INDICATED PRESSURE OF INTERNAL COMBUSTION ENGINE

Ing. Repka J.[1], doc. Ing. Labuda R. PhD.[1], Ing. Kovalčík A. PhD [1], doc. Ing. Bárta D. PhD.[1], Ing Skrúcaný T.[2]
The Faculty of Mechanical Engineering – University of Žilina, the Slovak Republic [1]
The Faculty of Operation and Economics of Transport and Communications – University of Žilina, the Slovak Republic [2]
jan.repka@fstroj.uniza.sk

Abstract: *the contribution deals with problems of measurement indicated pressure of internal combustion engine. Indicated pressure measurement allows better monitoring of change state quantities during implementation working cycle of internal combustion engine. Measurement is realized with the mobile unit on the vehicle under the specified mode, the real conditions of transport, as well as on brake bench in the laboratory. By analysing the results of experiments can be more precisely to quantify efficiency of power transmission and energy flows in the drive mechanism of the vehicle.*

Keywords: INDICATED POWER, MEAN INDICATED PRESSURE, INDICATOR DIAGRAM, BRAKE TEST BENCH, SPARK PLUG

1. Introduction

To complexly assess work, economy and adverse ecological impact of conventional piston combustion engines, various parameters and their dependence – characteristics are used. Based on their values the combustion engines are qualitatively ranked. Main parameters are: mean effective pressure, mean indicated pressure of a cycle, indicated and effective engine power as well as engine losses power, specific consumptions of operating materials, specific engine efficiency and produced emissions (of gases, noise and vibrations). [5] For a closer classification and evaluation of combustion engines characteristics in practice, comparative characteristics are used. They describe also other properties and values needed for mutual comparability of engines regardless their size, power, construction, operating principle, etc.

Theoretical – ideal cycles, are reversible processes according to which the ideal engine works. To be closer to reality, open theoretical cycles are solved, i.e., the replacement of a cylinder charge is considered. Real work cycle describes real processes taking place in the engine cylinder.

2. Detection of indicated power P_i

We usually work with an indicator diagram, i.e. the dependence of pressure change on an instantaneous value of a cylinder volume – Fig. 1. If this change is evaluated in dependence on the angle of rotation of a crankshaft or on time, we speak of a developed indicator diagram – Fig. 4b.

The processes connected with energy transformation are frequently assessed according to their power outputs.

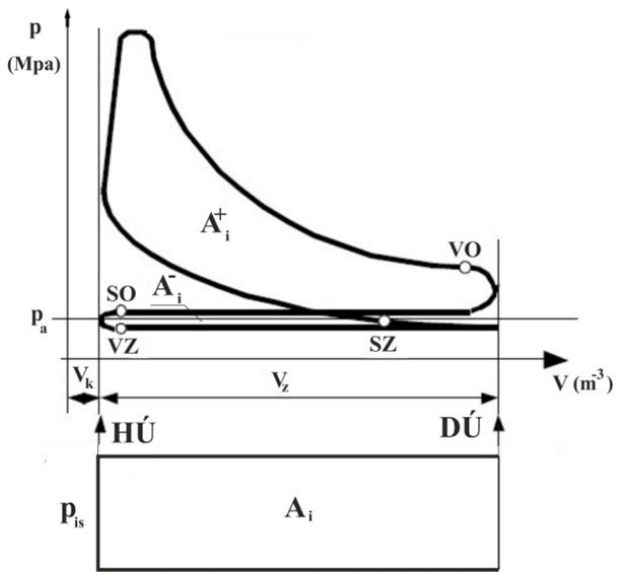


Fig. 1 *Indicator diagram.*

Indicated engine output P_i is obtained from work cycles in the combustion engine regardless of losses. The indicated power output is experimentally collected from measurements of an indicator diagram or by the cylinders shut down.

An area closed by the indicator diagram A_i (given by difference $A_I^+ - A_I^-$) – Fig. 1 is proportional to the work of one work cycle ($J.cyk^{-1}$). Positive area of indicator diagram A_I^+ present the work received during the expansion stroke. Negative area A_I^- presents the work consumed to replace the capacity of the cylinders. [4]

The indicator diagram area is replaced by a rectangle area with an identical basic side (corresponding to V_z (m^3)). The mean indicated pressure thus represents an imaginary constant mean value of pressure acting on the piston; when within one stroke, the work equal to the quantity of indicated work performed in the duration of one stroke, would be done. The mean indicated pressure (Pa) is defined by the relation:

$$p_{is}=A_i / V_z \tag{1}$$

Fig. 1 presents the indicated work A_{i1} of one cylinder of the internal combustion engine area that can be determined by multiplying the values of mean indicated pressure p_{is} and stroke volume V_z:

$$A_{is}=p_{is} . V_z \tag{2}$$

Indicated power of one cylinder:

$$P_{i1}=A_{i1} / t_1 \tag{3}$$

The duration of one cycle internal combustion engine:

$$t_1=1 / (2 . n) . z \tag{4}$$

P_i (W) is given by the indicated work of a cycle, number of cylinders i and by the cycle duration t (s), depending on a number of engine revolutions n (s^{-1}) and strokes z per cycle (two-stroke z = 2, four-stroke z = 4). The resultant relation for a four-stroke engine is of P_i:

$$P_i=(p_{is} . V_{z1} . 2 . n . i) / z \tag{5}$$

3. Measurement of indicated power P_i in brake test bench

Measurements indicated pressure of combustion engine of road vehicle was released in selected driving modes on brake test bench, with using the measuring equipment Kibox to go – Fig. 3. The main goal of a series of experimental measurements was to determine the energy terms during the operation of a road vehicle.

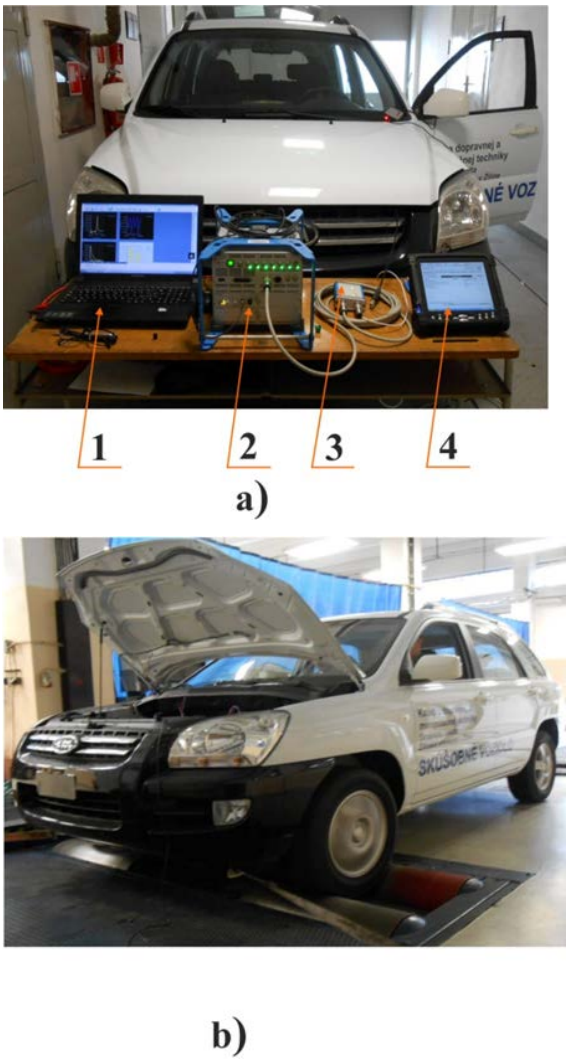


Fig. 2 *a) Measuring equipment Kibox To Go: 1 – PC, 2 – Kibox To Go, 3 – converter, 4 – serial diagnostic, b) Vehicle on the brake test bench.*

For the measurement was used Kia Sportage vehicle with a displacement of 2.0 l, power of 104 kW at 6000 rpm and torque 184 Nm at 4500 rpm. Brake test bench simulated load 1500N - 2000N. The measurement was realised on road vehicle with third speed gear. During the measurement rpm were change in range of 1000 – 5000 min-1.

Indicated power of the individual measurements was determined from the indicator diagrams. For the measurement of indicated pressure was used special spark plug with pressure sensor – Fig. 3.

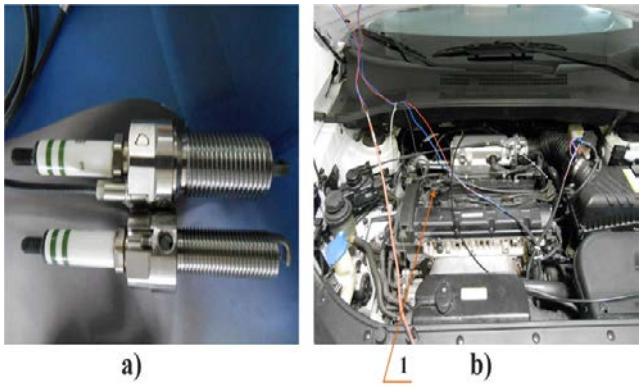


Fig. 3 *a) spark plug, b) position of spark plug (1).*

Measuring equipment make digital data recording of rpm of combustion engine, pressure of positive and negative area of indicator diagram, cycle count and the displacement in the dependence of crank angle.

In rpm range of 1000 – 5000 min-1 was made record of one hundred cycles of combustion engine. Fig. 4 shows the real indicator diagram and developed indicator diagram from real measurement.

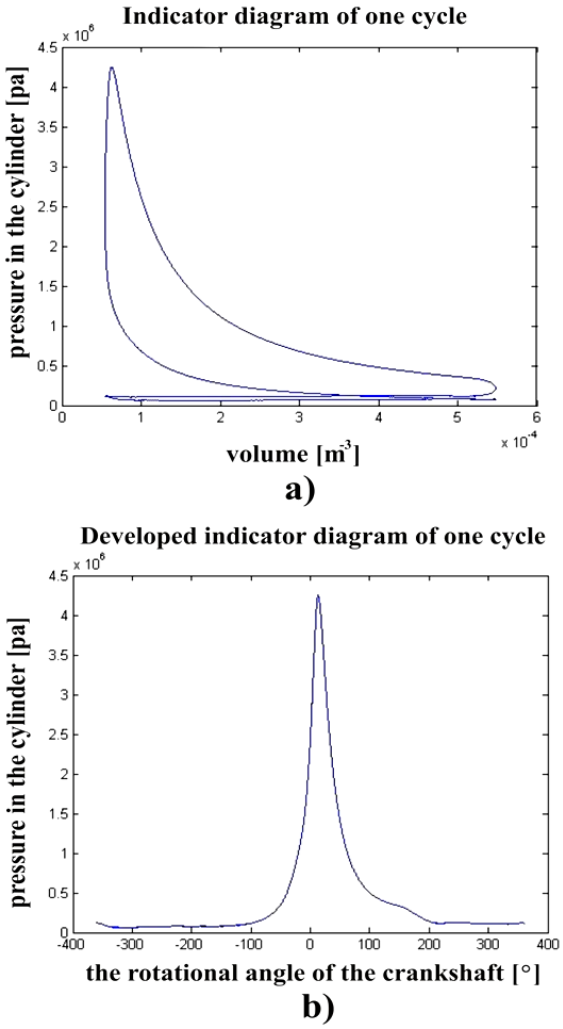


Fig. 1 *Real diagrams – a) indicator diagram, b) developed indicator diagram.*

The results of the measurements are graphics dependencies monitored parameters during the selected driving regimes of a road vehicle. In the tables 1, 2 are shown the values of the monitored operation parameters of a road vehicle.

Table 1: *Measured values, third speed gear, load 1500 N*

n (min^{-1})	p_1^+ (Pa)	p_2^- (Pa)	p_{is} (Pa)	P_{i1} (W)	P_{im} (W)	A_{i1} (J)
1000	719001	-20019	685990	2760	11040	34431
2000	753160	-34796	718360	5704,9	22820	35842
3000	778690	-49254	729430	9301,8	33720	36394
4000	823720	-63913	759800	12560	50239	37910
5000	842740	-84043	758700	15552	62208	37854

Table 2: *Measured values, third speed gear, load 2000 N*

n (min^{-1})	p_1^+ (Pa)	p_2^- (Pa)	p_{is} (Pa)	P_{i1} (W)	P_{im} (W)	A_{i1} (J)
1000	925001	-11519	913452	4885	19540	45851
2000	958750	-26254	932500	8558,1	34232	46526
3000	981610	-41542	940070	12108	48433	46904
4000	999940	-54380	945560	14500	57998	47102
5000	1036900	-88720	948220	19682	78728	47310

n – rpm, p_1^+ - pressure of positive area of indicator, p_2^- – pressure of negative area of indicator, p_{is} – indicated pressure, P_{i1} – indicated power of one cylinder of the combustion engine, P_{im} – indicated power of the combustion engine, A_{i1} – indicated power

The indicated power of one cylinder and combustion engine was calculated from measured values in tables 1, 2 by using calculation formula 4. Figure 5 shows a comparison the changes in magnitude of pressure in positive p_1^+ and negative p_2^- area of the indicator diagram and indicated pressure depending on the rpm with various loads.

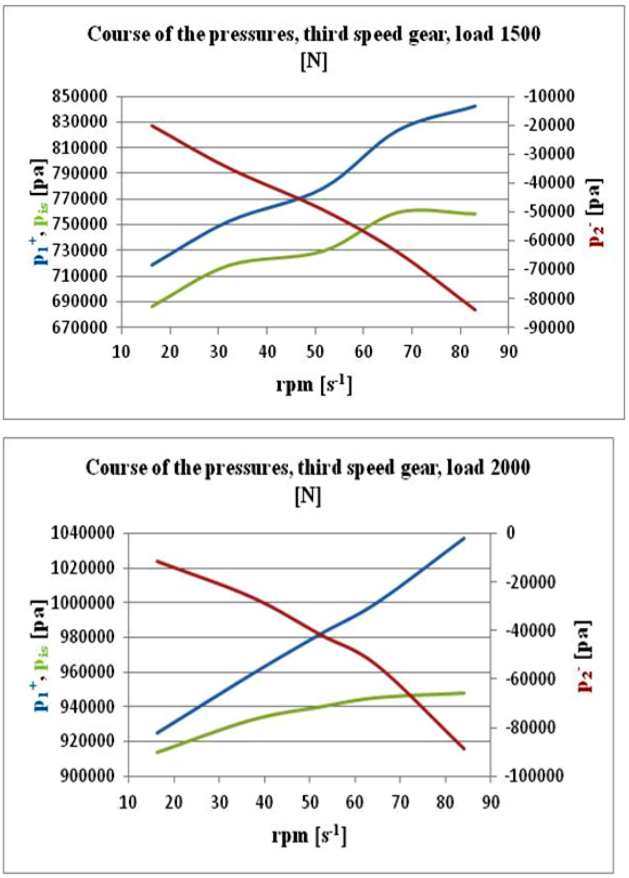


Fig. 5 *The course of the pressures, third speed gear, load 1500 and 2000 [N], p_1^+ - positive pressure of the indicator diagram, p_2^- - negative pressure of the indicator diagram, p_{is} – indicated mean effective pressure*

The change of load involves a change of a size of the individual pressures. The increasing of the load caused the growth of the individual pressures. The pressure in the cylinder and indicated mean effective pressure increasing too. Pressure dissipation increases with the increasing rpm of the combustion engine and with the increasing load due to increase in losses. Fig. 6 shows comparisons of changes of the indicated power P_{i1} of one cylinder and the entire P_{im} combustion engine with various loads.

By the measurement of mean indicated pressure is possible to identify power of accessory equipment of the combustion engine. It is no-load measurement. Indicated power equal the sum of effective power and losses power according to formula (5):

$$P_i = P_e + P_l \qquad (5)$$

In this measurement $P_e = 0$ and $P_i = P_l$. Indicated power in this case equal to losses power of accessory equipment of the combustion engine. Table 3 show the measured values of indicated parameters. The courses of indicated parameters are shown in Fig. 7.

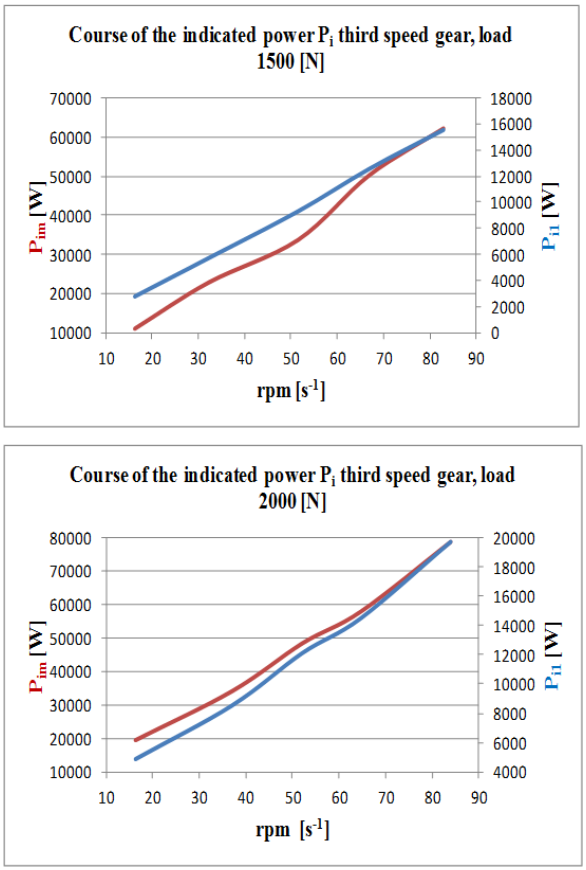
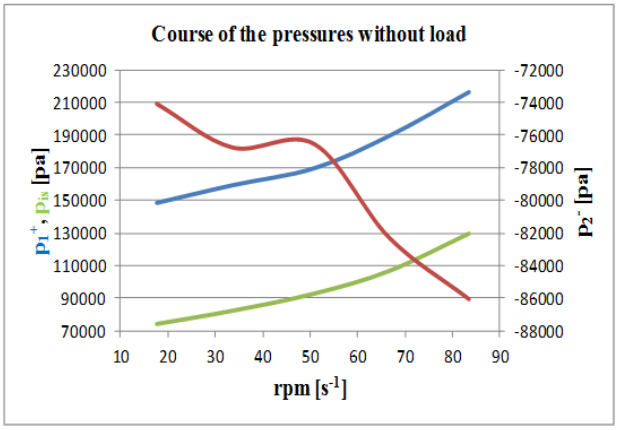


Fig. 6 *The course of the indicated power, third speed gear, load 1500 and 2000 [N], P_{i1} – indicated power of one cylinder of the combustion engine, P_{im} – indicated power of the combustion engine.*

Table 3: **Indicated parameters in no-load measurement**

n (min^{-1})	p_1^+ (Pa)	p_2^- (Pa)	p_{is} (Pa)	P_{i1} (W)	P_{im} (W)	A_{i1} (J)
1000	148160	-74091	74071	324,7348	1298,9	3695,7
2000	158970	-76770	82204	684,5862	2738,3	4101,5
3000	169430	-76571	92856	1171,4	4685,8	4632,9
4000	189160	-82304	106800	1762,3	7049,3	5381,3
5000	215950	-86069	129880	2682,8	10731	6480,1



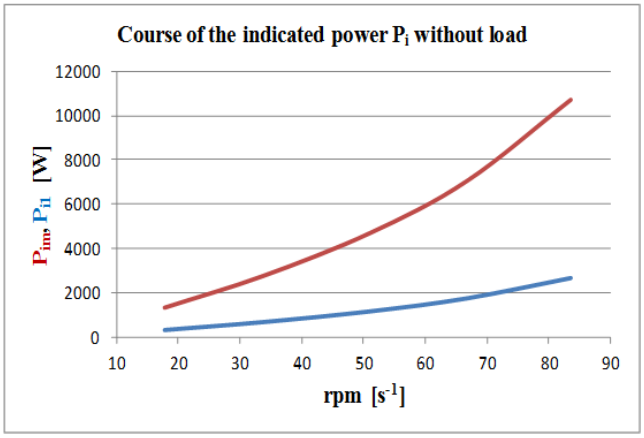


Fig. 7 *Courses of indicated parameters in no-load measurement.*

In series of experiment was made another measurement of indicated pressure during downhill driving. The power in this case equal to power that could by accumulated. Indicator diagram of downhill driving is shown in Fig. 8.

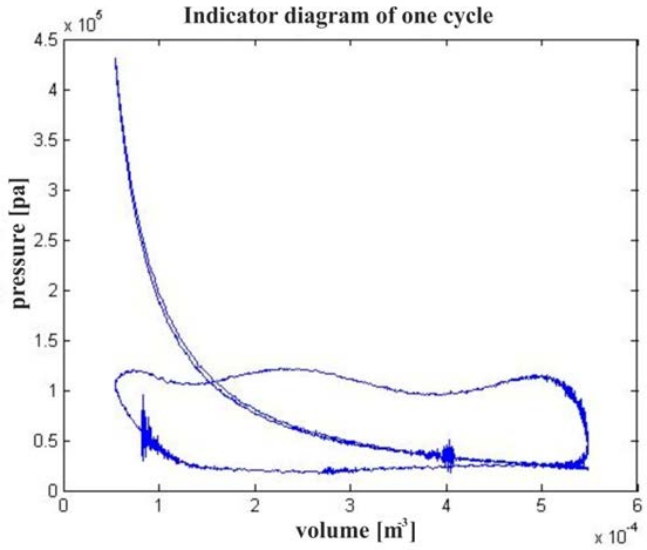


Fig. 8 *Indicator diagram of downhill driving.*

Conclusion

Measuring apparature Kibox to go, that was used during a series of experimental measurements, offers a wide range of use. Apparature allows the measurement of the pressures in the cylinder, measurement of the heat release, identification the beginning and end of combustion, TDC (top dead centre) identification, sensing the rotational angle of the crankshaft and others.

In addressing the issue of energy consumption of road vehicles is planned a series of measurements during the operation of a road vehicle in real traffic.

Acknowledgement

This contribution was created within the framework of the projects ITMS: 26110230107 supported by the Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic for EU Structural Funds.

References

[1] Zvyšovanie výkonových parametrov spaľovacích motorov optimalizáciou zapaľovacej krivky / Michal Puškár - 2009.In: Zdvihací zařízení v teorii a praxi. No. 2 (2009), p. 47-50. - ISSN 1802-2812

[2] Príspevok k problematike vysokého kompresného pomeru a jeho vplyv na výkonovú krivku u pretekárskych dvojtaktných motorov / Michal Puškár - 2010. In: Zdvihací zařízení v teorii a praxi. No. 1 (2010), p. 57-59. - ISSN 1802-2812

[3] Zvyšovanie výkonovej charakteristiky motora / Michal Puškár, Roman Kux - 2011. - 1 elektronický optický disk (CDROM).In: Bezpečnosť - Kvalita - Spoľahlivosť : 5. medzinárodná vedecká konferencia : zborník : Košice, 2011. - Košice : TU, 2011 S. 240-244. - ISBN 978-80-553-0612-4

[4] Influence of throttleless load control of petrol engine on its effectiveness / Juraj Saniga, Pavol Kukuča. In: TRANSCOM 2011 : 9-th European conference of young research and scientific workers : Žilina, June 27-29, 2011, Slovak Republic. - Žilina: University of Žilina, 2011. - ISBN 978-80-554-0375-5. - S. 179-182.

[5] Analýza parametrov ovplyvňujúcich tlak v piestovom stroji / Rastislav Isteník, Pavol Kukuča. In: XXXIV. mezinárodní konference kateder a pracovišť spalovacích motorů českých a slovenských vysokých škol : Liberec 10.-11. září 2003 : sborník přednášek vydaných při příležitosti 50. výročí založení vysoké školy v Liberci. - V Liberci: Technická univerzita, Katedra strojů průmyslové dopravy, 2003. - ISBN 80-7083-742-X. - S. 116-121.