RESEARCH ON THE UTILIZATION OF SECONDARY ENERGY RESOURCES AND FUEL SAVING IN INTERNAL COMPUSTION ENGINE POWER PLANTS

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Abstract

Heat of exhaust gases from stations operating with internal combustion engines (ICE) and heat of cooling water have been investigated in the paper. In such situations, 60% of the fuel heat is lost through the exhaust gas from the engines and cooling water. Various schemes are proposed for using this heat. When implementing these schemes, steam, hot water and cold can be obtained from waste gases. Then the efficiency of the station increases, specific fuel consumption and the amount of flue gases emitted into the atmosphere and environmental loads are reduced.

Keywords: diesel engines, flue gases, cooling water, fuel economy, efficiency, ecology

I. Introduction

Currently, in Azerbaijan, the majority of electricity is generated in steam turbine, combined, recycled, steam-gas and modular power plants with an internal combustion engine (ICE) [1]. Internal combustion engines of modular power plants are mainly used to maintain balance in the energy system. These stations are quickly launched and stopped quickly. In variable modes it is advisable to use such stations. ICEs of modular power plants mainly use natural gases.

Exhaust gases with a temperature of 500-520^{0}C are released into the atmosphere. Thus, in such stations, 50-60% of the fuel heat is released into the atmosphere by exhaust gas and cooling water and pollutes the environment. By using different schemes, heat of the flue gases can be used and ultimately the efficiency of the installation increases, specific fuel consumption and the environmental load are reduced.

II. Research

The studies were carried out at the Sangachal modular power plant with a capacity of 300 MWt. The station houses 18 four-stroke diesel engines. The power of each engine is 16.6 MWt. The engines run on gas. Below is the composition of the gas:

CH_4=93,9%; C_2H_6=3,1%; C_2H_8=1,1%; C_4H_{10}=0,3%; C_5H_{12}=0,1%; CO_2=0,2%; N_2=1,3%; Q^w_l=33500 kJ/m^3.

Each unit has a fuel consumption of B = 3500 m^3/hour. The temperature of the exhaust gas from the engine is 500^{0}C. Calculations were carried out according to [2].

For combustion of 1 m^3 of fuel, air consumption V_0=9.8 m^3/ m^3, the amount of flue gases produced during combustion is V_g=13.032 m^3/m^3. The excess air coefficient is accepted as α=1.2.

For stations, the total fuel consumption is:

B_{total}=18*3500=63000 m^3/hour.

The heat received in one unit is:

Q_{unit}=B* Q^w_l=3500*33500=117,25*10^6 kJ/hour.

The heat throughout the station is:

Q_{unit}=18* Q_{unit}=18*117,25*10^6=2110,5*10^6 kJ/hour=586,2 MWt.

A scheme is proposed for using the heat of exhaust gases from the engine and cooling water, it is shown in Fig. 1.

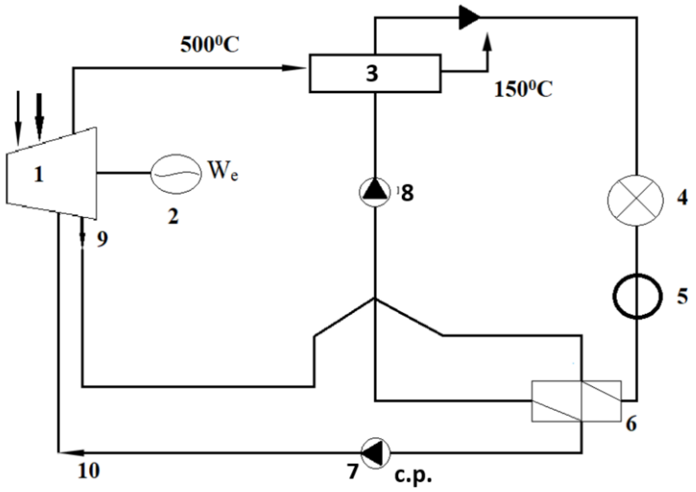

Figure 1: *Scheme of using the heat of exhaust gases and cooling water for heating and hot water supply*

1-Internal combustion engine; 2-electric generator; 3-recovery boiler; 4-heat consumer; 5-network pump; 6-heat exchanger; 7-circulation pump; 8-feed pump; 9-warm water leaving the engine (85-90^{0}C); cooled water (75-77^{0}C) for the engine.

The waste leaving the internal combustion engine at a temperature of 500^{0}C is fed into the waste heat boiler. The steam or hot water produced in the boiler is supplied to the heat consumer. From the consumer, condensate is supplied to the heat exchanger using a network pump. There, due to the heat of the cooling water leaving the engine, it is heated and supplied to the waste heat boiler using a feed pump. In the heat exchanger, the incoming hot water from the engine gives off its heat to the condensate, then cools and returns to the engine.

Enthalpy of gases entering the waste heat boiler [2]:

H_g=7963.67 kJ/m^3

The temperature of the gases leaving the boiler is accepted $t_{e.g.}$ = 150^{0}C, then the enthalpy of the exhaust gases is:

$H_{e.g.}$=2295 kJ/m^3

Then, when burning 1 m^3 of gas in a waste heat boiler, the heat used is:

$\Delta H=H_g-H_{e.g.}$=5568 kJ/m^3; Q_g= B_{total}*ΔH=63000*5668.27 kJ/m^3=357*10^6 kJ/m^3=99 MW

Then heat savings

$\Delta\eta$=(99/586.2)*100%=16.8%

Gross station efficiency is η^{gr}_{st}=51%

When using exhaust gases from the engine, the gross efficiency of stations η^{gr}_{st}=51%+16.8%=67.8%

Specific fuel consumption under normal conditions:

V^{gr}_{st}=123/ η^{gr}_{st}=123/0.51=241 g/kW

When using exhaust gas heat

V^{gr}_{st}123/0.678=181.41 g/kW

Specific fuel consumption savings:

ΔV^{gr}_{st}=241-181.41=59.6 g/kW

Fuel savings across the entire station will be 17,880 T/h.

III. Calculation of heat loss of cooling water

In each engine, the cooling water leaves at a temperature of 85^0C, is cooled in the heat exchanger to a temperature of 77^0C and returns to the engine. Water circulates in the system for 120 T/h (Fig. 2).

In one engine the heat loss is:

Q=120 T/hour * (85-77) ^{0}C*1,16 $\frac{kW*h}{T*°C}$ =1113,6kW

Throughout the station:

∑ Q=18*1113,6=20044,8 кW=20 MW

20 MW of heat is lost with cooling water. To use this heat, the surface of the heat exchanger is calculated

F= Q*10³/K* Δt_{av}= $\frac{1113,6*10^3}{2000*11,3}$ =50 m²

Average temperature difference

$$\Delta t_{av} = \frac{\Delta t_{big} - \Delta t_{small}}{\ln\frac{\Delta t_{big}}{\Delta t_{small}}} = \frac{17-7}{ln\frac{17}{7}} = \frac{10}{ln2,43} = 11,3°C$$

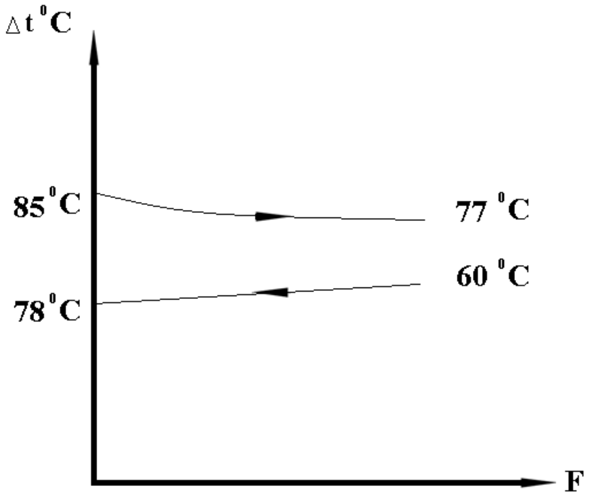

Figure 2: *Change in temperature difference across the surface of the heat exchanger*

Each unit will require a heat exchanger with a heating surface of 50 m². At the plant, the heat loss from exhaust gases is 99 MW, and with cooling water – 20 MW. Together, 119 MW of heat is lost at the station.

The calculation shows that for the climatic conditions of Baku, the heating load per 1000 people will require 780 kW of heat, and for hot water supply per 1,000 people will be needed 349 kW of heat [3]. Thus, to provide 1000 people with heating and hot water supply, 1129 kW or 1.129 MW of heat is needed. Then 99 MW of heat can be provided to $\frac{99\cdot1000}{1,029}$ = 96210 population with heat and hot water supply.

In such powerful power plants, additional electrical energy can be obtained from the heat of exhaust gases [4]. In industry, secondary energy resources are used to produce electrical energy. The most common method to generate electricity from secondary waste is the Rankine steam cycle (Fig. 3).

Here, secondary resources (exhaust gases coming from the engine) are used to produce steam in the recovery boiler. The resulting steam is then fed into a steam turbine. In a turbine, thermal steam is converted into mechanical energy, and in an electric generator, mechanical energy is converted into electrical energy. Also, in modular power plants exhaust gases 500^{0}C, along with thermal and electrical energy, can be used to produce cold (trigenation scheme) [5].

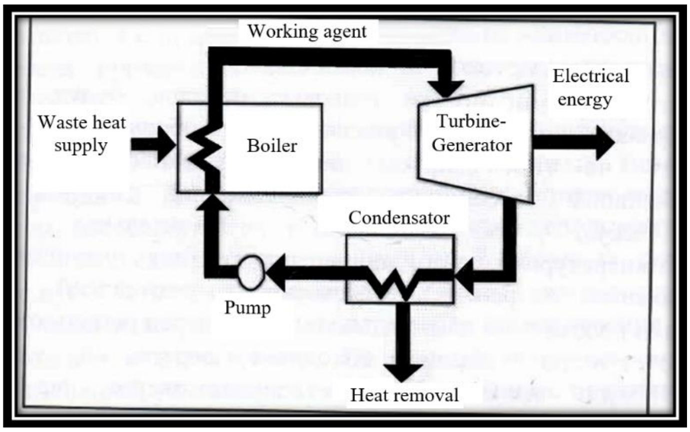

Figure 3: *Rankine cycle of a heat engine*

Currently, absorption refrigeration machines (ARMs) are widely used in industry. These machines require the following sources to operate:

1. Heat source.

A) Hot water with a temperature above 85^{0}C

B) Steam with a pressure of 0.1 MPa

B) Exhaust gases with temperatures above 230^{0}C

D) Natural gases

It can be seen that such sources are located in modular stations.

ARM consists of heat exchangers (generator, condenser, evaporator, absorber) in which on one side a LiBr solution or water (or water vapor) circulates under a vacuum, on the other side cooled water and cooling water circulate and a heating source in this case is water.

ARM operating principle:

The supplied heating source - hot water - heats the LiBr aqueous solution in the generator and generates water vapor from the solution, which in turn heats the cooling water in the condenser of the refrigeration machine and condenses to clean water. The resulting clean water then enters the evaporator (in a high vacuum state) and is dispersed over the copper pipes in the evaporator, taking heat from the cooled water, cooling it to 7^{0}C. The heated cooling water in the condenser, in turn, enters the cooling tower to discharge the resulting heat into the ARM. Water vapor from the evaporator enters the absorber, where it is absorbed by the concentrated solution coming from the generator. The resulting diluted solution is pumped back to the generator for heating, forming a cycle.

The main advantage of absorption plants in comparison with steam compressors is the low electricity consumption of up to 5-10 kW, for example, to produce 1 MW of cooled water, the ARM will consume 4.9 kW, then a freon cooler. It consumes about 250-300 kW.

ABHM have other advantages:

The use of cheaper energy (thermal) for drive compared to expensive electricity uses environmentally friendly refrigerant water. Service life is up to 30 years without major repairs. It has less noise and vibration. It is easier to operate, and has automatic control system it is used. In a power plant with an internal combustion engine.

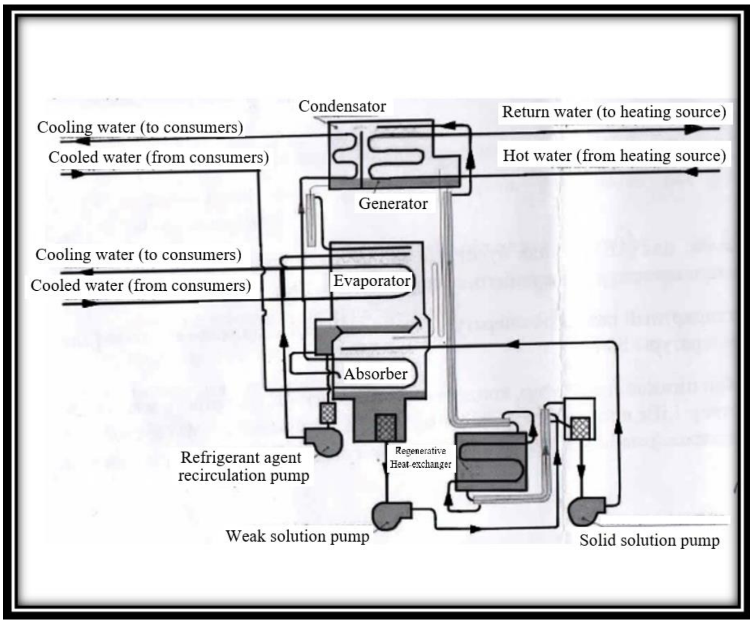

Figure 4: *Absorption lithium bromide refrigeration machines*

Power plants with combined production of heat, electricity, and cold (trigeneration plants) use fuel in the most efficient way and at the same time reduce carbon dioxide emissions. The overall efficiency of the station can exceed 90%. Trigeneration plants provide the ability to produce three important products - electricity, heating and cooling - using one power plant. Such stations can also be used for large facilities such as airports, shopping centers and other building complexes. This versatility does not compromise high reliability and excellent flexibility.

IV. Conclusions

1. The operation of modular power plants with a diesel engine with a capacity of 300 MW has been studied.
2. It was revealed that the loss of heat, fuel from exhaust gases is 99 MW, and with cooling water 20 MW.
3. Different schemes are proposed to use these losses, and by using heat at the station, additional electrical energy, steam, hot water and cold can be obtained.
4. The resulting thermal energy can provide 93,310 people with heat and hot water supply, the efficiency of the station increases by 16.8% and fuel savings will amount to 17.880 T/hour, the amount of emitted flue gases and environmental loads will decrease.
5. The introduction of trigeneration schemes increases the efficiency of the station, gives additional electrical energy received and steam generation, hot water and cold.

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