METHODS OF INCREASING THE EFFICIENCY OF GAS TURBINES

***Mihaela Claudia Carstea*, Liceul Tehnologic Turburea, Gorj**

Abstract: *The paper present methods of increasing the efficiency of gas turbines. The gas turbines are machines that work directly with ambient air, then anything that causes a change in the inlet air condition, effect on turbine efficiency. Gas turbine has low efficiency compared to steam power plants, Gas turbine has so many advantages, and it is important to look for some methods to raise its performance.*

Key words: methods, efficiency, gas turbines, mechanical work, energy.

INTRODUCTION

The gas turbine is a thermal motor machine (which converts thermal energy into mechanical work) that uses the enthalpy fall of a gas or gas mixture to produce through a system of nozzles and blades that rotate around a shaft an amount of mechanical energy available on the turbine shaft. The gas turbine requires a number of auxiliary installations to operate (compressor, combustion chamber, etc.). For this reason it is also known as the gas turbine installation (ITG).

The operating principle of the plant at the simplest gas turbine is comprised of a compressor that is mounted on the same shaft with a turbine. The compressor absorbs air from the atmosphere and compresses it to the pressure of a few bars. The compressed air enters a combustion chamber where a fuel is also introduced. This is where burning takes place at constant pressure, with the increase in temperature and volume of the gases produced by combustion. Burning gases decompose in the turbine, producing mechanical work, and then evacuated into the atmosphere. The thermodynamic cycle of such a gas turbine is the Brayton cycle.

At installations in power plants shown schematically in Figure 1, the turbine also drives the compressor and the electric generator. The air is sucked through the filter 5 and the exhaust gases are exhausted through the silencer 6.

To start, the turbine and compressor spindle must be rotated using the external torque given by the launch engine 4.

Since the gases constitute the working environment in the turbine, they should not contain solid particles that could have an erosive effect on the blades. For this purpose the suction air filter is used and the fuel must be of superior quality, with the same purity as for diesel engines. The gas turbine can only use natural gas, diesel and fuel oil, all well filtered. Attempts to burn coal dust made so far have not yielded positive results.

The temperature in the burner is below the theoretical combustion temperature. In order to get to this situation, a large excess of air is needed. For gas turbines the value of this excess is 4-5.

Due to the excess of air, the exergetic burning efficiency is low. The exhaust gas temperature is 420-460 ° C. For these reasons, the efficiency of the gas turbines is low and has lower values than steam cycle efficiency.

The gas turbine in Figure 1 needs cooling only to maintain the temperature of the lubricating oil. The low water consumption of this plant is one of its essential technical advantages that makes it easier to apply it to water-free places.

Unlike the steam cycles, the fall of the heat used in the gas turbine is reduced to about 340 kJ / kg and therefore the specific power developed is contained in the single gas turbine. The gas flow has a particularly high volume and for the simple installation the blade length is reached at powers not exceeding. Starting the open-gas turbine is done within 3-5 minutes.

The volume of the plant is low and the investment cost lower than that of the steam turbines by about 20%.

These technical features place the gas turbine in the open circuit as a solution for equipping power or backup power plants and for its use for special purposes, in water-less places or for transportable energy units.

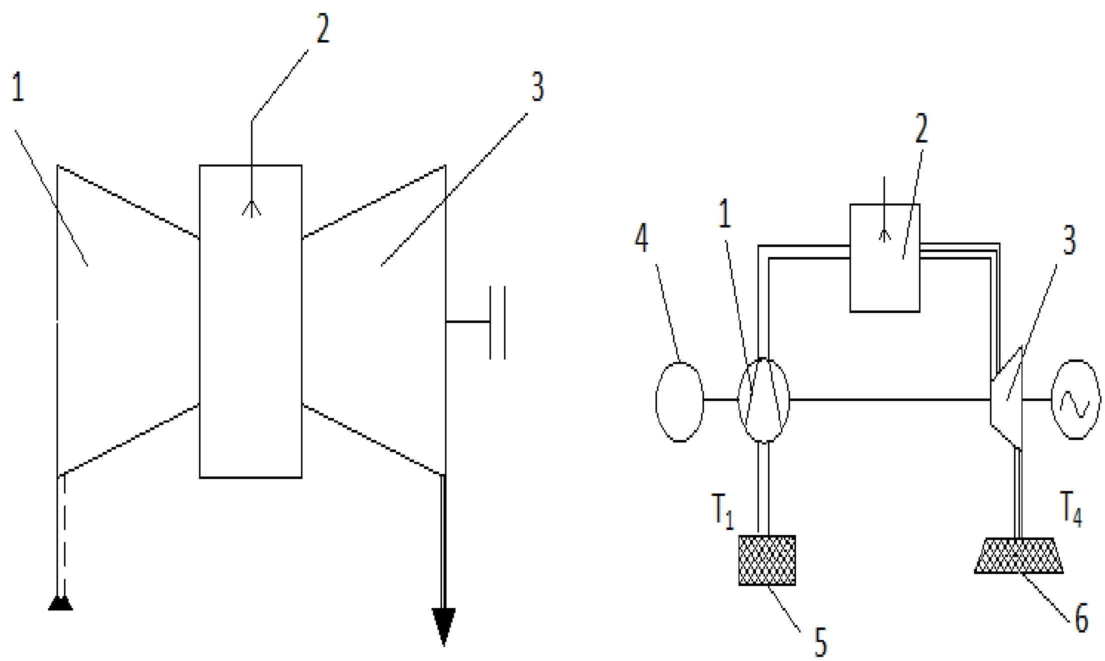

Figure 1. Gas turbine installation: a) single cylinder turbine; b) stationary turbine installation for driving an electric generator; 1- compressor; 2- the burner; 3-turbine; 4-stroke engine; 5- air filter; 6- silencer

The theoretical cycle of the open-gas gas turbine consists of an adiabatic compression of 1-2, an isobortional pressure of 2-3, and an adiabatic expansion in turbine 3-4. Ideally, the gases leaving the turbine cool down into the atmosphere and close the cycle through isobar 4-1 (Figure 2).

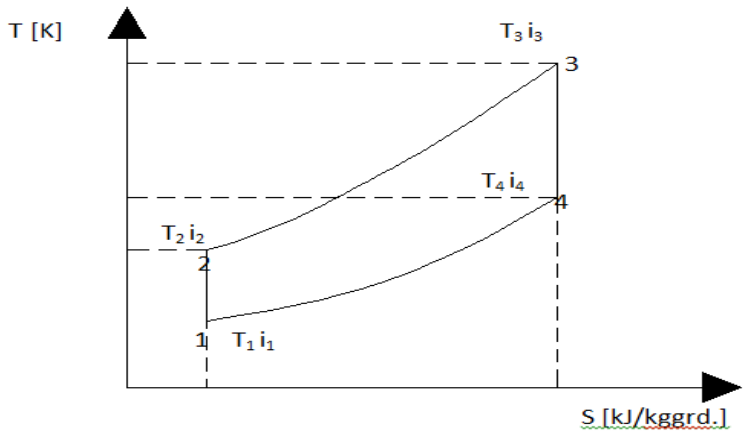

Figure 2. The theoretical diagram of the open-circuit gas turbine

In the real cycle, compression and relaxation are irreversible politropos processes with entropy growth. Aspiration in the compressor, the pressure is less than the theoretical because of the aerodynamic resistance of the air filter, and at the turbine outlet the pressure is higher than the atmospheric pressure because of the exhaust muffler resistance. Pressure drops also occur between the compressor and the turbine entry due to friction in the gas flow. The actual gas turbine cycle is shown in figure 2, where it can be written:

$$Q_1 = i_3 - i_2 = c_p (T_3 - T_2)\ [kJ/kg]$$
$$Q_2 = i_4 - i_1 = c_p (T_4 - T_1)\ [kJ/kg] \quad (1.1)$$

$$\eta_{teor} = \frac{L}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = \frac{c_p (T_3 - T_2) - c_p (T_4 - T_1)}{c_p (T_3 - T_2)} = 1 - \frac{T_4 - T_1}{T_3 - T_2} \quad (1.2)$$

In the hypothesis of adiabatic decomposition and compression it can be written:

$$\frac{T_2}{T_1} = \frac{T_3}{T_4} = \left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}} \quad (1.3)$$

By comparing the compression ratio

$$\frac{p_2}{p_1} = \varepsilon \quad (1.4)$$

şi

$$\frac{k-1}{k} = m \quad (1.5)$$

result that:

$$\eta_{teor} = 1 - \frac{T_1}{T_2} = 1 - \frac{1}{\varepsilon^{\frac{k-1}{k}}} = 1 - \frac{1}{\varepsilon^m} \qquad (1.6)$$

In the theoretical cycle, the yield is therefore dependent on the compression ratio.

ITG YIELD - GROWTH METHODS

As the ITG yield is reduced compared to steam turbines - mainly due to the lower enthalpy of the combustion gases, and on the other hand the fuel used by ITG is only superior fuel (with high cost), there is the question of increasing the ITG yield .

Preheating the air. The high temperature of the exhaust gases allows to preheat the compressed air at the burner inlet by means of a heat recovery device R (Figure 3).

In order for the heat exchange to take place, the following conditions must be met:

$$T_5 > T_2^{'} \text{ şi } T_4^{'} > T_6 \qquad (1.7)$$

The subunit ratio is defined τ as the recovery rate

$$\tau = \frac{T_6 - T_2^{'}}{T_4^{'} - T_2^{'}} \qquad (1.8)$$

This ratio is an indicator of the amount of heat recovered Q_{REC} (the area hatched on the diagram in Figure 3).

The yield of the recovery cycle is as follows:

$$\eta_{inst} = \frac{(i_3 - i_4)\eta_t - (i_2 - i_1)\frac{1}{\eta_c}}{Q_1 - Q_{REC}} = \frac{(i_3 - i_4)\eta_t - (i_2 - i_1)\frac{1}{\eta_c}}{i_3 - i_6} \qquad (1.9)$$

Cycle yield is higher by reducing the fraction denominator, but additional pressure losses occur in the recuperator, which limits the beneficial effect of recovery.

Finally, then $\eta_{inst} = f(\varepsilon, \tau, \sigma)$ (1.10)

The additional investment that is made with the recovery plant is to be recovered through the fuel savings achieved.

Investments in gas turbines designed to cover the peak are not provided with heat recovery systems, these being installed only if the number of hours of use of installed power exceeds 2000-2500 h / year.

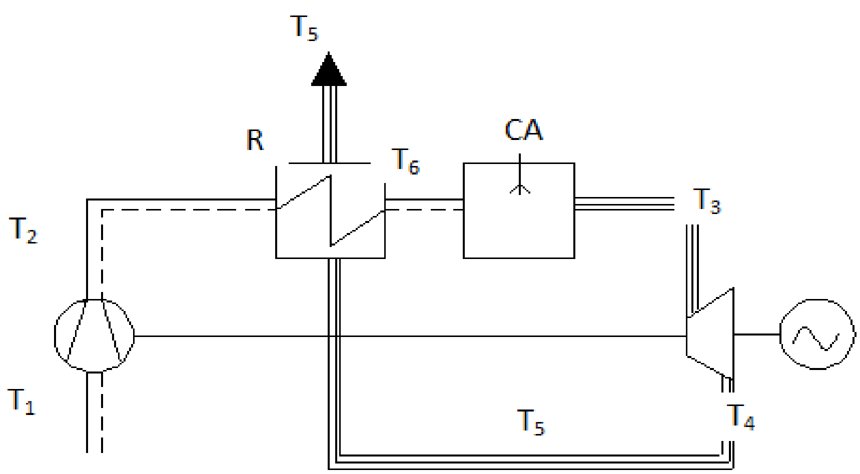

Figure 3. Preheating of the air by heat recovery: R - recuperator preheater; CA-combustion chamber

Raising the combustion temperature and lowering the suction temperature. Both temperature T_1 and T_3 variations influence the cycle yield and useful mechanical work as shown in Figure 4.

When the combustion temperature increases, the excess air decreases, the optimal compression ratio is higher and the efficiency increases.

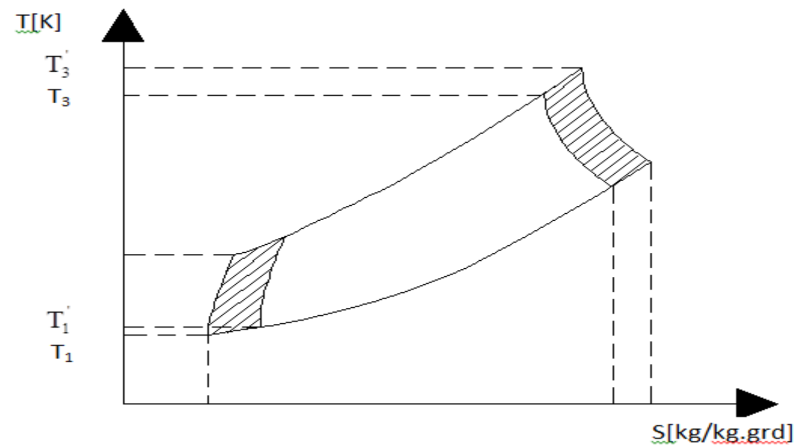

Figure 4. The effect of lowering the suction and lifting temperature of the final temperature

The influence of hot-water temperature on efficiency is stronger in gas turbine cycles than in steam turbines, so at superheated temperatures, the efficiency of the gas turbines equals that of steam cycles (1100 ° C), and then exceeds it.

Due to the efficiency of raising the temperature and the reduced amount of steel in the hot zone, gas turbines, unlike steam ones, are built using austenitic steels. The temperatures currently used are as follows:

- for gaseous fuel $750-850°C$ ($870°C$ to a US unit by General Electric);
- for liquid fuel with high vanadium and sulfur content $700-750°C$.

Tests with a service life of more than one year for a turbine operating temperature have been made $1000-1050°C$. The raising of the temperature still appears technically possible.

In such turbines, the blades are cooled with water or air and are covered on the surface with refractory ceramic materials.

If the aspirated air temperature decreases, the specific weight increases and the maximum flow rate of the working fluid increases, which allows an additional amount of fuel to be burned in the combustion chamber to obtain a power boost. In the T-S diagram of FIG. 4 this corresponds to the increase of the useful surface of the cycle with the hinged portion inclined to the right.

CONCLUSIONS

ITG are power generation solutions with certain investment advantages, the possibility of rapid load variation and the fact that they are not dependent on a cooling water source. The main disadvantage is the high cost of fuel and the reduced Brayton cycle yield. As a consequence, the cost of electricity produced in this type of installation is quite high, in most cases ITG being used only when the specific conditions of the consumer do not allow connection to the grid or when the use of a particular fuel (liquid or gaseous) economic advantages (such as the Brazi OMB Petrom thermal power station). Consequently, there is a question of increasing ITG efficiency to reduce the cost of electricity produced. The paper describes thermodynamically the most used methods for increasing ITG efficiency, namely the regenerative preheating of the combustion air and the reduction and respectively the increase of the combustion temperature. These methods can lead to a significant increase in ITG yield, making them competitive power generation facilities at costs comparable to those of coal-fired power.

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