

MODELING AND SIMULATION WITH DISCRETE EVENTS OF THE ASSEMBLY PROCESS USING ARENA SOFTWARE

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Abstract—This paper demonstrates how to design and develop a simulation model for an assembly line Festo. The layout consists of 7 process stations. The complete assembly line processes consist of one robot. The study was conducted on a automated FESTO line. The simulation was made using ARENA software considering the line as a computer integrated production system. As input data it were considered the real data of the physical model and the model was verified in real functional conditions. In the simulation different scenarios were tested in order to optimize and balance the line.

Keywords— modeling and simulation, Didactic Festo Line, queuing, Arena software

I. INTRODUCTION

THE role of simulation in virtual environment systems increased in the last decade, with the imposition of stricter requirements in terms of resource consumption. Until recently, research and development process began with the creation of a real prototype system that requires a large amount of raw materials (components are usually made by cutting processes in semi-finished block) and working hours [1].

This prototype was then subjected to a series of tests of various kinds to be analyzed. By definition prototype was not a perfect mechanism and most its parts had to be changed. This meant investment in other types of resources. Thus, since the development of information systems virtual simulation environments were also developed allowing simulation of both reduced complexity models (processing machine) and the complex ones (an entire factory with multiple production lines) [2].

Through virtual simulation systems can reveal much of the risks to which they are subject in the real world and can be removed before the real system is affected.

The system can determine what functions can not fulfill their role in the current technical solution and enables the developer to reject that concept which does not work, in an early stage of the project. It is also simply

and cost effective to replace a component in a virtual machine than the real one. Also the lead time for introducing a new model is shortened often with months or decades.

For tests that can be performed in a virtual environment, their number can be unlimited (depending on available time), with low cost and does not affect in any way the physical components.

The results of the tests can be useful to improve the system before it becomes real.

1. II. CASE STUDY FESTO LINE

A. General consideration

Festo Didactic Line is a flexible manufacturing system which is designed based on modern technologies, one of them being MPS - Modular Production System (modular manufacturing) [3].

This means that the line is made up of several modules which may be arranged in almost any band which may be representative of a comprehensive line of computer integrated manufacturing.

Festo Didactic line from SmartLab laboratory of the Faculty of Engineering, is made up of seven modules (workstation) and a transmission line.

The seven modules are:

- 1) *Distributing station (MPS Distributing);*
- 2) *Testing station (MPS Testing);*
- 3) *Assembly station (MPS Assembly);*
- 4) *Robot station (MPS Robot);*
- 5) *Milling machine EMCO Mill 55;*
- 6) *Handling (MPS Handling);*
- 7) *Sorting (MPS Sorting).*

Distribution station has the role to pick parts from warehouse with a capacity of 8 pieces and sends it to the test station.

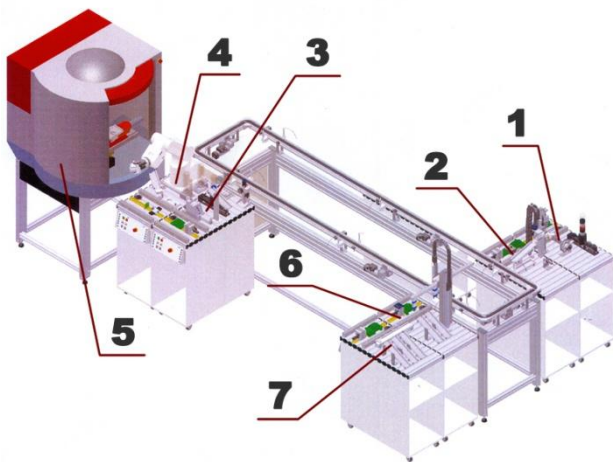


Fig. 1 FESTO Line

A. FESTO Line – Input data

To model the system we need input data. They consist of pieces which are used in final assembly and processes that are performed during assembly.

The final piece, cylinder, consists of the following components: housing, valve, spring and cap. The case is of three types: Red, Black and Chrome and goes through stations 1 and 2 distribution and sorting (black parts being scratch). The good parts are transported by conveyor to 3, 4 and 5 stations.

Here are picked from the conveyor to the robot module and begin the assembly process. When launching a slide by sorting station to assembly station, robot takes a lid and place it in the milling machine to achieve a milling operation.

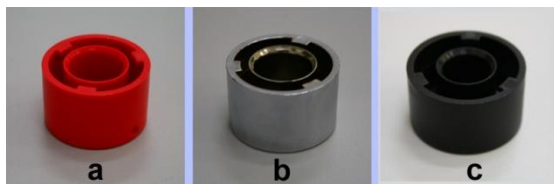


Fig.2. Housing types

This cover is also of two types: *Not processed* and *processed*. At assembly station components are processed in a row: it pick up the valve of the conveyor and is taken to the place of assembly is positioned in the valve housing, then add the spring, and then remove the machined cover from milling machine and close the cover, ending the assembly process. The valve is then placed again on the conveyor and sent to handling and sorting station.

Another input parameter is given by the number of carts that are simultaneously on the conveyor. Their purpose is to transport the parts on line, from one station to another.

B. Implementation of data entry in ARENA 14 software

To achieve FESTO line modeling there were used many of the features of the Arena 14 academic software.

To simulate entities representing the subcomponents of final assembly or final assembly itself, the Create process was used. This creates entities in a time interval and in a number set by the user [4] - [6].

The process of making the simulation model is logical module, module pre-assembly, assembly and animation.

As a starting point, logic modules were created that represent subcomponents or final assemblies using objects from „Basic Process”, „Advanced Process” and „Transfer”. These modules allow you to create entities and establish the properties of each, is observed in Fig.3.

Entity - Basic Process		
	Entity Type	Initial Picture
1	Carcasa	Initial
2	Carcasa_Rosu	Rosu
3	Carcasa_Crom	Crom
4	Carcasa_Negru	Negru
5	Capac_NP	Cap_NP
6	Capac_P	Cap_P
7	Arc	Pic_Arc
8	Supapa	Pic_Supapa
9	Ventil	Cap_P

Fig.3. Creating entities

Added processes Create: Distribution - issues Housing entities representing the stock at distribution station; S_Capac - Capac_NP issue entities that are unprocessed cover; S_Arc - issuing entity type Arc; S_Supapa - issuing entity type Supapa; S_Ventil - issuing entity type Ventil, which is the final assembly.

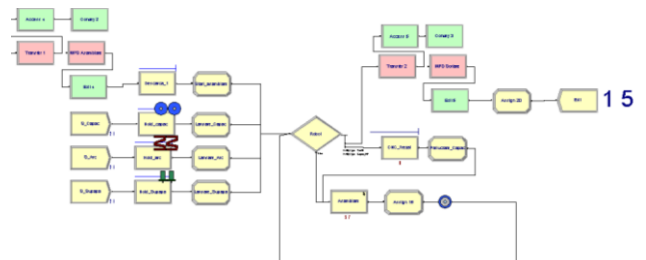


Fig.4. Overview of the flowchart, including robot and assembly stations

Once you have been issued carcasses, they go through the process Decide (Body color) to simulate predetermined percentage of different types of carcasses, such as: red carcasses received 60%, 35% chrome housings and casings 5% black. To make the transition from simulation Carcasa entities to the type Carcasa_Rosu, Carcasa_Crom and Carcasa_Negru using the Assign (Red, Chrome, Black) process. However it done and change the icon assigned to each type of entity. The Record type process (NR_Rosu, NR_Crom, NR_Negru) count each entity which passed through it, thus obtaining the exact number of types of carcasses.

Once modified type of entity result, they go through another process of decision (Testing) that determines whether the parts are good or scrap. Thus if the part is

entity Carcasa_Negru type the Dispose (scrap) by which entities are removed from the simulation.

The good parts get Hold (Transfer_carucior) that simulates adding a carcass on the conveyor cart to be passed to the next station. In this process a verification if carts are available at the test station is made via variable Nr_Carucior.

This variable is set at the beginning of the simulation. If it is greater than zero then at least one carriage is available and the housing can enter the line. In the very next Assign (Carucior), Nr_Carucior variable decreases by one unit and Carcasa_lansat variable increases by one unit. The latter determines launching is send Capac_NP type to be transported to the type Process (CNC_Frezat). When a case goes to trial Descarca_1 - Hold variable string, Pr_asamblare, transits from state off to state on. This simulates assembly process start.

Once begun assembling, no other housing entity can not enter Robot decision process that determines the following: if the entity is a type Capac_NP is send CNC_Frezat process; if type Ventil, put it back on the conveyor to be transported to the handling and sorting, and if any other type sends the submodel Assembly, which simulates the assembly process. CNC_Frezat process simulates the machining of workpiece retaining entities for 45 seconds, after which it launches in the Processing Cap - Assign to turn them into Capac_P entities.

In submodel assembly simulates following: Asamblare_elemente - Decide determines what kind of entities are to count what components have already entered in assembly by Ass_Carcasa, Ass_Supapa, Ass_Arc and Ass_Capac variables, after it are removed from the simulation (Dispose 5); S_Ventil - Create process issues entities type Ventil to the Asamblare_finalizata that retains entities until all subcomponents entered in assembly. On leaving the submodel, the Assign 15 resets all variables that determine the assembly process from baseline in order to resume the assembly process.

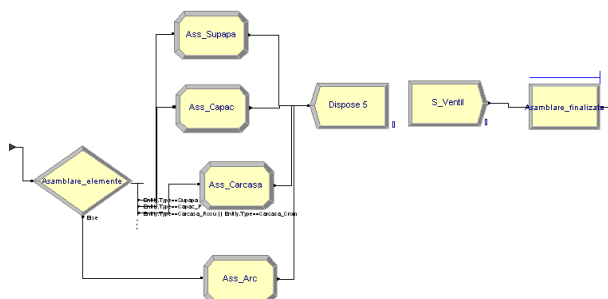


Fig.5. Assembling submodel

The resulting entity Ventil again pass through Robot, after which it is transferred to the cart and reach the final station, where the cart is released. Thus Nr_Carucior variable increases by one unit.

The flow of material is not certain, being controlled by selective structures written in VBA language. These

structures will be set as control functions for input or output of an entity that is on a Process object, such distribution station, a new entity will be passed to the Transfer process only if it is not busy.

III. FESTO LINE SIMULATION

To simulate FESTO line it is necessary to know all the times for each process, from the distribution station to the storage of parts. All these times are considered input data for the simulation model.

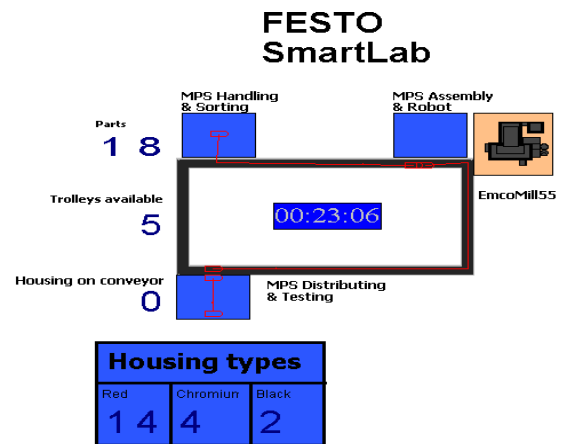


Fig. 6. Animation modul

For data visualization and a good presentation of the results for certain processes there were introduced Chart type objects. These monitor the percentage of stations that are in the active phase, staging, blocked or inoperable. These graphs were assigned Robot and EMCOCO55Mill objects type because they realize most operations and have the lowest operative time.

Thus, the two simulations were performed to achieve the 50 products with different housings, following the processing time in each module and time of product development in different conditions:

- 1) Parallel operation of two modules assembly and processing;
- 2) Simultaneous use of several transport units.

At the first test performed, the throughput time decreased when placing 2 transport units, thus reducing queues, Fig. 7.

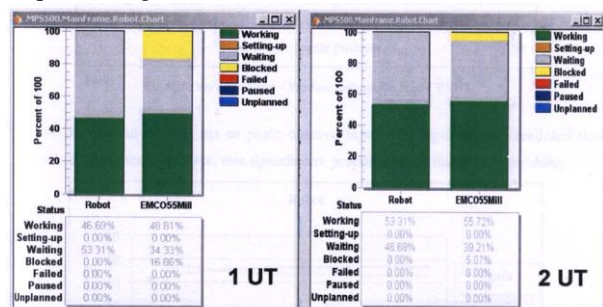


Fig.7 Percentage of objects Robot and EMCOCO55 Mill

If you increased the number of products required, the realization time also increased but little, because the

entities begin to accumulate to module assembly and processing. Previous entity going on schedule, only when the module is free.

In the case of the second test was applied JIT process (number of products required by the client) and many transport units.

After the simulation it is seen that the module Robot is pretty much blocked or waiting time as its operating time is related to the total and not in its own time. A good time was obtained to the introduction of a odd number of transporters, Fig. 8.

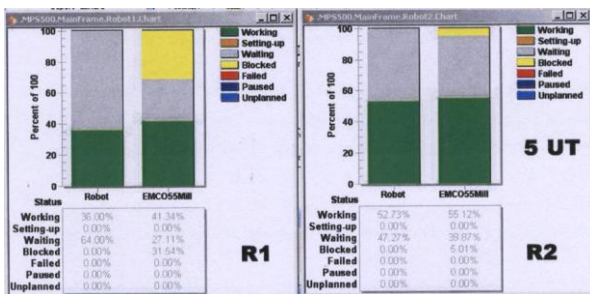


Fig. 8. Percentage activities for 5 units transport

To find the required number of simulation runs for the plant data, one could use equation 1. The number of replications is determined using the equation (1) per Kelton [4]- [5].

$$n = \left(\frac{Z \cdot s}{p} \right)^2 \quad (1)$$

where,

n = Number of replications

Z = Z value taken from the Normal Probability table with % of confidence interval

S = Six sigma Standard Deviation

P = Value, How close to actual mean.

In Table I is presented the number of replications required for the different simulation run close to actual mean prediction values.

TABLE I
NUMBER OF REPLICATION REQUIRED

Actual Mean	CI = 95% (α = 5%)
10	134
25	19
30	16
50	9

The simulation result produced average cycle times for each station, throughput time, wait times, work-in-process. From the simulation result, the main bottleneck for this layout is the station 1 - Assembly.

IV. CONCLUSION

After many scenarios performed by simulating line FESTO and how assembly and machining is made, we can highlight some subsequent conclusions to help the development of the process:

- 1) for a better execution of the whole process on FESTO line it is important to establish the number of transport units, in this case 2 units;
- 2) increase of the capacity of assembling and machining, that are the critical resources in the simulation of this process could lead to increased production.

The use of this modern tool for computer assisted planning of processes gives us the possibility of a better anticipation of the manufacturing process and planning of capacities, especially for the critical resources that create bottlenecks and queues. Also it helps to obtain an optimized load of the shop and reduce throughput time.

The line FESTO which is a flexible manufacturing system based on modular technology stations, adding new stations in line is relatively is easy and cost effective. So, by simulation using Arena software, planning and scheduling of production takes place without any additional costs.

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