Material flow in Flexible Assembly Company

[1]Ján ILKOVIČ (3rd year), [2]Peter PAPCUN (1st year)
Supervisor: [3]Ján JADLOVSKÝ
[1,2,3]Department of Cybernetics and Artificial Intelligence, FEI TU of Košice, Slovak Republic

[1]jan.ilkovic@tuke.sk, [2]peter.papcun@tuke.sk, [3]jan.jadlovsky@tuke.sk

***Abstract*— This article describe material flow view to Flexible Assembly Company. The main task is to describe material flow at this system and create the procedure to create a system simulation model. Article contains material flow verbal description and then material flow diagram and at the end the draft of simulation model created in CPNTools environment.**

***Keywords*— flexible assembly system, model, simulation, coloured Petri Net, CPNTools.**

I. Introduction

Over the last years flexible manufacturing systems became a very usual way in solution of all kinds of industry and manufacturing. Growth of production caused interest of increase production efficiency by reason of price reduction per produced goods and also its production time reduction.

It is uneconomic to establish a complex model system or create the required system only for the purpose of testing the system state. The system efficiency increasing and predicting its behaviour can be performed on an existing system, but much cheaper and to create a system model and perform debugging at this model.

This aspect opens the doors for the research in the area of manufacturing system modelling and simulation.

Modelling is a process that studies and analyzes quantitative aspects of a real-world problem. The modelling process results in a model, where mathematics is used to describe the nature of the problem and in many cases a proposed solution.

We had focused our research to a discrete processes and systems, to its modelling and analyzing. The head reason of this our decision was affected by the aspect of system that we wish to research. We look at the system in terms of material flow.

The fundamental principle on which the discrete process model is based is the assumption that all mechanical processes occur not only in discrete space but also in discrete time. Thus, a process is seen as a transition of the system from one state to another at every step in the discontinuous time. These transitions from one state to another during a step in time – the process – are controlled by transition conditionals [5].

Mathematical model is a base requirement for creating a computer interpretable model of knowledge or standard specifications about a kind of process and about relevant facilities of the system.

When we were looking for the best mathematical tool for an implementation our modelling procedure to the system, we have to analyze our requirements for the tool first. Ability to modelling the parallel systems was main attribute for the searching. Another important option we were looking for was possibility to make discrete event mathematical model with the possibility of computer implementation. As follows we have found Petri Nets with its modification: Petri Nets with modification in Coloured Petri Net. Coloured Petri Net (CPN) is an mathematical and graphical tool supported by wide simulation software base (Matlab, CPNTools,..) we could use for our implementation.

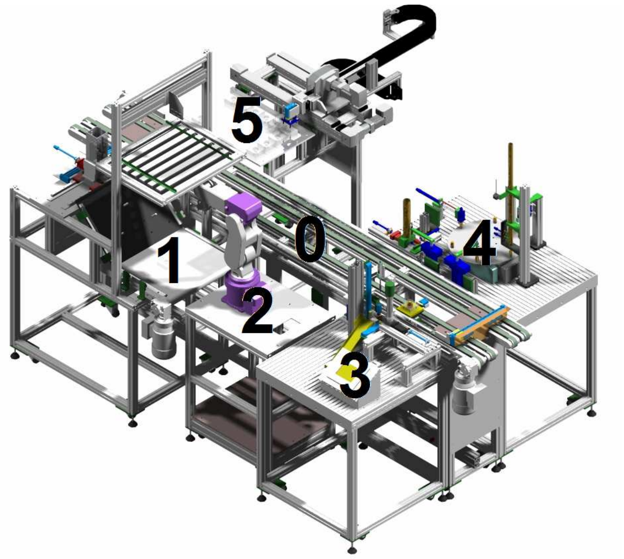

Fig. 1. Graphic design of the assembly line with the numbered posts.

II. Petri nets

Petri nets, or place-transition nets, are classical models of concurrency, non-determinism, and control flow, first proposed by Carl Adam Petri in 1962. Petri nets are bipartite graphs and provide an elegant and mathematically rigorous modelling framework for discrete event dynamically systems.

Definition:

A Petri net is a four-tuple (P,T,IN,OUT) where:

- $P = \{p_1, p_2, p_3 \dots p_m\}$ is an set of places;
- $T = \{t_1, t_2, t_3 \dots t_n\}$ is an set of transitions;
- IN : (P x T) is an input function that defines directed arcs from places to transitions;
- OUT : (T x P) is an output function that defines directed arcs form transitions to places;

Graphically places are represented by circles and transitions are represented by horizontal or vertical bars interconnected by arcs represented by arrows. Places of Petri nets usually represent states or resources in the system while transitions model the activities of the system. [2]

III. COLOURED PETRI NETS

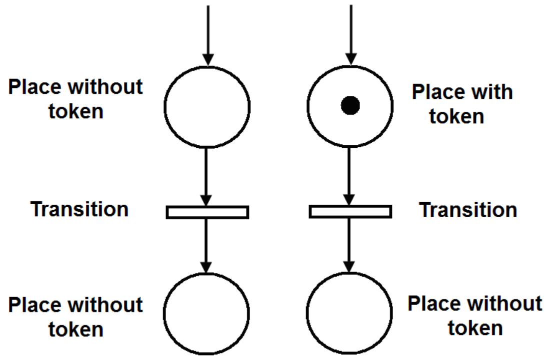

Fig. 2. Left: unmarked PN. Right: marked PN.

Coloured Petri Nets (CPN) is a language for the modelling and validation of systems in which concurrency, communication, and synchronization play a major role. Coloured Petri Nets is a discrete-event modelling language combining Petri nets with the functional programming language Standard ML. Petri nets provide the foundation of the graphical notation and the basic primitives for modelling concurrency, communication, and synchronisation. Standard ML provides the primitives for the definition of data types, describing data manipulation, and for creating compact and parameterisable models. A CPN model of a system is an executable model representing the states of the system and the events (transitions) that can cause the system to change state. The CPN language makes it possible to organise a model as a set of modules, and it includes a time concept for representing the time taken to execute events in the modelled system.

CPN Tools is an industrial-strength computer tool for constructing and analysing CPN models. Using CPN Tools, it is possible to investigate the behaviour of the modelled system using simulation, to verify properties by means of state space methods and model checking, and to conduct simulation-based performance analysis. User interaction with CPN Tools is based on direct manipulation of the graphical representation of the CPN model using interaction techniques, such as tool palettes and marking menus. A license for CPN Tools can be obtained free of charge, also for commercial use. [1]

IV. FLEXIBLE ASSEMBLY COMPANY

Assembly line named Flexible Assembly Company (FAC) was designed and completed at the department of Cybernetics and artificial intelligence by the led of Doc. Ing. Ján Jadlovský CSc.. Model FAC is located in laboratory V147 at Vysokoškolská 4, Košice. The model and its situation at the department laboratory are shown in Fig.1.

The FAC model serves as support for research and diagnostic of industrial communication networks, the production lines modelling and analysis, but the important task of this model is to improve the quality of the teaching process. Therefore, the model was specifically designed and this fact explains the details and selected technologies. In practice would be better to choose alternative technologies to optimize the reliability and simplify the assembly process, bud the model purpose was not to optimize proposal and a subsequent programming of the model, but summarize in one place as much possible technological elements as it possible.

Students have the opportunity to become acquainted with multiple technologies and solutions, which are used in practice, and all in the one place because of using this configuration. The FAP model obviously does not contain all the technologies used in practice, but the designers decided to use just those which he frequently use in the practice, and which also would graduates work with in their practice in the future. More information about the technologies and design of this model are described in [3].

V. FAC MATERIAL FLOW

FAC containing 4 input stores and 1 output one.

As already mentioned above we look at the system in terms of material flow so the main goal of our research is tracing the flow of material in the assembling process. We bind a unique identifier to the products and intermediate products in the simulation model by using witch we can track the movement and state of the goods in any time of the production process in the simulation model. It's necessary to know the system and examined its material flow even before the creation of its model. The following section lists a brief description of the assembly FAC process.

The aim of the FAC assembly process is to make a product that is shown in Fig.3 (B). The resultant product consists of four intermediate parts (Fig.3 (A)). These are assembled together by the assembly process in such way that the first part of product is placed on pallette and proceed through the process posts and the intermediate products are progressively mounted together until a resultant product is completed. The product is saved to the output store after assembling finished and there is waiting for order finalization. The entire assembly process can be divided into five positions – posts (Fig.1). The entire assembly operations are divided between these five posts till to store the finished product warehouse. Each post has a well defined action and these are directly linked to each other, i.e. that each post is waiting to close on the previous post, except the post number 1, where the entire assembly operation begins. The synchronization of individual activities

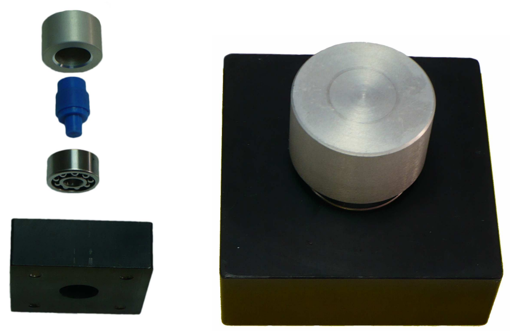

Fig. 3. Individual parts of the product in the order they are assembled (A). The resulting product (B).

so that there are no collisions in the production process is matter of course. Consecutive posts have the ability to arrest the intermediate product on belt conveyor until then, when the next post released, although the previous post has already finish its activity. Assembly line work will be cyclically repeated, up to the fulfilment whole order. Products are transferred between the various posts by using a special palette. This palette is not part of the finished product and hence will not be placed in output store. The pallets are situated on a central belt conveyor all time and they are waiting in the queue at the beginning of the assembly process or move product between the posts assembly line.

A. Post 0 – Central belt conveyors

There are two belt conveyors situated in the middle of the FAC. These conveyors serve the transfer of products at each assembly line posts.

B. Post 1 – Ejecting the blocks and camera system

On the Post 1 (Fig.4) starts the assembly process. This post contains a input serviser for black plastic blocks into which will be inserted other parts of the product (bearing, plastic shaft and metal cap). Blocks are pneumatically removed from the serviser to sloping surface. Subsequently, randomly rotated block gets on a wide white belt conveyor located behind the sloping surface. There is also an industrial camera above the belt conveyor.

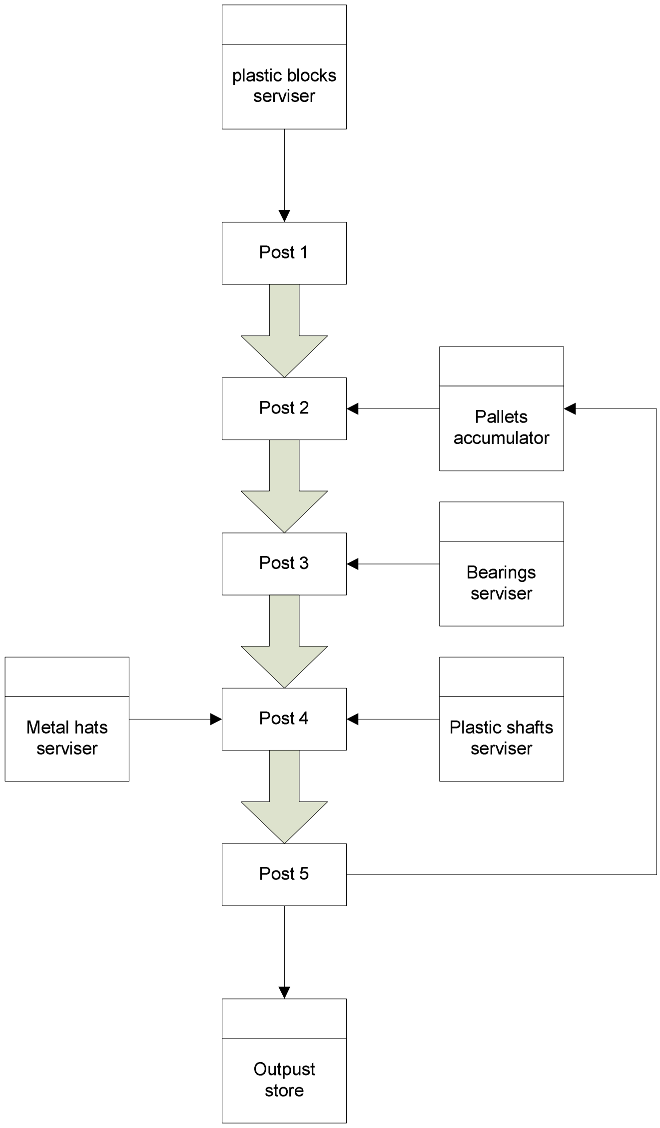

Fig. 4. FAC material flow diagram.

C. Post 2 – Robotic arm

The block is displaced from the first post (from the belt conveyor) to the central belt conveyor by the robotics arm Mitsubishi RV-2SDB. The robot uses the information from the camera system about the block position.

D. Post 3 – Inserting bearings

After the previous activities is the block transferred by the palette and central belt conveyor to the next post. This post performs inserting a bearing to the product. Bearing, however, must be the correct dimensions. So bearings are picked from a serviser, measured and then inserted into the block. And these activities are carried out in the post 3 (Fig.4).

E. Post 4 – Inserting plastic shafts and metal hats.

Final assembly work is carried out at the post 4 (Fig.4). A plastic shafts and metal caps have to be inserted into the imbedded bearings in the plastic block.

This post consists of sensors, servisers and pneumatic handlers, whose job is to choose caps and shafts with the right parameters and then use those to complete the final product. After the inserting components in the correct order to the block with bearing is the assembling process finished and proceed to the final post 5.

F. Post 5 – Warehouse

Product stops at the last post and triaxial manipulator moves product from the pallet to its position in the warehouse. Warehouse is implemented as a metal table, where milled positions for products are marked with letters of the alphabet from A to Y. Together there are 24 positions. Final position for each product will be stored in the information system of the FAC.

Exporting the finished products from warehouse performs operator by hand.

VI. PROCEDURE FOR MODELLING

A. Preparation of model creating

At the beginning of the modelling process it is necessary to know examined system in terms of material flow. First we have to define system inputs and outputs with its properties. Input and output properties are useful for consecutive declaration of inputs and outputs in the simulation model. The properties will be implemented in the model as parameters of item that will represent input or output.

Next step is to define others system elements that will be used for the material flow model. It’s necessary to create a list of system events and states. After that we can connect on each other according to rule: state-event-state. Detailed search and correct describe relations among them ensure success in model creation and in its informative capability.

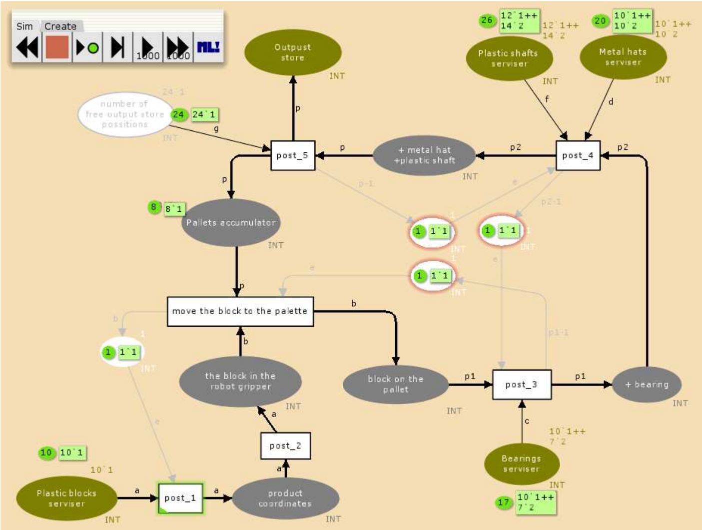

Fig. 5. CPNTools system model – configuration before the simulation starts.

B. *Procedure for creating a FAC model*

In this section we are going to describe a procedure how to create a simulation model of surveyed system using the Petri Nets. This model is created in the simulation environment CPNTools. We chose this environment for its wide range possibilities for coloured Petri nets modelling and possibility to implement the time variable in the model.

Another reason for our choice was the fact that this application is free downloadable and does not require purchasing a license and therefore whoever could easily download it and use. CPNTools beginner user has to acquaint him with the work at this new environment. There is a possibility to study the manual for work with this environment directly on its official website [4]. And so after a short time, the user can create, save and run modelled system by him and also debug it by running the simulation and its stepping.

We created a simulation CPN FAC model where we can see input and output stores (green ellipses), events (rectangles), system states (grey ellipses) and additive states. We attached figures; first one with system initial conditions [Fig.5] and the state of system at the end of simulation [Fig.6].

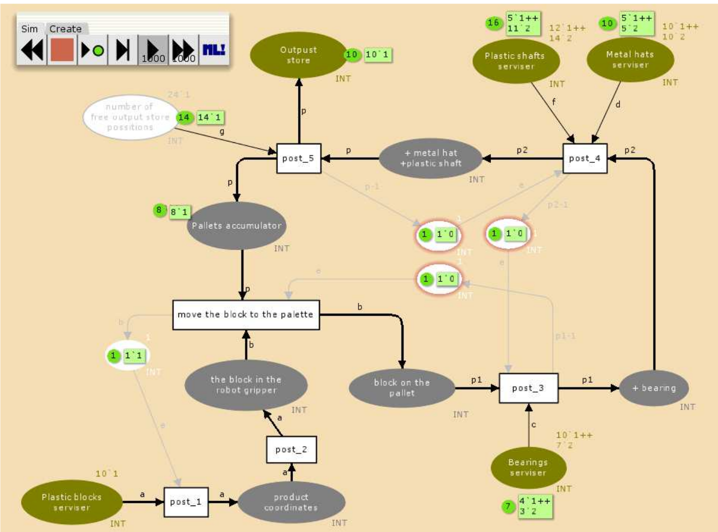

Fig. 6. CPNTools system model – state at the end of simulation.

VII. Conclusion

There is ability to use the mentioned procedure in general design for simulate a material flow for much discrete processes of assembly or manufacturing systems. The advantage of this procedure is that there's no requirement to build a system physically, but we can simulate the behaviour of the system, its initial and final state of material.

The CPNTools provides to run the simulation and there is also very useful option: to step the simulation, so we are able to examine the behavior of the system step by step. There is also possibility to add a time element to the model that provides another option for material flow analysis.

Acknowledgment

This contribution is the results of the Scientific Grant Agency of the Slovak Republic and of the project implementation: Centre of Information and Communication Technologies for Knowledge Systems (project number: 26220120030), supported by the Research and Development Operational Program funded by the ERDF.

References

[1] J. Kurt, K. Lars, L. Wells, *"Coloured Petri Nets and CPN Tools for modelling and validation of concurrent systems"*, in International Journal on Software Tools for Technology Transfer, vol. 3, pringer Berlin / Heidelberg, 2007, pp. 213-254.

[2] J. Ilkovič, "Modelovanie a diagnostika manipulačných a robotizovaných systémov", Písomná časť k dizertačnej skúške, Košice, 2010.

[3] J. Ilkovič, M. Čopík, T. Karoľ, *"Proposal control of manipulators controlled via technological network DeviceNet"*, In SCYR: 11th Scientific Conference of Young Researchers of Faculty of Electrical Engineering and Informatics Technical University of Košice: Technická univerzita, 2011, pp. 335-338, ISBN 978-80-553-0644-5.

[4] CPN tools - http://cpntools.org/

[5] K. Rainio,*"Discrete process model"*, University of Helsinky, ISBN 978-952-10-4547-9.