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System of operation monitoring and of early detection of technical condition changes of a marine piston diesel engine based on artificial intelligence

System kontroli pracy i wczesnej detekcji zmiany stanu technicznego okrętowego tłokowego silnika spalinowego opartego na metodach sztucznej inteligencji

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Key words: marine diesel engine, monitoring, safety, artificial intelligence

Abstract

In the modern systems of operation monitoring and of early detection of technical condition changes, additionally to the monitoring and measuring function, there is required the analysis of information in purpose to support the operator in making decisions. Such high complexity of a problem needs application of the fast methods of analysing the information in variety of aspects. Presently, in monitoring of a marine piston diesel engine tremendous importance the methods have, which are based on artificial intelligence both in a meaning of analysis of the individual processes and in complex analysis of a whole object. Merits of the artificial intelligence methods are – high flexibility, versatility and possibility to use the object for analysis with no need to have a mathematical description of the examined object, or occurring processes, what often imposes the considerable difficulty and restrictions in examination to be carried out.

Słowa kluczowe: okrętowy silnik o zapłonie samoczynnym, monitoring, bezpieczeństwo, sztuczna inteligencja

Abstrakt

Od dzisiejszych systemów kontroli pracy i wczesnej detekcji zmian stanu technicznego, oprócz funkcji kontrolno-pomiarowej, wymaga się analizy informacji, których zadaniem ma być wspieranie operatora w podejmowaniu decyzji. Tak duża złożoność problemu wymaga zastosowania szybkich metod wielotorowo analizujących informacje. Aktualnie w kontroli pracy okrętowego silnika spalinowego olbrzymie znaczenie mają metody oparte na sztucznej inteligencji zarówno w rozumieniu analizy poszczególnych procesów, jak i analizy kompleksowej całego obiektu. Zaletą metod sztucznej inteligencji jest ich duża elastyczność, uniwersalność i możliwość wykorzystania do analizy obiektu bez potrzeby posiadania matematycznego opisu badanego obiektu i zachodzących procesów, co często stanowi poważną trudność i ograniczenia w przeprowadzeniu badań.

Introduction

The marine piston diesel engine of self-ignition can be adjusted to fulfil various functions in the complicated technical object such as a ship. The marine engines can be divided into the following groups:

- main engines (SG) – used for driving (indirectly or directly) of the main ship propeller (the most frequently a screw propeller),
- auxiliary engines (SP) – used for driving (indirectly or directly) of the current generators, cargo pumps, important equipment of specialised ships,

– emergency engines (SA) – used for driving (indirectly or directly) of emergency equipment (pumps, compressors, generators).

Depending on the performed function, the engines are adjusted to fulfil the tasks formulated according to the tasks given to the objects, in structural and functional constructions.

The engine operating and control consist of many processes running in parallel or series organisation structures. Control by decisions of such type of object is connected with a fast, parallel analysis of many data in system [1, 2].

It depends on quality of the taken decisions, whether controlling is efficient. Decision quality depends on accuracy and reliability of the operating decision. Decision-making process is dependent on analysis result of the diagnostic parameters, among which there can be rated the diagnostic data attributed to technical condition of elements, knots, systems or a whole engine. Application of the artificial intelligence methods to monitoring of operation, detection and localisation of the damages or failures of the marine diesel engine allows to parallel process signals coming from the object. The artificial intelligence methods allow eliminating the complicated mathematical models and approximation of nonlinearity of the processes occurring in the engine.

Problem analysis

Control of the engines operation takes place according to two operating algorithms:

– algorithm of operational task of the object within the structures of which the engine functions and the purpose of it is to optimise the object's operating processes,
– algorithm of operational task of the engine and the purpose of it is to optimise the engine's own operating processes.

The operational tasks set for the main engine (SG) depend on the engine technical condition. Technical condition of the engine can be divided into three condition classes:

– condition of full worthiness – makes it possible to fulfil operational task with assumed efficiency,
– condition of not full worthiness – makes it possible to fulfil operational task with limited efficiency,
– condition of unfitness – makes it impossible to fulfil operational task.

Discussion / Practical implications

High complexity of the problem requires application of fast methods, which analyse the information in many aspects. Also, identifying as quickly as possible of the processes occurring in the engine is very important. Especially useful in the processes of operation monitoring and in early detection of changes are the neural networks due to their special properties of parallel information processing. Methods of information processing and selection as well as the way of decision making in nervous system are the examples of solving many problems related to information processing. Potential capabilities of neural networks, within which each one neuron working independently is an independent information processing centre, while a whole network is built of the thousands of neurons that are able to do many operations simultaneously, are enormous. Such a way of processing enables to obtain very high efficiency in analysis and calculations. The key element in marine engine controlling and operating is classification of its current condition. Full picture of the object is connected with analysis of many parameters related to each other. Classification is one of the most popular methods of data exploration. The classification task consists in creation of a model, which makes it possible to attribute a new, earlier not seen object, to one of predefined classes from the file. Model that makes such attribution possible is called a classifier. Classifier performs attribution on basis of experience gained during training on a teaching file. Efficiency of the majority of exploration methods falls dramatically with increasing number of the processed data.

The problem of neural networks application to monitoring of the marine diesel engine comes down to development of neural classified of the object conditions on basis of the collected and current measurement data. The approach can be adopted, which consists in recognition of the pictures as the current object conditions. The object such as a marine engine is, can be described with help of the map of conditions that illustrates the current values of system operating parameters as the points of a plane. Change in value of operating parameters is shown as the position change of the points in relation to each other on the plane. Application of neural networks carries the problems related to choice of network architecture and a way of teaching. In case of description of the engine object in a form of a topographic map of the conditions a solution is to use the Kohonen's neural network [3].

This type of network has a feature of reproducing the complex shapes; thanks to this ability neurons can learn any kind of reproduction. Another characteristic feature of this type of network is a process of self-learning consisting in competition between the neurons. The neural network responds to the input signals. Obtaining of the final order of the neurons system corresponds to the conditions of examined object. In this way use of Kohonen's network eliminates the need to teach network the new patterns. Network becomes an intelligent classifier of very high flexibility. Reduction of increase of a number of parameters to describe the object does not require changing the operating way of the control monitoring system, as it has the capability to adjust to the new working conditions [4, 5].

The neural classifier of the object conditions may be a detector of the hybrid system of operation monitoring and of detection of the changes in technical condition of a marine diesel engine. The neural networks analyse signals coming from the object undergoing a diagnosis. Associated with an expert system, which uses the obtained information about the object condition, they make a decision on the ways of responding to the emergency conditions. The expert systems have the capability to solve the set task with use of knowledge base, despite the fact that the information provided may be not accurate and logically conditioned at the same time. Association of such two methods together following a pattern of co-operation between receptors and a processing centre allows parallel processing of information and assessment of the object condition in actual time.

Conclusions

The presented concept of operation monitoring system combines the modern methods of parallel data analysis. Due to use of the Kohonen's neural network for classification of the object conditions, a very high ability of the systems to adjust and to analyse not typical conditions of object can be achieved. Associated with expert system it creates a hybrid system of operation monitoring and of early detection of the technical condition, which is able to learn during operating and respond in emergency situations to support the operator in making decisions, in particular under stress. This method can be used by application (SG, SP, SA) accordingly to a function fulfilled by engine in organisation structure of technical object (a ship).

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