Pressurization influence on power and ecological indication of the petrol engine

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Abstract. Indicated on dynamometric stand LPS 2510 dependences of the engine power and a torque on the crankshaft frequency have been presented in the article. The car VAZ 2123 “Chevrolet Niva” (without catalytic converter) and the engine VAZ 21214 with the mechanical supercharger (compressor) PK-23 have been tested. It is established that configuration of the engine with the compressor has allowed not only to restore the lost power of the motor as a result of extended operation, but also to increase it. It is shown that the content of carbon monoxide and products of incomplete combustion of hydrocarbons in the exhaust gases does not exceed standard values of volume fractions of CO and CH. It is established that registered by the indicator of OKTAN values of gasoline are identical to those declared by the manufacturer.

Keywords: crankshaft frequency, compressor, capacity, torque.

1. Introduction

Forcing an internal combustion engine by supercharging which is an element of car tuning nowadays, is connected not only with the possibility to raise power of the motor, but also to lower parametrical (noise) and ingredient (toxic components of the exhaust gases) environmental contamination [1-4]. The potential of engines with supercharge also includes application of cheap and nonconventional kinds of fuel [1]. All above mentioned allows to consider supercharge not only an attribute of tuning, but means of increasing power and ecological indicators of internal combustion engines. Therefore, carrying out motor work testing with supercharge is expedient and timely.

It should be noted that recently, as noted in a number of literature, turbocharging has become popular not only for diesel engines, but also for gasoline engines of cars. The use of boost on gasoline-powered power units has become most relevant in engines with direct fuel injection. With this method of supplying fuel, the effect of cooling the inside of the cylinder is achieved. The boost effect is associated with some drawbacks associated with an increase in the temperature of the exhaust gases offset by the improvement of boost units. So, for example, to prevent too much pressure increase after the supercharger, a bypass channel is created using the circulating air valve, which directs the excessive air flow into the cavity in front of the supercharger.

The purpose of the research was the power, the supercharged engine torque, environmental performance of exhaust gases, assessment of the effects of fuel grade on the toxicity of the power unit. To prepare the engine for testing, recommendations on the installation of components and assemblies providing engine acceleration given in the literature were taken into account, the reliability of the power unit was taken into account, and power calculations were made [5-7]. The information on improving the design of the intake manifold of internal combustion engines, on improving the performance of electromagnetic injectors has been examined. To test the vehicle with a transmission that allows to transfer torque from the engine to all wheels (all-wheel drive car) was considered to be expedient. The vehicle is not equipped with a catalytic converter.
2. Materials and methods

The car VAZ 2123 “Chevrolet Niva” (without catalytic converter) with the engine VAZ 21214 and a mechanical supercharger (compressor) of series PK-23 (model PC 0.5D was an object of research; with supercharge 0.5 bar). Before compressor installation, being guided by the recommendations presented in references, the engine was subjected to diagnostics, the actions corresponding to regulations of maintenance service subassemblies were carried out [2-4,8,9]. For maintenance of appropriate reliability which can decrease as a result of supercharging and increase loads at engine details regular hydro jacks (a valve hydro support) have been replaced by new valve hydro supports. Ordinary pushers of the valve (rockers) were changed for stronger pushers. Instead of a regular one, “Trofi” shaft (wide ranged, designed to operate both at low, and high turns) was installed. Atomizers Siemens DEKA VAZ 20734 with lower productivity have been replaced by Bosh 107 ones of high efficiency. Besides specified actions connected with preparation of the engine work together with the supercharge unit, other procedures necessary for operation have been also done [8-9].

Definition of power indicators of the engine power (N) and a torque was conducted on dynamometric stand LPS 2510 (Cartec), measuring parameters N and M by standard ISO 1585. For fuel, gasoline of a gas station trading network «Gazpromneft» AI-95 “G-DRIVE”, AI-98 “G-DRIVE”, AI-100 “G-DRIVE” was used. Gasoline octane number was defined by the indicator (octane meter) OKTAN. A measurement range of octane numbers (an octane number on a research method ONR), an octane number on motor method - ONM) varies from 67 to 98. The limit of a supposed absolute error of ON measurement makes up ±2 octane units OU). ONR measurements were conducted, using octant meter factory calibration.

Fractional composition of gasoline samples was determined by distillation temperatures measured by mercury thermometer included in the set of automatic apparatus for distillation of petroleum products ARNS-1E, the density of the fuel measured by oil densimeters.

Toxicity of the power assembly was estimated by the content of CO and CH in the exhaust gases (gas analyzer Infracar М-2Т.01).

3. Results and discussion

Average magnitudes’ calculations of the engine power were carried out according to power and torque values in tabular test reports and presented in the form of schedules (Figures 1, 2). Statistical functions of the program for work with spreadsheets Microsoft Office Excel were used. The disorder of values of power and a torque has made up 0.5-2.7 %.

Rated power (guaranteed by the manufacturer parameter N of the engine on a mode of a full throttle and the set frequency of crankshaft rotation) was 59 kW (5000 ob·min⁻¹), the maximum torque - 127.4 N·m (4000 ob·min⁻¹).

The result of power and torque calculation has shown that at the moment of testing the value N and M was accordingly 51.9±0.8 kW, 111.4±2.3 N·m. It is ~12.0-13 % below N values regulated by the manufacturer (power loss 7.1 kW) and M (decrease in traction properties of the car to 16 N·m). It is necessary to consider such difference of parameters of power and a torque quite natural because the run of the car VAZ 2123 “Chevrolet Niva” (2013) was 200000 km.
Figure 1. The graphic test report at stand LPS 2510 before compressor installation: dependences of power (kW, kW; a continuous line) and a torque (N·m, Nanometer ; a dashed line) the engine from frequency of rotation of a crankshaft (U/min, ob·min⁻¹).

Figure 2. The graphic test report at stand LPS 2510 after compressor installation: dependences of power (kW, kW; a continuous line) and a torque (N·m, Nanometer ; a dashed line) the engine from frequency of rotation of a crankshaft (U/min, ob·min⁻¹).
As evidenced by the data (Tables 1, 2) it follows that power of the engine with pressurization, also as well as its torque are greater than values \( N \) and \( M \) of the engine without the compressor. The power and torque gain in the specified range of frequencies of crankshaft rotation has made accordingly \( \approx 11 \) kW, \( \approx 28 \) N·m.

**Table 1.** Power of the engine (\( N \)) at rotation frequency of a crankshaft (\( n \)) before compressor installation, power change (\( \Delta N \)).

| \( n \), ob·min\(^{-1} \) | Before compressor installation | After compressor installation | \( \Delta N \), kW |
|-------------------|-----------------------------|-------------------------------|--------------|
| 3600              | 40.3±1.1 (±2.7 %)            | 48.5±0.9 (±1.8 %)             | 8.2          |
| 3900              | 44.1±0.8 (±1.9 %)            | 56.8±1.3 (±2.3 %)             | 12.7         |
| 4200              | 47.2±1.1 (±2.4 %)            | 58.9±1.3 (±2.3 %)             | 11.7         |
| 4500              | 49.9±0.6 (±1.3)              | 60.0±1.0 (±1.6 %)             | 10.1         |

**Table 2.** An engine torque (\( M \)) at rotation frequency of a crankshaft (\( n \)) before compressor installation, torque change (\( \Delta M \)).

| \( n \), ob·min\(^{-1} \) | Before compressor installation | After compressor installation | \( \Delta M \), N·m |
|-------------------|-----------------------------|-------------------------------|--------------|
| 3600              | 100.0±2.6 (±2.4 %)           | 132.4±2.3 (±1.7 %)           | 32.4         |
| 3900              | 111.0±1.5 (±1.4 %)           | 142.8±3.2 (±2.5 %)           | 31.8         |
| 4200              | 110.8±2.3 (±2.1 %)           | 137.8±2.8 (±2.1 %)           | 27.0         |
| 4500              | 108.8±0.6 (±0.5)             | 131.0±2.1 (±1.6 %)           | 22.2         |

The power parameter on the curves presented on figure 1, in the range of frequencies of crankshaft rotation from 4100 to 5400 ob·min\(^{-1} \) changes wavy. It can be connected with vibration (pulsation) of speed and air pressure in an inlet collector [10-15]. Similar changes of power are characteristic (typical) for the engine after installation the compressor on it (Figure 2). However, unlike the motor without the device of pressurization parameter variations of the engine power with supercharge are less expressed. So, on dependences of power of the engine on frequency of rotation of the crankshaft, constructed by the results of tests processed by a mathematical-statistical method, Waviness of parameter \( N \) of the engine with pressurization is hardly noticeable (Figure 3) on engine power dependences on crankshaft rotation frequency constructed according to the results of testing processed by mathematical-statistical method.

**Figure 3.** Dependence of engine power (\( N \)) from frequency of crankshaft rotation (\( n \)): 1 before compressor installation; 2 after the compressor was installed on the motor.
Sharp increase of power and a torque at frequency above ~3700 ob·min\(^{-1}\) (figures 2, 3) is observed on dependences N and M on n for the motor with pressurization. It differs from monotony of power increase and a torque decrease of the engine working without a supercharger. Such growth of power, as well as torque decrease are not considered as a positive result of pressurization since the course of dependences N and M from n the power unit with the turbine or a supercharger of mass production cars is similar to a course of curves of power and a torque of atmospheric engines.

**Table 3.** The maintenance (C\(_{CO}\), C\(_{CH}\)) in the fulfilled gases (FG) of carbon oxide and products of incomplete combustion of fuel during the operation of the engine with supercharging (without converter) in no-load conditions.

| Gas              | Petrol     | AI-95 “G-DRIVE” | AI-98 “G-DRIVE” | AI-100 “G-DRIVE” |
|------------------|------------|-----------------|-----------------|------------------|
|                  | n=950 ob·min\(^{-1}\) | n=2500 ob·min\(^{-1}\) | n=950 ob·min\(^{-1}\) | n=2500 ob·min\(^{-1}\) | n=950 ob·min\(^{-1}\) | n=2500 ob·min\(^{-1}\) |
| CO, %            | 1.5        | 0.6             | 1.0             | 0.6              | 0.3            | 0.7            |
| CH, %            | 189.8·10\(^{-6}\) | 63.4·10\(^{-6}\) | 143.4·10\(^{-6}\) | 39.9·10\(^{-6}\) | 267.3·10\(^{-6}\) | 101.0·10\(^{-6}\) |

CO and CH content in the exhaust gases of the engine with pressurization has been not more than 1.5 % and 300 million\(^{-1}\) accordingly. It is below standard values of CO and CH concentration. So, according to State Standard R 52033-2003 for cars of categories M\(_1\) and N\(_1\), not equipped with neutralizer, the volume fraction CO should not exceed 3.5 % (the idling, the lowered turns of the engine) and 2 % (the idling, the raised turns of the engine), CH volume fraction is 1200 million\(^{-1}\) and 600 million\(^{-1}\) accordingly.

By the results of gasoline octane numbers measurement it is established that registered by the indicator of OKTAN values ONR are identical ON, declared by the manufacturer. So, for example, the measured value of ONR gasoline AI-95 “G-DRIVE” has made 95.9 o.u., and AI-100 “G-DRIVE” - 100.0 o.u.

The comparison of the data (Table 4) it follows that in the fractional composition of gasoline AI-95 “G-DRIVE” and AI-100 “G-DRIVE” there are differences. So, 95% of gasoline AI-95 “G-DRIVE” evaporates at a temperature of 188\(^{\circ}\)C, AI-100 “G-DRIVE” - at 193\(^{\circ}\)C. In the data presented in table. 4 there are the same temperature values, for example, 80% of the fuel, regardless of its brand, evaporates when 144\(^{\circ}\)C. Despite the observed variation in the acceleration temperature, and hence the volume fraction of evaporated gasoline, the experimental values of the V\(_{ob}\) correspond to the normative indicators (Table 5). It should be considered unlikely that the observed differences in the experimental values of the fractional composition (Table 5) significantly affected the toxicity of the engine, i.e. the increase in the content of CH when the engine is running on gasoline AI-100 “G-DRIVE” (Table 3). Most likely, when using high-octane fuel for this particular power unit (with a compression ratio of 9), it is necessary to adjust the engine settings.

**Table 4.** Fractional composition of fuel

| AI-95 “G-DRIVE” | The temperature of the distillation fuel, \(^{\circ}\)C | The temperature of the distillation fuel, \(^{\circ}\)C | Volume fraction of vaporized gasoline, % |
|------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| 47               | 56                                           | 68                                           | 80                                           | 98                                           | 114                                          | 127                                          | 144                                          | 173                                          | 188                                          |
| 10               | 20                                           | 30                                           | 40                                           | 50                                           | 60                                           | 70                                           | 80                                           | 90                                           | 95                                           |
| AI-100 “G-DRIVE” | 51                                           | 60                                           | 72                                           | 82                                           | 97                                           | 113                                          | 127                                          | 144                                          | 169                                          | 193                                          |
| 10               | 20                                           | 30                                           | 40                                           | 50                                           | 60                                           | 70                                           | 80                                           | 90                                           | 95                                           |
Table 5. Values of volume fraction of evaporated gasoline (Vobs), the temperature of the end boiling point (tpe), the residue in the flask (vox inclusion volume fraction) under the specification (NZ), on passport on gasoline (actual value-FZ) and experimental values (EZ).

| Indicator | AI-95 “G-DRIVE” | AI-100 “G-DRIVE” |
|-----------|------------------|------------------|
| Vobs by 70°C in % | NZ | FZ | EZ | NZ | FZ | EZ |
| 15-50 | 33.0 | 34.0 | 15-50 | 24.5 | 26.0 |
| Vobs by 100°C in % | 40-70 | 51.0 | 54.0 | 40-70 | 46.7 | 52.0 |
| 150°C in % | tpe, °C | 75 | 84.0 | 82.0 | 75 | 84.4 | 83.0 |
| vox, % max | 215 | 199.0 | 205 | 210 | 204.8 | 209.0 |
| Vobs by 70°C in % | 2 | 1.0 | 1.1 | 2 | 1.0 | 1.1 |

4. Conclusion

Thus, the compressor established on the engine has allowed not only to restore the power lost as a result of long operation and a motor torque, but also to increase them. It is shown that the volume fraction of carbon monoxide and products of incomplete combustion of hydrocarbons in the exhaust gases does not exceed standard values CO and CH. The increase in the content of SN when the engine is running on AI-100 “G-DRIVE” gasoline is not associated with the characteristics of the fractional composition of the fuel. The differences in fractional composition observed in experimental values are not significant in order to influence the engine’s toxicity.

In a certain interval of crankshaft rotational speed, the power parameter changes in waves. It is because of the velocity and air pressure pulsation in the intake manifold. Similar fluctuations in speed and air pressure in the engine manifold after its tuning, changes in the geometry are less expressed.

The sharp increase in power and torque observed at a supercharged engine at a crankshaft rotation speed above 3700 ob-min⁻¹ is not a positive moment of the tuning performed, because the course of dependences N and M on n of the power unit with supercharging and without supercharging for commercially produced vehicles is identical. It should be expected that the overheating of the cylinder, valves, piston, high gas pressure which is characteristic of forced engines under the conditions of the above-mentioned sharp increase in power and torque characteristic for accelerated engines will manifest itself in the further operation of the power unit.

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