MANAGEMENT OF MANUFACTURING SYSTEMS' ADAPTING AND DYNAMIC STATE TIMES

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Abstract. This paper contains a checking of the times consumed on the manufacturing flow. Operational, auxiliary, adapting and dynamic regime times, for different manufacturing tasks and organizational types are pointed out and calculated. Determination of the item's and batch's manufacturing time, under the conditions of serial and parallel disposal of the workstations has been had in view. It starts from pointing out the motions within and outside of the workstation. Possible organizing cases of the activities needed for the system's adaptation to the manufacture of a new item and the consequences of partly overlapping the transient regime time on the adapting time, have been checked.

By calculating adapting and transient regime times for each of the cases identified hereby as being possible, premises of drawing up managerial decision variants have been created. The determination of these times is useful in fixing performances related to the system's output and to the calculation of manufacturing costs. They are essential in designing manufacturing systems

The optimal management of the item change adapting times and of the transitory regime times represents an important requirement of the actual economic reality. Ensuring the market competitiveness, presumes manufacturing cost reductions, firmly respected supplying terms and small manufacturing batches

Keywords: flexible manufacturing systems, dynamic state, adapting times

1. Introduction

In achieving material products and services, natural and artificial components are participating (row materials, resources, energy, tools, devices, technological equipment, buildings), manpower and production relations, concepts, labour organization and manufacture management, having as aim, to obtain market vendible final products and services. Actually, the sum of the above mentioned components generates a manufacturing system.

Manufacture is a component part of the production process, specific to the production of material goods. The manufacturing system executes the tasks of direct achievement of the product, by physical – chemical and formal transformations of materials, by means of the energy, whereby technological information are transferred on the product, under the imposed economical conditions.

Between the participating components to the achievement of products and services, there are mutual connections and influences, determining the measure of achieving the targets imposed for.

The specialty literature [1, 2, 3, 4, 5] offers mathematic and heuristic models, quantitatively and logically describing the manner as the above elements are mutually influencing themselves and are interacting.

One of the basic parameter in designing, operating and managing manufacturing systems is represented by the time. It is implied as technical output standards, manufacturing duration, periods of operating cycles, supplying times, moment needing synchronization. Time is considered as one of the factors having a major influence in determining manufacturing costs, being recognized as a "cost stimulator".

Within the actual economic context, economic contraction led to the manifestation of at least two phenomena, detected on all the fields. The first one is represented by the decrease of the goods' selling prices and the second one, by the reduction of manufacturing batches, conforming to the reduction of the products' life times. These phenomena are accentuating the attention over the factors, they directly are depending on. With this context, the time factor, with all its manifesting forms in operating the manufacturing systems, is an essential one.

2. Time factor on workstation level

The manufacturing system consists of several technological devices (which may be for processing or for installing), checking stations and logistic equipment. Alongside of the technological routing, half-product moves or stays during different times. In figure 1, the possible motions which may occur outside of the workstation PLi of a technological device UTi, is schematized presented. These motions and stays of the half-product are achieved by the internal logistic equipment.

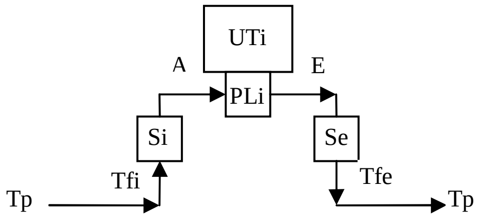

Figure 1. Motions outside of the workstation

Meaning of the notations: Tp is the transportation motion; Tfi is the transfer motion when entering in the workstation, Si represents the entering stockage. A represents the half-product supply of the workstation, E represents the exit, Se and Tfe are similar workstation exist parameters. Each of the above motions may also have, at their turn, specific components, such as: half-product catching-releasing, orientation, positioning, etc. They also may be significant differences between volume, mass and geometric configuration of half-products. These characteristics are reflected in the internal logistic equipment's structure and in the motions with the due times. These times shall be designated as auxiliary times.

By detailing a part of the motions within workstation PLi, for the case of milling machine, figure 2 is obtained.

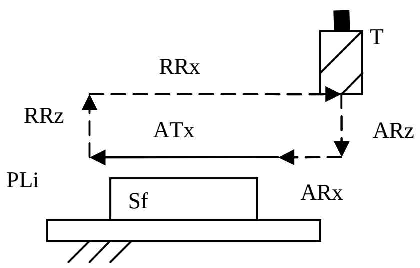

Figure 2. Motions within a workstation

The motions of tool T related to half-product Sf are schematized, noting by AR the fast feed motions, by RR the fast retracting motions and by AT the technological feed motion (where effective processing takes place).

Figure 2 does not contain all possible generating or down motions and which are depending on the number of the machine's axles. This figure also doesn't contain the positioning motions in the tool replacing point or the movements for the item size or the tool wear measurements. The times consumed within the workstation outside of processing, are designated as down times and the processing ones, as basic times. Their sum represent the operational times.

The times as these motions are executed, are determining the machine's output. That's the reason, why the value of these times and their technological feeding time's weight, are representing an issue of major interest. Basic times are determining the theoretical (maximal) output of a device, output which should be realized, if the sum of down times would be zero. On this consideration, several observations may be made.

On the actual moment, the achievement of some remarkable performances is considered, concerning down times reaching minimal values (sized in seconds or tenths of seconds), due to the high fast feed speeds, reaching minimal values [m/min]. Down time reducing reserves are small, but not neglecting.

Basic times have been considerable reduced by creating fast speed chip removing tools and machine-tools, presently being usual speed of ten thousands rotations per minute and chip removing speeds of thousands of meters per minute.

A strong future resource is represented by the reduction of *auxiliary times*, outside of the cycle. This is achieved by adequate managerial and logistic measures. Choosing of logistic starts from the fixing the optimal charging units on the transportation, transfer and storage routings, as well as, the available speeds of the respective equipment.

Organizational measures may refer to each workstation or may depend on the whole system. Within the workstation the design and management of processes resulted in law operational times is aimed.

The adapting of the machine to the item change represents another important component. This is fixed outside of the working cycle. With this regard, the main activities are: mounting tools in tool holders (outside of the machine), adjusting and pre/adjusting tools (realized outside of the machine), preparing operating devices (realized outside of the machine), preparing controlling and measuring devices (realized outside of the machine), mounting the controlling tools, devices, equipment and CNC programs (realized inside of the machine, time as this is not operating).

On the workstation level, activities are obvious, as content, duration and costs. On the system level, from this point of view, there have to be made differences.

3. Time factor on system level

Calculations concerning manufacturing times are carried out on item level and on batch level. Manufacturing duration of an item is given by the total time, as, within the manufacturing system, a half-product Sf is completely processed from item k, to be transformed into final piece Pf. In the most general case, for complete processing, a half-product moves and stops, during its processing, on several, serially arranged, workstations.

The situation of complete manufacturing on q workstations is shown by figure 3.

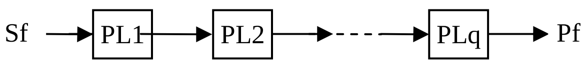

Figure 3. Item manufacturing scheme

On each workstation a distinguished group of processes is carried out (processing or mounting), designated by the specialty literature as technological operation.

The manufacturing duration of idem k (total manufacturing time of item T_{Rk}) will be [2]:

$$T_{Rk} = \sum_{i=1}^{q} \left(t_{op\ i} + t_{aux\ i} + \frac{t_{ad}}{n_{pl}} \right) \tag{1}$$

where: i–current machine m_i or current workstation index; k–current item index; q–number of machines and workstations the half-product is successively passing through; n_{pl}–number of pieces within batch k; $t_{op\ i}$–operational (operative) time for processing item R_k on UT_i; $t_{aux\ i}$–auxiliary time, outside of the workstation (cycle), due to processing R_k on UT_i; t_{ad}–adapting time at the entry into manufacturing of item k. The entry into manufacturing of an item needs a succession of operations:

The main components of t_{ad} are those needing the machine to stop for item change (the last activity group mentioned above). The adapting to the item change may be organized in two modalities.

The first one consists in using a small technical team, intervening successively in adapting each of the q devices. In this case, the total adapting time shall be the sum of the devices' adapting times $t_{ad\ i}$ and shall be given by relation:

$$t_{ad} = \sum_{i=1}^{q} t_{ad\ i} \tag{2}$$

The second one presumes the use of an extended technical team, having the availability to simultaneously intervene in adapting all devices of the system in the same time. In this case, the adapting time shall be given by relation (3).

$$t_{ad} = \max\left(t_{ad\ 1},\ t_{ad\ 2},\ \ldots\ldots\ldots,\ t_{ad\ q}\right) \tag{3}$$

The first of the above mentioned solutions leads to law manpower costs, but high adapting times, having as effect the reduction of the system's output. The second solution determines high manpower adapting costs, but, obvious, law adapting times.

Certainly, nor an intermediary solution is excluded, which combines the above mentioned two ones. A decision has to be taken from economic considerations and depends on the item characteristics, the size of manufacturing batch, hourly manpower costs and the cost of output loss, for the checked variants.

The determination of the item manufacturing duration allows the observation of some very important effectiveness indexes, such as: the ratio between operational and auxiliary times, the ratio between operational and adapting times.

From the calculation of the parameters on batch level, allows determining a lot of other parameters.

The batch manufacturing duration is given by the total time of complete processing all the n_{pl} identical pieces R_k of a manufacturing batch, equal to the total passing time of these, through the manufacturing system. The manufacturing duration is calculated in a different manner, according to the succession of technological operations and of the workstations.

At the serial disposal of the workstations, all pieces composing the batch have an identical routing. Any item R_k is successively processed on each of the q devices or workstations. Schematization is similar to that presented in figure 3. This disposal represents a technological flow line.

The manufacturing duration of batch k, consisting of the n_{pl} pieces represented by the same item, is the total manufacturing time T_{Lk} of the batch. This is calculated by the relation:

$$T_{Lk} = n_{pl} \cdot \max\left(t_{op\ i} + t_{aux\ i}\right) + t_{ad} + t_{rt} \tag{4}$$

where: t_{ad}–adapting time at the manufacturing entry of batch L_k, needed in equipping with tools, devices, CNC programs, adjustments, etc; t_{rt}–transient regime period (at the entering into manufacturing of batch L_k), comprised between the entering time on the processing line of the first specimen of the batch and the exiting time as this leaves the line as final product. The transient operating regime of the manufacturing system is also called dynamic state.

Regarding the adapting time to the item change, at the batch manufacturing within serial disposal, similar remarks to those of the item manufacturing may be made. But some differences may occur, becoming obvious if the adapting time's combination manner is checked with the transient regime time. It results, that according to the specific manufacturing, t_{ad} and t_{rt} may be partly overlapped. In this way, several cases may be limited.

The first of these cases is that as the adaptation of the manufacturing line of a new item starts at the moment of exiting from manufacture of the previous item, i.e. when the previous item leaves the last workstation and processing of the new item starts after adaptation is completely finished. In this case the adapting time is calculated by one of relations (2) or (3), and the duration of the transient regime shall be calculated by relation (5).

$$t_{rt}^{k} = \sum_{i=1}^{q}\left(t_{op\ i}^{k} + t_{aux\ i}^{k}\right) \tag{5}$$

The second case is that, as the adapting process of the new item manufacturing equipment starts just after the last half-product of the previous batch releases the respective workstation. Thus, if the condition fixed by relation (6) is fulfilled, than the adapting time is calculated by relation (7).

$$t_{op\ i}^{k-1} + t_{aux\ i}^{k-1} \geq t_{ad\ i-1}^{k} \quad , \quad i = 2, ..., q \tag{6}$$

$$t_{ad\ Lk}^{k} = t_{ad\ q}^{k} \tag{7}$$

If condition (6) is not fulfilled, than the adapting time is calculated by relation (2), or by combination between (2) and (7). For any of the variants given by relation (6), if the transient regime starts at the end of adapting the whole system, than the transient regime time is calculated by relation (5).

In processing two (or more) successive batches, according to the item manufacturing time, the transient regime time for the second batch may partly overlap on the adapting and manufacture exiting time of the previous batch's last specimen.

If on the same machine line composing the manufacturing system, successively several different items, grouped within batches, are processed (ex. the case of manufacturing heavy ball-bearings, where the manufacturing time of a single specimen amounts several weeks), than the manufacturing time of all batches is determined by summarizing manufacturing times due to each batch, by using every time relation (1).

On grounds of the batch manufacturing time, the run time (or manufacturing tact) and its reverse, i.e. frequency, may be calculated. Similar considerations also for the parallel disposal of the workstations may be made. In the parallel disposal, one piece of the batch may be completely processed on any of the system's workstations.

4. Conclusions

By determining the items' change adapting time and that of transient regime in several manufacturing process organization variants, the premise of optimal operation of material processing or mounting systems is created.

Knowing these times is useful also for the manufacturing systems designing stage, by reducing errors due to aggregate time incorporation. These approaches are in concordance with the requirement of solution development, applicable to the actual economic data.

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