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APPLICATION OF ARTIFICIAL INTELLIGENCE METHODS IN DIAGNOSTIC OF A SHIP COMBUSTION ENGINE – MAPS OF DIAGNOSTIC PARAMETERS

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Summary

In the real ship's conditions, the methodology of taking an operational decision is based on the analysis of simple diagnostic data. The quality of a correct multi-criteria analysis of such data is the more dependant on the SDG diagnostic system the lower the professional competences of the engine operator. The complexity of the problem requires application of quick methods that analyse the information in a multifaceted way. The description of the current states of the engine operation can be presented in the form of a topographic map showing the current values of the operation parameters of the system, as scaled and correlated points on a plane. A change in the values of the operation parameters is imaged as a change in reciprocal location of points on the plane. On the basis of a topographic description, a classification of the engine operation state can be carried out by means of a neural classifier. Such a method of the engine operation classification will allow for obtaining a very high capability of the diagnostic system for adaptation and analysis of untypical states of the object and an easily construed visualisation of results.

Key words: *artificial intelligence, diagnostic of a ship Diesel engine, map of diagnostic parameters, diagnostic system.*

1. Introduction

Different breakdowns of rates of a piston combustion engine operation can be encountered in the literature.
In the operational practice, a marine engineer operates an engine that can be diagnosed with the methods available on a ship. The diagnostic system (SD) existing on the ship consists of the diagnosed system – the engine (SDN) adapted in a specified way for fitting of a diagnostic system (SDG) to it, consisting of sensors. The accuracy and reliability of the diagnosis depends on many factors, including the accuracy of selection of measurement points, the type of measured parameters, the measurement accuracy, the correct analysis of diagnostic data and the quality of the drawn conclusions – as good as the knowledge and the experience of the engine operator and the knowledge of an engineer who designs a diagnostic system.

An essential problem is the multi-criteria analysis of the measurement data and imaging of results of such analysis. The competences of operators are very different and they are often not able to correctly read and use the results prepared and given by the SDG, which influences the level of rationalism of their operational decisions. In the real ship's conditions, the methodology of taking an operational decision is based on the analysis of simple diagnostic data that can include parameters of power media (most often the values of temperature and pressure) or accessible process parameters, e.g. the charge compression process in the cylinder or the combustion process. The quality of a correct, multi-criteria analysis of such data is the more dependant on the SDG diagnostic system the lower the professional competences of the engine operator.

The complexity of the problem requires application of quick methods that analyse the information in a multifaceted way. Identification in the shortest time of processes taking place in the engine is very essential. Therefore the description of current states of the engine operation can be presented in the form of a topographic map of states that images the current values of the operation parameters of the system as scaled and correlated points on a plane. On the basis of the topographic description, a classification of the engine operation condition can be carried out by means of a neural classifier. Such a method of the engine operation classification will allow for obtaining a very high capability of the diagnostic system for adaptation and for analysis of untypical states of the object and an easily construed visualisation of results.

2. Criteria structures taken for identification of the engine state

Example criteria structures that can be taken for identification of the engine state include:

- construction structure (different materials of specific physical and chemical properties, adequately fitted tribological systems, etc.),
- organisational structure (co-operating subassemblies and assemblies of devices and the engine, operating within a precisely specified time, adjusted and controlled),
- process structure (combustion process, cooling process, heating process, wear process (friction, oxidation, ageing, etc.).

There is a set of couplings between the structures that can be determined in an experimental way but they cannot be predicted in a computational way with too many non-measurable unknowns and the necessity to apply many simplifications.
Changes in the structures, in their serial dependences differ between themselves with their characters.
Changes taking place in the structure of interdependencies of mechanical parts are visible and immediately detectable and identifiable (vibrations, noise, pressure loss of media, tightness of systems, e.g. hydraulic, compression pressure systems, etc.).
Changes in the process structure are often detected with a long delay, are detectable but hardly identifiable, often with wrongly determined genesis and predictions (e.g. high temperature of exhaust gases – it may mean too low injection pressure, too large openings of an injector – but the reason can be different than the injector, e.g. too low fuel viscosity (too low temperature for a particular sort of fuel), wrong injection time, wrong ignition time, wrong time of valve opening, wrong process of head and cylinder liner cooling, leaky piston and cylinder system.

The parameters of the engine operation determining the technical condition of the engine, closely attributed to the adequate structure and the area of the engine can be topologically imaged on the "map of parameters" with anomalies, possibly explicitly geometrically or colouristically deformed and clearly suggesting the operational decision to the operator as an alternative to any graphs and fields of operation non-identifiable and non-comprehensible to the operator (with different levels of technical knowledge).

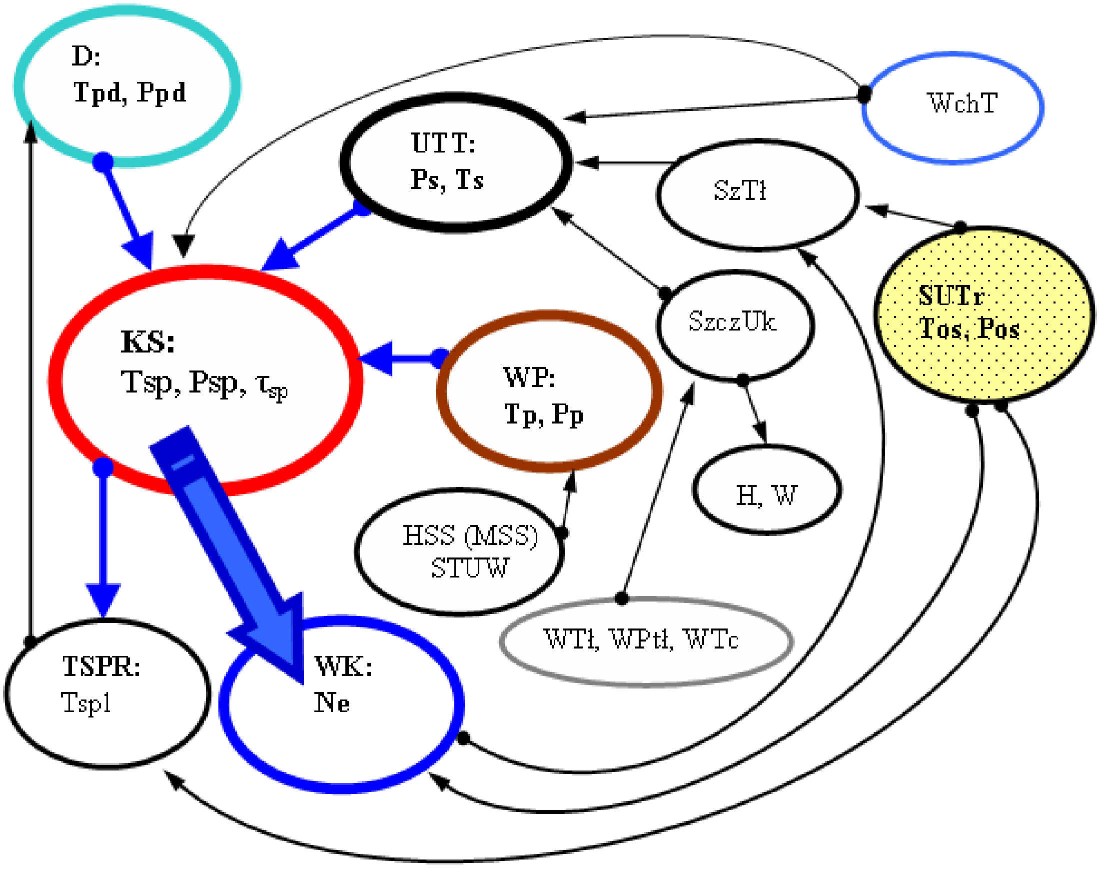

Fig.1 Dependence of the combustion process on the criteria structures of the engine:
KS – combustion chamber: *Tsp – combustion temperature, Psp – combustion pressure, τsp – combustion time*
D – supercharging: *Tpd – supercharging air temperature, Ppd – supercharging air pressure, TSPR – turbocharger,*
UTT – liner-piston system: *Ps – compression pressure, Ts – compression temperature, Tspl – temperature of exhaust gases, SzTł – piston speed, SzczUk – system tightness, WPtł – dimension of piston rings, WRtł – dimension of piston grooves, WTc– dimension of cylinder liner, WchT – cooling water for liner,* ***WP – fuel injection:*** *Tp –fuel temperature, Pp – fuel pressure, HSS – hydraulic controlling system, MSS – mechanical controlling system, STUW – technical condition of injection system,* ***WK – crankshaft:*** *Ne – shaft power,* ***SUTr – lubrication of tribological systems:*** *Tos – temperature of lubricating oil, Pos – pressure of lubricating oil*

3. Maps of diagnostic parameters of an engine

The Fig. 2 shows the idea of creating maps of diagnostic parameters of an engine. A circle is the simplest geometric figure, on the basis of which the initial model has been based. It is possible to create a ‘set of maps’ divided into ‘packages of maps’, the quantity of which is limited only by the capacities of electronic equipment. Due to editorial limitations, the idea has been presented on a single map.

The ‘map’ should, in a simple way, signal the trends of changes in particular structures. Centric circles set the rings (three outer ones separated from the inner ones by a dotted line) defining the values of parameters: the white ring means normal state, the broken ring (outside the white one)

means excess of parameters above the upper limit of normal values, the dotted ring (inside the white one) means excess of parameters below the lower limit of normal values.
In order to facilitate understanding of the idea, the image area (image on the screen) has been divided into four zones.

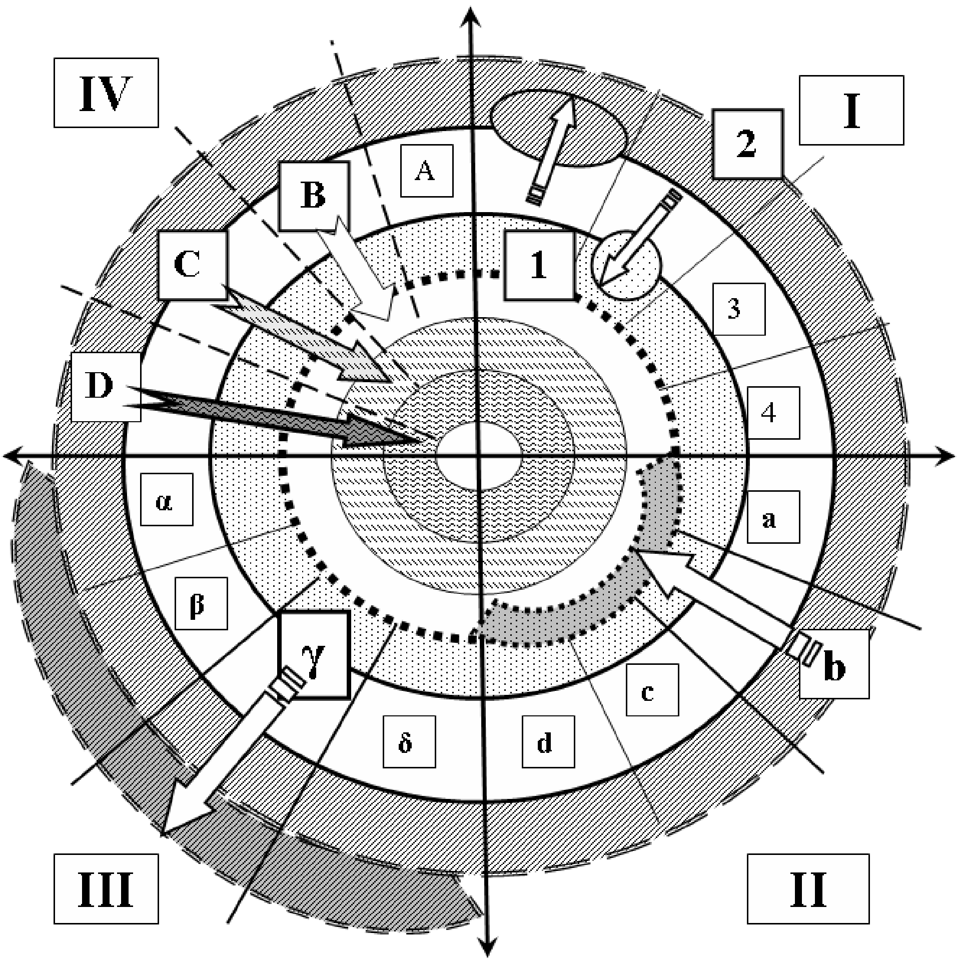

Fig. 2. Idea of creating of a map of diagnostic parameters of an engine:

- field "I-1" excess of the upper limit of the normal parameter relating to the dimension or the operation of an engine element or subassembly

- field "I-2" excess of the lower limit of the normal parameter relating to the dimension or the operation of an engine element or subassembly

- field "II-b" excess of the lower limit of the normal parameter relating to the dimension or the operation of a device or the engine system

- field "III-γ" excess of the upper limit of the normal parameter relating to the dimension or the operation of a device or the engine system

- field "IV-B" - a field determining the state of full efficiency of an engine

- field "IV-C" - a field determining the state of partial efficiency of an engine

- field "IV-D"- a field determining the state of inefficiency of an engine

-"outer circles" - a field determining normal values of parameters (green colour)

-"outer circles" - a field determining excess of the lower value of the normal parameter (yellow colour)

-"outer circles" - a field determining excess of the upper value of the normal parameter (red colour)

► In the zone marked with "I", excess of limits of parameters concerning particular systems or devices has been shown (depending on the class of the map detailing):

- in the field "1" visualisation of excess of the upper limit of the normal parameter has been shown,
- in the field "2" visualisation of excess of the lower limit of the normal parameter has been shown,

► In the zone marked with "II" and "III", excess of limits of parameters concerning subassemblies or the whole engine has been shown
After processing by the logic system, the influence of the parameter change on a subassembly or the whole engine can be shown:

- in the field "II" visualisation of excess of the lower limit of the normal parameter of the engine operation resulting from change in one or in several parameters of the engine elements operation has been shown (e.g. damage to the injection system in one system),
- in the field "III" visualisation of excess of the upper limit of the normal parameter of the engine operation has been shown,

► In the zone marked with "IV" visualisation of the condition of the whole engine has been shown ("inner" rings limited from outside with a dotted line):

- in the field "B", the white arrow shows the field (white) of normal operation of the whole engine marked with green colour,
- in the field "C", the grey arrow shows the field (marked with a thin wavy line) of limited operation marked with yellow colour,
- in the field "D", the dark grey arrow shows the field (marked with a dense wavy line) of unsuitability for operation marked with red colour,

In practice, such approach to the analysis of states of the engine operation can be accomplished with use of artificial neural networks. The advantages of such implementation methods are their high flexibility, versatility and possibility to use them for analysis of the object without the necessity of having the mathematical description of the object. The neural networks have got the ability for parallel processing of information and recognition of topographic maps reflecting the current state of an object under diagnosis.

For recognition of the object's condition one can use two types of networks: learning networks and self-learning networks.
The learning networks are most often used for well defined problems where we have got the knowledge what the network's response will be. For the learning networks it is possible to create a neural classifier of states (double-state or triple-state). However, the structure of such classifier is complex and the learning process is quite laborious. Input of new elements into the tested system requires changing of the neural network architecture and its re-teaching.

An alternative solution is the application of the Kohonen's neural network. Such networks have got the feature of topographic imaging of complex shapes, thanks to which they learn any imaging.

Another feature of such network is the process of self-learning consisting in competition between neurons. The neural network responds to the input signals. Obtaining of the final order of the system of neurons corresponds to the diagnostic maps of an object under testing. Input of new elements into the system does not require significant changes, and the neural network adapts itself to new tasks. A detector of the hybrid diagnostic system of a ship engine can make the neural classifier of the object's conditions. The neural networks analyse signals coming from the diagnosed object. On the basis of the base, the expert's system takes decisions by making use of the information about the current map of the object's state gained through the neural network.

4. Summary

Modern ship engines need rational operation aiming at both increasing their reliability and their efficiency. Therefore development of diagnosing systems that make use of the most modern technological achievements enabling processing of data is evident. Depending on the type of diagnostic information and the expected results of operation of a diagnosing system, different mutually supplementing methods of data processing are used.

Therefore, application of neural networks as a supplement of statistical and probabilistic methods used at different stages of the engine control and diagnostic processes allows for shortening the time for assessment of technical condition of elements, subassemblies as well as the whole engine. The idea of maps of diagnostic parameters presented in the paper is another trial of visualisation of the results of the SDG operation that allows a mechanic for determination of the condition of the engine in a short time as well as for monitoring the trends in changes of diagnostic parameters. At the same time, it may contribute to selection of an unambiguous operational decision of high degree of reliability worked out by the SDG to the mechanic.

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