Coordinate model of product basing in the technological process of assembling in mechanical engineering

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Abstract. Nowadays, the automated assembly of a product uses its coordinate model, which is represented by the coordinates of some set of discrete points associated with this product. These points are used, for example, to control the spatial position of the product and to control the positioning of its assembly. The selection of structure and position of these discrete points is carried out after construction of the scheme of product basing is done, thus they are indirect technological bases of a product. The article suggests using discrete points connected with elements of product design as the indirect technological bases which are setting the scheme of a product basing.

1. Introduction
Technological bases of the product and the bases defining necessary restrictions on product transportation at different disturbing influences are defined in the course of its manufacture and operation in traditional manufacture of the scheme of product basing. Taking into account the principle of preserving uniformity of bases, the technologist aspires to choose the technological bases coinciding with design ones. But it is not always possible, because not only the geometric parameters of the product are taken into account, but also its interaction with other objects of the technological system, such as tools, equipment, technological equipment, control systems, etc. That is why the technological bases which do not coincide with the design ones are often chosen, which in relation to the latter are indirect, and to a certain extent reduce the accuracy of manufacturing the product, because they increase the length of the dimensional chain. However, the technological advantages of choosing indirect technological bases determine their increasing use in modern manufacturing. So it considerably simplifies technological assembly equipment at use as indirect technological bases of the various apertures connected with a product [1, 2]. Indirect technological bases in the form of discrete points connected with the product are widely used, which provide automation of control and spatial positioning of the product [3].

2. Model of a product basing
In machine-building manufacture the basing scheme is defined as a set of the basic points symbolizing the chosen bases of a product for definition of the set position of it in the chosen system of coordinates and imposing of necessary limiting communications on its movements (figure 1) [4]. The choice of the coordinate system is made taking into account the maximum stability of the position of the carriers of...
the main body bases, which determine the coordinate system. In manufacturing, the coordinate system of the main body (bed, body, frame) is defined by the set of bases, in relation to which the spatial position of all components of the assembly unit is determined. To simplify the basing scheme in figure 1, it is shown in the plane, where design and technological bases are symbolically represented by reference points.

![Figure 1](image)

**Figure 1.** Assembly layout: 1 - main body defining the selected coordinate system; 2 - assembly component A; 3 – assembly component B; 4, 5 – basic design bases of the assembly component A; 6 - auxiliary design bases of the assembly component A; 7 – basic design bases of the assembly component B; 8 – the technological bases of the product, which define the component's basing accuracy B; 9 – based on the element T of the technological equipment, which sets the definition of the component basing B; 10 – an element of the technological equipment that defines the force closure of the assembly.

The mutual spatial arrangement of all components of assembly unit is defined by means of design bases of a product. The error of basing is defined by known procedures of the dimensional analysis, and within the limits of admissible errors of basing the unique position of any component of assembly can be defined by the task of some set of discrete points. Such points actually replace symbolically represented reference points of the traditional basing scheme, i.e. determine indirect bases. The selection of the position of such discrete points associated with the product in modern production is most expedient to produce in the virtual space of automated systems of 3-dimensional geometric modeling of the product [5]. In such systems various objects of technological system of manufacture are easily enough and evidently modeled: the product as the object of manufacture, and also means of technological equipment, the process equipment, control and measurement means, etc. Each of material objects of technological system of manufacture in system 3D-modelling is set in own local system of coordinates in which it is also possible to set some discrete points connected with bases of each object. Mutual coordination of local coordinate systems of objects of technological system allows to define the co-ordinated schemes of basing on indirect bases not only for the main product, but also other objects of technological system.

The conducted dimensional analysis of the assembly unit basing errors allows predicting the values of deformation errors for the surfaces accepted as the product bases, which can arise from various disturbing influences, for example, pressing forces during fixation of the product, the impact of the tool, etc. [6]. Such systematic basing errors can be taken into account as compensation corrections to the calculated coordinate values of the discrete points determined.

The listed features of the discrete points connected with a product, allow to use them as the indirect bases defining its scheme of basing. The reasonability of such a solution is determined by the presence of modern technical means of coordinate control of points associated with the product in the physical space of the technological production system, such as laser tracker [7], laser radar [8], 3D scanner [9].

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At designing of technological process of assemblage of assembly unit various technological bases are chosen, in particular, necessary for the decision of a problem of spatial positioning and the current control of position of a product during assemblage. Combination of such technological bases with design bases for performance of a problem of positioning not always expedient as geometrical features of design bases in some cases complicate their control and realization of the directed moving at positioning [10]. In such cases the chosen discrete points connected with a product, can be used as indirect technological bases. Such discrete points connected with the product, we name base points.

The selection of these baselines is conditioned by the technical characteristics of the applied coordination tools and must meet a number of conditions:

- the assembly component should contain bases on which it is possible to identify and set the position of the base points, allowing their explicit physical connection with the product or the possibility of implicit connection, determined using the technical means of coordinate control;
- position of base points in relation to other bases of a product should be set with possibility of their technological reproduction and with possibility of preservation of stability within admissible errors taking into account disturbing influences;
- carriers of reference points associated with the product should provide access to them by technical means of coordinate measurements with a minimum number of their re-installations;
- technological processes that use coordinate controls should eliminate critical interference measurement procedures such as vibrations, access restrictions to the measured point, temperature extremes, etc;
- the number of base points is determined by taking into account the unambiguous certainty of the position of each component of the assembly unit, for example, to determine the position of the part of the "bush" type is enough two base points for a solid body - three base points are not lying on a straight line, while the position of the "cladding" part of low stiffness is achieved by specifying a set of base points.

The coordinates of the base points associated with the product make it possible to clearly define the position of the product in the selected coordinate system. Thus, under the coordinate model of basing we will understand a set of the base points connected with a product and defining position of the product in the chosen system of coordinates. For the assembly unit basing scheme shown in figure 1 the coordinate model of basing will look as shown in figure 2 with a simplification the basing scheme in a plane.

The coordinate system of the main body defines the basic coordinate system, which is defined by three points in space (in Figure 2 in the plane these points are $K_1$ and $K_2$. Structural elements of the main body determine the bases for specifying the coordinate certainty of the assembly component position $A$ – the basic component of the assembly. Components of the assembly unit have coordinate models represented by reference points: for the component $A - P_1, P_2$; for the component $B - P_3, P_4$. The assembly equipment may also have a coordinate model defined in its own or basic coordinate system. Then the basic element of the assembly equipment can be defined by the coordinate model – $F_1, F_2$. 
Figure 2. The coordinate model of basing the assembly unit:

Values of coordinates of all basic points defining coordinate models of objects of technological system, are formed in the course of technological designing. In particular, the coordinate models of the assembly unit and the technological equipment in the construction of the basing scheme are performed in the system of 3D modeling. It is thus important to consider that position of the base points defining both own coordinate systems of assembly unit and technological equipment, and the base points defining the scheme of basing, should be chosen taking into account possibility of their reproduction in physical space of industrial division and with possibility of access to them of system of coordinate measurements.

Thus, for the decision of one of essential problems of technological process of assemblage - definition of bases for the task of spatial definition of a product in the chosen system of coordinates of the basic body and management of spatial positioning of a product, the co-ordinate model of assembly unit can be accepted as the scheme of basing, i.e. the basic technological document for designing of technological process of spatial positioning of components of assembly unit. Such coordinate model of basing an assembly unit has its advantages:

- the possibility of a variable selection of technological and measuring bases of the component of the assembly unit, available for the current control, especially when access to the control of explicit bases of the product is difficult due to the high density of interference in the control zone;
- combination of technological and measuring bases of the assembly unit component to ensure the coordinate control of the product position at different stages of the assembly process with the possibility of ensuring the unity and constancy of bases [11];
- the possibility of taking into account in the basing scheme the deviations arising from technological influences in the performance of structural elements in a single assembly unit, which are taken into account at the stages of preliminary modeling of the distortion of the geometry of the product [12], as well as deviations of the form in the performance of robotic assembly [13];
- and others.

In order to reduce the error of the coordinate model of basing associated with the increase of the dimensional chain in determining the position of the carriers of the basic points of the product can be used the method of compensation. This method involves redistribution of a component of assembly unit, including positioning while defining position of a product in the chosen system of co-ordinates, the procedure of calibration is carried out, i.e. measurement of the actual position of indirect technological bases of a product on its co-ordinate model set earlier at a stage of technological designing. The revealed values of deviations from nominal position of base points of coordinate model are entered as compensating correction in coordinate model for performance of the next stage of technological process of assemblage.
3. Conclusion
The offered coordinate model of basing of a design of assembly unit can be created at many modern enterprises of machine-building manufacture. For this purpose it is necessary to equip the enterprise with 3D-modelling systems and technical means of spatial coordinate control of the base points connected with the product. Such coordinate model of basing of a product sets unequivocal definition of basing of components of assembly unit, and also possibility without additional transformations to use this model at the decision of industrial problems of management of spatial positioning of components of assemblage and the current control of their space position in the chosen system of coordinates of the given technical system.

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