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Process of vacuum metallisation – a simulation in the taylor program

S. Topolska
Division of Quality Management, Institute of Engineering Materials and Biomaterials
Institute of Engineering Materials and Biomaterials, Silesian University of Technology,
ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: santina.topolska@polsl.pl

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Analysis and modelling

ABSTRACT

Purpose: This paper is the result of the cooperation with metallization industry. Small industry plants often have problems with production planning so it was interesting to test the possibility of application a computer simulation system.

Design/methodology/approach: In this work two main research methods have been used: observation of real processes and simulation of virtual ones. The theoretical scope was to test the possibility of simulation the metallization processes.

Findings: This work includes two main conclusions. Firstly, it is possible to simulate such specific processes like metallization ones. Secondly, the application of a simulation program results in higher effectiveness of the metallization process.

Research limitations/implications: Presented results indicate that it is important to develop these researches by analyzing more complex process and galvanic ones.

Practical implications: The practical implication of this work is the statement that even in small plants it is profitable to introduce production simulation programs.

Originality/value: This paper provides the information about simulation such specific processes like metallization. It is valuable for small plant managers.

Keywords: Vacuum metallisation; Simulation; Taylor system

1. Introduction

Man in everyday life surrounds practical and aesthetically looking objects. It depends on things which possesses and uses not only him to be functional, but he fulfilled his expectations also in order to their appearances. Unfortunately not always given object was been possible to be obtained from materials which possess decorative properties. During the development of material engineering came into being the surface engineering, that includes all scientific and technical aspects of production, investigation and applying the superficial layers, which possess better than basic proprieties, mainly anticorrosive, anti-fatigue, anti-abrasive and decorative [5].

In last years the progress of science in the field of plastic materials permits on more and more different their use. Materials these are light, plastic and what follows it they are easy processed and formed as well as they are corrosion proof. Expensive in production metals were replaced by plastics, which in aim of assimilation to them are covered with the coat simulating the given metal [1, 3, 4].

Among methods of production of superficial layers, only three of them are suitable to use to cover the plastic materials. Developing process of vacuums metallization deserves on special attention.

The tendencies of large growth of mechanization and automation, in industrial institutions, were noticed recently. Even the robotization of processes of production the superficial layers is noticed, first of all at the burdensome operations which are harmful for man.

It is also noticed the tendency to avoid the production processes of superficial layers, which are energy-consuming and replacing them with processes that need smaller energy. Produced energy in one process was used on needs of different processes. Also are used the technologies and techniques which in smaller level pollute natural environment. One pays larger attention to the preparation the surface under the coat. One also applies the more effective technologies and techniques of cleaning, washing and rinsing. Therefore in last years more and more wide was introduces the microcomputer control of technological lines, individual devices. In close future one can observed the elaboration of computerized plant departments.

During the vacuum metallization one can observe three phases of the process of coating manufacturing [2]:

a) metal evaporation, it means the process of changing the state of a metal (from solid, through liquid into gas one),
b) diffusion of a metal vapor from the source of evaporation to the coating product or the wall of a vacuum chamber,
c) condensing of a metal vapor on the product surface and creating the continuous metal layer.

The process of vacuum metallization must be conducted in separate rooms. Also the particular departments should be isolated (Fig.1) [2]. On the other hand the process of metallization could be conducted using next equipment:

a) equipment for vacuum generation and it maintaining (and also it improving),
b) proper vacuum chambers for metallizing,
c) measuring apparatus for controlling the vacuum, the thickness of a metal layer and for investigation its features (e.g. resistance).

The structure of a layer and its features are depended on following parameters: conditions of processes (conditions of coating processes), cleanness of a vacuum chamber and features of an atom and molecules flux. The main element that influences the structure of a manufactured layer is the method of a base preparation. It could largely change the properties of obtained the metal film. During the treating of a product in acid bathes, alkaline bathes or water ones on the surface of a product could form pores and craters. It leads to the porous form of a coating. Also the mechanical machining could change the structure of a layer. The important changes forms also as the result of cleaning products in a process of electric or ion bombardment. But it is needed to state that this last process allows increasing the adhesion of a metal layer to the base. On the other hand one should point that the structure of a metal layer is considered with the temperature of metal melting. The metal with a high melting temperature (over 1900^{o}C) like W, Ta, Ir, Co, Ge, Si, create tight and fine-grained layers, without particular orientation. The metals from the other group (with a melting temperature from a rage 600 ÷ 1900 ^{0}C) like: Au, Ag, Cu, Ni, Fe, Cr, create tight and coarse-grained layers. The metals with a melting temperature below 650^{o}C create layers built with oriented crystals, which size proportionally depends on the layer thickness [1, 2].

The process of vacuum metallization includes following operations and activities:

a) cleaning (in emulsified bathes or in dissolvents),
b) drying and placing products on the plating racks,
c) ground lacquering and surface tightening and second drying,
d) metallization,
e) painting with proper lacquer and drying,
f) quality control.

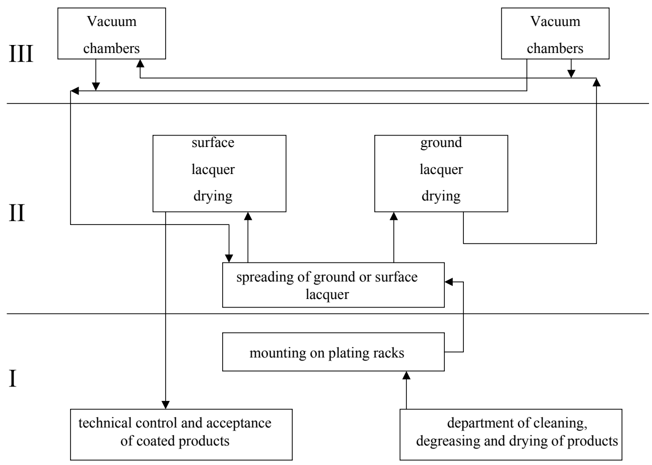

Fig. 1. The scheme of a metallization department (com. [2])

The outer lacquer layer should protect the metal layer against the harmful influence of the atmosphere, mechanical and chemical damages during exploitation. The proper thickness should be from the range: 5 ÷ 10µm. Such lacquer should not react with the coating and ground layer. The lacquer could penetrate the metal layer and ground layer damaging the last one. When the colorless lacquer is applied then the obtained color is depended on the metal used in the metallization process (e.g. aluminum lets obtain a silver color). However when the dye is applied then the obtained color depends on the dye color (e.g. gold one for the gold dye) what presents. If the lacquer layer is too thin then the iridization is observed. When the layer is too thick the cracks and saggings could happen.

2. Simulation and results

Program Taylor is the program used in production and logistics. The aim of this program is analyzing and estimation the dynamic character of processes. It makes possible to state whether given system is configured correctly. Program this can facilitate the utilization the machines and remaining devices of a system, such as, e.g. inter-operations buffers, output and input magazines or high storing magazines. The program helps also to solve the problems of costs and size of production series. The modeling in the system Taylor posses many advantages - the full visualization of conducted simulation, very simple method of data introduction and receiving the results, as well as its own, built-in, language of programming.

To create the model one need a plan. Model is built from component units. One can use on of nine units: 1 - machine, 2 - transporter, 3 - buffer, 4 helper - worker of service, operator of a system, 5. conveyors, 6. path, 7. magazine, 8 reservoir, 9 input/output.

In simulation the most important notions are: magazine, action or transportation. In the program was accepted that the magazine is represented through buffer, input/output, reservoir, magazine and conveyor. However action is represented through machine, helper and transportation. After placing the rule units, one can introduce the characteristic values of given position. After simulation program makes possible to receive results in the form of a report or graphs.

2.1. The main assumptions of simulation of the process vacuum metallization

The model of the production system consisting of 46 units:
Input magazine - 1;
Buffers - 2, 6, 11, 12, 13, 16, 18, 20, 32, 33, 34, 37, 38;
Dividers - 3, 5, 8, 10, 19, 21, 22, 24, 25, 26, 27, 29, 30, 31, 35, 39, 41, 42;
Machines - 4, 7, 9, 17, 23, 28, 36;
Trolley - 14;
Path - 15;
Output magazines - 40, 43;
Helpers - 44, 45, 46.

The time is represented by:
1 unit represents 1 minute;
60 minutes represent 1 hour;
12 hours represent 1 working day;
5 days represent 1 working week;
4 weeks represents 1 month.

Products to system are delivered according to stochastic distribution.

The times of work during individual stages:
Washing (4) - 90 min;
Coating (7) - 15 min;
Painting (9, 23, 28) - 20 min;
Drying (11, 12,13, 32, 33, 34) - 120 min;
Metallizing (17) - 15 min;
Quality control (36) - 30 min.

2.2. The description of the process of vacuums metallization in program Taylor

Semi-finished products at input (1) are delivered to the buffer (2), which aim is transporting the semi-finished products as one series using the conveyor (3) to automated washing section (4). After washing and drying operations the series of semi-finished products is transported, using the conveyor (5) to the coating section (6 and 7). Semi-finished products in the buffer (7) are putted on hangers. Palettes with elements on hangers are moved using the conveyor (8) to the painter's cabin (9), in which elements are painted with priming varnish. Then, using the conveyor (10), palettes are transported to dryers (11, 12, 13). After drying elements are placed on trolley (14), which transfers them, to the vacuum chamber (17) using path (15). After the process of vacuum metallization elements are taken off from the trolley, which comes back then to take next series of semi-finished products from dryers (11, 12, 13). Palettes with semi-finished products are transferred with the help of the conveyors (19, 21 22, 26, 27) to painter's cabins (23, 28), in which elements are covered with top varnish. In dependence of the type of semi-finished product they are painted on gold color in painter's cabin (28) or with colorless varnish in painter's cabin (23). After painting elements are placed in dryers (32, 33, 34) using conveyors (24, 25, 29, 30, 31). When the drying process finishes the painted elements, using conveyor (35), are shifted to the automated control section (36). After control elements are transported to output magazine (40), however elements with defects are removed to the magazine of defected elements (43).

At the coating unit (7) works the helper (46), which task is putting individual elements on hangers. The helper (45) helps servicing the trolley (14), as well as the vacuums cabin (17). However the task of the helper (44) is repairing the break-downs on positions (4, 9, 11, 12, 13, 17, 23, 28, 32, 33, 34, 36).

2.3. The description of simulation of vacuums metallization in program Taylor II

The model of simulation is created on the basis of placing the component units (Fig.. 2).

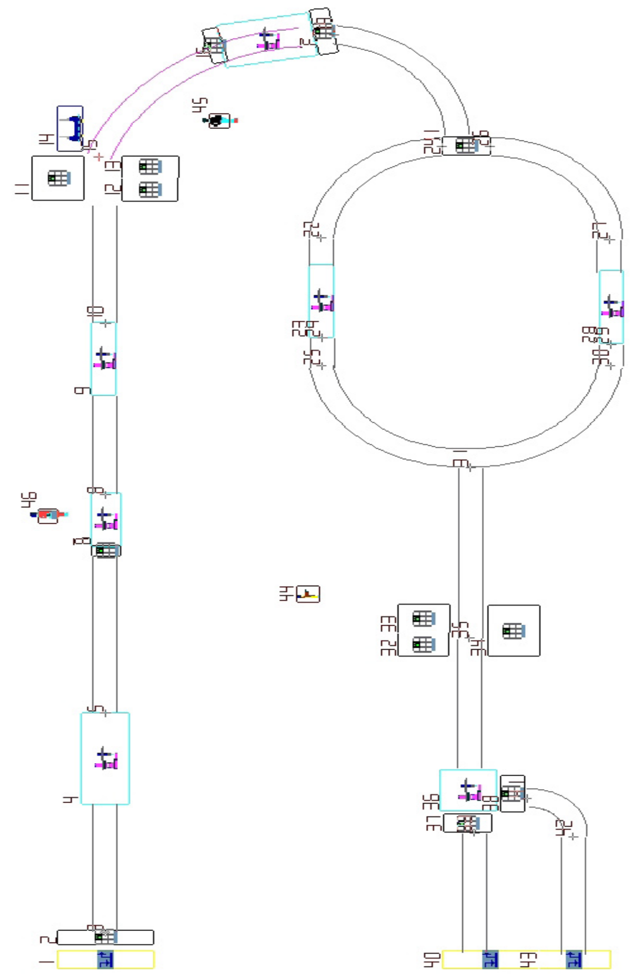

Fig. 2. Scheme of the analyzed process

Next, the time parameters are fixed (Fig. 3).

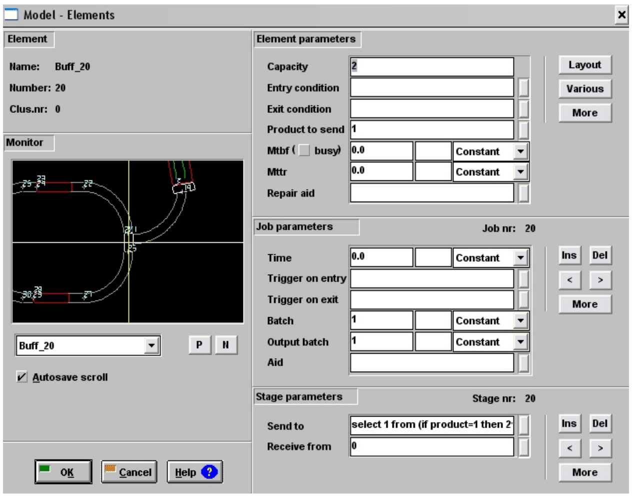

Fig. 3. Parameters window

In the dialogue window are introduced the input data for each component element of the simulation process (Fig. 4).

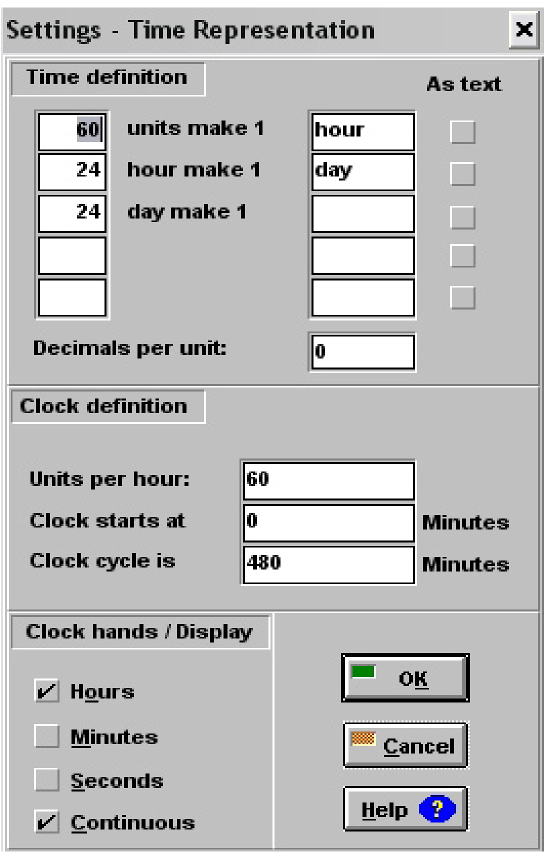

Fig. 4. Dialog window for input data

The simulation process for the previously assumed parameters is presented in the Fig. 5.

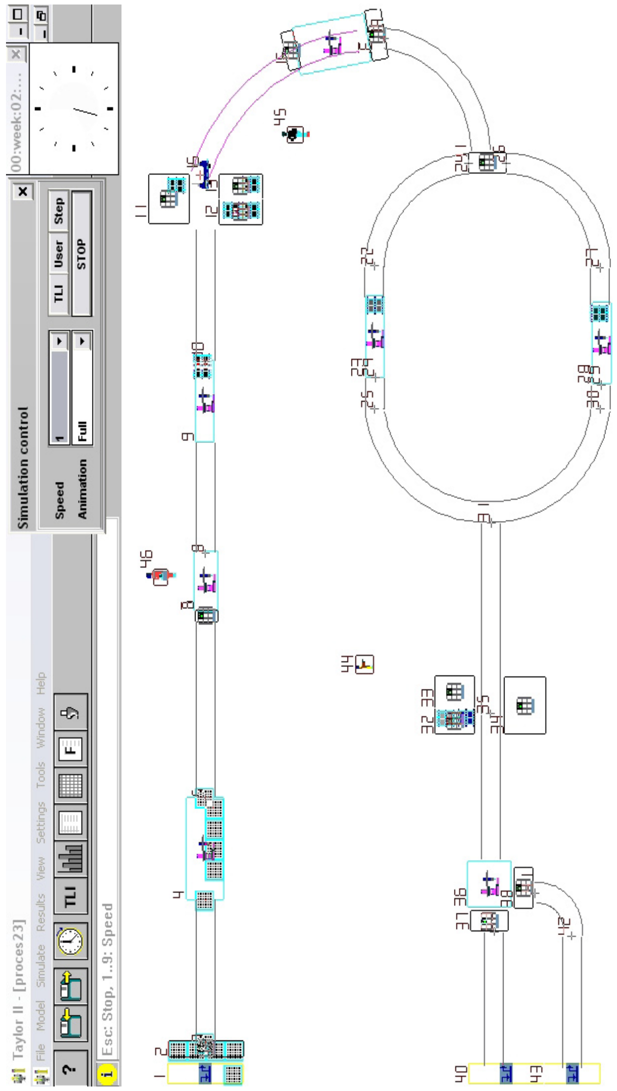

Fig. 5. Illustration of the simulation process

2.4. Results of simulation

To simplify the identification of graphs, their numbers are subordinated to the numbers of simulation.

a) the diagram illustrating the state of every unit during one work week (Fig. 6)

b) results considering the washing section (4) during one work week (Fig. 7 – 10)

c) results considering the coating section (7) during one work week (Fig. 11 – 14)

d) results considering the trolley (14) during one work week (Fig. 15 – 18)

e) results considering the vacuum chamber (17) during one work week (Fig. 19 – 22)

f) results considering the quality control section (36) during one work week (Fig. 23 – 26)

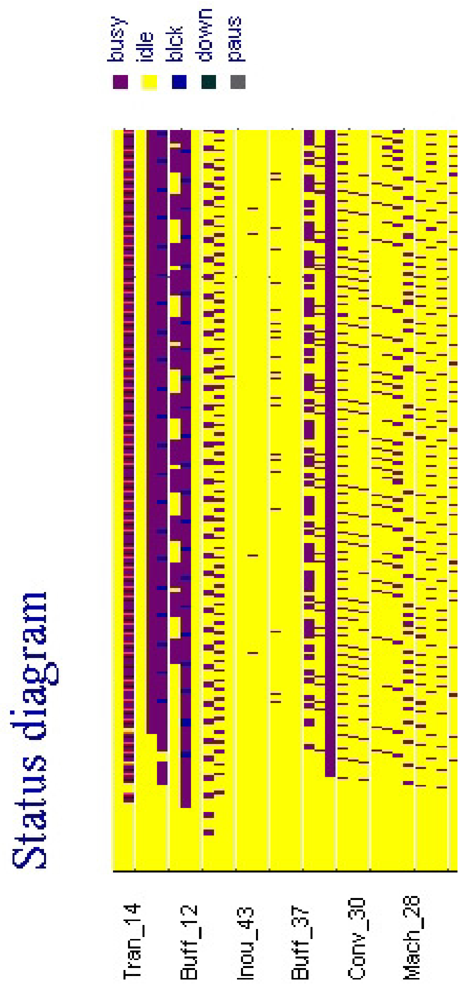

Fig. 6. Gantt chart for the analyzed process

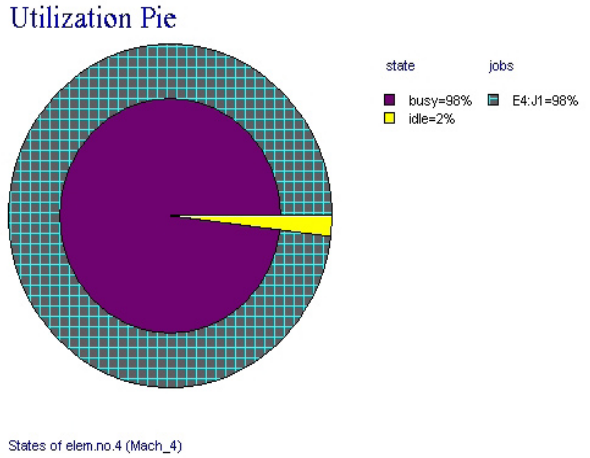

Fig. 7. Utilization of the washing section (4)

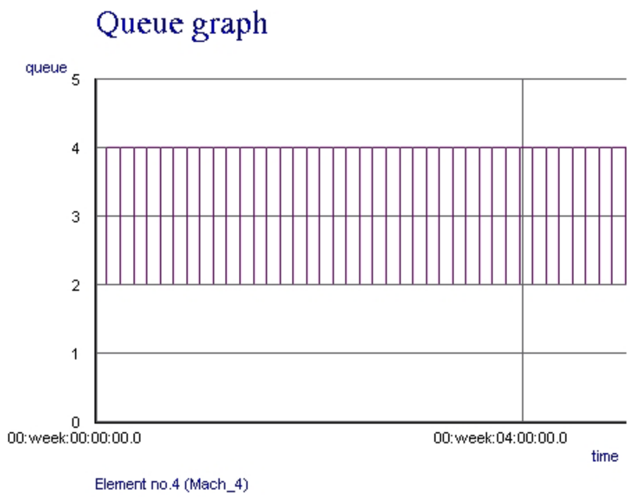

Fig. 8. Graph presenting the queue at the washing section

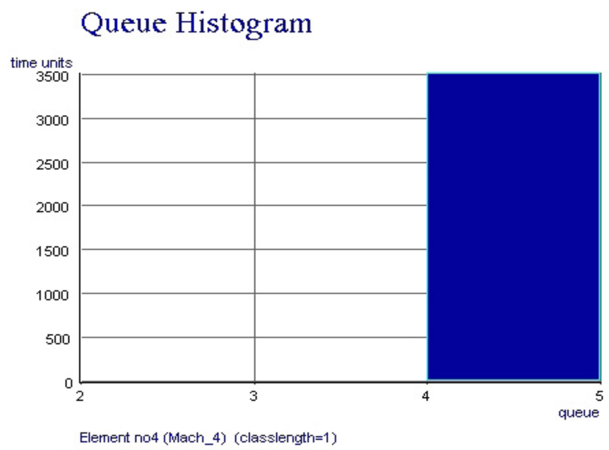

Fig. 9. The histogram of the queue at the washing section

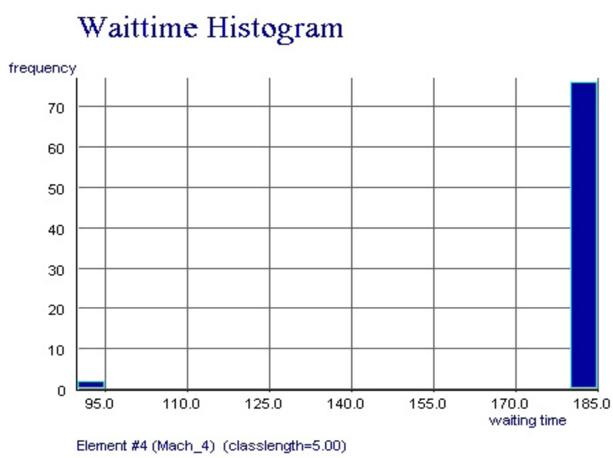

Fig. 10. The histogram illustrating the waiting time of the washing section

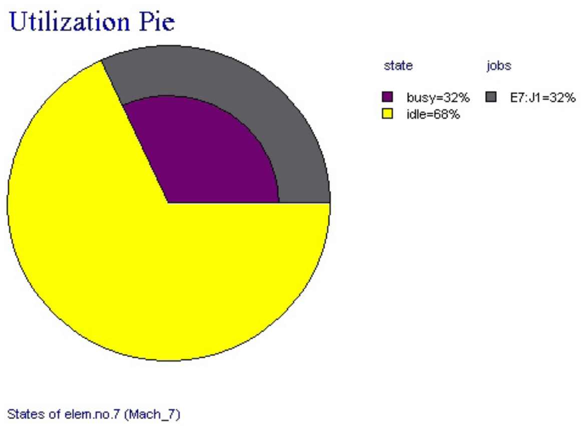

Fig. 11. Utilization of the coating section (7)

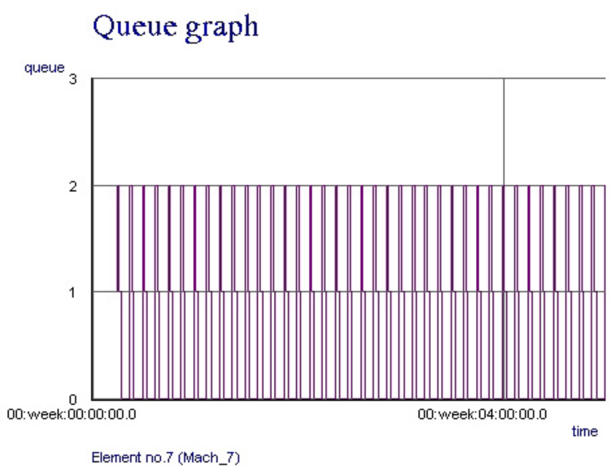

Fig.12. Graph presenting the queue at the coating section

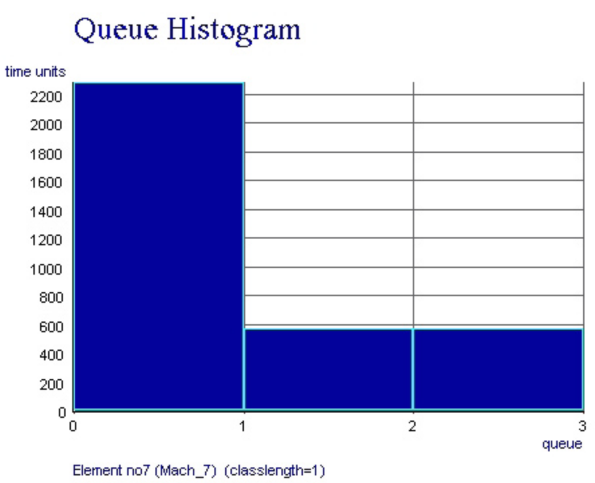

Fig. 13. The histogram of the queue at the coating section

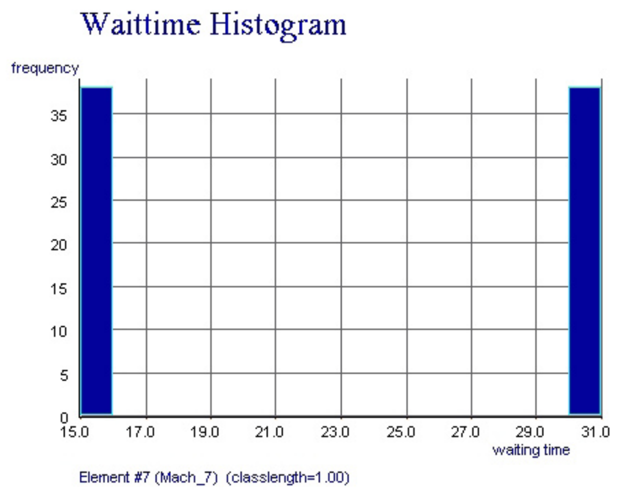

Fig. 14. The histogram illustrating the waiting time of the coating section

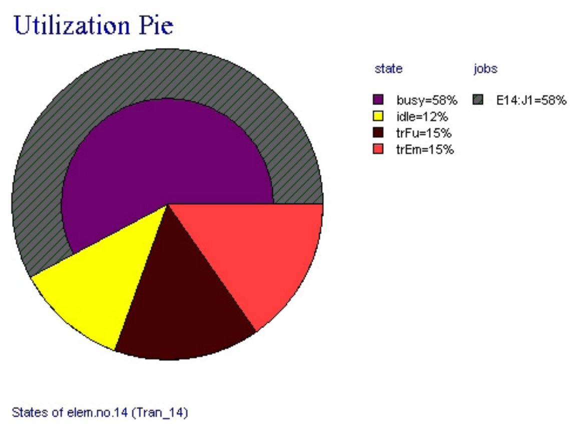

Fig. 15. Utilization of the trolley (14)

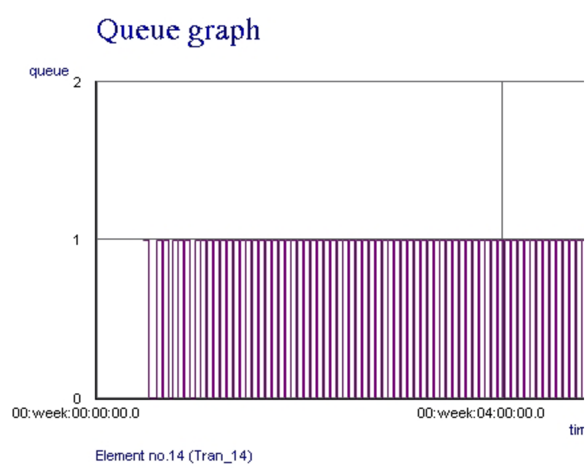

Fig. 16. Graph presenting the queue for the trolley

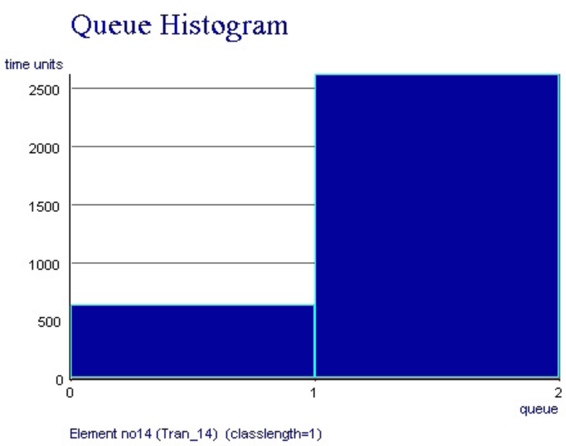

Fig. 17. The histogram of the queue for the trolley

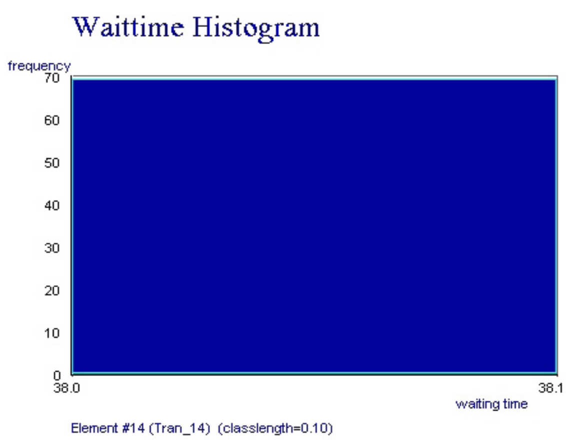

Fig. 18. The histogram illustrating the waiting time for the trolley

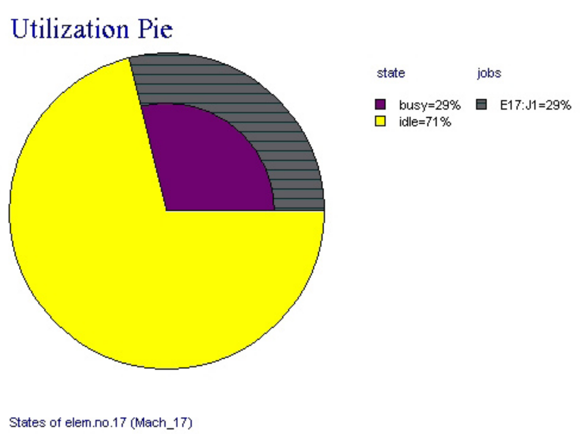

Fig. 19. Utilization of the vacuum chamber (17)

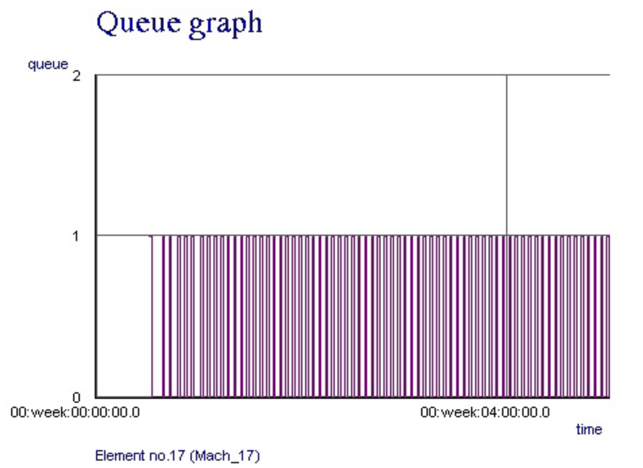

Fig. 20. Graph presenting the queue at the vacuum chamber

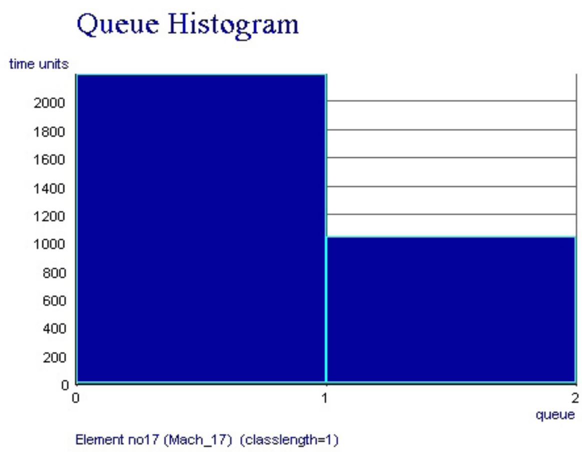

Fig. 21. The histogram of the queue at the vacuum chamber

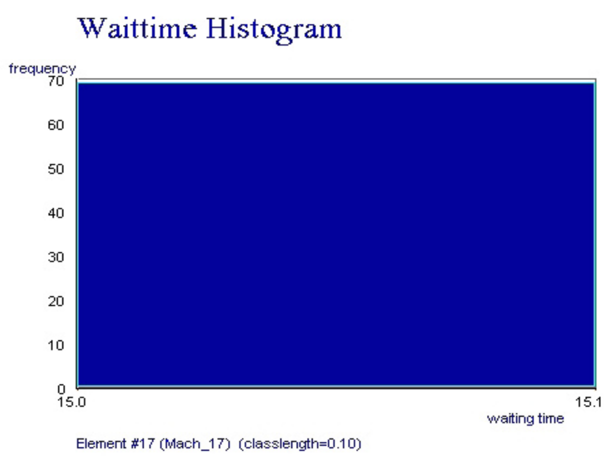

Fig. 22. The histogram illustrating the waiting time of the vacuum chamber

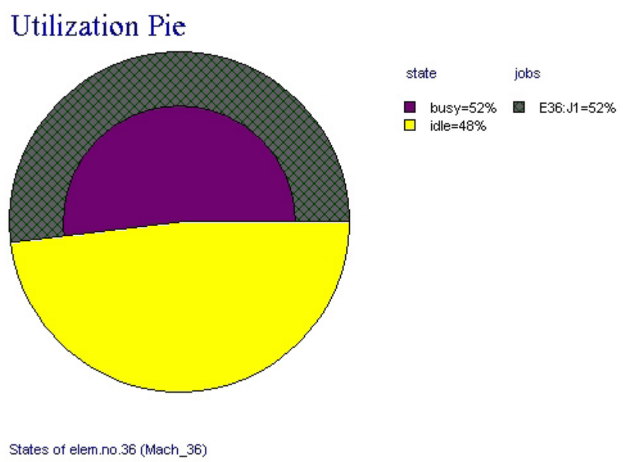

Fig. 23. Utilization of the quality control section (36)

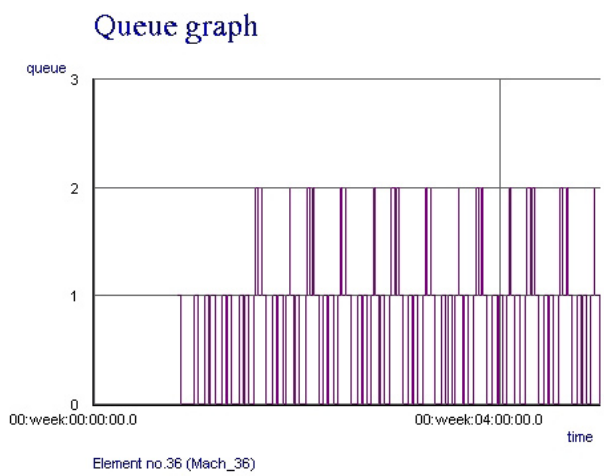

Fig. 24. Graph presenting the queue at the quality control section

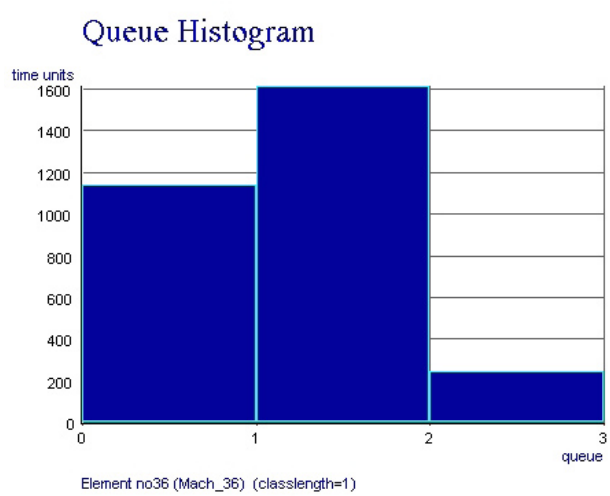

Fig. 25. The histogram of the queue at the quality control section

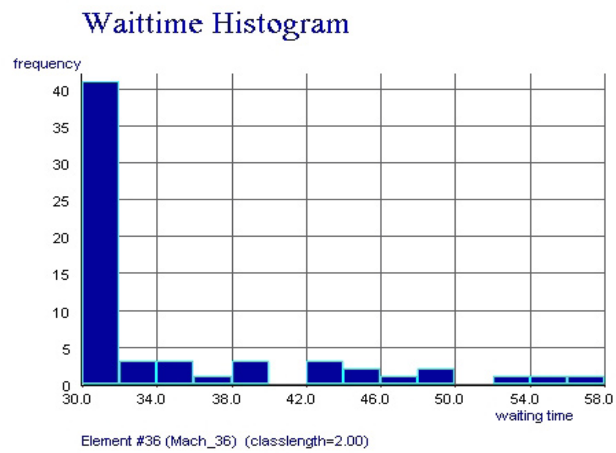

Fig. 26. The histogram illustrating the waiting time of the quality control section

3. Conclusions and discussion of results

Described simulation is based on data coming from the real production process of vacuum metallization. Therefore also some input data that means time of processing on individual manufacturing stages was definitely determined. After execution tens of simulations with different number of elements it has been found the most optimal model of analyzed process.

In this simulation it has been assumed that one product represents one palette of individual elements. One palette represents one charge to the vacuum sublimation chamber. So the size of production is elastic and it could be controlled by decreasing processing times on individual stages of the process.

Generated results show that the majority of units are not fully used. The most effective devices of the process are dryers (they average work during the 80% of total time) and washing section (96% of total time). The vacuums chamber, during a work week, executes about 70 units of palettes what is equal to 30% of it productive possibilities. Painter's cabins also are used faintly, about 20% of it productive possibilities. The results of the simulation are approximate values, because units are not delivered regularly and therefore also every next executed simulation results in different times of work and number of units.

After a week of work of the system it has been received 62 palettes, from which 52 pallets have been executed correctly and 10 has been made with defects. The quality control section works about 52% of total time, and the coating section only about 32%.

It seems that the enlargement of the efficiency of the washing section could results in increasing of the efficiency of the rest of devices. Unfortunately such operation would lead to blocking the dryers. The elements after painting have to wait long on to be moved to dryers, what would result in incorrect varnish drying as well as in defects formed metallized layer. On the other hand the enlargement of the efficiency of dryers causes blocking next devices which work time is fixed. To enlarge the production capacity it would enlarge the number of devices or modernize the stages, which work time is the longest.

4. Results

Following conclusions were formulated on the basis of conducted investigations:
1. Total automation of vacuum metallization process is difficult to achieve, because some stages of production need a human control. As examples one can point next operations: putting elements on hangers as well as placing them on a trolley that is shifted to the vacuum chamber.
2. The production process is dependent on the type of metallized elements. It is known that different stages are at metallization of films, and different at metallization of small things of daily necessity. Not every element requires painting with priming or top varnish.
3. Such simulations let us to tune the individual stages of metallization process as well as to avoid mistakes, which can appear in the process planning period. The correcting of mistakes in real time can results in huge costs. Thanks to simulation it is possible to choose the suitable efficiency for every device and machine taking part in the production process.
4. In presented simulation it is also possible to introduce of data relating the direct costs (like the usage of materials, direct labor costs with overheads) as well as the fixed and variables costs. Program will present the results of profits or losses, basing on which it would be possible to estimate the profitability of given production. The simulation permits on such selection of input parameters that let us to estimate if the production is profitable at assumed costs level.
5. Unfortunately the complex mechanization of low-series production is not profitable. Costs of mechanization of all production stages would be too large to be covered by short time profits. Enterprises of large-series production could be mechanized profitably. To realize that it is necessary to mechanize productive processes. Simultaneously one should limit a human factor to minimum.

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