D420 Sound Generated by Bubbly Flow Passing Through an Orifice

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Abstract. The sound generated by the bubbly flow passing through an orifice of a pipe was investigated experimentally. The sound pressure level was measured for the bubbly flow with different void ratios. The sound was found to be sensitive to the water flow rate rather than void ratio. However, if the water does not contain bubbles, no sound is generated. The sound generated near the orifice in the bubbly flow was explained by the breakup mechanism of a single bubble through the orifice.

Key Words : Sound , Noise, Bubbly Flow, Orifice, Pipe

1. Introduction

There are many examples related to bubbly flow phenomena undergoing pressure change: flows in valves, orifices, etc. Cavitation will occur in each component of pipe if the pressure decrease until the vapor pressure. The noises and unusual vibration from the components are related to the bubble formation and breaking up under the steep pressure change. In practical situation, a water flow frequently contains bubbles. The pressure change in the components induces vibration and deformation of the bubbles. The noises and vibration from the components may arise because of such bubbles even if the pressure never be reduced to the vapor pressure.

Bubble dynamics under several conditions have been studied. Ivany et al. (1966) reported that cavitating bubbles collapsed in a venturi. Wang and Brennen (1998) studied bubbly cavitating flow through a converging-diverging nozzle by a numerical simulation. Mitchell and Hammitt (1973) showed the mechanism of the bubble breakup subject to the pressure gradient and slip velocity. However, there is little information available in the literature deal with the sound generated by the bubbly flow passing through an orifice.

The purpose of this study was to investigate the sound generated by bubbly flow passing through an orifice in a vertical upward pipe. The results of this study may lead to better understanding of the characteristics of the bubbly flow through the orifice as a typical component of a pipe.

2. Experimental Setup

An original experimental setup was designed. A schematic figure of the setup is shown in fig. 1. The test section was made of an acrylic pipe with 51 mm inner diameter and 300 mm length. An orifice with the sharp edge has $\beta = 0.3137$, where β is the ratio of orifice's diameter to pipe's diameter. The orifice was set at the middle of the test section. The test section is positioned at a distance $25d$ from a mixer, where d is inner diameter of a pipe. This distance is enough to neglect the effect of mixing methods on the structure of the bubbly flow (Herringe and Davis, 1976).

The water flows into the mixer, in which air is injected through 5 nozzles with 1 mm inner diameter. The water mixed air flows upward as a bubbly flow with some void ratio related to the injected air flow rate. The air-supply system consists of a compressor, a pressure regulator and an air flow meter.

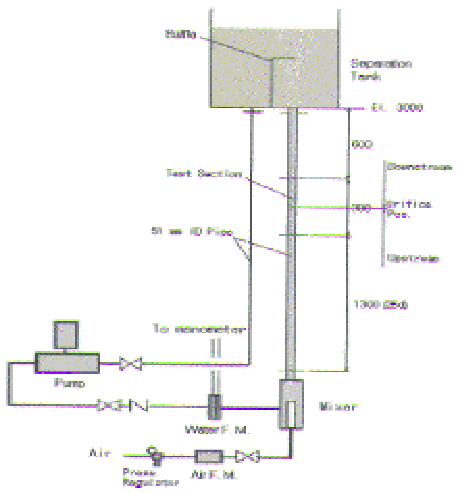


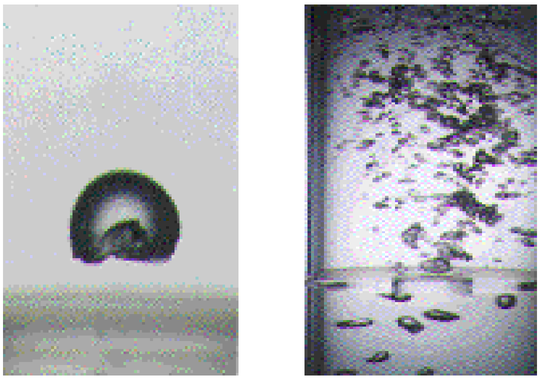
Fig.1. Schematic figure of the experimental setup.

The sound generated by a single bubble and the bubbly flow were measured under the many combinations of water and air flow rates. The examined flow-rate ranges were 10 - 70 l/min of water and 0 - 2 l/min of air.

A precision sound meter was used to measure the generated sound out of the test section. The output signal from the sound meter was recorded by a digital recorder. This measurements provide us the sound pressure level (SPL) of the generated sound.

3. Results

The steep pressure change across the orifice make bubbles break up. Thus, noise is generated near the orifice. All the bubbles broke up after passing through the orifice in every combinations of the water and air flow rates. The single bubble passing through the orifice was found to break up as following the sequence. (1) The upstream side of the bubble was flattened at first near the entrance of the orifice, (2) a micro jet grew from the bottom of the bubble just after passing through the orifice as seen in fig.2 a, (3) the micro jet hit the downstream side of the bubble, and then (4) the bubble broke up into fine bubbles. The sound was generated during the process. The bubble breakup mechanisms of bubbly flow were more complicated than that of the single bubble. The interactions of each bubble may play important role.



(a) (b)

Fig. 2. Breakup mechanism of the bubble. (a) a single bubble, (b) bubbly flow.

Figure 3 shows the relation between SPL of a single bubble and the water flow rate. The bubble supplied by a nozzle positioned near the orifice at 0.15 Mpa of reservoir-pressure. The diameter of the bubble is about 2-3 mm. This indicates that the SPL increases with increasing the water flow rate.

Figure 4 shows the SPL of the bubbly flow against the air flow rate. If the water does not contain bubbles, no sound is generated.

Introducing small fraction of air in water flow caused significant increase in noise. For example, when 0.1 l/min of air was added to 10 l/min water flow, the SPL increased from 45.5 dB to 53 dB (16.48 % increase). In the higher water flow rate, the influence became bigger. For example, at water flow rate 37 l/min, introduction of 0.1 l/min of air made the SPL increase from 46.5 dB to 68.5 dB (47.31 % increase). This graph also indicates that the water flow rate strongly affects the noise level, while the air flow rate did not effect the noise level so much.

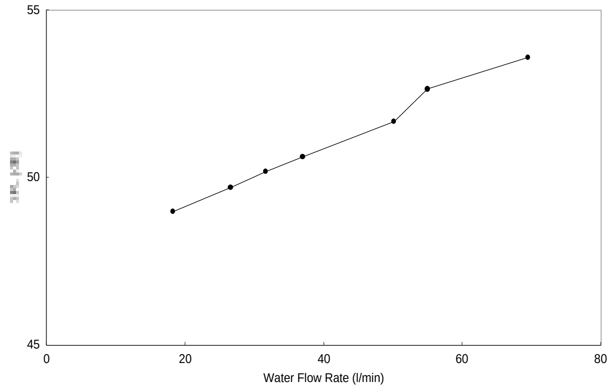


Fig. 3. SPL generated by breakup of a single bubble as a function of water flow rate.

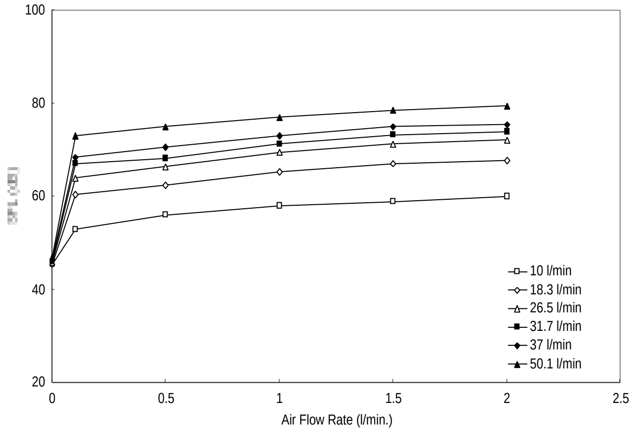


Fig. 4. SPL vs. air flow rate for bubbly flow.

4. Conclusion

The sound generated by bubbly flow passing through an orifice have been studied. The results show that the generated sound is strongly affected by water flow rate.

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