Artificial intelligence in technical diagnostics in the example of a marine auxiliary diesel engine

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Abstract. The necessity of improving methods for determining the technical condition of ship power plants is justified, using the example of an auxiliary engine. A brief analysis of the most common systems of self-diagnostics is given. Features of development and use of artificial intelligence for diagnostics of internal combustion engines are described. The algorithm for conducting experimental studies to obtain a sample of diagnostic features is incorrect. The characteristics of synthesized neural networks are given and the accuracy of determining the technical state is estimated.

Introduction.
The increase in the complexity of technical systems due to the development and improvement of technology leads, in turn, to an increase in the requirements for the qualification of personnel and the quality of work related to the operation of equipment [1]. This makes it necessary to improve methods and tools for determining the state of technical systems, which can improve reliability and durability. Of particular interest are Express methods of technical diagnostics based on the principles of non-destructive testing, among which a significant place is occupied by an integrated approach using thermal fields. Thus, technical diagnostics based on the use of information from the thermal field of power plant components and aggregates, including ship and stationary ones, that are part of the coastal infrastructure is one of the promising methods of technical control of high-risk objects. The purpose of thermal diagnostics of power plants of offshore facilities is to quickly determine the technical condition through an engineering express audit of components and assemblies, taking into account the load level, conditions and terms of operation, the prospects for repair and replacement of equipment elements. From this point of view, express diagnostics is a highly effective means of reducing technological and man-made risks.

However, such methods require prompt processing of the array of parameters of the power plant, and as a result, not only the appropriate software, but also experienced highly qualified diagnostic engineers, the availability of which is limited.

In this regard, one of the rational ways to solve this problem is to use artificial intelligence based on the theory of pattern recognition, including the synthesis and use of neural networks [3]. Modern marine main engines have advanced diagnostic and self-diagnostics systems, for example, such as CEDC by Sulzer (Switzerland), DETS by Norcontrol (Norway), PED fioma Pilstick (France), diagnostic complex «Admiral» (Russia) and others, providing both continuous and discrete measurement of working process parameters and analysis of technical condition [2].
At the same time, auxiliary engines serving to ensure the operation of generators of ship power plants and other electrical equipment necessary for the performance of various types of work, for example, compressors, pumps and having much smaller dimensions and power lag behind in the development of such systems, which is primarily associated with considerations of economic feasibility. However, not only the power supply of the ship, but the reliability of its operation in general depends on the reliable operation of auxiliary engines.

Experimental technique for obtaining diagnostic features for a marine auxiliary engine

To assess the significance of diagnostic signs and create a neural network, well-known standard software packages can be used, for example, such as "STATISTIKA", "STATGRAF", etc. In this case, the greatest difficulties are associated with training the neural network, since this process requires a wide array of diagnostic parameters corresponding to specific faults in the power auxiliary unit. Thus, the key task is to collect and analyze statistical information during operation, or to simulate faults in an experimental laboratory facility, which is much easier from a technical point of view.

To conduct experimental studies to assess the significance of diagnostic signs used in the implementation of thermal vibration express diagnostics of ship auxiliary engines, the method of experimental studies of the dependences of operational thermal and vibration indicators on modes, developed at the VMPI VUNC VMA "Naval Academy", was used. Diesel 3D 6 was used as an object of research.

Laboratory experimental studies can solve the following problems:
1. Formation of an experimental laboratory setup.
2. Experimental determination of the reference values of temperature and vibration parameters at various modes of diesel operation.
3. Experimental determination of thermal and vibration parameters depending on the technical condition of the fuel equipment (cyclic fuel supply; fuel injection pressure; fuel advance angle). In loading and unloading modes
4. Experimental determination of quantitative values of diagnostic signs for further use in models of pattern recognition of the technical state of research objects.

Upon completion of the development of the goal and objectives of the experimental study, the experiment is planned, methods of its implementation and the choice of measuring instruments are developed.

The experimental laboratory setup consists of a liquid-cooled 3D6 (Figure 1) diesel engine and a hydraulic brake with a load indicator (1). A standard tachometer is provided for measuring the rotational speed (2). To measure the temperature of the coolant and oil, standard thermometers were used. The diesel engine gas exhaust system was prepared with chromel-alumel thermocouples. In this case, six thermocouples are installed inside the exhaust manifold opposite each cylinder.

Fig. 1. Experimental laboratory setup.
Fig. 2. Dependence of exhaust gas temperature on load.

A thermocouple mounted on the surface of the collector allows comparison of readings with those of the thermal imager. Experimental studies allowed us to create a database of dependencies of exhaust gas temperature and vibration level on the load (Fig. 2), speed (Fig. 3) and possible violations of engine adjustments (Fig. 4).

Figure 3. Dependence of exhaust gas temperature on speed.

Modeling a neural network begins with the formulation of a classification problem. For this purpose, the goal is categorized (belonging to the first, second, or third class of technical condition) and the designation of the number and parameters of the input data (values of temperatures and vibration levels). One of the ways to solve this problem is to divide the data array into two or three subgroups. The first of which is a training set, intended for training a neural network, i.e. analyzing the relationship between input and output data, creating a neural network model that predicts with minimal error. The second one is intended for the examination of the quality of the neural network and is used in testing mode. The third, the approver, is used for final control. The resulting neural network designed for determining the technical condition of a four-cylinder diesel engine contains nine inputs and three outputs (targets). Generalization of corresponding data to the highest determination
accuracy, is a priority when modeling a neural network. A significant amount of initial data (sample) and, therefore, the presence of noise significantly complicates the task of classification.

Figure 4. Dependence of exhaust gas temperature on fuel injection pressure

Automated neural networks (ANS) in the Statistica10 package at the initial stage of the modeling stage made it possible to choose the percentage of the training control samples, codes for using the training and control samples, the type of neural network, the minimum and maximum allowable number of neurons in the inner layer. ANS, upon completion of the verification of the operation of the neural network, indicates the accuracy during training and testing and due to what algorithms and functions this is achieved. Thus, the construction of an effective neural network is reduced to multiple enumeration of various network parameters in search of an optimal solution.

When determining the technical state of the engine, two neural networks were modeled, the architecture of which made it possible to obtain the accuracy of determining the belonging to one of the classes from 93.3 to 99.8 percent, depending on the data randomization. Modeling showed that the radial basis (RBF) type neural network achieved the highest accuracy. Quite accurate results were obtained when using a network with thirteen neurons of the inner layer (9-13-3) using the BFGS algorithm, the cross entropy error function (CE), activation of the inner layers using the Gaussian function, and activation of The Softmax layer [2].

Conclusion.
The use of artificial intelligence in rapid diagnostics of marine auxiliary engines is a complex, but promising scientific and technical task, the implementation of which can provide a high level of reliability by identifying faults at the early stages of their occurrence. The developed methods in combination with the thermal method of internal combustion engine diagnostics [3] allow us to synthesize neural networks for determining the technical condition of not only auxiliary ship engines, but also industrial engines

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