Journal of Polish CIMAC
Gdansk University of Technology
The Faculty of Ocean Engineering and Ship Technology

# DIAGNOSTICS OF VESSEL POWER PLANTS

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***Abstract***

*In this paper, the problems of diagnostics of main propulsion marine engines are presented. Marine engine is a complex technical object. For the purpose of diagnostics 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. The diagnostic system of marine 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. Marine 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.*

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

## 1. Introduction

Type and number of technical parameters which require assessment without disassembling, can affect diagnostic method and have indirectly influence at 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 which 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. 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, diagnostic evaluation without disassembly, 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, tribological units [3].

## 2. Description of test equipment

Contemporary exploitation of machines requires certain level of supervision, due to their high level of complication of the structure. That kind of supervising relay on detection of pre-failure states and evaluation of condition of elements or modules. In the frame of development of research capacity in Mechanical Faculty of Gdynia Maritime University, has been developed the exploitation decision assistance system for industrial machinery, including marine mechanisms, in the way of building from scratch the laboratories of:

- Technical Diagnostics
- Tribology
- Surface Engineering

Those three laboratories, which equipment was funded by Ministry of Science and High Education in the frame …….are expected to enable realization of advanced research programs and contracted research in diapason of technical diagnostic, technical security engineering, analysis of mechanisms reliability, tribology and surface engineering.
The Technical Diagnostic Laboratory consist of equipment listed below:

- ✓Vibration Analyzer PULSE by Brüel & Kjaer,
- ✓ Acoustic Emission Set by Vallen System,
- ✓Analyzer/Recorder of working process by Sefram Instrumens & Systems,
- ✓Mobile Gas Analyzer by Testo,
- ✓Industrial Video endoscope XLG3 by Everest,
- ✓ Thermo vision Camera by NEC Avio Co.,Ltd,
- ✓Electronic Indicator of cylinder pressure of the piston engine

### 2.1. Vibroacoustics

Vibration signals are carrying much information about technical condition of a machine and are a base for utilization in signals' monitoring systems as a condition trends factor of a machine. Spectral analysis of signals enables an identification of a failure type. Vibration signals monitoring is useful also for evaluation of bearing nodes, condition of shafts, and frictional couplings, including gears meshing and blades arrangements into rotary machines.

The vibration analyzer is the 6. channel recorder type 3050-A-60, the module LAN-XI 51,2 kHz (CCLD, V) Brüel & Kjaer. The set includes also the acoustic calibrator 4231 and the calibration's exciter 4294. The set consist also the tachometer probe MM360, set of microphones 4189-A-021 and the accelerometer 4515-B. Measurements and analysis are carried out using computer program PULSE time (FFT analysis program, harmonic analysis, signals' recorder). All is governed by the central station. The range of output voltage for typical accelerometer/microphone with build-in amplifier CCLD is 120 dB for broad band 10 Hz – 51 kHz, and 160 dB for narrow band 6 kHz. Maximum peak voltage is 10 V, and linearity ± 0,03 dB in the range of 120 dB. Data processing in the analyzer is 24 bit mode. Registered frequencies band is DC – 51 kHz. Measurement's windows are presented in the fig. l.

## 2.2. Oil spectral analysis

The spectrometer is analyzing traces of radicals coming from: oil additives, wear processes and outer contamination. Comparison of results with previous ones and permitted limits enables observation of the normal mechanical wear process or early detection of potential damage, at its early stage. Moreover, enables evaluation of oil condition in reference to content of additives. It concerns mostly synthetic oils.

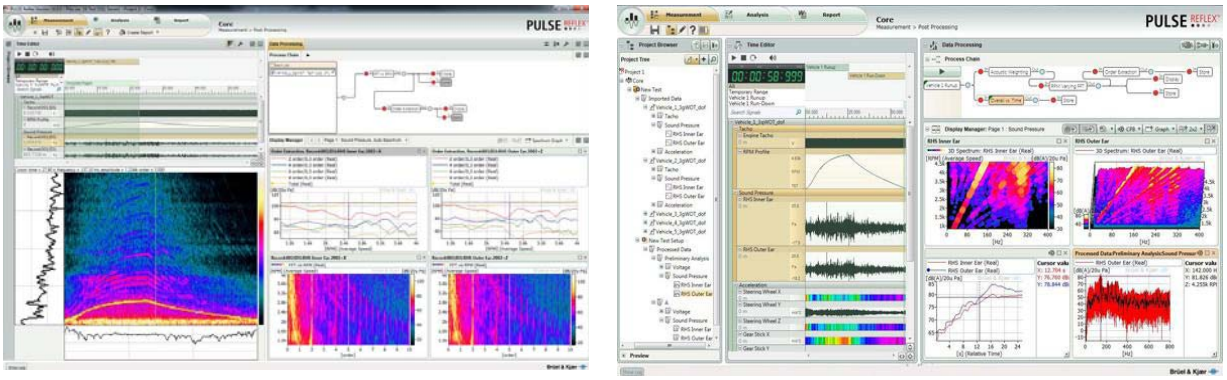

*Fig. 1. Samples of display windows*

The spectrometer measures contents of radicals dissolved or floating particles in mineral or synthetic products, using the method of a rotational disc electrode (RDE). Basic configuration of the spectrometer enables detection of 22 radicals, ie. : Al, Ba, B, Cd, Ca, Cr, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Si, Ag, Na, Sn, Ti, V, Zn.

The spectrometer range can be extended, what let detection additional radicals:
Sb, Bi, As, In, Co, Zr, W, Sr, Li, Ce and detection of radicals In cooling liquids and water. In the fig.3. is presented the picture of Spectrometer Spectroil Q100.

*Fig.2. Picture of spectrometer Spectroil Q100*

## 2.3. Video endoscope research

Video endoscope Everest XL G3 enables evaluation of technical condition of internal spaces, for example marine engines and machines, permanent and mobile pressure tanks, pipelines and masts, with possibility of dimensional evaluation of defects, visualization at LCD display and

video recording. 3D phase measurement enables inspection and measurement of defects by only one lens, what eliminate necessity of its replacing by measurement lens. It lets scanning and measurement in 3 dimensions every detected discontinuity. Phase measurement analyzes available in observation zone ($105^0$) surface, and creates 3 dimensional movable model. Working probe in the system XL G3 is exchangeable. The sample of quantity evaluation of a damage is presented in fig.3.

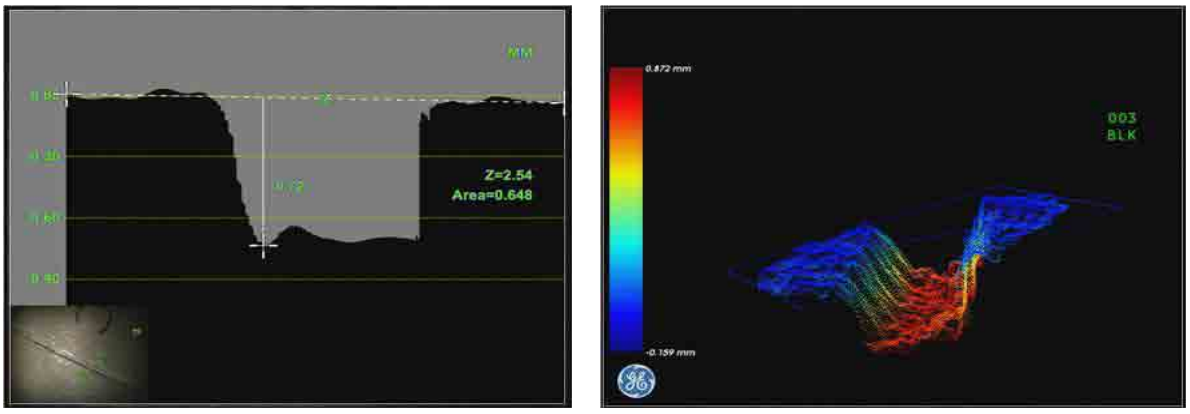


*Fig.3. Sample of evaluation of damage parameters*

## 2.3. Thermo vision research

Thermo vision camera Thermo Gear G100 from Japanese manufacturer NEC-AVIO Co., Ltd. enables tracking processes related to changes of temperature or emission in time or related to differentiation of thermal pictures of selected individual objects. The camera gives to operator many possibilities if measurement. It has a temperature preview function for 5 random points of the picture, with possibility of setting up individual coefficients of emission for every point. The camera enables also maximum/minimum temperature at whole display or in selected area, the value of difference of temperatures between two selected points, or linear profile of temperature.
As the camera is equipped with the optical focus with resolution 2 000 000 pixels, also registration of optical picture is possible. Pictures can be presented separately, parallel (one next to one at the display) or in penetrating mode.

During analysis of the picture one has to put attention at changes of mutual position of pictures in relation to the distance from observed object. In fig 4. the sample of modified optic-thermal picture is presented.

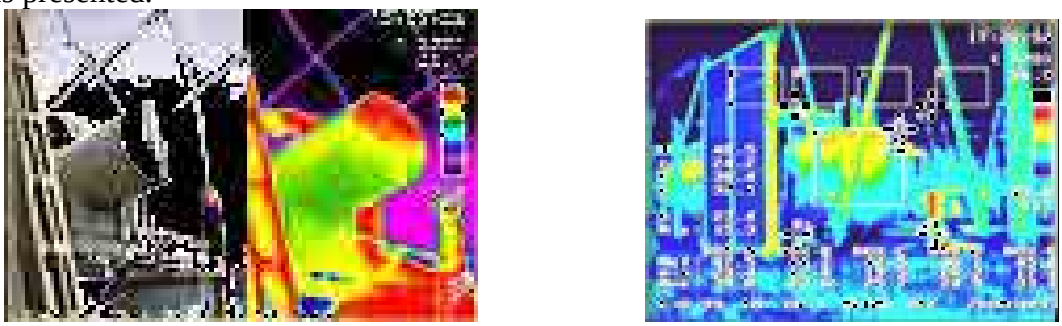

*Fig.4. Samples of thermal camera pictures*

The camera enables broad implementation for diagnostic research of machines and mechanisms as well research of technologic or energetic process.
The camera is equipped with the detector with dimension 320x249 elements. Works in real time, with refreshing frequency 60Hz. It has thermal sensitivity at least 0,08 $^0$C at ambient temperature

$30^0$C. The camera can register temperatures in diapason from -$400^0$C to $500^0$C, divided to two sub-ranges: -$400^0$C to $120^0$C and $0^0$C to $500^0$C with accuracy ±$20^0$C or ±2%.

### 2.4. Acoustic emission measurement method

The AE method relay on detection and analysis of acoustic signal, emitted by a material being under mechanical stress. Emitted elastic waves are a result of interval elastic energy release. Thus energy is a phenomenon related to physical process taking place in materials or at their surface. Processes accompanying by acoustic emission are plastic displacement, cracking, structural and phase changes, corrosion, leaking and fibers cracking in composite materials. Accurate analysis enables definition of sources and kind of acoustic emission. Fig.5. presents the sample of AE signal run.

The set for non-invasive (without disassembling or destroying) measurement of a wear level of machines elements being under stress, deformations or load e.g. the wear of injectors, pumps, hydraulic elements, stress state of a fuselage or a hull sheets, pipelines e.t.c.

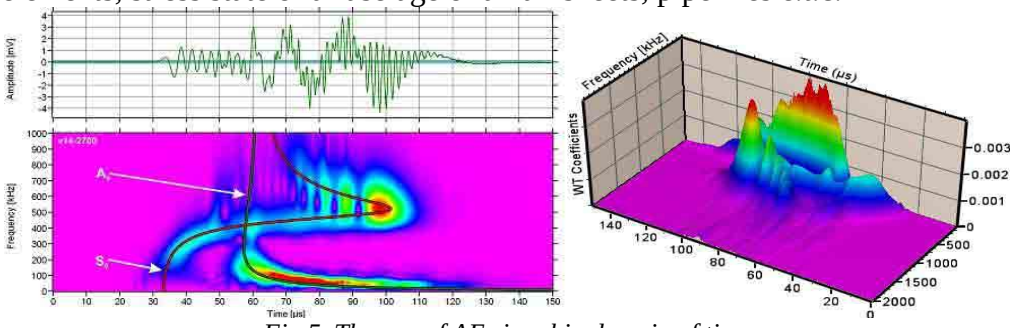


*Fig.5. The run of AE signal in domain of time*

The AE measurement set consist of 4 channels signal recorder AMSY 6 and the measurement module ASIP-2/S by Vallen System (Fig.6). The system is equipped with pre amplifier with a frequency range 20kHz to 1MHz and amplification 34dB, and AE signal sensor with range 100 – 450 kHz. The set has the recording module, putting down 8 MB's data bunches for every channel and data registration and analysis program.


*Fig. 6. The AE method measurement set by enterprise Vallen*

### 2.5. Marine engines exhaust gas analysis

The mobile set dedicated for marine engines exhaust gas analysis enables measurement of emission of exhaust gases' toxic substances of different kinds of internal combustion engines, stationary or locomotive.

The set consist of high quality exhaust gas analyzer 350 XL by TESTO, including a industrial probe with particles filter, a infrared sensor calibration system and a rigid case. The analyzer has

the Germanischer Lloyd Certificate, giving legacy for tests on board ships, in accordance to MARPOL Convention Attachment VI. Moreover, the set is equipped with the integrated temperature and humidity sensor, and atmospheric pressure gauge. Sensors are connected by 16 channels digital - analog transducer with industrial computer with dedicated programs, as a recorder. The recorder lets simultaneously connect all gas sensors, ambient parameters gauges and additional 13 random physical values sensors having standard 0-10 V outputs. The recorder has built-in parallel port RS-232, for connection with the recorder of TESTO analyzer. In fig.7. is presented the set of Exhaust gas analyzer Testo 350XL, and in tab.1.,exhaust gas measurement range.

*Fig.7. Exhaust gas analyzer Testo 350XL*

*Tab. 1. Gas analyzer measurement range*

| Parameter | Range | Unit |
|---|---|---|
| **oxygen - $O_2$** | **0 – 21** | **% Vol.** |
| **carbon monoxide - CO** | **0 – 5000** | **ppm** |
| **carbon dioxide - $CO_2$** | **0 – 20** | **% Vol.** |
| **nitric oxide - NO** | **0 – 2500** | **ppm** |
| **nitro dioxide - $NO_2$** | **0 – 500** | **ppm** |
| **sulphur dioxide - $SO_2$** | **0 – 3000** | **ppm** |
| **gas temperature at measurement point** | **0 – 1000** | **°C** |
| **dynamic pressure** | **do 20** | **kPa** |

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