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Plant Management by a Ball SAW Gas Chromatograph Installed on a Drone

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1. Introduction

The safe and efficient operation of chemical and energy plants requires management through frequent inspections. However, there is a problem that many places are inaccessible to humans due to high altitude, high temperature, or hazardous gas emissions.

Observation by cameras mounted on drones and measurement by radiation sensors, infrared sensors, etc. are being carried out, [1,2)] but in order to discover abnormalities, it is necessary to analyze the gas composition of each part of the plant. For this purpose, a gas chromatograph with a maximum drone payload of 4 kg or less is required.

Therefore, we installed an ultra-compact and lightweight ball SAW gas chromatograph (GC) [3,4)] on a drone and examined its applicability to plant management.

2. Experimental method

A ball SAW GC (Sylph SY-401, weight 1.25kg) and a battery were installed on a drone (DJI Matrice 300RTK). The communication module using a cellular phone line enables collection, analysis and reception of data during flight. To shorten the analysis time, the length of the metal solenoid column, which is normally 30m, was changed to 10m. In addition, to reduce the effect of the propeller wake during gas collection, a 3m-long sampling unit made of a CFRP pipe was connected as shown in **Fig. 1**. **Fig. 2** shows the drone mounting the ball SAW GC with a sampling unit.

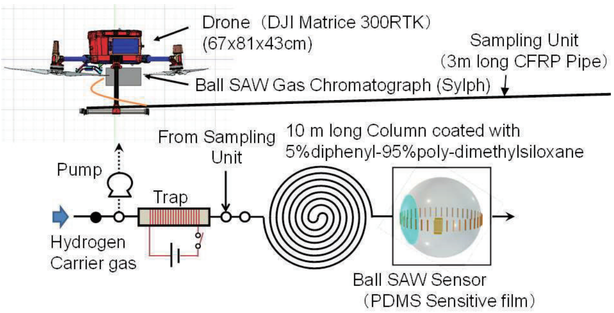

Fig. 1 Drone and a ball SAW GC

Fig. 2 Drone mounting a ball SAW GC with a 3 m long sampling unit

The gas collection experiment was conducted at the test plant of the Fukushima Robot Test Field, a national project aimed at building a new industrial base to restore the industry in the Hamadori area, which was damaged by the Great East Japan Earthquake and the nuclear accident.[5)] **Fig. 3(a)** shows a test chimney C used for the first experiment.

Fig. 3(b) shows the inside of the chimney. At the lower space **Fig. 3(c)**, a polar liquid such as

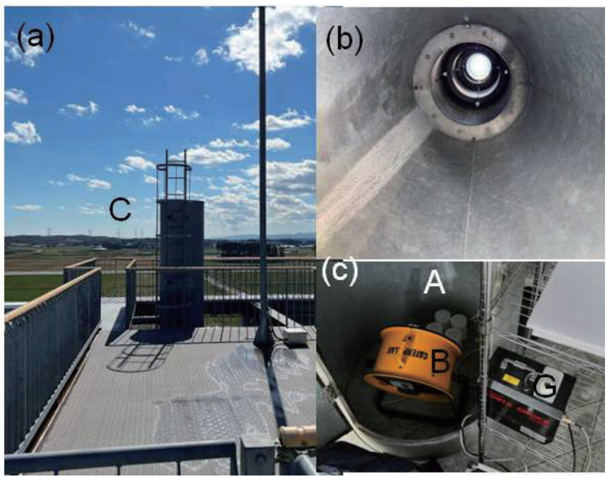

Fig.3 Test chimney (a) Appearance (b) Inside (c) Generation of test gas in the lower space.

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propylene glycol was vaporized by the smoke generator G to generate white smoke-like gas. In addition, an equivalent mixture of heptane (C7), octane (C8) and nonane (C9), which are petroleum components normally detected in plants, was sprayed with ultrasonic humidifiers A and blown upward with a blower B.

3. Results and discussions

As shown in **Fig. 4**, the drone approached the top of a chimney with a diameter of 1 m and a height of 12.5 m, collected gas emitted from the chimney for 0.5 minutes (10 ml) during flight, and started analysis.

Fig. 4 Collection of gas at the top of a chimney.

Fig. 5 shows a 2.5-minute chromatogram of the gas collected at the chimney. In addition to the peak of air and water vapor, petroleum components C7-C9 were detected.

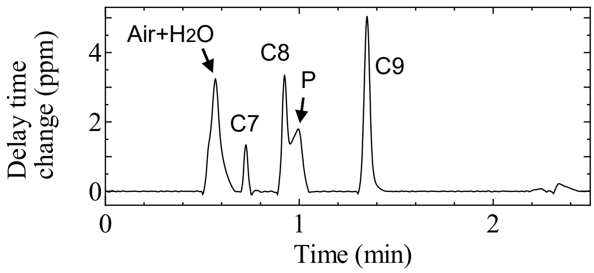

Fig. 5 Chromatogram of collected gas. C7: Heptane, C8: Octane, C9: Nonane, P: Propylene glycol

To quantify the collected gas components, the calibration curve was obtained as shown in **Fig. 6** using nonane (C9) at concentrations of 10ppmv and 95ppmv (•) under the same conditions as in the experiment. Since the peak area during collection in Fig. 5 was 0.188 ppm·min, the average concentration of nonane (C9) during collection was found to be 17.4 ppmv from the calibration curve, as indicated by the symbol ×.

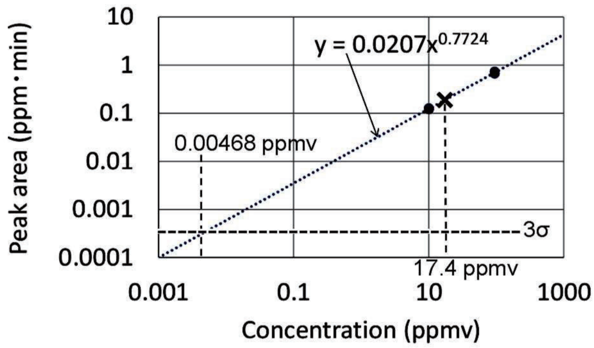

Fig.6 Calibration curve of nonane (C9).
Symbol ● shows concentration of standard gas for calibration, and symbol × shows the calibrated concentration at the top of a chimney.

In addition, the root mean square (RMS) noise of the chromatogram in Fig.5 was as small as δ=3.2 ppbv, and the noise in the peak area was 3σ=0.329 (ppb min), so from the calibration curve in Fig.6, the lower limit of detection (LOD) was estimated as LOD=0.00468 ppmv=4.68 ppbv.

Furthermore, propylene glycol (P) was clearly detected near the octane (C8) peak. This substance is generated by hydrolyzing glycerin in the presence of a copper-based catalyst, and is not generated during normal plant operation. Thus, the chromatogram in Fig. 5 shows the possibility of a ball SAWGC mounted on a drone to detect abnormal gas generated by plant failure separately from normal gases.

4. Conclusions

A palm-sized ball SAW GC was mounted on a drone and a demonstration test was conducted. A wide variety of different types of gases were detected with high sensitivity in a short period of time (3 minutes). This indicates that the world's first drone-mounted gas chromatograph analysis may be useful for plant management[1).

References

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