Evaluation of liquid film front behavior during rewetting process based on visualization experiment

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The precursory cooling (PC) and heat transfer coefficient (HTC) during rewetting phenomena was experimentally investigated by a using single pin water-air test section.

Keywords: Precursory cooling, Rewetting

1. Introduction A rewetting phenomenon by liquid film propagation is one of key factors to evaluate peak cladding temperature and dryout duration after the occurrence of the post-boiling transition. The Atomic Energy Society of Japan (AESJ) standard (2003) proposed the empirical correlation to predict the rewetting velocity in the anticipated operational occurrence (AOO) conditions, which was recently applied to the evaluation of fuel rod surface temperature during an anticipated transient without scram (ATWS) for the safety review on the Japanese new regulation. These conditions are characterized by high heat flux and high mass flux. Previous study by the authors [1] have revealed that the rewet velocity is enhanced by heat transfer in the dryout area immediately ahead of liquid film front. The well heat transfer in this area is defined as PC in the present study. The mechanism of the PC is still not clarified because of insufficient related studies. In this view point, this study visually investigates liquid film front behavior on a single heater pin surface with air-water flow at atmospheric pressure. Results showed oscillatory formation of dry patches in the liquid film in the vicinity of the rewetting front. This oscillation continued until the heated rod was completely cooled.

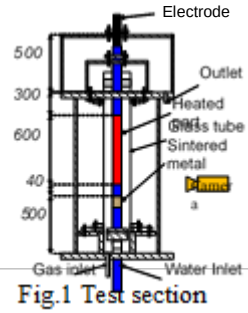

Fig.1 Test section

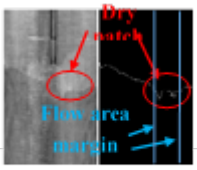

Fig.2 Edge detection of liquid

2. Experimental Figure 1 shows the PC test section with a heated rod with diameter of 11.2 mm and the heated length of 600 mm. The sintered metal was used to supply water into the test section as a liquid film. To detect the surface temperature, 12 thermo-couple with diameter of 0.5 mm were embedded on the rod surface. The Photron high speed camera was used for visualization. The experiments were performed with the wall temperature ranged from 300 to 600°C, water flow rate from 0.09 to 0.15 l/min, air flow rate from 30 to 70 m^3/h and the pressure of 0.1 MPa.

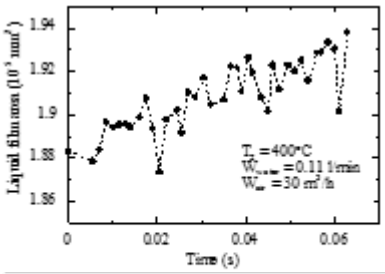

Fig.3 Liquid film area change during rewetting process

3. Results Figure 2 shows the captured pictures and detected edge of the liquid film during rewetting with a width of 7.1 mm which is nearly one-fifth of the heater rod perimeter. The detected edges showed the oscillatory rewetting front propagation including temporary dried patch formations below the front edge of the liquid film. In order to show quantitatively the oscillatory behavior, the liquid film area was evaluated for a region shown in the front view in Fig.2. The dry patches may appear at random in various places near the liquid film front. Therefore, the elevation was performed by dividing the analyzed area into several sub-regions with 1.2 mm width and 28.5 mm length. Figure 3 shows the result of image processing obtained in this way. The liquid film area was increase such that the liquid film flowed upwardly to rewet the dried surface temporarily, then decrease due to the quickly evaporation of liquid front and the appearance of dry patches. The formation process of the dry patch is shown in Fig. 4. Moreover, the oscillatory formation of partial dried area affected the evaluated liquid film area. This oscillatory formation repeated typically in 5 msec until the heated surface temperature finally decreases sufficiently.

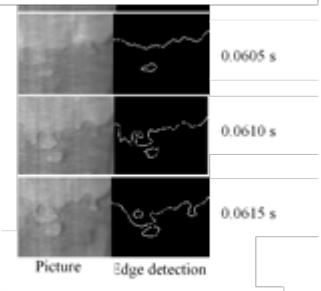

Fig.4 The formation of dry patch

4. Conclusion The mechanism of PC was visually investigated from the images of liquid film front, which has shown the oscillatory rewetting front propagation. This oscillation occurred until of the heated rod was cooled sufficiently.

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References

[1] A.Satou, *et al.*, *Experimental Investigation of Post-BT Heat Transfer and Rewetting Phenomena*. ANS Best Estimate Plus Uncertainty International Conference (BEPU 2018). Italy, May 13-19, 2018 (BEPU2018-270)