International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012

DOI: 10.7321/jscse.v2.n11.1

Computer simulation of manual assembly procedures verification of automotive components ABS using SW tool Plant Simulation.

[1]Peter Poór,* [2] Peter Takáč
[1]*KPIaM FST Západočeská Univerzita v Plzni,*
[2] *KPIaM, SjF Technická Univerzita v Košiciach*
E-mail: [1]poorp@kpv.zcu.cz;[2]peter.takac.2@tuke.sk

Abstract. **The aim of simulation and verification is a creation of such optimized models, by which the process will be much more efficient, reduces the investment risk, continuous production time is truncated and maximizes the utilization of production resources, improves logistics flow and thereby increases overall productivity. Presented article deals with simulation experimentation and verification of manual assembly procedures. The object of examination is final assembly of electrical-engineering automotive part - ABS, which was realized in laboratory conditions. Simulation models designed and developed in this way could help designer to solve problems in process of manufacturing conditions for small batch production. When developing simulation models, simulation software Plant Simulation 1.10 was used. Designed and developed simulation models help solve problems in production process especially for conditions of medium-sized and small-lot production.**

Keywords: *assembly, simulation, modelling, ABS*

** Corresponding address:*
Ing. Peter Poór, PhD.,
Department of Industrial Engineering and Management, University of West Bohemia, Univerzitní 8
306 14 Plzeň
E-mail: poorpeter@gmail.com
Tell: +420 377 638 401 Fax: +420 377 638 402

1. Introduction

Implementation of innovative methods for labor productivity increasing is for enterprise in current period of growth and changes in competitive business environment a prerequisite for this environment stood and prospered. As part of such methods are undoubtedly methods of modeling and simulation of manufacturing systems, which progressive and purposeful use brings many benefits. Simulation is a process of creating a model of real system and design of experiments with this model in order to achieve better understanding of studied system behavior, or for purpose of assessing different variants of the system [3]. Computer simulation estimates characteristics of existing or projected enterprise systems through copying operation of these systems in form of computer model. Model is a relationship between two systems, one of which is modeled system (original) and the other simulating. Modeling is the process of compiling model [3]. Computer simulation and verification are main research objectives of this article. By this we can predict behavior of system and thus eliminate its lack, which could occur after its launch. Company can use simulation to save huge amounts of money. Simulation is a versatile method for analysis of complex processes, which thanks to development of computer technology offers creation of more complicated models. Once intensive programming, in compiling simulation models, was gradually transformed into work with pre-defined objects that require sense for logical thinking and creativity. This study was needed for improving production processes. Using the best variant production will become more efficient, also investment risk is reduced. Another advantage is truncation of continuous production time and maximizing of resources utilization. Last but not least, this study was needed because of improvement in logistics flow, what in

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012
DOI: **10.7321/jscse.v2.n11.1**

result will increase overall system productivity. However, this research has some limitations. As most serious limitations were evaluated insufficient computer technology (lack of computing power), lack of input data and unpredictable occurrences. Another fact is, that not all components could have been disassembled into details (for example PCB, main body …) That why into simulation process enter such as single components, such as groups of components.

2. Assembly process

Assembly process can be defined as sum of operations of joining components into units to finished products in a technically and economically purposeful sequence corresponding to predetermined technical conditions [1]. Since the assembly process consists of assembly operations from simple components to nodes, subassemblies and finished products in a certain quantity, quality, at defined time has to be realized in a specific technically and economically efficient sequence. During assembly processes it is necessary to optimize also preparation, support and service activities that support and rationalize entire process. Assembly processes take place in specific technical, technological, organizational and economic conditions [1][2].

Assembly processes are carried out according to predetermined rules, resulting from structure of assembled products, and are final and most difficult stage of manufacturing process. In terms of the degree of automation they can be divided into manual, automated and hybrid. Based on knowledge of assembly process was designed a process of assembly systems design, which is shown at Figure 1.

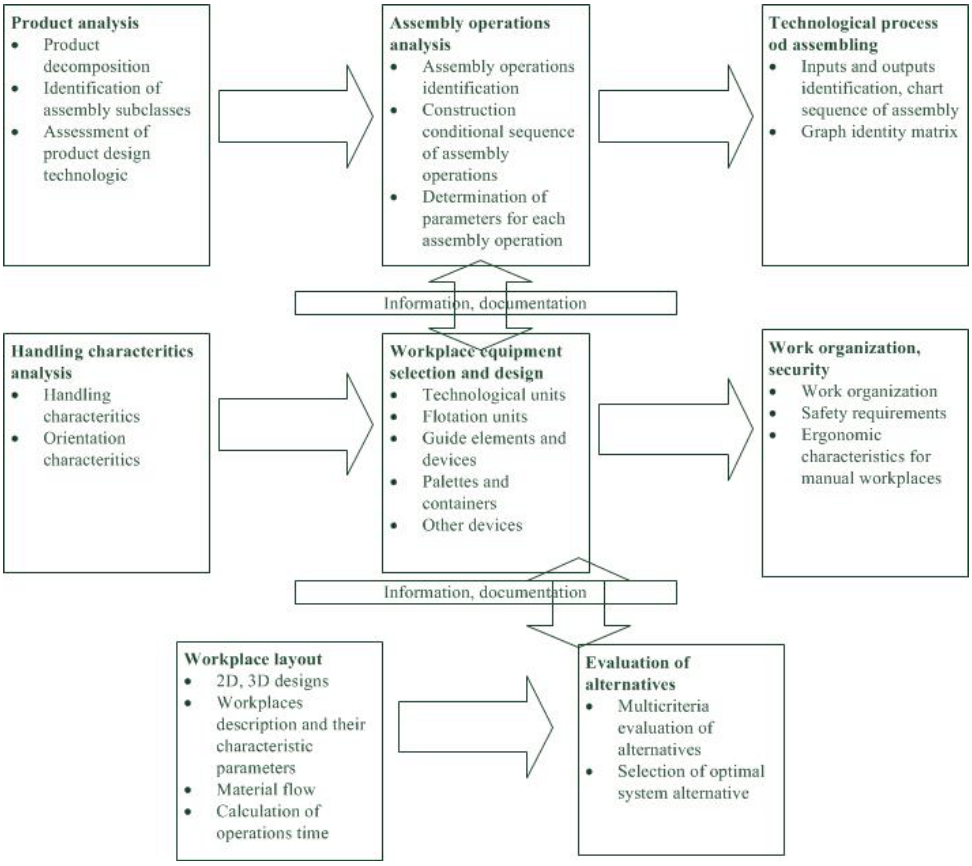

Figure 1. Process of assembly systems design

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012

DOI: 10.7321/jscse.v2.n11.1

One of the options, how these types of assembly procedures verify and optimize is use computer simulation processes.

3. Experimental simulation verification of ABS assembly process

The basis for success of computer simulations is to correctly define the problem and set goals that we want to achieve by simulation. The object of examination is final assembly of automotive component, ABS type VW 6X0 907 379 B [10], which was realized in laboratory conditions. It is a device that provides directional maneuverability of vehicle even during intense braking regardless road conditions. Using this system vehicle becomes, in all critical situations, maneuverable and stable, which results in secure control of vehicle and safe driving experiences. Main objective is to design simulation models of installation procedure of these types of products that will copy actual assembly procedures. Simulation models will be designed according to following criteria:

- Number of finished products,
- Number of employees,
- Utilization of resources,
- WIP at each workplace,
- Length of waiting times of individual departments.

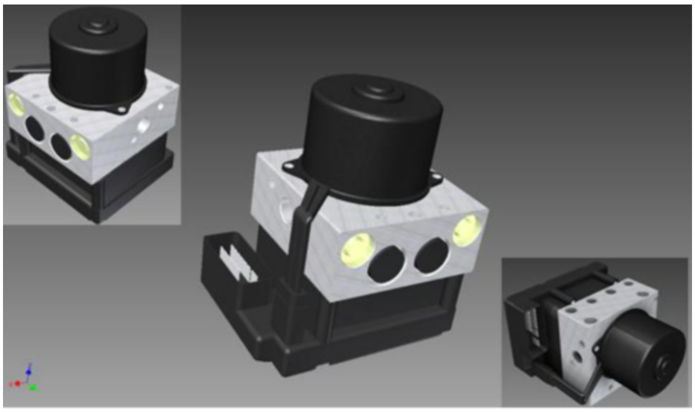

Figure 2. ABS 3D models

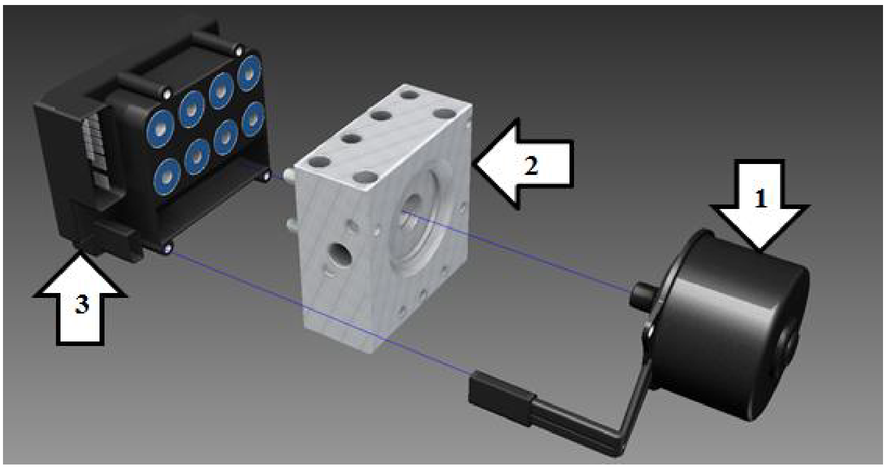

Figure 3. 3D model of ABS main parts assembly

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012
DOI: **10.7321/jscse.v2.n11.1**

The article is focused on very final assembly and components entering into it. Into final assembly process enter individual components as well as finished subgroups of some components, which are outputs of other departments.

ABS consists of three main parts (Figure 3):

1. Pump – when reducing pressure it supplies brake fluid, which flows into brake drums, back into main brake cylinder,
2. Hydraulic unit - converts commands of control unit and based on its instruction, regardless on the driver, adjusts pressure in cylinders,
3. Electronic controller - converts calculation, regulation, control and warning of system failures.

Basic parts are composed of other components and subgroups of components, which overview provides Figure 4 and their description is in Table 1.

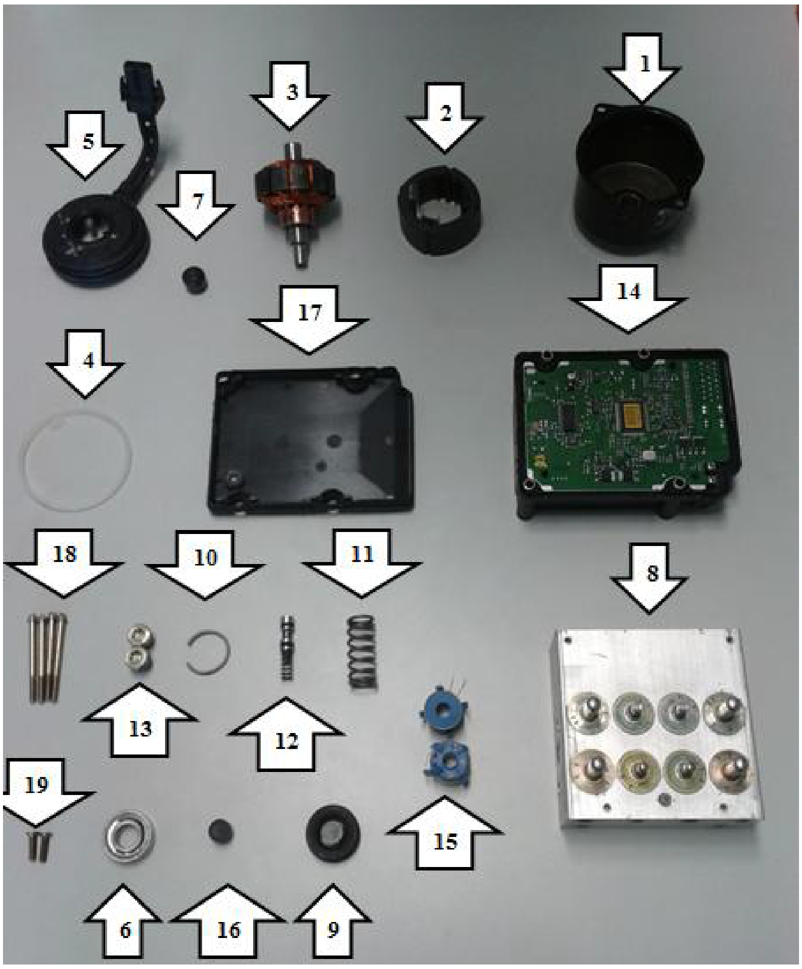

Figure 4. Overview of ABS components and subgroups of components

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012
DOI: 10.7321/jscse.v2.n11.1

Table 1. ABS components description

Main ABS part	Part number	Name of component or subgroup of component	Pieces
Pump	1.	Pump metal container	1
	2.	Magnetic bed (magnets + metal parts)	8
	3.	Reel	1
	4.	Seal	1
	5.	Pump housing with cable	1
	6.	Bearing	1
	7.	Reel cover	1
Hydraulic unit	8.	Hydraulic unit body with valves	1
	9.	Plastic cap	2
	10.	Mat	2
	11.	Spring	2
	12.	Brake chamber valve	2
	13.	Torx screw	2
Electronic controller unit	14.	PCB molded into plastic case	1
	15.	Small coil	8
	16.	Coil rubber cap	8
	17.	Back case	1
Other	18.	4cm screw	4
	19.	1cm screw	2

3.1. Technological process of assembling

The technological process of assembling consists of assemblies of various product subgroups, their mutual connections into a unit and also control and packaging of final product (Table 2).

Table 2. Technological process of assembling

Main ABS part	Label	Assembly operation	Time [min]
Pump	MO1	Seating of magnetic bed into metal part of cylindrical shape	0:52
	MO2	Coil imposition	0:10
	MO3	Seal insertion	0:11
	MO4	Connecting of top cover with cable	0:12
	MO5	Bearing imposition	0:15

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012
DOI: **10.7321/jscse.v2.n11.1**

Hydraulic unit	MO6	Seating of plastic plugs with springs into hydraulic unit body	0:18
	MO7	Imposition of brake chambers valves	0:24
	MO8	Torx screws insertion	0:12
Electronic controller unit	MO9	Installation of small coils into case with PCB	0:56
	MO10	Back cover connection	0:15
Other	MO11	Pump assembly with hydraulic unit	0:16
	MO12	Electronic controlling unit connection	0:24
	MO13	Check	0:25
	MO14	Packaging	0:15
Together			5:05

By defining assembly processes based on identified parts and components it is possible to begin their modeling.

3.2. Abstract model proposal

Based on previous studies and information about assembly process a structural piece list (annex 1) and process model of technological process of ABS assembly was built.

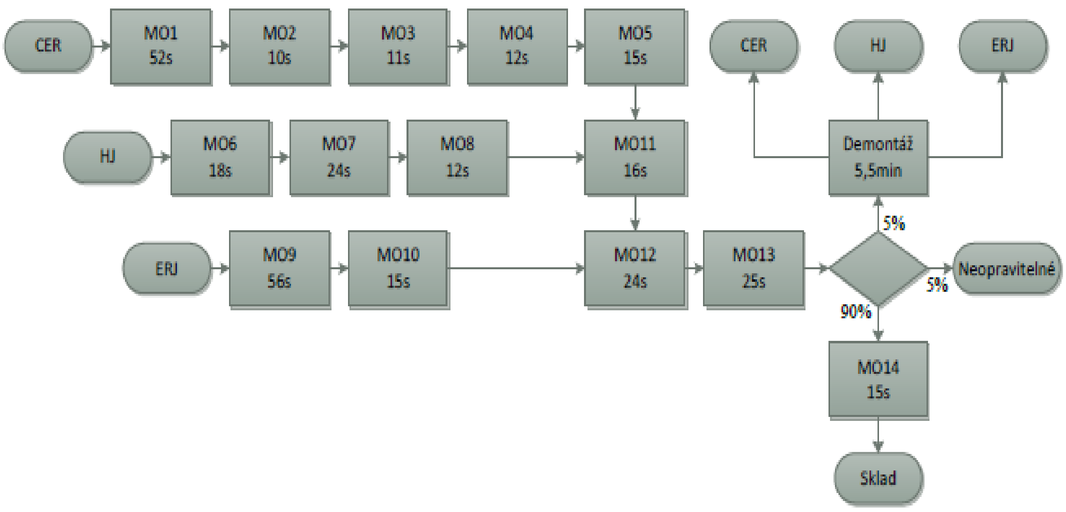

Figure 5. Process model of technological process of ABS assembly

Description of process model elements:

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012
DOI: 10.7321/jscse.v2.n11.1

1. CER – pump,
2. HJ – hydraulic unit,
3. ERJ – electronic controlling unit,
4. MOx – x-th assembly operation.

3.3. Computer model compilation and simulation experimenting

Presented model is a discrete model. Because from the point of view of simulation will be simulated only time moments, where there is a change of system state variables (discrete simulation). Based on process model a computer model of assembly process was designed in environment of Plant Simulation 10.1. The methodology of research was not new but resulted from earlier experimentation (full list mentioned in references). Principles of assembly are results of works of Kováč [1] and Lešková [2]. Practical work (simulation experiments) is the outcome of works of Ulrych [6]and Cendelín [7]. Also, other open researches, mainly Das et al.]12] and Burbank et al. [11]. Experiments were designed to achieve the following objectives:

Sub-goal A: Find the most efficient model of assembly given the number of workers and number of final products.

Conditions:

- experimentation time is one week (5 working days),
- only one shift,
- shift is 8 hours, including a 1 hour break in two intervals,
- at each workplace is an employee.

Sub-goal B: At a constant output of final products using the most efficient model from previous sub-goal A, determine the efficiency of assembly process in one-, two- and three-shift system and compare them with each other.

Conditions:

- experimentation time is one week (5 working days),
- working on one, two or three shifts,
- shift is 8 hours, including a 1 hour break in two intervals,
- at each workplace is an employee,
- number of finished products is constant (approximately 6300 pieces)

Four differents variants were proposed:

Variant 1

Each assembly operation is performed on one workplace, 14 workplaces in total. Number of final products is 2024 pieces.

Variant 2

Each assembly operation is performed on one workplace, except for operations MO1, which is performed at 3 workplaces, MO7, MO9 and MO911 which are performed at two workplaces (each of them), what means 19 departments in total. Number of final products is 4045 pieces.

Variant 3

Each assembly operation is performed at one workplace, except operations MO1, which is carried out at 3 workplaces parallely, MO7, MO11 and MO13, which are performed on workplaces together (each of them), and assembly operations MO9 MO10 are merged into one operation MO9a10, and

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012
DOI: 10.7321/jscse.v2.n11.1

there are four of these departments. Together there are 21 departments. Number of final products is 6291 pieces.

Variant 4

Assembly takes place at 12 workplaces and assembly operations are as follows:

- "PracMO1" - MO1
- "PracMO2" - MO2, MO3, MO4 and MO5 (two workplaces),
- "PracMO3" - MO6, MO7 and MO8 (two workplaces),
- "PracMO4" - MO9 and MO10 (two workplaces),
- "PracMO5" - MO11 and EMO12 (two workplaces),
- "PracMO6" - MO13
- "PracMO7" - MO14

Number of final products is 3191 pieces.

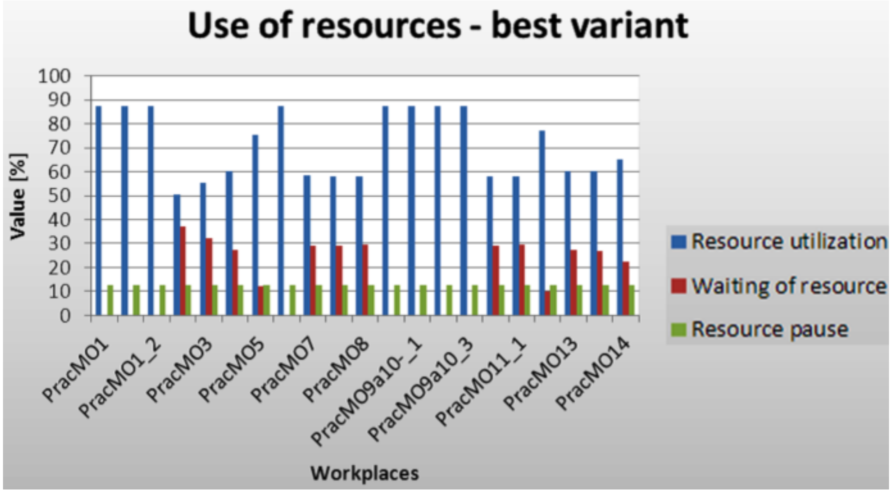

Figure 6. Process model of technological process of ABS assembly

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012
DOI: 10.7321/jscse.v2.n11.1

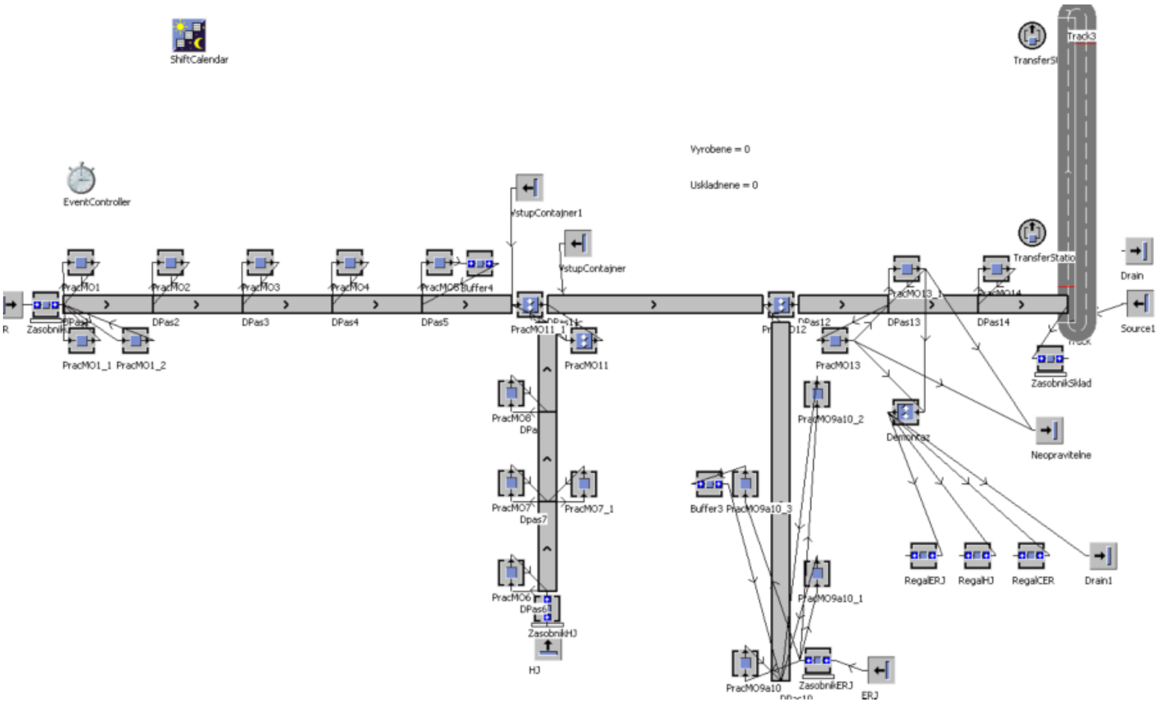

Figure 7. Most effective model

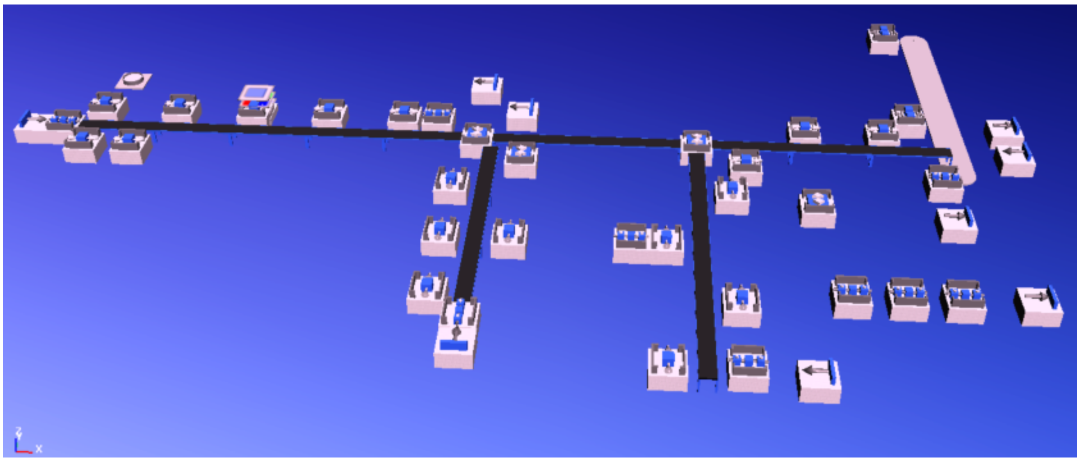

Figure 8. 3D visualisation of assembly process

4. Evaluation of simulation results and conclusion

During many experiments a lot of simulation models have been developed, of which several were selected for comparison. By evaluation of results of simulation experiments, when completing sub-goal A, it can be concluded that the most effective model of assembly of the four selected variants of model variant 3, which offers the possibility of assembling finished products up to 6291 pieces with help of 21 workers involved in assembly process. This model is also most advantageous from economic point of view, when considering amount of finished products due to number of employees. The higher the number of products per worker is, the lower are costs associated with production. Comparison of different models per one employee is shown in Table 3.

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012
DOI: 10.7321/jscse.v2.n11.1

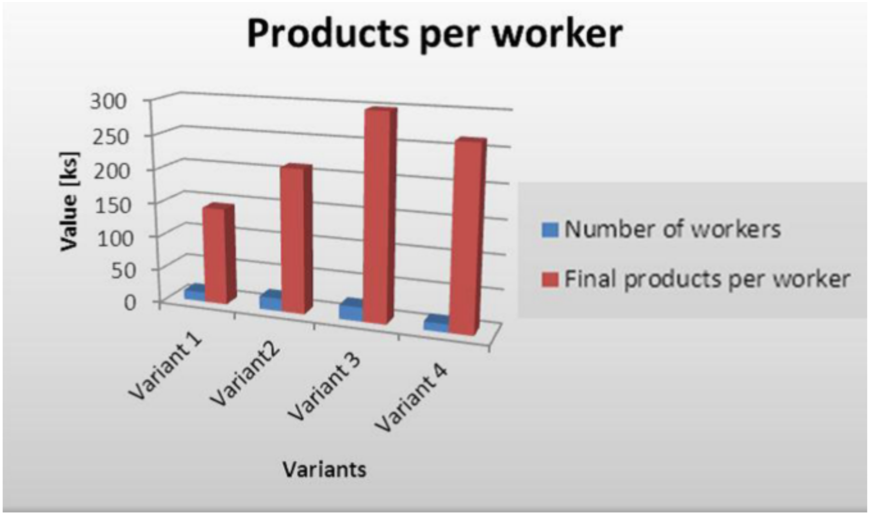

Figure 9. Ratio of number of products per worker

By evaluation of simulation experiments results, fulfilling the purpose of B sub-goal, it can be concluded, that at the same amount of finished products, approximately 6300 units, are in one-shift models and 3-shift models minor differences in terms of products made per worker during individual shifts.

Table 4. Model comparison during 3 workshifts

	1 workshift	2 workshifts	3 workshifts
Number of workers in one workshift	21	12	7
Productivity [pcs]	6291	6382	6297

From an economic point of view, we can expect differences in cost for work area, tools, utensils and other equipment used at work and also energy required to operate. 2-shift operation no longer appears to be advantageous, since the number of workers compared to the other, is up to 12 in one shift.

Based on the analyzes performed and presented solutions for further research development we can recommend to focus on modeling and simulation verification of project solutions of selected types of manufacturing processes and systems through use of top software products (Tecnomatix, Delmia, etc.). When designing workstations and manual installation systems it should be paid particular attention also to ergonomic factors, as main role in this process plays human. Such solutions are offered by JACK module. Addressing the assembly plant layout from the layout view allows FactoryCAD module. Their integrated environment allows design systems and processes to solve complex tasks.

In conclusion, we would like to express thanks for the support of the projects SGS-2012- 063 titled "Integrated proposal of production system as a metaproduct with multidisciplinary approach and using elements of virtual reality" dealt with in Internal grant agency of University of West Bohemia.

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012

DOI: 10.7321/jscse.v2.n11.1

References

[1] KOVÁČ, J., KOČIŠ, R.: Interactive participatory design of production systems In: SAMI 2012 : 10th IEEE Jubilee International Symposium on Applied Machine Intelligence and Informatics : proceedings : Herľany, Slovakia, January 26-28, 2012.Pp. 153-155. - ISBN 978-1-4577-0195-5,

[2] LEŠKOVÁ, A., SVOBODA, M.: Projektovanie organizácie montážneho procesu. In: Transfer inovácií : TU-SjF, 2002. s. 15-20. ISBN 80-7099-952-7,

[3] SOKOLOWSKI, J. A. - BANKS, C. M.: Principlesof Modeling and Simulation: A Multidisciplinary Approach. John Wiley & Sons 2011, 280 p, ISBN: 978-1-1182-1094-9,

[4] BALCI, O.: Principles and techniques of simulation validation, verification, and testing. In: Proceedings of the 1995 Winter Simulatio nConference, Arlington, VA, s. 147 – 154,

[5] CENDELÍN, J., KINDLER, E.: Modelování a simulace. 1. vyd. Plzeň: Západočeská univerzita, 1994. 230 s. ISBN: 80-708-2165-5,

[6] ULRYCH, Z. - Simulace ve strojírenství - cvičení - Plant Simulation, Západočeská univerzita Plzeň, 2010,

[7] X.F ZHA, S.Y.E LIM, Intelligent design and planning of manual assembly workstations: A neuro-fuzzy approach, Computers & Industrial Engineering, Volume 44, Issue 4, April 2003, Pages 611-632, ISSN 0360-8352, 10.1016/S0360-8352(02)00238-3,

[8] TAKÁČ, P.: Optimalizácia montáže referenčných výrobkov s využitím nástrojov modelovania a simulácie. In. MOPP 2011: Modelování a optimalizace podnikových procesu. 13. ročník medzinárodného semináře. Plzeň 2011, ISBN 978-80-261-0060-7,

[9] ALLEN, T.: Introduction to Discrete Event Simulation and Agent-based Modeling: Voting Systems, Health Care, Military, and Manufacturing, Springer, 2011, ISBN 9780857291387,

[10] FRITZEN, P.: Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica, John Wiley & Sons, 2011, 224 p., ISBN 9781118094242,

[11] BURBANK, J., KASCH, W., WARD, J: An Introduction to Network Modeling and Simulation for the Practicing Engineer, John Wiley & Sons, 2011, 250 p., ISBN 9781118063637,

[12] DAS, B., SANCHEZ-RIVAS, J., GARCIA-DIAZ, A., MACDONALD, C.: A computer simulation approach to evaluating assembly line balancing with variable operation times", Journal of Manufacturing Technology Management, Vol. 21 Iss: 7, pp.872 – 887, ISSN: 1741-038X

[13] http://www.tav-autoverwertung.de/shop/ABS-HYDRAULIC-UNIT-VW-6X0-614-117-6X0-907-379-B-Ate-10020401904-10094903483 visible on November 10, 2012

International Journal of
Soft Computing And Software Engineering (JSCSE)
e-ISSN: 2251-7545
Vol.2,No.11, 2012
Published online: Nov 25, 2012
DOI: 10.7321/jscse.v2.n11.1

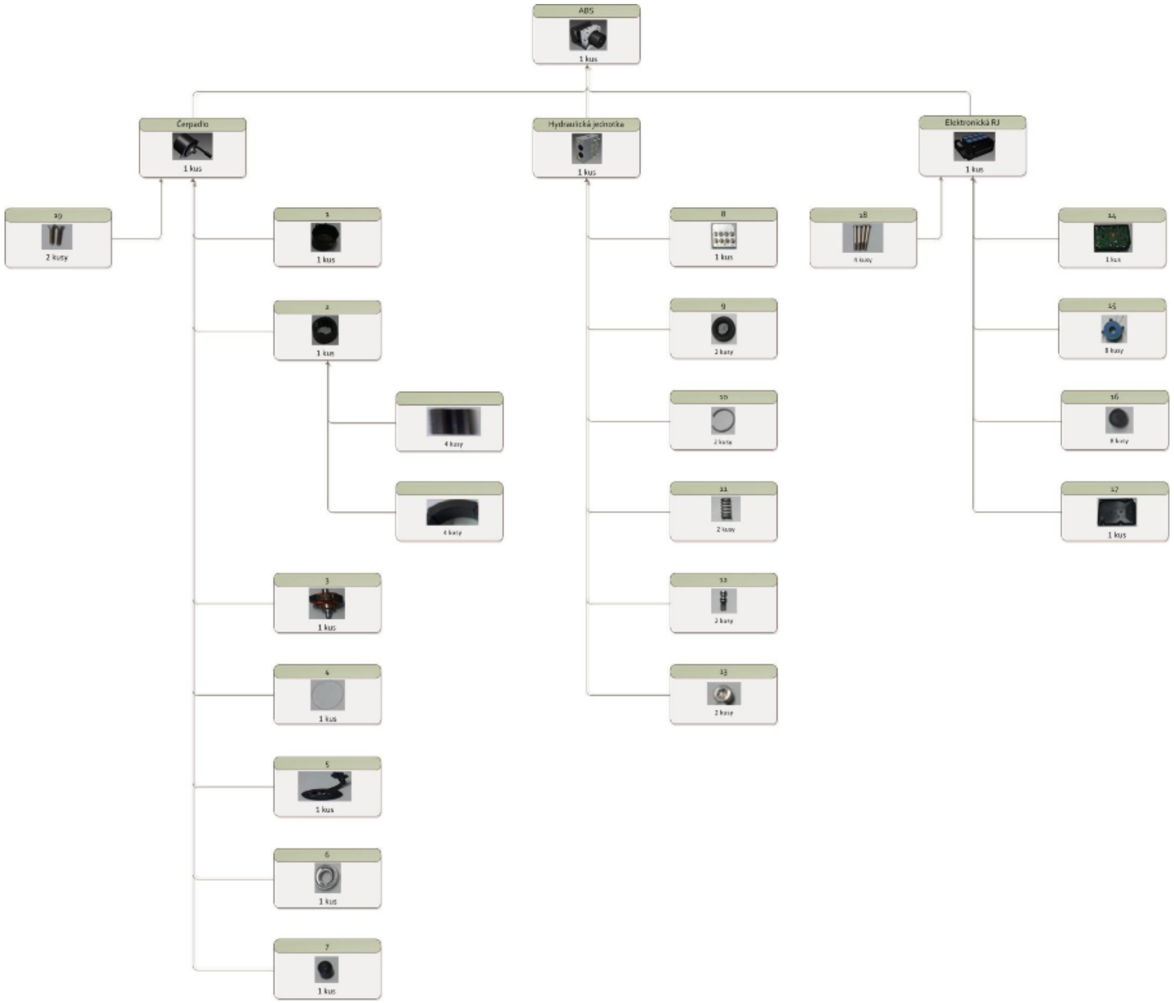

Figure 10. **ABS piece list**