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Proceeding Paper

Development of a New Heat Source Based on Inducing Heat for Greenhouses †

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Abstract: In Fukuroi City Japan, greenhouses are usually used for crown musk melon (CMM) cultivation. When the temperature inside the greenhouse is lower than 25 °C, the CMM quality deteriorates. Hence, from late autumn until the middle of spring, oil is used to supply hot water to greenhouses from a boiler through a heat exchanger . However, since oil prices have recently soared, fuel expenses have drastically increased which heavily pressures the CMM business. In addition, with the promotion of the carbon-neutral policy, environmentally friendly heat sources are emphasized instead of fossil fuels. The TSK corporation has produced a new inducing heating (IH) source where heat is generated by rotating a plate on which a couple of permanent magnets are mounted using a motor. Since the rotation speed is easily controlled, the IH heat source capacity can be freely adjusted. To apply the IH source to the greenhouse, an experimental system was created in this study. During the experiment, water inside a vessel (maximum volume of 90 L) was heated to 70 °C by the IH system. Then, the heated water was circulated for heat dissipation through a heat exchanger by a pump. When the temperature of the water was lower than the target temperature, the IH system restarted to heat the water back up to 70 °C. Under several experimental conditions, the heating time, reheating time, and electric power were measured and evaluated. It was confirmed that the new IH heat source could possibly be applied to greenhouses.

Keywords: greenhouse heat source; IH; carbon-neutral; permanent magnet

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1. Introduction

Fukuroi greenhouse crown musk melons (CMMs) are a branded product of Fukuroi City. Producing CMMs requires strict temperature control. From mid-autumn to mid-spring, the temperature of the soil in greenhouses must be maintained above 25 °C. Usually, oil is used to produce warm water for greenhouses. However, fuel prices have continued to soar due to the impact of recent high crude oil prices and the weaker yen, which pressures farmers. In addition, the exhaust gas from heavy oil fuel contains greenhouse gases including carbon dioxide and NOx, which have a negative effect on the environment. Therefore, while the government promotes decarbonization policies, it is necessary to also introduce electric heat source technology in the greenhouses used for growing CMMs [1].

The TSK corporation, located in Fukuroi City, has developed MAGHEAT as a heat source, which uses a magnet for high-speed heating. MAGHEAT is a new type of heater that rotates a disk with a strong magnetic field bundled with permanent magnets to heat non-ferrous metals such as aluminum alloys and allow for self-heating by Joule heat. Compared to conventional heating methods, MAGHEAT is economical, responsive, controllable, and space-saving. In this study, we established the following research objectives based on the current use of hot water boilers, taking the greenhouses owned by members of the Fukuroi Greenhouse Crown Melon Association and exchanging information with representatives of the association and the TSK Corporation. We built a new hot water supply system for melon greenhouses using a new electric heat source instead of a hot water supply system (conventional heat source). A small pilot hot water supply system using MAGHEAT was created and a series of experiments were conducted to verify the possibility of using MAGHEAT.

2. Principle of MAGHEAT

MAGHEAT is an electromagnetic induction heating device (Figure 1). It consists of a motor, a MAGHEAT magnet board, and permanent magnet arrays. Electromagnetic induction is generated using the magnet board in which a magnet is embedded and an eddy current is generated inside the metal. The current (eddy current) is replaced by heat (Joules) due to the internal resistance of the metal. The quantity of the eddy current is supposed to be proportional to the motor rotation speed, which means that the heating time can be adjusted if the motor rotation speed is controlled.

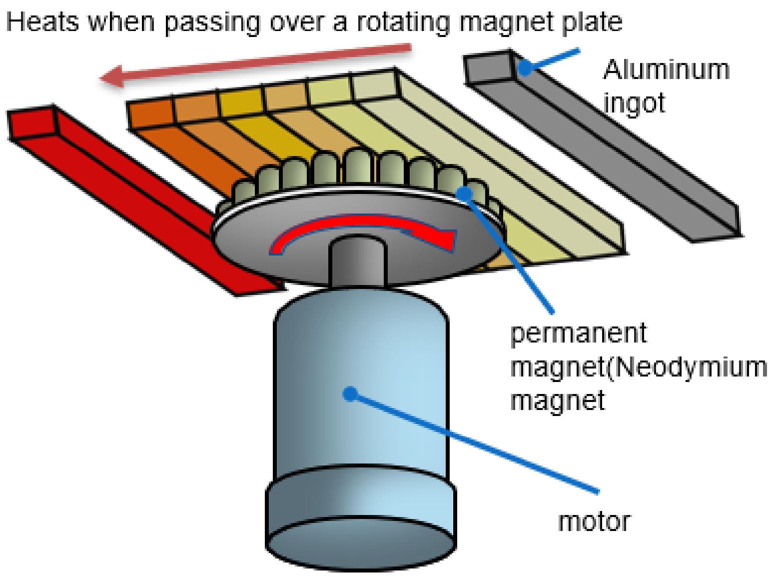

Figure 1. Structure of MAGHEAT.

3. Experiment

The experimental system using MAGHEAT as a heat source for heating water is shown in Figure 2. It consists of a vessel, MAGHEAT (with a motor with an output of 55 kW), water pump, heat exchanger, flowmeter, thermocouples, and PLC controller. During the experiment, first, water in the vessel was heated by MAGHEAT to 70 °C. Then, the power of the MAGHEAT was turned off while water pumps were powered on in order to circulate the water through the heat exchanger. When the temperature after cooling reached the target value, the MAGHEAT restarted to heat the cooled water back to 70 °C. This process was repeated several times. In the experiment, the heating time, cooling time, and electric energy were measured at different motor rotation speeds, target temperatures, and water quantities. The experimental conditions are shown in Table 1, and the MAGHEAT heating source is presented in Figure 3.

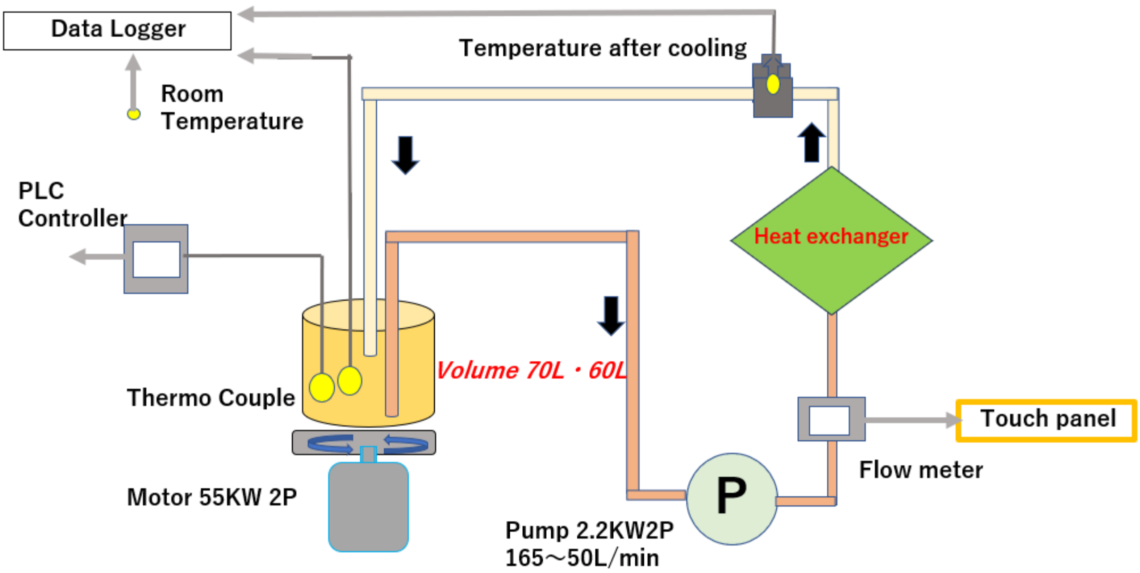

Figure 2. Experimental system using MAGHEAT as a heat source for heating water.

Table 1. Experimental conditions (Flow rate = 30 L/min).

Ex.No	1	2	3	4	5	6
Water Quantity (L)	70	70	70	70	90	90
Target temperature (°C)	60	60	50	40	60	60
Motor Rotation speed (rpm) 10^3	2	3	2	2	2	3

Figure 3. MAGHEAT heating source.

4. Results and Discussions

4.1. Heating and Cooling Process

The temperature changes in the heating and cooling process are shown in Figure 4. This result was obtained under the conditions of 2000 RPM and 70 L/min. At the beginning, the water in the vessel was heated by MAGHEAT to 70 °C, and then the MAGHEAT was stopped to begin cooling. When the temperature value after cooling reached 60 °C, the MAGHEAT was restarted to heat the cooled water back to 70 °C. This heating and cooling process was repeated 5 times. MAGHEAT efficiently started and stopped according to the target temperature, which showed that MAGHEAT could be used as the new heat source for the greenhouse. The first heating time was 604 s because water had to be heated from 18 °C. The average time for heating was 160 s, which was shorter than the first heating time. The accumulated consumed electric energy was 12 kWh.

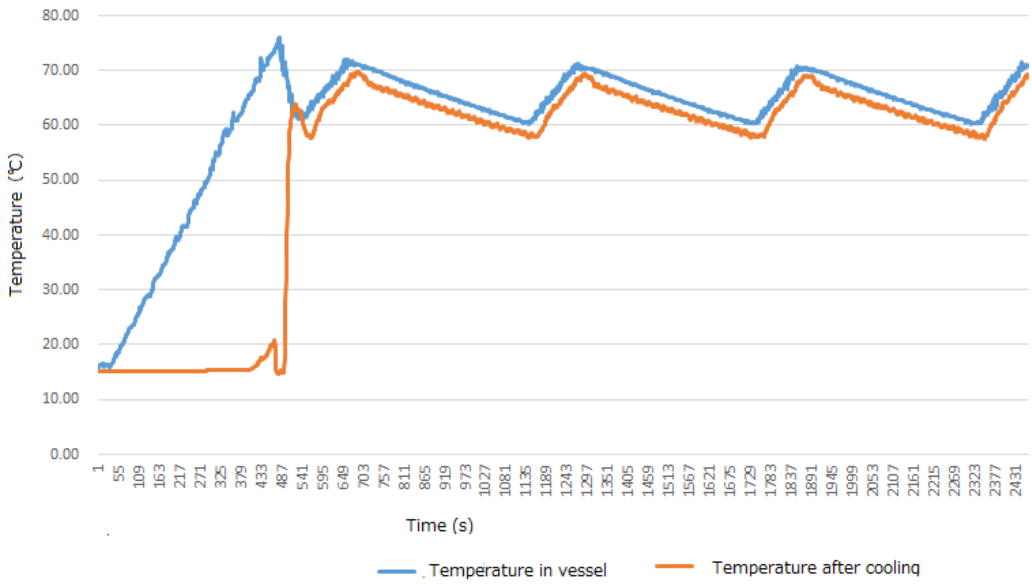

Figure 4. Temperature changes in the heating and cooling process.

4.2. Effect of Motor Rotation Speed on Heating Time

The effect of motor rotation speed on heating time is shown in Figure 5. The heating time was 604 s at 2000 RPM and 456 s at 3000 RPM. The average time for the rest of the heating process was 160 s at 2000 RPM and 120 s at 3000 RPM. The heating time was shorter than that at 3000 RPM. Higher motor rotation speed increased heating and shortened the heating time.

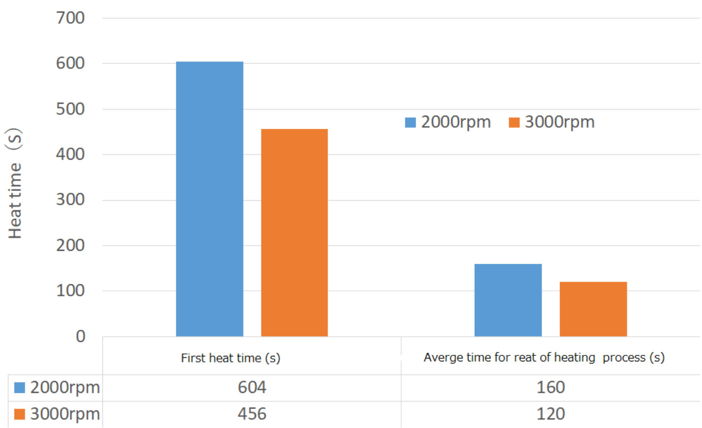

Figure 5. Effect of motor rotation speed on heating time.

4.3. Effect of Motor Rotation Speed on Heating Time

The effect of motor rotation speed on the accumulated electric energy is shown in Figure 6. At 2000 RPM, it was 12 kWh, while at 3000 RPM, it was 11.4 kWh. At 3000 RPM, the energy conversion efficiency became better.

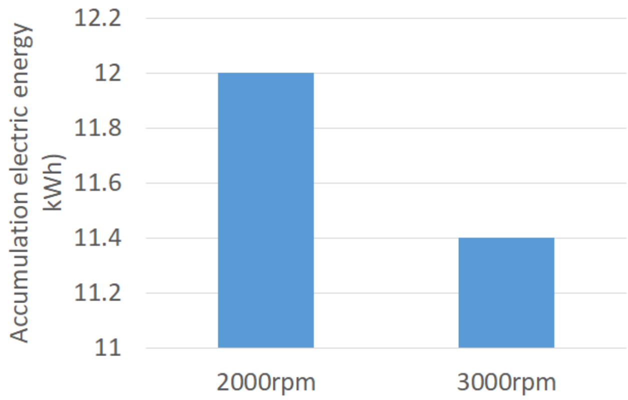

Figure 6. Effect of motor rotation speed on the accumulation of electric energy.

5. Conclusions

To validate the use of MAGHEAT as a new heat source for greenhouses, an experiment was conducted to investigate the effect of rotation speed on heating and accumulated electric energy. It was found that MAGHEAT can be the new heat source for controlling temperature changes and heating processes and applied to greenhouses. In addition, we found that a higher motor rotation speed shortened the heating time and improved energy conversion efficiency.

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Conflicts of Interest: Authors Shigeru Kubono, Hiromi Fujimura and Mitsuhiro Sakamoto were employed by TSK cooperation. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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