Film boiling heat transfer from a wire to upward flow of liquid hydrogen and liquid nitrogen

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ABSTRACT

In this study, the heat transfer coefficient of the Type 1 wire heater at P=0.4 MPa and liquid subcooling of 0 K was measured with the effect of liquid flow velocity from 0.9 to 7.23 m/s. The mass flow rate was measured by the weight change of the main tank. The mass flow rate was calculated by the weight change of the main tank and the pressure change of the sub-tanks.

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RESULTS AND DISCUSSION

Comparison of all the experimental data of liquid nitrogen with the new correlation.

Comparison of all the experimental data of liquid hydrogen with the new correlation.

Comparison with the Experimental Data

CONCLUSIONS

Film boiling heat transfer coefficients were measured for the two types of heater blocks with the same diameter of the heater wire and different heater lengths and gaps of the conduit. Experimental results led to the following conclusion:

➢ The heat transfer coefficients are higher for higher pressure, subcooling and higher flow velocity.
➢ The heat transfer coefficients for the Type 1 and Type 2 heater are for the same flow velocity are almost the same, though the length 1 and equivalent diameter D_e of the Type 2 heaters are about 1.7 times and 0.56 times as long as those of Type 1, respectively.
➢ We have assumed that the vapor film layer around the heater wire would be thinner by a very narrow gap. A new correlation was presented by extending the Shiotstu-Hama equation by introducing a new constant, to express the gap effect.
➢ The experimental data of liquid hydrogen and liquid nitrogen are expressed well by the new correlation.
➢ It can be expected that this correlation can express forced flow film boiling heat transfer of cryogenic and non-cryogenic liquids for a wide range in conduits.

EXPERIMENTAL APPARATUS

The mass flow rate is estimated by the weight change of the main tank, which is put on a scale. The mass flow rate is calculated by the weight change of the main tank and the pressure change of the sub-tanks.

Surface temperature T_w of the heater wire was calculated by solving the conduction equations in a radial direction of the heater using the measured average temperature and the heat flow.

Comparison of the film boiling heat transfer coefficients for Type 1 and those for Type 2 at P=0.4 MPa under saturated condition.

Comparison of the film boiling heat transfer coefficients for Type 1 with those for Type 2 at P=0.4 MPa under saturated condition.

The length L and the equivalent diameter D_e of the Type 2 heater are about 1.7 times and 0.56 times as long as those of Type 1, respectively.

The first heat generation rate was gradually increased for a low flow velocity (0.9 m/s). Boiling initiates at point A and AB is nucleate boiling regime. The mass flow rate was measured by the weight change of the main tank.

Film boiling heat transfer coefficient for the Type 2 heater at P=0.4 MPa and liquid subcooling of 0 K and 8 K with flow velocity as a parameter. The heat transfer coefficients are higher for higher pressure and liquid subcooling.