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OPTIMIZATION IN ADVANCED PRODUCTION SYSTEMS

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Abstract

The problem of optimizing advanced production systems as dynamical systems, complexes involving large investments has an important role, these systems must operate economically in order to recover the values embedded in them and in the shortest time. This object is achieved by the use of the optimization calculations. Also, the high degree of automation of advanced production systems resulting in high productivity of the system requires the application of optimization methods in concrete conditions for flexible production systems. In this context, research in this paper are directed towards the study of advanced production systems in order to know their behavior and performance as well, and if possible, even before the physical realization and to establish scientifically mathematical models dimensioning, optimization and simulation of these systems with an upward trend.

Keywords: production systems, modeling, optimization, simulation

INTRODCUTION

Production systems have been in recent years and continue to subject to a process profound transformation with increasing dynamics. The novelty element in the current design of production systems development is the "flexibility". Flexibility is the most significant response of producers in relation to the trend of diversifying product needs perceptible in today's world. Flexibility, representing both a feature and an absolute prerequisite in manufacture, gets increasingly in industrial structures, representing a prerequisite for development, involving the highest level automation and computerization [3].

Much of the complex issues that occur in industrial production and management of advanced production systems are optimization problems. Mathematical modeling of optimization problems, provide the possibility of determining the optimal solution with immediate consequences on the growth of economic efficiency of the system.

Optimization problems are at the confluence of two disciplines: mathematics, science offering optimization methods (solutions) and practical knowledge to be applied in the optimization. An optimization model must have a decision criterion for selecting the best alternative and at the same time to prove that the alternative is optimal. Thus, there must be a technical method to evaluate each element of a set, the objective set in correlation with the criterion established and leading to optimal element.

In most areas of technical sciences designing a system, a certain part, device or installation can be done in several alternatives, depending on the underlying design criteria. Whatever the criteria, resulting design leads to the choice of values for the design variables can be different physical sizes. Thus appears to the designer's work, optimal layout design, because these values can be chosen in a wide range, provided satisfying certain limitations and restrictions. It is considered the optimal solution of the problem, the solution that leads to the best choice of the values of variables in a manner that meets all limitations, conditions and restrictions. It is considered the optimal solution of the problem, the solution that leads to the best choice of the values of variables in a manner that meets all limitations, conditions and restrictions.

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Optimization methods appeal to numerical calculations, therefore their practical application is directly related to computer use. These methods do not, in general, to obtain qualitatively different solutions to the problem of the study, but also result in selection of the best values, i.e. optimizes the design solution of the design of the user.

The flexible manufacturing systems are part of the large group of manufacturing systems, that are, in their turn, components of production systems. The flexible production systems are those manufacturing systems designated to effect the great typological diversity of manufacturing tasks, of great complexity, assuring minimal delivery times and costs, manufacturing being unpredictable in time, and organized in small lots, with frequent interchanges. Form the global characteristics point of view; the flexible manufacturing systems are superior to the systems that they replace in the mass production [4]. The FMS efficiency increases at the same time with the increase in flexibility, in integration capabilities, command and monitoring with a hierarchical network of computers in CIM (Computer Integrated Manufacturing) and applying the JIT (Just in Time) constraints. The decisive influence of the production level on the manufacturing efficiency is observed. And so, at a reduced level production of single items, the naturally adaptable manufacturing is the most efficient, having the lowest costs. For high levels of production volumes, the most efficient solution is the rigidly automation production. It is worth mentioning that FMS becomes efficient only in-between limits, when low or medium production series are processed, which are repeated at an unpredictable rate in time.

For a conventional system, the statistical determinations have revealed that from the total time that a part goes through a production system, over 90% is slack and preparation time, and 10 % is the operational time on the machine, from which 70 % is used for auxiliary activities, during the cycle. In these circumstances, the total time of actual machining is reduced to 5-10 % of the total time [2]. The percentage of the actual machining time in the case of FMS increases to 50-80 % of the total manufacturing time of the product, at the same time with the increase in production capacities. The number of machining tools is reduced, but their complexity level is increased. The percentage of used production capacities increases from 60% to 95% [2], due to the integration of the complex technological process, of the auxiliary activities external to the process, of all the subsystems in the system and of the command and monitoring with a hierarchical network of computers. With the goal of dimensioning, configuring, reconfiguring and optimizing the machine systems, modern procedures of modeling and simulation are used.

The necessity of attaining the system, generally and manufacturing systems modeling and simulation techniques is imposed, especially for approaching structure optimization problems and behavior study of these systems, based on specific optimization criteria. Given the importance of the optimisation problems in FMS, large, complex systems, appealing to some basic optimisation methods in operational research, presented at the most general [7] below, some of them are applied to practical the dimensioning and configuration of FMSs in round shafts processing.

FORMULATION OF OPTIMIZATION PROBLEMS

The optimizing process uses a multitude of initial values and corresponding solutions, which are user defined or random generated by the algorithm. Optimizing algorithm generates then successive these kind of values, leading to an optimal one. When more than one variant are possible, the best possible solution is to be chosen.

Mathematical modeling of optimizing problems offers the opportunity to find the optimal solution (solutions), with immediate consequences for the system's economical efficiency increasing. These problems are resolved using mathematical programming. Multi-objective optimizing is a matter of study for mathematical programming. This type of optimizing starts with the premise that the number of potential solutions is infinite, by solving it, the optimal solution (solutions) is determined. For the general formulation of the problem, it is considered that a n-dimensional vector x_i is applied to the input of the system, a m-dimensional x_e vector is obtained from the output and the parameters of the systems are described by p-dimensional vector q. Mathematical programming is a maximizing or minimizing problem for one or more functions defined by variables, called objective-function (functions), purpose-function (functions) or efficiency-function (functions), whose variables satisfy a system of restrictions expressed by equalities or inequalities.

Objective-function is also a r-dimensional vector of r functions. Having the linking relations between input, output and parameters and also the limiting conditions imposed, the overall shape of *the multi-objective optimizing* is the following:

$$R_k(x_i , x_e , q, t) \leq 0, \; k=1,\ldots,k$$
$$\text{optimum} [f_1(x_i , x_e , q , t),\ldots, f_r(x_i , e_e , q , t)] \tag{1.1}$$

In the above written relations *t* means the time, and *k* is the total number of linking and conditioning relations between mentioned values. These relations are called *restrictions*. Requested optimizing for the second expression is usually obtained by minimizing some of those *r* components and maximizing other.
If both restrictions and objective-functions are linear functions in relation with variables and also are time independent, then the problem becomes a multi-objective linear one. When the objective function vector has a single component it leads to a linear programming mono-objective problem.

The model for mathematical programming problem [1, 2] is the following:

$$\max (\min)(z_h=f_h(x_1,x_2,\ldots,x_n)), \; h=1,\ldots, r$$
$$g_i(x_1,x_2,\ldots,x_n)\rho_i, \; i=1,\ldots, m$$
$$\rho_i \in \{\leq, =, \geq \; i=1,\ldots, m \tag{1.2}$$

If $r > 1$, the relation above is multi-dimensional; $r = 1$ the objective function has a single component => *linear mono-objective programming.*
When the objective functions f_h (h=1,…,r) and g_i (i=1,…,m) are linear, the (1.2) model is named *linear.*

The mathematical model is made from three parts:
- input parameters, which values are known;
- output parameters, given by processing;
- Functional relations between input and output values, algebraic equations, deferential equations, integral equations, etc.

For resolving linear mono-objective programming problems we can use solving algorithms, the most known is SIMPLEX. The SIMPLEX algorithm is a systemic and economic method for basic programming exploring (precisely the transit between basic programs to the advanced ones), that the objective function values always improve, until it reaches the optimal. The algorithm gives criteria for the case in which the linear programming problem has no program or has infinite optimal ones. The optimizing models with representative restrictions (mathematical programming), with multiples applications possibilities into techniques, economics, socials systems and processes optimizing, there are: linear models, discreet models, bivalent models, convex models, quadratic models, transport models, special models for non-linear programming. By using linear programming, can be solved manufacturing domain problems like: optimal organization of a production sector, plant layout problems, choosing the optimal technologies problems, manufacturing and supply problems, investments problems, the optimal capability of production equipments problems, etc.
If the objective function given in the (1.2) model are non-linear with respect to the unknown ones and the objective function vector has a single component, then the problem become a *non-linear programming*. A lot of problems, even the ones mentioned above as accessible by linear programming, they all have a linear attribute. This category includes also the flexible manufacturing systems problem.
For describing technical, economical, etc. processes which develop in time is used *dynamic programming model*, [3], which is based on Bellman's optimal principle:
- Assuming that the time element $[t_0, t_f]$ divides in steps, so the system state changes by passing over one stage to another, depending on external decisions of the system. Inside each step it accepts only a decision;
- The system status is analyzed and described by a status vector $x= (x^1,x^2,\ldots,x^m)\in R^m$, the decision by a decision vector $u= (u^1,\ldots,u^r)\in R^r$. The components of these vectors are named status values (x^i), decision values (u^i).

The dynamic programming determines a sequence of decisions $\left(u_1^*, u_2^*,\ldots,u_n^*\right)$ and a sequence of corresponding states $\left(x_0^*, x_1^*,\ldots,x_n^*\right)$ which gives the *optimal value* for total evaluation (of the

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objective-function). Where fj, g_j - objective functions; x_j - possible states from the states domain $\Sigma_j \subseteq R^m$; u_j - possible decisions from decisions domain $\Omega_j(x_{j-1}) \subseteq R^r$.

The mathematical model is the following:

$$\text{opt}\sum_{j=1}^{n} g_j(x_{j-1}, u_j); x_0\text{-dat } x_j = f_j(x_{j-1}, u_j);\ j=1,n;$$
$$x_j \in \sum_j\ ,j=1,\dots,n;\ u_j \in \Omega_j(x_{j-1}),\ j=1,n \qquad (1.3)$$

The evolution of the system (process) is shown bellow (Figure 1).

Optimizing is build from algorithms in which properties can be quantified in the terms of functions. The optimizing process uses a multitude of initial values and corresponding solutions, which are user defined or random generated by the algorithm. Optimizing algorithm generates then successive these kind of values, leading to an optimal one. When more than one variant are possible, the best possible solution is to be chosen.

Mathematical models will contain a number of parameters and optimisation criteria, objective function, performance indicators, average optimal synthesis and real time.

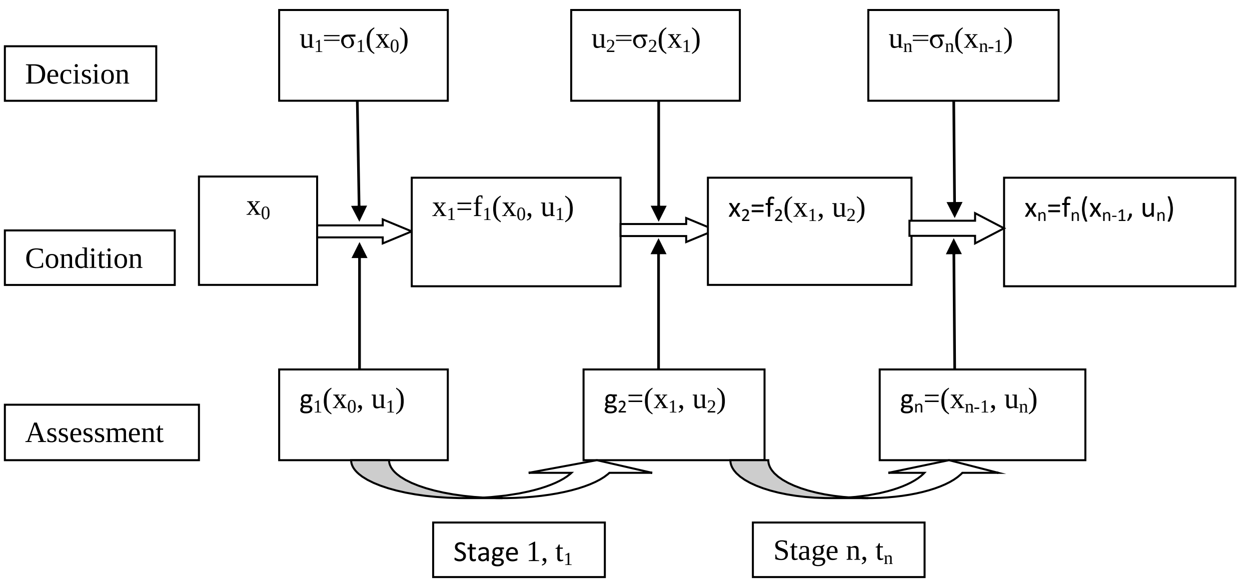

Figure 1. The evolution of the system

Given the importance of optimization problems in flexible production systems, large systems, complexes calling on some basic optimization methods in operational research. Classical optimization is used: determining the size of the manufacturing batch; determination regimes (in the conditions of system flexibility); dimensioning storage equipment located in or before the processing modules. Linear programming used to determine the static configuration of a flexible manufacturing system (FMS) and to establish the optimal working conditions. Dynamic programming is used to determine the optimal route FMS technology, but also to optimize system operation. Graph theory is successfully used to optimize flexible manufacturing systems for optimizing the input sequence types of items in FMS. It is useful in determining the optimal trajectories of moving parts in the system and for calculations of reliability of flexible manufacturing systems.

Modeling and optimization of flexible production system

A flexible manufacturing system (FMS) is a advanced production system consisting of a set of identical and/or complementary numerically

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controlled machines which are connected through an automated guided vehicle system. Since FMS is capable of producing a variety of part types and handling flexible routing of parts instead of running parts in a straight line through machines, FMS gives great advantages through the flexibility, such as dealing with machine and tool breakdowns, changes in schedule, product mix, and alternative routes. Flexible manufacturing is of increasing importance in advancing factory automation that keeps a manufacturer in a competitive edge. While FMS offers many strategic operational benefits over conventional manufacturing systems, its efficient management requires solution to complex process planning problems with multiple objectives and constraints.

Mathematical modeling of optimizing problems offers the opportunity to find the optimal solution (solutions), with immediate consequences for the system's economical efficiency increasing.

In flexible manufacturing systems, the following are to be optimized [1, 2]:

- improving manufacturing structure ;
- raising manufacturing automation rate, at higher levels, especially for information processing;
- reducing the size of manufacturing batches;
- raising the typological diversity of the manufactured parts;
- fast adaptability with low costs of the manufacturing system configuration to simultaneous processing of various manufacturing tasks;
- raising the complete processing capability for a part;
- improving auxiliary functions like: clamping, handling, transportation, storage for all parts from the manufacturing task and for all necessary tools;
- fast adaptability ability for all subsystems when current manufacturing task is modified (process parameters and processing programs);
- insuring maximum admissible loads for all subsystems, especially for complex and expensive equipments;
- minimizing manufacturing and delivery time;
- minimizing production costs;
- maximizing work efficiency;
- optimizing global objective functions: production costs, productivity, tools durability, process quality;
- construction by module; automated external / internal diagnosis for machines, processes and machining quality control for parts.

Multi-dimensional decisions have many criteria and it is based on mathematical programming with many objective functions. There are different ways to approach multi-attribute problems [4]: utilities theory (analyses the way in which activity is conditioned by the independence property of criteria); methods for the optimal alternative choice, which takes into account both the favorable consequences arguments and the unfavorable ones; mathematical programming methods having multiple optimal criteria.

Fuzzy measures of the (degree of) satisfaction of each one of the three objectives are taken for each feasible alternative. These measures are weighted according to the importance of each criterion, obtaining a "score" for the given alternative. This "score" represents the degree of satisfaction of the overall objective by a certain alternative, and is given by:

$$\mu_0(x_k) = [\mu_{c_1}(x_{k_1})]^{\alpha_1} \cdot [\mu_{c_2}(x_{k_2})]^{\alpha_2} \cdot [\mu_{c_3}(x_{k_3})]^{\alpha_3} \quad (1.4)$$

In (1.4) $\mu_0(x_k)$ is the overall objective degree of satisfaction corresponding to the k-th alternative, $\mu_{c_i}(x_{k_i})$ is the degree of satisfaction of the i-th objective (relatively to the k-th alternative) and α_I its weight. The alternative corresponding to the highest overall objective degree of satisfaction is chosen. The importance of each criterion is given by the weights obtained from a pair wise comparison matrix through the λ_{max} technique. The pair wise comparison matrix (in this case 3 x 3) usually contains human expert linguistic estimates of pair wise comparisons between the objectives importance. This decision structure is completely defined once the pair wise comparison matrix and the membership functions for each objective are given. The membership function for low workload and low processing time, is piecewise linear at first and then exponential, and is completely defined (for any objective) by three parameters. The membership function for low distance is a discrete one and it is arbitrarily assigned. It will be assumed that experts already specify the pair wise comparison matrix, e.g.

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A specific algorithm of treating the information features the fuzzy modeling. Fuzzy systems are processing information according to an own philosophy, carrying out of principle on grounds of the following flow:

{input variables} $\Rightarrow$ *(fuzification)* $\Rightarrow$ *(interference)* $\Rightarrow$ *(composition)* $\Rightarrow$ *(defuzification)* $\Rightarrow$*{output variables}.*

In view of structural analysis of a FMS for round shafts processing, former [2] the decomposition of the system into component sub-systems was carried out, connections among these and the transfer function were established. On grounds of the structural decomposition draft the fuzzy model may be elaborated, which shall contain a linguistic equation group (group of rules), model that is used in achieving the functioning algorithm. Finally for the connected sub-systems within the FMS for round shafts processing, the final group of rules shall be generated, out of which the system outputs may be extracted. The program is written as a set of the rules due to each sub-system (work stations, robots, conveyors, stocks).

The fuzzy model is elaborated on macro-level, for connections between adjacent sub-systems. Fuzzy logic is a general conclusion of the classic, bivalent logic, replacing its discrete character in (0, 1) with one of continuous nature. The fundamental fuzzy logic is made of the multivalent logic. So as for the deterministic bivalent logic "1" is associated to TRUE and "0" is labeled FALS, in the fuzzy logic for a deterministic positive real number variable, the associated linguistic variable may have linguistic degrees: BIG, AVERAGE, SMALL. Because of the expression by linguistic variables, mathematical modeling by fuzzy logic may be easily approached within the complex structure study, such as FMS for round shafts processing. A fuzzy rule appears when it exist a premise concerning the event, which implies a certain logic consequence (conclusion): IF (conditions, restrictions) THEN (effect / consequences) ELSE (consequences / risks). The fuzzy rule base is built up by putting fuzzy multitudes associates to output variables, in logic contact with fuzzy multitudes of the input variables. The fuzzy rule group modeling as linguistic equations the FMS for round shaft processing function is presented further on.

Fuzzy rules for state estimation. In the case of MISO (Multi Input Single Output) – type systems, the group of rules shows like:

R1: IF X IS A1,…,& Y IS B1 THEN Z IS C1

R2: IF X IS A2,…,& Y IS B2 THEN Z IS C2

⋮

Rn: IF X IS An,…,& Y IS Bn THEN Z IS C1

(1.5)

where: X, Y, Z are linguistic variables, representing the system state. Ai, Bi, Ci are linguistic values of the linguistic variables x, y and z. A more general shape is that, where consequences are represented by a function having as variables the process states:

Rt: IF X IS At,…,& Y IS Bt THEN $Z = f_t(x,..,y)$

(1.6)

and t represents the evolution on of the system at different moments.

The optimization models determine the optimal configuration of flexible manufacturing system within the relevant objectives, this resulting from crossing a finite number of calculation steps (Fig. 2). One can distinction between models that are based on mathematical optimization models based on the concepts of artificial intelligence (knowledge bases and expert systems). In the literature are found different mathematical optimization approaches covering a vast space of different decision variables [5, 6]. Modeling and simulation of a system generally and a flexible manufacturing system, in particular, involves creating a model of the system and its implementation in a computer utility program aimed verify system operation and its performance evaluation. Type models (AI) is the conceptual qualitative leap from traditional mechanism to algorithms that process the rule-based knowledge and reasoning. Artificial intelligence is involved in process modeling theory in the following situations: the design of systems based on fuzzy control, development of expert systems, neural network implementation, development of genetic algorithms. In order structural analysis of FMS, a first step was carried decompozarea system into subsystems

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components were determined couplings between them and the transfer function. On this basis it was developed a fuzzy model, which comprises a group of equations linguistic model that was used for the algorithm operation.

In contrast with mathematical optimization models, the concept of artificial intelligence [7] offers the designer support flexible system easier to find the best way, an optimal solution. It also provides an environment in which proposals for different variants of a single FMS can be investigated further. The proposals are based on a series of knowledge contained in a knowledge base and the relationships between decision variables. This knowledge is in the form of rules that concern the characteristics of FMS and their interdependence.

Modeling and simulation of a system generally and a flexible manufacturing system, in particular, involves creating a model of the system and its implementation in a computer utility program aimed verify system operation and its performance evaluation. Type artificial intelligence models are conceptual the qualitative leap from traditional mechanism to algorithms that process the rule-based knowledge and reasoning. Artificial intelligence is involved in process modeling theory in the following situations: the design of systems based on fuzzy control, development of expert systems, neural network implementation, development of genetic algorithms. In order structural analysis of FMS, a first step was carried decomposition of system into subsystems components were determined the couplings between them and the transfer function. On this basis it was developed a fuzzy model, which comprises a group of equations linguistic model that was used for the operation algorithm [2].

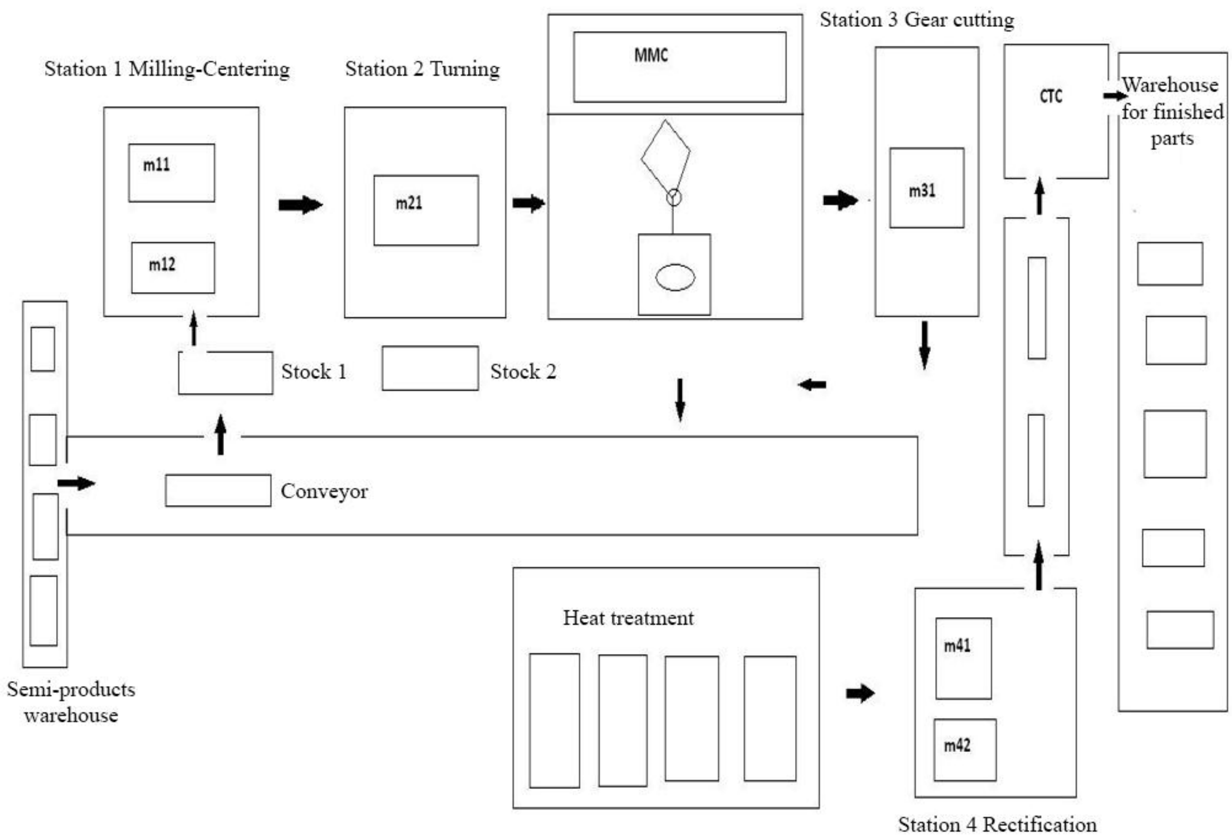

Figure 2. The Flexible Manufacturing System optimized

CONCLUSION

Creating virtual enterprise entity type and effective monitoring activity in these entities constitute the

majority of its fields of operation, one of the most modern approaches. IT infrastructure necessary for proper functioning of the whole is characterized by a complex architecture, virtual enterprise is essentially a heterogeneous distributed system.
From this point of view is essential the use of standardized solutions and flexible manufacturing systems, namely, integration of equipment and applications to provide interoperability and flexibility features. Therefore a professional option is to use a specific technology integration and flexible manufacturing systems.

The use of modeling and simulation techniques for optimizing system structure and behavior is determined by the present conditions regarding the management systems, international affairs systems, which have the tendency of becoming more and more complex, under the influence of a growing number of internal and external factors. Models are used that are abstract representations of reality or of the system behavior, with the use of adequate languages.

Because in any given real situation, the necessary effort and the wanted benefit can be expressed in terms of a function with well defined decision variables, optimizing can be defined as finding the conditions which give the function has minimum or maximum values. Optimal searching methods are known as mathematical programming functions and are studied as parts of operational research. Optimizing is build from algorithms in which properties can be quantified in the terms of functions. The optimizing process uses a multitude of initial values and corresponding solutions, which are user defined or random generated by the algorithm. Optimizing algorithm generates then successive these kind of values, leading to an optimal one. When more than one variant are possible, the best possible solution is to be chosen.

Current research [7] demonstrates that the use of expert systems in which automation is extended step by step leads to search for a flexible manufacturing system optimal. Whether used a mathematical optimization model or an expert system or other system dimensioning and configuration of flexible manufacturing systems towards an optimum that seek aims same central requirement, ie must be performed quickly and accurately evaluating alternatives that satisfy relevant performance criteria. The analytical models used to estimate the performance of a system allowing more accurate assessment of them. At the end of the evaluation is recommended to use a simulation model as a tool for investigations detailing a flexible manufacturing system configurations. At first you can use performance evaluation procedures that quickly creates a rough estimate of the performance of a flexible manufacturing system. Thus, it is possible to eliminate a large number of alternative configurations earlier and with a lower calculation effort. The investigation continues progressively until several configurations FMS remain to be studied in detail using simulation models.

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