SIMULATION OF A FLEXIBLE MANUFACTURING SYSTEM

PÉTER TAMÁS[1], BÉLA ILLÉS[2], SÁNDOR TOLLÁR[3]

Abstract: The study describes the simulation testing conducted in connection with the expansion of the department of Audi Hungaria Motor Ltd. for manufacturing small-scale bodyworks, during which the future operation of an extremely complex manufacturing system was modelled. The reason for demand of modelling was the improvement of the manufacturing activity with the primary importance of revisionary investigation of the company conception. The modelling has been carried out by using the frame software Plant Simulation on base of own worked data structure and algorithm. The innovation of the application is that due to its data model developed it is able to simulate the future operation of the system, and determine the storage area dimensions and machine resource requirements necessary for the production.

Keywords: simulation, storage area, small-scale components manufacturing

1. Introduction

In practice, from material flow point of view the flexible manufacturing systems used in the production of small-scale products can be characterized by significant complexity. This primarily stems from that the technological equipment applied process numerous product types, and the material flow processes of the preparation of finished products significantly differ from each other [1, 2]. The simulation testing of these production systems is an extremely important task, because the logistics indicators characterising the operation of the system (e.g. expected utilization of the machines, storage capacity requirements, manufacturing lead time, etc.) can be determined with high accuracy already prior to the production [3]. This is a major competitive factor, because the different production plans can be evaluated and compared prior to the manufacturing of the products, and the necessary interventions can be performed in time [4]. The study presents the simulation testing carried out for the department of AUDI HUNGARIA MOTOR Ltd. engaged in manufacturing small-scale body parts, where the revision of a system to be created by a future manufacturing capacity expansion from material flow point of view and the calculation of the size of inter-operational storage were realised. In the paper the creation of the model under investigation is shown step by step, that is the objects and links among them of the system under elaboration and also the data tables and algorithms necessary for their operation. According to the confidentiality undertakings towards the company, the original data were modified for the purpose of this study but from the point of the worked-out investigational methodology it is full-valued.

[1] PhD., assistant professor, University of Miskolc
alttpeti@uni-miskolc.hu
[2] university professor, dean, head of department, University of Miskolc
[3] researcher, University of Miskolc
H-3515 Miskolc-Egyetemváros, Hungary

2. Objective of the study

The objective of the study had been the presentation of a material flow system examined in connection with the small-scale body parts manufactured by AUDI HUNGARIA MOTOR Ltd., and the description of such general data structure capable to describe the data necessary for the simulation testing of all manufacturing systems. Furthermore, the description of the operating principle of the prepared simulation program is also important objective of the study. The company's expectations towards the research were the revision of the initial installation layout, the calculation of the size of warehouses, inter-operational storages, as well as the showing of the evaluation of different production plans in respect of an envisaged manufacturing system functioning in the future.

3. Presentation of the simulation model

In chapter 3, the material flow system of the simulation testing, the received company data and the data charts used by the simulation program will be presented.

3.1. Description of the examined material flow system. The description of the material flow system will be carried out in two steps. Description will primarily entail the material flow indicators related to the sources and sinks of the fine-scale system, secondly the possible transport connections between them.

3.1.1. Description of the material flow indicators of sources and sinks. Six source and sink objects have been dealt with in the simulation program, each one different from material flow point of view (hereinafter material flow nodes), described as follows:

1. **Presses**: The task of the three presses shown in Figure 1 is forming the plates purchased by the company into the desired shapes. The material flow between the presses may depend on the geometrical complexity of the product to be produced. Thus, in some cases, repeated use of the presses is necessary to create the product.

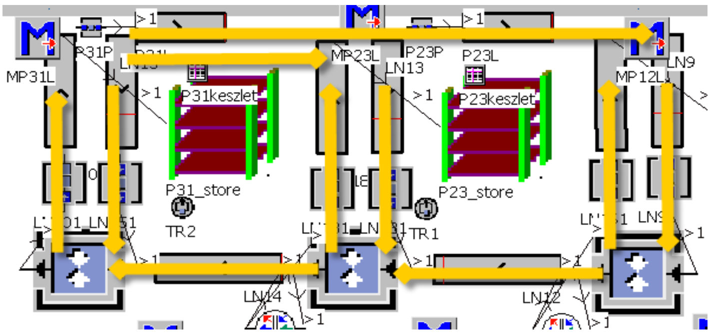

Figure 1. Presses

2. **Laser cutting machine**: Laser cutting is necessary for cutting for the required size of the platinum plates or the pressed plates. This object used during the simulation testing is shown in Figure 2. In the simulation program every laser cutting machine has two

work tables and cutting the products for the desired size can be performed by using any of them.

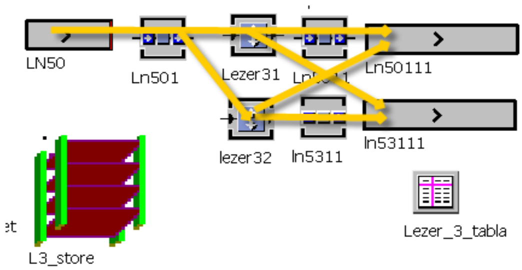

Figure 2. Laser cutting machine

3. **Assembly operations**: In the simulation program, any and all operations in the cells are called assembly operations (riveting, welding, cleaning, etc.). The object shown in Figure 3 was used during the 16 different operations located in the assembly cell. The transmission between the assembly operations may be realised directly or by using a material handling tool.

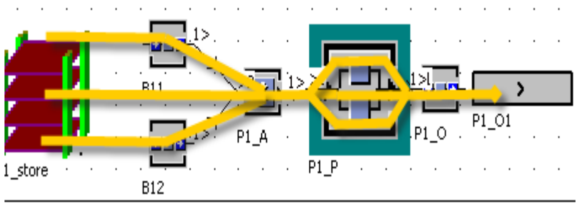

Figure 3. Assembly

4. **Hardening**: The heat treatment of the products' surface can be performed simultaneously in the three load unit formation equipment as shown in Figure 4. For the heat treatment, the products are transferred to storages of temporary use.

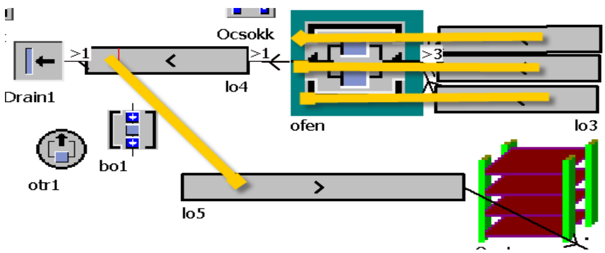

Figure 4. Hardening

5. **Final processing**: The majority of body parts requires also final control and processing operations. These can be accomplished in three different spots depending on the material of the finished products (aluminium, steel, stainless steel).

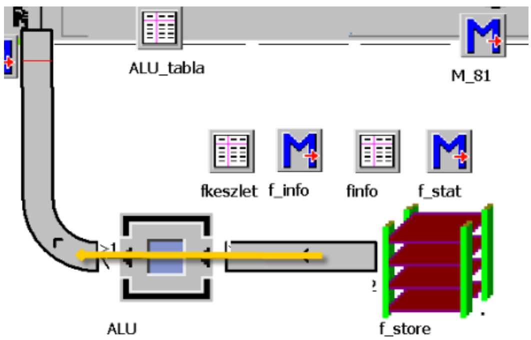

Figure 5: Final processing

6. **Warehouses/inter-operational storages**: In the whole system examined, the products are placed in the form of floor-mounted storage. The LUFEs (Load Unit Formation Equipment; ERKE in Hungarian) of the incoming and processed components are at the pressing and laser cutting operation completely, at the assembly operations partially different. The LUFEs of the incoming and processed products are the same at the hardening and final processing operations.

3.1.2. Description of material flow connections between sources and sinks. Figure 6. describes the transport connections between the material flow nodes, where nodes are indicated by numbers 1-6 given at their description. The manufacturing processes of the finished products to be prepared and their components significantly differ from each other, which creates a complicated material flow system. Though, due to space limits the figure does not illustrate it, but in the simulation there are 16 further operations within the 3 assembly operations with also complex material flow connections among them. Electric and hand-operated forklifts perform the transport between material flow nodes. The reason for the material flow processes' complexity shown in Figure 6. is that for the production of a finished product several components are needed and produced in-house. Pressing, laser cutting, assembly, hardening and final processing operations may be necessary, even by backward material flow.

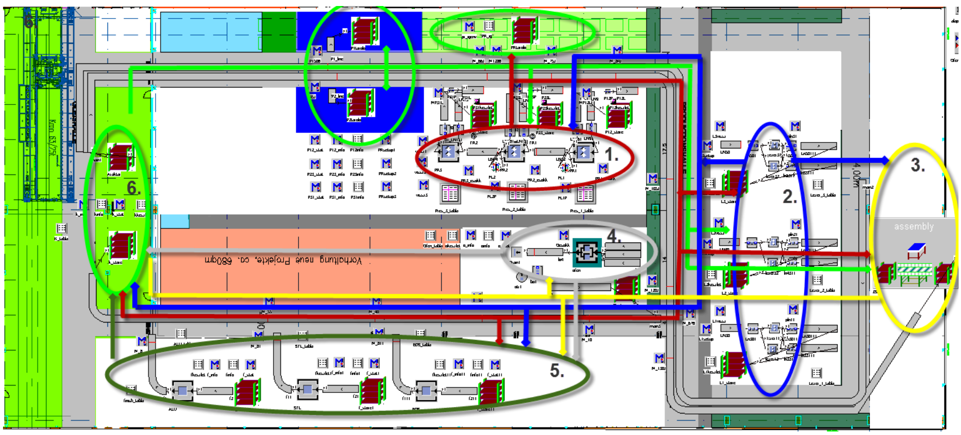

Figure 7. Material flow connections between sources and sinks

3.2. Presentation of company data received. The following company data and information were given to the preparation of simulation testing:

1. **Initial layout**: AutoCAD document including the scale space layout of the important objects (technological equipment, transport routes, layout of storage areas) of the manufacturing system to be created.
2. **Chart of manufacturing processes**: Description of material flow method of the products using graph, where the nodes describe the operations and the item numbers of the processed products; the edges describe the material flow connections.
3. **Chart of manufacturing information**: These include the operating and conversion times of the products at certain technological spots.
4. **Chart of unit load information**: Excel table including the important parameters (width, length, height, ability to create sets) of the LUFEs applied and the quantity of products that can be placed in them.
5. **Initial stock level data**: Chart including the data concerning the initial stock level stored in the warehouses and inter-operational storages at the launching of the simulation, by product type.
6. **Weekly manufacturing program chart**: Chart describing the tasks to be performed at the single technological equipment by shifts in weekly periods.

To illustrate the size of the task, from charts 2-4 more than 60 were provided, because one chart only includes information about one finished product.

3.3 Description of the data charts of the simulation program. To simulate the manufacturing process, it was necessary to create a database, which contains the necessary information for the program in a manageable form. The charts used by the program and their content are presented below.

1. **Chart of manufacturing information:** This chart contains the important information of the operations belonging to the products. Its first column contains the name of the finished product, the second column the name of the initial material or semi-finished product, and the fifth column shows the name of the initial material or semi-finished product created during the given operation. These two columns may also be called input and output data columns.

TR_470831052D

	string 1	string 2	integer 3	string 4	string 5	string 6	integer 7	time 8	time 9	string 10
string	Termeknev	Input objektum nev	Inp db/obj	Megm kod	Output Objectum nev	ERKE	db/ERKE	utemido	atall ido	
1	TR_470831052D	PLA_470831465	1	PR3	TR_470831465_UG0	CONT_2105161	50	36.0000	40:00.0000	
2	TR_470831052D	PLA_470831209	1	PR3	TR_470831209_UG0	CONT_2105161	50	36.0000	40:00.0000	
3	TR_470831052D	PLA_470831205	1	PR2	TR_470831206C_UG0	CONT_210495	50	48.0000	40:00.0000	
4	TR_470831052D	PLA_470831106	1	PR1	TR_470831106A_UG0	CONT_524162	50	48.0000	40:00.0000	

Figure 7. Chart of manufacturing information

This chart does not include commercial goods, only components produced or to be processed in the manufacturing unit. The third column provides the number of components to be integrated in the single product. The fourth column identifies the operation to be performed. The sixth column contains the identification of storage of the unit completed at that spot, and the seventh column contains the number of elements to be placed there. The eighth column provides the time necessary for the manufacturing of a single unit, and the ninth column shows the transfer time required for the manufacturing of the product– once before to the commencement of the set. If the product is not put into the storage following the operation, but forwarded to the next stage, the seventh section of the chart contains the term “direct”.

2. **Chart of LUFE information**: Because one of the objectives of the simulation is to calculate the size of the necessary storage areas, thus in case of floor-mounted storage, one needs to know the space required for the storage of the single parts. Therefore, our second chart shows the data relating to storage.

TR_470831052D

	string 1	string 2	integer 3	string 4	string 5	string 6	integer 7	time 8	time 9	string 10
string	Termeknev	Input objektum nev	Inp db/obj	Megm kod	Output Objectum nev	ERKE	db/ERKE	utemido	atall ido	
1	TR_470831052D	PLA_470831465	1	PR3	TR_470831465_UG0	CONT_2105161	50	36.0000	40:00.0000	
2	TR_470831052D	PLA_470831209	1	PR3	TR_470831209_UG0	CONT_2105161	50	36.0000	40:00.0000	
3	TR_470831052D	PLA_470831205	1	PR2	TR_470831206C_UG0	CONT_210495	50	48.0000	40:00.0000	
4	TR_470831052D	PLA_470831106	1	PR1	TR_470831106A_UG0	CONT_524162	50	48.0000	40:00.0000	

Figure 8. Chart of LUFE information

All elements contained in the second and fifth column of the previous chart are listed in the first column. Each element stands with its own load unit formation tool together with the relating data. At this place also the initial stock can be provided. In case of a specific simulation this means the number of parts stored in the warehouse or in the inter-operational storages in case it is necessary. At the beginning of the simulation, the program fills in this information based on the conditions provided previously.

3. **Weekly product plan data chart**: This chart contains the designation of the product (column 1), the number of pieces (column 2), the necessary technological equipment (column 3), and time of production (column 3-5) to be planned with for the manufacture.

Termeknev	db	Megm kod	OBJ	nap	műszakszám
SH_420809405	54	PR	2011.04.20	SZE	1
SH_420809406	54	PR	2011.04.20	SZE	1
TR_470831205C_UG0	86	PR	2011.04.20	SZE	1
TR_470831206C_UG0	86	PR	2011.04.20	SZE	1

Figure 9. Weekly product plan chart

4. **Control chart:** In order to run the program we needed a manufacturing structure, on the basis of which the chart can calculate in case of the manufacturing of certain products in the given number, and show which elements shall undergo which operations to become the finished product. The manufacturing structure is shown in Figure 10 - it is generated by the program on the basis of the previously described manufacturing chart. This chart provides the name of the element(s) (column 2) necessary for the manufacturing of any element (column 3) belonging to any product (column 1), its number, the place of processing and the material of the product. Due to

the lack of space we do not describe the chart generation method; this will be the subject of a separate publication.

	string 1	string 2	string 3	intege 4	intege 5	intege 6	intege 7	intege 8	intege 9	intege 10	intege 11	intege 12	intege 13
string	Termeknev	Input	Output	PR1	PR2	PR3	LZ1	LZ2	LZ3	Z_P1	Z_P2	Z_P3	Z_P4
1	DA_420817111E	PLA_420817111C	DA_420817111C_UG0	1	1	1							
2	DA_420817111E	DA_420817111C_UG0	DA_420817111C			1							
3	DA_420817111E	DA_420817111C	DA_420817111E				1						
4	DA_420817111E	DA_420817111E	DA_420817111E										
5	FK_420823021A	PLA_420823263A	FK_420823263A			1							

	integer 14	intege 15	intege 16	intege 17	intege 18	intege 19	integer 20	integer 21	integer 22	integer 23	integer 24	integer 25	intege 26	intege 27	intege 28	t 2
string	Z_P5a	Z_P5	Z_P6	Z_P7	Z_P8	Z_P9	Z_P10	Z_P11	Z_P12	Z_P13	Z_P14	Z_P15	OFN	FNS	KAR	p
1																1
2																1
3																
4															1	
5																4

Figure 10. Control chart

5. **Data charts of technological operations:** The simulation program automatically fills in the data of Figure 11 on the basis of the data in the weekly product plan, the control and the manufacturing chart. A chart of this kind exists at every single technological operation. These charts show which products (column 2) in what amount (column 3) and from which spot (column 4) need to be "called in" to the given technological operation (column 5), as well as the LUFE at this operation into which the finished products shall be placed (column 6) and in what amount. Furthermore, the chart also contains the operation (column 8) and transfer time (column 9) necessary for the creation of the product.

Termeknev	Input objektum nev	db	Betap iranya	Output Objectum nev	ERKE	db/ERKE	utemido	atall ido	muveletszam
TR_420831051A	TR_420831111	200	PRES1	TR_420831111	CONT_505633	36	42.6000	1:15:00.0000	2
TR_420831052A	TR_420831112	200	PRES1	TR_420831112	CONT_505633	36	42.6000	1:15:00.0000	2
LT_4H0810649B	LT_4H0810649B	300	PRES1	LT_4H0810649B	KLT_6280	30	48.0000	1:10:00.0000	2
LT_4H0810650B	LT_4H0810650B	300	PRES1	LT_4H0810650B	KLT_6280	30	48.0000	1:10:00.0000	2
UFS_8K9807835E	UFS_8K9807835E_L00	200	L3_tarolo	UFS_8K9807835E_UG0	CONT_111925_2	20	54.0000	45:00.0000	2

Figure 11. Data chart of technological operations

6. Description of the operating principle of the program

The objectives of the current version of the simulation program were the calculation of the size of warehouses and inter-operational storages as well as the examination of the correctness of the installation layout. The program performs these tasks in the following steps:

Step 1: Filling in charts 1-3 of the simulation program based on data provided by the company.

Step 2: Filling in the data of the control chart – by the simulation program – on the basis of the manufacturing chart.

Step 3: Filling in data charts of technological operations – by the simulation program – on the basis of the data in the weekly production plan, the control and manufacturing chart.

Step 4: Showing the products and LUFEs used in the simulation on the basis of the data of LUFE chart.

Step 5: Launching the simulation program, during which the initial stocks of the warehouse and inter-operational storages are loaded, and the manufacturing operations are carried out on the basis of the data of the charts of technological operations.

During the running of the simulation program, the relative frequency diagrams related to the storage areas are also calculated for the warehouses and inter-operational storages on the basis of which the space required for the storages can be determined. The correctness of the installation layout had been verified by Sankey diagram, where it can be determined that the objects in close material flow connections are the closest possible to each other.

7. Summary

The study described the simulation of a flexible manufacturing system by describing the fine-scale material flow system, the data structures received from the company and used by the program, and the operating principle of the simulation program. A method had been drafted, which is capable to calculate the size of warehouses and storages in case of floor-mounted storage for all manufacturing systems. It is important to note that the program is also capable to run different weekly product plans and compare them with each other. Furthermore, the installation layout was also evaluated by Sankey diagram during the research. By the further development of the structured simulation model and program, the efficiency of the forklift optimisation and production scheduling tasks of the model examined can be increased, which can be the subject of further researches.

Acknowledgements

"This research was carried out as part of the TAMOP-4.2.1.B-10/2/KONV-2010-0001 project with support by the European Union, co-financed by the European Social Fund."

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