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Simulation of Efficiency in Improving the Performance of Cylindrical Vertical Furnace Using Indirect Method

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ABSTRACT

One of the essential pieces of equipment at the Pertamina Refinery Unit V Balikpapan is the Furnace F-3-04 Vertical Cylindrical type. Furnace operation efficiently becomes very important given the vast energy consumption and directly influences the level of refinery profits. Therefore, it is necessary to do a simulation to increase the efficiency value to minimize energy use. This study aimed to determine the effect of O_2 Excess and Flue Gas temperature on efficiency and to find the best efficiency from the simulation results on a Vertical Cylindrical Furnace. In this study, the furnace's efficiency is calculated and simulated using the indirect method. The heat entering the furnace is reduced by the heat lost compared to the heat entering. Initial data processing is a normality test to determine whether the data is usually distributed and can be used for data to be entered into the mathematical simulation of furnace efficiency. The efficiency value produced by Furnace F-3-04 is 86.3%, with an O_2 excess value of 7.25% and a Flue Gas temperature of 419 ^{0}C. From the simulation carried out, it can be seen that the operating parameter that most affects efficiency is O_2 Excess of 0.15 – 0.18% for every 0.5% decrease in O_2 Excess for 5 simulations. Meanwhile, the Flue Gas temperature gets a value of 0.02 – 0.03% for every 2 ^{0}C decrease for 5 simulations. The best efficiency value is 87.7%, with O_2 Excess of 4.75% and Flue Gas temperature of 409 ^{0}C.

INTRODUCTION

PT Pertamina (Persero) through Sub Holding Refinery & Petrochemical, namely PT. Kilang Pertamina Internasional (PT. KPI) is currently in the process of transforming into a world-class refinery. One of the efforts is building a well-managed and sustainable energy management system. Refinery Unit V Balikpapan as part of PT. KPI is no exception, it also runs an energy management program in collaboration with the Energy Management System (EMS) program. EMS is a controlled system that is part of an organization to implement energy management and improve efficiency on an ongoing basis [1-5].

A furnace or fired heater is fired equipment that transfers heat from the combustion reaction. In contrast, the combustion reaction is a swift chemical reaction between combustible materials (fuel) and oxygen (in the air) by releasing heat (exothermic) and light. The fluid passing absorbs the heat from this combustion through the tube in the furnace. The heated fluid or raw material is in the form of crude oil or oil derived from crude oil. The fuel combustion can be fuel oil, fuel gas, or a mixture of both. In general, the primary form of a furnace is a cylinder and a cabin. The simplest form is Vertical Cylindrical [6-9].

Combustion efficiency is defined as the ratio between the total heat absorbed by the heated fluid and the total heat generated by the combustion of fuel in the furnace. If the amount of air in the reaction exceeds the stoichiometric requirement, residual air will not be burned as much as the given air minus the stoichiometric air. This remaining air is called Excess Air. Measurements carried out in the furnace are by measuring the residual oxygen in the flue gas through the stack, or Excess Oxygen (remaining O2 in the air) and measured in weight percent %wt of the total exhaust gas [10-14].

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The indirect method is calculating efficiency based on heat loss, commonly referred to as the Heat Loss method. Furnace efficiency is calculated after subtracting sensible heat loss in flue gas, loss due to moisture in flue gas, heat loss due to furnace openings, heat loss through furnace walls, and other unaccounted losses [15-16].

EXPERIMENTAL METHOD

In this research, the process stages include data management and simulation models. After that, simulate going through the normality test to analyze the results. At the same time, the desired output is to obtain optimal furnace efficiency from the influence and settings of each parameter.

Research Method

a. Preparation Step
At the preparation stage to be carried out, among others, conducting preliminary research related to furnace efficiency, determining F-3-04 as the research subject, preparing software in the form of Microsoft Excel 365 and SPSS, determining the research time, namely September 2021, and preparing data related to operating conditions. F-3-04.

b. Research Step
At the research stage, which will be carried out, among others, note the operating parameters of F-3-04 in the form of feed flow rate, furnace inlet & outlet temperature, O_2 Excess, flue gas temperature, air temperature, and furnace efficiency. Measuring additional operating parameters that are not included in routine monitoring, performing normality tests on operating condition data using SPSS to obtain certainty whether it is feasible to be used as input for modeling simulations. Making simulation designs using indirect methods and calculating and processing data related to efficiency, which :

$$\text{Efisiensi } (\eta) = \frac{\text{Heat input} - \text{Heat Loss}}{\text{Heat Input}} \times 100\ \% \quad \text{.........(Eq. 1)}$$

Excess Air =

$$\frac{(O2\ \%) - \left(\left(\frac{1}{2}\right) x\ (CO\%)\right)}{\left((N2\ \%)\ x \left(\frac{21}{79}\right)\right) - \left((O2\ \%) - \left(\frac{1}{2}\right) x\ (CO\ \%)\right)} \times 100\ \% \quad \text{.........(Eq. 2)}$$

From the calculation steps, it can be described the modeling scheme in Furnace F-3-04 B as follows :

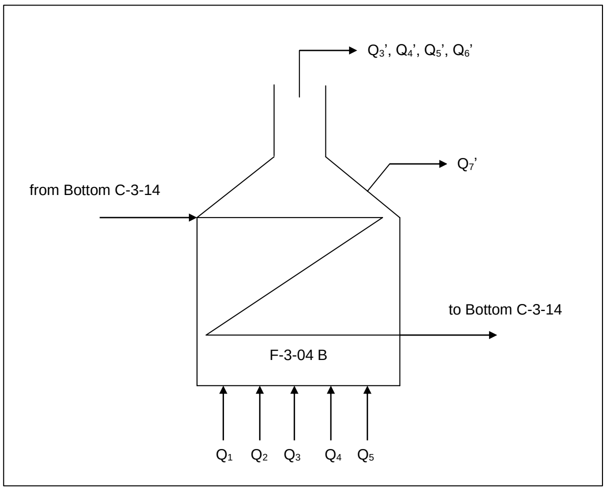

Figure 1. Simulation Sceme of *Heat Balance*

Where :

1. Heat of Fuel Combustion
Q_1 = NHV x m fuel……………….…….….(Eq. 3)
2. Sensible Heat of Fuel
Q_2 = Hs x m fuel………………..;……...(Eq. 4)
3. Sensible Heat of Dry Air
Q_3 = m O_2 x ratio O_2 x m fuel………......(Eq. . 5)
4. Sensible Heat of Water Contained in Air
Q_4 = m H_2O x Cp x Δt…………………..(Eq. 6)
5. Sensible Heat of Atomizing Steam
Q_5 = H Steam x m Steam……….……...(Eq. 7)
6. Heat loss due to dry Flue Gas
Q_3' = Qfg x m fg………………..………(Eq. 8)
7. Heat loss due to moisture present in air
Q_4' = m H_2O x Cp x Δt………..……...…(Eq. 9)
8. Heat loss due to Steam
Q_5' = m Steam x Cp x Tfg……..…........(Eq. 10)
9. Heat loss due to evaporation of moisture present in Fuel
Q_6' = m H_2O x Cp x Δt…………...…...(Eq. 11)
10. Heat loss due to Radiation
Q_7' = hi x Ai x Δt……………………....(eq. 12)

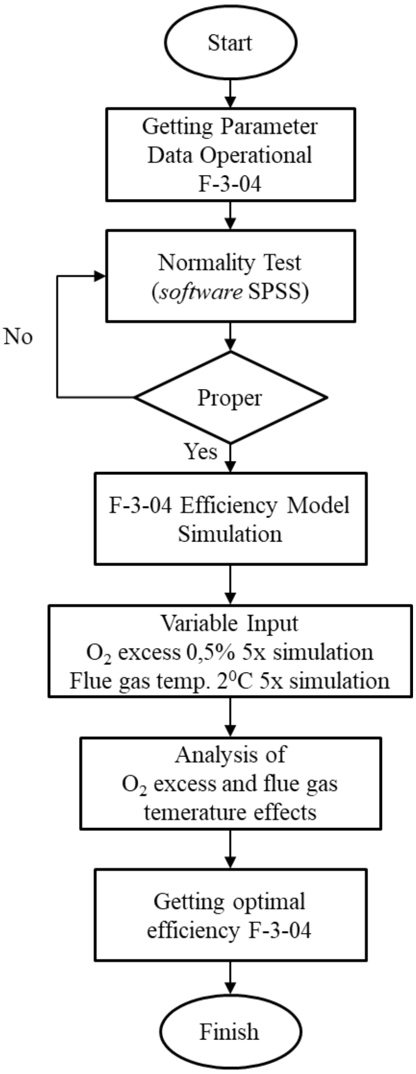

Figure 2. Research Flowchart

RESULTS AND DISCUSSION

1. *Heat Balance* F-3-04

From Figure 1. Heat Balance Furnace Simulation Scheme F-3-04, the calculation results for each heat are as follows :

Table 1. Heat Value

Heat in (Q_{in}) (Kcal/h)		**Heat out (Q_{out}) (Kcal/h)**	
Q_1	28522800.41	Q_3'	1543622.94
Q_2	298947.4181	Q_4'	318216.55
Q_3	483672.3022	Q_5'	19295.97
Q_4	23146.11185	Q_6'	1150980.51
Q_5	67534.40565	Q_7'	868946.82
Total	29396100.65	Total	3901062.805

Total Heat Used (Q_{used}) based on Tabel 1 are :

$Q_{used} = Q_{in} - Q_{out}$

$= 29396428{,}2 - 3929514{,}854$

$= 25466913{,}34$ Kcal/h

Table 2. Heat Balance

Heat Balance F-3-04			
In (Kcal/h)		Out (Kcal/jam)	
Q_{in}	29396100.65	Q_{out}	3901062.805
		Q_{used}	25495037.84
Total	**29396100.65**	Total	**29396100.65**

From the simulation, the efficiency of F-3-04 is 86.73% with an O_2 Excess of 7.25% or equivalent to 46.83% excess air and an average Flue Gas temperature of 419 ^{0}C. Furnace efficiency can be increased by improving the excess air value and lowering the flue gas temperature [17].

2. *O_2 Excess Simulation*

In O_2 Excess as the independent variable, a simulation of a 0.5% decrease from the initial conditions was carried out 5 times in succession, and the results are as follows :

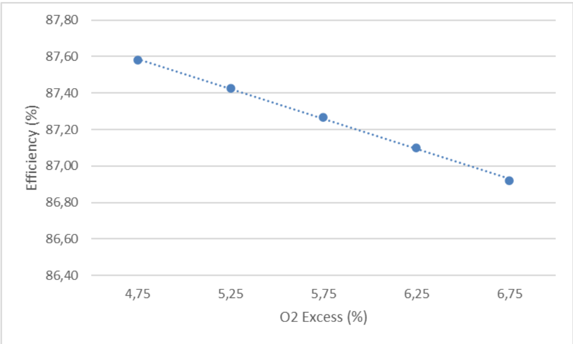

Figure 3. Trend of Efficiency with O_2 Excess effect

From Figure 3. if it is correlated as a whole with excess air and the amount of heat lost as follows :

Table 3. O_2 Excess Simulation Result

O_2 Excess	Excess Air	Efficiency	Total Heat Loss
4.75	26.41	87.58	3642532.89
5.25	30.03	87.43	3688360.04
5.75	33.86	87.27	3736885.57
6.25	37.92	87.10	3788355.04
6.75	42.23	86.92	3843044.73

From Table 3. The efficiency increase results are 0.15 – 0.18% for every 0.5% decrease in O_2 Excess. The simulation results prove that the smaller the value of O_2 Excess, the higher efficiency will be [17-18].

3. Flue Gas Temperature Simulation

In Temperature Flue Gas as the independent variable, the second simulation was carried out for a decrease of 2 ^{0}C from the initial conditions 5 times in succession, and the results are as follows :

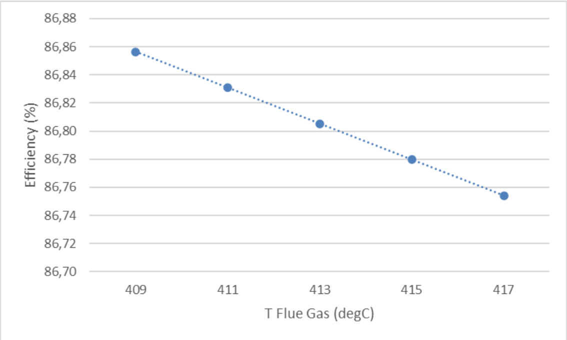

Figure 4. Trend of Efficiency with Flue Gas temperature effect

From Figure 4, if it is correlated as a whole with excess air and the amount of heat lost as follows:

Tabel 4. Flue Gas Temperature Simulation Result

T Flue Gas	Excess Air	Efficiency	Total Heat Loss
417	46.83	86.75	3893739.44
415	46.83	86.78	3886216.82
413	46.83	86.81	3878698.78
411	46.83	86.83	3871185.29
409	46.83	86.86	3863676.35

From Table 4. The results of an increase in efficiency of 0.02 – 0.03% are obtained for every 2 ^{0}C decrease in Flue Gas temperature. The simulation results prove that the smaller the value of the Flue Gas temperature, the higher the efficiency [17-18]

4. Best Efficiency Simulation Result

The collaboration of the O_2 excess variable and the flue gas temperature on the efficiency value is as follows :

Table 5. O2 Excess and Temperature Flue Gas on the Efficiency of Simulation Results

O_2 Excess (%)	Temp. Flue Gas (^{0}C)				
	417	415	413	411	409
6.75	86.95	86.97	87.00	87.02	87.05
6.25	87.12	87.15	87.18	87.20	87.23
5.75	87.29	87.32	87.34	87.37	87.39
5.25	87.45	87.48	87.50	87.53	87.55
4.75	87.60	87.63	87.65	87.68	87.70

The best efficiency value that can be generated from the simulation is 87.7%, with O_2 Excess of 4.75% and Flue Gas temperature of 409 ^{0}C.
All simulation results for optimizing Furnace F-3-04 efficiency are obtained with the assumption of complete fuel combustion and no water vapor in the combustion air. The actual reduction of O_2 Excess and Flue Gas temperature can be made by setting the air register/damper and operating the soot blower.

CONCLUSION

Based on the simulation results that have been carried out, several conclusions can be drawn as follows:

1. In the simulation model, it can be seen that the efficiency of the F-3-04 furnace is 86.3%, with an O_2 Excess value of 7.25% and a Flue Gas temperature of 419 ^{0}C.
2. Every 0.5% decrease in O_2 Excess from 5x simulations increases to 0.15 – 0.18% efficiency, while for Temperature Flue Gas, it gets an increase of 0.02 – 0.03% for every 2 ^{0}C decrease for 5x simulation.
3. The best efficiency value is 87.7%, with O_2 Excess of 4.75% and Flue Gas temperature of 409 ^{0}C.

RECOMMENDATION

The research conducted is limited to O_2 Excess and Temperature Flue Gas on heat loss, air requirements, and efficiency and does not cover other operational costs in operating the F-3-04 furnace. It is assumed that the flame is stable, and there is no adjustment to the shape of the flame. It is hoped that there will be other research that is more comprehensive and covers the costs of using fuel gas and other operational costs.

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