ECONOMICS AND ORGANIZATION

OPTIMIZATION OF SCHEDULE GRAPHS FOR AUTOMATIC PROCESS CONTROL SYSTEMS IN MEDICAL ENGINEERING FACTORIES

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In the creation of automatic process control systems (APCS) in medical engineering factories based on ES computer models, particular importance must be given to production planning, allowing for restrictions imposed by resources and equipment, and for information on actual performance of the graph during the previous planning interval (day, 10-day period, month, and so on), and also for the observance of offloading the finished product to the consumer. Optimization of schedule graphs of production is an urgent problem, for a considerable economic effect from the creation of APCS is expected from the automatic solution of the problems of optimal planning and production analysis.

THE PROBLEM AND DEFINITIONS

The problem is to work out schedule production graphs for departments (production units) based on the criterion of minimization of the total time taken in finishing the part.

Suppose that in the department on j (j = 1, m) pieces of equipment i (i = 1, n) parts are finished. The stock of working time of the j-th piece of equipment

\[ f_j = f_{jN} \lambda_j (1 - \mu_j), \]  

where \( f_{jN} \) is the nominal stock of time; \( \lambda_j \) the coefficient of renewal; \( \mu_j \) the coefficient of loss.

The order of finishing the parts is assigned by the matrix \( F \);

\[
F = \begin{pmatrix}
F_1 \\
\vdots \\
F_n
\end{pmatrix},
\]

where

\[
F_i = \{x_{i1}, \ldots, x_{ij}, \ldots, x_{in}\},
\]

\[
x_{ij} = \begin{cases} 1, & \text{if } i\text{-th part is finished on the } j\text{-th piece of equipment}, \\
0, & \text{if it is not finished}. \\
\end{cases}
\]

In this case \( x_{ij} = 1 \), if the i-th part is finished on the j-th piece of equipment, and \( x_{ij} = 0 \) if it is not finished. The work content of finishing a batch of \( i \) parts on the j-th piece of equipment is:

\[
t_{ij} = \frac{x_{ij} P_{ii}}{k_j},
\]

where \( t_{ij} \) is the standard time for the operation per part; \( P_{ii} \) the size of the batch at the start; \( k_j \) the coefficient of overfulfillment of the norms.

The time \( t_{ij} \) of transportation and the time \( t_{ij} \) of readjustment are known. In that case the matrix \( T \) assigns the work content of the part operations:

where

\[ T_i = \{ t_{i1}, \ldots, t_{ij}, \ldots, t_{im} \}, \quad (i = \overline{1,n}), \quad (j = \overline{1,m}). \]

Let \( t_{i}^{b} \) denote the time of beginning of performance of the operation and let \( t_{i}^{e} \) be the time of ending of the finishing work, so that the standstill time between operations of the \( i \)-th part before the \( j \)-th operation will be

\[ p_{ij} = -t_{i}^{e} + t_{i}^{b}, \quad (i = \overline{1,n}), \quad (j = \overline{1,m}). \]

For each part within the interval \([0,P]\) the planned period of output \( P_{i} \) is known, and in that case the acceptable standstill time \( a_{i} \) in the process of finishing will be

\[ a_{i} = P_{i} - t_{i}, \quad (i = \overline{1,n}). \]

Let us define:

\[ t_{i} = \sum_{j=1}^{n} t_{ij}, \quad (i = \overline{1,n}). \]

and in that case, from the relationship

\[ t_{j} - t_{ij} = d_{j}, \quad (i = \overline{1,m}) \]

the acceptable standstill of the \( j \)-th machine \( d_{j} \) is determined.

Next, it is natural to suggest that the values of \( a_{i} \) and \( d_{j} \) are not negative, i.e.,

\[ a_{i} \geq 0, \quad d_{j} \geq 0, \quad (i = \overline{1,n}), \quad (j = \overline{1,m}). \]

Let us make the following assumptions: The finishing and transfer of the parts are done in batches; at any one work place more than one part cannot be finished at the same time; if the finishing of a part has begun, it will not be interrupted until the part is completely finished.

Definition 1. The part will be called critical if \( a_{i} \leq R^{*}, \quad i \in W \) where \( R^{*} \) is the assigned level of criticality for parts, determined from the concrete conditions of production; \( W \) is the set of critical parts.

Definition 2. The equipment will be called critical if its acceptable standstill \( d_{j} \leq R^{**}, \quad j \in \Omega \), where \( R^{*} \) is the assigned level of criticality for the operations, defined on the basis of the concrete conditions of production; \( \Omega \) is the set of critical equipment.

Definition 3. Let a state of conflict be the name given to a situation in which, on the \( j \)-th piece of equipment at the \( l \)-th iteration \( n - 1 \); \( m \), the columns of the matrix \( F \) regarded as iteration), \( N \), \( N > 1 \) part are claimed and condition \([1]\) is fulfilled:

\[ \left[ \left( t_{ij}^{e} \right)_{k=\overline{1,N-1}} \right] \cap \left[ \left( t_{ij}^{b} \right)_{k=\overline{2,N}} \right] = \emptyset. \]

The graph formed without conflicting situations can be called optimal, for the min of total time of performance of all the operations of the production cycle in finishing the parts is achieved.