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# Furnace Oil as an Alternative Fuel in Heating Furnace for Bending Plates

Mandar.P.Sathe[1], A. H. Ingle[2], G. R. Navnage[3]
[1] Assistant Professor, Department of Mechanical Engineering, SRPCE, *mandarsathe_2007@rediffmail.com*
[2]Associate Professor and Head Department of Mechanical Engineering, SRPCE, *anil_ingle943@rediffmail.com*
[3]Assistant Professor, Department of Mechanical Engineering, Ram Meghe College of Engg., Amaravati, *g.navnage@hotmail.com*

***Abstract***—This topic is based on the operation of Heating Furnace for the purpose of bending of the plates in the Industry which is used for Tower Manufacturing. The material or the metal used for the Tower manufacturing are Mild Steel (M.S.) Plates.LPG is commonly used as a fuel in the heating furnace for bending operation. As the cost of LPG affects the production, Furnace Oil as an alternative fuel if considered for the heating furnace operation can be used for bending of plates used in Tower manufacturing. Here, as a consideration of fuel will be on the basis o availability, cost, flash point , calorific value etc.

***Keywords****-Heating Furnace,LPG,Ethanol,M.S.Plates,Bending Operation of Plates etc.*

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## I. Introduction

Alternative fuels are the fuels used as an alternative option for the specific purpose. Basically, there are three types of fuels namely Solid, Liquid and Gaseous fuels.Solid fuels like Coal, wood etc. Then Liquid fuels like Petrol, Kerosene, biodiesel, diesel etc. Gaseous fuels like LPG, Hydrogen etc. Alternative fuels are selected on the basis of availability, cost of fuel, easy transportation, easy storage, suitability for the operation or system etc. As per the technical aspects, alternative fuel is also selected on the basis of the technical properties like Flash point, calorific value, specific gravity, grade of fuel, etc. In recent years, the use of biodiesel fuel is also increased rapidly. Biodiesel fuel means extract from plants and flowers blended with Ethanol, Methanol etc. The use of the particular fuel also depends upon the type of operation to be performed. A furnace is an equipment to melt metals for casting or heat materials for change of shape (rolling, forging etc) or change of properties (heat treatment).Even it is used for the operation of bending of plates by heating them.

### *A. Classification of Different Furnaces*

Based on the method of generating heat, furnaces are broadly classified into two types namely combustion type (using fuels) and electric type. In case of combustion type furnace, depending upon the kind of combustion, it can be broadly classified as oil fired, coal fired or gas fired.

- Based on the mode of charging of material furnaces can be classified as:-
  (i.) Intermittent or Batch type furnace or Periodical furnace and
  (ii) Continuous furnace.

- Based on mode of waste heat recovery as recuperative and regenerative furnaces.
- Another type of furnace classification is made based on mode of heat transfer, mode of charging and mode of heat recovery as shown in the Figure 4.1 below.

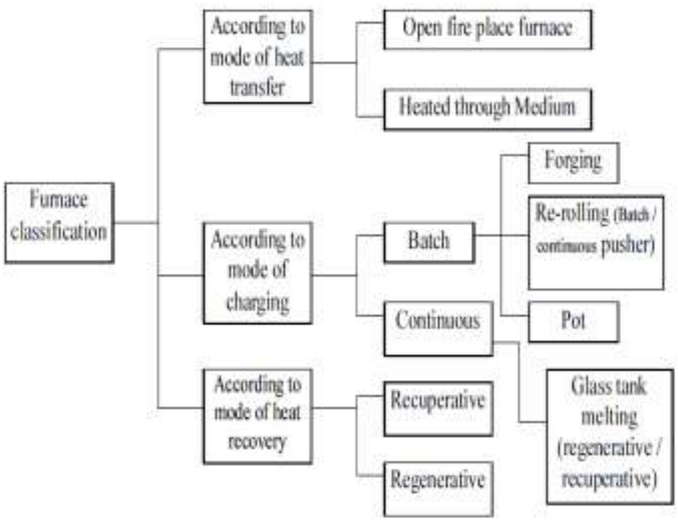


Figure 1.1 CLASSIFICATION OF FURNACE

## II. CONSTRUCTION

 ISSN: 2454-4248
242 – 247

**Heating Furnace.**

[1] Gas Incoming pipe with Valve:-This is the pipe which supply the LPG fuel through it. Valve is attached to this pipe to stop or supply the gas
[2] Filter (Red Color):-To purify the gas coming .Its main purpose is to remove impurities from the gas and supply the pure gas.
[3] Pressure Regulator (Blue Color):- This is used to maintain the particular pressure applied.
[4] Pressure Gauge: To know the amount of pressure of gas being supplied.
[5] Sensitraul Valve:-Solenoid valve is used to start/stop the supply of fuel according to the rated supply given to the valve.
[6] Burner :- To give the supply of the flame of burning fuel to the workpiece.The blower for air supply is also present inside the red nozzle box.
7] Heating Furnace :- This is the main location or spot where the heating of the plates or work piece takes place.

## III. WORKING PRINCIPLE:

1] In this Gas fired furnace running on LPG, the system get started by the Sequence controller supplies power to the blower which is attached with motor.
2] On the other side, the gas is supplied by the Solenoid valve to the nozzle box.
3] The blower is inbuilt in the nozzle box which supplies air. Ignition transformer to starts the system comprises of combustion air blower inbuilt in the red box of nozzle. Here, the ignition transformer gives electric spark through the spark plug to the nozzle.
4] If LPG catches fire and starts burning, heating to the plates for bending occurs.
5] If LPG fire does not take place, the flame sensor conveys signal to the sequence controller.
6] Thus, Sequence controller stops the supply of LPG gas by Solenoid switch. If proper burning is done, then further operation goes on.
7] This is the whole working process of Gas Fired furnace running on LPG.

## IV. METHODOLOGY:

- Study of the current system
- Study of Literature for the current system
- Study of LPG and Furnace Oil to suggest Alternative fuel.
- Analysis of properties of fuels.
- Comparison of fuels on basis of factors like properties, availability, cost, flash point etc.
- Suggesting suitable fuel for the operation.
- Analytical Calculations.
- Result
- Modeling of the system using any CAD software like CREO..
- Result and Conclusion.

## V. CALCULATIONS:

The Furnace has 1500mm * 870mm wall on the billet extraction outside which is 850mm high. The other data is given below. Find the Efficiency of the furnace ($\eta_f$).
Exit flue gas temperature = 410$^o$C.
Ambient temperature = 40$^o$C.
Specific Gravity:
For Furnace Oil =0.92
Calorific Value:-
LPG = 11,650 K-Cal/Kg
Furnace Oil = 10500 K-Cal/Kg
Density of Mild Steel (M.S.) = 7845.
Area of Heating = 1500 * 200 = 300000 mm$^2$.

Sol.) The furnace is used bending M.S. Plates by heating.
1 K-Cal/Kg = 4.1868 K-J/Kg.
Calorific Value:-
LPG = 11,650 K-Cal/Kg
Ethanol = 29,700 KJ/Kg
Methanol = 23,000 KJ/Kg
Furnace Oil = 10500 K-Cal/Kg
Light Diesel Oil (LDO) = 10,700 K-Cal/Kg

To Find: - Efficiency of Heating Furnace($\eta_f$)

### 5.1 FOR OIL-FIRED FURNACE(USING LPG):-

1.) Heat Supplied by fuel(Qs):-
Qs= $m_f$ * C.V.
Where:- $m_f$ = Fuel consumption/hr
= 6750Kg/month(26days)
= 6750/(1*26*24*60*60)
$m_f = 3.004*10^{-3}$ kg/sec

C.V = Calorific Value=11,650 K-Cal/kg
=11,650 * 4.1868 (1K-Cal/kg=4.1868KJ/kg)
C.V = 48776.22 KJ/kg

Qs = 3.004 * $10^{-3}$ * 48776.22
Qs = 146.5237 K-W

2.) Heat absorbed by plates($Q_{plates}$):-

$Q_{plates} = m_{plate} * C_{Pplate} * (T_{P2}-T_{P1})$
= 200 * 0.416 * (800-40)
= 63232KJ /15 min (1 Batch)
= 63232 /15
= 4215.466 KJ/min
= 4215.466 / 60
$Q_{plates}$ = 70.257 K-W

% of Heat Utilized for Plate Heating ($\eta_f$) = $Q_{plate}$ *100 / Qs
= 70.257 * 100 /146.5237
$\eta_f$ = 47.95 %

3.) Sensible Heat loss in Flue Gas ($Q_{Sensible}$) :-
$Q_{Sensible} = m_g * C_{PG} * (T_g-T_a)$
Where:- $m_g$ = Mass of combustion gas formed = $m_a$+ $m_f$

1 kg of LPG = 12.1 kg of air required for combustion.
So, to burn $3.004*10^{-3}$ Kg/ sec of LDO= ma
$m_a = 12.1 * 3.004 * 10^{-3}$
$m_a = 0.03785$ Kg/sec

$m_f = 3.004 * 10^{-3}$ Kg/sec
$m_g = 0.03785+3.004 * 10^{-3}$
$m_g = 0.040$ Kg/sec.

Combustion Gas Temperature ($T_g$) = 410 $^o$C.
Atmospheric Temperature (Ta) = 40 $^o$C.
Specific Heat of LDO Combustion (CPg) =1.005 KJ/Kg-K.

So, $Q_{Sensible} = m_g * C_{PG} * (T_g-T_a)$
$= 0.040 * 1.005 * (410-40)$

$Q_{Sensible} = 14.87$ K-W

% Heat lost in Combustion = $Q_{Sensible} * 100/ Q_s$
= 14.87 * 100 / 146.5237
% Heat lost in Combustion = 10.14 %

4.) Heat loss Due To Moisture ($Q_m$) :-

$Q_m = m_m * C_{Pm} * (T_g-T_a)$
$m_m$ = Mass of moisture = 9 * $H_2$ %* $m_f$
$= 9 * (17.85/100) * 3.004 * 10^{-3}$ (LDO contains 15% of H2)
$m_m = 4.8259 * 10^{-3}$ Kg/sec.

$C_{pm}$= Specific heat of moisture = 4.18 KJ/Kg-K.

$Q_m = 4.8259 * 10^{-3} * 4.18 * (410-40)$
$Q_m = 7.4637$ K-W

% Heat lost in moisture (%$Q_m$) = $Q_m$ * 100 / Qs
= 7.4637 * 100/ 146.5237
%$Q_m$ = 5.09 %

5.) Unaccounted Heat:-
Unaccounted Heat = Qs – ($Q_{Plate}$+ $Q_{Sensible}$+ $Q_m$)
= 146.5237-(70.257+14.87+7.4637)
Unaccounted Heat = 53.93 K-W
% of Unaccounted Heat = Unaccounted heat * 100/ Qs
= 53.93 * 100 /146.5237
% of Unaccounted Heat = 36.80%

6.) Efficiency of Gas Fired Furnace ($\eta_f$) :-

a.) Sensible heat loss in flue gas=10.14 %
b.) Loss of heat due to moisture = 5.09 %
c.) Unaccounted Heat = 36.80 %

Total Heat Loss = 10.14+5.09+36.80
= 52.03%

Efficiency of Oil Fired Furnace ($\eta_f$) = 100-51.79
$\boxed{\eta_f = 47.95\ \%}$

**5.4 FOR FUEL-FIRED FURNACE(USING FURNACE OIL):-**

1.) Heat Supplied by fuel(Qs):-

Qs = $m_f$ * C.V.

Where:- $m_f$ = Fuel consumption/hr
= 8110 lit/month (26 days)
= 8110 / 624=12.99 lit/hr
= 12.99 *0.92=11.95 kg/hr (1 lit. of LDO=0.86 Kg of LDO)
= 11.95 / 60*60
$m_f = 3.3196 *10^{-3}$ kg/sec

C.V= Calorific Value
= 10,500 K-Cal /kg
= 10,500 * 4.1868 (1K-Cal/kg=4.1868KJ/kg)
C.V= 43961.4 KJ/kg

Qs = $3.3196 * 10^{-3} * 43961.4$
Qs = 145.93 K-W

2.) Heat absorbed by plates($Q_{Plates}$):-

$Q_{Plates} = m_{plate} *C_{Pplate} * (T_{P2}-T_{P1})$
= 200 * 0.416 * (800-40)
= 63232KJ /15 min (1 Batch)
= 63232 /15
= 4215.466 KJ/min
= 4215.466 / 60
$Q_{plates}$= 70.257 K-W

% of Heat Utilized for Plate Heating= $Q_{Plate}$ * 100 / Qs
= 70.257 / 145.93 * 100

% $Q_{Plate}$ ($\eta_f$) = 48.14 %

3.) Sensible Heat loss in Flue Gas ($Q_{Sensible}$) :-

$Q_{Sensible} = m_g * C_{PG} * (T_g-T_a)$

Where:- mg = Mass of combustion gas formed = ma+ mf

1 kg of Furnace Oil = 13.5 kg of air required for combustion.

So, to burn $3.3196 *10^{-3}$ Kg/ sec of LDO= ma

$m_a = 14.2 * 3.2540 * 10^{-3}$

$m_a = 0.0448$ Kg/sec

$m_f = 3.3196 * 10^{-3}$ Kg/sec

$m_g = 0.04620+3.2540 * 10^{-3}$

$m_g = 0.0481$ Kg/sec

Combustion Gas Temperature ($T_g$) = 410 $^o$C.

Atmospheric Temperature ($T_a$) = 40 $^o$C.

Specific Heat of LDO Combustion ($C_{Pg}$.) = 1.005 KJ/Kg-K.

So, $Q_{Sensible} = m_g * C_{PG} * (T_g-T_a)$

= 0.0481 * 1.005 * (410-40)

$Q_{Sensible}$ = 17.89 K-W

% Heat lost in Combustion = $Q_{Sensible}$ * 100/ Qs

= 18.22 * 100 / 145.7794

% $Q_{Sensible}$ = 12.26 %

4.) Heat loss Due To Moisture ($Q_m$) :-

$Q_m = m_m * C_{Pm} * (T_g-T_a)$

$m_m$ = Mass of moisture = 9 * H2 %* m

= 9 * 12/100 * 3.3196 * $10^{-3}$ (Furnace Oil contains 12% of H2)

$m_m = 3.5851 * 10^{-3}$ Kg/sec.

$C_{pm}$= Specific heat of moisture = 4.18 KJ/Kg-K

$Q_m = 3.5851 * 10^{-3} * 4.18 * (410-40)$

$Q_m$ = 5.5448 K-W

% Heat lost in moisture ($Q_m$) = $Q_m$ * 100 / Qs

= 6.7940 * 100/ 145.7794

% $Q_m$= 3.7 %

5.) Unaccounted Heat :-

Unaccounted Heat = Qs – ($Q_{Plate}$+ $Q_{Sensible}$+ $Q_m$)

= 145.7794-(70.257+18.22+6.7940)

Unaccounted Heat = 52.23 K-W

% of Unaccounted Heat = Unaccounted heat * 100/ Qs

= 50.5084 * 100 /145.7794

% of Unaccounted Heat = 35.79%

6.) Efficiency of Oil Fired Furnace ($\eta_f$) :-

a.) Sensible heat loss in flue gas=12.49 %

b.) Loss of heat due to moisture = 4.66 %

c.) Unaccounted Heat = 34.6471 %

Total Heat Loss = 12.26+3.7+35.79

= 51.75%

Efficiency of Oil Fired Furnace ($\eta_f$) = 100 - 51.75

$\eta_f$= 48.20 %

% Heat lost in moisture (%$Q_m$) = $Q_m$ * 100 / Qs

= 7.4637 * 100/ 146.5237

%$Q_m$ = 5.09 %

7.) Unaccounted Heat:-

Unaccounted Heat = Qs – ($Q_{Plate}$+ $Q_{Sensible}$+ $Q_m$)

= 146.5237-(70.257+14.87+7.4637)

Unaccounted Heat = 53.93 K-W

% of Unaccounted Heat = Unaccounted heat * 100/ Qs

= 53.93 * 100 /146.5237

% of Unaccounted Heat = 36.80%

8.) Efficiency of Gas Fired Furnace ($\eta_f$) :-

d.) Sensible heat loss in flue gas=10.14 %

e.) Loss of heat due to moisture = 5.09 %

f.) Unaccounted Heat = 36.80 %

Total Heat Loss = 10.14+5.09+36.80

= 52.03%

Efficiency of Oil Fired Furnace ($\eta_f$) = 100-51.79

$\boxed{\eta_f = 47.95\ \%}$

## VI. RESULT:

[1.] Alternative fuel Furnace Oil is available in the market and with reasonable cost.

[2.] There was some other fuel like Ethanol, Methanol, Bio-Diesel etc. as discussed earlier. But by considering amount of consumption of fuel, Cost, availability and properties like flash point, calorific value etc., Furnace Oil is found to be alternative fuel.

[3.] Efficiency of Furnace is 47.95 %.

ISSN: 2454-4248
242 – 247

THERMAL ANALYSIS:

[A.] STEADY STATE THERMAL ANALYSIS:

The figure shown below is of the model of the system in ANSYS software. The analysis done in this section is Steady State Thermal Analysis. Here, Steady State means constant heat supply.

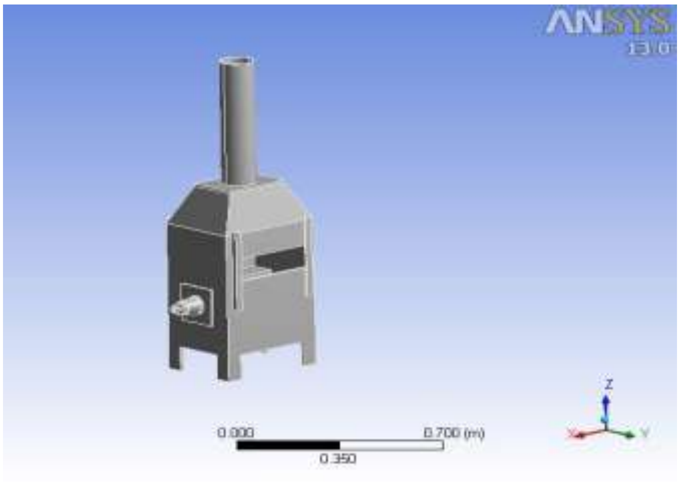


Figure 7.1 Analysis of the System

The Graph shown below represents Steady State Thermal Analysis. The y-axis represents the load i.e. heat input. Here e+5 means $10^{+5}$.

The x-axis represents the Surface area.

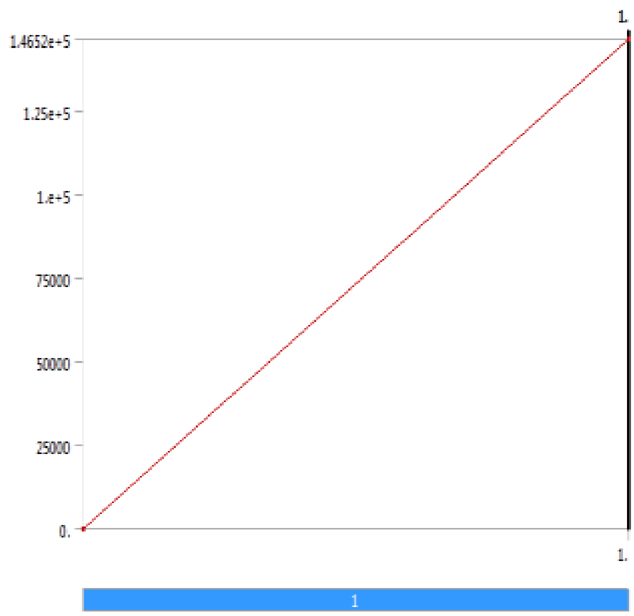


Figure 7.2 Model (A4) > Steady-State Thermal (A5) > Heat Flow

**TABLE 7.1**

**Model (A4) > Steady-State Thermal (A5) > Loads**

| Object Name | Heat Flow | Temperature | Temperature 2 |
|---|---|---|---|
| State | Fully Defined | | |
| **Scope** | | | |
| Scoping Method | Geometry Selection | | |
| Geometry | 4 Faces | 5 Faces | 2 Faces |
| **Definition** | | | |
| Type | Heat Flow | Temperature | |
| Define As | Heat Flow | | |
| Magnitude | 1.4652e+005 W (ramped) | 800. °C (ramped) | 100. °C (ramped) |
| Suppressed | No | | |

**TABLE 7.2**

**Model (A4) > Steady-State Thermal (A5) > Solution (A6) >**

**Results**

| Object Name | *Temperature* | *Total Heat Flux* |
|---|---|---|
| State | Solved | |
| **Scope** | | |
| Scoping Method | Geometry Selection | |
| Geometry | All Bodies | |
| Shell | | Top/Bottom |
| **Definition** | | |
| Type | Temperature | Total Heat Flux |
| By | Time | |
| Display Time | Last | |
| Calculate Time History | Yes | |
| Identifier | | |
| **Results** | | |
| Minimum | 100. °C | 6.9389e-018 W/m² |
| Maximum | 1.8267e+005 °C | 9.3418e+007 W/m² |
| **Information** | | |
| Time | 1. s | |
| Load Step | 1 | |

| | | |
|---|---|---|
| Substep | 1 | |
| Iteration Number | 1 | |
| **Integration Point Results** | | |
| Display Option | | Averaged |

## VII. CONCLUSION:

To suggest alternative fuel some fuels are considered like Ethanol, Methanol, Furnace Oil and finally Furnace Oil is selected. Properties of alternative fuel suggested i.e. Furnace Oil is also studied like cost, availability, Flash point, etc.

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