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ANALYSIS OF A COMPLEX MANUFACTURING SYSTEM MODELED WITH PETRI NETS

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Abstract *: The paper presents an example of monitoring and control for a complex manufacturing system modeled with Petri nets. It also proposes a method to monitoring and control in case of some repairs, or the maintenance according to the technical book of machines that are part of manufacturing process analyzed. The method uses a classical complex manufacturing model simulated with Petri network based on specifications, and implements the hierarchical and distributed control of the manufacturing chosen system. The paper is structured in two stages. First, the activities are analyzed in a conceptual level, and are defined by a Petri network model, having as support the contract documents, corresponding to manufacturing process. The second stage is dedicated to the procedure for carrying technological flow with the analysis of equipments that are involved in flux, without major losses occur. The study is appropriate for hierarchical and distributed control systems. The method can be extended to complex automated systems.*
Keywords: *Petri Net, manufacturing system*

1. INTRODUCTION

Due to the need of flexibility industrial system, were introduced industrial robots in manufacturing systems for automating the technological operations without recourse to a significant design. This flexibility resulted from the general structure of the manufacturing system, from the control of tracking and reprogrammable systems, and it can be exploited if the robot is programmed accordingly. A single robot cannot perform tasks in optimum conditions if this is used in systems with additional equipment. In this sense, usually in order to integrate the robot in manufacturing system, are used numerically controlled machine tools, conveyor belts or other machines with special purpose.
Because the robotic systems are made to work in parallel and are asynchronous, it cannot accurately predict when interest events for the robot program may appear. Thus the signal lines are supported by systems fitted with a robot that serves to coordinate more robots, machine tools or machines. So far there is an adequate computing language and strictly dedicated to a complete manufacturing system optimization, in parallel and in real time with specific constraints. In general are used relatively short programs with links between them, in order to ensure the continuity of manufacturing system operation.
The structure of a working system in a complex manufacturing system consists of one or more lines, each consisting of one or more equipments such as robots, intelligent machine tools. Inside the cell, the machine executes cooperation tasks such as processing, assembling, storing.
The task execution stages of a system consisting of a robot or a machine tool are provided as follows - the transfer of the object from the starting position into a position target is a sequence of next secondary tasks: it moves his arm in the starting position, grabbing the object, then it moves into the specified position, and put the object at the specified location. Thus the tasks are divided into a hierarchical system.
One effective method used to describe and control such systems is the library of Petri networks, which is a modeling tool for asynchronous and competing systems with discrete events. A Petri network model used for analyzing distributed and hierarchical control for manufacturing systems with discrete events includes control algorithms and it is accessed to control the manufacturing process.

The Petri networks used in this paper are analyzed based on oriented graph with which is associated manufacturing system. With the help of Petri networks it can model, simulate and control manufacturing systems with discrete events.

2. SYSTEMS DISCRETE EVENTS USING PETRI NETWORKS

A manufacturing process is characterized by the objects flow that passes through subsystems and receives adequate commands. Each subsystem executes manufacturing operations which are decomposed in machining operations, assembly and transportation operations, such as loading, transportation and unloading.
A characteristic of control for systems with discrete events is that a manufacturing process can be decomposed into a set of discrete events and conditions linked.
A working example for robot operations: the arm waits until it reaches a piece for processing; it takes the piece and sends it to the next operation. The steps are:

- it is conditioned the robot on hold;
- it is analyzed the event when the piece reach to the work area;
- it is analyzed the state of piece that is on hold;
- is launches the event and the robot arm begins manipulating; the arm is occupied with the work piece;
- the robot arm continues manipulation; it is conditioned – the manipulation was completed; it is analyzed the event with the work piece sent to another operation.

This system is one with state event. These events have the following characteristics:

- Asynchronies, the events occur when conditions are fulfilled;
- Conditioning, that is defined by conditions before and after the event;
- Parallel, that is into a system of two or more conditions can occur simultaneously events, and those that do not interact, can occur independently;
- Mistakenly, that is the overlapping the prior condition with the one that defined the event.

Because of these characteristics may occur some shortcomings such as: when the system reaches a state which it is not feasible to satisfy any event; in case of existence of one condition the previous event occurs, it may appear the striking effect (injury).

3. THE ANALYSIS OF PETRI NETWORKS

Petri network is intended to define the process-type behavior of the system network. The network captures the event appearance of the analyzed system. The graphical representation of the manufacturing process is based on the graphical representation of the appearance by labeling network elements.
Let be ¥ $=(\Sigma, M_o)$ a Petri net from [1]

$$\Sigma = (P, T, F, K, W) \quad (1)$$

that is called process of the network ¥ any couple ® $= (N, °)$, where $N = (B, E, F')$ is a finite network of occurrences, and $° : B \cup E \to P \cup T$ (2)
is a function that satisfies:

a) $°(B) \subseteq P$, $°(E) \subseteq T$

b) $M_o(p) = \left| °^{-1}(p) \cap {}^{o}N \right|$ for any $p \in P$

c) $W(p, °(e)) = \left| °^{-1}(p) \cap {}^{o}e \right|$

$W(°(e), p) = \left| °^{-1}(p) \cap e^{o} \right|$ for any $e \in E$ and $p \in P$

The network evolution P/T marked can be defined as the set of all processes in the network.
Starting from defining the processes [1] are introduced by N^o in Σ, M_{N^o}, according to the relation:

$$M_{N^o}(p) = \left| \{ b \in N^o \cap B \mid °(b) = p \} \right|, \forall p \in P \quad (3)$$

To build the sets or to determine network processes it proceeds as [1]:

- Π_o(¥) contains only pairs of form $(N, °)$ where $N = (B, ¤, ¤)$, $|B| = \Sigma_{p \in P} M_o(p)$ and B contains $M_o(p)$ different conditions b, $B = °^{-1}(p)$ for each $p \in P$,

- It is assumed that Π_i(¥) for $i \geq 0$ it was constructed. For each ® $= (N, p) \in \Pi_i$(¥), where $N = (B, E, F')$ and each $t \in T$ such that $M_{N^{\circ}}|t\rangle$, let's define ®$' = (N', p')$ where $N' = (B', E', F'')$, satisfies the conditions:
  - B', E', F'' include B, E, F',
  - For any $x \in B \cup E$, $\circ'(x) = \circ(x)$,
  - It adds a new element *e* to the network N with $\circ'(e) = t$. For each $p \in P$ with $W(p,t)\rangle 0$ it chooses $W(p,t)$ different conditions *b* labeled by $p(\circ(b) = p)$ and it adds the arcs (b,e) to F''. Similarly for each $p \in P$ with $W(t,p)\rangle 0$ it adds $W(t,p)$ different conditions *b* labeled by $p(\circ'(b) = p)$ and it adds the arcs (e,b).

Then Π_{i+1}(¥) consist of Π_i(¥) and all ®$' = (N', \circ')$ constructed.

In Figure 1 is presented a Petri network Σ and it is illustrated a process ® of the network. The locations and the transitions from the process are labeled as suitable locations and transitions for the manufacturing process. In figure it observes the conflict situations at various locations bordered by transitions, but these can be solved by building the model and so the conflict is resolved.

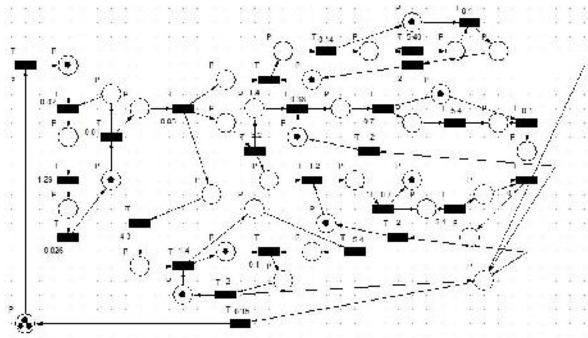

Figure 1. Manufacturing model constructed by Petri network

4. THE SYSTEM MODELING

The model used for modeling describes a manufacturing system consisting of a set of sorting or selection of matter. After that, using the conveyor belt properly for five workstations or flexible cells occur the robot arm that loads the material to be processed, and it takes after processing. The processed material is transported in mobile warehouses from where the process continues, but is not shown in the model. The processing times are real times selected from the specifications of processes and the transport times were selected following a modification of placement system of the machines to optimize transportation times, but without interfering waiting strings.

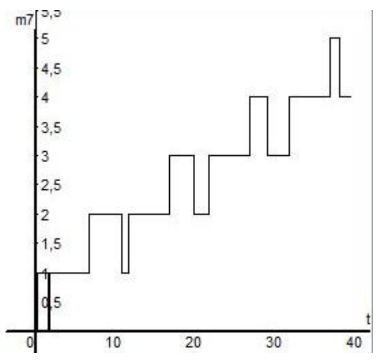

Figure 2: The graphical representation of the average duration for the first conveyor transport

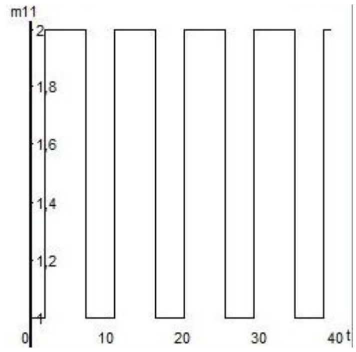

Figure 3: The graphical representation of the average duration occupancy of the machine

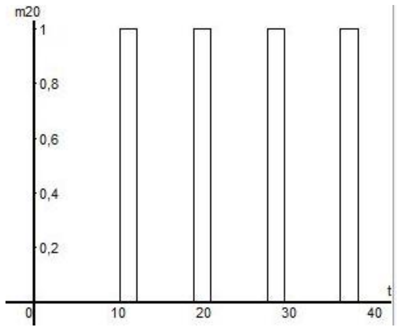

Figure 4: The graphical representation of the average duration occupancy of the machine through the robotic arm

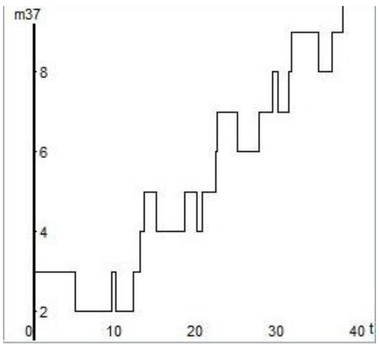

Figure 5: Graphic representation of the average number of conveyor thrugh the collection point

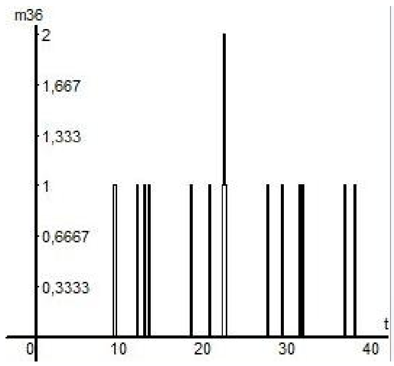

Figure 6: The graphical representation of the average number of conveyor through warehouse

According to the technical documentation, it is ensured the maintenance and in case of some errors, current repair occurs. To illustrate this, in the manufacturing model we assumed an intervention at first machine in the system.

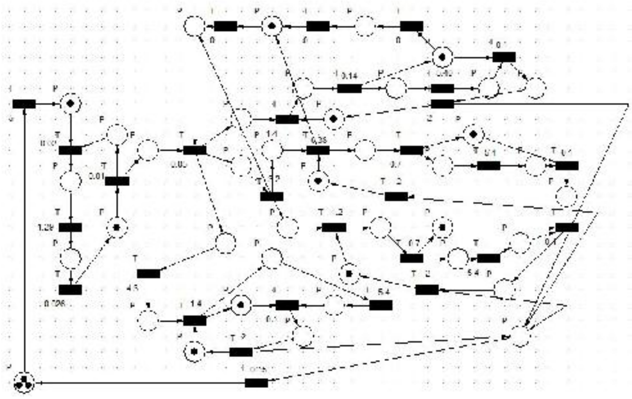

Figure 7: Network with intervention system

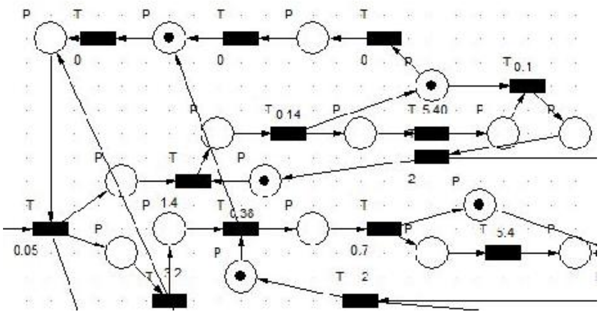

Figure 8: Illustration of the intervention system

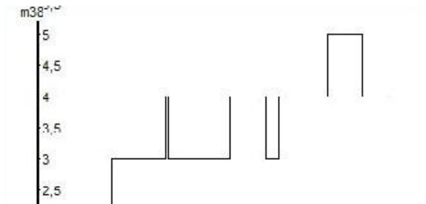

Figure 9: Graphical representation for tracking the intervention at the first machine.

5. CONCLUSION

Applying the product manufacturing times and the transport times obtained by applying the recommendations from the documents that accompany the manufacturing process, it is obtained graphics representations that highlight the average time of the transport activity, but also the evolution of the average manufacturing based on the transport activities times using as parameters lots of finished products

In analyzing the transport it is aimed the study of suggested simulation solutions. Initially the method was developed for a flexible system and in time it was developed also for complex systems even in the case of intervention for repairs systems such as not to be seriously economically affected the manufacturing process.

The graphs analyze applies in solving problems seeking a representation method that allows to study easily the entire problem and to highlight all the results.
It was elaborated the transportation system model that established the sizing, the internal structure and corresponding couplings. Besides workstations, in the system were included control stations and relevant logistics subsystems.
The Petri nets use as parameters the average value of the exponential distribution parameters assigned to the position which models the transport availability. Is obtained graphical representations regarding the evolution of the average times manufacturing, the average length of occupancy, the graphical representation of the average transport for each conveyor and graphical representation of the average number of conveyors from storage.

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