Available online at www.elixirpublishers.com (Elixir International Journal)

Thermal Engineering

Elixir Thermal Engg. 112 (2017) 49029-49031

ISSN: 2229-712X

Thermodynamic Optimization of Combined Gas and Steam Power Plant

Amir vosough[1] and Zahra kosarian[2]

[1]Department of mechanics, Mahshahr branch, Islamic Azad University, Mahshahr, Iran.

[2]Musculoskeletal Rehabilitation Research Center, Ahvaz Jundishapur University of Medical, Ahvaz, I.R. Iran.

ARTICLE INFO

Article history:

Received: 11 October 2017;

Received in revised form: 11 November 2017;

Accepted: 20 November 2017;

Keywords

Combined gas and steam power plant,

Irreversibility rate,

Energy and exergy efficiency,

Condenser pressure.

ABSTRACT

The aim of this study was to thermodynamic analyses of combined gas and steam power plant under different conditions. Methods/Statistical Analysis: At different thermodynamic conditions the energy and exergy plant efficiency were studied. Also to achieve a better approach near to the actual condition, the energy and exergy analysis considered via the condenser pressure. The result shows that best places that appropriate for optimization is combustion chamber following by turbine due to the most irreversibilities rate. Ambient temperature increasing has undesirable effect on exergy efficiency. Increase in Condenser pressure is an important parameter that must study carefully.Results of this research may help optimization of energy consumption and decreasing the pollution of the environment.

I. Introduction

Fossil fuels particularly coal and natural gas, are essential for electricity generation. Despite growing evidence on implication of renewable energy such as solar and wind power, the need for fossil fuels is expected to continue for decades. Despite environmental concerns such as climate change and the exhaustion of fossil fuel reserves the growth in oil demand is assumed to increase 47.5% between 2003 and 2030, 91.6% for natural gas and 94.7% for coal [1-2]. Therefore, depending on continued reliance on fossil fuels for some time, enhancement of energy efficiency is needed, in order to decrease environmental pollution [3]. In The First Law of Thermodynamics, analyses is related to quantity of energy. On the other hand, quality analyses of energy is obtained by exergy analyses in the Second Law of Thermodynamics. Exergy is the maximum useful work potential of a given amount of energy at some specified state. In design and simulation of thermal systems, the exergy analyses is used to gain insight of its efficiency and potential for further improvement. [4] Previous studies have examined exergy analysis [5-12]. For example Korneos et al. [13-15] used Exergy analysis to assess various design schemes of a power plant. Another study was conducted by Aljundi [16], which was aimed to study energy and exergy analysis of AL-Hossien power plant in Jordan. The results of this study reviled that maximum exergy destruction occurs in the boiler (77%) followed by the turbine (13%).

Hence, the aim of this study is to investigate the effect of thermodynamic parameter on the performance and pollution of cogeneration power plant.

II. Energy and exergy analysis

The interest of using exergy analysis for different components of a thermal system is increasing, since it can offer a better understanding of the process and quantifies the sources of inefficiency in each component. Complete equilibrium of the system with environment is essential in the exergy analysis, including the chemical and thermal equilibriums. During this process the Exergy lost of every component in the cycle is defined and consequently the total cycle irreversibility can be calculated. The exergy balance in a system in connection with n heat sources which has a net produced work equal to $\dot{W}$,and has multiple inlets and outlets is represented as follows(5):

$$\dot{E}_{x,w} = \sum_{\iota=1}^{n}\left(1-\frac{T_0}{T_\iota}\right)\dot{Q}_\iota + \sum_{int} \dot{m}e_x - \sum_{out} \dot{m}e_x - T_0\dot{S}_{gen} \quad (1)$$

Generally, flow exergy which can be shown by the following equation, is separated into thermo-mechanical and chemical exergies:

$$\dot{E}_x = \dot{E}_x^{tm} + \dot{E}_x^{ch} \quad (2)$$

Thermo-mechanical exergy contains kinetic, potential and physical exergies which can be demonstrated as follows:

$$\dot{E}_x^{tm} = \dot{E}_x^{ph} + \dot{E}_x^{ke} + \dot{E}_x^{po} \quad (3)$$

From the following relation the physical exergy of the flow is calculated (Cengel, 1994):

$$e_{x,ph} = (h-h_0) - T_0(s-s_0) \quad (4)$$

In thermodynamic tables the exergy of the fuel constituent parts ($\bar{e}^{ch}_{x,i}$) can be found (Kotas, 1985). From the following relation, the molar chemical exergy of gas mixture is found (7):

$$\bar{e}^{ch}_{x,f} = \sum_i y_i\,\bar{e}^{ch}_{x,i} \quad (5)$$

Where y_i is constituent part of the molar ratio of the fuel. From the following equation, the molar chemical exergy of the combustion gases is obtained (7):

Tele:
E-mail address: vosoogh_amir@yahoo.com

$$\bar{e}^{ch}_{x,combustion} = RT_0 \sum_i X_i \, Ln\left[\frac{y_i}{y_i^e}\right] \quad (6)$$

Where y_i^e is environment elements in molar ratio and X_i is the undentified coefficients calculated in the combustion process.

Figure 1 shows the 440 MW Schematic diagram of combined Gas and steam power cycle. Table 1 shows thermodynamic properties of the cycle at different nodes.

The energy and exergy analysis of different components can be obtained by using these data that illustrate in table 2.

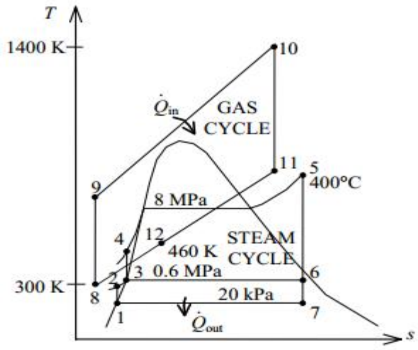

Figure 1. Schematic diagram of combined Gas and steam power cycle.

Table1. Operating values of the power plant.

Item	Pressure (kPa)	Temperature (K)	Enthalpy (kJ/kg)	Entropy (kJ/kg.K)	Exergy (kJ/kg)
1	20	300	251.4	0.832	286.3
2	600	300	252	0.832	286.9
3	600	432	670.4	1.931	1033
4	8000	432.8	678.5	1.931	1041
5	8000	673	3817	6.365	4823
6	600	432	3092	6.544	4400
7	20	333.2	2580	6.804	4056
8	14.7	300	579.2	6.256	168
9	205.8	699.2	1346	6.368	613.6
10	205.8	1400	1847	7.157	1652
11	14.7	820.6	1039	7.299	1024
12	14.7	460	749.3	6.688	458.6

Table2. Irreversibility at different component of combined gas and steam power plant.

Item	Irreversibility (kW)	Irreversibility/ total Irreversibility %
Combustion engine	280126	65.33
Gas turbine	50311	11.73
compressor	39653	9.24
Heat exchanger	27632	6.44
Steam turbine	21705	5.06
condenser	9445	2.20
total	428872	100

Figure 2 illustrate the effect of pressure ratio on the energy and exergy efficiency of a combined gas and steam power plant

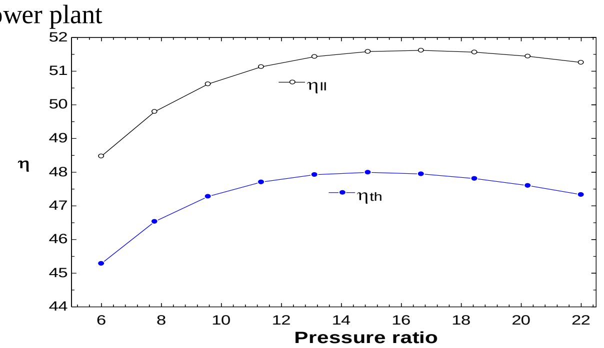

Figure 2. The effect of pressure ratio on the energy and exergy efficiency of combined gas and steam power plant.

Table 3 shows the effect of pressure ratio on the performance of combined gas and steam power plant

Table 3. Pressure ratio vs Mass ratio gas to steam, W˙_(net gas), W˙_(net steam), η_th.

Pressure ratio	Mass ratio gas to steam	$\dot{W}_{net\,gas}$ (KW)	$\dot{W}_{net\,steam}$ (KW)	$\dot{W}_{net}$ (KW)
6	4.462	304937	217567	522504
7.778	4.964	315278	195587	510865
9.556	5.418	317461	179175	496636
11.33	5.84	315225	166227	481452
13.11	6.239	310404	155621	466025
14.89	6.618	303997	146694	450691
16.67	6.983	296590	139025	435615
18.44	7.337	288548	132328	420876
20.22	7.681	280104	126404	406508
22	8.017	271416	121106	392521

In consequence, on the power plant performance, the effect of variable ambient condition and consequently variable pressure in condenser are discussed. In figure 3, the effect of ambient temperature on exergy efficiencies is depicted. Irreversibility of different components of the power plant at different ambient temperature is shown in figure 4. As ambient temperature increases the irreversibilities of all components increase.

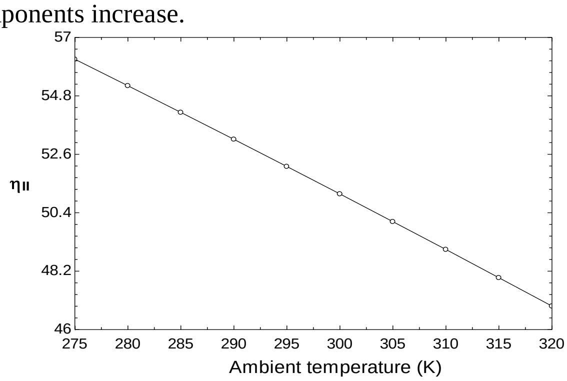

Figure 3. The effect of ambient temperature on the energy and exergy efficiency of combined gas and steam power plant.

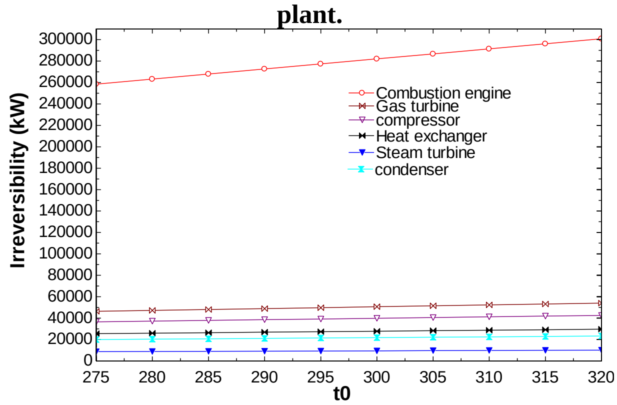

Figure 4. The effect of ambient temperature on the irreversibility of combined gas and steam power plant.

The condenser is located next to the turbine is a large shell-and-tube type heat exchanger in order to receive a large flow rate of low pressure steam. In the condenser, a phase change from vapor to liquid water occurs for this steam. In order to transport the heat of condensation of the steam away from the plant, external cooling water is pumped through thousands of tubes in the condenser. The condensate is at a low temperature and pressure, when leaving the condenser. Removal of this condensate may be regarded as continuously maintaining the low pressure in the condenser. The effects of condenser pressure on the cycle performance is shown at figure 5.

It is evident that with an increase in the condenser pressure parameters, the efficiency decreases. Following a decrease in the cycle condenser pressure and temperature, higher power output for the same mass flow rate of gas, steam and fuel input in the ignition engine will result, resulting in higher work output of the turbines.

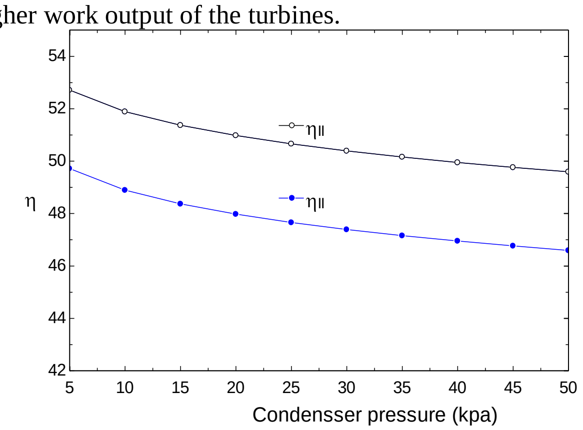

Figure 5. The effect of condenser pressure on the energy and exergy efficiency of combined gas and steam power plant.

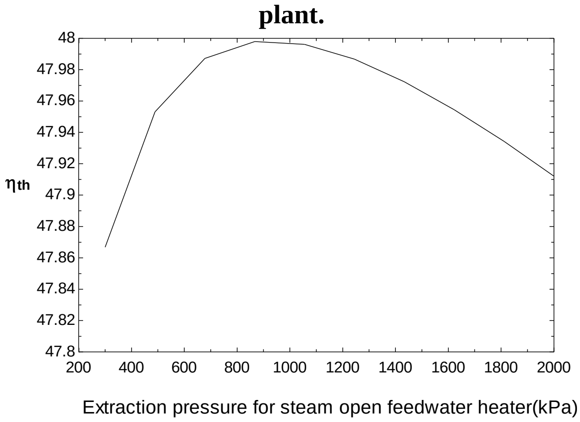

Figure 6. Extraction pressure for steam open feed water heater vs energy efficiency.

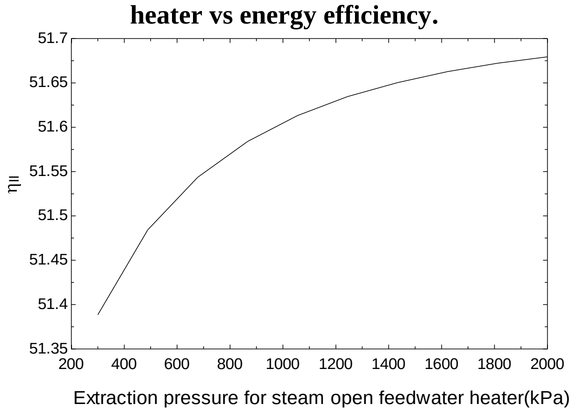

Figure 7. Extraction pressure for steam open feed water heater vs exergy efficiency.

Figure 6 and 7 show the Extraction pressure for steam open feed water heater via energy and exergy efficiency.

Conclusion

In the present study, energy and exergy analysis was used to investigate the irreversibility rate of different components of a combined gas and steam power plant at different ambient temperatures and condenser pressure. The results from exergy analyses showed that the most irreversibility occurs in combustion engine in consequent to gas turbine and compressor. It was found that increasing in pressure ratio leads to increase energy and exergy efficiency. There is an optimal value for this parameter that can be found from figure 2. It was also found that increasing the ambient temperature; decrease the exergy and energy efficiency of the power plant. The analyses also show that the condenser pressure is an important parameter that affects the output power, power potential and thermal and exergy efficiency of the cycle. Considering the inherent limitation of this parameter as well as the turbine limitation, the minimum allowable condenser pressure should be chosen to produce maximum efficiency and output power. This pressure should be always controlled during the power plant operation

Reference

[1]Kaygusuza, K., Bilgena, S.,“Thermodynamic Aspects of Renewable and Sustainable Development,” Sources, Part A: Recovery, Utilization, and Environmental Effects,Vol. 31, 1999, pp. 287-298.

[2]Som, S.K., Datta, A., “Thermodynamic irreversibilities and exergy balance in combustion processes,” Progress in Energy and Combustion Science, Vol.34, 2008, pp. 351–376.

[3]Regulagadda, P., Dincer, I., and Naterer, G.F., “Exergy analysis of a thermal power plant with measured boiler and turbine losses,” *Applied Thermal Engineering*, Vol. 30, 2010, pp.970–976.

[4]Saidur, R., Ahamed, J.U. and Masjuki, H.H., “Energy, exergy and economic analysis of industrial boilers,” *Energy Policy*, Vol. 38 2010, pp.2188–2197.

[5]Kotas, T.J., *the Exergy Method of Thermal Plant Analysis*, 1985, Butterworths, Essex.

[6]Moran, M.J., and Sciubba.E. “Exergy analysis: principles and practice,” *Journal of Engineering Gas Turbine Power*, Vol. 116, 1994, pp.285-302.

[7]Bejan, A., Tsatsaronis, G. and Moran, M., “*Thermal Design and Optimization*,” 1996, Wiley, New York.

[8]Szargut, J., Morris, D.R., and Stewart, F.R.,“*Exergy Analysis of Thermal, Chemical and Metallurgical Processes*,” 1998, Hemisphere Publishing Corporation.

[9]Rosen, M.A., “Second-law analysis: Approaches and implications,” *International Journal of Energy Research*, Vol. 23, 1999, pp.415–29.

[10]Rezac, P. and Metghalchi, H., “A brief note on the historical evolution and present state of exergy analysis,” *International Journal of Exergy*, Vol. 1, 2004, pp.426–437.

[11]Dincer, I., and Rosen, M.A., “*Exergy, Energy, Environment and Sustainable Development*,” 2007, Elsevier, London.

[12]Dincer, I., Al-Muslim, H., “Thermodynamic analysis of reheat cycle steam power plants, *“International Journal of Energy Research*, 2001, Vol. 25, pp.727-739.

[13]Koroneos,ʼ k., Haritakis, i., Michaloglou,ʼ k., Moussiopoulos, n., “exergy Analysis for Power Plant Alternative Designs”, Part I, Energy Sources, Vol. 26, 2004 , pp. 1277-1285.

[14]Kanoglu, M., Dincer, I. and Rosen, M.A.,“energy and exergy efficiencies for improved energy management in power plants”,*Energy Policy*, Vol.35, 2007, pp.3967–3978.

[15]Kopac, M.,Hilalci, A., “Effect of ambient temperature on the efficiency of the regenerative and reheat çatalağzı power plant in turkey”, *Applied Thermal Engineering*, Vol. 27, 2007, pp.1377–1385.