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A. Mazurenko, DSc, Prof.,
O. Klymchuk, DSc, Prof.,
G. Luzhanska, PhD, Assoc. Prof.,
P. Ivanov,
I. Sergeiev
Odessa Polytechnic National University, 1 Shevchenko Ave., Odessa, Ukraine, 65044; e-mail: luzhanska@op.edu.ua

ENSURING INCREASED RELIABILITY AND EFFICIENCY OF HEAT SUPPLY SYSTEMS DUE TO THE USE OF MICROTURBINES IN CONDITIONS OF UNSTABLE POWER SUPPLY

А. Мазуренко, О. Климчук, Г. Лужанська, П. Іванов, І. Сергеєв. **Забезпечення підвищення надійності та ефективності систем теплопостачання за рахунок використання мікротурбін в умовах нестабільного енергоживлення.** Дослідження ефективності використання мікротурбін для надійного енергозабезпечення при роботі котельних, теплових насосів та інших систем малої та нетрадиційної енергетики. З огляду на тотальну світову економію паливно-енергетичних ресурсів, важку енергетичну ситуацію в Україні на перше місце виходять питання енергозбереження та надійної роботи систем теплопостачання, в тому числі автономних. Все більш актуальними стають розробки та впровадження нових технологій у галузі малої енергетики. Компактні розміри генераторів енергії, і, відповідно, їх мобільністьмвикликають інтерес у дослідженнях, розробці та застосуванні в малій енергетиці сучасних автономних енергетичних установок. В якості автономних можуть бути застосовані теплоенергетичні установки з різними типами агрегатів, кожен може виявитися раціональним для тієї або іншої конкретної сфери застосування і виду палива. На сьогодні існує ряд проблем, що по позволяє здійснювати організацію надійного енергопостачання. Серед них: енергодефіцит в регіонах, відсутність якісної енергетичної інфраструктури, перебої в енергопостачанні, низька енергоефективність генерації, високий знос устаткування теплових електростанцій і мережевої інфраструктури, відсутність централізованого теплопостачання на видалених територіях, висока енергоємність виробництва. Зараз для споживачів виникають ряд перешкод в надійній роботі системи енергопостачання, тому застосування мікротурбін в якості джерела енергії для об'єктів різноманітного призначення дозволять ефективно вирішути цю проблему. Застосування протитискових парових мікротурбін в котельних з паровими котлами – найбільш простий спосіб утилізації енергії парового потоку для вироблення електроенергії та подальшої утилізації тепла пари в бойлері. Переведення існуючих котельних у міні-ТЕЦ дозволить зробити ці підприємства високорентабельними. У розрахунках були прийняті в якості базових котли серії ДКВР, які є переважаючими нині на котельних. Розрахунок робочого колеса мікротурбіни робиться спираючись на рівняння Ейлера для плоскопаралельної течії. Аналізуючи виконані дослідження роботи мікротурбіни, можна зробити висновок про доцільність її використання для підвищення ККД та надійності функціювання автономних енергетичних установок.
Ключові слова: автономні енергетичні установки, мікротурбіна, системи енергопостачання, паровий котел

A. Mazurenko, O. Klymchuk, G. Luzhanska, P. Ivanov, I. Sergeiev. **Ensuring increased reliability and efficiency of heat supply systems due to the use of microturbines in conditions of unstable power supply.** Research on the effectiveness of using microturbines for reliable energy supply during the operation of boilers, heat pumps and other small and non-traditional energy systems. In view of the total global economy of fuel and energy resources, the difficult energy situation in Ukraine, the issues of energy saving and reliable operation of heat supply systems, including autonomous ones, come first. The development and implementation of new technologies in the field of small energy are becoming more and more relevant. The compact size of energy generators, and, accordingly, their mobility, arouse interest in research, development and application in small energy of modern autonomous power generation installations. Thermal power plants with different types of aggregates can be used as autonomous units, each of which can be rational for one or another specific field of application and type of fuel. Today, there are number of problems that make it possible to organize a reliable energy supply. Among them: energy deficit in the regions, lack of high-quality energy infrastructure, interruptions in energy supply, low energy efficiency of generation, high wear and tear of thermal power plant equipment and network infrastructure, lack of centralized heat supply in remote areas, high energy intensity of production. Now for consumers there are a number of obstacles in the reliable operation of the energy supply system, so the use of microturbines as an energy source for objects of various purposes will allow to effectively solving this problem. The use of counter-pressure steam microturbines in boiler rooms with steam boilers is the easiest way to utilize the energy of the steam flow to generate electricity and further utilize the steam heat in the boiler. The transfer of existing boiler houses to mini-CHP will make these enterprises highly profitable. In the calculations, the boilers of the DKVR series, which are predominant today in boiler rooms, were taken as the basic boilers. The calculation of the microturbine impeller is based on the Euler equation for plane-parallel flow. After analyzing the studies of the microturbine, it is possible to conclude about the expediency of its use to increase the efficiency and reliability of the operation of autonomous power plants.
Keywords: autonomous power plants, microturbine, power supply systems, steam boiler

Introduction

Today, turbines occupy a central place in the large-scale energy industry, they have proven themselves excellently with their operational characteristics, and have almost completely supplanted all

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competitors. Engines of this type are installed at all traditional power plants – thermal power plants, nuclear power plants, hydroelectric power stations, and there are no alternatives to them in the near future.

Turbines are less common in the small energy sector. For quite a long period of time (1950...1990), the large-scale construction of distributed energy systems was held back by the lack of an appropriate technological base. Today, new technologies and materials make it possible to make compact power plants available for autonomous power supply of individual plants, small factories and settlements. The mass production of such generators makes it possible to create new interesting solutions based on them, while using the source of energy that was always nearby, but yesterday did not bring any energy benefit.

Small-scale energy is a direction of energy related to the production of heat and electricity independent of centralized networks [1, 2]. The compact size of modern generators and their mobility are all attractive and characteristic features of installations in the small energy sector. As a result, the development and widespread use of autonomous energy systems (AES) in everyday life is an urgent issue in small power generation [3].

The areas of use of the low-power AES are very wide, namely: heating boilers, industrial enterprises, medical institutions, residential cottages, business centers and other objects of large cities; main gas pipelines, gas distribution stations, oil pipelines that require energy supply for normal functioning; enterprises for the processing of household waste; developing areas where there are currently no energy sources and power lines; energy deficit areas; reservation of power transmission lines that feed responsible energy consumers, as well as filling the electricity deficit caused by natural disasters and other emergency situations; mobile sources of electrical and thermal energy for the needs of the Ministry of Emergency Situations; small towns, cottage villages and villages, many of which still have not resolved the issue of centralized heat and power supply; etc., which require electrical, thermal, mechanical energy, water supply and compressed air [4, 5].

Thermal power plants with different types of units can be used as autonomous units: internal combustion engines; steam and gas turbines or their combinations. Each of these types of units can be rational for one or another specific field of application and type of fuel.

Analysis of the latest research

Today, there are number of problems that prevent the organization of reliable energy supply. Among them are energy deficit in the regions, lack of high-quality energy infrastructure, interruptions in energy supply, low energy efficiency of generation, high wear and tear of thermal power plant equipment and network infrastructure, lack of centralized heat supply in remote areas, high-energy intensity of production.

The most effective use of microturbines as an energy source is proposed to meet the energy needs of agriculture and communal infrastructure [4, 6, 7]. This contributes to ensuring and maintaining energy security, significantly reducing energy intensity in the industry. Microturbines enable the efficient use of renewable energy sources (biogas) for energy supply in rural areas and the use of heat pump stations [8, 9, 10].

The use of microturbines as a source of energy also contributes to preventing the growth of prices for heat and electricity for end consumers. Microturbines make it possible to effectively using the steam of low-potential boiler houses with steam boilers, as well as renewable energy sources (biogas) for energy supply in rural areas [9].

Now for consumers there are a number of obstacles in the reliable operation of the energy supply system. Centralized networks sometimes cannot allocate the necessary amount of electricity due to the lack of reserve capacities. Tariffs for the use of electricity are constantly increasing. In this regard, more and more users are looking for ways to reduce power costs, for example by using alternative sources. Overloading of municipal networks leads to interruptions in power supply, voltage fluctuations, and power grid failures. In other words, the user risks being left without electricity, heat and light, not to mention the failure of expensive equipment.

Goal

The purpose of the work is to create a microturbine generator for electricity production with integration into the steam boiler plant scheme.

Presenting main material

In the existing conditions of the energy crisis, the constant growth of energy prices, the construction of mini-thermal power plant based on back-pressure turbines, which are used as power-generating

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equipment, is relevant [6]. Counter-pressure turbines, which are installed in boiler rooms with *two-drum boilers* or others, work in the scheme of the boiler room instead of the reduction and cooling unit, or in parallel with it on the pressure difference of the saturated steam of the enterprise, which goes from the boiler to the technology, to heating and hot water supply.

If a steam turbogenerator is installed parallel to the reduction unit and steam reduction is done in the turbine, then instead of throttling in the reduction unit, electricity will be produced by the unit's generator.

The conversion of existing boiler houses into mini thermal power plants will make these enterprises more reliable and highly profitable [4].

Installation of a turbogenerator behind a steam boiler is under consideration. Based on this, the initial parameters of the steam entering the turbine are identical to those of the steam generated in the boiler. It should be taken into account that steam boilers in heating boiler rooms are operated at reduced pressure, excluding the super heater.

In the calculations, it was customary to focus on two-drum boilers, currently prevailing on boiler rooms. The steam temperature before the turbine corresponds to the saturation temperature at a given pressure. Steam is considered dry and saturated. The measure of pressure reduction, φ, is determined taking into account the pressure to which the steam is reduced. The internal relative efficiency coefficient of the turbine, η, is set based on the data of similar developments. The ratio of the average diameter of the outlet to the diameter of the impeller χ is set according to the required design characteristics. The enthalpy, h_0, and entropy, s_0, of the steam before the turbine is determined according to the temperature and pressure of the coolant at that point. The enthalpy of the steam at the exit from the turbine at an isentropic heat transfer corresponds to the coolant with parameters P_2 and s_0. The speed of the steam in front of the nozzle blades can be assumed to be within 30 m/s. The further calculation is based on the Euler equations for plane-parallel flow, which were applied for this type of turbine. To determine the main characteristics of the microturbine, we use the method of calculating radial-axial turbines and determine the analysis of the influence of the given power on the characteristics of the microturbine.

The results

We will perform a study of the performance characteristics of the microtubule under various parameters.

Variant 1

The calculation was carried out in the power range of 100...1000 kW with constant parameters:

– rotation frequency n=40000 rpm;
– efficiency η=80 %;
– degree of pressure reduction φ=4;
– parameter X_{ai}=0.8;
– parameter χ=0.6.

The results are summarized in Table 1 and also presented in diagrams (Figs. 1, 2).

Table 1

Results of thermal calculation in the power range for 1 variant of microturbine operation

N, kW	n, rpm	η, %	φ	D_1, mm	X_{ai}	G, t/h	χ	l_1, mm	l_2, mm	D_{2k}, mm	D_{2mid}, mm	D_{2p}, mm
	40000	80	4	214	0.8	2	0.6	3	6	123	128	134
200	40000	80	4	214	0.8	4	0.6	7	12	117	128	140
300	40000	80	4	214	0.8	6	0.6	10	18	111	128	146
400	40000	80	4	214	0.8	7	0.6	13	23	105	128	152
500	40000	80	4	214	0.8	9	0.6	17	29	99	128	158
600	40000	80	4	214	0.8	11	0.6	20	35	93	128	164
700	40000	80	4	214	0.8	13	0.6	24	41	87	128	169
800	40000	80	4	214	0.8	15	0.6	27	47	82	128	175
900	40000	80	4	214	0.8	17	0.6	30	53	76	128	181
1000	40000	80	4	214	0.8	18	0.6	34	59	70	128	187

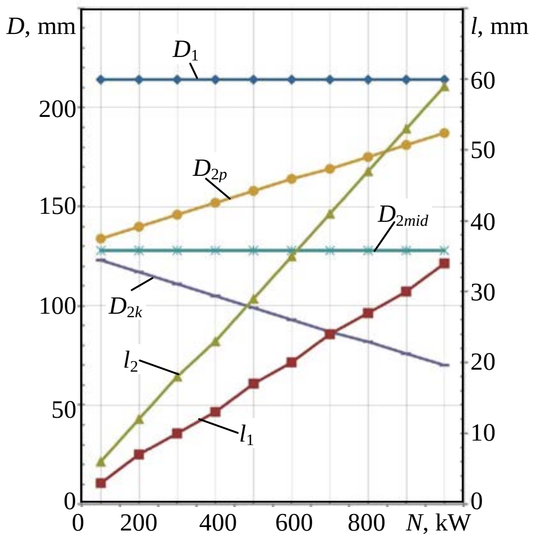

Fig. 1. Graphic representation of the results of the design calculation in the power range for 1 variant of microturbine operation

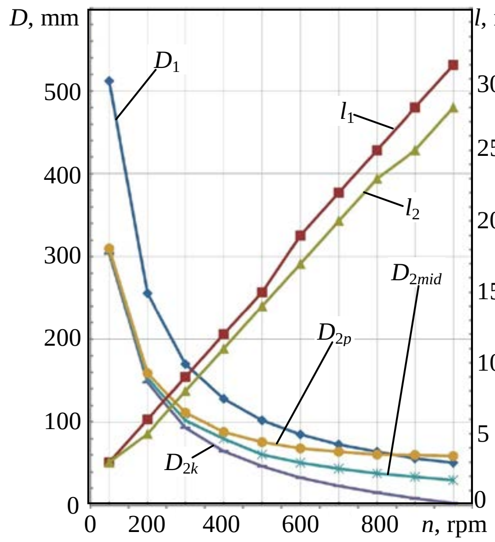

Fig. 3. Graphic representation of the results of the design calculation in the range of rotation frequencies for the 2nd variant of microturbine operation

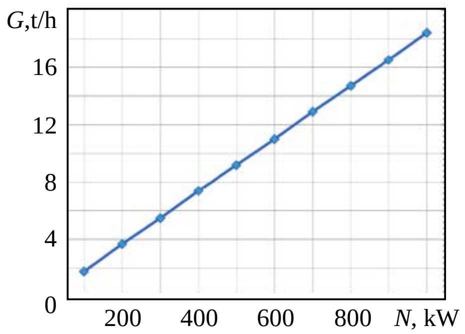

Fig. 2. Graphic representation of thermal calculation results in the power range for 1 variant of microturbine operation

Variant 2

The calculation was carried out in the speed range of 10,000-100,000 rpm with constant parameters:

– power N_t=200 kW;
– efficiency η=75 %;
– degree of pressure reduction φ=4;
– parameter X_{ai}=0.5;
– steam consumption per turbine *G*=4 t/h;
– parameter χ=0.6.

The results are summarized in Table 2 and presented in the diagram (Fig. 3).

Table 2

Results of thermal calculation at variable rotation frequency for the 2nd variant of microturbine operation

N, kW	*n*, rpm	η, %	φ	D_1, mm	X_{ai}	*G*, t/h	χ	l_1, mm	l_2, mm	D_{2k}, mm	D_{2mid}, mm	D_{2p}, mm
200	10000	75	4	512	0.5	4	0.6	3	3	304	307	310
200	20000	75	4	256	0.5	4	0.6	6	5	148	153	159
200	30000	75	4	170	0.5	4	0.6	9	8	93	102	111
200	40000	75	4	128	0.5	4	0.6	12	11	65	80	88
200	50000	75	4	102	0.5	4	0.6	15	14	47	61	76
200	60000	75	4	85	0.5	4	0.6	19	17	33	51	68
200	70000	75	4	73	0.5	4	0.6	22	20	23	44	64
200	80000	75	4	64	0.5	4	0.6	25	23	15	38	61
200	90000	75	4	56	0.5	4	0.6	28	25	8	34	60
200	100000	75	4	51	0.5	4	0.6	31	28	2	30	59

Conclusions

Analyzing the obtained results of the calculation of the structural and thermal characteristics of the microturbine of variant 1, we observe a linear increase in the steam consumption with an increase in the required power of the turbine, which was to be expected. The height of the vanes at the inlet and outlet of the flow is correlated in proportion to the flow rate. In the range of small powers, the low height of the blades can negatively affect the efficiency of the unit. It can be seen that in the area of the graph, the diameter of the impeller and the average diameter of the flow outlet remained unchanged, which results in a decrease in the root diameter with increasing power. It is worth paying attention to this, since this circumstance will lead to a decrease in the diameter of the shaft and possible inconsistency of its strength characteristics with the required ones. The shaft can be destroyed by the twisting moment when transmitting power to the generator. Therefore, it makes sense to calculate the strength of the shaft. From the results of the microturbine according to the 2nd variant, it can be seen that a decrease in the frequency of rotation of the rotor leads to an increase in dimensions. Another negative consequence of reducing the rotation frequency is the reduction of the channel width of the flow part, which leads to a decrease in overall efficiency. For these reasons, microturbines are made as high-speed as possible. However, an excessive increase in the rotation frequency will cause large centrifugal forces during the operation of the equipment. The possibility of operation of the structure under the specified conditions is controlled by calculation of strength.

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Мазуренко Антон Станіславович; Anton Mazurenko, ORCID: http://orcid.org/0000-0002-0165-3826
Климчук Олександр Андрійович; Oleksandr Klymchuk, ORCID: http://orcid.org/0000-0002-5207-7259
Лужанська Ганна Вікторівна; Ganna Luzhanska, ORCID: https://orcid.org/0000-0002-3784-5926
Іванов Павло Олександрович; Pavlo Ivanov, ORCID: https://orcid.org/0009-0002-8897-0222
Сергєєв Ігор Володимирович; Igor Sergeiev, ORCID: https://orcid.org/0009-0003-0476-717X

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