

# Improvement of Dimensional Accuracy Analysis for Assembly of Engineering Parts

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**Abstract**—This publication proposes approaches to improve accuracy of assembly of mechanical engineering parts based on the use and application of dimensional analysis. The conclusions drawn show that by determining appropriate tolerances for elements of fixtures, the specified accuracy of the processed parts is ensured.

**Keywords**—*fixture, assembly, accuracy, accuracy analysis.*

## I. INTRODUCTION

Improving assembly accuracy by improving approaches for fast and accurate orientation of the connected components is an important stage in the fixture design process. The applied approaches regarding the use of dimensional analysis to calculate the error of locating crankshaft-type parts will help reduce the amount of scrap when assembling the journal bearings of a coaxial crankshaft[1]. This makes the goal of this work relevant and contributes to improving the quality and productivity of the technological assembly process. The choice of assembly method and approach is made depending on the specific design features of the product, the size of the production program, the content of the operations and the technical requirements. For the implementation of the study, technological dimensional chains have been compiled, through which the relevant accuracy indicators of the assembly process have been analyzed.

Quality of assembled mechanical engineering parts included in the design of various machine units to a certain extent depends on accuracy of the used fixtures [1]. In a number of cases, the ultimate goal - assembly accuracy is achieved entirely through appropriate design and high-quality manufacture of an assembly fixture [2]. The increased requirements in modern mechanical engineering for the quality of assembled parts impose a new approach

to the dimensioning of the elements of technological equipment [3].

This is based on the wider application of dimensional analysis [4]. At present, the determination of dimensional tolerances when designing fixtures is carried out conditionally (depending on experience of the designer). In this way, significant errors are allowed and often lead to unnecessary expenditure of labor, funds and time in technological preparation [5].

## II. MATERIALS AND METHODS

The work presents an approach to improving the accuracy of assembly of mechanical engineering parts, based on the application of dimensional analysis. In it, the accuracy of the elements of the fixtures is regulated, proceeding from the accuracy of the assembled parts [6].

Dimensional analysis is widely used in the design and assembly of special fixtures, regardless of their type and degree of automation [7]. For fixtures intended for fixing and fastening basic parts and assemblies, dimensional analysis is not necessary. They are intended to provide the necessary stability of the parts during the assembly process and are usually not subject to requirements for the accuracy of the position of the fixed part.

For special fixtures for accurate and rapid orientation of assembled parts, the accuracy of their constituent elements is of particular importance [8]. Therefore, the determination of their tolerances must be carried out using dimensional analysis. When using such fixtures, the operator is freed from the need to ensure the mutual position of the assembled parts. This is done automatically by bringing the assembled parts into contact with the supporting and guiding elements of the fixture. In addition, this significantly increases labor productivity. As an

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example, Fig. 1 shows a fixture for assembling a composite crankshaft [9]. It achieves alignment of the main journals 1 and 4 [10]. This shaft can be assembled without a fixture, but the correction of the misalignment of the main journals must be carried out by the adjustment method [11]. The nuts 5 and 7 are slightly unscrewed, the inaccuracy is corrected, they are screwed in again and the displacement is measured. This process can be repeated many times, requiring high qualifications of the adjuster operator, and the process itself is of low productivity. When using the fixture, the position of the main journals is ensured by their single installation in the support prisms, after which nuts 5 and 7 are fastened.

In the design variant of the fixture shown in Fig. 1, the crankshaft is assembled in a vertical position. In this case, the misalignment of the main journals will depend on the accuracy of the dimensions of the fixture.

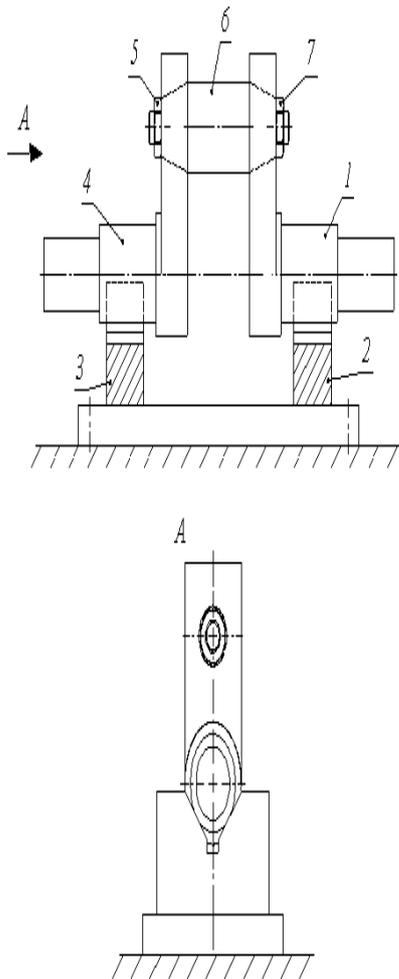


Fig. 1. Device for assembly of crankshaft.

### III. RESULTS AND DISCUSSION

In the assembly process, the products are included in technological dimensional chains. In these chains, the achieved accuracy indicators of the assembled products are closing links. Component links are the dimensions of the parts and the inaccuracies and clearances in the joints of the

fixtures. Fig. 2 shows the dimensional chain for achieving the alignment of the main journals  $A_{\Delta}$  of the crankshaft, assembled using the fixture from Fig. 1. For convenience in creating the chain, here the two prisms are shown one above the other, while maintaining the common base surface of the fixture plate. The dimensional chain is symmetrical, and the component links are:

$A_1, A_6$  - distance from the axis of the prism to the axis of the pin hole;

$A_2, A_5$  - clearance between the hole in the prism and the pin;

$A_3, A_4$  - distance from the base surface to the axis of the pin hole.

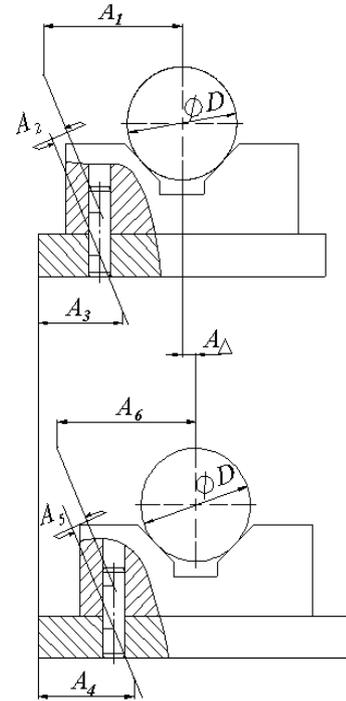


Fig. 2. Dimensional chain.

Depending on the number of units, the method of complete interchangeability is applied (if the number of units is more than 4) [12]. The solution of the straight-line problem is carried out by initially applying the principle of equal tolerances. i.e.

$$T_1 = T_2 = \dots = T_{n-1} = T_{av}. \quad (1)$$

$$T_{av.} = \frac{T_{\Delta}}{\sqrt{n-1}}$$

The calculated average value is indicative. The tolerances of the individual units are determined taking into account the accuracy of the technological method of processing and the size of their nominal values. The displacement of the prism relative to the average position as a result of the clearances  $A_2$  and  $A_5$  can occur in both directions, therefore they participate in the dimensional chain with the full value of their tolerance. After the correction, a check is carried out according to the known equation for the tolerance of the closing unit.

$$T_{\Delta} = \sqrt{\sum_{i=1}^{n-1} T_i^2}. \quad (2)$$

A characteristic feature of this design variant, as shown by the composite dimensional chain, is that the misalignment of the main necks  $A_{\Delta}$  is influenced only by the structural dimensions and clearances of the fixture. The inconvenience of this type of basing is that the operator must hold the shaft by hand until the nuts are screwed in. The same fixture can be made in another variant, in which the wedge neck is in a horizontal plane and can rest on a solid stop. This will facilitate assembly, since holding by hand is not necessary. In the second variant, the dimensional chain changes and the accuracy of the closing link is influenced by other dimensions of the fixture parts. This can be seen from the diagram constructed in Fig. 3.

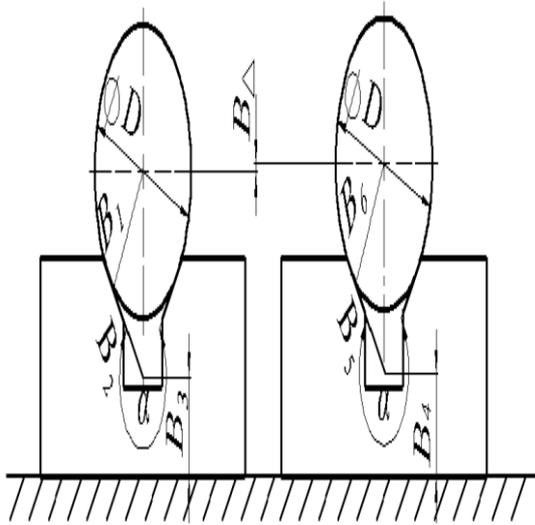


Fig. 3. Second design option.

For convenience in its compilation, the prisms are shifted in a horizontal plane with the upper surface of the plate remaining as a common base. The dimensional chain in this case is also symmetrical. The constituent links are:

$B_1, B_6$  - radius of the main journal;

$B_2, B_5$  - distance from the contact point to the top of the prism (the intersection of the two inclined surfaces);

$B_3, B_4$  - distance from the top of the prism to its base.

For convenience in determining the error of the closing link, only one (left) branch of the dimensional chain can be considered [13]. The value of the nominal value in the left branch  $B'$  will be determined by the expression.

$$B'_{\Delta} = -\frac{D}{2} \sin \frac{\alpha}{2} - \frac{D}{2tg\frac{\alpha}{2}} \cos \frac{\alpha}{2} - B_3 \quad (3)$$

$$B'_{\Delta} = -\frac{D}{2} \left( \frac{1}{\sin \frac{\alpha}{2}} + 1 \right) - B_3 \quad (4)$$

After mathematical transformations of equation (4) based on the theory of dimensional chains, the dimensional error is obtained as:

$$T'_b = \frac{T_D}{2} \left( \frac{1}{\sin \frac{\alpha}{2}} + 1 \right) + T_3 \quad (5)$$

Since the dimensional chain is symmetrical, the total error of the closing link  $T_b$  will be obtained by doubling the  $T'_b$ :

$$T_b = \frac{T_D}{2} \left( \frac{1}{\sin \frac{\alpha}{2}} + 1 \right) + 2T_3 \quad (6)$$

From this it can be seen that the error obtained when setting a composite crankshaft in a horizontal position will depend not only on the dimensions of the fixture parts, but also on the tolerance of the diameter of the main journals.

#### IV. CONCLUSIONS

Based on the analyses and calculations made for the example of assembling a composite crankshaft, it can be seen that dimensional analysis can be used to determine appropriate tolerances for manufacturing the elements of the fixtures. The results of the study can be applied not only in cases of initial assembly of products after the stage of their manufacture, but also in cases of repair. This contributes to the creation of conditions for the implementation of flexibility in assembly operations and control of the technical parameters of the assembly operation of composite crankshafts. In some cases, dimensional analysis helps to justify or reject a given design variant of the fixture. The latter must be carried out under well-defined specific production conditions. It is also necessary to know the technological capabilities for manufacturing the elements of the fixture, the accuracy of the diameter of the main journals and the required requirement for the alignment of the main journals. In individual cases, if the accuracy indicators of the assembly process are unsatisfactory, further processing of individual surfaces of the assembled crankshafts is allowed in order to ensure the necessary dimensional tolerances.

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