Measurement of pool boiling CHF for SUS 304 & SA 508 flat plate under downward-facing and atmospheric conditions

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1. Introduction

Heat transfer performance of downward-facing conditions are important especially in severe accident mitigation strategy (IVR-ERVC & Core-catcher). Heat transfer limit, in other word, critical heat flux (CHF) is important value in this basis to guarantee the integrity of the system. For the application point of view in nuclear power plant, carbon steel surface should also be considered since reactor pressure vessel (RPV) in IVR-ERVC strategy consists of carbon steel, and core-catcher in EU-APR1400 is also composed of carbon steel [1-3]. In this perspective, carbon steel surface was used in previous studies [4-5]. In this study, CHF of both stainless steel and carbon steel material were measured under pool boiling condition with various inclination angles and dimensions.

2. Methods

Information for test sections and test vessel are described below. In addition, test conditions are introduced.

2.1 Test Sections

To account for both the length and width effects, two kinds of length (100 & 200 mm) and width (40 & 50 mm) were prepared, respectively. Width of the test section was based on the observation from SBLB test facility where characteristic size of bubbles were 30-40 mm. Thickness of the test sections were fixed to be 1.2 mm. High temperature silicon rubber was located on top of the test sections to insulate the system, and a layer of ceramic was located above it. Copper electrodes connecting the test sections and the copper electrodes coming from the lid were changed to make different inclination angles.

2.2 Test Vessel

Cylindrical vessel was designed to endure more than 15 bar condition with two view windows. Additional layer of stainless pipe surrounded the vessel for the following purposes: insulation during experiments and water path to cool down the system in short time during pressurized experiments. Pre-heater was located at the bottom part of the vessel, and power was supplied with DC rectifier with a maximum capacity of 45 kW (15 V, 3000 A). Two thermocouples located at the elevation of test section measured bulk temperature to keep the system saturated. An air cylinder was located next to the vessel to lift-up or –down the lid at the top. Condenser is installed to keep the system pressure especially during the pressurized conditions.

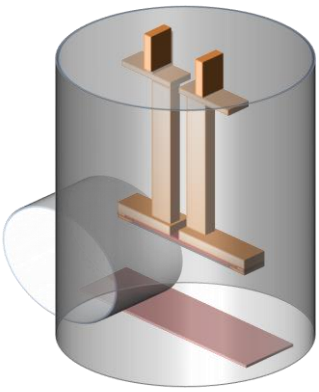

Fig. 1. Schematic of test vessel.

Fig. 2. Drawing of test section composed of test section, silicon rubber and ceramic.

2.3 Test Conditions

To account for the inclination angle effect, angle was changed from horizontally downward condition to vertical position in 15 degree unit. Two kinds of length (100 & 200 mm) and width (40 & 50 mm) were prepared, respectively, to assess the dimensional effect. Furthermore, SUS 304 & SA 508 material were prepared to account for the material effect, and for the practical purpose.

Power was supplied with a DC rectifier with a maximum capacity of 100 kW (25 V, 4000 A) up to CHF point, and CHF was calculated as power supplied divided by area where heat is transferred. In the calculation heat dissipated in the copper electrodes and joint parts were considered.

3. Results

3.1 SUS 304 results

There was a width effect as angle increases, but it disappeared as approached to horizontally downward condition. Besides, there was almost no length effect for both of the width since the size of coalesced bubble was far smaller than the length of short test section (100 mm).

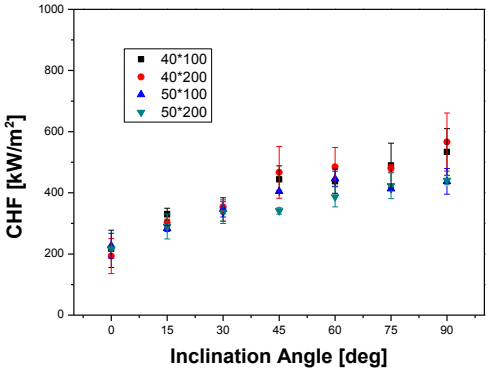

Fig. 3. CHF experimental results for SUS 304.

3.2 SUS 304 VS. SA 508

SA 508 showed enhanced results at high angles for 40 mm-width case even though no oxidation occurred on the surface during the experiments. However, there was no enhancement effect for 50 mm-width case. Wettability of both surfaces were marginal that other contributing factor should be considered.

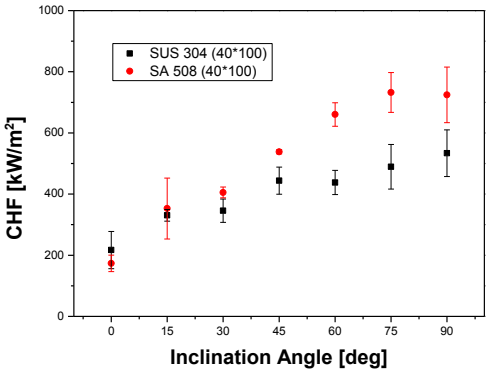

Fig. 4. Comparison between SUS 304 & SA 508 for 40 mm-width case.

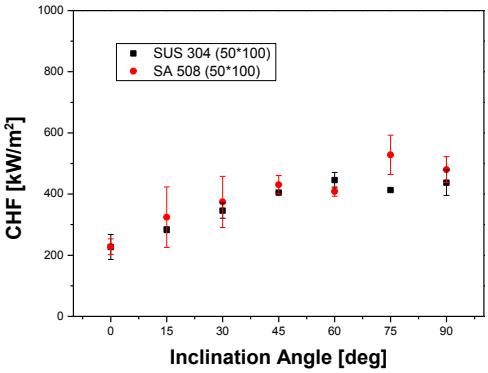

Fig. 5. Comparison between SUS 304 & SA 508 for 50 mm-width case.

REFERENCES

[1] M. Kim, J. Suh, and J. H. Lee, Development of Core Catcher for EU-APR1400, Proceeding of KSME, Vol.10, 2011.
[2] V. S. Granovsky, A. A., Sulatsky, V. B. Khabensky, M. B. Sulatskaya, V. V. Gusarov, V. I. Almyashev, A. A. Komlev, S. Bechta, Y. S. Kim, R. J. Park, H. Y. Kim, J. H. Song, Modeling of Melt Retention in EU-APR1400 Ex-Vessel Core Catcher, Proceedings of ICAPP'12, Chicago, USA, 2012.
[3] B. W. Rhee, S. W. Noh, K. S. Ha, R. J. Park, J. H. Song, A Scaling Study of the EU-APR1400 Core Catcher Cooling System Test Facility and Test Progress Status, Proceedings of ICAPP 2013, Jeju Island, Korea, 2013.
[4] T. G. Theofanous, S. Syri, The coolability limits of a reactor pressure vessel lower head, Nuclear Engineering and Design, Vol.169, 1997.
[5] H. M. Park, Y. H. Jeong, S. Heo, Effect of heater material and coolant additives on CHF for a downward facing curved surface, Nuclear Engineering and Design, Vol.279, 2014.