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Algorithm of the Choice of the Optimum Technological Route and the Group Equipment.

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ABSTRACT: The problem of optimization of technological process basically is solved with reference to available park of the equipment at the enterprise. In work some aspects of the given problem are in detail considered and methods of its decision in which basis the method of dynamic programming lays are offered. In the present item statement of a problem of a choice of an optimum technological route is offered in view of cost of processing on the given equipment. She is formulated as a problem about a covering and algorithms of their decision are offered.

KEY WORDS: technological process, the optimum route, the automated line, linear programming, a time interval.

I.INTRODUCTION

Suppose that the number of considered parts is d_j $j=1,n$, can be processed on CT_i, $i=1,m$ machines using technological routes [1], $S_1,\dots,S_l$, and each detail using different technological routes S^i_K, $k=1, U_i$, where $\bigcup_{i=1}^{n}\{S^i_1,\dots,S^i_{U_i}\}=\{S_1,\dots,S_i\}$.

The choice of the optimal technological route for each part for a given production volume should ensure its minimum technological cost or minimum reduced costs for the production of all parts.

The technological cost $C^i_{S_j}$ of processing parts d_i on route S_j consists of the cost of processing this part on individual machines:

$$C^i_{S_j} \sum\nolimits_{t\in I_{S_j}} C^{i,j}_t$$

where is I_{S_j} the set of values of machine indices belonging to the technological route; S_j, C^{ij}_t - cost of processing the *i*-th part on the machine CT_i along the route S_j. It is assumed that the cost of reconfiguration of the machine is included in the cost of processing and the problem of coverage is solved without taking into account the time spent on parts, which greatly simplifies the solution of the problem. In this paper, issues related to the consideration of time spent on sleep are not considered.

Consider the matrix $A=\left\|\alpha_{ij}\right\|_{l\times n}$ for the problem of choosing the optimal route.

$$a_{i,j}=\begin{cases}1,\ \text{if a d}_j\ \text{go round}\ S_i\\ 0\ \text{otherwise (i=1,l,j=1,n)}\end{cases}$$

We introduce the line weights: $P_i=\sum_{j=1}^{n} a_{ij}C_{ij}$. As it was noted, the choice of the optimal technological route is carried out taking into account the cost of processing the part on this equipment.

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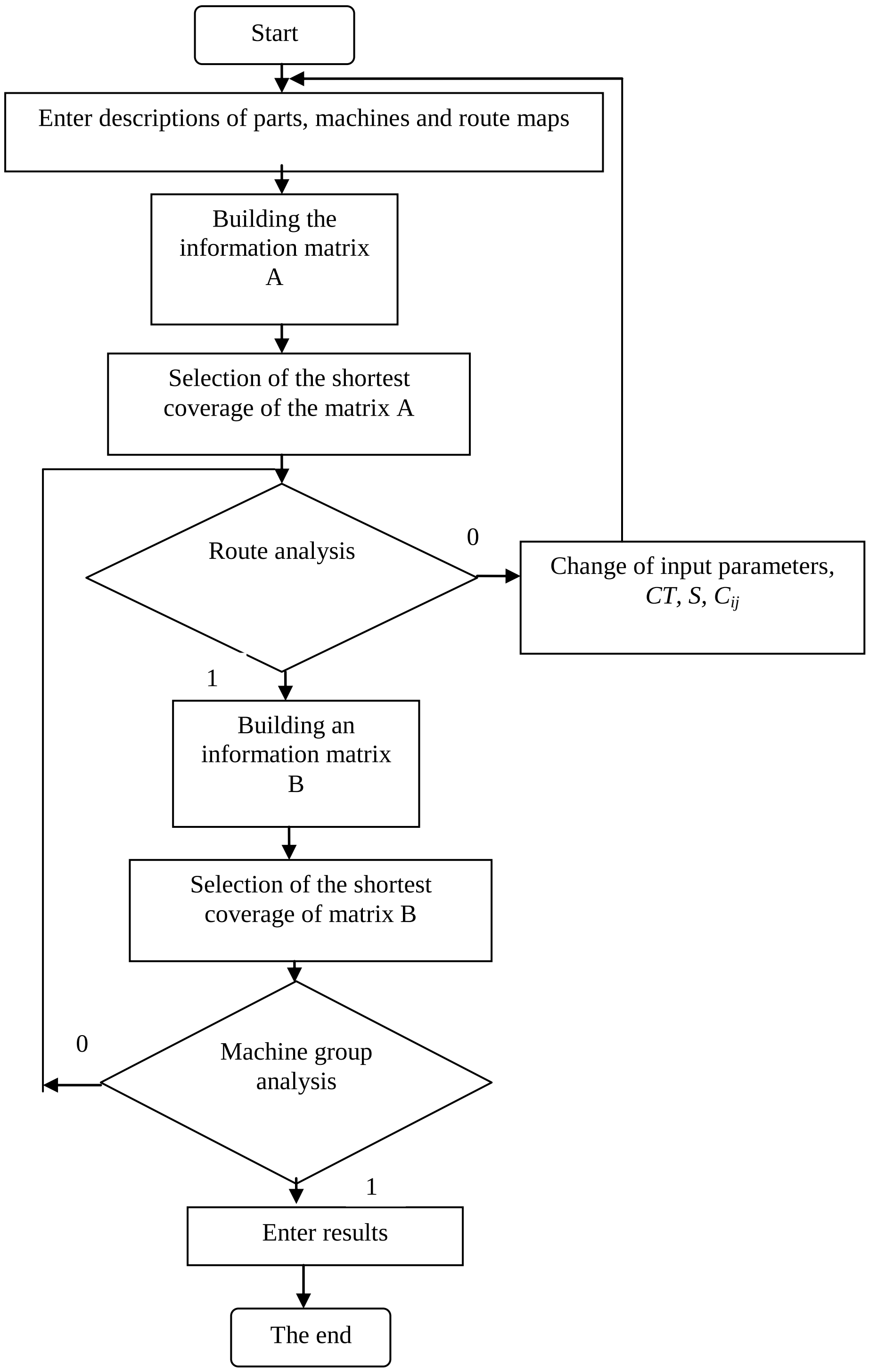

Fig.1. Block diagram of the choice of the optimal technological route and group equipment.

II. SIGNIFICANCE OF THE SYSTEM

Suppose that there are many complex parts $P^k = \{d_1^k d_2^k,...,d_m^k\}$ and a set of $CT=CT_1,CT_2,...,CT_n$ whose elements are equipment types; then you can create a matrix $B = \left\|\beta_{ij}\right\|_{m\times n}$ for solving the problem of equipment selection:

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$$\beta_{i,j} = \begin{cases} 1, \text{ if a } d_j \text{ go round } CT_i \\ 0 \text{ otherwise } (i=1, j=1, n) \end{cases}$$

Let C_{ij} denote the cost of processing the j-th part on the i-th machine. We introduce the weights P_i of the rows of the tables: $P_i = \sum_{j=1}^{n} a_{ij} C_{ij}$. Let $P_1, \ldots, P_m$ be the weights of the $CT_1, CT_2, \ldots, CT_m$ machines, respectively. It is clear that solving the problem of covering the columns of the matrix B with rows allows you to select the most efficient machines from the set *CT*, with which you can organize the processing technology for all parts D_i, $i = 1, n$. Let now $P_1^{'}, \ldots, P_l^{'}$ be the weights of the routes $S_1, \ldots, S_l$, respectively. Then the task of finding the optimal technological route is to solve the problem of covering the columns of matrix *A* with rows. Algorithms for the selection of group equipment and the optimal technological route are shown respectively in pic.1.

Consider the problem of organizing *TM* from machine tools and auto operators (robots). This problem can be broken into two [2]:

— selection of the number of machines of this model in the line;

— minimization of the time of supplying products to the line and the number of auto operators servicing the line.

Currently, to solve the first problem, there is a generally accepted method for calculating the amount of equipment on a line, depending on the specified annual program for the production of parts processed on this line [3].

Consider the second problem. To solve it, there are various approaches [4]. In the problem under consideration, it is false to single out several criteria for the efficiency of a production line: minimizing capital investments in creating a line, minimizing equipment downtime, increasing line productivity, etc.

When solving this problem, a number of informal restrictions arise, for example, related to territorial restrictions, resource restrictions, etc.

All the described criteria are interrelated, but in the two proposed approaches to solving this problem, the main criterion for improving the indicator that interests us is the line capacity.

At the substantive level, the essence of the first approach is as follows. Let the group of parts is $\tilde{A}_i = d_1^i, \ldots, d_m^i$ chosen for which the production line is organized and some line layout scheme is given. Suppose there are *n* models of machines.

The processing time of each part of the group on each model is also set, and t * is the time during which the robot serves one machine. It is clear that the number of sections, on each of which one specific operation is performed in accordance with the technological route, is equal to the number of machine models on this line. Then the number of robots in the line section can be determined as follows:

$$Z_l = \left] \frac{\min t_j^k}{t^*} \right[$$

where is the processing t_j^k time of the *k-th* part on the *j-th* model of the machine; *l-is* the area number.

The second proposed approach [5] is to reduce the number of auto operators if they are of the same type, i.e. for a given set of machines, this type of auto operator can serve any of the models of machines. Then the problem can be set as follows.

On the automated line serves the same type of product at regular intervals *t*. Each product is sequentially processed at one of n *PM*. It is necessary to minimize the time *t* of supply of products to the line and the number *S* of auto operators servicing the line.

III. EXPERIMENTAL RESULTS

This task can be divided into several subtasks depending on the conditions:

Minimize time *T* with *S=1:*

a) a task without strict restrictions on the delay time [6].

Each product is processed on *i-m* $(i = 1, n)$ PM for the time t_i, the auto-operator transfers the product from PM *i* to the aggregate (PM) $i+1$ during the time τ_i, the duration of the transition from PM *i* to PM $i+1$ is set by S_{ij}.

The route $\pi = \pi_1^i, \pi_2^i, \ldots, \pi_n^i$ of the auto operator is searched for, at which time *t* is minimal.

It is obvious that the route will be valid if there are no two events of the approach of the operator to the RM at the same time in it.

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To determine the route, we calculate T_i - the end time for processing the product at the i –*th* PM:

$T_i\sum_{k=1}^{i} t_k + \tau_k$, $i = 1, n$ where - τ_0 the time of transfer of the product from the warehouse to the production line.

Put $T = \max(\max_i t_i, \max_i \tau_i)$. Sort by increasing value $T_i(\bmod T)$, $i = 1, n$.

If, as a result, a number of strict inequalities are formed $T_{i_1}(\bmod T) < T_{i_2}(\bmod T) <,...,< T_{i_n}(\bmod T)$, then the auto-round procedure bypasses $\pi = \{\pi_{i_1}, \pi_{i_2} ..., \pi_{i_n}\}$ the desired order

In the case of the existence of two different quantities, $T_{i_1}(\bmod T) = T_{i_j}(\bmod T)$ the first place should be the value for which the expression is less $\tau_0 + S_{i+1}$;

b) a task with strict restrictions on the delay time. Here an additional condition appears: the time delay of the product at the PM after the end of processing is zero. From this condition, the condition of the compatibility of service units.

Enter the value:

$$\delta_{ij} = \begin{cases} T_j - T_i \text{ if a } T_j \geq T_i \\ T + T_j - T_i \text{ if a } T_j \leq T_i \end{cases}$$

The condition of the compatibility of the maintenance of the units along the route is $\pi = \{\pi_{i_1}, \pi_{i_2} ..., \pi_{i_n}\}$ the fulfillment of the conditions: $\theta_{ij} = \delta_{ij}$, $\mathrm{i}_{j+1} - \tau_{ij} - S_{i_{j+q}}, i_{j+1} \geq 0$.

If the θ_{ij} value is non-negative for the entire route π, then the route π is valid for the given time *T*. We assume the initial $T = \max(\max_i t_i, \max_j t_j)$ and determine the route π_j as in p. A).

We check the route for admissibility. If the route is invalid (exists $\theta_{ij} < 0$), then we set *T=T+I* and repeat the calculation from the beginning.

Minimize the time *T* and the number of auto operators with *S>1*. It is known that in any ordered set (with a relationship graph) pairwise disjoint chains can be distinguished, containing together all the elements of this set. We present the well-known theorem [7].

Theorem 1. The minimum number of chains in the decomposition of an ordered set *N* is equal to the maximum number *S* of pairwise incomparable elements of this set.

Proceeding from this, we define the time intervals $W_i = (T_i, T_i + \tau_i)$, where they are introduced T_i, τ_i. Let us specify $W = \{W_1, W_2, ..., W_n\}$ the order relations on the set. We say that the interval precedes if $T_i - T_j \geq \tau_i + S_{ij}$. We are looking for the smallest number of pairwise disjoint ordered subsets (chains) of the set *W* covering this set. By the theorem, this number is equal to the maximum number of pairwise incomparable elements of the set *W*. For this, one can use the existing methods of linear programming.

Let $\{C_1, C_2, ..., C_l\}$ be some decomposition of the ordered set *W* and the chain C_n has the form $i_1 \to i_2 \to ... i_r$. Let us compare this decomposition with the set of values of *(n + 1)* variables x_{ij}, i, j=1,0, assuming $x_{00} = n-1, x_{oj} = 1$ that *j* is the minimal element of some decomposition chain (in particular,); if j is maximal in some decomposition chain $x_{0i_1} = 1, x_{jo} = 1$ if in some chain of decomposition *i*, the value of *i* immediately precedes *j*; the values of the other variables are set to zero [8].

In order for a set of variable values to correspond to some decomposition $\sum_{j=0}^{n} x_{oj} = 1$, it is necessary to fulfill the constraints, $x_{ij} \geq 0$, *i*, j=o,n .

IV. CONCLUSION

If, in addition, we require that the variables x_{ij}, with the possible exception of x_{oj}, take only zero and one values, and each time *i* does not directly precede *i* in a certain decomposition chain, $x_{ij}=0$, then it is possible to establish a one-to-one correspondence between the set of all expansions and a set of sets of values of variables x_{ij}. In this case, we face a special case of the linear programming transport problem, which has an integer solution.

In practice, the following particular case of this problem most often occurs. Each auto operator can serve only a group of RMs, arranged sequentially one after the other in the order of product processing, i.e. seems to be a connected group. The number of such groups is equal to the number of auto operators on the line.

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