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The method of calculating the relative correction for calculating the power of the gas turbine engine (GTE-10V) when tested at the plant's stand

For the correct determination of GTE-10V power at a compressor station (CS), an analysis of the GTE 10V power value obtained from measured GTE parameters and a supercharger 235-21-01 at Reshetilovskaya CS was made.
The obtained parameters were compared with the passport data of the specified supercharger.

1. The purpose of the work and methods of analysis of existing data.

The difficulty of determining the power of the supercharger is due to the fact that the supercharger in the gas pumping station (FMS) often works in the area of characteristics that is far from optimal. This does not allow the use of classical approaches (for example, the cubic dependence of the power on the rotational speed of the supercharger turbine), but requires the introduction to the method of determining the power of the turbine supercharger (TS) of the full supercharger characteristics, which allows determining the power in the area of non-calculated angles of attack on the blade crowns of the supercharger.

From Figure 1 follows that at Reshetilovskaya CS we are dealing with such a case.

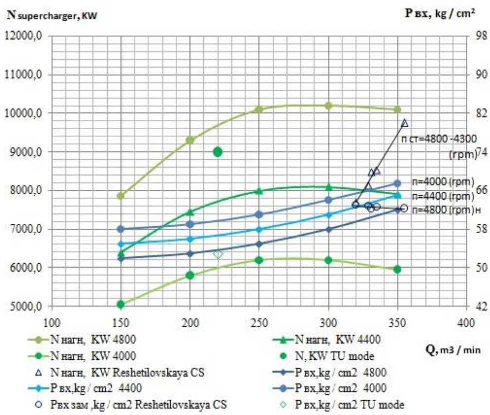

Fig.1. Operating points on the general characteristics of the supercharger when GTE-10V is operated at Reshetilovskaya CS (TU mode should be understood as nominal)

From Fig. 1 it also follows that in order to correctly calculate the power of the supercharger, it is necessary to take into account not only the flow rate of the gas being pumped, but also the degree of pressure increase in the supercharger. This is because the position of the operating points on the field of the supercharger characteristics significantly affects the power (efficiency) of the supercharger.

In order to determine the power of the GTE-10V at the compressor station, was developed a method for calculating the power of the TS GTE using the measured parameters of a gas turbine engine, the measured gas parameters in the supercharger 235-21-01, and the general gas-dynamic characteristics of the supercharger, which are given in the supercharger TU.

Supercharger power can be represented as follows:

$$N_{spr} = G_g \times \Delta i_{\text{istr}} / \eta_{spr}, \tag{1}$$

where G_g- consumption of the pumped gas through the supercharger;

The isentropic specific work of compression is determined by the dependency:

$$\Delta i_{\text{istr}} = (t_{g\ in} + 273) \times C_p \times (\pi_k^{\frac{R}{C_p}} - 1), \tag{2}$$

where η_{spr}- supercharger isentropic efficiency.

The consumption of the pumped gas by the supercharger in one case was determined by the measured volumetric flow through the supercharger.

$$G_g = Q_{meas\ nc} \times \rho_{nc}\ , \tag{3}$$

and in another - on the characteristics of the supercharger 235-21-01, given in the TU.

When determining the gas flow consumption rate according to the gas-dynamic characteristics schedule:

$$G_g = P_{meas}/P_{gr} \times Q_{gr} \times \rho_{nc} \times \sqrt{273/293}, \tag{4}$$

where Q_{gr} is determined by the values η_{gr} , π_k:

$$\eta_{gr} = \eta_{spr} \times \sqrt{288 \times R \times Z_{red}/((t_{g\ in} + 273) \times R \times Z_{meas}})\text{=const}, \tag{5}$$

$$\pi_k = P_{g\ ex}/P_{g\ in} \tag{6}$$

graph-analytical method, using the generalized gas-dynamic characteristics of the supercharger.

The efficiency of the supercharger for both cases was determined by the magnitude of the power given on the gas-dynamic characteristics of the supercharger.

$$\eta_{spr} = f \times (n_{spr\ meas}, \pi_{k\ spr}) = (G_g \times \Delta i_{\text{istr}})/\ N_{spr} \tag{7}$$

for given

$$n_{spr\ meas} = n_{spr} \times \sqrt{288 \times R \times Z_{red}/((t_{g\ in} + 273) \times R \times Z_{meas}})=$$

const, for the characteristics of supercharger.

The compressibility factor Z was determined by dependencies, which are taken from [5]:

$$\tau = \frac{T}{T_{kr}};\ \pi = \frac{P}{P_{kr}} \tag{8}$$

herewith the given temperature made up $\tau = \frac{T}{T_{kr}} = \frac{300,5}{197,1} = 1/522$, and the given pressure: $\pi = \frac{P}{P_{kr}} = \frac{5,95}{4,61} = 1,291$ (T_{kr} =197,1 K, $P_{kr} = 4,61\ MPa$)

At these quantities: R×Z_{meas}=518×0.89 = 461 (J/(kg K))/

To determine the power of the turbine supercharger, additional losses were taken into account due to the turbine's external characteristic and the mechanical losses in the supercharger, which were assumed to: $\eta_m \times \eta_{ex} = 0,99$.

Figure 2 shows the values of the superchargers efficiency in the studied range of characteristics.

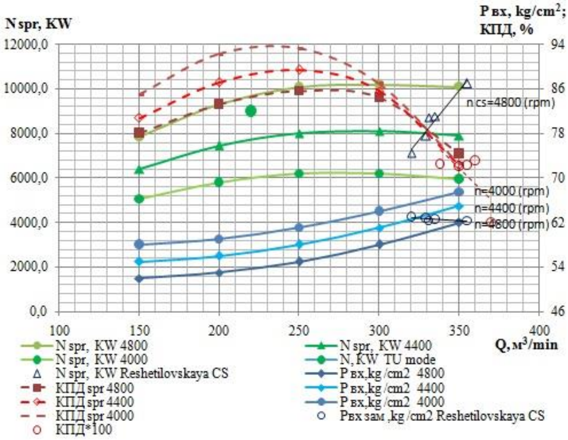

Fig.2. Dependence of the supercharger efficiency, obtained from the power given in the gas-dynamic characteristics of the supercharger (the TU mode should be understood as nominal)

The power of the supercharger turbine and other GTE parameters in the next step were given using the reduction formulas for B=101,3 kPa; $t_{nc} = +25\ ^0$C:

$$N_{TS\ red} = N_{TS\ meas} \times \alpha \times \beta \qquad (9)$$

given rotation frequency: $n_{red} = n_{meas} \times \alpha$, (10)

given temperature: $T_{red} = (273 + t_{meas}) \times \alpha^2$ (11)

given fuel consumption: $G_{F\ red}$=$G_{F\ meas} \times \alpha \times \beta$ (12)

where: $\alpha = \sqrt{298/T_{nc}}$; β =101,3/P_{nc} (13)

2. Analysis of the magnitude of the power of the TS GTE-10V as part of the compressor station.

Using the above dependencies, the capacity of the gas turbine engine DR59L was determined as part of the Reshetilovskaya CS. The magnitude of the efficiency of the supercharger was controlled by the gas-dynamic characteristics of the supercharger 235-21-1. In determining the power of the turbine supercharger by the gas-dynamic characteristics of the supercharger, an additional correction was made for the external characteristic of the turbine supercharger and the mechanical loss in the supercharger equal to 0.99.

Figure 3 shows the parameters of the GTE DR59L measured at Reshetilovskaya CS. The graph shows two TS power lines, which are obtained both from the measured gas flow through the supercharger and using the characteristics of the supercharger [1]. When processing the experimental data, the compressibility index was assumed to be 0.89.

On the other hand, this graph shows the parameters of the GTE DR59L, which are taken from the table of the volumetric flow rate measurements of gas through the supercharger. The coincidence of power with the data in [4] is obtained only when it is determined from the total gas-dynamic characteristics of the supercharger, given in [1]. The power obtained from the measured volumetric gas flow through the supercharger is (6-7)% less, calculated using the characteristics of the supercharger.

The obtained power value of the GTE DR59L correlates well with the data taken from [4]. Rated power GTE DR59L equal to N_{TH} = 10000 kW we get when n THPC = 7550 rpm and tnc = + 25C.

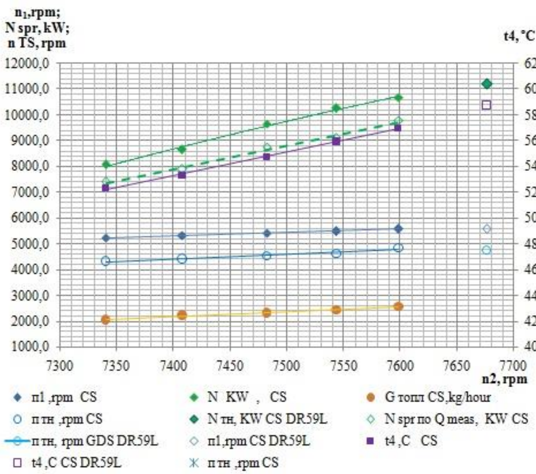

Fig.3. Change of parameters at testing GTE DR59L№2 at Reshetilovskaya CS 20.08.15. (tn + 25ºC, B = 0.1013 MPa)

Dependencies for GTE-10V No. 5 and No. 6. It should be noted that the actual power of the supercharger is greater, and has been increased by 4% compared to the theoretical one. The data are taken from the results of a supercharger examining [6]

From the obtained graphical dependences it follows that the power of the turbine supercharger (in the first approximation the power of the supercharger) obtained from the measured flow rate of the pumped gas is less than that obtained from the characteristics of the supercharger. The difference in TS power is more than 20%.

From the obtained balances it also follows that the power NTH=10000 кW is obtained in GTE-10V at N $_{THPC}$ =7750±30 rpm and tnc=+25C.

It can be seen from the above dependencies that:

1. Experimental data obtained at Reshetilovskaya CS as a whole confirms that the power of GTE-10V Nspr=10000 об/мин as part of the compressor station is obtained at THPC =7750±30 rpm and tnc =+25C.

2. The dependences obtained show that the determined measurement of the flow rate of the pumped gas does not coincide with the value obtained from the characteristics from 0 to 20%.

3. The experimental data obtained can serve as a basis for determining the power of the GTE-10B as part of a compressor station according to the gas-dynamic characteristics of the 235-21-1 supercharger.

3. Conclusion.

1. Refined formular data for GTD-10V on the dependence of the HP power and specific fuel consumption on the outside temperature were obtained.

2. The turbine power of the GTD-10V supercharger was determined according to the gas-dynamic characteristics of the supercharger 235-21-1.

3. Gas turbine engine GTD-10V, operating as part of a compressor station, with tn = + 25C and B = 101.3 kPa provides power to the flange of the supercharger turbine = 10,000 kW at a rotation frequency of THPC equal to 7750 ± 30 rpm.

4. The previously obtained parameters for acceptance testing of the CCD, in addition to the power of the supercharger turbine, can be used as formulary.

5. New dependencies are presented in the technical report.

6. For further collection of statistics on dependencies, it is proposed to perform measurements of the following parameters upon delivery of the next engine:

- set the measuring cylinder and determine the air flow through the CCD by modes;
- set the combs of thermocouples and the total pressure in the support ring of the pump and measure the total pressure and the total temperature according to the modes;
- install static pressure nipples and thermocouple combs at the inlet to the TN and measure the static pressure and the total temperature by modes.

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