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THE EVALUATION OF THE METHOD OF LOT SIZE DETERMINATION IN MANUFACTURING SYSTEM

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Abstract: *The paper gives the final results of the research project: "The proposal of an alternative procedure of manufacturing lot size determination in flexible manufacturing systems by simulation optimization." The authors present the alternative method for determination of lot size. The method uses the simulation optimization as a base procedure. The authors demonstrate the important stages of the method. The solution is compared with classic mathematic methods.*
Key words: *manufacturing, lot size, method, simulation optimization*

1. INTRODUCTION

The lot size is one of the directions of production which markedly influences production costs. The lot size influences a production flexibility, an amount of parts in process, flow time, capacity utilization etc. The goal is to determine the lot size so that production costs will be minimal (Tomek & Vavrova,2000).

There are several known methods for determination of the lot size in the world. One of them is called economically optimal lot size. This method defines the mathematical formula which minimizes the set-up costs and storage costs. This lot size is expressed by mathematical model that solves the compromise between the reduction of fixed costs per piece and increasing of lot size, and on the other side increasing of the storage costs (Habchi & Labrune, 1995).

The optimal lot size is determined as follows:

$$D_o = \sqrt{\frac{2 * Q_p * N_{pz}}{N_j * n_s * t}} \tag{1}$$

D_o - optimal lot size in pieces, Q_p – planned number of parts in pieces, N_{pz} – batch set-up costs, N_j – costs per one piece, n_s – annual storage costs including credit interest, t – fraction – period of the year (Gregor et al, 2000).

Another approach is based on a search of minimal lot size which is needed for effective utilization usually as bottleneck or capital-intensive capacity unit. The lot size, defined in this way, provides economical utilization of chosen capacity units (bottlenecks).
The minimal lot size is determined as (Gregor et al, 2000):

$$a = \frac{t_{pz}}{t_K * D} \Rightarrow D = \frac{t_{pz}}{t_K * a} \tag{2}$$

t_{pz} – time for set-up in min., t_k – part time in min., D – lot size in pieces, a – coefficient. a = 0,04 for complicated parts and a = 0,1 for production with automatic machines.

2. THE NEED OF ALTERNATIVE SOLUTION

The classic calculation methods of lot size consider just few factors which influence lot size. That is why the attribute "optimal" is applied only for strictly defined conditions. The necessary input values of set up costs or storage costs are in fact qualified approximations but not exact values. Such calculated optimal lot size is at least approached to optimal values.

The authors assume that lot size is influenced by other factors not only by considered classic methods of calculation. Here belong: production type, orientation of material flow, system flexibility, organization of manufacturing process etc. The authors have designed the alternative method that can determine lot size more accurate than standard methods. The method uses simulation and simulation optimization as the base procedures.

3. METHOD STAGES

The method for determination of lot size includes these basic steps:

- Creation of model

The method assumes the building of a very detail simulation model of the production system. The simulation model has to respect the number and types of machines and also their interchange ability, definition of storage subsystem, definition of transport subsystem, number of human resources. The material flow orientation is implemented into the simulation model. Every part enters the model into the batch that has defined its lot size. The model has to be validated (Masar et al, 2009).

- Calculation of production costs

The model of costs calculation is very important stage of this method. We propose only variable costs in the model for calculation. The variable costs depend on produced quantity. Then the total production costs include operation costs, set up costs, transport costs, labour costs and storage costs. The production cost is computed according to the following function in the realized model.

$$Total\_costs = \sum_{i=1}^{p} OC_i + SC_i + LC_i + TC_i + STC_i \tag{3}$$

P is the number of entered parts, OC – operation costs, SC – setup costs, LC – labour costs, TC – transport costs and STC – storage costs.

The individual costs items are calculated in entities of the discrete-event simulation model. Therefore the costs will be calculated only if the defined event occurs; for example when the technological operation is finished. In this way the costs calculation is very accurate. The value of total production costs is growing up with rising of the number of finished parts. Therefore it is not proper to use it as an objective function. The objective function will calculate the production cost per finished part.

- Definition of the objective function

As it was mentioned, the lot size is influenced not only by costs but by more factors. The authors in the process of definition of the objective function went out of production

goals. There were also included the number of finished parts, machine utilization and flow time in objective function besides the costs which represents the important goals of production.
The objective function was defined as follows:

IF No_out_parts () > default value of finished parts AND Machine utilisation () > default value of machine utilisation AND Flow time () < default value of flow time
Unit_Costs = SumCosts / No_out_parts
RETURN Unit_Costs
ELSE
Unit_Costs = SumCosts / No_out_parts + constant
RETURN Unit_Costs
ENDIF

Default value represents quantitatively evaluated production goals. The constant should be about order higher than Unit_Costs value. Partial values of the objective function are always calculated when the specific element of production system finishes its activity.

- The selection of the optimization method

The selection of method is very important step of solution procedure. Simulator Witness was used. This simulator provides several algorithms. Result used by algorithm will find the global extreme of the objective function (Waller,2004).

The selection of input parameters is realized in optimizing module. It is very important to constrain the input parameters meaningfully. We recommend to set up the constraints of input parameters through special designed preparatory simulation experiments.

4. METHOD VERIFICATION

The authors have prepared the simulation model of flexible manufacturing system for verification of proposed method. This model is a typical flexible manufacturing system for batch production in machine industry. The manufacturing system has been designed to produce two kinds of parts (hydraulic cylinders for hydraulic equipments) at the same time. They are labelled as VD1 and VD2. These parts were produced in batches.

Each workstation of the FMS is defined as an independent module. All these modules form the structure of FMS according to the following rules:

- 2 compatible machines constitute the Group1 and the Group2,
- the workstation SRP1 and the workstation SRP2 are the components of the Robotic cell,

Each workstation has its own input and output buffers. The transport system consists of four automated guided vehicles (AGV). In the given FMS, there is used a combined storage, (main storage is also system input and system output of the FMS; each workstation as well as FMC has own buffer and there is one emergency storage).

The objective function is defined as real function inside the simulation model in Witness.

4.1 Results of optimization and their comparison

Minimal value of the objective function has been found according to proposed method. We have obtained the following results according to the proposed method for the given FMS.

The result of optimization process evaluates optimal lot size 6 for batch VD1 and a lot size 3 for batch VD2. The optimal values of input intervals have been calculated at the same time. These values for input intervals are 22 minutes for VD1 and 11 minutes for VD2. The followed parameters and production goals have been reached (see Table 1).

We have compared the results according to our method with calculation according to economically optimal lot size method that is defined by formula (1). We have used the values obtained from simulation model in the best experiment. The values are in Table 1.

Parameter	Quantitative Value
Unit costs	3.134 €
Average capacity utilisation	70.31%
Average flow time	54.21 min.
Number of finished parts	784 parts per day
Storage costs per day	300.40 €
Set up costs per day	130.70 €

Tab. 1. The gained results with optimal lot sizes of batches

The gained values have been used for calculation of the lot size value according to economically optimal lot size method:

$$D_o = \sqrt{\frac{2*Q_p*N_{pz}}{N_j*n_s*t}} = \sqrt{\frac{2*784*130.70}{3.134*300.40*1}} = 14.76 \cong 15 \qquad (4)$$

The computed value 15 represents the sum of the both values of lot size. It means that the result according to our method is more accurate because it brings lower unit costs than mathematical calculation.

The result according to formula (2) is 8 pieces in one batch. It means that our method is more accurate. The method accepts the real conditions of the manufacturing process. If the conditions change, it will be possible to repeat the method.

Here it is important to notice that no classic methods determine input intervals for batches. It is very important parameter that is determined by our method unambiguously. We have tested and have compared our alternative method on the next different manufacturing systems. We can certify that the method has brought more accurate results than classic procedures.

5. CONCLUSION

It is necessary to mention some important facts that have to be fulfilled. The simulation optimization is more accurate method for determination of lot size than the classic methods because it is able to respect much more factors which influence lot size. But it also requires the existence of simulation model. On the other side the simulation model allows research in the detail way of the real manufacturing process. Classic methods are fast and simple. The simulation optimization can take a long time according to the restriction of the possible solving combinations. The simulation optimization seems as proper method for accurate method for determination of lot sizes, especially for flexible manufacturing systems where the set up time is markedly reduced.

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