EXPERIMENTAL ANALYSIS OF THE GAS TURBINE PLANT WITH EXTERNAL HEAT RECOVERY

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Abstract: The paper analyzes from experimental point of view the energetic and exergetic characteristics of a gas turbine plant (GTP) with heat recovery boiler (RB). For the experimental study of the cogeneration plant are represented the dependences of the thermodynamic parameters and the exergetic flows of the working fluids in the characteristic operating regimes. Unlike the experimental results obtained for the thermal power of RB, those who regard the second principle of thermodynamics conclude the scientific importance of the exergetic analysis.

Keywords: cogeneration, gas turbine, recovery boiler

1. INTRODUCTION

Many gas turbine applications today require the gas turbine to run nearly continuously. As operating cost has become more important, technology development has been focused on improving efficiency, primarily through increasing firing temperature.

The literature indicates significant work in the domain of cogeneration plants by C.D. Moné, D.S. Chau, P.E. Phelan [1], A. Martens [2], A. Valero et al. [3], V. Verda and R. Borchiellini [4], A. Bejan, G. Tsatsaronis, M. Moran [5].

In this paper we make an experimental study of the energetic and exergetic characteristics of the gas turbine plant with external heat recovery (GTPEHR). Experimental research was performed on 130 GTP Titan group of 14.3 MW and on heat recovery boiler of 22 MW.

2. PRESENTATION OF THE EXPERIMENTAL PLANT

The state parameters from the characteristic points of the GTPEHR cycle were measured and will be used for the analysis of the operating regimes of the cogeneration plant. They are determined using the measuring devices, which are framed according to the scheme in Fig. 1.

Were measured the following points of the thermodynamic cycle: the air pressure at the air filter (AF) inlet, p_0, [bar]; the air temperature at the AF inlet, t_0, [ºC]; the air pressure at the air compressor (AK) inlet, p_1, [bar]; the air temperature at the AK inlet, t_1, [ºC]; the air pressure at the AK outlet , p_2, [bar]; the combustion gas temperature at the gas turbine (GT) inlet, t_3, [ºC]; the combustion gas pressure at the GT outlet, p_4, [bar]; the combustion gas temperature at the GT outlet, t_4, [ºC].

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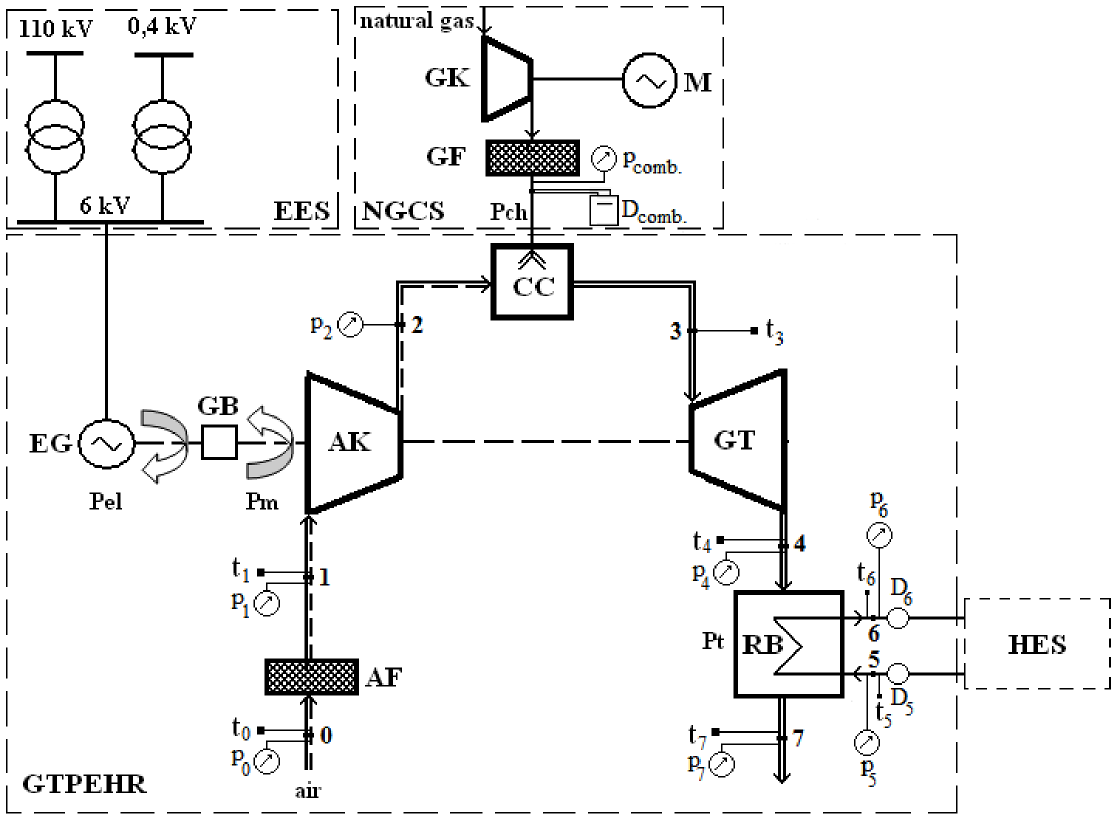

Fig.1. Scheme for framing the measuring devices of the GTP: NGCS - natural gas compression subsystem, HES - heat exhaust subsystem and EES - electricity exhaust subsystem.

The combustion gas temperature (t_7, [°C]) and pressure (p_7, [bar]) at the recovery boiler (RB) outlet are measured through a thermo-resistances type Pt100 RTD, respectively a differential pressure transmitter.

The operating parameters of the RB are measured with the help of t_5, [°C], and t_6, [°C], thermometers, p_5, [bar], and p_6, [bar], manometers, and through D_5, [kg/s], and D_6, [kg/s], water meters.

3. PROCESSING PROCEDURE OF THE EXPERIMENTAL DATA

The experimental parameters are recorded every 1 hour for the following equipments and circuits of the cogeneration plant:

- AK, combustion chamber (CC), GT and electric generator (EG) group;
- hot water RB assembly;
- gas compressor (GK).

The heat flow taken by the water in the RB is determined with the relation:

$$\dot{Q}_a = D_5 \cdot c_{pa} \cdot (t_6 - t_5) \cdot \eta_{TC} \, [kW] \tag{1}$$

in which D_5 is the water mass flow rate at the RB inlet, [kg/s]; c_{pa} - specific heat of water at constant pressure, [kJ/(kg · °C)]; η_{TC} - RB heat transfer efficiency ($\eta_{TC} = 0.95$).

The exergy of heat supplied in the district heating is defined with the following relation:

$$\dot{E}x_{P,CR} = D_5 \cdot [(i_6 - i_5) - T_R \cdot (s_6 - s_5)] [kW] \quad (2)$$

in which i_5, [kJ/kg], s_5, [kJ/(kg·°K)], are the water enthalpy, respectively entropy at the RB inlet; i_6, [kJ/kg], s_6, [kJ/(kg·°K)], - water enthalpy, respectively entropy at the RB outlet; $T_R = 288{,}15$, [°K], - reference temperature.

4. RESULTS AND DISCUSSION

The graphics $\dot{Q}_a = f(t_0)$ at different electric power values (P_{ITG}, [kW]) and flow rates of primary thermal agent circulated through the RB (D_5), are presented in Fig. 2 and 3. In these figures, the points represent the experimental data and the lines represent the linear regression of these data.

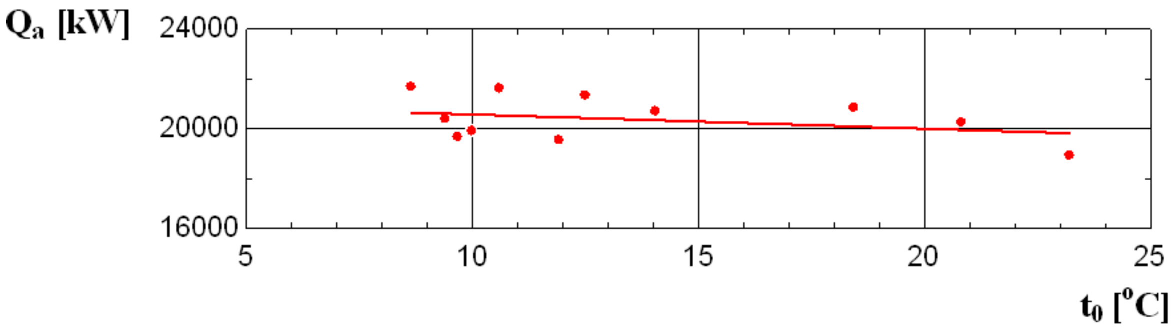

Fig. 2. Variation of the heat flow with atmospheric temperature for I regime

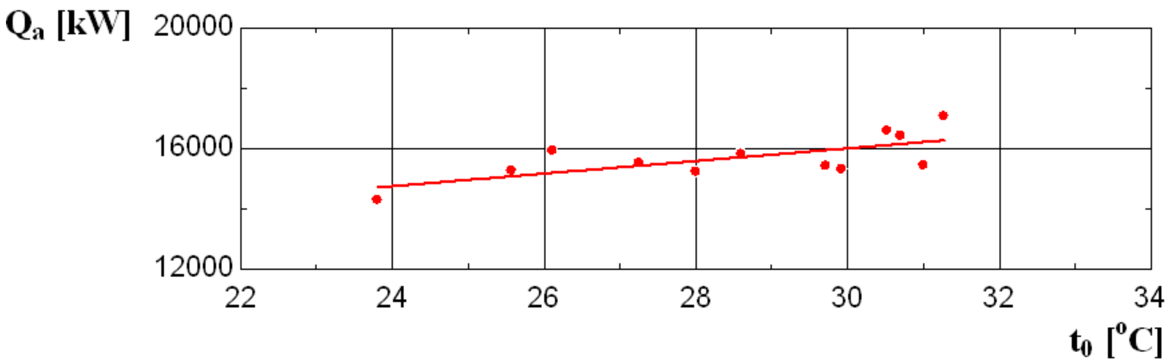

Fig. 3. Variation of the heat flow with atmospheric temperature for II regime

For the first operating regime of the cogeneration plant, at values of the electric power between 12802 ÷ 14040 [kW] and constant water flow ($0.72 \cdot D_n$ [kg/s]), is highlighted an increase trend of the heat ($\dot{Q}_a$) with the decrease of the atmospheric temperature (t_0), (Fig. 2).

For electric powers between 7421 ÷ 8315 [kW] (second regime) and constant water flow ($0.84 \cdot D_n$ [kg/s]), is highlighted an increase trend of the heat ($\dot{Q}_a$) with the increase of the atmospheric temperature (t_0), (Fig. 3).

The graphics $\dot{E}x_{P,CR} = f(t_0)$ at different values of the exergy corresponding to the electric power ($\dot{E}x_{P_{ITG}}$, [kW]) and flow rates of primary thermal agent circulated through the RB (D_5), are presented in Fig. 4 and 5.

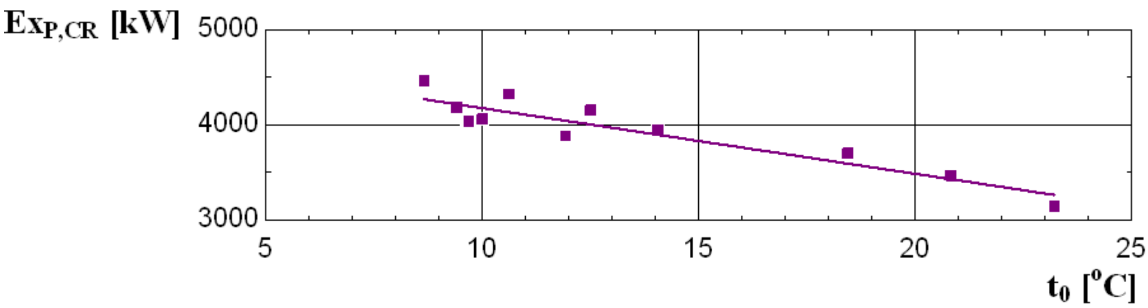

Fig. 4. Variation of the exergy of heat with atmospheric temperature for I regime

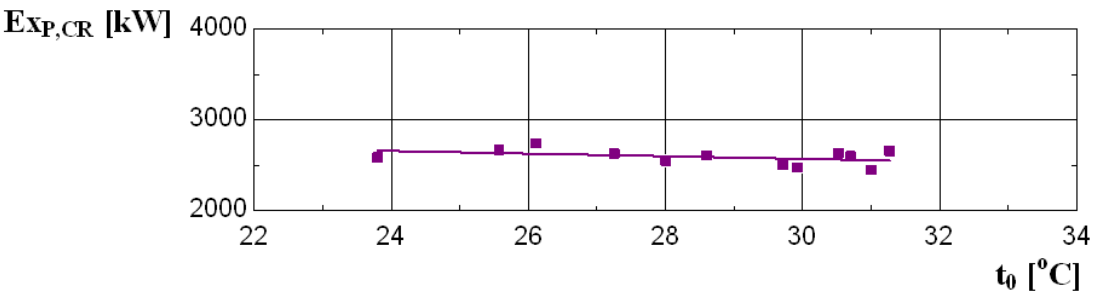

Fig. 5. Variation of the exergy of heat with atmospheric temperature for II regime

For all the values in the intervals of the exergy corresponding to the electric power in which operates the GTPEHR, at constant water flow, it shows an increase of the exergy of heat supplied in the district heating ($\dot{E}x_{P,CR}$) with the decrease of the air temperature at the AF inlet (t_0).

5. CONCLUSIONS

We establish the thermal scheme of framing the measurement devices.

Energetic data shows the heat flow quasi-independence of the atmospheric air temperature variation.

Unlike the experimental results obtained from the energetic data, those who regard the second principle of thermodynamics (exergetic data), shows an increase of the exergy of heat supplied in the district heating with the decrease of the atmospheric air temperature.

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