Optimum conditions of selective non-catalytic reduction by activated ammonia generated by DBD pulsed plasma

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Abstract—Selective non-catalytic reduction of NO_x by activated ammonia injection has been developed to broaden and lower the narrow temperature window for de-NO_x. A temperature window enlargement of 150 °C was achieved at the lower boundary of the window using activated ammonia injection. Hydrogen played a key role in the expansion of the temperature window in activated ammonia injection. The purpose of the present study was to investigate an optimum condition to improve the efficiency of De-NOx. The optimum conditions of de-NOx reactions was investigated by using an NH_3/H_2 gas mixture in the temperature range of 500°C—750 °C. The optimum conditions of de-NOx reaction changed by the reaction temperature. The biggest NOx removal efficiency didn't change with the reaction temperature in an optimum, and it was 80% in NH_3/NO = 1.0.

Keywords—DeNOx, SNCR, Hydrogen

I. INTRODUCTION

Recently, the establishment severe NOx concentration control of discharge starts to be put into effect for an area agreement, and which is de-NOx equipment is being needed combustion facility of the small-to-medium-sized scale of the waste incinerator. Selective non-catalytic reduction (SNCR) is wished for in a face of the installation area and the equipment cost at a burning furnace of the small-to-medium-sized scale. But there is a reaction temperature range in SNCR in a high-temperature range of 850-1175 ºC (as Temperature window) [(1)], reaction time by a high-temperature range can't be secured sufficiently by a burning hearth and an incinerator of the small-to-medium-sized scale, and there is a problem that NOx removal efficiency falls. It's desirable to install SNCR equipment in a hearth exit by an incinerator, but the hearth exit temperature is the 750 ºC degree, and it isn't possible to apply SNCR. The plan into which Temperature window is expanded on the cold side is necessary for a solution of these problem. Temperature window magnifies 150 ºC on the cold side with to inject the NH_3 excited by atmospheric pressure plasma (dielectric barrier discharge: DBD) in an exhaust gas[(2)-(3)]. There is a possibility that a burning hearth of the small-to-medium-sized scale and SNCR for incinerators can be established by using the ammonia reformed in DBD (as Reforming ammonia SNCR).

From the former study, we inferred that H_2 was the reforming ammonia chemical kind which makes promote de-NOx. The purpose of this research was to make the de-NOx effect of H_2 clear and confirm the optimum of de-NOx by H_2 addition. It was investigated about a change in the NOx removal efficiency when adding H2.

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II. METHODOLOGY

Fig. 1 shows experimental setup for SNCR with hydrogen addition. Equipment consists of model gas supply system, de-NOx gas supply system, preheating department, gas mixture office, reaction department, gold furnace and NOx, N2O, analysis installation. Gold furnace can do temperature control of a preheating department and a reaction independently respectively.

The gas to which the oxygen density (8.2%), the NO density (500ppm), the NH3 density (400 – 500 ppm) and the general flow rate (3.0 L/min fixing) were adjusted by a mass flow controller with a gas blender was supplied from the preheating part side. H_2 was injected in the gas mixture part, and after mixing with model gas, a Thermal reaction has been caused in the reaction part. The temperature of the reaction part was heated from 600 ºC to 750 ºC and the temperature was made regular. The pressure in the system was controlled in the atmospheric pressure neighborhood (103.1 ± 0.1 kPa) by the style pressure equipment.

After removing slip ammonia by an adhesion pill during dense fog so as not to affect an analyzer, the gas treated with hydrogen addition introduced into a NOx meter and N2O meter by a gas sampler with a pump and analyzed continuously. NOx removal efficiency was asked by gauging the density of NO in the reaction part temperature 500 ºC ($[NO]_{in}$) and the density of NO of whole exit gas in each experimental conditions ($[NO]_{out}$) with NOx total (Eq. 1).

$$\text{NO removal} = ([NO]_{in} - NO]_{out}) / [NO]_{in}) \times 100 \quad \text{Eq. 1}$$

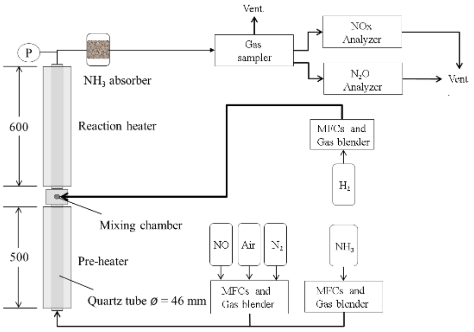

Fig. 1 Schematic diagrams of hydrogen addition De-NOx experimental apparatus

III. RESULTS

Fig. 2 shows Characteristics of NO_x removal by hydrogen addition SNCR when NH_3/NO molar ratio (M_{R1}) = 1.0. NOx removal efficiency rose by addition of hydrogen. While it was NOx removal efficiency 50% at H_2/NH_3 molar ratio (M_{R2}) = 0, in which temperature range did NOx removal efficiency also even rise in 80% by addition of hydrogen. NOx removal efficiency was rose by increasing H_2 addition amount, and after becoming biggest, it was fixed. When being equivalent in the price of the M_{R1}, the one with the high reaction temperature becomes small in the necessary hydrogen quantity. I can think you can get high NOx removal efficiency by adding H_2 beyond the most suitable H_2 amount when the amount of the NH_3 is more fixed than this thing.

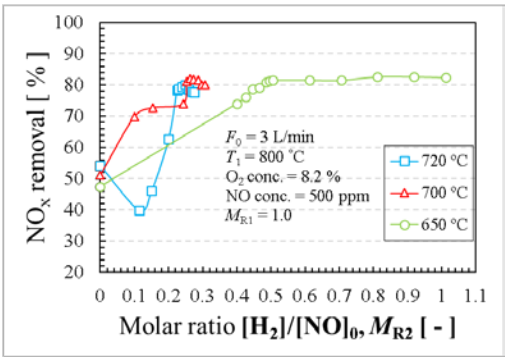

Fig. 2 Characteristics of NO_x removal by hydrogen addition SNCR

Fig. 3 shows the tendency of the optimum hydrogen amount in hydrogen addition de-NOx. It becomes so little that the price of M_{R1} is big in the same temperature range. The optimum conditions respectively by the value of M_{R1} and the temperature range. Therefore, it's important to will can find the optimal condition in the respective temperature range and M_{R1} for practical use.

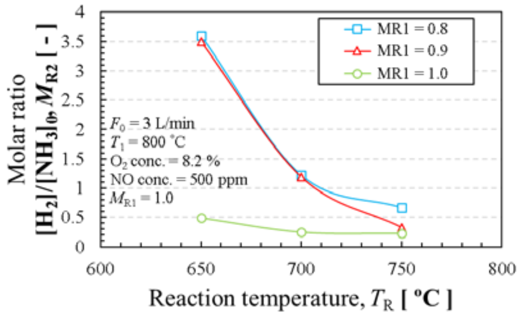

Fig. 3 The tendency of the optimum hydrogen amount in hydrogen addition de-NOx.

Fig. 4 shows comparison of the biggest NOx removal efficiency in the optimum condition. Addition of actived ammonia by plasma or H_2 made the reaction temperature range expand to the cold side. Addition of the optimum hydrogen added the de-NOx efficiency of more than 80 % of NOx removal efficiency in reaction temperature range more than 650 °C.

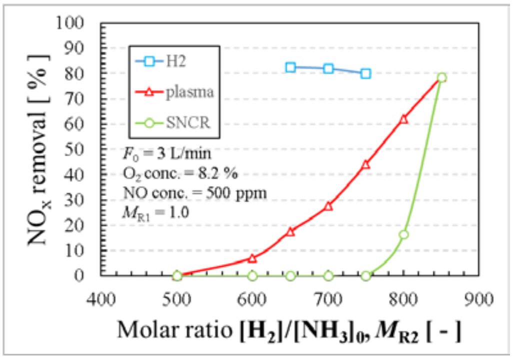

Fig. 4 Comparison of the biggest NOx removal efficiency in the optimum condition.

IV. CONCLUSION

The experiment which finds the most suitable hydrogen addition amount in hydrogen addition de-NOx was made. We found the most suitable hydrogen addition amount at MR1 = 0.8, 0.9, 1.0, TR = 650 - 750 °C. When the value of M_{R1} is fixed, the necessary hydrogen addition amount decreases with a rise of the reaction temperature. Since putting it in the same temperature range, when the value of M_{R1} becomes high, the most suitable hydrogen percentage decreases.

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