

Determination of measurement errors when testing YAMZ engines

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Abstract. Internal combustion engine testing after repair work is a modern and up-to-date type of repair quality analysis. Normalization of measurement errors of controlled quantities plays an important role in the process of testing and checking engine parameters. The article defines the measurement errors of a number of values controlled during the testing of YAMZ diesel engines, which allow you to select the appropriate control and measuring devices. Formulas and equations used to process the data obtained during the tests are also considered. The list of controlled parameters has been updated based on the current standards.

1 Introduction

Active development of modern agricultural technologies is impossible without engineering. High-performance and economical types of various machines are being created [1], their durability is increasing [2, 3] and methods of fault diagnosis are being formed [4].

Evaluation of the quality of processes of agricultural machinery maintenance enterprises currently requires more and more attention from the point of view of reducing defects [5, 6] and increasing the satisfaction of the consumer – producer of agricultural products. It is necessary to significantly improve the quality of work and reduce consumer risks when operating machines [7].

Metrological support is a system of measures to create organizational and scientific foundations, instruments, standards necessary for the unification of calculations and their accuracy based on technical and economic indicators that determine production efficiency and product quality [8, 9].

When repairing machines, the processes of detecting and controlling defects are important management factors [10]. Measurement errors of a number of parameters during engine repair are indirect values, it is rather difficult to evaluate them [11].

The purpose of this work is to study the metrological support of acceptance tests of engines during repair.

The subject of the study is the unification of theoretical and practical elements in the field of metrological maintenance of running in and testing of repaired internal combustion engines.

The following tasks were set and completed:

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- Methods of selection of measuring instruments are considered.
- The basics of metrological support of engine testing are considered.
- The existing methods of selection of control and measuring devices for testing engines are analyzed.

2 Methodology of analysis of metrological support of tests

After the repair work of the internal combustion engine, acceptance control tests and checks are mandatory to maintain the proper quality of the product.

Control analyses are carried out according to the following indicators:

- Maximum and minimum stable idle speed;
- Oil pressure in the main oil line;
- Power and fuel consumption at the rated speed and position of the regulator regulators corresponding to the full fuel supply.

Diesel is tested without a fan (air-cooled diesels are tested with fans), an air cleaner for noise mufflers, a spark suppressor, an exhaust pipe, with the generator, hydraulic pump and compressor disconnected.

When installing diesel engines on test benches, it is necessary to make sure that the connections of exhaust gas removal, cooling, lubrication and power supply devices, as well as measuring instruments, do not have sharp bends and constrictions that can lead to changes in power and fuel consumption. It is also necessary to check the correct adjustment of the gaps between the rocker arms and the ends of the valve rods of the valve timing mechanism, as well as the angles of the beginning of the fuel supply.

The tests are carried out on M-10 G₂ or M-10 B₂ engine oil and diesel fuel "L" (GOST 305-82) in the following sequence: warm up the diesel to a normal thermal state; measure the maximum idle speed; determine power and fuel consumption; measure oil pressure at the rated engine crankshaft speed.

The thermal regime of diesel engines during testing is controlled by changes in the temperature of the coolant at the outlet of the diesel engine and the oil temperature in the pan. The temperature must be maintained within 90 ± 5 °C, except in cases specifically specified in the regulatory and technical documentation.

In addition, during the test, the oil pressure in the pipeline, atmospheric pressure, temperature and humidity of the ambient air in the test stand room are measured. The ambient air temperature is determined in the intake air flow before entering the diesel air intake at a distance of no more than 0.15 m from the entrance.

The measurement of the controlled parameters begins after the diesel engine has reached the set thermal mode and has been working steadily on it for at least 5 minutes. The measurement is carried out at least twice and is taken as the true average value.

The maximum speed of the crankshaft at idle is determined in the following order: on a diesel engine running without load, the fuel supply control lever moves smoothly to the position corresponding to full feed, and then the speed is measured.

The diesel power is determined by gradually increasing the load until the rotational speed reaches the nominal value.

Fuel consumption begins to be measured after the diesel engine has been running in this mode for at least 5 minutes, and the temperature of the oil and coolant reaches the required values.

The values of torque and oil pressure in the lubrication system are recorded in accordance with the indicators of the weighing mechanism of the stand. The duration of the fuel consumption measurement to improve the measurement accuracy should be at least 60 seconds.

The test results are recorded in a special log, and then the data is processed. The measurement results are processed using the following equations.

The effective power, kW, is determined by the expression [12]:

$$N_e = 9550^{-1} M_k n, \quad (1)$$

where M_k – is the torque, N · m; n – is the rotational speed, min⁻¹.

Fuel consumption, kg/h, is determined by the formula [12]:

$$G_t = 3.6 Q_t t^{-1}, \quad (2)$$

where Q_t – is the mass of fuel consumed by the diesel engine during measurement, h; t – is the duration of the experiment, s.

The specific fuel consumption, g/(kWh), is determined by the dependence [12]:

$$g_e = 1000 G_t N_e^{-1}, \quad (3)$$

where G_t – is fuel consumption, kg/h; N_e – is the effective power, kW.

3 Results of measurement of controlled quantities and their errors during testing of YAMZ engines

The stand and the room intended for testing must be equipped with equipment and devices that allow measuring the controlled parameters with the accuracy specified in Table 1 [12].

Table 1. Controlled values and permissible errors of their measurements.

| Controlled value | Unit of measurement | Parameter designation | Error of the measuring device, no more than |
|---|---------------------|------------------------|---|
| Torque | N · m | M_k | $\pm 0.005 M_k \max$ |
| Rotation frequency | min ⁻¹ | n | $\pm 0.005 n_{\text{nom}}$ |
| Fuel consumption | kg/h | G_t | $\pm 0.005 G_t \text{nom}$ |
| Atmospheric pressure | kPa | P_{env} | ± 0.1 |
| Boost pressure | MPa | P_b | ± 0.0005 |
| Oil pressure in the pipeline | MPa | P_o | ± 0.02 |
| The temperature of the coolant at the outlet of the diesel engine | °C | t_c | ± 3 |
| Oil temperature in the pan or at the outlet of the diesel engine | °C | t_o | ± 3 |
| Crankcase gas pressure | kPa | P_{cg} | ± 0.1 |
| Ambient air temperature | °C | t_{env} | ± 1 |
| Exhaust gas temperature in the exhaust manifold | °C | t_g | ± 10 |
| Fuel temperature at the entrance to the coarse fuel filter | °C | t_f | ± 1 |
| Oil consumption for waste (for 10 hours) | kg | G_m | ± 0.005 |
| Relative humidity of the air | % | φ_{env} | ± 0.3 |
| Duration of operation of the diesel engine | s, min, h | τ | $\pm 0.01 \tau$ |

Next, we calculate the errors of the following values: effective power (N_e); hourly fuel consumption (G_t) and specific fuel consumption (g_e).

Table 2. Values of measurement errors when testing YAMZ engines.

| Controlled value | Unit of measurement | Parameter designation | Value | Error of the measuring device, no more than |
|-----------------------------|---------------------|-----------------------|-------------------|---|
| YAMZ 240 | | | | |
| Torque when measuring power | N · m | M_k | 1130 | 5.65 |
| Rotation frequency | min ⁻¹ | n | 1900 | 9.5 |
| Fuel consumption | kg/h | G_t | 55 | 0.275 |
| Effective power | kW | N_e | 221 ⁺⁷ | 1.6 |
| YAMZ 238 | | | | |
| Torque when measuring power | N · m | M_k | 728 | 3.64 |
| Rotation frequency | min ⁻¹ | n | 2100 | 10.5 |
| Fuel consumption | kg/h | G_t | 41.5 | 0.208 |
| Effective power | kW | N_e | 157 ⁺³ | 1.1 |
| YAMZ 236M2 | | | | |
| Torque when measuring power | N · m | M_k | 596 | 2.98 |
| Rotation frequency | min ⁻¹ | n | 2100 | 10.5 |
| Fuel consumption | kg/h | G_t | 31 | 0.155 |
| Effective power | kW | N_e | 127 ⁺⁴ | 0.99 |

Thus, it can be seen from the data in Table 2 that the lower the engine power value, the more accurate measuring instruments are required to reliably determine its value. Considering that the power of the engines is the result of indirect measurement, i.e. it is formed by multiplying the torque by the rotational speed, such requirements should be imposed on devices for measuring these parameters.

4 Conclusions

In this paper, the main controlled values and parameters of several types of internal combustion engines that change during repair work are presented and considered, permissible measurement errors and indicators that allow selecting appropriate control and measuring devices are determined. Formulas and equations used to process the data obtained during the tests are also considered. The list of controlled parameters has been clarified on the basis of current standards.

When calculating and analyzing the metrological support of the tests, measurement errors were indicated for such parameters as engine torque, crankshaft speed, fuel consumption, atmospheric air temperature in the intake tract, coolant temperature, oil temperature, fuel temperature and others.

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