The modular design of robotic workcells in a flexible production line

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Abstract. In the case of large-scale and mass production lines often the same model of an industrial robot is used in various places of the line and is intended to various task. However, the replacement of one industrial robot to another is a long lasting and arduous process. It requires stopping all the production line and sometimes even dismantling the whole workcell. Such situations are not frequent in production lines that are not flexible. They are related the most often with the failure on an industrial robot. However, during the designing of a flexible production line the ability to replace any robot, which is unrestricted, fast and trouble-free, greatly increase the flexibility level of such line. It could be realized by modular design of the proposed production line. In this way it could be possible to change any elements of such production system. But this approach needs to apply the specialized informatics system. This paper presents the obtained design of several versions of the same production workcell. Each, succeeding version of the designed production workcell contains more and more modular elements. Thereby it would be presented the evolution of a workcell design beginning from the typical design and ending with the fully modular one. One of tools needed to realize this task is the elaboration of a base of modules and typical joint and mounting elements that could be utilised in the described designing process. It is also presented the guidance information about the designing and programming processes useful at each stage of analysed process.

1. Introduction
Because of years we have robotics and now we cooperate with the company on increasing the flexibility of their cell, it was necessary to present opportunities to increase the flexibility of the cell. To this end, we chose a sample cell and we modelled successive stages of increasing flexibility. Many manufacturers offer elements to increase the flexibility of the cell figure 1. However sometimes industrial robotics development is very slow because of cost a robot. The first step is the application of industrial robots to the most dangerous tasks [1, 2]. In this case, the person is made the pieces together, and a robot welding them together. After working robot leaves the safety position and the man pulls made the item and put the next one [3, 4]. Such work is dangerous and ineffective, although the quality of the weld is better but not much increase efficiency [10, 11].
2. Successive stages of increasing flexibility robotics workspace

The next step is to the old workcell, new equipment apply. Sometimes it happens that a robot from another manufacturer is cheaper, and then workcell looks like in figure 2. Such workcell can work without major problems for many years [12]. The cost of maintaining such a workcell is high, because periodic repair, you have to call two different teams. False economy is expensive to maintain, so you should buy works from the same manufacturer [13, 15].

In this case, it is easier to configure communication between robots and periodic repairs are cheaper. Such workcell is easier to maintain, both robots have the same components and the same software. So it is easier to reprogram the entire workcell. All robots can be loaded onto the same programs and just the right is running. It is easier to train an employee to operate an industrial robot. When welding robot is damaged, you can replace it with a second robot, until repair. If this type of robots are many in our factory, you can have one additional pre-loaded with all programs. This robot robot can replace any downtime will be shorter then, and lose less time and less money.

This workcell not flexible, changing the workpiece in this cell is connected with its complete reconstruction. If, instead of clamps is permanently mounted plinth, we will use the universal table, and clamp mount on it, it is easy to change the clamp and do something else. Production is more flexible in that workcell [5, 6]. This table can be made outside workcell then downtime of the production line is shorter. Note if workcell is busy at the same time may be made to the two elements. In this case, it is necessary reconfiguration workcell that robots do not disturb each other. When one robot is welding element, the second robot is composing the second element. [7, 8, 9].
Replacement of a specialized clamp, the constructed specifically for the element and workcell, the modular unit that can be easily modified increases the flexibility of such a cell. Introducing modularity remember the exact positioning of the robot. If the new table is not fixed to the ground at exactly the same place as the old one, set the frame again. You can help with a special tool but also on the table should be points for easy setting frames. The robot operator should know how to set the frame. If the developer builds a virtual cell should be strictly defined frames, each fixed elements of the cell. If he draws an existing workcell to reprogram robots must know the robot frame.
When made in workcell element changes need to replace the tool fixed to the robot wrist. For easy tool change and to be able to use the tool for different types of robots it is necessary to make the adapter. This adapter will not only facilitate the exchange of tools, but also made properly extend life of the robot wrist and tools.

Such an adapter is shown in figure 5 is composed of two parts, one fixed permanently to the robot wrist and the other attached to the tool. Both parts are typically connected by screws. Use an adapter also makes it easy assembly and disassembly tool.

Flexible workcell is also flexible update tool attached to the robot wrist. Many manufacturers figure 1 produce such a quick change systems. For example, as shown in figure 6 quick change systems Schunk. But keep in mind that you need to make the robot grippers parts store. Each gripper used in workcell should have your own space and the robot needs to know where the gripper is.

3. A fully modular cell
The last method presented in this article is a division workcell on modules. Currently, robot and all non-moving parts workcell are mounted directly to the ground. When we want to move a robot or another part of the attachment we have to destroy the old and make new ones. It is a work of long-term and very dangerous. After a few such moving on our floor can be completely destroyed and we can not fix properly robot in a new place.

Use of special pallets attached to them, robots or parts is a good idea. If we can build workcell as puzzle taking ready modules [13, 14]. They can be freely configured by building his own cell. This facilitates both workcell design and its implementation. Modules can be prepared on the outside and the time and cost of installation will be incomparably lower.
4. Conclusions
Only factories producing the same item without any modification for many years may have not flexible production lines. Development of the forces of production line flexibility and forces you to increase the range of products. It is important that cell was less downtime as the most, and it was easy to reconfiguring the variable production.

Previously designed robotic production lines are composed of individually designed production cells. It happens that each robotic cell is designed by another person. At the end, the entire robotic cell is submitted as non-matching blocks by another person. Often supervisor must match the adjacent elements robotic cell.

This method causes each individual cell is not reproducible. The components are designed specifically for the cell and cannot be used anywhere else. If it was possible to unify even some elements of the cell would have reduced costs and easier repair. Using the same model in several cell robot also reduce cell maintenance costs.

If the design stage in a few places will use those same elements in several places reduce the cost of generation and number of spare parts. In addition, parts are designed more flexibly which increases the flexibility of the cell.

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References
[1] Hetmanczyk M P 2015 The prediction oriented analysis of mechatronic machine structures in terms of the signal stream flow Solid State Phenomena, 220-221 pp 423-428
[2] Hetmanczyk M P and Michalski P 2014 The self-excitation phenomenon of quasi shielded inductive proximity switches Advanced Materials Research 837 pp 405-410
[3] Herbuś K, Kost G, Reclik D and Świder J 2014 Integration of a virtual 3D model of a robot_manipulator_with its tangible model (phantom) Advanced Materials Research 837 pp 582-587
[4] Gwiazda A, Herbuś K, Kost G and Ociepka P 2015 Designing mechatronics equipment based on the example of the Stewart platform Solid State Phenomena 220/221 pp 419-422
[5] Gwiazda A, Herbuś K, Kost G and Ociepka P 2015 Motion analysis of mechatronic equipment considering the example of the Stewart platform Solid State Phenomena 220/221 pp 479-484
[6] Ociepka P, Herbuś K and Gwiazda A 2014 Application of the CBR method for adding the design process of module manipulators *Advanced Materials Research* **1036** pp 1011-1016

[7] Herbuś K, Ociepka P and Gwiazda A 2014 Application of functional features to the description of technical means conception *Advanced Materials Research* **1036** pp 1001-1004

[8] Herbuś K, Ociepka P and Gwiazda A 2014 Conception of the integration of the virtual robot model with the control system *Advanced Materials Research* **1036** pp 732-736

[9] Ociepka P, Herbuś K and Gwiazda A 2014 Application of the method basing on engineering knowledge and experience for adding the hexapod design process *Advanced Materials Research* **1036** pp 1005-1010

[10] Paprocka W, Kempa M, Kalinowski K and Grabowik C 2014 A production scheduling model with maintenance *Advanced Materials Research* **1036** pp 85-890.

[11] Paprocka W, Kempa M, Kalinowski K and Grabowik C 2014 On Pareto Optimal Solution for Production and Maintenance Jobs Scheduling Problem in a Job Shop and Flow Shop with an Immune Algorithm *Advanced Materials Research* **1036** pp 875-880

[12] Paprocka W, Kempa M, Grabowik C and Kalinowski K 2014 Sensitivity Analysis of Predictive Scheduling Algorithms *Advanced Materials Research* **1036** pp 921-926

[13] Paprocka W and Kalinowski K 2014 Pareto Optimality of Production Schedules in the Stage of Populations Selection of the MOIA Immune Algorithm *Applied Mechanics and Materials* **657** pp 869-873

[14] Sękala A, Banaś W and Gwiazda A 2014 Agent-based systems approach for robotic workcell integration *Advanced Materials Research* **1036** pp. 721-725

[15] Sękala A and Dobrzanska-Danikiewicz A 2015 Possibilities of application of agent-based systems to support functioning of e-manufacturing environment *Mechatronics systems and materials VI. [Ed:] A.V. Valiulis. Solid State Phenomena* **220/221** pp 781-784