Hybrid Technology Incinerator For Solid Waste Processing Using an Evaporative Cooling System

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Abstract An incinerator is a combustion device that burns waste at high temperatures. The incinerator in this research uses hybrid technology, which uses an evaporative cooling system to reduce environmental pollution from combustion residue. Analysis of incinerator performance based on indicators: efficiency of combustion use, level of residual combustion waste and B3 waste levels, and levels of air emissions from the combustion process. Emission measurements include particulates, CO2 gas, CO gas, heavy metals, NO2, SO2, HCl, HF and total hydrocarbons. The method used as a result of the development of this incinerator is a field experiment, namely a field trial using the process of burning B3 solid waste and calculating parameters, which are indicators for measuring the effectiveness of the working system of the incinerator development. Hasil uji lapangan insinerator dengan system pendingan evaporative diperoleh bahwa efisiensi pembakaran pada kapasitas 50 kg/jam selama 3 kali proses uji coba pengolahan limbah di Universitas Negeri Malang yaitu pada tanggal 18 Sebtember, 19 Sebtember dan 20 Sebtember 20 23 secara berturut sebesar 95,4%, 9 1,2% dan 98,1%. Efisiensi terbaik didapat pad a tanggal 20 Sebtember 2023 sebesar 98,1 % dengan massa limbah 75 kg, massa abu 1kg, suhu operasi 310 - 6 10°C dan pengolahan selama 4,2 jam

Keywords: Hybrid Technology, Incinerator, Evaporative Cooling System

1 Introduction

Indonesia, as one of the developing countries in the world, is experiencing very rapid industrial growth [1]. Industrial activities, especially chemical-based industries, cannot be denied, producing hazardous and toxic waste (B3), which is difficult to process [2]. According to data from the Ministry of Environment and Forestry (KLHK), in 2014, B3 waste in Indonesia reached 206 million tons and 193 million tons were successfully managed. From this data, B3 waste that was not successfully managed was 13 million tons. Indonesia is one of the countries that is still unable to process all B3 waste produced by both industry and hospitals due to inadequate facilities and infrastructure. The production of B3 waste from industry and hospitals is high, so incineration technology is needed to process B3 waste [3].

Incineration is an effective waste disposal method that is capable of reducing significant weight and has no harmful effects on humans and the environment. It can destroy hazardous components, reduce waste volume by 5–15% to ash, and produce energy [4] [5]. The burning process in solid waste processing incinerators, both general and medical, at a temperature of 800 – 1,000°C to reduce the volume of combustible waste, which can no longer be recycled and can kill viruses, bacteria and toxic chemicals [6][7]. On the other hand, choosing the right incineration technology can reduce the potential for pollution caused by combustion ash residue and combustion exhaust gases. On the other hand, using an inappropriate incinerator carries a risk of air pollution if the incineration process is not controlled and is not equipped with a control device. air pollution [7][8]. To ensure that the incineration process is carried out optimally and has a high level of efficiency and effectiveness of up to 90% to process waste without polluting the environment, it is necessary to test the performance of the incinerator [9][10].

Types of Combustion Waste

The waste used in testing the performance of the Hybrid Technology Incinerator for Solid Waste Processing Using an Environmentally Friendly Evaporative Cooling System comes from B3 waste from various environmental and hospital wastes. The type and amount of waste used in each combustion process are conditioned to be the same. The types of waste used can be seen in Table 1.

Table 1. Composition of incinerated waste

No	Types of B3 Waste	Characteristics	Composition %
1	Advanced contamination	Poisonous	10
2	Reject plastic packaging	Poisonous	40
3	*Filter bag/plastic*	Poisonous	10
4	*Saw dust/sawdust*	Poisonous	5
5	Used packaging	Poisonous	20
6	Pharmaceutical waste	Poisonous	10
7	*Oil/paper filter*	Poisonous	5

Incinerator Type

The incinerator used for the trial was an incinerator using an evaporative cooling system. The incinerator consists of a combustion chamber with a heat-resistant layer (refractory-lined) which reaches a temperature of 800°C-1000°C with a cooling system using water particles to capture ash particles that escape the filtering process. The gas and heat resulting from burning waste in the combustion chamber will be filtered with water particles contained in the chimney to reduce environmental pollution. The supply of waste to the incinerator is carried out by entering the waste through the combustion door. A visualization of the incinerator used can be seen in Figure 1.

Fig 1. Incinerator visualization

The combustion gases and residual ash then go to the pollution controller, namely the cyclone muffler. Dust particles resulting from combustion residue will be captured in the cyclone muffler. The gas formed from combustion will go to the muffler and be captured by water particles.
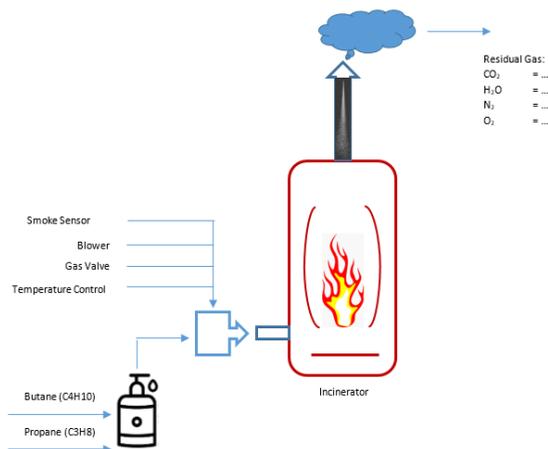

Fig 2. Incinerator Unit

The technical specifications of the incinerator used are presented in Table 2.

Table 2. Incinerator specification data

No	Parameter	Technical Specifications
1.	Function	B3 Waste Processing
2.	Operating Time	24 hours
3.	Capacity	50 kg/hour
4.	Design	Evaporative cooling system incinerator
5.	Waste feeding	Manuals
6.	Air pollution control equipment	Automatic
7.	Operational temperature	800ºC-1000ºC
8.	Chimney diameter	110mm

The exhaust gas is generated from the combustion reaction, and these particulates are passed through several filters, including the Cyclone Muffler and Water Particles so that almost 99.9% of it will be trapped in the filter. The flue gas that then comes out of the chimney is completely free of dangerous components. The main components of the incinerator system with an evaporative cooling system consist of a burner, combustion chamber, filter and muffler, which can be seen in detail in Figure 2.

The calculation begins by calculating the material balance and heat balance in the combustion system, then determining the amount of heat that arises and the heat that leaves the system. The equilibrium balance is obtained from waste feed data, fuel requirements, combustion products (Ash) and combustion exhaust gas; a description of the system can be seen in Figure 3.
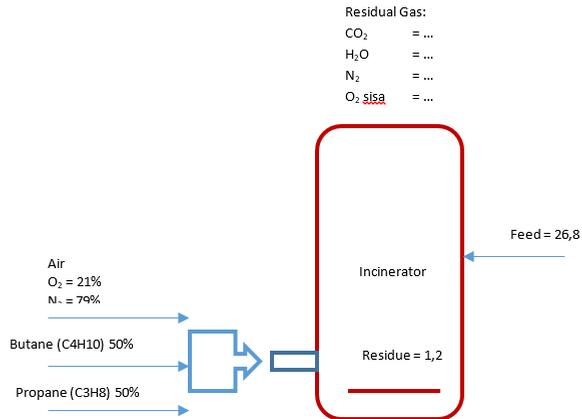
Residual Gas:
CO_2 = ...
H_2O = ...
N_2 = ...
O_2 sisa = ...

Feed = 26,8

Incinerator

Air
O_2 = 21%
N_2 = 79%

Butane (C4H10) 50%

Propane (C3H8) 50%

Residue = 1,2

Fig 3. Incinerator Heat Balance

Table 3. Incinerator Waste Processing Data

Date	M_1 (kg)	M_1 (kg)	t (hours)		T (ºC)	T_{GB} (ºC)
18/09/2023	26,8	1,2	0,5		400-600	588
20/09/2023	67,9	4,8	2		243-520	575
22/09/2023	72,1	1,1	4		320-620	600

Table 4. Incinerator Mass Balance

Component	Input (kg)	Output (kg)
C4H10	0,6	-
C3H8	0.6	-
O_2	10.5	1,5
N_2	34,4	34,4
H_2O	-	3,7
CO_2	-	7,8
Feed	26,6	-
abu	-	1,2
Total	72,7	48,6

Heat of Combustion Analysis

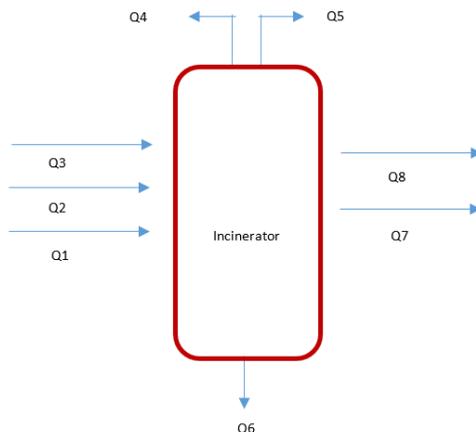Calculating the mass balance of the incinerator calculating the Q value for each can be seen in Figure 4.

Fig 4. Incinerator Mass Balance

Q1 = Heat from HHV LPG   Q5 = Sensible and Latent Heat of Water
Q2 = Air Sensible Heat   Q6 = Sensible heat ash
Q3 = Heat Sensible Bait   Q7 = Heat Utilized
Q4 = Exhaust Gas Sensible Heat   Q8 = Absorbed Heat

Table 5. Incinerator Heat Rate Balance

Komponen	Input (kg)	Output (kg)
The heat from HHV LPG	27407	-
Air Sensible Heat	54	-
Heat Sensible Bait	207	-
Exhaust Gas Sensible Heat	-	6338,5
Sensible and Latent Heat of Water	-	2743
Sensible heat ash	-	1044,5
Heat Utilized	-	1048
Absorbed Heat	-	830
Head is Loss	-	15663
Total	27668	27668

$Q = m.\, C_p.\, T$

$\%\ \text{head Loss} = \dfrac{head\ loss}{total\ heat\ inlet} x\ 100\%$

$= \dfrac{15663\ kcal}{27668\ kcal} x\ 100\%$

$= 56{,}51\%$

$\%\ \text{Thermal Efficiency} = \dfrac{Q\ output}{input}\ 100\%$

$= \dfrac{12004\ kcal}{27668\ kcal} x\ 100\%$

$= 43{,}4\%$

$\text{Burning Rate B}_{bt} = \dfrac{m}{t}$

$= \dfrac{26{,}6\ kg}{0{,}5\ hours}$

$= 53{,}2 kg/hours$

$\%\text{Efficient Incinerator} = \dfrac{m_{in} - m_{out}}{m_{in}} x\ 100\%$

$= \dfrac{26{,}6\ kg - 1{,}2\ kg}{26{,}6} x\ 100\%$

$= 95{,}4\%$

2 Results And Discussion

The results of incineration efficiency calculations are presented in graphical form in Figures 5 and 6.
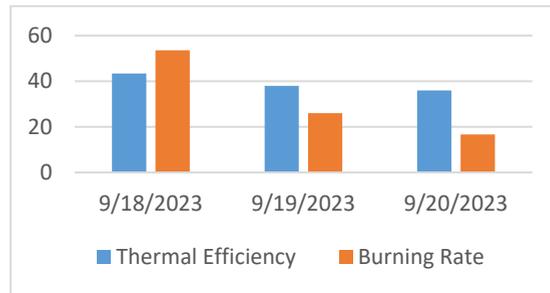

Fig 5. Thermal Efficiency and Burning Rate

In Figure 5, it can be seen that the higher the combustion heat efficiency, the greater the feed combustion rate in the incinerator. This shows that the higher the combustion temperature in the incinerator burner, the shorter the residence time required for the feed to burn completely. The heat efficiency of the incinerator is 40 - 80%. The calculated heat efficiency is in the range of <45% because when operating the incinerator, the operating temperature used is around 250-600°C while the incinerator design temperature is around 850 - 1000°C.
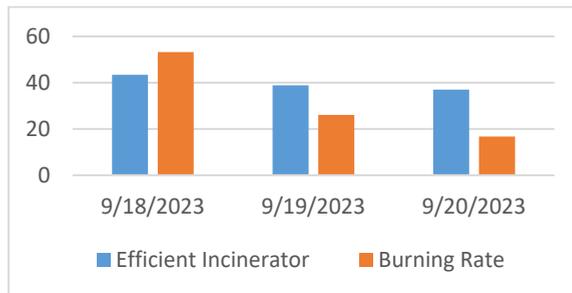

Fig 6. Efficient Incinerator and Burning Rate

Figure 6 shows that the smaller the combustion rate, which indicates that the longer the waste stays in the incinerator, the higher the incinerator efficiency. However, the data on 19 September showed that the incinerator efficiency was lower than the efficiency of the incinerator on 18 September, while the burning rate was greater. This could be influenced by several factors, namely the operating temperature, which was not optimal and the composition of the waste feed, which contained a lot of water and rubber.

3 Conclusion

Calculation of the performance efficiency of an incinerator with a capacity of 50 kg/hour during three trials of waste processing at the State University of Malang, namely on 18 September, 19 September and 20 September 20 23, respectively, amounting to 95.4%, 9 1.2% and 98, respectively. 1%. The best efficiency was obtained on 20 September 2023 at 98.1% with a waste mass of 75 kg, ash mass of 1kg, operating temperature of 310 - 6 10°C and processing for 4.2 hours.

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