Analysis of sound generated by the vibration of a bubble film

*Kazuya Yamakawa[1], Mie Ichihara[1]

1. Earthquake Research Institute, University of Tokyo

Introduction

Bubble sounds have been measured with active degassing at volcanoes and used to estimate the gas flux (Vergniolle and Brandeis, 1996; Johnson et al., 2008; Bouche et al., 2010). The estimation assumes a specific mechanism of generating bubble sounds. However it is challenging to distinguish the specific mechanism from other possible mechanisms in the acoustic data observed at volcanoes. Here we investigate the characteristics of bubble sounds and a sound generating mechanism in laboratory experiments.

Experimental method and observations

It has been reported that bubble sounds differ by fluid rheology. We follow the experiments by Lyons et al. (2013) which used a viscoelastic transparent gel. Bubbles rise in the fluid with coalescence and oscillation, and finally escape from the fluid surface. The sequences are recorded by microphones and a high speed camera.

We find two main processes generating sound: (1) bubble detaching from a nozzle and (2) rising bubble above the fluid surface. In this experimental model, no sound signal is detected with bubble bursting. We focus on the signals generated by (2), because they are clearly distinguished from other signals and noise due to the following particular features.

The features about sound frequency: the sound frequency glides to the higher. The features about sound amplitude: the envelope has a spindle shape with the maximum mostly occurring when about a half to 2/3 of the bubble is on the surface. The amplitude is not always proportional to the radius of a bubble. Sudden damping occurs after the maximum amplitude, which is sometimes caused by drops touching the film of bubble. When the bubble bursts, the amplitude decreases quickly. The signal is very weak when a bubble bursts earlier. The amplitude is significantly large when an oscillation of bubble is excited before it appears on the surface.

Model Calculation

Here we call ‘head’ as the part of bubble on the fluid surface, ‘tail’ as the part below the surface. The bubble behaviors are separated into the three time parts: (A) the head rising, (B) the head absorbing the tail, and (C) the shape being settled.

In the focused process, the sound is generated by vibration of the head. Referring to Verginiolle and Brandeis (1996), who discussed the same mechanism, we formulate the vibration equation of a spherical shell with adding an internal excitation term due to the increase of the head radius. The radial motion the head is converted to the far-field acoustic wave (Blackstock, 2000), of which waveforms are similar to the experimental observation.

Both amplitudes of the radial oscillation of the head and acoustic wave grow when the radius of head is increasing in (A) and (B) and is damped in (C). Then, the spindle-shaped envelope of the signal is reproduced.

Incorporating the head and tail change with the model enables the oscillation to start without an external excitation. When an external excitation is initially given, the amplitude becomes larger without changing the waveform.

The followings are suggested by model. A bubble needs an excitation under the surface to generate a

sufficiently large acoustic signal on the surface.
The controlling factor of the frequency gliding is the ratio between the volume of the head and the tail in (A), the radius of the head in (B), and the film thickness in (C).

Discussion and Future Tasks
We discuss whether we can estimate the bubble volume using the sound of the focused mechanism. The amplitude is not useful because it is significantly affected by the condition of the head of bubble and external excitation. The upward gliding frequency is the feature used to identify this mechanism. The beginning of the frequency change is controlled by the radius of the head so that it is potentially useful to estimate the bubble volume.

Keywords: bubble, sound, volcano