

MODELING OF HIGH STORAGE SHEET DEPOT WITH PLANT SIMULATION

Andrzej Jardzioch¹, Jędrzej Jaskowski²

¹ Department of Mechanical Engineering and Mechatronics, West Pomeranian Technical University of Szczecin, al. Piastów 19, 72-300 Szczecin, Poland, e-mail: andrzej.jardzioch@zut.edu.pl

² Department of Mechanical Engineering and Mechatronics, West Pomeranian Technical University of Szczecin, al. Piastów 19, 72-300 Szczecin, Poland, e-mail: jjaskowski@zut.edu.pl

Received: 2013.01.21
Accepted: 2013.02.18
Published: 2013.03.15

ABSTRACT

Manufacturing processes are becoming increasingly automated. Introduction of innovative solutions often necessitate processing very large number of signals from various devices. Correctness tests of the components configuration becomes a compiled operation requiring vast expenditure of time and knowledge. The models may be a mathematical reflection of the actual object. Many actions can be computer-assisted to varying degree. One example is construction of simulation models. These can also be simulation models developed in advanced software. The stages of creating a model may be purely random. This paper aims at a closer analysis of the simulation model based on the high storage sheet depot modeling using Plant Simulation software. The results of analysis can be used for optimization, but this stage is a separate issue.

Keywords: Plant Simulation, simulation, model, warehouse, sheet depot.

INTRODUCTION

Nowadays, simulation is one of the most important techniques supporting production management [1]. Market economy forces companies to solve increasingly complex problems in the shortest possible time. Modeling of manufacturing systems is aimed at understanding the structure and operation of constructed facilities. Models can be material (physical) and abstract (e.g. a computer model). They are necessary because the industrial equipment, and even consumer products, are becoming increasingly complex. In most cases, multiple models are created to present different approaches towards the same or different parts of the system [2]. Modeling and simulation are widely used in many industries. Due to strong competition in global markets, manufacturing companies cannot afford even the slightest error or delay in production. Such errors can result in increased production costs, as well as significant losses. It is vital to strive to improve the technological and economic conditions of the enterprise. This can be achieved by modeling and simulation.

A large number of variants of possible solutions are often developed in the process of design and analysis of automated manufacturing systems. The number of variants and their complexity often make a simple and clear selection of an appropriate solution impossible. The problem can also be a quick reaction to change in production by modifying the schedule currently carried out. In this case we can speak of a dynamic production scheduling [19]. The results of simulation studies prove useful in such a case.

A characteristic feature of the simulation experiments is a comprehensive examination of the manufacturing system configuration, i.e. analyzing not only the throughput of the system itself, but also the impact of other resources, such as, for example, interoperable buffers and transport system [3].

Measures aiming at building the simulation model and performing the test using a simulator usually have a cyclic multifaceted nature. They require many iterations and modifications to obtain a model that resolves the issue and achieves the goal. Unambiguous separation of these activi-

ties into independent sequences is a matter not possible to be solved explicitly [4-13, 17]. The proposed methodology distinguishes three sets of activities:

- Identification of research tasks,
- Identification and modeling of the system,
- Experimental research implementation.

The paper presents the problem of developing a simulation model of automated high storage sheet depot. Attempts have also been made to determine the effect of the depot working time on the whole production system. Section 2 of the paper presents definition of depots and describes automated high storage sheet depot. Section 3 presents the stages of depot modeling. Efforts have also been made to analyze the various tools offered by Plant Simulation. Section 4 contains verification of simulation model operation. Section 5 summarizes the works carried out and plans for model development and subsequent research.

PROCESSES IN AUTOMATED HIGH STORAGE SHEET DEPOT

According to the definition provided in [14] the term “depot” can be used to describe the structure designed specifically for the purposes of receiving, storage, shipment and preparation for shipment of materials intended for shipping or further processing. Another definition used by the author of the publication [15] denotes it as an organizational – functional facility, having separate space, equipped with technical devices, registration devices and trained personnel to operate them. The last definition found in the literature [16] defines it as planned organizational – functional space for efficient storage and movement of materials.

Storage units are generally arranged in two different ways, occupying storage space in the block or in-line system [16]. Block layout is a free arrangement of units where repeated stacking of units can be observed. It is one of the ways to save space. The disadvantage of this approach is difficult organization and computerization of depot works. Movement of units located deeper inside the storage space forces the movement of the outside units. It should be remembered that each operation costs, so the total cost involves movements that do not add any value. The in-line system of arrangement means storing units in rows, allowing free access to each packaging

unit [16]. The disadvantage of this solution is the large number of transport routes and worse rate of space utilization. The advantages include better access to the packaging unit which, simultaneously, facilitates better use in terms of organization and information technology. Both the block and the in-line arrangements have the third dimension - the height of storage. The number of storage levels depends on the type of component part and storage facility. A specific type of in-line storage is a high storage sheet depot where load units are stored in racks arranged in rows so that each level is limited by the height of storage shelf slot. From the perspective of the depot organization and standardization of depot operations, high storage sheet depot is the best solution [16].

Analysis of the storage processes in high storage sheet depot

The analysis of the processes occurring in the high storage sheet depot will be conducted on the example of Europe’s Product Systems shown in Figure 1. This depot is used for storing the material in a form of sheets or plates. The raw material is placed on separate shelves. Number of shelves depends on customer requirements. Shelves capacity depends on the type of stored material. To collect a specific shelf, the carry unit is equipped with a chain which removes the shelf from its space in the rack. Then both (shelf and carry unit) lowers it to the bottom of the depot. Then, using the roller conveyor and another chain, the shelf is moved underneath and goes to the right side of the unload station.

Six types of material shelf-storage can be distinguished. A typical solution is storing only the new sheets. In this case, you can define two storage options. In the first option, a separate shelf for each type of material is designed; in the second case, the material is stored on the shelves in random order. The first solution makes it easy



Fig. 1. Inside the depot [20]

to manage your inventory, however, it strongly limits the number of material types. In the latter case, the management is more complicated. It is necessary to regularly update the current inventory list. The vital information is the location of the material - which container and position in the particular container stack it is in. This solution greatly increases the number of different materials. However, there may be the case of production unit where, after excision from the sheet, a large piece of unused material still remains.

The problem of determining when to classify the residue as waste, and when to allocate it for further use, is a task that cannot be unambiguously resolved. To simplify, a minimum number of conditions, depending on the length of the surface and edges of the remaining material, can be assumed. For example, to qualify the material for re-use, the surface residues must fulfill the minimum requirements. This assumption is not good because if the residues have a form of a web, the area can meet the above requirement, but it will be impossible to lay any minimum cut-out on it. A better requirement will be the possibility to enter the circle in the remaining area. The diameter of this circle is the diameter of the circle circumscribed on the minimal object possible to manufacture. The minimum size of the object can be determined on the basis of many categories. The form of a table cutter where the sheet will be processed is important here, as well as the availability and the capability of fastening, mounting and handling tools that will be used to hold the sheet and retrieve the finished product. After determining the minimum dimension of the object, the conditions can be formulated in terms of defining the boundaries for classifying the remain-

ing as material or waste. In the case of classifying the sheet as material, it returns to the depot, while in the latter case it goes to the waste storage.

There are two storage options worth considering for partially used material. The first case assumes that the depot has provided separate empty shelves for both returned material and unused material. In this variant, storage capacity is considerably limited by the necessity to plan the empty shelves for returned material. This makes it easier, however, to conduct inventory of the depot, identify the material and implement IT processes. In order to save space separate shelves can be planned for particular types of new material. Common shelves can be planned for material that is not fully utilized. Such solution would complicate inventory management processes to a great degree. It can lead to a situation where many manipulative operations would have to be performed in order to access the required sheet and each operation costs, as mentioned in the introduction. Another option is to store each type of new and returned material in a separate container. This solution is the most transparent from the point of view of management, IT processes and inventory.

It is also the least possible solution of using different types of material. In the cases where we deal with returned material, it is hard to unambiguously determine the use of storage space. The number of returned sheet is strongly correlated with the specific character of particular enterprise. Depot works options have been shown schematically in Figure 2.

The following section of the paper presents the analysis of the modeled magazine where the material is stored according to the first variant.

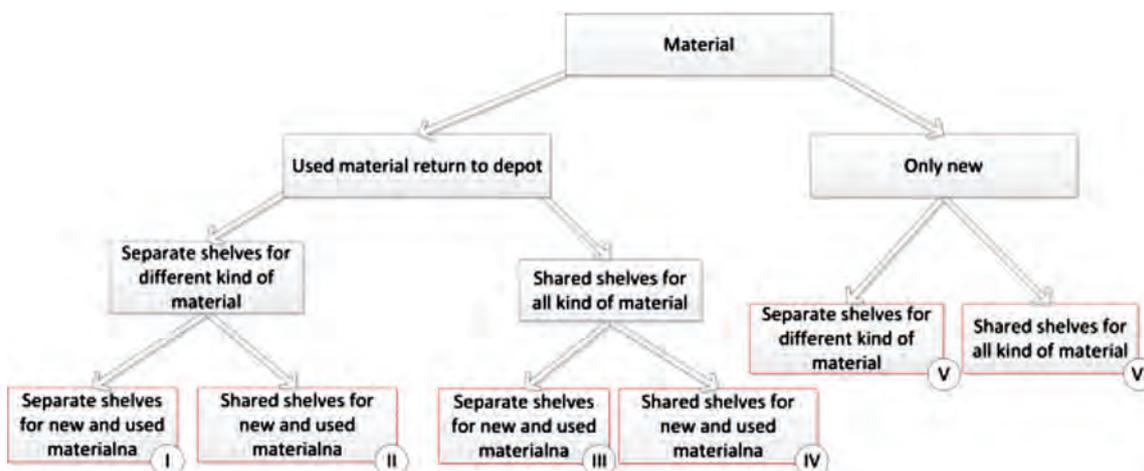


Fig. 2. Options for storing the material in the depot

It was assumed that at the beginning of works that there is only new material on the shelves. The computer transmits signal specifying the number of shelf where the specific sheet is retrieved from. The cart moves horizontally to the appropriate container, and then chain system is activated, which removes the container from the shelf. After collecting the container, the cart is pulled down. Afterwards, using another chain system, the container is pulled to the unloading station and then material is used for processing. Should there be unused material left after processing, the management system sends the information in which container the returned sheet is to be stored in. The procedure of container collection is repeated. If the depot is to work in accordance with the adopted variant 1, empty shelves must be provided from the beginning. The assumption has been adopted, that the depot will have 10 shelves, 5 for the new and returned material respectively. The amount of material stored on the shelf depends on its type. Shelf capacity and the amount of space between the shelves is the limit. There will be more material that is light and thin at the same time, than the one that is thick or heavy. In order to simplify the planned study, it has been assumed that each container holds 10 sheets.

Depot possible working cycle is shown in Figure 3, indicating the most important operations. It has been divided into two parts: the first

part is related to the logical operations of the management system; the second part shows the control system operations. The essential element worth noticing is the fact that the work of the depot is strictly dependent on information regarding the status of the sheet after excision.

SIMULATION MODEL

Stages of simulation model construction, possible tools and common features of the program have been presented below.

Plant Simulation Program has a readymade “Store” type object which was presented in Figure 4. This is equivalent to the pallet yard. Its parameters include the X, Y dimension. Defining the dimension enables changes in the storage capacity. All moving objects available in the software can be stored.

Using „store“ object is justified when we are not interested in processes taking place directly in the depot. With advanced parameters, the time necessary to collect the item can be defined. „Failure“ tool has an interesting feature: it is used to generate the object failure in a wide range of ways provided by software manufacturer.

The next step was projecting the assumption that storage capacity is 10 containers of 10 sheets each. The container can be modeled in several

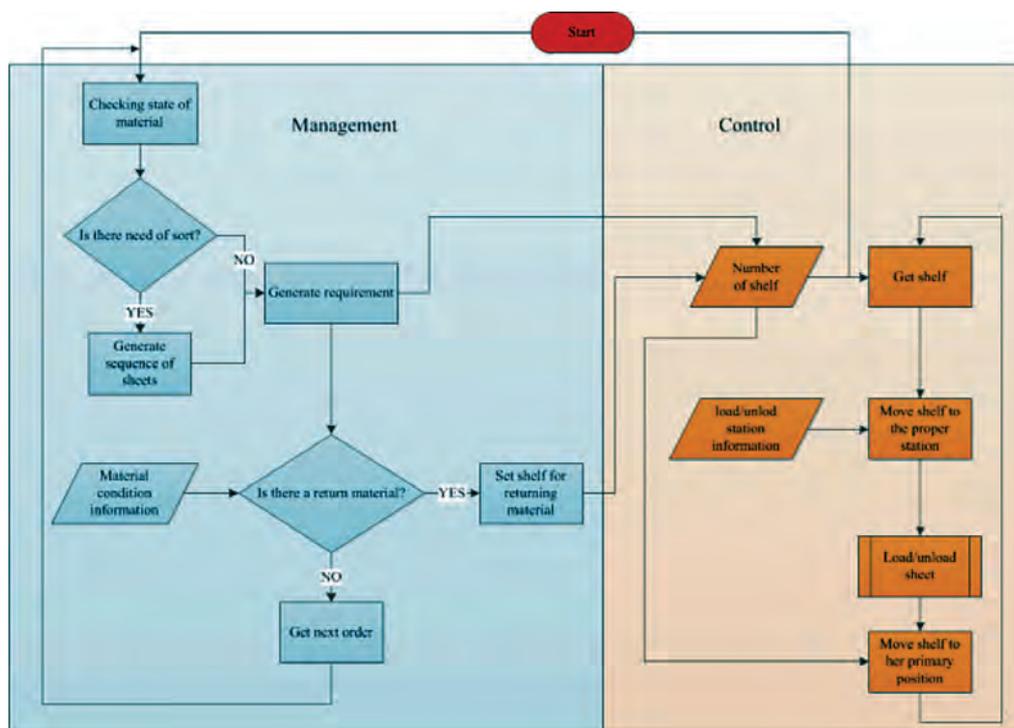


Fig. 3. Simplified diagram of the depot operation

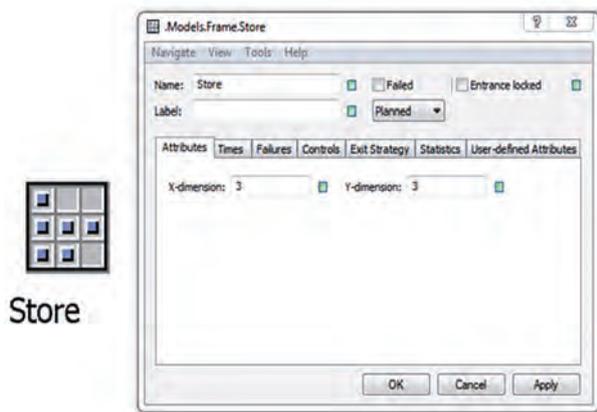


Fig. 4. „Store” object

ways. It may be symbolized by a moving „Container” type object. It is an object that literally corresponds to the actual pallet type object. As far as the parameters are concerned, the dimension that has been set to suit the capacity can be changed. This is not the only object within Plant Simulation. Another object that can be used for container simulation is „Transporter”. It symbolizes the cart. As in the previous facility, dimension responsible for capacity can be changed, or random failures set. Additional advantage is the ability to change the speed of the conveyor movement.

It has been defined that for the correct simulation it is necessary to create a model responsible for the movement of the cart. According to the construction of the actual object, the cart is responsible for moving containers to the loading or unloading station. The easiest way to replace the cart is a conveyor. Plant Simulation has a „Line” type object shown in Figure 5. It is exact projection of the conveyor belt.

The parameters describing the object are length, velocity and acceleration. It is the method

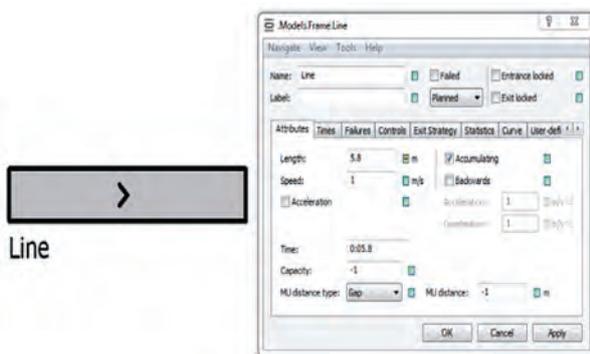


Fig. 5. Line object and its parameters

to reproduce the properties of the actual object. Additionally, sensors can be set in a line at certain distances. After activating the sensor, a program corresponding to a particular sensor is triggered. This way an object can be stopped on a particular position in the line.

The problem occurs when the line is to work in both directions. It is possible to move backwards, by selecting the “backwards” option in the parameters. At this point, the direction of motion is reversed. However, the location of the entry does not change, which by default is left. To easiest solution to this problem is using the second line, as shown in Figure 6.

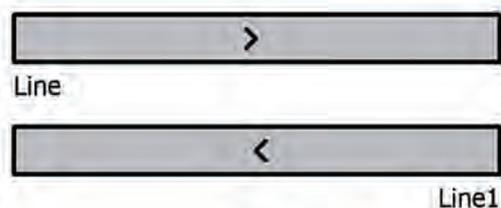


Fig. 6. Using the second line for object return

This solution is good but not the best. The line serves its purpose when the item is moved from the beginning to the end of the line. Otherwise, the object cannot be placed at random segment of the line. This problem can be avoided by using line segments as presented in Figure 7.

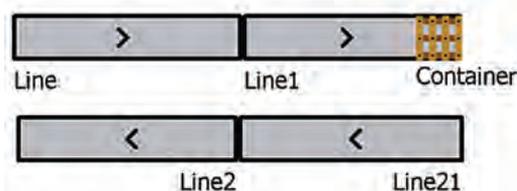


Fig. 7. Use of line segments

Each section corresponds to the route between depot floors. If you want to change the direction of object movement to the opposite when it gets to the end of the line, it should be moved to the line corresponding to inverse direction, as shown in Figure 8.

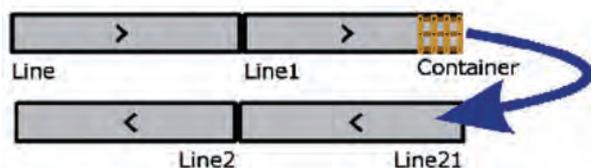


Fig. 8. Moving the object to return line

Another solution designed to simulate the route is to use “Track” object, particularly “TwoLaneTrack”, as shown in Figure 9.

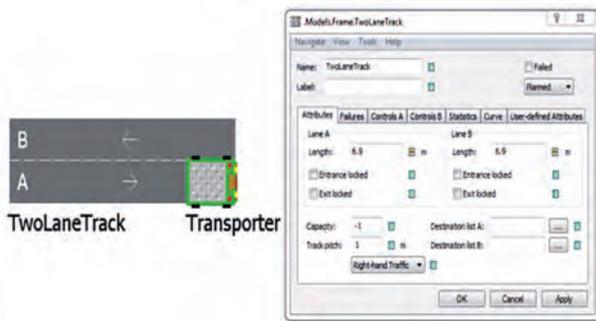


Fig. 9. TwoLaneTrack and its parameters

This object represents the vehicle route. In contrast to “Line”, the container cannot move directly along it. Instead, it has an opportunity to move in 2 ways. This movement is carried out similarly to the use of two “Line” objects side by side, but in this case a single object is implemented. This simplifies the procedure for setting the sensors. Unfortunately, in this case you also cannot put the vehicle on a random segment of the route.

In the next step of model creating it was necessary to specify the time of the cart passage between the respective stations while sorting containers. This can be achieved using the aforementioned “TwoLaneTrack” and the transporter. The values can be determined based on the transporter speed and the length of the passage. Additional advantages of this solution are: possibility of independent failure simulation for the passage and the transporter, placement of sensors symbolizing the limit switches, inclusion of acceleration and deceleration of the cart.

The last stage was to create a combination of the aforementioned objects into a coherent whole, reflecting the depot operations. The model is shown in Figure 10. Horizontal paths symbolize collection and deposition of containers. The vertical path is responsible for the simulation of cart movement between floors. “Store” objects have been used to model the containers. In the course of work the cart moves to the appropriate container, then moves horizontally, what symbolizes the process of container collection. In the next stage a sheet of material is loaded and the cart is moved back to the vertical line and moves down along it, symbolizing the movement of the container to the bottom of the storage.

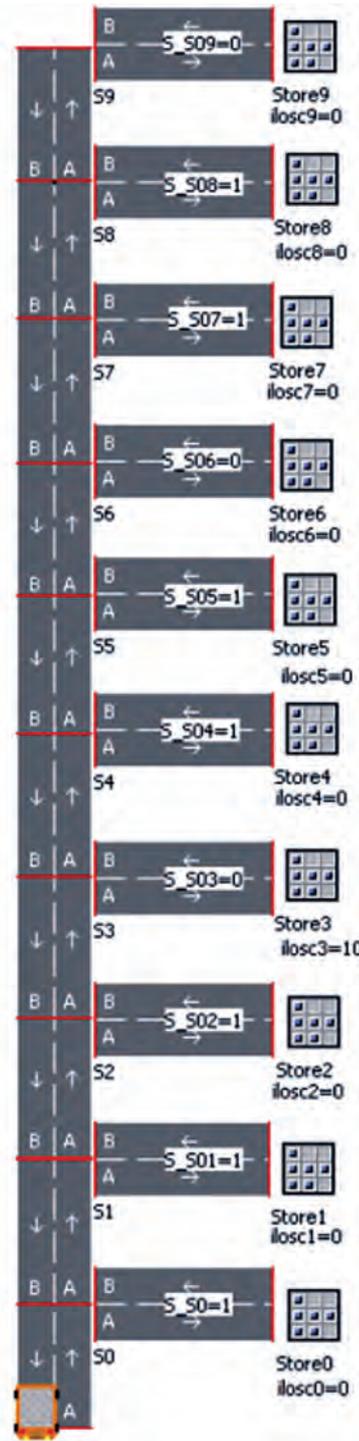


Fig. 10. Depot – final form

Such storage model requires control logics. Plant Simulation allows saving complex algorithms using Sim-Talk language. Each object has built-in parameters, which offer many useful features. If the model requires more detail, or very different properties, they must be programmed. Programming with the aforementioned language requires the use of a ‘Method’ type object shown in Figure 11.

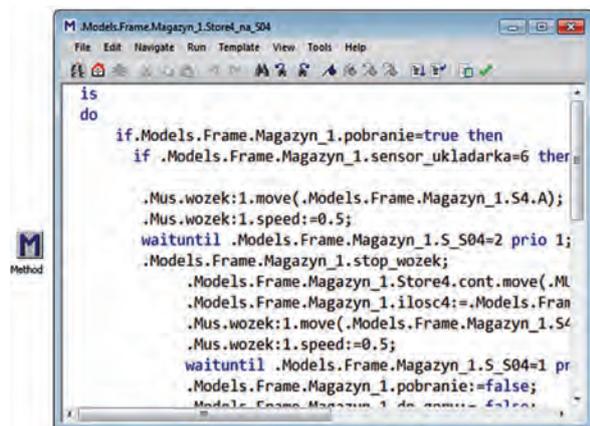


Fig. 11. „Method” type object

Each method has the following structure:

```
[parameters]
[data type of the return value]
is
[local variables]
do
[source code]
end;
```

Parameters – The structure begins with the declaration of parameters. If you do not need any parameters, you do not have to declare any.

Data Type of the Return Value – Enter the data type of the return value next if the Method is going to return a result (see Result of Function Value of a Method).

Is – The keyword is separates the declaration of parameters from the declaration of local variables.

Local Variables – Declare a local variable by entering its name and its data type (see Local Variables). If you do not need any local variables, you do not have to declare any.

do – The keyword do designates the start of the source code proper.

Source Code – Enter the source code, which the Method executes. You can enter built-in methods, assignments, control structures, method calls, branches, and loops.

end – The keyword end, followed by a semicolon, designates the end of the source code. After end you can only enter a comment. When Plant Simulation issues a syntax error in this line it is likely that you did not enter the closing end followed by a semicolon of a loop or branch [18].

Using the appropriate functions, commands were created. They are responsible for: the work of sensors, the direction of cart movement, movement to appropriate containers, collection and

deposition of sheets. Five methods were created for each container, responsible for: signals from sensors on vertical route, sensors on horizontal route, horizontal direction, vertical direction, collection and deposition of the sheet. In addition, a separate algorithm identifies the status of containers. This algorithm uses a table stored in “Table” object. It is a structure of embedded tables, what means that the cell may correspond to the next table. Such embedding is used until grade ,3 as shown in Figure 12.

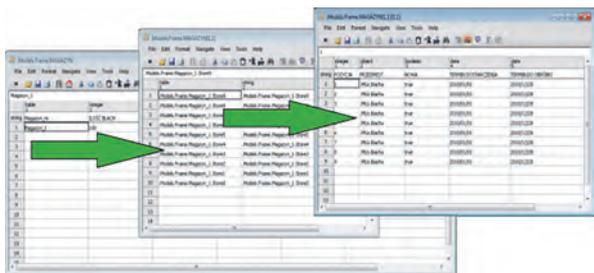


Fig. 12. Tables embedding representing the stock

MODEL VERIFICATION

Data

In order to verify the correctness of the model simple tests were carried out. It was examined how the speed of the cart affects the time of carrying out a sample set of manufacturing orders. The speeds of cart movement is the following: 1, 0.5, 0.1 [m / s]. It was assumed that distance between shelves is 0.4 m. The parameters and their order are shown the Table 1. A and B.

Sheets are transported to a cutting machine. Then, each shear is collected separately and transported for further processing. Another sheet is delivered after the last shear has been collected and residues removed from the working space of the shearing machine.

Results

System working time was longer than the total time of production of orders. It is due to a number of factors, including the depot working time. Table 2 shows the total working time of the system and the differences obtained for each cart speed, comparing each time with the best result.

Times differences in Table 2A show that for orders with long processing time and large number of items, the impact of the depot working time is minimal. The difference in time is no longer

Table 1. Orders used to carry out research

A

Thickness	Workpieces	Sheets	Cutting time [h:min:s]
2	100	10	01:40:00
3	10	1	00:15:00
4	1	1	01:00:00
3	28	1	00:13:00
5	100	4	01:00:00
4	40	1	00:17:00
4	10	1	01:00:00
2	5	1	00:05:00
2	2	1	00:02:00
2	75	3	00:15:00
5	66	3	00:30:00
5	100	5	01:40:00
3	10	1	00:05:00
3	77	1	01:17:00
2	128	2	02:08:00
3	256	4	02:08:00
5	15	3	00:30:00
4	40	1	00:40:00
4	32	1	00:50:00
2	11	1	00:33:00
Total:		46	16:08:00

B

Thickness	Workpieces	Sheets	Cutting time [h:min:s]
2	10	1	00:05:00
3	10	1	00:15:00
4	33	1	00:10:00
3	28	1	00:37:00
5	100	4	00:25:00
4	40	1	00:17:00
4	10	1	00:25:00
2	5	1	00:05:00
2	2	1	00:02:00
2	75	3	00:15:00
5	66	3	00:30:00
5	10	5	00:50:00
3	10	1	00:05:00
3	17	1	00:17:00
2	28	4	00:28:00
3	56	4	01:00:00
5	15	3	00:30:00
4	40	1	00:40:00
4	32	1	00:50:00
2	11	1	00:33:00
Total:		39	08:19:00

than 23 minutes. Comparing it to over 41 hours of the total time, it turns out that increasing the speed of the material lift has virtually no effect on the working time of the system. In fact, increasing the speed 10 times (from 0.1 to 1 m / s) would

Table 2. Summary of results

A

Speed [m/s]	Working time [d:h:min]	Difference [min]
1	01:17:16	0
0,5	01:17:18	-2
0,1	01:17:39	-23

B

Speed [m/s]	Working time [d:h:min]	Difference [min]
1	00:12:19	0
0,5	00:12:21	-2
0,1	00:12:38	-19

generate increased costs of renovation and maintenance, and achieving such results would often be impossible for technical reasons. Table 2B shows the results for the second set of orders. Set B was designed for single and non-mass production. In this case more attention should be paid to transport operations and less to the processing times itself, which are much shorter due to smaller number of elements. Here, although the time difference is not great, it starts to be more important when equated to ca. 12 hours of work. Another important conclusion is that increasing the speed 5 times (from 0.1 to 0.5 m / s) can improve the times by respectively 21 and 17 minutes. This result is just 2 minutes worse from the best obtained for the velocity 1 m / s.

SUMMARY

Modeling methodology presented here shows different solutions for various stages of creating a model offered by modern software. Depot example illustrates how precisely object work can be projected. Each step of building the model shows at least two possible methods of achieving the goal. In developing the model, it is possible to grasp the enormity of tasks, which the actual operator often performs automatically, without even paying any attention. Creating a fully automated system, or its model, requires saving all these activities. This often involves dealing with a large compilation of “if ... then ...” conditions. Additional verification of the model proves correctness of its construction. There is a certain doubt, however, concerning the control algorithm and only comparing it with other algorithms – such as FIFO, SJF, EDF – will provide unambiguous results.

During the research, the depot overflow phenomenon occurred. It took place at longer work interval, after several stages of adding new sheets. The amount of returned material exceeded the capacity of containers provided. Determining the suitability of the material used and the appropriate scheduling and combining orders are the issues requiring separate studies. Another question is the justification for the disposal of material if there is no prospect for its use in the near future and depot work is at risk. Further analysis of the depot work requires planning and conducting additional research. In subsequent studies, additional elements of manufacturing system, management control system algorithms and algorithms using artificial intelligence methods will be developed. Certain steps will also be taken towards validation of simulation model with a miniature actual model.

Acknowledgment

The work was financed from the Resources for National Science Centre as a research project no. N N503 193237.

REFERENCES

1. Świder J., A. Baier, P. Ociepka, K. Herbuś. 2005. Zastosowanie metod obiektowych w procesie projektowo – konstrukcyjno – wytwórczym. Inżynieria Maszyn.
2. Mrozek. Z. 2003. Modelowanie fizyczne. *Pomiary Automatyka Robotyka* 4/200.
3. Zdanowicz. R. 2007. Modelowanie i symulacja procesów wytwarzania. Silesian University of Technology Press.
4. Barton R.F. 1977. Wprowadzenie do symulacji i gier. WNT, Warsaw.
5. Fishman G.S. 1981. Symulacja komputerowa. Pojęcia i metody. PWE, Warsaw.
6. Gordon G. 1974. Symulacja systemów. WNT, Warsaw.
7. Jaźwiński J., Pabis S., Wieremiejczyk W. 1975. Zasady symulacji systemów technicznych. OPT, Katowice.
8. Koleśnik K., Huzar Z., Fryźlewicz Z. 1976. Symulacja komputerowa. Warsaw University of Technology Press, Warsaw.
9. Kondratowicz L. 1978. Modelowanie symulacyjne systemów. WNT, Warsaw.
10. Martin F.F. 1976. Wstęp do modelowania cyfrowego. PWN, Warsaw.
11. Naylor T.H. 1975. Modelowanie cyfrowe systemów ekonomicznych. PWN, Warsaw.
12. Rajski J., Tyszer J. 1986. Modelowanie i symulacja cyfrowa. Poznan University of Technology.
13. Zeigler B. 1984. Teoria modelowania i symulacji. PWN, Warsaw.
14. Polish Standard: PN-ISO-6707-1.
15. Kaczmarek A., Korzeniowski A., Skowroński Z., Weselik A. 1997. Zarządzanie gospodarką magazynową. PWE, Warsaw.
16. Majewski J. 2006. Informatyka w magazynie. Institute of Logistics and warehousing. Poznan.
17. Ruta R., Mazurkiewicz A. 1991. Modelowanie symulacyjne systemów eksploatacji. Radom.
18. Bangsow S. 2010. Manufacturing Simulation with Plant Simulation and Simtalk. Springer-Verlag GmbH.
19. Jardzioch A., Honczarenko J. 2004. The Application of eM-Plant Software for Constructing Virtual Manufacturing System. 1st International Conference “Virtual Design and Automation”. Poznan 3-4 June 2004.
20. <http://www.europasystems.pl>