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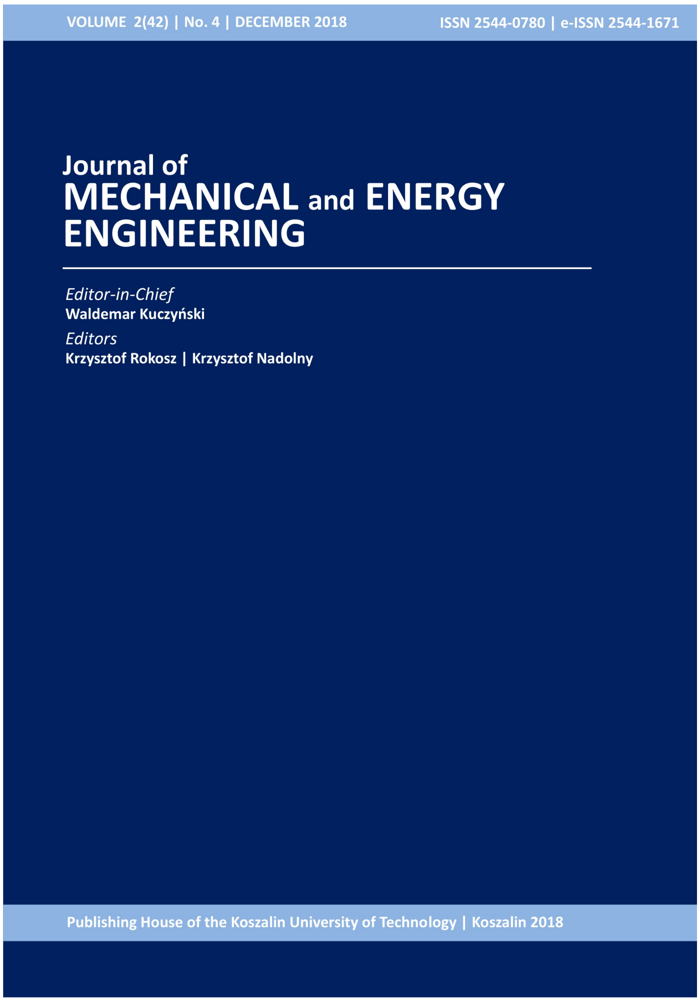

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CHARACTERISTIC OF DIDACTIC MODULAR PRODUCTION SYSTEMS

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Abstract: The project presents the design of production systems equipped with miniaturized devices, which are commonly used in industry. Despite the reduced scale, the modules have full functionality and reflect real-world systems. In addition, system designs provide for the possibility of scientific and research work in the design of production systems with a high level of automation.

Keywords: modular production system, didactic production system, production system

1. INTRODUCTION

The system is a system of elements, a set of relations between these elements and relations of transforming input factors into output factors of the system. Production, on the other hand, is a conscious activity of a human being or a group of people, which is aimed at the production of products in the form of material goods or services to meet human needs [1].

Assuming these two definitions, it can be stated that a production system is a purposefully designed, organised and executed material, energy, informational and man-made system, which is used to produce specific material and non-material goods and services to meet various needs [1].

The production system consists of five basic elements [1]:

- a vector of entry X, covering all the ingredients necessary for production;
- output vector Y, covering all material, energy and informational effects that emerge from the production process;
- the process of converting the input X vector into the output Y vector, called the production process;
- the system management process;
- material, energy and information couplings between the abovementioned components of the production system.

The first three elements mentioned above together with material, energy and information couplings are called a processing or production subsystem. In turn, the system management process together with information feedback is referred to as a management subsystem [2].

Modeling and simulation tools are increasingly used in production and didactic processes. Physical models of real industrial systems give an opportunity to get acquainted with the principles related to the functioning of real production systems. These principles range from configuration, through programming and commissioning, to the identification and elimination of system malfunctions [4].

This paper analyses source materials in the scope of didactic production systems and their design. The analysis consists of the characteristics of three miniaturised didactic production systems developed in the following research centres:

- Silesian University of Technology (Modular model of flexible production system) [3],
- Poznań University of Technology (Modular system of automated production line) [5],
- Bosch Rexroth (Mechatronic Modular System) [6,7].

The projects present system concepts consisting of miniature devices, which are widely used in industry.

2. FLEXIBLE PRODUCTION SYSTEM OF THE INSTITUTE OF AUTOMATION OF THE SILESIAN UNIVERSITY OF TECHNOLOGY

The system presented in this chapter is a scale model of a modular, flexible production system. The stand is equipped with systems that are physical models of systems used in industry. Despite the reduction in size, the modules retain the characteristics of industrial solutions and allow for tests that would not be possible in a functioning company. Figure 1 shows a general view of this system [3].

On the stand it is possible to assemble the product, which consists of production disks made of different materials with different colors. After the assembly operation, the product is marked with a reusable magnetic marker.

The stand allows to simulate such modules of the production process as:

- multilayer assembly;
- production planning;
- planning of component deliveries;
- planning material needs;
- capacity planning;
- mismatch in the efficiency of production sections;
- bottlenecks;
- rearmament;
- quality control;
- palletisation;
- management of the storage process.

2.1. Components of the modular didactic production system

The stand has been equipped with modules such as:

- gravitational input warehouse for feeding production materials with the possibility of adjusting the frequency of material feeding;
- belt conveyors enabling transport of components between executive modules of the teaching station;
- pneumatic separator equipped with a number of sensors enabling identification of components and change of their production route;
- 2-axis manipulators (pneumatic and electro-pneumatic), which allow simulation of assembly and palletization processes;
- product marking mechanism equipped with an automatic changeover system, which allows for product marking depending on the selected version;
- vision sensors to ensure that components are checked and identified, e.g. for correct assembly or product type;
- exit warehouses equipped with a system of sorting finished products according to the type of product or quality of assembly.

The most important modules of this production system are shown in Figure 2.

The production process in the described system begins with the extraction of material from the gravitational input warehouse. The discs from the warehouse are fed to the first conveyor belt. The colour sensor at the height of the carousel warehouse then checks whether the colour of the disc corresponds to the production schedule. If not, it is transported to the carousel warehouse, which acts as a buffer.

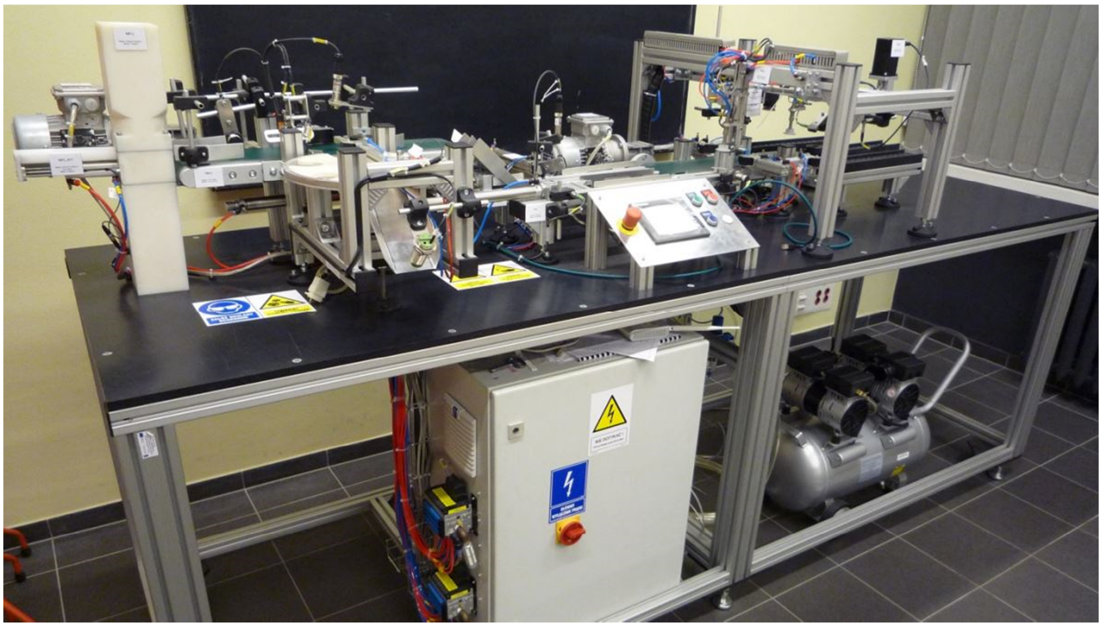

Fig. 1. Research stand of the flexible modular production system developed at the Silesian University of Technology [3]

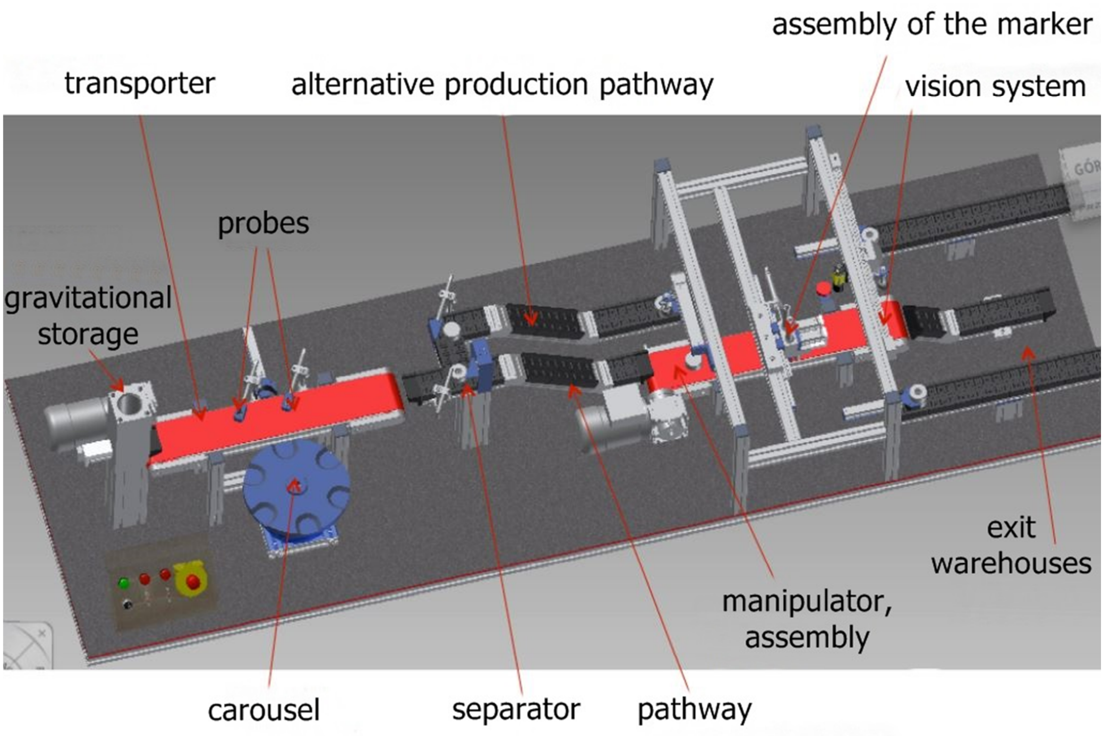

Fig. 2. View of the teaching station [3]

2.2. Description of the production process

The discs in the carousel warehouse are not returned to the line until later. Then the discs are divided between two independent tracks. After transporting the discs to the ends of these tracks, the assembly process begins.

The discs are superimposed on each other by means of a manipulator with vacuum gripper. The magnets overlapping each other connect with each other. In the next stage, the finished semi-finished product is transported by means of a belt conveyor from the assembly station to the marker allocation station.

There is a mechanism for marking semi-finished products, which allows you to mark a product depending on the selected version. Depending on the order, a large or small marker is placed, or the set remains without it.

Then the finished product is moved to the quality control station. Correctness of assembly and compliance with the production schedule is checked by the vision system. Depending on the quality control result, the finished product is stored in one of the three output warehouses.

3. MODULAR SYSTEM OF AUTOMATED PRODUCTION LINE MADE AT THE POZNAŃ UNIVERSITY OF TECHNOLOGY

The system built for the Poznań University of Technology is intended for teaching and research purposes. Its components reflect systems that are commonly used in industry. The possibility of flexible configuration of transport lines of the modular system of automated production line allows for free modeling of production processes. This system is shown in Figure 3 [5].

Fig. 3. Modular system of an automated production line at the Poznań University of Technology [5]

3.1. Components of the modular system of an automated production line

The stand has been equipped with the following modules:

- modules of transport routes built on the basis of TS2 system from Bosch Rexroth;
- a system controlling the production line using Siemens products;
- RFID module based on ID 200 system for identification of products and pallets;
- the IRB 140 robot from ABB that works with the IVC-2D vision system;
- the IRB 140 robot from ABB, which cooperates with a station of interchangeable grippers;
- FMS (Flexible Manufacturing System) machining centre, shown in Figure 4, which includes a CNC lathe (Computerized Numerical Control), CNC milling machine and a Movemaster robot with a gripper.

Fig. 4. FMS machining centre [5]

3.2. Production line control system

All processes of the production line are controlled by a central control system, which consists of such elements as:

- PLC S7-300, CPU 317 2PN/DP IWLAN;
- operator touch panel TP1500 Comfort;
- PC operator station with SCADA software.

3.3. Programming and modelling of the production process

The production process begins with the loading of pallets on the transport line in the AS1 module. It is a module in which the operator places materials necessary for the manufacturing process, as well as enters into the system data about the type of product and information about the sequence of operations performed in the process.

In each of the pallets there are memory elements of the RFID system, in which the information characterizing the state of each of them is stored. The state of the pallets can be read, changed and saved when the memory element in the pallet is within the range of the RFID antenna, which is located in the production area.

The following data are stored on pallets:

- the identification number assigned to the pallet;
- the identification number assigned to the product;
- the schedule of operations to be carried out;
- information on the implementation of individual operations.

The operator then enters the data into the memory elements of the RFID system, approves the production cycle and the pallet starts its journey on the production line. Depending on the pallet programming, it is stopped at individual production stations, which are located within the range of conveyors' work.

The production stations were constructed as stations simulating various processes and as stations with real equipment. The pallets are stopped at the simulation station and the production cycle continues after the programmed operation time. A synchronization signal exchange system is activated at the production station with a real device. From the pallet transport system information is sent to the device at the stand that the pallet has been delivered. The device then sends a signal to the transport system to indicate that the operation has started. When it is finished, the device sends the appropriate signal to the transport system, the pallet is taken away and the device sends a signal that the device is ready for the next cycle. Next, the information concerning the execution of an operation at a given stand is stored in the pallet memory, and then the transport system moves the pallet to the next stand, where according to the schedule, the next one is to be executed.

After the programmed technological operations for a given product, the pallet is transported to the AS2 segment, which is the final stop in the transport system. The finished product ends its journey and should be taken from the pallet. At the end, the empty pallet is transported to the AS1 segment where it is reused.

4. MECHATRONIC MODULAR SYSTEM FROM BOSCH REXROTH

Bosch Rexroth has developed a modular mechatronic MMS system for schools and technical colleges. The line simulation kit consists of 4 modules [6]:

- semi-finished products warehouse;
- feeder and pneumatic press;
- feeder and hydraulic press;
- warehouse of finished products.

Each module is equipped with an independent pneumatic and electric power supply. All modules are equipped with independent L20 controllers, which can be connected to the network via Profibus DP interface. This configuration gives you a high degree of didactic flexibility. This system is shown in Figure 5.

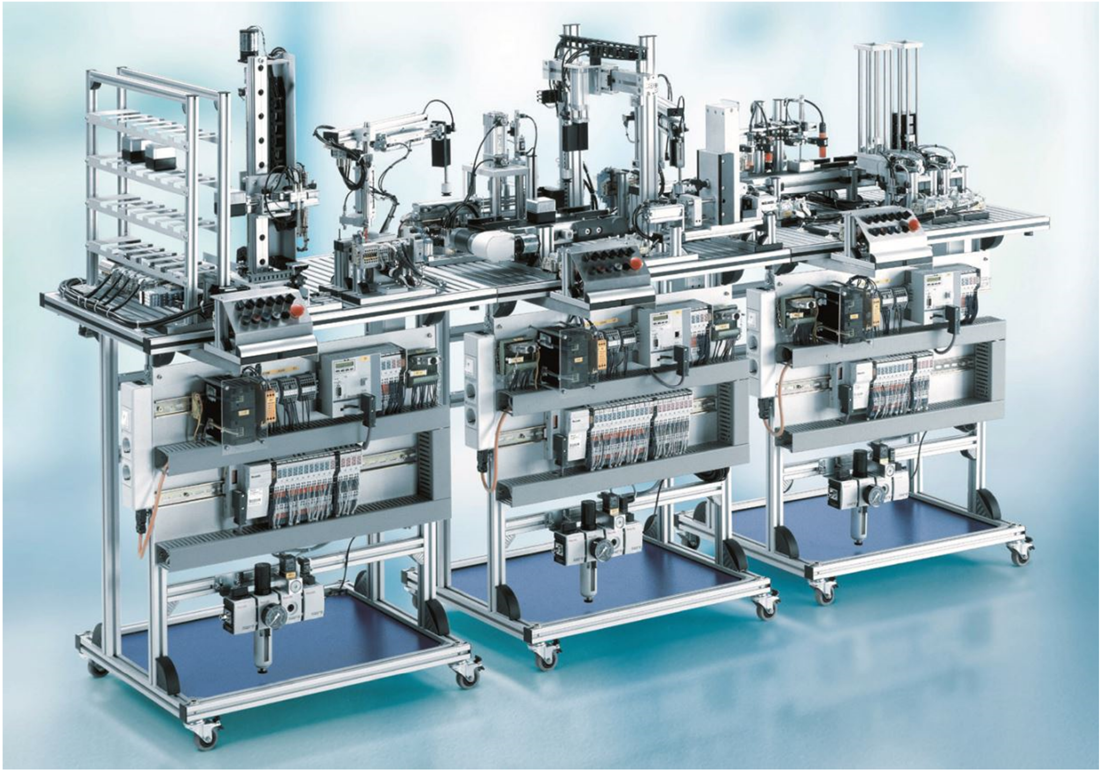

Fig. 5. Mechatronic Modular MMS System from Bosch Rexroth [7]

In the semi-finished goods warehouse, the stored parts are checked in detail by means of a number of sensors. Depending on the test results, the semi-finished products are rejected or transported further to the operating positions, just like in real production lines. At the next station the semi-finished products are processed with the use of pneumatic or hydraulic presses. The stand is equipped with an emergency stop that can switch off the stand or the entire line. The next stand is the high bay warehouse for finished products with space for the 15th position of the product. The warehouse is equipped with a double-axis pneumatic robot, a light curtain and a housing with an emergency stop. The last element is a profile trolley, which is the control center of individual stations. Photographs of the components of individual modules are shown in Figure 6.

The Mechatronic Modular System consists of the following units:

- a semi-finished product testing device;
- a robot working in the Cartesian system;
- a portal through which the assembled products are conveyed;
- a rotating module;
- manipulator used to transport goods;
- press for joining elements;
- positioner for storing finished products;
- L20 drivers;

units preparing compressed air AS2.

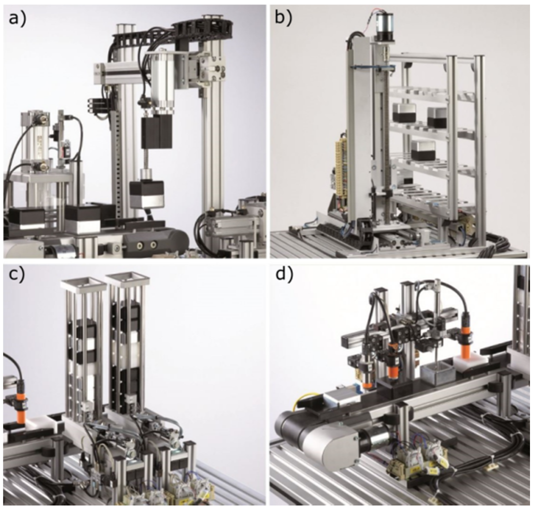

Fig. 6. MMS components: a) portal for moving assembled products; b) finished products warehouse with a Cartesian robot; c) semi-finished products warehouse; d) semi-finished products testing device [7]

5. SUMMARY AND CONCLUSIONS

This paper presents projects of didactic production systems. Their descriptions were composed of identification of their elements, description of their operation, and description of production processes taking place in them.

On the basis of the above work, the following conclusions have been drawn.

1. In didactic production systems it is possible to simulate production processes in laboratory conditions.
2. With the simulation of production processes, you can gain a lot of knowledge about production planning, material planning, capacity planning, bottlenecks and storage process management.
3. When designing miniaturised production systems, it is important to bear in mind that there are few ready-made solutions for individual subsystems on the market and that, in most cases, all components should be designed specifically for a given production system.

Nomenclature

Acronyms

MMS – Mechatronic Modular System
FMS – Flexible Manufacturing System

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Biographical note

Piotr Jaskólski defended his diploma thesis with honors in 2018 at the Faculty of Mechanical Engineering of the Koszalin University of Technology, majoring in Management and Production Engineering, specializing in Computer Technology in Production Engineering. During his studies and diploma thesis he was the leader of a team of students performing a physical model of a modular didactic production system, leading to its launch and implementation into didactic classes in the field of Management and Production Engineering. Currently he is an employee of the Koszalin University of Technology at the Faculty of Mechanical Engineering. His scientific interests include issues related to automation of manufacturing processes and modern technologies in production engineering.

Krzysztof Nadolny received his M.Sc. degree in Mechanics and Machine Design and next the Ph.D (with honors) as well as D.Sc. degree in Machinery Construction and Operation from the Koszalin University of Technology, in 2001, 2006 and 2013, respectively. Since 2006, he has been a researcher in the Department of Production Engineering at the Koszalin University of Technology, where currently he works as an associated professor and the head of the research-didactic team for production planning and control. His scientific interests focus on problems concerning machining processes and tools, efficiency, monitoring and diagnostics of machining processes as well as tribology. He has participated in 2 international and 3 national research projects, presenting results of his work at 10 international and 21 national conferences, published more than 200 scientific papers in international and national journals, book chapters, as well as conference proceedings. He is also the author of 5 monographs and 12 national patents.