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The Effect of Emission Control Using Electrolytic Seawater Scrubber

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Abstract : It is well known that SOx and NOx concentration has a considerable influence on the N_2O emission of the greenhouse gas properties. The quantity of SOx generated during combustion, on fuel specific basis, is directly related to the sulfur content of the fuel oil. However, restricting the fuel oil sulfur content is only a partial response to limiting the overall quantity of SOx emissions, as there remains no over control on the fuel oil consumption other than the commercial pressure which have always directed the attention. This study was carried out as a new basic experiment method of emission control, manly targeted to the vessel. In the experiment, where the scrubbing was achieved through spray tower with high alkaline water made from the electrolysis of seawater, the combined action was to neutralize the exhaust gases (SOx, PM, CO etc.), dilute it, and wash it out. The results showed that SOx reduction of around 95 percent or over could be achieved when using in the high alkaline water, and also leaded to a reduction in the stability of the each pollutant components including the PM (Particulate Matter). The results suggest that the seawater electrolysis method has a very effective reduction of emissions without heavy cost, or catalysts particularly on board.

Key words : Heavy Fuel Oil, Electrolysis, Emission, Scrubber, Seawater

1. Introduction

The world fleet is currently in excess of 85,000 ships over 100 gross tonnage of these over 99 percent are motor vessels[1]. Consequently, it is the emissions from diesel engines which form the bulk of the overall air pollution from marine combustion machinery. Now, the seawater scrubber to remove the SO_2 and SO_3 by absorption on board is an interesting possibility, but as with the SCR (Selective Catalytic Reduction) system to control NOx emission, the highly desirable removal efficiency of 90 percent or over would be largely accompanied by costs[2][3]. The effectiveness of these systems, which is achieved through directed contact with seawater (pH typically around 8.1), may rely mainly on the cooling and washing actions in the exhaust gas stream[4][5]. However, considerably less work has been on the effect of alkalinity on the emission control. So there has been renewed interest in our laboratory in the

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neutralizing chemical action of flue gas with using alkaline by the electrolysis of seawater on board.

2. Experimental apparatus and method

Fig. 1 shows the schematic of the experimental apparatus that we set up for exhaust gas scrubbing with using the electrolytic of seawater, which Fig. 2 shows an example of it. The combustor, at left side of the Figure, allows the several hundred cSt (50℃) of heavy fuel oil to be combustible, the fuel oil combustion rate is 11~13 kg/hr, and the calorific capacity is about 50,000 kcal/hr. The combustion conditions are as follows ; the flow rate of fuel oil 12.3 ℓ/hr, the injection pressure of fuel oil 22.0 kg/cm^2, the heating temperature of fuel oil 140℃, the combustion air pressure from 80 to 120 mmAq, the air excess ratio (λ) from 1.96 to 1.25. The specification used fuel oil is shown in Table 1. First, the exhaust gas from the combustor flows directly the spray tower of alkaline water via funnel, and the cleaned gas is discharged into the atmosphere after scrubbing. The reaction water, therefore, is sprayed to counterflow of the exhaust stream. In this case, the exhaust gas amount is about from 3.6 to 5.6 m^3/min as with the air excess ratio, and the reaction water is fed only 0.5 percent(0.02~0.03 m^3/min) of it in the scrubber, while decreased from pH 9.9 to pH 2.7 in usual. The pollutants of SO_2, PM (DS, SOF), NOx, CO and CO_2 with the exhaust gas temperature were measured at the each of three positions – the combustor outlet, the scrubber inlet and the scrubber Outlet. Generally, about 10 minute was required by the measuring to arrive at stability for each sample.

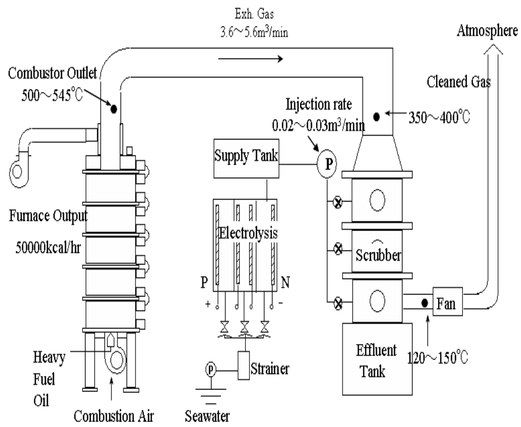

Fig. 1 Schematic of experimental apparatus

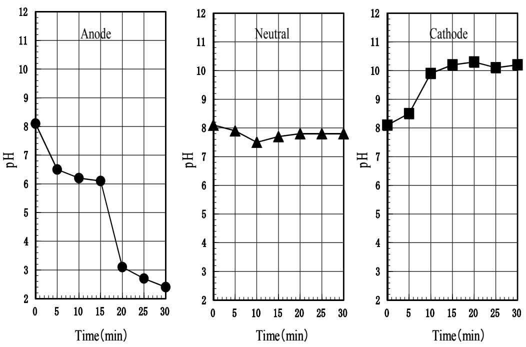

Fig. 2 Electrolysis of seawater (3.5A, 10V, 13.0 ℓ/min)

Table 1 Property of heavy fuel oil

Density	g/cm^3	0.982
Flash Point	℃	74.0
Kinematic Viscosity(50℃)	mm^2/sec(cSt)	177.0
Pour Point	℃	-10.0
Residual Carbon	mass%	12.3
S	mass%	2.56
H_2O	vol%	0.50
Ash content	mass%	0.02
High Calorific Value	MJ/kg	42.780

3. Results and discussion

First, to compare the SO_2 concentrations of exhaust emissions, the SO_2 and the exhaust gas temperature are measured by stepping the quantity of combustion air and holding the fuel oil rate 12.3 ℓ/hr. Fig. 3 shows that the exhaust gas temperature is decreased, but SO_2 concentration is increased according to the quantities and pressures of the combustion air. In any conditions, SO_2 washed and neutralized by the alkaline water in the scrubber is lowered by at least 95 percent. Despite the low quantity of the reaction water (0.5%) like the previous described, the high effectiveness of its reduction is ascribed to the restoration reaction by means of a positive ion from the electrolysis of seawater. The system is thus smaller and lighter, which means such aspects as the reaction water supply rate requirements can be reduced.

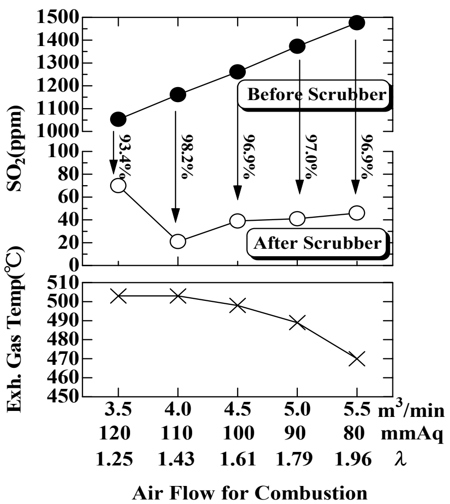

Fig. 3 Effect of SOx reduction

From the following, the results of each pollutants after the scrubber are described the effect of the different alkalinity on the extent of the washing, neutralizing and diluting. First, as shown in Fig. 4, the SO_2 concentration is reduced from around 1250 ppm to about between 180 ppm and 10 ppm. The alkaline water at over pH 9 particularly increases the dissociation of the SOx oxides. NOx concentration is reduced from around 260 ppm to 70 ppm on an average, even though the results respectively have the variance as shown in Fig. 5. It seems to be sufficient to reduce or dilute NOx with using the any reaction water.

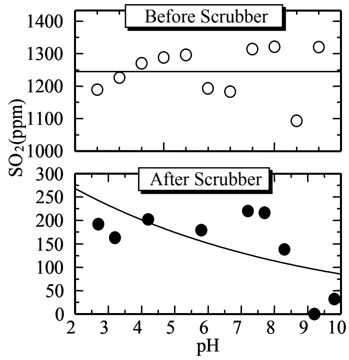

Fig. 4 SO_2 reduction versus alkalinity

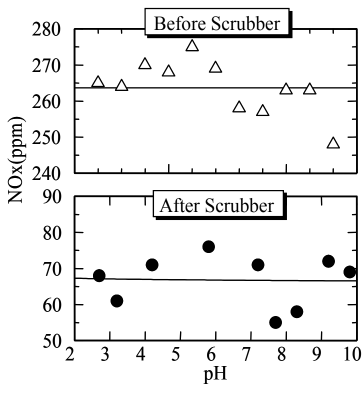

Fig. 5 NOx reduction versus alkalinity

Fig. 6 and 7 respectively show CO and CO_2 concentrations washed and diluted by the reaction water. The both are leaded to a reduction in the stability of the each pollutant components, and it unexpectedly shows that raising the alkalinity decreases CO concentration. It is supposed that a portion of themis inactivated at the temperature of the reaction mixture to some degree.

Finally, it has generally been expressed that the hydrocarbon and particulate matters could have a detrimental environmental effect. Fig. 8 and 9 respectively show SOF and DS quantities washed and dissolved by the reaction water. In any case, SOF is dissolved nearly 100 percent, and also DS is washed out around 50 percent.

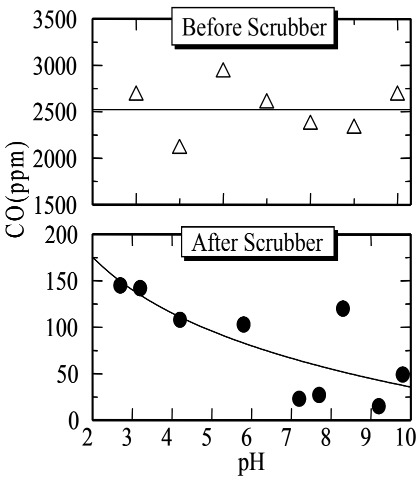

Fig. 6 CO reduction versus alkalinity

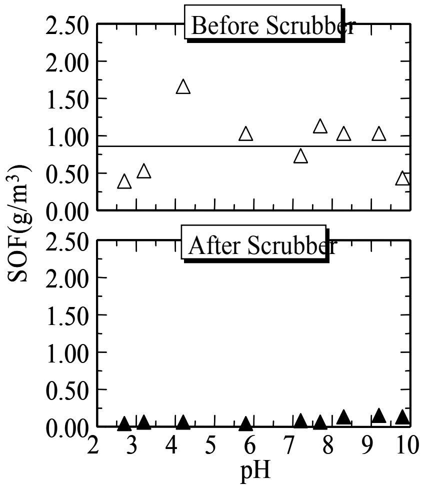

Fig. 8 SOF reduction versus alkalinity

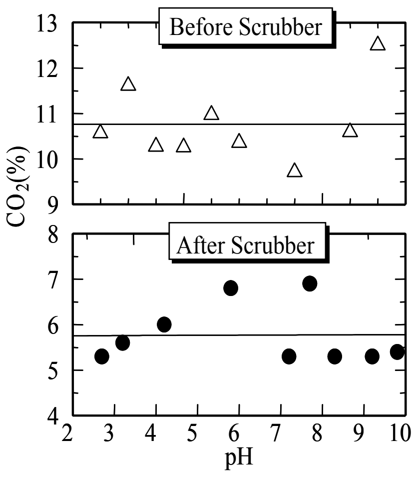

Fig. 7 CO_2 reduction versus alkalinity

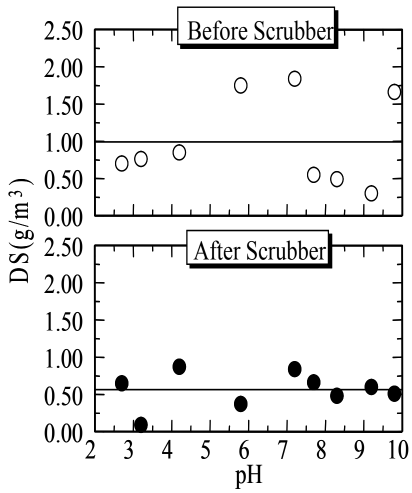

Fig. 9 DS reduction versus alkalinity

4. Conclusion

This experiment was directed toward identification of the effects of alkalinity on flue gas in the hope that the result would yield information on the useful possibility of seawater electrolysis on board. The results showed that the desulfurization of around 95 percent or over could be achieved when using in the high alkaline water, and also leaded to a sufficient reduction in the stability of the each pollutant components and particularly the SOF of PM (Particulate Matter). Furthermore, the advantages of seawater applying on board include the fact that the operation would be possible without need to capital investment as with high emission control effectiveness.

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