

Study on Exhaust Gas Reduction Technology for Generator

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Abstract

The energy produced through biomass, a bio-organism, is called bioenergy. Recently, the amount of biogas generated from food waste is increased, and the development of technology to deal with food waste urgent. The main ingredient fermented from food waste is more than 60% of methane, and the generation of electricity generated by using cogeneration as fuel is more than 35% of total energy. However, the amount of NOx generated in the exhaust gas discharged from the power plant using biogas is increased significantly, and a technology for reducing the amount of emission is needed. By applying De-NOx system (SCR) applied to the vehicle, the existing diesel generator was concerted and applied to the generator for bioenergy. As NOx increases, the amount of emissions increases and the temperature of the exhaust gas increases. Especially, NOx is more exhausted and the exhaust gas temperature increases as the exhaust volume increases and in order to improve the purification efficiency, an apparatus for controlling the exhaust gas temperature is required to increase the optimal purification efficiency. This paper aims to develop a technology to improve NOx reduction efficiency when applying SCR to reduce NOx generated by using methane gas in biogas engine.

Keywords: Biogas, Bioenergy, Biomass, SCR (Selective Catalytic Reduction), CH₄

1. Introduction

Biomass refers to bio-organisms, and bioenergy can produce liquid fuels such as ethanol, methanol, and bio-diesel, which are fuels, and produce gaseous fuels such as hydrogen or methane. There are various kinds of biomass on the earth, and livestock manure such as animals and plants and food waste are all possible as biomass. In its raw state, it is possible to produce thermal energy from itself. In addition, it is possible to obtain energy sources such as methane, biodiesel, hydrogen and ethanol through processing, and can be used as biodiesel automobile, ethanol fuel or fuel for power generation [1][2]. Combustion of biomass resources or biochemical processes using microorganisms or bacteria through biomass anaerobic digestion or fermentation, in particular food waste or livestock manure generates gas using bacterial while blocking air [3][4][5]. Biogas is produced from waste disposal using anaerobic digestion of organic matter. It is composed predominantly of methane, carbon dioxide, hydrogen and nitrogen, and can produce enhanced engine performance and reduce emissions compared to conventional fuel such as gasoline or diesel. Natural gas and LPG are easily obtained from petroleum-based fuels but biogas can be available in various sources for

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example, in waste organic materials. Biogas can be obtained from animal waste or plant matter such as leaves and water hyacinth. Those materials can be digested through the anaerobic process and used as energy sources so called biogas. However, large amount of nitrogen oxides are emitted when the engine is run using biofuels [6]. Two techniques are generally applied to reduce NO_x . Representative technologies are LNT (Lean NO_x Trap) and SCR (Selective Catalyst Reduction). LNT is a principle that captures NO_x in lean fuel conditions, which is a general operating area of an engine, and then discharges it in a rich fuel atmosphere to convert it into nitrogen and carbon dioxide by a catalyst. However, in the case of large diesel engines, it is difficult to apply LNT because it is difficult to create rich conditions unlike gasoline engines. In addition, the use of fuel as a reducing agent causes deterioration of fuel efficiency and increase of CO_2 , and is a device suitable for small passenger cars. SCR is a catalyst that selectively reduces NO_x in exhaust gas, and most of urea water is used as a reducing agent [7][8][9][10]. In case of industrial engine with constant driving condition, ammonia is used as a reducing agent. However, if driving condition changes every time like a car, the use of ammonia can release the remaining ammonia to the atmosphere, which can be harmful to the human body and environment. In the SCR system, when urea water is supplied from the top of the catalyst, part of the urea water is separated into an ammonia component and occluded in the storage material. Thereafter, the NO_x component and the oxygen contained in the exhaust gas are selectively reacted and converted into N_2 and H_2O . SCR has better purifying ability and stable purifying performance than LNT, but if the proper injection of urea water is not controlled according to the engine condition, unreacted ammonia is discharged, causing secondary pollutants. On the other hand, because nitrogen oxide is very sensitive to high temperature, it is also important to lower the temperature of the exhaust gas. To reduce this, SCR and coolers were introduced. This study aims to develop a technology to improve the NO_x reduction efficiency when applying SCR to reduce the nitrogen oxides generated by using methane gas in biogas engine.

2. Experiment

2.1. Experimental set up

Fermentation of foods generated from wastes generates biogas stored in storage tanks and then sulfuric acid of less than 10ppm is produced through a desulfurization facility and supplied to the engine. The engine applied is 350KW diesel engine, which was used for biogas, and the actual output is 200KW. SCR was applied as a post-treatment device, and a De- NO_x system equipped with a thermostat that lowers the temperature of exhaust gas from the 200KW engine by using a gas cooler at a temperature of about 400°C . A detailed schematic is shown in [Figure 1]. An SCR device is introduced to remove nitrogen oxides contained in the exhaust gas emitted from the generator. In order to reduce NO_x through the SCR device, the optimum urea water and the optimal amount of air stored in the urea water storage tank are injected from the front end of the SCR through the urea water injection module through the urea water injection system. The injected urea water reduces nitrogen oxides by reducing the NO_x contained in the exhaust gas. Excessive injection of urea can induce fine dust, so optimal urea injection technology is important. In order to reduce nitrogen oxide in the commercial generator (200KW), the nitrogen oxides were measured after the SCR was installed, and the temperature, pressure and nitrogen oxides concentration before and after the exhaust manifold measured according to the measurement conditions.

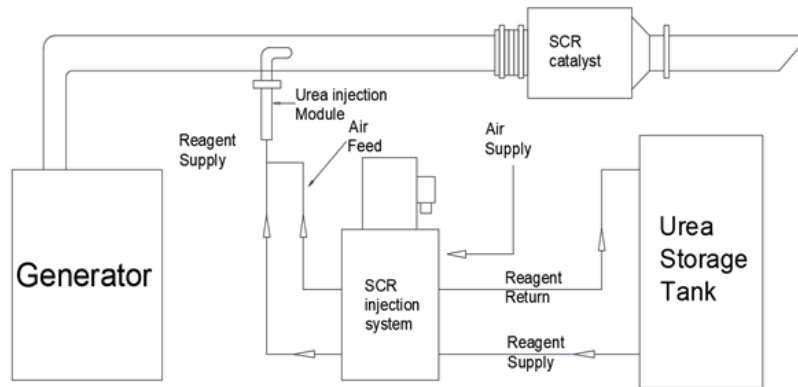


Figure 1. Schematic diagram for over-all emission reduction system

2.2. Biogas fuel composition

The components of biogas fuel generated from food waste used as fuel are shown in the [Table 1] after desulfurization of biogas.

Table 1. Biogas fuel property and composition

Property of composition		Unit	Index
Gas amount		Nm ³ /h	854
Temperature		°C	35
Pressure		mmAq	1500
Gas composition	CH ₄	%	64.81
	H ₂ O	%	0.93
	O ₂	%	0.27
	CO ₂	%	33.98

2.3. SCR Reaction Process

Urea liquid is injected into NO_x contained in the exhaust gas and converted into harmless N₂ and H₂O. The reaction process is as follows [Figure 2]. After fermenting the food waste, the sulfur contained in 3~4ppm is desulfurized and the generated biofuel is used as generator fuel. At this time, the exhaust gas discharged from the manner folder is sent to the DOC catalyst after lowering the exhaust temperature through a cooler and a fan. Purification efficiency of nitrogen oxide contained in exhaust gas is improved by injecting urea using metering pump before SCR catalyst and the process was shown in [Figure 3]. When low-sulfur (3-4 ppm) biogas obtained from food waste is supplied to the bio-engine, the engine is operated and the exhaust gas is emitted. In order to reduce the exhaust gas, harmful emissions are reduced by sequentially passing through DOC, SCR, and AOC catalysts. Among them, AOC (Ammonia Oxidation Catalyst) is a post-treatment device to prevent urea water remaining after urea water is injected into the SCR and reduced. In addition, a gas cooler was installed in front of the DOC (Diesel Oxidation Catalyst) to reduce the exhaust gas temperature.

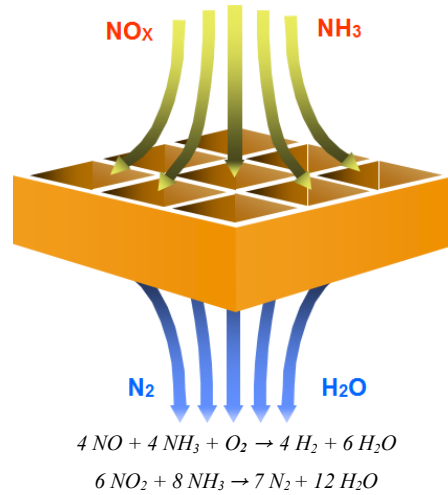


Figure 2. Chemical reaction process in SCR catalyst

3. Experimental results

3.1. Urea liquid consumption

In order to supply urea liquid, a quantitative flow pump is used, which is a pressure controlled pump. The Y-axis represents the flow rate supplied at the flow rate (cc/min), and the X-axis represents the flow rate along the scale by dividing the mechanical flow control of the pump by 4 scales and shown in [Figure 4]. In the generator capacity of 200KW, the exhaust temperature was 300°C, and the proper urea liquid supply amount was 15cc/min with the frequency of 30Hz and the scale fixed at 2.5 [Table 2].

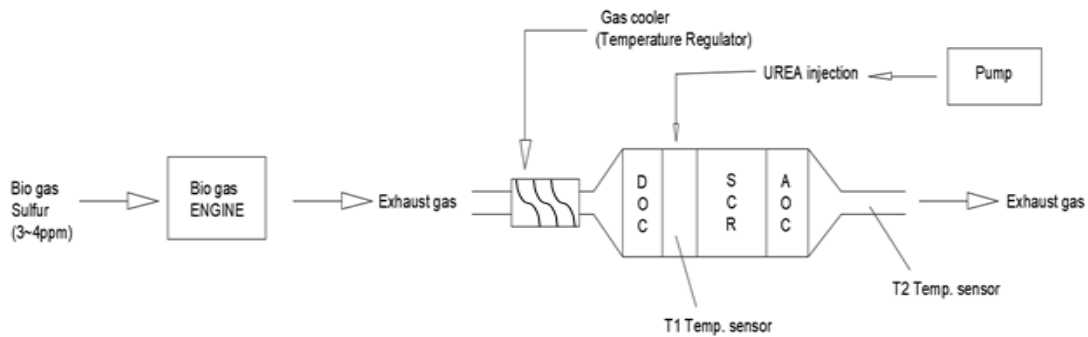


Figure 3. Purification process from SCR catalyst

The experiment was carried out to measure the generation of nitrogen oxide after installing SCR to reduce nitrogen oxide in commercial generator (200KW), and to measure the temperature, pressure and concentration of nitrogen oxide before the after the exhaust manifold according to the measurement conditions. It was necessary to confirm the presence of muffler as a factor that could affect the back pressure among the measurement conditions.

And to reduce the exhaust gas temperature, fan and urea liquid method were applied, and the experimental conditions were separated for the application of urea liquid according to SCR application. The experiment was conducted several times in order to create an optimal temperature condition with the maximum purification efficiency. The temperature and pressure are important parameters for exhaust gas purification in the front and near stages of SCR device, a nitrogen oxide reduction device, and the nitrogen oxide was measured at 190ppm. The optimal cooling temperature is realized at 300~350°C.

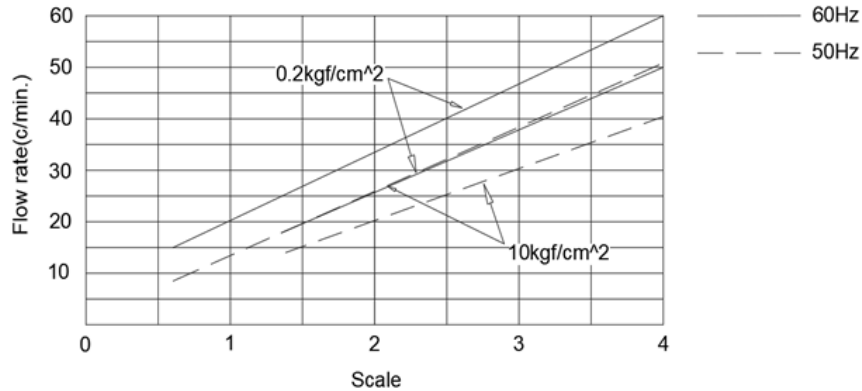


Figure 4. Flow rate of urea liquid by using a quantitative flow pump at 50Hz and 60Hz

Table 2. Urea consumption by engine load

Engine Load (KW)	Temp. (°C)	Cycle (Hz)	Scale	Urea amount (cc/min)
200	300	30	2.5	15

3.1. Effect of NO_x reduction by applying SCR, Fan and Cooler

The exhaust temperature of 200KW bio-engine is 400°C and the nitrogen oxide concentration at that time was 190ppm. As a result of applying the cooler and SCR device, the temperature dropped to 360°C and the nitrogen oxide concentration at that time was 70ppm. As a result, the temperature of nitrogen oxide concentration was 15ppm and the overall optimum purification efficiency was 92% and the summary was shown in [Table 3].

Table 3. Applying device and NO_x reduction

Applying Device	NO _x Concentration (ppm)	Emission Temp. (°C)
Exhausted Emission	190	400
SCR	90	400
SCR +Cooler	70	360
SCR+Cooler+Fan	15	300

4. Conclusion

The biogas engine was operated using biogas from food waste and SCR was introduced to reduce nitrogen oxides from biogas engines. It was found that the reduction efficiency of nitrogen oxides depends on the exhaust gas temperature and the amount of urea applied to the SCR. In order to apply SCR technology, the optimum urea injection amount was experimentally determined. In addition, since the amount of nitrogen oxides increased at high temperatures, a heat exchanger equipped with a cooling fan was installed to lower the temperature of the nitrogen oxides. At engine load 200KW, the NO_x reduction efficiency was about 90% at 300~350°C. Injected urea liquid was used to identify changes in the purification efficiency that varied with injection flow rate. Therefore, it was confirmed that nitrogen oxide can be reduced by applying a De-NO_x system of SCR and a cooling device to commercial biogenerators.

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