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Energy Efficiency of Nozzles for Axial Microturbines

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Abstract

The work is devoted to solving important problems of applied gas dynamics of turbine stages, concerning the low efficiency of the nozzle apparatus axial microturbines (angles of exit nozzles do not exceed 9 °), operating at supercritical differences of enthalpy, and is aimed at increasing the speed ratio of the nozzle apparatus (the ratio of actual downstream speed of the nozzle apparatus to the maximum possible - theoretical flow rate) and the prediction angle downstream from it.
The work is based on the results of mathematical modeling of gas-dynamic processes based on the of the results of a physical experiment. The results are presented as a formalized mathematical regression model type functions - the machine nozzle velocity and flow rate output therefrom angle depending on the following factors - the expansion nozzle; nozzle exit angle; angle of the front edge of the impeller; the theoretical value of the Mach number; dimensionless peripheral speed.
Such a presentation of the results allows not only for their numerical analysis and physical interpretation of the purpose of a comprehensive assessment of the impact on the speed ratio of the nozzle apparatus and the downstream corner of it, studied factors, but also for the performance of the optimization calculations.

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Keywords: nozzle; microturbine; rotor wheel; Mach number; efficiency.

1. Introduction

At the present stage of development of production reserves more economical running of the powerful stationary turbines are limited. This does not apply to turbines operating with limited weight and size characteristics: the gas flow and rotor speed. The turbines of the latter species are widely used in shipbuilding, traction devices, rail and road transport, decentralized energy systems, thermal plants, gas distribution stations, cryogenic engineering, and

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manufacturing. Such turbines are used as main engines, drive engines generators, pump aggregates and compressor stations, to boost diesel engines, in the turbo, while the transportation of gas to be used in the process of reducing the latter. They are also used as a motor for a manual air tool, cathodic protection systems, etc. In the future, these turbines are proposed to use for emergency cooling nuclear reactors when disconnected from the power supply [1].

2. Topicality

The relevance of the work is determined by its focus on solving the most important for the economy and industry of the problems associated with the development of highly efficient power plants, the need for an objective selection of the best technical solutions for microturbines used in power engineering.

The relevance of research is confirmed by numerous works of various authors in this field [2-7]. Also in these works reflects the application of turbines of this type.

3. Formulation of the problem

Turbine with relatively low power often work in conditions of deficiency of gas flow and the power required for the gas should have a high initial pressure and temperature. In this case, the density of the gas increases and the flow area of the nozzle flow is necessary to carry out extremely small. In this case, the turbine is made or partial supply of gas to the impeller or the height of the turbine blades do significantly less than the recommended value. Both options significantly reduce the efficiency of the turbine.

Alternative partial turbine stages are in the turbine nozzle outlet angle which is reduced to 5°. This design enables the turbine with a full gas supply at an acceptable height of the flow, which increases the efficiency of microturbines by eliminating the energy losses associated with partial supply, but such turbine elements and their solid parts still insufficiently investigated and have low efficiency. This is due to non-optimal regimes of the gas flow in the channels, as well as relative values with large surface roughness and long inlet and outlet channels, edge thickness and size of gaps. All this causes a relatively "thick" boundary layer flow and increased non-uniformity, which lead to a sharp decrease in efficiency of the turbine.

The main direction in which should be addressed to improve the efficiency of microturbines, gas-dynamic is improving nozzles nozzle units, providing a reduction in the kinetic energy of the gas loss, characterized by speed ratio nozzle units. Such a determination of the effectiveness of the nozzle apparatus allows to evaluate and compare its quantified at various variants of embodiment nozzles.

In recent years, the decision in the channels and the expiration of the supersonic gas flow problems are of great advances in the theory known as the "Mathematical theory of control physical fields in continuous media." This theory is intensively developing in our country, and abroad. One of the leading places in the world to address this type of control problems for models of continuum mechanics takes scientific group, which under the leadership of G. Alekseev developed a common management tasks for the research method and hydrodynamic models of heat and mass transfer, and developed efficient numerical algorithms for control problems for a number of models of continuum mechanics [8-11]. However, the results obtained on the basis of the aforementioned theoretical investigations do not currently have sufficient accuracy. This is due to the complexity of the mathematical description of the processes occurring during the movement of gas in the flow of the nozzle having a small size and a large three-dimensional non-uniformity of the flow at the exit of them, which is exacerbated by the presence of a rotating impeller. In connection with this investigation, it was decided to carry out on the basis of experimental methods, which not only lost its relevance but has gained prominence with the verification of the adequacy of the results obtained theoretically.

The results of the analysis of previous studies have shown that the greatest impact on the efficiency of the turbines has the perfection of the nozzle apparatus [12-13]. In this regard, this article discusses the results of efforts to improve the nozzle apparatus. Besides the direct impact on the design of the nozzle unit of the turbine efficiency at different operating conditions, the value of the static pressure depends on it in the area between the nozzle assembly and the impeller [14-16], which is related to the terms of the impeller [17].

Preliminary design development [18] and studies [19-21] have shown the possibility and prospects of selected areas of work. Furthermore, in [22] presents the results of studying the effect of various factors on the secondary