SIIC069

MODELLING OF ROTARY KILN INCINERATOR FOR THE DISPOSAL OF HAZARDOUS WASTE

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Abstract:
The generation of hazardous wastes is currently increasing in Malaysia. These wastes originated from industrial and medical related activities, which pose health risk to human and the environment. There are various methods of treatment available for the disposal of these wastes such as thermal and non-thermal technique. However, the thermal treatment through incineration is found to be the best available option for the disposal of these hazardous wastes because it is fast and complete reaction with tremendous volume reduction. Typically and commercially, rotary kiln type incinerator is commonly used for this purpose as it can handle any combination of wastes may it be in the form of solid, liquid, or sludge. Thus, this study presents the modeling of rotary kiln incinerator based on a typical hazardous waste composition taken into consideration of three main inputs, which are waste inlet, excess air inlet, and fuel inlet with flue gas outlet as the main output by using the Microsoft Excel spreadsheet. Reliability of model is determined by comparing the percentage error of flue gas composition between two (2) different compositions of typical hazardous waste. For both values, it is found that the percentage errors are 0.31% and 1.20% respectively. Model was able to predict a low percentage error of 5% and below. Addition data can be tested for further determination of the model's reliability

Keywords**:** *Modelling, Incineration, Mass Balance, Rotary Kiln Incinerator, Flue Gas Emission.*

Objectives:

- To develop an analytical spreadsheet of mass balance for the modelling of a rotary kiln incinerator.
- To simulate and compare the developed model with actual available data from existing incinerator plants.

Methodology:

1. ***Rotary Kiln Working Principle***

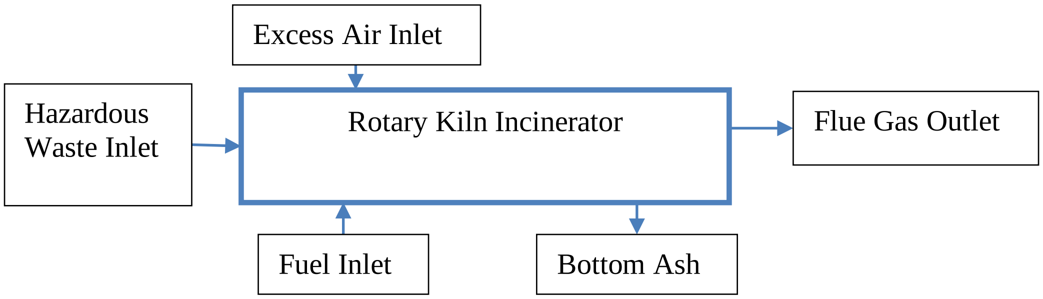

Figure 2.1: Rotary Kiln Working Principles

2. *Typical Waste Inlet*

Table 2.1: Waste Componential Composition with Addition of Water

Waste Componential Composition					
Element	%w/w	kg/hr	Atomic Weight	kg-atom	%Atom
C	0.00	0	12.01	0.00	0.00
H	0.00	0	1.01	0.00	0.00
Cl	0.00	0	35.45	0.00	0.00
S	0.00	0	32.06	0.00	0.00
O	0.00	0	16.00	0.00	0.00
N	0.00	0	14.00	0.00	0.00
H_2O	0.00	0	18.00	0.00	0.00
Ash	0.00	0	-	0.00	0.00

3. *Rotary Kiln Mass Balance*

Equation 2.1 presents the standard equation on the reactions that will occur in the rotary kiln. Balanced of equation will depend on the waste compositions.

$$C_0H_0S_0Cl_0N_0Cl_0 + O_2 + N_2 + H_2O \rightarrow CO_2 + N_2 + SO_2 + O_2 + H_2O + HCl \quad (2.1)$$

4. *Excess Air and Fuel Inlet*

Equation 2.2 shows the equation for oxygen needed.

$$Oxygen\ Needed = Oxygen\ Required - Oxygen\ Generated \quad (2.2)$$

Fuel gas that comprises of natural gas and diesel as both are commonly used as fuel gas for an incinerator, natural gas has the elements of carbon, hydrogen and nitrogen while sulphur comprises of carbon, hydrogen and sulphur.

2.5 Comparison Method

The comparison will be done with two (2) actual data which are categorized as Typical waste A and Typical waste B.

Table 2.2: Typical waste A and B compositions

	Typical Waste A	Typical Waste B
Total Waste Feed	3200 kg/h	1400 kg/h
Elements	Composition	Composition
C	24.10%	29.00%
H	3.30%	4.00%
Cl	3.10%	2.00%
S	0.40%	1.00%
O	3.30%	4.00%
N	1.3%	3.10%
H_20	51.00%	44.00%
Ash	13.20%	13.00%
TOTAL	99.70%	100.10%

Percentage error is calculated by the given Equation 2.3.

$$\left|\frac{Actual\ Data - Simulated\ Data}{Actual\ Data}\right| \times 100 \qquad (2.3)$$

Results:

1. Overall Modelling Structure

Firstly, tabling structure of the waste inlets for raw waste composition and ultimate wet analysis are shown in Table 3.1.

Table 3.1: Raw Waste Compositions and Wet Ultimate Analysis

	Raw Waste Composition	Ultimate Analysis (WET)
Elements	Composition	Composition
C	30.00%	17.14%
H	5.00%	2.86%

Cl	4.00%	2.29%
S	5.00%	2.86%
O	3.00%	1.71%
N	2.00%	1.14%
H20	60.00%	60.00%
Ash	12.00%	12.00%
TOTAL	121.00%	100.00%

Excess air table structure is presented in Table 3.2 for the percentage of excess air at 157% of the required oxygen of 3054.13 kg/h.

Table 3.2: Excess Air Structure

Air	Mass Flowrate (kg/h)
Oxygen Required	705.43
Oxygen Generated	17.14
Oxygen Needed	688.28
Elements of Air	
O_2	1080.60
N_2	4013.68
H_2O	51.46
TOTAL	5145.74

Table 3.3 shows the flue gas composition based on the values inserted in Table 3.1. Table 3.3: Flue Gas Composition

Elements	Mass Flowrate (kg/h)
CO_2	627.43
N_2	4025.10
SO_2	57.14
H_2O	900.20
O_2	392.32
HCl	23.50
Ash	54.00
Total	6079.69

2. Comparison with Actual Data

Table 3.4: Comparison with Typical Waste A and Waste B

	Typical Waste A		Typical Waste B	
Flue	Mass Flowrate (kg/h)	Percentage	Mass Flowrate (kg/h)	Percentage

Gas	Actual	Simulated	Error	Actual	Simulated	Error
CO_2	3018	2846.44	5.68 %	1820	1482.51	18.54 %
N_2	17031	17689.08	3.86 %	11447	11793.52	3.03 %
SO_2	26	25.82	0.69 %	18	27.94	55.22 %
H_2O	2905	2781.39	4.26 %	1565	1257.53	19.65 %
O_2	2188	1956.36	10.59 %	1607	1692.12	5.30 %
HCl	103	102.84	0.16 %	22	28.72	30.55 %
Ash	211	211.20	0.09 %	28	27.30	2.50 %
TOTAL	25523	25444.16	0.31 %	16507	16309.63	1.20 %

Conclusion:

In conclusion, this model presents the simulated working condition of an actual working rotary kiln incinerator system. It focused on the subtle detail starting at the feed of hazardous waste at the inlet towards the variation changes in addition of excess air and fuel gas for the assist in the full combustion of waste until the flue gas exited the rotary kiln. The simulated values gained from the stoichiometric and mass balance equations present a similar condition and value with the actual data of the typical hazardous waste composition values with a bare minimum of percentage error. Capability of cooperating moisture content and wide range of different waste composition into the modelling that proportional with the current array of waste compositions in Malaysia. Providing a better solution and alternative of using modelling in determining the flue gas composition of a rotary kiln incinerator apart from previous manual sampling directly to the stack where the process consume excessive usage of energy and manpower, longer period of analyst and expensive usage on capital whereby the developed model can ease tremendously and shorten the period of time in determine the flue gas composition for any plant. It was verified that the model shows a promising close to actual values to the actual operating incinerator plant in Malaysia that was generated by the model under the acceptable error margin of less than 5%. To establish a better thorough finding and verification on the reliability of model, more trials for the comparison of data can be done to measure the model capabilities of simulating varieties of waste composition as the limitation of this study is to be compare solely with the two (2) set of actual data.