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Enhanced CHF with Bubble Cutter and Artificial Flow in Nuclear Plants

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1. Introduction

Enhanced critical heat flux (CHF) is one of our prospective aims for nuclear power plants (NPPs). Previous work [1, 2] has studied the flow boiling CHF enhancement with surfactant solutions under atmospheric pressure because surfactant solutions or surface conditions have an effect on the behavior of occurrence air bubbles on a heated surface.

Another possible improvement is to improve efficiency of heat transfer or to body out some types of bubble breaking (and/or pushing, breaking) systems or an artificial flow of fluid that can tear off air bubbles or push hot liquid and bubbles on a surface of heater. During this study, it will be observed that those possible structures can elicit increased CHF by means of maintenance of contact with a coolant such as water. The main goal of this paper is to body out the notions of forced convection system for enhanced local streams and air bubbles cutting (and/or pushing, breaking) system to explain how CHF can be improved and how those bubble cutter systems are applicable to NPPs.

In this paper, the bubble cutter system and an artificial flow system which can cut (and/or push and break) air bubbles is bodied out to drag bubbles. It also make the surface wet condition of heated surfaces and improve heat transfer and prevent on creation of bubbles on the heated surfaces or heat exchangers or reactor cores. Namely, concepts and application methods to increase CHF are presented for NPPs.

2. Systems Design

The various types of an air bubble cutter system can be designed to push or to pull bubbles on heated surfaces that represents as heat source in heat exchangers or reactors core for NPPs.

2.1 System Description

Relying on many theories on the bubble dynamics and heat transfer, many works have explained how air bubbles break loose from its attachment to a heated surface. Figure 1 shows growth and departure of two bubbles for a wall superheat of 10°C, which the original drawing is taken from the reference [3]. The figure 1 shows the experimental method and the numerical method are basically the same thing with few differences. Especially, motion of cool liquid in figure 2 in (a) case is worthy of notice. Air bubble cutter system is a structure such as rotating cutters (or movable cutters) or an artificial flow of fluid from the system which can accelerate the motion of cool liquid or departure of air bubbles for enhanced local streams near a targeted heated surface.

Red triangle section in (a) case of figure 2 means a structure such as the bubble cutter or an artificial flow of fluid. If a structure of a bubble cutter rotates a heated surface in order to cut (and/or bush, break) bubbles, there can be two types of cutter mounting, which is seen in figure 3.

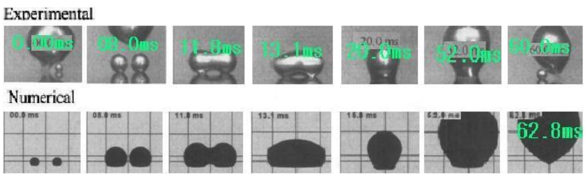

Fig. 1. Growth and departure of bubbles [3]

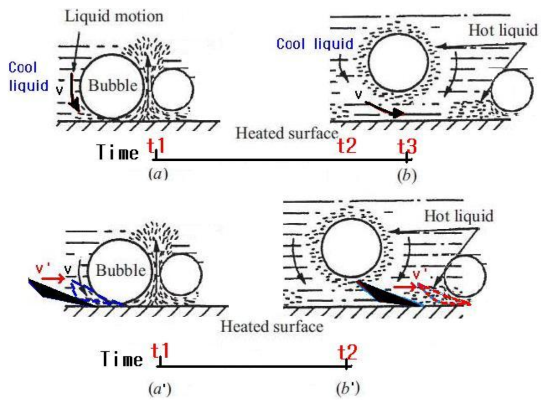

Fig. 2. A basic concept of proposed bubble cutter systems

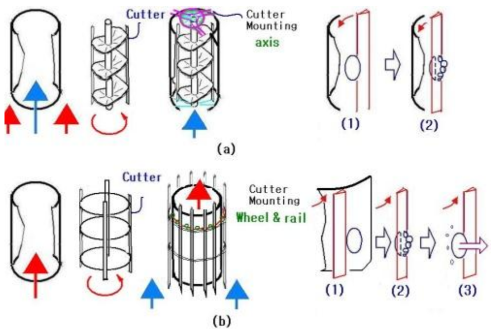

Fig. 3. Sample types of cutter mounting

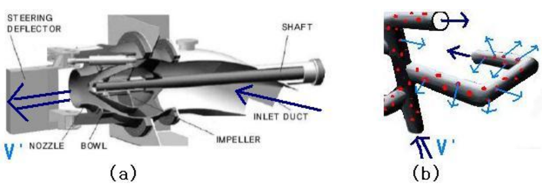

Fig. 4. Two sample sources of an artificial flow of fluid

Naturally, the bubble cutter can be designed for reciprocation motion which is the way that looks like windshield wipers.

Secondly, an artificial flow of fluid toward a heated surface can be produced from many kinds of sources such as an impeller and a cool liquid induction pipe which are seen in figure 4. In (b) case of figure 4, cool liquids from outlets of the induction push hot liquid by the action of artificial flow of fluid. Effective outlet velocity and flow rates and energy difference between hot liquid and the cooling liquid will be only as strong as its enhanced CHF.

2.2 Enhanced Critical Heat Flux in PWRs and LWRs

In NPPs, especially in a PWR, the primary coolant (water) is pumped under high pressure to the reactor core where it is heated by the energy generated by the fission of atoms. The heated water then flows to a steam generator where it transfers its thermal energy to a secondary system where steam is generated and flows to turbines which, in turn, spin an electric generator. In contrast to a boiling water reactor, pressure in the primary coolant loop prevents the water from boiling within the reactor. A U-shaped heat exchanger is used to transfer the thermal energy to a secondary system as shown in figure 5. In reference, all LWRs use ordinary water as both coolant and neutron moderator.

A bubble cutter system may be not embodied easily due to an intricate piece of machinery of reactor core in PWR and all LWRs. But an artificial flow of water can be produced by the bubble cutter system which has an impeller for watering toward a heated surface of the reactor core. Of course, all heated water by each nuclear fuel rod of the reactor core will not be affected by an artificial flow of fluid in every part of reactor in this way.

In the case of a heat exchanger system as shown in figure 5, some bubbles are not seriously affected by produced swirls while some bubbles flow under the influence of an artificial flow of water. If all bubbles are needed to affected by a bubble cutter (and/or an artificial flow), each pipe needs to be surrounded by bubble cutters that was connected by a rotor as shown in (b) case of figure 3. In such a case, the bubble cutter system cannot be applied for curved parts of the pipes of the heat exchanger. But, many induction pipes which are inserted between the pipes can be with luck on its side, a cool liquid induction pipe type artificial flow can be produced from the engineered fluid flow design.

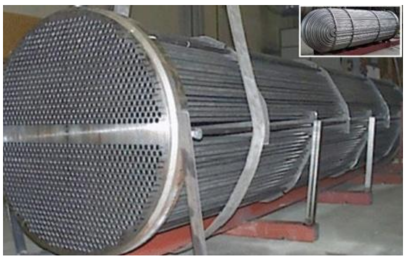

Fig. 5. A sample type of U shaped heat exchanger in PWRs

3. Results and discussion

The motion of cool liquid in (a) case of figure 2 is worthy of notice. Air bubble cutter system is a structure such as rotating cutters or an artificial flow of fluid which can accelerate the motion of cool liquid or departure of air bubbles. The engineered fluid flow design may apply to extreme case of any kind of fluid resistance from a complicated shape.

In the case of rotating bubble cutter system, volume of cool liquid or the speed of departure of air bubbles is in proportion to speed of revolution of bubble cutters. But its system cannot be adapted to intricate structures such as a reactor core in some cases.

On the other hand, in the case of an artificial flow of fluid system, volume of cool liquid or the speed of departure of air is in proportion to speed and flux and thermal energy difference between the supply water and the hot liquid form the system. While its system can be adapted to intricate structures such as a reactor core or a U type heat exchanger, the affection of the artificial flow of fluid to heated surfaces is not uniform. So, if the system needs to be adapted to an intricate piece of machinery of a reactor core or a heat exchanger, computational fluid dynamic analysis may be needed to analyze its effect well.

To investigate its meaning of a bubble cutter system with NPPs, we proposed a basic meaning of bubble cutter. And then we explained artificial flow of water from the bubble cutter system. Ultimately, the system is bodied out for NPPs.

In all cases, the problem of frictional wear needs to be discussed later. For example, when the bubble cutter grazes along a surface in order to keep in contact with a heated surface, it is worth considering to prevent abrasion on the heated surface.

Acknowledgments

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