International Journal of
Science and Engineering Investigations vol. 5, issue 59, December 2016
ISSN: 2251-8843

Performance Analysis of a Production System

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Abstract- In a rapidly changing world, in the context of large increase in the typological diversity of products, and the requirements and preferences regarding their performance there are imposed mutations and profound transformations in the structure of production systems. Considering the complexity of flexible production systems, this paper presents a performance analysis model of a flexible manufacturing system previously designed. The developed model aims to know the system behavior as well as it performance, and if possible, even before their physical realization. The parameters and performance indicators will be set in order to optimize the synthesis of the system in real-time environment.

Keywords- *production system, flexibility, optimization*

I. Introduction

Currently we witness to a rapid development of advanced manufacturing systems by introducing automation and computers in most industries, but also as a result of market diversification, increased consumption of products / services and perfecting the management methods.

The evolution of these systems was so motivated by increasing productivity on the one hand, and increasing the number of types of products that can be made in the system, on the other hand. A solution was offered by the implementation of flexible production systems, whose main characteristic is flexibility. The notion of Flexible Manufacturing System (FMS) is linked to the new conception which includes integrating manufacturing computer components and flexible manufacturing [1, 2].

Currently, the research area of advanced manufacturing systems, led by computer is booming, considering the future, based on robotics, automation and integrated manufacturing. Impetuous development of this area lately and the insistence that industry require and uses integrated manufacturing systems are arguments for extending the scope of research and increase the level of complexity and detail required.

Flexible production systems must occupy a central place in national and international research, more so in the university, considering the implementation of new methods to increase productivity and quality of production, and consequently the performances of production systems.

Flexible manufacturing system is a complex system that involves complete study of the systems components, such as processing subsystem, industrial logistics subsystem, process management subsystem, control and monitoring of the operation in real time. Analyzing the system from this point of view, it can be establish the conditions that satisfy the requirements of flexibility and automation [2].

Lack of consecrated mathematical models in the design of flexible production systems makes the creation of such systems difficult, with consequences upon their performance. Because it is imposed the new property of production systems "flexibility", there can appear some conception errors, and designers can't anticipate precisely the optimal flexibility degree. As far as the approach method of the large topic of flexible manufacturing systems is concerned, it must be remarked the fact that there were and there still are different methods and interpretations, but no model confirmed practically has been imposed.

The modelling of flexible manufacturing systems functioning represents currently the most dynamic and controversial research area in the domain. Mathematical modelling of complex systems, so of flexible manufacturing systems as well, leads in general to large dimensions models. There are problems concerning the model dimension, more precisely, even if this model is very large it can't include all the interactions between component subsystems and between them and the exterior environment. If a larger model is wanted to be realised, and its precision degree must be high, it can be difficult to be realised, and the relevance of the problems to be solved decreases, fact which is mentioned in the speciality literature [2, 3]. An impediment in flexible fabrication systems design is represented by the fact that up to now there is no formal method, design methodology accepted by everybody in order to create a FMS. This conclusion is quite frequent in the speciality literature [4, 5, 6].

Although the designer designs the line to produce efficiency of 100%, in practice this is impossible. To operate in real production line are taken to analyze several indicators of efficiency and performance of the analyzed 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 [7].

II. ANALAISYS OF MANUFACTURING TASK

The fundamental element which must be the basis of a flexible production system design is the current manufacturing task, characterised by a predetermined typology.

A. *Synthesis stages of the manufacturing task*

The first stage in the design of any flexible manufacturing system is the manufacturing task analysis. The importance of the manufacturing task analysis and its complexity derive from the fact that flexible production systems are destined to small series production, characterised by a typological diversity and instability in time. It is estimated that about 70 % from the actual production is realised by methods which are specific to the small / individual series production.

The references family, the version or the reference as technological entity, which is manufactured by mechanical processes is considered having configuration – geometrical and technological properties given, known from execution drawings. Or, while designing any flexible production system, the designer has sometimes a partial typology, undefined significant, insufficient relevant, taken from execution drawings which are available. Under these conditions, the analysis of manufacturing task opens a large research field, and for now it is not elaborated any analytical model of the manufacturing task for the synthesis of FMS.

The manufacturing task is defined by a series of parameters, such as: typological diversity of products results in the output system, the diversity of manufacturing processes as a method in the system, production volumes, production type and size of manufacturing and plan of the itineraries technology. The manufacturing task may be determined either by analysis or synthesis. Task analysis of production lies in its establishment by selecting parts from a collection once, they constitute the "typology nucleus, that the extension of using filters extension, established on the basis of affinity is determined generalized manufacturing task " [1].

The method leads to determine a generalized tasks production incomplete, imprecise and subjective. Synthesis of establishing the production task based on typological nucleus that will include the whole typology of possible parts belonging to a class, families or variants landmarks, limited by constraints imposed on a field. The method has the advantage of establishing a comprehensive generalized manufacturing task in a field required, but also the disadvantage of laborious activities.

The steps required for the manufacturing task synthesis, are: synthesis of the landmarks class including general properties of the family, of the variants and individual items; the establishing typological nucleus and set the target of generalized manufacturing.

The three main stages of establishing the manufacturing task extended to determine the typology crowd of pieces were detailed in a case study for class the cylindrical parts [7]. Therefore, were analyzed a set of items and by applying analytical models were formed several classes, families and variants, some of which are presented for illustration in Figure 1.

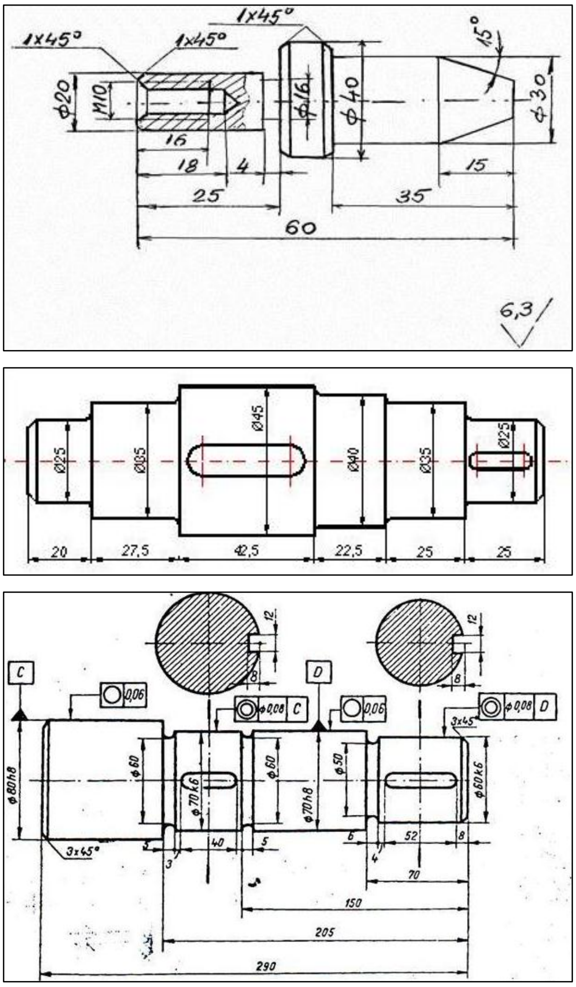

Figure 1. Manufacturing task

In order to achieve the generalized item was conducted a detailed analysis of all the parts of the class cylindrical pieces. This is a fictional representative item contains all the elements, constructive geometry of the family (F) or variant (V), logically ordered and natural.

B. *Program to establish the manufacturing task*

Express generalized item "typological nucleus" that will be the basis design of flexible manufacturing systems. Generalized manufacturing task will was obtained by extension "typological nucleus" using "filters extension" set based on the degree of affinity of the parts [1]. Knowing generalized item can be established the generalized manufacturing technology influencing the structure of manufacturing system and underpins any production.

It was later drafted database containing basic geometric components manufacturing task, consisting of drawings, symbols and notations corresponding mathematical model previously developed [7].

In order computer simulation of the generalized item and the whole tasks of production it was developed in Visual Basic, a program that combines different figures from the database, expressing symbols of strings ordered. In Figure 2 is shown a sequence of application [7].

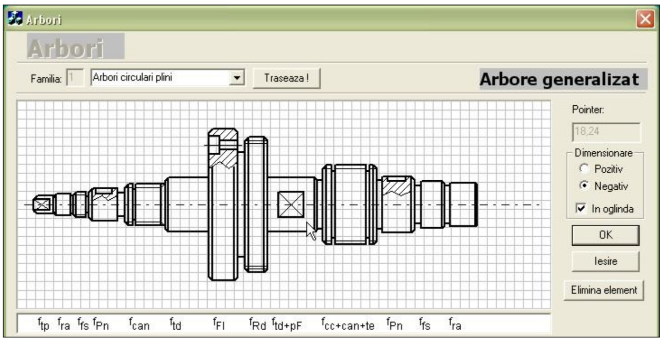

Figure 2. The sequence of manufacturing task simulation

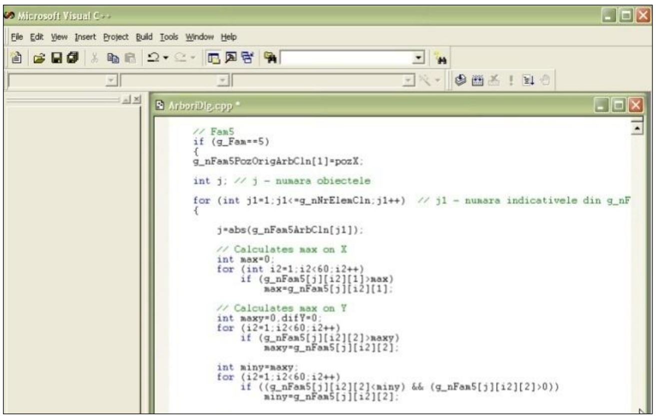

Figure 3. The sequence of simulation software for manufacturing task

The program simulation conducted aims to design various applications in flexible manufacturing systems for processing and circular shaft has been extended to processing other cylindrical pieces.

III. Analysis of the System Performances

A. *The input data. Case Study*

In the following, will be established the inputs in order to design a flexible manufacturing system for the processing a cylindrical pieces. Shall be taken into account the following parameters: h = 8 h / shift work; s = 2 shifts / day; zs = 5 days / week; $\eta_{tu} \geq 0,9$; jetsam = 1%.The adapting times (t_{ad}) and auxiliary times (t_{aux}) are 3 hours / batch production for milling machines.

Have been taken for analysis three families of cylindrical parts / items (I_k).Weekly production plan set by management is presented in Table I, in which: n_{PLk} is the manufacturing lot size and n_{Lk} - frequency of batch manufacturing.

TABLE I. PRODUCTION PLAN

I_k	n_{PLk} [pcs / batch]	n_{Lk} [batch/week]
I_1	40	15
I_2	30	20
I_3	50	10

Technological operations flow, operative times (t_{op}) and auxiliary times (t_{aux}) necessary production and bottlenecks times (t_b) are recorded in Table II, in which: TO_i-technological operations, WSt_i-workstation, MT_k- manufacturing task; m_i – machines; t_{tf} –transfer time; p_{bi}-blocking probability; number blocking causes – n_{bc}.

TABLE II. THE TECHNOLOGICAL FLOW-THE INPUT DATA

MT_k	WSt_i	Technological operations TO_i	Precedence conditions	Machine type M_i	t_{opi} [min /cycle]	$t_{aux\,c}$ [min /cycle]	t_{tf} [min /cycle]	Blockages				$t_{aux\,o}$ [h/ batch]	t_{ad} [h/ batch]
								p_{bi} [stopping /cycle]	n_{bc} [no. causes / cycle]	t_{bi} [min/ blockage]	Blockage type		
1	1	Grip / Detachment	-	Man	-	2	0.5	-	-	-	-	0.2	0.5
2		Debiting	1	Man-FM	2	2	1	0.01	2	5	l_{low}	0.4	1
3	2	Grip / Detachment	2	Man	-	2	0.5	-	-	-	-	0.2	0.5
4		Milling and Centering / left	2,3	Aut-AFC									
5		Centering / right	2,4	Aut-AFC	6	4	1	0.02	4	10	l_{up}	0.4	1
6	3	Grip / Detachment	5	Man	-	2	0.5	-	-	-	-	0.2	0.5
7		Turning roughing	4,6	Aut-SCN									
8		Turning finishing	7	Aut-SCN									
9		Chamfering	8	Aut-SCN	3	1	1	0.008	8	8	l_{up}	0.4	1
-	4	Heat treatment	-	-	-	-	-	-	-	-	-	-	-
10	5	Grip / Detachment	9	Man	-	2	0.5	-	-	-	-	0.2	0.5
11		Grinding roughing	10	Aut-MRR									
12		Grinding finishing	10,11	Aut-MRR	10	1	1	0.04	6	12	l_{up}	0.4	1
-	6	Final control	-	-	-	-	-	-	-	-	-	-	-

B. Determination of technical and economic parameters

The analysis will be performed for the following parameters needed in the design and optimization of the production system:

- Technical and economic parameters for all items;
- Periods of real work cycle;
- Rhythm of prodution;
- Real-time manufacturing for each production task;
- Material flow graph;
- Allocation of the manufacturing tasks in workstation;
- Scheme of composing system;
- The degree of utilization for each workstation.

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 the layout of the system.

For each item, technical and economic parameters of functioning [2] are calculated with ecuations (1)…(10) and presented in the attached tables III….VI.

The duration of total manufacturing, T_m [h], in Table III.

$$T_m = \sum_{k=1}^{r} t_{op\,k} \cdot n_{PLk} \cdot n_{Lk} + \sum_{k=1}^{r} t_{ad} \cdot n_{Lk} + t_{aux} \cdot t_{tf} \cdot n_{Lk} + t_h \cdot n_{Plk} \cdot n_{Lk} \quad (1)$$

Average unit through production time - $\overline{T}_{m\,u}$ [h/pcs] is calculated and presented in Table III.

$$\overline{T}_{m\,u} = \frac{T_m}{n_{PLk} \cdot n_{LK}} \quad (2)$$

The period of the machine cycle - T_c [min/pcs] is calculated and presented in Table III.

$$T_c = t_{op} + t_{aux} + t_h \quad (3)$$

TABLE III. MANUFACTURING TIMES

T_c, T_m, T_{mu}	I_1	I_2	I_3
M_1	5.85	8.25	5.85
M_2	10.02	12.42	10.02
M_3	7.18	9.58	7.18
M_4	14.27	16.67	14.27
M_5	-	21.17	20.33
T_m	235.41	387.21	368.29
T_{mu}	0.392	0.645	0.737

The rhythm of production - R_p [pcs/min], [pcs/h], is presented in Table IV.

$$R_p = \frac{1}{T_c} \quad (4)$$

TABLE IV. RHYTHM OF PRODUCTION

R_{pi}	I_1		I_2		I_3	
	pcs/min	pcs/h	pcs/min	pcs/h	pcs/min	pcs/h
M_1	0.171	10.256	0.121	7.273	0.171	10.256
M_2	0.100	5.990	0.081	4.832	0.100	5.990
M_3	0.139	8.353	0.104	6.261	0.139	8.353
M_4	0.070	4.206	0.060	3.600	0.070	4.206
M_5	-	-	0.047	2.835	0.049	2.951

The degrees of utilization in time for workstation - η_{tu} and in days - η_{du} are determined and presented in Table V.

$$\eta_{tu} = \frac{T_m}{F_{rt}} \quad (5)$$

$$\eta_{du} = \frac{n_{PLk} \cdot n_{Lk}}{R_p \cdot T_m} \quad (6)$$

TABLE V. DEGREE OF UTILIZATION WORKSTATIONS

	I_1		I_2		I_3	
η_u	η_{tu}	η_{du}	η_{tu}	η_{du}	η_{tu}	η_{du}
M_1	0.27	0.722	0.37	0.73	0.21	0.77
M_2	0.40	0.817	0.50	0.81	0.32	0.85
M_3	0.31	0.761	0.41	0.76	0.24	0.80
M_4	0.54	0.864	0.64	0.85	0.44	0.89
M_5	-	-	0.79	0.88	0.60	0.92

The emergence of bottlenecks in flexible manufacturing systems is unpredictable and random and therefore are probabilistic treated. Blockages that occur can be grouped into two categories:

- Blockage of short duration and are analyzed the low limit, for example: breaking tools, hidden defects of the material, discarding parts, et al.
- Blockages during long time analyzed at the upper limit, for example: damage to the machine, workstations, technological installations, industrial logistics subsystem, control-measuring equipment, et al or organizational and managerial dysfunction.

Blockages frequencies (f_{bi}) at upper limit (f_{up}) and lower limit (f_{low}), are determined by the equations (7) ... (10) and analyzed in Table VI.

$$f_{up} = \sum_{i=1}^{q} p_i \quad (7)$$

$$f_{low} = 1 - \prod_{i=1}^{q} (1 - p_i) \quad (8)$$

Calculation of average period blocking (T_{bi}) at upper limit ($T_{b\,up}$) and lower limit ($T_{b\,low}$) is performed with the equations (9), (10) and presented in Table IV.

$$\overline{T}_{b\,up} = f_{l_{up}} \cdot n_{b_{up}} \cdot \bar{t}_{b_{up}} \quad (9)$$

$$\overline{T}_{b\,low} = f_{l_{low}} \cdot n_{b_{low}} \cdot \bar{t}_{b_{low}} \quad (10)$$

TABLE VI. ANALIZA BLOCAJELORBLOCAJELOR

f_{bi}, T_{bi}	I_1	I_2	I_3
f_{up}	0.108	0.108	0.148
f_{low}	0.010	0.020	0.020
$T_{b\ up}$	36.29	36.288	49.728
$T_{b\ low}$	0.1	0.398	0.398

Technical and economic parameters previously determined for a case study - the manufacture cylindrical pieces, are the basis of the system optimization in order to improve its performance by: determining the optimal type and number of workstations in the system; choosing optimal handling logistics system; optimization of the layout of the system; modeling and simulation of flexible manufacturing system functioning.

C. *Material flow diagram*

Material flow diagram represented by graphs provides information about the movement of materials and coordination the points of origin with the point of destination. Material processing flow diagram provides information on times manufacturing, fabrication cycle times, the loading of machines in the system, et al. In the transport stream diagram is recorded information on the number of deliveries over a period of time, distances between workstations or production transported.

Figure 3 is graphically representing the material flow for the item generalized for the FMS designed.

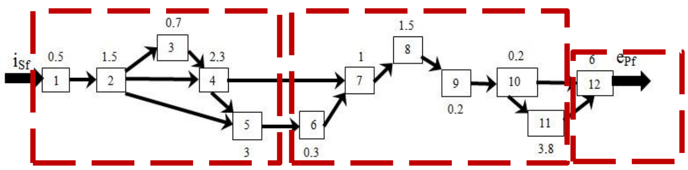

Figure 4. Graful fluxului material

D. *Performance indicator of the FMS*

A performance indicator of fairness the balancing a flexible manufacturing system is the loss of production line [2]. By balancing the manufacturing system was done loading all workstations with manufacturing tasks by which were obtained minimizing asynchronies, delays and the expectations that occur in the system. By minimizing the asynchronies is resulted maximizing loading degree of workstations.

Determination of loss of production line (L_{PL}) for the reviewed system is conform equation (11).

$$L_{PL} = \frac{q \cdot T_c - \tau_m}{q \cdot T_c} = 1 - \frac{\tau_m}{q \cdot T_c} \qquad (11)$$

in which: τ_m total manufacturing time on a batch of production piece is calculated in equation (12).

$$\tau_m = \sum_{i=1}^{n} t_{mej} \qquad (12)$$

where: q is the number of workstations; T_c - theoretical period of manufacturing cycle; t_{mej} - manufacturing time. Result:

$$L_{PL} = 1 - \frac{21}{3 \cdot 8} = 0{,}125 \qquad (13)$$

$$L_{PL} = 12{,}5\% \leq \max 20\%$$

The system analyzed is composed of three workstations in which have been assigned the tasks of production, ensure system balancing losses 11% within a maximum of 20%.

IV. CONCLUSION

Introducing a flexible production system in an integrated manufacturing system, is a major result, leading to the optimization of the entire material and information flow of a company. The concept of flexible production system is linked to the new conception which includes integrating manufacturing components by computer and flexible manufacturing.

The analysis was conducted based on an original method of synthesis of the current production task and consumption of a database and computer program that performs simulation for real items of production, previously developed by the authors [7].

After applying this model to analyze the flexible manufacturing system performance asynchronies have been minimized in the system, namely reducing waiting times, delays that occur in the dynamic operation of these systems. For complex systems with multiple tasks and difficult production, the model developed can easily be transposed to your computer, in order to simulate the operation and system balancing.

The applicative character consists in dynamic simulation, performed in real-time environment and flexible manufacturing system designed for the check and validation of its performance.

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