HEAT PUMPS IN ENERGY PRODUCTION UNITES OF MEAT-PROCESSING PLANTS

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Abstract: *The paper presents the scheme of energy (heat, cold, electricity) supply unit for the meat - processing plant which consists of gas engine-driven heat pump and turbo expander, installed on the gas pressure reduction station for producing electricity. Proposed scheme has following distinctive features: a) reduced cost of electrical energy generated by the turbo expanders due to the use of heat pump as a source of heat and cold for the plant; b) increased COP of the heat pump due to the use of gas engine heat; c) production of thermal energy, electricity and cold during the whole year with maximum efficiency due to the use of adsorption chiller and cold and heat accumulators.*

Keywords: *Heat pump, energy efficiency*

1. Introduction

The food processing plants in Republic of Moldova that use fuel and electricity are mostly electricity-demanding. The Moldovan slaughterhouse and meat processing plants (SMP) that use fuel and electricity require energy saving technologies from the beginning of energy production process. Boilers are used as a source of the heat energy, and electric power grid is a source of electric energy Utilization of gas engine-driven heat pumps as a source of heat, cold and electricity and utilization of turbo expanders that use excessive pressure in gas pipelines for their functioning is an opportunity to reduce costs and is discussed in this paper.

The fact that the gas before turbo expander must be heated and the temperature after it should not be lower than 0°C is well known. The temperature till which gas must be heated depends on pressure drop on expander stage. In a lot of investigations construction of hybrid-power systems was examined; most of them were focused on how to avoid high pollution and fuel consumption. The utilization of an internal-combustion engine (ICE) loaded on mechanical load and electric generator, when ICE is a heat pump compressor drive often allows ICE to work with high efficiency and low emission [1-3].

The goal of our paper is an elaboration of energy supply scheme of meat processing plant with predominant electricity consumption rather than heat load, due to the utilization of turbo expanders and gas engine-driven heat pump.

2. Block diagram of architecture of energy production system

Let's examine the heat pump "(air, water)-water" with the gas engine as a drive for the heat pump compressor, which is a heat source for gas heating before the two-stage turbo expander, installed on the gas pressure reduction station for electricity production.

The two-stage turbo expander unit can serve as the source for generation of electric energy and cold for the SMP as well. The heat pump is a source of additional heat energy, electricity and cold for SMP (Fig.1, 2).

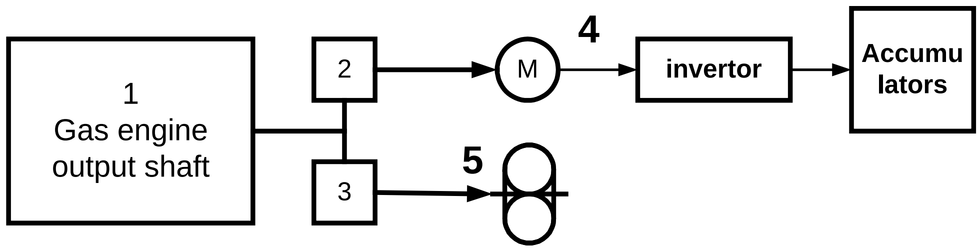

Figure 1. The scheme of electric energy production by gas engine. 1 – gas engine output shaft, 2,3 – automatic hydraulic transmissions, 4 – electric generator, 5 – heat pump compressor.

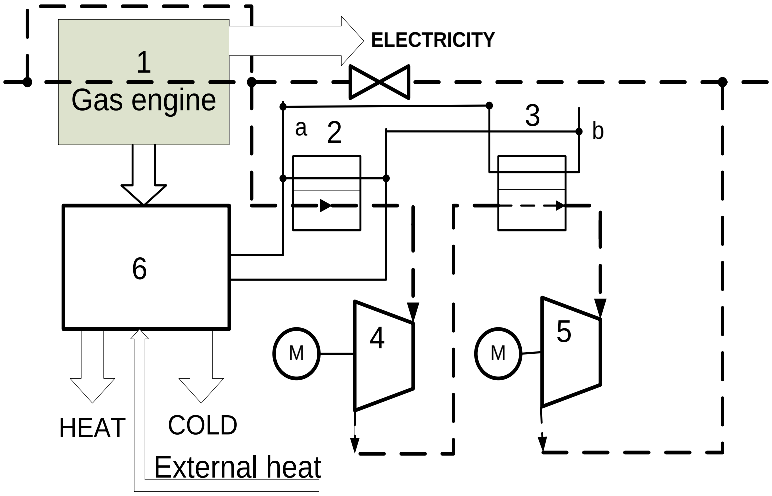

Figure 2. The scheme of energy production in SMP (a, b – see Fig.3). 1- gas engine, 2,3 – heat exchangers for gas heating before turbo expander stages, 4,5 – turbo expander stages, 6 – heat pump.

3. Heat pump scheme

The heat is used in meat-processing plants: for production of hot water at different temperatures, for dehumidification of the air in the shops, for drying plants for heating (in cold seasons), etc. Cold is used for air conditioning in the rooms cooling meat to different temperatures (depending on the technology).

Figure 3 shows a block diagram of the two-stage heat pump for simultaneous production of heat and cold.

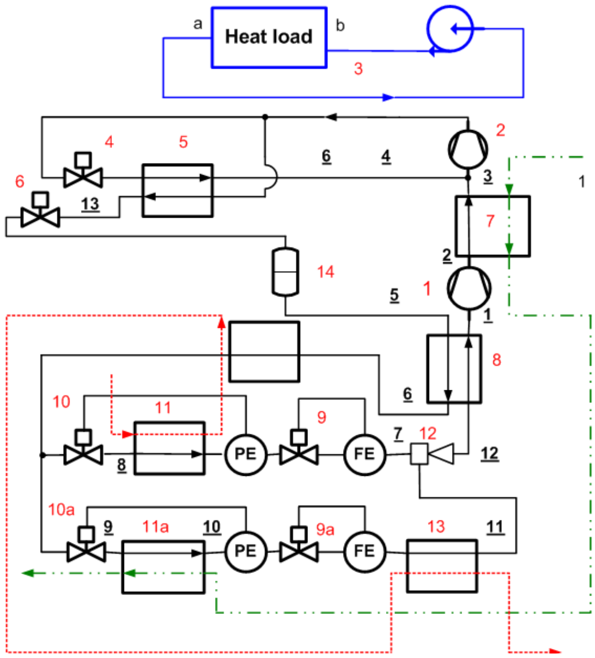

Figure 3. Heat pump scheme (blue line (including heat load) – heat production, green line (chain line) – air, red line (dotted line) – exhaust heat from gas engine). 1,2 – two-stage compressor, 3 – gas cooler, 4,6,10,10a –control valves, 5,7,13 – heat exchangers, 9,9a,10,10a- control valves for evaporator regime control, 11,11a- evaporators.

The heat load and cooling load are supplied also by heat and cold accumulators (in Figure 3 are not shown). Number of evaporators and gas coolers is determined by number of different temperature levels of heat and cold. The diagram shows two evaporators: one for supply of the cold of certain potential, and second one to display the operating point of the compressor inlet in position providing maximum COP.

The scheme in Figure 3 uses several evaporators and gas coolers (item 3, item 11) connected in parallel, for different refrigeration and thermal loads, respectively. The letters "a" and "b" show the conditional load of heat exchangers heating gas before turbo expanders. The proposed scheme is similar to the scheme developed by the authors in [4]. Gas - driven engine heat pump and turbo expander must ensure the plant's needs for electricity, heat and cold.

Let us consider the problem of estimation of the power of parallel type gas drive of the heat pump plant that generates in wide limits heat, cold and electricity [5]. Let's denote maximal thermal capacity is N_h , maximal mechanical capacity N_{mc} and electric capacity is N_e . Electric power of refrigeration and air conditioning equipment is denoted as N_c . Electric power of drives of other equipment and of lighting we denote as N_m

$$N_m = N_e - N_c . \tag{1}$$

Determination of gas drive power of the heat pump is based on the following assumptions: 1) thermal power extracted from flue gases and cooling system of the engine jacket should be enough to maintain the regime of evaporator 11 (Fig. 3), which ensures the maximal COP of the heat pump; 2) power of additional electric power generator of gas drive should be enough to ensure electrical load of factory equipment, of lighting, and of refrigerating rooms where the cold is produced without heat pump evaporators using additional adsorption chiller that uses heat of flue gases and heat from other sources.

The surplus electrical power may also be sent to an electric power grid. Total heat capacity of the gas-driven heat pump should provide maximum heat output (heating gas before turbine expander stages, heating of houses in winter, producing hot water of different thermal potential for sanitary purposes, heat for air drying in the shops of the plant, preparation of hot water for technological devices, etc.). One part of the gas engine heat output from the combustion of fuel is spent on the production of electrical energy (k1), the second part of the gas engine heat output from the combustion of fuel (k2) is spent on the production of electrical energy and the third part (k3) – are losses. Of course, these coefficients are approximate and vary depending on the type of engine and its operation conditions.

$$k1 + k2 + k3 = 1 . \tag{2}$$

Let the COP of the heat pump will be equal to φ . Then thermal power spent on technological purposes, will be equal to

$$N_H = N_m \cdot \varphi \cdot \eta \quad , \tag{3}$$

where η – efficiency of compressor, heat exchangers, etc. Turbo expander electric power depends on gas flow rate, gas pressure, gas temperature, number of stages of expander, pressure drop on expander stage.

Load scheduling

In process of energy production we consider the following situations:

1) required heat (or cooling) power of the heat pump is more than power necessary for production;
2) required heat (or cooling) power of the heat pump is less than power necessary for production;
3) electric power of electricity production unit installed is more than electric power necessary for the production;
4) electric power of electricity production unit installed is less than electric power necessary for the production;
5) situation 1(2) and situation 3(4) together.

<u>Situation 1</u>. In this situation it is necessary to use additional heat to: 1) generate additional cold; 2) collect heat in the heat accumulator;

<u>Situation 2</u>. If generated thermal (cold) power of heat pump is maximal, then it uses part of the heat from flue gases and heat recovery loop of cooling jacket of the engine and heat stored in the heat accumulator to generate additional cold or electric energy, which is consumed by refrigerators or air conditioning systems.

<u>Situation 3</u>. If generated electric power is more than required than a part of the electricity is sent to external consumers.

Situation 4. In the situation when generated electric power energy is less than necessary, electrical power is not sufficient for operational reasons, and the situation must be solved using more electricity obtained from the network.

Situation 5. Solution of the problem consists in the implementation of actions in situations 1-4.

The accordance of thermal, cold and electric capacities with the generated energy is ensured with the use of the following procedure:

1) definition for a given maximum thermal load and its quality indicators (temperature, flow of coolant) the mode of operation of the heat pump (maximum compressor capacity) and thermal power, which should be aimed at improving the COP of the heat pump (to reduce the power required to drive the compressor);

2) subtraction from the required electrical power the one, which is produced due to cold generation by the heat pump and electric power produced by turbo expander;

3) computation of the fuel consumption of gas engine to ensure required electrical load taking into account the condition of the heat pump COP maximization.

Proposed scheme differs from the known schemes [6] with: a) reduced cost of electricity produced by turbo expanders due to the heat pump as a source of heat for natural gas heating before turbo expander stages and cold produced for production needs; b) increased COP of the heat pump due to use of the heat of the gas engine; c) production of thermal energy, electricity and cold whole year with maximal efficiency due to the use of adsorption chiller and accumulators of heat and cold.

4. Conclusions

The scheme of energy (heat, cold, electricity) supply unit for the meat–processing plant which consists of gas engine- driven heat pump and turbo expander, installed on the gas pressure reduction station to produce electricity can ensure independent production of heat, cold and electric energy. Proposed scheme differs from the known schemes with: a) reduced cost of electricity produced by turbo expanders due to the heat pump as a source of heat for natural gas heating before turbo expander stages and cold produced for production needs; b) increased COP of the heat pump due to the use of heat of the gas engine; c) production of thermal energy, electricity and cold whole year with maximal efficiency due to the use of adsorption chiller and accumulators of heat and cold.

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