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DIAGNOSIS MODERN SYSTEMS OF MARINE DIESEL ENGINE

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Abstract

In this paper, in terms of diagnostic tests, functional systems composed of a technical object that is marine diesel engine piston were presented. This decomposition enables the identification of diagnostic systems, where failures occur most frequently and those whose failure may cause serious This decomposition enables the identification of diagnostic systems, where failures occur most frequently and those whose failure may cause serious consequences further consequences. Marine diesel engine was divided into the following functional systems: piston-crank exchange of the working medium, fuel supply, lubrication, cooling, starting, starting and reversing. Operating practice shows that the most common marine engine failure include damage to the injection system, the injectors, injection pumps, fuel system, speed controllers, lubrication system, timing mechanism, as well as the cooling system malfunctions. In this paper, examples of currently used diagnostic systems were described. In addition, the unconventional methods of diagnosing piston engines were presented.

These are new, increasingly completely without disassembly and without any interference in the process of the internal combustion engine technical condition testing methods. Measurement systems computerization causes they are used with the simultaneous use of artificial intelligence and especially expert systems. These include, inter alia, vibration analysis, marine engine exhaust gas analysis, acoustic emission, endoscopy and quick photography in research diagnostics. Then infirmities cooling system were presented. The problem of development of methods of diagnosis and diagnostic system for marine diesel engine cooling system was formulated. It has been found that the developed diagnostic system would be a good complement to the existing electronic surveillance systems of the marine engine technical state.

Keywords*: technical diagnostics, diagnostic methods, piston engines, cooling systems*

1. Introduction

Research of the technical condition allows assessment of the operation and determining the degree of wear of the marine diesel engine in terms of its ability to perform the tasks for which it was intended.

Currently, the diagnosis of marine diesel engines is carried out mainly on the basis of measurements of selected parameters of engines operating under specific conditions. Therefore, the devices and the diagnostic tools are developed that are used in methods relating to, for example, analysis of the work of the injection system. For them, at least partial dismantling of the engine or its systems is required.

However, more often new, completely without disassembly and without any intervention in the process, research methods of the technical condition of marine engines are used. Electronization and computerization of the measurement systems makes these methods are used with the simultaneous application of artificial intelligence and expert systems in particular.

2. Marine diesel engine as an object of diagnosis

Modern commercial vessels are equipped with a main propulsion and auxiliary implemented mainly by the marine diesel engine.

Marine diesel engine a complex technical object and its main function are to convert the energy, which was created as a result of fuel combustion, in the torque. Marine diesel engine can be divided into a number of systems (subsystems) functional useful in solving the diagnostic problems. These include:

- piston-crank assembly,
- turbocharging system,
- fuel system,
- lubrication system,
- cooling system,
- starting/reversing system,
- combustion chamber.

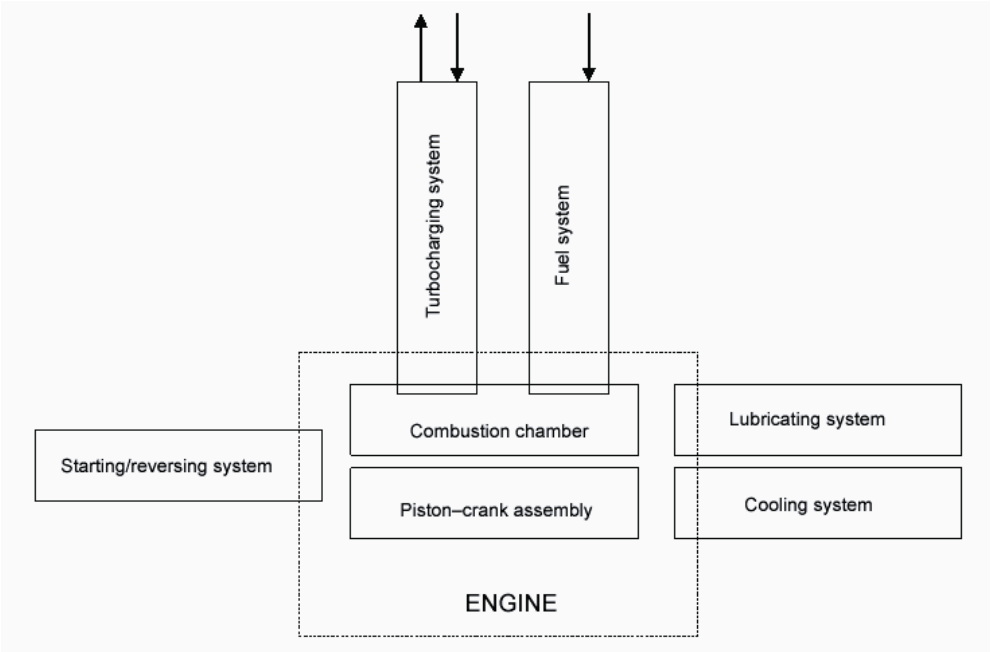

Fig. 1. Fundamental marine engine functional systems [3]

The most common marine engine failure belong damage to the injection system, the injectors, injection pumps, fuel system, speed controllers, lubrication system, valve timing mechanism, as well as damage to the cooling system [7].

A comprehensive assessment of the engine technical condition is made on the basis of external visual inspection of the engine and its units, control engine operation and testing of diagnostic parameters.

Diagnostic tests may be subjected to the entire object, assembly, subassembly or even a single part, more often in the next stages of their existence. Diagnosis of engine condition allows thus lead service strategy dependent on engine condition prevent most unplanned shutdowns. In addition, by detecting defects at an early stage of development, the diagnosis can reduce the scope and cost of repairs and service [2, 10].

3. Examples of currently used diagnostic systems

Currently used diagnostic systems can be divided into two groups, i.e. the systems offered by major manufacturers of marine engines such as MAN Diesel, Wärtsilä and Mitsubishi, while the second group includes diagnostic systems developed by manufacturers of the ship measurement and automation, such as Autronica, Norcontrol, ASEA, STL. As the most famous are the following systems in the shipbuilding:

1. The Data Trend system developed by Norcontrol [5], which on the basis of diagnosis parametric methods allows assessing the condition of the elements of the piston-cylinder system, turbocharging system, the engine injection system and additionally the utilization boiler.

2. The CC-10 system produced by B&W [8] was built to control the technical condition of the main propulsion engines. The system controls the following engine functional systems: charge exchange system, piston-cylinder assembly, fuel injection system, auxiliary machinery that supports the engine. The measuring signals are analysed by the microprocessor system. Information transmitted to the operator is primarily trend analysis and limit alarm.
3. Comos and DMTAS systems created by MITSUBISHI [9] support the main propulsion and auxiliary engines The parameters are measured on an ongoing basis and compared with the reference values. Trend analysis of these parameters is conducted.
4. CoCoS-EDS system prepared by MAN-B&W (Computer Controlled Surveillance – Engine Diagnostics System) [12] for monitoring, recording and archiving engine operating parameters and conducting trend analysis of these parameters. The system operates continuously and it is connected to the engine room alarm systems.
5. CAPA system (Computer Aided Performance Analysis software program) [13] the company MANB&W is a computer program used for monitoring continuously of working 2-stroke engines main propulsion of this manufacturer. The parameters measured are converted to standard conditions and compared with the reference values. Based on the detected failure and the special procedures system generates the appropriate operational decisions and recommends to perform certain maintenance.

4. Modern methods of marine engine diagnosing

Depending on the engine decomposition comprehensive and accurate method of diagnosis are distinguished. The first method, which does not require disassembly of the engine, based on the measurement of parameters useful. Methods for detailed diagnosis relate to the assessment of the engine systems and assemblies. Obtaining parameters that are used here requires partial disassembly of the engine.

Parameter that best describes the condition of the engine is the value of generated useful work. It is measured as the torque of the motor. The value of the torque changes with wear and aging processes in the operation. Therefore, the optimal solution is the possibility of obtaining indicator diagrams. These graphs show the actual course of the pressure in each engine cylinder, depending on the position of the piston or the crank angle. In addition, they support the identification of the engine technical condition. In a power plant ship in operating conditions engines indication using mechanical indicators is commonly used, which however are replaced by electronic indicators. The disadvantage of this is that each cylinder must be equipped with an indicator valve for mounting the sensor and in order to simultaneous measurement the number of sensors must be equal to the number of cylinders [7].

Nowadays more often a much simpler system momentary angular speed is used. As for the non-invasive signal recording system allowing for continuous measurement, that is non-invasive signal recording system allows continuous measurement. Momentary angular speed of the crankshaft is the quantity directly related to the course of pressure changes in the cylinder. This means that rotary motion of the crankshaft is the carrier of information contained in the indicator diagram. For this reason, the diagnostic use of the rotation parameters have found particular application in the automotive engine diagnostic systems, engine generating sets small and high-power, or for monitoring clutches and gears and rotating machines. More recently, the solution in marine engines is used (damage to the fuel system, powertrain).

Modern marine engines are equipped with more and more perfect control and measurement systems that measure parameters characterizing the state of the load. Despite this, in operational practice cases serious damage to the engine are known, the original causes were not detected in a timely manner.

For maintenance of marine engines at constant technical readiness, it is required to collect and track information about their condition under operating conditions; therefore appropriate diagnosis methods of internal combustion engines were developed.

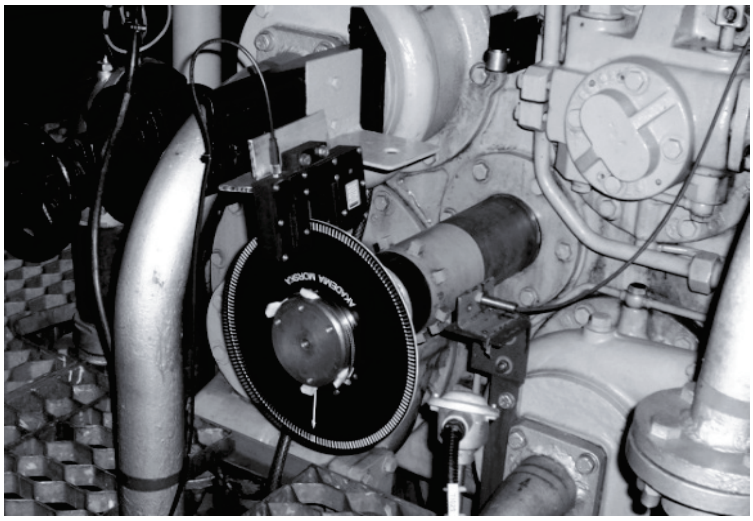

Fig. 2. An optical encoder disc mounted on the engine crankshaft [4]

The exploitation of marine diesel engines commonly also new methods have been introduced. These methods also allow diagnosis of marine engine components without any intervention in the process. These include vibration analysis, endoscopy, acoustic emission, exhaust gas composition analysis.

4. 1. Vibroacoustic methods

4.1.1. Measurements of vibration, noise, and their analysis

Parameters associated processes that occur as a secondary effect of overlapping operating processes in the engine (vibration, noise, thermal processes, wear and the amount and composition of the toxic components) are used to diagnose a specific engine condition and the location of unfitness. Due to the large number of sources that generate vibration, resulting in the engine vibroacoustic signal includes a plurality of components, which the separation is not easy. This is due to; inter alia, the complex nature of the vibrations generated by the engine, processes in it, co-existence of multiple sources of vibration, as well as the complex kinematics.

The source of the vibration is, in fact, every element of a working machine. However, as a result of the wear this components change, the amplitude of vibration generated and the nature of the spectrum – in the case of on-line systems, is basically possible immediately detect possible anomalies or damage.

Examples of multiband analyses 1/n octave (based on FFT analysis or digital filter) of measured vibroacoustic signals carried by multichannel dynamic signal analysers were shown in Fig. 3 [2].

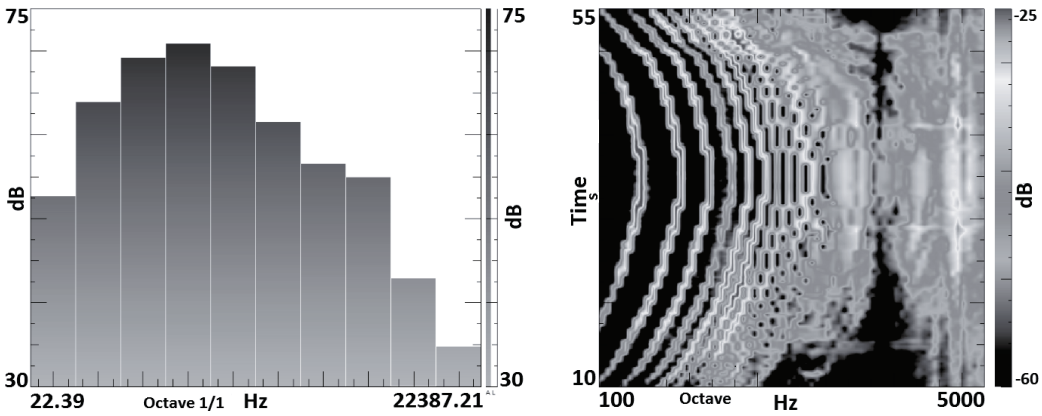

Fig. 3. Examples of measured vibroacoustic signals multiband analyses 1/n octave [11]

4.1.2. Research using acoustic emission

In the vibroacoustic research, is also used acoustic emission method, in which the phenomenon of vanishing elastic wave is used. It is the result of a sudden release of stored energy in the material by propagation micro-damage in the material. Reason, which causes change of steady state of the material, may be a change of stress or temperature. It can also be a progressive process of corrosion, and even radiation or particle beam bombardment.

The phenomenon of acoustic emission accompanied a rapid release of energy, which propagates through the structure in all directions. The amplitude of these vibration decreases with the passage of time and increasing distance from the centre. Beside the vibration range, is dependent on the properties of the material, the shape of the object and the environment. As an illustration of these possibilities, the material sample having internal defect subjected to an additional load of ΔБ in Fig. 4 was presented [1].

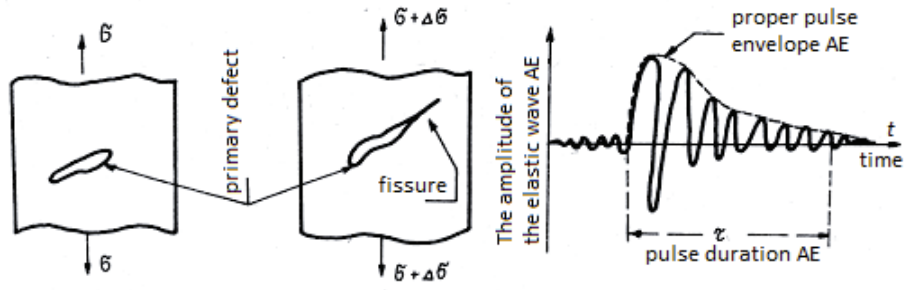

Fig. 4. An illustrative representation of the sample fissure and the related acoustic emission – AE [1]

4. 2. Endoscopic tests

Endoscopy is the method of implementation review of the visual and optical inner space of machines and devices using specular instruments called endoscopes. Endoscopes have a particularly high usefulness in hard to reach areas, such as combustion chamber when disassembly of the cylinder head is difficult and time-consuming; turbocharging system or internal spaces of mechanisms coupled it with the crankshaft of the engine [6].

After removing the injector and place the endoscope in its nest, it is possible to evaluate the technical condition of the piston, cylinder liner surface, head and other components installed in it: atomizer, the other injectors, intake and exhaust valves, starting valves, etc.

Videoendoscopy enables 3D phase measurement, which is an inspection and defect measurement using a single lens, eliminating the need to change the lens on the measuring lens. It allows you to scan and measure the 3-dimensions of each discontinuity detected during the inspection.

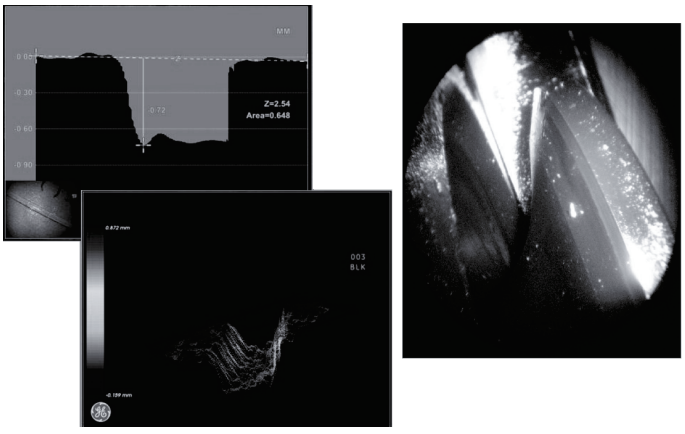

Fig. 5. Defects identified during the measurement phase 3D using industrial videoendoscope XL G3 [3]

4.3. Analysis of the exhaust gases composition

Currently, the analysis of the composition of marine engine exhaust can be considered in two aspects. The first is associated with regulations to reduce air pollution from ships contained in Annex VI of the MARPOL Convention. It comes down to the analysis of the exhaust gas composition and to check whether the contents of the individual components emitted into the environment is consistent with the applicable standards. To analyse the composition of the marine engines exhaust gas stationary flue gas analysers and test station for research positions are used. Increasingly common in use are also mobile sets, which could allow direct measurements of emissions of toxic compounds during the operation of marine vessels (Fig. 6).

Fig. 6. Portable exhaust gas analyser Testo 350XL [3]

The second reason is related to the marine engine diagnostics, because the analysis of the exhaust gas composition can be used to locate faults and then make repair and regulatory activities in the engine. Typical failures that affect the composition of the exhaust gases include inter alia: improper atomization of the injected fuel due to injectors malfunction, improper adjustment of injection timing, deterioration of the engine condition [3].

5. Malfunction of the cooling system

The most common marine engine failure include damage to the injection system, the injectors, injection pumps, fuel system, speed controllers, lubrication system, valve timing mechanism, as well as the cooling system malfunction. Shown above diagnostic systems deal with the diagnosis above-mentioned defects with the exception of cooling system failure.

Proper operation of the cooling system is very important because of its task to achieve and maintain the engine suitable working conditions. In the event of damage to the cooling system occurs a rapid temperature rise of the engine essential elements. This results in a deterioration of lubrication (loss of lubricating properties of the oil and its combustion), the occurrence of premature ignition (self-igniting) fuel-air mixture. In the end may be excessive thermal expansion of the piston in the cylinder, which is usually completed in damage to the engine.

Too low operating temperature also is not appropriate, because then the evaporation of the fuel takes place in worse conditions. This distorts the combustion process and may result in increased emissions of harmful substances. Working at low temperatures may also lead to flushing oil from the cylinder liner, which is very detrimental to the conditions lubrication.

These considerations show how important for the proper operation of the engine is its cooling. The most common faults include sediments in the engine water channels, cracks in the walls of the water channels, damage to the actuator, which controls the three-way valve (jamming of the actuator, pollution bellows by the control air). Consequently, it would be advisable create

a diagnostic system for supporting the proper operation of the cooling system. The system, which would allow the identification of damage on the basis of changes in temperature and pressure of the coolant, would be a good complement to the existing electronic surveillance systems of the marine engines technical condition, such as Data Trend, System CC-10, SEDS, CoCoS-EDS.

The essence of research would be to determine the diagnostic relations between the parameters of the coolant and its impact on other factors thermodynamic and structural materials. The next step would be to develop a diagnostic system, which would allow for engine exploitation, providing predictability for further use.

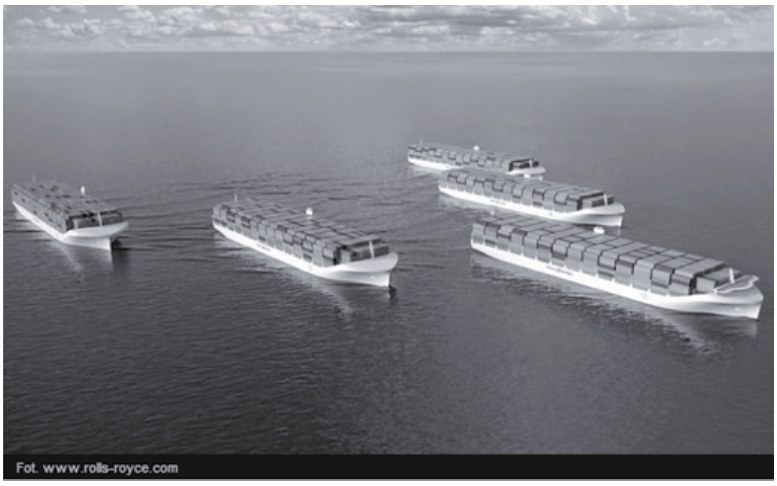

Fig. 7. Unmanned cargo ships – visualization

Developed diagnostic system connected with the control system of the cooling system (for example, automatic cleaning of the engine water channels, pipelines and coolers) could be part of a larger system, for example on the remote control of the ship from the mainland.

5. Conclusions

Currently, diagnostic systems are used to monitor and diagnose marine diesel engines, including among others elements of the piston-cylinder system, charge exchange system, the injection system. In the cooling system may also be damaged, which have a significant impact on the engine constructional materials, its proper operation or the formation of a combustible mixture.

Methods of marine diesel engine diagnosis presented in this article indicate their development towards methods without dismounting of the engine. They allow diagnosis of marine engine components without any interference with the same engine and the processes that occur in it. Currently, basic diagnostic procedures use the working process parameters, but more often associated process parameters, such as vibration, noise, thermal processes and wear and the amount and composition of the toxic components are used. In the connection with the development of electronic surveillance systems of the ship technical condition it would be advisable to complement them with a diagnostic system, that would allow for the identification of defects in the engine cooling system, which would be a good complement to existing diagnostic systems.

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