

Research Article

NO Removal from Simulated Diesel Engine Exhaust Gas by Cyclic Scrubbing Using NaClO₂ Solution in a Rotating Packed Bed Reactor

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Experiments were conducted to remove NO from simulated flue gas in a rotating packed bed (RPB) reactor with NaClO₂ as wet scrubbing oxidant and diesel exhaust gas as carrier gas. The effects of various operating parameters (rotational speed, solution pH, NaClO₂ concentration, liquid-gas ratio, and NO and SO₂ concentrations) on NO removal performance were investigated preliminarily. The results showed that with the increase of rotational speed, oxidant concentration, and liquid-gas ratio, NO removal efficiency increased obviously. NO removal efficiency increased largely with the decrease of solution pH, and a complete removal of NO could be attained at pH 4. NO concentration imposed little effect on NO removal efficiency while coexisting SO₂ in exhaust gas could enhance NO_x removal greatly.

1. Introduction

Around the world, more than 80% of trade cargos are transported through shipping, and ocean-going ships have made great contributions to the development of world economy [1]. However, marine low-speed two-stroke diesel engines in operation emit a large amount of air pollutants, such as SO_x, NO_x, and PMs [2], which cause serious damage to atmospheric environment [3, 4]. Since more and more stringent environment regulations on marine pollutant emission come into force, global ship owners are under great pressure to take measures to abate the emission of exhaust gas pollutants [5]. At present, a number of De-SO_x and De-NO_x technologies have been developed for large vessels [3]. Some wet flue gas desulphurization (WFGD) techniques have been successfully applied on board to remove SO_x effectively [6]. Though selective catalytic reduction (SCR) and exhaust gas recirculation (EGR) are two relatively mature De-NO_x methods for marine diesel engines [7] and their NO_x challenges efficiencies are high enough, there are

still some problems limiting their large-scale applications. Especially when they combine with De-SO_x techniques to simultaneously remove SO_x and NO_x from marine exhaust gas, such an integrated system is bound to have the disadvantage of large volume, high cost, and complex operation [8, 9].

For ocean-going ships, an exhaust gas posttreatment system with small size and low energy consumption is of great potential. Aiming to integrate with the wet desulphurization process in order to simultaneously remove SO_x, NO_x, and PMs, various wet De-NO_x methods have been researched extensively during the past decades [10, 11]. Generally, NO accounts for more than 95% of NO_x in diesel exhaust gas, but its solubility is very low [12, 13]. Therefore, one of the key points for wet De-NO_x methods is to intensify mass transfer reactions at the liquid-gas interface. At present, a lot of additives such as Fe^{III}-EDTA [14, 15], H₂O₂ [16], KMnO₄ [17, 18], O₃ [19, 20], NaClO [21, 22], NaClO₂ [23–25], ClO₂ [26, 27], and persulfate (PS) [28] have been used to improve NO solubility or to oxidize NO into other

higher valence NO_x . Among them, NaClO_2 is found to be one of the most efficient chemicals for NO oxidation due to its strong oxidation power [24, 25]. In recent years, a lot of experiments have been carried out to investigate NO_x removal performance with NaClO_2 as oxidant, most of which are based on conventional reactors, such as packed column [29], spray reactor [23], bubble column [30], etc. Although a satisfactory NO_x removal efficiency could be obtained based on these conventional scrubbers, the reactor sizes are still comparatively large for applications on board. A compact scrubber with high pollutant removal performance is preferable for ships due to the limited space and resources on board. Thus, it is of great meaning to develop a novel wet scrubbing process with NaClO_2 as an oxidant and a compact scrubber as a reactor to remove NO_x efficiently.

The rotating packed bed (RPB) reactor is a kind of Higee technology, and it has some advantages in gas-liquid reaction applications due to its small size and high mass transfer efficiency. The high gravity environment in a RPB reactor can be created through centrifugal force by rotor rotation. A large number of liquid droplets, films, and ligaments will be generated by the shearing function of the high-speed packing in the rotor. So, it could intensify the gas-liquid mass transfer and micromixing efficiency up to 1–3 orders of magnitude larger than that in a conventional packed column [31]. Thus, RPB reactors can be widely used in gas-liquid reaction processes, such as distillation [32], wastewater treatment [33], SO_2 removal [6], and CO_2 capture [34]. Some experiments have also been done to remove NO_x from flue gas by wet scrubbing method based on RPB reactors in recent years. Zhang et al. adopted a RPB reactor for the first time to remove NO from flue gas by wet scrubbing using $\text{Fe}^{\text{II}}(\text{EDTA})$ solution [14]. Sun et al. proposed to oxidize NO into NO_2 with ozone for the first step and then absorb NO_x efficiently by wet scrubbing using NaOH solution in a RPB reactor [35]. The results indicated that the hydrolysis reactions of NO_x were the rate-determining steps in the NO_x absorption process, and thus, they are the main factors hindering NO_x removal during the wet scrubbing process. The pioneering work indicates that RPB reactors have great potential in NO_x removal application through a wet scrubbing process in view of their small size, low temperature, and short gas retention time.

To the best of our knowledge, the investigation on NO removal by wet scrubbing using NaClO_2 solution in a RPB reactor is few. In this paper, a series of preliminary experiments were conducted to study NO_x removal from simulated diesel exhaust gas by cyclic wet scrubbing using NaClO_2 solution in a RPB reactor. The effects of various operating parameters such as rotational speed of RPB rotor, pH value of absorbent solution, NaClO_2 concentration, liquid-gas ratio, and NO and SO_2 concentrations on NO_x removal performance were investigated. Also, the relevant reaction mechanism had also been discussed.

2. Experimental

2.1. Materials. The reagents of sodium chlorite (NaClO_2) powder, sodium hydroxide (NaOH), and hydrochloric acid (HCl) were purchased from Aladdin Co., Ltd. Deionized

water was prepared in a two-stage ELGA PURELAB Option R15 purification system and had a resistivity of 15 $\text{M}\Omega\cdot\text{cm}$. NO (purity of 99.9%) and SO_2 (purity of 99.9%) pure gases were purchased from Dalian Special Gases Co., Ltd.

2.2. Experimental Setup and Procedures. The experimental system for NO_x removal is schematically shown in Figure 1. The exhaust gas emitted from a turbocharged diesel engine (6105AZLD, 121 kW) was used as the carrier gas. The diesel engine idled in operation during the whole working process. The inherent pulsation of diesel exhaust gas was alleviated through the exhaust manifold and a long pipeline. Both flow rate and temperature of exhaust gas were stable in the tests. The gas flow was $\sim 280 \text{ m}^3/\text{h}$, and the temperature of exhaust gas measured at inlet port of the RPB reactor was $\sim 100^\circ\text{C}$. Note that NO, NO_2 , and SO_2 concentrations in initial diesel exhaust gas were measured to be ~ 200 ppm, 70 ppm, and 0 ppm, respectively. For each test, the concentrations of NO and SO_2 at inlet port of the RPB reactor were adjusted by injecting NO and SO_2 pure gases into the carrier gas. The injection rates of NO and SO_2 pure gases were regulated by flowmeters. An infrared multigas analyzer (MRU MGA5, Germany) was used to measure the concentrations of NO, NO_2 , SO_2 , O_2 , and CO_2 .

The RPB reactor was made of stainless steel, and its specifications and the operating conditions are shown in Table 1.

Firstly, the exhaust gas emitted from the diesel engine passed through a vortex-shedding flowmeter (2), and then it was mixed with injected NO and SO_2 pure gases. Typical NO concentrations in marine diesel exhaust gas were in the range of 500–1500 ppm. Since the flow rate of exhaust gas was comparatively high in our tests, an initial NO concentration of 500 ppm was chosen as the basic condition to simulate marine diesel exhaust gas in order to reduce the usage of NO feed gas. After exhaust gas enters the RPB reactor, it would contact with the absorbent solution in the packing in a concurrent way which was in favor to reduce the back pressure loss. The gas analyzer was used to determine the concentrations of NO, NO_2 , and SO_2 in exhaust gas at inlet and outlet ports of the RPB reactor.

For each test, 30 L absorbent solution was used in a cyclic way through a circulating pump. Since gas flow rate was kept unchanged, the liquid/gas ratio could be adjusted by the regulating valve (8) to change the liquid flow rate. Note that there was heat transfer between exhaust gas and scrubbing solution in the RPB reactor during the cyclic scrubbing process, and the circulating solution would be heated from the room temperature to 35°C after running for several minutes. So, the absorbent solution was heated to 35°C before the start of each test, in order to reduce the fluctuation of scrubbing solution temperature during the whole test. 1 mol/L HCl solution or 1 mol/L NaOH solution was used to adjust the initial pH values of absorbent solutions. Considering that the absorbent solution pH would vary obviously with the proceeding of the cyclic scrubbing process, 1 mol/L NaOH solution was continuously titrated into the scrubbing solution to maintain pH values of absorbent solutions at the set values during the whole tests.

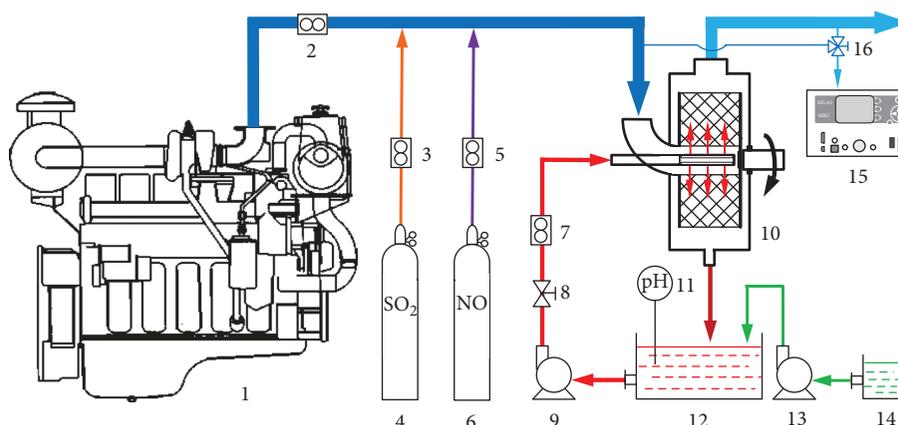


FIGURE 1: Schematic diagram of the experimental system. 1: diesel engine; 2, 3, and 5: gas flowmeters; 4: SO₂ cylinder; 6: NO cylinder; 7: liquid flowmeter; 8: regulating valve; 9 and 13: pumps; 10: RPB reactor; 11: pH electrode; 12: scrubbing solution; 14: alkaline solution; 15: gas analyzer; 16: three-way valve.

TABLE 1: The specifications and operating conditions of the RPB reactor.

Items	Values
Packing type	Stainless steel wire mesh
Inner diameter of packing (mm)	100
Outer diameter of packing (mm)	280
Height of packing (mm)	200
Volume of packing	0.43 m ³
Fiber diameter of packing (mm)	0.20
Voidage of packing	0.97
Specific surface area of packing	1500 m ² /m ³
Rotational speed (rpm)	200–1000
Gas flow rate (m ³ /h)	280
Liquid flow rate (L/h)	600–1400
Liquid/gas ratio (L/m ³)	2.1–5.0

NO oxidation efficiency and NO_x or SO_x removal efficiency of η could be calculated as follows:

$$\eta = \frac{(C_{in} - C_{out})}{C_{in}} \times 100\%, \quad (1)$$

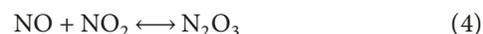
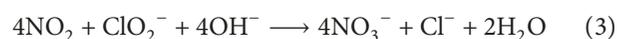
where C_{in} is the concentration of inlet NO or NO_x or SO_x in ppm and C_{out} is the concentration of outlet NO or NO_x or SO_x in ppm. Here the concentration of NO_x refers to the sum of NO and NO₂ concentrations.

3. Results and Discussion

3.1. Effect of Rotational Speed of RPB Rotor. Firstly, experiments were conducted to investigate the effect of rotational speed of RPB rotor on NO_x removal performance, and the results are shown in Figure 2. The basic conditions are as follows: the flow rate of diesel exhaust gas was about 280 m³/h, the gas temperature at the inlet port of the RPB reactor was about 100°C, NaClO₂ concentration in 30 L solution was 0.20 mol/L, the flow rate of absorbent solution was set at 1000 L/h, and the absorbent solution temperature was maintained at 35°C. During the cyclic scrubbing process, absorbent solution pH was kept at 6 by adding

NaOH solution continuously. Inlet NO, NO₂, and SO₂ concentrations in diesel exhaust gas were 500, 100, and 0 ppm, respectively.

As shown in Figure 2, with rotational speed increasing from 200 rpm to 1000 rpm, outlet NO concentration decreased obviously from 240 ppm to 130 ppm while outlet NO₂ concentration increased from 189 ppm to 224 ppm. When RPB rotational speed was 1000 rpm, NO oxidation efficiency was 74%. The results suggested that NO could be oxidized efficiently in the RPB reactor. During the cyclic scrubbing process, the absorbent solution entered into the rotating packed rotor and collided to the porous packing violently; then, a great amount of fine liquid droplets, films, and filaments were formed, which had a large gas-liquid effective interfacial area. So, the reactions between NO and absorbent solution mainly took place at the gas-liquid interface in the packing of the RPB reactor. Since the absorbent solution had a fast interface renewal rate in the packing, it intensified the mass transfer process greatly [35]. The oxidation and absorption of NO_x by NaClO₂ solution mainly takes place through the following equations [36]:



On one hand, the increase of rotational speed would reduce the retention time of absorbent solution in the packing, thus limiting the absorption of NO_x. On the other hand, it will also result in a high running cost. This effect might counteract the abovementioned benefits of high rotational speed and lead to a relatively stable NO_x removal

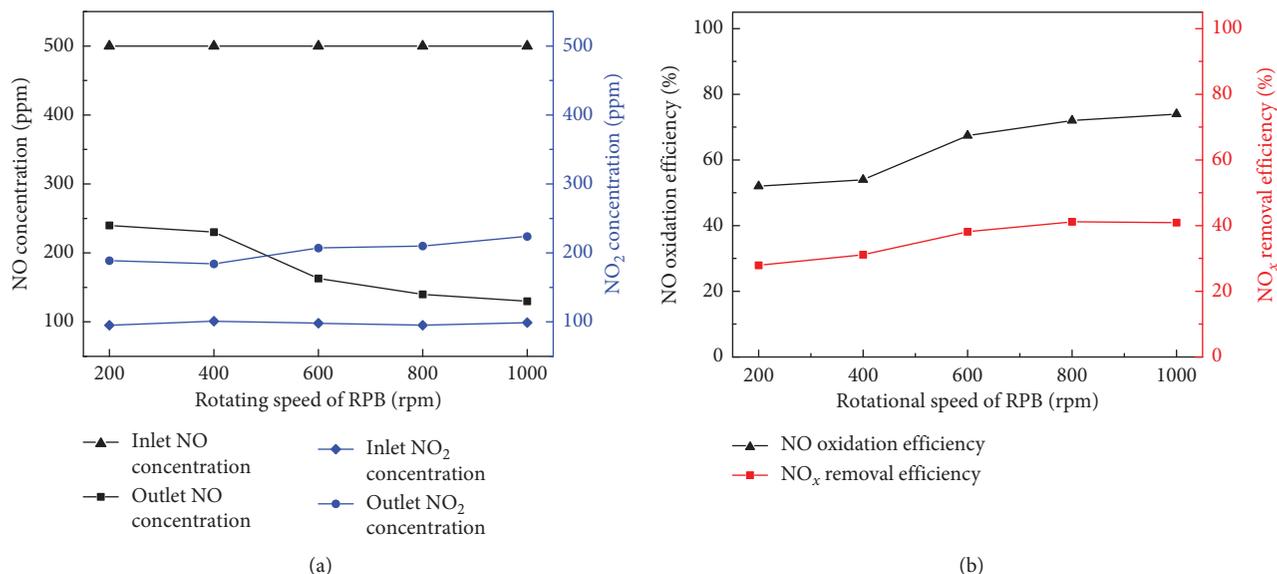


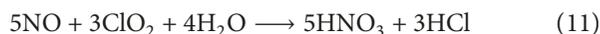
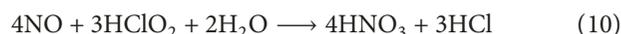
FIGURE 2: Changes of NO_x concentrations at inlet and outlet ports of the RPB reactor (a) and NO_x removal efficiencies (b) with rotational speeds.

efficiency. So, outlet NO concentration decreased only a little when rotor speed increased from 800 to 1000 rpm. In addition, when rotational speed was 1000 rpm, the increment of inlet and outlet NO₂ concentrations was 124 ppm, which was much smaller than the decrement (370 ppm) of inlet and outlet NO concentrations. It implied that NO could be oxidized efficiently during the cyclic scrubbing process while the hydrolysis of NO_x was the key factor that hindered NO_x removal efficiency obviously.

3.2. Effect of Solution pH. It is known that solution pH is a crucial parameter for NO removal during the wet scrubbing process. For practical application, cyclic scrubbing method is usually adopted to clean flue gas, in which it is necessary to maintain the solution pH in a certain range with the proceeding of the scrubbing process. In our experiments, the absorbent solution pH was kept at set values by adding NaOH solution continuously during the scrubbing process. The effects of absorbent solution pH on NO_x removal performance had been investigated, and the results are shown in Figure 3. The basic experimental conditions are the same with the abovementioned ones except that the rotational speed of RPB rotor was set at 800 rpm, and the absorbent solution pH was in the range of 4–12.

As shown in Figure 3, the lower the absorbent solution pH was, the less NO left in outlet gas was. With solution pH decreasing from 12 to 4, NO oxidation efficiency increased from 8.4% to 100%. The results showed that NO oxidation ability of absorbent solution increased with the decrease of solution pH, and NaClO₂ solution in strong acidic ambient exhibited extreme high oxidation power. That is because the effective compositions in NaClO₂ solution are available chlorine or active chlorine species, which mainly consist of HClO₂, ClO₂, and ClO₂⁻ [30]. The oxidative power for these active species is in the order of HClO₂ > ClO₂ >> ClO₂⁻. The

fractional compositions of active chlorine species in NaClO₂ solution vary largely with solution pH [24]. Thus, HClO₂ and ClO₂ are generally considered as the effective substances to effectively oxidize NO into NO₂ [30]. Since the fractional compositions of HClO₂ and ClO₂ would become much more with solution pH decreasing from 12 to 4, it results in an increase of NO oxidation rate. The relevant reactions are presented as follows:



It can be seen from Figure 3(a) that with solution pH decreasing from 12 to 6, NO₂ concentration in outlet gas increased obviously due to the increase of NO oxidation rate, but when absorbent solution pH decreased further from 6 to 4, NO₂ concentration decreased from 217 ppm to 166 ppm while outlet NO concentration decreased from 140 ppm to 0. It implied that strong acidic condition not only enhanced NO oxidation but also promoted NO₂ absorption. When NaClO₂ solution pH was kept 4, NO_x removal efficiency of 72.3% could be obtained during cyclic scrubbing in the RPB reactor.

3.3. Effect of NaClO₂ Concentration. Experiments were conducted to investigate the effect of NaClO₂ concentrations in absorbent solution on NO_x removal, and the results are shown in Figure 4. In the tests, the rotational speed of RPB rotor was set at 800 rpm and absorbent solution pH was kept at 6 during the scrubbing process by adding NaOH solution

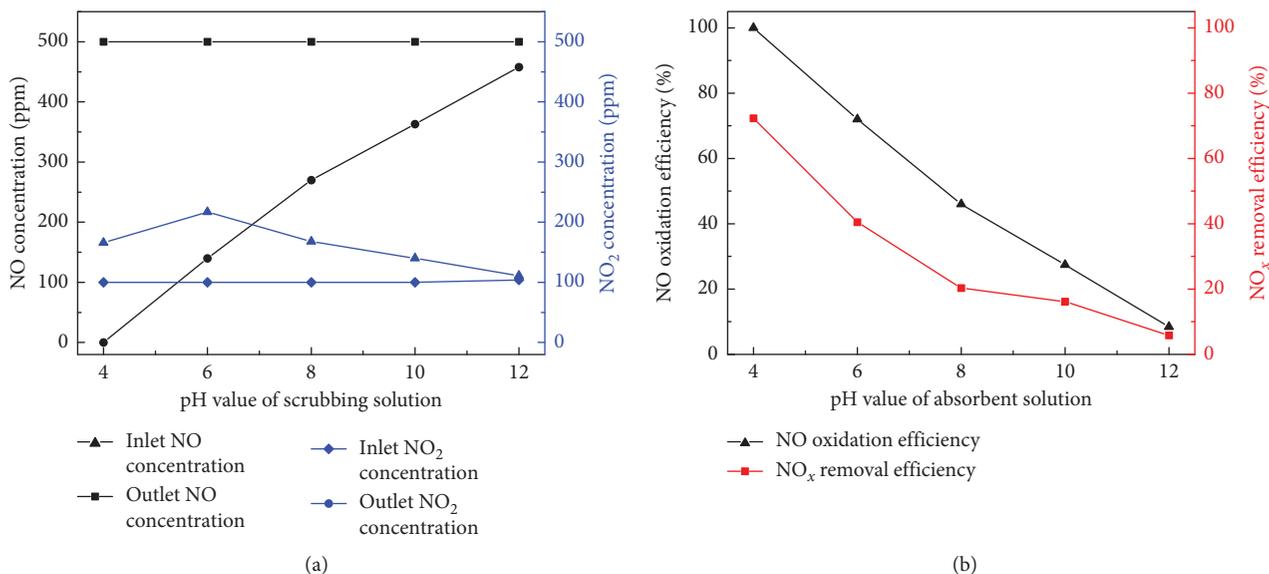


FIGURE 3: Changes of NO_x concentrations at inlet and outlet ports of the RPB reactor (a) and NO_x removal efficiencies (b) with solution pH.

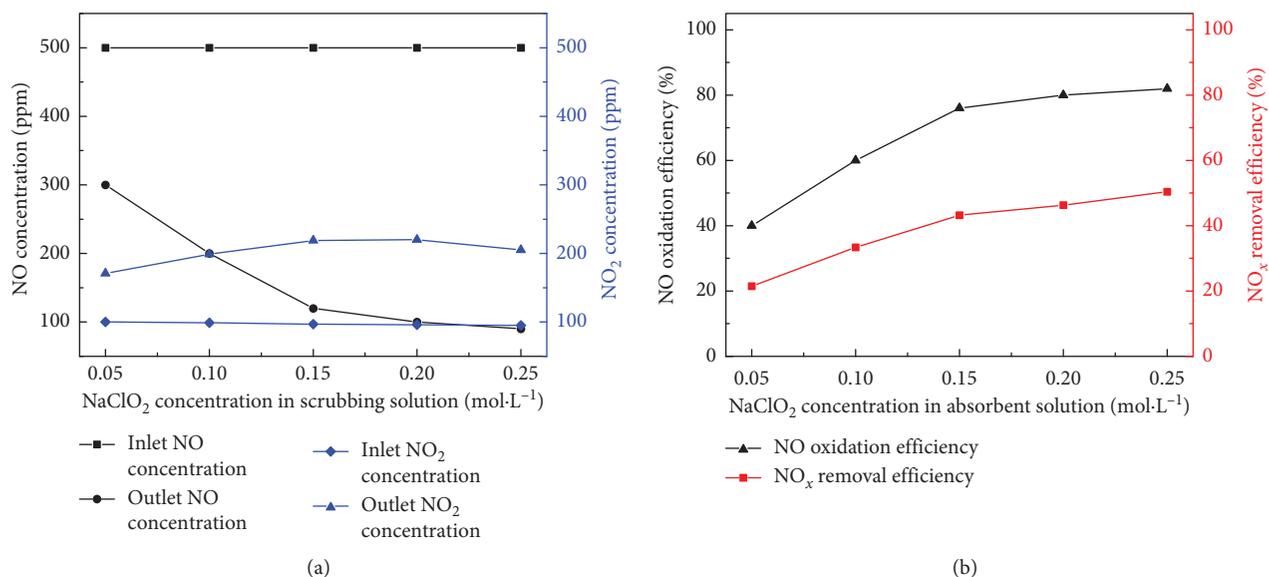


FIGURE 4: Changes of NO_x concentrations at inlet and outlet ports of the RPB reactor (a) and NO_x removal efficiencies (b) with NaClO₂ concentrations.

continuously. NaClO₂ concentrations were varied in the range of 0.05–0.25 mol/L.

With NaClO₂ concentration in absorbent solution increasing from 0.05 mol/L to 0.15 mol/L, NO concentration in outlet gas significantly decreased from 300 ppm to 120 ppm while outlet NO₂ concentration increased from 171 ppm to 219 ppm. The increase of oxidant concentration would enhance the mass transfer at the gas-liquid interface [36], which is favorable for improving NO oxidation, but when further increasing NaClO₂ concentration from 0.15 mol/L to 0.25 mol/L, the changes of NO and NO₂ concentration in outlet gas were very gentle. It suggested that when NaClO₂ concentration was high enough, factors other than NaClO₂ concentration become the main ones that limit the NO

oxidation and NO_x absorption during the scrubbing process in the RPB reactor.

3.4. Effect of Initial NO Concentration. The results of the experiments performed to test the effects of inlet NO concentration on NO_x removal are illustrated in Figure 5. In each test, NaClO₂ concentration was 0.2 mol/L and solution pH was kept at 6. NO pure gas was injected into the diesel exhaust gas to adjust the inlet NO concentrations in the range of 200–1000 ppm. Note that the inlet NO₂ concentration in diesel exhaust gas increased gradually with the increase of inlet NO concentration due to the oxidation of NO by coexisting O₂ in flue gas. Table 2 presents the initial

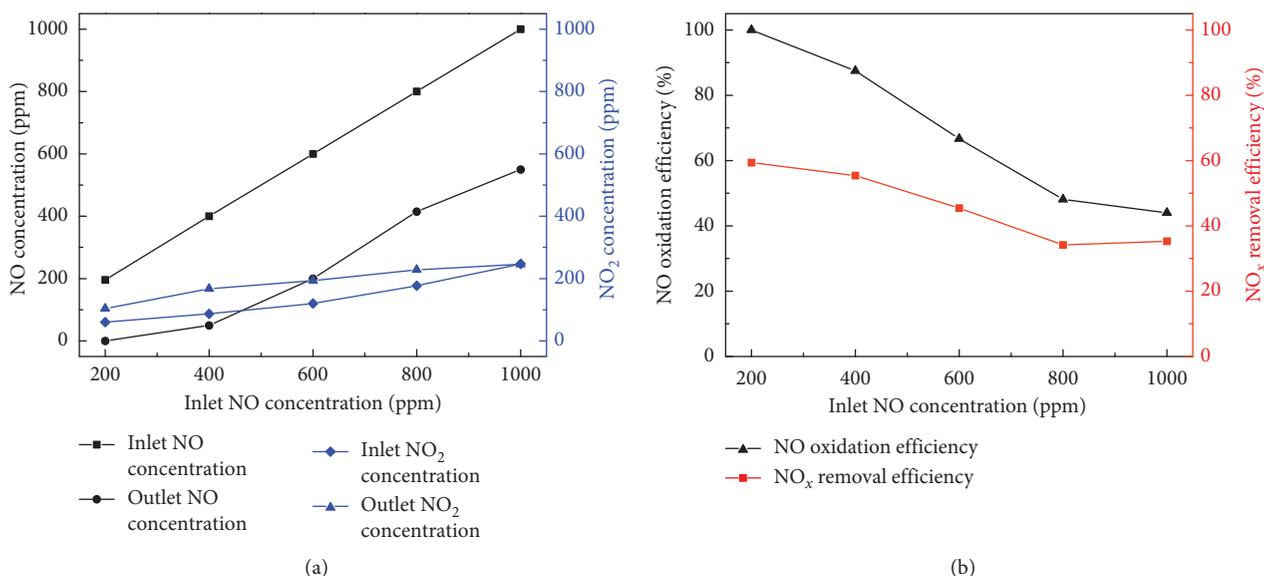


FIGURE 5: Changes of NO_x concentrations at inlet and outlet ports of the RPB reactor (a) and NO_x removal efficiencies (b) with inlet NO concentrations.

TABLE 2: The initial concentrations of NO, NO₂, NO_x, O₂, and CO₂ in exhaust gas.

Initial NO concentration (ppm)	200	400	600	800	1000
Initial NO ₂ concentration (ppm)	60	87	120	177	247
Initial NO _x concentration (ppm)	260	487	720	977	1247
Initial O ₂ concentration (%)	18.3	18.4	18.2	18.3	18.2
Initial CO ₂ concentration (ppm)	395	332	371	366	373

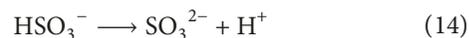
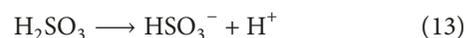
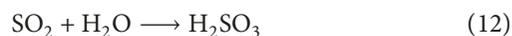
NO_x concentrations in diesel exhaust gas at inlet port of the RPB reactor.

As shown in Figure 5, with inlet NO concentration decreasing from 1000 ppm to 200 ppm, outlet NO concentration decreased from 550 ppm to 0 ppm, and the corresponding NO oxidation efficiency increased from 44.0% to 100%. At the same time, outlet NO₂ concentration decreased slightly from 246 to 104 ppm, and the corresponding NO_x removal efficiency increased from 35.0% to 59.4%. It can be seen that the decrement of inlet and outlet NO concentrations approaches each other with initial NO concentrations in the range of 400–1000 ppm. It seemed that NO removal amount was stable for the RPB reactor which was independent from the initial NO concentration in exhaust gas. Normally, the increase of inlet NO concentration would enhance the mass transfer at the gas-liquid interface, thus enhancing NO oxidation performance [24]. However, this trend was not obvious in our experiments. In other words, the results illustrated that under certain conditions, the change of NO concentration in exhaust gas imposed little effect on NO removal amount. The possible reason is that the retention time of exhaust gas in the RPB packing is a key factor that limits the reaction rates between NO and absorbent solution. When NO concentration in flue gas increased from 200 ppm up to 400 ppm, more NO could be removed due to the enhanced mass transfer, but when further increasing NO concentration, the retention time of

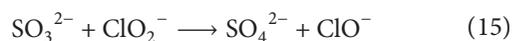
flue gas in the packing becomes the rate-determining step which results in an almost constant NO removal amount. It suggested that, for practical application, once the RPB scrubbing process was optimized at the highest level of NO concentration, then a high NO removal performance might be obtained for the whole NO concentration range.

3.5. Effect of Coexisting SO₂. The effects of SO₂ concentration in diesel exhaust gas on NO_x removal were investigated, and the results are presented in Figure 6. In the experiments, initial NO concentration was kept at 500 ppm and solution pH was maintained at 6. SO₂ pure gas was injected into diesel exhaust gas to adjust initial SO₂ concentrations in the range of 0–800 ppm.

When coexisting SO₂ concentration was in the range of 200–800 ppm, SO₂ was removed completely during the cyclic scrubbing process in the RPB reactor. SO₂ is very soluble in water, and it could be absorbed through quick hydrolysis reactions as the following equations [7]:



Then, the ions of SO₃²⁻ in solution will be oxidized into SO₄²⁻ by NaClO₂ and O₂ as the following equations:



As shown in Figure 6, when coexisting SO₂ concentration in diesel exhaust gas increased from 0 ppm up to 200 ppm, outlet NO concentration decreased from 139 ppm

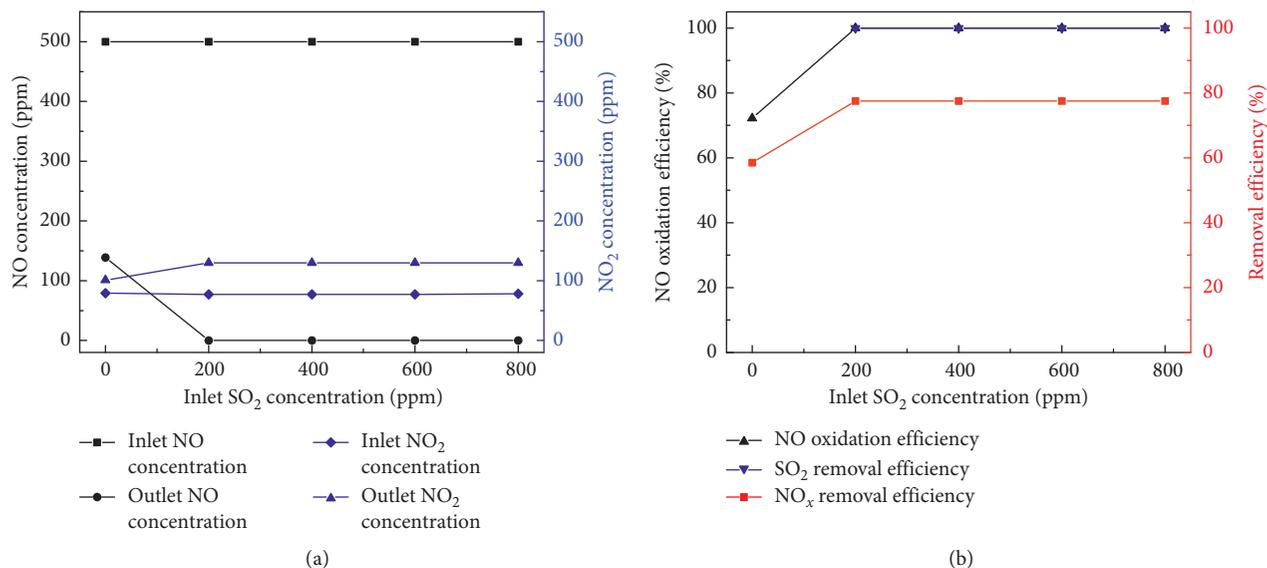


FIGURE 6: Changes of NO_x concentrations at inlet and outlet ports of the RPB reactor (a) and NO_x removal efficiencies (b) with SO₂ concentrations.

to 0 ppm while outlet NO₂ concentration increased from 101 ppm to 130 ppm. The results illustrated that the coexisting SO₂ had improved NO oxidation obviously. It should be pointed out that the absorption of both SO₂ and NO will acidize the absorbent solution. Though the pH value of cyclic scrubbing solution was maintained during the scrubbing process by adding 1 mol/L NaOH solution continuously, the pH of scrubbing solution was measured and adjusted in the circulating tank, but the oxidation and absorption reactions of SO₂ and NO_x with fine liquid droplets, films, and filaments mainly take place in the RPB packing. So, the pH of absorbent solution, especially at the surface of fine liquid droplets, films, and filaments, will be lowered instantaneously. Since the instantaneous decrease of solution pH will enhance the NO oxidation efficiency greatly, it is helpful to obtain a complete removal of NO.

It can be seen from Figure 6 that when coexisting SO₂ concentration increased from 0 ppm to 200 ppm, it indicated a slight enhancement effect of NO₂ removal performance through comparing the decrement of NO concentrations and the increment of NO₂ concentrations, but when coexisting SO₂ concentration was in the range of 200–800 ppm, outlet NO₂ concentration did not change obviously. There is a competition between SO₂ and NO_x to react with NaClO₂ in solution. Though the instantaneous decrease of solution pH in the RPB packing might be enhanced with the increase of coexisting SO₂ in flue gas, more oxidant will also be consumed to oxidize ions of SO₃²⁻ [25, 30]. In addition, SO₃²⁻ in solution may react with NO₂ through equation (17) to improve NO₂ absorption. Since SO₃²⁻ can be easily oxidized by NaClO₂ and O₂ during the scrubbing process, the enhancement effect of NO₂ absorption is not so obvious in our experiments.



3.6. Effect of Liquid-Gas Ratio. Figure 7 shows the effect of liquid-gas ratio on NO_x removal performance. In the experiments, the rotational speed of RPB rotor was set at 800 rpm, the flow rate of diesel exhaust gas was about 280 m³/h, NaClO₂ concentration in 30 L solution was 0.20 mol/L, and absorbent solution pH was maintained at 6 during the cyclic scrubbing process. Inlet NO, NO₂, and SO₂ concentrations in diesel exhaust gas were 500, 100, and 0 ppm, respectively. The liquid-gas ratio was regulated by adjusting the flow rates of absorbent solution. Table 3 shows the data of flow rates of absorbent solution and the corresponding liquid-gas ratio.

As shown in Figure 7, with liquid-gas ratio increasing from 2.1 to 5.0 L/m³, outlet NO concentration decreased significantly while outlet NO₂ concentration almost kept stable. When liquid-gas ratio was 5.0 L/m³, NO could be removed completely, and NO₂ left in outlet gas was about 200 ppm. A NO_x removal efficiency of 67.4% had been obtained. The results demonstrated that high liquid-gas ratio could enhance the mass transfer at the liquid-gas interface in the RPB reactor [6]. Therefore, it promoted the NO oxidation obviously and the NO_x absorption slightly during the cyclic scrubbing process in the RPB reactor.

4. Conclusions

A cyclic wet scrubbing process with NaClO₂ as an oxidant and RPB as a reactor was proposed to remove NO_x from marine diesel exhaust gas. The effects of some key operating parameters on NO_x removal performance had been investigated preliminarily. The results showed that the increase of rotational speed of RPB rotor could enhance NO_x removal performance obviously. The absorbent solution pH imposed a great effect on NO oxidation efficiency. When absorbent solution pH decreased down to 4, a complete removal of NO

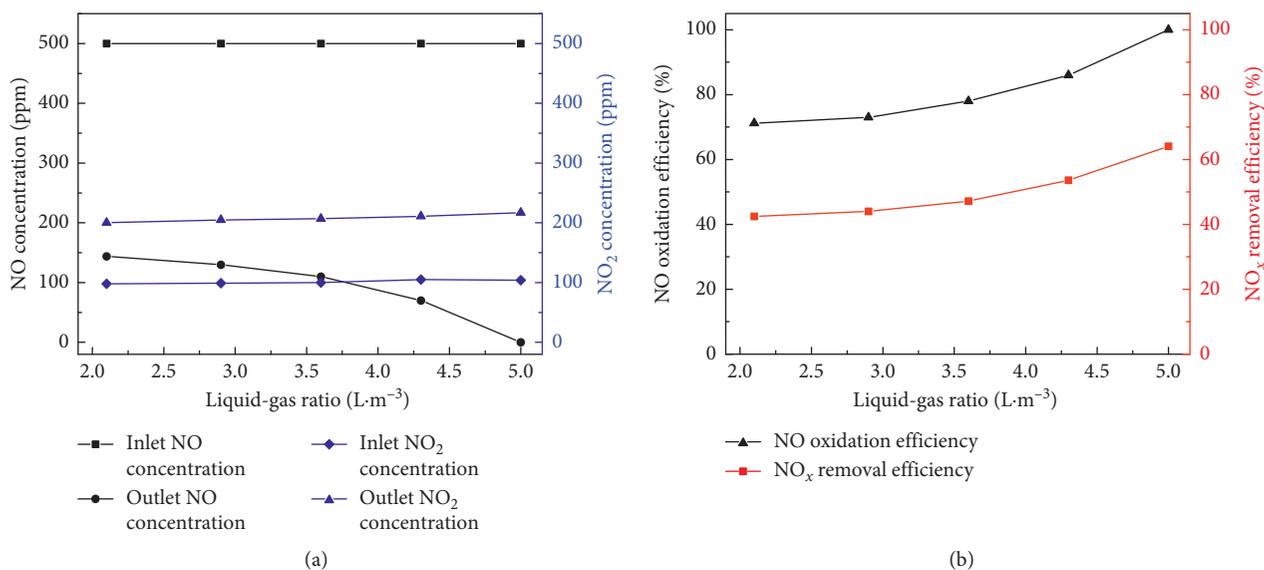


FIGURE 7: Changes of NO_x concentrations at inlet and outlet ports of the RPB reactor (a) and NO_x removal efficiencies (b) with liquid-gas ratios.

TABLE 3: The data of flow rates of absorbent solution and liquid-gas ratio.

Flow rate of absorbent solution (m ³ ·h ⁻¹)	0.6	0.8	1	1.2	1.4
Liquid-gas ratio (L·m ⁻³)	2.1	2.9	3.6	4.3	5.0

had been obtained. With the increase of NaClO₂ concentration, NO_x removal efficiency increased apparently, but there was an obvious downtrend of NO oxidation efficiency with inlet NO concentration in flue gas increasing from 200 ppm to 1000 ppm, while the decrement of inlet and outlet NO concentrations was almost the same when inlet NO concentration was in the range of 400–1000 ppm. A complete removal of NO was obtained after the introduction of coexisting SO₂ in flue gas, which might intensify NO oxidation through lowering the scrubbing solution pH instantaneously in the RPB packing. With the increase of liquid-gas ratio, NO_x removal efficiency increased gradually because the liquid-gas ratio could enhance mass transfer greatly between liquid-gas interfaces. The relevant reaction mechanism had also been discussed. The results demonstrated that NO_x could be removed efficiently by cyclic wet scrubbing using NaClO₂ in a RPB reactor, and it could also offer some theoretical guidance for practical applications.

Data Availability

The experimental and analytical data used to support the findings of this study are included within the article. All of the data included in this manuscript are free to share with other researchers.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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