THE USE OF TIMED COLOURED PETRI NETS IN A MANUFACTURING PROCESS MODELING AND SIMULATION

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ABSTRACT. The paper presents a case study of petri nets applications in modeling and simulation of manufacturing process. For this purpose the CPN TOOLS program is used. By using the timed colored petri nets within this program, it can be model and simulate the manufacturing process for a certain period of time. Transitions used in the model are mainly associated with assembly operations and positions are associated with workstations. In order for the simulation to be faithful to the manufacturing process it is necessary to know precisely the operating times for each operation. In the paper it's analyze the functioning of the manufacturing process over a duration of 8 hours, making several simulations.
.KEYWORDS: CPN TOOLS, modeling, simulation, petri nets

1. INTRODUCTION

The tight competition in today's industry makes the design of the manufacturing process important. Thus, there are tools for modeling and simulation of products manufacturing, which allow us to track the evolution of stocks and the rate of transmission of the parts from one station to another. One such tool is the CPN Tools program. The CPN Tools program allows to model, to simulate and analyze the performance of a production system and beyond. Also, this program allows both the tracking of blockages during the manufacturing process and the number of parts in the workstations at a time. [1]

In this paper is presented a case study on how is the model and simulate of a product manufacture process obtained by assembly. To obtain the product are required 7 components.

2. COMPONENTS OF MANUFACTURING PROCESS

- The assembly consists of 7 components:
- Component 1 - The lamellar arc
- Component 2 - Textile fabric
- Component 3 - Aluminum tube
- Component 4 - Aluminum tube cap
- Component 5 - The metal bow
- Component 6 - Metal spring bush
- Component 7 - Cassette

The first two operations of the manufacturing process use one component, which be cleaned and then either linearly applied to a polypropylene strip. In the 3rd operation are included two components, where the textile material is glued.

After the end of the pasting cycle, the piece is removed from the machine and placed on the next operation, while the component 3 that will be used in the operation 5 is prepared [2].

It can be seen from the figure 1 describing the order of operations that the operation 8 needs the component 5, which is obtained at operation 7. It is mentioned that operation 4 and 7 is performed by a single operator.

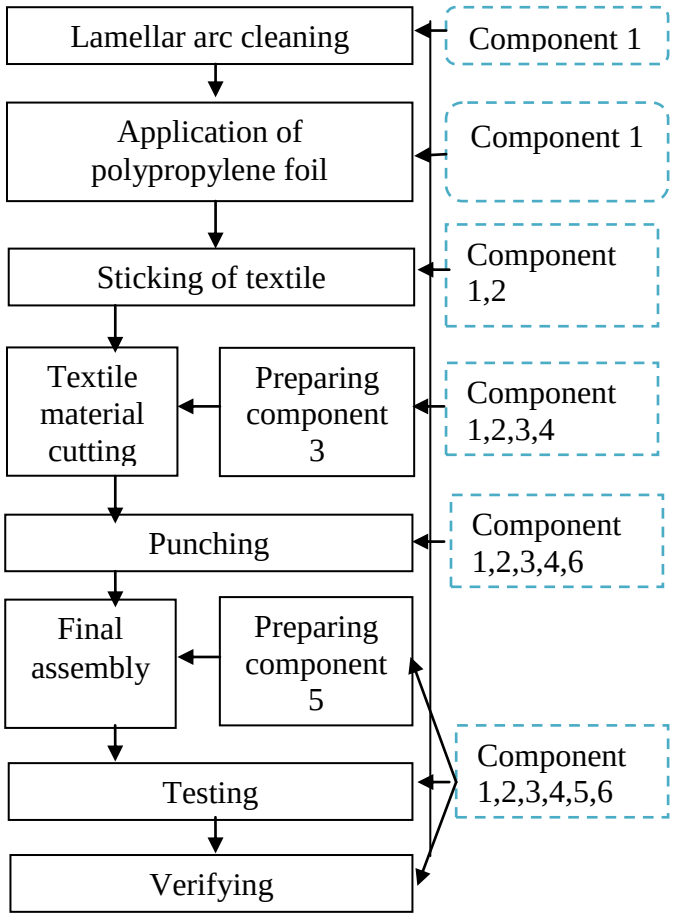

Figure 1. Manufacturing process operations

In order to correctly analyze the production line's balancing, the 10 stations are entered in the form, and then 10 production times of each station are measured in the production line. We measure 10 times to compare the following:

- Average time
- The longest time
- The shortest time

Balancing analysis of the production line is done to improve the work process, to observe where it's bottlenecks in the process, and to analyze the work of the operators.

In the design of the colored Petri Nets model, we must take into account the following constraints of the manufacturing process:

- At Operations 1 and 2 only one operator works.
- At Operations 5 and 7 only one operator works.
- At Operations 6 and 8 a single operator works.
- At Operations 9 and 10 a single operator works.

3. TIMED COLOURED PETRI NETS MODEL

To achieve the model with coloured petri nets, 17 positions and 11 transitions were defined. The 17 positions contain tokens of different colours.

Table 1. Positions used in modeling with Petri Nets

Position nbr.	Name
P1	The lamellar arc are in the storage
P2	The lamellar arch after cleaning
P3	Lamer arc applied with polypropylene
P4	The textile material is in the stock
P5	Textile material applied to steel strips
P6	Textile material resulting from cutting excess material
P7	The aluminum tube is in the warehouse
P8	Aluminum tube after mounting the cover
P9	Roll after mounting the aluminum tube
P10	Roll after the steel strips were cast
P11	Confirmation of aluminum tube installation
P12	Confirmation of metallic arc preparation
P13	Metallic arc in storage
P14	The metallic arch after the needles was glued to the double-sided tape
P15	The roll after the final assembly
P16	Roll after test
P17	Roll after verification

All 11 transitions have been defined to highlight how components are being transmitted and assembled. These transitions coincide with the operations required to obtain the product. Each transition is associated with a time to perform the action that symbolize it.

Table 2. Transitions used in Petri nets modeling

Transition	Explanation	Time [s]
T1	Lamer arc cleaning	43
T2	Application of polypropylene foil	87
T3	Sticking of textile	80
T4	Cut excess of material	44
T5	Aluminum tube preparation	32
T6	Fitting	12
T7	Punching	9
T8	Metal arc preparation	26
T9	Final assembly	50
T10	Testing	54
T11	Verification	44

The following colors specific to the production process were defined: parts, arc, status, material, tube, metallicarc.

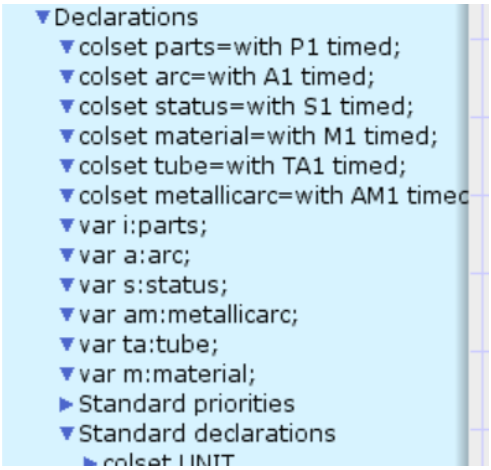

Figure 2. Defining color and variable types

The actions modeled by the T5 and T8 transitions are made by the same operator. Thus, the two transitions are interconnected via P11 and P12.

Simulation of the production process can be done by specifying a number of steps to go through or specifying a running time for the process [3]. In the design of the coloured petri nets model, rules of model design are followed. Each position is attached to a colour so that the position can contain only one token color type..

It is essential for the proper functioning of the production system that the stock of textile material and the parts required for the preparation of component 4 and 7 are adequately supplied. For this purpose there is at least one initial token in P4, P7, P13 positions. The colors used in the model were defined according to the components involved in the manufacturing process. Each arc of the petri nets has attached a variable of a certain color type and this can only carry one color type tokens [4]. Another

thing to be emphasized is that the preparation of component 3 and component 7 is performed by the same operator. In the coloured petri nets model, the T5 transition and the T8 transition are associated with the preparation of the two components. If the operator prepares component 3, the P11 position will have a token, and if the operator prepares component 7 then the P12 position will have a token The T5 transition is executable if we have a part in the storage and if the operator is free. The T8 transition is executable only if we have a part specific to the component 7 in the storage and if the operator is free

4. SIMULATION WITH CPN TOOLS PROGRAM OF MANUFACTURING PROCESS

The simulation of the manufacturing process can be done in several ways.[5] The first way is by specifying the number of steps necessary for the simulation. The second way to achieve the simulation is by specifying the running time of the process simulation. In figure 3 can be seen the model before the simulation.

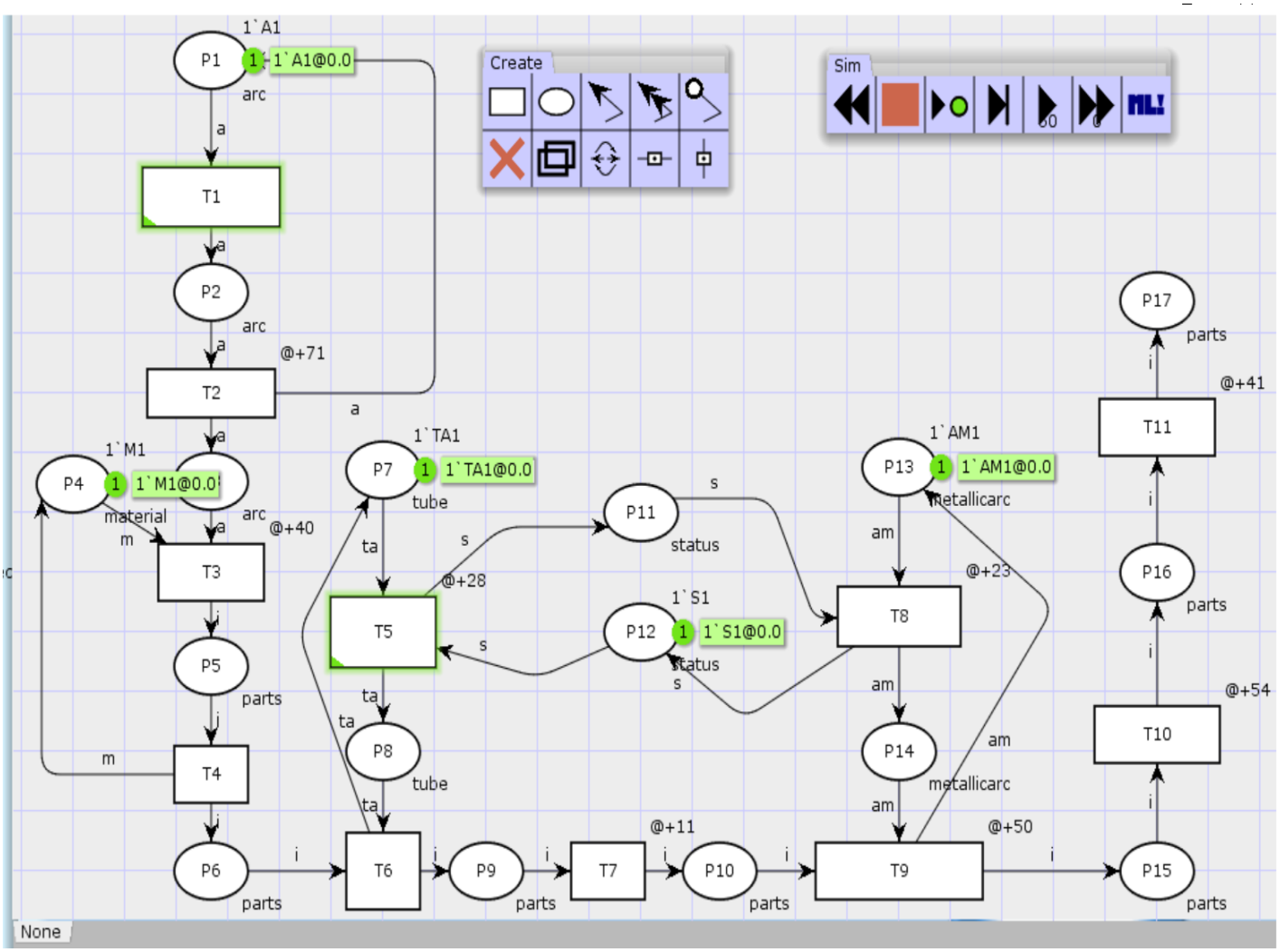

Figure 3. Modeling the production system with Coloured Petri Nets

In order to be able to model and simulate the production system for an 8-hour shift, timed coloured petri nets will be used. Timings are associated with transitions according to the table 2. It should be taken into account that the production line rhythm in this case will be given by the longest time, the operation 3 time.

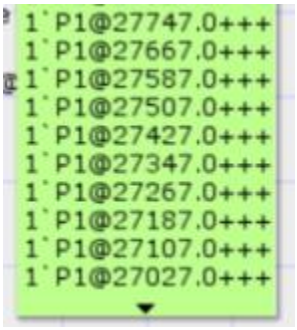

Figure 4. Moments of time at which the manufacturing process ends for each piece

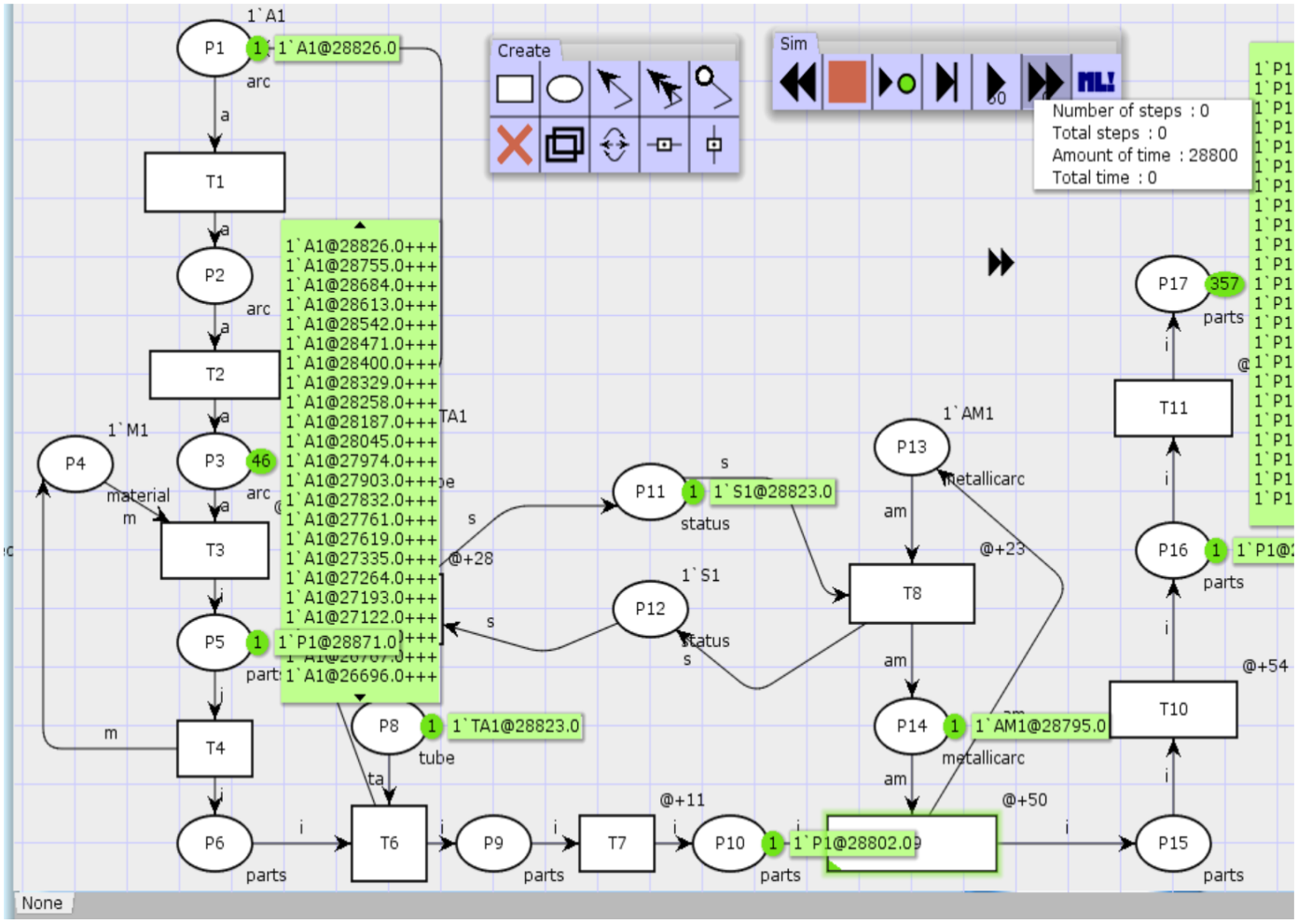

Figure 5. Modeling the production system using Timed Coloured Petri Nets

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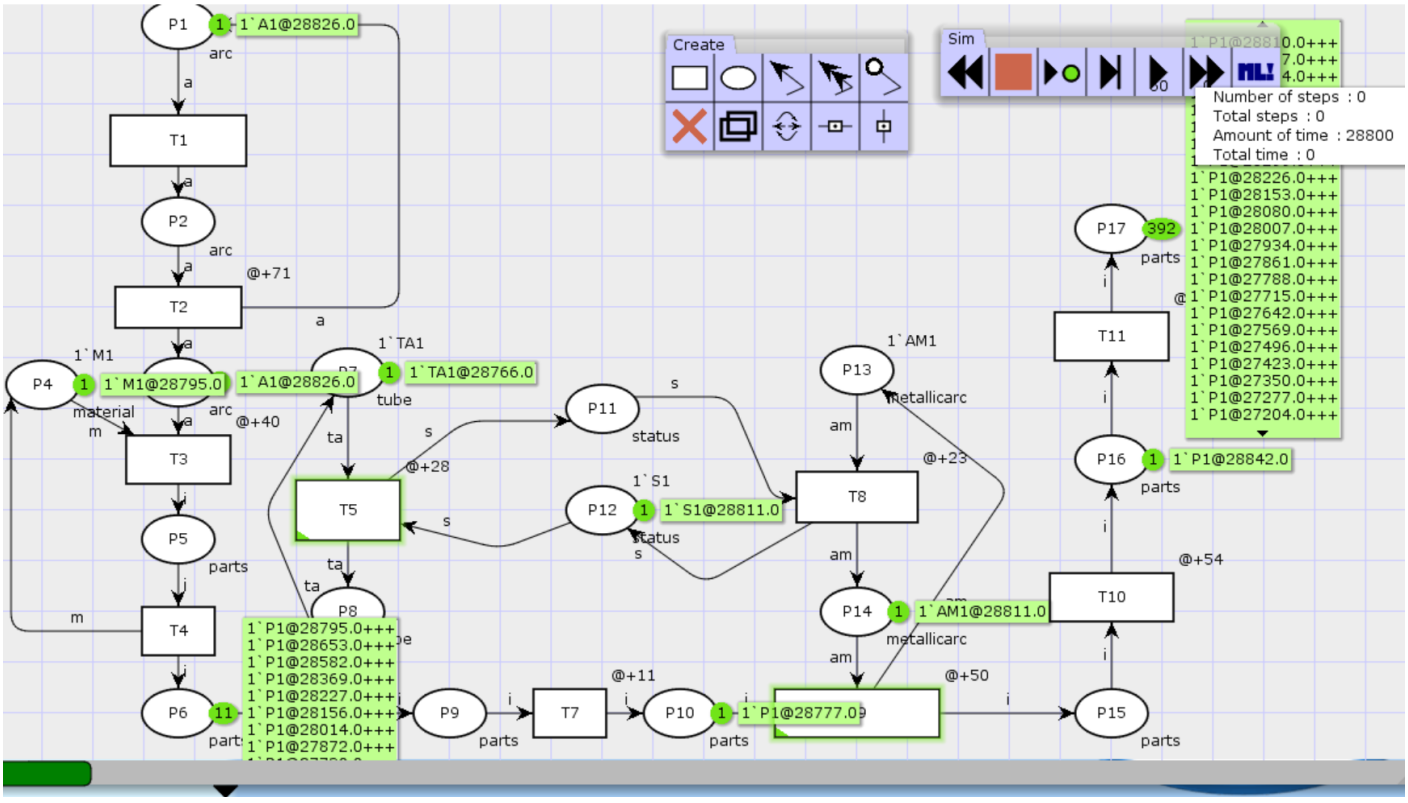

Figure 6. Simulation of the production process over 8 hours of work

It can be seen in figure 5 that after 8 hours of work there were processed 357 pieces. It can also be seen in figure 4 when the production process ends for each piece.

It is noted that the highest operational time is recorded in the soldering and cutting operations.

If two workstations are use for these operations, the pattern with timed coloured petri nets looks like in Figure 6. After 8 hours the number of machining pieces is 392 pieces. In this latter case of simulation, the rate of transmission of the parts in the production process will be given by the time of the test operation time that is 54 seconds.

5. CONCLUSION

The use of programs dedicated to modeling and simulation of production systems makes the occurrence of blockages possible to be removed. The CPN Tools program is an efficient tool in using petri networks. The combination of the user interface and the analytical part based on programming rules makes this program can be used for both simple cases and for more complex structures.

The assembly process studied in this paper is simulated over a period of 8 hours. The number of parts obtained during the manufacturing cycle is determined for 2 variants of the manufacturing process. In the first processing using a single workstation at operation 3, 357 pieces were obtained. To improve the performance of the fabrication process in the second simulation version, 2 work stations were used to bond the textile material, thus obtaining 392 pieces.

It can be concluded that by using coloured petri nets and CPN Tools program, the modeling and simulation of production process performance can be improved.

6. REFERENCES

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