Multifunctional energy-technological complex on the basis of a steam-piston power plant for autonomous facilities of various purposes

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Abstract. The article substantiates the urgency of creating a multifunctional energy-technological complex based on a steam-piston power plant for autonomous facilities of various purposes. It is proven the possibility of creating such energy complexes and systems. The use of these complexes at the same time will also help to solve environmental issues on the territory of their application. The basic preliminary design parameters of the considered power complex are presented.

1. Introduction

The normative act [1] provides a list of available technologies that ensure energy efficiency improvement (Reference document on best available techniques for energy efficiency) in various activities. The document contains information on the possible application of modern existing energy efficiency technologies, as well as for the achievement and research in this field carried out in accordance with Article 17 (2) of Directive 2008/1 / EC [1]. In particular, it says [1, paragraph 1.1.6.] that the issues of economic efficiency of energy supply systems have a significant impact on the state of the environment in the adjacent territories. Any kind of energy is a very important resource for production. Its use is associated with financial costs and, importantly, has a beneficial effect on the environment; therefore, effective energy management is an important factor in reducing costs, increasing business competitiveness and reducing the negative impact on the environment.

Besides that, the scientists A. Nostar and D. Pierce (Canada) [2], when describing the combined hybrid photovoltaic system at the same time note that the usage of effective combined heat and power production for use in residential buildings is rather urgent. These and other materials [4, 5] are proving that the governments of different countries are interested in developing such efficient energy complexes that would meet the modern demands of the economy.

Therefore, improving energy efficiency in various areas of industry and in agro industrial complex is one of the most urgent tasks of the current century. The place of our society in a number of industrial and economically developed countries of the world, as well as the improvement of the living standards of citizens, depends on the results of solving this urgent task.

Our country has a high intellectual potential, as well as an indispensable production and natural resource for solving its energy problems. In addition, the country is also a supplier for European and
other countries, while exporting oil, oil products and natural gas to the extent required for importing countries.

Work in the field of energy saving is classified as a strategic state task, being at the same time the main activity for ensuring energy security, as well as the real and only way to maintain high export revenues from hydrocarbon raw materials.

The energy resources required for economy development can be obtained not so much by increasing the extraction and processing of hydrocarbon raw materials in hard-to-reach areas and building new energy-supplying complexes for this, but also by directly saving these resources at their consumption points, particularly in large and small settlements.

Increasing of the energy resources efficiency is attractive not only in itself, but also has a positive impact on the level of energy efficiency of enterprises in various industries located in the territory under consideration, as well as the energy efficiency of the region and the country as a whole. The goals of energy saving coincide with other goals in all areas of their implementation, in particular, such as improving the environmental situation, increasing the efficiency of energy supply systems and etc.

The work on improving the energy efficiency of the economy meets the goals and objectives of the federal law "On Energy Saving" [3]

The use of modern automated and autonomous energy systems and complexes together with combined production of thermal and electric energy (cogeneration plants) based on internal combustion engines and deep external utilization of the withdrawn heat, provides the necessary energy reliability and availability of reserves [4] in the system of centralized power supply. At the same time, and further, with the development of modern small-scale power units including those based on steam-piston machines, they will not only be an alternative to a centralized power system, but also a basis for rapid construction, as well as the creation and implementation of an autonomous (local) decentralized heat and power supply in remote locations and in newly developed and already developed areas, which don’t have a centralized power supply system.

In addition to what has been said, it should be noted that the use of the cogeneration plants at sites of various purposes increases its energy security [5].

Equally important, especially in agricultural production, is the use of the heat of spent steam, and sometimes the steam taken directly from the boiler. The heat of steam can and should be widely used for drying grain, for preparing animal feeds, heating water, for heating and hot water supply for livestock farms, poultry farms, incubators, for all primary processes for processing and storing agricultural products at dairy, dairy, canning, cheese, felted and other types of production.

In this paper, the urgency of developing an energy complex with a steam engine for private farms is considered. In this case, when developing, for example, new lands under the "Far Eastern hectare" program, a problem arises with the electrification of these lands, since their development began relatively recently and the electrification of these sites by large power plants will not happen soon, in the absence of new capacities. Also, the above complexes are able to cover the needs of private farms located in these areas, in a very diverse range of drives of various process equipment.

2. Modern problems of ecology

Of great importance is the fact that mankind is faced with ever more escalating contradictions between its increasing needs and the inability of the biosphere to provide them without destroying the latter.

The careful [6] and rational use of natural resources is now becoming increasingly important. The solution of this urgent national economic problem presupposes the development of effective non-waste technologies at the expense of more complex use of the raw materials. This leads to the elimination of the large environmental damage caused by "cemeteries" of waste of various compositions. The very concept of "various wastes of consumption and production" for many of these "wastes" becomes conditional. They can turn into a very effective, valuable, and sometimes scarce raw materials. The development of scientific and technological progress is accompanied by increasing the production both in industry and in the agricultural sector, in which more and more natural resources are involved.
However, the degree of rationality of their application as a whole remains very low. So annually about 10 billion tons of mineral and almost the same amount of organic raw materials are used. At the same time, the development and use of the majority of the most important minerals in the world occur faster than the exploration of their reserves. For example, the costs in the industry of the CIS countries for raw materials, fuel and energy are estimated at about 70% of the cost.

The increased consumption of mineral raw materials leads to the accumulation of huge volumes of waste, and their elimination and storage ceases to be economically justified. Industrial production is increasing all over the world every year, and in proportion to its growth, the amount of waste is also increasing, approximately 2 times in 8-10 years. The total weight of various solid wastes generated annually only in the United States is 3.5 billion tons, that is, about 50 kg per capita.

The consumption of various energy resources is growing most intensively. Since the beginning of its existence, mankind has used almost 90 billion tons of equivalent fuel [6].

At each enterprise, whether industrial or agricultural, a certain amount of various wastes is generated and accumulated by the process. In total, the accumulation of only industrial waste in Russia per person per year is from 18 to 20 times higher than the norms for the accumulation of household waste.

Ecological balance is expressed in a sharp pollution of the environment associated with the formation of waste in the form of dump fields, as well as various emissions. In our country, a particularly acute situation has developed in the 43 most polluted cities in Russia such as Ufa, Omsk, Samara, Volgograd, Norilsk, Chelyabinsk, Moscow and many others.

On the territory of the Orenburg region there are a large number of enterprises and departments that are sources of waste generation. About 2 thousand hectares of land are occupied in the area of waste storage. About 16 million tons of household waste and about 1 billion tons of industrial waste have already been accumulated. Of particular concern is the fact that the dumps of solid domestic wastes which were formed spontaneously, without corresponding registration of land allotments and approvals by controlling bodies, represent unauthorized landfills [6].

The environmental situation at industrial enterprises is directly related to the existing methods of processing primary and secondary raw materials [7], associated production waste, as well as the development of new high-performance processes with wastewater treatment in closed water systems, with collection, recycling and regeneration processes spent oil products in transport, in the agro-industrial complex and in other branches of the economy.

When addressing environmental issues, it is necessary to take into account the fact that industrial enterprises are engaged in the development and production of new materials. These include new food products, plastics, polymers, colloidal solutions and composite fluids used as raw materials for the biological, pharmaceutical, chemical and other industries.

3. **Multifunctional energy and technological complex**

Based on the foregoing, the development of an energy complex becomes a critical importance in which it is possible to use various types of fuel including some domestic wastes, while generating the useful energy that is being used.

To solve these problems for autonomous objects of different purposes, a multifunctional energy-technological complex based on a steam-piston machine can be used.

The above multifunctional energy-technological complex can include various components and equipment, depending on its purpose and application, as well as on the type of the production serviced.

The list of basic standard equipment includes a gas generator for gas production, using fuel of various properties and composition, including various types of solid domestic waste. Here it should be noted that it is possible to use additional equipment to prepare fuel for use in a steam boiler.

The complex also includes a steam boiler to obtain steam of required parameters for the operation of the steam piston machine and, the steam-piston machine itself.

Steam, obtained by heating the water in the boiler, enters the cylinder of the steam engine through a short steam line. The piston of the cylinder rotates the flywheel of the steam engine through the crank-and-rod mechanism.
Generally, a piston steam engine can have various applications, for example, for generating electric power (an electric generator), driving any technological equipment (for example, a compressor, a pump, a sawmill, a conveyor and etc.). Here it should be considered the possibility of installing a reducer or be able to provide the necessary gear ratio taking into account the operating conditions of the equipment used.

Waste steam from the cylinder is further used for heating of various objects such as buildings in private farms.

4. Basic requirements for the energy complex
An autonomous multifunctional energy and technological complex and its components should have the simplest design and minimum operating costs. Also, the personnel of minimum required professional training can also be used to service this complex. It also does not require a high degree of automation. Nevertheless, it will require training of specialists for the features of effective operation of the complex at the site of application.

To increase the energy and economic efficiency of the application of such a complex, it is advisable to use local fuel of various properties, taking into account the minimization of their transportation costs, which is of rather importance in calculating the cost of heat and electricity and other economic indicators.

Besides that, the energy complex should have a long service life, be distinguished itself by the ease of maintenance and repair work to ensure that these operations can be carried out under operating conditions. The automation system should meet all technical requirements for performing technological operations during the complex operation, while at the same time being extremely compact, simple and easy to operate and maintain.

5. Parameters of the energy complex
The parameters of the energy complex are calculated depending on its purpose. At the same time, first of all, it is necessary to analyze the parameters depending on the purpose of the multifunctional energy and technological complex, defining its technical characteristics. Further, it is necessary to determine the parameters of the steam-piston machine itself - pressure and temperature of steam, its flow rate and the rotor speed. And only then the design research of the steam-piston machine and its equipment.

Also, one should take into account the possibility of using the heat of waste steam of a steam-piston machine for heating and hot water supply of a residential or industrial complex, or both.

The estimated calculations of the future proposed steam engine with the generation of an effective electric power is 150 kW.

The most suitable layout of the machine is horizontal, two-cylinder (high-pressure cylinder and low-pressure cylinder) with double expansion. The diameter of the high-pressure cylinder is 310 mm, the diameter of the low-pressure cylinder is 460 mm, while the steam pressure required for its operation is 1.2 MPa (12 kg / cm2) with a temperature of 573 K (300°C), its consumption is 1887 kg/h. The speed is 2.66 s-1 (160 RPM).

A steam engine rotates the generator to generate an electric current through a mechanical transmission. Generator BG-160M-4 by the Baranchinsky electromechanical plant was selected from the catalog. Technical characteristics of the generator are as follows: rated power – 160 kW; nominal rotor speed – 25 s-1 (1500 RPM); stator current – 289 A, efficiency – 91.6%. The transmission ratio is 9.4.

According to the preliminary design work of the steam piston machine, its dimensions are 4500 x 4200 x 1000 mm, and additional necessary power equipment and components can be selected from serially produced equipment. The typical scheme of the power complex is shown in Figure 1.
Figure 1. Typical scheme of the energy complex

1 – steam boiler, 2 – steam flow meter, 3 – steam pressure regulator, 4 – steam piston machine, 5 – high pressure cylinder, 6 – receiver, 7 – low pressure cylinder, 8 – generator, 9 – oil separator, 10 – consumer’s heating system, 11 – condenser, 12 – condensing pump.

6. Conclusion

Based on the above data, it follows that the development and use of multifunctional energy technology complexes based on steam-piston machines for autonomous objects of various purposes is an urgent and timely issue.

Among other things, this is confirmed by such positive aspects as minimum operating costs, the possibility of using different types of fuel, which also affects the cost reduction in its operation. With the use of various production wastes, including household waste, it is possible at the same time to improve the environmental situation on the territory of its operation. The availability of different production and intellectual potential in each particular territory makes it possible to manufacture it in various versions.

The availability of this source material on the design of a piston steam engine and its parameters gives a chance to carry out further studies on the calculation of the efficiency of its application in an energy complex for various purposes, taking into account the already necessary set of auxiliary equipment with their specific parameters.

References

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