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CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 9, Issue, 7(B), pp. 27793-27796, July, 2018

ISSN: 0976-3031

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Research Article

THERMODYNAMIC ANALYSIS OF GAS TURBINE POWER PLANT BASED ON ENERGY AND ENTROPY ANALYSIS

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DOI: http://dx.doi.org/10.24327/ijrsr.2018.0907.2333

ARTICLE INFO

Article History:

Received 9th April, 2018
Received in revised form 9th May, 2018
Accepted 16th June, 2018
Published online 28th July, 2018

Key Words:

Gas turbine, Co generation, Thermodynamics, Heat, Power.

ABSTRACT

In this paper a comprehensive review has been reported in the field of gas turbine based cycle with their various integration system and analysis. The thermodynamic analysis of the interconnected reactant gas turbine cycle has been examined. Utilizing the waste heat from gas turbine outlet two heat exchangers has been used i.e. recuperation and intercooler. In the are of heat exchanger design, heat transfer can be enhanced by reducing Liquid temperature difference from fluid and damage by increasing the heat surface area. In this paper the energy and entropy generation within the cycle has examined for wide range of pressure ratio and operating turbine inlet temperature. From the analysis It has been observed that the use of the recuperator improves the performance of the gas turbine cycle significantly.

INTRODUCTION

In traditional power plants, one of the major source of power production being gas turbine. Energy saving and enhanced efficiency is an immediate requirement in gas turbine engines and aircraft jet engines. Heat exchangers such as reincarnation, precooler and intercooler are used to enhance fuel efficiency. Gas turbine works on the principle of the Brayton cycle, wherein combustion chamber is filled with the compressed air coming from the compressor. The high temperature and high pressure of combustion products from the combustion chamber enters the gas turbine where they expand to low pressure and work is produced. In the combustion chamber due to incomplete combustion as well as small expansion of high temperature and high pressure combustion products in the gas turbine, leads to loss of energy to to the environment. This loss of energy may sometimes be capable of operating another thermal power plant. In a simple gas turbine, the turbine outlet temperature ranges between 370-540°C. Warm exhaust gases have great thermodynamic efficacy which will be lost, if the hot gases are not being used and simply discarded to the environment that's in any other case lost while the exhaust fuel is released at once into the encompassing regions. One way to use this capability is through internal heat recovery in which exhaust gases are used as a stock of heat. Steam injection and regenerative heat exchanger can be employed for this purpose. The air coming out of the compressor is preheated before entering the combustor by using regenerative heat exchanger thus reduces the accounted fuel which is burnt in the compressor. The thermal energy of the exhaust gas is transferred to an auxiliary fluid in heat recovery steam generator (HRSG) unit which is then injected into the combustor by using steam injection technique. In HRSG water passes via counter flow with the outlet gas in economizer, vaporizer and superheater. Turbine work increases by steam injection by increasing flow rate of working fluid and its specific heat [1]. Steam injection technique has the benefit of controlling NOx emissions from the gas turbine combustor in addition to increase in turbine output [2].

Ward *et al.* [3] customized waste warmth recuperation in micro-fuel turbine packages the use of advanced humidified standards inside the fuel turbine cycle. Simulation indicated that mGT's air has a sizable useful effect at the cycle performance due to the expanded waste heat recovery from humidity, resulting in excessive electrical power generation (at constant rotating speed) or reducing fuel intake (non-stop power technology On) the performance of the energy elevated.

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Tsujikawa *et al*. [4] from the angle of the second one law of thermodynamics, the layout approach of the reseller of the fuel turbine cycle implemented to the entropy generation is presented. For the constant fee of compressor pressure percentage, the variety of entropy era units is calculated and the most fulfilling temperature performance of the generator determines the minimal warmness switch floor vicinity.

Alklaibi *et al*. [5] for the thermodynamic analysis of the gas turbine cycle with the wind turbine cycle, the 1 and 2 law analysis has been implemented to compare the efficiency ratio with the conventional combined cycle along with the modified gas turbine cycle. Both the modified gas turbine and the modified gas turbine include an intercooler and rehab exchangers with air basement cycle. They concluded that the loss of clearance with the exhaust gas of ordinary gas turbine is a major part of 47% of total exhaust destruction. This gas turbine has reduced by 31% with wind cycling.

Mahmood *et al*. [6] checked the thermodynamic overall performance of a fuel turbine cycle ready with a double appearing sterling engine results display that hybrid fuel turbine and stirling engines enhance efficiency from 23.6 to 38.8%.

In the previous research, several routes were proposed and studied for MGT cycle humidification for waste warmness recovery. Many researchers centered on classical steam injection [7, 8-15] or water injection [11,15] by way of studying these specific options on diverse MGTs. All researchers pronounced an critical electrical performance growth (and an increase in capability electrical technology output if operated at steady rotation speeds). This boom depends on MGT length, injection technique (Liquid water or steam) and injection point inside the cycle.

In my work I have investigate a Gas turbine cycle, which utilizes waste heat from the gas turbine to power up the cycle. where Intercooled recuperated gas turbine cycle has been considered. Which have higher efficiency as compared to conventional gas turbine cycle.

In my work I have performed 1st and 2nd thermodynamic analysis which reveals the effect of each parameters on the thermal performance of gas turbine power plant. Parameter such as, compression ratio, turbine inlet temperature, and component efficiency factor. Moreover from 2nd law analysis the entropy generation within the cycle has been identified and through this the entropy can be minimized which result in increase in efficiency of power plant.

Mathematical Modelling

Compressor

Compressor is defined in the form of isentropic efficiency

$$\eta_c = \frac{W_{cs}}{W_{ca}} = \frac{h_{2s} - h_1}{h_2 - h_1} \tag{1}$$

$$\frac{T_{2s}}{T_1} = \left(\frac{P_2}{P_1}\right)^{\left(\frac{\gamma-1}{\gamma}\right)} \tag{2}$$

$$T_{2s} = T_1 \left\{ 1 + \frac{1}{\eta_c}\left(\left(\frac{P_2}{P_1}\right)^{\left(\frac{\gamma-1}{\gamma}\right)} - 1 \right) \right\} \tag{3}$$

$$P_2 = P_1 \times r_{pc} \tag{4}$$

Entropy generation within the compressor is also written as follows:

$$S_{gen,c} = \left(c_{pa} \ln \frac{T_2'}{T_1} - R_a \ln \frac{p_2}{p_1} \right) \tag{5}$$

Recuperator
The effectiveness of the recuperator is defined as

$$\varepsilon_{Recup} = \frac{T_3 - T_2}{T_5 - T_2} \tag{6}$$

From mass conservation, $\dot{m}_2 = \dot{m}_3$ and $\dot{m}_5 = \dot{m}_6$. Thus, rates of entropy generation within the heat exchanger can be evaluated as follows.

$$S_{gen,Recup} = \dot{m}_2\left(s_3 - s_2\right) - \dot{m}_5\left(s_6 - s_5\right) \tag{7}$$

Combustion Chamber

$$\dot{m}_g = \dot{m}_a + \dot{m}_f \tag{8}$$

$$\dot{m}_f \times LHV \times \eta_{comb} = \dot{m}_g \times h_3 - \dot{m}_a \times h_2 \tag{9}$$

For combustion, the entropy balance can be written as equation

$$\dot{m}_3 s_3 + \left(\dot{m}s\right)_{fuel,comb} + \frac{\dot{Q}_{comb}}{T_{comb}} + \dot{S}_{gen,comb} - \dot{m}_4 s_4 - \frac{\dot{Q}_{loss}}{Tsurr} = 0 \tag{10}$$

Gas Turbine (GT)
The gas turbine work is given by:

$$\dot{W}_{GT} = h_4 - h_5 \tag{11}$$

Isentropic efficiency of the turbine,

$$\eta_{GT} = \frac{\dot{W}_{GTa}}{\dot{W}_{GTs}} = \frac{h_4 - h_5'}{h_4 - h_5} \tag{12}$$

Entropy production rates during the expansion process

$$\dot{S}_{gen,GT} = \dot{m}_5\left(s_5 - s_4\right) \tag{13}$$

METHODOLOGY

Governing equations of the current recuperative gas turbine cycle have been solved using MATLAB code. The schematic diagram of the current gas turbine cycle is shown in Figure 1. Operating parameter of recuperative gas turbine cycle is tabulated in Table 1

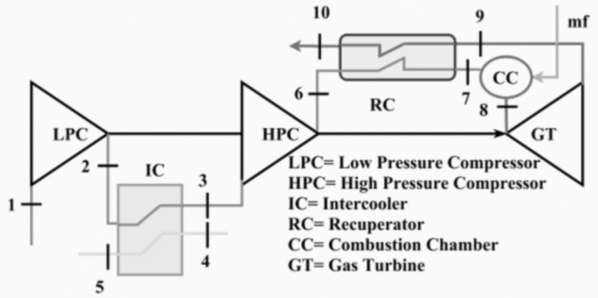

Figure 1 Schematic diagram of Recuperative gas turbine cycle

Table 1 Operating parameters

Gas Turbine cycle	
Compressor efficiency (ηcomp)	0.7
Turbine efficiency (ηGT)	0.75
Recuperator effectiveness (ηRecup)	0.8
Combustor efficiency (ηComb)	0.90
AC generator efficiency (ηGen)	0.98
Turbine Inlet Temperature	1700
Compression ratio, ($r_{p,c}$)	12
Pressure losses	
Recuperator gas / air sides (%)	2
Fuell cell stack (%)	2
Combustor (%)	2
Ambient conditions	
Temperature (K)	288 – 300
Pressure (atm)	1
Flow conditions	
Air flow rate	1000kg/s
Fuel flow rate	AFR
LHV of Fuel (kJ / kg)	42000

RESULT AND DISCUSSION

In this section the results obtained from the parametric analysis have discussed and various information have drawn which helps in studying and design waste heat recovery power cycle.

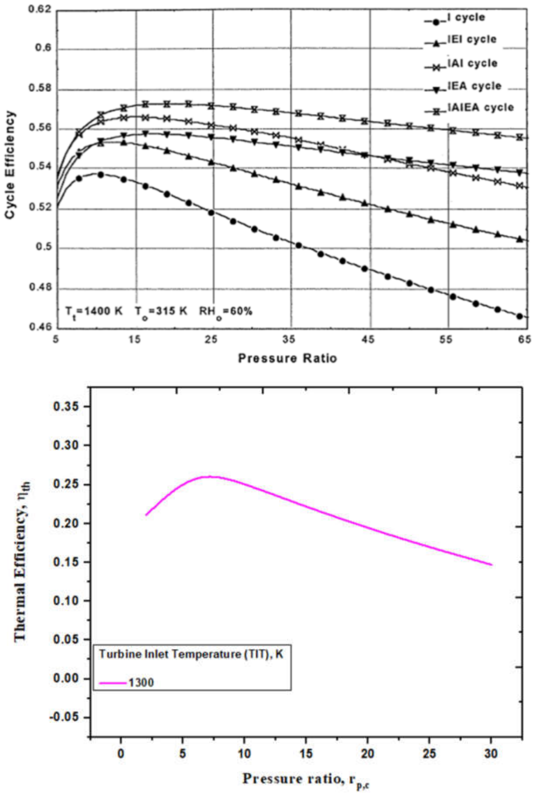

Figure 2 Comparative thermal performance of regenerative (recuperative) and simple cycle.

Comparative thermal performance of reproducible and simple cycles can be illustrated with fig 2. It has been observed that the increase in the compression ratio increases the thermal efficiency of the Renaissance cycle until it reaches optimal thermal efficiency and then decreases. Whereas, the thermal efficiency of the simple cycle ultimately increases.

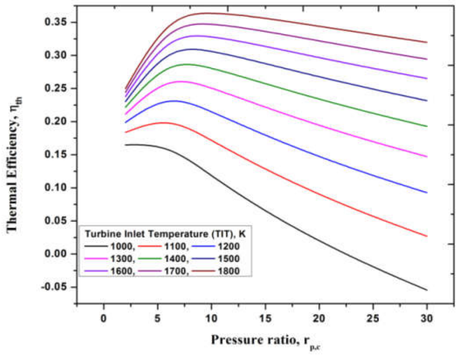

Figure 3 Effect of pressure ratio and turbine inlet temperature on thermal performance

Figure 3 demonstrates effect of pressure ratio and turbine inlet temperature on thermal performance. It has been observed that the increase in TIT increases significantly in thermal efficiency and increase in compression ratio increases the thermal efficiency first and then decreases comfortably.

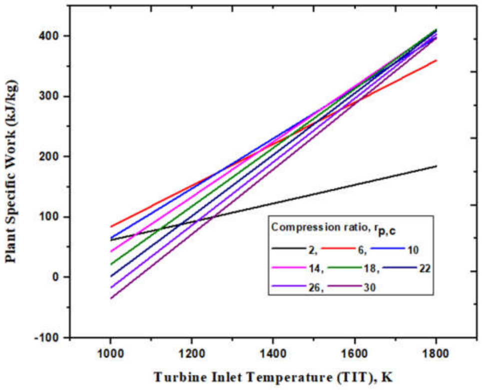

Figure 4 Effect of turbine inlet temperature on plant specific work

Figure 4 shows the influence of the turbine inlet temperature on the plant's specific work has been seen to increase the turbine inlet temperature, the plant specific work eventually increases. High tissue-specific work is produced in low TIT 6 compression ratios, while higher TIT high-pressure compression ratio high plants perform specific functions.

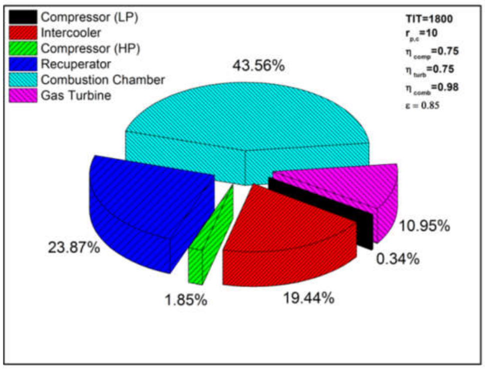

Figure 5 Entropy generation rate of the cycle.

Figure 5 shows the entropy generation rate of the cycle. It has been observed that combustion chamber is the major contributor of the entropy within the cycle. While compressor is the major contributor. The entropy generation is basically representing the presence of irreversibility within the system.

CONCLUSION

From the thermodynamic analysis various conclusions have been drawn

1. The cycle thermal efficiency increases as turbine inlet temperature increases.
2. Using intercooler and Recuperator the performance of gas turbine cycle increases remarkably
3. The level of entropy generation increases as the cycle temperature increases.
4. At low TIT 6 compression ratio yields higher plant specific work, while at higher TIT higher pressure compression ratio gives higher plant specific work.
5. Combustion chamber is the major contributor of the entropy within the cycle

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How to cite this article:

Vinay Singh and Laxminarayan R Bhandarkar.2018, Thermodynamic Analysis of Gas Turbine Power Plant Based on Energy and Entropy Analysis. *Int J Recent Sci Res.* 9(7), pp. 27793-27796. DOI: http://dx.doi.org/10.24327/ijrsr.2018.0907.2333

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