The Problem of Choice Between Measurement Techniques

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Abstract. The assessment of the current conditions of any technical object is based on measurement. Thus, choosing the qualitative descriptor of the object that is to be assessed represents a relatively complex task. This is related both to the informative value of the qualitative descriptor and to the need for applying one or another measurement technique. There are three different ways to deal with the designated task. One possibility is to fix the required level of informative value and choose the measurement technique based on criteria such as the least money expenses for measuring, the shortest measurement duration and the specialization level of the measurement instruments. The second option is to choose specific measurement techniques and obtain the most complete information possible. The third possibility consists in a compromise between the information content of the descriptor and the overall expenses for measurement techniques. By convention, the first option is applied while facing this task, in which the information on the technical conditions of the object is obtained choosing adequate measurement techniques. Determining the value of the structural parameter of the technical conditions is not always possible. The diagnostic parameter, in its turn, is determined by the structural parameters only at a certain level of probability. The producers of machinery are constantly improving their products, upgrading the design of mating parts, changing the properties of wearing surfaces and introducing new materials. As a result, the aforementioned interrelations between the structural and diagnostic parameters are significantly redetermined, whereas the previously engineered diagnostic devices and the implemented methods lead to the ambiguity of the diagnostics. The areas of such ambiguity are here taken into account using a compression vacuum method in order to determine the technical conditions of the sleeve assembly of an internal combustion engine.

1. Introduction

The requirements for internal combustion engines have been constantly changing along with their historical development. Car manufacturers typically advertise high power per litre, high torques, low fuel consumption and compliance with the latest emission standards. However, for car engine operators, reliability and durability have always played the most important role.

As a result of the energy crisis of the 1970s, in research and development works special attention began to be paid to the issue of efficiency, i.e. to a reduction in fuel consumption. In the production of cars, fuel injection systems have been serially introduced. This gave the opportunity to reduce fuel consumption while increasing the engine power.

In the 1980s, environmental aspects were out front in engine development. Due to the environmental requirements in the field of internal combustion engines, the most significant changes
have since then been taking place as regards the mix preparation and exhaust gas treatment systems. If previously the mixing in diesel engines was mainly carried out by indirect injection using mechanical high-pressure fuel pumps, nowadays engines with high-pressure direct injection with electronic control and turbocharging are used.

Taking into account these as well as other requirements, the internal parts of engines have undergone constant improvement and modification. The production processes in engine manufacturing have been optimized, the production levels of tolerance and weight of specific components have been reduced, while the quality of the materials has been increased. The shape of the combustion chambers and the gas paths has been optimized in order to reduce the fuel consumption and exhaust gas emission. Despite these significant design changes on the surface of the engine and inside of it, there have been no significant changes in the descriptor of piston and cylinder damage. As before, the main causes of engine defects are reduced to malfunctions and disturbances due to thermal or mechanical overload. As a result, engine parts are damaged under particularly high loads, especially on the pistons.

2. Results and methods

As in medicine, the assessment of the engine damage requires a holistic approach in order to identify a cause (or causes), which is not always unequivocal. Quite often, after engine repair, damage and failures appear again because, after replacing defective parts, the causes of deterioration itself have not been eliminated. Therefore, when a defect is found, it is necessary to identify its causes on reasonable grounds. When eliminating the consequences of failures, the repair technician is often presented with only the defective part, without additional information about the service life or the extent of the damage. In this case, however, the diagnostics can only be general and not specific to the given damage [1].

The paper marked as [2] presents an original conception of the quality perception process, according to which some guidelines for improving the process needed for diagnosing specific technical objects can be determined.

![Quality perception process](image)
In this regard, the methods and means of technical diagnostics are of particular importance, since they provide a means for determining the technical conditions of a unit or assembly on a differentiated basis, taking into account potentially important information which might be sieved away.

With this in mind, the concept of the complete diagnostic model proposed by Voronin V.V. should be applied [3-6]. An important part of the model is represented by the information about the structure of the object undergoing diagnostics. Let us consider the structure of a technical product undergoing diagnostics by using a diesel internal combustion engine as an example.

![Flow chart of an internal combustion engine](image)

**Figure 2.** Flow chart of an internal combustion engine.

In the structure of the internal combustion engine, several kinematic circuits can be distinguished, connected in parallel and in series, which link the engine mechanisms. At the same time, both kinematic chains and their components have a different degree of potential information content when assessing the values of the parameters that characterize them. The procedure for determining the information capacity of the diagnostic tests becomes possible:

\[
I_0 = \sum (I_i^i + I_j^{d1} + I_k^{d2})
\]  

(1)

where \(I_0\) is the information capacity of any specific diagnostic test;  
\(I_i^i\) is the information capacity of the assessment of any structural parameter;  
\(I_j^{d1}, I_k^{d2}\) represent the information capacity of the assessment of the diagnostic parameters of the first and second levels, respectively.

Reliable conclusions can be drawn from the received volume of diagnostic information, provided that it corresponds to the volume of knowledge about the possible defects:

\[
\sum D_i \equiv \sum I_{0n}
\]  

(2)

Defects are generally interlinked; moreover, the structure of such links reflects the structure of the object undergoing diagnostics. The set of the conditions, diagnostic tests and output signals can be mathematically described by the following relationship:

\[
\sum C \supset \sum D \supset \sum S
\]  

(3)

The set of the diagnostic signals \(S\) contains elements of the diagnostically significant information \(D_i\), on the basis of which the set of the conditions \(C\), which characterizes the object undergoing diagnostics, can be determined.
Thus, it is necessary to use the potential information capacity of the set of the diagnostic signals \( \Sigma S \), which is methodologically identical to an increase in the bandwidth of the pragmatic filter (see Fig. 1).

Methods that implement such an approach can be identified in the compression vacuum method (CVM) for the diagnostics of the sleeve assembly of autotractor internal combustion engines [7] and other related methods. The essence of a differential method based on the example of the CVM consists in the identification of a malfunction (its cause) with high reliability; this allows to determine the type and amount of maintenance and technological activity, starting from simple adjustments (including the in-place reparation of friction pairs based on the latest nanotechnologies), minor repair and other works regarding ordinary maintenance, overhaul and recovery [8].

In order to determine a malfunction occurring in the engine cylinders, the following table on the combination of malfunctions in diesel engines with direct fuel injection can be used [9–10] (Table 1):

| Malfunction No. | \( P_1 \) | \( P_2 \), kg/cm\(^2\) | \( P_k \), kg/cm\(^2\) | \( P_k \), kg/cm\(^2\) |
|-----------------|----------|----------------|----------------|----------------|
| 0.9…0.94       | P\(_k\), kg/cm\(^2\) | 0.14…0.17 | 28…32 | 0 |
| 0.8…0.94       | P\(_k\), kg/cm\(^2\) | 0.2…0.25 | 0.26…0.3 | 0…0.12 | 0.3…0.45 | 0.5…0.7 |
| 0.72…0.8       | P\(_k\), kg/cm\(^2\) | 24…30 | 20…26 | 26…32 | 20…27 | 16…22 |
| 0.4…0.65       | P\(_k\), kg/cm\(^2\) | 0.1…0.25 | 0.3…0.45 | 0.5…0.7 | 0.1…0.2 |
| 0.35…0.6       | P\(_k\), kg/cm\(^2\) | 18…24 | 15…20 | 5…12 | 22…30 |
| 0.26…0.36      | P\(_k\), kg/cm\(^2\) | 0.28…0.36 | 0.3…0.45 | 0.5…0.7 | 0.1…0.2 |
| 0.0…0.35       | P\(_k\), kg/cm\(^2\) | 0.1…0.25 | 0.3…0.45 | 0.5…0.7 | 0.1…0.2 |
| P\(_k\), kg/cm\(^2\) | 10 | 11 | 12 |

Where: \( P_1 \) – full vacuum; \( P_2 \) – remaining vacuum; \( P_k \) – compression.

Detailed explanation of the malfunction codes:

- 0 – nominal conditions of the sleeve assembly;
- 1 – current wear conditions;
- 2 – wear limit of the compression rings;
- 3 – coking, breakage of the oil scraping rings;
- 4 – wear of the piston grooves;
- 5 – coking of the compression rings;
- 6 – breakage of the compression rings;
- 7 – severe wear (skellering) of the cylinder liner;
- 8 – wear of the liners along with coking of the piston rings;
- 9 – failure in the phase of the emission valve tending to advanced opening;
- 10 – failure in the tightness of the valve-seat junction due to mechanical damage or absence of the expansion gap;
- 11 – piston burnout;
- 12 – breakage of the valve springs of the induction or emission valves.
Based on statistical information obtained over 10 years of observation on 1,083 vehicles, we considered the appearance of ambiguity areas should be taken into account when using the compression vacuum method, while additional corrections and the application of auxiliary methods are needed in order to reduce such ambiguity areas and increase the accuracy of the diagnostics.

The cylinders of the engines of the vehicles have been assessed (examples are presented below):

1. Mitsubishi Fuso Canter truck: 1 cylinder – ambiguity area; 2 cylinder – breakage of the compression rings; 3 cylinder – ambiguity area; 4 cylinder – ambiguity area.

2. Mercedes Benz truck: 1 cylinder – ambiguity area; 2 cylinder – ambiguity area; 3 cylinder – severe wear (skellering) of the cylinder liner; 4 cylinder – ambiguity area; 5 cylinder – ambiguity area; 6 cylinder – ambiguity area.

3. UAZ 469B off roader: 1 cylinder – current wear conditions; 2 cylinder – current wear conditions; 3 cylinder – current wear conditions; 4 cylinder – current wear conditions.

4. PAZ–4203 ‘Aurora’ bus: 1 cylinder – breakage of the compression rings; 2 cylinder – wear of the piston grooves, coking; 3 cylinder – wear of the piston grooves, coking of the compression rings; 4 cylinder – breakage of the compression rings.

The results of the study show that the compression vacuum method requires: firstly, the introduction of new differential algorithms for finding and identifying the malfunctions based on software and new IT solutions, taking into account the influence of additional external and internal factors; secondly, the expansion of the diagnostic information field by attracting accompanying diagnostic methods such as organoleptic and indicator methods, which allow for a further increase in the level of reliability of this diagnostic method.

3. Conclusion
The assessment of the conditions of technical objects significantly depends on the applied methods and measurement techniques. However, along with unambiguous assessments, uncertain results can be obtained as well. This situation is typical when determining the values of diagnostic parameters, since the measurement of the value of a structural parameter is not always possible. In order to achieve the goals of diagnostics, while taking into account the process of quality perception by the subjects performing the diagnostics and their knowledge of the structural features of the object undergoing it, the application of a differential diagnostic method is necessary. The measurement of the values of diagnostic parameters in their optimal combination allows achieving significant results from a practical point of view.

4. References
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