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Effects of Compressor Pressure Ratio and Combustion Chamber Exhaust Gases Temperatures on Gas Turbine Cycle Performance

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ABSTRACT

Today, we are seeing an increasing share of gas power plants in the production and supply of electricity therefore, it is essential to know the impact of different factors on the performance of these plants.The main purpose of this study is to investigate the effect of different parameters such as compressor pressure ratio and temperature of the combustion chamber on the performance of gas turbines.First, the thermodynamic relationships governing the gas turbines are studied and then the effect of changing parameters is investigated by coding. In general, the results showed that increasing the compressor pressure ratio increases the compressor and turbine work and the cycle network and efficiency.At the same time, increasing the outlet temperature of the combustion chamber will also increase the turbine operation and cycle network and cycle efficiency.Investigating the results can lead to optimal conditions So that it achieves maximum network and efficiency but the work consumed by the compressor is decent.

Keywords: *Gas Turbine, Compressor Pressure ratio, Combustion Chamber, Cycle net Work, Efficiency*

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INTRODUCTION

A gas turbine is a rotating machine that operates on the energy of combustion gases.each gas turbine comprises a compressor for compressing air, a combustion chamber for mixing air with fuel, and a turbine for converting hot and compressed gas energy into mechanical energy.part of the mechanical energy generated in the turbine is spent rotating the compressor itself, and the rest of the energy may rotate an electric generator (turbogenator), depending on the use of the gas turbine or accelerate to the air (turbojet and turbofan)Either directly (or after gearbox rotation) or as such (turboshaft, turboprop). Given the importance of gas turbines, this issue has always been of interest to researchers, and researchers have tried to increase its efficiency in various ways [1–2].

Simulation and modeling of gas turbine engines are considered as one of the most complex dynamical systems available, always as an attractive issues in order to improvement the performance and control techniques, has been considered [3–5]. In order to analyze the performance of turbine engines in the design phase based on the aero thermodynamic behavior of engine and its components, the engine mathematical model is provided and using it, the engine performance is simulated and evaluated [6]. Zarepour et al. Studied the specific fuel and fuel consumption of a turbofan engine.In another study, Doustdar et al**.** studied the effect of compressor pressure ratio and combustion chamber temperature on the turbojet engine performance [7–8]. In 2008, Mr. Bethel has presented a simple design for fuel consumption performance and two-shaft turbofan engine thrust [9]. In 2008, Yonosof et al. offered a design to control aircraft engine thrust by using of flight information aircraft engines of diagnostic devices [10]. Francisco et al. had provided a turboshaft engine of 1000 kW for non-linear dynamic modeling and utilized this model to control the turboshaft engine system [11]. They also developed this engine in start condition, cruise control until snuff state. In Iran, the valuable papers in the field of turbojet engines have been offered. Homaei far and his colleagues have presented a method for improving the turbofan engines performance using a general algorithm method [12]. In 2008, Montazerin et al. proposed a method for improving the jet engines fuel system [13]. The main purpose of this study is to investigate the effect of various parameters such as compressor pressure ratio and temperature of combustion chamber gas on the performance of gas turbines.

METHODOLOGY

In this study, coding was used to investigate the effect of parameters, therefore, it is 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.

The cycle function is as follows:

1Isentropic Densities (Inside Compressor)

$$q_c - w_c = h_2 - h_1$$

$$w_c = h_2 - h_1,$$

$$W_c = \dot{m}_c (h_2 - h_1),$$

$$h_2 - h_1 = Cp(T_2 - T_1)$$

3–2constant pressure increase heat (inside combustion chamber)

$$q_H - w_{2-3} = h_3 - h_2$$

$$, Q_H = \dot{m}_f \times LHV = \dot{m} \times (h_3 - h_2)$$

$$q_H = h_3 - h_2,$$

$$h_3 - h_2 = Cp(T_3 - T_4)$$

4–3 Isentropic Expansion (inside turbine)

$$q_{3-4} - w_t = h_4 - h_3$$

kj/kg$w_t = h_3 - h_4$ [],

$$W_t = \dot{m}_t (h_3 - h_4),$$

$$h_3 - h_4 = Cp(T_3 - T_4)$$

$$q_L = (h_4 - h_1),$$

$$Q_L = \dot{m} \times (h_4 - h_1)$$

$$h_4 - h_1 = Cp(T_4 - T_1)$$

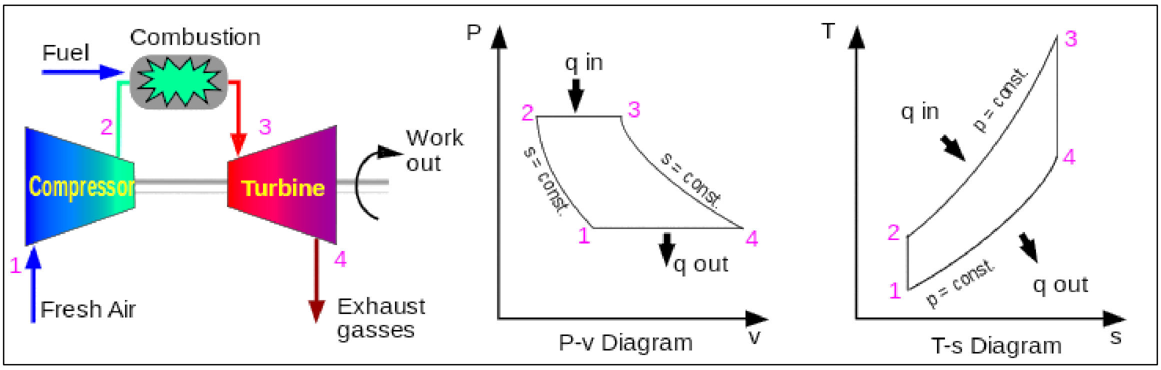

Fig. 1. *Schematic of a gas turbine engine [14].*

4–1 Constant Heat Reduction (Ambient)

$$P_1=P_4$$

The thermal efficiency of the cycle is ideally defined as the compressor pressure ratio:

$$\eta_{th}=W_{net}/Q_h=1-T_1/T_2=1-1/(rp)^{(k-1)/K}$$

Also network can be obtained from the following relation:

$$w_{net}=w_t-w_c,$$
$$W_{net}=W_t-W_c$$

RESULTS

The SGT-600 Industrial Gas Turbine-25 MW gas turbine data was used for the analysis (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

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

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

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 network increases at a fairly constant rate.

In addition, increasing the temperature of the exhaust gases from the combustion chamber increases the cycle network.

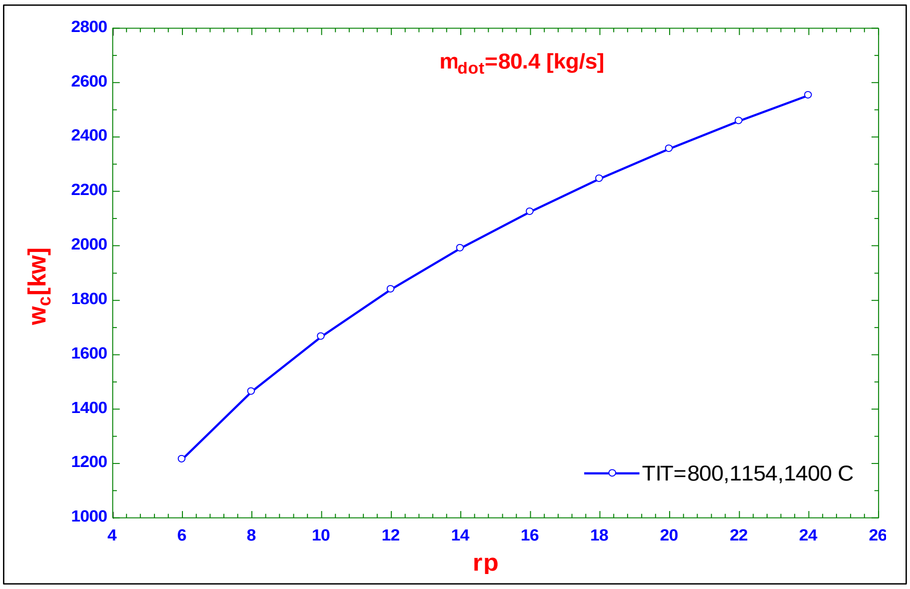

Fig. 2. *Relationship between compressor performance and compressor pressure ratio.*

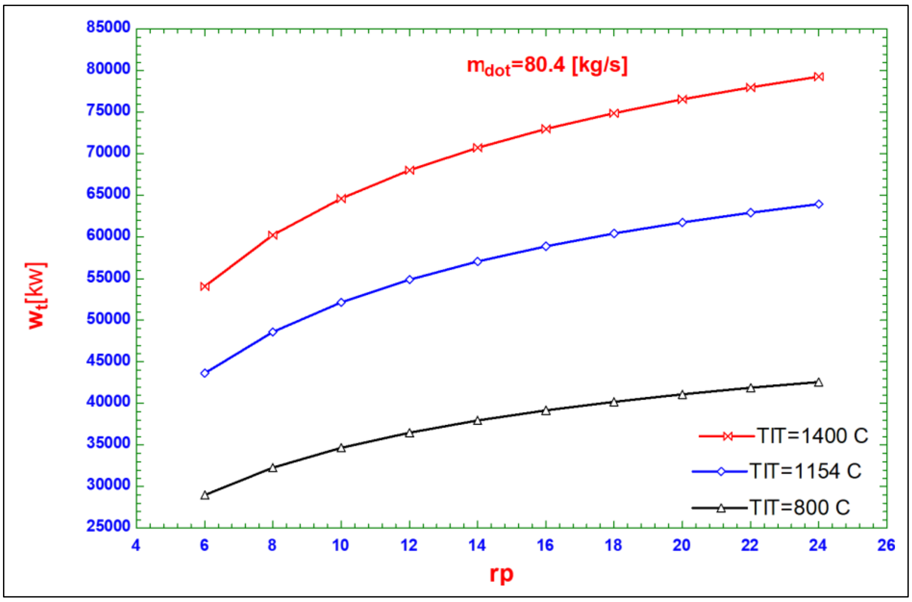

Fig. 3. *Relationship between turbine operation and compressor pressure ratio at different temperatures of combustion chamber exhaust gases.*

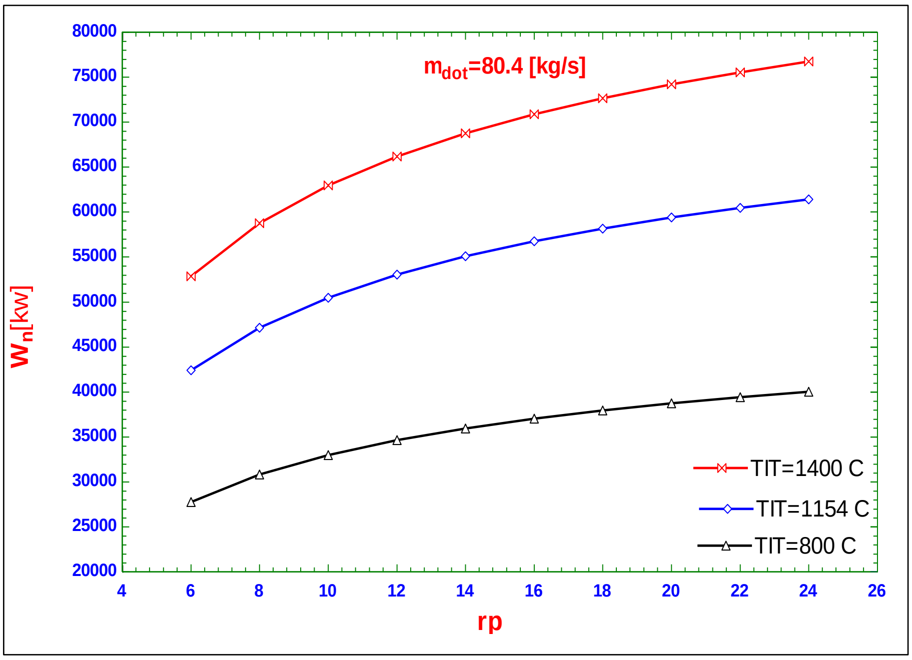

Fig. 4. *Relationship of cycle network with compressor pressure ratio at different temperatures of combustion chamber exhaust gases.*

Figure 5 shows the relationship between cycle efficiency and 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 efficiency increases. In addition, increasing the temperature of the exhaust gases from the combustion chamber increases the cycle efficiency.

DISCUSSION

In general it can be seen from the diagrams in Figures 2–5 that increasing the compressor pressure ratio increases the compressor and turbine work and the net

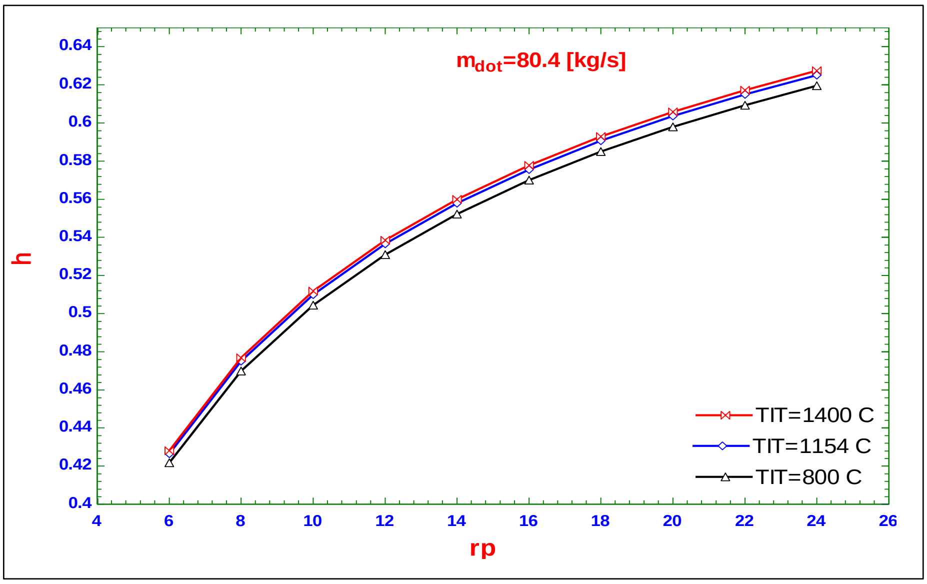

Fig. 5. *Relationship between cycle efficiency and compressor pressure ratio at different temperatures of combustion chamber exhaust gases.*

work and cycle efficiency. Increasing the outlet temperature of the combustion chamber also increases the turbine work and network cycle efficiency. This information helps designers find the optimal operating conditions for a gas turbine.

CONCLUSION

In this study, the gas turbine cycle was studied and the effect of different parameters was investigated. Thermodynamic analysis and coding were used for analysis. The results showed that:

1. Increasing the compressor pressure ratio increases the compressor and turbine work, network and cycle efficiency.
2. Increasing the outlet temperature of the combustion chamber also increases the turbine work and network cycle efficiency.

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