Research of the effect of washing of fuel system engines on traction-speed properties of cars

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Abstract. The results of tests on the Cartec LPS 2510 dynamometer stand (test mode P-max) according to ISO 1585 are presented. Regardless of car model, year of manufacture, mileage and engine size, power unit power loss and a decrease in torque are observed. Flushing the fuel system with special fluids and ultrasonic cleaning of the nozzles allow the restoration of engine power and torque.

1. Introduction

Traction-speed properties of a car are one of the main indicators of its effectiveness. Their evaluation is carried out by calculating the parameters of power and traction force or by determining the traction-speed parameters (TSP) on roller stands [1-6]. Using the stands, they estimate not only the fuel mixes, but also determine the irregularity of the fuel dosage, estimate the energy and environmental parameters of engines operating on various fuels, including ethanol added to gasoline [7-12].

On the power (dynamometer) bench, the power at the wheel and the power of the mechanical losses (power loss to work in the vehicle's transmission) are measured. The engine power on the traction stands is not directly measured, but is calculated as the sum of the power at the wheel and the power of mechanical losses. The change in engine power depends not only on the amount of car mileage, but also on many factors, which include pollution of the injectors, the presence of deposits and carbon deposits on the parts of the power unit. Timely assessment of power, adjustment, troubleshooting of engine components will improve the efficiency of the vehicle.

2. Methodology and results

2.1. Experimental part

The test was carried out with cars having different mileage. So, for example, by the time of his research, the Chevrolet Lanos SX (release of 2009) had a mileage of (L) of 100 and 170 thousand km, and a
Chevrolet Lacetti of 127 thousand km (Table 1). The power (N) and torque (M) of the engine were determined on a Cartec LPS 2510 dynamometer (test mode P-max) according to ISO 1585 (Figure 1). The standard regulates the measurement of net power – the real engine power.

Table 1. Car make, year of manufacture, engine displacement (V\text{\text{eng}}), car mileage (L), rated power (N\text{\text{nom}}) and nominal torque (M\text{\text{nom}}) according to passport data, current maximum values of power, torque (N\text{\text{L}}), (M\text{\text{L}}) from the frequency of rotation of the crankshaft \( n \)

| Automobile      | Year of issue | V\text{\text{eng}}, l | L, thousand of km | N\text{\text{nom}} / n, kW/min\(^{-1}\) | M\text{\text{nom}} / n, N·m/min\(^{-1}\) | N\text{\text{L}} / n, kW/min\(^{-1}\) | M\text{\text{L}} / n, N·m/min\(^{-1}\) |
|-----------------|--------------|------------------------|-------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|
| Mitsubishi Lancer 9 | 2007         | 1.6                    | 95                | 72/5000                                | 150/4000                               | 70/5105                                | 148/3654                               |
| Chevrolet Lanos SX | 2009         | 1.5                    | 100               | 63/5800                                | 130/3400                               | 49/5266                                | 99/3558                                |
| VAZ-2121         | 2012         | 1.6                    | 170               | 59/5400                                | 116/3400                               | 43/5266                                | ----                                   |
| Chevrolet Lacetti | 2009         | 1.6                    | 50                | 80/5800                                | 150/4000                               | 77/5793                                | 148/3708                               |
| Volvo S 40       | 2003         | 1.8                    | 127               | 90/5800                                | 170/4000                               | 83/5744                                | 152/4180                               |
| VAZ-2123         | 2013         | 1.7                    | 204               | 59/5000                                | 127/4000                               | 53/5200                                | 109/4084                               |
| Hyundai Solaris  | 2013         | 1.4                    | 80                | 78/6300                                | 135/5000                               | 69/5621                                | 124/4299                               |
| Volvo S 40       | 2002         | 1.6                    | 205               | 80/5800                                | 145/4000                               | 76/5709                                | 134/4755                               |

For a correct assessment of the N and M parameters recorded at the stand (after removing the initial characteristics of the engine), the injection system (IC) of the vehicles was washed with WYNN’S liquid. The engine was flushed with WYNN’S fluid by supplying it from a single-circuit reservoir (GX-100B) running on compressed air.

**Figure 1.** Chevrolet Lanos SX car at the Cartec LPS 2510 dynamometer: 1 – gas exhaust pipe; 2 – lateral displacement limiter; 3 – tension belts; 4 – engine speed sensor; 5 – oil temperature sensor.

2.2. Analysis of the results

Table 1 shows the passport data of gasoline engines of cars and the current maximum value obtained at the stand.
It is well known that the loss of power of the power unit associated with the natural wear of engine parts is ~ 10% of the passport parameter (nominal) \(N_{\text{nom}}\). Indeed, from data analysis (Table 1) it follows that in most cars the power of the power unit differs from \(N_{\text{nom}}\) by 3 ... 12%. The exception was the car Chevrolet Lanos SX: engine power with mileage was 68 ... 78% of the passport parameter \(N_{\text{nom}}\).

In figures 2–4 show graphic protocols for testing cars on the Cartec LPS 2510 dynamometer bench in accordance with ISO 1585.

From the analysis of the presented curves (Figure 2, 3), it follows that the dependencies of power on the crankshaft rotation speed are different for the Chevrolet Lanos SX and Chevrolet Lacetti. Moreover, the dependence of power on the crankshaft rotational speed of the Chevrolet Lanos SX is typical for engines with unchanged intake manifold geometry, in which gas distribution processes are influenced by the installation of camshaft timing [13].

**Figure 2.** Graphic protocol of a 3-time test of a Chevrolet Lanos SX car with a mileage of 170 thousand km before washing the injection system with WYNN’S liquid: curves of engine power (kW) versus crankshaft rotation speed (min\(^{-1}\)), (1, 2 and 3 – the serial number of tests).

**Figure 3.** Graphic protocol of a 3-time test of a Chevrolet Lacetti car with a mileage of 127 thousand km before flushing the injection system with WYNN’S fluid: curves of engine power (kW) versus crankshaft rotation speed (min\(^{-1}\)), (1, 2 and 3 – the serial number of tests).
Crankshaft rotation speed, n, min-1

**Figure 4.** Graphic protocol of a 3-time test of a Chevrolet Lanos SX car with a mileage of 170 thousand km after flushing the injector system with WYNN’S fluid: engine power curves (kW) versus crankshaft rotation speed (min⁻¹), (1, 2 and 3 – the serial number of tests).

Flushing the engine power system is reflected in its power positively. Its scatter is much lower than the scatter of the values of this parameter recorded before cleaning the injection system (Figure 2 and 4). The amount of power increases after washing.

The scatter of power values, most clearly manifested in the testing of the car Chevrolet Lanos SX, reaches values much higher than the scatter values that were obtained in tests with the Chevrolet Lacetti. So, at \( n = 4600 \text{ min}^{-1} \), the power can reach values from 41 kW to 45 kW (Figure 2). Therefore, not three, but 5 parallel tests were conducted. The correspondence of the taken number of experiments to the required number of measurements \( n_x \) ensuring the representativeness of the sample was evaluated by the expression [14]:

\[
n_x = \frac{t^2 \sigma^2}{\Delta x^2}, \quad (1)
\]

where \( t_a \) is the Student’s criterion, \( \sigma^2 \) is the variance of the general population; \( \Delta x \) is the measurement error.

So, for the values \( \Delta x = 2.5 \text{ kW}, t_a = 2.8, \sigma^2 = 3.9 \text{ kW}^2 \), obtained by processing the maximum engine power data (before washing the injection system), the value of \( n_x \) was 5, identical to the number of tests performed.

Error estimation was performed using the expression [6]:

\[
\tau_{\max} = \frac{1}{\sqrt{(n-1)/n}} \cdot \frac{x_{av} - x_{ch}}{s_n}, \quad (2)
\]

where \( \tau_{\max} \) is the maximum relative deviation; \( x_{av} \) is the arithmetic mean value of the parameter; \( x_{ch} \) - checked parameter value; \( s_n \) is the standard deviation.

According to expression (2), the values of \( \tau_{\max} \) for the minimum \( (x_{av}) \) and maximum \( (x_{ch}) \) power values were calculated by comparing the \( \tau_{\max} \) with the table value.

Data processing was performed using statistical functions and analysis of Microsoft Office Excel package.
Figure 5. The dependence of the Chevrolet Lanos SX engine power on the crankshaft rotation frequency (mileage 100 thousand km): 1 – before flushing the injection system with WYNN’S fluid; 2 – after flushing the injection system with WYNN’S fluid; 3 – after washing the injector system with WYNN’S fluid and cleaning the nozzles with ultrasound.

Figure 6. Dependence of Chevrolet Lanos SX engine’s torque of the on the crankshaft rotational speed (mileage 100 thousand km): 1 – before washing the injection system with WYNN’S fluid; 2 – after flushing the injection system with WYNN’S fluid; 3 – after washing the injector system with WYNN’S fluid and cleaning the nozzles with ultrasound.

Figures 5-6 show the results of data processing resulting from changes in the parameters \( N \) and \( M \) of the Chevrolet Lanos SX engine, depending on the rotational speed of the crankshaft. When the course of the presented dependences is identical, the values of \( N \) and \( M \), obtained after flushing the fuel system
with WYNN’S liquid and ultrasonic cleaning of the nozzles, exceed the same parameters recorded on the stand before the indicated procedures.

**Table 2.** Maximum power \((N)\), torque \((M)\) of the Chevrolet Lanos SX engine, loss \(\Delta N\).

| Parameter | According the passport data | Mileage, thousands of km | Before flushing the injection system | After flushing the injection system | Before flushing the injection system | After flushing the injection system |
|-----------|---------------------------|--------------------------|---------------------------------------|-----------------------------------|--------------------------------------|-----------------------------------|
| \(N, kW\) | 63.3                      | 49.0                     | 54.7                                  | 43.3                              | 47.1                                 |
| \(M, H\cdot M\) | 130                       | 98.8                     | 109.5                                 | ----                              | ----                                 |
| \(\Delta N, kW\) | ----                     | 14.3                     | 8.6                                   | 20.0                              | 16.2                                 |

**Table 3.** Maximum power \((N)\), torque \((M)\) of the Chevrolet Lacetti engine, loss \(\Delta N\).

| Parameter | According the passport data | Mileage, thousands of km | Before flushing the injection system | After flushing the injection system |
|-----------|--------------------------|--------------------------|---------------------------------------|-----------------------------------|
| \(N, kВт\) | 80                       | 76.9                     | 78.4                                  |
| \(M, H\cdot M\) | 150                       | 147.8                    | 155.2                                 |
| \(\Delta N, kВт\) | ----                     | 3.1                      | 1.6                                   |

### 3. Discussion

The presented data (Table 2) indicate that the maximum engine power with a mileage of 100 thousand km is less than \(N_{ном}\), by 14.3 kW, and with an operating time of 170 thousand km. at 20.0 kW. Flushing the injection system will increase power by 4-6 kW. Unlike the Chevrolet Lanos SX engine, the power of the Chevrolet Lacetti power unit increased by 2 kW (Table 3).

The contamination of nozzles with deposits, varnishes and impurities leads to the need for ultrasonic cleaning [15, 16]. Therefore, the nozzles were cleaned with ultrasound, using an ultrasonic bath, which is part of the device for cleaning and analyzing AT & E fuel nozzles (model HP-6B) [17]. Evaluation of the degree of cleaning of the nozzles by ultrasound was evaluated by their performance on the AT & E installation. A solution consisting of water, ethanol, and surfactants was used as a cleaning agent.

The evaluation of the working status of the injectors was carried out in automatic and manual modes for setting the frequency \((n_T)\), width \((\tau)\) and the number of pulses \((N_T)\). The parameters of the automatic mode are presented in Table 1 (performance in \(cm^3\)). In the manual mode: \(1 - n_T = 2400 \text{ min}^{-1}\), \(\tau = 12\) ms, \(N_T = 2000\) pulses; \(2 - n_T = 3600 \text{ min}^{-1}\), \(\tau = 6\) ms, \(N_T = 2000\) pulses. The first setting simulates a multipoint spray and the working condition of the injectors at maximum load, the second one – a multipoint spray and working condition at high speeds of the vehicle. The time spent on testing in all experiments ranged from 30 to 43 sec. In table 2 shows the change in performance \((\Delta)\), expressed in \(cm^3\cdot\text{min}^{-1}\).

From a comparison of the data (Table 4) it follows that the performance of the nozzles changes after exposure to ultrasound. Therefore, in order to establish the reliability of the data obtained, tests of SIEMENS DEKA ZMZ 6354 (SIEMENS) and BOSCH 280 150 996 (BOSCH) injectors were conducted with a mileage approximately equal to the mileage of the Chevrolet Lanos SX.

SIEMENS nozzles, unlike BOSCH and GM, were prewashed before ultrasonic cleaning by placing in a beaker filled with a solution (the volume of the liquid phase was 20 ml) under a slope so that only the lower part of the device was washed with a magnetic stirrer. The cleaning process was carried out...
with the help of a “reanimator” – nozzle-Reanimator V2.0 on the objects of study working impulses. Firstly it was carried out for 30 seconds, and then for 1 minute. After each such impact, the nozzles were left (without turning off the mixing) for 10 minutes in a beaker and then measured pH (pH) and electrical conductivity (σ) of the liquid phase. Before measurements, the liquid entering the upper part of the nozzle was taken with a single-channel pipette and placed back into the beaker. The total time of contact of the liquid with the object of study and the temperature of the liquid phase were, respectively, 1 hour and 200 ° C.

Table 4. Performance of GM 96334808 (GM) injectors after flushing the fuel system of a Chevrolet Lanos SX with WYNN’S liquid under various test conditions

| nozzle | Before ultrasound clearance | After ultrasound clearance |
|--------|----------------------------|-----------------------------|
|        | «X.X.», n= 650 min⁻¹ τ= 3 ms, Nτ=2000 pieces. | «X.X.», n= 650 min⁻¹ τ= 3 ms, Nτ=2000 pieces. |
|        | «loading», n= 2400 min⁻¹ τ= 12 ms, Nτ=1000 pieces. | «loading», n= 2400 min⁻¹ τ= 12 ms, Nτ=1000 pieces. |
|        | «max», n= 3600 min⁻¹ τ= 6 ms, Nτ=1000 pieces. | «max», n= 3600 min⁻¹ τ= 6 ms, Nτ=1000 pieces. |

Table 5. Performance change of nozzles (Δ) *

| Manual settings’ mode | SIEMENS DEKA ZMZ 6354 | BOSCH 280 150 996 |
|-----------------------|------------------------|-------------------|
| Δ, cm³·min⁻¹ | F2 | F3 | F4 | F1 | F2 | F3 | F4 |
| 1 | 4.0 | 2.0 | 4.0 | 6.0 | 4.0 | 0 | 0 |
| 2 | 5.6 | 5.6 | 5.6 | 2.8 | 1.4 | 0 | 0 |

*Δ = PR1-PR2 (PR2-performance before cleaning; PR1-performance after cleaning).

Table 5 shows the performance changes of the SIEMENS and BOSCH nozzles. From a comparison of the data (Table 5), it follows that the performance of BOSCH nozzles increases or does not change after exposure to ultrasound. Consequently, the data obtained for GM, indicating a decrease in productivity after exposure to ultrasound, is the measurement error. Test results in which performance does not change should be considered reliable. That is, not all contamination can be removed by exposure to ultrasound. After pretreatment (using the “reanimator”), productivity increases (Table 5, SIEMENS). Data with zero Δ is not observed. The relative error in measuring performance was ± 0.4-1.0%. When calculating the errors in determining the performance, the value of the confidence probability was α = 0.95, and the value of the confidence limit (tα) was 2.262.

4. Conclusion

The use of ultrasound as a cleaning method has been known for a long time. Therefore the result obtained in the study is quite natural. However, taking into account the fact that the SIEMENS nozzles were subjected to preliminary washing (using a “reanimator”), it should be concluded that it is advisable to monitor the operating parameters after applying this procedure.

From a comparison of the data (Table 6), it follows that ultrasonic cleaning, after flushing the fuel system with WYNN’S liquid, allows the engine to recover another 2 kW.
Table 6. Maximum power (N), torque (M) of the Chevrolet Lanos SX engine, loss \( \Delta N \)

| Parameter | According the passport data | Mileage, thousands of km | After flushing the injection system with WYNN’S | After flushing the injection system with WYNN’S and ultrasound cleaning |
|-----------|-----------------------------|--------------------------|-----------------------------------------------|---------------------------------------------------------------------|
| N, kW     | According the passport data | 63.3                     | 49.0                                          | 54.7                                                                |
| M, N·m    | 130                         | 98.8                     | 109.5                                         | 121.0                                                               |
| \( \Delta N \), kW | ---- | 14.3                     | 8.6                                           | 6.3                                                                |

Thus, from the test results and their analysis presented, it follows that regardless of the vehicle model, year of production, mileage and engine size, the power loss of the power unit and the decrease in torque value are recorded. Flushing the fuel system with WYNN’S fluid and ultrasonic cleaning of the nozzles will allow you to restore engine power and torque. It has been established that pretreatment of the nozzles with a washing solution using a “resuscitator” (Reanimator V2.0) will increase the effectiveness of the effect of ultrasound on decontamination.

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