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THE IDENTIFICATION AND ELIMINATION OF INTERFERENCE IN PRESSURE COURSE IN THE CYLINDERS OF INTERNAL COMBUSTION ENGINES MEASURED UNDER MARINE POWER PLANT EXPLOITATION CONDITIONS

ABSTRACT

This article presents some of the problems which occur in the course of transforming signals of work process parameters in the testing of internal combustion engines, when power is supplied to a measuring appliance from a shipboard system under certain conditions and on the same measuring path. It characterizes the interference which has an influence on the results of measurements of pressure course in a diagnostics test conducted under marine conditions. In order to identify and to eliminate interference the wavelet analysis of signals of pressure in cylinders of internal combustion engines was carried out. As a result of the analyses it was found that the sources of interference are: electricity grid, electrical power equipment, indicator channels and valves, as well as sensors and measuring sets.

Key words:
sea-going ships, marine power plants, generator sets, interference in pressure course signals.

INTRODUCTION

A seagoing ship is a vessel having a high concentration of machinery and appliances which are a source of electrical interference. In electric installations there occurs electric grid-related interference caused by the irregular rotational

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speed of engines, especially by fast and sometimes substantial changes in engine load. The main component elements of electrical power systems are: energy sources, main and emergency distribution boards, cabling and various electricity receivers. In electronic systems there always occur undesirable signals, referred to as interference and noises [1, 4].

Any, other than useful, signal occurring in a measuring set [4] is an undesirable signal. Interference is those signals among the undesirable signals which cause faulty functioning of a component or a measuring set. In most cases undesirable signals cannot be fully eliminated, but their level can be lowered. With regard to the source or origin of interference it can be divided into [2–5] mechanical, environmental, electrical, (own noise, time fluctuations, signals from radio transmitters, galvanic, electrolytic, triboelectric signals, signals from switching on/off and control devices and lighting equipment, etc.).

The main objects in ships having a high level of internal and external effect are the main propulsion engines and generators which cause noise and changes in the constant component of a signal [1, 3, 6, 8]. Interference also adversely affects assessment of the technical condition of supervised objects [5, 8, 9].

Interference in measured signals is caused by a process present in the flow--through of a working medium in an internal combustion engine: delay of pressure wave in a channel, local loss and linear pressure in channels, pressure pulsation of medium in a channel, etc. Interference can also be generated in elements of measuring systems such as: sensors, analogue-digital transducers, amplifiers, computers, etc. Environmental conditions influence the level of interference [8].

SIGNAL INTERFERENCE AND ITS MINIMIZING IN MARINE ELECTRIC POWER SYSTEMS

There are possibilities of passive and active control of the level of interference in a shipboard electric power system and measuring paths. In order to control the level of interference or noisy technological solutions, and appliances which eliminate or significantly lower interference [4, 5] are used. Most often methods used methods in this connection are: shielding, smoothing chokes, multi-impulse power transmission systems, phase shifting transformers as well as passive and active filters [2, 5, 10, 11].

The Publication [2] presents the use of electronic filters for minimizing interference in pressure course signals in the cylinders of a marine internal combustion engine under laboratory conditions. In shipboard conditions this task is much more difficult. The authors of the publication [10] present examples of the decomposition of an indicator diagram of a marine medium-speed engine, carried out with selected filters available in the software package Mathematica. Finding the right filter for signal decomposition depends on its shape and properties.

OBJECTS OF TESTS

Objects used for testing were internal combustion engines in electric power generating sets used in bulk cargo ships. The ships were equipped with one main propulsion engine and three auxiliary engines, made under license by Sulzer Ltd and the Wärtsilä Qiyao Diesel Company Ltd, and used to drive three-phase generators (fig. 1). The auxiliary engines were located in the same self-contained compartment of the marine power plant. The measuring path consisted of a pressure tensometer, amplifier, power supply, connecting terminal and portable computer [7, 8]. The power to the measuring path was supplied from the shipboard electric grid, from an electric socket having voltage 220 V AC. Although the same measuring paths were used and the elements were localized at the same places [7, 8] in some ships under testing, significant interference of work and accompanying processes were recorded. Clear interference was recorded in 13.45% of the 50 tested engines, including 8.33% relating to the signals of the pressure distribution in cylinders. Publication [8] describes residual process-related interference (displacements, velocities and accelerations of vibration), and this article presents the measurement results relating to the distribution of work processes in the cylinders of the engines tested.

Fig. 1. Electric power generating sets with engines type 4L20D2 made by Wärtsilä

Shielded cables were used to extract any signals. An attempt was made to exclusively use a battery to supply power to the portable computer, which proved to be an effective way of eliminating interference. The tests were carried out during the stay of ships in harbors. In some cases the tester influenced the condition of ship installation due to the limited time of stay.

CHARACTERISTICS OF THE TEST RESULTS

In most cases the pressure distribution recorded in the cylinders of internal combustion engines showed small interference [7], but there were cases of significant interference recorded (fig. 2). The interference seen in figure 2 is noises and single impulses. It was interference which holds in steady states. It was demonstrated that this was the signal interference coming from the power supply source of the measuring apparatus. Distribution of impulses occurring in electricity grids cause 90% of interference with regard to computers [4]. Figure 2 shows that the interference occurs at pressures of low magnitudes.

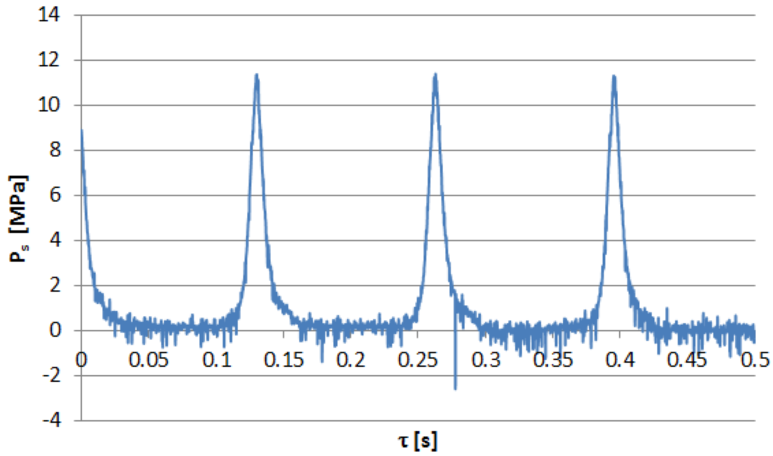

Fig. 2. Distorted course of absolute pressure over time P_s in a cylinder of the auxiliary engine at 64% relative load

Interference relating to voltage can be estimated using voltage distortion coefficient:

$$K_u = \frac{\sqrt{\sum_{n=2}^{\infty} \tilde{U}_i}}{\tilde{U}_c} 100\% , \tag{1}$$

where:

$\widetilde{U}_i$ — effective magnitude of i-th voltage component;

$\widetilde{U}_c$ — effective magnitude of the whole voltage distribution in time.

Interference can be determine, i.e. interference which can be described with mathematical dependences or it can be random, i.e. interference described by means of statistic magnitudes such as [4, 5]: mean-square magnitude, effective magnitude, power spectral density, probability density. It is necessary to eliminate interference in signals which can be useful in diagnostics of objects in marine power plants, i.e. smoothing the distribution or extracting the interference itself [10]. Averaging over time replaces a fluctuating magnitude for an equivalent constant magnitude:

$$\overline{P}_s = \lim_{T \to \infty} \frac{1}{T} \int P_s(\tau) d\tau , \qquad (2)$$

where:

τ — time;

T — period.

Distributions of absolute pressure P_s were averaged over time by means of the software DaqView, which resulted in smoothing the course, and in lowering noises and impulses (fig. 3).

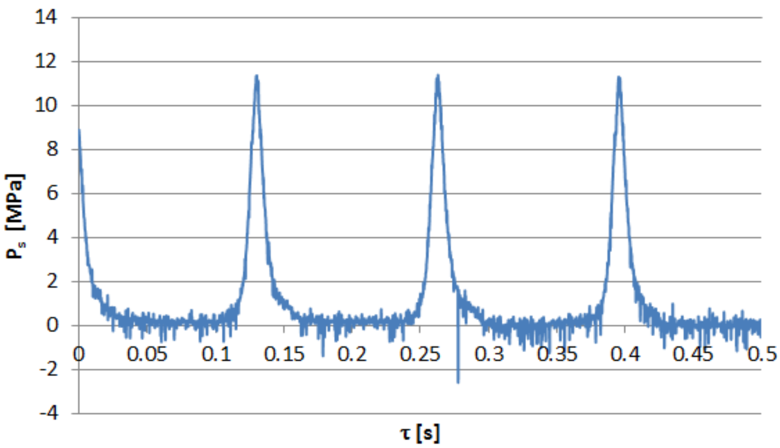

Fig. 3. A pressure signal course from fig. 2 averaged over time in order to change the image of interference in the diagram

A spectral analysis was made of the distorted course over time presented in figure 4a in order to select a boundary filter frequency in the signal acquisition software DaqView. For comparison, an example of the spectrum of an undistorted signal is presented in figure 4b. The spectrums in figure 4a differ from each other not only in occurrence of noise but also in amplitude magnitudes of principal components.

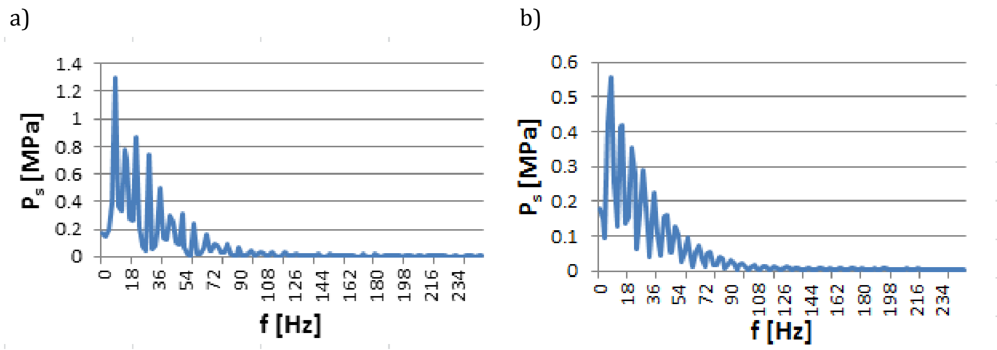

Fig. 4. A spectrum of (a) a distorted signal of pressure in an engine cylinder at 56% relative load and (b) an undistorted signal at 56% relative load

In one of the tests interference was recorded in one auxiliary engine, and was not recorded in the other two, in the same ship during an overhaul in a shipyard. Figure 5 presents a distorted distribution of pressure over time in a cylinder in no. 1 auxiliary engine and not distorted distribution of pressure over time in a cylinder in no. 3 auxiliary engine in the same ship at the same load, when measurements were separated by a one day interval. When the no. 1 auxiliary engine in the same ship was tested again after one and half years, no significant interference was recorded.

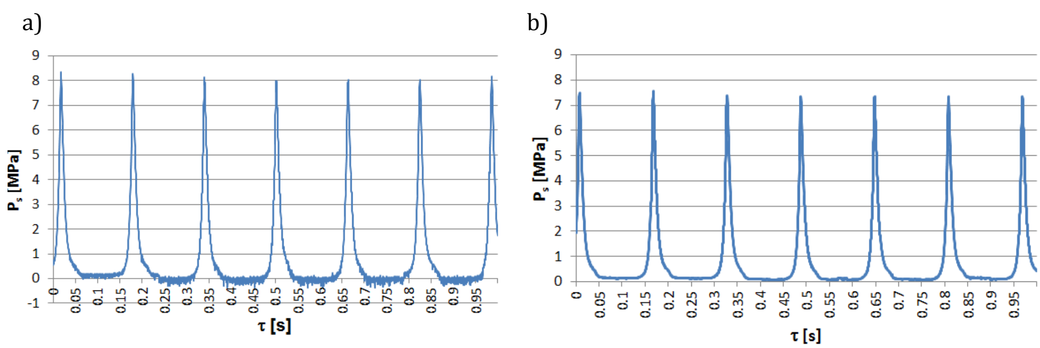

Fig. 5. At 50% load: (a) a distorted distribution of pressure over time in a cylinder of no. 1 auxiliary engine cylinder and (b) a less distorted distribution of pressure over time in a cylinder in no. 3 auxiliary engine

Attempts were made do apply the wavelet decomposition in order to separate useful signals from the interference. Signal $P_s(\tau)$ can be presented as a composition of sufficiently smooth distribution and certain fluctuations (of details). In order to decompose the signals the wavelet transform was used to separate a useful signal from a noise. In the course of the decomposition the signal is divided into (a) a low-pass element and (b) a high-pass element:

$$P_s = a_1 + d_1 = a_2 + d_2 + d_1 = a_3 + d_3 + d_2 + d_1. \quad (3)$$

In the process of signal synthesis the same algorithm is used in the reversed direction. This recording presents ideas how to carry out a decomposition and synthesis of an original signal (6). This way the signal useful in pressure distribution in cylinders was separated from the interference. A lot of graphic options of discrete wavelet transform can be employed.

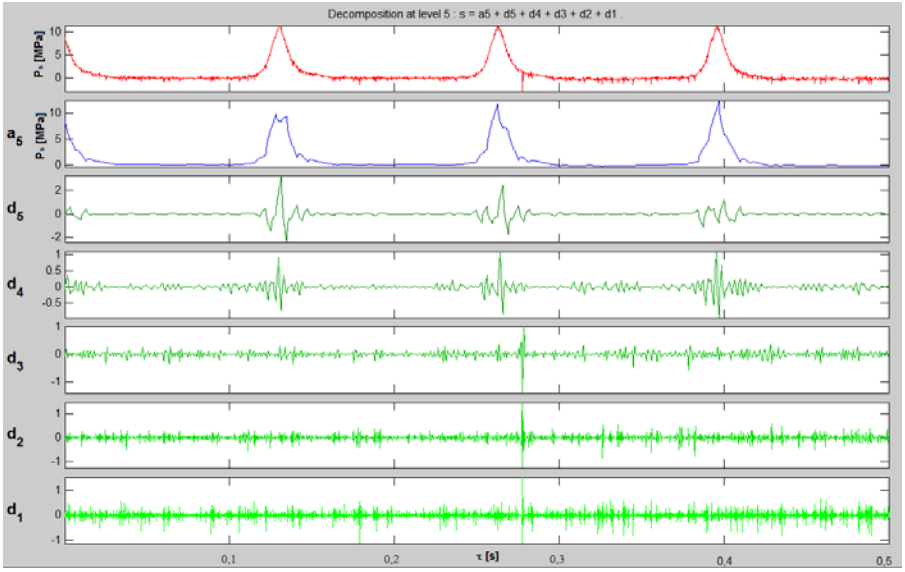

Fig. 6. Wavelet decomposition of a distorted signal

CONCLUSIONS

Results of diagnostics tests focused on internal combustion engines conducted on sea-going ships can be distorted. Conditions occurring in sea-going ships in which internal combustion engines are operated are often much diversified. In an analysis of a chain of measurement data, components of noise having low and high frequencies can be highlighted. In diagnosing objects of marine power plants there occurs interference of systematic type, i.e. it can contribute to making wrong diagnostic decisions. In order to obtain reliable results it is necessary to minimize measurement-related interference at the stage of processing and analyzing signals.

The tests which involved the same type of objects subjected to measurements and the same measuring path used indicate the presence of electric grid related interference, which is shown by the improved condition when an autonomic power supply is applied to a computer with an acquisition system and signal analysis. It is possible to separate interference from useful measured signals through: filtration, approximation, averaging and wavelet decomposition.

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IDENTYFIKACJA I ELIMINACJA ZAKŁÓCEŃ PRZEBIEGU CIŚNIENIA W CYLINDRACH SILNIKÓW SPALINOWYCH MIERZONYCH W WARUNKACH EKSPLOATACJI SIŁOWNI OKRĘTOWYCH

STRESZCZENIE

W artykule przedstawiono problemy występujące w czasie przetwarzania sygnałów parametrów procesów roboczych w trakcie badań silników spalinowych, przy zasilaniu aparatury pomiarowej z sieci okrętowej, w określonych warunkach i tym samym torze pomiarowym. Scharakteryzowano zakłócenia mające wpływ na wyniki pomiarów przebiegu ciśnienia w badaniach diagnostycznych prowadzonych w warunkach eksploatacji statków morskich. W celu identyfikacji, a następnie eliminacji zakłóceń zastosowano analizę falkową sygnałów ciśnienia w cylindrach silników spalinowych. W wyniku wykonanych analiz przebiegów czasowych i widmowych oraz ich dekompozycji falkowych ustalono, że źródłem zakłóceń są: sieć zasilająca i urządzenia energetyczne, kanały i zawory indykatorowe oraz czujniki i układy pomiarowe.

Słowa kluczowe:
statki morskie, siłownie okrętowe, zespoły prądotwórcze, zakłócenia sygnałów przebiegu ciśnienia.