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Investigation on Hydrodynamic Cavitation of a Restriction Orifice and Static Mixer on Crud-like Deposits

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1. Introduction

Axial Offset Anomaly (AOA) referring to an unexpected neutron flux depression is also known as Crud Induced Power Shift (CIPS). Fuel assemblies removed from an AOA core have shown a thick porous deposition layer of crud on fuel clad surface [1]. The deposition layer was induced by precipitation reactions of both boron species and crud during sub-cooled nucleate boiling. Therefore, to resolve the AOA issues, a fuel cleaning technology using ultrasonic cavitation has been developed by EPRI and applied to the domestic NPPs by KNF. However, the performance of crud removal during maintenance of NPPs is known to be not enough.

Hydrodynamic cavitation is the process of vaporization, bubble generation and bubble implosion which occurs in a flowing liquid as a result of decrease and subsequent increase in pressure. Hydrodynamic cavitation generates shock pressure of a few tens MPa due to bubble collapse like the cavitation generated by Ultrasonics [2]. It is well known that the cavitation can erode the metal surface.

The idea of the current study is that such energetic cavitation bubble collapses could help to remove the crud from the fuel assembly. Therefore, the current study first investigates effects of hydrodynamic cavitation occurred from a single hole orifice and static mixer fundamentally.

2. Experiment

2.1 Experimental facility

Experiments are carried out using 2 inch looped water piping system. Test section is 50 mm in inside diameter and is made of the transparent acrylic pipe to observe the effects of the cavitation flow. The water which is pumped up by a centrifugal pump (35 m^3/h x 1.1 MPa), flows through the 2 inch piping, goes to the test section via a flow meter, and returns into a reservoir tank.

The type of experiment was tested to compare flow condition when conducted in static mixer and orifice combination for investigating erosion efficiency and cavitation diameter. The mixing in test section is achieved by the combination of static mixer and orifice, allowing cavitation to be achieved under swirl flow conditions with the net flow.

2.2 Experimental Methods and Conditions

The shock pressure is produced by the collapse of bubbles in downstream of a single-hole orifice with 17 mm diameter used to restrict the flow or generate cavitation bubbles. Therefore, the spatial distribution of cavitation shock pressure inside the pipe at the downstream of the restriction orifice is examined through observing the bubbles using a high speed camera and the crud-like sample holders are installed inside the pipe at 1D and 2.5D distances from the orifice in order to investigate the cleaning effects by collapse of bubbles. (D: pipe inside diameter). The process is executed at room temperature.

2.3 Preparation of Test Specimens with Deposits

Crud consists primarily of magnetite, nickel ferrite, cobalt ferrite, and so on [1]. For only checking the cavitation effects in this work, however, specimens made of SS 316L, alloy of Cr, Ni and Fe are simply deposited by silicon carbide nanoparticles. It shows a crud-like deposition structure.

We were dispersed the SiC nanoparticles in the water and using quenching method, SiC nanoparticles were attached to the surface of the sample. Thereafter, the SiC coated samples were heated in the furnace in order to be attached SiC nanoparticles more well. Complex oxide generated in the process, is judged as having a porous structure similar to crud. The experiment was done using these specimens.

Fig.1 shows that a three-layer configuration of a particle deposition, consisting of SS 316 sheet, oxide, SiC, has made up SiC nanofulid in order to make the similar crud specimen.

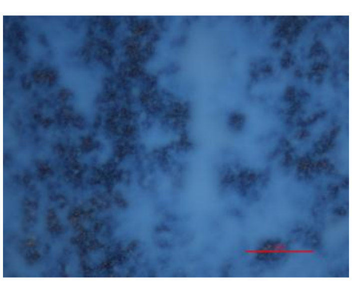

Fig. 1. Optical image of SiC-coated sample.

3. Results and Discussion

Most of the cavitation clouds appeared in 1D and 2.5D position, so specimens of our experiment were installed in inside of the pipe at 1D and 2.5D distances from the orifice in order to investigate the cleaning effects by collapse of bubbles.

We investigate the bubble flow condition and bubble diameter image. Fig. 2 shows a generated cavitation in the test section by orifice.

Length of cavitation was increased due to the flow toward the center by the combination of an orifice and static mixer. Static mixer doesn't make high pressure drop. It makes just different flow tendency.

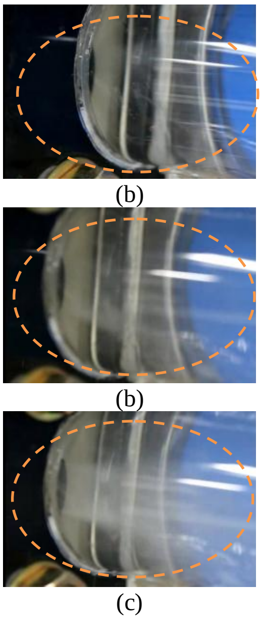

Fig. 2. The cavitation occurrence according to the flow rate: (a) 150 LPM, (b) 170 LPM and (c) 190 LPM.

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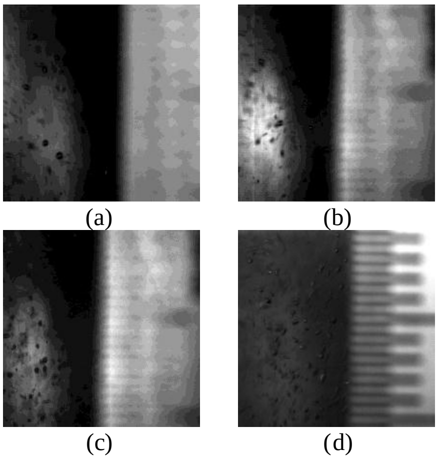

Fig. 3. Image of cavitation flow: (a) 130 LPM, (b) 150 LPM, (c) 170 LPM, (d) 190 LPM.

We investigate the cavitation flow for characterizing the bubble size and flow behavior. To record cavitation images, we used a high speed camera as shown in fig. 3. High speed images are recorded at 4600 frames/s. The results of the experiment for occurrence of cavitation due to the restriction orifice show that the cavitation size can be different by condition as shown in fig. 4 and table I.

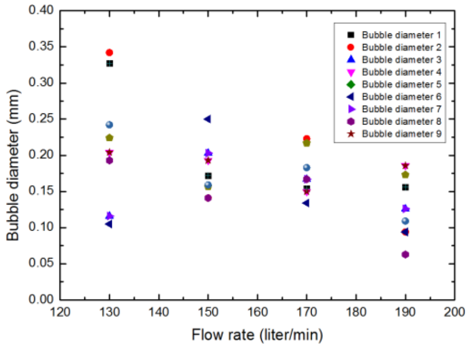

Fig. 4. Distribution of bubble diameter at each flow rate.

Table I: Bubble size distribution in an each flow rate

Flow rate (LPM)	Differential pressure (bar)	Bubble diameter (mm)
130	1.37	0.219
150	1.61	0.177
170	2.22	0.174
190	2.87	0.125

4. Conclusions

The cavitation size is dependent on the flow rate and differential pressure. The generation of cavitation is a versatile and extremely complex physicochemical process. Many variables influence the cavitation generation that it will be long before every one of them can be investigated and its influence on the process determined. And we will quantify the cavitation characteristic between cavitation number and intensity of cavitation.

Further study will be carried out to more thoroughly quantify the effects of the crud removal performance. To characterize do this, above all cavitation number is required to distinguish the characteristic induced by cavitation from those arising from pressure drop.

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