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国際宇宙ステーション沸騰・二相流実験で得られた透明伝熱管試験部における気泡挙動と壁面温度特性

Characteristics of flow behavior and wall temperature of the transparent heated tube section in microgravity flow boiling experiments onboard International Space Station

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Recently, heat generation density of electronic devices in space is increasing, so effective thermal management system for the future space activity is required. Flow boiling cooling system is highly-expected an efficient heat management system due to heat transport by latent heat, and efficiently removes heat compared to single-phase flow and a compact cooling system can be designed. However, effect of gravity on flow boiling heat transfer is still unclear, thus it is necessary to investigate the influence of gravity on flow boiling, and to know appropriate operating conditions and occurrence condition of critical heat flux for thermal management in space.

Two-series of Two-Phase Flow (TPF) experiment, TPF-1 and TPF-2 were conducted on "KIBO" in ISS by authors group during July 2017-March 2018, February 2019-July 2019, respectively. Purpose of TPF project [1)] is deeply understanding for gas-liquid behavior and heat transfer characteristics on flow boiling under various conditions (heat flux, flow rate and inlet condition) by taking advantage of the characteristic of obtaining a stable and long-duration microgravity environment. The TPF facility is constructed by some test sections. In this study, some experimental results obtained by the glass heated section which is one of the heated sections will be reported.

The glass heated section has three transparent heated tubes are arranged in series. There are Segment 1, 2 and 3 from upstream side, these tubes have heating length of 50 mm, 50 mm and 5 mm, respectively. The transparent heated tube is made of Pyrex glass which is coated with an extremely thin gold film on the inner-wall and has an inner diameter of 4 mm, outer diameter of 6 mm. The thin gold film is used as electric heater and measure inner-wall temperature as resistance temperature detector, in addition can observe gas-liquid behavior through the wall [2)]. The test section has three transparent heated tubes and 4 flanges. Segment 1 and Segment 2 have a completely same dimension and structure. Each heated tube is electrically insulated.

The heated tube has a gold thin film part and an electrode part consisting of a copper electrode plate and silver paste. Applying voltage to the electrode plate, a gold thin film is heating up and measure the overall resistance at the same time. The resistance value of the gold is proportional to inner-wall temperature, therefore inner-wall temperature is derived by using relation between temperature and resistance.

Single-phase heat transfer coefficients of laminar flow regime at Segment 2 and Segment 3 are shown in **Fig. 1**. Experimental conditions are mass velocity 30, 100, 300 kg/m^{2}s, heat flux 2~12 kW/m^2 and inlet subcooling 27~33 K. *Nu* number is calculated by using heat flux, inner-wall temperature, and fluid temperature. In this figure, heat transfer coefficient derived by Shah-London's equation [3)] with Pr = 11.5 which is average of experimental liquid temperature range. It was found that the trend of heat transfer coefficient for both segments. Though these experiments were conducted under

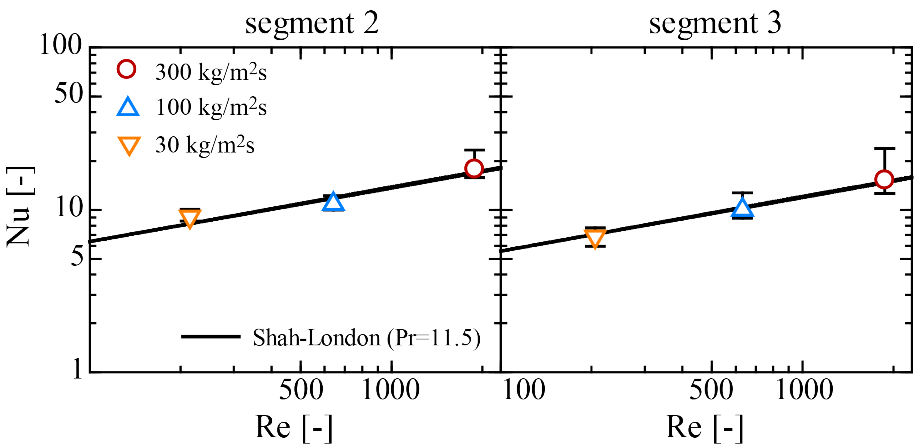

Fig. 1 Single-phase heat transfer characteristic at Segment 2 and Segment 3 under laminar conditions.

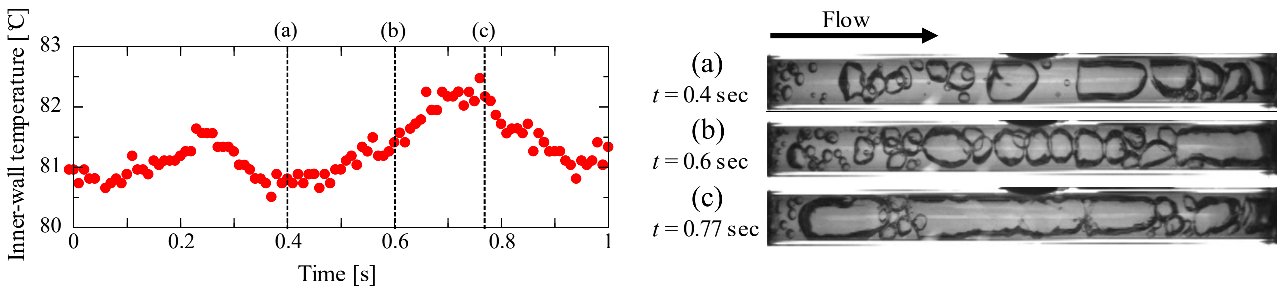

Fig. 2 Relation between flow pattern and inner-wall temperature under low mass flow rate at Segment 2 (Inlet temp. 50.3℃, heat flux 19.5 kW/m^2, mass flow rate 101 kg/m^{2}s).

microgravity condition, heat transfer coefficient even in extremely low mass velocity was indicated the same tendency with terrestrial environment.

The relationship between inner-wall temperature T_{iw} and gas-liquid behavior at Segment 2 was described in **Fig. 2**. The experimental conditions of this figures were as follow; mass velocity 101 kg/m^{2}s and heat flux 19.5 kW/m^2. As shown in **Fig. 2**, generated bubbles at low mass velocity were grown into elongated bubble along the tube axis (a) and were transferred to the mixing flow of continuous bubbles and elongated bubbles (b). Then, an elongated bubble covered the entire tube (c), the inner-wall temperature was taken a peak value. After that, an elongated bubble collapsed, and small bubbles were generated again.

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