Evaluation of the Efficiency of the Combustion Furnace of the Delayed Coking Unit by Manipulating the Parameters that Affect the Furnace Efficiency

Mahmoud Adam Hassan Salih, Ahmed Abd Alazeem Mohammed, Basil Yousif Khalifa, Fatima Omar Elamin, Nihad Omer Hassan

Department of Petroleum Transportation and Refining Engineering, Faculty of Petroleum Engineering and Technology, Sudan University of Science and Technology, Khartoum, Sudan

Email address: Moatazedhmar@gmail.com (M. A. H. Salih), Ahmedalldndrawee@gmail.com (A. A. A. Mohammed), fatmasara1994@gmail.com (F. O. Elamin)

To cite this article: Mahmoud Adam Hassan Salih, Ahmed Abd Alazeem Mohammed, Basil Yousif Khalifa, Fatima Omar Elamin, Nihad Omer Hassan. Evaluation of the Efficiency of the Combustion Furnace of the Delayed Coking Unit by Manipulating the Parameters that Affect the Furnace Efficiency. American Journal of Quantum Chemistry and Molecular Spectroscopy. Vol. 2, No. 2, 2018, pp. 18-30. doi: 10.11648/j.ajqcms.20180202.11

Received: August 13, 2018; Accepted: September 17, 2018; Published: October 19, 2018

Abstract: Furnaces and fired heaters provide the energy associated with running hydrocarbon processes and chemical plants. They are required to maximize heat delivery of the process-side feed while minimizing fuel consumption, as well as Maximize heat delivery with varying fuel quality, and Minimize heater structural wear which caused by operation. Furthermore, minimize stack emissions and Maximize safety integrity levels. In this study the suitable and best way to gain high efficiency of the furnace has been determined by manipulating the parameters that affect in efficiency of the furnace which is represented in: The effect of excess air and stack temperature on furnace efficiency, the effect of preheating the inlet air on furnace efficiency, and the effect of nitrogen to oxygen ratio in combustion air on the efficiency. Aspen exchanger design and rating (EDR) was used to design fired heater and the results were used in aspen HYSYS to determine the effect of these parameters consequently obtaining the best effective way for high efficiency which represent in reducing the percent of nitrogen. This study also includes controlling and monitoring three major parameters: (Fuel gas/fuel oil pressure, Excess air and Furnace draft fan), and using excel sheets for estimating the Cost of the furnace.

Keywords: Furnace, Efficiency, Excess Air, Stack Temperature, Heat Loss

1. Introduction

Fula crude oil is one of the types of crude oil in Sudan, one of its characteristics it contains high percentage of asphalt as well as high density and viscosity that is why delayed coking unit (DCU) has been stablished in Khartoum refinery company, this unit works on removal of asphalt from the crude hence reduce its viscosity and its density therefore high percentage of the desired products in Sudan market can be produced. In addition, delayed coking unit upgrades material called bottoms from the atmospheric or vacuum distillation column into higher-value products. With delayed coking, two or more large reactors, called coke drums, are used to hold, or delay, the heated feedstock while the cracking takes place. Coke is deposited in the coke drum as a solid. This solid coke builds up in the coke drum and is removed by hydraulically cutting the coke using water. The yield of coke from the delayed coking process ranges from about 18 to 30 percent by weight of the feedstock residual oil [1]. Delayed coking unit consist of various numbers of primary facilities such as coke drums, fractionator, pumps as well as furnace.

1.1. Furnace

Fired heater is a device used to heat up chemicals or chemical mixtures. It’s classified as direct fired or indirect fired. Direct-fired furnaces can be identified by the amount of volume, the combustion gases occupy inside the furnace. fired heater can be also classified as natural, induced, forced, or balanced draft. Fired heaters are used in many processes, including distillation,
reactor processes, olefin production, and hydrocracking. The primary means of heat transfer in a fired heater are radiant heat transfer and convection and consist essentially of a battery of pipes or tubes that pass through a firebox [2]. In general, a Fired Heater can be divided into three zones:

(i) Radiant zone
(ii) Convective zone
(iii) Economizer zone

1.2. Furnace Efficiency

Running furnaces efficiently is a major operating concern because two thirds of a plant’s fuel budget is needed for furnace fuel cost. Furnace efficiency is linked to environmental regulations that stipulate a clean operation. Most furnaces use fuel gas or fuel oil. Natural gas burns cleaner and more efficiently than oil [2].

Furnace efficiency or total furnace efficiency is the ratio of heat usefully absorbed and total heat supplied.

\[
Efficiency = \frac{\text{heated usefully absorbed by heated medium}}{\text{total heat supplied}} \times 100 \quad (1)
\]

1.3. Combustion Reaction

The combustion reaction in the burner model of the Fired Heater performs pure hydrocarbon (CxHy) combustion calculations only. The extent of the combustion depends on the availability of oxygen which is usually governed by the air to fuel ratio. Air to fuel ratio (AF) is defined as follows:

\[
AF = \frac{\text{Mass of flow O2}}{\text{Mass of flow fuel}} \times \text{mass ratio of O2 in air} \quad (2)
\]

1.4. Problem Statement

Reduction in the operation efficiency compare to design efficiency and increase in heat losses.

1.5. Objectives

1. Determine furnace efficiency.
2. Investigate different parameters that affect in thermal efficiency:
   - (a) The effect of excess air and stack temperature on furnace efficiency.
   - (b) The effect of preheating the inlet air on furnace efficiency.
   - (c) The effect of nitrogen to oxygen ratio in combustion air on the efficiency.
3. Furnace control.
4. Furnace cost.

1.6. Scope of this Study

The scope of this project is to give detailed study for efficiency of the furnace in delayed coking unit (DCU), control of furnace and cost of furnace.

2. Heat Transfer

Fired Heater heat transfer calculations are based on energy balances for each zone. The shell side of the Fired Heater contains five holdups:

(a) three in the radiant zone
(b) a convective zone
(c) an economizer zone

For the tube side, each individual stream passing through the respective zones is considered as a single holdup. Major heat terms underlying the Fired Heater model are illustrated in the figure below.

Figure 1. Major heat terms underlying the Fired Heater model.
The heat terms related to the tubeside are illustrated in the figure below.

![Figure 2. The heat terms related to the tubeside.](image)

Taking Radiant zone as an envelope, the following energy balance equation applies:

\[
\frac{d(M_{rad}H_{rad})}{dt} + \frac{d(M_{RPFtube}H_{RPFtube})}{dt} = (M_{RPF}H_{RPF})_{in} - (M_{RPF}H_{RPF})_{out} + (M_{FG}H_{FG})_{in} - (M_{FG}H_{FG})_{out} - Q_{\text{rad wall to tube}} - Q_{\text{red wall sur}} - Q_{\text{con sur}} + Q_{\text{rad wall tube}} - Q_{\text{con to wall}} + Q_{\text{reaction}}
\]

(3)

Where:

\[
\frac{d(M_{rad}H_{rad})}{dt} = \text{energy accumulation in radiant zone holdup}
\]

Radiant Heat Transfer
For a hot object in a large room, the radiant energy emitted is given as:

\[
Q_{\text{convective}} = UA(T_2 - T_1)
\]

(4)

T1 = temperature of hot surface 1, K
T2 = temperature of hot surface 2, K

Convective Heat Transfer
The convective heat transfer taking part between a fluid and a metal is given in the following:

\[
Q_{\text{convective}} = UA(T_1 - T_2)
\]

(5)

where:

U = overall heat transfer coefficient, W/m²K
A = area exposed to convective heat transfer, m²
T1 = temperature of hot surface 1, K
T2 = temperature of surface 2, K

Conductive Heat Transfer
Conductive heat transfer in a solid surface is given as:

\[
Q_{\text{convective}} = -KA \frac{(T_1 - T_2)}{\Delta t}
\]

(8)

where:

k = thermal conductivity of the solid material, W/mK
A = area exposed to conductive heat transfer, m²
T1 = temperature of inner solid surface 1, K
T2 = temperature of outer solid surface 2, K

U_{\text{used}} = U_{\text{specified}}(\text{Mass flow at time } t)^{0.8}

(6)

U_{\text{used}} = U_{\text{specified}}(0.001)^{0.8}

(7)

The U actually varies with flow according to the following flow-U relationship if this Flow Scaled method is used:
2.1. Heating Values

Heating value of fuel (units of KJ/kg or Mj/kg are traditionally used to quantify maximum amount of heat that can be generated by combustion with air at standard condition (STP) (25°C and 101.3 kpa). The amount of heat release from combustion of the fuel will depend on the phase of water in the product. If water is in gas phase in the product, the value of total heat denoted as the lower heating value (LHV) [14].

2.2. Excess Air

The terms excess air and excess oxygen are commonly used to define combustion. They can be used synonymously but have different units of measurements. The percentage of excess air is the amount of air above the stoichiometric requirement for complete combustion. The excess oxygen is the amount of oxygen in the incoming air not used during combustion and is related to percentage excess air. Additional air beyond the theoretical “perfect ratio” needs to be added to the combustion process—this is referred to as “excess air.”

3. Furnace Efficiency

There are two methods to calculate efficiency: -

(a) Direct method: -
\[ e = \frac{\text{heat absorb by crude} + \text{heat absorb by steam}}{\text{fuel compustion calorific value}} \times 100\% \] (9)

(b) Indirect method: -
\[ e = \frac{(\text{LHV}+\text{Ha}+\text{Hf})-(Q_{s}-Q_{r})}{\text{(LHV}+\text{Ha}+\text{Hf})} \times 100\% \] (10)

\[ e \] = Net thermal efficiency.
\[ \text{LHV} \] = Lower heating value of fuel (BTU/LB).
\[ \text{Ha} \] = Heat input in form of sensible heat of air (BTU/LB).
\[ \text{Hf} \] = Heat input in form of sensible heat of fuel (BTU/LB).
\[ Q_{s} \] = Heat stack losses (BTU/LB).
\[ Q_{r} \] = Radiation heat losses (BTU/LB).

This research focus on indirect method as a source of high accuracy because all loses (stack losses, radiation losses) are taken into account.

\[ \text{Weight} = (\text{volume fraction} \times \text{molecular weight}). \]

\[ \text{Heating value} = (\text{net. heating value} \times \text{weight}) \]

\[ \text{Stoichiometric oxygen} = (\text{oxygen from combustion reaction} \times \text{volume fraction}). \]

Figure 3. Relation between excess air % and oxygen% in flue gas [11].

- Actual oxygen required = Stoichiometric oxygen + (excess air * Stoichiometric oxygen).
- Actual air required = actual oxygen required * \( \left(\frac{100}{21}\right) \).

- Estimate stack component (CO₂, H₂O, SO₂, O₂, N₂).
- Amount of CO₂ in flue gas = (total formed + CO₂ reported as fuel).
- Amount of H₂O in flue gas = (total formed + H₂O reported as fuel).
- Amount of SO₂ in flue gas = (total formed + SO₂ reported as fuel).
- Amount of O₂ in flue gas = (actual O₂ supplied − actual O₂ used during combustion).
- Amount of N\textsubscript{2} in flue gas = (79\% of moles of air + N\textsubscript{2} reported as fuel).

3.1. Lower Heating Value

\[
LHV = \frac{\sum \text{heating value}}{\sum \text{weight of component of fuel}}
\]

(11)

3.2. Stack Losses

1. (amount of stack component * molecular weight).
2. (result from (1) / amount of fuel enter the furnace).
3. result from (2) * enthalpy for each stack component).
4. summation of all result in (3).

3.3. Radiation Losses

The radiation heat losses were determined by multiplying heat input fuel (LHV) by the radiation losses expressed as percentage Therefore, radiation heat losses = (1\% + 3\%)/2 = 2\% of heat input (LHV).

3.4. Sensible Heat Correction for Combustion of Air (H\textsubscript{a})

\[
H_a = \frac{\text{lb of air}}{\text{lb of fuel}} \times C_p \text{air} \times (T_t - T_d)
\]

(12)

\[T_t = \text{combustion air temperature.}\]

\[T_d = \text{datum temperature (60\degree F).}\]

3.5. Sensible Heat Correction for Fuel (H\textsubscript{f})

\[
H_f = C_p \text{fuel} \times (T_t - T_d)
\]

(13)

4. HYSYS Simulation
Evaluation of the Efficiency of the Combustion Furnace of the Delayed Coking Unit by Manipulating the Parameters that Affect the Furnace Efficiency
5. Cost Estimation

Cost estimation is required for any industrial process and determination of the necessary investment is an important part of plant design project.

Cost estimation include the determination of:
1. Fixed cost (Capital cost, Installation cost, Transportation).
2. Operation cost:
   (a) Utilities (electricity, fuel gas, compress air).
   (b) Operator Labor.
   (c) Maintenance Labor.
   (d) Depreciation.

5.1. Cost Estimation Calculations

5.1.1. Fixed Cost

The capital cost in Delayed Coking Unite furnace in Khartoum Refinery Company estimated by the manufacture company [15].

\[
\text{Total fixed cost} = \text{capital cost} + \text{installation cost} + \text{transportation} \quad (14)
\]

\[
\text{Installation Cost} = 0.4 \times \text{capital cost} \quad (15)
\]
Transportation = 0.05 \times \text{capital cost} \tag{16}

5.1.2. Operation Cost

\text{Depreciation} = (\text{capital cost} \times 0.9)/\text{anticipated life} \tag{17}
\text{Est. Downtime hr} = \text{no. days} \times 24 \ \text{hr} \tag{18}
\text{Est. Operating hr} = \text{no. days} \times 24 \ \text{hr} \tag{19}
\text{Total Available Hours/ Year} = \text{est. downtime} + \text{est. operation} \tag{20}
\text{Operator Labor} = \frac{\text{hr/furn/yr} \times \text{price of hr} \times \text{no. operator}}{24} \tag{21}
\text{Maintenance Labor} = \frac{\text{hrs/furn/yr} \times \text{price of hr} \times \text{no. operator}}{24} \tag{22}

5.2. Utilities

\text{Electricity} = \text{full load KW} \times \text{Price of KW} \tag{23}
\text{Fuel gas} = \text{lb/hr} \times \text{price of lb} \tag{24}
\text{Comp air} = \text{lb/hr} \times \text{price of lb} \tag{25}
\text{Annual Furnace Operating Cost} = \text{Depreciation} + \text{electricity annual cost} + \text{fuel gas annual cost} + \text{compressed air annual cost} + \text{Operator Labor} + \text{Maintenance Labor} \tag{26}
\text{Total cost} = \text{operation cost} + \text{fixed cost} \tag{27}

6. Results and Discussions

6.1. Results

6.1.1. Excel Results

These contain two type of result (furnace efficiency, the effect of stack temperature and excess air on thermal efficiency).

6.1.2. Furnace Efficiency Result

The data we use to calculate efficiency is (combustion sheet and combustion reaction)

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|}
\hline
Component of fuel & Vol. fraction mole/hr & Net heating value BTU/Lb \\
\hline
Methane & 49.67 & 21500 \\
Hydrogen & 9.48 & 51600 \\
Ethane & 19.57 & 20420 \\
Ethylene & 3.12 & 20290 \\
Propane & 5.11 & 19930 \\
Propylene & 3.09 & 19690 \\
Butane & 1.93 & 19670 \\
Butylene & 0.92 & 19420 \\
Pentane & 0.84 & 19500 \\
Nitrogen & 1.38 & 0 \\
Carbon monoxide & 2.44 & 4345 \\
Carbon dioxide & 2.43 & 0 \\
Hydrogen sulfide & 0.0036 & 6550 \\
Total & 99.9836 & \\
\hline
\end{tabular}
\caption{Combustion work sheet.}
\end{table}

- From these data the thermal efficiency of DCU furnace in Khartoum refinery = 86.43%.

6.1.3. Effect of Stack Temperature and Excess Air on Thermal Efficiency

The effect of stack temperature has been examined and excess air on thermal efficiency and the results were found as shown in figure below.
Figure 6. Effect of excess air and stack temperature on efficiency.

6.1.4. Aspen HYSYS Simulation Results

Table 3. EDR data [11].

| Process data:|-|                                                                                                                                 |
|--------------|----------------------------|
| 1-stream     | Total mass flow rate       | 125 T/Hr                                                                |
|              | Inlet temperature          | 270°C                                                                  |
|              | Outlet temperature         | 320°C                                                                  |
|              | Inlet vapor mass fraction  | 3%                                                                     |
|              | Outlet vapor mass fraction | 40%                                                                    |
| Flue gas:-   | Inlet temperature to convection section | 290°C                                                                 |
|              | Ambient temperature       | 33.1°C                                                                 |
| Injection steam:- | Mass flow rate     | 360 kg/Hr                                                              |
|              | Pressure                  | 2.5 Mpa                                                                 |
|              | Temperature               | 420°C                                                                  |
| Firebox:-    | Fire heater type           | Twin box                                                                |
|              | Tube row layout           | Refactory baked                                                         |
|              | Fire box dimension:-      |                                                                         |
|              | Height                    | 13700 mm                                                                |
|              | Length                    | 18834 mm                                                                |
|              | Width                     | 16530 mm                                                                |
|              | Evaluation of floor firebox| 2550 mm                                                                |
|              | Evaluation of top fire box| 13700 mm                                                                |
| Burner details:- | Bumer location | Bottom                                                                 |
|              | Type of burner            | Flat flame                                                              |
|              | No. of burner             | 98                                                                     |
|              | Burner diameter           | 100 mm                                                                  |
| Main tube rows:- | Process steam in firebox | 4                                                                      |
|              | Tube passes               | 4                                                                       |
|              | Evaluation of main tube in firebox | Horizontal                                                               |
|              | Tube straight length      | 18420 mm                                                                |
Process data:

- Height of lowest tube above firebox: 500 mm
- Tube to wall clearance: 200 mm
- Tube – U bend location: Inside firebox
- Tube lay out angle: U-shell
- Flow direction in first tube: Up flow

Tube location:

<table>
<thead>
<tr>
<th>Tube location</th>
<th>Main</th>
<th>main</th>
<th>Main</th>
<th>Main</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of tube per pass</td>
<td>12</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Tube material</td>
<td>316L</td>
<td>316L</td>
<td>316L</td>
<td>316L</td>
</tr>
<tr>
<td>Pipe schedule</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Tube outside diameter (mm)</td>
<td>114.3</td>
<td>168.28</td>
<td>219.08</td>
<td>273.05</td>
</tr>
<tr>
<td>Tube wall thickness (mm)</td>
<td>8.56</td>
<td>10.97</td>
<td>12.7</td>
<td>15.09</td>
</tr>
<tr>
<td>Tube Spacing (mm)</td>
<td>203.2</td>
<td>304.8</td>
<td>406.4</td>
<td>508</td>
</tr>
</tbody>
</table>

Gas of take:

- Flue gas off take width (mm): 2800
- Flue gas off take length (mm): 40430
- External diameter (m²): 3070

Convection bank:

- Process stream in bank: 2
- Stream inflow form: Bank2
- Stream out flow: Inlet
- Tube No. used in bank: 1
- Tube alienation in bank: Horizontal
- Flue gas flow direction: Up
- Duct width (mm): 1553
- Duct other side (mm): 1553
- Tube length (mm): 15700

Gas flow:

- Stack diameter at bottom: 3070
- Stack diameter at top: 2800
- Height to bottom of stack: 14903
- Height to top of stack: 55217
- Height of damper in stack: 14903

### Table 4. Inlet stream parameter.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Calculated thermal load</th>
<th>Design thermal load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td></td>
<td>Crude</td>
<td>steam</td>
</tr>
<tr>
<td>Flow</td>
<td>Kg/hr</td>
<td>123010</td>
<td>9650</td>
</tr>
<tr>
<td>Inlet pressure</td>
<td>Mpa</td>
<td>0.9</td>
<td>1.25</td>
</tr>
<tr>
<td>Outlet pressure</td>
<td>Mpa</td>
<td>0.57</td>
<td>1.15</td>
</tr>
<tr>
<td>Inlet temperature</td>
<td>°C</td>
<td>270</td>
<td>191</td>
</tr>
<tr>
<td>Outlet temperature</td>
<td>°C</td>
<td>320</td>
<td>300</td>
</tr>
</tbody>
</table>

6.1.5. Cost Estimation Results

### Table 5. Cost estimation data.

<table>
<thead>
<tr>
<th>Capital Cost</th>
<th>1301300 $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Est. Downtime day</td>
<td>30 day</td>
</tr>
<tr>
<td>Est. Operating day</td>
<td>335 day</td>
</tr>
<tr>
<td>Anticipated life</td>
<td>20 year</td>
</tr>
<tr>
<td>Throughput</td>
<td>162300 ton/hr</td>
</tr>
<tr>
<td>Electricity full load</td>
<td>20397000 Kw</td>
</tr>
<tr>
<td>Electricity price</td>
<td>0.13 $/kw hr</td>
</tr>
<tr>
<td>Fuel gas full load</td>
<td>2280.7 lb/hr</td>
</tr>
<tr>
<td>Fuel gas price</td>
<td>0.06$/lb</td>
</tr>
<tr>
<td>Compressed air full load</td>
<td>39630.5 lb/hr</td>
</tr>
<tr>
<td>Compressed air price</td>
<td>0.003$/lb</td>
</tr>
<tr>
<td>Number of furnace operator labor hour per year</td>
<td>8760 hr</td>
</tr>
<tr>
<td>Price of hour for operator labor</td>
<td>1.3$/hr</td>
</tr>
<tr>
<td>Number of operator labor</td>
<td>67 man</td>
</tr>
<tr>
<td>Number of furnace maintenance labor hour per year</td>
<td>8760 hr</td>
</tr>
<tr>
<td>Price of hour for maintenance labor</td>
<td>1.6$</td>
</tr>
<tr>
<td>Number of maintenance labor</td>
<td>19 man</td>
</tr>
</tbody>
</table>
6.2. Discussions

The furnace efficiency has been put under light in this research as one of the important facilities in the refinery and for the fact that its consume a huge amount of fuel so huge amount of cost. The efficiency of DCU furnace in Khartoum refinery has been calculated using indirect method.

The results show that furnace efficiency is about 86.43%, which indicates the furnace efficiency obtained according to use heat exchanger in the top of the furnace to deliver heat from the stack gases to preheat air that enters the furnace.

Inlet air preheats result show that thermal efficiency has been increased with increasing of air temperature.

The effect of excess air and stack temperature on thermal efficiency shows that the thermal efficiency has been reduced according to increase in excess air and stack temperature and vice versa. Increasing the fraction of the oxygen in the inlet air will lead to increase in thermal efficiency based on the fact that nitrogen absorb heat hence decrease thermal efficiency.

**Furnace Control:**

*Process Side* – Fluid heated inside the tubes must be controlled for efficient heat transfer and to minimize tube fouling and coking. Flow distribution at the inlet is very important. All fluid passes should have an equal amount of fluid flowing through the tubes. In most liquid or fouling services, it is important to have an individual pass flow controller to avoid flow imbalances due to coking or localized overheating. Another variation is to use feed forward control. Any load change in the feed minimizes the outlet feed temperature variation [13].

Fluid flowing through the tubes should have an adequate pressure drop in the fired heater to ensure good fluid distribution in a multiple-pass heater.
Firing Controls – Two major parameters that should be controlled and monitored are:
- Fuel gas/fuel oil pressure.
- Furnace draft.

Furnace Draft – Flue gas analysis is the single most powerful tool available to maximize combustion efficiency. One improved control scheme automatically controls oxygen in the flue gas by varying the furnace draft [13]. Control schemes have been installed in balanced draft systems to more accurately control excess air and draft. Some of these schemes involve controlling the air/fuel ratio. Several problems have been experienced in measuring the fuel and air flow rate accurately.

Closing the stack damper reduces the furnace draft. To adjust excess air, the stack damper must be adjusted in conjunction with the air registers. A step-by-step procedure to adjust the draft and excess air in balance draft furnaces is shown in Figure (4-6).

7. Conclusions

In this research the parameters that affect in furnace efficiency (excess air / stack temperature are examined using equations and excel sheets. The results show that increasing in stack temperature at constant excess air will lead to reverse proportion with the efficiency of the furnace and vice versa. Furthermore, the result of oxygen percentage in air and preheated air from Aspen HYSYS simulation software and EDR ‘aspen exchanger design and rating’ of DCU both provides direct proportion with the efficiency. In addition, cost of furnace has been estimated by excel sheets as well as controlling different parameters that affect in operation.

References


