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Study on suppression of hydrogen generation by using heated simulated incineration ash and water simulating an ash conveyor environment

Hideyuki Onodera[1], Ryoji Imai[2], Masahiro Sakai[2]

1. Japan Aerospace Exploration Agency

2. College of Design and Manufacturing Technology AerospaceSystem Engineering Research Unit, Muroran Institute of Technology

Correspondence: onodera.hideyuki@jaxa.jp: Tel: +81-185-52-7123

INTRODUCTION & AIM

In municipal solid waste incineration plants, explosions have been reported inside ash conveyors, near ash discharge devices, and within ash pits. These explosions are believed to be caused by the reaction between metallic aluminum contained in the ash and the water used for ash cooling and dust suppression, which generates hydrogen gas. The chemical reaction between aluminum and water is shown in Equation (1).

$$2Al+6H_2O \rightarrow 2Al(OH)_3+3H_2 \quad (1)$$

Due to this background, countermeasures such as ventilation systems and stagnation prevention mechanisms have been implemented to mitigate the risk of equipment damage (e.g., conveyors) and operator injury caused by explosions. However, these measures alone cannot completely prevent hydrogen explosions. To effectively prevent such explosions, it is necessary to fundamentally suppress the generation of hydrogen, which is the root cause.Although several studies have been conducted on hydrogen gas generation from incineration ash, no method has been identified to completely stop the reaction between incineration ash and water.In this study, we examined whether the findings of our previous research on "suppression of hydrogen generation from the reaction between actual aluminum-containing incineration ash and water" [1] could be applied to the conveyor systems of incineration plants. In our earlier work [2], we found that when aluminum-containing incineration ash and water were placed in a reaction vessel, heating the vessel to 90 ° C to generate hydrogen gas, followed by natural cooling to 30 ° C, could successfully terminate hydrogen generation. However, it remained unclear whether hydrogen generation could still be suppressed after incineration ash, heated in the furnace, was dewatered by the ash discharge device and subsequently exposed to the atmosphere inside the ash conveyor.Therefore, in the present study, we conducted hydrogen generation experiments using simulated aluminum-containing incineration ash to verify whether the reaction between the ash (heated to approximately 200 ° C) and water could be suppressed, following the same experimental procedure described in our previous work [2].

METHOD

In the hydrogen generation experiment, water was first placed in a reaction vessel and heated to approximately 90 ° C. Subsequently, incineration ash containing aluminum powder, preheated to 200 ° C on a hot plate, was added to the reaction vessel to initiate hydrogen gas generation. After hydrogen gas was collected during a 30-minute natural cooling period, the aqueous solution and aluminum-containing incineration ash were dewatered. Following dewatering, the hydrogen gas concentration around the aluminum-containing incineration ash was measured.After the hydrogen concentration measurement, the separated aqueous solution and incineration ash were mixed again to regenerate hydrogen. The generated hydrogen was then collected by the water displacement method during a 360-minute natural cooling process.

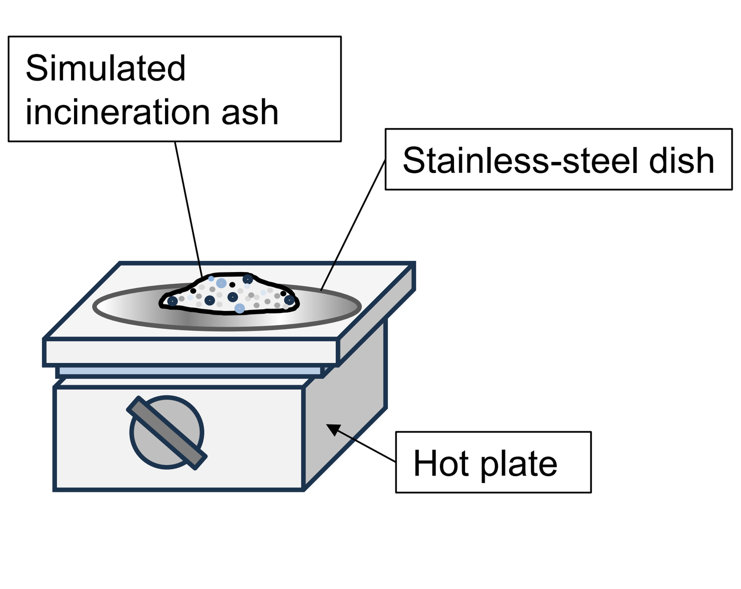

Fig. 1. Experimental setup for heating the simulated incineration ash.

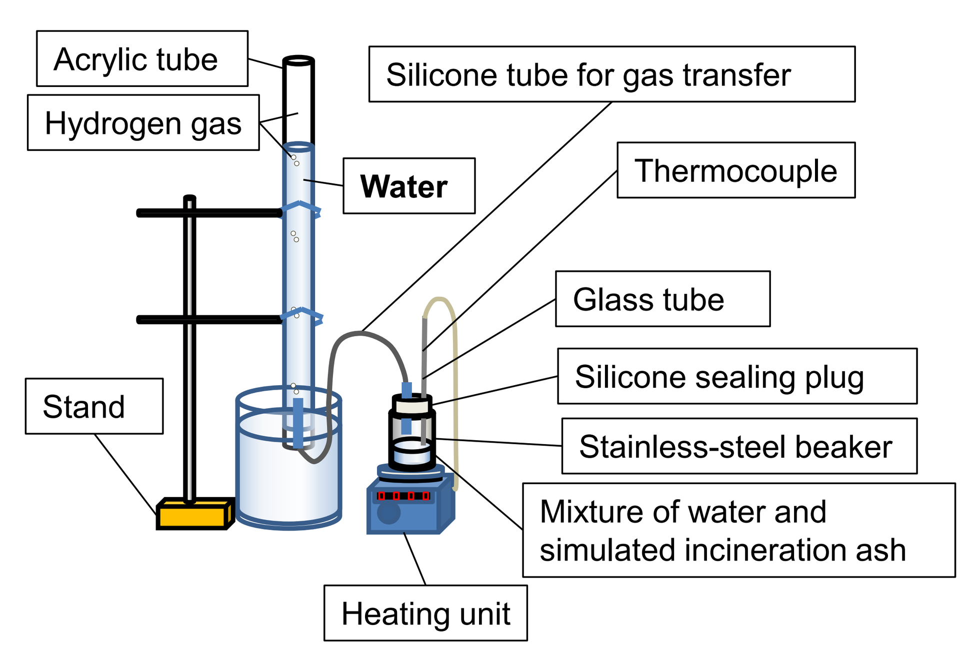

Fig. 2. Experimental apparatus for hydrogen collection by the water displacement method.

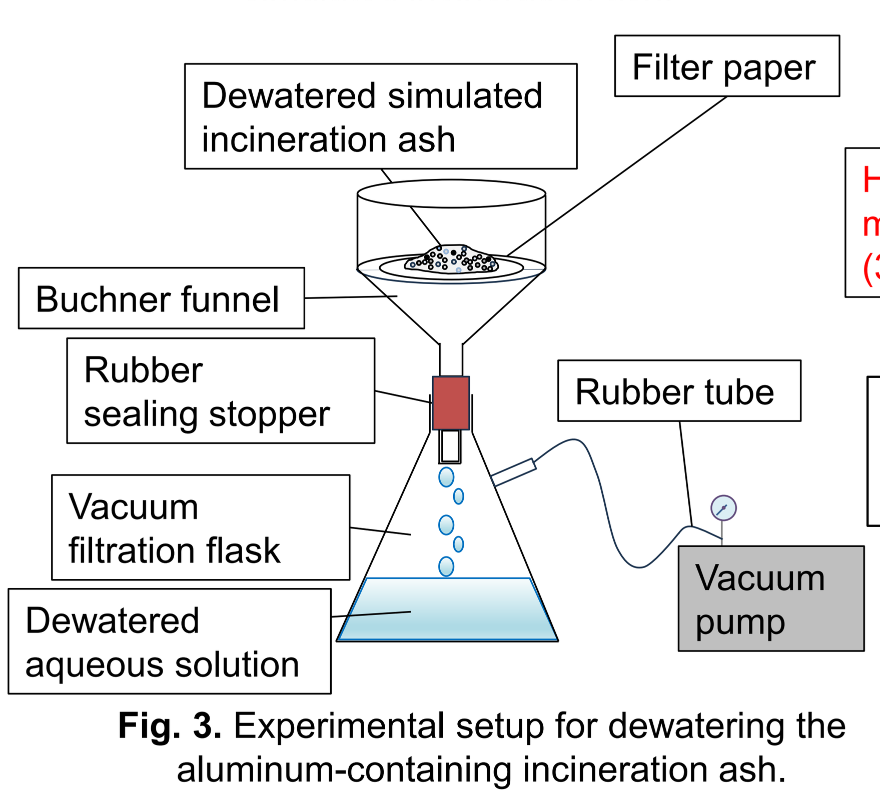

Fig. 3. Experimental setup for dewatering the aluminum-containing incineration ash.

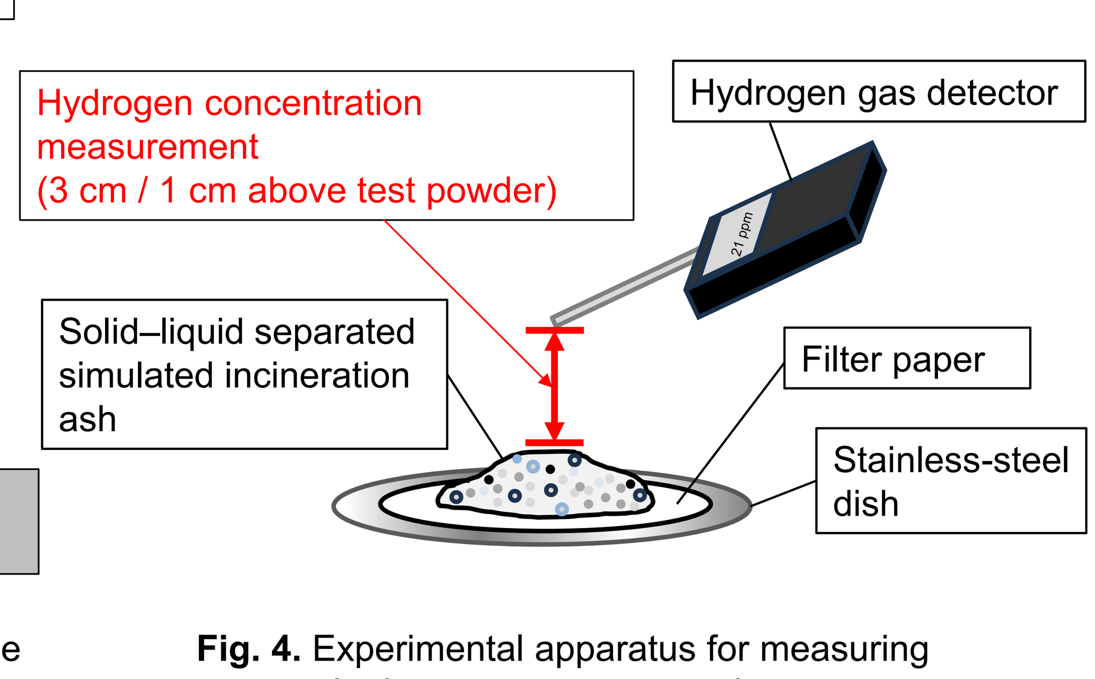

Fig. 4. Experimental apparatus for measuring hydrogen gas concentration.

Experimental ApparatusFigure 1 shows the experimental setup used for heating the simulated incineration ash. The simulated ash was placed in a stainless-steel dish and heated on a hot plate until its temperature reached 200 ° C.Figure 2 illustrates the apparatus used for hydrogen collection by the water displacement method. The system consists of a magnetic stirrer equipped with heating and temperature control functions, a stainless-steel reaction vessel for reacting the test powder with water, a silicone plug to seal the reaction vessel, a silicone tube for transferring the generated hydrogen gas to the collection tube, an acrylic tube for collecting the gas, and a stand to support the acrylic tube. Hydrogen gas generated in the stainless-steel reaction vessel was transferred through the silicone tube to the acrylic collection tube.Figure 3 shows the experimental setup used during dewatering. Filter paper was attached to a suction funnel, and a mixture of aluminum-containing incineration ash and water was poured onto it. Dewatering was performed by creating a negative pressure inside the suction flask using a vacuum pump.Figure 4 presents the apparatus used for hydrogen concentration measurement. The hydrogen gas detector sampled gas at positions 1 cm and 3 cm above the dewatered incineration ash to measure the hydrogen concentration.

RESULTS & DISCUSSION

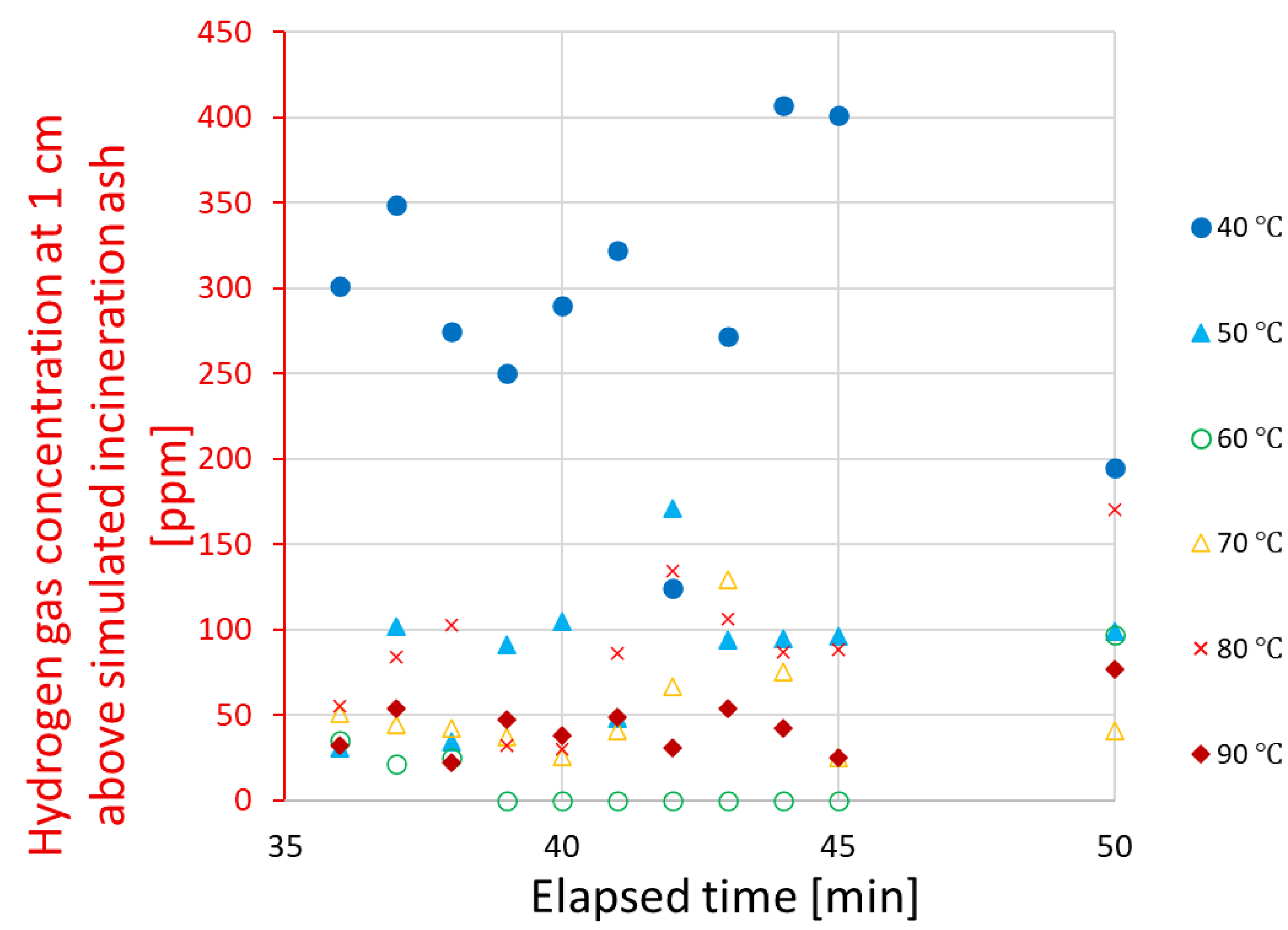

Fig. 5. Effect of heating temperature on the time variation of hydrogen gas concentration at a position 1 cm above the test powder.

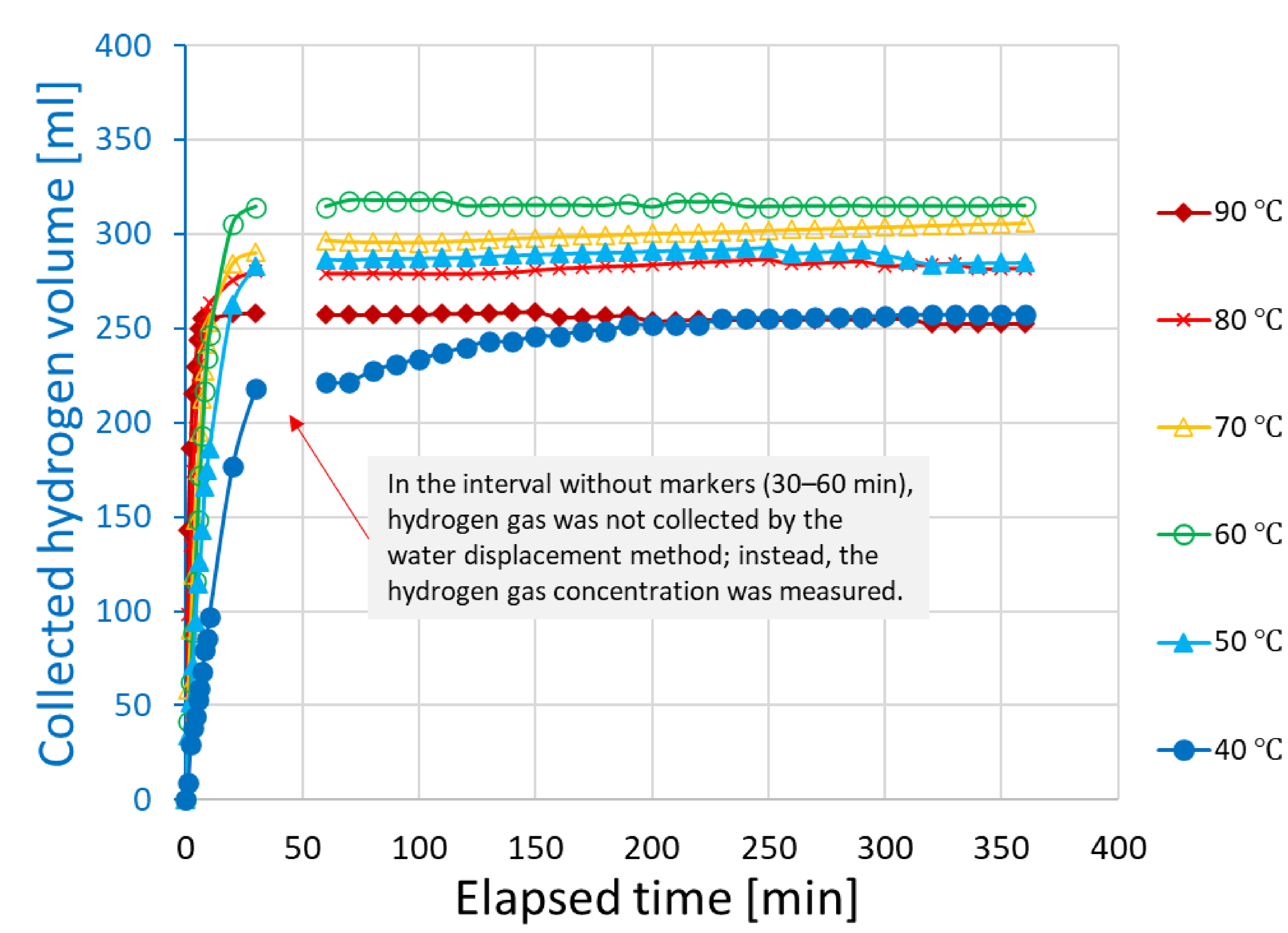

Fig. 6. Effect of heating temperature on the time variation of hydrogen gas volume.

CONCLUSION

In this study, simulated incineration ash heated to 200 ° C was immersed in water to generate hydrogen gas. The results showed that when the ash was immersed in water at temperatures above 50 ° C and then allowed to cool naturally, hydrogen generation was effectively suppressed. In contrast, when the water temperature was 40 ° C, hydrogen generation continued for up to 300 minutes after the start of the experiment. Furthermore, it was found that the higher the water temperature, the lower the hydrogen gas concentration.The suppression of hydrogen generation at higher water temperatures is considered to result from the formation of a more stable oxide film on the surface of the aluminum particles, which inhibits the reaction responsible for hydrogen evolution.

FUTURE WORK / REFERENCES

In this study, experiments were conducted using 8 g of the test powder and 200 mL of water. Future work will involve experiments using larger quantities of incineration ash with the aim of practical application in actual incineration plants. In parallel, a predictive model for hydrogen generation in incineration plants will be developed to enable early detection of potential hydrogen explosions and to establish a system that can prevent such accidents in advance.

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[2] Higashino, K., Onodera, H., Sugioka, M., Imai, R., Masuda, I., 2015, Memoirs of Muroran Institute of Technology, vol. 64, 17-22