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Nag Hammadi Fiber Board Company's Heating Unit: Energy and Exergy Analysis

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ABSTRACT : In this study, energy and exergy analysis are studied to examine and understand the performance of the combustion chamber (furnace) of the heating unit in Nag Hammadi fiber board Company (NFB) with a capacity of 22 MW, utilizing natural gas and biofuel together where the combustion chamber is designed to burn natural gas and wood dust at the same time to decrease the operating cost of the heating unit. The main purpose of combustion chamber is to burn natural gas and biofuel to supply the heating unit by high temperature combustion products. There is no heat transfer inside the combustion chamber except heat losses through the wall of the combustion chamber. The purpose of the heating unit in the factory is to supply the manufacturing processes by hot flue gases for dryer unit, hot thermal oil for hot press system and saturated steam for the digester. The energy and exergy efficiencies are found to be 69 % and 28 %, respectively. This study is carried out to identify and quantify the energy and exergy losses in the combustion chamber.

KEYWORDS: Energy analysis, Exergy efficiency, Fiber board, Combustion, Heating

1-Introduction

Today, increasing the energy demand is a major challenge facing the researchers all over the world. All over the world there is increase in energy demand, but the energy resources are limited. So it becomes necessary to understand the mechanisms witch degrade the quality of energy (ability to do work)[1].

1.1-Exergy definition

The first law of thermodynamic is conventionally used to the energy utilization, but it is un- able to account the quality of energy [2]. That is where exergy analysis becomes relevant. Exergy is a consequent of second law of thermodynamics. It is property that enable us to determine the useful work potential of a given amount of energy at specified state. Exergy evaluation is a technique that estimates the efficiency, energy quality, and available work in processes [3]. It also gives the ability to specify the maximum performance of a system[4] . Exergy can be defined as the maximum useful energy that can be obtained from a system as it comes to equilibrium with its surroundings [5]. Exergy analysis has been widely use in design, simulation and performance evaluation of thermal and thermo-chemical systems. Exergy analysis is usually aimed to get the maximum performance of the system and identify the sites of exergy destructions. Exergy can be destroyed or lost due to irreversibilities of a process and this provides a measure of the thermodynamic losses in the system and help to locate and quantify wasteful energy utilization in the process [6].

1.2-System description

The main purpose of Nag Hammadi fiber board Company is the production of medium density fiberboard (MDF) from sugarcane bagasse (sugarcane detritus). The production process is achieved through a lot of manufacturing processes as shown in figure (1) . The manufacturing processes by arrange is washing, digesting, refining, gluing, drying, matt forming, cold pressing, hot pressing and finally finishing the surface by sanding machines.

The function of heating unit in the manufacturing process is supplying the digester by saturated steam at 15 bar, supplying the dryer by hot flue gases and supplying the hot press and wax tank by hot thermal oil. The detritus of sanding machines (dust) is transferred to the combustion chamber of the heating unit. In the heating unit the combustion chamber utilizing natural gas and biofuel (dust) to supply the heating unit by high temperature combustion products as sown in figure (2).

1.3- Study objectives

This study aim to calculate the efficiency of the combustion chamber by the first and second laws of thermodynamics with the variation of the natural gas and biofuel ratio.

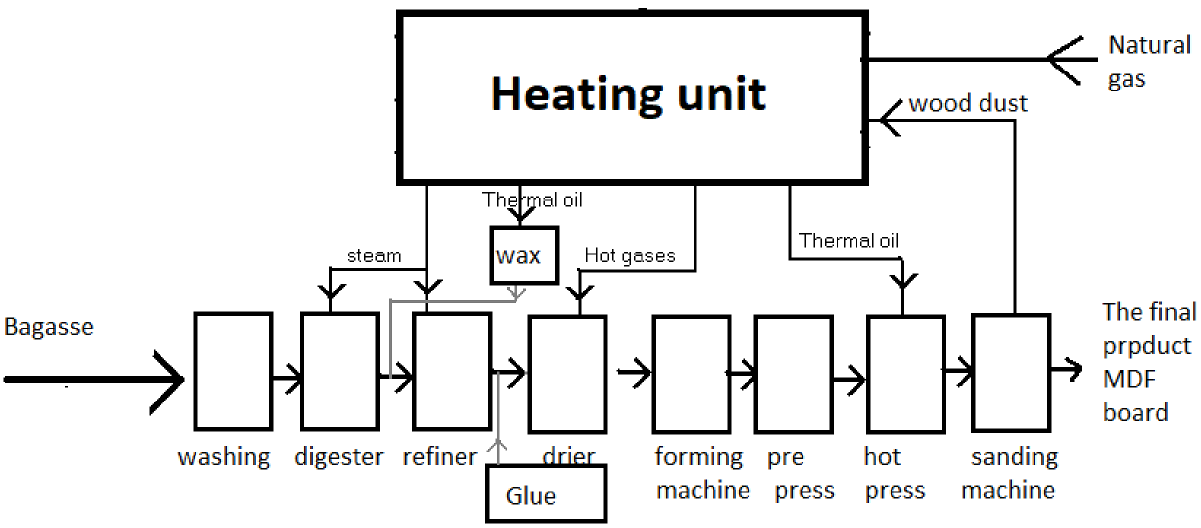


Figure (1) , Schematic diagram of the manufacturing process in (NFB).

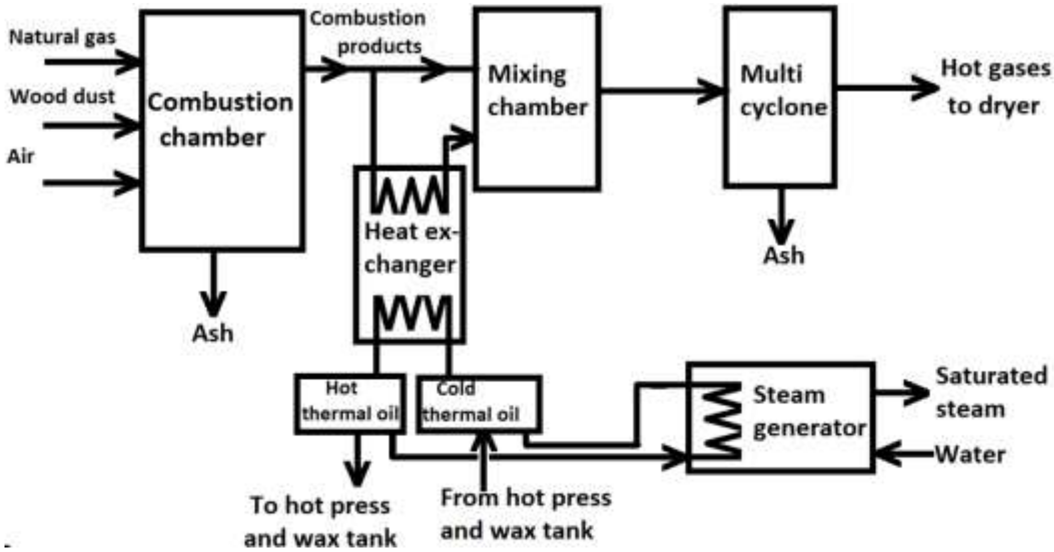


Figure (2) , Schematic diagram of the heating unit in (NFB) .

2-Methodology

2.1 First law analysis on combustion chamber.

At steady state and with negligible kinetic and potential energies, energy balance can be expressed as the following [7].

$\dot{E}_{in} - \dot{E}_{out}$ = **Error!** = 0 = = > steady (1)

$\dot{E}_{in} = \dot{E}_{out}$ (2)

$\dot{m}_f h_f + \dot{m}_a h_a = \dot{m}_p h_p$ (3)

The first law efficiency can be written as:

η = **Error!** (4)

2.2 Second law analysis on combustion chamber.

The maximum power output o reversible power is determined from the exergy balance applied to combustion chamber assuming the environment temperature is $25C^0$ (T_0 =298K),at steady state and with negligible kinetic and potential energies. The exergy balance formulation can be expressed by using this methodology [8].

$\dot{X}_{in} - \dot{X}_{out} - \dot{X}_{destroyed} =$ **Error!** $= 0 = = >$ steady (5)

$(m_f\ \varepsilon_f + m_a\ \varepsilon_a) - m_p\ \varepsilon_p - I_c = 0$ (6)

The second law efficiency can be written as

$\psi =$ **Error!** (7)

2.3 The specific exergy of fuels.

The specific exergy of natural gas is 49.45 MJ/kg [9]

The specific exergy of wood dust (sugarcane bagasse) is 13.2 MJ/kg [10]

3-Readings

Control volume on the combustion chamber figure (3). At steady state and various operating condition the parameters of the combustion chamber is as inserted in the table (1).

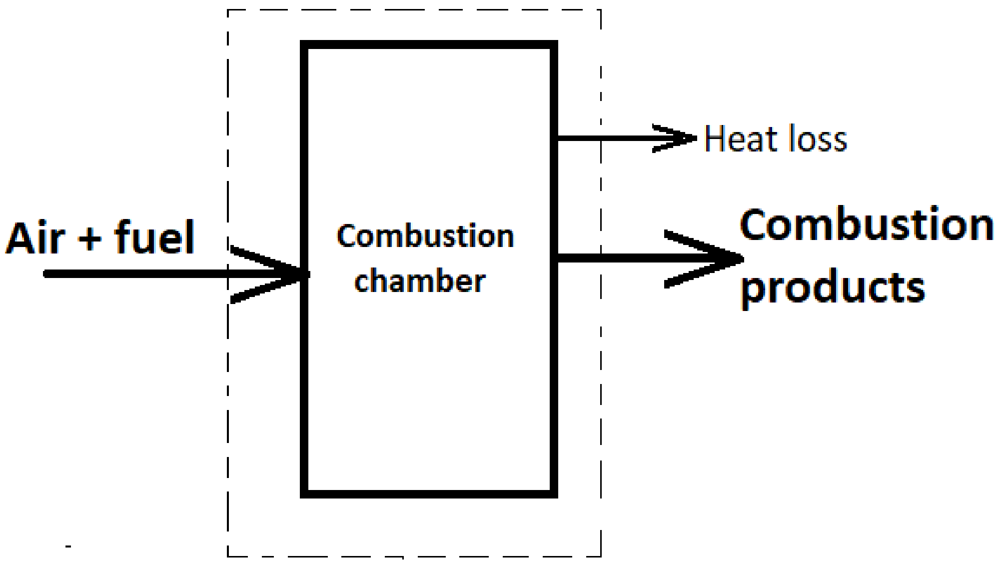


Figure (3), Schematic diagram of the combustion chamber in (NFB) .

Table (1) , Readings

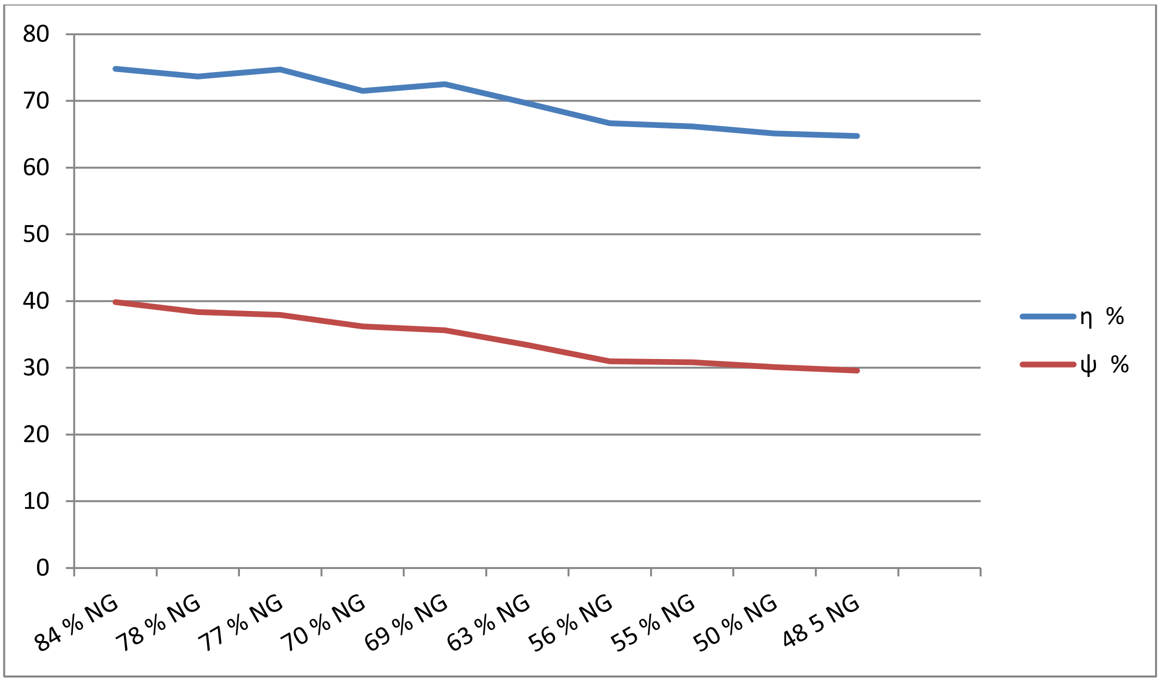
Reading number.	$\dot{m}_{NG}$ (kg/s)	$\dot{m}_{BF}$ (kg/s)	$\dot{m}_{air}$ (kg/s)	$\dot{m}_{Products}$ (kg/s)	$T_{Products}$ (k)
1	0.306	0.1718	16.154	16.631	1050
2	0.273	0.227	16.3	16.8	1000
3	0.2548	0.212	16.48	16.95	960
4	0.234	0.2816	16.79	17.31	925
5	0.214	0.27	16.9	17.39	890
6	0.193	0.32	17.28	17.8	845
7	0.163	0.377	17.81	18.35	795

8	0.1 6 1	0.3 88	17.85 1	18.4	790
9	0.1 4 7	0.4 33	18	18.6	780
10	0.1 3 9	0.4 43	18.16	18.75	765

4-Results and Discussions

Applying the first and the second laws of thermodynamics on the combustion chamber, The enthalpy and entropy values from table A 9 [11]. the curves show the change of energetic and exergetic efficiencies for the combustion chamber with the change of natural gas percent in the total fuel.

The curves shows that the energetic and exergetic efficiencies for the combustion chamber decrease with the decreasing of natural gas percent and increasing of biofuel (wood dust) percent. The reason of this that it is easy to get a complete combustion in natural gas but it is difficult to get a complete combustion in the biofuel.



5-Conclusion

The energy and exergy analysis are investigated to evaluate the performance of the combustion chamber of the heating unit in Nag Hammadi fiber board Company with a capacity of 22 MW. The natural gas and biofuel are used together where the combustion chamber is designed to burn natural gas and wood dust at the same time. The results concluded that although the efficiencies decrease with the increasing of biofuel (wood dust) percent but the operating with high biofuel percent is the best because the biofuel is cheaper than natural gas. In addition, during peak load the best choice is increasing natural gas percent to supply the heating unit by extra power because the curves shows that the natural gas is more effectiveness than biofuel.

References

[1] Barinaadaa Thaddeus Lebele-Alawa, Jerry Mike Asue "Exergy analysis of kolocreek gas-turbine plant" Canadian journal on mechanical science &engineering Vol. 2 No. 8.December 2011.

[2],[9] R. Saidur, J.U. Ahmed, H.H. Masjuki "Energy, exergy and economic analysis of industrial boilers" Energy policy 38 (2010) 2118-2197

[3] Omid Mahian, Mohammad Reza, Alibakhsh Kasaeian, Seyed Hossein Mousavi "Exergy analysis in combined heat and power systems" Energy conversion and management 226 (2020) 113467.

[4] Saidur R, Boroumandjazi G, Mekhilef S, Mohammed HA "A review on exergy analysis of biomass based fuels" Renew. Sustain. Energy Rev. 2012;16(2): 1217–22

[5] Ahamed, J.U., Saidur, R., Masjuki, H.H., Mekhilef, S., Ali, M.B., Furqon, M.H. "An application of energy and exergy analysis in agricultural sector of Malaysia" Energy Policy, December 2011, Pages 7922-7929.

[6] Wark, K., & Richards, D. E. (1999). Thermodynamics(6). WCB McGraw-Hill. ISBN: 0070683050(hb), 0073038482(cd), 9780070683051(hb), 9780073038483(cd).

[7] Cengel, Y. A. and Boles, M. A. (2006), Thermodynamics: An Engineering Approach, 5th Edition, McGraw Hill.

[8] M. Hasanuzzaman, R. Saidur and N. A. Rahim "Energy, exergy and economic analysis of an annealing furnace" International journal of physical science vol. 6(6), pp. 1257-1266, 18 March, 2011

[10] Sanober Khattak, Richard Greenough, Vishal Sardeshpande, Neil Brown " Exergy analysis of a four pan jaggery making process" Energy reports 4(2018) 470-477.

[11] Sonntag, R. E. and Borgnakke, C. (2007) Introduction to engineering thermodynamics. 7th ed. Hoboken, N.J.: John Wiley

Notations

h_f = specific enthalpy of fuel, KJ/kg.

h_a = specific enthalpy of air, KJ/kg.

h_p = specific enthalpy of products, KJ/kg.

$\dot{m}_f$ = mass flow rate for fuel, kg/s.

$\dot{m}_a$ = mass flow rate for air, kg/s.

$\dot{m}_f$ = mass flow rate for products, kg/s.

$\dot{m}_{NG}$ = natural gas mass flow rate, kg/s.

$\dot{m}_{BF}$ = biofuel (wood dust) mass flow rate, kg/s.

$\dot{m}_{air}$ = air mass flow rate , kg/s.

$\dot{m}_{Products}$ = combustion products mass flow rate , kg/s.

$T_{Products}$ = combustion products temperature in kelvin (k).

Biofuel =wood dust = (sugarcane bagasse + additives)

Greek symbols

η = Energy efficiency

ψ = Exergy efficiency

ε_f = exergy of fuel

ε_a = exergy of air

ε_p = exergy of products