Study on Kinetic Threshold of Raindrop Splash Bubble Sound
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Abstract. Rainfall noise is mainly composed of the initial impact sound and bubble sound. Bubbles are divided into three categories according to the diameter of the raindrops. It is generally believed that only a small raindrop hitting the water surface will produce the first type of bubble, larger diameter rains will only produce the second and third types of bubbles. In this paper, in order to verify the relationship between the diameter of raindrops and the type of bubbles, experiments were carried out to hit free water surface with different particle sizes of raindrops. The critical conditions for the raindrops to hit the water surface and generate air bubbles are found, and the kinetic thresholds of the raindrops under the critical conditions are obtained. The results show that in addition to the generally considered small raindrops will produce the first type of bubbles, the large raindrops and great raindrops will also produce a certain level of bubbles. Kinetic energy threshold is not a constant, but with the diameter and height of the drop.

Introduction

Medwin\(^{1,2}\) proposed that rainfall noise depends on the size distribution of the raindrops. The effect of bubble pulsations on rainfall noise is larger than that of initial impact. He also demonstrated the mechanism of three types of bubbles. The bubbles generated by the raindrop \((0.8\text{mm} \leq D \leq 1.1\text{mm})\) are the first type of bubble; the probability of production is 100%. The rainfall noise produced by such raindrops is called regular bubble pulse radiation sound. When the approximate diameter of the raindrop reaches 2.2mm-4.6 mm, the second type of bubble pulse radiation sound will appear at about 50ms after the initial impact. This type of bubble sound is called irregular bubble pulse radiation sound for the large randomness of this type of bubble’s generation. The third type of bubble is produced by the great and the large raindrop splashing free water surface. The difference is that the third type of bubble is generated after the initial impact of about 100ms. This type of bubble is produced by a second splash of water splashing free water, so it is known as a “delayed bubble”, the pulse radiation sound caused by which is called “delayed bubble pulse radiation sound”. Rainfall noise is mainly composed of initial impact sound and bubble sound.

Chen Fengqin\(^{3}\) et al. used the laser raindrop spectrometer to record rainfall characteristics under different simulated rainfall conditions, the kinetic energy of raindrop was calculated, the influence of raindrop diameter on total rainfall kinetic energy is analyzed. Shang Dajing\(^{7,8}\) used the reverberation method to measure and forecast the underwater sound field. This paper describes the noise characteristics of raindrops from the perspective of raindrop particle size, landing kinetic energy and acoustic energy. The noise characteristics of raindrop are described by experimental measurement analysis.

Measuring Principle of Raindrop Speed and Kinetic Energy Threshold
Raindrops \((0.05\text{mm} \leq D \leq 1.9\text{mm})\) are suitable for modified Yu-qing Sha formula \([4,6]\), raindrops...
(1.9mm ≤ D ≤ 6.5mm) apply modified Newton formula[4,5], when knowing the raindrop size, raindrop final landing speed can be calculated. Through the final speed of raindrops, we can calculate the speed of raindrops falling to any height can be calculated. Based on the kinetic theorem, the kinetic energy of the raindrop can be obtained from the given particle size of \( d \):

\[
E_i = \frac{2}{3} \pi \rho v^2 (d/1000)^2 [1 - \exp(-2gh/v^2)]
\]  

(1)

Raindrops from the natural world fall from the sky, landing at the final speed, the kinetic energy of the impact surface is only related to the particle size of raindrops. However, the raindrops in the experimental conditions can not reach the final speed when they land, so, they cannot get the maximum kinetic energy when hitting the water surface. Therefore, under the experimental conditions, the particle size and the falling height of raindrops are changed to find the kinetic threshold of the bubbles generated when the raindrop impacts the surface of the water.

**Experimental Measurement of the Kinetic Energy Threshold of Single Raindrops**

The experiment was carried out in the water tank, the length of the water tank is 1.2m, the width is 1.2m, the height is 1.0m, the water depth is 91.5cm. The tank was filled with tap water and was left to stand for a week to remove air bubbles. The sampling frequency was 51.2kHz and the sampling length was 10s. In the experiment, nine kinds of raindrops that were selected. In the actual observation, the raindrops of above particle sizes can breakdown the water from a lower distance, and the height of the phenomenon will not change this, so the splash height was controlled within 50cm below, whether the raindrops breakdown of the water surface and produce bubbles was determined by measuring the different particle size of the raindrops spilled in the sound of the sound signal in the sound pressure signal and visual observation of the phenomenon of splashing. Changing the height of the splash until the raindrops can no longer breakdown the water and produce bubbles, this height is the raindrop kinetic threshold corresponding height.

**Measurement Results and Analysis**

Nine different sizes of raindrops were subjected to splashing experiments with different heights, The critical splash height of the bubbles with different particle diameters is obtained, and the kinetic energy threshold is calculated, as shown in Table 1:

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Raindrop size(mm)</th>
<th>Height(cm)</th>
<th>kinetic energy threshold(10^{-5})J</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.00</td>
<td>18.0</td>
<td>0.7125</td>
</tr>
<tr>
<td>2</td>
<td>2.43</td>
<td>14.3</td>
<td>1.0058</td>
</tr>
<tr>
<td>3</td>
<td>2.63</td>
<td>14.5</td>
<td>1.3659</td>
</tr>
<tr>
<td>4</td>
<td>2.84</td>
<td>13.5</td>
<td>1.6098</td>
</tr>
<tr>
<td>5</td>
<td>3.04</td>
<td>11.3</td>
<td>1.5598</td>
</tr>
<tr>
<td>6</td>
<td>3.31</td>
<td>11.4</td>
<td>2.0151</td>
</tr>
<tr>
<td>7</td>
<td>3.47</td>
<td>9.8</td>
<td>2.1145</td>
</tr>
<tr>
<td>8</td>
<td>3.83</td>
<td>7.5</td>
<td>2.2822</td>
</tr>
<tr>
<td>9</td>
<td>4.45</td>
<td>5.5</td>
<td>2.6933</td>
</tr>
</tbody>
</table>

It can be seen from the table that the threshold value of the kinetic energy of a single raindrop splashdown on the surface of a free-water surface is not fixed. The larger the particle size of the raindrop, the lower the critical height and the higher the kinetic energy threshold. The measurement results of droplet spillage from the critical height and the lower height are shown in figure 2 and figure 3. The experiment shows that the raindrops from the critical height splashing free water vertically would break through the water and produce bubbles. Below the critical splash height, the raindrops were no longer 100 percent bubbling; it became a probability event. When it did not
produce bubbles, it would produce a rebound spray, resulting in secondary shock. With the height descending, bubbles and bouncing sprays disappeared, splash even could not produce a significant impact of the cavity at a very low height, the initial impact is gradually weakened, and finally buried in the background noise.

Bubble Oscillation Radiation sound appeared after the initial shock 20 ms. Theoretically, bubbles in the 2.2mm ~ 4.6mm particle size impacting free water will have the probability of generating the second type and the third type of bubble; however, the occurrence of these two types of bubbles had not been observed in this experiment. This is due to the raindrop in nature are falling from the high altitude, impacting water surface at final speed, they obtained enough kinetic energy to produce bubbles of the second and third classes. However, the height of the raindrops in the experimental conditions was lower; the kinetic energy is not enough to excite these two types of bubbles, but satisfy the conditions that excite the first type of bubble.
Summary

In this paper, the kinetic energy thresholds of bubble sound generated when different diameter raindrops splash on free water surface are studied. The results show that:

1. At lower altitudes (less than 0.5 m), large droplets of different particle sizes produce a first type of bubble at the landing surface at a specific height. When the bottom of the cavity formed by the impact of the water droplet on the water surface does not produce the first type of bubble, a secondary impact with an amplitude exceeding the initial impact will be generated.

2. The kinetic energy threshold of a single raindrop penetrating the water surface is not constant but rather proportional to the particle size of the raindrop, resulting in a bubble mechanism similar to the first type of bubble. Tiny raindrops can not penetrate the water surface to generate bubbles at low height.

Acknowledgement

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References


