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Determination of installation bases of parts during their mechanical processing

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Abstract. The article discusses the issues of determining the installation bases of parts during their machining. To solve this problem, its graph model was used in the place of the part itself, reflecting its structural dimensions of the connection. In this case, the determination of the installation bases was achieved by dismembering the original graph of the detail, not subgraphs, followed by their evaluation by the corresponding optimization criteria.

1 Introduction

Parts basing is one of the key issues in mechanical engineering. The quality of processing and its economy depends on the correctness of the decision.

It is known that when solving the issue of basing, the task arises of determining the laughter of installing parts during their processing. In terms of its content, the installation scheme of parts basically redefines the scheme of their basing. Therefore, from the set of installation, guides and support bases necessary for processing parts, the installation defining positions of the surfaces of the parts relative to the cutting tool on the machine have the highest priority.

The purpose of the work is to determine the installation bases of parts during their machining.

Substantiation of the method for determining the installation bases is explained below. It is known that a lot of attention is paid to the basing issues in the scientific and technical literature [1-5]. However, they are of a generalized nature and are aimed at solving particular specific problems. At that time, in the technical and educational literature, little attention was paid to determining the installation bases of parts.

When developing technological processes for machining parts, there are general patterns despite the variety of their geometric shapes, sizes, and technological requirements. These patterns primarily relate to determining and choosing the optimal amount required for the complete processing of the details of the installation bases, assessing their significance and establishing the order of their application. The correctness of the solution of these problems largely predetermines the achievement of the required accuracy of parts

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during its processing with a smaller number of transitions, which contributes to an increase in the efficiency of the technological process as a whole.

2 Materials and Methods

The solution of these problems is achieved on the basis of the analysis of the geometric shape of the parts and the identification from this shape of such a combination of surfaces (taking into account dimensional relationships), from which the positions of most other surfaces are given. Moreover, to solve this problem, it is convenient to operate not with the detail itself but with its abstract model, reflecting its structure (surfaces and its interconnections). The most appropriate model, in this case, is the graph model.

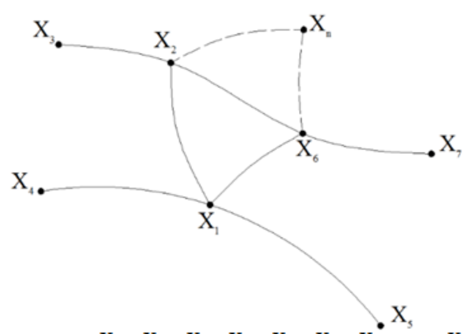
The graph model (design) G (X, U) of the i-th part is shown in Fig. 1, where the vertices of the graph xi are the surfaces of the part, and the edges ui are its dimensional relationships. By the condition of the problem, the graph G (X, U) is undirected.

The possible amount of laughter of basing the i-th part in this case, without considering its dimensional relationships of surfaces, is.

$$PG = n! \quad (1)$$

where n is the number of surfaces of the part.

From expression (1) it follows that with an increase in the number of surfaces in the details, the possible variants of their basing increase exponentially. However, as follows from the design graph of the i-th part (see Fig. 1), there are surfaces in the parts from which the position of most of its other surfaces is set. The choice of these surfaces, the assessment of their significance and the establishment of the order of their application is formalized by dividing the design graph of the part into the corresponding subgraphs, taking into account certain optimization criteria.



$$R=\begin{array}{c|ccccccccc}
 & X_1 & X_2 & X_3 & X_4 & X_5 & X_6 & X_7 & \dots & X_n \\
\hline
X_1 & 0 & 1 & 0 & 1 & 1 & 1 & 0 & \dots & 0 \\
X_2 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & \dots & 1 \\
X_3 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & \dots & 0 \\
X_4 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & \dots & 0 \\
X_5 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & \dots & 0 \\
X_6 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & \dots & 1 \\
X_7 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & \dots & 0 \\
. & & & & & & & & \dots & 0 \\
X_n & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0
\end{array}$$

Fig.1. Graph model G = (X, U) and its adjacency matrix $R = \|r_{ij}\|_{n\times n}$ i-th detail

The initial condition for dividing the graph G = (X, U) of the i-the detail into subgraphs Gi = G_i= (x_i, u_i), $x_i \subseteq x$, $u_i \subseteq u$, $i \in I$= {1,2, …, 1}, where 1 is the number of subgraphs into which the graph is divided, for compliance is described by a logical expression $\forall G_i \in P(G)[G_i \neq \emptyset]$.

$$\forall G_i, \forall G_j \in P(G)\left[G_i \neq G_j \Rightarrow \mathrm{x}_i \cap \mathrm{x}_j = \emptyset \& \, u_i \cap u_j \neq \emptyset \, \sqrt{} u_i \cap u_j = u_{ij}\right], U_i = G$$

Where $P(G) = \{G_1, G_2, \dots, G_n\}$ the set of subgraphs of the graph; $u_{ij} \subseteq u$ is a subset of edges (links) between subgraphs.

The problem of dividing the graph G = (X, U) into subgraphs belongs to problems of combinatorial-logical type, the obtained optimal solution of which is associated with a large enumeration of different variants of the partition [7].

The essence of sequential algorithms for dividing a subgraph is that first, according to a certain rule, a vertex or a group of vertices is selected, to which other vertices are then attached to form the first subgraph. The process is then repeated until a complete split is obtained. The main criterion, in this case, is the minimum of links between subgraphs and the maximum of links of the corresponding subgraphs, which fully complies with the requirements for choosing the installation bases [2].

To achieve this goal, it is necessary to specify the initial graph G = (X, U) of the i-th detail in the form of an adjacency matrix

$$R = \left\|r_{ij}\right\|_{n \times n}$$

Using the adjacency matrix for each vertex of the graph G = (X, U), we determine its local degreex_i

$$\rho(x_i) = \textstyle\sum_{j=1}^{m} x_j \qquad (2)$$

and form a set Γx_j peaks interconnected with it

$$\Gamma x_j = \{x_1, x_2, \dots, x_m\}$$

where m is the number of adjacent vertices$\mathrm{x}_\mathrm{j}$associated with the top. Moreover x_i

$$\cup_{i \in j} \Gamma x_i = X, x_i \cap x_j \neq \emptyset$$

By the greatest local degree of vertices of the graph, we define the original vertex and its adjacent vertices, and thus form the first subgraph $G_1 = (X_1, U_1)$ of the graph G. The vertex of the first subgraph of the detail in terms of content is its first (initial) setting base $\rho(x_i) = \underset{x_i \in X}{max} \rho(x_i)$.

In the case of equality of the local degrees of the vertices of the graph, their coverage coefficients are calculated. For this, a matrix of its paths is built.

In the case of equality of the local degrees of the vertices of the graph, their coverage coefficients are calculated. For this, a matrix of its paths is built.

$$D = \left\|d_{ij}\right\|_{n \times n}$$

Moreover, before respect is given to that vertex (row in the matrix of paths) which has the greatest number of vertices associated with it at a given level of dismemberment of the graph G = (X, U).

We pass to the formation of the second subgraph G_2.

$$\delta(x_i) = \rho(x_i) - \sum_{k=1}^{m} U_{ik} \tag{3}$$

where, $\sum_{k=1}^{m} U_{ik}$ is the number of edges of the graph connecting to the verticesx_i of the set Γx_j. By the minimum value $\delta(x_i) = \rho(x_i) - \sum_{k=1}^{m} U_{ik}$, we choose an initial vertex from the set Γx_j and form the second subgraph $G_2 = (x_2,\ u_2)$.

The process is repeated until a complete partition of the graph G into l subgraphs is obtained. In this case, when forming each subgraph, its weight is calculated.

The process is repeated until a complete graph partition is obtained. Ginto l subgraphs. In this case, when forming each subgraph, its weight is calculated.

$$\mathrm{K}(G_{k_i}) = \frac{1}{x} \sum_{i=1}^{n} x_i \tag{4}$$

Where x is set of vertices of the graph:
$\sum_{i=1}^{n} x_i$- is set of vertices in subgraphs.

$$\sum_{i=1}^{l} k_i(G_k) \to 1$$

The partition of the graph G = (X, U) into l subgraphs is considered complete at k = 1.

In this case, the degree of dismemberment of the graph G (criterion k_i) shows the number of installation details for its complete processing. However, in practice, there may be cases when k> 1. This indicates excessive dimensional references of the surfaces of parts during its design. Based on the above, we write down the algorithm for determining the installation details.

This indicates excessive dimensional references of the surfaces of parts during its design. Based on the above, we write down the algorithm for determining the installation details.

1. Using the i-th detail drawing compiles its graph model $G = (X, U)$.
2. We define the graph G as an adjacency matrix $R = \|r_{ij}\|_{n\times n}$
3. Using the adjacency matrix R, we determine the local degree $\rho(x_i)$ of each vertex (x_i) of the graph G and construct the set Γx_j
4. By the maximum value of $\rho(x_i)$, we determine the original and its adjacent vertices - the set Γx_j, the first subgraph $G_1 = (x_1,\ u_1)$.
5. Calculating the relative weights of the vertices - $\delta(x_i)$ of the first subgraph - of the set Γx_j from the minimum value $\delta(x_i)$, we determine the original and associated vertices of the second piece $G_2 = (x_2,\ u_2)$.
6. Calculating the relative weights of the vertices - the first subgraph - of the set by the minimum value, we determine the original and associated vertices of the second piece.$\Gamma x_j \delta(x_i) G_2 = (x_2,\ u_2)$
7. We check the completion conditions of the graph partition, $k \to 1$
8. For k = 1, the process of dividing the graph G (X, U) into subgraphs ends.

3 Results and Discussion

Implementing the theoretical prerequisites for determining the installation bases of parts will be carried out using the example of the hub of the pulley of the crankshaft of an internal combustion engine. Based on the analysis of the drawing of the hub, sixteen of its surfaces are installed (Figure 2).

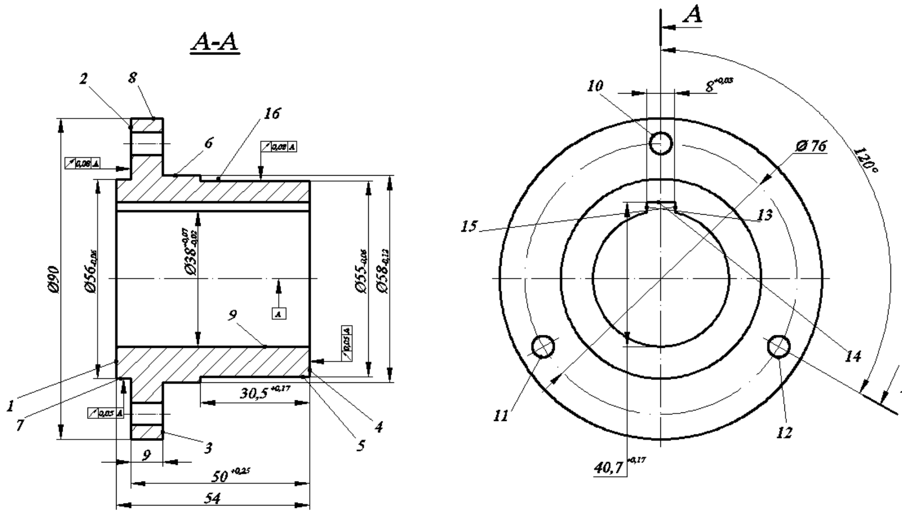


Fig.2. Engine crankshaft pulley hub

All these theoretical hub surfaces are their potential bases. To determine their set, we will compose the graph model G (X, U) of the hub (Figure 3).

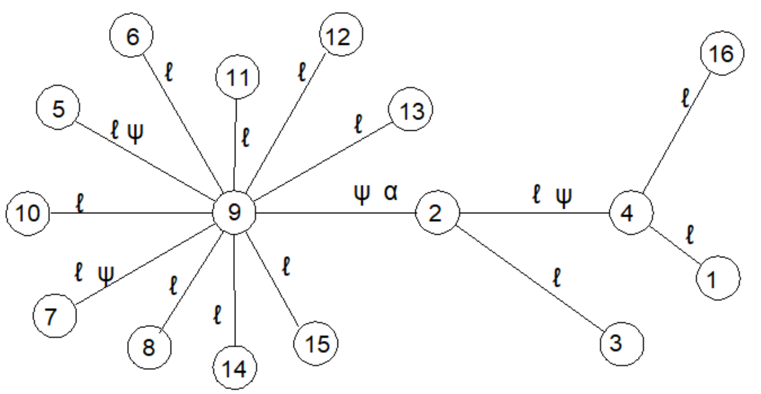


Fig. 3. Graph model G (X, U) dimensional and angular connections of the surfaces of the crankshaft pulley.

where ℓ and α are dimensions and angular bonds, ψ are special conditions

Based on the analysis of the graph of the hub model, the adjacent vertices of the graph are determined, and its adjacency matrix R = $\| |r_{ij}|_{nxn}$ which looks like this:

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$$
R=\begin{array}{c|cccccccccccccccc}
 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 \\
\hline
1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
2 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
3 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
4 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
9 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 \\
10 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
11 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
12 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
13 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
14 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
15 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
16 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{array}
$$

We begin to determine the installation bases of the pulley hub by dividing its graph into subgraphs. For this, by the adjacency matrix R= $\| |r_{ij}|_{nxn}$ graph of the model of the hub, we define the local step of each of its vertices. Their results are summarized in Table 1.

Table 1. Local degrees of vertices of the hub graph

Vertices graph model X_i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Local degree of vertices $\rho(x_i)$	1	3	1	3	1	1	1	1	11	1	1	1	1	1	1	1

As follows from this table, the highest local degree $\rho_{max}(x_i) = 11$ has the vertex 9 of the corresponding inner surface of the hub. For this vertex of the graph, identifying its adjacent ones, we form the first subgraph $G_1(x_1, u_1)$ and form the sets Γ_{x9} of the vertices interconnected with it (Figure 5).

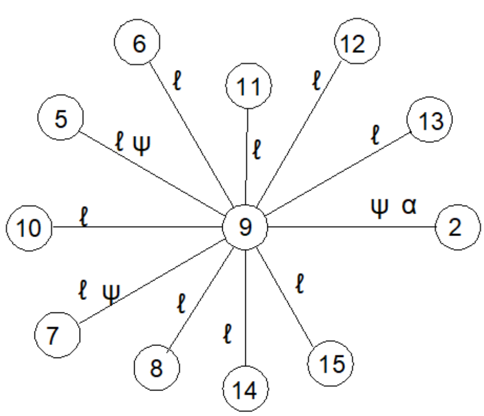

Fig.5. Subgraph $G_1(x_1, u_1)$ graph model hub: $\Gamma_{x9} = \{2,5,6,7,8,10,11,12,13,14,15\}$

Determine the weight of the first subgraph $К_{G1} = 11/16 = 0.6875$. The original surface X_9 of the first subgraph is the first setting base for the hub surfaces for inclusions in the sets Γ_{x9}.

We pass to the formed second subgraph. To do this, we calculate the relative weight of the vertices of the first subgraph G_1 included in the sets Γ_{x10} and summarize its results in Table 2.

Table 2. Relative weight of vertices of the first subgraph of the hub model graph

Vertices X_i of the first subgraph	2	5	6	7	8	10	11	12	13	14	15
Relative weight *δ(x)*	9	11	11	11	11	11	11	11	11	11	11

From Table 2, it follows that the minimum relative weight min $\delta(x_i)$=9 has vertex 2. This is the end surface of the hub. For this vertex, identifying its adjacent (outside the first subgraph, we form the second subgraph $G_2(x_2, u_2)$ of the graph of the hub model and form the sets Γ_{x2} interconnected with it (Figure 6, a).

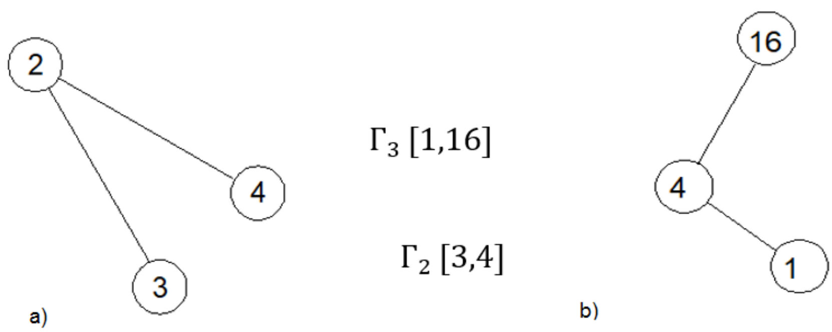

Fig. 6. Subgraphs a-$G_2[X_2, U_2]$ and б-$G_3[X_3, U_3]$ hub model graph hub model graph

Determine the weight of the second subgraph $К_{G2} = 2/16 = 0{,}125$. We pass to the formed third subgraph. For this, we calculate the relative weight of the vertices of the second subgraph G_2 included in the sets $\Gamma_{x2} = \{3,4\}$. Their relative weights are $\delta(x_3)$=3 and $\delta(x_4)$=2. In this case, $G_3(x_3, u_3)$ has the minimum relative weight min $\delta(x_i)$=2 for vertex 4. For this vertex, identifying its adjacent vertices, we form the third subgraph $G_3(x_3, u_3)$ the graph of the hub model and form the sets $\Gamma_{x4} = \{1,16\}$of the vertices associated with it (Fig. 6, b). Subgraph weight.

$$K_{G3} = 2/16 = 0.125$$

Since the surfaces included in the sets Γ_{x4} do not have adjacent vertices, the dismemberment of the pulley hub model G (X, U) is considered complete.

Checking the conditions for the dismemberment of the graph

$$K_{G1} + K_{G2} + K_{G3} = 0.706 + 0.117 + 0.117 = 0.94$$

Given the original vertex, the graph of the hub model

$$K_{G1} + K_{G2} + K_{G3} + K_{исх} = 0.706 + 0.117 + 0.117 + 0.06 = 1$$

Consequently, all surfaces of the pulley hub are covered with installation bases ⊆{10.2.4} and there are no missing dimensional references in the hub. Also, the weight of the pieces of the model graph as a whole is equal to one. This means that there are no unnecessary dimensional references in the hub.

4 Conclusions

When developing technological processes for machining parts, it is important to determine their installation bases. The achievement of the required accuracy and efficiency of the entire technological process of processing as a whole depends on the correct solution to this problem.

In the work, based on the dismemberment of the graph of the crankshaft pulley hub model, with a minimum of transitions, the necessary installation bases for its complete processing are determined.

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