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Paweł MARZEC[1]

AN EXAMINATION OF VEHICLES AT THE BRAKE-CHASSIS TEST BED IN THE RANGE OF THE PARTIAL ENGINE LOAD

Summary. The performance of a ZI engine is presented in the paper, as well as a project involving a device for applying a partial load in the performed examinations of a brake-chassis test bed. The device was prepared for an Opel Astra and enabled the determination of exterior characteristics of the engine for different values of the engine load. The indicating pressure sensor and the angle marker on the crankshaft allowed for the recording of the indicating pressure obtained at different values of the load. The analysis of heat evolution in the process of burning, based on the registered results of the measurements at the brake-chassis test bed, has also been included in the presentation.
Keywords: Partial load of the engine; external characteristics of the engine; indicated pressure.

1. INTRODUCTION

The advancement of technologies, as applied in vehicles, forces the development of the automotive market as well as the testing and diagnosing of vehicles. Therefore, servicing and diagnosing service workshops are a vital issue. The used measuring equipment should be universal, precise, reliable and easy to use for different types of vehicles. The brake-chassis test bed has become commonly used in car servicing. This equipment enables the testing of a vehicle’s parameters in a non-invasive way and shows the actual conditions of the engine. The

[1] Faculty of Transport, The Silesian University of Technology, Krasińskiego 8 Street, 40-019 Katowice, Poland. E-mail: pawel.marzec@polsl.pl.

brake-chassis test bed is not only used for testing vehicles in use, but also for testing vehicles straight after they have been produced in the form of quality tests.

The performed examinations are of the same type for all kinds of engines and cars. Measuring wheels' torque at the total engine load and at the full range of rotational speed is the basic test procedure and shows the engine's characteristics, which, in turn, can be compared with the technical documentation of the vehicle. It must be noted here, however, that the engine's full load is not a typical state of a car's exploitation. In practice, only a certain part of an engine's power is used. It is problematic to carry out tests with a partial load of the engine because the used standards are not repeatable in terms of obtaining the applied loads. The brake-chassis test bed regarding R&D and vehicle diagnoses calls for further solutions of this problem. The method presented in this paper allows for the use of partial loads, which correspond to the mode of street traffic.

2. THE IDEA AND THE CONSTRUCTION OF THE DEVICE

The measuring method requires a device to be constructed, which can be placed under the accelerator pedal and comprise pads limiting the pedal travel (Fig. 1).

Fig. 1. The work of an accelerator pedal with an applied device mounted on the original flat bar of the cabin floor

The device has been made for a car, but it can also be used in other types of vehicles because of its simple construction. The possibility of fixing the device on the cabin floor, instead of the original limiter under the accelerator pedal, has to be checked first. Such a solution ensures a stable and repeatable fixing of the device during the performed measuring tests.

A set of pads limiting the pedal travel concerning different heights has to be constructed so that the pads can be easily changed. The length of pads is adjusted by the depth of pressing the accelerator pedal, which, in turn, correlates with the degree of the throttling valve's opening.

Dimensioning of the space under the accelerator pedal makes it possible to determine the maximal dimensions of the device, as well as the angle between the floor and the flat bar, which stands out. This is essential for the proper position of a device (against the flat bar), which must convey the load force applied by the operator from the accelerator pedal through the base of the device on the cabin floor.

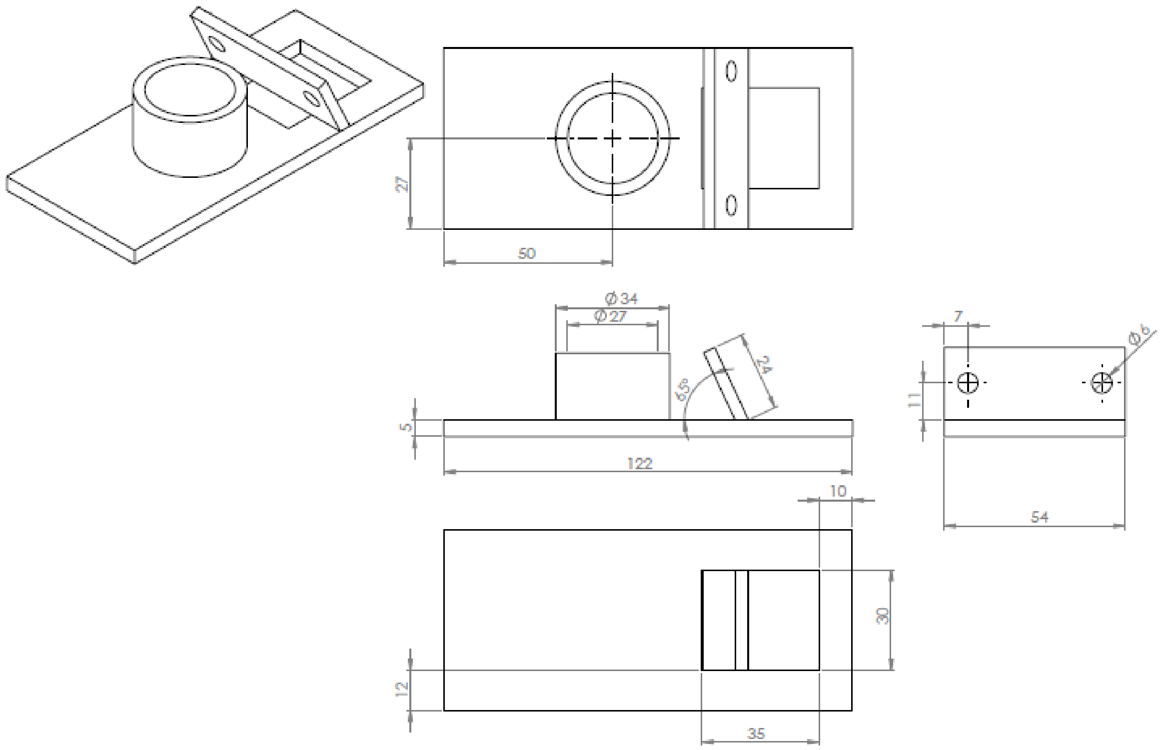

Fig. 2. Drawing of the device

The drawing of the device was created using the SolidWorks 2013 program. The following elements have been taken into consideration at the stage of graphic designing: the base of the device, the assembly jig and the seat where the pads of different length can be placed. The dimensions are presented in Fig. 4.

Fig. 3. Mounted device in a car

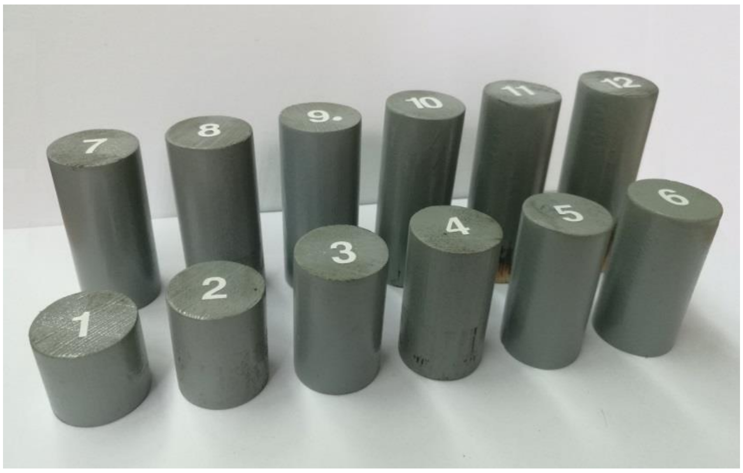

Fig. 4. The device's changeable pads for adjusting the depth when pressing the accelerator pad

3. CALIBRATION OF THE DEVICE

The next step is to define the dependence between the height of the limiting pads and the degree of the opening of throttling valve. The linear dependence of the degree of the opening of the throttling valve regarding the function of TPS signal has been elaborated first. Meanwhile, the diagnostic tester, which can measure a signal from the TPS sensor, has been used. The dependence of the tension values of the TPS sensor from the position of the pedal has been established, taking into account the boundary values of the tension in terms of the minimal and maximal pressing of the accelerator pedal. In turn, the degree of opening of the throttling valve for every pad in a given set has been determined. The results are presented in Table 1.

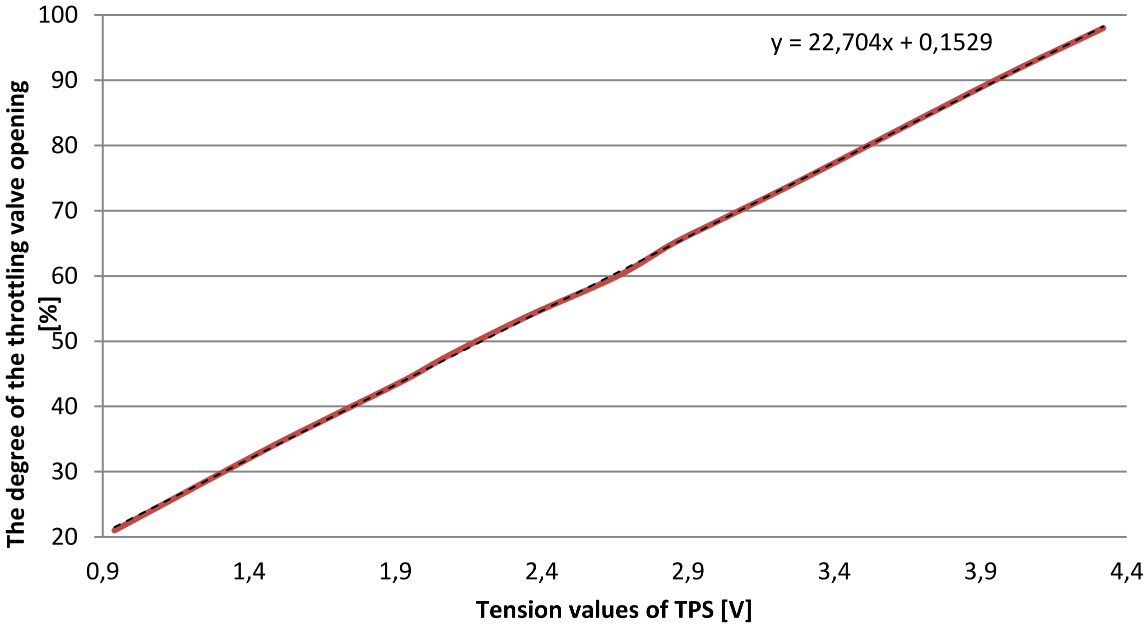

Fig. 5. Linear dependence of the throttling valve opening in the function of the TPS signal

Table 1. Defining the degree of the throttling valve opening for the produced pads

No.	Tension values of TPS [V]	Height pads limiting the pedal [mm]	The degree of throttling valve opening [%]
1	4.32	26	98
2	3.95	33	90
3	3.30	42	75
4	3.03	46	69
5	2.85	49	65
6	2.66	52	60
7	2.36	56	54
8	2.09	61	48
9	1.93	63	44
10	1.66	67	38
11	1.44	71	33
12	0.94	73	21

4. THE SUBJECT AND THE RANGE OF PERFORMED EXAMINATIONS

The Opel Astra F with a 1.6 dm^3 engine for unleaded fuel has been examined (Fig. 6).

Fig. 6. Car at a test stand

Table 2. Technical data of the tested engine

Engine designation	X16SZR
Number/cylinder layout	4 R
Engine capacity	1,596 cm^3
Degree of compression	9.6
Cylinder diameter	79.0 mm
Stroke of the piston	81.5 mm
Max. power	55 kW
Power rotation max.	5,200 obr/min
Torque max.	128 N·m
Torque rotation max.	2,800 obr/min

The range of performed examinations comprise the external characteristics of the engine, its maximal power, and the torque depending on the level of load. The performed examinations are in accordance with procedures of the BOSCH FLA203 brake test bed producer, whereby the direct gear speeds up to the maximal engine rotation and then freely slows down when idle running. Unleaded fuel 95 was used in the tests. The following engine loads have been used in the tests: 21, 33, 48, 60, 75, 90 and 100%. The car engine was also equipped with an indicating pressure sensor placed in the sparking plug and a KISTLER angle marker mounted on a pulley of a crankshaft. The measurement and acquisition of indicating pressure values were therefore possible. On the basis of the obtained data, further simulation calculations of the burning process were carried out.

5. ELABORATION OF MEASUREMENT RESULTS

5.1. Exterior characteristics of the engine

Maximal values of power and moment, as well as respective rotational speed, are presented in Table 3.

It can be easily noticed that the increase of power and torque depend directly on the rotational speed of the engine and load. The bigger the load, the higher the torque and engine power.

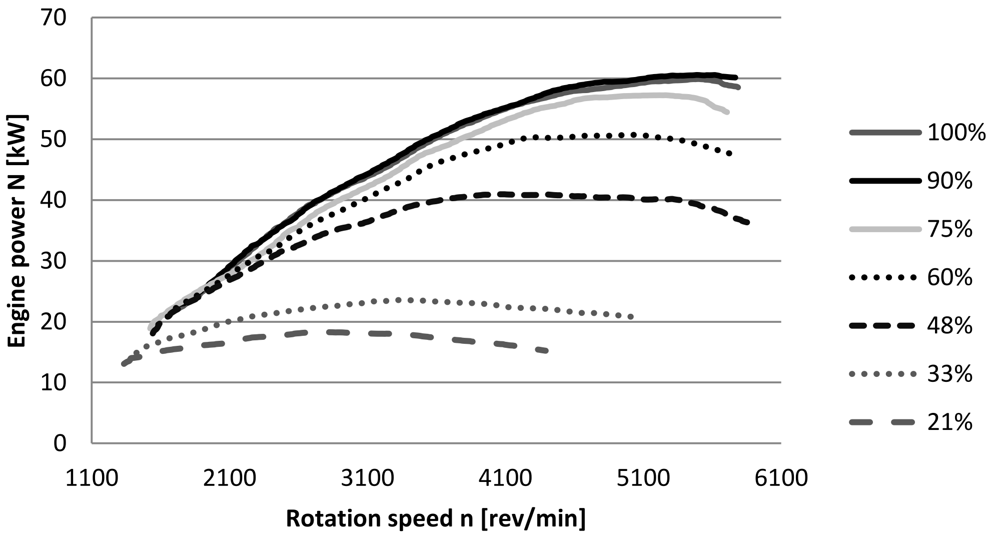

Fig. 7. Course of power depending on the engine rotation at different engine loads

The course of engine power at 100 and 90% is almost identical, whereas the lower the load, the bigger the diversity of the obtained power for the examined loads. It is particularly so at high rotational speed. The smallest differences can be observed at low rotational speed: at 2,000 rotations/min, the obtained power is almost the same for loads of 100, 90, 75, 60 and 48%. Loads of 33 and 21% feature low power and a characteristic course within the whole range of rotational speed. The obtained curves are almost flat, while power is at a constant level (Fig. 7).

Comparing all measured curves of torque, it can be noticed that clear anomalies occur at the lowest loads (33 and 21%), as well as the power curves. The diagrams feature a linear course, while they intensively drop down with an increase in rotational speed. They feature big differences in the value of torque between the initial and final parts of curves up to more than half of their value. The other curves have natural curve-like shapes. The smallest differences of rotational moment values are at the highest loads (75, 90 and 100%). A diagram of obtained maximal values is made based on the values in the table below (also see Fig. 9).

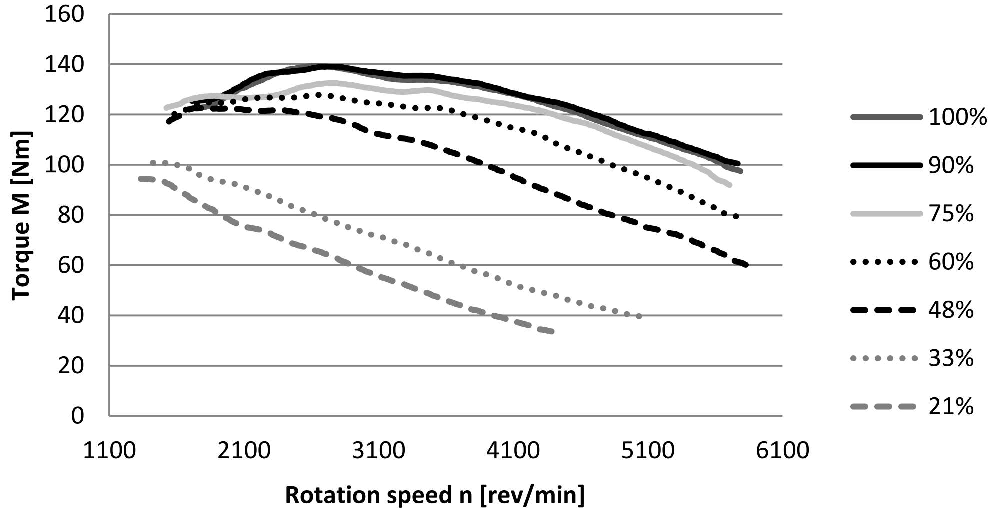

Fig. 8. Course of the vehicle's torque depending on engine rotations at different engine loads

Table 3. Maximal values of power and torque of the engine at different loads

Engine load	Engine speed [rev/min]	Maximum power [kW]	Engine speed [rev/min]	Maximum torque [Nm]
100%	5,469	59.87	2,630	139.41
90%	5,618	60.56	2,760	139.08
75%	5,260	57.24	2,770	132.56
60%	4,981	50.76	2,640	127.81
48%	4,025	40.95	1,784	122.56
33%	3,317	23.56	1,455	100.83
21%	2,760	18.32	1,375	94.42

5.1. Changes of indicating pressure and heat evolution in the process of burning

A representative sample of the examined states of engine load has been elaborated on the basis of 200 registered consecutive cycles of indicated pressure changes. The pressure changes have been presented in the form of a closed indicating diagram. The analysis of this diagram reveals the fact that, at loads above 50%, there are slight differences, whereas the value of the pressure drops dramatically, together with a decrease in the load below 50%, while the area of loop gets smaller (Fig. 10).

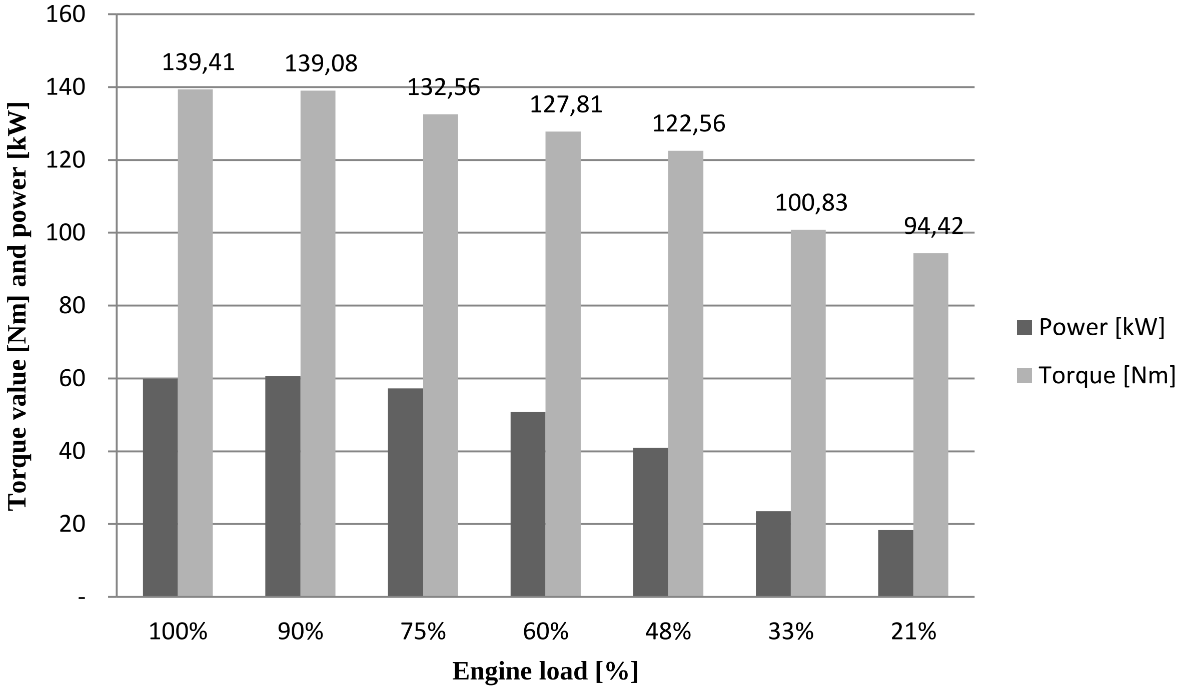

Fig. 9. Cumulative diagram, with maximal values (power and torque) in the total range of the examined loads

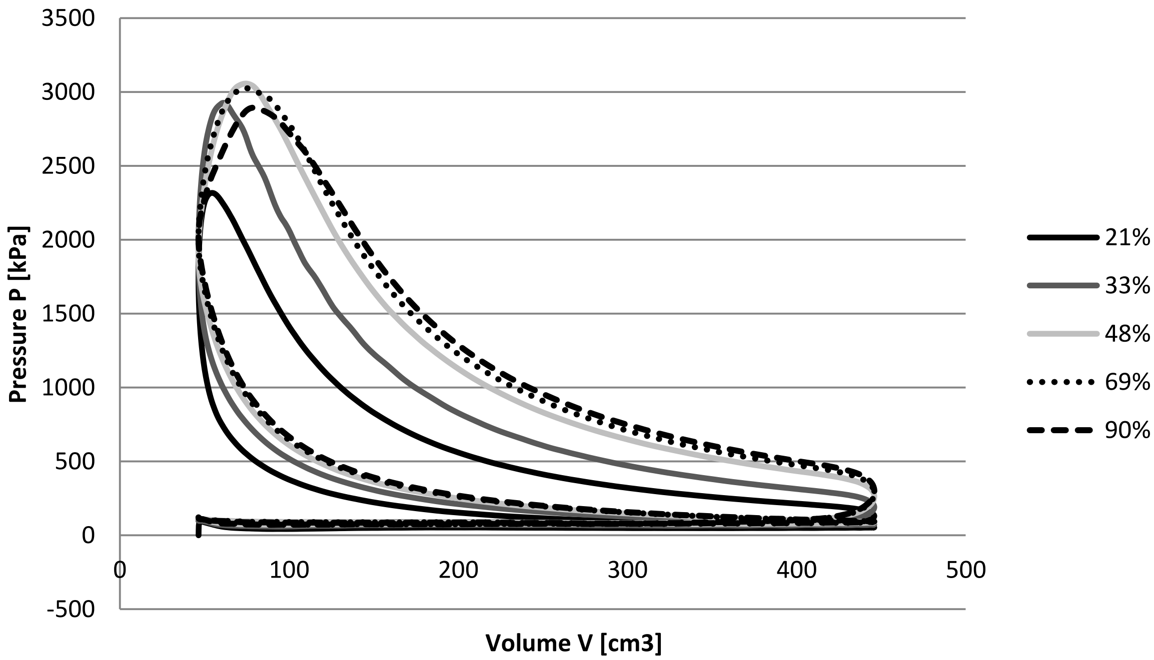

Fig. 10. Cumulative diagram of pressure change depending on the volume of combustion chamber; n=2,500 rotations/min

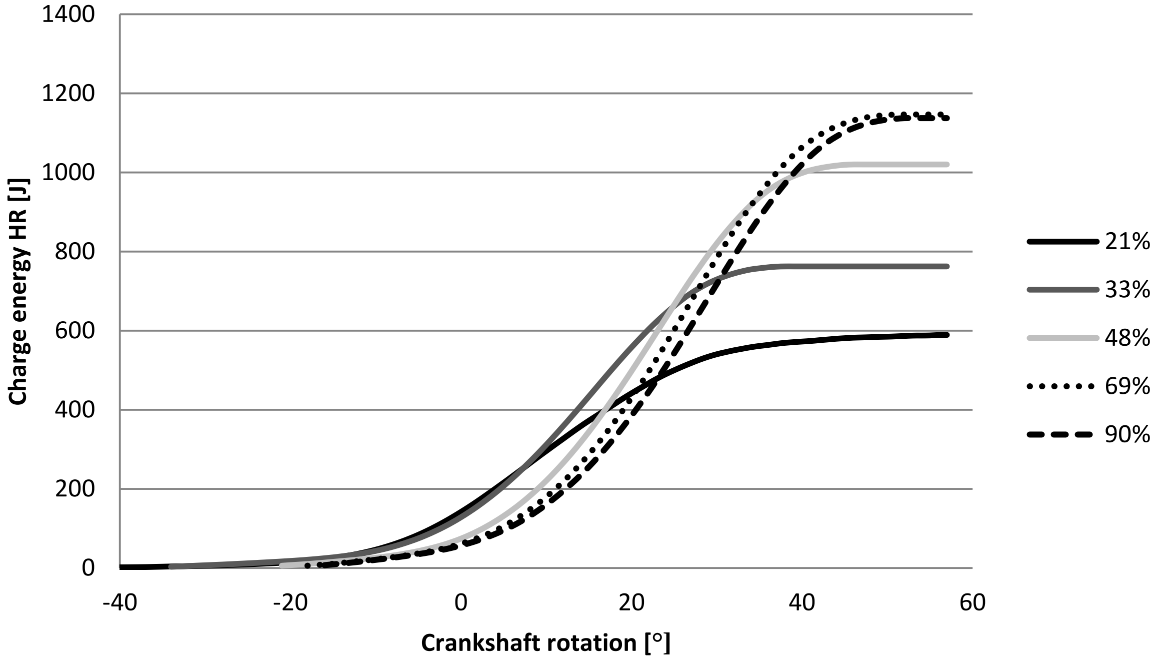

Fig. 11. Obtained energy in the process of burning

Experimental results were the basis for calculating the changes in functions of heat evolution in the process of burning. These changes are presented in diagram form (Fig. 12 and Fig. 13).

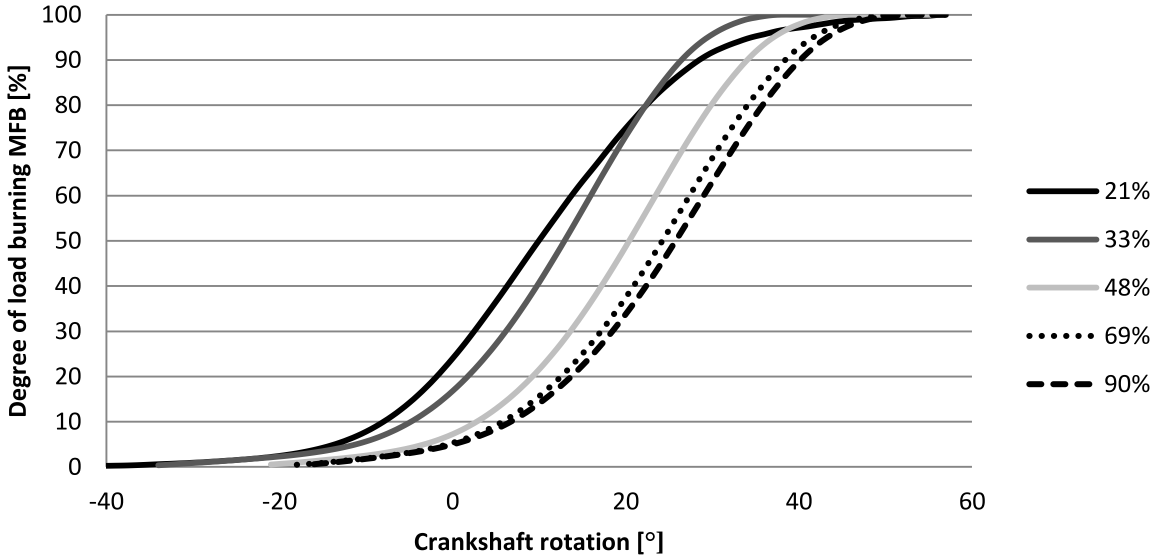

Fig. 12. Percentage degree of load burning

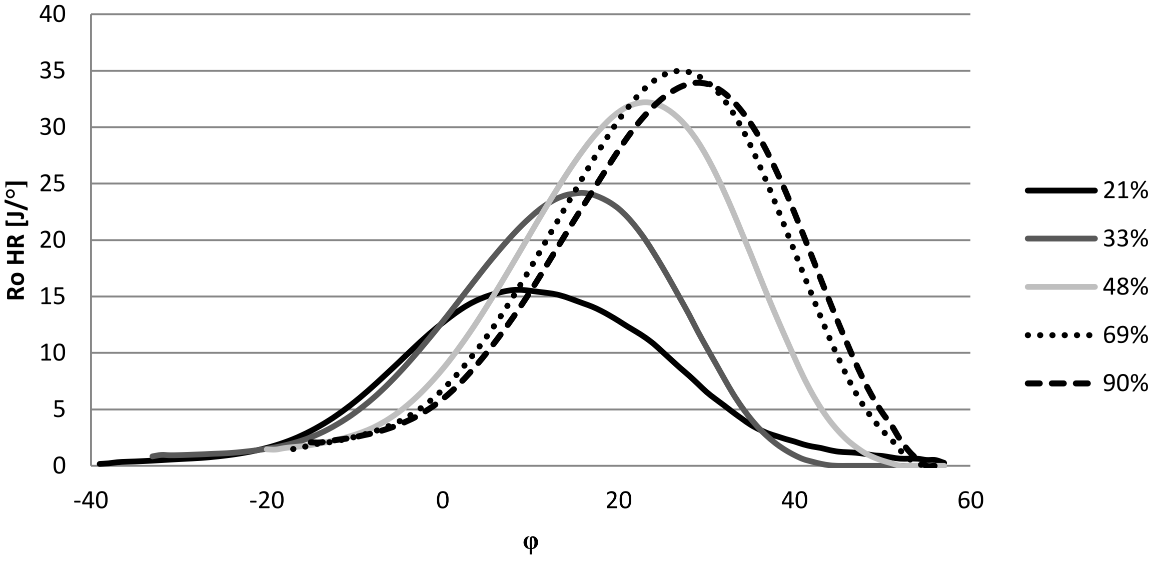

Fig. 13. Speed of heat emission

The speed of heat evolution is comparable to the highest engine loads (69 and 90%). The smaller the load, the lower the speed of heat emission and the longer the process of burning.

6. FINAL CONCLUSIONS

- Vehicles in city traffic and road traffic use maximal rotational speeds of the engine. Most frequently, they work within the range of low and medium rotational speeds due to the requirements of torque. Such engine conditions work with partial engine loads.
- The designed device presented in this paper allows for repetitive conditions of the engine to be obtained for the load in the course of examinations involving the brake-chassis test bed.
- The presented design is suitable for the Opel Astra in terms of dimensions, while the idea seems to be fairly universal.
- Above 60% of engine load, there is a slight change in the torque value and power. Below 50%, the values drop dramatically.
- The amount of produced energy (Fig. 11), which changes in the engine's work at different loads, is due to a new load that is closely connected with the efficiency of engine feeding.

References

1. Tadeusz Rychter, Andrzej Teodorczyk. 2006. *The Theory of Piston Engines*. Warsaw: Publishing House of Communications and Connections.
2. Sławomir Luft. 2006. *Basics of Engine Construction*. Warsaw: Publishing House of Communications and Connections.
3. Kubica G. 2013. *Efficient Energy Conversion in a Spark Ignition Engine Fueled with Low-carbon Gaseous Fuels*. Radom: Publishing House of the Institute for Sustainable Technologies. ISBN 978-83-7789-218-3.

4. Maciej Bernhardt, Stanisław Dobrzyński, Edward Loth. 1988. *Car Engines*. Warsaw: Publishing House of Communications and Connections.
5. Janusz Mysłowski, Józef Kołtun. 2000. *Flexibility Piston Internal Combustion Engines*. Warsaw: Scientific and Technical Publishing House.

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