Automated complex for researching high-speed electric turbomachines

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Installations operating on the organic Rankine cycle can be autonomous sources of heat and electricity for decentralized systems of small distributed energy. In addition, ORC installations make it possible to utilize low-potential waste heat from industrial enterprises, thermal power plants and vehicles, which increases the overall efficiency of the equipment, being an additional source of useful electrical energy, and also reduces thermal pollution of the environment.

Rankine cycle diagram

Example of p-h diagram of Freon
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Possible technical solutions:
- Rated power 1-150 kW
- Rated speed up to 200,000 rpm

The main parts of the turbine unit:
- High-speed turbine
- Synchronous Generator with permanent magnet
- Foil gas-dynamic bearings
- Power and information electronics

High speed turbogenerator

installation on ORC
Increasing in the speed of rotation entails a decreasing in size. For flow part of microturbines is characterized by the partial supply of the working fluid and/or low height of the blades, which reduces the efficiency of the flow part. For the competent design of the machine, it is important to correctly assess the impact of losses at ends of the blades and partial losses. An experimental study is needed to study the flowing in the turbogenerators!
Since the testing of high-speed turbomachines for ORC installations requires the creation of special gas stands, it involves the purchase of complex equipment included in the cycle, it is advisable to test the flow and electromechanical parts of the turbogenerator on an air stand, satisfying of condition of gas-dynamic similarity.

Mechanically similar incompressible fluid flows

\[ Fr = \frac{u_0}{\sqrt{L \cdot g}} \]  - Froude number

\[ Sh = \frac{L}{u_0 \cdot t_0} \]  - Strouhal number

\[ Re = \frac{u_0 \cdot L}{\nu} \]  - Reynolds number

\[ M = \frac{u_0}{a} \]  - Mach number

\[ K = \text{const} \]  - isentropic rate

\[ E = \frac{\sqrt{u^2}}{u_0} \]  - turbulence rate
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Gas-dynamic stand for the study of critical components of high-speed turbomachines, as well as full-scale tests of low-power turbogenerators

1 - turbogenerator, 2 - compressor, 3 - dehumidifier, 4,5 - medium and fine filter, 6 - pressure regulator "before itself", 7 - shut-off valve, 8 - pressure regulator "after itself", 9 - liquid phase separator 10 - steam trap; 11 - noise mufflers. Electrical part - load in the form of incandescent lamps.
For high-speed, low-power turbogenerators, the best option for bearings are foil gas-dynamic bearings, since they have greater reliability compared to ball bearings, do not need an additional energy source, like electromagnetic and gas-static bearings, do not require lubrication, operate reliably at a wide temperature range, in conditions vibrations and shaking.
Foil gas-dynamic bearings are one of the most critical parts of high-speed machines. Bearings determine the type of construction, the magnitude of the axial and radial clearance, the frequency at which the gas layer appears, the maximum possible temperature of the housing, the required minimum starting torque, the number of reliable starts and stops of the machine. Since foil gas-dynamic bearings are not mass-produced, it is necessary to study their technical characteristics.
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At the stand, it is possible to test various sizes of gas-dynamic bearings with a wide range of diameters and air gaps between the shaft and the bearing housing, variations in the location of steel lobes with a special antifriction coating to obtain a picture of the wear of the foils and improve their profiling. It is possible to test the bearing capacity and damping properties, the frequency of “self-lifting”, the running-in time of the coating, also testing bearings in “Start-Stop” modes and continuous operation at a rotor speed of 10 to 12000 rpm with an adjustable bearing load up to 120 N.
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All presented stands are equipped with automatic measurement registration and processing systems. Information is transmitted via the interface to a personal computer with LabView software preinstalled, which allows for manual control of power installation elements in a graphical programming environment, as well as data collection, processing and storage schemes not only on a personal computer, but also in a cloud storage.
The created stands are part of an automatic complex for the study of high-speed electric turbomachines with the help of which is possible to study of both the power installation and its individual components.

Realized capabilities of the complex:
- Obtaining aerodynamic characteristics of flowing parts
- The study of dynamic and transient processes of electrical machines
- Testing of foil bearings in various configurations in accordance with ISO 13939: 2019
- The study of electromagnetic processes in high-speed magnetoelectric turbogenerators of low power
- Conducting a student learning process and using a stand as part of postgraduate research.
Thank you for attention!

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