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ASSIGNMENT METHOD OF TECHNOLOGICAL EQUIPMENT IN FLEXIBLE MANUFACTURING SYSTEMS

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Abstract: In this article an assignment solution of technological equipment disposed on a line or in the plane on two or more lines is presented. On the assignment's grounds is a mathematical programming issue having its solution in a numeric calculation method, called MatLAB.

1. GENERAL ASPECTS

Assignment of the technological equipment within flexible manufacturing systems (*FMS*), is influenced by several factors, out of which two are determinative[1]:

- shape and ratio of the spacing surface sizes;
- number of item changes between equipment.

Further on the case of a spacing surface having a rectangular shape, as it is the case of most real situations, is analyzed. But the sizes ratio is the parameter which influences spacing, as follows:

- if the width of the spacing surface has a comparable size order, but larger than the maximal width of the technological equipment, spacing is made compulsory rectilinear on a single line;
- if the width of the spacing surface is larger than 2 x the width of the equipment, there may exist several alternatives: spacing on two lines of the same conveying path, spacing on a single side, but more conveying paths, combinations of these, complex paths, etc.

In the case of *FMS* for cases, in the most of cases the rectilinear shape of the conveying path and combinations of rectilinear paths are used. Conveying – transferring paths more complexes are met in the case of sole exemplar production (such as *FMS* for master patterns), where the whole technical – economical base is of an other nature. Conclusion may be drawn, that the analysis of spacing opportunities of the equipment on different combinations of rectilinear paths is covering in the case of cases processing *FMS-s*.

A very influent parameter [4],[5] both for fixing the order of devices and in solving the above alternatives, is represented by the number of item changes between devices, during the time *T* (as the basic batch designed is processed).

2. DEFINITION OF THE OBJECTIVE FUNCTION

The proper solving of the spacing issue is made on grounds of the results obtained in the sizing stage in stationary regime of the processing subsystem. Known are: the number and type of the technological devices with all their specific parameters, the technologies applied within the system and the number of each item type manufactured by each technology, executed on each device. This information allow the calculation of the item number conveyed between two devices within the system.

There are at least three reasons for which devices with a high number of mutual item changes have to be neighbors, related to other, with lower number of changes. These reasons are:

- conveying time is lesser;
- conveying costs are lesser;
- traffic control is facilitated.

Considering the total conveying cost as objective function, the issue of its minimizing is put.

If conveying between two stations is made with a shifting robot or an individual transport system, than between two stations, the transport system shifts according to a law, which, very simplified is presented in figure 1:

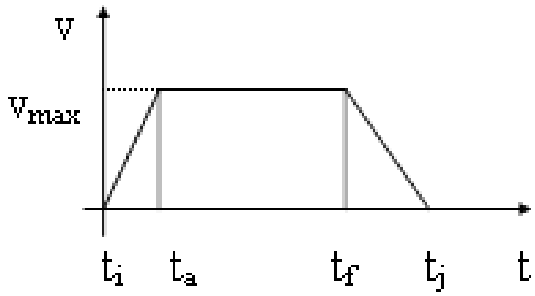

Fig.1. Displacing law of the conveying system

t_i – starting time from station *i*; t_f – initial braking time; t_j – arriving time to station *j*; t_a – final accelerating time; *v* – displacing speed.

Spaces path during time spans (t_a-t_i) and (t_j-t_f) are the same, regardless to the distance between the two stations. These two stations S_a and S_f are representing constants of the individual conveying system, insignificantly changed by situations, such as: tension decreases of the storage battery, etc. What makes the difference between the cost and conveying time is the space routed by the conveying system during the time span (t_f-t_a), S_{ij}.

Total conveying cost between station *i* and station *j*, will be:

$$C_{ij} = C_a S_a + C_f S_f + C_{v_{max}} S_{ij} \quad (1)$$

where: C_a – accelerating cost;
C_f – braking cost;
$C_{v\,max}$ – unit cost of the spacing as per speed v_{max} .

These costs include the energy consumed, spoilage, damping, maintaining, etc.

The total space routed by the conveying system between stations *i* and *j* will be:

$$S_{tij} = d_{ij} S_{ij} \quad (2)$$

where: d_{ij} – is the number of displacements between the two stations and is calculated on grounds of the results obtained in sizing the processing subsystem.

Considering a half-axis where the two stations are disposed at the positions y_i and respective y_j (fig.2.), the relation as below may be written:

$$\left|y_j - y_i\right| = S_a + S_{ij} + S_f \tag{3}$$

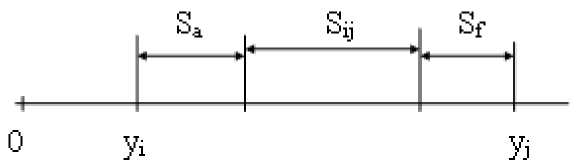

Fig.2. Two technological devices linear disposed

Further on we presume that all devices are arranged on a half-axis having in its origin the central store (in position $y_0=0$) and in the opposite part, the central store in position y_{G+1} , and in position y_j , *j=1, 2, …, G*, technological devices are placed (fig. 3.). *G* represents the total number of technological devices.

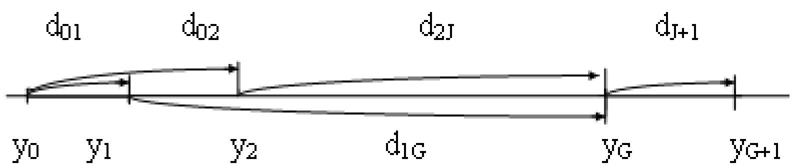

Fig.3. Linear spacing of J devices

The total cost of N_u conveying operations (N_u known) will be:

$$C = C_{v_{\max}} \sum_{i=0}^{G-1} \sum_{j=0,\, j=i}^{G+1} d_{ij} \left(\left|y_j - y_i\right| - \left(S_a + S_f\right)\right) + N_u \left(C_a S_a + C_f S_f\right) \tag{4}$$

Minimization of the expression (4), containing characteristic parameters of the conveying system: $C_{v\ max}$, S_a , S_f , C_a and C_f is to be followed. The issue of conveying not being definitive in this stage of the project drawing up, the circle may be broken in to manners:

a) by using recommended average values by the literature or company catalogues;

b) by remarking the fact that the above mentioned parameters appear as constant values in the expression (4), which are subtracted or added in equal quantities, regardless to the arrangement manner of devices, being used as objective to minimize the expression (5.):

$$D = \sum_{i=0}^{G} \sum_{j=0,\, j=i}^{G+1} d_{ij} \left|y_j - y_i\right| \tag{5}$$

Expression (5), represents the variable part of expression (4), and it will finally determine the minimal cost value. This expression will be further used.

3. SPACING CASES OF TECHNOLOGICAL DEVICES

The effective spacing is made by considering three cases:

- length *L* (or width) of the spacing rectangle being higher than the sum of spaces required by each device;
- length of the surface allotted is not sufficient;
- number of technological devices is too high.

3.1. The length *L* (or width) of the spacing rectangle is higher than the sum of spaces required by each device

It's the case of a small number of devices. We are considering that the technological devices, or contrary, the loading – unloading stations of the conveying system are disposed at equal distances (figure 3) at a well-known distance *d*. Distance *d*, has to be larger than the space needed to the largest device and has to take into account also the probable need of local stockers.

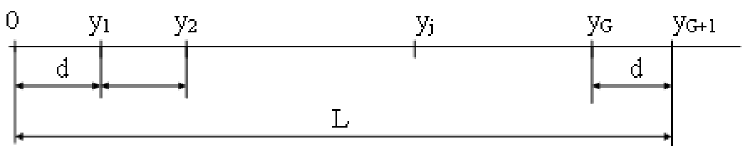

Fig.4. Linear spacing on a line of the devices

Position y_j *(j=1, 2, …, G),* of the device *j*, is obtained by solving the optimization issue:

$D \rightarrow \min.$

$$\begin{aligned} &\sum_{j=1}^{J} y_j = dJ \\ &\sum_{i=1}^{G-1}\sum_{j=i+1}^{G} y_i y_j = d^2 \sum_{i=1}^{G-1}\sum_{j=i+1}^{G} ij \\ &. \\ &. \\ &. \\ &y_1 y_2 y_3 \ldots.. y_J = d^J G! \end{aligned} \tag{6}$$

As it may be observed, the constraints of the issue (6) are even the Viete relations, giving the coefficients of a polynomial equation of grade *G*. In stead of this, for *G* times it could have been written and once for each y_j , a polynomial equation.

In this case, the optimization issue of the device's position *j*, has the shape (7):

$D \rightarrow \min.$

$$y_p^J - d^2 \sum_{i=1}^{G-1}\sum_{j=i+1}^{G} ij y_p^{G-1} + \ldots. + d^G G! = 0 \;;\; p=1, 2, \ldots, G \tag{7}$$

The constraints are imposing the multitude of possible positions (relations are symmetrical related to the variables y_j), and the objective function decides the final positions according to the intensity of the mutual changes.

3.2. The length of surfaces allotted is insufficient

In this case, the devises may not be disposed rectilinear on a single part, either because of the to small length of the allotted surface, or because too long paths are obtained. Thus it is rational to make a disposition on two lines, but having the same carrying system (figure 5)

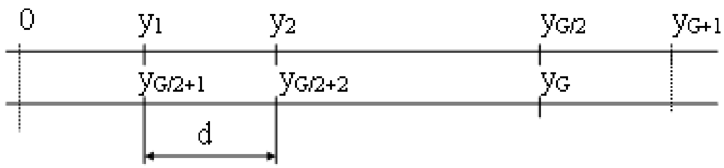

***Fig.5**. Linear spacing on two lines of the devices*

In this case, the objective function rests the same, but the number of constraints in model (7) is progressively reduced up to obtaining an arrangement of the type as shown in fig. 5 The choice of constraints kept in the optimization model and of those being eliminated is represents an option.

3.3. The number of technological devices is too high

If the number of technological devices is too high, it appears the need of a sectional rectilinear spacing (cells or isles) as shown in figure 6.

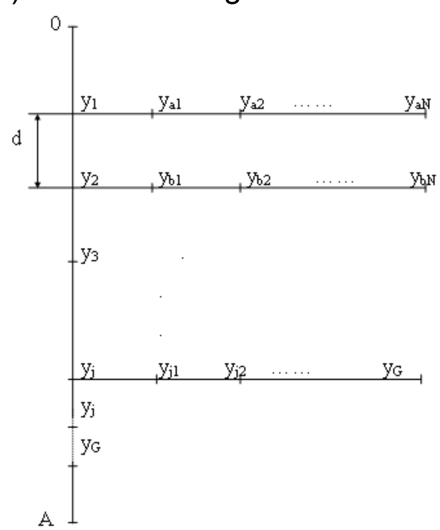

***Fig.6**. Sectional linear spacing of technological devices*

If the number of groups to be divided is *g*, than, for a spacing, the following steps have to be routed:

a. as a fiction, al devices are considered to be disposed on line segment OA, equal to the length (width) of the rectangle taken into consideration;

b. the optimization issue is successively solved by progressively subtracting the number of constraints, until obtaining the *g* isles or cells;

c. the spacing within each isle is achieved.

It has to be clarified that if in writing parameters d_{ij} which are giving the number of shifts between station *i* and station *j* , there are device groups not carrying out changes with other device groups – than the spacing issue may be decomposed heuristically in a number of issues, each containing devices with more intensive changes of half-products.

4. CONCLUSIONS

By solving the mathematic programming issue proposed hereby, the optimal arrangement of technological devices, on grounds of the minimal path criterion. Spacing is obtained by solving numerical this model.

Being an issue of non-linear programming, for approaching the absolute minimum also the method in paper [3] may be used. The programming media which can be used for solving this model is "MATLAB" and the minimal computing power is that of a performing PC of the actual generation.

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