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№ 6575

Domestic Waste Incinerator Design With Bio-Mass Fuel

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September 13, 2021

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Abstract

The high activity of offices, households or industries causes a lot of waste and it's still a major problem that requires a solution with minimal impact. The combustion process is an alternative method of effective waste treatment. Incineration is a solid waste treatment process by burning at more than 800°C to reduce combustible waste that cannot be recycled, kill bacteria, viruses and toxic chemicals. Currently, the use of incinerator technology requires a lot of combustion energy from fuel oil or gas, so the operational costs are high and the the unit price is relatively very expensive. Incinerator's design without a combustion engine, it is hoped that will save combustion energy to minimize operationals and production costs of the incinerator. The incinerator design process provides the type and yield of the incinerator, operating conditions, and the basic size of the reactor shaped of a cylindrical with a diameter of 24 cm and a height of 50 cm. The incinerator prototype construction uses assembly techniques and basic welding for metal materials and refractory cement casting. Incinerator's Prototype testings show that the incinerator is capable to burn several types of waste, including: plastic, paper, wood, organic waste, etc. where the incinerator's combustion chamber temperature can reach 1091^{O}C. The incinerator's capacity will accommodate 10 kg of waste while the processing time varies according to the kind of waste.

Keyword: incinerator, bio-mass, waste

1. Introduction

Globalization & technological developments require highly activity from the office, household or industrial, which will caused of the large amount of waste. Waste problem still a common topic related to the environment and urban planning. It's required solution with minimal impact. There are several waste treatment technologies, such as Composting, Recycle, Combustion and others [1]. The combustion process is an alternative method of effective waste treatment. This system has advantages to produce heat energy and requiring a short degradation time, compared to composting, landfill and open dumping systems. Combustion process be able to reduce the waste volume up to 90% while compost, landfill and open dumping are only able to reduce the volume by 40% [2].

There are several methods can be used for combustion process in waste treatment, one of which is incineration. Incineration is a solid waste treatment process by burning at a temperature of more than 800°C to reduce combustible waste that cannot be recycled, kill bacteria, viruses and toxic chemicals [3]. This process is carried out in a device called an incinerator. Through the incineration process, waste can be destroyed quickly, controlled and not require a large area.

The incineration process involves burning organic matter at high temperatures which can reduce the waste volume up to 75-80%. It's produces combustion residues in the form of ash which is dry and free from decay. The combustion temperature average in the incinerator reach to 900˚C. Despite having advantages, combustion using an incinerator called incineration process brings other problems like air emissions in the form of particulate matter (PM), SO2, CO, CO2, HCl, dioxins, furans and heavy metals. It's happened due to incomplete combustion process result by the temperature can't reach the requirements. Therefore, incinerator needs to be equipped with an emission controller system and exhaust system to ensure the smoke coming out of the combustion chamber is neutral.

A Research conducted by Rahardjo [4] have made a cylindrical incinerator using refractory bricks for the walls of the combustion chamber. For the purposes of combustion process, this incinerator uses 3 (three) gas-fueled burners. Another study conducted by Girsang and Herumurti [5] evaluated the processing of hazardous solid waste resulting from incineration process in RSUD Dr. Soetomo Surabaya. They used Rotary Klin Incinerator. In one day, the incinerator can burn medical waste until 4 times.

Even though the incinerator unit have been produced and followed by research, using of existing incinerator technology requires a lot of combustion energy from fuel oil or gas. Its will cause the operating costs are high and unit price of an incinerator relatively very expensive. To overcome this, the authors develop an incinerator technology design for energy efficient implemented in domestic waste treatment, using bio-mass fuel and without a burner. An Incinerator design without a combustion engine expected to save combustion energy so it will minimize the operational costs. incinerator design is simpler than the burner system incinerator design expected to minimize the production costs.

2. Material & Method

Research activities include designing, manufacture of incinerator prototype and testing. The final result of this research, hoped that the incinerator can be used by office institutions, households or industries to solve domestic waste problems..

A few method using in this research, such as:

a) Literature Study
   Literature study provide a theoretical basis which will applied and developed in this research, , especially about develop an incinerator technology patents. Literature studies are obtained from books, scientific journals and internet;

b) Material Selection
   This stage selects the right material for manufacture a prototype.

c) Incinerator Prototype Design and Manufacturing
   This activities starts from designing the incinerator like incinerator reactor, air supply system and exhaust chimney model, and then fabricating the prototype;

d) Incinerator Prototype Testing
   Incinerator testing is carried out to determine the performance of incinerator by burning various types of domestic waste.

3. Process Principle

3.1 Incenerator's Design

Incinerator design aims to obtain the design of the type of incinerator, operating conditions and the basic size of the reactor. To determining the incinerator's dimensions, referring to incinerator's modification design with a waste burning rate of about 10.66 kg/hour [6]. Beside the data, another reference based on the author's experience, known that a garbage container with size of 2 meters x 1 meters x 1 meters fit to accommodate 1 ton of garbage. Based on the data, calculation analysis show that to carry out waste treatment with an average weight of 10 kg/hour, were obtained the cylindrical diameter of 24 cm and a height of 50 cm. the design of incinerator's hardware involves structural and mechanical components, such as the first reactor, the second reactor, insulators, air supply holes, chimneys and others.

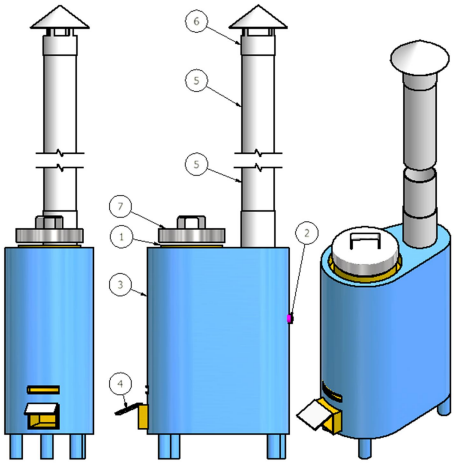

Fig 1. 3D Incinerator's Design: (1) chamber (2) intake (3) cover (4) door (5)chimney (6) cowl (7) chamber's lid

3.2 Prototyping

Manufacturing process of incinerator prototype purpose to implement the design and testing the performance's by applying in domestic waste treatment. Fabrication process of prototype uses commercial materials that easy to obtain, easy to fabricate and easy to maintain, it is expected to minimize production costs. The incinerator's construction uses basic assembly and welding techniques for metal materials also refractory cement casting. The tools and materials used in this research to produce a set of small-scale incinerators according to the dimensions mentioned above include:

a) Fire bricks - SK34
b) Mortar Clay - C17
c) Ribtec refractory
d) Vermikulit insulin
e) Mortar SK34
f) Stainless steel sheer 316 1 mm
g) Stainless steel sheet 316 5 mm
h) Stainless steel sheet 304 1 mm
i) Stainless steel rod 10 mm
j) Stainless Steel Electrod 2 mm

An incinerator declared that have good quality if it's can burn at the temperatures between 800^0C-1000^oC. To achieve these criteria, it is necessary to use of adequate materials to maintain the strength of the incinerator in retaining heat..

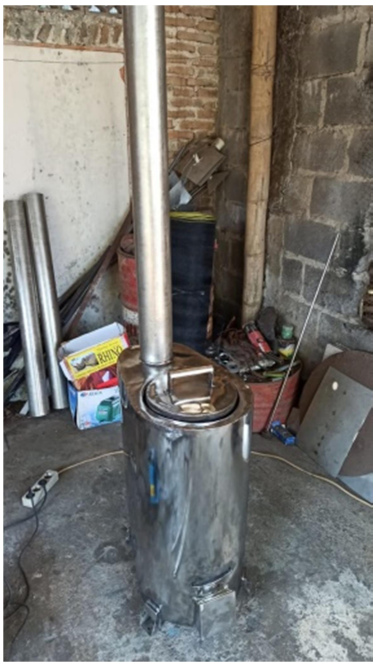

Fig 2 Incenerator's Prototype

4. Result & Discussion

The incinerator prototype testing phase aims to see the suitability of the design parameters with the product that has been built and observe the performance. The incinerator expected to be able to burning various types of waste. The prototype testing scheme can be seen in the diagram below:

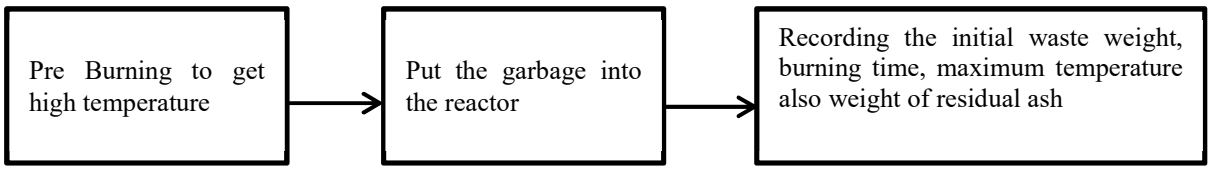

Fig 3. Prototype testing's scheme

The incinerator prototype working test method doing by the following steps below:

a) Giving water to the reactor lid gap as an insulator and combustion safety;

Fig 4. Water as an insulator on reactor

b) Prepare biomass to be used as initial fuel. In this research using coconut shell;

Fig 5. Coconut Shell as initial Fuel

c) Fill the reactor with biomass as the starting burner;

Fig 6. Fill the reactor

d) Ignite the fuel, from the bottom.

Fig 7. Ignite the fuel

e) Measure the combustion temperature. The incinerator is ready to use when the temperature reaches 900^{o}C.

Fig 8. Initial temperature

f) Weigh the waste to be burned to determine the initial weight;

Fig 9. Initial weight of organic waste

g) Open the reactor lid, put the waste into the reactor and let it burn out;

Fig 10. Opened reactor condition

Fig 11. Put the waste into the reactor

When the combustion process is complete, cooling down the reactor. When it is felt that the temperature is no longer hot, take the ash from the combustion and weigh it if there is any ash from the combustion.

Fig 12. Weighting the ash

The incinerator prototype testing results that the incinerator is capable to burning various types of waste including: plastic, paper, wood, organic waste, etc. During the test, the incinerator combustion chamber temperature was able to reach the temperature up to 1091^{O}C.

Fig 13. Temperature maximum

Results of the incinerator prototype test can be seen in the following table:

Table 1. Incinerator's Testing Result

Kind of waste	Initial Weight (Gr)	Temp Max (^{0}C)	Combustion's time (minute)	Ash Weight (Gr)
Bio Mass (Coconut Shell)	5.000	900	12	-
Wet Organic (Leaves)	10.000	1.015	16	135.0
Plastik (Plastic)	10.000	1.091	4	25.5
HouseHolds / Canteen	10.000	1.006	21	163.7

When doing testing the prototype, visual observations showed that at the first 10 minutes of initial combustion, the smoke coming out of chimney was white. However, when the temperature reached to 800^{o}C the smoke begins invisible from the cowl.

Incinerator's testing stage also shows that the combustion temperature reaches more than 1000^{o}C. According to the guidelines from the Ministry of Environment regarding to the requirements for an incinerator using in medical waste treatment that must have minimum combustion temperature at 1000^{o}C, so this incinerator's prototype considered to full fill the requirements. To prove it, another observation on this testing have been doing to see the result.

a) Face Mask
   The test was carried out by burning 3ply face masks which are widely used today. Observation result show that the combustion temperature reaches more than 1000^{o}C. This combustion process does not produce residual, means that the face mask has been burned;
b) Glass bottles/ampoules
   When burning the glass bottles/ampoules, using coconut shell as biomass fuel. The combustion temperature reaches more than 1000^{o}C and the final result of combustion show the presence of molten glass.

Fig 14. Glass Burning Residu

c) Syringe (Injection Equipment)
Syringe is a hazardous waste in medical area if disposed off without special treatment. When perform combustion test by burn syringe, the combustion temperature reach up to 1050°C. The results shows that the plastic syringe parts were burned out and the surface/coating on the needles had peeled off, so the needles would be more easily destroyed/corroded.

Fig 15. Injection Equipment (Befor & After Combusting)

5. Conclusions

This research develop an incinerator prototype for small-scale waste treatment that can be used for offices, households or industries. As we know that this incinerator prototype capable to combustion with temperature more than 1000^0C. Besides as a combustion technology, this prototype can be used as an incinerator in small-scale power plants with bio-mass fuel and or waste. Incinerator designs are mostly empirical based on past experience. End results from prototype's testing shown that this incinerator capable to accommodate 10 kg of waste with the duration of combustion process various according to the type of waste used.

In the next stage of development, the incinerator need improvements in few parts to improve it's performance.

Some suggestions for the next stage of incinerator's development include:

a) Developing some incinerator's parts in order to meet the requirements from government about requirement for medical waste treatment. When it's fullfillment, so the incinerator can be used for hazardous and toxic waste or medical waste treatment. Based on the test results, it is known that the combustion temperature reaches 1091°C, where the temperature value is suitable for processing hazardous and toxic waste.
b) Produce the incinerators with the type or specifications as developed by this research. In this pandemic conditions, incinerators for small-scale will be very usefull for medical waste treatment to destroy waste like face mask, hazmat clothes, etc.
c) Improvements the incinerator by added scrubber in the exhaust area in order to remaining the residual combustion are not wasted along with the smoke
d) Do the exhaust emission testing

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