Metrological support of cylinder liner inspection

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Abstract. On the example of the technological process of repairing cylinder liners, a method for assigning control points has been developed to assess the quality of the process by stages of its implementation. Methods and means of measurement have been selected for each control point.

Much attention is currently being paid to the quality of control processes and metrological support of production in mechanical engineering [1]. Increasing requirements for the reliability of units lead to stricter requirements in relation to the accuracy of machinery and equipment in order to ensure the durability of critical connections in movable landings [2,3] and in fixed mates of parts [4,5]. To improve the accuracy, methods of incomplete interchangeability are also used [5]. An increase in the accuracy of manufacturing and assembly of joints leads to the need to ensure the accuracy of the means and methods of their control [6,7]. Separately, we can single out the technologies for ensuring the accuracy of sealing devices during assembly [8, 9].

When organizing control, economic losses are formed associated with the costs of measurements and losses from the measurement error [10, 11]. New approaches are being formed to the choice of measuring instruments [12,13], including elements of risk management [14], which ultimately ensures the quality of repair processes [15].

Continuous and purposeful quality management at repair enterprises is ensured by a number of measures, including metrological support and the use of statistical quality management methods (figure 1) [16, 17]. This requires the formation of a technical control scheme. The technical control scheme includes details and technological operations for which it is necessary to carry out selective control or to justify the expediency of continuous control. It is also necessary to establish the frequency, the required number of checks and inspectors.

To ensure the compliance of the ongoing monitoring of the quality of the technological process with the requirements of the modern quality management system, it is necessary to determine the control points where the compliance check will be carried out. Control point (CP) - a place in the technological process of repair, designated for the purpose of monitoring parts or processes to determine defects or inconsistencies. Based on the results of the control, a conclusion is made whether the part is subject to further operation, repair, or the part is unusable and is rejected completely.
Components of quality in repair production. 1 – metrological support; 2 – quality in repair production; 3 – statistical methods of quality management.

In figure 2 shows a diagram of the location of control points in the technological process of repairing the cylinder liner.

Table 1 describes the metrological support of control points during repair. The classification of control types, measurement methods and recommended control means are given.

Table 2 shows the use of statistical methods and quality control tools for control points in the repair of cylinder liners.

The first operation in the technological process, prior to the repair of the cylinder liner, is cleaning and washing. The subsequent stages of work and all repairs depend on its quality. Contamination of parts is divided into 2 groups: contamination of external surfaces and internal surfaces (oils, resinous deposits). It is impossible to make accurate and reliable measurements of contaminated parts. It is extremely difficult to detect hidden defects and malfunctions under the layers. Therefore, cleaning from dirt, oil residues, scale and carbon deposits of engine cylinder liners is a mandatory procedure before the subsequent operation - troubleshooting.

Justification of control points of the process of repairing cylinder liners.
### Table 1. Metrological support of control points during the repair of cylinder liners.

| Check Point | Controlled parameter | type of control | by product selection method | by influence on the object of control | by time of control | by measuring instruments | by stage of the technological process | Method of measurement | Recommended control tool |
|-------------|----------------------|----------------|-----------------------------|----------------------------------------|-------------------|--------------------------|----------------------------------------|-----------------------|-------------------------|
| CP1         | Complete cleaning    | 100% control   | 100% control                | 100% control                           | incoming inspection| incoming inspection      | characteristic method               | -                     | loupe                   |
| CP2         | Inner diameter of cylinder liner cracks, shells, etc. | 100% control | 100% control | 100% control | continuous control | inspection | incoming inspection | direct measurement method | Indicator bore gauge |
|             | Shape deviation      | 100% control   | continuous control          | Control by measurement, registration control | Organoleptic inspection, Visual inspection | incoming inspection | -                       | -                     | Indicator bore gauge |
|             | diameter of the size for rings | 100% control | continuous control          | Control by measurement, registration control | registration control | incoming inspection | Direct measurement method | -                     | lever bracket calipers |
| CP3         | Shape deviation      | 100% control   | continuous control          | Control by measurement, registration control | Acceptance inspection | -                     | -                       | Indicator bore gauge |
|             | Inner diameter of cylinder liner | 100% control | continuous control          | Control by measurement, registration control | Acceptance inspection | -                     | -                       | Indicator bore gauge |
|             | Roughness of the working surface | 100% control | continuous control          | Control by measurement, registration control | Acceptance inspection | -                     | -                       | profilograph          |

### Table 2. Application of statistical methods and tools for quality control of control points in the repair of cylinder liners.

| Check Point | Controlled parameter | Recommended control tool | Statistical quality management techniques | Process planning | Determination of the level of defectiveness | Process stability management | Defectiveness assessment |
|-------------|----------------------|--------------------------|------------------------------------------|------------------|---------------------------------------------|------------------------------|--------------------------|
| CP1         | Complete cleaning    | loupe                    | Ishikawa diagram                         | Process planning | checklist for registering types of defects | -                            | -                        |
| CP2         | Inner diameter of cylinder liner cracks, shells, etc. | Indicator bore gauge | Ishikawa diagram                         | Process planning | checklist for registering the distribution of the measured parameter | -                            | -                        |
|             | Shape deviation      | Indicator bore gauge     | Ishikawa diagram                         | Process planning | checklist for registering types of defects | -                            | -                        |
|             | diameter of the size for rings | Indicator bore gauge | Ishikawa diagram                         | Process planning | defect location checklist                   | -                            | -                        |
| CP3         | Shape deviation      | Indicator bore gauge     | Ishikawa diagram                         | Process planning | checklist for registering the distribution of the measured parameter | -                            | -                        |
At the planning stage of the process, it is recommended to use the Ishikawa diagram to assess the parameters that affect the quality of the cylinder liner repair process.

During the inspection of the cylinder liners received at the repair plant, it is recommended to evaluate the defectiveness using control sheets.

When controlling the parameters, it is recommended to determine the level of defectiveness of the finished product, taking into account economic losses, using a checklist.

At the stage of adjusting the process, it is recommended to assess the level of defectiveness. Analysis requires collecting data on each step of the process. This data can be presented in checklists, checklists also provide information on the progress of the process. At the beginning, it is necessary to assess the stability of the technological process of honing cylinder liners, if the process is in a stable state - record the data in the check sheets and build control charts. If the process is in an unstable state, it is necessary to adjust the technological equipment and carry out repeated measurements, repeating until the process is in a stable state.

CP1 is a control point where the quality of cleaning is checked by the organoleptic method of visual inspection, in case of incomplete cleaning, the parts are re-sent to the washing. If the washing quality is satisfactory, the parts are sent to the next operation - fault detection.

CP2 is a control point, where the control of the cylinder liner is carried out according to geometric parameters, such as the inner diameter of the liner, deviations of the liner shape, diameters of the belts, height. Possible seizures, cracks and etc.

When measuring the diameter of the sleeve, a conclusion is made whether the sleeve is subject to further use, it will be sent for restoration (boring under the 1st or 2nd repair size), or, if the diameter exceeds the allowable value, is greater than the last repair size, the cylinder liner is rejected, as a result of which the cost of purchasing a new part increases.

CP3 is a control point, where the final quality control of the cylinder liner restoration (boring to the oversize) is carried out, while the liner is controlled by the inner diameter. If the diameter corresponds to the established limit dimensions, then the liner is sent for selective assembly with a piston of the corresponding size group, or sent to a correctable or irreparable marriage.

They also check the roughness of the cylinder liner mirror, because the engine operation depends to a large extent on the quality of the cylinder liner mirror manufacturing, namely, such indicators as the wear resistance of the cylinders and piston rings of the engine, oil consumption, resource and engine durability.

During the final control, the deviation from the shape is also assessed accordingly, it should be no more than the group tolerance. Decrease in ovality of cylinders helps to reduce the wear rate of rings and piston grooves, which in general improves the performance of piston rings and improves combustion chamber seals.

Ovality of cylinders is one of the criteria the performance and environmental friendliness of engines and the setting of parts in major repairs. Upon reaching the maximum permissible ovality engines are economically and environmentally unreasonable to operate. If the ovality value is exceeded, the cylinder liner must be bored to next repair size.

For continuous provision and control quality assurance metrological assurance and the use of statistical quality control tools should go in parallel (figure 1).

Based on the above, 3 control points were assigned - at the stages of cleaning, fault detection and control. In this case, the input data for the use of statistical methods can be the results of measurements during quality control of the technological process.
So, at the control point CP1, the quality of cleaning is controlled by a visual method, these types of defects are recorded in the control sheet.

At the second control point CP2 - in the process of flaw detection - the presence of defects on the working surface of the cylinder liner is monitored, these types of defects are also entered in the control sheet of the corresponding type. At this stage, it is necessary to select the appropriate measuring instrument that satisfies the values of the measuring range and the values of the permissible error. When checking for deviations from the shape, it is also recommended to record the localization of defects in the check sheet. Data must also be recorded on checklists.

At the final stage - at the third control point KT3 - control - the final control is carried out - defects are visually assessed - cracks, scratches, etc., the roughness, deviation from the shape and the inner diameter of the cylinder liner are controlled to determine the selection group. They also determine parameters for sorting - the number of incorrectly accepted and incorrectly rejected parts that fell into the neighboring selection groups when checking the cylinder liners.

The results of the control of the inner diameter of the cylinder liner are data for evaluating the technological process of processing the cylinder liner for a repair process, if the process is in an unstable state, they eliminate special causes of process variability and re-evaluate the technological process. If the process is in a stable state, a control chart is built and proceeds to the analysis of size scattering, in this case the output will be a histogram, polygon and distribution law.

The last step in the third checkpoint is the registration of types of defects, taking into account economic losses - the results are entered into a checklist, which allows you to calculate internal and external losses from defects.

At the same time, during the inspection of the cylinder liner - CP3, it is also necessary to carry out the incoming inspection of the pistons supplied to the repair plant. At the same time, a visual inspection of defects is carried out, an appropriate means of measuring the diameter of the piston skirt is selected, and their 100% control is carried out. They also determine parameters for sorting - the number of incorrectly accepted and incorrectly rejected parts that fell into neighboring selection groups during control. A complete control of the pistons of overhaul dimensions received at the enterprise is necessary due to the fact that in our work, in order to reduce the work in progress, it is recommended to apply the method of intergroup interchangeability.

The final stage is the assessment of the work in progress of pistons and cylinder liners, the application of the method of inter-group interchangeability, as well as the assessment of the level of defectiveness.

The recommendation of control instruments for the repair production processes was carried out. It is recommended to use the Ishikawa diagram to identify parameters that affect the quality of the repair of the "piston-sleeve" connection. The use of Shewhart control charts of sliding ranges and individual values will allow assessing the stability of the technological process of finishing the liner. The checklist will allow you to determine the number of recoverable and irreparable defects and losses across the entire range of possible defects.

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