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# APPLICATION OF THE ADJUSTED HEATING TURBINES ON INDASTRIAL HEATING ELECTRICAL UNITS

*There had been determined the main factors for operation of the combined steam turbine plants on industrial heat electric nets, created on the base of counter pressure and adjusted heating turbines in conditions of variable loading.*

***Key words**: steam boiler, steam turbine, counter pressure turbine, adjusted turbine, heat electric nodes.*

## Current state of the problem

The idea of combined manufacturing of electric energy and heat, which was suggested at the beginning of the previous century, stipulated for decrease in losses of fuel for production of the unit of energy product (electric energy and heat). This idea was realized by building electric generator plant (EGP). Using EGP allows to save fuel in energy supply system and is a perspective verified technology, which allows to solve the problem of energy saving. Apart from that, use of combined manufacturing of types of energy products is one is of the ways to decrease the emission of carbon dioxide ($CO_{2)}$, oxides of sulfur and nitrogen. Due to these advantages the combined manufacturing of heat and electric energy is recognized as one of the priority directions of energy manufacturing development in Ukraine [1].

The most appropriate condition for using EGP is the stability of thermal loading. However, current situation stipulates for decrease in consumption of technological steam on industrial EGP, which does not allow to reach the rated capacity. Industrial HEN produce electric energy on the base of heat release. Recently, however, due to reorientation of industrial manufacturing, or due to reduction in industrial manufacturing, the release of heat with steam for industrial needs have been considerably reduced. Especially difficult situation is in HEN with counter pressure turbines which operate with half loading or completely stopped. Operation with low loading is characterized by considerable decrease in efficiency factor (EF) of turbine plant and stream generator which results in fuel over losses. Operation with low loading is characterized by considerable decrease in efficiency factor (EF) of turbine plant and steam generator which results in fuel over losses. Large number of counter pressure turbines operates on industrial EGP of processing industries, many of which had been closed down. Down time of thermal energy equipment on industrial EGP increases losses of enterprise, repair and tax payment which results in increase of output cost and decrease in its competitiveness. It should also be noted that the decreases in energy generating capacities increases the scarcity of the necessary manoeuvring electric capacities in energy system and considerably complicates operation in peak modes [2].

Nowadays one of the priority directions in the development of native heat energy production is modernization of the existing heat and energy equipment. Heat energy generation has the real possibilities for using new efficient technologies at the cost of native, not foreign, investors. Total loading of industrial turbines of the type Р, П, ПТ, ПР may be ensured due to adjusted turbines which operate on steam parameters in industrial discharges or in counter pressure turbine Р.

Turbine machine engineering enterprises developed and continue development of different types of turbines which may operate with small initial steam parameters пари [3 – 5]. Choice of the modification for the adjusted turbine depends on availability of steam consumers, heat loading and sources of technical water supply, It is clear that the use only condensing adjusted turbines is not appropriate due to their low efficiency caused by low initial steam parameters, considerable water consumption for steam considering and electric energy losses for own needs.

Previous research [8] considered the use of the adjusted pressure turbines. There had been assumed the availability of industrial or heating steam from the adjusted turbine. There had been determined that the optimum operating mode of the combined plant is within the pressure range of the adjusted turbine form 0,4 – 0,18 MPa. The disadvantage in using the counter pressure turbines which supply steam to the heating system is the sharp decreases in loading in the summer seasons, in the result of both, the main and the adjusted turbines will operate considerable under loaded, that is, inefficient.

The above- mentioned stipulates for the task to determine the operation efficiency of the combined plant which consist of the main counter pressure turbine and adjusted heating turbine under conditions of load variables.

**Main results**

Counter pressure steam turbine P-6-35/6 was chosen as the main turbine, which is widely used at industrial EGP of small capacity, which is characteristic for the processing enterprises. Steam parameters before the main turbine: pressure $P_o$=3,5 MPa temperature $t_o$=435$^o$C, and behind the turbine (in counter pressure): $P_s$=0,6 MPa, $t_s$=245$^o$C. Pressure in heating collector of the adjusted turbine and in condenser: $P_1$=0,14 MPa, $P_c$=5 KPa, correspondingly. Principle heating diagram of the combined plant is shown in fig. 1.

In comparison with heating diagram of the main stream turbine plant, it differs by the availability of the adjusted heating turbine 8 with electric generator, condenser 9 with condensation 10 and circular pumps; regenerating heater 11 with drenage pump 12.

The main operating conditions of the combined plants is the fact, that the main counter pressure turbine must operate under stable nominal electric loading (N=6 MWt), and, consequently, with constant steam discharge for the turbine $D_0$, independent i=on the steam discharge for the industrial consumers $D_{sc}$. The balance equation has to come true during the operation of the combined plant.

$$D_0=D_{ad}+D_{sc}, \tag{1}$$

where $D_{ad}$ –steam discharge for the adjusted turbine.

In turn, the equation of the material balance of the adjusted turbine looks like:

$$D_{sc}=D_d+D_{rh}+D_{nh}+D_c, \tag{2}$$

where $D_d$, $D_{rh}$, $D_{nh}$, $D_c$ – steam discharge in deaerator, on regenerating heater of condensate, on net heater of heating system and on condenser, correspondingly.

It is clear that fuel consumptions remains constant during the operation of the combined plant, since the loading of steam generator remains also constant. Steam discharge on the adjusted turbine depends on the segment of steam consumers loading from the counter pressure of the main turbine: $\alpha_{ad}=D_{sc}/D_0$.

Calculations of heating diagram and main factors of combined plants with different values of $\alpha_п$ are made according to methods, presented in [9]. It had been assumed that heating of the condensate u=in the regenerating heater is 27$^o$C; temperature of feeding water is 104$^o$C; steam generator efficiency of turbine plant 0,91; electromechanical efficiency of turbine plant 0,96. It had also been assumed that limiting allowed steam discharge, which was estimated as 20% o total steam discharge $D_{sc}$ is fed to condenser of condensating adjusted turbine.

Fig. 2 shows the change of electric power $N_{ad}$, MWt (line 1) and released heating power $Q_{ad}$, MWt (line 2) of the adjusted turbine, depending on the share of loading of the industrial consumers $\alpha_s$. Conditions $\alpha_s$=1 corresponds the mode, when steam discharge on the adjusted turbine equals zero, that is, only the main turbine is working. Increase of $\alpha_s$ linearly decreases the capacity of the adjusted turbine. Heating capacity, released with the steam for heating, also decreases.

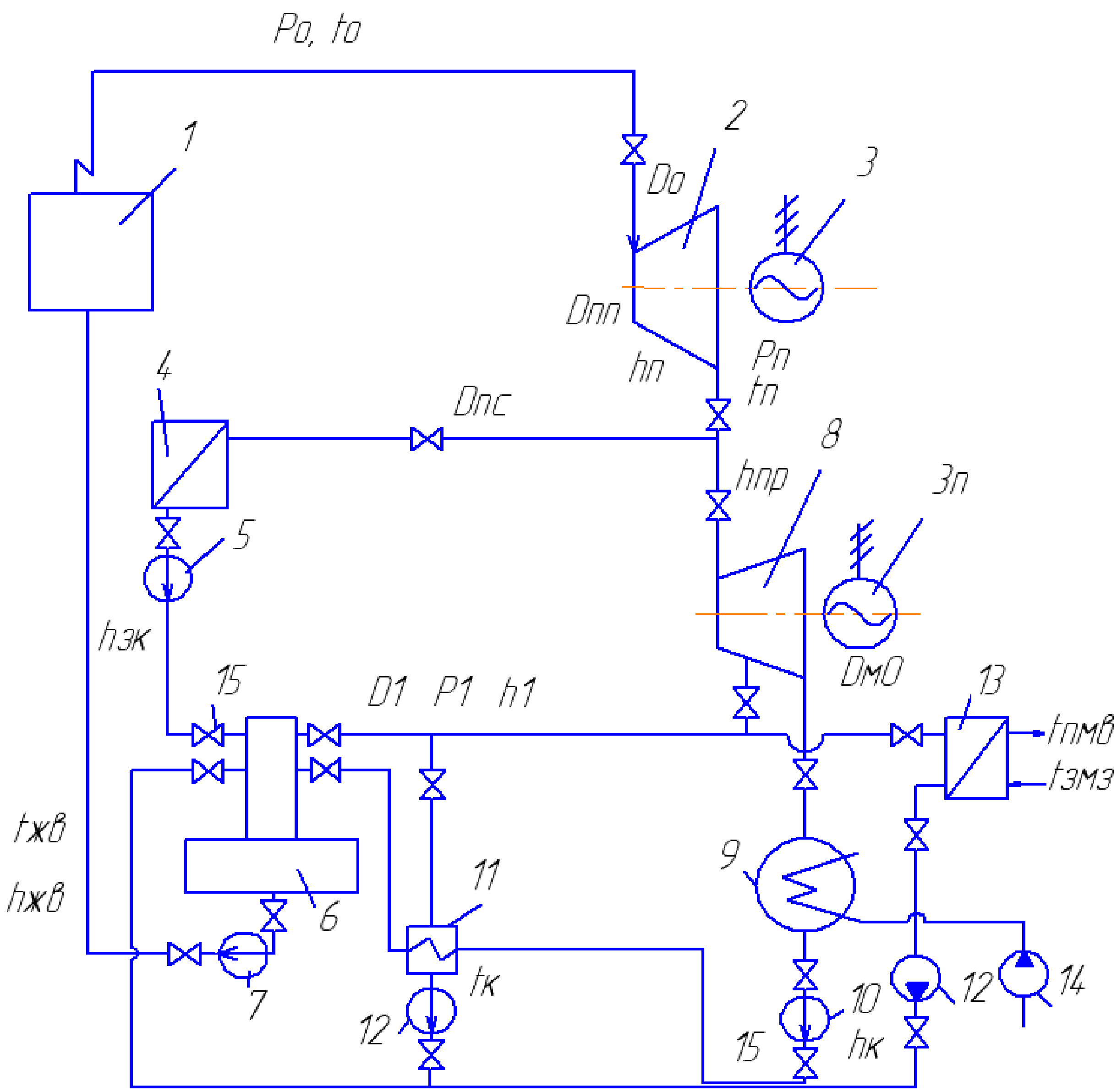


Fig. 1. Principle diagram of the combined plant with main counter pressure and adjusted heating stream turbine plants: 1 – steam generator; 2 – main counter pressure turbine; 3 – electric generator; 4 –industrial consumers of steam; 5 – pump for reverse condensate; 6 – deaerator; 7 – feeding pump; 8 – adjusted heating turbine; 9 – condenser; 10 – condensate pump; 11 – regenerating heater; 12 – drenage pump; 13 –boiler of the heating system; 14 – circulating pump; 15 – stop valve.

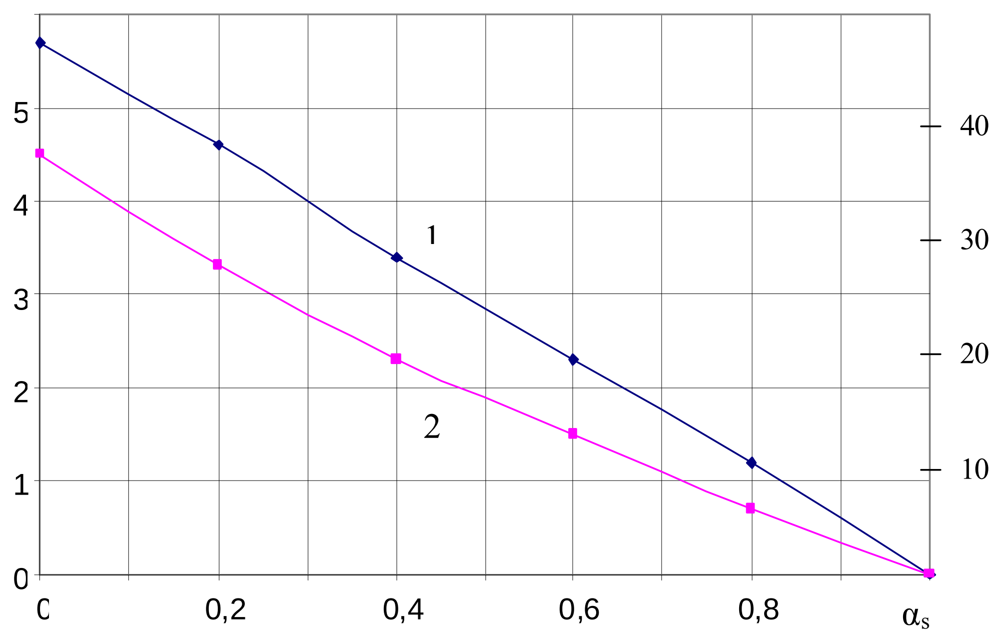


Fig. 2. Dependences $N_{ad}=f(\alpha_{ad})$, $Q_{ad}=f_1(\alpha_{ad})$

Change of electric capacity $N_c$ for the combined plant takes place analogically, but the change of heating capacity $Q_c$ has quite different character (fig. 3). It is explained by the fact, that the increase of $\alpha_s$ causes the increase in heating capacity, which is released from the counter pressure of the main turbine to the consumers.

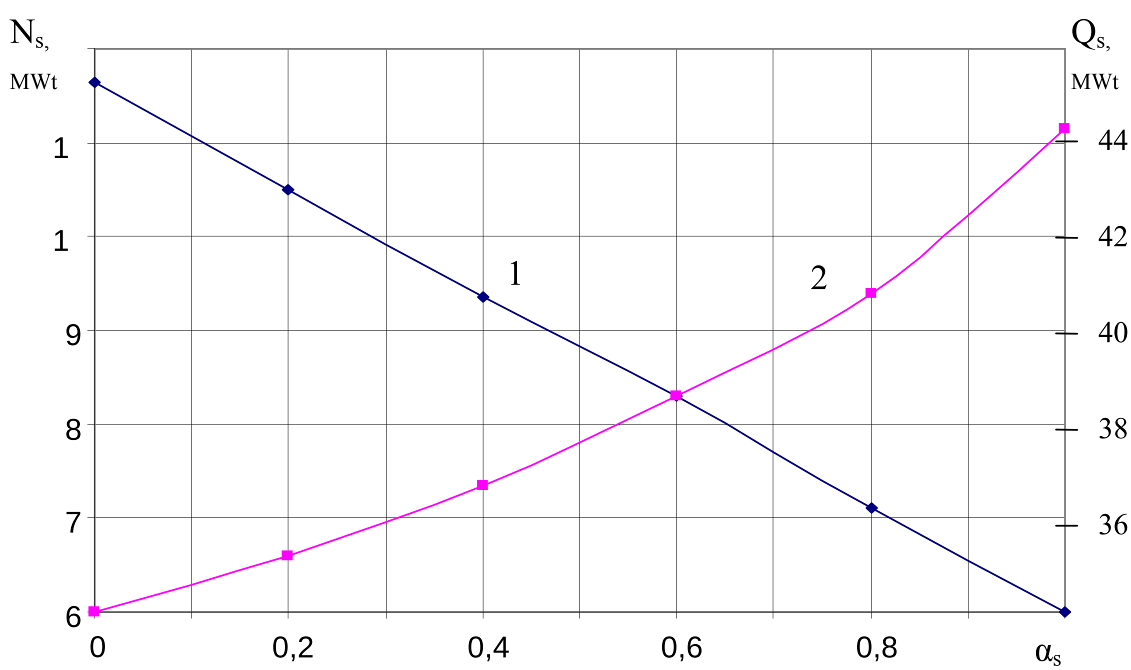


Fig. 3. Values of $N_c$ and $Q_c$ in combined turbine (see symbols in fig. 2)

Operating efficiency of the combined EGP is characterized by the specific discharge of standard coal equivalent for common production of heating and electric energy b, kg/MJ. It is well-known that the combined production of these types of energy product stipulates for economizing fuel on energy generating system. In such a case the production of additional capacity by the adjusted turbine is mode without the additional losses of steam in steam generator. Economizing in standard coal equivalent may then be considered as its consumption for production of this additional capacity on condensational thermal electric power stations of this energy system.

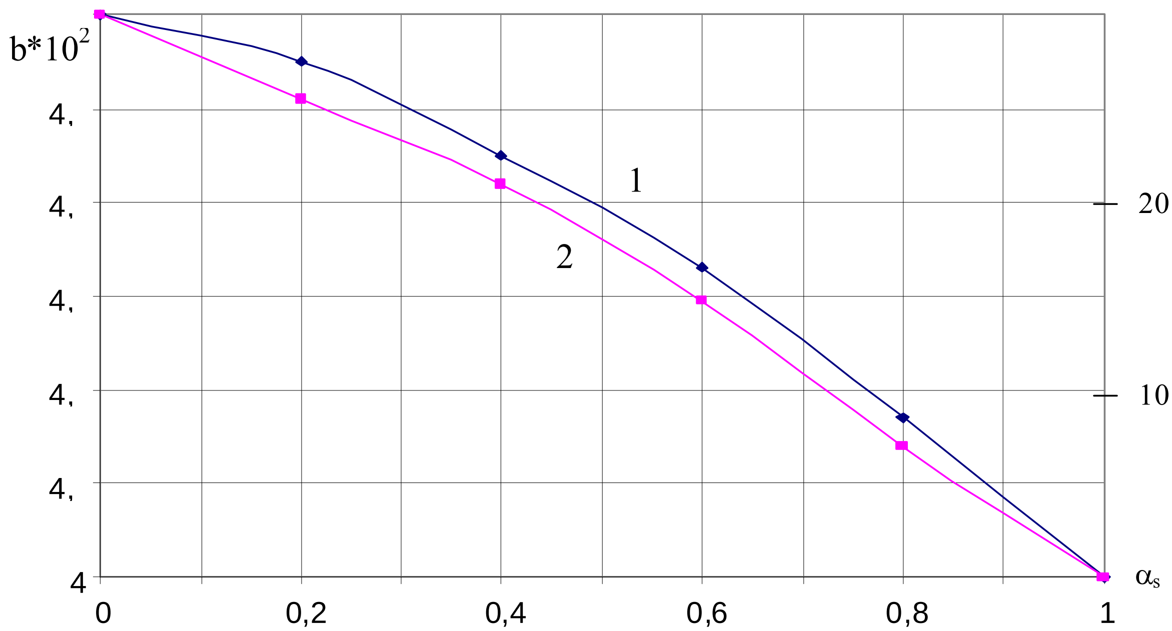


Fig. 4. Dependences b, kg/Mdz and ΔB of loading section of industrial consumers

Fig. 4 presents the dependences of change in specific consumption of standard coal in gross (curve 1) and fuel economy in percentage in energy system ΔB (curve 2). Fig. 4 shows that specific consumption of standard coal equivalent decreases as the loading segment of industrial consumers from the counter pressure in the main turbine increases, and specific consumption reaches its minimum values in case of their fuel loading, that is when the adjusting turbine is not loaded. Loading of the adjusted turbine ($0<\alpha_s$) causes the increase in value b due to heat losses in condencer of heating adjusted turbine. But on condition of maximum loading of the adjusted turbine ($\alpha_s=0$), we observe the biggest production of electric energy and, correspondingly, the biggest economy of fuel in energy system. It should be noted, that the additional production of electric energy without the additional consumption of fuel causes the decrease in emissions into the atmosphere in proportion to fuel economy.

The obtained results show the efficiency in application of heating adjusted turbines in case of non-full loading of counter pressure turbines or turbines with industrial stream supply. They are necessary condition for the solution of the type and characteristics of the adjusted turbines and previous evaluation of operating efficiency of the combined plant with the adjusted turbines.

**Conclusions**

1. With the availability of consumers of low pressure stream, the adjusted heating turbines allow the base turbine to operate in the economy mode.

2. Additional production of electricity by the adjusted turbines is achieved without loss of fuel.

3. Fuel economy for the manufacturing of additional electric capacity which nearly equals the capacity of the base turbine, makes up 30%.

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