ISSN: 2454-4248
167 – 170

Energy Analysis of 73 Mw Co-Generation Thermal Power Plant

Dharmarajsinh J. Rana
Mechanical Engineering Department
V.V.P. Engineering College,
Rajkot, India
ranadharmarajsinh786@gmail.com

Harpalsinh G. Jadeja
Mechanical Engineering Department
V.V.P. Engineering College,
Rajkot, India
harpalsinh.jad@gmail.com

Dr Rupeshkumar V. Ramani
Mechanical Engineering Department
V.V.P. Engineering College,
Rajkot, India
rvramani1975@gmail.com

Harshdeepsinh J. Jhala
Mechanical Engineering Department
V.V.P. Engineering College,
Rajkot, India
harshdeepsinhzala30@gmail.com

Shaktirajsinh V. Gohil
Mechanical Engineering Department
V.V.P. Engineering College,
Rajkot, India
gohil.shaktirajsinh@gmail.com

Abstract— For any country in the world the development is depend upon the how much energy is produced by the country. Energy is mainly in terms of electricity. The major part of energy is produced mainly in thermal power plant. The efficiency of thermal power plant is less, so we have to want increase efficiency of thermal power plant. For increase the efficiency we have to do Exergy analysis, Exergy is the useful energy which is convert into work. The method use for exergy analysis is the first law of thermodynamics and second law of thermodynamics. First law of thermodynamics is deal with quantity of energy while second law is deal with quality of energy. In exergy analysis we find a chemical exergy and physical exergy. The results show that the boiler has the greatest exergy destruction among the thermal power plant components.
Keywords*- Exergy analysis, Thermal power plant, Efficiency*

*****

I. Introduction

Thermal power plants are widely used throughout the world for electric power generation and coal is used as fuel in these plants. But the coal reserve is less and sufficient only for two decades. So, we have to use coal effectively. For effective utilization of coal, we have to improve the efficiency and performance of plant through some modifications for that purpose we have to do exergy analysis of plant.

The first law of thermodynamics cannot give the proper value of efficiency and thermodynamic losses so we have to use the first and second law of thermodynamic combined. The first law of thermodynamics gives that energy is converted into work but it does not show that how much energy is converted into work this problem is solved by the second law of thermodynamics, second law of thermodynamics provides the clear distinction between energy loss to the environment and internal irreversibility in the process. Exergy analysis is a method by which we check the performance of devices and process involves in power generation. In thermal power plant coal is coming from coal bunker then according to requirement coal is supplied to the boiler through the burner, in the boiler, coal is converted into a flue gas this flue gases converted water wall's water into steam and this convert into superheated steam. This superheated steam is then going to the turbine. By the energy of this steam, the turbine rotates and power is developed. Then steam is going to the condenser at where phase changed and steam converted into water. This water is pumped to the boiler by boiler feed pump.

The temperature range is high at 500-550 C in the plant. Because of that, the steam is more superheated. In turbine, there are 2 extractions done, by this the steam is going for the utilization process. The pressure is high up to 110 bar which is attained in the boiler. The power developed at the generator is around 73 MW.

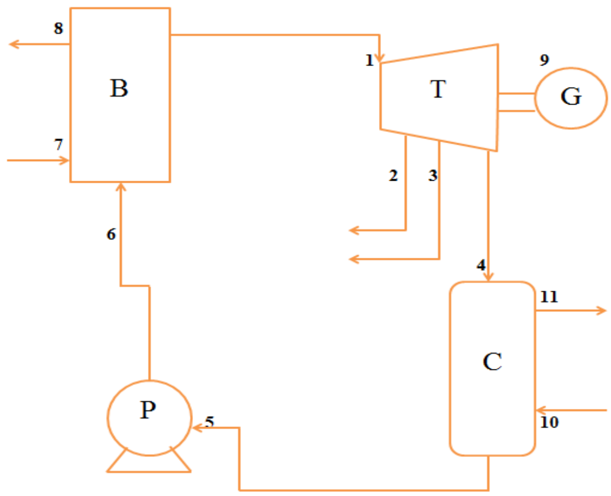

Figure 1 Schematic of 73 MW Power plant

B= Boiler C= Condenser
T= Turbine P= Pump
State 1= Main steam inlet to the turbine
State 2= Extraction 1
State 3= Extraction 2

ISSN: 2454-4248
167 – 170

State 4= Steam out/ Inlet to condenser
State 5= Outlet of condenser/ Inlet to BFP
State 6= Outlet of BFP/ Inlet to the boiler
State 7= Coal in
State 8= Flue gases out
State 9= Generator
State 10= Cooling water in
State 11= Cooling water out

Table 1: Readings of key components

Section	Mass flow rate (kg/sec)	Temperature (^{0}C)	Pressure (bar)	Vapor fraction
Main steam out	190	537	104	1
Extraction 1	78	399	40.22	1
Extraction 2	103	275	13.75	1
Turbine outlet	8.33	56	0.107	1
Condenser outlet	8	45	10.8	0
Cooling water inlet	2142	32	-	0
Colling water outlet	2142	41	-	0
BFP inlet	8	45	10.8	0
BFP outlet	136.11	140	120	0

II. EXERGY ANALYSIS

The simple meaning of exergy is that the energy that is available to be used. Exergy is the Greek word made up of ex and ergon meaning “from work”. The concept of exergy was developed by J. Willard Gibbs. Energy is neither created nor destroyed it changes from one form to another form. While exergy is always destroyed when a process is irreversible. This destroyed exergy has been called anergy. Exergy is mainly made up of two parts. The first one is physical exergy and the second one is the chemical exergy. Exergy is the maximum useful work which can be extracted from a system as it reversibly comes into equilibrium with its environment.

The Physical exergy is the maximum useful work obtained by passing the unit mass of a substance of the generic state to the environmental state through purely physical processes. The physical exergy of a system consists of thermal exergy (due to system temperature) and mechanical exergy (due to system pressure). Physical exergy stated: Ease of Use

$$E^{PH} = m\,[(h-h_0) - T_0(S-S_0)] \quad (1)$$

Where,

m=mass flow rate (kg/sec)
h=enthalpy
h_0=enthalpy at 298 K (kJ/kg)
=104.8 kJ/kg
S=entropy (kJ/kg K)
S_0=entropy at 298 K (kJ/kg K)
=0.367 kJ/kg K
T_0=298 K

Similar to physical exergy, Chemical exergy depends on the temperature and pressure of a system as well as on the composition. The key difference between chemical exergy and physical exergy is that physical exergy does not take into account the difference in a system and environment’s chemical composition. If the temperature, pressure or composition of a system differs from the environment’s state, then the overall system will have exergy. Chemical exergy is defined as the maximum work that can be obtained when the considered system is brought into reaction with reference substance present in the environment. Chemical exergy stated as:

$$E^{CH} = e^{ch}\, m/M \quad (2)$$

Where e^{ch} =standard molar chemical exergy at 298 K (kJ/Mol)
m=mass flow rate (kg/sec)
M=molar weight of steam and water
Total exergy is,
$E = E^{PH} + E^{CH}$

III. EXERGY CALCULATIONS

In each state firstly, we calculate the physical and chemical exergy and then find total exergy from above equations. This is as follow:

Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

A. State I

Substance: Superheated steam
Pressure: 104 bar
Temperature: 537 ^{0}C
Mass flow rate: 190 kg/sec

$$E_{PH} = m\,[(h_1-h_0)-T_0\,(S_1-S_0)] \quad (3)$$
$$= 190\,[(3462.16-1014.8)-298.15(6.6890-0.367)]$$
$$= 279762.028 \text{ KW}$$

E_{CH}= 0 (because, chemical exergy of steam is zero as it is working fluid)

$$E_{TOTAL} = E_1 = E_{PH} + E_{CH} \quad (4)$$

E_1 = 279762.028 + 0
E_1 = 279.762 MW

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

ISSN: 2454-4248
167 – 170

B. State II

Substance: superheated steam
Pressure: 40.22 bar
Temperature: 399 ^{0}C
Mass flow rate: 78 kg/sec

$E_{PH} = m [(h_2-h_0)-T_0 (S_2-S_0)]$
$= 78 [(3215.7-104.8)-298.15(6.773-0.367)]$
$= 93674.1$ KW
$= 93.674$ MW

$E_{CH} = 0$

$E_{TOTAL} = E_2 = E_{PH} + E_{CH}$

$E_2 = 93.674 + 0$

$E_2 = 93.674$ MW

Now, as continue calculate the exergy at different state we get following values which are shown in table No.2.

Table 2: Exergy analysis of different States

State	Physical Exergy in MW	Chemical Exergy in MW	Total Exergy in MW
State 1	279.762	0	279.762
State 2	93.674	0	93.674
State 3	97.357	0	97.357
State 4	0.868	0	0.868
State 5	1.078	0	1.078
State 6	61.752	0	61.752
State 7	0	714.5	714.5
State 8	19.46	1.54	20
State 9	73	0	73
State 10	0.59976	0	0.59976
State 11	3.863	0	3.863

Now, we have to calculate exergy destruction in each and every component and also calculate exergetic efficiency of each component from the following equations.

Boiler: $Ed_{boiler} = E_7+E_6-E_1-E_8$

Turbine: $Ed_{turbine} = E_1-E_2-E_3-E_4-E_9$

Condenser: $Ed_{condenser} = E_4+E_{10}-E_5-E_{11}$

Pump: $Ed_{pump} = E_5-E_6+W_{pump}$

The value of exergy destruction and its rate is calculated from above equations and shown in following table.

Then we find the exergetic efficiency of different components from following equations:

$\eta_{boiler} = E_1+E_8- E_6 / E_7$

$\eta_{turbine} = E_9 / E_1-E_2-E_3-E_4$

$\eta_{condenser} = E_4+E_{10} / E_5+ E_{11}$

$\eta_{pump} = E_5-E_6 / W_{pump}$

The values of exergetic efficiency of different components are shown in below table.

Table 3: Exergy destruction in different components

Component	Exergy destruction in MW	Total exergy destruction rate	Exergetic efficiency
Boiler	476.49	88.8%	33.33%
Turbine	14.863	2.77%	83.08%
Condenser	3.053	0.56897%	49.65%
Boiler feed pump	42.177	7.86%	68.3%
Cumulative	536.583	100%	-

IV. RESULTS & DISCUSSION

We performed exergy analysis of thermal power plant at each state. According to the obtained results, we see that the boiler has the maximum exergy destruction around 89% of total exergy destruction and its exergetic efficiency is low around 33%. The condenser has the lowest exergy destruction among the components. While turbine has the maximum exergetic efficiency among the components.

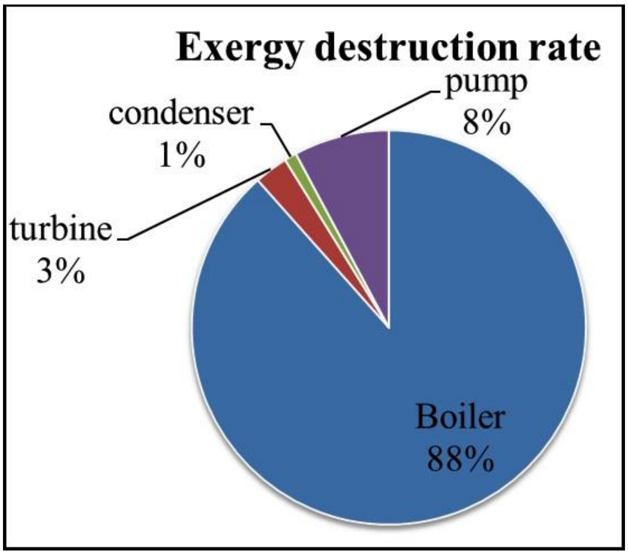

Figure 2 Exergy destruction rate chart

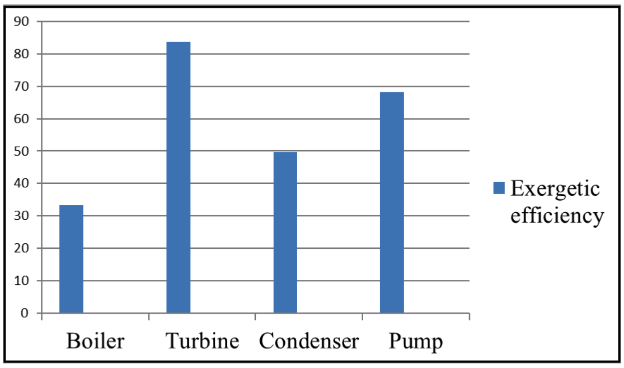

Figure 3 Exergetic Efficiency distribution

ISSN: 2454-4248
167 – 170

V. CONCLUSION

In this paper, exergy analysis for a coal-based thermal power plant is performed, in which we studied major components such as boiler, turbine, condenser and pump. From the result, it is shown that the major exergy destruction is done in the boiler around 475 MW, which is around 89% of total exergy destruction. The maximum efficiency is of turbine around 83%. The major part of energy loss is done in the boiler, so we should focus on to the boiler for different modifications.

REFERENCES

[1] A.G. Kaviri, M.N.M. Jaafar, M.L. Tholudin, and H.B. Avval, “Exergy analysis of a steam power system for power production”, International Journal of Renewable Energy Resources, Vol. 2, No. 2, pp. 58-62 (2012).

[2] J. Kansagara, D. J. Jivani, S. R. Rathod and J. K. Dhulia, “Exergy analysis of thermal power plant”, 1st international conference on automation in industries, (ICAI), pp.160-163 (2016).

[3] R. Dang, S. K. Mangal, and Gaurav, “Energy & exergy analysis of thermal power plant at design and off design load”, International Advanced Research Journal in Science, Engineering and Technology, Vol. 3, No. 5, pp. 29-36, May 2016.

[4] Y. Verma, and K. P. Kaurase, “Exergy analysis of thermal power plant”, International Journal of Engineering & Science Research, Vol. 4, No. 12, pp. 940-945, December 2014.

[5] E. Querol, B. Gonzalez-Regueral, and J.L. Perez-Benedito, chapter 2: Exergy concept and determination, practical approach to exergy and thermoeconomic analyses of industrial processes, 2013.

[6] M. Kataria, H. Khunt, and P. Ghodasara, “Energy analysis of thermal power plant”, International Journal of Engineering Development and Research, Vol. 4, No. 3, pp. 703-709 (2016).

[7] M. Sanjay, and N.S. Mehta, “Easy method of exergy analysis for thermal power plant”, International Journal of Advanced Engineering Research and Studies, Vol. 1, No. 3, pp. 245-247, April-June 2012.

[8] S. Suryavanshee, and A. Chaube, “Exergy analysis of thermal power plant; a review”, International Journal of Engineering Research & Technology, Vol. 2, No. 7, pp. 668-673, July 2013.

[9] R. Naik, T.R. Madhuri, Md. A. Hussian, K. M. Sai, and V. Chinni, “Exergy analysis of 120 MW coal based thermal power plant”, International Journal of Engineering Research & Technology, Vol 2, No. 4, pp. 558-560, April 2013.

[10] V. Patel, and I.J. Patel, “Energy and exergy analysis of thermal power plant”, International Journal of Scientific & Engineering Research, Vol. 5, No. 12, pp. 111-114, December 2014.

[11] S. Gulhane, and A.K. Thakur, “Exergy analysis of boiler in cogeneration thermal power plant”, American Journal of Engineering Research, Vol 2, No. 10, pp. 385-392, (2013).

[12] O. Christian, O. Anthony, and O. Adeyinka, “Energy and exergy analysis of a 75MW steam power plant in Sapele”, International journal of innovative research in advanced engineering, Vol. 2, No. 6, pp. 169-179, June 2015.

[13] M. K. Pal, A. Kumar, and H. Chandra, “Energy and exergy analysis of boiler and turbine of coal-fired thermal power plant”, International Journal of Engineering Research & Technology, Vol. 2, No. 6, pp. 1428-1440, June 2013.

[14] V. Satish, and V. D. Raju, “Energy and exergy analysis of thermal power plant”, International Journal of Engineering Science and Computing, Vol. 6, No. 8, pp. 2636-2644, August 2016.