Development of a Method for Operational Vibration Diagnostics of a Combustion Chamber GPA-C-16C

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Abstract. The paper identifies the main causes of the GCU combustion chamber vibration, as well as emerging for this reason failures and defects. It describes the main elements of the developed method for operative diagnosing the GCU combustion chamber on vibration signals in real time. The expected efficiency of the implementation of this method is described.

1. Introduction

Currently, manufacturers and customers tend to conduct operation of gas turbine engines (GTE) on the gas-compressor stations, depending on their technical condition. Among the most important performance indicators are the costs of maintenance and repairs. And their minimization is practically impossible without effective control, monitoring and diagnostics in cases where the technical system is maintainable.

For many years, the issue of increasing the reliability and efficiency of the equipment of different areas of the industry by means of control and vibration diagnostics has been the subject of study of various scientists and authors. And today at CS a large number measuring and control devices and diagnostic systems is tested and operated, the introduction of which has already produced a positive result. Typically, these systems are built on a parametric control and diagnostics of thermal and gas-dynamic parameters of GCU. However, to date the most effective recognized systems are those based on the analysis of vibration characteristics responsible for the operation of the GCU and its serviceable or fault condition.

Unlike aircraft engines, turbines at gas compressor stations are facilities where vibration diagnostics can be implemented in its entirety. Operational statistics confirm the high efficiency of vibration diagnostics methods in the control of gas turbine unit state. Return of funds spent on the purchase and operation of diagnostic systems, usually occurs during the first fault prevention [2]. Operational vibration diagnostics and the development of new methods for detecting the causes of vibrations in the combustion chamber of the GCU will provide new options for assessing the effectiveness of its work, which determines the relevance of this work.

2. Research

One of the main units of the engine is its combustion chamber. Its work has an impact on the longevity and reliability of the engine, as well as its cost-effectiveness and impact on the environment. The combustion chamber of a gas turbine engine is a system in which complex and diverse processes take place.

Developing vibration diagnostics methods of the engine combustion chamber is an urgent task for today due to the fact that the combustion chamber of the engine is a resource-limiting element.

The intensity of vibration is expressed in vibration velocity rms value (mm/s) and by a method for monitoring the technical condition of the engine. The measurement is performed in a frequency range of 10 to 5000Hz, since this is the most appropriate range for the determination of the general condition of mechanisms and is a good indicator of destructive forces that affect these mechanisms.
To diagnose the technical condition of machinery and troubleshoot problems there is a method of spectral vibration diagnostics, since the vibration intensity monitoring allows you to detect malfunction of the unit, but does not indicate the cause of the excessive vibration [7].

Spectral diagnostics of the combustion chamber helps to identify potential threats to the functioning of the engine at an early stage and is a preventive procedure in large enterprises.

Visual diagnostics brings visible results, since during the inspection it is very difficult to detect flaws and damage to parts of equipment, which in turn deteriorates the quality of work and takes too much time. Therefore, the spectral vibration diagnostics is the perfect way to ensure effective diagnosis of equipment.

Sensors read continuously emerging vibration waves, as well as their size and amplitude resulting from the entire CS operation. Thus, monitoring can be carried out directly during the operation and does not interfere with the production cycle.

Diagnostics is carried out using the analyzer built on the basis of computer complexes.

It includes:
- a multichannel analog-to-digital signal conversion device (ADC);
- a personal electronic computer.

At present, equipping gas compressor units (GPU) with modern complexes is of great importance, allowing diagnosis of their technical condition during operation. Vibration diagnostics takes a special place among them, using modern means of digital and analog computers. Today, vibration methods are more efficient and the costs of their implementation have been declining. However, besides that their advantage lies in the fact that monitoring and diagnosis can begin at any time, including a few years since the equipment was put into operation, when the cost of routine maintenance and repairs will exceed the economically viable value [6].

As a result of years of research into the causes of failures and defects in the GCU equipment it has been revealed that a significant number of them is accompanied by a high level of vibration [1], in particular due to the inefficient operation of the combustion chamber and the resonance phenomenon. The combustion chamber is among the busiest elements of the GCU. Its parts are working under conditions of high static, dynamic and thermal loads, which directly affects the reliability of the mechanical part of the GCU. Its work has an impact on the longevity and reliability of the engine, as well as its cost-effectiveness and impact on the environment. Development of vibration diagnostics methods of the engine combustion chamber is an urgent task for today due to the fact that the combustion chamber of the engine is a resource limiting element.

The developed method is based on the identification of high-frequency vibration of the ship's engine DG-90 as part of GPA-C-16C using a piezoelectric transducer. According to the method, installation of three sensors is proposed in the combustion chamber housing in a circle every 120 ° (Figure 1). A vibration sensor MV-04 converts mechanical vibrations into an electrical signal proportional to the vibration acceleration.

![Figure 1](image_url)
A vibration sensor is mounted on the combustion chamber housing and under oscillations produces an electrical signal that is proportional to the vibration velocity. An amplifying and conversion device as a module integrates and amplifies the received signal. As a result, the output signal is produced proportional to the vibration displacement. This signal can be observed on the screen of the module and the computer. At this stage, we applied the method of automatic amplitude-frequency decomposition of the time recording of the vibration signal by the method of fast Fourier transforms and the subsequent presentation of the amplitude-frequency spectrum of the signal as a result of the analysis. According to the obtained spectrum, we judge on the vibrating state of the GTU.

As a result of the measurement, each sensor produced a spectrum of vibration velocity of the CS housing at predetermined points.

The obtained spectrograms give the analysis of a frequency range of 2500-5000 Hz which corresponds to the operating frequencies of a combustion chamber [3]. The resulting spectrogram of the CS housing vibration at the same mode shows that the sign of the pressure pulsations are identified easily enough by the vibration sensor at a frequency of 3850 Hz with an amplitude of vibration velocity of 5.9 m/c². This is likely to indicate a malfunction of one of the flame tubes.

In order to determine which of the 16 flame tubes runs with deviations, made vectors are construction based on available spectrograms. The vector length is set according to the amplitude of vibration velocity. The angle between the vectors is 120° according to the sensor location. Vector “a” is 1.3, vector “b” is 6, vector “c” is 1.9. We find the resultant vector using the cosine theorem, which points to a faulty flame tube. As a result of calculations we obtain the resultant vector “e” 4.37 in length and at an angle of 76.89° of the first vector. This vector points to flame tube 1 that requires inspection for faults (Figure 3).
3. Conclusion

It is vibration monitoring and diagnosis due to the specifics of vibrational signals that are primarily responsible for the overall control of the engineering state of the equipment and the prevention of accidents associated with the development of a variety of mechanical damages. However, if vibration diagnostics systems are paid much attention to down to the construction of automatic and adaptive systems of vibration diagnostics and systems of expert analysis of the vibration information, vibration monitoring systems are often referred to as just a necessary part of the overall system ensuring the operational reliability of the equipment. Organizations operating gas turbine engines lack confidence that the result they obtain by the vibration diagnostics systems are correct. This and the possibility of false removal and the lack of functionality and reliability of hardware-software complexes prevented the promotion of vibration diagnostics systems operation to the full.

The emergence of microprocessor technology, personal computers, compact computers for industrial and military use, powerful operating systems, advanced multi-channel, multi-bit analog-to-digital converters (ADCs), new tools, software solutions has intensified the process and led to the creation and implementation of numerous diagnostic complexes both for a special purpose and universal for a wide range of application. The use of vibration monitoring systems is one of the main solutions to the problem of sustainable functioning of the GCU, as it allows assessing the actual situation and on this basis taking informed decisions on the continuation of its operation.

The effectiveness of the implementation of the method of vibration diagnostics is made up of several indicators. First of all, a real turnaround time increases due to the fact that the unscheduled repairs are eliminated (according to statistics, unreasonable repairs reduce the required turnaround time by 15-30%). In addition, the rate of repair cost is reduced due to accurate detecting of defects. Eliminating these defects does not require dismantling the equipment and reduces the amount of backup equipment in separate processes and the amount of work as a whole is significantly minimized. Savings are also achieved by reducing costs unrelated directly to production costs. There is also reduction in the wastage rate resulting from downtime, production of rejects, as well as the costs of accident response. Due to the fact that the operation of the engine does not stop completely after failure detection, foreign experts estimated savings of up to 6% of the annual volume of production of the enterprise.
References
[1] Gareev R R and Yamaliev V U 2012 Determination of dynamic equipment based on the results of diagnostic measurements of a technical condition Oil and Gas Business 10-3 78-82
[2] Perevezentsev V T 2011 Diagnosis of gas compressor units with gas turbine engines
[3] STO GAZPROM 2-3.5-051-2006. Norms of technological design of gas mains
[4] Passport of turbine engine DG-90.
[5] GOST R ISO 13373-1-2009 2010 Condition monitoring and diagnostics of machines. Vibration monitoring of machine condition. Part 1. General methods (Moscow; Standartinform)
[6] Ishkov A G, Hvorov G A and Yumashev M V 2011 Formation of highly efficient energy-saving innovation technologies in the main gas transport in OAO “Gazprom” Science and technology in the gas industry 1
[7] 2008 Investigation of thermal processes at pipeline transportation facilities Edited by Zemenkov Yu D (Tyumen: Vector Buk) 224