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EVALUATION OF COMPRESSION REALIZATION IN DIESEL ENGINE BASED ON PERFORMANCE INDICATOR CHANGES

Jacek Rudnicki

Gdansk University of Technology
ul. Narutowicza 11/12, 80-233 Gdańsk, Poland
tel.: +48 58 3472973, fax: +48 58 3471981
e-mail:jacekrud@pg.gda.pl

Abstract

In the article a method of evaluation of a diesel engine during the realization of processes of working circuit on the example of compression is described. The method is based on the use of the quantity called performance indicator in the description of the engine's work, which contains the information on the energy values, which may be disposed using the engine and the time at which it can be delivered. Theoretical information has been supplemented with information processed, in accordance with the proposed procedure, experimental results, which helped to illustrate the essence of this method.

Keywords: *operation,* working circuit, diesel engine

1. Introduction

An objective assessment of the reliability of any marine diesel engine forces the evaluative (quantitative) approach to this problem and the search for such measures, which are the most reliable in describing this feature of the engine.

On the other hand, the precise definition of the task except for the conditions of performance, requires specifying the duration as well. This issue is so important that the specific tasks in maritime transport is generally associated with the necessity of long-term operation of essential equipment of the vessel, especially its main drive.

Thus, it becomes particularly important, not only what the amount of energy which can be disposed using the main engine, but also the time in which it can be delivered.

Therefore, it is sensible to consider engine's operation (it's functional systems) in such an approach, so it could be described simultaneously by both energy and time.

Operation (D) in the time interval [0, t] can in this case be interpreted as a product of the physical quantity determined as the ratio of the time variable energy $E = f(\tau)\ \tau$ and time:

$$D = \int_0^t E(\tau) d\tau \qquad (1)$$

Method of processing of the engine in such a way as has been described inter alia in thesis referred to[1, 2, 4, 5, 6].

Because the concept of operation is also used e.g. in mechanics theory, to prevent the discussion, the D value described with general relation (1) it was decided to describe it as the performance indicator.

Description of the engine operation in the references above pertains to the time scale of the operation, which results from the fact that tasks duration in maritime transport can reach very high values and hence the value of the definite integral (1), which, for the assumptions taken is a measure of the engine operation, will also be very high .

Thesis [6] was, therefore, an attempt to answer the question, if one can "move" the considered performance assessment in a micro scale, that is to reduce the considered time - up to a maximum execution time of a single working circuit of the engine. This study is presented to verify and expand the considerations presented there and analyzes based on the results of experimental tests on in laboratory conditions with diesel engine.

2. The description of the test bench and measurement equipment

The study was carried out on a laboratory engine „Farymann Diesel" type D. It is a single cylinder diesel engine, four-stroke, naturally aspirated, fuel-injected into the pre-swirl of the combustion chamber, cooled by evaporation.

Tab. 1 Basic information about Farymann Diesel type D engine

Rated power	6 kW
Bore	100 mm
Nominal speed	1500 rpm
Displacement volume	765 cm^3
Compression ratio	22

The engine has a manual start and decompression valve for easy starting a cold engine. It also has a casting ignition paper screwed in the cylinder head. Threaded hole of the paper cast ignition has scored thread M14x1, 25 which was used to install the valve cylinder pressure.

a) b)

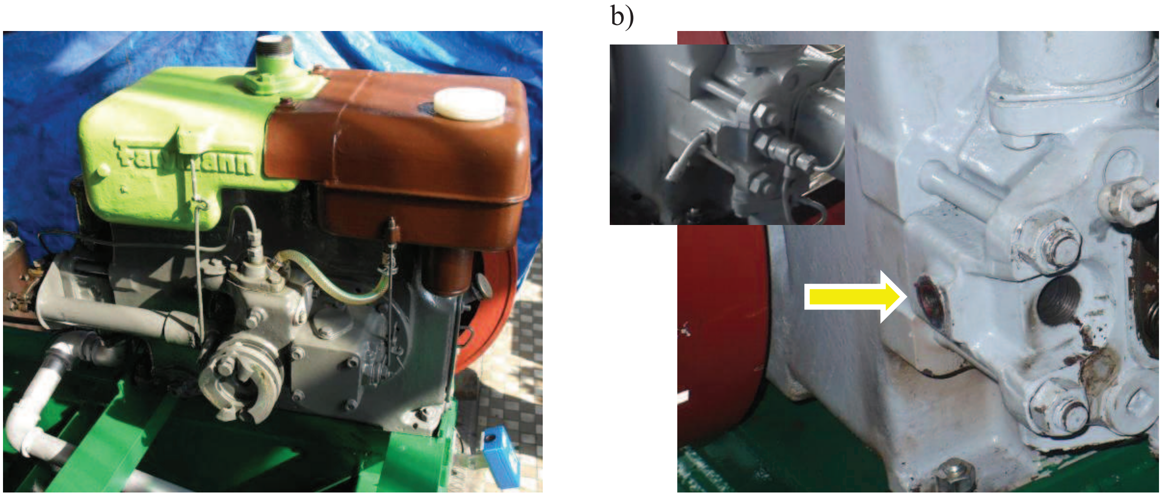

Fig. 2 View Farymann Diesel engine type D (a) and slot indicator assembly (b) at the ignition paper holder

For the measurement of pressures inside the cylinder electronic indicator PREMET C, XL version was used (http://www.lemag.de/premet_c.0.html).

Tab. 2 Basic information about electronic indicator PREMET C XL

Ignition pressure range	0 – 25 MPa
Speed range	40 – 1800 rpm
Max. number of cylinders	20
Max. number of measurements/cylinder	30
Manufactured according to ISO 9001	
Compensation of temperature	
PC connection	USB
Stainless steel housing with isolated thermogrip	
High resolution colour display	
Accuracy	better than 1,6

a) b)

Fig. 2 Indicator valve installed in a place of holder of ignition paper (a) an electronic indicator PREMET C on a laboratory stand (b)

The set of experimental results, which were used to verify the theoretical considerations contained in [6] has been accumulated during the 1.5 years of the use of the engine, in which the engine worked for about 50 hours. During this time were no operator action taken affecting the condition of the piston - cylinder unit, which has a decisive influence on the process of compression in the engine.

From this set of results containing approximately 60 indications, 4 samples were selected on the following assumptions:

• the identity of the measurement conditions (load and engine speed)

• subsequent spacing of the indicated time, the results of which were taken into account - at least 10 hours of operation,

• due to the fact that at the test bench there is no possibility of compression pressure measurement, the end of the compression was believed to be the position of the piston 10 ° before TDC (the angle of injection timing for the engine to be tested is about 8.5 before TDC).

Sample results (for readability of the graph, only the first and last indications) for the chosen subset are shown in Figure 3.

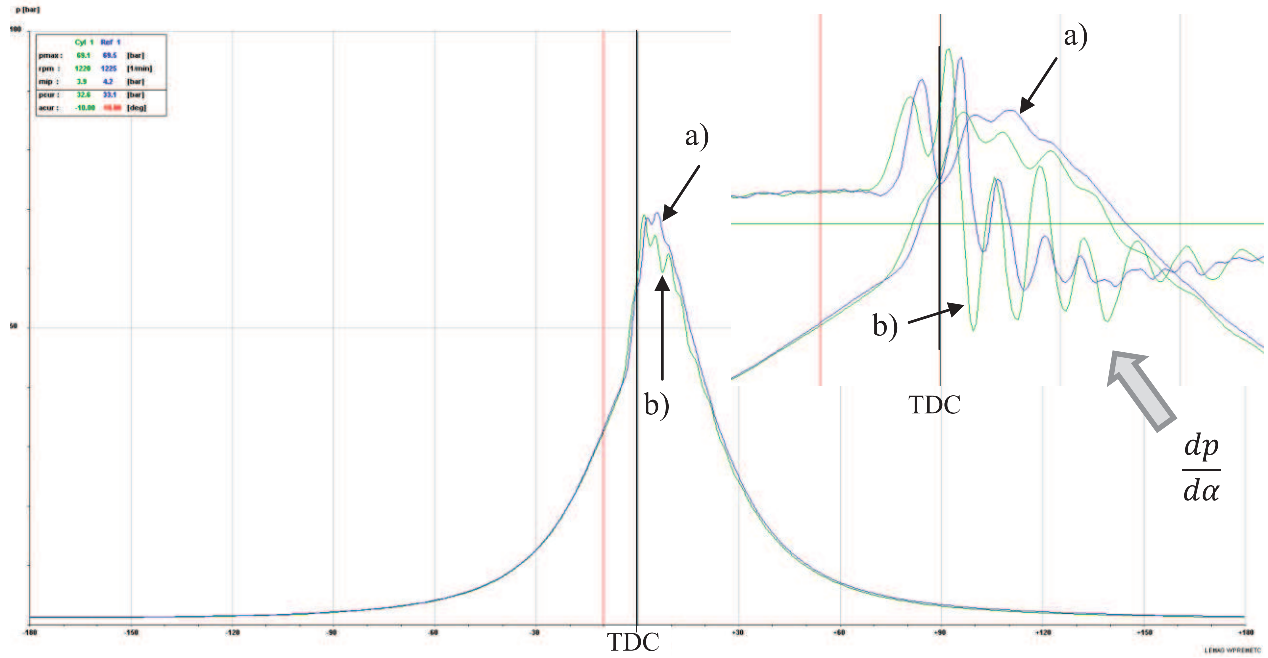

Fig.3 Results engine indications, dated. 26.05.2011 r - (a) and 31.08.2012 - (b); TDC – top dead center of the piston

As you can see in the charts compression differ practically unnoticed. You might also notice quite a significant difference in the combustion duration and the fact of more hard work after that engine use - higher value $\frac{dp}{d\alpha}$.

3. Evaluation of the implementation process of compression using pressure measurements inside the cylinder and index of operation

Indicator charts and analysis play a crucial role in assessing the operation of the engines during the operation. Indicated above, further discussed inter alia in the above-cited works a quantitative assessment of the engine using the operation ratio D *(t)* provides the possibility of another processing the results obtained during indication.

Strictly limiting to the analysis of this compression process requires:

- changes in the upper limit of integration in equation (1) for the duration of the concerned process – t_{com},
- a decision which the volume associated with the course of the compression process can be regarded as time-variable power according to equation (1).

The first of the problems described above, of course, does not present any difficulty because of making the assumption of shut-off fuel inflow to the cylinder concerned, in the general case this duration, is a duration of a stroke and is expressed in the formula:

$$t_{1str} = \frac{1}{2} \cdot t_{1obr} = \frac{1}{2 \cdot n} \tag{2}$$

where:

t_{1str} – duration of one stroke [s],
t_{1obr} – duration of one crankshaft rotation[s],
n – frequency of crankshaft rotation [s^{-1}].

In the absence of possibility to turn combustion in the cylinder off and create the contractual end of compression for a given value of the angle of the crankshaft position (in this study endcom $\alpha_{endcom} = 10^{o}$ of crankshaft rotation before TDC) relationship (2) is modified as follows:

$$t_{1com} = \frac{1}{2} \cdot t_{1obr} = \frac{1}{2 \cdot n} \cdot \left(1 - \frac{\alpha_{endcom}}{180}\right) \qquad (3)$$

where:

$\alpha_{end\ com}$ – angle of a contractual end of compression process (expressed in [^{o} owk] before TDC),

The issue of selecting a quantity that corresponds to the time – variable energy may cause some doubts, because the very concept of energy, as the scalar size describing the state of the system creates a fairly wide range of interpretation. Considered the context of earlier results pressures inside the cylinder and opportunities they are presented in the coordinate system p - V (volume - pressure), it seems appropriate for the processing of work (a form of energy transfer) as the search value.

Limiting ourselves to the concept of absolute work [3] and assuming the contractual principle that the work done by the working medium is positive, and the work associated with environmental impacts in the factor - a negative sign, during the compression process engine performance can be determined by solving the following equations:

- operation indicator considered for the entire stroke - no fuel combustion in the cylinder:

$$D_{CS} = \int_0^{t_{1str}} L(\tau)dt = \int_0^{t_{1str}} \left(\int_{V_1}^{V_2} p(V)dV \right) dt \qquad [J \cdot s], \qquad (4)$$

where:

V_1 – workspace volume corresponding to t = 0 (Total volume of the workspace),

V_2 – workspace volume corresponding to $t \le t_{1com}$ (compression chamber volume),

or:

- operation indicator considered as a function of time (index value until time t) – time interval $[0,\ t_{1com}]$ (if there is a possibility of turning off the combustion in the cylinder $t_{1com} = t_{1str}$)

$$D_{CS}(t) = \int_0^{t \le t_{1com}} L(\tau)dt = \int_0^{t \le t_{1com}} \left(\int_{V_1}^{V_t} p(V)dV \right) dt \qquad [J \cdot s], \qquad (5)$$

where:

t_{1com} – contractual time of a completion of the compression (for a given value of the angle position of the crankshaft $\alpha_{end\ com}$),

V_t – workspace volume corresponding to $t \le t_{1com}$.

Interpretation of the operation indicator D presented above for the compression process as a value – D_{CS} and $D_{CS}(t)$ can be the basis of the evaluation of operation circuit in the engine.

Using equations (4) and (5) an evaluation of the compression process can be carried out by:

- comparative analysis of the set values of performance indicators - D_{CS} and $D_{CS}(t)$, of the reference of a new engine capable of technical efficiency and full fitness
- in case of lack of data mentioned above, eg. in reference to theoretical (izentrop pV^{κ} - idem) realization of the process. Such an index can be defined as follows (limiting to equation (5)):

$$\psi(t) = \frac{D_{CS}(t)}{D'_{CS}(t)} = \frac{\int_0^{t \le t_{1com}} \left(\int_{V_1}^{V_t} p(V) dV \right) dt}{\int_0^{t \le t_{1com}} \left(\int_{V_1}^{V_t} p_1 \cdot \left(\frac{V_t}{V_1} \right)^{\kappa} dV \right) dt} \quad [-], \tag{6}$$

where:

$\psi(t)$ – engine performance evaluation index during the compression process (as a function of time)

$D_{CS}(t)$ – operations indicator during the compression in real engine,

$D'_{CS}(t)$ – operations indicator during the compression in realization of theoretical circuit

p_1 – pressure at the beginning of compression stroke

V_1 – workspace volume corresponding to t = 0

V_t – workspace volume corresponding to $t \le t_{1com}$

κ – izentrop index

4. The results and analysis

On the basis of the results, the analysis of the engine was carried out as outlined in section 3 of this thesis (for the considered data of indicated and accepted the contractual end of the compression process t_{1com} = 0,0944 s).

The result is:

- value of $D'_{CS}(t)$ index calculated for the compression process carried out according to the isentropic equation pV^{κ} - idem,
- values of operation indexes $D_{iCS}(t)$ calculated as in equation (5) for analyzes set of indications (i=1,2 …, 4) Results were presented in figure 4 and due to poor readability in the time interval referring to the whole process, in the figure 5 - magnified.

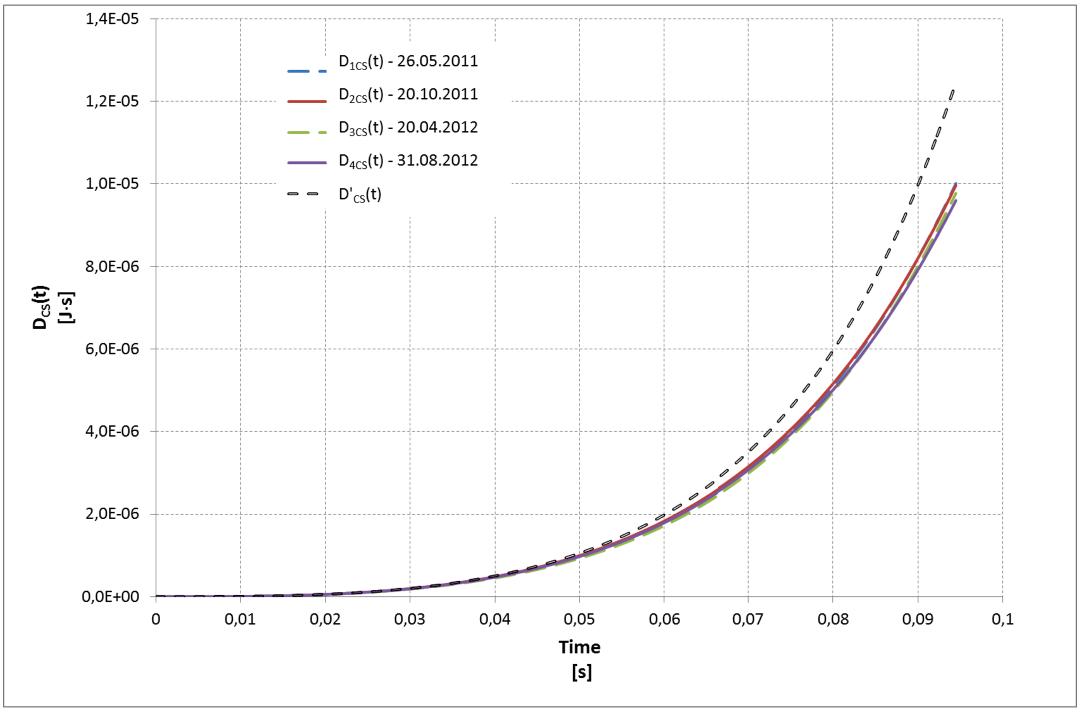

Fig.4 Values of operation indexes $D_{iCS}(t)$

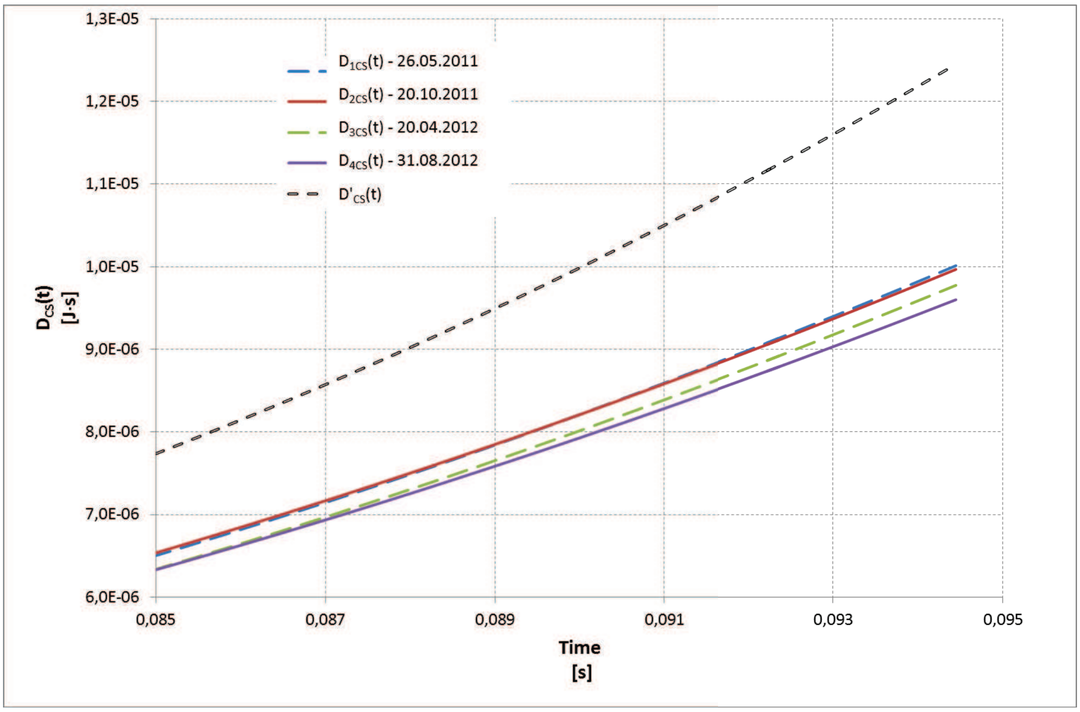

Fig.4 Values of operation indexes $D_{iCS}(t)$(zoomed part of the plot)

- assessment indexes values $\psi_i(t)$ calculated according to equation (6) to concerned set of results of indication (i = 1,2 ..., 4). The results are shown in Figure 6 (due to low readability of the graph in the time interval relating to the duration of the whole process - only magnified fragment).

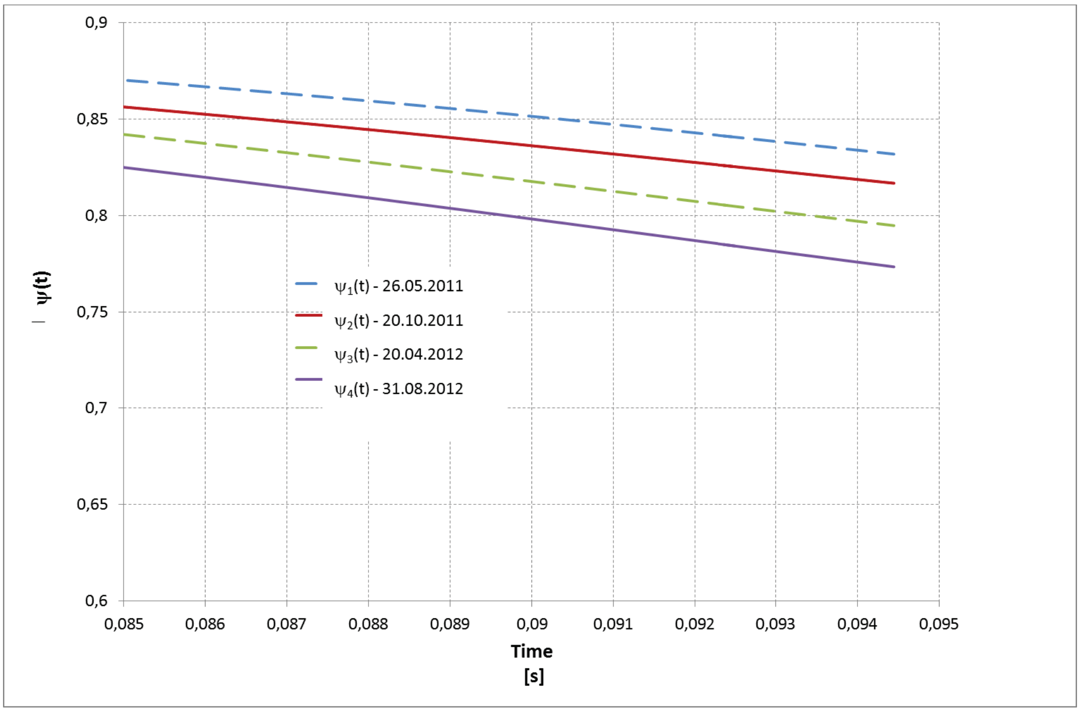

Fig. 5 Values of assessment indexes $\psi_i(t)$

The analysis of the data presented in Figure 4 - 6 gives rise to the following conclusions:

- evaluation of the compression process using a defined relationship (6) evaluation index $\psi(t)$ is possible - for the progressive degradation of engine condition, the value of the rate is lower, which is consistent with the assumptions taken into account in the definition and nature of the real processes occurring in the engine,

- chanes of value of the index ψ(t) with the progressive wear engine are more pronounced, and therefore more easily to notice than, for example to register the change in compression
- determination of the intensity of changes in ratio ψ(t) may result in defining the quantity describing the real engine reliability in terms of the implementation of the compression process - but this requires further study, a longer period of use [4].

5. Summary

The presented method appears to be an acceptable addition to the methods of assessment the quality of execution of a working circuit of the diesel engine used so far. The possible utility of course requires further theoretical studies and field tests. Due to the fact that marine engines indication is widespread and routine testing, access to the results of such tests is relatively easy, and thus is conducive to the development the assessment tools of the method.

The main advantage of this method is correlation of the assessment of the work and the time at which the task is performed - in this case the engine operating circuit.

Not without significance is also the fact that all the necessary calculations are relatively simple and can be made on the basis of the indicator diagram alone. The development of modern electronic indicators, so-called pressure analyzers allows for seamless implementation of these calculations in the software environment of the device.

The practical utility of the results can now be questionable - but further empirical research can lead to practical application of the proposed method for evaluation of such engines.

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