Development of CAD elements for automated selection component parts during assembly multi-bearing unit of an internal combustion engine

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Abstract. The article describes the implementation of the task of computer selection of component parts of multi-bearing units when using the computer-aided design system for internal combustion engines. Describes the elimination of harmful technological heredity of production of machines at the assembly stage, by means of an automated selection of liners to compensate for errors in the supports of crankcase, using the proposed mathematical model. A method for determining the optimal assembly option using an automated process control system for assembling multi-bearing support units is given. Given the functional structure of the system, illustrates the composition and application of elements of CAD in the framework of the proposed approach.

To obtain new design solutions for various components of the internal combustion engine using CAD systems, design documentation is often released using a software package for two-dimensional or three-dimensional design. However, there are a number of design stages, the automation of which allows to obtain the necessary information for the formation of the technical solution itself. Technological heredity in engineering production [1] significantly affects the interaction of parts of mobile joints. Also the reliability of machines and mechanisms associated with the processes of their assembly and operation [2]. It is necessary to take into account the influence of technological heredity of machining on the tolerances of the links of the dimensional chains of coaxial sliding bearings. The tolerances themselves influence the diametrical gaps in coaxial friction pairs and the parameters of the oil layer of coaxial main bearings of diesel engines [3].

To eliminate harmful technological heredity at the assembly stage, it is necessary to compensate for the geometric errors of the contact surfaces of some parts with the geometric errors of other contact surfaces of coaxial friction pairs. This will influence the destabilization of the gaps in them [3] and reduce the effect of tolerances of the links of the dimensional chains of coaxial sliding bearings on the parameters of the oil layer [4]. The use of CAD elements [5-10] allows you to automate the process of selecting component parts and optimize the diametrical gaps in coaxial friction pairs of a multi-bearing unit of the support of shafts (MBUSS) [11].

Creating the conditions for technological support of the process of selective assembly of the MBUSS allows one to organize diametrical gaps in the range from the minimum functional gap $S_{min}$ to the optimal $S_{opt}$. Accordingly, the limits of the minimum $h_{min}$ and optimum $h_{opt}$ thickness of the oil layer when
assembling MBUSS will be provided, as well as the greatest factors of the stock for wear of \( S_t \) and work duration \( K_t \) by compensating for the actual errors of their machining and individual assembly. The basis of the technological support for the automation of selection is a developed system of designations for tolerances and landings of crankcase main supports, sliding bearing shells and crankshafts journals included in MBUSS.

To accomplish the task, a system of designations of tolerances and landings on the contact surface of the components of the MBUSS was developed, which is used in the automated selection of its components.

To ensure that bearing wear is minimal and uniform, equal working conditions are necessary. This can be achieved by computerized individual assembly, which compensates for deviations of the diametrical dimensions and alignment of the crankcase main bearings, which arise as a result of their machining. According to the traditional technology, the measurement of the crankcase main bearings and liner thickness is performed at the inlet control. According to the new technology, the selection of components requires the results of the control to be entered into the computer database and used in the selection.

A database of actual liner thickness dimensions is created. After that, the compensating values of different thicknesses of the upper and lower liners by automated selection are taken in the section corresponding to the closest approach of friction pairs. This method allows, after laying in bed and tightening the bearing caps, to obtain the required dimensions of the working openings of the bearings with a tighter tolerance of arrangement than with traditional technology. To do this, in the \( i \)-th main support after boring on special metal-cutting machines with coaxiality \( \Delta n.s.1 \), where \( j \) is the sequence number of the support from left to right, for example, when the 2nd is misaligned (denoted \( j \)-th) relative to 1-d (or \( i \)-th) \( \Delta n.s.1 = \pm 0.03 \text{ mm} \) (similarly to \( \Delta n.s.2 = \Delta n.s.3 \)), set preselected from database upper and lower liner so that their volumes fill the working gap \( t_P \) between the surface of each main support and main neck with the formation of the minimum optimal technological gap lie within \( (0.0008 \div 001) \) \( d = 0.088 \div 11 \text{ mm} \).

To implement the automated selection of liners to compensate for errors in main crankcase supports (figure 1), a mathematical model has been proposed, in which it is considered to be

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S_t + D = t P_i ,
\]

where \( D \) is a variable parameter of the actual thicknesses of the top \( t_{vk.v.i} \) or lower \( t_{vk.n.i} \) liners, and in the automated system, the thickness of the upper and lower liners are included in one database.

To ensure compensation for misalignment of crankcase main bearings with different thickness of liners, it is necessary to have an appropriate system of tolerances and landings.

Let us assume that the axis common to the main necks of the shaft coincides with the axle of the main supports. Then this axis will be common both for the main supports and for the main necks.

The working clearances are determined by the difference of the eponymous (belonging to one bearing support) of the actual dimensions of the main supports and necks and are used to calculate the selectable thickness of the liners. For example, the difference between the actual size \( D_{p2} \) of the main support 2 (figure 1) and the value of the actual size \( D_{sh2} \) of the main neck gives the value of the actual diametral clearance in the friction pair in question, which is within the optimum radial clearance, in the calculated friction pair equal to the sum of the thicknesses of the upper and lower liners in the plane of the closest approach of the neck of the shaft and bearing. The automated selection of liners presented in the article was carried out on this principle and showed satisfactory results.

This approach allows you to create the possibility of improving the accuracy of the assembly due to selective group or individual assembly and to ensure uniformity of the gaps in the friction pairs of the main bearings. The selection process of components includes the calculation of the mounting gap on the actual dimensions of the contact surfaces of the component parts, which is produced relative to the common axis of the extreme openings of the main supports and the main necks of the crankshaft, combined with the common axis.
Figure 1. The design scheme of the longitudinal section of the five-support MBUSS diesel engine with printed designations of fields, compensating values for errors of longitudinal section of crankcase and crankshaft without liners: 1 - crankcase; 2 - crankcase main support; 3, 4 - upper and lower liners of the sliding bearing, respectively; 5 - crankshaft \( t_{p1}, t_{p2} \) - working clearances above and below the axis O1-O5, respectively; \( S_{r1} \) - radial clearance above the axis O1-O5, \( S_{r2} \) is the radial clearance below the axis O1-O5.

The calculation is performed so that the values of the thicknesses of the upper and lower liners, folded with the minimum allowable clearance, are equal to the mounting design gap. The mounting gap is determined by calculation using modules, and the dimensions of the components that provide a more rigid, compared to the design technological installation gap, are selected from the database. This gap should be between the values of the minimum functional and optimal clearances of the entire series of coaxial friction pairs of the multi-support unit. The position of the forming working surfaces of the lower liners of the intermediate bearings and the mounting clearances of the bearing supports are calculated so that they provide the allowable diametrical clearances in coaxial friction pairs. To do this, develop a geometric model MBUSS: the centers of the bearings are shifted in the direction of the vectors of their favorable location, and the axes of the outermost and intermediate bearings are located in the plane of the closest approach of the friction surfaces of coaxial friction pairs. This enables the radial displacement of the axis of each main bearing and allowance for the runout of the main bearing. In this case, the bearing axis is radially shifted due to the different thickness of the upper and lower liners of the single bearing unit to be calculated.

Shown in figure 2 functional structure of the system, illustrates the composition and application of elements of CAD in the framework of the proposed approach.

The modeling subsystem performs the following functions:

a) refers to the database of crankcases and reads the information necessary for the calculation;
b) refers to the shafts database and reads the information necessary for the calculation;
c) calculates the working gap depending on the position of the gap;
d) records the result obtained in the table of working gap thicknesses.

The technical and economic efficiency of the creation and application of the developed system for the selection of component parts of the MBUSS for various methods of ensuring gaps in friction pairs can be estimated from the estimated values of the reserves for wear \( S_{\text{max-min}} \), the accuracy and the ratios of the accuracy factors for accuracy and the reserve factors for wear for a multi-support knot at group assembly.

In the approach proposed in this article to solving the problem of computer selection of component parts of multi-bearing bearing assemblies, in comparison with the known methods of selective assembly, conditions are created for increasing the efficiency of selection of component parts. This is realized as a result of stabilization of the mounting clearances in coaxial friction pairs, which improves the accuracy of the clearances and reliability of the unit by creating increased reserves for wear in the friction pairs.
The system of automated selection of components when assembling a multi-support bearing unit of an engine.

**Simulation subsystem**
- Measures the working clearance
- Generates a table of working clearances

**Optimization subsystem**
- Generates a picking table of optimal
- Performs picking optimal assembly
- Generates a table of sets of optimal
- Calculates optimal liner thicknesses
- Forms a table of recommended liner

**Database Management**
- Creating a new record in the database
- Editing a previously created entry
- Deleting a previously created entry
- Moving through databases

**Storage subsystem data**
- Stores the picking table of optimal
- Stores the working gap size charts
- Stores a table of sets of optimal
- Stores database table
- Keeps a table of recommended liners

**Recommendation subsystem**
- Formation of a table of recommended liners

**Figure 2.** The functional structure of the automated selection of components in the assembly of multi-bearing bearing assembly engine.
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