THE RESEARCH OF TURBOCHARGING SYSTEM OF MARINE DIESEL ENGINES BY MEANS OF SIMULATION CHAGES OF TECHNICAL STATE

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Summary

This paper presents an innovatory diagnose method of workspace areas inside marine diesel engines equipped with turbocharger. The main aim of the conducted research is diagnosing workspace areas inside engines without indicator valves. This is a fundamental diagnostic issue because these engines are in common operation in the Polish Navy. The proposed method is based on the measurements of exhaust gases pressures in the characteristic cross sections of the exhaust channel connecting engine's cylinders with turbocharger's turbine.

Keywords: diagnostics, workspace area, marine piston engine.

BADANIA UKŁADU TURBODOŁADOWANIA SILNIKA OKRĘTOWEGO PO WPROWADZENIU SYMULOWANYCH ZMIAN STANU TECHNICZNEGO

Streszczenie

W artykule zaprezentowano nowatorską metodę diagnozowania przestrzeni roboczych okrętowych tłokowych silników spalinowych z turbodoładowaniem. Celem opracowywanej metody jest parametryczna ocena stanu technicznego przestrzeni roboczych silników niewyposażonych standartowo w zawory indykatorowe. Celowość prowadzenia badań nad alternatywną do indykowania metodą diagnostyczną wynika z powszechności stosowania silników niewyposażonych przez producentów w zawory indykatorowe. Proponowana metoda umożliwia ocenę stanu technicznego przestrzeni roboczych silnika na podstawie pomiarów ciśnienia w przekrojach charakterystycznych kanału wylotu spalin łączącym cylindry silnika z turbiną turbosprężarki.

Słowa kluczowe: diagnostyka, przestrzenie robocze, okrętowe tłokowe silniki spalinowe.

1. INTRODUCTION

The main reason for taking of research is a creating a new diagnostic method of marine diesel engine's workspace areas in the operation while the engine is not equipped with indicator valves.

The proposed diagnostic's method will be based on the measurements of exhaust gases pressure in the characteristic cross section of the exhaust channel.

In the beginning of scientific activities devoted to such an issue the authors create physical model of gas dynamical processes inside exhaust channel. The physical model gives a possibility to elaborate mathematical model and computer simulation program. In the next stage of research authors conduct examinations on the real object as a SULZER marine diesel engine 6AL20/24 type.

2. THE METHODOLOGY OF RESEARCH

The methodology of research takes following procedure elements into account [1]:

- construction and parametric identification of marine diesel engine's SULZER type 6AL20/24,
- construction of physical model of gasdynamical processes inside exhaust channel,
- construction mathematical model which is based on physical model,
- making tests in different technical state of the real object,
- making tests in different technical states being implemented into the mathematical model,
- comparing timing courses from the model and a real object and makes it possible to verifier of balance equation of the mathematical object.

In the result of simulation tests, the diagnostic method of the described marine engine will be drown up. The diagnostic method considers the following diagnostic key questions:

- what and where to measure,
- how and when to measure,
- how to infer,
- whether the engine is primary defected i.e. dirty or out of adjustment, or it is secondarily defected as a result of the dirt or being out of adjustment,
- what remedy should be used (what decision should be made about the range of the service or the operation decision about the future utilization),
- how often the diagnostic test should be repeated to assure a required durability, reliability and economical operation,
- which diagnostic parameters are the most useful in operation, which of them include the most of diagnostic information and which one is easy to measure.

3. THE IDENTIFICATION OF THE RESEARCH OBJECT

The research object is a SULZER marine diesel engine 6AL20/24 type which is a part of the laboratory test bed in the Polish Naval Academy. The engine's flow system is presented in figure 1.

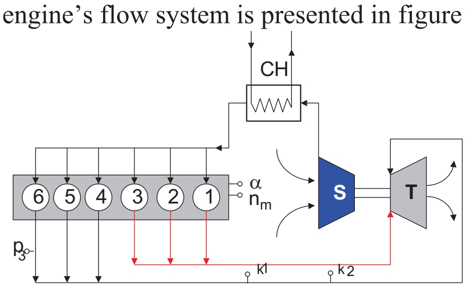

Fig. 1. The flow system of SULZER marine diesel engine 6AL20/24 type

Figure 1 shows two characteristic cross section k1 and k2. There are two pressure sensors OPTRAND type to control pressure in those sections and additionally there is one pressure sensor in the turbine's outlet channel. The transverse section of exhaust channel which connects engine's cylinders and turbine of turbocharger is showed in figure 2.

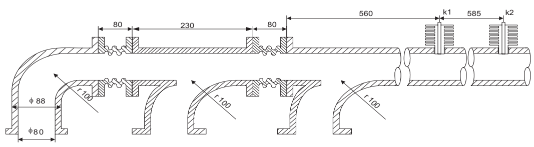

Fig. 2. The transverse section of SULZER's exhaust channel

All parameters of exhaust gas was measured and registered by especially designed computer measurement system MA2005 with the sampling frequency of 10 kHz. The computer measuring system cooperates with OPTRAND pressure sensors type C11294-Q and OPTRAND pressure sensor type C31294-Q type. First type of sensors is used to measure gas pressure inside the exhaust channel. The last one sensor type is used to measure pressure inside combustion chamber.

4. THE RESEARCH PROGRAM

The main aim of research is to obtain the pressure in two cross sections of the exhaust channel which connects cylinders number 4, 5 and 6 and turbine of the turbocharger. The additional cross section for the pressure measurement is localized behind the turbine of turbocharger. Moreover the pressure inside the combustion chamber number 6 is measured as well.

Within the research program the authors established that measurements will be carried out for the following parameters of the engine's technical state:

- while the engine is fully efficient (no changes in engine's technical state),
- while the engine is partly efficient, orifice plate which decreases the face area of the exhaust channel by 50%,
- while there are leakages of the working medium from combustion chamber,

The measurements will be done for three different loads: 0, 50 and 100%. The 100% load is a last load when the engine works with established crankshaft's rotational speed. All the settings of the engine are put into table 1.

Table 1. The energetic status of engine during tests

Crankshaft's rotational speed	Load
[rpm]	[%]
600	0
	50
	100
650	0
	50
	100
700	0
	50
	100
750	0
	50
	100

The first stage of research was conducted with the fully efficient engine. In the second stage of the research authors use the measuring orifice plate in order to decrease the face area of exhaust channel by about 50%. The measuring orifice plane is demonstrated in the figure 3.

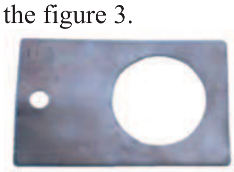

Fig. 3. The measuring orifice plane

The leakages of working medium from the sixth combustion chamber was simulated by opening an indicator valve.

5. THE METHOD OF DATA ANALYSES

The analysis of the measured date was conducted with the usage specialistic author's computer program. The computer program gives a possibility to assign following energetic parameters:

- the real crankshaft rotation speed on the bases of synchronise signal like the pressure inside combustion chamber or acceleration of chosen elements of the engine,
- dispose enthalpy flux in characteristic cross section,
- gas wave front velocity inside the exhaust channel,
- comparative analysis of the registered pressure courses as a function of angular displacement or time,

The crankshaft rotation speed is determinated by the time of engine's work cycle. The time of work cycle can be defined as the time between impulses of pressure inside the engine's combustion chamber [2, 3]. The crankshaft rotational speed is defined as follow:

$$n = \frac{2 \cdot \tau_{\acute{s}r}}{s} \qquad (1)$$

where:
n – crankshaft rotation speed,
$\tau_{\acute{s}r}$ – average time of the engine work cycle's duration,
s – number of strokes.

The dispose enthalpy flux being assigned in the characteristic cross section represents an area under pressure course as a function of angular displacement. The function of pressure can be cut for particular cylinders. The way of calculation of the particular dispose enthalpy flux is showed in figure 4 and numerical results of this method are showed in figure 5.

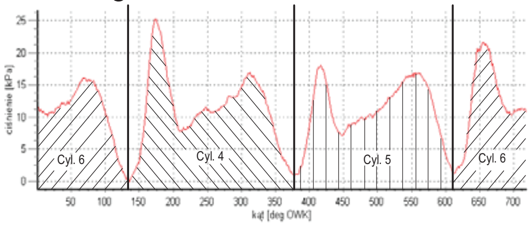

Fig. 4. The way of calculating the disposes enthalpy fluxes from the engine's cylinders

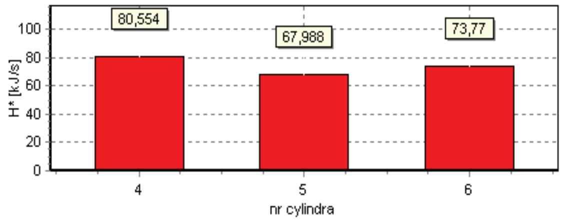

Fig. 5. Dispose enthalpy flux form individually engine's cylinders

The next diagnostic parameter is taken from the calculation of the velocity spreading the wave front of gas pressure in the exhaust channel. This velocity is determined by the measurement time of pressure impulse dislocation in the known length between two exhaust channel's cross sections. The theory of wave front velocity calculation was showed in figure 6. The practical application of the method presents figure 7.

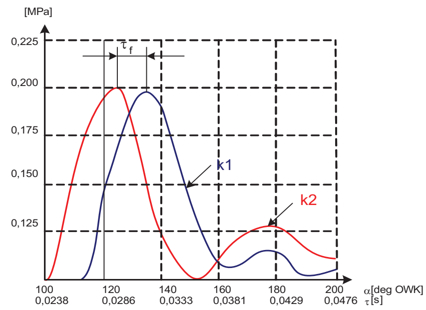

Fig. 6. The theory of wave front velocity calculation

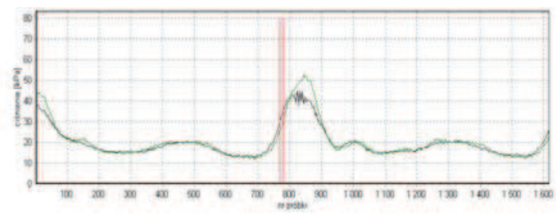

Fig. 7. The method of wave front velocity calculation in practice

Additionally it is possible to compare the courses of pressure as a function of crankshaft's angular displacement put on one graph. The result preparing for analysis is showed in figure 8.

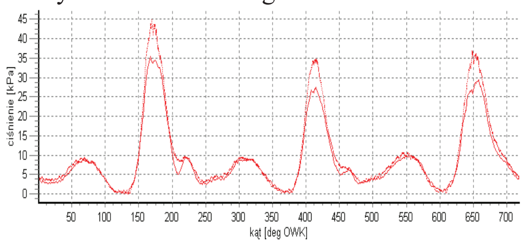

Fig. 8. The comparing analysis of registered pressure courses as a function of crankshaft's angular displacement

6. THE RESULTS OF THE MEASUREMENTS

In the first stage of the analysing the measured data was established dispose enthalpy fluxes from individual engine's cylinders. Table 2 and 3 contains calculated dispose enthalpy fluxes form cylinders for different technical state of the engine. In the column marked "OK" there is data for fully efficient engine, in the column marked "change" there is data for the simulating change exhaust channel face area (table 2) and for leakages of the working medium (table 3).

Table 2. The dispose enthalpy fluxes for the engine with changed exhausts channel's face area

Crankshaft rotation speed	Cylinder 4		Cylinder 5		Cylinder 6	
	OK	Change	OK	change	OK	change
500	45	49	38	44	45	31
600	73	78	68	66	80	59
700	108	115	103	95	128	106
750	225	152	224	152	251	177

Table 3. The dispose enthalpy fluxes for the engine with leakages of working medium from cylinder nr 6

Crankshaft rotation speed	Cylinder 4		Cylinder 5		Cylinder 6	
	OK	change	OK	change	OK	change
500	45	49	38	42	31	49
600	73	81	68	74	59	93
700	108	112	103	109	106	133
750	225	148	224	146	177	175

In the next stage of measuring data analyses there was defined gas wave front velocity inside the exhaust channel. The results of data analysis are grouped in table 4.

Table 4. The wave front velocity for different technical state of engine

Crankshaft rotation speed [rpm]	Wave front velocity [ms^{-1}]		
	While the engine is fully efficient	During leakages of the working medium	During changes of the exhaust channel's face area
500	564	644	555
600	615	580	604
700	662	650	644
750	639	594	580

7. CONCLUSIONS

The research conducted on the real object proved, that proposed diagnostic method can be useful for identification and the localization of the simulated states of unfitness. In my opinion the most promising method of data analyses is the dispose enthalpy flux from individual engine's cylinders.

The dispose enthalpy flux gives a possibility to identify an individual cylinder where there is a change of technical state.

The another method (the using wave front velocity) carries information that something is wrong in engine's workspace areas but we can't exactly recognize what it is. We expect that in the nearly future this method of data analysis might be applied in practise during engines operation.

LITERATURE

[1] Cannon R. H. jr.: *Dynamika układów fizycznych* Warszawa Wydawnictwa naukowo-Techniczne 1973.
[2] Korczewski Z.: *Diagnozowanie okrętowego silnika spalinowego na podstawie wyników badania procesów gazodynamicznych w układzie turbodoładowania*. Zeszyty Naukowe AMW, nr 3/2002 s. 67-77.
[3] Korczewski Z. Zacharewicz M.: *Diagnostyka symulacyjna układu turbodoładowania okrętowego tłokowego silnika spalinowego*. Zeszyty Naukowe AMW, nr 2/2007 s. 73-101.
[4] Kordziński C.: *Układy wylotowe szybkobieżnych silników spalinowych.* Warszawa, Wydawnictwa Komunikacji i Łączności 1964r.

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