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Second Law Analysis Of Gas Based Thermal Power Plant To Improve Its Performance.

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Abstract: **To examine the degradation of energy during a practice, the production of entropy, and loss of work opportunities exergy is analyzed. This analysis provides an alternative plan to ensure superior performance of a power plant.Exergy analysis is carried out for URAN Gas based thermal power plant (Bokadvira Maharashtra) by conducting mass, energy and exergy analysis of each component in the gas turbine power plant. Parametric analysis of various factors like compression ratio (r_p), compressor inlet air temperature (AT), Turbine inlet temperature (TIT), on irreversibility of each and every component of Gas Turbine plant is carried out. The paper addresses how the fluctuation in cycle temperature influences the exergetic efficiency and exergetic destruction in the plant. The rate of exergy destruction in Turbine is about 5.2% whereas that in combustion chamber was about 36.4%, According to the result of study, the combustion chamber and Turbine are found to be chief means of irreversibility's in the plant. It is also found that the exergetic efficiency and exergy destruction are dependent on alteration of turbine inlet temperature.**

Keywords: Brayton cycle, First law efficiency, exergetic efficiency, compression ratio, turbine inlet temperature.

I. INTRODUCTION

A gas turbine power plant has a low capital cost as compared to fossil-fuel- fired thermal power plant, It has environmental advantages and short construction lead time. Presently a number of researchers such as Cenegel and Boles [1], Jones and Dugan [2], Moran and Shapiro [3], Aljudani [4] have chosen the topic of "exergy analysis in thermal design" and provided a considerable amount of literature on it. Basically the performance of system is assessed by exergy analysis as it is derived from the second law of thermodynamic which makes it rise from the limitation of an energy based analysis. Exergy is annihilated in the system rather than conserved. The chief source of inefficiency in a system is amount of irreversibility which is exergy destruction. Thus, in a thermal system the location, the amount and the cause of thermodynamic deficiencies are determined by exergy analysis evaluating the degree of exergy destruction [5-7] .The entropy-generation of the components is precisely calculated in the exergy analysis and this enables us to forecast thermodynamic performance of an energy system and the efficiency of system components [8].Bejan et.al.[9] developed analysis methodology for gas turbine system. A method to determine chemical and physical exergy of various components of plant is determined by Kotas [10].Efficiency of gas turbine system with single dual and triple pressure heat recovery steam generator is determined by Sriniwas [11]. Exergy analysis of 50 MW lignite fired thermal power plant is carried out by Ganpathi. By using advanced blade material s and cooling technology turbine inlet temperature as high as 1288°c and higher can be obtained with consequent increase in power and thermal efficiency.[12]. The effect of ambient condition on the performance of simple gas turbine cycle in Turkey was investigated and it is found that electric power output of GT vary according to the ambient condition which greatly affects electricity production and fuel consumption as suggested by Hasan and Suleman. Exergy analysis of Baggasse based cogeneration power plant of sugar factory by varying the condenser back pressure is carried by kamte and Gangawati [13] in the analysis they employed exergy method in addition to more conventional energy method to evaluate component efficiency and to asses thermodynamic losses. Dincer and Rosen [14] presented effect on the result of energy and exergy of variation of dead state properties. Dincer et.al.[15] presented an efficiency analysis, accounting for both energy and exergy consideration of a design for a cogeneration based district heating system. A case study is considered to assist the plant engineer in decision making, optimization and also to locate areas where losses are maximum

In this paper exergy analysis of Uran gas turbine power plant is carried out .Each component is studied under the light of law of energy and mass conservation along with air preheated(heat exchanger).Exergy balance equation developed by Oh et al. [16]is used for this analysis and for each component a quantitative exergy balance was derived

II SYSTEM DESCRIPTION:

Schematic and T-s diagram of closed cycle Brayton cycle is represented in the diagram

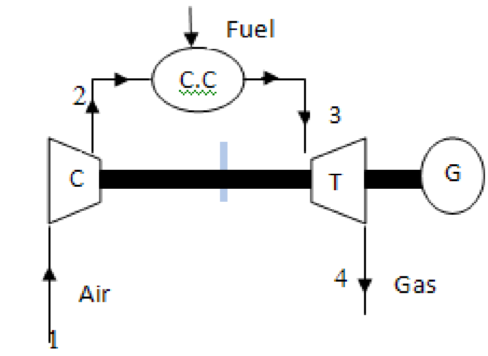

Fig. 1 Schematic Diagram

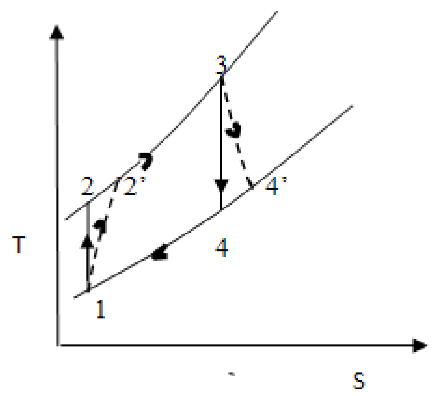

Fig. 2 T-s Diagram

The gas turbine power plant is a simple open cycle plant located at Bokadvira Maharashtra . The power plant uses natural gas of low heating value (in kJ/kg). The simplified schematic diagram and T-s diagram are represented in Fig. 1 and Fig. 2 respectively. The system consists of an air compressor (C), combustion chamber (C.C.) and a gasTurbine (T).

III. CYCLE ANALYSIS:

The gas based Brayton cycle thermal power plant is represented by a system of algebraic equations, which is based on modified semi perfect model of gas turbine based cycle as suggested by woods (1991). The plant was divided in to number of control volumes and exergy balance is determined for each components. Energy and exergetic performance criteria based on daily operating data were performed on the entire plant . The operating data performed are compressor inlet temperature (AT),turbine inlet temperature(TIT), and compression ratio($r_{p)}$.Data outside the operating design parameter were simulated and their effect on first law and second law efficiency of the plant was critically studied. Thermo mechanical exergy flow equation as suggested by Cortes and Rivera has been used. Both the laws of thermodynamic are used to derive the following set of exergy equations which can be related to any component of a thermodynamic system.

$$\varepsilon_{in}^{m} - \varepsilon_{out}^{m} = \left(\varepsilon_{in}^{T} - \varepsilon_{out}^{T}\right) + \left(\varepsilon_{in}^{M} - \varepsilon_{out}^{M}\right) \qquad (1)$$

For an ideal gas having constant specific heat, the thermal and mechanical components of the exergy flow can be represented as

$$\varepsilon^{T} = mC_p[\left(T - T_{ref}\right) - T_{ref} l_n \left(\frac{T}{T_{ref}}\right)] \qquad (2)$$

$$\varepsilon^{M} = mRT_{ref}\ l_n\left(\frac{p}{p_{ref}}\right) \qquad (3)$$

General exergy balance equation derived on the basis of decomposition is given by

$$\varepsilon^{w} = \varepsilon^{ch} + \left(\Sigma_{in}\varepsilon_{in}^{T} - \Sigma_{out}\varepsilon_{out}^{T}\right) + \left(\Sigma_{in}\varepsilon_{in}^{M} - \Sigma out \varepsilon out M + Tref(\Sigma in s in - \Sigma out s out + Qcv Tref\right) \qquad (4)$$

Exergy Balance Equation for Gas Turbine Plant:

With the help of general equation for exergy balance specific exergy balance equation can be determined for different components of gas turbine plant. Exergy balance equation for each components of plant are given as.

Exergy balance equation for compressor

$$W_g = (\varepsilon_1^T - \varepsilon_2^T) + (\varepsilon_1^M - \varepsilon_2^M) + T_1(S_1 - S_2) \qquad (5)$$

Exergy balance equation for air pre heater

$$(\varepsilon_2^T - \varepsilon_3^T + \varepsilon_6^T - \varepsilon_7^T) + (\varepsilon_2^P - \varepsilon_3^P + \varepsilon_6^P - \varepsilon_7^P) + T_1(S_2 - S_3 + S_6 - S_7 + \frac{Q_{AH}}{T_1}) = 0 \qquad (6)$$

Exergy balance equation for combustion chamber

$$\varepsilon_{ch} + \left(\varepsilon_3^T + \varepsilon_f^T - \varepsilon_5^T\right) + (\varepsilon_3^M + \varepsilon_f^M - \varepsilon_5^M) + T_0(s_3 + s_f - s_5 + \frac{Q_{cc}}{T_0}) = 0 \qquad (7)$$

Exergy balance equation for Turbine

$$W_t = \left(\varepsilon_5^T - \varepsilon_6^T\right) + \left(\varepsilon_5^M - \varepsilon_6^M\right) + T_1(s_5 - s_6) \qquad (8)$$

IV. RESULT AND DISCUSSION:

Table 1 gives chemical thermal and mechanical exegy flow rates and entropy flow rates .Properties like pressure, temperature and mass flow rates are used to determine these flow rates. With the suitable polynomial, placed as thermo physical figure in the JANAF tables which help in determining different incoming and outgoing exergies of different components of the cycle.

Net flow rates of the different exergies passing through the each component in the gas turbine plant at rated circumstances along with the exergy destruction in each component is represented in table 2. Exergy flow rates of products are represented by positive value whereas negative value stands for exergy flow rate of source or fuel. For each component and for the plant the exergy flow rates of products, resources and destruction add to give off value of zero, zero signifies that exergy of a system is completely balanced.

Table 1: Thermal, Mechanical, exergy and entropy flow rate at different properties.

State	Temperature(K)	Pressure(bar)	Mass flow rate(Kg/sec)	ε^T(MW)	ε^M(MW)	s(MW/sec)
1	296	1.013	504	0	0	0
2	591	10.85	504	50.12	137.65	0.066
3	798	10.85	504	116.42	131.23	0.0231
4	330	22.00	9.7	0	9.48	-0.0213
5	1425	10.42	512.8	384.04	133.48	0.0543
6	891	1.042	512.8	180.37	6.54	0.642
7	705	1.024	512.8	94.57	2.12	0.523

Table 2: Exergy flow rate and exergy destruction in different components of Gas Turbine plant at rated condition'

Component	ε^W	ε_D	ε^M	ε^T
compressor	-209.54	17.98	131.76	71.32
Air pre heater	0	10.98	-7.65	-8.64
Combustion chamber	0	379.88	-8.34	326.33
Turbine	369.34	19.21	-127.65	-236.43
Total cycle	159.8	428.05	-11.88	152.58

Shift of exergetic efficiency of system components with ambient temperature is shown in fig. 3 , For compressor second law efficiency decreased from 88.23% to 84.12% whereas for combustion chamber it fell from 46.80% to 44.35% . The fig. no. 3 also representing change in second law efficiency of other components of the cycle.

Fig. 4 represent the exergetic efficiency of different components of the plant . Exergetic efficiency of total plant is also represented in this figure which comes out to be nearly 41%. The figure depicts that the second law efficiency of combustion chamber is the lowest as compared to other components of the plant, as combustion chamber has maximum irreversibility's.

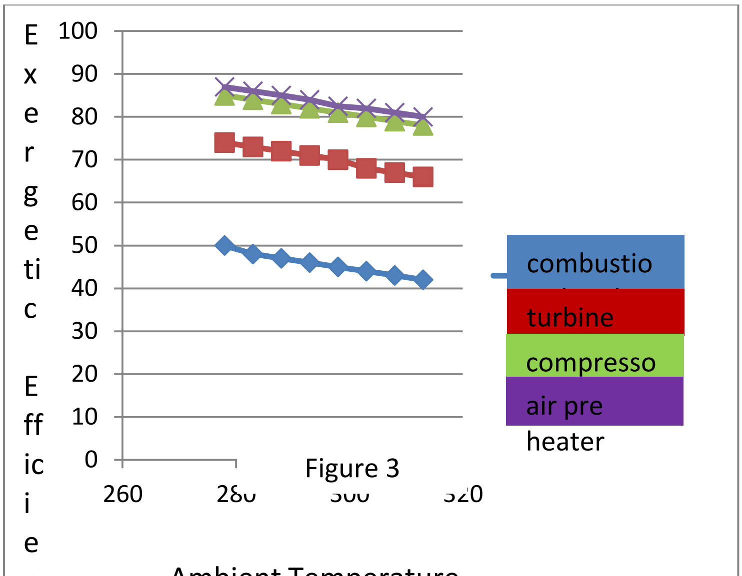

Fig:3

Exergy destruction in different plant component is represented in Figure 5. Maximum exergy destructionis found to be in combustion chamber where as total exergy destruction in the plant is nearly 62%.

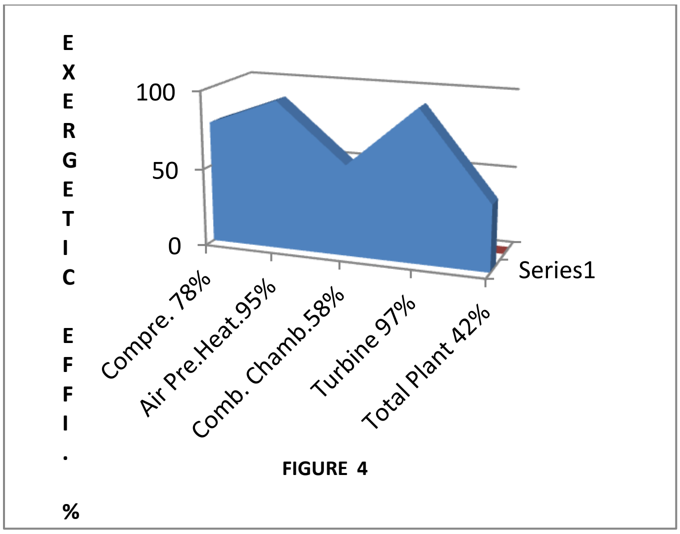

FIGURE 4

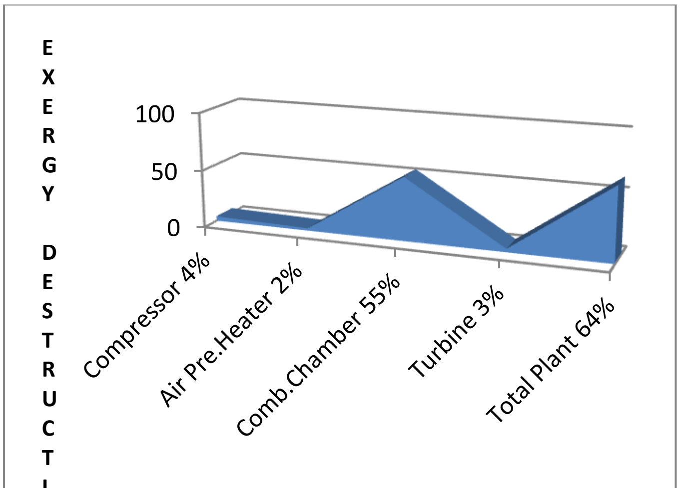

FIGURE.5

Effect of change in turbine inlet temperature on exergetic efficiency is calculated, An effect of 125% increase in turbine inlet temperature on components of plant is represented in Fig. 6.A slight increase in second law efficiency of turbine is observed whereas compressor exergetic efficiency remain unchanged with increase in turbine inlet temperature. Working of compressor remain unaffected, whereas total exergy destruction of combustion chamber shows a huge decline . Exergy destruction in air preheated amplifies whereas total exergy destruction of plant reduces nearly to 20%, because of the preponderance of irreversibility in the combustion chamber as concluded from figure 7.

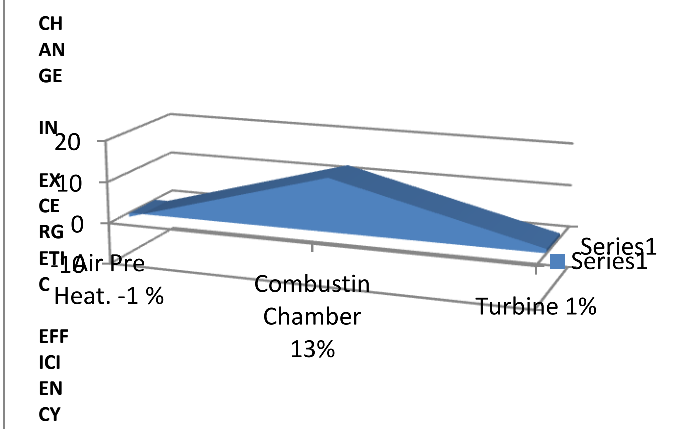

FIGURE 6

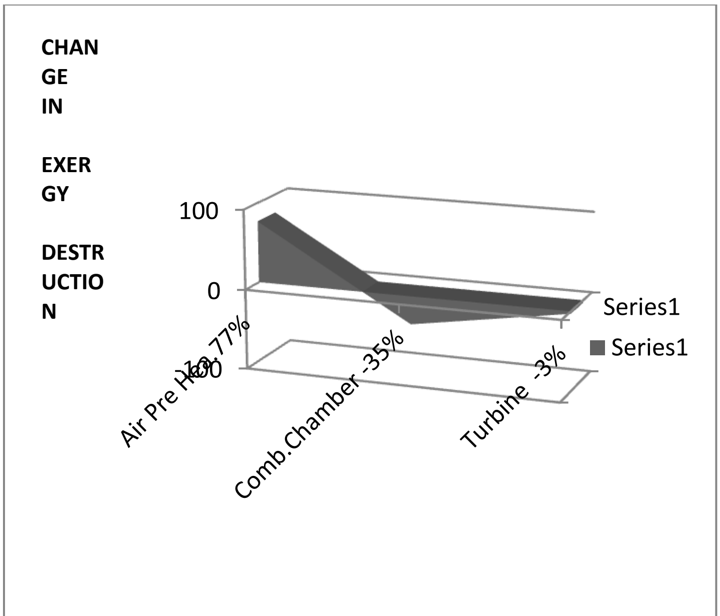

FIG.7 CHANGE IN E XERGY DESTRUCTION IN %

V. CONCLUSION:

Use of exergy balance equation to the components of thermal power plant helps to determine total consumption of available work potential or exergy provided as the input to the system under consideration. The irreversibility involved in the component of any system can be quantitatively measured with the help of exergy loss. The analysis made in this paper gives the idea of impact of the inlet temperature of the turbine on the exegetic competence and exergy destruction in gas turbine system. The paper analyzed that this factor greatly influences the second law efficiency exergy destruction in the combustion chamber. Since the exergy loss in combustion chamber is only the significant one therefore turbine inlet temperature affect greatly exergetic efficiency and exergy destruction of the plant.

Nomenclature :

AFR	Air Fuel Ratio
C_p	Specific Heat at Constant pressure.
DT	Destruction of total plant exergy at inlet.
GT	Gas turbine
m	Mass flow rate (Kg/sec)
p	Pressure (bar)
Q	Heat transfer rate
R	Universal gas constant (kJ/KgK)
S	Entropy flow rate (kJ/KgK)

T Temperature (k)

TIT Turbine Inlet Temperature

T_0 Ambient temperature

W Power (kW)

Greek Symbols:

η_I = Energy Efficiency

η_{ii} = Exergy Efficiency

E = Exergy flow

Subscripts:

m = Material

Ch = chemical

T = Thermal

M = Mechanical

W = Work output.

REFERENCES:

[1] Cenegel,Y.A. ,Boles, M.A.(1998) ,Thermodynamics-An Engineering Approach, Boston, McGraw Hill.

[2] Jones, J.B., and Dugan, R.E. (1996),Engineering Thermodynamics, Upper Saddle River: Prentice Hall.

[3] Moran, M.J. and Shapiro H.N.(2000) Fundamental of Engineering Thermodynamics 4th Edition. New York Wiley.

[4] Aljudani,A.H., 2002, Energy and Exergy Analysis of Thermal power plant, Applied Thermal Engineering Vol. 23,.

[5] Kotas,T.J.(1995) The Exergy Method in Thermal Plant Analysis, reprint edition, Malabar ,Krieger.

[6] Kwak,H. ,Kim,D.,and Jeon,J.,(2003) Exergetic and Thermoeconomic analysis of Thermal Power Plants',Energy Vol. 38 pp 343-360

[7] Kwon,Y.,Kwak,H.,and oh,S.,(2001),Exergoeconomic analysis of Gas turbine cogeneration system, Exergy an Inter. Journal Vol.1 pp 31-40.

[8] Oh,S.,Pang,H.,Kim,s.,and Kwak,H.,(1996),Exergy analysis for a gas turbine cogeneration system,Exergy an Inter, Journal Vol.118 pp 782-981.

[9] Bejan,G.,Tsatsaronics,M.J.,Moran Optimization and thermal design,Willey,1996.

[10] T. J. Kotas, "Exergy Criteria of Performance for Thermal Plant: Second of Two Papers on Exergy Techniques in Thermal Plant Analysis," International Journal of Heat and Fluid Flow, Vol. 2, No. 4, 1980, pp. 147-163.

[11] Sriniwas,T.,(2010) Thermodynamic Modelling and optimization of a dual pressure reheat combined power cycle.Sadhana, 35(5) 597-608.

[12]. A. Franco and A. Russo, "Combined Cycle Plant Efficiency Increase Based on the Optimization of the Heat Recovery Steam Generator Operating Parameters," International Journal of Thermal Sciences , Vol. 41, No. 9, 2002, pp. 843-859

[13] S. C. Kamate and P. B. Gangavati, "Exergy Analysis of Cogeneration Power Plants in Sugar Industries," Applied Thermal Engineering , Vol. 29, No. 5-6, 2009, pp. 1187-1194

[14] I. Dincer and M. A. Rosen, (2005)"Effect of Varying Dead-State Properties on Energy and Exergy Analyses of Thermal Systems," International Journal of Thermal Sciences ,Vol.33 ,NO. 3 pp 112-121.

[15] Dincer,I.,Naterer,G.F.,(2010) Exergy analysis of thermal power plant with measured Boiler & turbine losses.

[16] Oh,S.,Pang,S.,Kim,H.,(1996) 'Exergy analysis of cogeneration Gas Turbine power plant' Int. J of gas turbine 118(4).782-791.