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NO-AUXILIARY FUEL INCINERATOR LOW EMISSION (NAFILE) FOR DESTROYING UNUSABLE PLASTIC IN URBAN AREAS

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ABSTRACT

The problem in plastics world are its nondegradable natural properties so the waste and its product has ultimately been accumulating in recent years. Fractions of plastics may degrade in reuse and recycle programs, but the quantity of remaining plastics in environment (unusable) has increased. Incineration of these plastics seems to be a good solution. However, the emission of combustion and energy auxiliary required are obstacles in the incineration process. An unusable plastic waste with high energy such as polypropylene, polyvinylchloride, and polyethylene are subjected. These materials as main fuel used to design low emission incinerator in this study. Average composition, heat, and emission were analyzed for criteria result. The chamber dimension for prototype incinerators in 0.4 x 0.3 x 0.4 m^3 show good performance for 2 kg unusable plastics combustion every 10 minutes and air excess was about 100 %. Plastic combustion test obtained low emissions with F/A above 1.5, and burning temperature above 700 ^{0}C. Twelve repetition tests for this design showed the maximum temperature achieved was 901 ^{0}C, and average was 850 ^{0}C after stable burning (is about 16 minutes time needed).

KEY WORDS : HDPE, LDPE, PP, Gasification, Heat of burning, Plastics waste.

INTRODUCTION

The increased production and use of plastics caused plastic waste to accumulate in the environment. Even though the recycling and recovery program is getting better, the actual plastic waste generated is increasing in the existing waste (European Commission's Directorate-General Environment, Nov. 2011). Unusable plastics base material has a wide impact in environment concern. Recently, about 50 % of unusable plastic waste disposed in domestic disposal facility, as remains of reuse and recycle process (Tchobanoglous *et al.,* 1993). The plastic content in domestic waste is more than 1,64 % in urban area of Surabaya city (Government, 2012). It caused various environmental impacts, i.e. disturb ecosystems, urban drainage, soil mature, etc. It has the large potential for injury and killing of mayor species in sea ecosystems (Derraik, 2002). It also reduces the lifetime of domestic waste disposal facility, because of the non-degradable characteristics of its material. It has been reported that some plastics bags declared compostable or biodegradable have proved difficult to decompose naturally. The plastic containing of PE and additive no significance change in physic and color for 12 days process naturally in soil (Vaverkova *et al.,* 2014). Unfortunately, only 2 of 10 sample plastic declared compostable is completely biodegradable (Markowicz *et al.,* 2019).

One method offered to deal with plastic waste is by incineration. Incineration is a thermal destruction method of the waste. This method is to convert solid waste into carbon dioxides, ash, water vapor (John and Swamy, 2011), and potential useful energy (Themelis *et al.,* 2002). In developed countries such as the United States, about 0.9 million tons of waste are burned using incinerators each year and produce 620 kWh/ton of energy (Themelis *et al.,* 2002). The completely process of incineration is related to the principles of chemical and physical engineering. These principles including the calculation of energy.

The waste must achieve calorific value at least 7 MJ/kg for operation able incinerator or must never bellow 6 MJ/kg (Rand *et al.*, 2000). Several factors influence in performance i.e. temperature, excess air, feed caloric, stoichiometric calculations, and pollutant emission design (Nabizadeh *et al.*, 2016).

In general, the composition of incineration product is 20-30 % bottom ash, 2-6 % as air pollution control residues including fly ash, and 70 – 75 % by weight of gas emission. The minimum heat of combustion is 850 ^{0}C and time of combustion minimum 2 second (Affairs, 2003). The plastics as waste has a high calorific value and potential to produce energy to help combusting waste perfectly. In general, plastics waste may be converted into liquid fuels by thermal process, such as plasma processes (Maczka *et al.*, 2013), or thermal transformation and depolymerization (Marczak, 2019). The incineration of non-reusable plastic waste is expected to increase the efficiency of incinerators so that the use of oil or gas can be reduced, or will be zero. In this study the combustion process of plastic waste on incinerators was carried out by varying composition of plastic waste and organic waste. It is expected to achieve the right composition, so the combustion process can be self-burning in chamber and low emission produced and very low of ash (negligible). Its processes may be influenced by water content, air supply, temperature and residence time.

Incineration for Plastics in Principles

In principles, plastic consist of carbon and hydrogen (majority), and trace of heavy metal, chlor-substances, and other toxic substanced. The hazardous waste obtained is detoxified by subjecting to the incineration process. It is gaining popularity as a disposal technology in the field of hazardous waste management. There are many types of incinerators, i.e. single chamber, multiple chamber, controlled-air, rotary kiln, etc. (John and Swamy, 2011). The higher heating value of plastics than other solid waste, gives the potential to design low-fuel incinerator for plastics as wastes. In contrast, the toxic emission produced by plastics incineration, was potentially give the large environmental impacts.

For complete combustion, all of material plastics are mainly converted to CO_2 and H_2O gasses. Some other compounds are formed in case non carbon containing material added in plastics. For example, chloride material in polyvinylchloride (PVC) lead to HCl form in gas combustion product. In general, for X = halides, the stoichiometric for burning plastic reaction, as below:

$$(C_aH_b)_n + \left(a+\tfrac{b}{4}\right)O_2 \rightarrow aCO_2 + \tfrac{b}{2}H_2O \quad .. \text{(Eq. 1)}$$

$$(C_2H_3X)_n + \tfrac{5}{2}O_2 \rightarrow 2\,CO_2 + H_2O + HX \quad .. \text{(Eq. 2)}$$

The best condition when combustion occurs completely, the process will produce the best emission (all materials are completely degraded), no CO formed, and energy requirements are lowest (high efficiency).

In practice, burning of plastics may produce gasses as emission. Some of these gasses include pyrolysis product such as octane, which will increase as LDPE increase in combustion process (Hosseini *et al.*, 2014). Burning plastic mixed with other material as waste, shown emission such as volatile and fixed carbon compound in particulate matter with active-redox component (Vreeland *et al.*, 2016). The other gasses produced, including harmful organic halogens from PVC burning, and may some brominated compound and dioxins from polystyrene (Verma *et al.*, 2016). However, these emission is reduced by maintaining mass balance to ensure sufficient air for complete combustion (Olisa *et al.*, 2016), presence of fixed carbon and oxidant, temperature of burning (Lopes *et al.*, 2015), and using of heat generated (Abaka *et al.*, 2017).

However, recently the problem of air pollution is a very significant problem in major cities of developing country (Assomadi *et al.*, 2016). So, the operation of the incinerator must not increase the burden of air pollution. Controlled incineration process is needed to minimize fuel consumption, emission, and maximize reduction of waste volume. It is to ensure cleaner and more complete combustion of waste, to even more reduce plastic waste in highly-dense urban populations. The control include temperature, fuel to air ratio for ensuring sufficiency of oxygen requirement (Akpe *et al.*, 2016), combustion time, input of heating value to volume of chamber ratio, etc. The controlled parameters will be translated into an effective incinerator design. There are however, a number of technical, social and environmental problems associated with incineration (John and Swamy, 2011). These potential pollutants are contained in the emissions and residual solids remaining after the combustion process. So, the design of controlled incinerators and effective emission absorbers is very important.

Design and Calculation

This study is aimed to produce prototype of low emission portable incinerator. The main focuses are portable, i.e. less area needed, mobility capability, easiness of operation, and low emission, i.e. meeting ambient air pollution regulation from local government. Those focuses will be achieved if the incineration process is maintained at completely burn process. This design is needed to assist in-situ destruction of plastic waste near sources or in temporary waste collecting facility.

Waste quantifying

From the study it can be concluded that average wastes quantification in Surabaya city area is covering many activities as domestics, trading, industries, public's facility, etc. Its estimate about 10.000 m^3/day of waste is entering to waste disposal facility. So, potential quantity for plastics as waste is 1,64% x 10.000 m^3/day equal to 164 m^3 plastic/day. If assume that density for plastic is 100 kg/m^3 (mentioned 80 – 2300 kg/m^3 in bulk density as fired (John & Swamy, 2011)), the potential quantity for plastics as waste is about 16 ton/day.

Chamber Design

For prototype of portable incinerator, the design of main chamber for burning process, its initial volume is 1 – 2 kg plastics in a period combustion. It will then shift to continuous process with 1 – 2 kg/10 minutes of plastics waste feeding. Assume the maximum void for complete combustion is 100 % of waste volume. Maximum volume chamber (V) based on waste volume = 200 % x 2 kg x 1 m^3 / 100 kg = 0.04 m^3. Assuming a suitable height (H) of 0.4 m, therefore the area of chamber is calculated for the area (A) for burning chamber, A = V / H = 0.04 m^3 / 0.4 m = 0.1 m^2. Assume length and wide as 1.2:1, therefore L/B =1.2 lead to L = 1.2 B. The dimension of burning chamber = L x B x H. The dimension is A = L x B, 0.1 m^2 = 1.2B x B = 1.2B^2. We obtain B is equal to 0.29 m, L is 0.35 m, and H is 0.4 m. The volume chamber is equal to 0.0406 m^3.

Calculation of Heat and Material Balance

Heat balance and material balance is important tool in designing incinerator and its evaluation procedure. The calculation is based on mathematical evaluation of input and output parameters of the incinerator. All mathematical calculations use conservative mass and energy. The total mass and energy input must equal to the total of mass and energy output. This method can be applied to determine the air and auxiliary fuel required to burn a given waste. This also can be used to determine the boundary of an existing incinerator while loaded with a knowing waste.

The assumptions for this calculation are designed that incinerator is capable to incinerate a mixture of many types of plastics in waste (polypropylene, polyethylene, high and low dense plastics). For material input is to be 10 kg/h of plastics as waste. The supporting fuel in this design is Liquid Petroleum Gas (only if necessary), for ignition process the plastics at initial. Design requirements are recapitulated as burning chamber temperature is about 750 ^{0}C until 1,000 ^{0}C, flue gas residence time is about 1-1,5 second; and residual oxygen in flue gas is 10 - 6 % minimum. From that design requirement, step of design calculation is done as follows:

Assumption development

For simplify calculations connecting incinerator are usually based on several assumptions developed. In this design, the assumption was:

1. The chemical formula, the molecular mass and the range of heating values for each of the main components of plastics as waste have been taken as Table 1.
2. Input temperature of plastics waste, LPG fuel, and air for auxiliary are equal to ambient temperature, i.e. is about 30 ^{0}C.
3. Air contains 21% by volume of O_2 and 79% by volume of N_2, or 23 % by weight O_2 and 77 % by weight N_2.
4. Air contains 0.0232 kg H_2O/kg dry air at 80 % relative humidity at 30 ^{0}C atmospheric temperature.
5. For any ideal gas 1 kg mole is equal to 22.4 m^3 at 0 ^{0}C and 101.3 kPa.
6. Latent heat of vaporization of water is 2460.3 kJ/kg

Material input calculations and Heat Input of Plastics Waste

The above Table provides a range of characteristics for various types of unusable plastics as waste as data in study area specifically. It should be exercised to make usable of this table to assign the fractional component weight required performing heat balance calculations. The input of waste is 10 kg mixture of plastics for operational reason (1 – 2 kg / 10-minute operation), from finding out preliminary study can be estimating the following composition:

Table 1. Chemical Characteristic of Plastics as waste

Components	Empirical Formula	Molecular Mass (kg/mol)	Heating Value (kJ/kg)
Poly ethylene	$(C_2H_4)_n$	28.1 x n	23.304
Poly propylene	$(C_3H_6)_n$	42.2 x n	13.500
Poly vinyl Chloride	$(C_2H_3Cl)_n$	62.5 x n	11.630

Determination of Stoichiometric Oxygen needed for Burning Mole of Wastes

In the incineration process, mainly combustion reaction, oxygen is needed to completely oxidize of plastics material and convert to CO_2 and H_2O gasses. This oxygen required to oxidize the waste is calculated by the theoretical stoichiometric chemical equilibrium equations for each of the individual components of unusable plastics waste and are provided in the following:

$$(C_2H_4)_n + 3\,O_2 \rightarrow 3\,CO_2 + 2\,H_2O \quad ..3$$

$$(C_3H_6)_n + \tfrac{9}{2}O_2 \rightarrow 3\,CO_2 + 3\,H_2O \quad ..4$$

$$(C_2H_3Cl)_n + \tfrac{5}{2}O_2 \rightarrow 2\,CO_2 + H_2O + HCl \quad ..5$$

The molecular weight of monomer of plastics materials are mentioned as for PE = 28 g/mol, PP = 42 g/mol, and PVC = 62 g/mol. For 10 kg total waste as Table 2 fractionated, based on stoichiometric oxidizing above, it can calculate number as mentioned in Table 3 (noted molecular weight of O_2 is 32 g/mole).

In assumption of oxygen contain in air is 23 % by weight, the stoichiometric air for combustion is 32.24 kg/h x 100/23 = 139.74 kg/h, whereas in 100 % of excess air the total air for combustion is 139.74 kg/h x 2 = 279.48 kg/h. From this condition, the water content in atmospheric air is equal to the relative humidity and temperature.

For assumption above, the total water content in air for combustion is calculated as below:

Total water content (kg/h) = water content x air for combustion

= 0.0232 (kg H_2O/kg air) x 279.48 kg air/h

= 6.484 kg H_2O/h

Determination of Material Balance

Assuming the process without accumulation, all material input in incinerator system will be completely come out as materials output. Generally, based on material characteristics and stoichiometric above, the material balance is stated as follow:

For the air excess is 139.74 kg/h, then the combustion products are calculated as below:

Gas N_2 emitted = (100/77) x 139.74 kg/h = 107.60 kg/h

Gas CO_2, H_2O, and HCl emitted are calculated in basic of stoichiometric reaction above (Eq 1 to Eq 5). Mole total of each that parameter as shown in Table 4. Molecular weight for CO_2 = 44 g/mole, H_2O = 18 g/mole, and HCl = 36.5 g/mole.

Total on combustion product is sum of N_2, CO_2, HCl, and H_2O from stoichiometric calculation above.

Table 2. Composition of plastics waste and fractional weight

Component	Formula	Fractional Weight	HHV kj/kg	Total Heat kj/h
Poly ethylene	(C_2H_4) n	0.6 x 10 kg = 6 kg	46,304	277,824
Poly propylene	(C_3H_6) n	0.3 x 10 kg = 3 kg	26,500	79,500
Poly vinyl chloride	(C_2H_3Cl) n	0.1 x 10 kg = 1 kg	22,630	22,630379,954
Total		10 kg		

Table 3. Stoichiometric oxygen required calculation result and excess 100 %

Component	amount (kg; mole)	Oxygen req (mole)/h	Oxygen reg kg/h	Oxygen + excess (kg/h)
(C_2H_4) n	6; 214.3	642.9	20.57	41.14
(C_3H_6) n	3; 71.4	321.3	10.28	20.56
(C_2H_3Cl) n	1; 16.1	40.25	1.29	2.58
Total	10;	1004.45	32.14	64.28

Table 4. Stoichiometric CO_2, H_2O, and HCl product calculation based on stoichiometric

Component	Amount (kg; mole)	CO_2 prod (mole/h)	H_2O prod (mole/h)	HCl prod (mole/h)
(C_2H_4) n	6; 214.3	428.6	428.6	
(C_3H_6) n	3; 71.4	214.2	214.2	
(C_2H_3Cl) n	1; 16.1	32.2	16.1	16.1
Total	10;	675	658.9	16.1

Its summary shown in material balance scheme as in Figure 1.

Each of gasses are calculated as:

CO_2 = 675 mole/h x 44 g/mole x 1kg/1000g = 29.7 kg / h; 29.7/139.74 = 21.25 %

H_2O = 658.9 mole/h x 18 g/mole x 1 kg/1000 g = 11.86 kg/h; 11.86/139.74 = 8.48 %

Total H_2O = moisture + H_2O product = (6.484 + 11.86) kg/h = 18.344 kg/h; 13,12 %

HCl = 16.1 mole/h x 36.5 g/mole x 1 kg/1000 g = 0.59 kg/h; 0.59/139.74 = 0,42 %

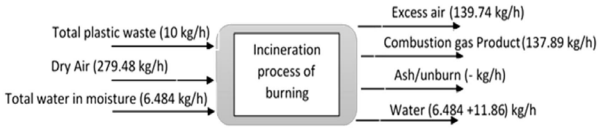


Fig. 1. The material balance scheme of design process incineration of unusable plastic

Determination of Heat Balance

Total heat in from all material input is equal to the sum of each material heat content. In this research total heat in = 379,594 kJ/h is available for its conversion to increase temperature of burning chamber. If in assumption 7 % heat loss in fugitive process (radiation), therefore radiation loss (i) = 7 % x 379,594 kJ/h = 26,596.78 kJ/h. The other heat losses are due to (ii) heat to ash, (iii) heat to air emission (dry combustion products), (iv) heat to increasing moisture temperature. Total heat loss is calculated below:

(i) Radiative loss = 13,411.58 kJ/h

(ii) Heat to ash = negligible

(iii) Heat to air emission = m.Cp.dT,

with assumption, initial temperature = 27 ^{0}C (environment temperature in location study), and target of temperature burning is 750 ^{0}C, so dT = (750 – 27) ^{0}C = 723 ^{0}C, Cp = mean heat capacity for dry air = 1.086 kJ/kg^{0}C, and m = total gas production emission.

heat to air emission = (139.74 + 137.89) kg/h x 1.086 kJ/kg^{0}C x 723 ^{0}C = 217,988.97 kJ/h

(iv) heat to moisture = m.Ca.dT + mHv + m.Cu.dT

for this equation, m = 18.344 kg/h (mass rate of water production and moisture), Ca = heat capacity for water = 4.187 kJ/kg^{0}C, Hv = latent heat of water vaporation = 2460.3 kJ/kg, and Cv = heat capacity for water vapor = 1.996 kJ/kg^{0}C.

heat to moisture = 18.344 kg/h x ((4.187 x 73) + 2460.3 + (1.996 x 650)) kJ/kg

= 74,532.61 kJ/h.

From calculation above, the total heat losses in combustion = 305,933.16 kJ/h. In this design, remaining heat is accumulated in process 379,594 kJ/h - 305,933.16 kJ/h = 73,660.84 kJ/h. Its calculation results expressed in energy balance scheme as in Figure. 2.

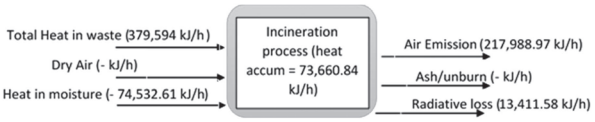


Fig. 2. Heat Balance for temperature burning chamber is designed for 750 ^{0}C

Determination of maximum temperature reachable

The heat remaining from this process is usable energy, that is generated from waste conversion. In case the heat remaining is not used, the temperature of burning chamber will increasing to reach heat remaining equal to zero (maximum burning temperature reachable).

$Q_{in} = Q_{out}$

= radiative losses + heat to air emission + air to moisture

= 13,411.58 kJ/h + m_g.Cp.(T_f-T_{in}) + m.Ca.(T_{boil} – T_{in}) + mHv + m.Cu.(T_f – T_{boil})

= 13,411.58 + 277.63 x 1.086 x (T_f – 27) + 18.344 x (4.187 x 73 + 2460.3 + 1.996 x (T_f – 100))

= 64,150.18 kJ/h + (301.51 (T_f – 27) + 36.615(T_f – 100)) kJ/h

For Q_{in} = 379,594 kJ/h; then T_f = 967.8 ^{0}C.

It means, if no auxiliary fuel added for combustion process, the incinerator designed is capable to reach high temperature combustion with maximum around 967 - 968 ^{0}C.

Estimation of oxygen content and gasses emission quality in air emissions

From resume of stoichiometric reaction data as seen in Table 3, air requirement for process is 139.74 kg/h, or total is 279.48 kg/h with 100 % excess. In this process, half of the gas will come out again (as excess) along with emission, as seen in the material balance scheme. Due to half the amount of oxygen used for combustion process, the emission produced have no oxygen. Thus, the calculation of oxygen content and quality other parameters of gas emission stream are based on the dilution phenomena, as bellow:

(i) The residual oxygen at total emission is:

$$\%\ O_2 res = \frac{air\ excess\ x\ [\%\ O_2] + air\ emission\ x\ [\%\ O_2]}{air\ excess + air\ emission}$$

$$\%\ O_2 res = \frac{139.74\frac{kg}{h}\ x\ [23\ \%] + 137.89\frac{kg}{h}\ x\ [0\ \%]}{139.74\frac{kg}{h} + 137.89\frac{kg}{h}} = 11{,}58\ \%$$

(ii) The maximum content of CO_2 and HCl at total emissions, assuming complete combustion, based on the mass balance, is:

$$\%\ CO_2 res = \frac{air\ excess\ x\ [\%\ CO_2 excess] + air\ emission\ x\ [\%CO_2 emission]}{air\ excess + air\ emission}$$

$$\%\ CO_2 res = \frac{139.74\frac{kg}{h}\ x\ [0\%] + 137.89\frac{kg}{h}\ x\ [21.25\ \%]}{139.74\frac{kg}{h} + 137.89\frac{kg}{h}} = 10{,}55\ \%$$

$$\%\ HCl\ res = \frac{air\ excess\ x\ [\%HCl\ excess] + air\ emission\ x\ [\%HCl\ emission]}{air\ excess + air\ emission}$$

$$\%\ HCl\ res = \frac{139.74\frac{kg}{h}\ x\ [0\%] + 137.89\frac{kg}{h}\ x\ [0.42\ \%]}{139.74\frac{kg}{h} + 137.89\frac{kg}{h}} = 0.208\ \%$$

(iii) The maximum water (H_2O) and N_2 content in emission stream are:

$$\%H_2O\ res = \frac{air\ excess\ x\ [\%H_2O\ excess] + air\ emission\ x\ [\%H_2O\ emission]}{air\ excess + air\ emission}$$

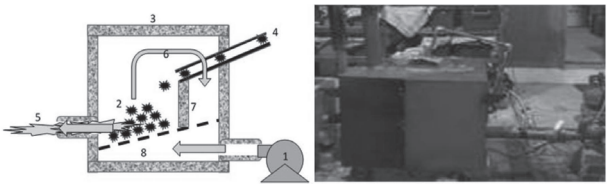
$$\%\ H_2O\ res = \frac{139.74\frac{kg}{h}\ x\ [0\%] + 137.89\frac{kg}{h}\ x\ [13.12\ \%]}{139.74\frac{kg}{h} + 137.89\frac{kg}{h}} = 6.52\ \%$$

$$\%\ N_2 res = \frac{air\ excess\ x\ [\%\ N_2 excess] + air\ emission\ x\ [\%N_2 emission]}{air\ excess + air\ emission}$$

$$\%\ N_2 res = \frac{139.74\frac{kg}{h}\ x\ [77\%] + 137.89\frac{kg}{h}\ x\ [78.1\ \%]}{139.74\frac{kg}{h} + 137.89\frac{kg}{h}} = 77.55\ \%$$

RESULTS AND DISCUSSION

The prototype was designed as a semi batch type. The main parameters are rate of air supply for combustion, system of combustion, and rate of waste amount to be burned. In special case during performance test, the prototype configuration was main combustion chamber with direct burning system, stack dimension, air supply duct with blower (about 220 m^3/h), and the ash chamber. The required dimensions had been calculated in the design and calculation sub-chapter. The design scheme and the physical prototype is shown in Figure. 3.



1. Blower for air supply (± 220 m^3/h) 2. Plastic unusable material burning (2 kg/10 minute), 3. Primary chamber with metal plat (0.8 cm) and stone insulation for heat (5 cm), 4. Feeder for material plastics, 5. Fire flares, 6. Gasification and circulation unburn gas, 7. Separator wall, 8. Blowing air

Fig. 3. Principle Scheme of Prototype Primary Burner of Incinerator designed

Performance testing is done by burning 2 kg of plastic every 10 minutes. This plastics material was fed through the feeder gradually for every 10 minutes. The blower is fully turned on to give airflow around 220 m^3/hour (based on the calculation of the required air for combustion). During operation, the temperature in the combustion chamber was monitored with a thermocouple set analysis and the data generated automatically read and saved every 4 minutes.

In principle, the heat of combustion results indicates the designed combustion performance. As reference, the temperature design calculated for the conditions set for, the heat in the combustion chamber (or combustion heat) is 750 - 968 ^{0}C. Thus, the heat measurement data in the combustion chamber will be compared with the design calculation results. Combustion performance is categorized as good, if the combustion temperature is between 750 - 968 ^{0}C (design calculation temperature) or above. The combustion temperature test results can be seen in Figure 4.

From the tests that had been carried out with 12 repetitions, the measured temperature profile in the combustion chamber, as in Figure 4, showed good combustion performance. The measured temperature shows the temperature from room temperature to reach about 800 ^{0}C in 16 minutes,

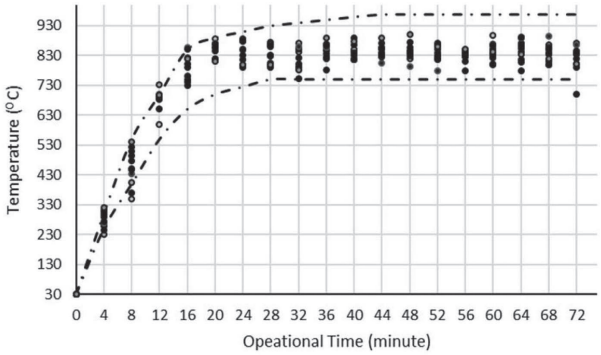


Fig. 4. Designing temperature range and measured temperature in burning of 2 kg unusable plastic every 10 minutes operational

and then the temperature is relatively stable at an average temperature of 830 - 880 ^{0}C for next combustions. The maximum temperature that can be achieved was 901 ^{0}C. These results have shown that the prototype tested, has had good performance. At the resulting combustion temperature, it can scientifically guarantee the formation of dioxin at emissions become very small. These results can be used as a strong basis, to continue the prototype and refine it, to become a no-auxiliary fuel incinerator that will be used for the destruction of unusable plastic waste in urban areas or elsewhere.

CONCLUSION

In general, unusable plastic waste is contaminated by water, soil, and coloring materials. Plastic combustion test showed promising results (low emissions) with F/A about 1.5 or higher, and theoretically minimum or no dioxin produce if it burns in above 600 ^{0}C conditions. The dimension calculation for prototype incinerators is of 0.4 x 0.3 x 0.4 m^3 net volume chamber. This chamber capacity was for 2 kg unusable plastics for every 10 minutes with around 100 % of air excess. Test performance showed the maximum temperature achieved was 901 ^{0}C, and average of 850 ^{0}C after stable burn. The time needed to reach a temperature of around 800 ^{0}C is about 16 minutes. Test results showed the prototype design of this incinerator is exceptionally good performance.

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