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THE EFFECT OF SODIUM HYDROXIDE ABSORBENT ON THE EXHAUST EMISSIONS FROM INTERNAL COMBUSTION ENGINE

[1,2,3]Mechanical Engineering Department, State Polytechnic of Malang, Malang, Indonesia

Correponding email [2] :
wirawan@polinema.ac.id

Ilham Zainul Arifin[1], Wirawan Wirawan [2], Hari Rarindo [3]

Abstract. Exhaust emissions are the residue from burning fuel which can cause air pollution. To overcome this problem, it is necessary to design a system for reducing exhaust emissions of internal combustion engine. This study aims to determine the effect of absorbent concentration on the exhaust emission from internal combustion engine. The research was carried out in 2 stages, namely designing a system for reducing exhaust emissions from internal combustion engines and processing exhaust emissions by channeling exhaust emissions into an exhaust emission reduction system. The internal combustion engine used pertalite. The exhaust emissions consisted of CO, CO_2 and HC. The absorbent concentrations were 0.05 M, 0.1 M and 0.15 M. The engine speeds were 800, 1000, 1500 and 2000 rpm. The paired-t test showed that the exhaust emission reduction system in this study can reduce exhaust emission. The one-way Anova test resulted the absorbent concentration affect the exhaust gas emissions, both CO, CO_2 and HC which are expressed in the efficiency of reducing exhaust emission.. The greatest efficiency in reducing exhaust emission is CO_2 of 67.95%. The lowest efficiency of reducing exhaust emission is CO, which is 46.92%, while the efficiency of reducing HC emission is 62.47%.

Keywords : exhaust emission, emission reduction system, internal combustion engine, engine speed, absorbent.

1. INTRODUCTION

An internal combustion engine is a machine that converts heat energy released by burning fuel in the engine cylinder [1]. Combustion of fuel produces a combination of chemical energy, heat energy and exhaust gases [2]. The internal combustion engine has 4 cycles consists of the intake cycle, compression cycle, combustion cycle and exhaust cycle [1]. Exhaust gas pollutants consist of nitrogen oxide compounds (NO_x), water (H_2O), CO gas (carbon monoxide), CO_2 gas (carbon dioxide) which is a greenhouse gas, hydrocarbon compounds (HC) in the form of hydrates of charcoal as imperfections in the combustion process as well as loose particles [3]. These exhaust emissions can cause health problems and respiratory tract diseases as well as acid rain and even air pollution.

Research on the design of the suction device has been carried out by several previous researchers. The design used ejector mechanism [4] and double filters system [5]. Another researches used dual type wet scrubber technology [6], chemical absorbent [3], [7], [8]. Exhaust gas reduction researches included CO_2 capturing from the flue gases [9] and conversion of CO_2 into useful chemical [10]. One of the technologies used in the absorption of exhaust emissions is the wet scrubber technology. Wet scrubber technology is used to describe a tool to remove pollutants using liquid [6]. Over the past decade, wet scrubbing techniques have been widely used to reduce SO_x, NO_x, and other pollutants including CO and CO_2 together [10]. In the wet scrubber technique, the flue gas flow is flowed with the scrubbing fluid through a spraying process, where the scrubbing fluid is sprayed in the opposite direction to the flue gas flow. Some of the exhaust emissions that enter the suction chamber can be neutralized or absorbed by the absorbent. Water is the most widely used absorbent in the industrial world [7]. The use of chemical absorbents is based on an acid-base neutralization reaction. In addition, some absorbents also act as oxidants [8].

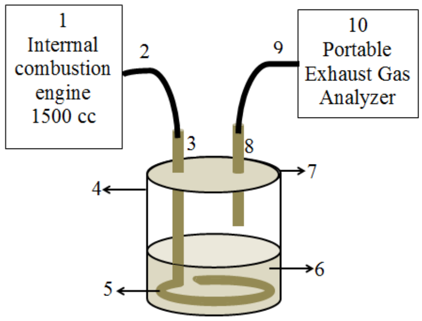
In the wet scrubber technique, the liquids used as absorbents include potassium hydroxide (KOH), sodium hydroxide (NaOH), magnesium hydroxide ($Mg(OH)_2$) [6], monoethanol amine (MEA) [9], calcium hydroxide ($Ca(OH)_2$), hydrogen peroxide (H_2O_2), potassium permanganate ($KMnO_4$), calcium hypochlorite ($Ca(ClO)_2$) and sodium hypochlorite (NaClO) [8]. The choice of absorbent is based on its ease of use, high absorption efficiency, low cost and appropriate technology.

2. METHODS

This research is an experimental laboratory research which consists of two stages. The first stage is to create a system for reducing exhaust emissions from internal combustion engines. The second stage is to process the exhaust gas from the internal combustion engine by channeling exhaust emissions into the exhaust emission reduction system.

2.1 Experimental Set up

The reduction system in this study used internal combustion engine. The engine speeds were 800, 1000, 1500 and 2000 rpm. The absorbent solution in this study was a NaOH solution 0.05 M, 0.1 M and 0.15 M with a volume of 5 liters. NaOH solution is made by dissolving solid NaOH in 1 liter of distilled water and then diluting it to a volume of 5 liters. NaOH required at a concentration of 0.05 M is 10 grams while at a concentration of 0.1 M it takes 20 grams of NaOH and at a concentration of 0.15 M as much as 30 grams. The experimental set up is visualized in Figure 1.



Description:

1. Internal combustion engine
2. Anti-burn connecting hose
3. Inlet pipe
4. Reactor tube
5. Reactor pipe
6. Absorbent solution
7. Reactor tube lid
8. Outlet pipe
9. Probe hose
10. Exhaust gas analyzer

Figure 1. Experimental set up

2.2 Data Analysis

Data was collected based on the measurement of exhaust emission before and after entering the exhaust emission reduction system. The measured exhaust emissions included CO, CO_2 and HC. Measurements were carried out 3 times each and then the average was calculated. Data Analysis used paired-t test [13] and one way Anova test [14].

3. RESULTS AND DISCUSSION

3.1 Reduction of Exhaust Emission

The fuel of internal comsbustion in this study was pertalite with an octane number of 90 [11], [12]. The main content of pertalite is a hydrocarbon compound consisting of 90% isooctane (2,2,4-trimethylpentane) and 10% n-heptane). The main contents depend on the octane number because the octane number is the same as the percentage of isooctane in fuel and the rest is n-heptane [15]. In the internal combustion engine, gasoline (C_8H_{18}) combustion will produce CO_2, H_2O and energy [16]. The reaction equation for complete combustion is:

$$C_8H_{18\,(g)} + 12.5O_{2\,(g)} \rightarrow 8CO_{2\,(g)} + 9H_2O_{(g)} \qquad (1)$$

In inadequate supply of air, CO and H_2O. The reaction equation is:

$$C_8H_{18\,(g)} + 8.5O_{2\,(g)} \rightarrow 8CO_{\,(g)} + 9H_2O_{(g)} \qquad (2)$$

CO_2 is a product of combustion and they are exhaust gas that can cause air pollution These pollutants can be reduced by adding absorbent in the reduction system of exhaust emission. NaOH solution will react with exhaust gases, especially CO_2 to produce sodium carbonate (Na_2CO_3) and H_2O [6] with the reaction equation 3.

$$2NaOH_{(aq)} + CO_{2\,(g)} \rightarrow Na_2CO_{3(aq)} + H_2O_{(l)} \qquad (3)$$

The design of the internal combustion engine exhaust emission reduction system is shown in Figure 2.

Figure 2. Reduction system of Internal combustion Engine Exhaust Emission

Figure 2 visualizes the reduction system of internal combustion engine exhaust emission. Combustion of fuel produces a combination of chemical energy, heat energy and exhaust gas [2]. Exhaust gas from the muffler of the internal combustion engine is connected to the anti-combustion hose and flowed to the reactor tube pipe through the inlet pipe. In the reactor tube there is a circular reactor pipe with small holes as showed in Figure 3.

Figure 3. Reactor pipe

The flue gas flowing through the reactor pipe then it is flowed into the reactor tube through small holes in the reactor pipe so the flue gas can react with the absorbent solution. The reacted exhaust gas then flowed through the outlet pipe and measured with an exhaust gas analyzer.

Measurement of CO emissions are expressed in volume percent (% Volume) and stated in Table 1.

Table 1. CO emission

Engine speed (rpm)	NaOH (M)	CO Emission (%V)	
		Before treatment	After treatment
800	0.05	6.27	4.08
	0.10	7.21	3.41
	0.15	7.23	2.31
1000	0.05	6.55	2.47
	0.10	6.61	2.87
	0.15	6.63	1.54
1500	0.05	5.65	2.81
	0.10	5.71	2.42
	0.15	6.18	2.74
2000	0.05	4.15	3.43
	0.10	4.15	3.32
	0.15	4.15	3.70

Table 1 shows that CO emissions decrease after entering reduction system. The analysis results of the paired-t test using microsoft excel 2010 program shows that t-calc of CO is 6.43. This t-calc of CO is greater than the value of t-table = 1.80, so it can be concluded that there is an effect of reducing exhaust gas emissions from internal combustion engines on the quality of CO. Then, Table 1 is described in Figure 4.

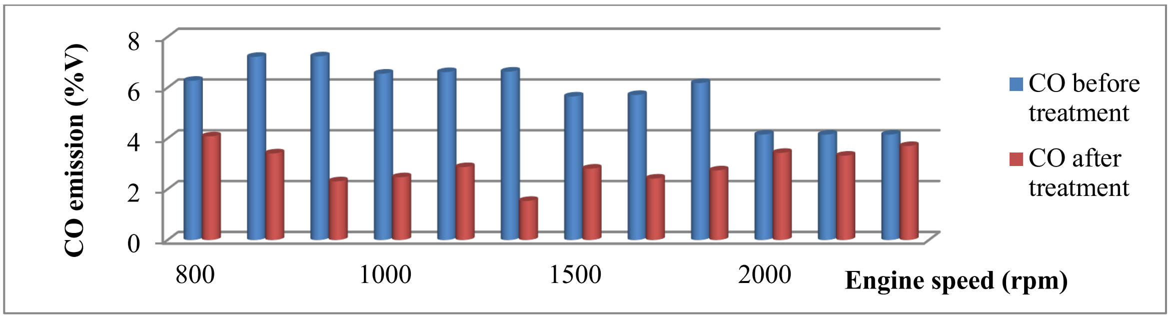


Figure 4. CO emission

Based on Figure 4, the CO emissions after entering the emission reduction system decrease with increasing absorbent concentration. First column in 800 rpm is CO with 0.05 M NaOH solution. Second coloumn for 0.1 M NaOH solution and third column for 0.15 M NaOH solution. This visualization also applies for 1000 to 2000 rpm. This emission reduction indicates that the emission measurement results is lower than before entering the reduction system. A significant CO emission decrease in pertalite occurred in the 800 rpm which is characterized by lower CO emissions with increasing absorbent concentration. At engine speed of 1000 rpm to 2000 rpm CO emission reduction is fluctuating with increasing NaOH concentration.

CO is created from partially burned fuel due to incomplete combustion or due to lack of air. The CO released from the rest of the combustion products is much influenced by the ratio of the fuel and air mixture that is too rich (lack of air) that is sucked in by the engine, to reduce CO the ratio of this mixture must be made lean, but this method has another side effect, namely NO_x will arise more easily [17]. CO is very dangerous because it has no color or smell, causing dizziness, nausea.

CO_2 emissions are expressed in volume percent (% Volume) and indicate the results of combustion in the engine. CO_2 emissions are stated in Table 2.

Table 2. CO_2 emission

Engine speed (rpm)	NaOH (M)	CO_2 Emission (%V)	
		Before treatment	After treatment
800	0.05	8.33	1.77
	0.10	6.37	1.43
	0.15	7.63	0.70
1000	0.05	8.43	1.70
	0.10	8.47	0.87
	0.15	7.93	0.40
1500	0.05	9.67	5.23
	0.10	9.30	2.83
	0.15	9.10	4.07
2000	0.05	8.37	5.87
	0.10	8.37	3.07
	0.15	8.37	5.03

CO_2 emissions also decrease after entering the reduction system. The results of the analysis of the paired-t test using microsoft excel 2010 program show that t-calc of CO_2 is 11.89 and this t-calc is greater than the value of t-table = 1.80 so it can be concluded that there is an effect of reducing exhaust gas emissions from internal combustion engines on the quality of CO_2. Table 2 can be described in Figure 5.

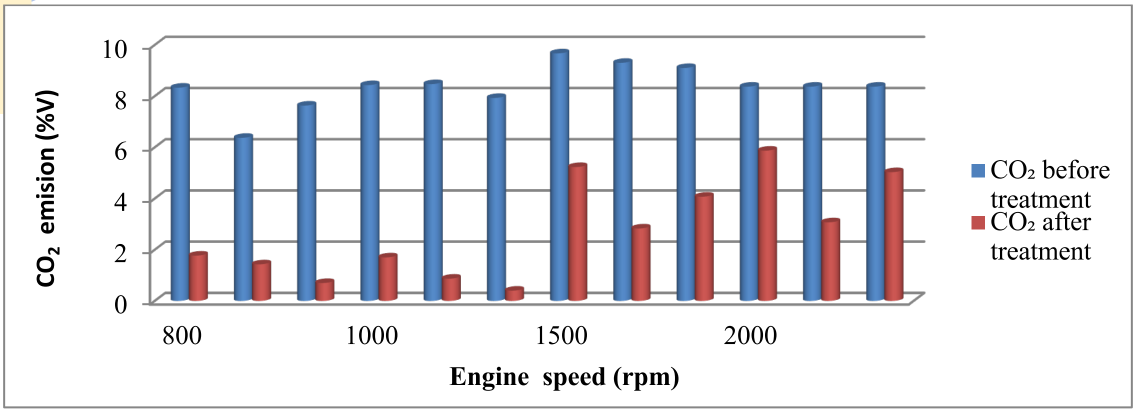


Figure 5. CO_2 Emission

Figure 5 shows CO_2 gas emissions. The results showed that there was a large reduction in CO_2 emissions after entering the exhaust emission reduction system. Three column in each engine speed visualizes CO_2 emission with 3 types of absorbent concentrations, they are 0.05 M, 0.1 M and 0.15 M NaOH solution. The higher absorbent concentration causes a very significant decrease in engine speed of 800 rpm and 1000 rpm, while at engine speed of 1500 rpm and 2000 rpm the emission reduction is fluctuating with increasing absorbent concentrations. CO_2 emissions after entering the exhaust emission reduction system increase with increasing engine speed. This is caused by the higher engine speed lead the combustion process increases so CO_2 emissions also increase. CO_2 emissions also come from burning CO so the emissions increase.

HC is expressed in ppm (parts per million). HC emissions indicate the remaining gasoline in the exhaust. The results of measuring exhaust emissions before and after entering the reduction system with pertalite fuel are stated in Table 3.

Table 3. HC emission

Engine speed (rpm)	NaOH (M)	HC Emission (ppm))	
		Before treatment	After treatment
800	0.05	515.67	243.67
	0.10	526	221
	0.15	493.67	148.67
1000	0.05	356.33	119.67
	0.10	377.33	150.67
	0.15	373.33	91.67
1500	0.05	256	105.33
	0.10	265.67	104.67
	0.15	285.33	118
2000	0.05	654.33	304.33
	0.10	654.33	223.67
	0.15	654.33	198.33

Table 3 shows that HC emissions decrease after entering the reduction system. The results of the analysis of the paired-t test using microsoft excel 2010 program shows that t-calc of HC is 6.69. this t-calc of HC is greater than the value of t-table = 1.80, so it can be concluded that there is an effect of reducing exhaust gas emissions from internal combustion engines on the quality of HC. Then, Table 3 is described in Figure 6.

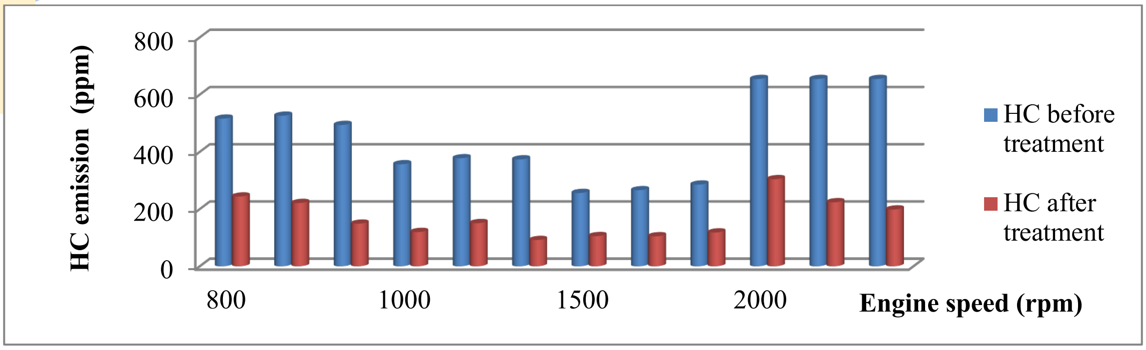


Figure 6. HC Emission

Based on Figure 6, HC emissions also show a decrease in emissions after entering the exhaust emission reduction system. First column in 800 is 0.05 M NaOH solution. Second coloumn for 0.1 M NaOH solution and third column for 0.15 M NaOH solution. This visualization also applies for 1000 to 2000 rpm. The significant decrease in HC emission with increasing NaOH concentration occurred at engine speed of 800 and 2000. While at 1000 rpm it was fluctuating and at 1500 rpm the emission reduction tended to be stable with increasing NaOH concentration. HC emission occurs because the fuel has not been burned but has been wasted along with the exhaust gases due to incomplete combustion and evaporation of fuel. HC are divided into two, namely unburned fuel so that it comes out as raw gas, and fuel that is split due to a hot reaction turning into other HC that come out with exhaust gases [17].

The effect of absorbent concentration to reduce exhaust emission in this study can be tested by one-way Anova test. One-way Anova test analysis was carried out using the Microsoft Excel 2010 program [14]. The results of the one-way Anova test showed that F-calc > F-table so it can be concluded that the NaOH absorbent affects the exhaust gas emissions of both CO, CO_2 and HC. The results of the one-way Anova test are stated in Table 4.

Table 4. The results of CO, CO_2 and HC one-way Anova test

No	Exhaust Gas Emission	F-calc	F-table
1	CO	57.82	4.30
2	CO_2	86.94	4.30
3	HC	34.24	4.30

The effect of absorbent concentration can be efficiency of the exhaust emission reducing device as shown in Table 5.

Table 5. The efficiency of CO, CO_2 and HC

Engine speed (rpm)	NaOH (M)	CO efficiency (%)	CO_2 efficiency (%)	HC efficiency (%)
800	0.05	34.93	78.75	52.75
	0.10	52.70	77.55	57.98
	0.15	68.05	90.83	69.88
1000	0.05	62.29	79.83	66.42
	0.10	56.58	89.73	60.07
	0.15	76.77	94.96	75.45
1500	0.05	50.27	45.92	58.86
	0.10	57.62	69.57	60.6
	0.15	55.66	55.27	58.64
2000	0.05	17.35	29.87	53.49
	0.10	20	63.32	65.82
	0.15	10.84	39.90	69.69
sum		563.10	815.50	749.60
average		46.92	67.96	62.47

Based on Table 5 the efficiency of exhaust emissions is between 10.77% (CO at 2000 rpm with NaOH 0.15 M) to 94.95% (CO_2 at 1000 rpm with NaOH 0.15 M). CO emission at 2000 rpm is the lowest emission and it indicates partially burned fuel due to incomplete combustion or due to lack of air [17]. The highest CO_2 efficiency indicates almost all carbon dioxyde reacted with sodium hydroxide so the CO_2 emission after entering reduction system is the lowest. HC efficiencies are more than 50% and indicates hydrocarbon emission that come from unburned fuel or fuel evaporation [17]. These results are then depicted in Figure 7.

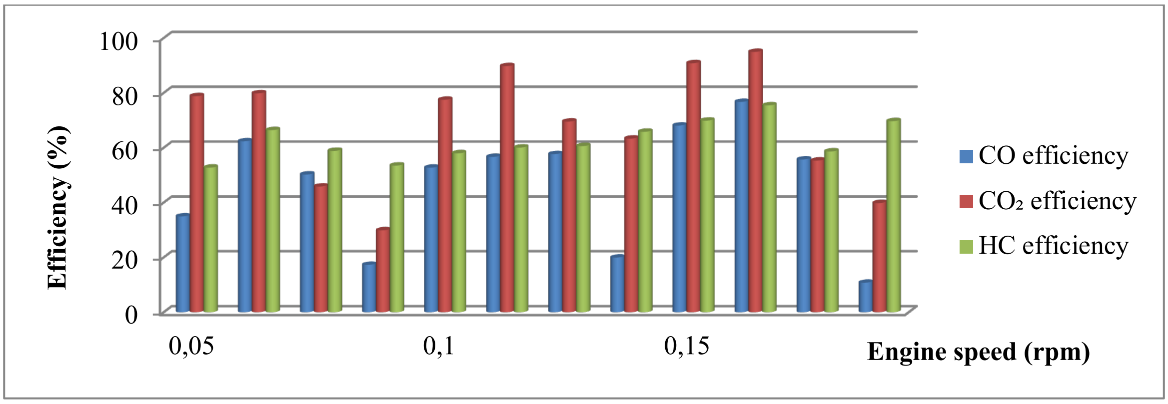


Figure 7. The efficiency of exhaust gas emission

Figure 7 shows that the exhaust emission reduction system of the internal combustion engine in this study can reduce exhaust emissions in various ways. The highest average efficiency of reducing exhaust emissions is indicated by the efficiency of reducing CO_2 emissions, which is 67.95%. The smallest reducing of exhaust emission efficiency is shown by the CO with emission reducing efficiency of 46.92% while the HC emission reducing efficiency is 62.47%. The greater the efficiency of reducing exhaust emissions can indicate the better quality of the exhaust emissions so that the air quality is also getting better because the number of pollutants is reduced.

4. CONCLUSION

Reduction system of internal combustion engine exhaust emission with NaOH absorbent in this study can reduce exhaust emissions of internal combustion engines. The concentration of absorbent affects the quality of the emission. In this study, the greater concentration of the absorbent, the efficiency of reducing exhaust gas emissions also tends to be greater. although there are some fluctuating emissions, there is still a decrease in emissions. The highest average efficiency of reducing exhaust emissions is shown by the efficiency of reducing CO_2 emissions, which is 67.95%. The smallest efficiency of reducing exhaust emission is shown by the CO reducing emission efficiency of 46.92% while the efficiency of HC reducing emission is 62.47%. If the efficiency of reducing exhaust emissions is greater, so the exhaust emissions quality is better. It means the air quality is also getting better because the number of pollutants is reduced..

5. ACKNOWLEDGEMENT

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