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OPTIMIZING FLEXIBLE MANUFACTURING SYSTEMS

FOTA ADRIANA
Transilvania University of Brasov, fota.a@unitbv.ro

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Abstract: Most of the complex problems, which appear in the manufacturing domain, and the management of manufacturing systems (flexible manufacturing systems) are optimizing problems. To optimize is the action of obtaining best results for some given circumstances. In design and maintenance activities, engineers have to make series of technological and managing decisions at different levels; the purpose of these decisions is to minimize necessary actions or to maximize the benefit. In this paper is presented the optimizing flexible manufacturing systems.

1. INTRODUCTION

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

2. OPTIMIZING FLEXIBLE MANUFACTURING SYSTEMS

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

- 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 (R_k) form 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 (*m_i*), processes (*PrR_k*) and machining quality control for parts (R_k).

2.1 The minimization of the duration of the total manufacturing

For a manufacturing system with lots of given machines $\{m_i\}$ date and a manufacturing task $S_aF_a \triangleq \{R_k\}$ typo-dimensional diversified, *the planning of the production is definite as allocation, in time, funds of available manufacturing, of some manufacturing tasks with the aim to satisfy a set of objective*. The planning of the production is served on the strength of the hypotheses: $\min t_{ad} \rightarrow 0$ what presupposes the overlap of the preparation machines (m_i) and of the logistic industrial subsystem (S_bLI) across a time - t_{op}; time -t_{ad} are charge independent of current manufacturing what presupposes that the preparation of each machine (m_{ij}) is heteronymous across processing every current tasks; t_{ad} are dependent on the part (R_k) and technological operations -OT_i current and included, at least partial, in time: $t_{op_{ik}} = t_{\ell_{ik}} + t_{ad_{ik}}$.
These hypotheses lead to an algorithm (the method) heuristics in which the human experience has a decisive role.

The input information and the hypotheses for the algorithm of planning are:

- The manufacturing task $S_aF_a \triangleq \{R_k\}$: the typology of the marks, the annual plan of production (*APP)* recouped on typo-dimensional parts the measure of the lots of manufacturing -$n_{PL}(R_k)$ recouped on lapses, the consistence and the stability of the process, the plan of manufacturing itineraries $(P_\ell I_t T_h)$,.
- The machines-system -$SM = \{m_{ij}\}$: the type machines -m_{ij}, their number, the assignee technological operations -$OT_i(R_k)$ *asign* m_{ij}, $t_{\ell_{ik}}$, $t_{op_{ik}} = (t_\ell + t_g + t_{ad})_{ik}$,
- The technological operations are un-preferential, subdued to the constrains of precedence.
- The times -$t_{\ell_{ik}}, t_{g_{ik}}, t_{ad_{ik}}$ are know, give; $t_{ad_{ik}}$ it doesn't overlap, at least partial, across $t_{\ell_{ik}}$, resulting $t_{ast_{ik}}$,
- The preparation machine -$m_{(i+1)}$ is done heteronymous across processing machine -m_i, through a procedure of planning heuristics.
- Any machines, in a finite lapse predetermined Δt, executes either a technological operation OT_i of proceed in time t_{ℓ_i}, either found in prepare for the acclimation to technological operations -$OT_{(i+1)}$ in time -$t_{ast}(t_{ad})_{(i+1)}$,
- The activities to prepare any machines $\forall m_i$, always, precedes a technological operation $OT_{(i+1)}$, without another activity or t_{ast} between they,
- The route of the parts R_k between the moments t_{f_i} and $t_{in(i+1)}$ is from machine m_i to machine $m_{(i+1)}$ and knows heuristics to expert.
- Is neglected the breakdowns of the components of flexible manufacturing system.

- Any mark from the string of central expectation (sac) is accessible to any machine - $\forall m_{ij}$ among series and parallel $(q+p)_k$ necessary machines from systems.
- The multitude of machine- $\{m_{ij}\}$ is consisted of equipments, station of work (UT_i, S_{t_i}) of same type and of different types.

Objective of the algorithm is:

$$\min \tau_{f_k} = \min \sum_{i=1,k=ct}^{q+p} t_{op_{ik}} \tag{1.4}$$

$$t_{op} = t_\ell + t_g + t_{ad} + t_{man} + t_{ast}$$

2.2 The minimization to unused times of m_i machines

Considered give the machines $\{m_{ij}\}$ and the marks R_k with $k = ct.$

To *balanced* a systems of machines $SM = \{m_i\}$ means to organized the activity of human operators and to planed the material flux for proceed $(P_\ell I_t T_p)$ so in order to minimize the unused times of any machines $\forall m_{ij}$, for a manufacturing rhythms enforced $\forall S_{t_i}$ (remaking, assemble or check), through a *still more uniform load and more complete of workstations (S_{t_i}) and of other components of flexible manufacturing systems (FMS) and of human operators,* taking count of a sets of restrictions specify.

The equilibration is realized through the equalization (approximately) of operations times. The equilibration technological operations (OT_i) of processing is else difficult than for assemblage/ mounting.

The equilibration of the manufacturing structures involve proceed of the following stages: the elaboration process $P_r R_k$, the settlement of relationships of precedence and conditioning, the settlement of an objective function, the define of the interval of variation of the rhythm R_f, assignee of the partial tasks of manufacturing on each S_{t_i} with the time $t_{op_i} \approx \frac{1}{R_f}$ or $t_{op_i} \approx k \cdot \frac{1}{R_f}, k \in \aleph$ (multiple of R_f) in order to assign a regime of stable work and the optimization of the objective function.

The classification of the equilibration problems for manufacturing structures of lines types of manufacturing in flux and *flexible manufacturing systems (FMS)*.

There are the criterions of classification:

1) The time t_{ℓ_i} of technological operations OT_i: t_{ℓ_i} necessitations and stochastic with functions of repartitions known (for instance exponential negative),
2) The manufacturing rhythms R_f can be constant and determinist for *rigid manufacturing systems* and variable- determinist for structures type are *flexible manufacturing systems.*
3) The manufacturing task $\{R_k\} = S_a F_{ac}$ proceed in system; $\max k = 2,3$ marks in rigid manufacturing system (system orientated on product), $\max k = r$ (diversify typology) for flexible manufacturing system (system orientated on process of group technology).

4) The efficiency any workstations $\eta_{S_{t_i}} : \eta_{i\max} = ct$ for $\forall S_{t_i}$ - equal shipment, system *planed well-balanced*, $R_f = k_i \cdot \frac{1}{t_{op_i}}, k_i = ct \geq 1, \eta_i = \text{var}$ - load planed unequally with $k_i \frac{1}{t_{op_i}} \neq R_f$.
5) The interface man-machine: any workstation - $\forall S_{t_i}$ is attended of an alone man which supervisees the process, possibly he executes one tasks assignee special-sequential; some S_{t_i} can be attended of several workpeople with precise-assignees tasks for $P_r R_k, k = \text{var}$,
6) Restrictions of compatibility: exist and operate immeasurably or don't exist than the precedence
7) Exist hoardings between work stands S_{t_i}: exists the hoardings - ST_i with the capacity of accumulation $C_{ai} = n_{ap}$ or don't exist ST_i, therefore $C_{ai} = 0$,
8) Functions plausible objective: the total time of unused the system or of some among machines m_i from system $(z-q), t_{tnSFF}$ or time $t_{tn(z-q)}$ deterministic or stochastic, really or average; the total cost of unused system or a part from him $C_{tnSFF}, C_{tn(z-q)}; \min qS_{t_i}$ therefore the minimization of investment; $\min R_f$ and $\min t_{liv}$ for $\lim\limits_{t_{tn} \to impus} t_{tn(z-q)}$; the choice of the aggregate type (parallel, mixed, series) with harm of one or else peoples; restrictions of compatibility offer solutions for partitions of the multitude phases of work in operations and assignee of them S_{t_i}; the hoardings ST_i attend to a better equilibrations of work stands S_{t_i}.

2.3 The problem of optimal planning of production in flexible manufacturing systems on the criterion time operational/ machine, with consider to the integral flux of semis and tools.

Is considered the planning of the production in order manipulation subsystem and transporter subsystem ($S_b M_{an} + S_b T_p$) to their semis (Sf) and their tools (Sc).

The extensive model envisages: configurations of structures flexible manufacturing system (FMS) equipped with diverse subsystems of hoarding, transport and handle semis; configurations of flexible manufacturing system with composing: the subsystem of process of the machine tools type with the digital statement, of the stands of work.

Hoardings, workstations of type machine of measured, i.e.; the capacity of select any machines to transmits the program of proceed for a namely mark/ operation technological - R_k / OT_i; the capacity to plan the route selected (itinerary of transport) $I_t T_p(R_k), 1 \leq t \leq n_{t_p} \in \aleph, \max t = n_{t_p}$, transport real routes in FMS, from the multitude of feasibly itineraries $I_t T_p(R_k) \subset \{P_\ell I_t T_p(R_k)\}$ in minimum time $\min(t_{M_{an}} + t_{t_p})$; the capacity of balance FMS through restrictions of store the capacity of accumulation $C_{ai}(ST_i)$; the capacity of handle/ transport (change) of tools.

Problem is of hierarchically decision type on three stages: machine, tool and the logistic industrial subsystem.

2.4 The model for the global planning of material flux of semis and tools, in FMS

The planning optimal global of the production in the flexible systems manufacturing require a model which considers:

- $\exists\{m_i\}\supset m_i, 1\le i\le q\subset z \Rightarrow asignP_rR_k=\{OT_{ci}(R_k)\}, 1\le k\le r; \forall R_k \Rightarrow P_r(R_k)\Rightarrow$
  $\Rightarrow < OT_{ci}, 1\le i\le q\subset z >$
- $i=1\Rightarrow asignS_{t_i}, i=q\Rightarrow asignS_{t_d}$
- $\forall m_i \Rightarrow asignST_i(C_{ai})$
- $\exists S_bLI=\{S_{b\,id}, S_bA_\ell/E_v, S_bM_{an}, S_bT_f, S_bT_p\}\Rightarrow S_{t_{id}}, S_bA_\ell S_f, S_bA_\ell S_c, M_{anip}S_c, DS_c, RC, CV, S_{t_{P_a}},$
  $S_{t_{pregP_a}}, S_{t_{pregPS_c}}, S_{t_{preregS_c}}$
- $\forall R_k: T_c, t_{in}, t_f, t_f-t_{in}=T_c, t_\ell, t_g, t_{ast}, t_{ad}, t_{M_{an}}, t_{contr.}, t_{op}=t_\ell+t_g+t_{M_{an}}+t_{ad}, T_c=t_\ell+t_g+t_{M_{an}}+$
  $+t_{ad}+t_{contr.}+t_{ast}$.
- There are series aggregate of $qm_i(OT_{ci})$, parallel aggregate of $pm_j(OT_{sj})$, aggregation mix, series-parallel of $(q+p)m_{ij}$.

The model involves a customization of flexible structure *FMS* which satisfies the conditions of excelsior as the in Figure 1.1.

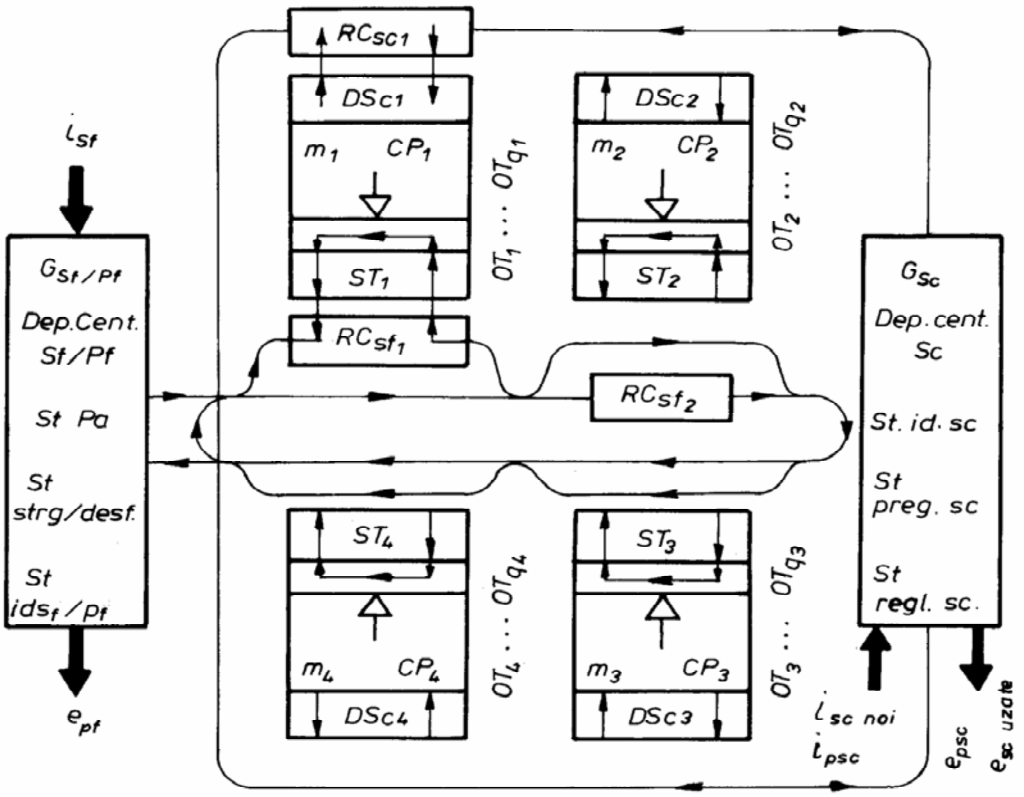

Fig. 1.1 The configuration of flexible structure

For such structure flexible customized the problem of global planning to the stage of workshop is put thus: to establish the charts (sequences) itineraries of transports

$I_t T_p(R_k)$ and of the process of proceed ($I_t T_h$), of process $P_r(R_k)$ the pieces and $I_t T_p(S_{cs}), P_r(R_k, S_{cs})$ of necessary tools thus that to $\min(\tau_f, t_{liv})$ of $LF(R_k)$.

The hierarchic decisional structure shall be one from the Figure 1.2.

The decision is taken on three stages: machine m_i, the tool and the logistic industrial subsystem $S_{cs}, S_b LI$.

Level 1: The decision consist in the selection m_i for a OT_i date, among q series and p parallel (redundant) $m_{ij}(R_k) \subset z\, m_i$ from SFF; the settlement of partition and sequences OT_i and FT_i in the process $P_r(R_k) - I_t T_h$; the settlement of the itineraries plan of transport $I_t T_p(R_k)$ (follow the routes); the graphic settlement of repartition OT_i on the $(q+p)m_{ij}(I_t T_h)$ and of their loading.

The decision can be *off-line* in report with processing which allow procedures of optimization on the computer of FMS lead or *on-line* when the repartition chart $I_t T_h - P_r(R_k)$ and the load m_{ij} are giving (preordained) and the programs numerical-control (NC) is communicated to the tool-machine with the numerical statement.

The procedure on-line require two solutions:

a. The appeal of the numerical statement program through the identification of the palette with marks;
b. The appeal of the palette with marks through numerical statement program give, which exist on the machine.

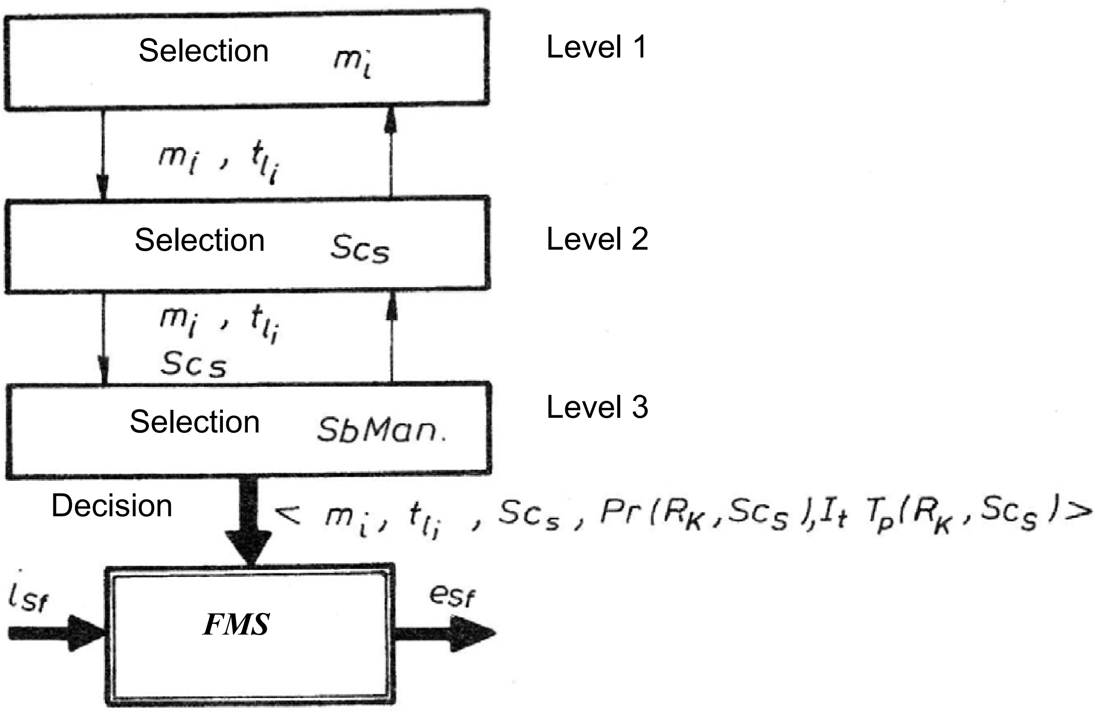

Fig. 1.2 The hierarchic decisional structure

Level 2: Is considered as $P_r(R_k):\{N_{S_c S_t}, N_{S_c S_p}\}, N_{S_c S_t}$ - the number of standard tools, $N_{S_c S_p}$ - the number of special tools necessary to proceed the mark which are stored in preliminarily in DS_c of machine m_i selected and some special/ standard tools, used by many m_i, are stored in a zonal warehouse of flexible manufacturing system and transferred with an rob car for tools on a separate route, to each machine selected.

The decision to this level consist in the graphic settlement (planning) of selection/ manipulation of tools and semis with the rob car, from the zonal warehouse to machines and inversely.

Level 3: The decision consist in the selection (the planning) transport routes from the itineraries plan of transport ($P_\ell I_t T_p$) of the semis/piece finite (S_f / P_f) and tools/ post tolls (S_c / PS_c) through palettes/ rob cars (P_a / RC_{S_f}) and port tools/ rob cars of tools (PS_c / RC_{S_c}) for any mark ($\forall R_k$,). This represents the stage of establish the itineraries chart of transport for semis and tools, using the logistic industrial afferent subsystem. The level 3 requires many types of auxiliary operations of handle semis and tools. The execution of these auxiliary operations is ordinate and with restrictions of precedence temporary.

The manufacturing period it will be the one needed to mechanical process entire lot of pieces:

$$\tau_f = \max_{\alpha_{\max}=n_{PL}, i=q, k=ct} t_{f_i}(R_{k\alpha}) - \min_{k=ct, i=1, \alpha_{\max}=n_{PL}} t_{in_i}(R_{k\alpha}) \tag{1.5}$$

Where: t_f- is the ending moment of last technological operations for all the lots of manufacturing and t_{in} is the begin moment of first technological operations.

2.5 The problem of minimization time for transport and handle in flexible manufacturing systems

This is referred to the time minimization for transport and handle semis/ tools in flexible manufacturing system through the optimization of configuration/ reconfiguration of flexible structures.

The location in FMS consist in finding the places of optimum placement for the components of flexible manufacturing systems: the machines, the hoardings and the itineraries of transport $m_i, ST_i, I_t T_p(R_k)$ of the logistic industrial subsystem in a space enforced with forbidden zones (walls, scales, existing components, and main transport routes).

The principal's criteria's of optimize the location are: the minimization of the length of transport routes with and without load (the material flux), the minimization used surface of whole flexible manufacturing systems. Technical restrictions: the assurance of minimum distances between of machines, the assurance parameters of evenness, the observance of the limits enforced to weights and to heights.

Evaluation indicator. The principal indicator of estimate the efficiency of the logistic industrial subsystem ($S_b LI$) and especially of the transport subsystem ($S_b T_p$) is give by the product: *the distance **x** transport speed **x** task transported*

$$I_{T_p} = L_{T_p}[m] \times V_{T_p}[m/h] \times G_{T_p}[daN] \tag{1.6}$$

In the place G_{T_p} can be used the number of units transported [*umt / buc*] and product $V_{T_p}[m/h] \times umt[buc] = R_{T_p}[daN\ m/h, buc\ m/h]$ is named the *rhythm of the transport*.

The efficiency of subsystem of transport - $S_b T_p$ is obtained for:

- $\max I_{T_p}$ through $\max R_{T_p}$ what is obtained through the enlargement G_{T_p} and *umt* and reduce the deadheads;
- $\min t_{T_p} = \min \frac{L_{T_p}}{V_{T_p}}$ what is obtained through the decrease L_{T_p} and the enlargement V_{Tp}.

3. CONCLUSION

The optimizing flexible manufacturing system is an important problem in phase of configuration and dimensioning. The absence to the mathematical models recognized is the projection of flexible manufacturing systems makes difficult the realization of these systems, having consequences to their performances.

The use of optimizing, modelling and simulation techniques for optimising system structure and behaviour 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 behaviour, with the use of adequate languages.

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