Modification design of incinerator multifunction continue type

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Abstract

Incinerator is an equipment to incinerate trashes with high temperature control to ensure that the combustion process was done completely. The previous design of batch type incinerator which has been designed by Pradipta has some disadvantages, such as heat transfer system, loading and unloading system, air supply system and utilization of heat energy. So, those designs should be modified to improve its performance. The performance parameters of incinerator are temperature of combustion, the rate of combustion, quality of exhaust gases, and utilization of heat energy. Modified incinerator has eight sections (combustion chamber, chimney, air inlet, hopper, boundary plate, ash chamber, charcoal chamber, and water heater pipe). The performance test shows that the highest combustion temperature is 689.6^{0}C, with combustion rate 5.78 kg / hour. The exhaust gas of incinerator has good quality. Utilization of thermal energy could increase water temperature up to 32^{0}C. Air inlet position was not in the proper place, so combustion temperature could not reach as high as expected. Therefore it needs improvement.

Keywords: combustion temperature; incinerator; continue; trash.

Introduction

The trash in urban areas from the traditional markets and offices. The survey results in Jakarta (2000), trashes of traditional markets for organic waste with the percentage of 95%, meanwhile the trashes of offices from inorganic waste with the percentage of 65% (Sudrajat, 2012). The trash problem is crucial, because trashes could be described as a matter of cultural affected that the impact on various aspects of life. Waste management is a comprehensive effort to handle produced of trashes. The example of waste management is burning.

Burning of trashes by the community generally carried out in the open space. Burning in the open space has an effect negative for environment like a smoke and smell, which can pollute the air. One of the solutions to waste management with the system combustion that safe is incinerator. Incinerator using process combustion controlled by high temperatures. The temperature of incinerator is 815-1095^{0}C (Pichtel,

2005). Incinerator with high temperatures cause trashes burning optimal, and produced heat energy to use something else.

The previous design of the batch type incinerator which has been designed by Pradipta (2011) has some disadvantages, such as heat transfer system, loading and unloading system, air supply system and use of heat energy. So, those designs should be modified to improve its performance. This research modified the previous design of the batch type incinerator to design of continuing type incinerator. The performance parameters of incinerator are a temperature of combustion, the rate of combustion, quality of exhaust gases, and use of heat energy. The change expected to increase the performance of the incinerator.

Method

Instruments and Materials

Material used is an easier plate with thick is 2 mm and 5 mm, pipes with diameter is 0.5 inches, and hollow circle. Instruments that will be used to take the data performance test of incinerator is thermocouple bar K type to measure of temperature in the combustion chamber with the range of -200^{0}C until 1370^{0}C, thermocouple CA type to measure of temperature in incinerator sides until 900^{0}C, Recorder Yokogawa 3056 types to record the data of measurement of temperature combustion at the incinerator, digital moisture tester to measure of moisture content of trashes (% wet basis), An anemometer to measure of wind speed, and alcohol thermometer to measure of temperature water in pipes. The test material used are mixed the organic and inorganic trashes that have a moisture content of 12-16 %.

Method

Modification incinerator has done to change some dimension geometry incinerator design that have been previously designed by Pradipta (2011). The method made it through three rounds with the follow

- Preliminary research

  Preliminary research conducted to decide the use incinerator and get the data parameters that ideal on the previously designed of the incinerator.

- Design of incinerator

  Incinerator designed to combustion trashes perfectly. The table of the previously designed and modification incinerator showed in Table 1

Table 1 Comparison the previous design and modify the design of incinerator

No.	Sections	Performance of the previous design (Pradipta,2011)	The modified design
1.	Air inlet	The number and diameter of air inlet not optimum so that the combustion temperature just only reached 413^{o}C – 748^{o}C (wide air inlet: 79.25 cm^{2})	The addition of a number of air inlet, or enlarge the diameter of the air inlet
2.	Chimney	The smoke is still making spicy of eyes operators (the height of the chimney: 180 cm)	Change of construction on a high chimney
3.	Water heater pipe	Utilization of energy for heating water is still minimum because it have only ranged from 9.97 – 16 KJ (length: 400 cm, pipe diameter: 1.27 cm)	Add the length of the pipe or enlarge the diameter of pipe and put the pipe close to the walls of the combustion chamber
4.	Charcoal chamber	Utilization of heat energy in charcoal process is still minimum because just only on coconut shell surfaces receive the heat energy	The period of time the combustion is made longer so that the results obtained at the maximum

The design of the structural parts of the incinerator type «i.e.

1. Combustion chamber

   The dimensions of the combustion chamber designed by 50 x 50 x 60 cm

2. Sieve the trash and ash

   Sieve the trash and ash is designed for separating garbage with ash. The sieve is made with easier plate thickness 1 mm

3. Chimney

   The design of chimney is done through the calculation shown in table 2 below

Table 2 Calculation of chimney design

No.	Equation	Note
1	A = s x s	A = Area (m^{2}); s = side of chimney (m)
2	Hd = 354 Hc ((1/T_o) – (1/T_i)) (Porges, 1979)	Hd = pressure air in combustion chamber (mm.air), Hc = high of chimney (m), T_o = temperature outlet (^{0}C), T_i = temperature inlet (^{0}C)
3	Q = c x A x [(2 x g x h) x ((T_i – T_o)/ T_o)]$^{1/2}$	Q = discharge of gases (m^{3}/detik), c = constanta of chimney (0.7), A = area of chimney (m^{2}), g = gravitation (m/s^{2}), h = high of chimney (m), T_i = temperature inlet (^{0}C), T_o = temperature outlet (^{0}C)

Chimney is designed to have a square shape with the size 150 x 150 x 1500 mm. The purpose of the design of the chimney is separating particles that carried by the smoke from the combustion chamber.

4. Air inlet

The design of air inlet is done through the calculation shown in Table 3 below

Table 3 Calculation of air inlet design

No.	Equation	Note
1.	W_{min} = (100/21) x ((1.96 x C) + (5.85 x H)) (Pitchel,2005)	W_{min} = minimum air requirement (m^3/ kg fuel), C = carbon content in fuel (%), H = hydrogen content in fuel (%)
2.	Bbt = m / t	Bbt = rate of combustion (kg/jam), m = mass of fuel (kg), t = time of combustion (jam)
3.	$Q_{ud} = W_{min}$ x Bbt	Q_{ud} = discharge of air (m^3/jam)
4.	$Q = Q_{ud}$ (1+40%) (Abdullah *et al*, 1998)	Q = discharge of air (m^3/s)
5.	A = Q/v	Q = discharge of air (m^3/s), v = air velocitry (m/s)

Air inlet designed has a diameter of 2 cm, with the number of 32 on the front and bottom of the combustion chamber side. Air inlet serves as the place of loading air for the combustion process.

5. Water heater pipe

The design of water heater pipe is done through the calculation shown in Table 4 below

Table 4 Calculation of water heater pipe design

No	Equation	Note
1	$T_f = [(T_\infty + ((T_i + T_o)/2)) / 2]$ (Purwadaria *et al*, 1996)	T_f = temperature of average (^{0}C), T_∞ = temperature of heating (^{0}C), T_i = temperature inlet(^{0}C), T_o = temperature outlet (^{0}C)
2	Red = (D x v_∞) / v (Lienhard IV dan Lienhard V, 2011)	Red = Reynold Number , D = diameter of pipe (m), v_∞ = water velocity (m/detik), v = viscocity of water (m^3/detik)
3	St = 0.023 x $Red^{-0.2}$ x $Pr^{-2/3}$ (Lienhard IV dan Lienhard V, 2011)	St = Stanton Number, Red = Reynold Number, Pr = Prandtl Number
4	$L = \ln((T_i-T_\infty)/(T_o-T_\infty))$ x (D / St x 4) (Purwadaria *et al*, 1996)	L = length of pipe (m), T_∞ = temperature of heating (^{0}C), T_i = temperature inlet (^{0}C), T_o = temperature outlet (^{0}C), D = diameter of pipe (m)

The results of the calculations get length of pipe is 4 metres with discharge water flow of 5 – 5.4 lt/min, water velocity of 0.2652 m/s, diameter of pipe is 2 cm, with a temperature combustion of pipe is 100^{0}C, and the temperature of heating water is 40-60^{0}C

6. Charcoal chamber

The charcoal chamber that designed has a size of 50 x 10 x 60 cm with the aim to utilize the heat energy of the combustion chamber in the form of smoke for charcoal process

- The test of incinerator performance

The performance parameters of incinerator are temperature of combustion, the rate of combustion, quality of exhaust gases, and utilization of heat energy. The testing of incinerator has done about nine times, where preliminary study five times, and research after the modification as many as four times. The temperature data using a thermocouple that stationed at 12 points. The point of the data can be presented in Table 2 and Figure 1.

Table 2 The point of measurement

No.	Sections	Number of Points
1	Hopper	1
2	Combustion chamber	2
3	Ash chamber	1
4	Boundary plate	1
5	Water heater pipe	1
6	Charcoal chamber	1
7	Chimney	1
8	Walls of Chamber Combustion	1
9	Inlet Water Temperature	1
10	Outlet Water Temperature	1
11	Ambient Temperature	1

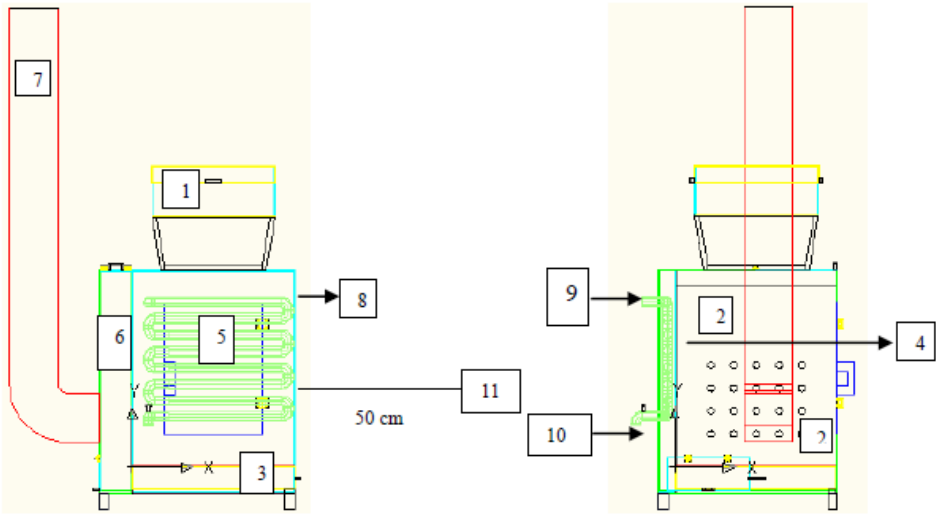

Figure 1 The point of measurement

Result and Discussion

The Design of Incinerator

The design incinerator made modified the previous design of the batch type incinerator.

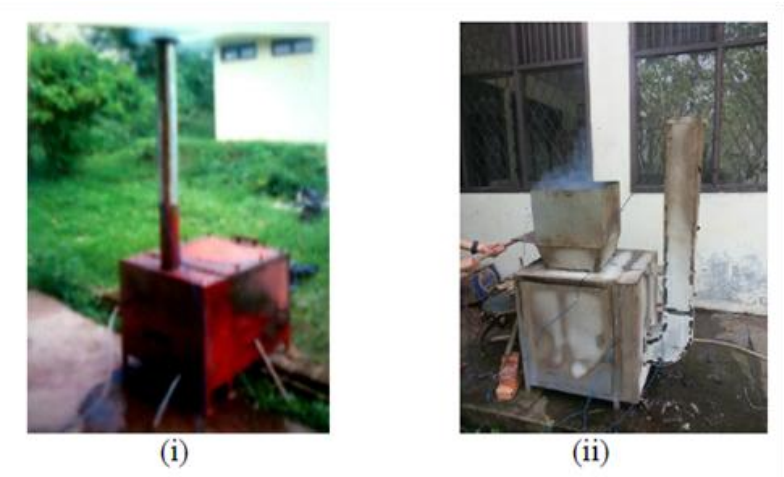

Figure 2 The previous design (i), and modified (ii)

The data results of the modification incinerator shown in **Attachment 1**. The combustion chamber made smaller for combustion was quickly and perfect. Hopper was designed so that the loading of the trash can be continued. The ash chamber designed for the shelter of ashes. The coconut shell in the charcoal chamber is used to filter the smoke is carrying of dirt particles. The chimney of quadrate have designed to make a smoke hit the wall chimney, so that the particles will fall and step back into the charcoal chamber. The boundary plate aims to make the pipe water heater not rapid damaged by corrosion because the effects of burning that conducted in simultaneously at combustion chamber. The diameter of the water heater pipe changed dimension of size, so that the temperature of the water and utilization of heat energy increased. Increasing of the number of air inlet have made air entering incinerator optimal.

The result test performance of incinerator

Comparing the test results performance of the previous design incinerator with modified incinerator to solving the problem of the previous design incinerator. The data of test results incinerator shown in **Attachment 2**.The rate of combustion in the modification of incinerator lowest because composition trash different in the test. Time of burning, and the moisture content of trash affect the rate of combustion. The moisture

content of little creates a burning time is brief and produces heat energy higher. Higher heat energy can be utilized to heat the water in the water heater pipe to increase the water temperature The large of water heater pipe diameter have made of water flow discharge is large and water velocity is small, so the heat energy can be utilized optimally. Charcoal chamber was able to make the charcoal process optimally, and smoke filtration system with cyclone system is able to separate smoke with particle. The temperature in the combustion chamber hasn't optimally caused the wind speed is unstable, also the position of air inlet was not in the correct place.

Conclusion

The result of design and testing index of incinerator continue type can be concluded that incinerator has five changes sections and three other sections. The combustion temperature in the combustion chamber of 689.6^0C is insufficient because the position of air inlet is not right. The rate combustion of 5.78 kg/h can increase the water temperature by 32^0C, because of changes in the diameter of the pipes that lead to changes of discharge and flow rate. Heat energy in the charcoal chamber used to charcoal process. The effectiveness incinerator has been good enough for combustion trashes with a short time. The next research will be carried out about the position of the air inlet and the addition of insulation to increase incinerator performance.

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Attachement 1 Comparison of the design of the previous design and modify the design of incinerator

No.	Work System	Sections	The previous design (Pradipta, 2011)			The modified design		
			Availability	Position	Dimension	Availability	Position	Dimension
1	Loading	Entrance	V	The Upper of combustion chamber	70 x 70 x 0.2 cm	-	-	-
		Hopper	-	-	-	V	Upper combustion chamber	38 x 38 x 15 cm (2 sections)
2	Combustion System	Combustion Chamber	V	The main part	70 x 70 x 60 cm	V	The main part	50 x 50 x 60 cm
3	Unloading	Exit	V	The frontside of combustion chamber	30 x 15 x 0.1 cm	-	-	-
		Ash Chamber	-	-	-	V	The bottom of combustion chamber	50 x 50 x 7 cm
4	Reduce of heat energy system	Boundary plate	-	-	-	V	The rightside of combustion chamber	50 x 60 x 0.1 cm
5	Heat transfer system	Water heater pipe	V	Passed of charcoal chamber and rotation of combustion chamber	Diameter : 1.27 cm Length : 400 cm	V	The rightside of boundary plate	Diameter : 2 cm Length : 400 cm
6	Utilization of heat system	Charcoal Chamber	V	The backside of combustion chamber	70 x 20 x 70 cm	V	The backside of combustion chamber	55 x 10 x 60 cm
7	Chimney system	Chimney	V	The upper of charcoal chamber	Diameter : 15 cm High : 180 cm	V	Bottom of charcoal chamber	15 x 15 x 150 cm
8	Air inlet system	Air inlet	V	Leftside (6), Rightside (6),Frontside (4), and Bottom (5)	Diameter : 2 cm Number : 21	V	Bottom (12), Frontside (20)	Diameter : 2cm Number : 32

Attachement 2 Comparison of the test result of the previous design and modify the design of incinerator

No.	Parameters	The previous of design (Pradipta,2011)	The modified design
1.	Capacity	10.5 kg – 18.3 kg	10 kg – 12.5 kg
2.	Moisture Content	14.52 % - 15.27 %	12.4 % - 15.3 %
3.	Time of burning	95 minute – 285 minute	130 minute – 190 minute
4.	Rate of Combustion	2.81 kg/jam – 6.82 kg/h	3.16 kg/jam – 5.78 kg/h
5.	Heat Energy	9.97 kJ – 16.26 kJ	42 kJ – 134.4 kJ
6.	Total Charcoal	200 gram – 500 gram	200 gram – 500 gram
7.	Discharge	3 lt/minute	5 lt/minute
8.	Water speed	0.394 m/s	0.2652 m/s
9.	Wind speed	1.105 m/s	1.822 m/s
10.	Colour of smoke	White	White
11.	Smell of smoke	Smoke	Smoke
12.	Particle	Nothing	Nothing
13.	Temperature :		
	Upper combustion chamber	413^0C – 672^0C	294.6^0C – 453.7^0C
	Bottom combustion chamber	472^0C - 748^0C	322.5^0C – 689.6^0C
	Walls	123^0C - 242^0C	136.8^0C – 284.5^0C
	Chimney	210^0C - 317^0C	133.5^0C – 326.1^0C
	Water heater pipe	130^0C - 140^0C	65^0C – 155.5^0C
	Water inlet	27^0C - 32^0C	28^0C – 32^0C
	Water outlet	42^0C - 47^0C	40^0C - 62^0C
	ΔT water	14^0C - 18^0C	10^0C - 32^0C
	Charcoal Chamber	317^0C - 405^0C	152.7^0C – 432.4^0C
14.	Various of Trash	60% - 70% Plastic, 70% Paper	42% - 96% Paper, 50% - 55% Plastic, 41% Dry Leaf