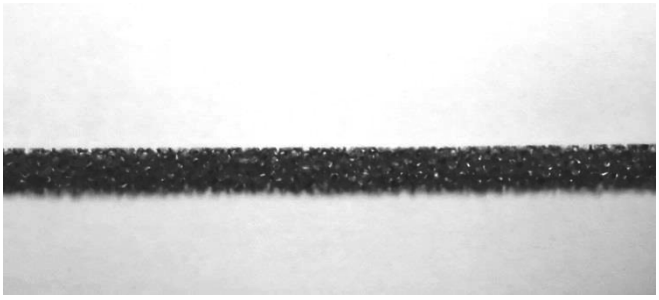

Fig.1 Picture of Nickel-Chrome foam

Introduction

Study of heat transfer in Liquid Nitrogen has been important issue for the application of cooling High Temperature Superconductor (HTS) devices. Specially, boiling heat transfer is one of the most interesting issue because of its rather large latent heat. For superconducting magnet, the large bubble may makes hot spots which induce quench. Thus the study of distribution and growth of bubble have been requested. The cooling channels are consisting of complicated many narrow channels. Thus the boiling heat transfer in forced flow in narrow channel were focused in this experimental study

Boiling in porous foam metal

For the understanding of heat exchanger with foam metal that has high porosity. The Nickel-Chrome foam shown in Fig.1 was used as a heater. And the boiling curve were measured by the four terminal method. Nickel-Chrome has a positive correlation between electric resistance and temperature in the temperature range of liquid nitrogen. Nickel-Chrome foam was cut by the electric discharge machining. The size of rod is 0.8 x 1.6 x 60 mm.

Figure 2 shows the boiling curve. In Fig.2, horizontal axis is resistance and vertical axis is heat flux which is calculated by the ratio between surface and volume of this foam metal 37000. When no boiling bubble generate, the resistance became large with heat flux. However, above the heat flux of nucleation onset, the resistance were getting slightly lower with increasing heat flux. Finally when heat flux reached critical heat flux, resistance turn to rise dramatically. Visualization were conducted simultaneously. The typical pictures of each mode were shown in Fig.3 (a)-(b).

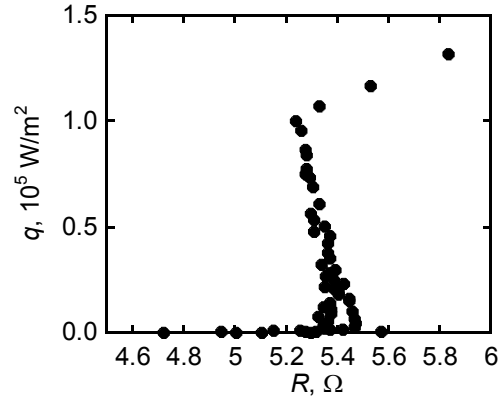

Fig.2 Boiling curve of metal foam of Nickel-Chrome alloy in saturated liquid nitrogen at atmospheric pressure condition

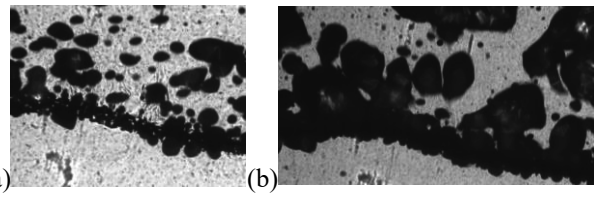

Fig3. Visualization result of boiling around foam metal in liquid nitrogen (a): nucleation boiling (b)film boiling

Heat transfer in forced flow at the exit of Cylindrical Annuli

The heat transfer in narrow channel between annular coaxial tubes were also investigated. The inlet pressure has simple correlation with velocity of liquid nitrogen. As shown in Fig.4, the transition between Churn flow and Atomization flow around 112 kPa of inlet pressure. When the transition occur, the averaged velocity of liquid nitrogen is about 1 m/s.

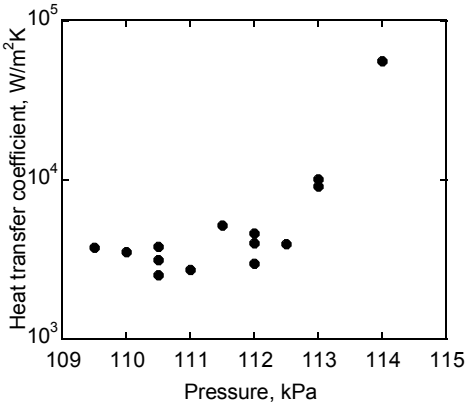

Fig.4 heat transfer coefficient against inlet pressure at the exit of Cylindrical Annuli at the fixed heat flux 5.28 W/cm^2