POSSIBILITIES OF PERFORMANCE MEASUREMENT OF COMBUSTION ENGINES

DANIEL MADER[1], MARTIN PEXA[1], BOHUSLAV PETERKA[1], MAREK DVORAK[1], MARTIN KOTEK[2]

[1]Czech University of Life Sciences Prague
Faculty of Engineering, Department for Quality and Dependability of Machines
Prague, Czech Republic
[2]Czech University of Life Sciences Prague
Faculty of Engineering
Department of Vehicles and Ground Transport
Prague, Czech Republic

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e-mail: maderd@tf.czu.cz

The paper deals with performance measurement of combustion engines. Currently, in combustion engines is not used only fuel from fossil fuel (diesel, gasoline), but also the fuel of biological origin. Due to most engines are designed for fossil fuels, it is possible to expect a reduction of power parameters (lower calorific value of fuel) of biofuels. Whether the vehicle (tractor) fulfill the operational requirements of the user in that conditions, it is often necessary to control by measurement. The measurement can performed by using static (dynamometer) or dynamic methods. It is usually necessary to expect, that performance parameters of the engine with a turbocharger can be distorted by using dynamic methods. In the article is stated a comparison both of methods on road vehicle Skoda Octavia 1.8 turbo and tractor ZetorForterra 8641.

KEYWORDS

biofuels, combustion engine, performance parameters, engines speed, torque, power, dynamometer

1 INTRODUCTION

The power of the combustion engine is an important diagnostic sign, especially useful in detecting the conditions of the piston group, engine timing mechanism, fuel system and for petrol engine's spark-ignition system, as well. [MÜLLER et al. 2009] The wear of functional surfaces is reflected in the change of the power parameters, thus causing the loss of effective energy (increased friction and vibration of the machine). [MASCESNIK et al. 2016, POSTA et al. 2016] But, power alone is not sufficient to establish the condition. In a measurement of power output it is necessary to determine the efficiency and secondary effects which have been used to achieve this power. [ARAPATSAKOS et al. 2008] For example, if the power of a diesel engine is within the tolerance of the nominal value, but smoke emissions are above normal, this may be an indication of the engine's poor technical condition.

Unlike the measurement of power parameters, in terms of engine production or extensive engine repair, significantly simpler diagnostic methods are ordinarily used. It is possible to use accurate dynamometric stands for the measurement of the dismantled engines, or tractors, measuring power parameters directly to power take off [SERRANO 2007], but it is not economically feasible for ordinary service. The same applies to the rolling test room for measuring power parameters, but it is not as accurate a measurement of dismantled engines. While it also offers the use of modern acceleration methods [HROMADKO et al. 2007], which are sufficiently accurate and low-cost, the measurement still has some complications particularly for engines equipped with turbochargers and other special electronical controls. [ASCANIO et al. 2008].

The aim of this paper is comparison of static and dynamic methods of performance measurement turbocharged internal combustion engine in road vehicles and agricultural machinery.

2 MATERIALS AND METHODS

As a representative of turbochaeged petrol engine was chosen the 1.8 20V Turbo fitted in the vehicle Skoda Octavia (mileage aprox. 170,000km). For static and dynamic measurement of performance parameters was used one and the same tester, in the premises of the CULS Prague.

For the static load of the vehicle was used roller testerconnected with swirling water cooled dynamometer from MEZ with maximum braking power of 125 kW. First step during the measurement is to press the accelerator to the maximum position on the selected gear. After reach the maximum speed of the engine crankshaft the braking torque increased by engaging swirling dynamometer, which is controlled by the connected computer. Increasing braking torque causes a decrease in speed of the internal combustion engine, but when the accelerator is constantly adjusted in maximum position. Then the engine speed of the internal combustion engines decreasedto speed near idle engines speed. Throughout this measurements phase are recorded values of the torque to the wheels of the vehicle and thespeed oftesting rollers. Consequently is determined torque across the measured system, which was observed by discarding gear and spin testing roller by an electric motor.

A dynamic measurement method, it is first necessary to determine the gear ratio between the engine and the testing rollers at the selected gear. In the second cycleis set all inertial mass reduced the circumference of rollers (rollers, engine, tires, gears etc.). This is done by starting and stopping the entire system using a known motor torque. From the values of acceleration, deceleration, and from the known inertialmass of testing rollers reduced to their final circumference is calculated inertial mass of the rotating parts reduced to the circumference of the rollers. In the third cycle, the measured rotation speed characteristic of the engine and is calculated the performance parameters of the internal combustion engine. After stabilizing idleengine speedthe accelerator is pressed to maximum position and then to accelerate to maximum speed, after reaching maximum engine speed the clutch pedal is full pressed, thereby the whole system decelerate. In the fourth step is measured inertia mass reduced to the circumference of the rollers when the neutral gear is selected. From difference of inertial mass reduced to the circumference of rollers is obtained moment of inertia of the internal combustion engine. During this measurements are sensed pulses corresponding to the rotational speed from which by the formulas 1 and 2, are calculated values of angular acceleration and angular velocity

$$\varepsilon_j = 4 \cdot \pi \cdot \frac{\frac{1}{t_{j+1}} - \frac{1}{t_j}}{t_j + t_{j+1}} \quad (1)$$

$$\omega_j = \frac{4 \cdot \pi}{t_j + t_{j+1}} \quad (2)$$

ε_j – angular acceleration of the crankshaft at an angular velocity ω_j, rad.s^{-2}

ω_j – mean angular velocity of the crankshaft between the j-th and j-plus first speed, rad.s^{-1}

t_j – duration of the j-th rotation of the crankshaft, s

t_{j+1} – Duration j-plus first rotation of the crankshaft, s

After that are performance parameters (torque and power) calculated from (3) and (4). The moment of inertia value of moving masses of the vehicle and roller tester reduced to the crankshaft of the engine isin Skoda Octavia10,39 kg.m^2.

$$T = I \cdot \varepsilon \quad (3)$$

T – engine torque, Nm

I – moment of inertia of the engine reduced to the crankshaft, kg.m^2

ε – angular acceleration of the crankshaft, rad.s^{-2}

$$P = I \cdot \varepsilon \cdot \omega = T \cdot \omega \quad (4)$$

P – engine power, W

T – engine torque, Nm

ω – angular speed of the crankshaft, rad.s^{-1}

As a representative of the turbocharged diesel engine was selected tractor Zetor Forterra 8641 with an engine designation 1204 (cubic volume 4,156 cm3).

Statically this engine was loaded by PTO vortex dynamometer MAHA ZV500 with maximum output of 500 kW. Gear ratio of engine speed to PTO is set by the idle speed of the engine and for tractor Zetor Forterra 8641 is 3,543. The entire test takes place automatically at preset measurement step and the settlement of individual measuring points.

Dynamically was loaded the engine itself. The vehicle, in this case a tractor was placed on the roller tester. Acceleration of the tractor combustion engine is carried out when the accelerater is full pressed until reaching overrun engine speed. Following release of the acceleraor to reach idle engine speed. In this case was speed sensedfrom air condition, because of the simplicity of the conection. For proper conversion speed air condition to the engine speed was determined ratio. The angular speed of the sensed pulses is calculated from(2), the angular acceleration of the sensed pulse from(1) and with the inclusion the ratio. Based on the calculated values of angular velocity and angular acceleration can be calculated engine torque from (3) and engine power from(4). Dynamic method of measurement was also performed with load, which created a drum mower connected to the tractor PTO.
All measured waveforms of performance parameters of internal combustion engines were usually repeated 3 to 5 times and the results shows only the average value of these measurements.

3 RESULTS AND DISCUSSION

According to the methodology described above was measured the test vehicle **Skoda Octavia turbocharged petrol 1.8 Turbo.** Originally was assumed that more facts will approach the static measurement method. However, this did not occur, and better results were obtained by measuring the dynamic method, when was achieved such a course of torque and power, which is closer to the characteristics indicated by the manufacturer of the test vehicle. This could occur by the loss correction of the engine to the rollers of the tester is very difficult and in some cases the source of inaccuracy.

Waveforms of performance parameters of the internal combustion engine Skoda are illustrated in Fig. 1. The most significant difference between the two methods was reflected in the first half of the speed range to 3,500 rpm, where was a significant deviation of torque characteristics. This difference is clearly seen in Fig. 1, where it is apparent that the increase of torque from idle engine speed to 2,000 rpm is almost identical. But then it occurs with the values measured by the dynamic method to a significant increase in torque, so this characteristic is closer to the characteristic indicated by the manufacturer of the test vehicle. After exceeding 3,500 rpm is a torque curve in the case of both methods again identical. From the torque characteristic obtained by using dynamic method implies that the engine can operate effectively in a wider speed range from 2,500 rpm up to 4,600 rpm, where the engine maintains a relatively constant torque of 205 Nm.

It is also important to achieve maximum torque, where in the case of dynamic methods reached 205 Nm at 2,500 rpm, but with static methods was measured 202 Nm, but up to 3,500 rpm.

The waveform of tne engine power, based on the torque, is different only in the above described area of enginespeed from 2,000 to 3,500 rpm. Over 3,500 rpm is a performance increase in both cases identical until reaching a maximum of 99 kW at 5,000 rpm for static method and 99.3 kW at 5,500 rpm for dynamic method.

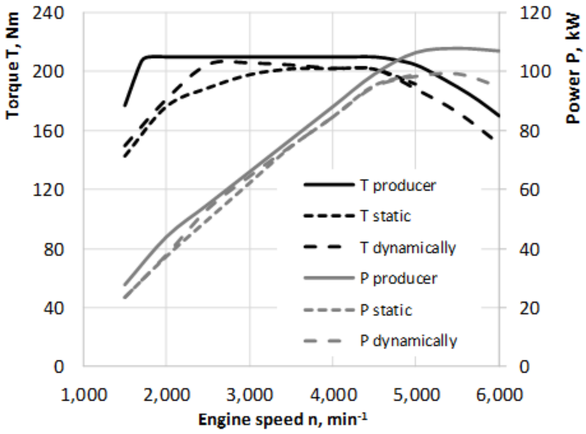

Figure 1. Comparison of static and dynamiccharacteristics of theengineSkoda Octavia

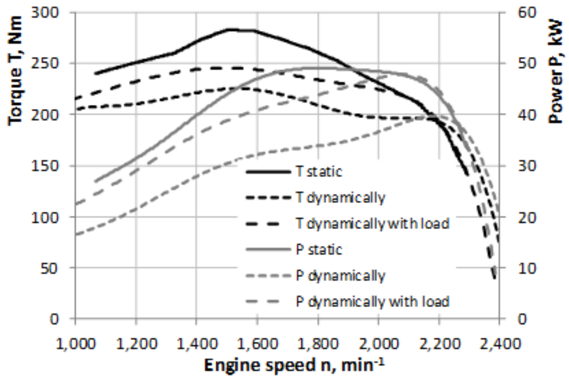

Figure 2. Comparison of static and dynamicmethods of measurement – Zetor Forterra

The measurement results of the internal combustion engine Zetor Forterra 8641 are shown in table 1 and in Fig. 2. Table 1 shows the comparison of torque rise for the used methods. The manufacturer guarantees a minimum excess of 35%, but on a dynamometer was measured at 46% drop in speed by 32%. Therefore, there was an increase in the backup torque of 11% and that caused blocked fuel filter. Free acceleration values was 16% with speed falls by 28%, and the value of the free acceleration with load came out 27% with the speed falls by 32%. It is clear that the dynamic measurement method without load was measured in advance torque 30% lower. In the dynamic method with load was measured value of backup torque 19% lower.

Parameter	TORQUE RISE, %	DECREASE ENGINES SPEED, %
VALUE MEASURED ON THE DYNAMOMETER	46.82	31.59
VALUE MEASURED DURING FREE ACCELERATION	16.14	28.23
VALUE MEASURED DURING FREE ACCELERATION WITH LOAD	26.96	32.18

Table 1. Comparison of torque and drop in speed both methods

InFig. 2 are noticeable high differences in torque values with variations in dozens Nm. In comparison with the curve measured on the dynamometer (statically), the waveforms of measured performance parameters dynamically differed significantly. Maximum torque measured by dynamic methods is only about one-fifth smaller than the methods measured on the dynamometer. It is also in the area of 1,300 to 1,400 rpm visible growth performance parameters in static measurements, because of the turbocharger switched on. During dynamic measurement of this phenomenon is slightly distorted.

4 CONCLUSIONS

Comparison of static and dynamic methods of performance measurement turbocharged engines has led to the following conclusions:

1. Dynamic measurement of performance parameters ofturbocharged combustion engines applied to **roller tester** a large inertia can bring comparable results with the static method. In some cases, individual measurements can bring even better results. This is mostly due to the fact that by a dynamic measurement method is described the entire course of the performance parameters of the engine rotation by rotation, while the static method measures only significant points, and measurement error at this point significantly affect the accuracy of the method. This is seen in Fig. 1, when a static method of measurementmeasured in rotations 2,500 rpm significantly lower engine torque.
2. Dynamic measurement of performance parameters ofturbocharged combustion engines applied to the engine itself far below the static accuracy of the measurement method. This is shown in Fig. 2 in particular during no-load measurements. In case of the tractor is possible to connect on the PTO additional load, which greatly affect the accuracy of dynamic measurement method. It can be assumed that a suitable choice of load can achieve similar waveforms of performance parameters such as the static measurement method.

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CONTACT:
Ing. Daniel Mader
Czech University of Life Sciences Prague
Faculty of Engineering
Department for Quality and Dependability of Machines
Kamycka 129, 165 21 Prague 6, Czech Republic
e-mail:maderd@tf.czu.cz