RESEARCH ON INFLUENCE OF GEOMETRIC PARAMETERS OF ENGINE BODY PARTS DURING REPAIR PROCESS

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Abstract. Exterior parts of complex constructions are widely used in internal combustion engines for various purposes, such as pumps, compressors, etc. Solving the problem of high-quality repair of parts of complex configuration, effective control of their technical condition during their reuse requires solving a number of engineering, technological and metrological tasks. The durability of modern cylinder blocks is ensured by the use of high-quality materials, improved element construction, equal strength of parts with optimal manufacturability, maintainability, quality of assembly and service. To conduct the research, technological schemes for monitoring and measuring deviations in the location of the main geometric parameters of the cylinder block were developed. Engineering documentation and technological support for the manufacture of a control and measuring device for controlling the alignment of the holes of the main bearings were developed. Processing of the measurement results by indicator devices in the workshop conditions shows that the deviation from the alignment or displacement of the middle root supports relative to the extreme ones can reach a value of -0.08 to +0.09 mm, which is significantly beyond the diameter limit. The values of the results show that the maximum deviations occur in the horizontal plane (180^0 - 360^0) with a transition to the lower part of the vertical plane. This direction of displacement can be explained by the zone of maximum values of the forces acting during the engine operation. It should be assumed that the values of actual deviations in the range of -0.04 to +0.04 can be accepted for the use of cylinder blocks. The construction of the device with indicator counting devices was developed to ensure control and measurement of the alignment of the holes of the main bearings. Laboratory tests of the device and metrological evaluation of the permissible measurement error were carried out. The results obtained made it possible to increase the productivity of defect detection work and develop recommendations for improving the aftermarket reliability of engines.

Keywords: technical condition, deviations from the form and location, defecting, cylinder block, control and measuring device.

Introduction

The problem of ensuring the reliable operation of mobile agricultural machinery is becoming increasingly relevant, since the intensity of its loss of efficiency significantly exceeds the pace of technical re-equipment of agricultural enterprises of Ukraine [1]. To predict failures of mobile energy facilities, and therefore, in order to prevent possible parametric and emergency failures of units in the field [2; 3], on livestock farms or on roads, there is a problem of reliability [4; 5]. Determining reliability indicators of machines, assessing the residual resource of components, becomes crucial for implementing a program to ensure their operational efficiency [7-9].

A special attention in mechanical engineering and machine repair is occupied by case parts of complex configurations, which are widely used in internal combustion engines for various purposes, pumps, compressors [6; 9]. Body parts have a large number of flat and cylindrical surfaces, which must be processed with high accuracy to diametrical and linear dimensions, as well as in shape and mutual arrangement with each other. Given the importance of the cylinder block, as well as the significant cost of the work that is necessary to restore the performance, it is necessary to assess those patterns that reflect the technical condition of the part during the period of operation of the engine using computer technology and expert systems [6; 7; 9].

The functioning of the block-cylinder within the engine structure significantly affects the operational cost of a mobile power unit, which depends on timely and accurate determination of its technical condition. This corresponds to the principles of operational reliability that characterize this group of components. In such circumstances, it is advisable to carry out timely repairs, since the guidance materials and recommendations do not always contain complete and justified principles.

The work is dedicated to increasing productivity and efficiency in controlling or measuring geometric parameters of body parts using the example of an engine block-cylinder in repair manufacturing conditions. The main focus is on deviations from the shape and location of basic technological surfaces, as well as geometric parameters of complex body structure parts. Based on the analysis of existing adaptations and methods used in mass and large-scale production, relevant conclusions are drawn regarding their inadequate conclusions in machine repair. Studying the presented issues requires a detailed analysis of the design and technological characteristics of parts in this group.

The purpose of the research is to improve the quality of defects in internal combustion engines that are being repaired by designing non-standard devices for controlling or measuring deviations in the shape and location of technological surfaces of block cylinders.

Materials and methods

In recent decades, both traditional and new methods and means of assessing the technical condition of components have been used to ensure the reliability of agricultural machinery and equipment. These methods include optical, physical, mechanical, and others. They have enabled the evaluation of machine condition during scheduled repair works [7; 10]. In the research, the results of investigations into the defects of the engine block-cylinder construction elements were utilized to assess the reliability indicators of internal combustion engines. This information positively impacted the engine operability.

The results of the analysis show that considering the high level of complexity in controlling the surface preparation, and the difficulty in controlling the prepared surface, defectoscopy methods were used to investigate localized areas of the engine block-cylinder construction. This was implemented in this work to study defects in the tractor engine block-cylinder.

The deviation control from coaxiality of the main bearing holes of the crankshaft with respect to the end ones is carried out using an adaptation developed at the Department of Technical Reliability of NULES in Ukraine. The adaptation consists of a housing – a hollow tube. Inside the housing, four fixed and two pressure-bearing supports are installed corresponding to the end supports of the block. The supports are positioned around the perimeter at an angle of 120° relative to each other. The fixed supports are ground to a nominal size of the main bearing holes (98 + 0.02). Inside the housing, in the same plane as the fixed supports, two indicator heads with a division value of 0.01 mm are installed. The deviation of the supports from coaxiality should be determined with the block in a vertical position.

Before measuring or controlling, the main bearing caps were tightened with a torque of 200-220 Nm, and the block was set in a vertical position using a stand-leveler. The adaptation was then installed into the block through the top and subsequent supports using movable spring-loaded supports, ensuring a centered position in the end supports. By smoothly rotating it into position, we aligned the indicator feet to rest on the 2nd and 3rd main bearing caps in the lower position of the caps. Through the inspection windows of the indicator scales, we set them to “zero”, and the deviation of the main supports relative to the end ones was determined by the maximum deflection of the indicator head needles during the smooth rotation of the adaptation according to the measurement scheme (Fig. 1).

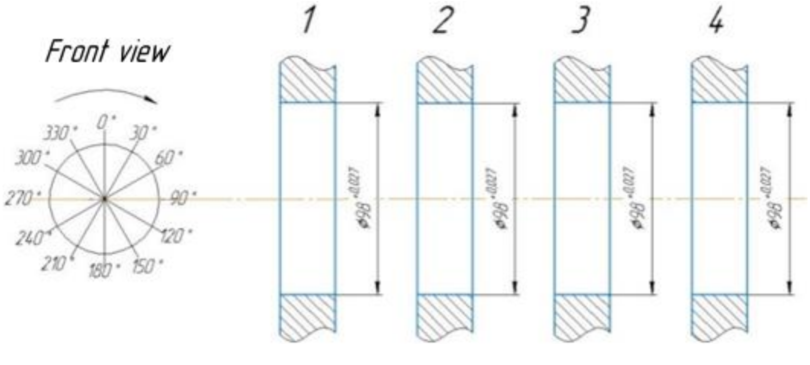

Fig. 1. **Measurement scheme for deviations from coaxiality of the main bearing supports relative to the end ones of the crankshaft**

The deviations from coaxiality are influenced by deviations in the shape of the bearing holes. Therefore, measurements of the diameters of the bearing holes are usually carried out according to the scheme (Fig. 1) to determine deviations from cylindricity of the bearing holes and establish the value of the deviation error from coaxiality. The measurements are performed using an inside micrometer.

Results and discussion

The coaxiality of the main bearing holes of the crankshaft should be perfect because it affects the complexity of assembly operations and, subsequently, the lifespan of the repaired engine during operation. In case of significant deviations from coaxiality, partial or even complete seizing of the crankshaft can occur, while minor deviations can disrupt clearances in sliding bearings, significantly impacting the lifespan of the connections.

It is evident that when there are defects in the parameters of the engine block-cylinder, special adaptations are necessary to ensure more precise control. For example, the control of deviations from coaxiality of the main bearing holes of the crankshaft relative to the end ones is carried out using the developed adaptation PKV-1 (Fig. 2), which consists of a housing where four fixed and two pressure-bearing supports are installed corresponding to the end supports of the block. The supports are positioned around the perimeter at an angle of 120° relative to each other. The fixed supports are ground to a nominal size of the main bearing holes ($98^{+0.02}$) in one setting. Inside the housing, in the same plane as the fixed supports, two indicator heads with a division value of 0.01 mm are installed. Before taking measurements, the main bearing caps were tightened with a torque of 200-220 Nm, and the block was set in a vertical position using a stand-leveler. The adaptation was then installed into the block through the top and subsequent supports using movable spring-loaded supports, ensuring a centered position in the end supports. By smoothly rotating it into position, we aligned the indicator feet to rest on the 2nd and 3rd main bearing caps in the lower position of the caps. Through the inspection windows of the indicator scales, we set them to “zero”, and the deviation of the main bearing supports relative to the end ones was determined by the maximum deflection of the indicator head needles during the smooth rotation of the adaptation.

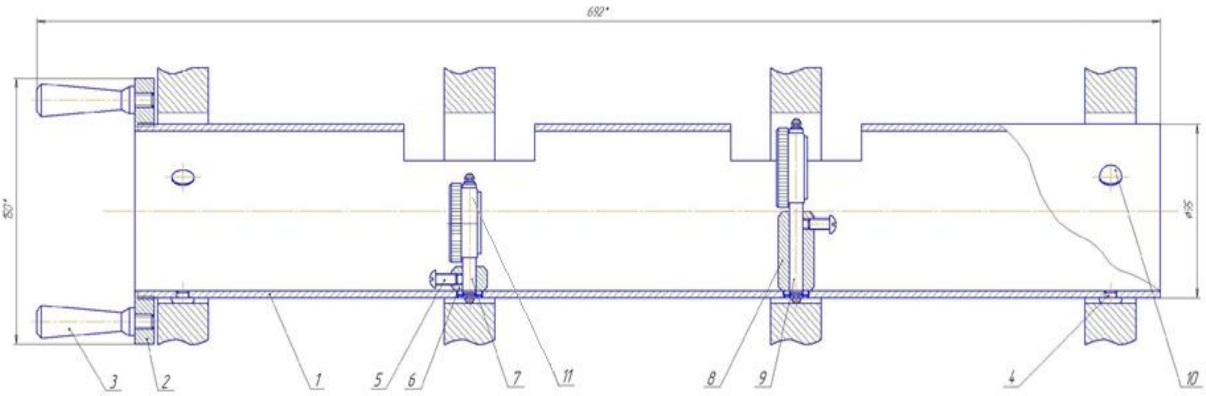

Fig. 2. **PKV-1 for controlling the coaxiality of the main bearing holes relative to the end ones consisting of the following components:** 1 – housing; 2 – flange; 3 – handle; 4 – pressure-bearing support; 5 – locking screw; 6 – stand; 7 – indicator head foot; 8 – long stand; 9 – long indicator head foot; 10 – support

Measurements of the deviation magnitude of the main bearing supports relative to the end ones were carried out according to the described methodology and in accordance with the scheme (Fig. 3). The measurements were conducted by recording the maximum deviation indicated by the pointer needles of the indicator heads (from the zero division).

The measurement of geometric parameters of the engine blocks intended for secondary use was carried out in workshop conditions according to the established methodology. To obtain reliable statistical data, a sample of visually suitable blocks consisting of 25 pieces was used. Micro-measurement charts were compiled based on the measurement schemes, and the measurement results were recorded on these charts.

According to the obtained measurement results, we have characteristics based on the arithmetic mean and standard deviation values, which are presented in Figures 4 and 5.

The processing of the measurement results using indicator devices in workshop conditions shows that deviations from coaxiality or displacement of the main bearing supports relative to the end ones can reach a magnitude of -0.08 to + 0.09 mm, which significantly exceeds the allowable diameter tolerance.

The value of the results indicates that maximum deviations are observed in the horizontal plane (1800-3600) (Fig. 6) with displacement towards the lower part of the vertical plane. This direction of displacement can be explained by the zone of maximum values of acting forces during engine operation. It should be noted that actual deviations within -0.04 to + 0.04 may be acceptable for determining the suitability of blocks for further use.

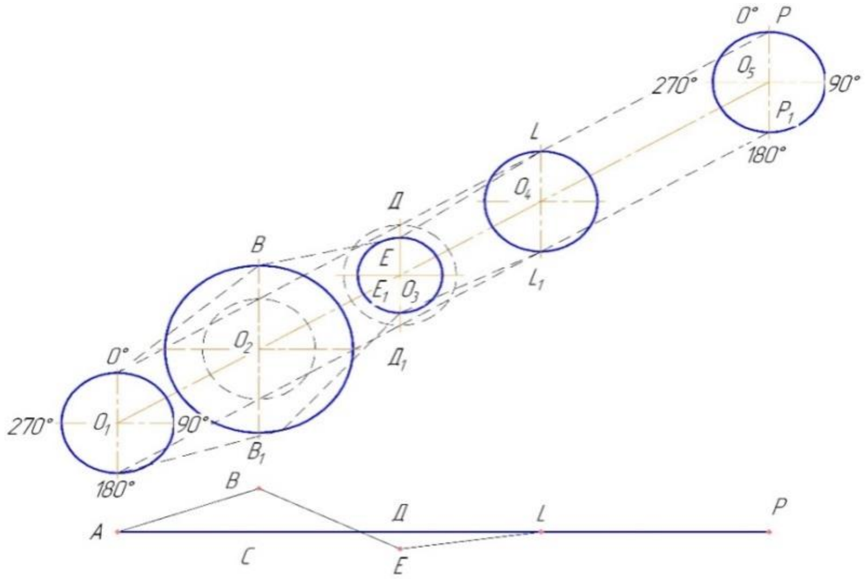

Fig. 3. **Scheme of deviations of the main bearing holes**

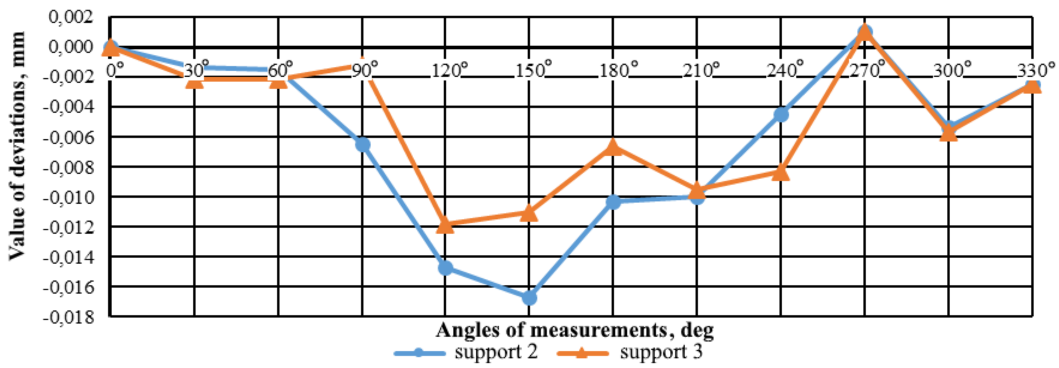

Fig. 4. **Average values of deviations from coaxiality of the main bearing supports relative to the end ones of the crankshaft**

Analyzing the results of the experimental research of the quality of defecting parts of internal combustion engines leads to the conclusion that most authors in recent years have developed and implemented various methods of defecting using computer technology [6; 11], without the use of instrumental methods and devices that cover the technological processes of defecting during the restoration of operability.

A lot of scientists are using computer diagnostics to model and improve the functioning of block cylinders systems [10; 12]. Scientific research and recommendations [10] are aimed at ensuring the quality of block cylinder and the formation of places for defecting during manufacturing. At the same time, these recommendations are not always relevant when assessing the technical condition of block cylinders that have been in operation and need to be restored. Research [12] claims that the use of such technologies can ensure the accuracy of detecting the cooling system defects over 88%.

Along with the possibility of effective defecting of external surfaces, the methods mentioned above do not provide the possibility of assessing the technical condition of the structural parameters of block cylinders, including the holes of the main supports.

The need for controlling or measuring non-coaxiality is justified by the non-technological nature of fitting the crankshaft (reducing working clearances in the plain bearings to zero). Minor reductions in clearance can be increased by fittings (shimming inserts). In this case, there are no principles of interchangeability. Non-coaxiality can be interpreted as "radial displacement" in terms of the deviation magnitude from the straightness of the bearing surfaces relative to the adjacent straight line.

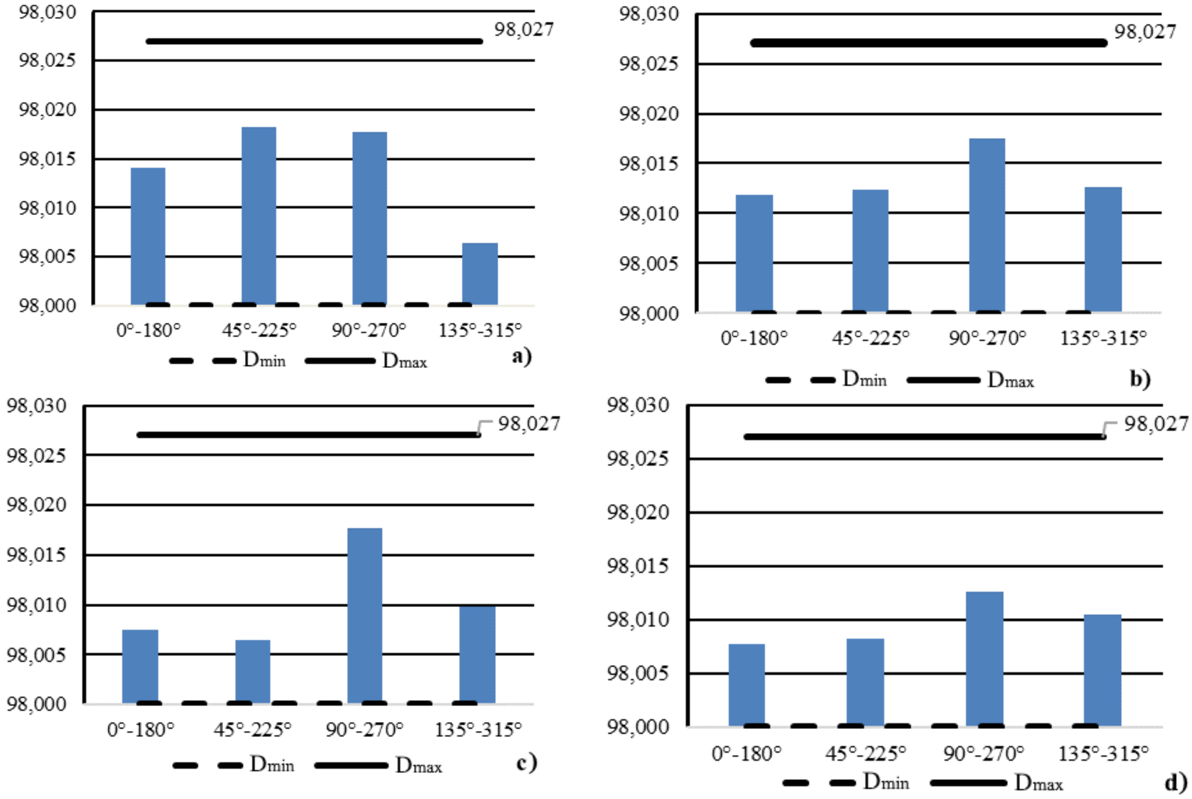

Fig. 5. **Root mean square values of the actual dimensions (mm) of the crankshaft supports relative to the horizontal plane (deg):** a – 1st support; b – 2nd support; c – 3rd support; d – 4th support

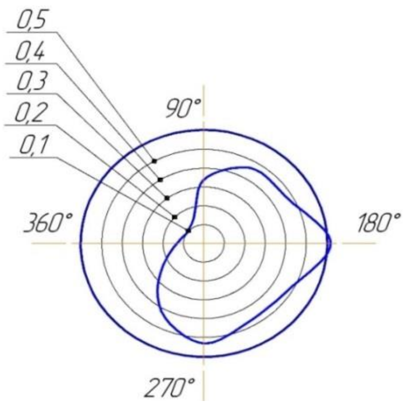

Fig. 6. **Deviation diagram of the main support holes**

Conclusions

1. The aim of the study was to solve the problem of increasing the lifespan of engines during secondary use by preventing the assembly of engine blocks with deviations from precision standards in the shape of technological surfaces and the arrangement of geometric parameters.
2. The solution to these problems is ensured by developing a design of adaptations and a methodology for their use to reliably assess the state of geometric parameters with a relatively high level of productivity in performing defect detection work.
3. The laboratory tests of the adaptations were conducted, and metrological evaluation of the permissible measurement error was performed. The actual deviation values within -0.04 to + 0.04 may be acceptable for determining the suitability of the blocks for further use.

4. The processing of the measurement results using indicator devices in workshop conditions shows that deviations from concentricity or displacement of the average main supports relative to the end ones can reach -0.08 to + 0.09 mm, which significantly exceeds the tolerance limits for the diameter. The results indicate that the maximum deviations occur in the horizontal plane (1800-3600) with a transition to the lower part of the vertical plane. This direction of displacement can be explained by the zone of maximum values of acting forces during the engine operation.

Author contributions

Conceptualization, A. N., V. M., methodology, V. B., validation, A. N., V. M., O. B., V. B. and S. S., formal analysis, A. N. and V. M., data curation, O. B., writing–original draft preparation, O. B. and V. B., writing–review and editing, A. N. and V. M., visualization, O. B., project administration, A. N., funding acquisition, A. N., V. M., O. B., V. B. and S. S. All authors have read and agreed to the published version of the manuscript.

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