Experimental analysis of clad rewetting in downward water/air flow

* Marco Pellegrini[1], Yutaro Umehara[2], Keisuke Yamagata[2], T. Okawa[2], M. Naitoh[1]
([1] エネルギー総合工学研究所, [2] 電気通信大学)

In operation of BWRs, AOO can result in clad film dry-out. The current regulations in Japan imposes such limits so that film dry-out should never occur. However, it has been shown that this condition, might not lead to high fuel temperature harming the plant safety. In order to control the temperature nevertheless the time and method of clad rewetting need to be modelled correctly. The correct evaluation of clad rewetting is complicated because the heat transfer across the rewetting front is difficult to be measured. The heat transfer is influenced by sputtering of the front crating a precursory cooling effect which affects the heat transfer shape. Even though recently investigated by several authors the dynamics of the precursory cooling are still not clear. In this experiment water is introduced from the top of the facility creating a film on the cladding moving downwards. Air is injected also from the top in a concurrent way. Such facility allows to perform experiments with and without air with the objective to evaluate the effect of the airflow on the sputtering and cooling effect. This set-up presents remarkable advantages compared to a more typical upward flow design.

Keyword：rewetting front velocity, precursory cooling, water/air flow

1. Introduction

The current BWRs regulations in Japan imposes that cladding film dry-out should never occur, however it has been shown that such condition might not lead to large fuel temperature in clad rewetting occurs within a reasonable time. The rewetting process is characterized by the rewetting front velocity which is influenced by various factors, such as the temperature of the clad, gas velocity and water flow rate. The rewetting front velocity itself can be described by the heat transfer on the rod which is generally divided into two regions: wet and dry. The dry region is typically the most controversial and it has been studied by various authors with different outcomes. At the wet front small droplets are generated (sputtering phenomenon) which are then transported by the steam flow and gravity and can impact the rod underneath the wet front or the neighboring ones. This study aims at explaining how the sputtering is generated and what the major influencing factors are.

2. Results

The facility for the study is presented in Figure 1 a). The pump takes water from the tank and delivers to the rod from the top. A compressors (not shown in the picture) moves air through a pipe connected to the top of the rod that is delivered around the film of water. The rod can be enclosed in a glass pipe to allow large velocities of air during the experiments. The first clarification that this experiment presented regards the sputtering generation without air injection during an experiment with clad temperature equal to 134 ºC, water injection but no air flow. As presented in Figure 1 b) and c) it was found out that sputtering is generated also without air injection due to the sudden evaporation of water at the cladding that generates droplets at the wet front. At the beginning (Figure 1 b) no film exists on the clad and various bubbles are generated with different dimension and trajectory. Some of these particles depart from the rod but others slide along the clad. The particles might be responsible for the precursory effect. Later (Figure 1 b) the film is generated in the top part and the sputtering regions is moved downwards.

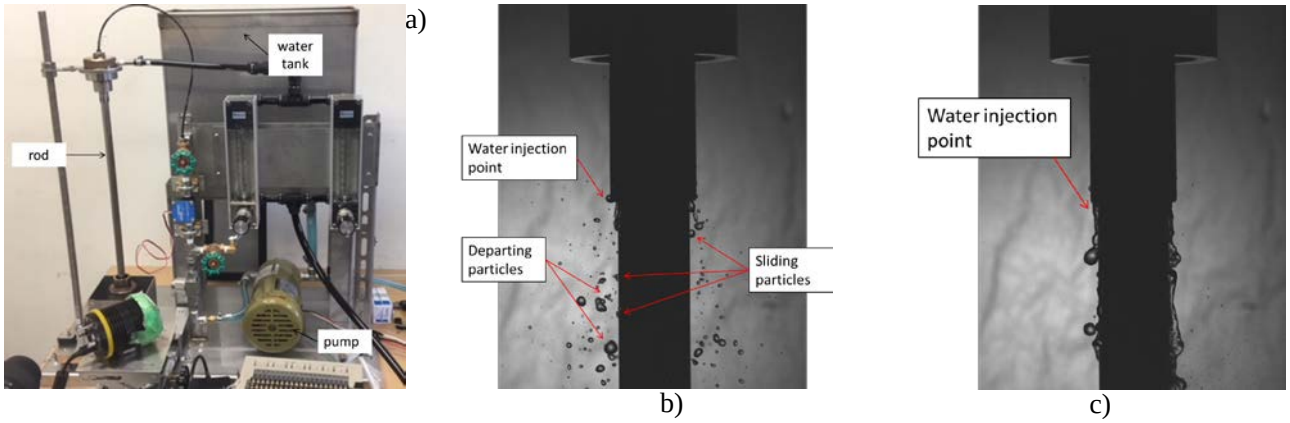

Figure 1 a) rewetting facility, b) beginning of rewetting, c) film created on the surface.

3. Conclusion

The preliminary study has presented that sputtering can be generated also without air flow. Sputtering generates droplets with various size and trajectories. Some of them slide along the surface influencing the heat transfer and resulting in the so called precursory effect. How the particle generation can affect the heat transfer and how the water flow rate and rod temperature influence the droplet generation is still not clear and will be investigated in future experiments. Also the differences that the air flow introduces will be the subject of future studies.