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Rational syntheses of technological processes of assembly

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ABSTRACT

Changing an organization of moving the products during constantly brings about one and same results: changes a total idle time values of equipment, changes duration of production cycle, and changes a total wait time of items that brings about work-in process change. The analysis of time structures of technological processes has allowed choosing typical structures, which are appropriate to various kinds of specialization of manufacture. The interrelation of time, reliability and cost parameters is considered and the ways of optimization of time technological chains are specified.

INTRODUCTION

In modern industrial conditions different operations are carried out in different conditions, and consequently, with their various duration. Operation synchronization at large engineering distinction of producing items is especially difficult and in many cases even impossible. At different duration each pair of adjacent operations absorbs or accumulates stock, if it is not available item storage or equipment standstill will be observed. Stock storage needs interpreting stores. However, store using essentially contradicts the requirement of manufacture continuity because the industrial areas and production cycle duration increase.

DETERMINATIONS OF COMPONENTS OF TIME CHAIN

In general the production cycle duration can be defined relation [1]

$$Tc = t_{tc} + t_k + t_{tr} + t_w, \quad (1)$$

Where t_{tc}- technological time;

t_k - control time;

t_{tr} - transporting time;

t_w - waiting time.

Time of storage and transportation makes about 90% of production cycle duration Fig. 1 shows work cyclogram at item assembly, during which three operations are carried out. For clearness transportation time is not taken into account. As Fig.1 shows, item manufacturing cycle duration Tc_j increases with item j-th quantity increase (work-in process increases). It is necessary to use the store for reversible stock storage between the second and third operations. Redundant quantity of manufacture objects before the second operation excludes possible waiting of second working place because the assembly units' being not available. The second working place is maximum loaded.

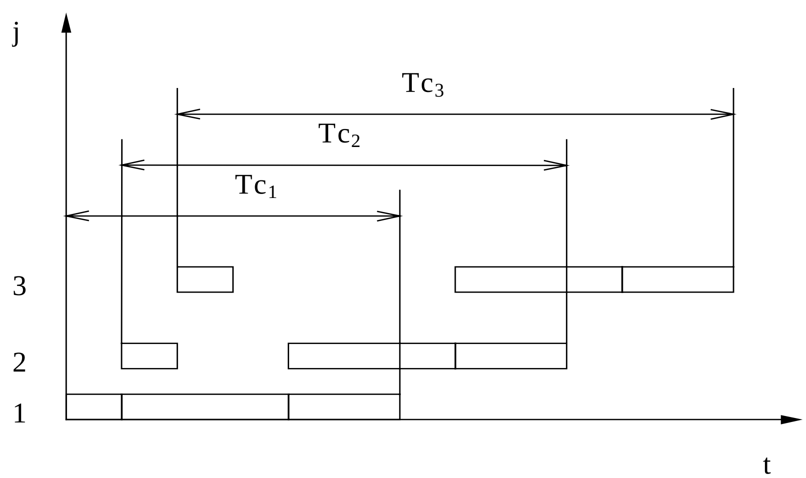

FIG. 1 - CYCLOGRAM OF ASSEMBLY OF PRODUCT

In conditions of CAM each technological equipment has determined reliability. Failure of automatic equipment bring about changing a running time of operations (Δt_{rel}). According to theories of time chains, each operation has certain tolerance of time for its execution (field of dispersion - ω), in conditions of production in series, at fabrication of products of different names also necessary reserve for setup (Δt_{set}).

While performing the task with casual duration of t_R, function of distribution y (t) and density of distributions W(t) = y' (t), the probability of the trouble-free functioning of the system will be the following [2]:

$$P(t,\Omega)=\int_0^{\infty}P\{t_R(x)<t\}dy(x)=\int_0^{\infty}P\{t_R(x)<t\}W(x)dx, \quad (2)$$

Where: Ω - set of parameters that determine the meanings of the reserve of time, ways of its use and updatings.

t – operation time;

t_R – real operation time.

To find the dependence between the sizes of fields of dispersion of the components of the time chain and its closing link by analogy with dimensions chains one can use the complete differential taking into account that the quantities of the fields of dispersion are a small quantity in comparison with the sizes of the components[3]:

$$t_\Delta = f(t_1; t_2; \cdots; t_{k-1}) \quad (3)$$

the complete differential of the function

$$dt_\Delta = \frac{\partial t_\Delta}{\partial t_1}dt_1 + \frac{\partial t_\Delta}{\partial t_2}dt_2 + ... + \frac{\partial t_\Delta}{\partial t_{k-1}}dt_{k-1} \quad (4)$$

By replacing differentials with small final increments, which represent in this case the sizes of the fields of dispersion we shall receive:

$$\omega_\Delta = \sum_{i=1}^{k-1}\left|\frac{\partial t_\Delta}{\partial t_i}\right|\omega_i, \quad (5)$$

Where: t_Δ - time of a closing link of a time chain;

t_i - making i-th part;

ω_Δ - field of dispersion of a closing link;

ω_i - field of dispersion i-th of a making link;

k - total of the components in a time chain,

$\frac{\partial t_\Delta}{\partial t_i}$ - numerical meanings of an expression of individual derivatives (gear relations) that show the influence of the field of dispersion of each component on the size of the field of dispersion of the closing link. If in a time chain there are parallelly located parts Eq.5 becomes the following:

$$\omega_\Delta = \sum_{i=1}^{k-1}\omega_i \quad (6)$$

From Eq. 6 it follows that the field of dispersion of the closing link of the temporary chain with parallel components is equal to a sum of absolute meanings of the sizes of fields of dispersion of all components.

Thereby early term of execution i operations will is:

$$t_i^{min} = t_i, \quad (7)$$

but late:

$$t_i^{max} = t_i + {}_\Delta t_i, \quad (8)$$

where

$${}_\Delta t_i = {}_\Delta t_{rel} + \omega + {}_\Delta t_{set} \quad (9)$$

BOUNDARY PROBLEMS TO OPTIMIZATION OF TIME STRUCTURES

Which duration of technological process allows this process to be made without intermediate stores; secondly, practically to decline to zero the time interpreting item, and consequently, about to reduce cycle duration of items' manufacturing for 90 %.

BUILDING OF STRUCTURE WITH MINIMUM DURATION OF PRODUCTION CYCLE

Let it is necessary to make an item, executing three operations Fig. 2. Fulfillment's time of each operation is t_i which has the admission Δt_i. For clearness we don't take into consideration transportation's time.

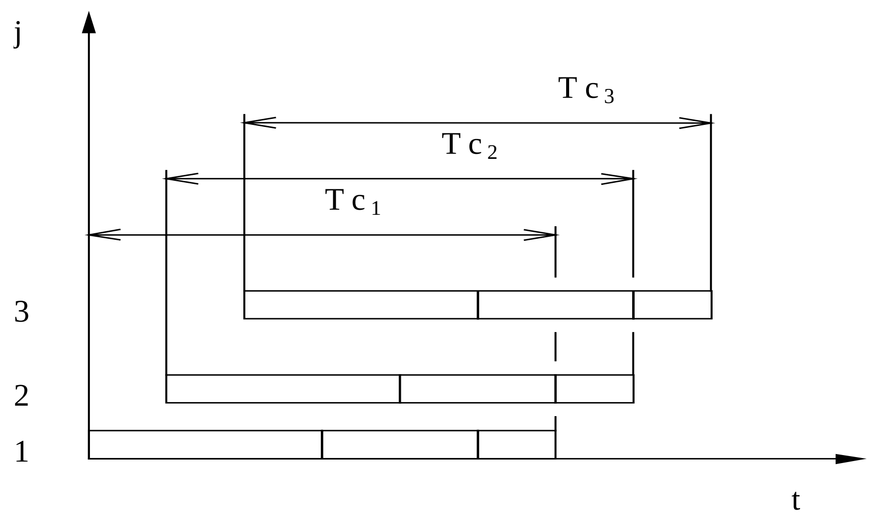

FIG. 2 - CYCLOGRAM Tc^{min} - STRUCTURES

It's necessary for work without interoperation stores that time of the second operation's fulfillment will be less or equal to the first operation's duration. As the second operation also has the certain time admission, the second operation's duration should be equal [4]:

$$t_2^{min} \le t_1^{min} + \Delta t_1 - \Delta t_2. \quad (10)$$

If this condition isn't executed, the object of manufacture will approach to the technological equipment earlier, than it will be released of the previous object's manufacturing, thus we'll receive result considered on Fig. 1 (an accumulation of parts between operations).

The execution of the following condition is necessary for the exception of the interoperating storage between the second operation the third one:

$$t_3^{min} \le t_2^{min} + \Delta t_2 - \Delta t_3. \quad (11)$$

Thus, the construction of operation sequence on their duration reduction not less than on the time admission size at the executive of the operation is necessary for work without interoperating stores. In this case interoperating storage of objects between working places is absent, the duration of a production cycle remains constant and minimum quantity of products in manufacturing is observed. In this case the interoperating storage’s time is equal to zero.

BUILDING OF STRUCTURE WITH MAXIMUM LOADING AN EQUIPMENT

Let it’s necessary to execute three operations for a products manufacturing , and the first operation has the least duration, and third has the longest one. In this case the accumulation of manufacture’s objects will be observed before each of the working places interoperating stores are necessary before each working place (except the first).

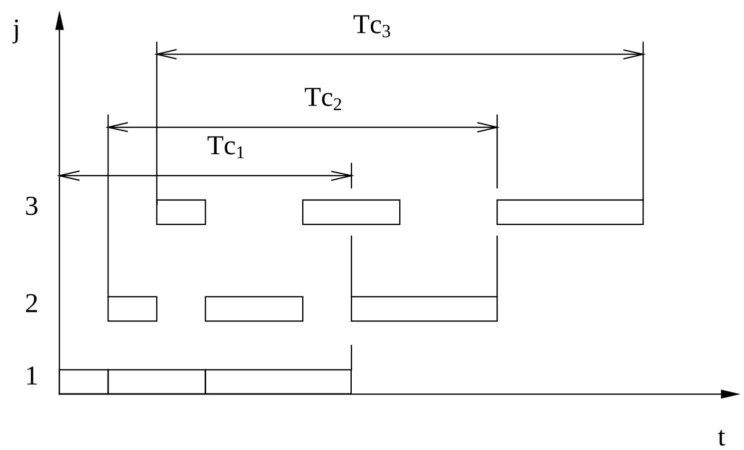

FIG. 3 - CYCLOGRAM OF STRUCTURE WITH MAXIMUM LOADING AN EQUIPMENT

The volume of uncompleted manufacture is increasing with the extension of executed products quantity (the quantity of products, which are in store, is increasing), that results in the gradual complication of the production control. However such a construction of operation’s sequence allows to exclude the standing idle of the equipment for the reason of the manufacturing objects absence. Factor of the machine tools’ load in this case will be maximum.

MATHEMATICAL MODELS OF BOUNDARY TIME STRUCTURE

From the executed analysis of various ways of a temporary sequence construction of operations it comes out, that between production cycle duration and the equipment exists load there is the contradiction, which disappears when the duration of all operation is equal.

For work with the maximum of the equipment load the following conditions are necessary [4]:

– When piece transfer of manufacture objects is used:

$$\sum_{i=2}^{k} t_{ij} + \sum_{i=2}^{k} (t_i - t_{i-1})(j-1) \ge \sum_{i=1}^{k-1} t(j+1)(i-1) + \sum_{i=2}^{k-1} (t_i - t_{i-1}) j, \qquad (12)$$

Where t_{ij} - time of executive i - th operation over j - th by a product;

j - number under the order of a made product;
k - total of operations.

When the lot transfer of production objects is used:

$$\sum_{i=2}^{k} t_{ij} N_j + \sum_{i=2}^{k} (t_i - t_{i-1})(j-1) \geq \sum_{i=1}^{k-1} t(j+1)(i-1) N_{j+1} + \sum_{i=2}^{k-1} (t_i - t_{i-1}) j, \tag{13}$$

Where N_J and N_{J+1} - accordingly the size of the lot in the output j - th. and (j + 1) - th. items.

The execution of the following conditions is necessary for work with the minimum duration of the production cycle :

– When piece transfer of manufacture objects is used:

$$\sum_{i=2}^{k} t_{ji} \leq \sum_{i=1}^{k-1} t_{(j+1)i} \tag{14}$$

– When the lot transfer of production objects is used:

$$\sum_{i=2}^{k} t_{ji} \cdot N_j \leq \sum_{i=1}^{k-1} t_{(j+1)} \cdot N_{(j+1)} \tag{15}$$

In the automated serial production, as a rule, the distance between the equipment, executing the separate operations of the technological process of each concrete product is different and that is why transportation time is different between the operations. When the structures analyses of the technological processes is executed, time of transportation is necessary to take into consideration in this case. As in the given formula.

$$t_{ji} = t_{ji} + t_{tri}, \tag{16}$$

Where t_{tri} - time of the transportation after the executive of i-th operation.

COMPARATIVE FEATURE OF WAYS OF BUILDING OF TIME STRUCTURES

The mode providing the minimum duration of a production cycle:

Advantages:

– Exclusion of idle standing of work items before the working places (operation complexes), hence manufacturing cycle reduction
– The time reserve for operation execution
– The uncompleted manufacture and turnaround means reduction
– The possibility for the issue tact regulation by the gradual reduction of the operation duration, which makes it possible to increase the productivity of the whole complex by the perfection of the equipment involved in the technological process execution
– The flexible duration of some operations
– The fund-returning and manufacture profitability increase

Disadvantages:

– The equipment downtimes before the execution of the next operation, hence the factor reduction.

The mode, providing the maximum equipment load:

Advantages:

– No equipment downtime, hence factor increase

– The `possibility for the issue tact regulation by the gradual reduction of the operation duration's starting with the last one
– The flexible duration of some operations

Disadvantages:
– The necessity for the intermediate savers
– The uncompleted manufacture increase
– The necessity for the additional load of the equipment completed its issue program
– After serial number of the handling detail increasing manufacturing cycle duration increases

CALCULATIONS OF FEATURES OF TIME OF PRODUCTION PROCESS

Time of running a production process is production cycle (Tc) characterized by length of, idle time (t_{idl}) values of equipment and wait time (t_w) of parts in the production. All three features, in particularities two last, powerfully hang from the value of maximum length of one of the operations, from average length of all operations and from degrees of asynchronous length of operations.
Our laboratory to automations of technological processes and manufactures (ATP&M), headed Prof. Nikolay Zakharov. is designed standard time structures, which are based on combinations of ways specified in sections 3. This structure-modulas are programmed on the certain economic effect, which value depends on amounts of production restrictions and spectrum to realization a structure on the concrete enterprise. Elements are presented by mathematical models, for the determination of output parameters which designed algorithm Fig. 4 and software [4].

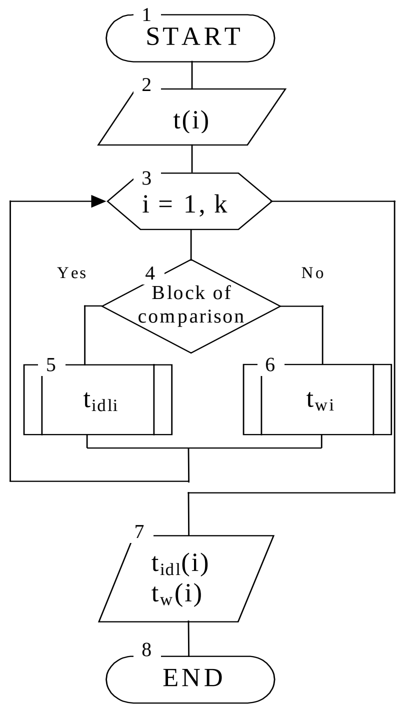

FIG. 4 - ALGORITHM OF CALCULATION t_{idl} AND t_w

Using these modulas possible to decide a direct problem. To Lead a rational technological system building, on output which it is necessary to get a given economic effect. As well as decide inverse problem to define a potential of existing structure and indicate ways of optimization.

Developping software handles arrays of data. Is it At the input formed array of data of running time t(i) of each operations, but on output arrays idle time $t_{idl}(i)$ of equipment and waiting time $t_w(i)$ after each operations.

In general event arrays of data will be of the form of Fig.5:

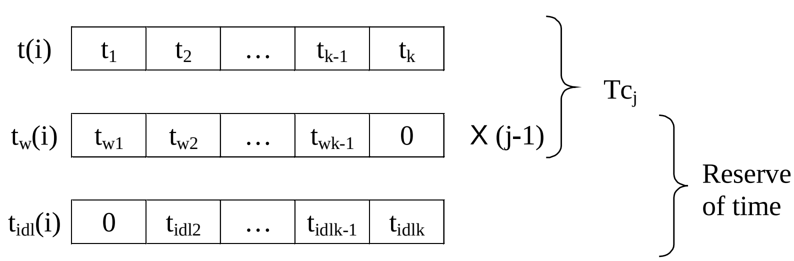

FIGURE 5. TIME ELEMENTS OF PRODUCTION PROCESS

Since after last operations is absent imet storage, but after first is absent idle equipment, corresponding array elements are a zero. Time of production cycle is defined as array element amount ti and twi:

$$Tc_j = \sum_{i=1}^{k} t_i + \sum_{i=1}^{k-1} t_{wji} \qquad (17)$$

In the event of full synchronizing the operations of technological process arrays ti and twi will be of the form of Fig6:

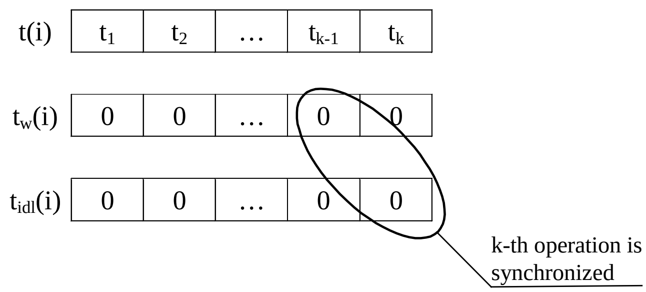

FIG. 6 - FULL SYNCHRONIZATION OF OPERATION

In rest events presence on i -th operations of zeroes in cells of arrays t_{idli} and t_{wi-1} indicative of synchronizing during given operations. The Rest array elements are not than other as renewed by the time reserve when performing the operations.

Besides t_{wi} - accumulated time reserve. In general type time reserve when performing i -th operations will is:

$$\Delta t_{rez.i} = t_{wi} + t_{idli} \qquad (18)$$

Time between failures this system, for period of t_{us} usage's, possible presence in the manner of graphics of using an time reserve t_{rez} Fig.7.

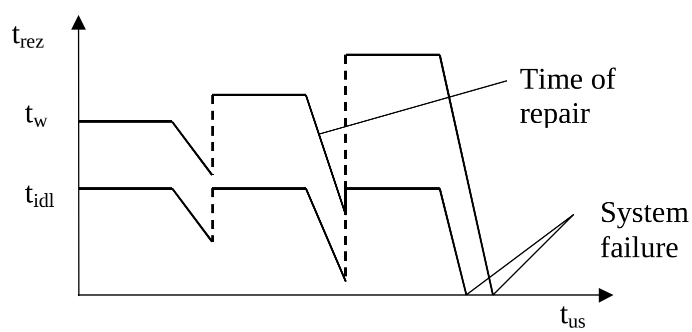

FIGURE 8. TIME BETWEEN FAILURES OF SYSTEM WITH TIME RESERVE

In that event, when time of repair after failure on concrete operations is not beyond the scope of total time reserve to this operations, the failure effects of equipment do not render influences upon functioning a technological system that all important in conditions of CAM.

It is possible to make the following conclusions from the analysis of dependencies between duration of the industrial cycle and charge of the equipment.

– The contradiction exists between the minimum industrial cycle and the maximum charge of the equipment, which disappears at equality of all operations duration.

– It is necessary to construct a sequence of operations on reduction of their duration as a minimum on size of the temporary admission between the adjoining operations for exception of interpreting storage of products during their manufacturing.

– It is necessary to construct a sequence of operations on increase their duration as a minimum according to size of the temporary admission between the adjoining operations for exception of equipment by reason of absence of the object of manufacture..

For rational organizations of production it is necessary in the complex to value an influence of all time elements of the technological process, on economic factors and reliability factors to usages, considering consequences to minimization.

CONCLUSION

The novelty of the approach to the analysis and maintenance of the reliability of technological process consists in «weighing» refusals according to the expenditure of time. It allows to open and use for maintenance of normal functioning of systems internal reserves (time in particular), incorporated in systems themselves , deeper penetration into the essence of the researched processes of functioning allows to reveal and to prove new, effective methods of maintainiry the reliability of complex systems in real conditions of operation.

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