Research of Emission Decrease using Venturi Vacuum in Three-Stage Filter Wet Scrubber Systems

Yulanda Kurnia Pradani, Rachmat Boedisantoso, Abdu Fadli Assomadi

Abstract: ***Control of gas emissions from incinerator combustion needs to be done to prevent air pollution. One of the tools to reduce gas emissions is by using a venturi vacuum in a wet scrubber three-stage filter system. This research was conducted to determine whether there is an influence of the filter media size and filter media height. The filter media that used are PVC pipes with filter media sizes varying 2 cm, 4 cm and 6 cm. The height of the filter media varies 5 cm, 10 cm and 15 cm. The parameters studied were NO, CO, and SO_2 gas emissions. Result data from the study was carried out statistical tests using One-way Anova to determine the relationship of the influence of variables and parameters on the efficiency of the wet scrubber three-stage filter reactor. The results of the study using a venturi vacuum reactor obtained the highest efficiency values of 66,67% (NO), 29,69% (CO), and 66,87% (SO_2). This is contrary to SO_2 which has the highest solubility value in water compared to the solubility values of NO and CO.***

Keywords: emission, three-stage wet scrubber filter, venturi vacuum, efficiency

I. INTRODUCTION

Waste is a serious problem that is being faced by various countries in the world, including in Indonesia. As technology develops, this problem will increase and can cause various kinds of impacts on living things and the environment. Various efforts have been made to reduce waste, one of which is by burning or incineration [1]. Incineration is a process of treating solid waste by burning at high temperatures to reduce waste. One of the modern garbage incinerators used is the incinerator. In operation, the incinerator produces exhaust gases released into the air. Exhaust gases from combustion containing hazardous substances that have an impact on human health and the environment. One type of scrubber that is commonly used in emission controls is a wet scrubber that uses liquid to remove pollutants. In the wet scrubber, dirty gas flow is directed to the filter media with a liquid absorber by spraying and then flowing it to the media filter [2]

In increasing the efficiency of the wet scrubber, a variety of tools with a vacuum venturi system are used. Venturi vacuum is a pipe that has a narrower cross section and is placed horizontally equipped with a control pipe to determine the surface of the water so that the amount of pressure can be calculated. In this venturi pipe the cross-sectional area of the pipe at the edge has a wider cross-section than the middle or the diameter of the pipe edge is greater than the middle [3]. The amount of vacuum pressure produced by the venturi is influenced by the acceleration of flow velocity due to the channel crossing which follows Bernoulli's principle. Flow velocity on the channel is influenced by the discharge generated by the pump that follows the law of continuity [4]. In addition to speed, channel input pressure is also a factor affecting pressure on venturi vacuum. The influence of the variable pressure and discharge of the driving fluid flow on the performance of the venturi. The result is a variable fluid pressure that enters the venturi greatly affects the performance of the venturi where the greater the pressure of the driving fluid the vacuum pressure will be lower [5].

The liquid is flowed through a pipe which has a larger appearance and then flows through the pipe which has a narrower cross-section, thus a change in velocity will occur. Venturi tubes are divided into 2 types, namely venturi without a manometer and venturi with a manometer. The working principle of venturi without a manometer based on the Bernoulli Principle "in the horizontal pipe is the highest fluid pressure is in the flow rate is the smallest and the smallest pressure is in the flow rate is the largest". While the working principle of a venturi with a manometer is a combined application of a venturi meter and a pitot tube that functions to measure the fluid rate. [6]

II. MATERIALS AND METHODS

A. *Reasearch Preparation*

Preparation of tools and materials for design of a wet scrubber. The wet scrubber is a co-current packed column tower type with a three-stage filter. Co-current is a type of scrubber with a gas emission flow system that goes in parallel with the water flow [7]. Processed exhaust gases come out through the outlet and the remaining processing water will come out in the waste water storage tank. Emissions released by incinerators have high temperatures and contain harmful gases left over from burning plastic. Before being channeled into the wet scrubber, high-temperature gas is flowed into the heat exchanger to lower the temperature. Then the gas is flowed into the scrubber column through a vacuum venturi pipe and in the scrubber, column will be in contact with the filter media made with a three-stage filter system. In the scrubber column the gas will come into contact with droplets sprinkled from the spray nozzle then the gas will flow into the wet scrubber outlet. The wet scrubber design can be seen in Figure 1.

Revised Manuscript Received on January 15, 2020.
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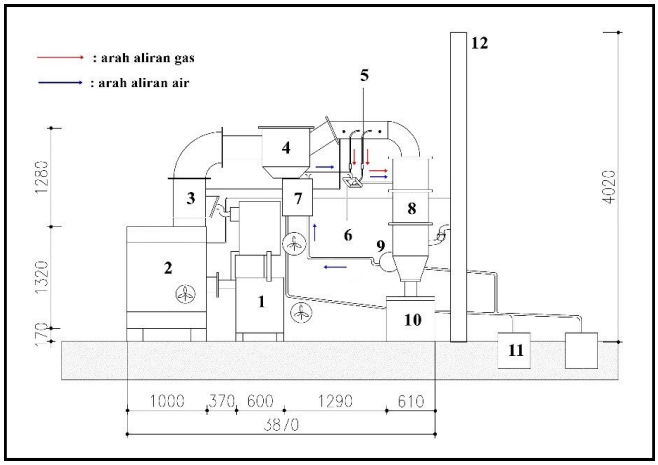

Figure 1. Reactor Design

Caption:
1. Burner
2. Primary chamber
3. Secondary chamber
4. Heat exchangers
5. Flowmeter
6. Venturi vacuum
7. Thermocouple panel
8. Wet scrubber column
9. Water pump
10. Wastewater tub
11. Tubs of clean water
12. Chimney outlet

B. *Research Implementation*

The study based on two variables. The first variation is the size of the filter media that is 2 cm, 4 cm, and 6 cm. The second variation is the height of the filter media that is 5 cm, 10 cm, 15 cm. The research procedure is as follows:

1. Prepare Polypropylene-plastic 1 kg as incinerator fuel.
2. Insert Polypropylene-plastic as the material into the primary chamber.
3. Arranging the reactor with the variation of research needed (the number of venturi, the filter media size, and the height of the filter media)
4. Turn on the burner as a trigger for fire in the primary chamber.
5. Turn on the blower as an air supplier to keep the fire burning during combustion.
6. Turn on the water pump to distribute water into the reactor.
7. Combustion emissions from the incinerator flow to the heat exchanger through the reactor pipe.
8. Adjust the rate of air flow into the wet scrubber by adjusting the gas discharge value on the flowmeter.
9. Monitor the temperature values on the thermocouple and make sure the combustion has reached the maximum temperature.
10. Turn on the stopwatch and take measurements.
11. Monitor and record the value of gas emissions at the wet scrubber inlet and outlet every minute on the gas analyzer within 10 minutes by burning 1 kg of Polypropylene-plastic.

III. RESULTS AND DISCUSSION

A. *Efficiency of using Venturi Vacuum*

This research was conducted to analyze the performance of the wet scrubber reactor in reducing emissions from incinerators of polypropylene (PP) non-reusable plastic waste incinerator to variations by measuring inlet and outlet emissions. Incinerator emission measurements are carried out periodically every one minute within 10 minutes at the wet scrubber inlet and outlet of the reactor. Emission values are taken from inlet and outlet gas samples at the reactor during the burning of 1 kg of plastic waste with charcoal and wood charcoal briquette fuel which lasts for 10 minutes of burning. Data from the measurement results of overall inlet and outlet gas emissions are analyzed and discussed to obtain the highest efficiency value.

The resulting incinerator emission gas removal efficiency value can show the performance of the three-stage scrubber wet scrubber reactor. The greater the resulting efficiency values indicate that the performance of the three-stage scrubber reactor is getting better. Efficiency values are calculated by Equation 1.

$$\eta = \frac{C\,in - C\,out}{C\,in} \text{ x } 100\% \qquad (1)$$

η = gas emission removal efficiency (%)
Cin = concentration of inlet gas (ppm)
$Cout$ = concentration of outlet gas (ppm)

The result of efficiency shown in Table 1. Table 1 shows that the performance of the reactor of reducing NO and SO_2 gas looks the most effective because H_2O as absorbent is able to absorb NO gases form plastic combustion. NO and SO_2 gas are easily soluble in water, this is supported by several researchers who revealed that SO_2 gas has a high solubility in water [8][9][10]. Besides being dissolved in water, SO_2 and NO2 gases are also absorbed by moisture that formed in the reactor. SO_2 gases are also very easy to dissolve in dew [8]. It was proven in research that reducing SO_2 content at the non-dewy condition and dewy condition. The result shows that SO_2 gas under non-dewy conditions can decrease to 25 ppbv, whereas when dewy conditions SO_2 gas decreases to 6.8 ppbv. While the results of the study show that SO_2 gas has a high-water solubility that is equal to 11.29 g/100 gr and NO_2 gas solubility of 10.19 g/100 gr so that the decrease in gas using water absorbent can be achieved higher.

Table- I: Efficiency of NO, CO, and SO_2

Height of Filter Media (cm)	Size of Filter Media (cm)	NO (%)	CO (%)	SO_2 (%)
5	2	35,29	29,69	44,99
	4	50,00	18,03	41,36
	6	54,55	10,59	33,66
10	2	46,67	2,34	60,68
	4	58,33	19,04	56,93
	6	66,67	2,98	52,98
15	2	43,75	3,60	66,42
	4	43,75	16,94	57,42
	6	60,00	5,19	54,77

B. *Statistical Analysis of Variables using One-way Anova*

The relationship of each variable was tested using the One-way Anova statistic test. The use of this type of test is based on the significance value of each variation. In the One-way Anova test, the relationship of each variable will be tested by the univariate test, which is an analysis to test the differences in data between two groups.

Data processing is processed using the IBM Statistics SPSS 20. To determine the effect of variations in the variables tested on the scrubber efficiency, statistical tests with a 90% confidence level were used. If the value of the statistical test results is less than the confidence level of 90% with a value of α 0.1, it can be concluded that the statistical conclusions on the proposed hypothesis are acceptable. The result of statistical test shown in Table 2.

Table- II: One-way Anova Statistic Test Results

Variables	NO	CO	SO_2
Height of filter media	0,091	0,01	0,285
Size of filter media	0,148	0,04	0,598

Based on the results of statistic tests using one-way Anova can be seen in Table 2. The results of the test parameter NO in the variable height of the filter media have a value less than α (0,1), the CO parameter in the variable height of the filter media and the size of the filter media has a value less than α (0,1), whereas all SO_2 values are above α (0,1). So that the NO and CO parameters are in accordance with the hypothesis, which is the variable influences efficiency.

IV. CONCLUSION

The highest efficiency value of NO parameters was 66,67%, CO was 29,69%, and SO_2 was 66,87%. Of the third parameter released which has the highest efficiency value is the SO_2 parameter. This is contrary to SO_2 which has the highest solubility value in water compared to the solubility values of NO and CO. The smaller the filter media size and the higher the filter media on the system, the three-stage wet scrubber filter will increase the value to eliminate gas emissions. This is even greater with the size of the filter media and the height of the filter media which can increase the area between contact with gas and air.

ACKNOWLEDGEMENT

Authors express gratitude to all lecturer of Department of Environmental Engineering, Faculty of Civil, Environment, and Geo- Engineering, Sepuluh Nopember Institute of Technology for every suggestion and viewpoint, as well to all of the government agency that gives permission and allows us to do this research. The authors also would like to thank LPPM ITS through the scheme of Penelitian Unggulan Perguruan Tinggi 2019 for funding this research.

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