USE OF SECONDARY ENERGY RESOURCES OF MODULAR POWER PLANTS WITH A GAS ENGINE AND REDUCTION OF HARMFUL EMISSIONS

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Abstract

The paper considers the use of exhaust gas heat in modular power plants. In this regard, fuel consumption at power plants will decrease, efficiency of power plant will increase the emission of harmful gases into the atmosphere and environmental burden will reduce.

Keywords: modular power plants, exhaust gases, heat supply, efficiency, fuel economy

I. Introduction

At present, reducing fuel consumption and harmful emissions into the atmosphere is the most pressing issue worldwide. The article is devoted to this issue.

Electrical energy is mainly generated at thermal power plants. For this purpose, steam turbine power plants, combined steam and gas units, modular power plants, etc. are used. Modular power plants with an internal combustion engine are usually used to store and maintain balance in power systems. Such stations start quickly and stop quickly. It is advisable to use such stations at variable loads.

Modular power plants mainly use natural gases. In many cases, exhaust gases from engines with a temperature of 350^0C - 370^0C are released into the atmosphere. Thus, 55 - 60% of the heat of the fuel is lost with the exhaust gas and cooling water, as a result, the exhaust gases pollute the environment and the atmosphere. By applying different schemes, it is possible to use the heat of exhaust gases, which ultimately increases the efficiency of the station, reduces fuel consumption and environmental loads.

A system for the beneficial use of the heat of flue gases (temperature 350-370^0C), is proposed, the heat supply of which is shown in Fig.1.

Exhaust gases from the gas engine with a temperature of 350^0C are fed through pipelines to the waste heat boiler, where, due to the heat of these gases, the heating system water is heated. Heated water is supplied through supply lines to heat consumers, where it is used for heating and hot water supply of settlements. Heating system and make-up pumps are installed in the circuits to implement this technological process.

The studies were carried out at modular power plants with a capacity of Ne=385 MW, where 21 four-stroke gas engines with a capacity of 18.333 MW each were installed. Natural gas, with a heat value $Q_H^P = 33520$ kJ/m^3 was used as a fuel. At each unit, the hourly consumption of natural gas is B_{ag}=4000 m^3/h, the fuel consumption for the entire station is B=84000 m^3/h.

Known formulas [2] determined the theoretical volume of air for burning 1 m^3 of fuel V^0=9.8 m^3/m^3 excess air coefficient α=1.1, exhaust gas temperature t_2 =350^0 C, exhaust gas enthalpy during combustion of 1 m^3 gas is H_2=5384.53 kJ/m^3. This heat can be usefully used in a waste heat boiler to produce hot water or steam [1].

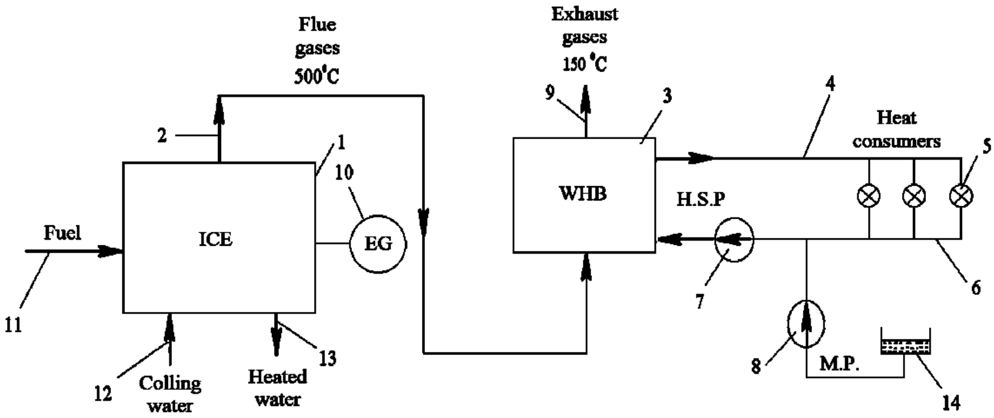

Fig. 1: *Heating system.*
1. Heat source of the internal combustion engine. 2. Exhaust gas pipeline. 3. Waste heat boiler for water heating. 4. Consumer supply line. 5. Heat consumers. 6. Return line from consumers. 7. Heating system pump. 8. Make-up pump. 9. Exhaust gases from the waste heat boiler. 10. Electric generator. 11. Fuel supply line. 12. Cooling water inlet. 13. Cooling water outlet. 14. A tank of nutrient (make-up) water.

The temperature of the exhaust gases from the waste heat boiler is assumed to be 150°C, and the enthalpy is found to be H_{ex}=2266.58 kJ/m^3. Used heat in the waste heat boiler per 1 m^3 of fuel

$$\Delta H = H_2 - H_{ex} = 5384{,}53 - 2266{,}58 = 3117{,}95\ \frac{kJ}{m^3}\ [1].$$

The total hourly fuel consumption for the entire station is

$$\text{B} = 21 * 4000 = 84000\ m^3/h.$$

Efficient use of heat in the waste heat boiler

$$Q_b = 84000 \cdot 3117{,}95 = 261{,}9 \cdot 10^6 \frac{kJ}{h} = 72{,}3\ MW$$

Taking into account losses in the boiler $Q_b = 72{,}3 \cdot 0{,}94 = 67{,}96\ MW$.

Heat loss with exhaust gas

$$q_2 = \frac{(H_{ex} - \alpha \cdot H^0_{c.a.}) * 100\%}{Q^P_H}$$

$H^0_{c.a.}$ – cold air enthalpy $\frac{kJ}{m^3}$;

$H^0_{c.a.} = 1.32 \cdot t_{c.a.} \cdot V^0$; cold air temperature is accepted

$t_{c.a.} = 18^0\text{C}$; $H^0_{c.a.} = 1.32 \cdot t_{c.a.} \cdot V^0 = 1{,}32 \cdot 18 \cdot 9{,}85 = 234 \frac{kJ}{m^3}$.

$$q_2 = \frac{(2266{,}58 - 1{,}1 \cdot 234) * 100\%}{33520} = 5{,}99 \approx 6\%$$

When the exhaust gases are cooled to cold air temperature, the theoretical heat released in the boiler

$$Q_{theory} = \text{B}(H_g - H_{c.a.}) = 84000(5384{,}53 - 234) = 432{,}6 \cdot 10^6 \frac{kJ}{h} = 120\ MW$$

Efficient use of heat in the boiler

$$\eta_\text{г} = \frac{Q_{use}}{Q_{theor.}} = \frac{67{,}96}{120} = 0{,}6$$

Heat saving $\Delta\eta = \eta_g \cdot \frac{H_g - H_{c.a.}}{Q^P_H} = 0{,}6 \frac{5380 - 234}{33520} = 0{,}12$

Power plant efficiency

$$\eta^{brut} = \frac{3600 \cdot W_e \cdot 10^3}{\text{B} \cdot Q^P_H} = \frac{3600 \cdot 385 \cdot 10^3}{84000 \cdot 33520} = 0{,}49 = 49\%$$

When using the heat of exhaust gases.

$$\eta^{brut}_s = \eta^{brut}_s + \Delta\eta = 0{,}49 + 0{,}12 = 0{,}61 = 61\%$$

The efficiency of the station is increased by 12%.

Specific reference exhaust consumption

$$\text{в}^{brut}_s = \frac{123}{\eta^{brut}_s} = \frac{123}{0{,}49} = 251{,}02\ \frac{gr}{kW \cdot h}$$

When using the heat of flue gases

$$B_s^{brut} = \frac{123}{0,61} = 201,64\ \frac{gr}{kW \cdot h}$$

Fuel economy is

$$\Delta B = 49,38\ \frac{gr}{kW \cdot h}$$

For all stations the fuel economy is 19.2 T/h.

In addition to all, it is possible to provide the population with heating and hot water supply using received hot water.

To provide 1000 residents with heating (in the climatic conditions of Baku) [3].

$$Q = q \cdot F$$

where F is the area of objects

$$F = f \cdot N$$

N – population: N=1000.

f - the required area per one f = 12 m^2 / men.

$$F = 1000\ \text{people}\ \cdot 12\ m^2/men = 12000\ m^2$$

q - heating indicator,

$$q = 65\ \text{W}/\ \text{m}^2$$

$$Q = 65\ \text{W}/\ \text{m}^2 \cdot 12000\ m^2 = 780000\ W = 780\ kW$$

(per 1000 men).

Heat load for hot water

$$Q_{h.w.s.} = \frac{C \cdot N \cdot a(t_2 - t_x) \cdot \rho}{3.6 \cdot 24 \cdot 10^3}(1 + \beta_{\text{т}})\text{Вт}$$

C is the specific heat capacity of water

$$C = 4,19\ \text{kJ/kg}$$

a - the rate of hot water per man

$$a = 120\,\text{l}/men; \ \ N = 1000$$

t_2 - cold water temperature

$$t_x = 5^0 C$$

ϱ is the density of water; ϱ = 1000 kg/m^3

β – heat loss in the system β = 0.2

$$Q_{h.w.s.} = \frac{4,19 \cdot 1000 \cdot 120(55 - 5) \cdot 1000 \cdot 1,2}{3.6 \cdot 24 \cdot 10^3} = 349166\ W = 349\ kW$$

$$\sum Q = Q_h + Q_{h.w.s.} = 780 + 349 = 1129\ kW = 1,129\ MW$$

(per 1000 men).

Efficient use of heat in the waste heat boiler Q_b=67.96 MW

Then,

$$\frac{67,96 \cdot 1000}{1,129} = 60194\ men$$

Thus, 67,96 MW of heat can be provided to 60194 people for heating and hot water supply.

Thus, using the heat of exhaust gases, it is possible to save fuel heat, increase efficiency of the stations, reduce fuel consumption and the amount of gases emitted into the atmosphere.

II. Conclusions

1. The heat of flue gases was determined in the amount of 67,96 MW.
2. Calculations show that when using this heat, the efficiency of the station increases by 12%.
3. The specific fuel consumption is reduced by 49.38 g/(kWh) and the amount of exhaust gases is reduced.
4. The use of such heat will reduce emissions of harmful substances such as CO_2 and NO_x into the atmosphere and reduce environmental burdens.

5. Using the heat of exhaust gases, it is possible to provide 60,194 residents with heating and hot water supply.

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