Quality assurance of control at machine-building enterprises of repair profile

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Abstract. The quality of repair of the units is significantly influenced by many factors, and this is not only the wear and tear of the parts coming for repair, the low qualification of the personnel, the old technological equipment, but also the poorly functioning system for organizing metrological support for production, from where there is a significant impact of the error of the measurement tools used on the conclusion of the validity of the parts. It is proposed to select control means not only according to the requirements of regulatory documentation, but also taking into account the impact of losses from measurement error. Dependence is given to estimate the economic effect of the replaced measuring instruments by more accurate ones. Using the example of crankshaft neck control under repair production conditions, it is shown that the use of universal measuring instruments with a lower error significantly reduces the level of losses from incorrect rejection and acceptance of critical parts. Features of incoming control of spare parts are disclosed and the feasibility of using only original parts of the manufacturer is justified.

1. Introduction
The repaired equipment has a low level of reliability, and one of the reasons is the lack of competent metrological support and poor quality of control operations at machine-building enterprises of the repair profile [1].

A feature of repair production is the problem of controlling the already worn-out dimensions of parts and the absence in some cases of the conditions for basing these parts, which were used earlier in their manufacture. During operation, there is a measurement of gaps and tightness in critical junctions of units and aggregates according to certain failure models [2, 3]. Most of the connections that come together with the unit for repair do not yet reach the limit state, have a margin for wear, are operational, but no longer meet the quality indicators of new ones. In some cases, unit failures occur due to oil leaks from the crankcases due to poor quality of the sealing units [4], then the consequences for a number of loaded connections can be significant and require replacement of almost all critical parts of the unit. In the technical requirements for repairs, technologies for assigning extended tolerances are used, which is why incomplete interchangeability methods are used in repair production – group Assembly, when it is possible to reduce the size tolerance by dividing it into groups [5], as well as selection and fitting.
Landings installed by the manufacturer’s design office are usually highly accurate [6] and cannot be provided during repairs, except in cases where new parts are used for Assembly into joints.

The quality of repair of aggregates is significantly affected by many factors, such as not only the wear and tear of parts coming in for repair, low qualification of personnel, old technological equipment [7], but also a poorly functioning system for organizing metrological support for production [8], which has a significant impact on the conclusion about the validity of parts of the error of the measuring instruments used [9].

2. Theoretical bases

When using a modern measurement management system, the quality of repairs will significantly improve due to the use of well-founded measurement tools in critical control operations. Technical and regulatory documents for metrological support of unit repairs should be formed in the form of requirements that are aimed at ensuring the uniformity of measurements and the required accuracy. The accuracy of measuring instruments should be assigned not only according to regulatory criteria, but also taking into account technical and economic calculations. This will reduce the cost of quality assurance, mainly in such categories as losses from internal marriage, external marriage, and there will be a change in the cost of control [10].

Modern metrological support for mechanical production is a quality control management system that includes standards for ensuring the uniformity of measurements at the enterprise, control at specified points, selection of measuring instruments based on cost and loss optimization models [11], and timely calibration of measuring instruments [12]. The system of metrological support should fit into the quality management system of the enterprise, built according to the model described in ISO 9001 [13,14].

Economic losses are formed from the implementation of control, but the losses in the absence of control are always much greater. For the manufacturer, this is a loss of customer and profit, and for the consumer—an extra waste of time and money. Comparison of measuring instruments for modern production conditions should be based on the price-quality ratio. you need to choose measuring instruments from a given range, where price is no longer the main factor. More important are the measurement costs, such as the controller's salary, energy, materials, calibration, and so on. The quality of measuring instruments is expressed in the form of its accuracy, or its inverse value—the measurement error, which affects the number of incorrectly accepted and incorrectly rejected products, which in turn leads to the formation of economic losses due to illiterate metrological support of production.

The economic effect of replacing the used measuring instruments with new ones is formed by reducing the current costs of their operation as a result of improving the quality characteristics (accuracy, reliability, speed, performance, energy consumption, etc.). as a basic option for comparison in this case, you should take similar characteristics of the replaced measuring instruments.

The economic effect is calculated using the formula

\[ E^G = C_{G2}^G \frac{V_{11}}{V_{12}} - C_{G2}^G = \left[ \left( C_{G1}^G + I_{Il1}^G \right) \frac{V_{12}}{V_{11}} - \left( C_{G1}^G + L_{Il2}^G \right) \right] - E_H \cdot K, \]  

(1)

where: \( C_{G1}^G, C_{G2}^G \) – the given costs based on the annual volume of control performed when using the basic and new measuring instruments, rub/rod; \( V_{11}, V_{12} \) – annual volumes of the control unit/year; \( C_{G1}, C_{G2} \) – cost of annual control volume, rub/year; \( L_i, L_2 \) – annual losses from measurement and control errors when using the basic and new measuring instruments, rub/year; \( K \) – additional capital investment for the purchase of measuring instruments, rub; \( E_H \) – standard coefficient of efficiency of capital investments.

The given costs based on the annual volume of control are determined by the formula

\[ C_{G2} = C_L + C_{TO} + C_{TP} + C_E + C_{SC} + C_A, \]  

(2)

where: \( C_L \) – costs for verification of measuring instruments; \( C_{TO} \) – the cost of maintenance of measuring instruments; \( C_{TP} \) – the cost of repair of means of measurement; \( C_E \) – energy costs for
measuring instruments and materials consumed during the monitoring process; $C_{SC}$ – salary costs for operators; $C_A$ – depreciation charges.

The objects of control of the repair enterprise include: the repair fund in the form of machines and their components, which were received for repair; repair materials and spare parts of all possible items received from factories or warehouses; units of various machine systems, new and repaired in special conditions; parts or simple assembly units, new or restored in specialized workshops; tools.

For materials and products that are not included in the approved list, but require control, it is rational to use common approaches to incoming control operations, taking into account the probability of fault detection.

3. Study results and analysis

More accurate measurement tools have greater efficiency due to a significant reduction in losses from the presence of measurement error, and their cost included in control costs is small and not comparable to the amount of loss.

Let us consider an example of the analysis of metrological quality assurance of engine crankshaft control of the Yaroslavl Engine Plant. In repair production, due to the small amount of work, universal measuring tools are used. For the control of crankshafts – this is a fairly wide nomenclature of measuring instruments, table 1. The micrometer is MK-100 specified in the overhaul specification as the recommended measuring instrument. The remaining measuring instruments were chosen as far as possible for crankshaft control - hand operation and versatility of the measuring instrument.

| Name device              | Convention | Price divisions, mm | Range dimensions, mm | Error, mkm |
|--------------------------|------------|---------------------|----------------------|------------|
| Micrometer               | MK-100     | 0.01                | 75-100               | ±15        |
| Lever micrometer         | MP-100-0.002 | 0.002             | 75-100               | ±7.5       |
| Indicator brace          | CI-100-0.01 | 0.01               | 50-100               | ±20        |
| Indicator brace          | CI-100-0.002 | 0.002             | 50-100               | ±6.5       |
| Micrometer with digital  | MKC-100-0.001 | 0.001           | 75-100               | ±3         |
| indicator                |            |                     |                      |            |
| Lever bracket            | CP-100-0.002 | 0.002             | 75-100               | ±2         |

Total annual costs were determined when monitoring the dimensions of the crankshaft necks for the repair program of 1000 engines per year. The results of the studies are presented in figure 1.

![Figure 1](image_url)

**Figure 1.** Costs, losses and total costs for measuring instruments when controlling the dimensions of the crankshaft crankshaft of the Yaroslavl Engine Plant.
It can be seen from the figure that the more precise the measuring tool, the less loss from incorrect rejection and incorrect acceptance of parts. The total annual costs are less for those measuring instruments whose accuracy is higher. The total annual costs represent the overall economic feasibility of using a specific measuring instrument for a monitoring object such as a crankshaft. It is advisable to carry out a feasibility study on the selection of measuring instruments for each important and expensive object of control.

4. Practical issues of input control quality assurance

At machine-building repair enterprises, in contrast to machine-building enterprises, measuring instruments are not subject to mandatory verification, and in the best case, they are calibrated. This feature makes a significant contribution to the formation of future losses of repair companies, since with an increase in the actual measurement error associated with wear and tear of the measuring instrument, it is possible to increase the number of incorrectly accepted and incorrectly rejected control objects, as well as unfounded claims to suppliers of spare parts and components.

Another feature of the work of any repair company is the fact that services, including car repairs, are not subject to mandatory conformity assessment (certification). A machine – building company is required to certify its products for safety and environmental performance, while a repair company is not. This makes it possible to use non-original parts from other manufacturers, worn parts and materials that do not have a certificate of conformity as replacement spare parts. It should be borne in mind that non-original parts are usually made with a violation of manufacturing technology, there are usually deviations in processing accuracy, strength characteristics, surface hardness parameters, shape deviations and surface roughness, and a number of other normalized parameters that are set in the technical documentation. When using such products, at best, there will be a decrease in durability and early failure, at worst, the consequences may lead to an accident, the victim will go to court and legal costs will begin. That is why competent organization of entrance control is so important for repair companies. There is a question about the feasibility of purchasing a variety of measuring instruments to control the above parameters, as well as the possibility of returning non-conforming parts to gray suppliers. Therefore, it is much more economical to use original products as spare parts, materials and components, and not to risk reliability, safety, legal claims and consumer dissatisfaction.

5. Conclusions

It is established that the quality of repair of units is significantly influenced by many factors, including a poorly functioning system for organizing metrological support for repair production. It is proposed to choose control tools not only according to the requirements of regulatory documentation, but also taking into account the impact of losses from measurement error. The dependence for assessing the economic effect of replacing the measuring instruments with a more accurate one is given. Using the example of control of crankshaft necks in the conditions of repair production, it is shown that the use of universal measuring instruments with a lower error significantly reduces the level of losses from incorrect rejection and acceptance of critical parts. The features of the input control of spare parts are revealed and the expediency of using only original parts of the manufacturer is justified.

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