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Original Article

EFFECTS OF THERMODYNAMIC PARAMETERS ON PERFORMANCE OF GAS TURBINE CYCLE WITH REGENERATOR

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ABSTRACT

One way to increase the efficiency of a gas turbine is to use a regenerator. The main purpose of this study is to investigate the effect of various parameters such as the outlet gas, outlet temperature, and the compressor pressure on the performance of the gas turbine with the regenerator. The analysis is based on coding and the effects of changing each parameter are examined. The results showed that each parameter has a great influence on the cycle performance. By increasing the compressor pressure ratio, the work consumed by the compressor and the work produced by the turbine is increased. By increasing the outlet temperature from the combustion chamber, work produced by turbines is increased. Furthermore, by increasing flow rates the work of the turbine and compressor is increased. A comparison of these effects may assist us to find the optimal cycle conditions.

KEYWORDS: Gas Turbine , Regenerator ,Compressor Pressure Ratio, Exhaust Gas Temperature, Performance

SYMBOLS / PARAMETERS

rp: Compressor pressure ratio
TIT: Combustion chamber exhaust gas temperature
ɿ: Efficiency
***S:*Entropy**
***h:*Enthalpy**
***P:*Pressure**

***T:*temperature**
***Q:*Heat Energy**
***W:* Work**
***Cp:* Heat capacity (isobaric)**
***LHV:* The calorific value of fuel**
***K:*Ration of the specific heats**

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INTRODUCTION

One of the ways to increase the gas turbine efficiency is to use a regenerator. In this type of cycle, the exhaust gases from the turbine are used to preheat the air before entering the combustion chamber. An important point to consider when using heat exchangers is that gas turbine engines with a high compression ratio have a gas outlet temperature higher than the gas output from the turbine, therefore, the use of heat exchangers reduces cycle efficiency. The use of heat exchangers with very high returns has two problems; increase of construction costs, and pressure drop

Gas turbines have always been of interest to researchers. Kakaras et al. [1] used of waste heat from gas turbine casings to increase the gas production capacity of the gas turbine was studied. Wang and Olivier [2] investigated the utilization of waste heat from gas-fired power plants in solid-liquid refrigeration systems. Ogreisk [2008] studied coupling with a power plant Calina Cyclone, to use the waste heat of smoke entering the chimney. Researches on optimization of synchronous production units in various terms such as current net worth, primary energy savings, annual cost [3], minimum energy costs [4], carbon dioxide emissions [5], and also, the simultaneous reduction of primary energy, annual total cost, and carbon dioxide alongside [6-7] have been performed, which are presented as a function of purpose in the operation of synchronous production systems. On the other hand, to model these criteria, linear programming, one of the most popular and classic models to reduce the costs of supplying demand in synchronous production systems, is often used. Zarepouret al [8] and Doustdaret al. [9-10] investigated the modeling the thrust and specific fuel consumption for a hypothetical turbojet and turbofan engine.

Simulation and modeling of gas turbine engines are considered as one of the most complex dynamical systems available, always as attractive issues to improve the performance and control techniques, has been considered [11-13].To analyze the performance of turbine engines in the design phase based on the aero thermodynamic behavior of the engine and its components, the engine mathematical model is provided, and the engine performance is simulated and evaluated [14-15]. Bethel presented a simple design for fuel consumption performance and a two-shaft turbofan engine thrust [16]. Yonosof et al. offered a design to control aircraft engine thrust by using flight information aircraft engines of diagnostic devices [17]. Francisco et al. provided a turboshaft engine of 1000 kW for non-linear dynamic modeling and utilized this model to control the turboshaft engine system [18-19]. They also developed this engine in start condition, cruise control until snuff state. Homaei far et al presented a method for improving the turbofan engine performance using a general algorithm method [20]. Montazerin et al. proposed a method for improving the jet engines fuel system [21].

In this research, the modeling of the gas turbine cycle with regenerator has been investigated and the effect of factors such as compressor pressure ratio, the outlet gas temperature of the combustion chamber, and mass flow rate on cyclic performance have been investigated.

MATERIALS AND METHODS

In this study, coding was used to investigate the effect of parameters; therefore, it was necessary to analyze the thermodynamic relationships of the gas turbine cycle. The Brighton cycle is the basis of the operation of gas turbines. Figure 1 schematically shows a simple gas turbine cycle with a regenerator.

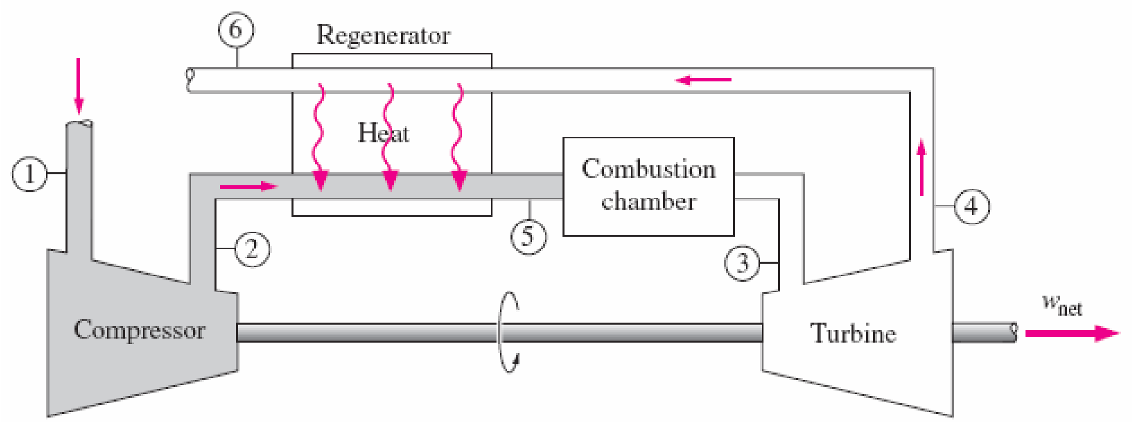

Figure 1: Gas Turbine Cycle with Regenerator.

- 1-2 isentropic condensation (inside compressor)
- 2-5 Cooling of hot gases Output from a fixed pressure turbine
- 5-3 Increasing the temperature in the combustion chamber with constant pressure
- 3-4 Isentropic expansion (inside turbine)
- 4-6 Heat to the inlet air to the constant pressure combustion chamber

- 4-1 Decrease heat by constant pressure

Compressor Analysis

The ibn-process is ideally reversible (isentropic), ie, S1 = S2. According to the first law of thermodynamics:

$$q_c - w_c = h_2 - h_1 \tag{1}$$

That is, regardless of q_c, the value of the compressor load is calculated:

$$w_c = h_2 - h_1, W_c = \dot{m}_c \left(h_2 - h_1\right), h_2 - h_1 = Cp(T_2 - T_1) \tag{2}$$

In this process, the ideal air inlet to the combustion chamber is preheated at constant pressure, ie

$$P_2 = P_5, P_4 = P_6 \tag{3}$$

$$Q_{2-5} = Q_{4-6} \rightarrow T_5 - T_2 = T_4 - T_6 \tag{4}$$

And the efficiency of the heat exchanger is defined as 100% for the ideal state, and for the actual state, between 85% and 90%.

$$\varepsilon = T_5 - T_2 / T_4 - T_2 \tag{5}$$

Combustion Chamber Analysis

During this process, it is ideal for the heating of the constant pressure

$$P_5 = P_3, q_H - w_{5-3} = h_3 - h_5, w_{2-3} = 0 \tag{6}$$

So:

$$q_H = h_3 - h_5 \tag{7}$$

$$Q_H = \dot{m}_f \times LHV = \dot{m} \times \left(h_3 - h_5\right) h_3 - h_5 = Cp(T_3 - T_5)$$

Turbine Analysis

This process is ideally reversible in the ideal case of adiabatic expansion

$$S_3 = S_4, q_{3-4} - w_t = h_4 - h_3, q_{3-4} = 0 \rightarrow \tag{8}$$

$$w_t = h_3 - h_4, W_t = \dot{m}_t \left(h_3 - h_4\right), h_3 - h_4 = Cp(T_3 - T_4) \tag{9}$$

Amount of Heat Dissipation

$$q_L = \left(h_4 - h_1\right) Q_L = \dot{m} \times \left(h_4 - h_1\right) h_4 - h_1 = Cp(T_4 - T_1) \tag{10}$$

General Cycle Analysis

The thermal efficiency of the cycle is ideally defined as follows

$$\eta_{th} = W_{net} / Q_h = 1 - rp^{k-1/k} / \tau \qquad (11)$$

$$\tau = T_3 / T_1 , r_p = P_2 / P_1 \qquad (12)$$

Also the Network of the Relationship

$$w_{net} = w_t - w_c , W_{net} = W_t - W_c \qquad (13)$$

RESULT

The above cycle is coded through EES software. For analysis of the turbine data, the gas turbine SGT-600 Industrial Gas Turbine - 25 MW was used (Table 1).

Table 1: Specifications of SGT-600 Industrial Gas Turbine - 25 MW

Specifications	Amount
Exhaust gas flow	80.4 kg/s
Exhaust gas temperature	543 deg C
Compressor pressure ratio	14.0:1

Effects of Compressor Pressure Change

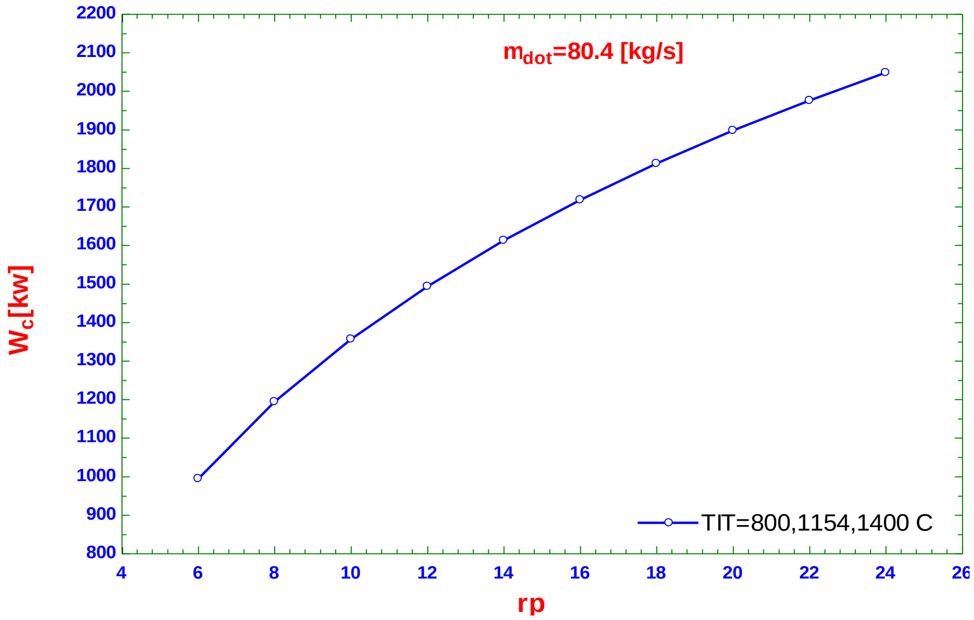

Figure 2: Compressor Work Changes with Compressor Pressure Ratio in Constant Flow Rate.

Figure 2 shows the relationship between compressor performance and compressor pressure ratio. As can be seen, by increasing the compressor pressure ratio the amount of work consumed by the compressor increases at a fairly constant rate.

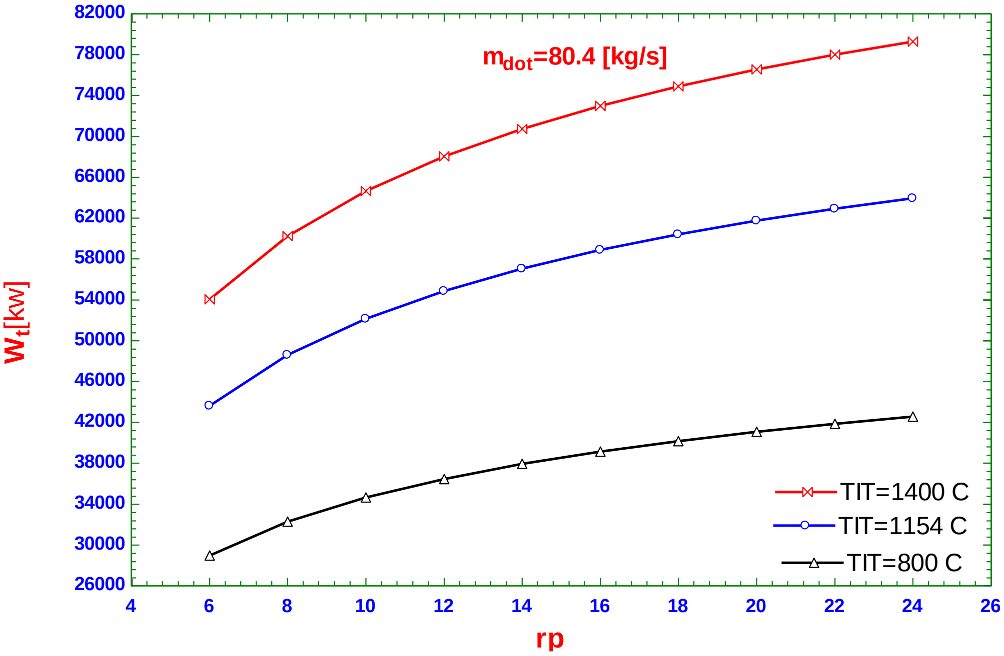

Figure 3: Turbine Work Changes with Compressor Pressure Ratio in Constant Flow Rate.

Figure 3 shows the relationship between turbine operation and compressor pressure ratio at different temperatures of combustion chamber exhaust gases. By increasing the compressor pressure ratio the amount of work produced by the turbine increases at a fairly constant rate.

Besides, increasing the temperature of the exhaust gases from the combustion chamber increases the work produced by the turbine.

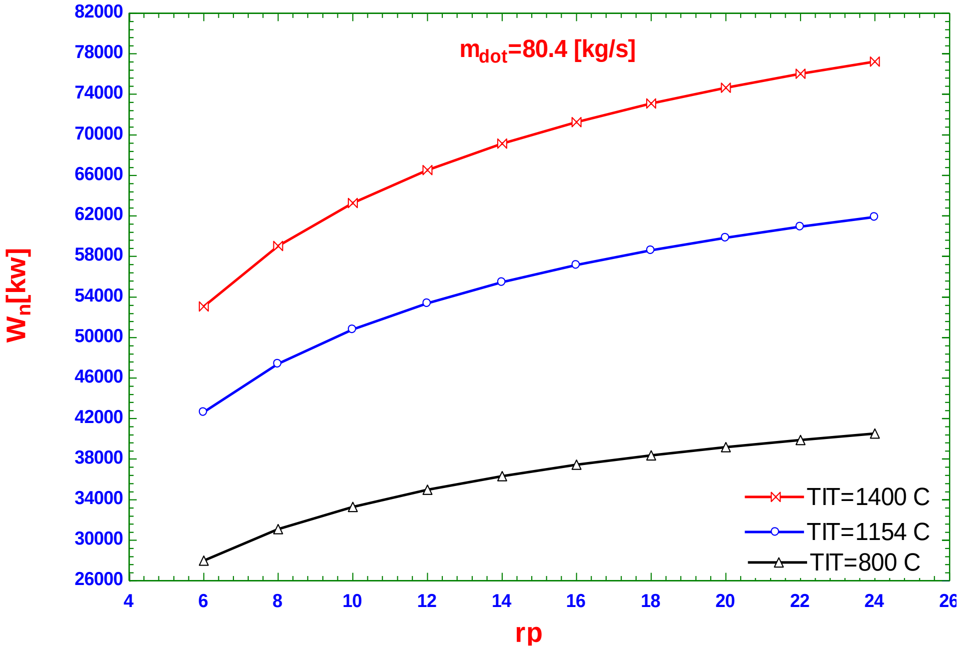

Figure 4: Cycle Net Work Changes with Compressor Pressure Ratio in Constant Flow Rate.

Figure 4 shows the relationship of cycle network with compressor pressure ratio at different temperatures of combustion chamber exhaust gases. As can be seen, by increasing the compressor pressure ratio, the amount of cycle net work increases at a fairly constant rate. Also, increasing the temperature of the exhaust gases from the combustion chamber increases the cycle network.

The Effects of Mass Flow Change

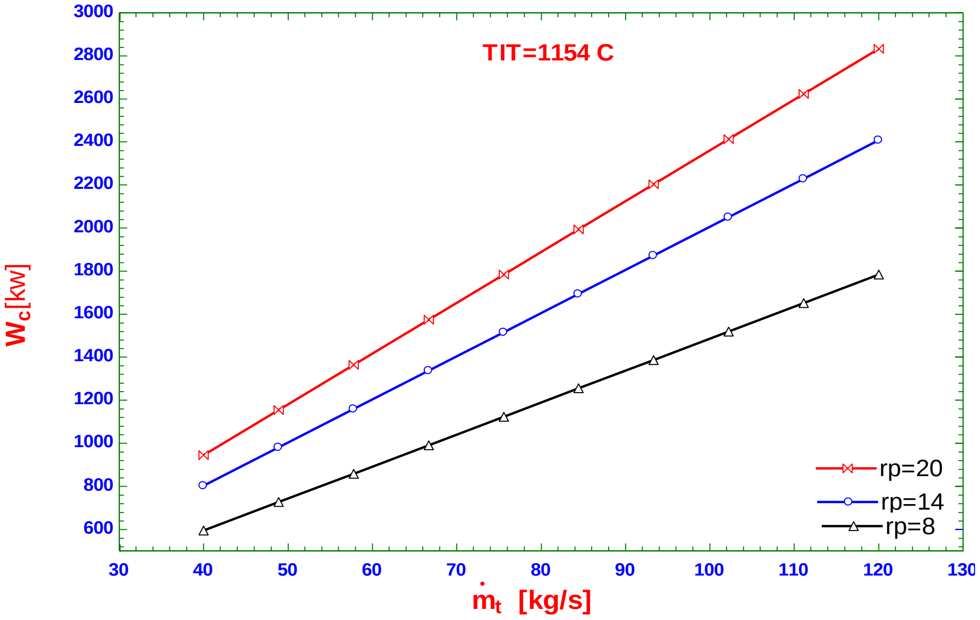

Figure 5: Compressor Work Changes with Flow Rate Changes in Output Temperature of the Combustion Chamber Constant Temperature.

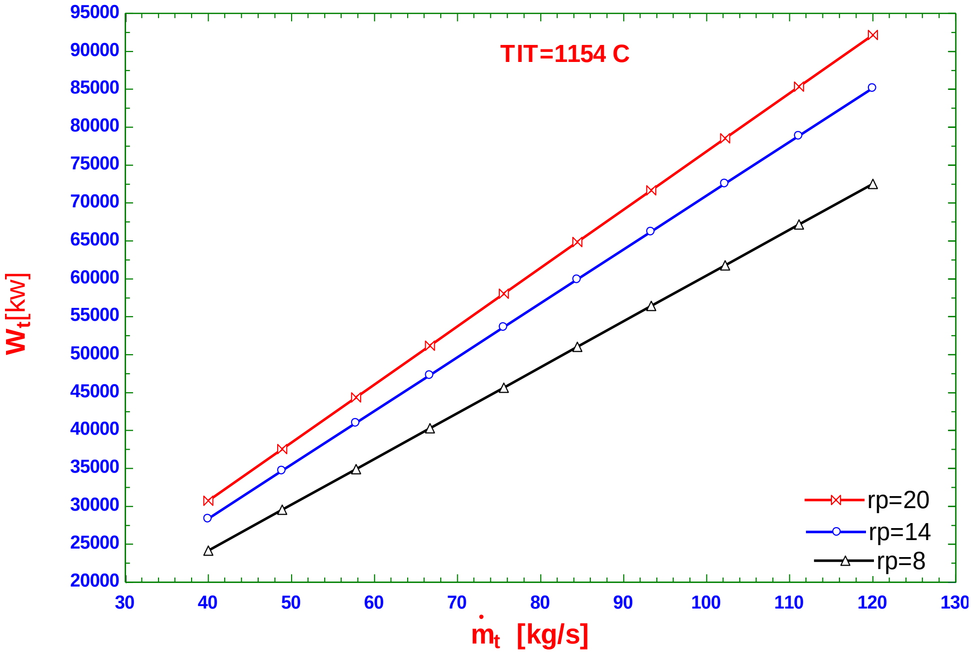

Figure 6: Turbine Work Changes with Flow Rate Changes in Output Temperature of the Combustion Chamber Constant Temperature.

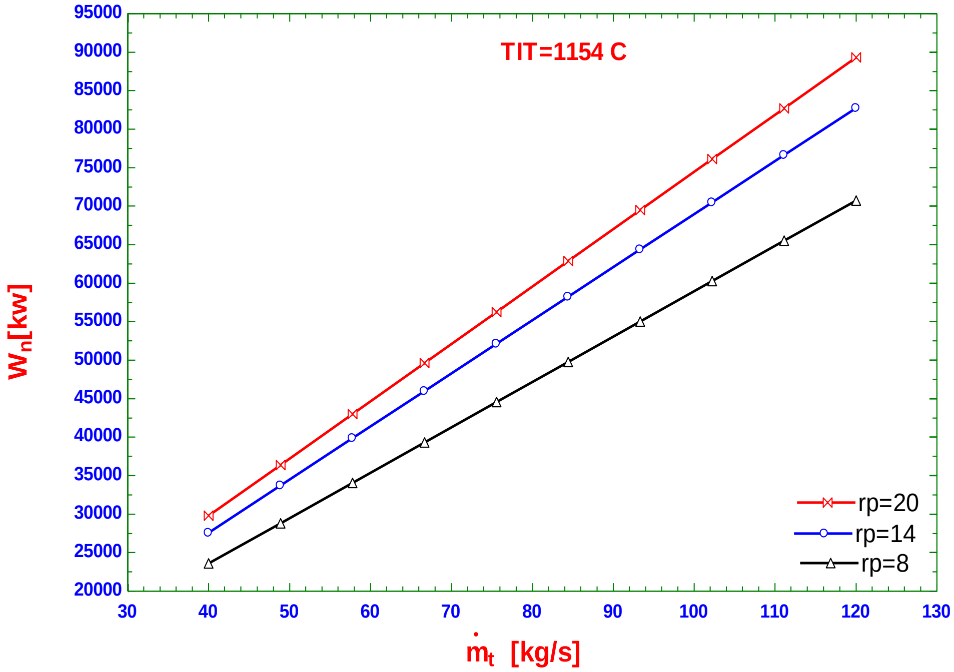

Figure 7: Cycle Network Changes with Flow Rate Changes in Output Temperature of the Combustion Chamber Constant Temperature.

As can be seen in Figs. 5–7 at a constant temperature of the exhaust gases from the combustion chamber, with increasing mass flow rate and compressor pressure ratio, the amount of compressor and turbine work and network increase with a constant slope.

DISCUSSIONS

As shown in the diagrams, at constant flow rates by increasing the compressor pressure ratio, the work consumed by the compressor and the work produced by the turbine increases. By increasing the outlet temperature from the combustion chamber, work produced by turbines increases which is due to the constant use of the compressor, therefore, the network of the cycle will be accompanied by an increase. With increasing flow rates the turbine and compressor work both increases given the fact that the work is produced by a more intense turbine therefore, the network cycle also increases. This information helps designers find the optimal operating conditions for a gas turbine.

CONCLUSIONS

In this paper, the gas turbine cycle with regenerator was modeled and the effect of parameters such as flow rate, compressor pressure ratio, and temperature of the exhaust gas from the combustion chamber on the cycle performance was investigated. The results indicate that each of the parameters has a great impact on the cycle performance including at constant flow rates by increasing the compressor pressure ratio, the work consumed by the compressor, and the work produced by the turbine increases. By increasing the outlet temperature from the combustion chamber, work produced by turbines a increase which is due to the constant use of the compressor therefore, the network of the cycle will be accompanied by an increase. With increasing flow rates the turbine and compressor work both increases given the fact that the work is produced by a more intense turbine therefore, the network cycle also increases. by comparing their effects, optimum cycle conditions can be achieved.

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