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Design and Development of oil-gas dual fuel burner

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ABSTRACT

Considering a need of continuous working of industrial heating equipments, there is a need of a burner which will give an uninterrupted service. In the event of shortfall of one type of fuel, dual fuel burners can fulfil such industrial requirements. The burner should fulfil same combustion requirement of the system by using both the fuels. The presented work here includes design and development of a burner of given capacity using dual fuels. The fuels considered are light diesel oil and natural gas/ LPG as alternative fuel. Burners are used in many applications like oil processing industries as in water bath heaters, Metal processing industries etc.It includes study of available technology of burners and designing the burner configuration meeting thermal requirements of the operation. Evaluating the different parameters affecting the combustion and carry out necessary design and thermal calculations for the same incorporating safety features in design. Preparing design drawings for manufacturing and preparing CAD model for the same and do trouble shooting if any. Doing critical analysis required if any for evaluating performance of the burner. The work also includes deciding the parameters which govern the performance of the unit.

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I. Introduction

Combustion has been the foundation of worldwide industrial development for the past 200years. Industry relies heavily on the combustion process. Depending on many factors, certain types of fuels may be preferred for certain geographic locations due to cost and availability considerations. Gaseous fuels, particularly natural gas, are commonly used in most industrial heating applications in the United States. In Europe, natural gas is also commonly used along with light fuel oil. In Asia, South America, and Middle East and in Iraq, heavy fuel oils are generally preferred although the use of gaseous fuels is on the rise. [1]

Burners are a key component in industrial combustion applications such as in metals, minerals and chemicals production and processing, power generation and industrial drying processes, waste incineration, steam generation in boilers. A classification by type of fuel gives solid, liquid or gaseous fuel-fired burners. The type of draft employed give rise to forced draft and natural draft burners, also type of mixing of fuel and oxidizer gives pre-mixed and diffusion burners. Air-fuel and oxy-fuel burners are burner types based on the type of oxidizer used. [2]

Spray combustion is a complicated subject because it involves many different processes. A typical sequence of events would be the injection and atomization of liquid fuel, mixing of droplets with oxidizing gas, heat transfer to droplets producing evaporation of liquid. Boilers (which mainly deals with spray combustion) were used extensively in manufacturing, processing, mining and refining industries to provide steam or hot water. [3]

To burn effectively, a liquid fuel has to be atomized into a fine droplet spray, with droplets appropriately distributed within the combustion chamber. In order to understand the importance of the problem it is enough to realize that a droplet with a diameter of 1μm contains about 10 billion molecules of fuel, each of which must be combined with several molecules of oxygen. [5]

The present work includes the design of the dual fuel burner, its calculation and CAD model which gives visualisation of the model.

II. BURNER DESIGN ANALYSIS

The various parameters of design of dual fuel burner depend on the capacity for which it is being designed. Here the capacity for which burner is to be designed is 3MMBTU (i.e. 880KW). Assume efficiency of the burner as 80%. This gives the heat release of 1100 KW as design consideration. The fuels which are used for design are L.D.O. and Natural gas. The LCV for both is given in TABLE I.

TABLE II

Fuel	LCV
Light Diesel Oil (L.D.O.)	10585 Kcal/kg
Natural Gas	8127l/m^3

A. Fuel mass flow rate:

DFB design will consume one fuel at the operation. The mass flow rate for both fuels can be determined by following expression:[4]

$$HR = mLCV \qquad (1)$$

Where, HR is the heat release, capacity for which burner is to be designed, m is the fuel mass flow rate, LCV is the heating value of the fuel. Expression (1) gives the mass flow rate as in TABLE IIIIV:

TABLE VVI

Fuel	Mass flow rate
Light Diesel Oil (L.D.O.)	89 kg/hr
Natural Gas	116 m^3/hr

B. Combustion Air requirement:

Calculation of the combustion air required is the important part of the combustion. The ratio of fuel and air decides the quality of combustion. Proper mixture of fuel and air reduces CO in the flue gas. The combustion air required for both fuel depends upon the content and chemical reaction equation. [4] The combustion air required for fuels is given in TABLE VIIVIIIIX:

TABLE XXIXII

Fuel	Combustion air
Light Diesel Oil (L.D.O.)	1119 m^3/hr
Natural Gas	1207 m^3/hr

C. Atomization:

The major goal of atomization is to increase the surface to volume ratio to enhance liquid evaporation and combustion.

Gaseous fuels are usually characterized by clean combustion, with low rates of soot and nitric oxides. The main problem is that of achieving the optimal level of mixing in the combustion zone. Many different methods have been used to inject gas into conventional combustion chambers, including plain orifices, slots, swirlers, and venture nozzles.[5] Here in this work orifice is designed as atomizer for gas.

To burn effectively, a liquid fuel has to be atomized into a fine droplet spray, with droplets appropriately distributed within the combustion chamber. The atomization of a liquid can be accomplished by means of special devices called sprayers, sprinklers, atomizers, injectors…etc.,[5].

(1) Gas atomization:

Fuel gas discharging through an orifice is to determine if it is operating above or below the critical pressure. Critical pressure ratio is given by:[1]

$$Pc = [\frac{2}{k+1}]^{k/(k+1)} \qquad (2)$$

Where, P_c is the critical pressure ratio and k is the ratio of specific heats of the fuel.

If $Pc > \left(\frac{P_b}{P_t}\right)$, then the fuel exits the orifice at sonic conditions, if $Pc < \left(\frac{P_b}{P_t}\right)$ then the fuel exits the orifice at subsonic conditions. The P_b and P_t terms represent atmospheric pressure and fuel pressure in absolute, respectively.

For sonic conditions:

$$m = \frac{c_d P_t g_c A}{\sqrt{\frac{T_t R g_c}{MW}}} \times k^{\frac{1}{2}} \times [\frac{2}{k+1}]^{\frac{k+1}{2(k-1)}} \qquad (3)$$

Where C_d is orifice discharge coefficient taken as 0.85, A is the orifice area, T_t is the temperature of fuel gas, R is the universal gas constant equal to 8314.34 J/kmol/K, MV molecular weight of the fuel, and g_c is gravitational constant equal to 1 kg.m/N.s^2.

For subsonic conditions:

$$m = c_d l_e A M_e c_e \qquad (4)$$

Where,

$$M_e = \sqrt{\frac{2}{(k-1)}\left[\left(\frac{P_t}{P_b}\right)^{\frac{(k-1)}{k}} - 1\right]} \qquad (5)$$

$$T_e = \frac{T_t}{1+\frac{(k-1)}{2}{M_e}^2} \qquad (6)$$

$$c_e = \left[\frac{kT_eR}{MW}\right]^{\frac{1}{2}} \qquad (7)$$

$$l_e = \frac{P_b}{\frac{T_eR}{MW}} \qquad (8)$$

The subscript *e* denotes the orifice exit, M_e is the Mach number of the fuel, T_e is the temperature of the fuel, c_e is the speed of sound in the fuel, and l_e is the density of the fuel.

Gas orifice design:

Assume standard atmospheric pressure (P_b) = 1.013 bar and pressure of the fuel P_t = 2.1 bar, then

$$\frac{P_b}{P_t} = 0.4794$$

Ratio of specific heat for gas k is 1.2871, so critical pressure P_c from equation (2) comes out to be 0.5480.

Here $Pc > \left(\frac{P_b}{P_t}\right)$, hence the fuel exits the orifice at sonic conditions.

Area of gas orifice can be determined from equation (3).

$$m = \frac{c_d P_t g_c A}{\sqrt{\frac{T_t R g_c}{MW}}} \times k^{\frac{1}{2}} \times [\frac{2}{k+1}]^{\frac{k+1}{2(k-1)}}$$

Where, m is mass flow rate of gas= 116 m^3/hr= 0.03222 m^3/s

T_t fuel gas temperature is 25°C (298.15 K),
MW molecular weight of the gas is 17.82,
C_d coefficient of discharge = 0.85
P_t fuel pressure at inlet= 2.1 bar
g_c is gravitational constant =1 kg.m/N.s^2
R is universal gas constant = 8314.34 J/kmol/K
k ratio of specific heats =1.2871

Therefore area of orifice,

$$A = \frac{0.03222 \times 373.1825}{178500 \times 1.1345 \times 0.5861}$$

$$A = 0.000101\ m^2$$

Orifice area comes out to be 0.000101 m^2. If we take 24 such orifices to distribute gas in combustion chamber then orifice area will divide in to 24.

$$a = \frac{A}{24} = 4.22 \times 10^{-6} m^2$$

The orifice area for single orifice will be (0.000101/24) = 4.22×10^{-6} m^2. Hence diameter of the orifice can be determined from equation

$$a = \frac{\pi d^2}{4}$$

$$d = \sqrt{\frac{4a}{\pi}}$$

$$d = \sqrt{\frac{4 \times 4.22 \times 10^{-6}}{\pi}} = 0.00232m$$

Diameter of orifices comes out to be 2.32×10^{-3}m (2.32 mm).

(2) Oil Atomization:

Nozzle are selected which works of the pressure atomization principle for atomizing the oil. The total mass flow rate for defined capacity comes out to be 89 kg/hr. This flow is divided in to two so as to achieve low fire and high fire condition as 62 kg/hr and 27 kg/hr.

For this standard monarch oil nozzle nozzles are selected with following specification:
Two nozzle of PLP series having semi hollow spray pattern, 60° spray angle, operating pressure of 7 bar of capacities 8.5 USGPH (27 kg/hr) and 19.5 USGPH (62 kg/hr).

Fig. (1): Monarch Oil nozzle

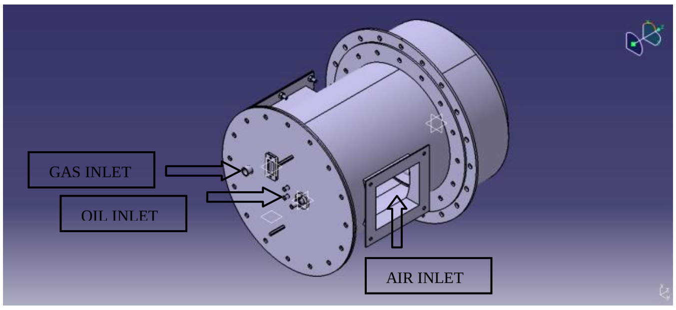

Fig. (2): Burner CAD model

III. DIFFUSER PLATE

The diffuser is plate is normally used by standard oil industrial burners. It improves the ignition and flame stability. It gives uniform velocity which helps in proper mixture oxidizer and fuel.[6]

Diffuser plate is of OD 340 mm and ID 60 mm having 5mm thickness. It has 126 holes of Φ10 mm diameter for primary air while 24 holes of Φ15 mm for gas entry at PCD of Φ 280 mm. Position of the diffuser plate is at a distance of 120mm apart from outer edge of the font refractory plate.

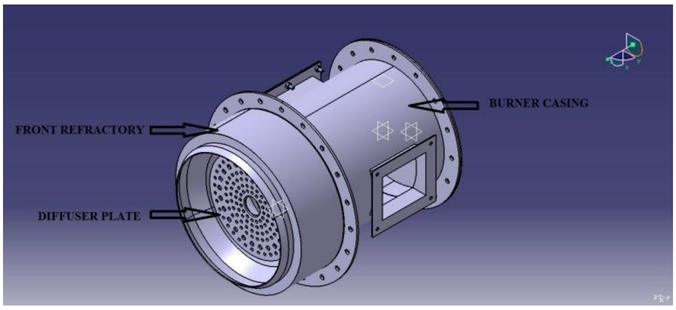

Fig. (3) : Diffuser plate position

IV. DFB DESIGN CONFIGURATION

DFB is designed for 20 inch fire tube size. The overall dimensions of the burner are as follows:

Overall length of the burner = 680 mm
ID of Combustion chamber = 380 mm
Gas orifice PCD = 280 mm
Two oil nozzles at centre 30 mm apart
Flange OD of burner = 605 mm

V. CONCLUSION

DFB design calculations and dimensions are determined in this work. The CAD model gives the view of the DFB. The orifice diameter for gas atomization found to be 2.32mm. After completion of the work, there will be one of the economical, most suitable options available for the industry.

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