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USE ASSESSMENT OF MODERN DIAGNOSTIC SYSTEMS OF INTERNAL MARINE COMBUSTION ENGINES AT THE SUPPORT PHASE OF EXPLOATATION DECISIONS IN THE ASPECT OF ECONOMIC CRITERIA

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Abstract

Modern diagnostics systems despite being equipped with the latest technical and technological solutions are usually systems only informing an engineer about values of tested parameters. Based on this information, an engineer has to determine the condition of the engine and undertake exploatational decisions based on his knowledge and experience under the pressure of knowing that any operational decision is associated with costs. It is the cost, which is the most important criterion for evaluation of a mechanic by the owner. Fear of negative evaluation by the owner is often the cause of late or Incorrect decisions which lead to breakdown. The article assesses gradation of the consequences of the decision-making performance by a mechanic on the engines of different economical purpose. An evaluation of selected diagnostic systems was made and a model for diagnosing system was proposed, which on the basis of economic criterion would facilitate making exploitation decisions by a mechanic.

Key words: diagnostics systems, model for diagnosing system, basis of economic criterion, exploitation decisions

1. Introduction

Marine engines can be divided according to use into main three groups:
- Main propulsion Engines (ME)
- Auxiliary Engines (AE)
- Emergency propulsion Engines (EE)

Each of these types of engines has its work performance determined by cost-efficiency, navigation safety and environmental protection. Especially because of the consequences (positive and negative) of the engine exploitation, for further analysis a main engine was chosen, which is used for direct propulsion of the ship.

Analyzing the importance of the criteria effecting decision-making, particularly related to a different types engine handling, paradoxically, the greatest importance should be attributed to an economic criteria.

Modern diagnostics systems (SDG) despite the latest technical and technological solutions are often only systems informing an engineer about values of the parameters or their changes. Based on this information, an engineer has to determine the condition of the engine and undertake exploatational decisions based on his knowledge and experience under the pressure of knowing that any operational decision is associated with costs. It is the cost, which is the most important criterion for evaluation of a mechanic by the owner. Fear of negative evaluation by the owner is often the cause of late or Incorrect decisions which lead to breakdown.

2. Engine exploitation

The main aim of the operation of the ME is to provide energy for the propulsion of the vessel to perform the designated exploitational tasks. Readiness of the engine to allow a vessel to perform designated tasks, the efficiency of operation and reliability of the engine when performing tasks and safety of its functioning depend on the quality of the exploitational process. In the exploitational system, the engine may be used or operated, or operated and used at the same time [5,6]. The specificity of the main engine operation in marine conditions requires process planning.
- ME use under "normal" circumstances, in which the efficiency is most important while keeping environmental protection requirements,
- ME use in conditions other than normal (complex, dangerous or emergency, or even catastrophic), where the priority is to get to the place which guarantees safety for crew and vessel,
- scheduled operating, during which there is no threat to life of the crew and loss of the ship, and the goal is the restoration of full functioning of ME
- unplanned use (needed in case of damage), often carried out in the sea, during unfavorable external conditions creating health risk to the crew and the risk of loss of vessel, which is aimed at restoring to at least to a state of partial functioning, allowing to get to a safe location.

During the exploitation of ME, while vessel is at sea, marine conditions create danger due to accumulation of adverse events, which forces the crew to put the necessity of keeping ME running as a priority over efficiency and environmental care - which is the only guarantee of saving the life of the crew and preventing the sinking of a ship. In critical conditions, the only criterion for the safety of the crew and the ship, in addition to buoyancy, may be depending on the condition of the ME, minimum maneuvering speed.

Analyzing the damage, including those that were considered failures of engines it can be concluded that at least some of them could have been avoided. The causes can be divided into several categories:
- design errors,
- hidden defects or damage to the structure of the material due to overheating during the heat treatment
- incorrect assembling
- incorrect exploitation (working outside the field of engine performance, poor supervision of the engine and so on)
- inappropriate selection and incorrect preparation of means, including incorrect mechanical processing, inadequate filtration, centrifugation, homogenization, lack of control and incorrect chemical treatment of energy agents), incorrect values of thermal parameters, lack of control and crossing of time intervals between handling of all kinds.

To avoid or reduce the occurrence of above causes, it is necessary to take appropriate steps individually to each cause:
- development of construction
- using original parts and elements or parts authorized by the manufacturer
- handling and montage according to Technical Documentation (TD),
- careful recruitment of the crew controlling and developing skills of the crews
- application of diagnostics to the needs of process of operation control of engines,

use of databases obtained in the process of diagnosis for the analysis of the occurring damage.

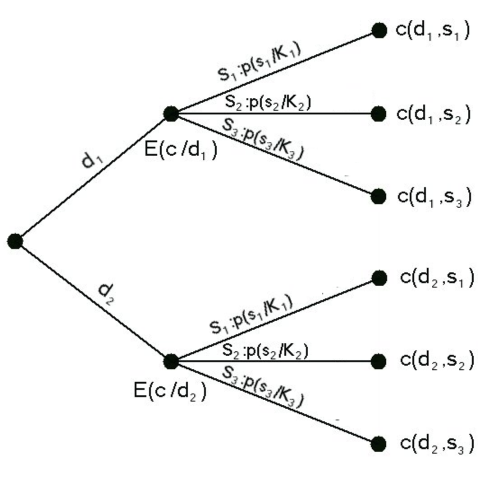
3. Diagnosis systems (SDG) – research and assumptions

ME is a complex object and its model enabling to obtain diagnostic information can be a combination of different forms of models.
The proper work of ME (in the so-called normal state) depends on the proper state of all its elements. Therefore it is important to identify the impact of the individual components or subsystem, as well as system, for the proper functioning of other elements, together with consequences being reflected in the quality of the processes occurring in the engine.

The variable and difficult marine conditions, in which exploitational decisions can cause even the loss of a ship and life of the vessel crew, the relevance of exploitational decisions is of particular importance.
The value of the consumption of the engine structure approaching the limits should be indicated, and even the replacement should be recommended. Manufacturers such as MAN and Wartsila have catalogue parts databases in their CoCoS and CBM systems.
Damage to main engine (ME) occurring in realistic conditions is a random event. The effects of each failure will depend on:

- time of identification of change of condition leading to damage
- accuracy of the identification of changes in the ME,
- accuracy of decisions being consequence of the identification of the condition change of ME

In the sea conditions, in which its assumed that the crew can only relay on its own skills and technical capabilities, timely detection of the existence of partial worthiness can help to rescue the crew and cargo, as it allows crew to ensure the safety of the ship. Therefore, it is important to use diagnostic system (DS) adopted for operational needs following a necessity of making decisions by the staff and the owner [6].
The main issues, which exploiter has to consider when deciding, are traffic safety of ME, environmental protection [9] and exploitational efficiency of the ME. There is therefore a need to construct a model of such decision-making process, that reflects these issues, while reducing to minimum risk of taking wrong decisions in-service [5,6].
In order to make the right operational decision, its needed to estimate the importance of this decision that is predict the consequences. Despite of the complexity of this issue, there are solutions developed by means of mathematical formula [5,6]. However, in real terms, particularly in random and variable sea conditions, it is very difficult to predict the consequences of exploitational decisions all the more because there are variable whether conditions and crew operating ME changes practically on random basis.



Pict.1 decision making dendrite, showing measurements of accuracy of diagnosis of the existence of the technical condition of the engine, provided there is an adequate diagnostic parameter vector K [6]

ME is a complicated object, model being information carrier can be a combination of different forms of models. On the basis of allocation of the selected engine operating states to the relevant diagnostic parameters, a diagnostic model was developed for the relations shown in Figure 2.

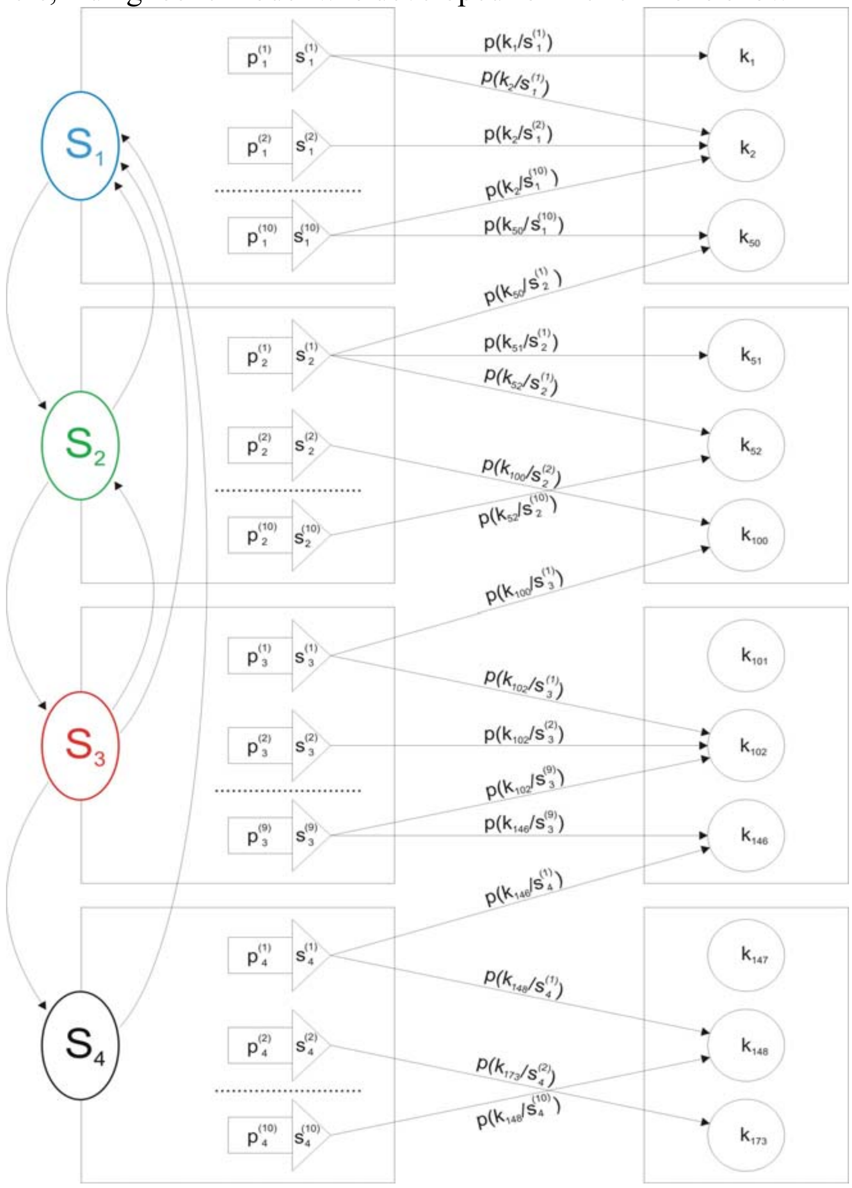


Fig. 2. Relations in the ME diagnostic model: pii - probablity of the sij, sij condition - the state of the engine from the set S (s1, s2, s3, s4), p (s / sij) - probability of occurrence of the diagnostic parameter s in the presence of the sij, s – Diagnostic parameter, S1, S2, S3, S4 - ME classes of conditions [8]

It should be emphasized that the results of decisions, which will enable verification (in real life), taken by human-operator, are the consequences of those decisions.

4. Existing diagnosing systems (EDS) - CoCoS (MANBW), CBM (Wartsila)

Modern computer programs are designed to imitate human thinking and eliminate human emotions. Therefore, work is underway to create "artificial intelligence" [9]. However, that programs creating "artificial intelligence" are as good as good is man (men) - "knowledge engineer" creating these programs. Therefore, the quality of the result of EDS, which is diagnosis, is dependent on the accuracy and reliability of diagnostic data, proper processing and use of that

data to determine the diagnostic parameters, to be used to correctly identify the technical condition of the engine, in order that the engineer (operator) undertakes
rational exploitation activities..

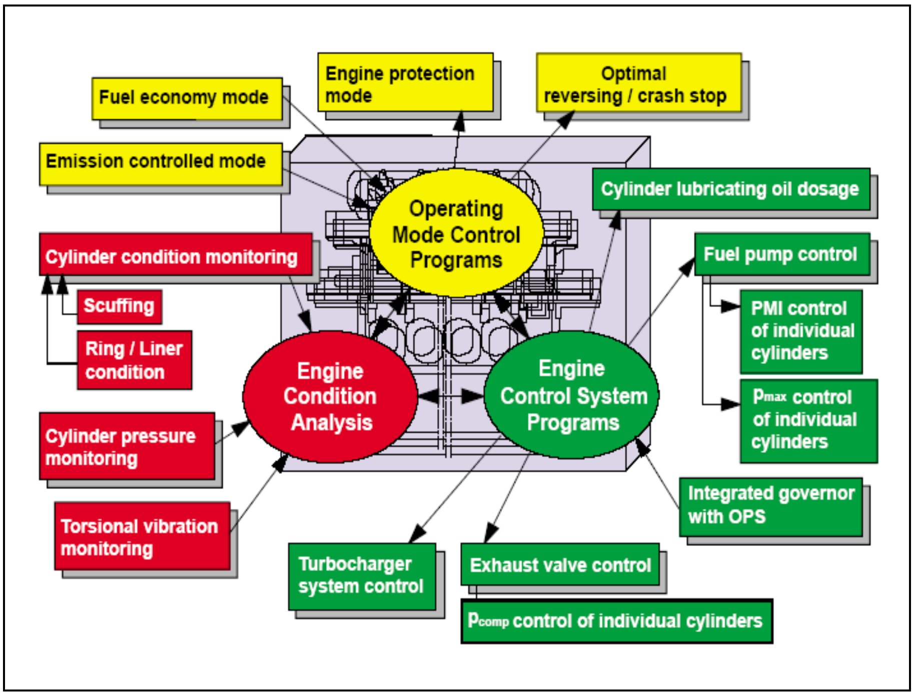


Fig. 3. Diagram of intelligent engine concepcion [10]

Engine manufacturers MAN and Wartsila, created their own models of the rational exploitation of engines. In the construction of systems (Cocos-MANBW, CBM - Wartsila) ship's reality, engine crew needs and the needs of the owner are visible. In both models a hierarchy of values of data measurement is displayed, access levels, considerate data archiving system and attention to detail in planning and reporting, saving time of a mechanic. Both systems based on Windows operating systems make it easy to use. Cooperation of the modules of the system, good communication and information flow are visible. Manufacturer's knowledge, acquired during the research and development, the experience of service and from engines users is a basis for ongoing development and improvement of "expertise know how" of EDS systems and DENIS, and a basis for adjusting the engine to the diagnostic instrumentation.

►►CBM system - Condition-Based Mainttenance (Wartsila)- [4, 11]
Wartsila decided to bring together the experience and expertise of its staff to support crews of vessels. Wartsila is aware that the user experience in the area of reliability of engines of the of the same type are different and result from the difference between knowledge and experience of crews, differences between the decisions of the owners, and thus the use of different grades of fuel, lubricating oils, spare parts quality, frequency and quality of scheduled handling. At the same time knowing that the first alarm signal can generate different decisions when operating in conditions of limited access to the highest level of marine technical knowledge and experienced servicemen.

CBM system consists of following panels:

a) **DENIS** - (**D**iesel **E**ngine Co**N**trol and opt**I**mizing **S**pecification) contains data needed to control the engine, it uses systems of companies: the Norwegian KMSS and Japanese NABCO,
b) WECS-9500 - (**W**artsila **E**ngine **C**ontrol **S**ystem) contains the elements needed for a computerized RT-flex engine type control, including programs, connectors, sensors, instrumentation, signal converters,

c) MAPEX- (**M**onitoring and m**A**intenance **P**erformance **E**nhancement with e**X**pert knowledge) panel containing technical solutions used as a tool to perform a specific task.

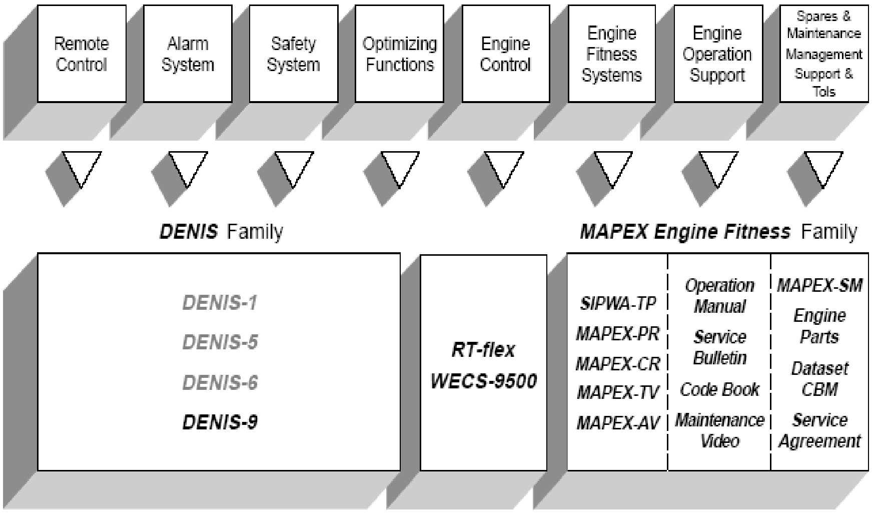


Fig. 4. General outline of CBM diagnosing system [5.12]

►► CoCoS - Computer Controlled Surveillance system (MANBW) [1,2,3]

Cocos System was created specifically to manage the operation and maintenance of the two-and four-stroke ME and AE. Tasks, which were set for the Cocos system are: collection, processing and analyzing data, planning, control, Ships assets management, crew training.

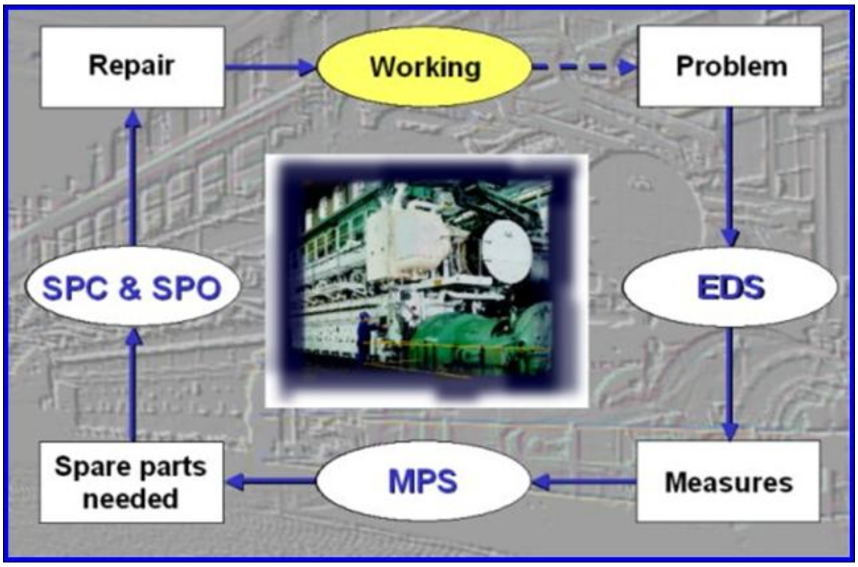


Fig. 5. outline of the CoCoS system functioning [4,11]

System consist of four modules [3]

a) **CoCoS EDS** (Engine Diagnosis System) – which includes fixed and portable instrumentation of the engine, computer equipment (hardware) and software operating the engine.

b) **CoCoS MPS** (Maintenance Planning System) – consists of: application software, and hard copies archive which are sets of papers and set prints

c) **CoCoS SPC** (Spare Parts Catalogue) – comprising of: application software, and hard copies archive

d) **CoCoS SPO** (Stock Handling and Spare Part Ordering) - includes the application software, and hard copies archive.

5. Exploitational decisions

Mechanics, based on the identification of the ME condition propose the concept of (reasonable) operating activities to the owner. Often fail to convincingly justify a decision on a specific preventive service (as diagnostic parameters do not exceed the limits) and they fear liability for any decision taken, which generate measurable cost. The value of these costs exceeds a dozen or several dozen times earnings of the decision maker, therefore it strongly affects the psychological area (fear of the opinion that worker generates costs) and influences taking irrational decisions. At the same time working conditions in the engine room, way of work on the ship, cultural diversity of the crew, random, changing working conditions (weather, sea conditions, operating situations that cause crashes, move cargo, etc.) require constant attention, causing fatigue, loss of sensitivity for stimuli and, paradoxically (to always changing conditions of life on the ship) routine, mindless exercise of their official duties, which reduces the capacity for rational action.

In exploitational reality, identification of the operational condition of the engine is based on the sequence of events making up the diagnostic process, which include:

- Collecting operating data by the diagnosing system (DS) of the engine in real time
- Comparing the current performance indicators with the indicators from the database developed by the manufacturer and with conditions designated by the manufacturer s_1, s_2, s_3,
- Reviewing by the engineer on the basis of his knowledge (theoretical knowledge and experience) and organoleptic tests, namely his psycho-physical abillities. Note that every engineer (SD operator) has a different knowledge and different experience (which make up his competency), which does not always produce positive results in the form of accurate and reliable diagnosis,
- Elaboration of an assessment result of these diagnostic measures, which sets the course of changes (forecasting)
- Elaboration of suggestions of actions to support the decisions of a mechanic to take reasonable action in service.

Exploitation operations of a mechanic may be results of diagnosis, which was made on the basis of information obtained through own research, and based on information from the DS as a tool to support rational decision-making service. Its mechanic's competence to decide what decision will he tak and the consequences of those decisions.

Factors effecting proper operation and adoption DS to testing main engine (SDN) is shown in Figure 6 [8]. The process of collecting, analyzing and processing of data is divided into seven blocks:

I - The organizational structure of the diagnostic system (SOSD)
II - The technical structure of the measurement of parameters (STPP)
III - organizational structure of measurements (SOP)
IV - current diagnostic parameters (BPD)
V - data analysis (AD)
VI - diagnosis (DGZ)
VII - operational decision-making (PDE).

The shape of each block is dependent on many different factors. This structure shows how complex operational decision-making process is and how important is the visualization of diagnosing system performance SDG.

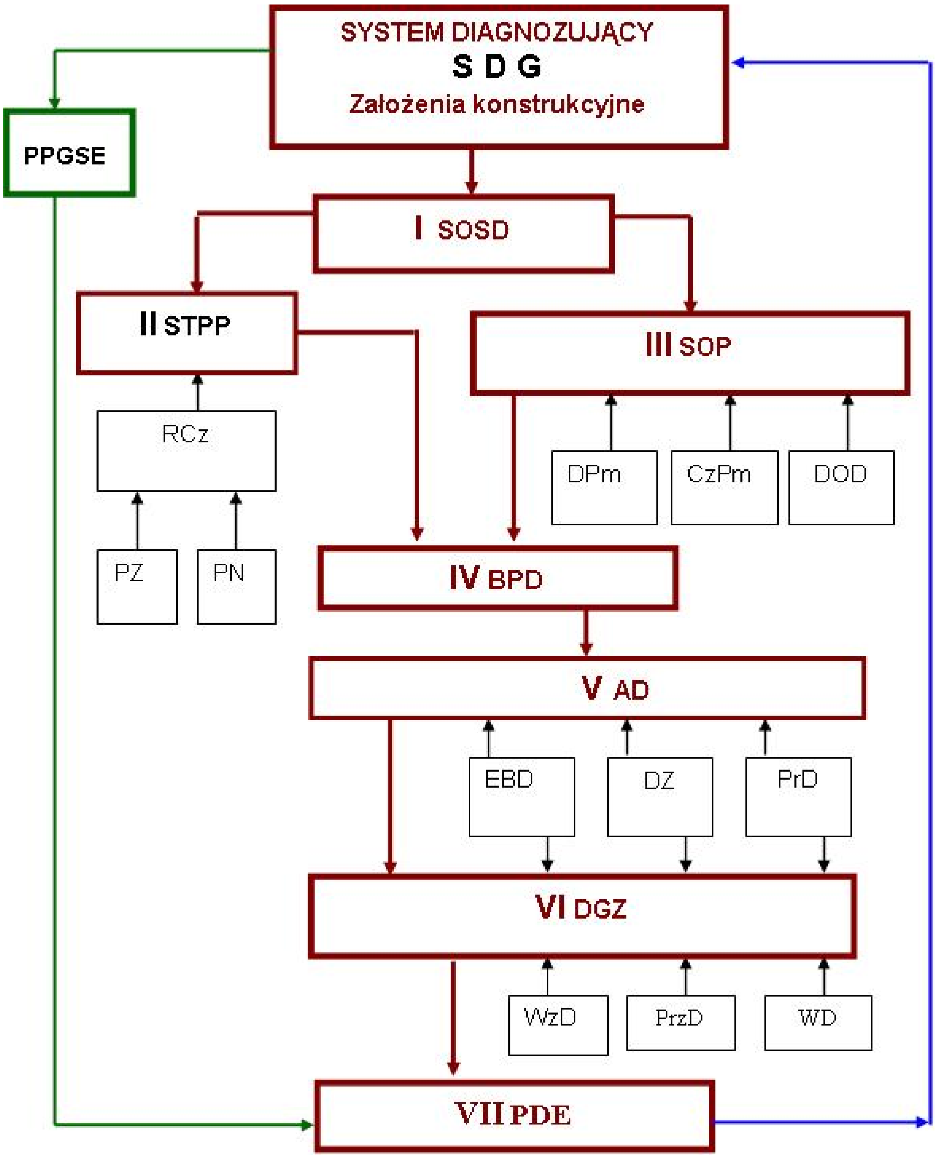


Fig.6. Factors effecting proper operation and adoption of SDG: I SOSD - organizational structure of the SD, II STPP - Technical structure of parameters measurement, RCz - the deployment of sensors, PZ - complex parameters, BS - required parameters, III - The measurement of organizational structure, DPm - accuracy , CzPm - measuring time, DOD - accuracy of data capture, IV BPD - current diagnostic parameters, V AD - data analysis, EBD - Expert database, DZ - the experience of the crew, PRD - diagnostic program, VI DGZ - diagnosis, Wzd –diagnosis visualization, PrzD usefulness of the diagnosis, WD - reliability of diagnosis, VII PDE - operational decision making, PPGSE - designed limit states of performance potentials [8]

Visualization of "genesis" and "forecast" should be clearly identified by a mechanic.

According to the author's belief, as a result of developing a "genesis" (the sequence of events preceding the change) further consequences can be determined (especially negative) and on the basis of experience in the manufacturer's continued operation, when determining the probability of an event or set of operating conditions of the engine, take into account the potential for lasting change of element node, or an entire system of main engine. Therefore the ongoing registration of limit values exceeding is suggested. It seems that the degree of reduction of potential may be determined by manufacturer who has a thorough knowledge of the experimental studies [10,11]. In the existing DS alarms and courses of changes of parameters are well marked and visible, but there is no clear suggestion of a mechanic activities. Therefore, the figure shows clearly an outline which allows suggesting a pattern of mechanics performance, based on economic calculation.

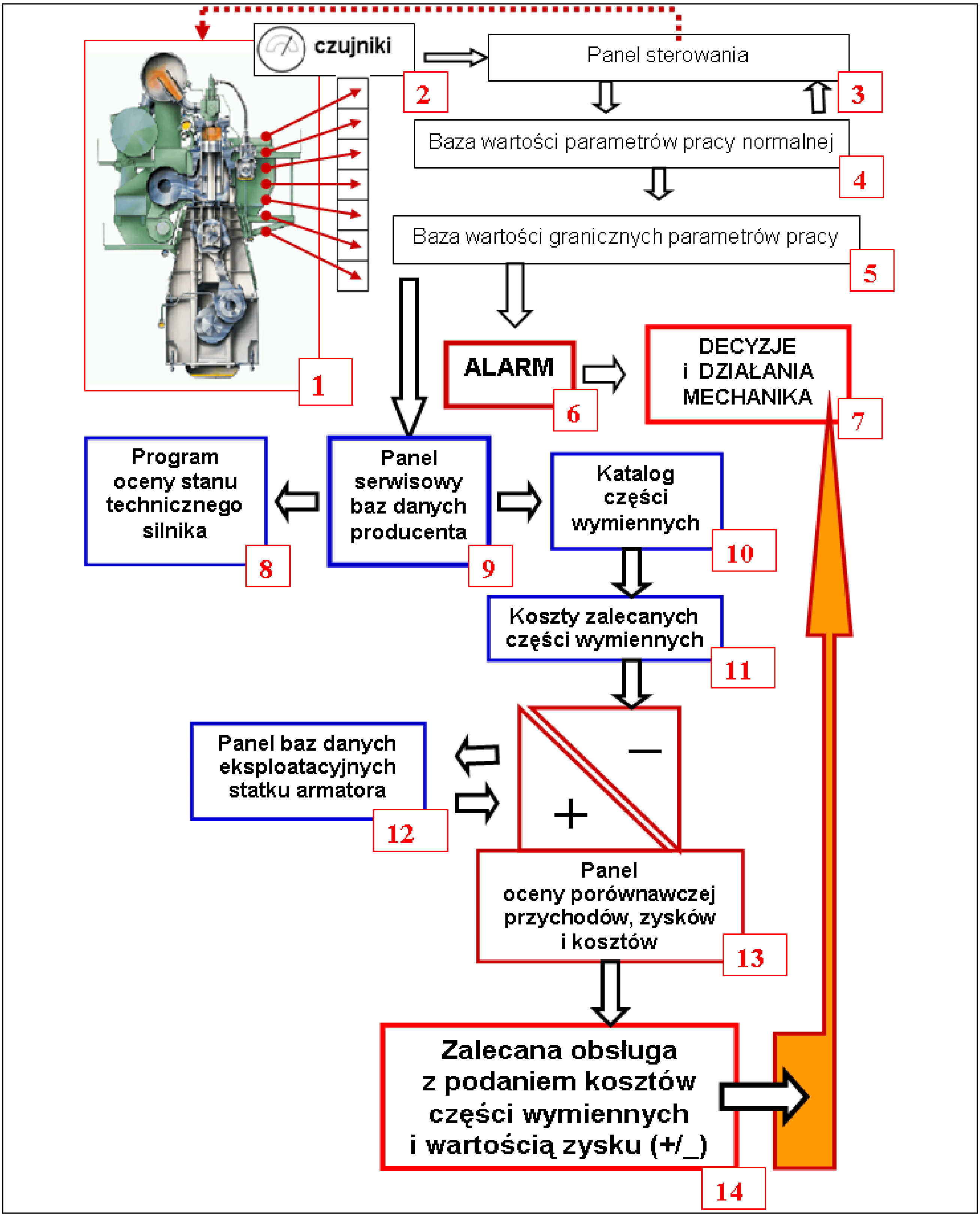


Fig. 7. DS outline enabling engineer's operational decision support through a clear suggestion of actions based on economic calculation. :1.Main Engine (ME), 2.detectors,3.control panel,4. the values database for normal operation, 5. database of performance limits, 6. alarm, 7. mechanic's operations, 8. evaluation of technical condition of the engine program,9. the service panel for the manufacturer's database,10. catalogue of spare parts, 11. the cost of recommended spare parts, vessel operating databases panel, - of the owner,13. a panel of comparative assessment of revenues, profits, and costs,14 recommended servicing giving the cost of replacement parts and value of profit

Conclusion

Modern systems CoCoS and CBM have many features suggesting an attempt by the manufacturers to find an optimal model diagnostic system. "By continuousl monitoring of activities of mechanics, systems are forcing them to constant skills improvement. They also enable to install instructional, simulation programs on board, and verification tests controlling knowledge and perception of mechanics. At the same time allowing insurance companies to accurately assess the classification and operation of the engine and allow manufacturers to compare the actions of the machine crew with the instructions contained in system programs. At the same time it should be noted that the full effectiveness of systems can only be achieved using the CoCoS on the engines from MAN B & W, and the CBM only Wartsila-Sulzer engines, and in close cooperation with the manufacturers [1,2,10,11].

How large is the role of human powers is evidently seen in today's DS and especially SDG. The most advanced mechani's decision support systems on a ship are based on the joint actions:

- Engineer on board (the operator) collecting data from SDG
- Owners experts who evaluate on the basis of data supplied from the ship, use owner's database, use own (subjective experience), but are not in direct contact with the engine,
- Manufacturer's experts who will evaluate on the basis of data supplied from the ship, use the manufacturer's database (including data from unpublished trials failed and the failure of other engines), use their own (subjective) experience, but are not in direct contact with the engine.

These actions can produce synergetic effect, but a mechanic has to decide which operating action to take. A mechanic is responsible for any decision.

At the same time, it appears that these are systems targeted at mechanics with extensive knowledge of the subjects of science and highly skilled.

The proposed model of developing suggestions for mechanic's operations based on economic calculation gives the mechanic a tool to justify rational exploitation activities to the owner.

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