Evaluation of strategies control of production system

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Abstract. *The paper is a contribution to effective using of simulation optimization. The article presents the results of the study evaluation of strategies control of production system. The authors have realized several control strategy on various simulation models. The simulation models of systems were created in the simulator Witness. The main goal was to show that mathematical formulas do not reflect so many factors, as like the objectives of production operates. The authors point out that the implementation of simulation optimization is better way to take into account the interdependence of the functions and limitations in the evaluation of control strategies.*

Keywords. Control strategy, simulation, optimization, production system.

1 Introduction

The flexible manufacturing system seems to be the key component in all yet defined computer integrated manufacturing (CIM) concepts. Modern flexible manufacturing systems are complicated, highly automated, computer controlled integrated systems. Frequent requests on the changes of the types of products and distribution problems especially in batch production incline frequently to change production strategies. Production strategies have to respect more production goals at the same time. These production goals are very conflicting therefore it is very difficult to reach them. The simulation is the proper method that allows solving these problems. In case, that the simulation results can be optimised, there can be find optimal values of the selected production goals for given the flexible manufacturing system.

2 Strategies control

The strategy is a sequence of steps to reach a predefined goal. It is a way of managing the material flow to meet the planned production volume, product assortment and timing of drainage by compliance of all production goals. Control strategy is based on changes in some factors affecting the control of the production system. This change is clearly defined and it is the independent variable. It specifies the basic input into the system and the quantified production goals are output variables. The scope and the sequence of changes are determined by preparatory experiments [1].

Under the control strategy we understand also building a purposeful state and corporate objectives, particularly in selecting the products which are manufactured in technologies and markets where they are sold. When the strategy has better quality, then the successes are more significant. The company creates conditions with its strategy for long-and short-term growth [2].

Currently selection strategy is determined by conditions of the market. If production strategies should be successful, they must comply with changes of conditions in market and modify production based on new approaches. New manufacturing technologies and philosophies such as group technology, manufacturing cells, Just in Time (JIT), robotics, have appeared in recent years. They require new models and approaches for successful applications. It is quite logical that the company directs its strategies in order of using their ability to strengthen its competitiveness and to achieve the economic effect [2].

3 Problem definitions

To solve problems in various control strategies, mathematical formulas are generally used, but they do not reflect a sufficient number of factors which affect the production goals. Therefore it is necessary to find new ways to solve this problem. One the way of solution is simulation and simulation optimization. The optimization methods, which take into account several parameters of the production process, are most used. It is opposed to mathematical calculations. These methods take into account also their interdependence.

3.1 Methods

The simulation optimization is the most significant simulation technology in the last years according to many authors. It eliminates one of disadvantages of simulation and it is used to find the best solution from many simulation experiments [3, 4, 5].

Today, the leading simulation software vendors have introduced optimizers that are fully integrated into their simulation packages. Simulation practitioners now have access to robust optimization algorithms and they are using them to solve a variety of "real world" simulation optimization problems [6].

There are many barriers which have to be over-came for broader simulation optimization using. Great skepticism predominates to the results of simulation optimization in concrete applications.

There are several characteristics of simulation optimization in literature. Here are some examples of them:

Simulation optimization is defined as optimization of outputs from simulation experiments. Especially it is based on optimization of outputs from discrete event simulation models [7].

Simulation optimization provides a structured approach to determine optimal input parameter values, where optimal is measured by a function of output variables (steady state or transient) associated with a simulation model. [8]

Simulation optimization involves two important parts:

– generating candidate solutions;
– estimating their objective function value;

The value of objective function cannot be evaluated directly, but it must be estimated as output from simulation run. It means, that optimization via simulation is computationally very costly. On the other side the definition of objective function is very simple without complicated mathematical formula.

The goal of optimization is to find maximum or minimum of objective function when different constraints have to be fulfilled.

As in ordinary optimization problem, also the simulation optimization problem is defined by primary components [7]:

– input and output variables;
– objective function;
– constraints;

Constraints are often welcome in optimization problems as they can significantly reduce the search space, thus accelerating the operation of an algorithm.

The objective function and constraints can involve both the input and output variables, and either (or both) can involve stochastic components. Since the output variables are simulation model performance measures, they are quantitative in nature. However, unlike standard mathematical programs, the input "variables" may be either quantitative or qualitative. For quantitative input variables, one distinguishes between the continuous values and discrete values, and in the discrete case between a large state space (uncountable, countable infinite, or just combinatorial large) and a relatively small one. In the latter case, the optimization problem is reduced to an exhaustive comparison of candidate solutions, for which ranking and selection methods are particularly suited [7].

3.2 Problem solution

The main aim of the work was to optimize production goals in the production system. To these production goals belong:

- to minimize the unit production costs;
- to maximize the capacity utilization;
- to minimize the flow time;
- to maximize the total number of finished parts;

These goals influence a lot of factors. The overview of these factors gives the following Table 1.

Table 1 Limiting factors

The group factor	The limiting factor
Produced parts	the type and number of parts
	the technological process
	cycle times
	time of transport, manipulation
Character production orders.	the type and number production workplace
	lot size
	the priority
	input intervals
	periods of delivering
Structure of the production system	the type and number of technological workplaces
	the material links
	the type and number of devices of transport and storage system
	the type and number of pallets
	the type and number of instruments
The production process	type of production
	the type and number of phases of the production process
	the number of operations carried out the production process
	capacity of the downstream production systems
	the type and number of failures in the production system

These factors can be free parameters in the simulation experiments. It is important to decide which parameters solution mentioned above, in defined solution, will be constant or will be changed. The input intervals of batches, lot size of batches will be considered as free parameters in this contribution. They are very important input parameters for management of production process in practice.

The procedure for implementation of control strategies for flexible manufacturing system (FMS) is shown in Fig. 1.

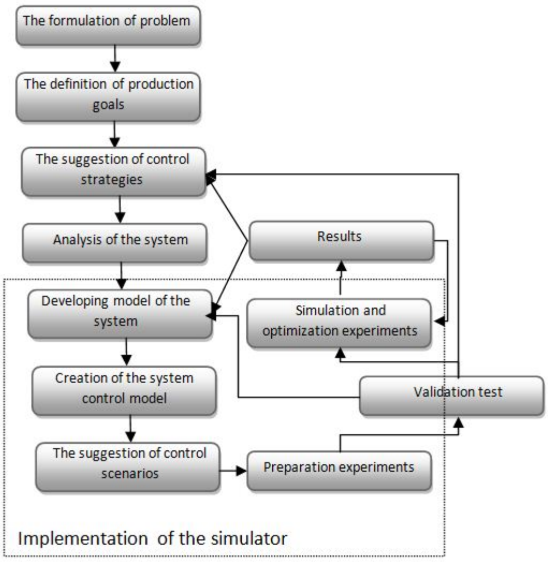

Figure 1. The procedure for implementation FMS

We show the problem of successful usage of simulation optimization for control strategies only on the chosen example. This process was used for searching of optimal values of lot size in the real production system. The simulation model of system was created in simulator Witness PwE Education Version Release 3.00 Manufacturing Performance Edition. See Fig. 2.

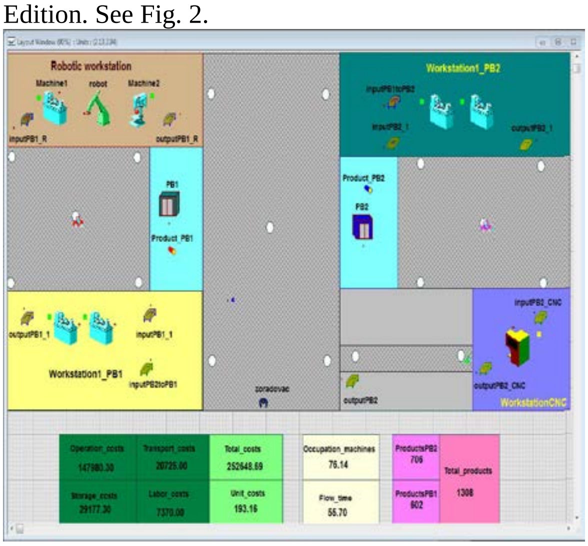

Figure 2. Simulation model

A FMS is a production system in which there is some amount of flexibility that allows the system to react in the case of changes, whether predicted or unpredicted. This system consisted of four machine groups. There were two relative kinds of products named PB1 and PB2 in the production system produced at the same time. The lot sizes were set up to 5 pieces. The schedule of operations was created for every type of the product. The sequence of operations was created for every machine group but the realization of operation on the concrete machine in the group was decided by immediate situation.

The definition of a specific objective function try to find the minimum or maximum value, it is appropriate to define at least one opposed limiting factor. Without entering it is the best result of optimization. It can also be found on such values of variables that will indicate redundant or overload system.

It is necessary to optimize each objective function for each individually defined control strategy. It was defined as a function directly in the simulation model. This definition of the objective function should be distinguished by adding respectively subtracting the constants to the return value depending on minimization or maximization of the goals.

The preliminary experiments were found that they are excellent results as the maximum the total number of finished parts and the minimum unit production cost. The system achieves a preference for the production of only one type of the product. This phenomenon may be caused by different types of products (production batches) pass each time in different workstations. Therefore it is appropriate to prevent this undesirable effect.

We recommend to next limitation factors add into the objective function e.g. maximum possible difference between the numbers of finished products.

Two objective functions have created for every control strategy. The first has proposed for optimization of the individual production goal and the second has optimized of several production goals at the same time. For example, to maximize the total number of finished parts is an objective function as follows:

1. ***production goals individually***
   Objective function - the maximum the total number of finished parts

   IF unit_cost ( ) < assigned value of the costs per unit **AND** difference ( ) < assigned value of the maximum difference (difference in the number of products by type)
   RETURN production_ number
   ELSE
   RETURN production_ number + constant
   ENDIF

2. ***production goals together***
   Objective function – the maximum number of finished products in meeting of production goals as other restrictive conditions

   IF unit_cost () < assigned a value of 1 unit cost of product **AND** flow_time () < assigned an average flow time production **AND** work_in_progress () < assigned a value of work in progress **AND** difference () < assigned value of the maximum difference
   RETURN production_ number
   ELSE
   RETURN production_ number + constant
   ENDIF

The goal of the experiments was oriented to study the influence of the production batch interval and its entry into the production of individual production goals without other changes in the simulation models. As opposed limiting the goal functions for minimum cost, time and continuous work in progress can be selected either the minimum required number of products or use the minimum required, the minimum number of selected finished products. If the objective functions were defined for maximum of the capacity utilization and maximum number of manufactured products than the restrictive criteria were chosen costs 1 unit of product. The including at least one conflicting objective goal because the optimization results without their definitions could represent redundant or overloaded system.

At the same time in the objective function defined the so called difference - that is the maximum possible difference between different types of paid products.

Table 2 shows the best results from experiments. These experiments were carried with changing of the sizes of production batches and their input interval.

The maximum number of finished products is achieved with the worse results of other production goals.

They were given stringent limiting conditions for the pursuit of production goals. The maximum utilization and maximum number of products were achieved slightly worse results, but with better production of other conflicting production goal.

4 Gained knowledge

After careful study of the results which are obtained by large number of performed experiments and compared with empirical studies, it has been concluded:

1) Identified objectives are contradictory, the improvement of the value of one or more production goals is reflected by deterioration other goals. Depending on the optimization goal, the optimal lot size is changed, for example by monitoring of minimum flow time or minimum work in a progress, the optimal batch do not have to mean also the optimal size of minimum cost

Table 2. Result of optimization experiments (IAT – Inter arrival time, PB – Production batch)

		Results of optimization experiments								
Objective function		**PB1**	**PB2**	**IAT1**	**IAT2**	**Unit cost [€]**	**Number of production[piece]**	**Machines utilization[%]**	**Work in progress [piece]**	**Flow time [min]**
Unit cost	Individually	4	4	12	15	**6.742**	862	67.25	23	37.891
	Together	4	4	12	15	**6.742**	862	67.25	23	37.891
Flow time	Individually	2	2	7	6	7.326	890	72.41	20	**29.395**
	Together	2	2	7	6	7.326	890	72.41	20	**29.395**
Work in progress	Individually	2	2	6	7	7.147	890	69.89	**20**	29.600
		4	4	13	13	6.961	886	70.71	**20**	37.590
	Together	2	2	6	7	7.147	890	69.89	**20**	29.600
		4	4	13	13	6.961	886	70.71	**20**	37.590
Number of production	Individually	12	10	26	27	9.97	**1164**	92.56	102	94.509
	Together	11	10	25	26	9.93	1159	92.78	91	93.371
Machines utilization	Individually	8	9	18	22	9.842	1153	**92.99**	141	110.267
	Together	11	10	25	26	9.93	1159	**92.78**	91	**93.371**

The optimization of production goals was realized individually and together. There are shown the achieving optimal results for the objective functions individually and more production goals in Table 2. They are labeled with bold.

The optimal production lot size in terms of the minimum cost achieved at batch 4-4 and 12-15 intervals. The minimum flow time is achieved by batch 2-2. The minimum work in progress achieved in the two batches levels and at batch 2-2, achieves an less flow time and at batch 4-4, where shall in turn lower the cost of a 1 unit of the product.

The production goals as maximum number of finished products and maximum utilization of workstations are unable to achieve simultaneously.

(the classic approaches use just minimization of costs). By using simulation optimization the management may to decide according to situation and priority goal, which criteria should be used for determining the lot size. The simulation optimization can optimize also the input interval of all batches but no classic methods determine input intervals for batches.

2) The maximum utilization of the workstations leads to increase of the flow production time and increase of the work in progress. It causes an increase of the total production costs simultaneously. Experimental results show that it is not effective to focus production on the maximum utilization of workstations. Higher utilization does not achieve the best number of

finished products. Based on performed experiments the most efficiently utilization of these types of systems is about 70% - 85%. This statement is confirmed also by the practice where just these values of workstations utilization can be achieved in flexible production oriented to small series and series production. A further increase of capacity utilization encounters usually with the problem of bottlenecks because these systems are never designed as production lines. It is important to pay attention to the elimination of bottlenecks by the increase of capacity utilization (for example by using methods optimized production technology or Lean Production).

3) Experiments focused on maximum number of finished products have shown that it is not always effective to achieve "maximum". The cost of production, flow time and work in progress will increase significantly after elimination of a certain number of finished products. This difference can be partly compensated by resizing of production lot sizes and their ranges of inputs. The large number of finished products (not maximum) with favorable values of all production goals is possible to achieve with lower batches. This control strategy is recommended to use especially for supply companies that can use the Just in Sequence (JIS) system and have a precise plan for individual planning periods.
4) The determination of the production lot size cannot be resolved without requirement on a number of finished products or without flow time production. These parameters are influenced by the input interval of production batch significantly, not only by the lot size. The classical approaches to determination of the production batch do not take into account the input interval. In simulation optimization, it is important to determine optimal lot size for objective function which minimalizes the unit cost and completes limitation to a defined number of units.
5) By the change of time for sorting machines x% the lot size is also reduced by the given percentage. This argument can be refuted by performed experiments. The optimal lot size is not significantly changed, if the requirement on the defined number of production units is not changed. The decrease of time for sorting machines is very useful, because it shortens flow time and decreases the unit costs. This argument is supported by experiments.
6) Interchangeability of workstations responses more flexibly to changes in the production plan. On the other hand it has a negative impact on the flow time and production costs. This is caused by more frequent sorting of workstations. The performed experiments without using flexibility of workstation have proved significant cost saving and lower the production flow times. Based on acquired results it is effectively to not use flexibility of production system in specific cases, but only on condition that every workstation is equipped with at least so many machines as many kinds of products flows through given workstations.

5 Conclusion

Basic parameters of the production process significantly affect the optimal results that are goals each business entity. Simulation optimization is a good choice, which makes it possible. However, it has its drawbacks and it is good to control them.

Evaluation of management strategies for the production system using simulation optimization is advantageous compared to classical calculations. It takes into account the interdependence between the lot size, number of units of production, continuous flow time and etc. No mathematical formula taking into account all factors that affect the production targets. Therefore, the authors recommend the use of iterative optimization methods, i.e. Gradual approximation of the objective function, which would take into account several parameters of the production process.

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