INFLUENCE OF INDICATOR VALVE CHANNEL UNTIGHTENS AND LOSS OF PATENCY ON THE PARAMETERS VALUES IMAGE OBTAINED FROM INDICATOR DIAGRAM

Dominika Cuper, Marek Łutowicz

Polish Naval Academy in Gdynia
Mechanical-Electrical Faculty
Śmidowicza Street 69, 81-103 Gdynia, Poland
phone: +48 792716356, +48 58 626 26 17
e-mail:ratsusia@gmail.com, marek@unitest.pl

Abstract

Indication process of big marine and industrial diesel engines are taken through indicating canals with indicating valves. Influence of these channels on parameters values obtained from engines indication is significant. Depending on chosen method of TDC determination the obtained image course error could achieved even 80% of measured value. It is assumed that this error is systematic and identical for whole engine cylinders or even for whole the same engines type. From these reasons such measurement are commonly used only for comparative tests. Engines exploitation caused technical degradation of indicators canals and valves. Unburnt fuels and oil particles deposits in channel changing its patency and also untightens in connections occurs. These are the reasons of changing in indication pressure diagram image. Process of degradation could be treated as random and measured parameters could be also burden by random error. During tests which were carried out on Sulzer type 6AL20/24 engine simulations of indicator canal malfunctions were made and their influence on obtained indication parameters were checked. Obtained parameters devalue sense of engine tuning in exploitation which based only on comparative tests of indicating pressure curves.

Keywords: *indicating valve, pressure measurement, piston engine, indicating*

1. Introduction

One of the basic inspection methods of combustion engines proper work is combustion process quality assessment. This assessment is carried out on the basis of cylinder pressure curve. Among research works carried out in the Polish Naval Academy Ship Propulsion Plant Chair whole number of Polish Navy diesel engines are indicated and additionally motor –compressors in gas pumping stations in Poland are tested. During the indication of the number of 136 cylinders it was discovered that 5 indicator valves were completely closed by channels tacking by soot deposits. It is presumption that in case of others channels despite preserving theirs patency there are partially choking (stemmed).

Additionally on many indicator valves conic connections damage was determined. This damage caused gas leakage during measurements which was not indifferent for achieved results.

In exploitation process also damage of poppet (mushroom) indicator valve frequently occurs. Raptured poppet works as a non-return valve causing significant deformity in indicating diagram curve. Changing in shape of diagram are such big that it is possible to recognize such malfunction and avoid false measurement results. Example of measurement made on indicator valve with such damage is shown on the Fig. 1.

Tuning of this engine was made with using pressure maxi meter without possibility of pressure curve image observing. Because of that the indicator valve malfunction was not detect and tuning was made in such way to achieve measured value of the maximum cylinder pressure. Real value of the pressure was much higher.

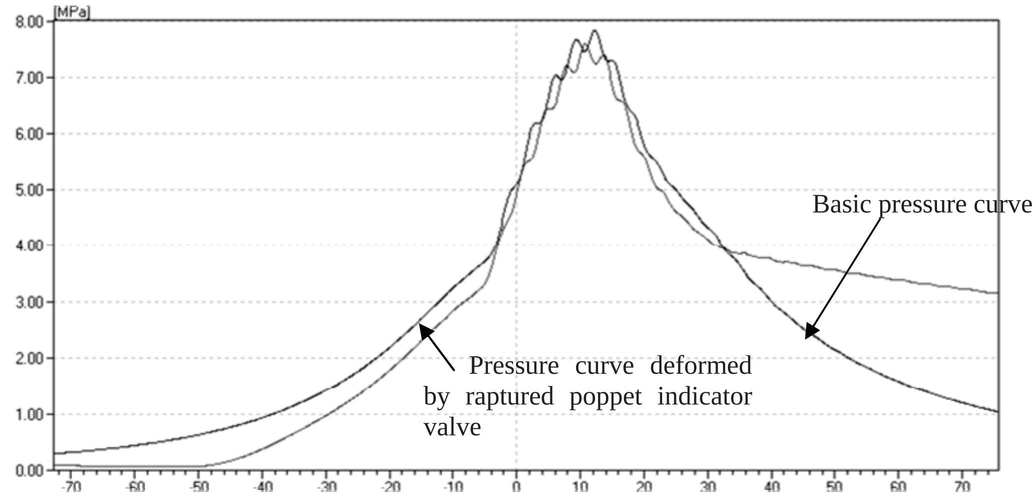

Fig. 1. In-cylinder pressure diagrams achieved on cylinder with damaged indicator valve and on the cylinder valve in good technical condition

These malfunctions influenced/lowered the level of made measurements credibility. It was decided to check during the research how partial patency of the indicating channel and untightens between indicating valve and pressure sensor influence results of engine indications. Because different engine indication apparatus are used such as mechanical indicators, maxim meters and contemporary preferred electronically indicating systems it was decided to check sensitivity of chosen indicating apparatus on changing in indicating channel patency during measurements. Values of errors caused by indicating channel are strongly involved by it dimensions and way in which pressure sensor is mounted.

2. Test stand

Tests were carried out no SULZER type 6AL20/24 marine diesel engine in Polish Naval Academy laboratory in Gdynia. This engine is equipped with channels with indicating valves as it is shown in Fig. 2.

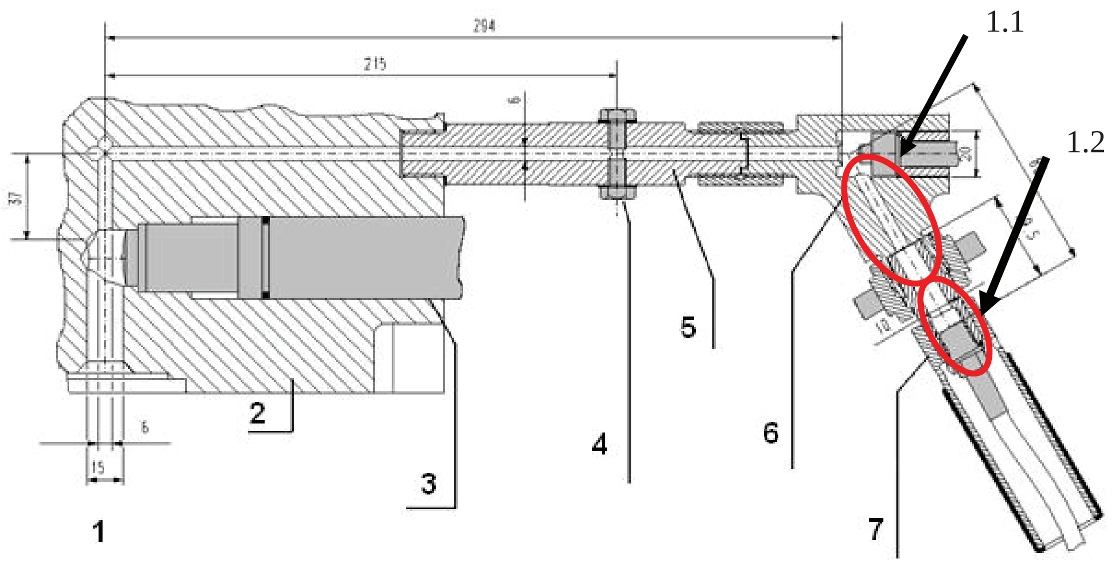

Fig. 2. SULZER diesel engine type 6AL20/24 indicating channel (1- combustion chamber, 2-cylinder head, 3-strting valve channel, 4- screws added to chocking/throttling gas stream during the experiment tests, 5-union piece, 6- indicating valve, 7- Thompson adapter with pressure sensor)

SULZER diesel engine 6AL20/24 type indicating channel consists of orifice with diameter of 15 mm in the begging part close to combustion chamber and in the further part changing into 6 mm orifice with length of 331 mm. In the end of channel chamber in which poppet valve moves is located and connecting channel to cone connection for pressure sensors (marked as ellipse 1.1) with volume of 4.45 cm^3. In element which mounted electronic sensor or in mounted mechanical apparatus occurs additional volume marked with ellipse 1.2 depending from kind of using sensor. In case of maxi Metter KISTLER type 2403 this volume is close to zero. But in case of pressure sensor KISTLER type 7613 which is mounted in Thomson's adapter this volume is equal 3.1 cm^3. In simplistic considerations length of channel was 331mm with diameter equal 6 mm and with additional volume being sum of volumes 1.1 and 1.2. During the exploitation when conditions to soot deposits build up occur active diameter of the channel would have been diminish.

3. Indicating channel influence on the cylinder pressure image

As a result of define channel length some delay occur between pressure generated in combustion chamber and the time when pulse of the pressure comes to the sensor forefront. Size of this delay – τ_k will depend on momentary value of sound velocity – a_x in the channel and from length of the whole channel – l_k, as in formula (1)

$$\tau_k = \frac{l_k}{a_x} = \frac{l_k}{\sqrt{\chi \cdot R \cdot T_x}} [s], \tag{1}$$

where T_x is momentary value of temperature in the channel in [K].

During this time crankshaft will turn around $\alpha_k°$ degrees

$$\alpha_k = \frac{n \cdot 360}{60} \cdot \tau_k = \frac{n \cdot 6 \cdot l_k}{\sqrt{\chi \cdot R \cdot T_x}} [°], \tag{2}$$

where n is crankshaft revolutions per minute - rpm [min^{-1}].

Putting into equitation lengths of tested channel and mean temperature in the channel estimated as 500 K expected shift for several different rpm values was calculated. Results are presented in the Tab. 1. In channel with constant diameter these shifts would be invariant from channel diameter.

Tab. 1. Calculated expected values of angle shifts

l_k / RPM [min^{-1}]	**0.417 m**
500	2.90°
550	3.19°
650	3.76°
750	4.34°

In real channel during engine work gases flow from combustion chamber trough channel to pressure sensor front. During the engine work difference in pressure value between combustion chamber and sensor front environment occur. This difference in pressure value caused by gases flow with relatively high speed close to sound velocity in the air.

Additionally gas flow out from channel to chamber with higher floating surface experience some pressure growth which is caused by kinetic energy change into potential energy. So in channels which have higher diameter close to pressure sensor front adequate pressure increase should be taken into account.

Additional pressure increase will take place after TDC point when pressures in both channel sides are equalized. Reason for gas movement in channel disappeared but accelerate gas column has kinetic energy yet which will be change into additional pressure potential energy what is visible as pressure increase short after maximum pressure pick into cylinder. Relations between channel diameter, length of the channel and size of extension are chosen in such ways that compensate these phenomenons. Throttling in the channel causes unbalance of these relations.

4. Tests

To simulate soot build up process into channel between engine block and indicating valve perpendicular to channel axis screwed orifice was made. In the orifice gas flow throttling screws were put. Surface of the gap between the screws during tests was not measured. Tests were restricted only to such screws positions that after valve opens gas flow exist and accompany of it acoustic effects. So such maximum throttling was achieved which would not be observed by human senses (in organoleptic way).

Untightens of indicating valve was simulated by 300 degree turns of indicating valve from fully open position which caused partial untightens of valve packing and acoustic effect similar to this in typical untightens.

Tests were carried out at 600 rpm and 210 kW load and 700 rpm at 315 kW load. Measurements were made with electronic analyzer type MA2009 produced in Polish Naval Academy in Gdynia equipped with KISTLER pressure sensor type 7613 and additionally maximum pressure values were compared with values measured on mechanical indicator KISTLER type 2403 and Russian maxi meter type M3M with non-return valve and manometer which are still commonly used on ships. Maximum pressure measurements results gathered in case of clean and tight channel (in good technical condition), in case of untighten connection between valve and pressure sensor and in case of throttling in the channel are shown in Tab. 2. Additionally relative decrease of measured maximum pressure value caused by simulated malfunctions was calculated.

Tab. 2. Maximum pressure measurements results for channel different technical conditions

n [min^{-1}]	Indicator type	Patent channel	Untightened connection		Throttling in channel	
		Pmax [bar]	Pmax [bar]	δPmax [%]	Pmax [bar]	δPmax [%]
600	MA2009	79.8	78.7	-1.38	71.2	-10.78
	M3M	83.0	80.0	-3.61	75.0	-9.64
	Kistler 2403	82.6	78.0	-5.57	72.0	-12.83
700	MA2009	97.8	94.2	-3.89	82.3	-15.85
	M3M	100.0	98.0	-2.00	89.0	-11.00
	Kistler 2403	99.9	98.9	-1.00	87.2	-12.71

It was determined that error caused by untightened connection has value in boundaries from 1 to 5.57%. It could be presumed that method of untightens simulation in measured connection between sensor and valve was unrepeatable which caused high scatter of obtained errors. Many times opening and closing of indicator valve during indicators changing had involved each time to set untightens. It was made in unrepeatable way and in the nearest future additional measurement with calibrated orifice screwed into modified indicating valve will be done. These tests could be treated as preliminary. They showed that error caused by untightens is decisive lower to these expected in start of the tests.

Throttling influence measurements were made in repeatable way because measures were made at constant connection regulating screws. During the measurements indicators and engine load were only changed. Model measurements with out of throttling were made one before throttling setting for first engine load and for second engine load after end of the tests and with removed throttling. Because of that measurements were limited only to two engine loads conditions.

Next measurements consisted registration of pressure curve. They were limited to throttling influence testing. Pressure curves achieved during tests were synchronized by reference pin. It gives possibility to superposition of curves with and without of throttling at these same load conditions. Effect of this superposition is shown in the picture 3 at 25% and 75% engine load.

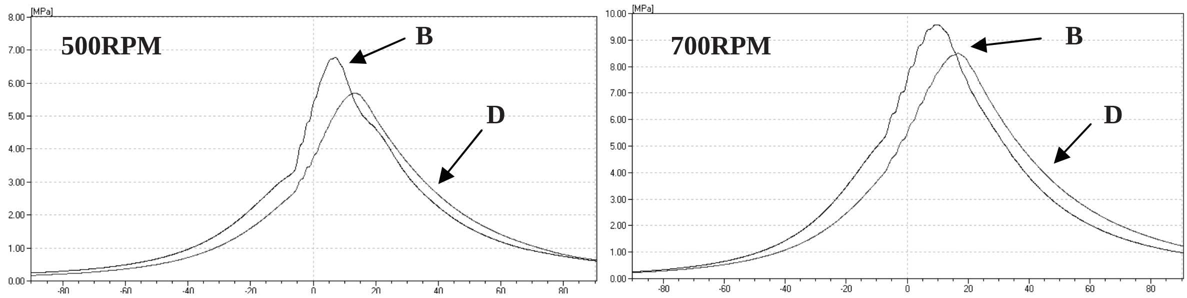

Fig. 3. Indicating diagram with throttling and TDC setting according to reference pin at 25% and 75% engine load (B- without throttling, D- throttling)

Significant angular delay caused by throttling in indicating channel equal 6.3 ° degrees at 500 RPM and 5.8^0 degree at 700 RPM were determined. It was the reason to calculate higher value of indicated power by about 43% at 500 RPM and by about 32% at 700 RPM. At higher rpm value influence of throttling was lower and it was caused by higher temperature and higher sound velocity. Gases flow with higher velocity caused quicker pressures trim.

To correct effects of delays caused by throttling in the channel TDC setting correction was made by compression curve extrapolation. Effects of these corrects are shown on Fig. 4.

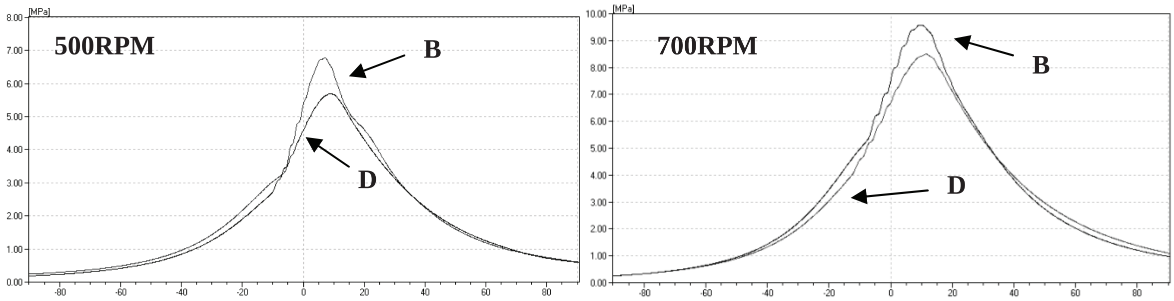

Fig. 4. Indicating diagrams with TDC correction at 25% and 75% engine load (B- without throttling, D- throttling)

Effect of improved determined value of mean indicated pressure and improved value of maximum pressure angle were achieved. Results of determined mean indicated pressures, compression pressures and maximum pressure angles are presented in Tab. 3.

Tab. 3. Results of determination of chosen parameters depending on channel technical condition and TDC setting method

Engine RPM/load	Type of measurement	TDC determination method	MIP [MPa]	Pmax [MPa]	Pcom [MPa]	α Pmax [deg]
$500 min^{-1}$ 105kW	Without throttling	According to reference pin	0.665	6.77	3.50	6.8
	throttling	According to reference pin	0.907	5.69	———	13.1
		According to extrapolation	0.715	5.69	3.14	8.7
$700 min^{-1}$ 315kW	Without throttling	According to reference pin	1.238	9.58	5.92	9,8
	throttling	According to reference pin	1.679	8.50	———	15.6
		According to extrapolation	1.351	8.50	4.66	10.9

5. Conclusions

Usually the base to assume that indication results are reliable is the certificate, attestation and sensors and analyzers certificates. Contemporary electronic indicators have accuracy of reading from 0.1 to 0.5 certificated by testing centres by statistical checks with pressure standards.

According to indication method it is presumed that measured values of compression and maximum pressures were made according to measurement device accuracy of reading. Untightens in pressure sensor and indicating valve has important influence on pressure measurements results determining their lower value by 1 to 3.9% according to carried out tests. Whereas simulated channel throttling which did not caused observed symptoms of no patency were the reason of 9.64 to 15.85% lower measured value of maximum pressure.

Carried out tests showed that electronic indicator with pressure sensor mounted in Thompson adapter has the biggest sensibility for changes in indicating channels conditions. It is caused by comparatively high internal volume of this adaptor.

It is assumed that achieved indicated pressure curves are deformed and these deformations influence results of calculated values of mean indicated pressures and heat release. Because of that most of measuring equipment manufacturers resigned from possibility to determine these values. Assertion that these deformations are systematic error because are equal in every engine cylinder is too optimistic.

Before enter into engine tuning it is vitally important to dismantle indicating valves and check state of indicating channels patency. Without information about technical condition of indicating channels with indicating valves achieved results are useless even for comparative tests.

Further works headed for preparing indicating channels test method without dismantling engine's parts to make more credible achieved indicating results are needed.

References

[1] Wajand, J., *Pomiary szybkozmiennych ciśnień w maszynach tłokowych*, Warszawa: Wydawnictwa Naukowo-Techniczne, 1974.

[2] Kluj, S., *Diagnostyka urządzeń okrętowych*, Gdynia: Studium Doskonalenia Kadr S.C. Wyższej Szkoły Morskiej w Gdyni, 1992.

[3] Łutowicz, M., *Analysis of application of chosen methods for TDC determination in marine diesel engines*, Journal of KONES Powertrain and Transport, Vol. 16, No. 4, Warszawa 2009.

[4] Łutowicz, M., *Evaluation of the Condition of Cylinder Systems of the Engine Based on an Compression Process Analysis*, Polish Journal of Environmental Studies, Vol. 18, No. 2A, Olsztyn 2009.