Improvement of the method of micrometry of cylinder liners

V V Lazar¹, M N Erokhin¹, Yu G Vergazova¹, Yu V Kataev¹ and E A Gradov²

¹Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, Institute of Mechanics and Power Engineering named after V. P. Goryachkin. 127550, st. Timiryazevskaya 49, Moscow, Russian Federation
²Federal state budgetary scientific institution "Federal scientific Agroengineering centre VIM», 109428, st. 1st Institutskiy proezd, 5, Moscow, Russia

E-mail: vera_lazar69@mail.ru

Abstract. The technique and features of micrometering of cylinder liners are presented. The main factors influencing the wear of the cylinder liner and the rules for assigning planes and sections when conducting a micrometer of its inner surface are theoretically substantiated. On the example of a study of used cylinder liners of engines of the Yaroslavl Motor Plant, it was revealed that the greatest wear is manifested in the place where the upper piston ring stops in the upper part of the liner, and the amount of wear will be greater in the swinging plane of the connecting rod due to the action of normal force during pressure distribution at the beginning of the expansion stroke. High wear at the top is also due to high temperatures and lack of lubrication. It was found that the diameter of the upper non-wearing band can be used to judge the initial size of the sleeve hole. The underside of the cylinder liner is subject to wear due to the friction of the piston skirt against its surface.

1. Introduction

Competent application of methods and means of measurement, testing and control at machine-building and repair enterprises is of paramount importance to ensure the specified quality of machines and the durability of their operation [1].

It is on the reliability of the measurement information that further questions about the adoption of one or another decision on the quality of mechanical engineering products depend. These issues are dealt with by the system of metrological support of production [2,3].

The issues of ensuring the durability of critical joints with certain clearances [4], with guaranteed tightness [5,6], including the accuracy parameters in seals [7,8], are becoming more and more urgent. In order to improve the accuracy of connections, methods of incomplete interchangeability are used [9, 10]. Improving the accuracy of manufacturing, assembling and repairing joints leads to the need for a rational choice of means and methods for their control [11,12].

The issue of using non-original parts of third-party suppliers as spare parts in the repair of machines and methods for assessing their compliance is quite acute [13, 14, 15, 16].

When new equipment and new parts are put into production, a study is made of the wear and durability of its critical connections. For this, micrometric operations are carried out.

Based on the micrometric data, control charts are formed for the defect detection of parts when they enter for repair.

The main tasks for flaw detection of parts are:
• control of parts in order to determine their technical condition;
• further sorting into groups: suitable, which are subject to further operation, parts to be repaired (restored) and unusable parts - sorting of parts by restoration routes;
• accumulation of information on the results of fault detection for further improvement of technological processes.

The efficiency of the repair production, as well as the quality of the repaired parts, assemblies and assemblies, is greatly influenced by the work on fault detection and further sorting of the inspected parts. In this regard, flaw detection must be carried out in accordance with the normative and technical documents and correctly interpreted the measurement data, comparing them with the limit values. Deviation from these conditions contributes to an increase in the cost of repairs and a decrease in quality. Installing parts with deviations degrades the quality indicators of repaired automotive engines.

The main document for determining the scope of repair and restoration work and the need for new parts, materials and spare parts are lists of defects, in which the results of defect detection are entered. Fault detection is carried out using special devices, instruments and equipment, universal measuring instruments and external inspection.

2. Description of the research object
The most important detail limiting engine life is the cylinder liner. The performance of the engine depends on the condition of the working surface of the cylinder liners. Over time, in the process of engine operation, cylinder wear occurs. This entails a decrease in power, a significant increase in fuel and lubrication consumption, an increase in oil consumption for waste, there are difficulties when starting the engine, etc. The wear of the surface of the cylinder liners is determined by an increase in diameter, a change in geometric dimensions - an increase in ovality and taper.

In the presence of wear of more than 0.35...0.50 mm, the connection of the liner with the piston comes to a limiting state and the engine is sent for repair to grind the liners to a repair size or replace with a new one. In other words, the cylinder liners are flawed.

But before flaw detection of new cylinder liners, it is necessary to carry out a micrometer of its surface in order to identify the places of greatest and least wear.

The object of research is the cylinder liner of the engines of the Yaroslavl Motor Plant (table 1).

| Parameter                          | Designation | Nominal value |
|------------------------------------|-------------|---------------|
| Sleeve height                      | L           | 270 ±0.68 mm  |
| Height from the upper end of the sleeve to the thrust collar | h           | 12.1 ±0.03 mm |
| Top centering collar diameter      | D1          | Ø 160 ±0.08 mm|
| Bottom centering collar diameter   | D2          | Ø 152 ±0.04 mm|
| Landing belt diameter              | D3          | Ø 151 ±0.04 mm|
| Inside diameter of the sleeve      | d           | Ø 130 mm      |
| Upper deviation of inner diameter  | ES          | +25 μm        |
| Bottom deviation of inner diameter | EI          | +5 μm         |
| Working surface hardness           | HRC         | 42...50       |
| Roughness of the cylinder mirror   | Ra          | 6.3 μm        |
| Weight of cylinder liner           |             | 7.8 kg        |

3. Research results and their analysis
The technique of conducting micrometering of cylinder liners is as follows. The working surface of the cylinder liner is controlled by the inner diameter, which is measured in eight sections from 1-1 to 8-8 and two planes A-A, B-B (figure 1).

In order to carry out micrometry of the cylinder liner, it is necessary to use an indicator bore gauge
with a digital head of increased accuracy with a division value of 0.001 mm.

Consider the data on the micrometer size of the new cylinder liner. The bore gauge is adjusted according to the setting ring 130.000 mm and the deviations of the sleeve diameter are measured in the indicated planes and sections (actual deviations). The results are recorded in table 2.

| Measured planes | Deviations from size 130.0 mm, in sections along the height of the sleeve, μm | Taper, μm |
|-----------------|-------------------------------------------------|----------|
| A-A             | +10 +9 +9 +11 +10 +9 +12 +11                     | 1.5      |
| B-B             | +15 +11 +13 +14 +14 +10 +15 +13                   | 2.5      |
| Ovality, μm     | 2.5 1 2 1.5 2 0.5 1.5 1                          | -        |

The change in the dimensions of the working surface of the cylinder liner occurs as a result of prolonged wear. In this case, the diameter of the sleeve increases, errors appear in the geometric shapes of the working surfaces of the part in the form of ovality and taper.

Consider the data of the micrometer size of the cylinder liner after its long-term operation on the DON 1500 combine, shown in table 3.

| Measured planes | Deviations from size 130.0 mm, in sections along the height of the sleeve, μm | Taper, μm |
|-----------------|-------------------------------------------------|----------|
| A-A             | +165 +253 +225 +142 +135 +122 +79 +39           | 107      |
| B-B             | +120 +189 +133 +92 +89 +83 +49 +20               | 84.5     |
| Ovality, μm     | 22.5 32 46 25 23 19.5 15 9.5                   |          |

The data presented in table 3 are displayed for clarity in figure 1. Here, a pattern of uneven wear of the cylinder liner surface is observed. The greatest wear is characteristic of the upper part of the cylinder liner, in the area of the piston rings. This is due to the strong abrasive effect of the piston rings due to the presence of poor lubrication conditions in this place and the high pressure of gases that expand the
rings, as well as the effect of high temperatures. Increased wear is also observed in the rocking plane of the connecting rod due to the action of the normal force.

If there is a misalignment and axial displacement of the crankshaft, then increased wear from the piston skirt in an axis perpendicular to the rolling plane of the connecting rod is possible.

In our case, the greatest wear was 253 microns in the rocking plane of the connecting rod, and 189 microns in the plane perpendicular to it.

Ovality is calculated from the results of measuring diameters in planes A-A and B-B according to the formula:

$$\text{EFK}_{i} = \frac{D_{iB} - D_{iA}}{2}$$  \hspace{1cm} (1)

where: i - section of the cylinder liner.

The actual value is taken to be the maximum ovality value selected from the calculations $\text{EFK} = \text{EFK}_{\text{max}}$.

Taper in planes A-A and B-B is determined by the formula:

$$\text{EFP}_{i} = \frac{D_{i\text{max}} - D_{i\text{min}}}{2}$$  \hspace{1cm} (2)

Actual taper is the maximum value $\text{EFP} = \text{EFP}_{\text{max}}$.

The obtained ovality and taper values for new sleeves should not exceed the limit values specified in the technical documentation.

For worn out liners, in our case $\text{EFK}_{\text{max}} = 46$ microns in section 2-2, and $\text{EFP}_{\text{max}} = 107$ microns in the A-A plane, this suggests that the natural wear of the cylinder liners manifests itself as a depletion in the area of movement of the piston rings.

In this case, the cylindrical shape of the hole is distorted and takes the form of an oval with great wear in the rolling plane of the connecting rod. The output is not symmetrical (relative to the longitudinal axis of the engine) due to the action of the normal force, while the ovality values in fact determine the size of the gap through which the gases break through into the crankcase.

4. Conclusion

Thus, the micrometering of the cylinder liners should be especially carefully carried out in the upper part of the cylinder liners. The greatest wear will occur in the place where the upper piston ring stops at the beginning of the expansion stroke, and the wear will be greater in the connecting rod swing plane due to the action of normal force. Therefore, before removing the cylinder liner from the block, it is necessary to mark this plane. All that is above is a belt that is not subject to mechanical wear, by the diameter of which one can judge the initial dimensions of the liner hole, although the size measurement will also take place here due to the influence of high temperatures, some change in the crystal lattice of the material, oxidation and the likelihood of the presence of combustion products in the form of carbon deposits. The underside of the cylinder liner is subject to wear due to the friction of the piston skirt against its surface. But the temperature is lower here, good lubrication is observed, and the contact area is much larger, respectively, the pressure is lower. Increased wear can be observed here only with distortions in the operation of the crank mechanism - mixing of the crankshaft axis or bending of the connecting rod.

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