THE APPLICATION OF SPECTRUM ANALYSIS OF COURSE OF PRESSURE IN COMBUSTION CHAMBER FOR DIAGNOSIS OF MEDIUM SPEED MARINE DIESEL ENGINES

Jan Monieta

Maritime University Szczecin, Institute of Marine Power Plant Operation
Waly Chrobrego 2, 70-500 Szczecin, Poland
tel.: (4891) 48-09-415; 48-09-479, fax: (4891) 480-95-75
e-mail: jmonieta@am.szczecin.pl

Jakub Rutkowski

Maritime University Szczecin, Research Association Investigation of Marine Power Plant
Waly Chrobrego 2, 70-500 Szczecin, Poland
tel: (4891) 48-09-415; 48-09-479, fax: (4891) 480-95-75
e-mail: ajuki.driver@interia.pl

Abstract

In this work has been undertaken a study test the application course of combustion pressure signals in combustion chamber the marine medium-speed engine to diagnostic. In research has been used active experiment. The pressure signals analysis in cylinder has been carried out in amplitude and frequency domain, as new method for result processing.

In preliminary research has been carried out with used marine engine 5BAH22 with current generator, be present in Engines Room Laboratory the Maritime Academy in Szczecin. Preliminary research has consisted in measurement the course of combustion pressure signals in individual cylinders and analysis the combustion pressure signals in time, amplitude and frequency domain at different engine load the combustion engine and has been checked that diagnostic parameters will be correlate with engine load. The current generator has been loaded with water resistor. The purpose of this work have been selected sensitive diagnostic symptoms and checked their usability in diagnosis marine diesel engine.

In principal research has been simulated inability the turbocharger air filter as his mechanical impurities. Useful diagnostic symptoms have been determined. The method were being verified, execute operating research on working marine diesel engines at port and shipyard.

Keywords: *piston marine diesel engine, course of combustion pressure, diagnosis, spectrum analysis*

1. Introduction

Nowadays piston combustion engines with compression-ignition are mostly applying in marine power plants as main drive for generator marine electric power plant, emergency generator and lifeboats. Mainly advantage of this engine is that, its have high effective efficiency, even over 50% feed energy with fuel to engine and there is unattainable for another thermal engines.

Technical condition knowledge the marine piston engine is indispensable for management effectively operating strategy. That strategy enable to planning routine maintenance activities, keep up fitness for use, maintenance and lessen the risk occur sudden failure. Construction development, alternations with operating and techniques of production the modern marine combustion piston engines involve changes of their technical condition methods assessment [2].

The modern construction of marine engines between among other things more often characterize electronic operating fuel ignition subsystems, electronic operating of timing angles, electronic dosage of quantity cylinder oil lubricating and electronic control of sequence

supercharging systems. Through lots of years the basic of operating strategy has been operating according to overworked time expression with hours. Nowadays more often that strategy substituted operating strategy with technical condition [2, 3].

That alterations conditioned by alternations proceed world economy and extorted alterations with operating the combustion engines, which are energy consuming and expensive most of all. In vessels operating are exists propensity to continuous reduce the crew by augmentation of automation stage up to unmanned engine room. There is connected with improvement the diagnostic systems and economic reason [5]. Engine wasn't being individual manufactured product to shipowner order. Engines structural modifications, change of operating principles and their techniques of production are being arisen a new diagnostic resources, deliver for engineers by engines producer or by producer of specialistic measuring apparatus [3, 8, 11].

The indispensable informations about current operating situation are being obtained in diagnostic process. These informations make possible in suitable time to make a operations tend towards to maintain and restoration the fitness use the marine combustion piston engine and also elimination causes of excessively intensive worsen their technical condition [2].

2. Diagnostic of the marine engines with utilization advantage of parameters course of combustion pressure and compression pressure

Nowadays for diagnosis combustion engines with use of combustion process parameters are being applied mainly electronic indicators [8, 12]. This indicators enable to give results of average values from more than ten or more than hundred. Usually parameters of combustion process are displayed on monitor's screen. There is most often: maximum combustion pressure, compression pressure, mean indicated pressure and indicated power of testing cylinder, rotational speed etc. In literature encountered mainly combustion pressure signals analysis in time domain.

In the prior author's research were taken advantage among other things of values of mean indicated pressure and indicated power [6]. These parameters have altered lineally together with alteration load indicator. The values of compression pressure, maximum combustion pressure, expansion pressure and ignition start also have altered together with increase load indicator but with less sensitiveness. Results of measurements the course of combustion pressure parameters burden essential errors at receive the signals from indicator valve. There has cause to used test the vibrations signals for evaluation the combustion pressure course [2, 4, 7].

Present state of diagnoses in operation marine combustion piston engines are being unsatisfactory and point at necessity wide and general implementation on board the ships diagnostic systems and devices, which will be more perfectly. Utilization diagnostic systems, knowledge and professional experience the engineer officers will guarantee effective, reliable and safe marine engines operating. Knowledge in the today world is the value itself in itself and there is extremely precious.

At present is being possibility to observed progress in different kind devices for estimation the marine engines technical condition. Some of those devices are result of firm's work deal with manufacture electronic measuring-control apparatus also marine engines manufacturer deal with the apparatus.

The grade of the advanced diagnostic devices and systems are very extensive and aim at to be supported on operating decision at recommendation the diagnostic system. That all will be bring to obtain big effectiveness in operating the marine piston engines if possible and occasion to will highest efficiency, top reliability will be safely and economical.

3. Work purposes

The purpose of this work have been carried out the research with used marine engine type 5BAH22 be present in Engines Room Laboratory the Maritime Academy in Szczecin. Preliminary research has consisted in measurement the course of combustion pressure in individual cylinders

and analysis the combustion pressure signals in time, amplitude and frequency domain at different engine load the combustion engine and has been checked that diagnostic parameters will be covariant with engine load. The purpose of this work have been also selected diagnostic symptoms and checked their usability in diagnosis marine diesel engine.

After preliminary research has been planned verify the method in principal research at laboratory and operating conditions. In preliminary research has been used active experiment and in principal research: active - passive experiment [12].

Will be make an assumption, that:

There is a possibility that selection diagnostic symptoms connected with the course of combustion pressure inside combustion chamber, which will be correlate with relative engine load of the marine combustion piston engine.

4. The research project

4.1. Research object

The object of laboratory research has been current generator with Sulzer engine type 5BAH22 (Fig. 1). The technical parameters engine and generator are following:

Power rating	220 kW
Rotational speed	500 r.p.m.
Cylinder diameter	200 mm
Piston stroke320 mm	
Specific fuel consumption at 100% load	234 g/kWh
Working mode	4 stroke, pulsatory turbocharger
Number of cylinders	5
Manufacturer	Plant of Technical Devices - ZGODA, licence Szuler

In operating research has been used marine auxiliary combustion engines Sulzer type 6AL20/24.

4.2. The investigative stand

The view of measuring stand has been showed on Fig 1. There combustion pressure have been measured by means of sensor PT - 5101E (Fig. 2) assigned for measurement of pressure in laboratory and industrial conditions. The strain gauge of pressure is operating on principle of measurement of elastic strain deforming of transducer element influenced by applied pressure.

A membrane is element of transducer, integral part of sensor body, with sticked on foil extensometers in bridge system. The pressure sensor PT - 5101E cooperated with measuring amplifier type AT - 5230 with current exit signal 4 - 20 mA. These signals become from measuring sensor of pressure were analyzed with the aid of computer program System Analysis of Signal (SAS) for PC [7]. SAS allows execution of basic analysis of signals in sphere of time, amplitudes and frequencies. The signals were analyzed in two frequency bands f = 0 - 125 Hz and f = 0 - 2.5 kHz. A photooptical sensor was for release start of canvassing of signal.

The sensor of combustion pressure PT - 5101E was calibrated before measurements, behind assistance of compressed air, for its determination of sensitivity. It has enabled introduction of multiplier for system analyses of signals.

4.3. The method and results of research

Method of carried research relied on measurement of course of combustion pressure in individual cylinders and in sphere of time analysis (Fig. 3), amplitudes and frequencies (Fig. 4) at different loads of diesel engines. These dynamic processes in cylinders of engines were conversed on diagnostic signals with the aid of measuring sensor of pressure and preliminary separation of

useful signal behind assistance of filtering. Dynamic processes condition in engine reflected it technical state and operational.

These diagnostic signals were at the nature determine and random, so they were according to different algorithms for different getting of type of parameter of signal process [1]. These parameters', depending on their kind, includes different properties of information signals transfer and features of processes and technical state.

Fig. 1. The measuring stand of engine type 5BAH22

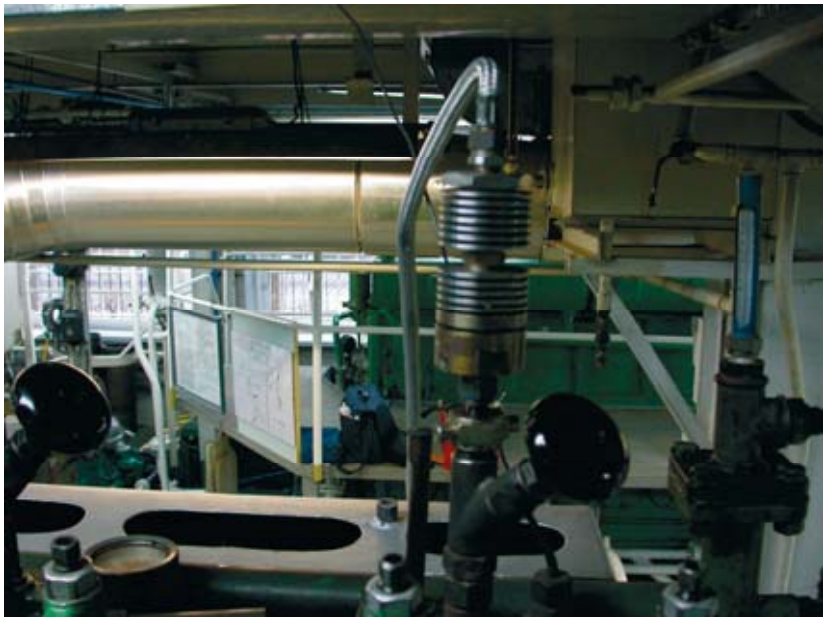

Fig. 2. View of pressure sensor PT - 5101E installed on indicator valve of cylinder number 5

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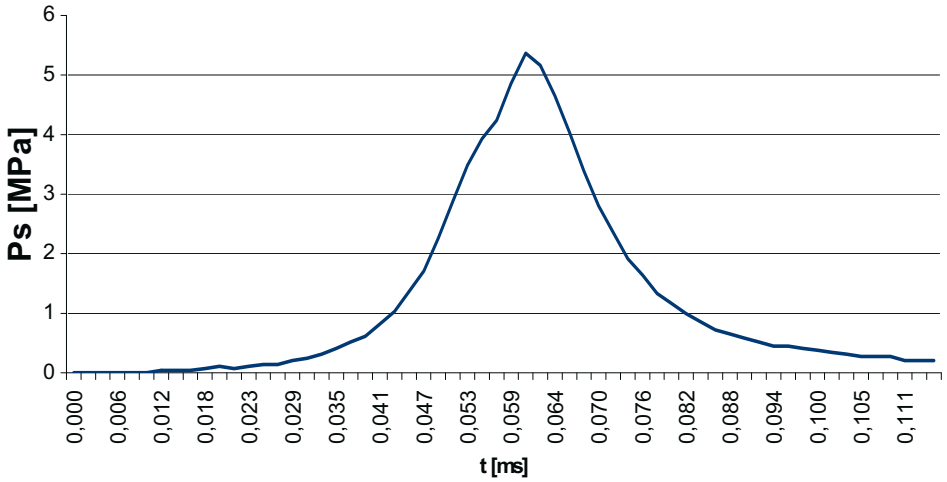

Fig. 3. Exemplary time course of combustion pressure in cylinder number 5 in frequency band f = 0 - 2.5 kHz, electric power N = 144 kW, load indicator W = 7

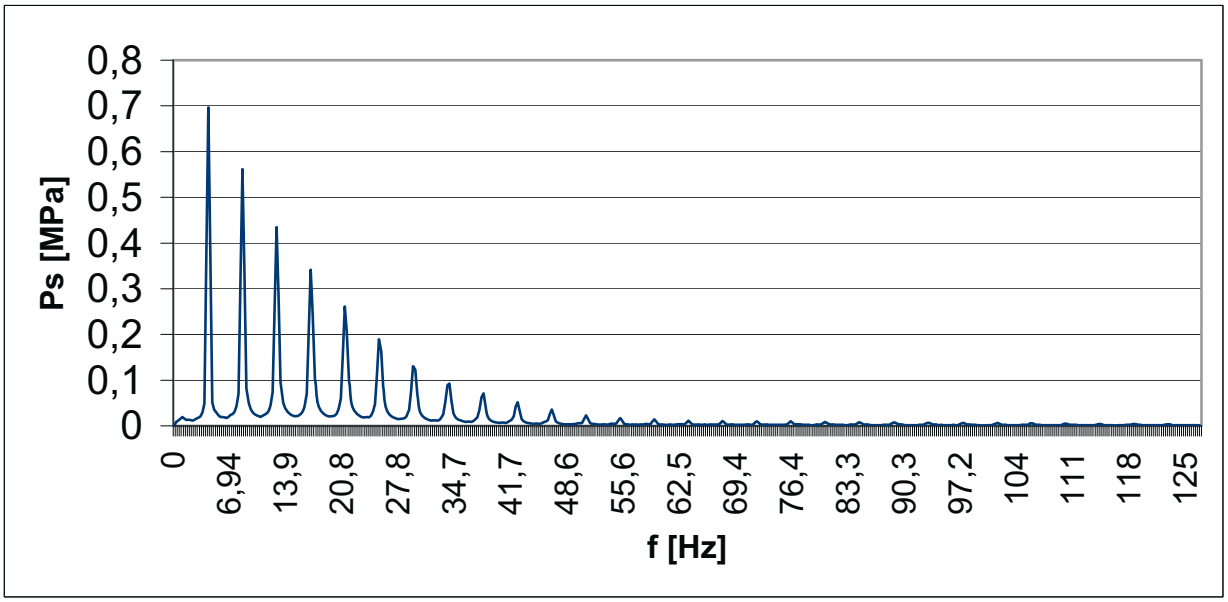

Fig. 4. Exemplary spectrum of signal of combustion pressure in cylinder number 4 in frequency band f = 0 – 125 Hz, electric power N = 170 kW, load indicator W = 9

Correctness of making a decision about state of object is predefined choice of optimal symptom, about big sensitivity on changes of qualities of objects, which have been measured. The calculation procedure of of amplitude estimates, independently on their kind it included averaging operations in sphere of amplitudes. Here have been analyzed sequences of signals, which were presented in the cascade form of [7]. In this option of analysis was possible assignment of: function estimates (of distribution function of amplitude and probability function) also pointiest estimates. Apart from amplitude estimates have been utilized spectrum measures - spectrum envelope of the amplitude harmonics except in chosen threads of analyses warehouse spectrum (Fig. 4, 5, 6).

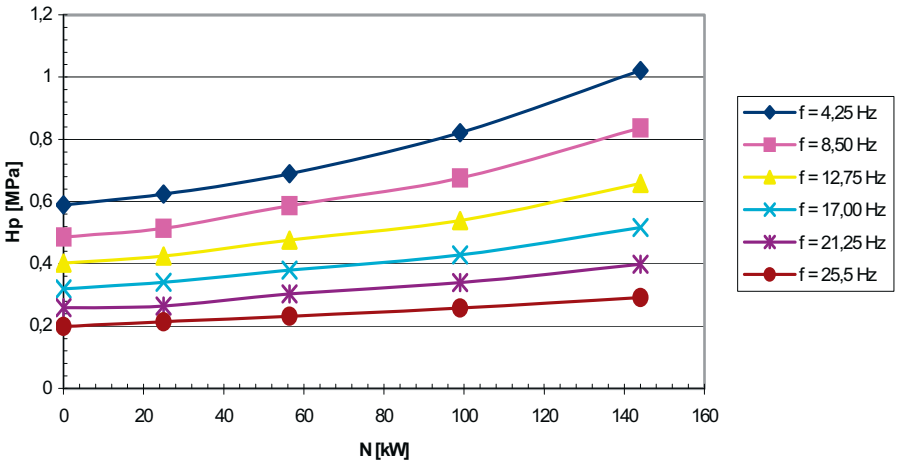

Fig. 5. The values of spectrum envelope of the amplitude harmonics of combustion pressure signal Hp depending on absolute load for cylinder number 5 in frequency band f = 0 - 125 Hz

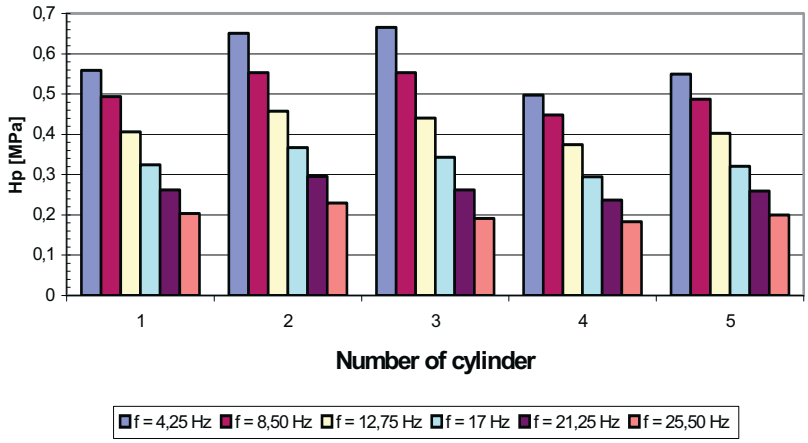

Fig. 6. The values of spectrum amplitude harmonics of combustion pressure signal in individual cylinders of engine for absolute load 0 kW in frequency band f = 0 - 125 Hz

There parallel with measurements of diagnostic parameters has been carried measurement of values parameters practice registered during laboratory research and exploitation of marine diesel engine, as well as values of parameters of environment [8, 10].

For estimate of interdependence of parameter diagnostic with load and technical state, have been utilized of correlation coefficient in research [6]:

$$k = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}, \tag{1}$$

where:

x_i - following value of given input quantity,
$\bar{x}$ - average value of given quantity in collection of observation
y_i - following value of given diagnostic parameter,
$\bar{y}$ – average value of diagnostic parameter.

In frequency band from 0 for 2.5 kHz (Fig. 7) only amplitudes harmonics about frequency f = 10 Hz are characterized considerable values. These remaining of amplitude harmonics are values less interdependence with load.

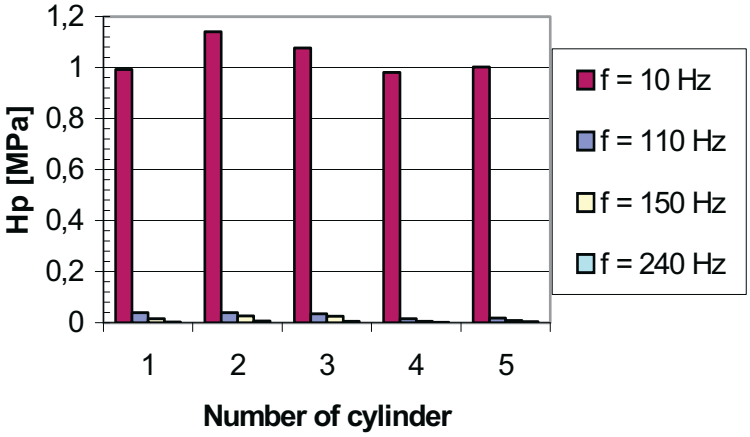

Fig. 7. The values of spectrum amplitude harmonics of course of combustion pressure signal in individual cylinders for absolute load 0 kW in frequency band f = 0 - 2.5 kHz

Comparing these values of amplitude harmonics for course of combustion pressure in frequency band from 0 to 2.5 kHz of incinerating in with not covered and covered air filter of turbosupercharger (Fig. 8), shows that for near 90 kW load of engine a lines of diagrams covered. Higher up of load 90 kW these values of amplitude harmonics of course of combustion pressure is with filter quarter of value of amplitude harmonics are small for covered of air filter. It is possible to notice also, that along with increase of engine load, grow linearly values of amplitude harmonics for f = 10 Hz of course signal of combustion pressure.

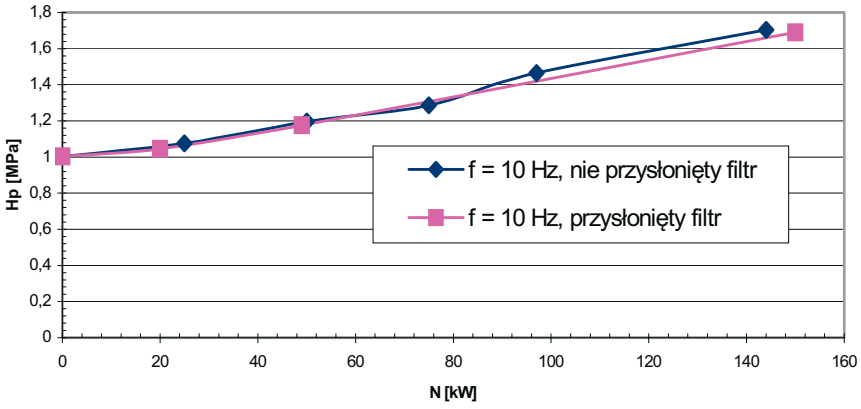

Fig. 8. The values of spectrum amplitude harmonics of combustion pressure for different values of absolute load of engine with simulation clean and contaminated air filter in frequency band f = 0 - 2.5 kHz

5. Conclusions from carried research

Taking into account current state of knowledge and carried diagnostic research come to mind following conclusion:

- is possible choice of such diagnostic symptoms, which will be correlated with relative load and

technical state of marine diesel engine,
- these spectrum measures of combustion pressure are good diagnostic symptoms,
- there amplitude estimates of course of combustion pressure in working chamber exhaust of internal combustion engine are interdependences with engine load but they are less correlated from spectrum measures,
- diagnose of marine piston diesel engine, it is obliged to proceed at constant load,
- t is obliged to proceed at constant load of engine,
- executed preliminary research have been verified in principal research,
- simulated pollution of air filter of turbocharger had influence on values of amplitude estimates and values of amplitude harmonics of spectrum signal of course of combustion pressure.

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