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ANALYSE OF MARINE DIESEL ENGINE PERFORMANCE

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Abstract

Ships safety and economic efficiency depends on the main and auxiliary diesel engines technical condition and technical operation. The probability of failure and a sudden stop of diesel at sea would be minimized if the routine monitoring of parameters is done and found defects removed on time. The purpose of this control is the even distribution of load between the cylinders under the condition of fuel equipment and main diesel systems normal state. The power plant capacity, fuel efficiency and compliance with MARPOL environmental restrictions depend on it. In this report we will discuss the survey methods of the ship's diesels working process, which improve their efficiency. Use of such methods will enrich the information capability and modeling quality of the PC based Engine Room simulators.

Keywords: *Engine Room simulators, turbocharger rpm, gas distribution mechanism, fuel injection and valves timing, monitoring*

1. Introduction

On low speed engines there are well known in seamanship mechanical drives for determining the basic parameters of the working process and indicator power of cylinders. They cannot be used for medium-and high-speed diesel engine because of mechanical drives inertia. For those of diesel engines, which make up the majority of the offshore and fishing fleet, only electronic control systems may be used.

Capabilities of most electronic systems are focused mainly on getting the indicator working process parameters such as maximum combustion pressure *Pmax*, maximum compression pressure *Pcomp*, mean indicated pressure *MIP*. However, besides these there are several other important diagnostic parameters of fuel injection equipment and gas distribution mechanism. Their control allows you to assess more accurately the technical condition and to adjust the marine diesel engines. First of all fuel injection timing and valve timing is included into such settings.

In the problem of determining the working process parameters, there is a problem of data synchronization, i.e. representation of them, depending on the phase rotation of the crankshaft, for example $p_{cyl}=f(\varphi)$. Traditionally, this problem is solved by means of sensors on the flywheel. Disadvantages of this method are that it is difficult to consider all the factors that influence the phase error. Besides, setting the sync sensor requires preliminary diesel preparation and definite expanses.

Thus, there are two problems to be solved for the perfect modeling and condition monitoring of marine diesel in operation: 1) parallel determination of the indicator work process parameters and timing of fuel injection and gas distribution; 2) the solution of sync problem in terms of improving its accuracy and efficiency.

An important element of diagnosis of a diesel engine is a characterization of turbocharging. On the main engine turbines tachometer and charge air pressure gauges can be installed. On the turbines for auxiliary diesel engines, as a rule, there are no such devices. In this article we shall discuss how during the operation such important parameter, as the rotational speed of the turbocharger can be determined. The above problems are solved in the PC based system for diesel condition monitoring.

Fig. 1. Equipment of the diesel engine performance analyzing system

2. Diesel engine performance analyzing system

The purpose of the system is to diagnose main and auxiliary marine diesel engines see Fig. 1. Also it can be used on other mobile and stationary diesel power plants. Gas pressure sensor and vibro sensor are included into the standard version. The system measures and calculates the following: *RPM, Pmax, Pcomp, MIP, indicated power, fuel injection and valves timing, gas pressure, fuel injection and valves vibro diagrams.*

Fuel injection and valves timing as well as estimation of technical condition of separate units are determined by means of contact vibrosensor. It records high frequency signals that occur during the ascent and landing injector and valves timing during engine working cycle, see Fig. 2.

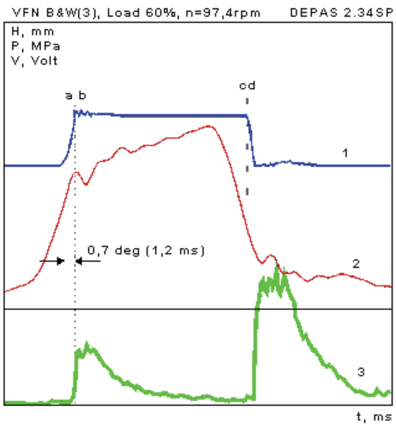

Fig. 2. Fuel injection timing with the help of vibrodiagram

Due to analyzing of fuel injection equipment and valve timing mechanism vibrodiagrams together with working process indicator diagram the spectrum of monitored parameters has been significantly widened. The engine cylinder technical condition diagnosis became possible not only by cylinder gas pressure but also by key data of fuel injection and valve timing.

3. Data synchronization method

The Top Dead Center (TDC) of a piston is calculated by analyzing diagrams of gas pressure in the working cylinder. Design algorithm of synchronization is based on the fact that in case of pure compression (without fuel injection and combustion) in the cylinder, the speed degree of increasing gas pressure is equal to zero: dP/dFi=0 at TDC position of the piston, see Fig. 3. On the referent diagram of pressure the site of pure compression before the beginning of combustion is allocated. Factors of non-linear mathematical model of a curve dP/dFi are calculated by means of minimization method. Mathematical data synchronization method leads to precise calculation of *MIP* and indicated power.

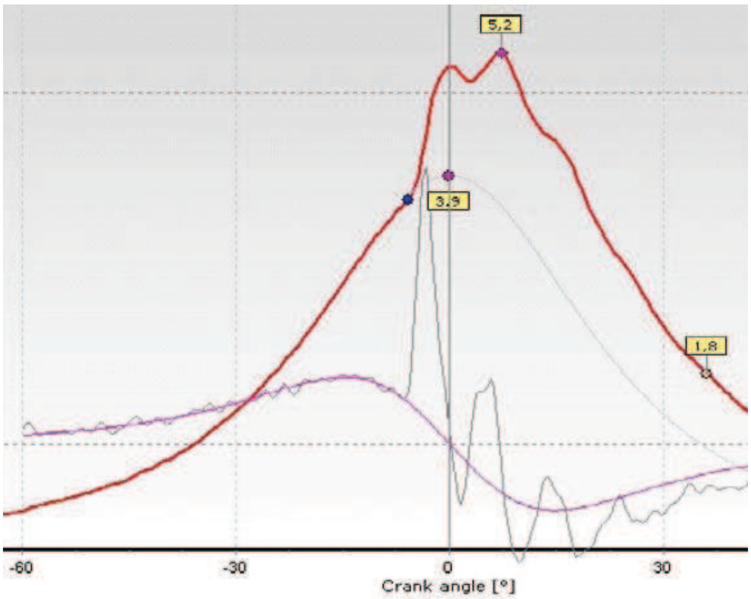

Fig. 3. TDC determination with the help of dP/dFi mode

4. Example 1. Four-stroke engine

Diagnosing the working cylinder of a medium speed diesel engine is shown at Fig. 4.

Fig. 4A shows the indicator diagrams of work process and results of the work process basic parameters calculation: indicated power, MIP, the maximum compression and combustion pressure, the angle of the start of combustion, etc. Fig. 4B shows the vibrodiagrams of fuel injection and gas distribution which is recorded simultaneously with the indicator diagrams. It may be noted the normal operation of fuel equipment according to specified vibroimpulses (without distortion) of rising (15º bTDC) and setting (4º aTDC) needle.

The first to the left vibroimpulse characterizes the signal while closing the inlet valves. Fractional value of the vibroimpulse shows the fact that inlet valves do not close simultaneously. It is a defect of gas distribution mechanism.

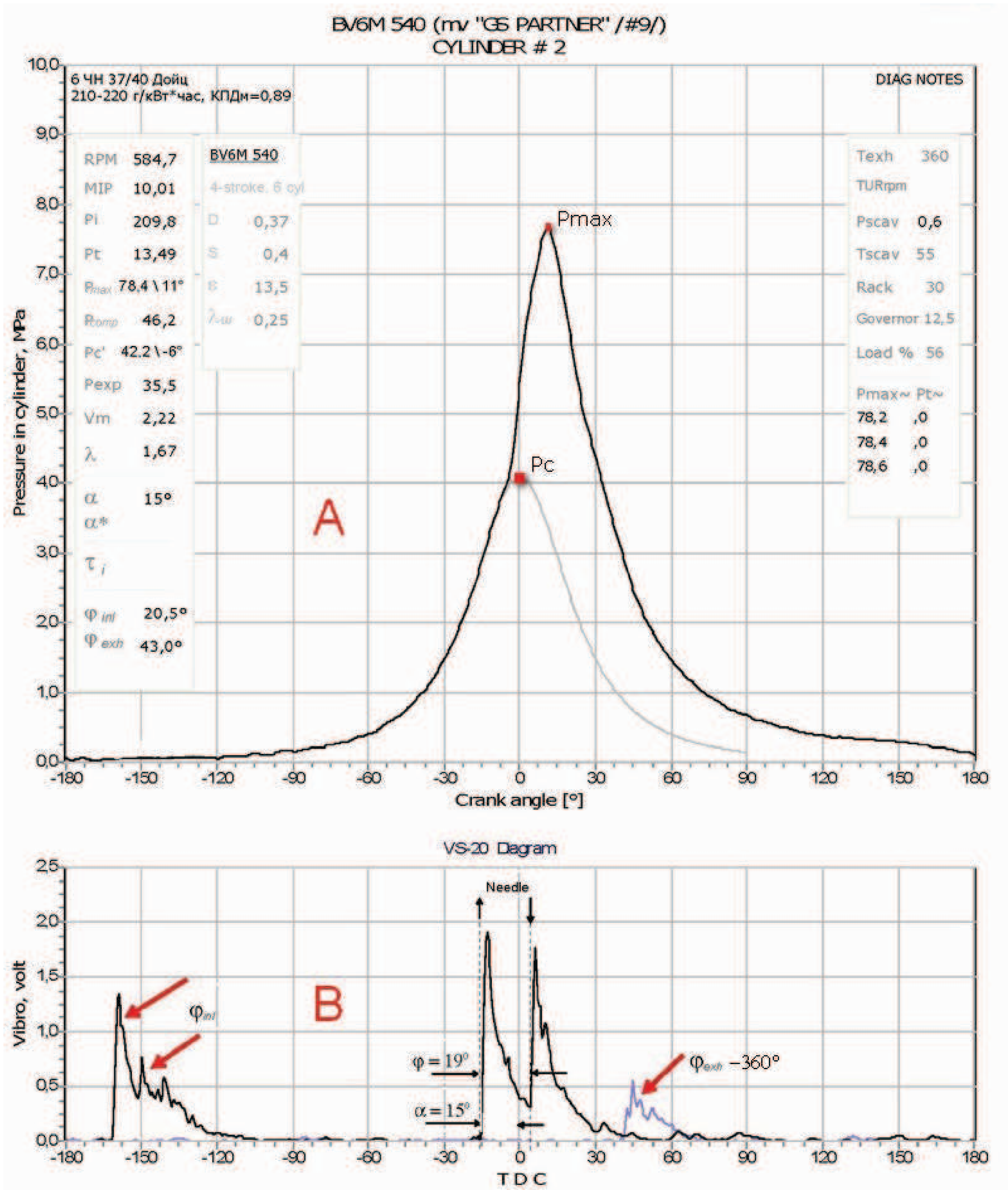

Fig. 4. Medium speed diesel engine working process

5. Example 2. Two-stroke engine

Another example of S60MC two-stroke low-speed main engine work process diagnosis shown on Fig. 5.

Reference points on diagrams:

1. Point on the indicator diagram which corresponds to a moment of the beginning of fuel self-ignition,
2. Geometrical advance angle of fuel feed by HPFP (a plunger is beginning to close the cut-off port),

3. Fuel feed cut off (the low edge of HPFP plunger is starting to open the cut-ff port),

4. Rising of injector circulation valve and termination of fuel circulation (P~1.0MPa),

5. Rising of injector needle (P=25.0±2MPa) – real angle of the fuel injection beginning,

6. Injector needle fit – real angle of the fuel injection termination,

7. Injector circulation valve fit – the beginning of fuel circulation,

8. Angle of complete closing of the exhaust valve – valve plate fit in its seat,

9. Angle of the beginning of damper action at the end of exhaust valve stroke,

10. Increase of a high-frequency noise level while opening the exhaust valve.

According to diagrams on Fig. 5 and obtained parameters, the condition of the cylinder, the high pressure fuel equipment and mechanism of gas distribution is normal.

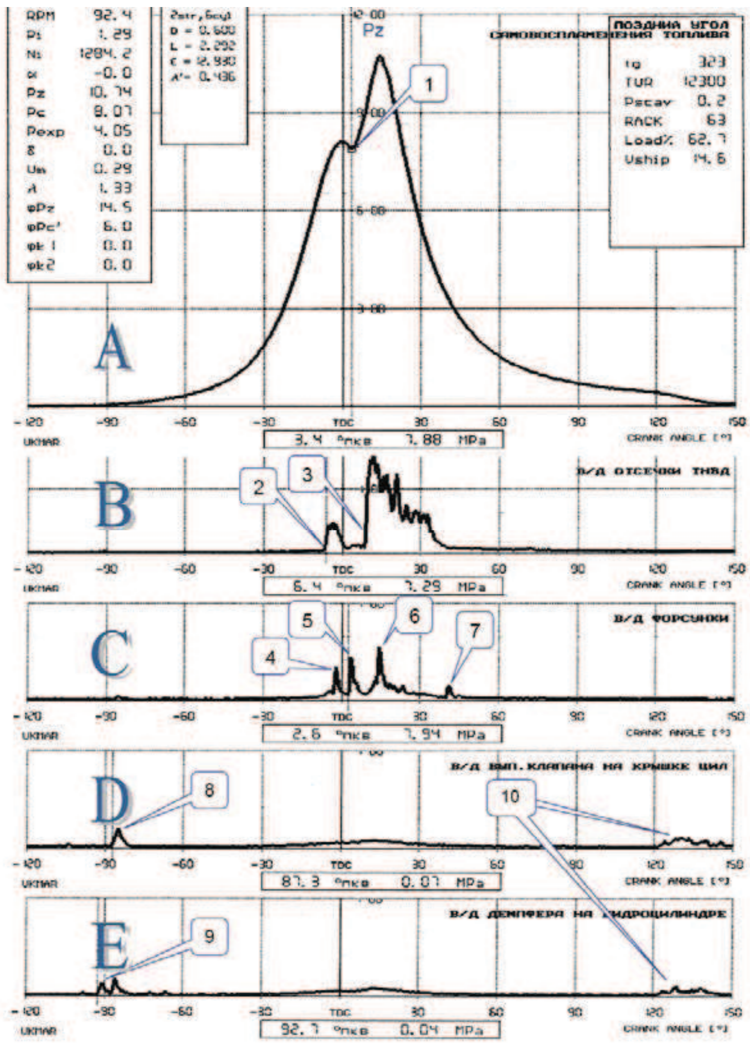

Fig. 5. Two-stroke low-speed main diesel engine working process

6. Determining the speed of TURBOCHARGER

Charge air pressure depends on the speed of turbocharger. In connection with this problem of its operational definition is especially important during the operation for all types of diesel engines. To determine the frequency of turbocharger rotation the amplitude spectrum of acoustic signal of an air compressor was used. The spectrum of the main engine turbocharger, see Fig. 6 and auxiliary engine turbocharger see Fig. 7.

The spectral analysis showed that the compressor side is generating audio signal with a frequency equal to the frequency of rotation multiplied by the number of blades.

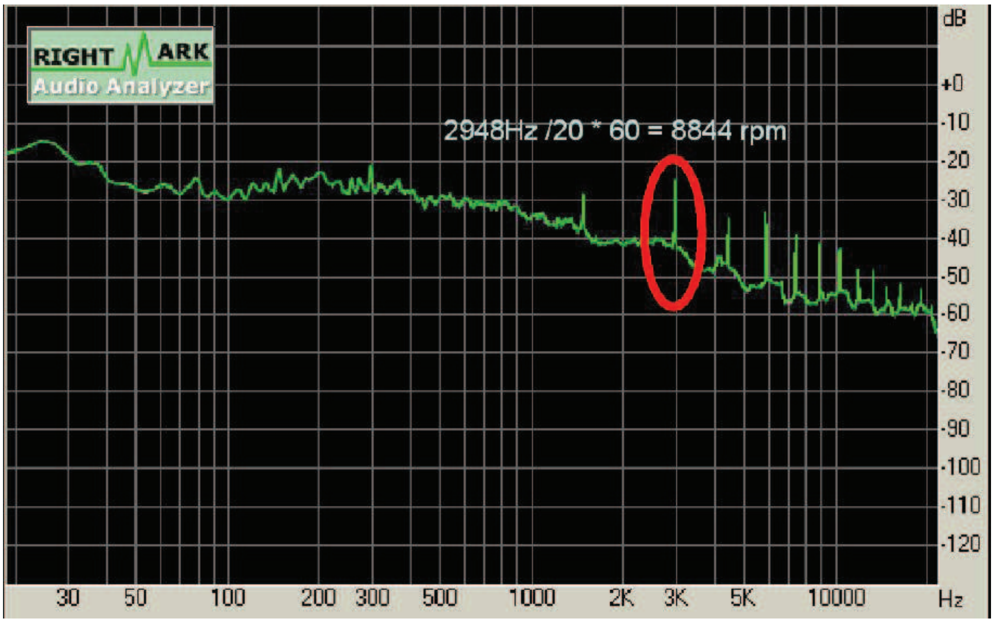

Fig. 6. Caption: Spectrum of the main engine turbocharger

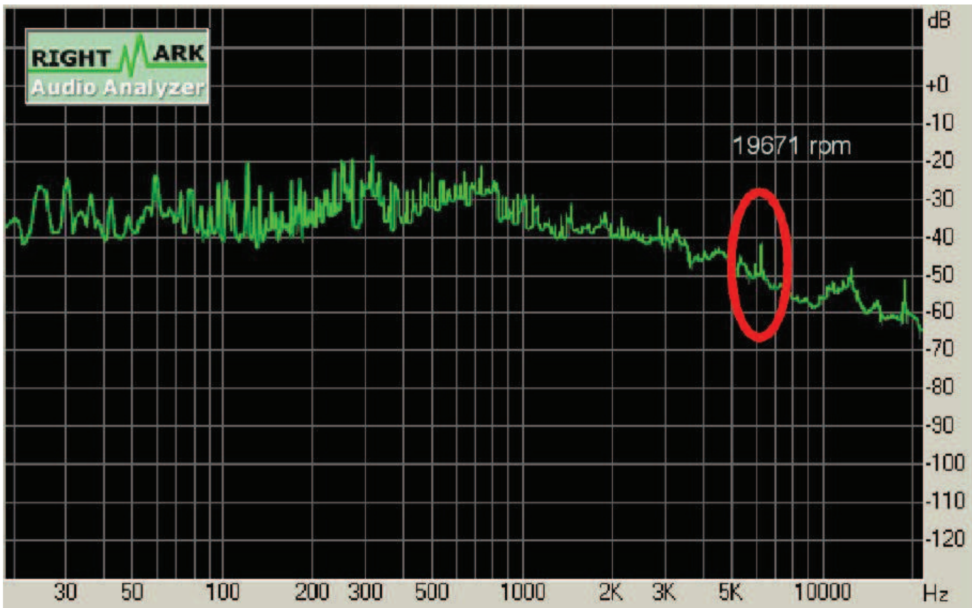

Fig. 7. Spectrum of the auxiliary diesel engine turbocharger

For diesel 6L80MCE with type TURBOCHARGER VTR 564-31 (20 of compressor blades) the expected frequency is equal to:

$$Fq = 9000 \text{ rpm} / 60 * 20 = 3 \text{ kHz}.$$

The minimum and maximum possible speed of TURBOCHARGER and, accordingly, the frequency of signals can be taken as follows:

MAX: 6000 rpm / 60 * 20 = 2 kHz,

MIN: 20000 rpm / 60 * 20 = 6667 Hz.

In this range there is only one distinct maximum, see Fig. 6. The corresponding frequency is:

TURrpm = 2948 Hz / 20 * 60 = 8844 rpm.

It is interesting to note that in the medium-auxiliary diesel Daihatsu 6PL 24 with a turbo-generator VTR 201, the number of compressor blades also turned to be 20. Using similar arguments we calculate the speed of the turbine rotor diesel mode at 380 kW:

TURrpm = 6557 Hz / 20 * 60 = 19671 rpm.

7. Conclusions

Diagrams and data shown in Fig. 4-7 are greatly valuable for engineers as they illustrate technical condition of working cylinder, its high pressure fuel equipment and auxiliary systems.

This method of working process monitoring can be very useful in practice. Besides, the received from ship’s diesel data will help to create more real models in PC based Engine Room simulators.