Experimental Study on Acoustic Attenuation of Bubble Wake

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Abstract. When ship sails on the water surface, it will form a wake containing a large number of bubbles for different scales. The existence of bubbles will cause the attenuation of sound waves. In this paper, bubbles with different sizes are generated in the pool by using ceramic tube array. An experimental study on the acoustic attenuation characteristics of sound waves in bubbles was carried out for still water, small bubbles, medium-sized bubbles and large bubbles. Through experimental research, it is found that the existence of bubbles makes the acoustic signal decay obviously. At different frequencies, bubbles decay more than 10dB relative to still water. Large bubbles have the strongest attenuation effect on acoustic signals, averaging over 20dB. The medium and small bubbles are similar to the attenuation of the acoustic signal. The acoustic signal intensity in static water and different scale bubbles is basically the same as the frequency.

1. Introduction

When ship sails on the water surface, it will form a wake containing a large number of bubbles. The particle size and number density of bubbles in the wake of a ship on the water surface are related to the ship’s sailing speed, draft, ship type, etc., and are not certain. The existence of bubbles changes the physical properties of the water body, from the original single-phase water medium to the two-phase medium in which water and bubbles coexist. The existence of bubbles changes the sound velocity in the wake. When the sound wave propagates in the two-phase medium mixed with bubbles and seawater, the sound attenuation will change. In order to study the sound attenuation characteristics under different bubble conditions, a bubble experiment measuring device is established through a pool simulation experiment. The influence of bubbles on the sound velocity and sound attenuation is studied through a pool experiment. This paper mainly introduces the pool test of acoustic signal attenuation and analyzes the acoustic attenuation characteristics in the bubble.

2. Experimental introduction

The laboratory uses ceramic tubes to generate bubbles. It simulates bubbles with different particle sizes and number densities. The pore diameter of ceramic tubes is 0.1μm and the length of the ceramic tubes is 40cm.

The ceramic tube array used in the experiment is shown in figure 1. Figure 2 shows the gas distribution device used in the experiment. The high frequency transducer is used for transmission and hydrophone is used for reception.
The bubble wake sound attenuation characteristic experiment is carried out in the anechoic pool. The size of the pool for length width and depth is 6m*3m*4m. Firstly, the experiment of bubble generation by ceramic tubes was carried out. The air compressor inflated different ceramic tubes through the gas distribution pipe. The air compressor could only provide air with a fixed pressure. The valve on the gas distribution device controlled the amount of air intake, thus controlling the size of bubbles. Nine ceramic tubes were connected in parallel to generate bubbles. In the experiment, the transducer is used to transmit signals of different frequencies before bubbles are generated. The hydrophone receives the signals. The depth of the transducer and the hydrophone in the pool is 1.3m. The distance between transducer and hydrophone is about 3.7m. The transmission signal has two types for chirp signals and single frequency signals. And the frequency of the transmission signal is 20-200kHz.

The experiment was carried out in four groups. The first group is a reference signal and does not generate bubbles. It measures the sound attenuation of still water. The second group generates small bubbles and it measures the sound attenuation of small bubbles at different frequencies. The third group generates medium-sized bubbles and it measures the sound attenuation of medium-sized bubbles at different frequencies. The fourth group generates large bubbles and measures the sound attenuation of large bubbles at different frequencies.

In the experiment, large bubbles simulate the initial stage of the wake. Medium bubbles simulate the bubble distribution in the middle stage of the wake. And small bubbles simulate the bubbles over a relatively long distance in the wake.

3. Analysis of experimental data
The transducer emits frequency modulated signals with frequencies of 20-40kHz, 40-80kHz and 100-200kHz under the four conditions of still water (corresponding to the situation before bubbles are generated), small bubbles, medium bubbles and large bubbles. The transducer is placed at one end of the pool emits signals. The hydrophone is placed at the other end of the pool which receives signals with a sampling rate of 5MHz. The pulse width of the transducer signal is 1ms and the pulse interval is 100ms. The number of processing pulses is 100.

3.1. 20-40kHz Signal processing
When the frequency is 20-40kHz, the signal strength of the hydrophone receiving signals at small bubbles, medium bubbles and large bubbles is shown in figure 3. In figure 3, the solid blue line is the acoustic signal intensity in still water. And the dashed red line, dashed dot black line and magenta star line are the acoustic signal intensity in small bubble, medium bubble and large bubble, respectively. It can be obtained from the figure that the acoustic attenuation in the bubble wake is much larger than that in still water. And the louder the bubble is, the greater the attenuation is. The signal intensity difference between still water and small bubble is 13.89dB on average. The signal intensity difference between still water and medium bubble is 16.87dB. And the signal intensity difference between still water and large bubble is 21.57dB on average.
3.2. Signal Processing at 40-80kHz Frequency

When the frequency is 40-80kHz, the signal strength received by the hydrophone at small bubbles, medium bubbles and large bubbles is shown in figure 4.

In figure 4, the solid blue line is the acoustic signal intensity in still water. The dashed red line, dashed dot black line and magenta star line are the acoustic signal intensity in small bubble, medium bubble and large bubble, respectively. It can be obtained from the figure that the sound signal attenuation in bubbles is very large relative to the sound signal intensity in still water. It is more than 10dB than that in still water. The sound attenuation in large bubbles is larger than that in small bubbles and medium bubbles. It can be obtained from the figure that the sound attenuation in small bubbles is smaller than that in medium bubbles. From the calculation of the difference of the acoustic signal intensity between still water and different bubbles, it can be obtained that the difference of the acoustic signal intensity between still water and bubbles is the largest when there are large bubbles. And in general, the difference of the acoustic signal intensity between small bubbles and still water is the smallest. The average difference of acoustic signal intensity is 18.53dB for still water and large bubbles, 11.77dB for still water and medium bubbles, and 10.13dB for still water and small bubbles.

3.3. Experimental Data Processing at Frequency of 100-200kHz

Figure 5 shows the comparison of the acoustic signal intensity in still water and bubbles. In figure 5, the solid blue line is the acoustic signal intensity in still water. The dashed red line, dashed dot black line and magenta star line are the acoustic signal intensity for small bubbles, medium bubbles and large bubbles, respectively. It can be obtained from the figure that the sound signal attenuation in bubbles is very large compared with the sound signal intensity in still water. And the sound attenuation in large bubbles is larger than that in small bubbles and medium bubbles. From the calculation of the intensity difference of acoustic signals between still water and different bubbles, it can be obtained that the intensity difference of acoustic signals between still water and bubbles is the largest when there is a large bubble. The difference in acoustic signal intensity between small bubbles and still water is the smallest. The average difference of acoustic signal intensity is 20.39dB for still water and large bubbles, 14.50dB in the case of still water and medium bubbles, and 7.62dB in the case of still water and small bubbles.
4. Conclusion
The acoustic signal intensity at different frequencies in still water is shown in figure 6. The abscissa is frequency, unit kHz, and the ordinate is acoustic signal strength, unit dB.

The blue plus line, the red circle line, the black star line and the magenta fork line in the figure correspond to the acoustic signal intensities at different frequencies for still water, small bubbles, medium bubbles and large bubbles. From the comparison of the acoustic signal intensity under different conditions in figure 6, it can be obtained that the variation rule of the acoustic signal intensity in still water and different bubbles is basically the same. The acoustic signal intensity below 50kHz and above 120kHz is relatively large. The acoustic signal intensity is relatively gentle between 50-120kHz. The acoustic signal intensity in the case of small bubbles and medium bubbles is generally not different. The attenuation in the case of large bubbles is the strongest. And the attenuation in the case of relatively still water is over 10dB.

Figure 7 shows the variation of the difference between still water and small bubble, still water and medium bubble, still water and large bubble with frequency. The abscissa is frequency, unit kHz. And the ordinate is the difference between the sound signal intensity in still water and bubble, unit dB. From the comparison of different curves in the figure 7, it can be obtained that large bubbles have the greatest attenuation effect on acoustic signals, while medium bubbles and small bubbles also have different attenuation changes on acoustic signals. The average attenuation at different frequencies are 13.19dB and 13.97dB respectively. Generally speaking, the influence of the two is not very different.
This paper summarizes the experiment of bubble sound attenuation. In the experiment, the air compressor is used to inflate ceramic tubes to generate bubbles. The ceramic tubes are connected in parallel and the air intake is controlled to control the size of the generated bubbles. Large bubbles simulate the initial stage of ship wake flow. Medium bubbles simulate the intermediate stage of ship wake flow. And small bubbles simulate the later stage of ship wake flow.

Through the analysis of acoustic signal intensity in different stages and still water, we can obtain some conclusions. The existence of bubbles makes the acoustic signal attenuate. At different frequencies, bubbles attenuate more than 10dB relative to still water. Large bubbles have the strongest attenuation effect on acoustic signals, averaging over 20dB. The change rule of acoustic signal intensity with frequency in still water and bubbles of different scales is basically the same. The acoustic signal intensity in low frequency and high frequency bands (below 50kHz and above 100kHz) is large. The acoustic signal intensity in the range of 50-100kHz is small. And the change with frequency is relatively gentle.

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