Performance Enhancement of Hot Water Generator Fuelled With Diesel and Bio-Diesel

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Abstract – *We knows that in world, day by day, the demand for energy is increasing, increasing energy prices and pressing ecological problems such as increasing GHG emission. For this we need to work hard to protect the global environment and develop an alternate solution which will reduce the fuel consumption as well as improves the efficiency of the system. For this first we perform the exergy analysis of the hot water generator this will find the causes or sources of inefficiencies. After that waste heat recovery system plays an important role in reducing the energy consumption and improving the efficiency of the existing system. The main objective of this Research paper is to give a theoretical comparison of energy analysis of hot water generator before and after modification. After the modification i.e, after the installation of Economizer we will reduce the energy (fuel) consumption and we will yearly reduce fuel expenses upto Rs. 14,05,348.The work also focused on several parameters that govern the recovery of waste heat in the industry.*

Key Words: **Increasing Energy demand, GHG emission, Exergy analysis, Waste heat recovery, Economizer etc.**

1. INTRODUCTION

Global warming, environmental pollution and limitations in conventional energy resources drive us towards environmentally friendly renewable resource and their efficient utilization. Therefore there is a great deal of interest and research on both alternative energy resource and their efficient use. The second law of thermodynamics is the tools to assess the effective and efficient use of energy.

Boiler is a significant part of energy utilization. They are used in both hot water generator and steam power plant for electric power generation. Today, Boilers run not only on conventional fuels but also on alternative, renewable fuels such as biodiesel, biogas, hydrogen and with blends. The performance and efficiency of Boiler can be increased by new technology. In this regard the exergetic efficiencies of hot water boiler fuelled with alternative fuels are very important. The new methodology is exergy analysis and its optimization component is known as thermodynamic optimization, or entropy generation minimization.

This new approach is based on the simultaneous application of the first law and the second law in analysis and design. Exergy is the maximum (theoretical) work that can be extracted (or the minimum work that is required) from the entity (e.g. stream, amount of matter) as the entity passes from a given state to one of equilibrium with the environment. As such, exergy is a measure of the departure of the given state from the environmental state, the larger the departure, the greater the potential for doing work. The most commonly-used method for analysis of an energy conversion process is the first law of thermodynamics.

However, there is increasing interest in the combined utilization of the first and second laws of thermodynamics, using such concepts as exergy and exergy destruction in order to evaluate the efficiency with which the available energy is consumed. Exergetic analysis provides the tool for a clear distinction between energy losses to the environment and internal irreversibility in the process. Exergy analysis is a methodology for the evaluation of the performance of devices and processes, and involves examining the exergy at different points in a series of energy-conversion steps. With this information, efficiencies can be evaluated, and the process steps having the largest losses (i.e., the greatest margin for improvement) can be identified. For these reasons, the modern approach to process analysis uses the exergy analysis, which provides a more realistic view of the process and a useful tool for engineering evaluation. As a matter of fact, many researchers have recommended that exergy analysis be used to aid decision making regarding the allocation of resources (capital, research and development effort, optimization, life cycle analysis, materials, etc.) in place of or in addition to energy analysis. Exergy analysis has become a key aspect in providing a better understanding of the process, to quantify sources of inefficiency, and to distinguish quality of energy used. Some researchers dedicated their studies to component exergy analysis and efficiency improvement; others focused on systems design and analysis. The objective of this dissertation work is to analyze ACG PVT LTD. Hot Water generator plant from an exergy perspective. And compare theoretically the exergy analysis of existing system before and after modification. Waste heat recovery system that is Economizer plays an important role in reducing the energy consumption and improving the efficiency of the existing system. Thus we theoretically perform the performance enhancement of hot water generator and compare the results.

This study present a framework to evaluate thermodynamics properties and performance variables associated with materials streams in boiler, such as, mass flow rate, enthalpy, entropy, energy, temperature and exergy transfer with chemical, heat and material interactions, efficiencies and exergetic losses in boiler.

2.1EXPERIMENTAL SET UP

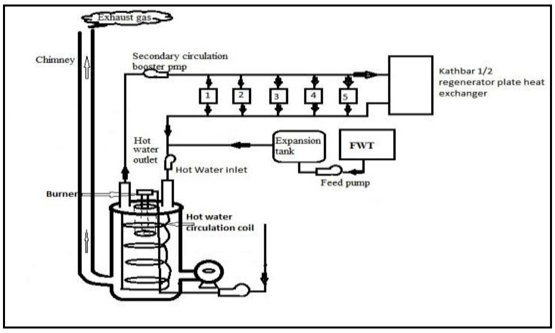

Fig.1

There are two boilers with one working and one standby with capacity of 1500000 Kcal/hr. These boilers are water-tube boiler fuelled with diesel and bio-diesel. Here, expansion tank is used to control the pressure of water in the flowing line and avoid the water from phase change. This hot water is then supplied to the working stations 1, 2, 3, 4 and 5 through the pipeline. These 1, 2, 3, 4 and 5 are water storage tanks. These tanks are constructed such as on outer side there is jacket in which hot water is circulated and in the inner side of the tank a Demineralised water (DM) is stored this DM water is used for Gelatine solution, HPMC solution preparation, Utensil cleaning etc.

2.2 PROPOSED EXPERIMENTAL SET UP

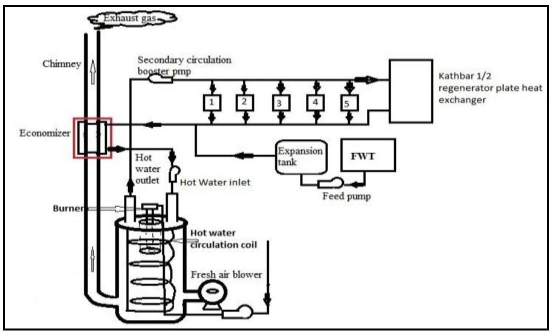

Fig.2

The above figure shows the proposed experimental set up of the hot water generator. It consists of boiler, economizer, pump, ID fan, chimney, valves, flow meter and piping system. It should be designed as per design specification.

Table-1

DETAILS OF EXISTING BOILERS & FLUE GASES			
Parameter	**Unit**	**Hot Water Generator-1**	**Hot Water Generator-2**
Working / Stand by	-	Working	Standby
Make	-	Thermax	Thermax
Nominal Capacity of Boiler (Kcal / Hour)	Kcal/Hour	15,00,000	15,00,000
Actual Readings (Average as per Log Book)			
Operating Pressure	kg/cm2 or Bar	4.5 to 6	
Operating Temperature (Supply Temperature)	Degree C	120	
Quantity supplied to Hot Water Tank	Ltr/week	8000 (Weekly Top-up)	
Quantity supplied to process	Kg/Hr	Closed pressurized loop (NA)	
Quantity supplied to PHE	Kg/Hr	NA	
Fresh Water Quantity/Day (Makeup Water)	Litres	1143	
Fresh Water Temperature	Degree C	30	
Return Water Temperature	7 Degree C	110	
Difference between Temperature	Degree C	10	
Fuel Details			
Type (Diesel / FO / PNG / Briquette / Coal / Others)	-	Bio-Diesel & Diesel	
Net Calorific Value of Fuel being used	Kcal	10,200	
Fuel Cost	Rs / Liter or Kg	38	
Fuel Consumption (Avg. Flow Rate)	Liters or Kg per Hour	62.5	
Fuel Consumption (Avg. Flow Rate)	Liters or Kg per Day	1500 (Avg.)	
Monthly Fuel Expenses	Rs.	17,10,000	
Annual Fuel Expenses	Rs.	2,05,20,000	
Local Electricity Tariff / DG Power Cost Rs./ Kwh	RS / Unit (Kwh)	8	
Operating Data			
Operating Hours / Day (Average)	Nos.	24	
Operating Days / Year	Nos.	365	
Flue Gas Data (Averages as per Log Book OR as per Flue Gas Analyser Readings)			
Flue Gas Outlet Temperature in main Exhaust header (or after Economizer, if any)	Degree C	230 (As per Temperature Logging done for 3# Days	
Air Fuel Ratio Considered for Flue Gas Volume	-	1:16	
Flue Gas Outlet Flow	KG / HR	1000	
Material of Stack	MS / Others	MS	
Stack Height above Ground Level	Mtr	15	

3. METHODOLOGY

3.1 EXERGY ANALYSIS PROCEDURE:

To carry out exergy analysis of steam power plant the following assumptions are considered

1. The process is carried out at steady state.
2. Changes in potential and kinetic energies are neglected
3. There are no heat losses over the surface of the components.
4. Cycle and cooling water are treated as pure.
5. There are no changes of the specific chemical exergies in the cycle

Exergy is the maximum theoretical useful work obtained as the system interacts with the environment. In the absence of nuclear, magnetic, electrical, and surface tension effects, the total exergy of a system ($\dot{E}$) can be divided into four components: physical exergy $E(PH)$, kinetic exergy $\dot{E}(KN)$, potential exergy $\dot{E}(PT)$, and chemical exergy $\dot{E}(CH)$

$$\dot{E}= \dot{E}(PH)+ \dot{E}(KN)+ \dot{E}(PT)+ \dot{E}(CH) \quad \text{(Eqn.1)}$$

If the kinetic, potential and chemical exergy are considered to be negligible the specific exergy is defined as by equation.

$$e = h - h_0 - T_0\ (s - s_0) \quad \text{(Eqn.2)}$$

and the total exergy rate of the system is given by the equation,

$$\dot{E}= \dot{m}[(h - h_0)\text{-}T0(s\text{-}s_0)] \quad \text{(Eqn.3)}$$

Where 'h' and 's' are specific enthalpy and specific entropy at a particular point in a system or in a cycle at a particular pressure and temperature. T_0 and P_0 are the temperature and pressure at a reference environment considered for the analysis are P_0 =101.325 KPa and T_0 =298.15 K.

Once the flow parameters (pressure, temperature and the mass flow rates) are known, the thermodynamic properties (specific enthalpy, specific entropy and specific exergy) are obtained and exergy flows associated with the fluid flow are derived.

A. Exergy of fuel:

The ratio (ø) of chemical exergy (e) of dry fuels to the net calorific value of fuel (NCV), with mass ratio of oxygen to carbon (O/C) varies from 0.667 to 2.67 in general and in particular for Diesel and Bio-diesel is given by Kotas,

$$e=\left\{1.0401 + 0.1728\left(\frac{h}{c}\right) + 0.0432\left(\frac{o}{c}\right) + 0.2169\left(\frac{s}{c}\right)\left(1 - 2.0628\left(\frac{h}{c}\right)\right)\right\} * LHV \quad \text{(Eqn.4)}$$

where c, h, o and n are the mass fractions of carbon, hydrogen, oxygen and nitrogen, respectively.

B. Exergy destruction rate:

Irreversibility's such as friction, mixing, chemical reactions, heat transfer through a finite temperature difference, unrestrained expansion, non quasi-equilibrium compression or expansion always generate entropy, and anything that generates entropy always destroys exergy. The exergy destroyed is proportional to the entropy generated.
Note that exergy destroyed is a positive quantity for any actual process and becomes zero for a reversible process. Exergy destroyed represents the lost work potential and is also called the irreversibility or lost work. For the decrease of exergy and the exergy destruction are applicable to any kind of system undergoing any kind of process since any system and its surroundings can be enclosed by a sufficiently large arbitrary boundary across which there is no heat, work, and mass transfer, and thus any system and its surroundings constitute an isolated system. No actual process is truly reversible, and thus some exergy is destroyed during a process. Therefore, the exergy of the universe, which can be considered to be an isolated system, is continuously decreasing. The more irreversible a process is, the larger the exergy destruction during that process.
No exergy is destroyed during a reversible process the decrease of exergy principle does not imply that the exergy of a system cannot increase. The exergy change of a system can be positive or negative during a process, but exergy destroyed cannot be negative.
To find out the exergy destruction rate in components of hot water generator, the following equations can be used.

Exergy destruction rate in,

Boiler

$$I_{boiler}=E_{fuel}+E_{in}-E_{out} \quad \text{(Eqn.5)}$$

Where, $Efuel$ represents total exergy of a fuel, Ein is a total exergy at inlet of a boiler, $Eout$ is a total exergy at outlet of a boiler.

Pump

$$I_{pump}=E_{out}-E_{in}+W_p \quad \text{(Eqn.6)}$$

Where, Ein is a total exergy at inlet of a pump, $Eout$ is a total exergy at outlet of a pump.

C. Exergy Efficiency:

In energy transfer and conversion processes of a thermal system or equipments, the ratio between the exergy used or gained and payment or consumptive exergy is defined as the exergy efficiency of the system or equipments.

Different definitions are being used for exergy efficiency. Common for the all types of efficiency is that they are valid for steady state processes, where the system boundaries are clearly defined and all irreversibility's associated with the process being considered are included. In the present work, the exergy analysis of hot water generator plant is calculated at all locations and the changes in the exergy are determined for each major component. The source of exergy destruction (or irreversibility) in the boiler is mainly combustion (chemical reaction)

Boiler efficiency:

$$\eta_{exB} = \frac{\dot{E}_{out}-\dot{E}_{in}}{\dot{E}_f}$$

Pump efficiency:

$$\eta_{exP} = \frac{\dot{E}_{out}-\dot{E}_{in}}{W_p}$$

4. Results and Discussion

Table-2

Exergy analysis Before Modification				
Sr.no.		Boiler 1 Fuel:Bio-diesel	Boiler 2 Fuel:Diesel	unit
1	e in	43.015	43.015	KJ/Kg
2	e out	52.906	52.906	KJ/Kg
3	e fuel	47774.029	45699.01	KJ/Kg
4	Ė in	477.89	477.89	KJ/s
5	Ė out	587.785	587.785	KJ/s
6	Ė fuel	829.357	790.592	KJ/s
7	İboiler	719.462	680.697	KJ/s
8	ηexB	0.1325	0.1390	

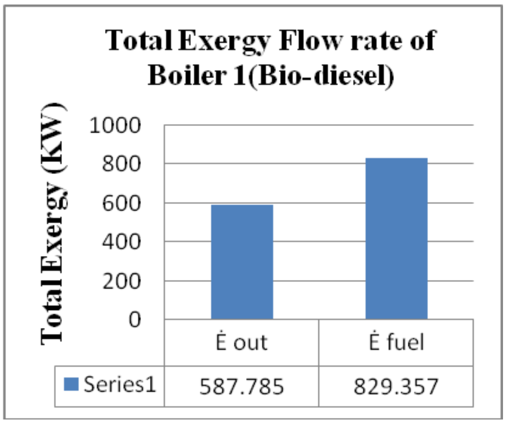

Chart -1

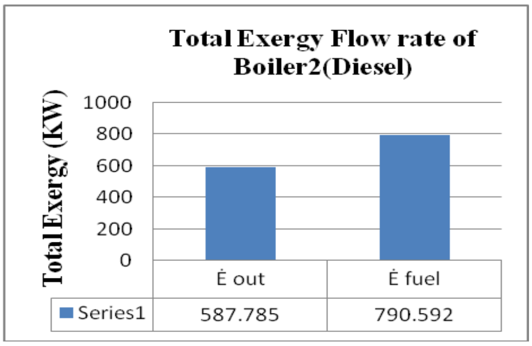

Chart -2

Above Table no.2 gives the exergy analysis of the hot water generator before modification. From this table we get to know exergy flow rate at inlet and outlet of the Boiler-1 and Boiler-2, exergy destruction rate as well as the exergetic efficiency of the Boiler-1 and Boiler-2. Fig.3 and Fig.4 shows the graphical representation of the total exergy flow rate in Kw. The graph compares the amount of exergy given by the fuel and from this amount of exergy, how much exergy is utilized by the boiler to heat the water. Among the exergy given by burning of the fuel, small amount is utilized by the Boiler-1 and Boiler-2. Difference between these two entities is high which clearly indicates that the large amount of exergy is destructed in the boiler-1 and boiler-2. This is mainly due to the irreversibility associated with the boilers. Chemical reaction during the combustion of fuel in the boiler is the main source of irreversibility. This is called the uncontrolled combustion of fuel.

Table-3

Exergy analysis After Modification				
Sr.no.		Boiler 1 Fuel:Bio-diesel	Boiler 2 Fuel:Diesel	unit
1	e in	48.01	48.01	KJ/Kg
2	e out	52.906	52.906	KJ/Kg
3	e fuel	47774.029	45699.01	KJ/Kg
4	Ė in	533.391	533.391	KJ/s
5	Ė out	587.785	587.785	KJ/s
6	Ė fuel	410.856	393.011	KJ/s
7	İboiler	356.462	338.617	KJ/s
8	ηexB	0.1324	0.1384	

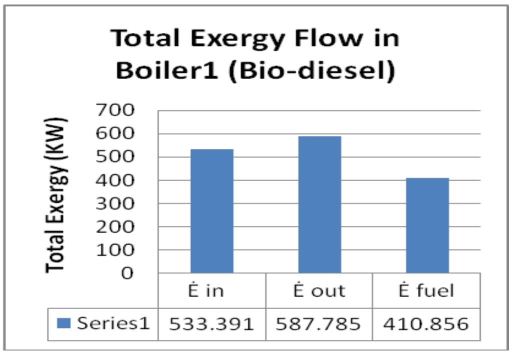

Chart -3

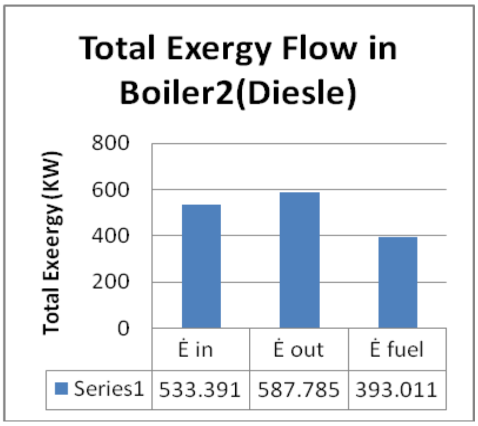

Chart -4

Above Table no.3 gives the exergy analysis of the hot water generator after modification. From this table we get to know exergy flow rate at inlet and outlet of the Boiler-1 and Boiler-2, exergy destruction rate as well as the exergetic efficiency of the Boiler-1 and Boiler-2. In this new system economizer is used to utilize the waste heat i.e high temperature exhaust gases. This waste heat is then used to increase the temperature of water and then this hot water is further supplied in the boiler as inlet water. This will reduce thermal load on the boiler as well as it will reduces the fuel consumption. Above results shows that the exregy given by the burning of fuel is totally utilized by both Boiler-1 and Boiler-2.

Table-4

Heat Recovery Analysis & Fuel Reduction Calculation				
Air Fuel Ratio	-	1:16		
Fuel Consumption/Day	Kg/day	1500		
Flue Gas Flow Rate	KG/HR	1000		
Flue Gas Inlet Temperature	°C	230		
Flue Gas Outlet Temperature	°C	50		
Heat Captured	Kw	50		
Hot Water Generation Potential Based on Current Operating Time				
Cold Water Inlet Temperature	°C	35	35	35
Hot Water Outlet Temperature (3# Options)	°C	90	85	60
StackMaxx Efficiency	%	90	90	90
Mass Flow Rate of Water in Kg/s	kg/s	0.20	0.21	0.43
Mass Flow Rate of Water in Kg/hr	kg/hr	702	772	1,545
Volume Flow Rate of Water in m3/hr	m3/hr	0.72	0.79	1.58
Volume Flow Rate of Water in m3/day	m3/day	17.21	18.93	37.86
Fuel Saving Calculations				
Fuel Savings per Hour	Kg/hr	4.22		
Fuel Savings per Day	Kg/day	101.32		
Fuel Savings per year	Kg/Year	36,983		
Cost of Fuel per Kg	Rs/kg	38		
Yearly Reduction in Fuel Expenses	**Rs/Year**	**1,405,348**		

Above table shows other three option as per the requirement of the organization .If we supply feed water to the economizer at a temperature of 35°C then this economizer will heat water and gain heat up to 50Kw.

Here we can achieve the three rang of outlet temperature by changing the mass flow rate of water. This theoretical work helps us in realizing that if we utilize waste heat that is high temperature exhaust gases we not only reduce energy consumption but also we can reduce the GHG emission. This reduced GHG emission will help in reducing the global warming effect and protect our environment.

5. Conclusion

This report deals with the comparison of theoretical exergy analysis of the Hot water generator fuelled with diesel and bio-diesel and the utilization of waste heat. This work concludes that Exergy analysis is one of the best methods because exergy analysis helps us in finding out causes or sources of inefficiencies. In the considered system, the maximum exergy loss was found in the boiler. Because the boiler is the major source of irreversibility's in the system. After the installation of economizer we utilize the waste heat. We reduce the thermal load on boiler by supplying the hot water from economizer to the boiler as a feed water and improve the performance of boiler as well as we reduce the fuel consumption that is we yearly save fuel expenses up to in Rs.14,05,348 and the payback period for this system is less than 18 months. This low temperature and clean exhaust gases ensures pollution free and environment friendly system operations. In future researcher have high scope in the field of waste heat recovery.

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