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Operational parameters estimation for a flexible manufacturing system. A case study

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Abstract. The complex structure of flexible manufacturing systems and rapid changes currently taking place with the evolution of the market and increase product diversity involves a detailed analysis of manufacturing processes. Manufacturing systems analysis can be done using methods based on analytical models and simulation. By applying these techniques one can view, analyze and forecast the performance of a dynamic system or of a new implemented system. Performance is one of the main factors affecting the design, development and configuration of any flexible manufacturing system. In this context, the present research will be directed to flexible manufacturing system structure analysis, to assess its performance, as well as simulating and validating these systems. It will generate and analyze key performance parameters, for the designed system by the use of specific software. Thus, it will study: the influence of the initial conditions or parameters on the behaviour of the flexible manufacturing system, the influence of the developing commands and system states on output or the influence of changes in the system structure on its behaviour.

1 Introduction

Flexible manufacturing systems (FMSs) are those manufacturing systems intended for manufacturing tasks of large typological diversity, high complexity, ensuring time delivery and minimal manufacture costs, while manufacturing is unpredictable , being held in small batches with frequent change. From the point of view of the global characteristics, flexible manufacturing systems are superior to manufacturing systems which they replace.

In their evolution [1] there can be noticed efficient flexible systems implementing for processing/assembly, but also many failures, determined most of the times by an over evaluation of technical solutions, by the impossibility of managing efficiently these systems which are extremely complex, by huge investment they need. It is very difficult a correct substantiation of the investment costs, which most of the times exceed the expectations. Current, flexible manufacturing systems are being increasingly implemented [2, 3]. Between them and standard machine tools or transfer lines it will be a coexistence with a tendency to increase the use of flexible manufacturing systems. Based on the many achievements of the FMS it is now possible to have fundamental data on the behaviour in service, the requirements for use and areas of utility, particularly with regard to the economic aspect.

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With regard to flexible manufacturing systems modeling operation, there are still several attempts, some recent, [4, 5] to define and analyse the performance indicators of the system. Achieving and introduction into service of a flexible manufacturing system involves a lot of expenses and the expected economic effect is hard to say. For this reason, both during the design and the operation of the FMS, modeling and simulation technique has been used [6, 7, 8].

In this context, the authors propose their analysis of the structure flexible manufacturing systems in order to assess their operational parameters and the knowledge of system behaviour through simulation before implementation. Using simulation we intend to clarify some issues regarding the description of the system operation, development of theories and hypotheses based on previous functioning, using the model to predict future functioning, namely the establishment of the effects of changes in the system.This paper is aimed at developing and applying optimization of flexible production systems in order to increase technical and economic performance of these systems, based on previous research conducted by the authors [9, 10].

2 Structure of the flexible manufacturing systems. Case study

The evolution in time of the condition of flexible systems for processing cylindrical parts, for dynamic systems could be described by algorithms or complex procedures [9], which in turn better describe the actual operation.

Figure 1 presents the structural scheme of FMS which will be used in the estimation of the operational parameters for cylindrical parts in real processes. Its validation was done by computer simulation for actual physical applications [10]. This system must implement a flow of operations as follows: cylindrical semi-automatic supply from a warehouse; the transport of the semi-finished on a conveyor to the drilling machine processing station; piece drilling operation, with control of the computer drilling depth and speed of advance; transport of the drilled piece towards the processing by turning simulation station; simulation of the turning process: clamping the piece between two tanks and turning it; checking the exterior odds of the piece via a measuring laser sensor (online control); displaying and recording of the measured data on the computer; transport the parts on the gear cutting station and grinding station and at final transport to the warehouse of finished goods; storing of the parts in the warehouse of finished products or ejection of rejects, which are not within the tolerances, settable via software SCADA.

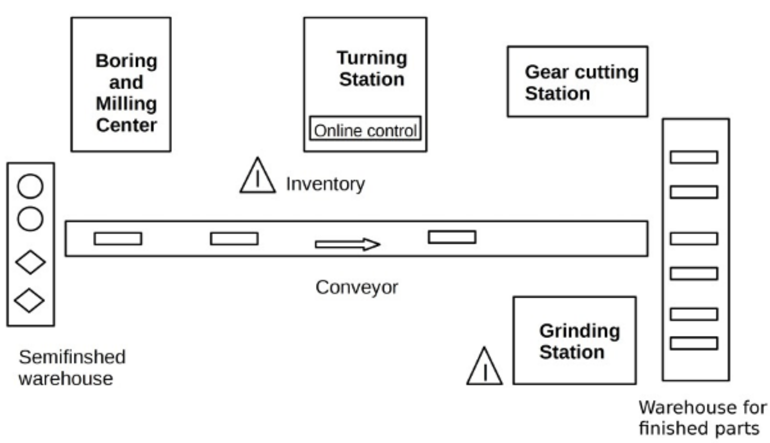

Fig. 1. Structural scheme of FMS.

3 Case study regarding estimation of operational parameters of FMS through simulation

The performance is one of the main factors affecting the design, development and configuration of FMS. Measurements, analytical models and simulation models are alternative performance analysis techniques. The models based on the simulation are preferable because they allow to obtain accurate results for complex and larger calculations, with fewer assumptions.

The methodology applied in the study of the processing of cylindrical parts in a FMS was by decomposing the system, detailing the internal structure of it, so the running processes of all its subsystems components could be algorithm-based and introduced step by step in the computer, observing accuracy and decision into account the interaction with the external environment, [9]. The evolution in time of the system state was described by algorithms or complex procedures that better express its actual functioning. Within the analysis through modeling, it will take into account the following categories of time: directly productive activities require working times (t_w); indirectly productive activities uses auxiliary times (t_a), which may be auxiliary times during the work cycle (t_{aw}) that are also called idle times and are composed of times for: supply / evacuation, positioning, waiting, change tools, grip / detaching in work device; auxiliary times off work cycle (t_{ao}): transport / transfer times, handling times, adapting times for manufacturing batch, waiting times. Major influences on system performance have waiting times which are generally unpredictable times, challenged by asincronysmus of the system. To improve performance of the system, during the design / manufacturing, activities that consume large auxiliary time are emphasized.

3.1 Input data

To study and analyse the performance of a cylindrical parts processing FMS, [10] will consider the following initial data of entry into model: current part in manufacturing (P_k, $1 \le k \le p$), p - number of types parts from typological diversified manufacturing task; the processing of parts P_r (k, $k = ct$). It considers serial production, manufacture executing on the size batches of the size of $n_b[pcs/batch]$, for $\forall P_k \in FP_k, k \in \aleph, k = [\overline{1,r}]$ with the frequency of occurrence of the lot $\nu_{bk}[no.batch/\tau]$. Any model is developed on a time interval τ (week, month, and year).Performance analysis simulation system will be made in relation to a number of operational parameters: the duration of manufacturing (T_m), the average manufacturing duration (T_{mk}) of a part on the whole system of machine, the production rate (R_p) on the part, on the machine (m_i), production capacity, average unit through production time - $\overline{T}_{mu}[h/pcs]$, the period of the machine cycle - $T_c[min/pcs]$, the degrees of utilization in time for workstation (η_{tu})and in days (η_{du}), production in processing (P_p). The developed model aims to know the system behaviour as well as it performance, and if possible, even before their physical realization.

3.2 Simulation of FMS

The simulation can intervene when designing the FMS to determine the static charge or for more elaborate validation solutions that rely on dynamic models. These techniques are used to substantiate decisions on the optimal exploitation of FMS. Selecting the programming language in which the simulation model will be coded has significant effects on the quality of results analysis through simulation of the systems.

This case study will use ARENA Simulation Software version 15.00.00001 (Arena Trial version), [11]. ARENA is built on the SIMAN simulation language. Alongside the encoded transcription of the simulation model, the simulation language performs a graphical animation, which allows to view on the display the behaviour of the simulation. ARENA is considered powerful software specialized in the analysis and evaluation of complex manufacturing systems [12, 13].

ARENA is software for dynamic simulation of discrete technical systems that includes FMS and uses terms like: *entity* is part of the system which constitutes a subsystem; *attributes* are characteristics of the entities; *activities* are dynamic processes that lead to modification of attribute values; *event* produces changing the value of an attribute. ARENA requires knowledge of random distributions, probability, and statistics.

3.2.1 Simulation modelling of proposed FMS. Results

For the realization of the imitative model of the FMS and its computer simulation were considered these dates: the number of the machines-tools from the system, the number and the type of vehicles and the transport speed, the number of deposits and their capacity, the type parts, the technological route, the cycle time of processing of each type of piece and each module of the flexible system, the matrix distances between machines; transfer time between transport means and machine-tools, the average adjusting time of each machine-tools. For analysis were used analytical and configuration models, previously designed FMS [9, 10].

Figure 2 presents the flexible system designed model and analyzed in the previous paragraph, model built using ARENA simulation software, which describes the logic of model. Arena is an easy-to-use, powerful modeling and simulation software tool that allows the user to construct a simulation model and run experiments on the model. Arena provides a simple method to setup the simulation parameters and the model input parameters [11].

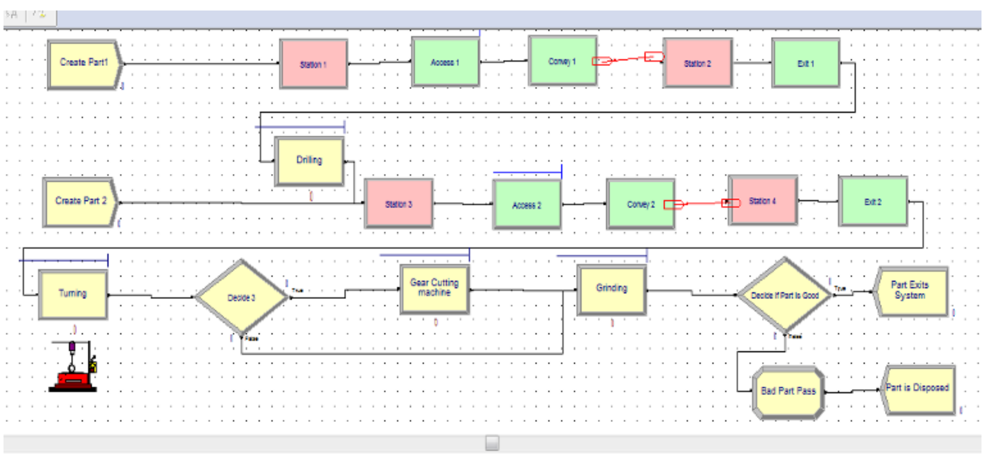

Fig. 2. Flowchart of the FMS model.

The software generates several reports as a result of a simulation run.

As a first result obtained by evaluating the flow of parts on machine and processing stations and examining conflicts regarding the application of limited resources, it could be evaluated and optimized the system layout, the selection of equipment and industrial logistic subsystem, as well as the operating procedures.

The analysis was performed for the following parameters required in the design and optimization of the production system: real manufacturing times for each task of production, production rate, laden workstations, analysis of bottlenecks, allocation of tasks on workstations, scheme of composing system.

After running of the simulation model show the result of throughput analysis such as average, minimum and maximum times for production.

Table 1 shows part of the Category by Replications report. For example, from this report the average VA time is 2.9776 minutes for Part 1 and 3.3240 for Part 2. The increase of the system performance was achieved by reducing the handling times of pieces, waiting time and duration of manufacturing.

Table 1. Category overview time in FMS.

SFF

Replications: 1 Time Units: Minutes

Entity

Time

VA Time	Average	Half Width	Minimum Value	Maximum Value
Part1	2.9776	(Insufficient)	2.6148	3.3871
Part2	3.3240	(Insufficient)	2.8805	3.8507

NVA Time	Average	Half Width	Minimum Value	Maximum Value
Part1	0.00	(Insufficient)	0.00	0.00
Part2	0.00	(Insufficient)	0.00	0.00

Wait Time	Average	Half Width	Minimum Value	Maximum Value
Part1	12.8531	(Insufficient)	0.8971	22.7689
Part2	12.2111	(Insufficient)	0.00	22.3008

Another important performance measure is also utilization of the workstations from the system. Table 2 shows part of the Resources report produced after the simulation run. The resource (Machine 2 - Turning and Machine 4 - Grinding, for example) utilization was 99.06% and 98.62% (average) and 100% (maximum). Analyzing the operational parameters of the system it aims to balance by raising the load Machines 3 (Gear Cutting) and Machine1 (Drilling). This will reduce the losses on the production line.

Table 2. The Resources report of the FMS model.

Resource

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
Machine 1	0.7188	(Insufficient)	0.00	1.0000
Machine 2	0.9906	(Insufficient)	0.00	1.0000
Machine 3	0.6365	(Insufficient)	0.00	1.0000
machine 4	0.9862	(Insufficient)	0.00	1.0000

Figure 3 shows part of the Queues report. Arena provides a facility to generate or draw dynamic plots of a simulation run (Figure 3).

SFF

Replications: 1 Time Units: Minutes

Queue

Time

Waiting Time	Average	Half Width	Minimum Value	Maximum Value
Access 1.Queue	0.5340	(Insufficient)	0.00	4.7441
Access 2.Queue	9.9123	(Correlated)	0.00	17.7556
Drilling.Queue	0.02810185	(Insufficient)	0.00	0.4967
Gear Cutting machine.Queue	0.4779	(Insufficient)	0.00	4.3909
Grinding.Queue	1.9665	(Correlated)	0.00	4.9092
Turning.Queue	0.2416	(Correlated)	0.00	0.8231

Other

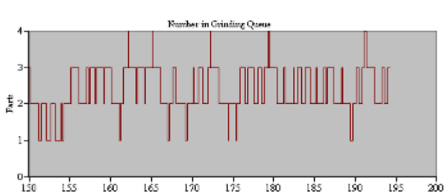

Fig. 3. The Queues reports of the FMS model and dynamic simulation run.

By knowing and evaluating these parameters it can be performed some optimizations on the process and the system by: determining the optimal type and number of workstations, choosing logistics system and developing the layout of the system. The parameters and performance indicators will be set in order to optimize the synthesis of the system in real-time environment. One obtained increasing production capacity and the degree of utilization. The reduction of production processing and the duration of manufacture have increased the production rate and thus to reduced production costs.

4 Conclusions

Modeling and simulation of a flexible manufacturing system involves creating a model of the system and its implementation in a computer utility program aimed verify system operation and its performance evaluation.

To achieve the research it was carried out verification and validation of the designed models, the stage by which their validity was confirmed by using existing software and modern equipment in the modelling and simulation laboratory of the production systems and the research centre. This work identified opportunities to shape the research and the application in industry. During the process of simulation cylindrical parts processing one were able to identify and eliminate errors, adverse situations and events.

In the simulation were used values of the transitions related to conditions from the real process so that the simulation better reflected the behaviour of the flexible line. Thus, they were able to study the complex interactions within the analysed flexible production system, which helped to increase the performances of the system. An important role in the FMS is knowing the number of processing subsystems, their layout and diversity. Layout-structure configuration of processing systems and logistics subsystem has a direct influence on the production capacity and adaptability through reconfiguration. In the simulation phase, assessing performance criteria allows the introduction of strategies for planning the system resources.

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