DIAGNOSTICS OF VESSEL POWER PLANTS

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Abstract

In this paper, the problems of diagnostics of main propulsion marine engines are presented. Diesel or turbine engines are used for main propulsion of vessel power plants. Marine engine is a complex technical object. For the purpose of diagnostics it is convenient to divide the engine into several units – subsystems such as: piston –crank assembly; working medium exchange system, fuel supply system, lubricating system, cooling system, starting up – reversing system; combustion chamber. The organization of the marine engine diagnostic process can usually come down to two stages, general diagnostics and damage location. Most popular in marine engine diagnostics have been the periodic run analyzers, called pressure analyzers, electronic indicators or MIP (Mean Indicated Pressure) calculators. Marine turbine engine operation requires professional technical supervision. The basic diagnostic system of marine turbine engine is able to assess the current engine condition and give forecast concerning its future operation in a complex way with the use of computer technology. Working out operating decision was based on proper preparation of operational parameters which were processed in a computer according to defined algorithms. Diesel engine diagnostic systems of merchant vessel engines are discussed. Finally, description of diagnostic methods implemented in turbine and piston engines in Polish Navy ships are introduced.

Keywords*: technical diagnostics, piston engines, gas turbine engines, vessel power plants*

1. Operating conditions of marine engines

Marine internal combustion engines operate under specific conditions which have a considerable influence on their characteristics change and can cause their increased wear and even failure.

Marine engines run in constant rolling conditions. Although rolling does not directly affect the characteristic change it can cause systematic wear of engine components i.e. bearings.

Most components of control systems and ship engine safety systems are related to fuel system. These installations require high purity of fuel which can constitute a serious problem on board vessels due to the possibility of water getting into fuel. Polluted fuel can cause engine start up problems, deterioration of load changes and can prevent proper work of control systems because of the structure change in relation to particular elements of automatic systems.

Fuel contamination with water can occur in ship conditions and can cause the wear of bearing units, which can not be repaired on board vessels.

2. Engine technical condition identification – parameters' number reduction

Type and number of technical parameters that require assessment without disassembling can affect diagnostic method and indirectly influence the costs of a diagnostic system. The most numerous are the engine construction parameters which are as follows:

- components dimensions in their wear areas,
- clearances,
- condition of working surfaces and their wear geometry,
- assembly and adjustment settings,
- cleanness of heat exchange surfaces and flow of working medium ducts,
- parameters characterizing static connections condition (bolts tension etc.).

The parameters that characterize the quality of lubricating oils, fuel, cooling water should be included in the set of engine technical condition parameters. Engine technical condition parameters with their graphic values and the frequency of overhauls and checks are given in operating manuals by the manufacturers. It appears that the number of engine technical condition parameters is about 50 only for one section of medium speed engine Sulzer type AL 20/24 for instance. If this number is multiplied by the number of cylinders and they are added to parameters characteristic for the whole engine, its machinery and systems – the total number will be enormous and as a result the task of technical condition evaluation without disassembly will practically be impossible. In marine engine diagnostics the evaluation without disassembly of most of these parameters is rejected and attention is paid to the most relevant parameters from the point of view of engine reliability, economical work and cost effective operation. Therefore each engine is divides into particular functional, trybological units [3].

One of the methods used for further limitation of the number of engine technical condition parameters is to determine the leading parameter considering the intensity of changes due to wear. For example it is possible to limit technical condition assessment to the upper compression ring in piston engine, which was adapted by Sulzer diagnostic system SIPWA.

In that case it was reasonably assumed that the wearing intensity of the remaining compression rings will be lower. However it is not always possible to determine a leading parameter or apply this method for other reasons.

Classical determination of engine technical condition is very often rejected and is related to symptomatic parameters of technical condition changes.

The change in reproduction level of technical condition evaluation requires proper testifying documents. Otherwise it will not be approved by ship owners, and especially be classification societies. However, it not easy to achieve a classification societies' approval of a new diagnostic method and measurement system as a substitute for a traditional overhaul with disassembly.

3. Diagnosing piston engines of vessels main propulsion plant

Marine engine is a complex technical object. For the purpose of diagnostics it is convenient to divide the engine into several units – subsystems such as: piston –crank assembly; working medium exchange system, fuel supply system, lubricating system, cooling system, starting up – reversing system; combustion chamber (Fig. 1).

The organization of the marine engine diagnostic process can usually come down to two stages, general diagnostics and damage location. The task of general diagnostics is to categorize the engine as one of the two states of being operable or inoperable. In case of an inoperable engine, the second diagnostic stage is to be carried out to define the reason of the ensuing situation [5]. Defining the reason is necessary to outline the range of service activities. Decomposing the engine into particular functional systems allows determining and developing diagnostic methods in relation to particular engine systems.

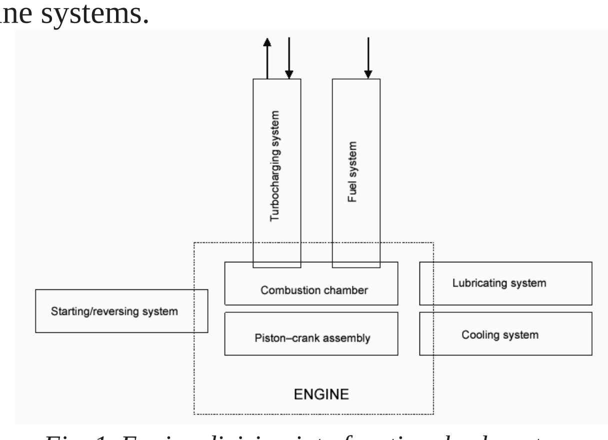

Fig. 1. Engine division into functional sub systems

3.1. Examples of diagnosing marine piston engines

Contemporary engine diagnostic systems can be divided into two basic groups. The first one comprises systems offered by the greatest marine engines manufacturers such as MAN Diesel, Wartsilia and Mitsubishi. These are usually complex systems assisting marine engine room management. Apart from evaluating engine condition these systems are responsible for managing overhauls, service activities, and spare parts store [6]. The second group forms diagnostic systems created by the producers of measuring equipment and ship automation. It is dominated by the so called MIP (Mean Indicated Pressure) calculators that enable measuring pressure changes in a cylinder which in turn is the basis for defining parameters connected with the combustion process. They are often equipped with the ability to measure extra parameters such as injection pressure or supercharging air pressure and temperature. Besides the above mentioned MIP calculators, it is also possible to come across complex systems enabling the operation evaluation of piston-cylinder assembly or engine main bearings for instance.

The most representative and well known diagnostic systems in shipping are:

1. “Data Trend” system by Norcontrol [7], which on the basis of parametric method of diagnosing allows evaluating the technical condition of piston-cylinder assembly, supercharging system, engine injection system as well as waste heat boiler.
2. CC-10 system by B&W [8] built for technical condition control of main propulsion system. The CC 10 system monitors:

- cargo handling system,
- piston-cylinder assembly,
- injection system,
- auxiliary mechanisms supporting the engine.

3. SEDS system by Sulzer [9] created to monitor and diagnose marine main propulsion engines. The system takes measurements of a dozen parameters and then enables quick access to their results as well as to the visualization of parameters measured.
4. Comos and DMTAS systems of MITSUBISHI [10, 11] service main propulsion engines and auxiliary engines. Parameters are measured systematically and are compared to their model values. The trend analysis of these parameters is also carried out.

So far the most popular in marine engine diagnostics have been the periodic run analyzers, called pressure analyzers, electronic indicators or MIP (Mean Indicated Pressure) calculators. They are built as stationary or portable. Such devices are utilized for measurement, digital record and visualization of combustion pressure graph and fuel injection in the function of crankshaft rotation angle at established working conditions of a marine engine. The most important elements of this electronic indicator are: sensors for combustion pressure and fuel injection, the sensor of crankshaft position and piston top dead centre (TDC), as well as signal amplifiers, analogue to digital converters and microprocessor central unit (computer). A well known analyzer is MIP Calculator NK-100 produced by Autronica [12].

3.2. CoCoS system by MAN Diesel

CoCoS system belongs to the most complex contemporary systems for diagnosing marine engines.

It was designed as modular expert system whose aim was the complex management of engine operation. It is composed of the following modules:

- CoCoS-EDS (Engine Diagnostic System) – a subsystem for supporting diagnostics,
- CoCoS-SPC (Spare Parts Catalogue) – an electronic catalogue of spare parts,
- CoCoS-MPS (Maintenance Planning System) – a subsystem to support planning the repairs and service activities,
- CoCoS-SPO (Stock Handling and Spare Parts Ordering) – to support the process of managing the spare parts store.

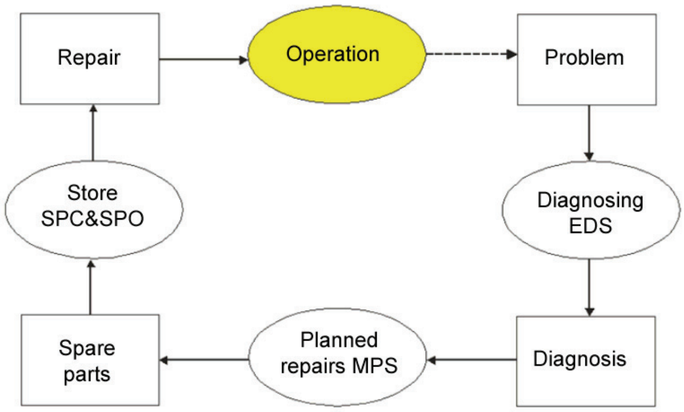

Fig. 2. CoCoS system configuration

All modules of CoCoS system can cooperate by an application called CoCoS shell or they can work independently. The configuration of particular elements and their possibilities of cooperation was shown in Fig. 2.

In case of a problem the diagnosis is performed by EDS module. The information of the engine condition is then used to plan service activities or repairs and to define required spare parts. With the help of SPC and SPO modules it is possible to check the stores or, alternatively, to order spare parts indispensable for carrying out repairs. The basis of system competence contains manufacturer's long experience gathered during design process, production and operation. EDS makes it possible to archive information and to monitor and analyze parameters recorded during operation. The diagnostics has been worked out on the basis of in-operational condition symptoms.

CoCoS system performs detection of engine damages such as filters wear and fouling but also detection of measuring sensors damages. CoCoS-EDS enables among other things, monitoring engine condition by measurement of working parameters and comparing them with model values.

Figure 3 presents chosen possibilities of engine parameters analysis.

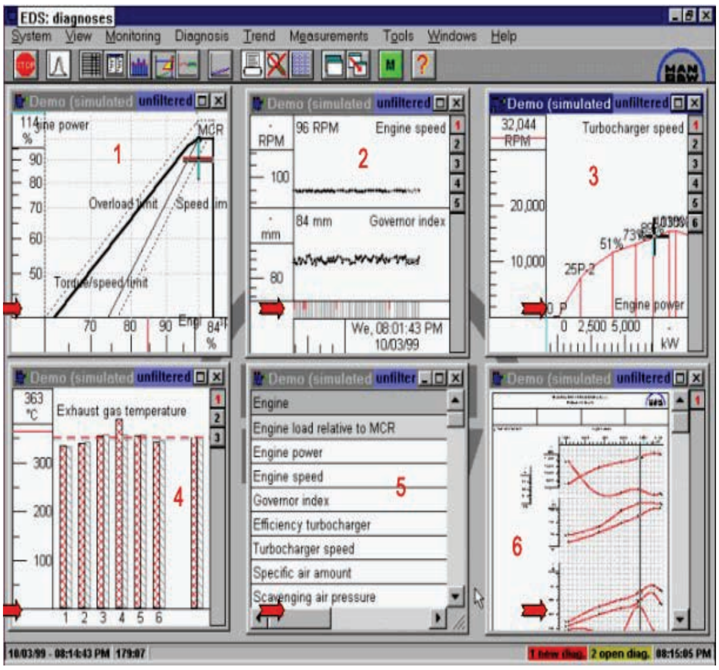

Fig. 3. Monitoring parameters In CoCoS-EDS module. 1 - engine running area with current running point, 2 – engine speed and load factor time graph, 3 – turbocharger speed in the function of engine horse power, 4 – exhaust gases temperatures on particular cylinders, 5 – values of selected engine parameters, 6 – general engine characteristics

4. Diagnosing navy vessels power plants

Appropriate engine type application results from the power required for the propulsion and its dimensions, taking into account its reliability and its susceptibility to diagnosis. Piston engines, used in naval vessels power plants, work in multi-shaft and multi-engine systems. The engines are of compact design, with high thermal loads and high degree of automation. Due to such requirements these engines are generally built in V and “star” arrangements with the number of cylinders reaching 56 or even 112 in blocked systems. Utilization of three or four engines in propulsion plants considerably complicates the engine room and gives the crew high requirements in the operation process and simply demands the application of diagnostic systems.

4.1. Pressure and vibration curves analyzers

Up till now, the periodic runs analyzers have been commonly used in marine engines diagnostics. They are designed to measure combustion pressure graphs and to determine their basic parameters and usually serve to measure and define pressure changes in injection pipes. The most well known and commonly used pressure analyzer is the one produced by Autronica. The microcomputer analyzer of periodic graphs was also developed in the Institute of Ship Technical Operation at Gdynia Naval University (GNU) [4, 5].

Cpt Stanislaw Polanowski was the concept creator and the author of the methodology of piston engines diagnosing which was introduced on Polish Navy vessels.

These are devices designated to measure, visualize and digitally record combustion pressure changes, injection and vibration curves in the function of crankshaft rotation angle at established engine working conditions. For that purpose the analyzer was provided with three 12 bit (100kHz) channels of analogue to digital converters.

The software for the analyzers makes it possible to accept any measuring configuration of the above mentioned values, for example setting to measure vibrations curves in all channels. Therefore the analyzer is suitable for diagnosing both marine powerful engines and car engines.

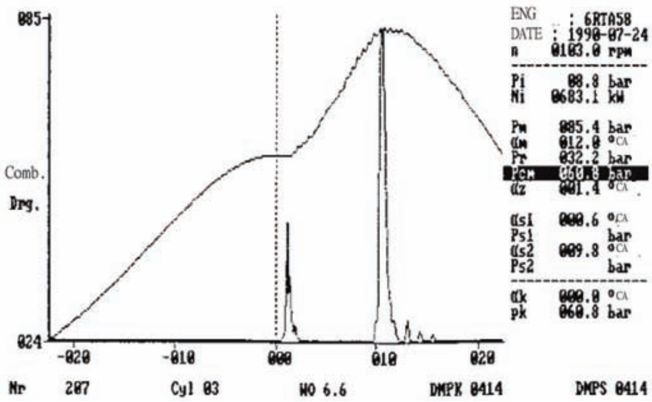

Fig. 5. Pressures recorded in cylinder and the vibrations curves with the use of GNU indicator

Sampling is based on angle axis impulses of 0.1^{o}OWK for n<1600 min^{-1} resolution. The runs are made average by the number of engine working cycles: 4, 16, 64 set by the operator.

The analyzer also performs the function of an automatic calculator of mean indicated pressure, the automatic gauge of basic parameters in a developed indicator graph and the engine speed meter.

Analyzers of this type apart from being utilized in piston engines diagnostics on navy vessels, were also applied in diagnosing engines on natural gas pumping. They were also installed on four merchant vessels built by Gdynia shipyard for a French ship owner.

5. Diagnosing marine turbine engines

Marine turbine engine operation requires professional technical supervision. This requirement can not be fulfilled by crews on small vessels of our Navy. Therefore, taking into account the level of crews competence in operating modern vessels with turbine engines, a concept of supporting ship crews by creating " Basic diagnostic system for turbine engines" was put forward in 1985 [1, 2]. This system was designed to carry out periodic inspection of technical engine condition, and particularly in case of:

- annual overhaul,
- prolongation of the period between repairs,
- identification of abnormalities in engine running found out by the crew during operation.

The basic diagnostic system is able to assess the current engine condition and give forecast concerning its future operation in a complex way with the use of computer technology. Working out operating decision was based on proper preparation of operational parameters which were processed in a computer according to defined algorithms.

It was assumed that the diagnostic information for creating basic diagnostic system would be collected:

- systematically – form the ship operating documentation (engine log book),
- periodically – with the use of automatic recording device,
- periodically – by examining special parameters characterizing engine condition, i.e. endoscope inspection, recording start up process etc.,
- periodically – based on interviews and experts opinions.

The basic diagnostic system allowed accomplishing the following tasks:

a) detection of engine condition in danger of failure or catastrophe,
b) diagnosis of technical condition of measuring – inspection equipment,
c) carrying out current evaluation of engine characteristics, the level of its fouling and consequently determining the necessity of flow track flushing,
d) organizing engine operation data base for each engine and vessel and forecasting changes of engines technical conditions.

The system configuration is based on the experience of plane turbine engines operation where computer records, examinations methodology and data base constitute original development [2].

To complete all tasks that ensure proper turbine engine operation the diagnostic system is equipped with the following specialized devices:

a) vibrations measuring device,
b) station for checking oil for metallic particles,
c) engine parameter measurement computer set during start up and shut down,
d) engine parameter measurement computer set at constant running,
e) engine parameter measurement computer set in transient stages,
f) fast –changing signal analyzer,
g) endoscope,
h) laser gauge of shafts coaxiality evaluation,
i) testers for checking the indications regularity of measuring – inspection equipment and engine protections,
j) computer data base.

This diagnostic system was introduced on board Navy vessels and was used to diagnose all types of Navy turbine engines. The system was highly appraised by engine manufacturers due to considerable improvement of engine operation which was observed by engine condition evaluation during periodic overhauls at the manufacturers. Over 20 years of system operation it was demonstrated that the concept adapted was correct and so novel that it has been used up till now with the same methodology.

6. Summary

1. The diagnosis of piston and turbine engines has been carried out on Polish Navy vessels since 1986 on the basis of the worked out methodology and diagnostic systems.
2. At present there are several methods and systems for diagnosing engine technical condition that are being developed by both research centers and by producers of engines and measuring equipment.
3. Contemporary marine piston engine diagnostic systems can be divided into two groups. The first one is made up by the co called calculators of mean indicated pressure (MIP Calculator). The second group comprises systems that additionally enable diagnosing the piston-rings-liner assembly.
4. In spite of the obvious benefits of using piston engines diagnosing systems, their application on board vessels is still limited due to high costs and the lack of data related to real economic advantages of their utilization.

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