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Research Article

Temperature and Pressure Dependence of Anomalous Heat Generation Occurring in Hydrogen Gas Absorption by Metal Powder

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Abstract

As reported in previous papers, anomalous heat generation occurs when nickel or palladium powder is exposed to hydrogen or deuterium gas, while there is also a chemical effect that occurs when hydrogen (or deuterium) gas is absorbed by mixed oxides of Pd and Zr. Many experiments were previously conducted while increasing either initial temperature or pressure in the reaction chamber. In this report, we conducted fundamental experiments of hydrogen gas absorption by metal powder, while increasing both temperature and pressure simultaneously. The experiments were conducted in conditions up to 244°C and 0.5 MPa, using a small constant-volume reaction system developed by us. As a result, about 4 K of temperature rise was observed in the experiment using nickel powder, and about 10 K was observed in the experiment using Pd-Ni-Zr composite powder. In these experimental results, there are positive correlations between the temperature rise and both the initial temperature and loaded gas pressure. This result may show that the temperature rise is assisted by not only preheating but also gas absorption under higher pressure.

Keywords: Anomalous heat, Gas absorption, Temperature dependence, Pressure dependence

1. INTRODUCTION

Anomalous heat generation when nickel or palladium powder was exposed to hydrogen or deuterium gas was reported in previous papers [1], [2]. It was also reported that anomalous effects occurred when hydrogen (or deuterium) gas is absorbed by mixed oxides of Pd and Zr, which may also be related to a chemical reaction [3]. In many previous studies, experiments were conducted while increasing either initial temperature or pressure in a reaction chamber. A few studies were done at both high temperature and high pressure [4], whereas they are not related to power or heat generation. Systematic data gathering and scanning are necessary to go further.

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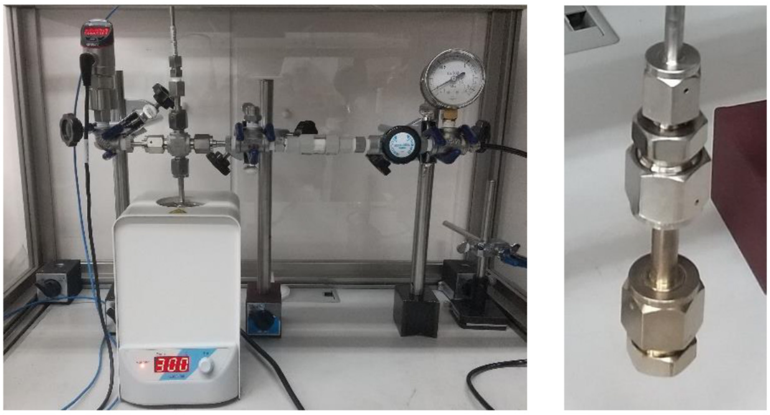

a) overall view b) reaction chamber

Figure 1. Reaction system.

In our previous report [5], we developed a small constant-volume reaction system (shown in Fig. 1) to validate excess heat generation, while increasing both temperature and pressure simultaneously. This is because a temperature increase alone may lead to a less powerful reaction due to the possibility that when hydrogen gas is heated, it degasses out of metal powder such as palladium or nickel. In this report, we conducted fundamental experiments of hydrogen gas absorption by metal powder, up to 244°C and 0.5 MPa.

2. EXPERIMENTAL DEVICE

Figure 2 shows the outline of the reaction system. The reaction system is constructed of a heater, reaction chamber, K-type thermocouple, two pressure gauges, two valves, gas supply device, and vacuum pump.

The reaction chamber is made of stainless steel (SUS316L). The volume of the reaction chamber is about 2 mL. The heater (GBSD-300, AS ONE CORPORATION) is used for preheating the reaction chamber. The maximum temperature to be set for the heater is 300°C. The K-type thermocouple (HTK0227, Hakko electric co., ltd.), whose tip is embedded in the sample, is used to measure the sample temperature. The gas supply device (LMX2-J-A7, FRONTO Co., Ltd) is used for providing gas while the experiments. The maximum pressure of gas allowed from the gas supply device is 0.7 MPa. The pressure of the gas provided in the reaction chamber is measured by the pressure gauges. The scroll pump (ISP-250C, ANEST IWATA Corporation) is used for evacuation. The ultimate pressure (the lowest pressure that can be reached within a realistic evacuation time) of the vacuum pump is 1.6 Pa.

To prevent damage to the reaction system, a safety valve (RAT2V-1000, IBS Inc.) is installed. It opens when the pressure in the reaction chamber exceeds 1.0 MPa.

Specifications of the reaction system are shown in Table 1.

3. EXPERIMENTAL PROCEDURE

The experimental procedure is shown in Fig. 3. First, the sample (nickel powder or Pd-Ni-Zr composite powder, designated PNZ10r [6]) is set in the reaction chamber. Then, the chamber is evacuated by the vacuum pump. After that, the chamber is preheated with the heater. After preheating, hydrogen gas (or nitrogen for the control experiment)

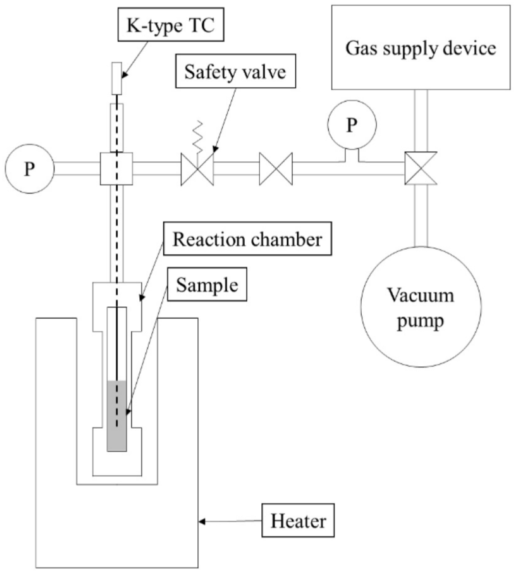

Figure 2. Schematic of the reaction system.

Table 1. Specifications of the reaction system.

Material of reaction chamber	**SUS316L**
Volume of reaction chamber	2 mL
Ultimate pressure of vacuum pump	1.6 Pa
Maximum pressure of loading gas	0.7 MPa
Maximum temperature of heater	300°C
Cracking pressure of relief valve	1.0 MPaG

is loaded into the chamber. The temperature increase of the sample is measured by the K-type thermocouple. At the end of the experiment, the loaded gas is exhausted, and the chamber is evacuated again to remove all of the loaded gas.

4. EXPERIMENTAL RESULTS

Experimental conditions are shown in Table 2. In the experiments, 3.0 g of nickel powder (NFP201S, JFE MINERAL COMPANY, LTD.) or Pd-Ni-Zr composite powder [6] was used as a sample.

The experiments were conducted using hydrogen gas, and nitrogen gas as the control experiment. (The control experiment using nitrogen gas is done before using hydrogen gas.) The experiments were conducted in the range of loaded gas pressure 0.12–0.5 MPa, and initial sample temperatures 95–244°C.

Results and conditions of the other experiments are shown in Table 3.

A result of the experiment using nickel (run No. 4) is shown in Figs. 4 and 5. An orange line for nitrogen gas loaded and a blue line for hydrogen gas loaded in Fig. 4 show the time-histories of temperature for the nickel sample, while Fig. 5 shows the temperature rise from the control experiment for nitrogen gas loaded, i.e., the temperature difference between cases of hydrogen and nitrogen loaded. In the experiment, a temperature rise began about 400 seconds after

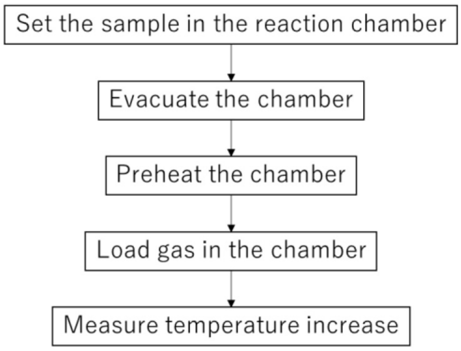

Figure 3. Experimental procedure.

Table 2. Experimental conditions.

Sample	**Nickel powder or Pd-Ni-Zr composite powder**
Sample mass	3.0 g
Kind of gas	Hydrogen or Nitrogen (control experiment)
Gas pressure	0.12-0.5 MPa
Initial temperature	95-244°C

Table 3. Results of the experiments.

No.	**Sample**	**Gas pressure**	**Initial temperature**	**Temperature rise**
1	Nickel 3.0 g	0.12 MPa	239°C	2.2 K
2	Nickel 3.0 g	0.5 MPa	94°C	1.2 K
3	Nickel 3.0 g	0.5 MPa	238°C	4.2 K
4	Nickel 3.0 g	0.5 MPa	240°C	4.4 K
5	Nickel 3.0 g	0.5 MPa	173°C	2.1 K
6	Nickel 3.0 g	0.5 MPa	241°C	3.9 K
7	Nickel 3.0 g	0.5 MPa	173°C	1.9 K
8	Nickel 3.0 g	0.3 MPa	243°C	4.0 K
9	Nickel 3.0 g	0.3 MPa	243°C	3.9 K
10	Pd-Ni-Zr 3.0 g	0.5 MPa	238°C	6.7 K
11	Pd-Ni-Zr 3.0 g	0.12 MPa	240°C	1.5 K
12	Pd-Ni-Zr 3.0 g	0.5 MPa	244°C	10.5 K
13	Pd-Ni-Zr 3.0 g	0.3 MPa	244°C	4.0 K

hydrogen gas loading. A temperature increase of about 4 K was observed in the experiment using nickel powder and hydrogen gas.

A result of the experiment using Pd-Ni-Zr (run No. 12) is shown in Figs. 6 and 7. Figure 6 shows the time-histories of temperature for the Pd-Ni-Zr sample, with an orange line for nitrogen gas loaded and a blue line for hydrogen gas, while Fig. 7 shows the temperature rise from the control experiment with nitrogen gas loaded, i.e., the temperature difference between cases of hydrogen and nitrogen loaded. In the experiment, temperature rise began immediately after hydrogen gas loading, and the temperature rise was sustained for about 200 seconds. A temperature rise of about 10 K was observed in the experiment using Pd-Ni-Zr composite powder and hydrogen gas.

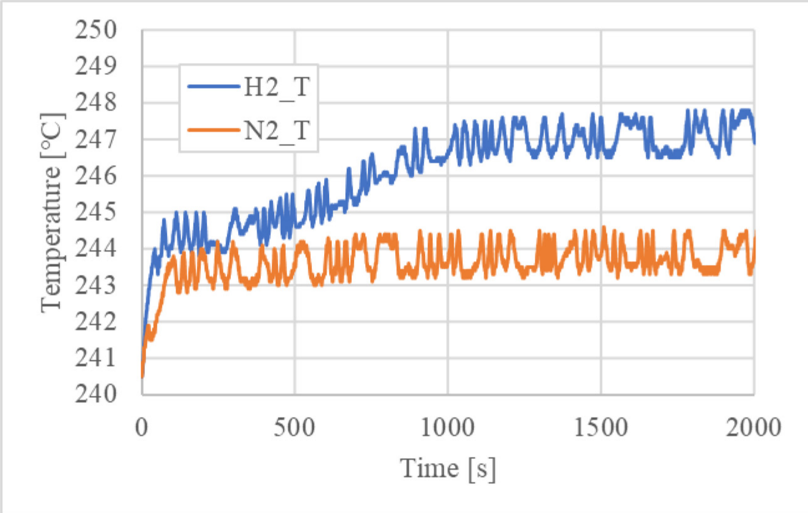

Figure 4. Result of the experiment (No. 4).

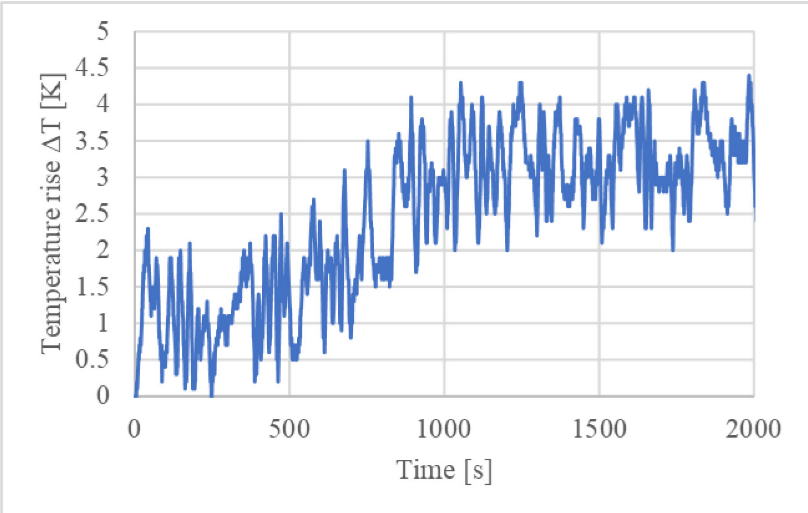

Figure 5. Temperature difference from the control experiment (No. 4).

5. TEMPERATURE AND PRESSURE DEPENDENCE OF TEMPERATURE RISE

Figure 8-10 shows the experimental temperature rise plotted against initial temperature or gas pressure. According to Fig. 8, there are positive correlations between initial temperature and temperature rise, where the correlation coefficient

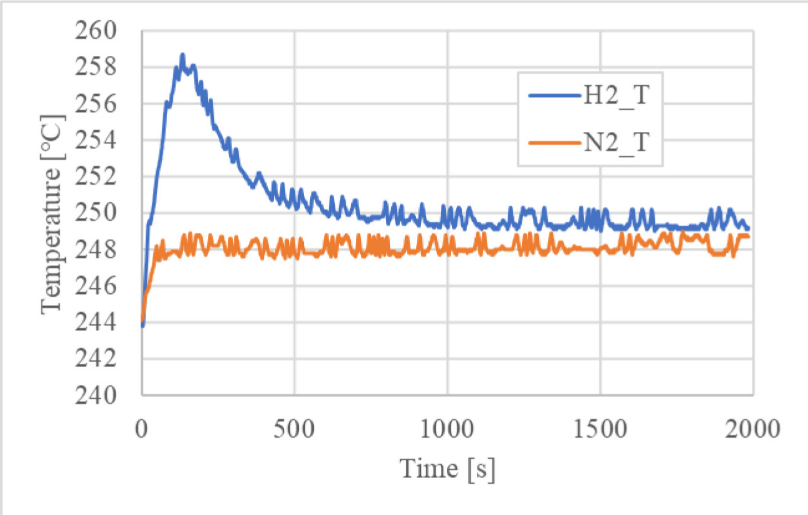

Figure 6. Result of the experiment (No. 12).

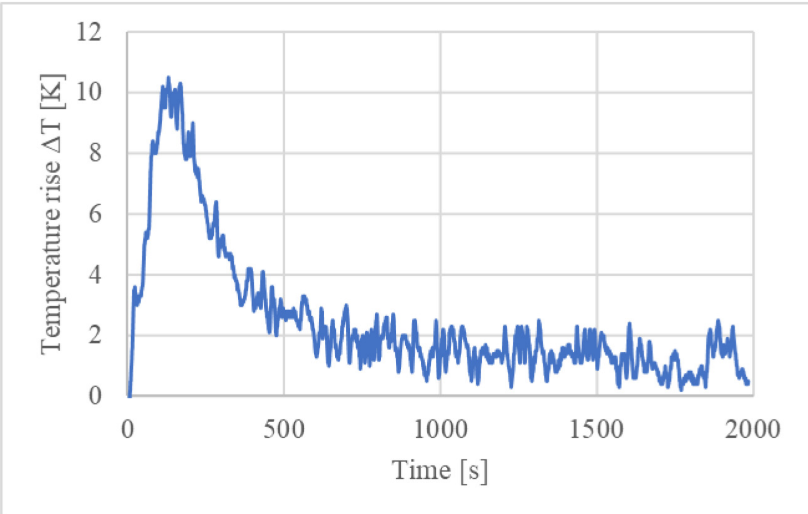

Figure 7. Temperature difference from the control experiment (No. 12).

between them is 0.95. In Figs. 9 and 10, there are positive correlations between loaded gas pressure and temperature rise, where the correlation coefficients between them are 0.84 and 0.91, respectively.

These results may show that temperature rise is assisted not only by preheating but also by gas absorption under higher pressure.

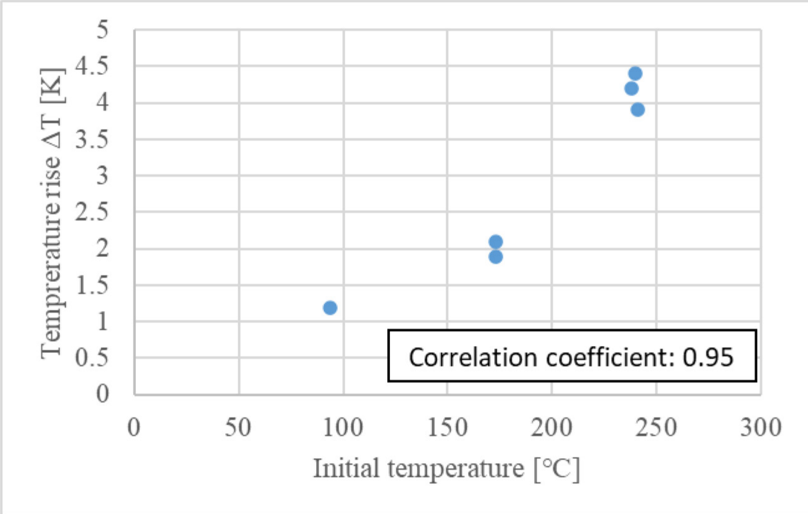

Figure 8. Result of the experiments using Ni at 0.5 MPa.

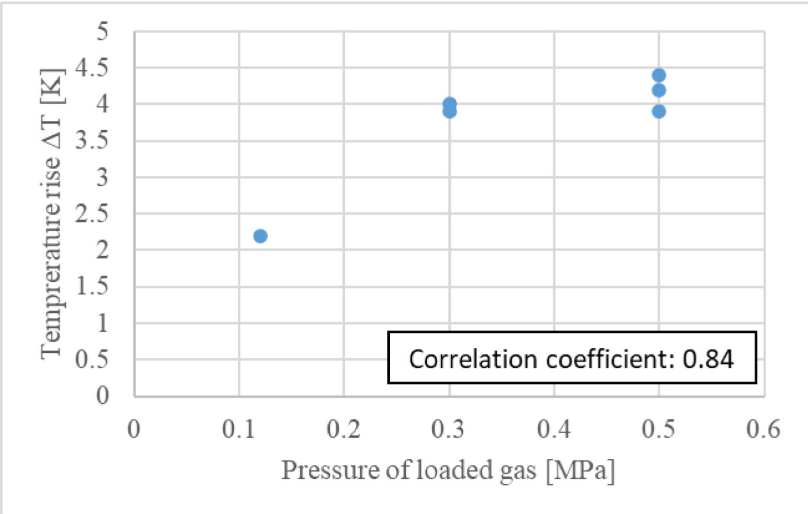

Figure 9. Result of the experiments using Ni at about 240°C.

6. CONCLUSION

We developed the small constant-volume reaction system and conducted fundamental experiments while increasing both temperature and pressure simultaneously.

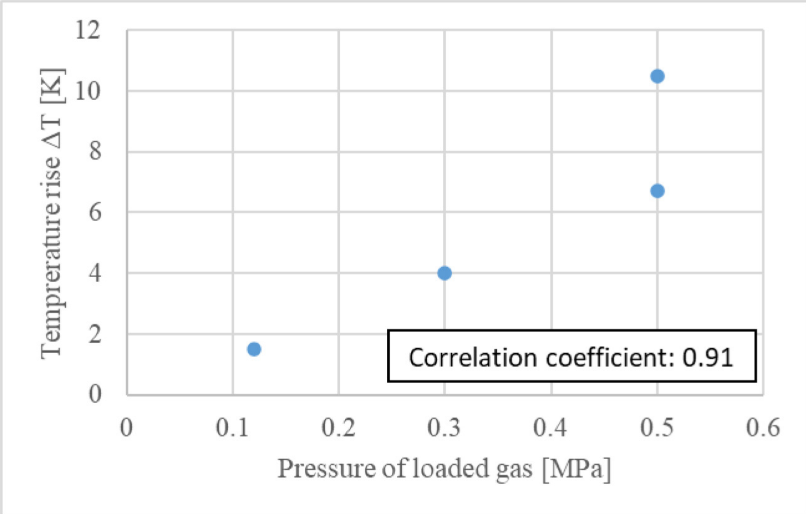

Figure 10. Result of the experiments using Pd-Ni-Zr at about 240°C.

As a result, a temperature rise of about 4 K was observed in the experiment conducted for nickel powder, continuing for about 1,000 seconds after the start of gas loading. We also conducted the experiments with Pd-Ni-Zr composite powder and about 10 K of temperature increase as maximum was observed in the experiments, until 200 seconds after the start of gas loading.

There are positive correlations between the temperature rise and both initial temperature and loaded gas pressure. This result may show that the temperature rise is assisted not only by preheating but also by gas absorption under higher pressure.

7. OUTLOOK

We developed a prototype of a high-power engine using the focusing compression due to supermulti-jets colliding with pulse [7]. This engine promotes chemical self-ignition of the fuel (hydrocarbon), because of both high temperature and high pressure around the center of the combustion chamber caused by colliding plural pulsated jets. We expect that the region of both high temperature and high pressure will also lead to anomalous heat generation if we put nickel (Pd-Ni-Zr) powder at the chamber center, while using collisions of pulsated jets of hydrogen gas. This is because the experimental results described in Sections 4 and 5, which are conducted under the condition of both high pressure and high temperature, show a possibility for accelerating the reaction in our prototype engine, which may lead to heat release larger than ordinary combustion. We are preparing to conduct some experiments using the prototype engine with hydrogen gas and nickel (or Pd-Ni-Zr composite) powder.

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