Developing a Method for Operative Diagnostics and Appraisal of Working Capacity of a Combustion Chamber DG-90

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Abstract. In the paper the problematics of gas transport system, main factors of an urgency of the development are described. Stages of a proposed reconstruction of combustion chamber DG-90 are introduced. Basic elements of the elaborated method for appraisal of risks of an emergency situation occurrence are given. The expected efficiency from implementation of the produced method is described.

1. Introduction
Currently, in the gas industry of the Russian Federation there is an especially sharp problem of complete reequipment of the basic process equipment on compressor stations (CS) – gas compressor units (GPU), as 30 % exhaust the design resource, and about 30 % have worked out more than 75 % of their resource [1]. In the urgency of the given problem a financial factor plays a relevant role as now the cost of transport services, repair and spare parts grows, as well as of power carriers. Thereof, the increasing value is placed on problems linked to the reliability and increase in performance of gas compressor equipment. Identifying the faults at the primary stages of their occurrence results in reduction in expenditures on drive operation, and diminishes the possibility of occurrence of more severe kinds of faults.

A considerable quantity of failures of aggregates with gas turbine units (GTU) consists in a gasdynamic system, monitoring and diagnostics of which use only thermogasdynamic performances (flow rate, temperature, pressure). Calculations based on these parameters help to identify the performance extent (or wear) of separate GPU systems. Their shortage complicates monitoring and diagnostics of many phenomena, for example vibrating combustion, stall, a surging, combustion chamber burn-through, flameout, clogging of flowing parts, etc. [2, 3, 4]. Connection of thermogasdynamic performances and oscillations in a combustion chamber of a GTU is known and proved [5, 6], which allows to increase the quantity of recognition of such failures. Therefore, developing a method for operative diagnostics and appraisal of working capacity of a combustion chamber DG-90 of a gas turbine engine is an urgent problem having a relevant scientific value and practical application.

Accidents and malfunctions during operation arise due to structural and technological errors, material defects, etc. These factors can lead to serious consequences, such as destruction of GTE, which further harms the environment, decrease in reliability, performance and efficiency of the unit. Every year, analysis of the effectiveness of existing gas lines allows not only assessment of the operating state, but also introduction to the industry of requirements such as: improving the quality of pipe metal; improving the quality of insulating coatings of pipes; industrial development of the internal pipe coating technology at the factory; increasing the service life of GTU components and increasing the inter-repair intervals; development of new effective cooling systems of compressed gas; construction of various types of gas storage facilities, including liquefied natural gas storage facilities; creation of special high-performance compressors for pneumatic testing of main gas pipelines; organization of production of special machines for the repair work on the linear part of the gas lines (bucket wheel excavators, cleaning and insulating machines for gas pipes with a diameter of 1020 -
1420 mm); development and implementation of high-performance block-complex systems for gas treatment in the fields; development and launching the production of means of technical diagnostics of the linear part of main gas pipelines; development of reliable independent power supply stations of cathodic protection, etc.

Russian Emergency Situations Ministry predicts the next few years as a period of the peak of technogenic catastrophes in Russia. This situation is caused by the wear of fixed production assets and technological equipment, primarily in the oil and gas industry. The current state of the technological equipment of the oil and gas industry is characterized as critical. To date, 13% of gas lines is operated for over 30 years, 20% - from 20 to 30 years and 34% - from 10 to 20 years [8].

2. Research

To realize the purpose of the research, development of a method for operative diagnostics after conducting retrofits on a gas turbine engine DG-90. It will allow diagnosing the operation in real time and enhancing the odds of early determination of possible faults. After that, operative repairs will be carried in the shortest terms, without leading up to the maximum risk of emergency occurrence.

Because of high pressure and temperatures, a technical solution consists in using a sensor “Sapfir-22EM”, model 2170, having pressure measuring limits acceptable for a given retrofit, as well as a margin of error no more than 0.2 %. It is intended for continuous transforming of the value of overpressure, underpressure and differential pressures into the output signal dispatched on a control panel of the compressor station directly in a combustion chamber. Having made an opening in a membrane perpendicular to it, a sensitive member of a pressure unit is mounted on a high steel rod 350 mm in length and 30 mm in diameter, and is tightly fastened on a screwed joint with a sealing ring (figure 1).

![Figure 1. The proposed retrofit of a combustion chamber of a gas turbine engine DG-90.](image)

The pressure sensor “Sapfir-22EM” built into the combustion chamber DG-90 will show the operating pressure in a combustion chamber depending on the operating mode, and will signal in the event that the pressure will appear different from the design one. In this case it is diagnosed that a fault has taken place in a combustion chamber, and to exclude part of the main and auxiliary equipment from the list of possible defects. The signal is then fed to a compressor station control panel. That is, the principle of operation is to determine the effects of differential pressure on the membrane of the measuring unit (pressure transducer) and prompts deformation of the sensor and the transmitter deflection resistance. Further there is transformation into the eclectic signal transmitted in the electronic transducer (a PC and a communicator). The advantage is that data is received not only on a stationary computer, but also a portable communicator, and the operator can obtain information in real time even if he is at some distance from the PC (figure 2).
Figure 2. The proposed wiring diagram of the sensor “Sapfir-22EM”.

Figure 3. Diagnostic signs of violations of processes on CS DG-90 (mm w.g., efficiency, sec).

Figure 3 shows the approximate dependence of the engine efficiency on the operating pressure swing amplitude of the CS and the pressure pulsations timeline in the combustion chamber as planned, and the area beyond the maximum permissible norm called a surge (it is an abrupt change in a parameter that occurs in less than 5 seconds and holds the value for longer than 15 seconds).

It is important to emphasize that the forecast, diagnostics and monitoring of the GCU state is connected with the recognition of damage leading to gradual failures. The time of the defect development to a critical level is sufficient to predict the moment of the GCU failure. Dividing failures into gradual and sudden is to some extent arbitrary, since any abrupt change of parameters (characterizes the sudden failure) is preceded by a process of gradual change of the defining parameters [7].

In this connection, in the evaluation of efficiency of the combustion chamber a risk matrix has been designed.

The used risk analysis method includes calculating the probability of occurrence of an undesirable event and assessing the implications based on the information collected. A typical risk matrix is shown in Figure 4: horizontally arranged are pressure drop values, and vertically - the angle of deviation. Risks are ranked according to the degree of danger, in this case - low (green), moderate (yellow) and high (red). The low level of the possibility of risk least of all affects the operation of the unit and therefore its degree is minimum. The high level is the one that in the event of occurrence will be havethe greatest value for the degree of danger and can lead to destruction of the equipment, damage to the environment and personnel. The values are a dimensionless empirical measure based on
operating experience. The composed matrix is a reference, information basis for rational decision-making in the processing of risks.

![Figure 4](image)

**Figure 4.** Risk assessment factors of an emergency situation (mm w.g., days)

### 3. Conclusion

Today, when the risk of accidents and disasters on large and environmentally hazardous facilities is great, one of the first tasks is to anticipate, forecast, prevent and mitigate their effects. Assessment of the accident risk exists to identify the probability (or frequency) and severity of the effects of the accident occurred, the danger to human health, environment and property of the enterprise and is an essential element of its management.

Development and implementation of technical diagnostics, along with the use of new techniques and technologies at the CS, as well as along with the introduction of automated control systems may be regarded as the most important means of improving the reliability and efficiency of the gas-transport equipment. The conducted studies and recommendations on retrofitting the GTD are characterized by a significant expected technical and economic effect:

- the economic advantage is in prolongation of the engine durability without overhauling;
- it will allow to prevent the off-schedule disablement of the aggregate and minimize the fuel gas over-expenditure by inefficient operation of the combustion chamber;
- improving the safety of operations, due to the construction of the risks matrix for accident occurrence, will allow timely fault detection when changing certain parameters, which will help prevent disabling it and further destruction. Currently, under the present conditions of production, transportation and processing of minerals, the developed method for operative diagnostics will help to maintain a reliable operation of the GTU.

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