Improving the processing accuracy of the valve seats of internal combustion engines using diagnostic measurements

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Abstract. Currently, the main tool of quality management at the enterprises of various industries are statistical methods of quality management. In the literature, mostly on examples of the successful application of control charts for dimensions. More sophisticated measures of quality details not given. The article illustrates a practical application of control charts applied to technologically sophisticated measure of the accuracy of the key indicator affecting the operation of the engine - radial runout of valve seat cylinder head. Data of measurements made in accordance with the standard metrological definitions are processed in the software product "Attestator". As a result, identify the potential percentage of possible marriage, revealed the existence of special reasons to change the values of individual indicators, the index of reproducibility and stability of the process, the decision about the certification process, but the factors of the process that need to be addressed to improve the quality of the products is not revealed. A universal methodology consisting of four steps, the implementation of which allows to develop such a scheme of measurement, which significantly improves the search performance of important technological factors. For example, the same technological operations and the accuracy rate shows the application of the methods. The result of the survey revealed two main factors of the process is bending of the boring bar and the error of the satellite-based suppression will significantly improve the quality of manufacturing of parts.

Keywords: improving the quality, accuracy, processing, automotive components, diagnostic components

1. Introduction

Enterprise for the production of components should follow the requirements of standard IATF 16949:2016. According to his requirements the organization shall:

– To monitor and measure product characteristics to verify and compliance with production requirements.
– To determine the process of continuous improvement.
– To take corrective action to eliminate causes of nonconformities to prevent their repeated occurrence.

The technological operations most often for this purpose apply statistical methods of quality management. The main tool is the control chart.

Under statistical control technologist puts the key (most important) quality characteristics. The management plan includes the scope and frequency of taking the sample. Examples of the application of quality management techniques described in the literature, as a rule, do not provide additional identification of the factors of the process [1-7]. Information about the efficient use of control charts for structurally complex in terms of accuracy is almost not given. In the works dedicated to the
detection equipment includes elements of identification of the factors of the process, but in turn poorly applied statistical methods of quality control [8-10].

2. Problem definition

Consider how effective the use of control charts as a separate management tool on the example of processing of the important parts of a car engine – head-cylinder. The key characteristics of items affecting the operation of the parts – the value of total radial runout of valve seats. Beating breaks the air tightness of the combustion chamber, reducing engine power. This indicator is formed in a continuous automatic line for boring operations. Runout measurement was performed by special measuring device, equipped with a dial indicator type, according to their metrological determination (the difference between the largest and smallest distances from all points of the real surface within the regulated area to the base axis). The measurements were performed according to the requirements of the current management plan, with the registration of the full magnitude of the radial runout every 15 min.

The measurement data were processed by the software product "Attestator" [11]. First, the constructed histogram and curve of the normal distribution (Fig. 1 a). The main parameters of a distribution the standard distribution and the mean value of the heartbeat, as well as indices of stability and reproducibility of the process. In the histogram the presence of two indicators, the limits of tolerance of the accuracy rate. Indexes of reproducibility have unsatisfactory values of RR=0.84 RRB=0.82. The potential number of nonconforming parts is 1.3%. This may not be certificated (tabl. 1).

Further analysis of Stewhart charts (Fig. 1 b) confirmed the conclusions of the statistical analysis and further gave the following results: unusual change in the sequence of points C1, C6, C7, C9, C10, indicating the presence of special causes in the process of boring seats.
b) Figure 1. Results for data processing in accordance with the requirements of the standards [1, 2]:

a) the histogram curve normal distribution, process indicators, b) the control chart of ranges and average values of the runout of the valve seat in) table of certification process. Setting the runout of the valve seat \( P_p, P_{pk} = 0.84, 0.81 \)

Table 1. Process certification

| #  | Characteristic               | Condition | The actual value | Execution |
|----|------------------------------|-----------|------------------|-----------|
| 1  | The runout of the valve seat | \( P_p \geq 1.33 \) | 0.835            | Not       |
| 2  | The runout of the valve seat | \( P_p \geq 1.33 \) | 0.835            | Not       |
| 3  | The runout of the valve seat | \( C_p \geq 1.33 \) | 2.417            | Yes       |
| 4  | The runout of the valve seat | \( C_{pk} \geq 1.33 \) | 2.35             | Yes       |
| 5  | The runout of the valve seat | Stability on X and R chart | X:points outside of the control of borders and a series; R series | Not       |

Thus the analysis only established only the presence of special causes process instability, but the specific causes of instability and special reasons can not be identified. To find them you need to perform additional research – such as disassembly of the individual modules with the assessment of wear and tear, or the performance of coordinate measuring machined features of a part. Beating is technologically complex figure. Affect the level, to reduce its size and to provide stability through a single characteristic is impossible. When there is insufficient training of engineers and workshop staff are the reason of instability could be found. The risk of issue of marriage will continue.

3. Theory
Let's consider what information the measurements should give to immediately reveal the limiting factors that act in the process of forming the indicator without carrying out additional engineering studies. At the first stage, we establish the structure and functions of the modules of the technological system in the process of forming the indicator, and form the list of key control characteristics. At the second stage, we determine the technological structure of the measured quality index and the response plans (corrections) for controlling the value of the significant technological components of the deviation. At the third stage, a measurement scheme is developed, which, based on the results of the measurement of the indicator, allows us to isolate as far as possible all the important key structural components. In the fourth stage, the diagnostic data of the key control characteristics are preliminarily registered, the absolute and relative values of the significant components of the quality index are modeled in the beat measurement field.

Processing of saddles is carried out on a two-spindle boring position using a special combined tool. First, the guide hole of the bushing is unfolded by machine scanning, and then, based on the shank of the sweep, the boring bar moves, chamfering the seat of the valve seat. Analysis of the scheme of processing allowed to identify the process factors and technological components, given in Table 2.

Table 2. The process factors affecting the value of the technological components of the total radial runout

| Technological level | The technological components of the runout | Tolerance of the indicator | Factors of the process of boring valve seat |
|---------------------|-------------------------------------------|-----------------------------|---------------------------------------------|
| Rotation            | Undulation                                | Not regulated               | The uneven size of the allowance            |
| Cutting stroke      | Deviation of the profile of the valve seat adjacent the circumference | 0,005 mm                    | The bending axis of the tool Axial runout of spindle |
| Cutting pass        | The radial size of the surrounding circle | 25,25±0,25 mm               | The wear of the forming tool feature The error of basing the insert |
| Position            | The deviation of the axis of the valve seat from the axis of the guide hole | Not regulated               | Error insertion of the guide sleeve         |
| Production task     | The deviation of the axis of the valve seat from the axis of the guide hole | Not regulated               | Error-based satellite in the position processing Error insertion of the guide sleeve |

4. Experimental results

From here the measurement scheme was developed, which allows using standard measuring means, with the registration of the values of 4 technological components. For this purpose, the readings of the instrument needle in the coordinate system of the part were registered in four angular coordinates (Fig. 2).
The initial adjustment of the device to zero value is performed on the reference part, in which all technological deviations are minimized. Before measuring, the instrument is set to zero, then the whole batch of parts is measured with the setting saved (Table 3). The table shows the scale of the instrument.

Measurements of the details of the wire are strictly in the order of their manufacture with the registration of the adjustment moments for the size or tool change.

Table 3. Fragment of coordinate measurement protocol (μm)

| Measurement No | Angular phase, deg. |
|----------------|---------------------|
|                | 0       | 90      | 180     | 270     |
| 1              | -15     | -12     | -10     | -15     |
| 2              | -21     | -20     | -19     | -21     |
| 3              | -18     | -13     | -12     | -17     |
| 4              | 3       | 7       | 6       | 2       |
| 5              | -21     | -16     | -14     | -19     |
| 6              | -5      | 2       | 2       | -5      |
| 7              | 6       | 9       | 11      | 7       |
| 8              | -15     | -10     | -8      | -12     |
| 9              | -36     | -31     | -29     | -29     |
| 10             | -11     | -8      | -9      | -10     |

The largest values of the indices are shown in Fig. 3. As seen from the graph, the most significant is the change in the position of the valve seat axis from the boring bar (1) in the batch, then the deviation of the position of this axis from the axis of the base hole (2) for each individual operation, and finally the smallest deviation is the deviation from the roundness of the profile on the diametrical size of the measuring tip (3).
The coordinates of the valve seat axis are shown in the graph (Fig. 4, 5). Their position from detail to detail is in the first and third quarters of the graph. The reason for this may be the error of positioning the satellite holding and moving the part from one operation to another, together with the bending of the axis with the guide.
5. The discussion of the results

Technologists, and after them mathematicians, systematizing the errors that lead to deviations from the ideal values of the output produce a systematic and random among them. Systematic errors can be controlled, directly affect them, and random errors can not be eliminated, they are the consequence of the variability of the process itself. For example, a change in hardness in a batch of parts is considered random. But if we identify at least the coordinates of the distribution of parts inside the furnace for the tempering of the parts and associate it with the numbers of the measured parts, then in a random manifestation of the hardness value a regularity is revealed that depends on the propagation of the temperature isotherms inside the furnace chamber, which can already be controlled, for example. The same applies, for example, to the indicator - beating. If only its value is known, but not known, its structure, or processing conditions, then we can not interpret the data for effective control of the process. Once a single measuring coordinate system has been introduced, associated with the technological coordinate system, the structure of the indicator has been singled out, so it becomes possible to effectively identify the specific factors that operate in the process. In this case, the processing of measurement data immediately gives specific suggestions for improvement, bypassing the various kinds of engineering searches by personnel for jobs.

It is due to the increase in the degree of identification of the conditions for the performance of the process that the developed methodology and the completed measurement data proved to be more effective in finding the causes of deviations than standard statistical methods. The result of the application of the methodology is a sharp increase in management efficiency, especially indicators with a complex technological structure, as well as a reduction in the time for corrective and preventive actions.

6. Conclusion

Thus, based on the results of measurements, immediately follow the suggestions for improvement. As a result, management effectiveness has sharply increased, as well as the required time for planning and corrective actions. Effective use of control charts is possible only for the indicator with the simplest internal technological structure, or on condition that the embedded technological components of the indicator are negligible or only one known cause predominates.

In the case where the equipment is worn out and the structure of the technological indicator is developed, the direct application of control charts or other statistical methods for improving the quality of products is rendered ineffective.
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