

Sawtooth wave-like pressure change and cyclic out-gassing observed in laboratory experiments

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1.Introduction

A sawtooth wave-like (SWT) pressure change was observed in laboratory syrup eruption experiments (Kanno and Ichihara, 2014, VSJ fall meeting).

Sawtooth wave-like inflation-deflation cycles have been observed with eruptions at many volcanoes (Genco and Ripepe 2010, Lyons et al. 2012, Nishimura et al 2013). We expect that clarifying the mechanism of a similar oscillation in this experiments helps understanding the actual volcanic phenomena. Conduit flow patterns are controlled by the gas volume fraction and relative velocity between liquid and gas (Vergnolle and Jaupart, 1986). Supposing that the SWT pressure oscillation was generated by transitions of flow patterns, we conducted experiments on flow in a tube with varying fluid rheology and injected gas flux. However we never observed the SWT oscillation.

In this study, we examine effects of the chamber below the tube on generation of the SWT oscillation.

2.Equipment and Method

Gas is injected to a transparent tube to generate alternate layered flow of syrup and gas. The viscosity of the syrup is about 1 Pa.s. The diameter of the tube is 5 mm. An acrylic chamber ($\phi=50$ mm, H=100 mm) is attached beneath the tube. A pressure transducers is mounted at the injection point in the tube and another at the bottom of the chamber. In addition, a microphone is mounted at the exit of the tube. Flow in the tube is recorded with a high-speed camera (Fig.1a).

We inject the syrup in the tube to the height of 60 mm from the bottom of the tube. In order to keep the syrup within the tube, we use a 800-mm long tube. We partially fill the chamber with water and control the volume of the chamber (V_c) by changing the amount of water. Injected gas flux (Q_{in}) is controlled by a regulator.

3.Result

We control V_c from 0 to 120 cm³ and Q_{in} from 0.1 to 30 μ m³/s for each V_c .

(1) Changing V_c with constant Q_{in}

For small values of V_c , quasi-sinusoidal pressure oscillation is observed with periodic ruptures of syrup layers at the top. The velocity and the thickness of the following syrup layers are nearly constant with a minor influence of the rupture.

The SWT oscillation is observed for sufficiently large V_c (Fig.1b). In this case, all syrup layers burst simultaneously to make pressure drop. After this event, syrup layers recover with deformation of syrup film flowing down the inner wall, and the pressure in the chamber starts to increase gradually. The syrup layers are accelerated with the pressure increase and their thicknesses become thinner. Then, the syrup layers burst again to cause pressure drop.

(2) Changing Q_{in} with constant V_c

When V_c is small, quasi-sinusoidal pressure oscillation is observed in all the experimental range of Q_{in} . The period of the oscillation is smaller when Q_{in} is larger. When V_c is sufficiently large, the SWT oscillation appears intermittently among the quasi-sinusoidal oscillation. The SWT oscillation dominates when Q_{in} further increases.

4.Discussion

For volcanic systems, asymmetric pressure change has been explained by a coupling mechanism among pressure in a magma chamber, conduit flux, and viscosity (Ida,1996; Barmin et al,2002; Nakanishi and Koyaguchi,2008).

Based on these models, we considered two effects:

(1) Viscous dissipation in the tube becomes larger (smaller) when the thicknesses of the syrup layers increase (decrease).

(2) The chamber plays a role of a buffer.

With these assumptions, the experimental system is formulated by simple ordinary differential equations.

This model generates a SWT pressure change with increasing V_c at constant Q_{in} (Fig.1c). When V_c is small, quasi-sinusoidal pressure oscillation is generated. For constant V_c , the waveform gradually changes from SWT to quasi-sinusoid with decreasing Q_{in} .

In this way, the model can qualitatively simulate the oscillation patterns that are observed in the laboratory experiments. In the

future, we will study effects of each parameter in more detail.

Keywords: Sawtooth wave, Analog experiment, Multi phase flow, Magma chamber, Conduit flow, Tilt motion

