TECHNICAL SCIENCES AND TECHNOLOGIES

DOI: 10.25140/2411-5363-2024-3(37)-101-107
UDC 621.8

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DESIGN OF ROBOTIZED EDUCATIONAL WORKPLACE IN OFF-LINE ENVIRONMENT WITH YASKAWA ROBOT

The article deals with the creation of 3D models of individual parts of a robotic workplace in the Creo Parametric environment. The created models of the workplace components were subsequently imported into the MotoSim offline environment, where three variants of the assembly process were designed and simulated at the robotic workplace with the Yaskawa GP8 robot. The selected variant was then imported into a real workplace, where it was debugged and tested. The goal was to create an educational workplace where it would be possible to carry out teaching and training online or offline on a robot from Yaskawa.

Keywords: *off-line environment; Yaskawa GP8; MotoSim; educational workplace; Creo PTC.*
Fig.: 6. References: 12.

Relevance of the research. The use of an off-line environment in the design of robotic workplaces brings a lot of advantages, which make it possible to increase the efficiency in the design of the workplace and shorten its installation and recovery time [1]. Renowned manufacturers of industrial robots in their offline environments offer customers specialized functions and tools that make it possible to use the potential of used industrial robots to the maximum extent [2; 3]. There are also more universal offline environments on the market in which it is possible to use robots from several competing manufacturers, but they have their limitations [4; 5].

Problem statement. The Yaskawa company has already installed over 600,000 robots worldwide, which creates a need for the use of appropriate tools to design, simulate and optimize robotic workplaces. In the eastern part of the Slovak Republic, new production facilities are being established, where Yaskawa industrial robots are also being deployed. Therefore, there was a need to ensure an educational process using online programming on Yaskawa robots, as well as a need to prepare graduates who would use the MotoSim offline environment. For this reason, a Yaskawa GP8 robot [6] was installed on the premises of the Technical University in Košice and 15 licenses for off-line programming in the MotoSim environment [7] were delivered.

Analysis of recent research and publications. In today's industry, robotic workplaces play a key role in increasing the efficiency and accuracy of production processes [8]. With the development of technologies, they become even more sophisticated and integrated, which allows better optimization of production procedures [9]. One of the main options that enables testing and simulation of these robotic workplaces is software programs for creating and programming these workplaces [10]. These programs provide the possibility of creating a virtual model of workplaces, which enables testing and tuning of their functionality and effectiveness before deployment in a real environment [11].

Uninvestigated parts of a common problem. Offline programming of robots is a method enabling programming based on the kinematic model of the robot in the CAD environment. Such an innovation is particularly important for tasks requiring high precision of movement and for minimizing downtime in a robotic workplace [12]. An active approach to programming provides additional options, allowing programmers to intuitively define the trajectory of the robot's movement and adapt it to the needs of the task at hand. The accuracy of the programming depends on the accuracy of the model in the 3D environment. This data is necessary for the implementation of the robot trajectory in a real environment. The use of offline programming is most effective for small and medium production systems, as it can provide a simpler and more efficient way to generate a robot program even in complex systems [10].

Research objective. The goal of the research was the optimal design of a robotic training workplace for online and offline programming of Yaskawa robots. In the first step, it was necessary to create 3D models of individual parts of the workplace in the Creo Parametric environment, which were subsequently imported into the MotoSim virtual environment. In the MotoSim environment, three variants of the assembly process were designed using two conveyors, a palletizer, a depalletizer, and an automatic tool changer. It was possible to test the designed and simulated variants in a real workplace so that the students also gained practical experience associated with the revival and launch of a robotic workplace.

The statement of basic materials. The robotic workplace consists of an industrial robot from Yaskawa GP8 and a control unit labeled YRC 1000 [6]. The robotic workplace has two conveyor belts, a workplace control cabinet, a palletizer and a depalletizer. The working space of the robot with the range of movement of the first axis of the robot +/- 170° is shown in Fig. 1.

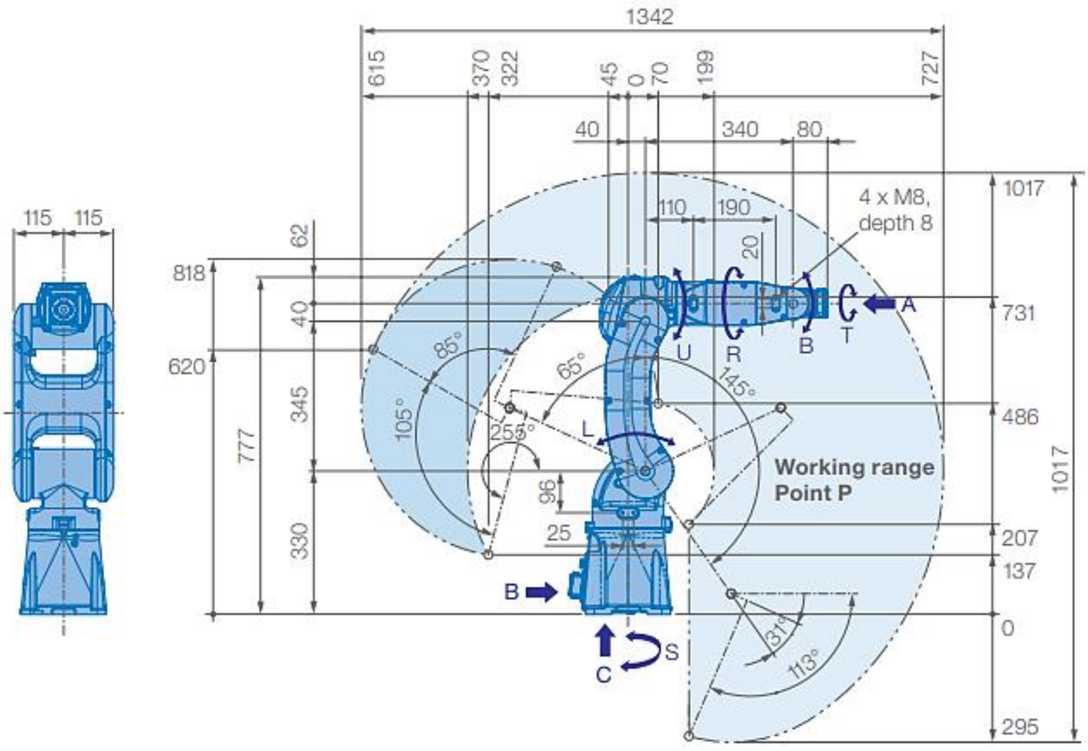

Fig. 1. Dimensions of the GP8 robot [6]

The robotic workplace contains a height-adjustable stand on which the robot is attached. The stand has a tool change system for two effectors, which is located on the side of the stand. It is capable of vertical displacement and rotation around the displacement axis. It contains cylindrical storage for effectors, which allows to increase the flexibility of the workplace. Two pneumatic grippers are located in the SMC MA310 tool changer, the Parker KURODA GPR10A, which is used for gripping non-rotating parts, and the SMC MHS3-25D, which is used for gripping cylindrical parts.

The conveyors used at the workplace are of different constructions. The first conveyor is a belt conveyor with a belt width of 300 mm and a belt length of 2000 mm. The second type of conveyor is a belt conveyor, which is used to move pallets with a width of 150 mm, while the length of the active surface of the belts is 2300 mm. The workplace also includes a depalletizer that serves to store and feed pallets onto a belt conveyor. The function of the palletizer is the opposite, i.e. it removes pallets from the belt conveyor.

All the listed components of the robotic workplace were measured and their 3D model was created in the Creo Parametric environment with an accuracy of up to 1 mm. The developed models created the overall workplace, shown in Fig. 2, with a floor plan area of 2380×3970 mm.

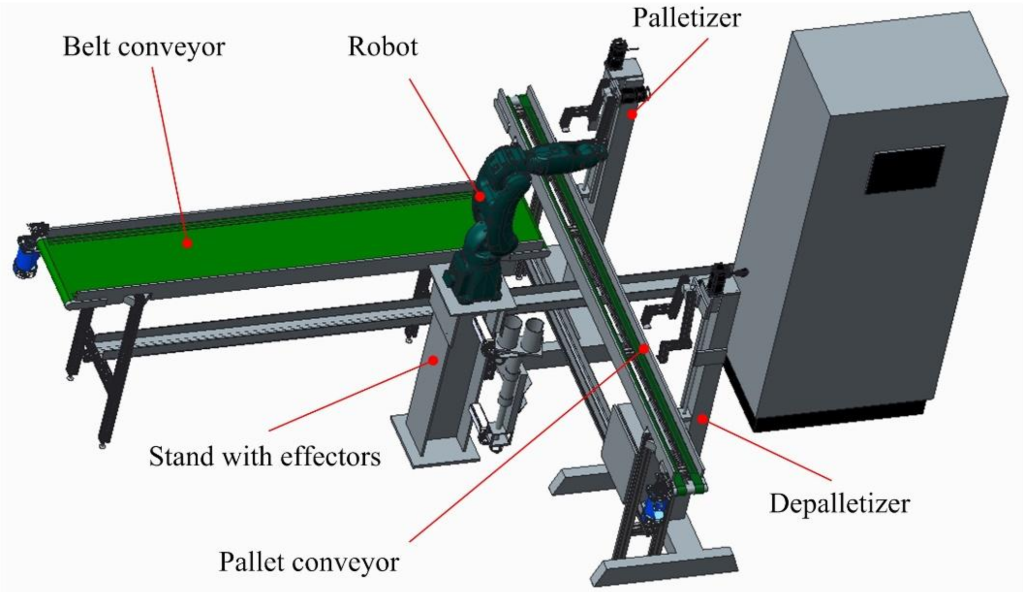

Fig. 2. Workplace model in Creo 3D environment

All created models of individual components, except for the robot, were imported into the MotoSim EG-VRC environment. To ensure the exact positions between the individual components of the workplace, the construction of the virtual workplace model was solved directly in the MotoSim environment. The relative positions of particular parts of the workplace are created using tools (connection) used by MotoSim. The reason is the possibility of modifying the offline workplace (modularity) according to the modification implemented at the real workplace. Components in 3D that were imported from another environment are displayed in gray, elements that are in the library of the MotoSim environment can have any color.

To move the conveyor models, it was necessary to create external conveyors through a function located directly in the MotoSim environment. After creating the conveyor, it is necessary to adjust its size, speed, start and end of movement. Subsequently, it is necessary to insert this model of the "block" shape into the CAD model of the conveyor in order to merge the moving surfaces. If the "MotoSim Conveyor" is moved to a non-zero position of the world coordinate system and subsequently, its parameters are adjusted, it will be moved back to the zero position of this system. To start the conveyors through the program, it is necessary to connect these conveyors to the robot through the settings in the virtual pendant. These settings can be seen in fig. 3, where "MotoSim Conveyors" are shown in green.

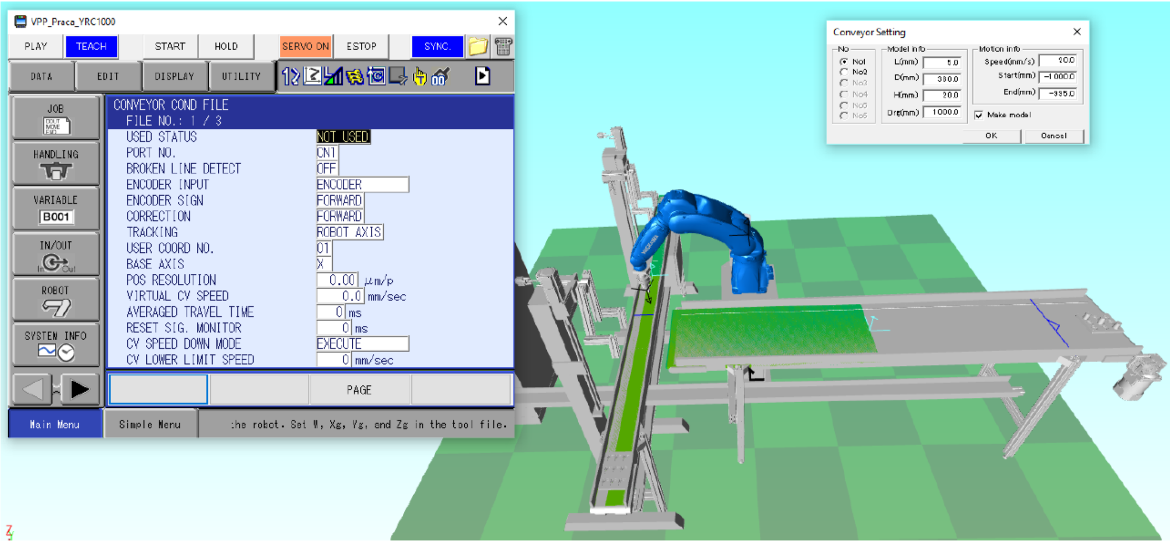

Fig. 3. Setting up the movement of conveyors in MotoSim

To test the workplace model, three proposals for simulations of work at this workplace were created. All three designs used different combinations of the available parts of the workplace, using the robot for manipulative activity with the test objects. The test objects were simple models of cylinders (cylinder size ϕ20×50 mm) placed on a pallet. Specifically, it was three cylinders placed diagonally on a pallet (pallet size 150×200 mm), as can be seen in Fig. 4.

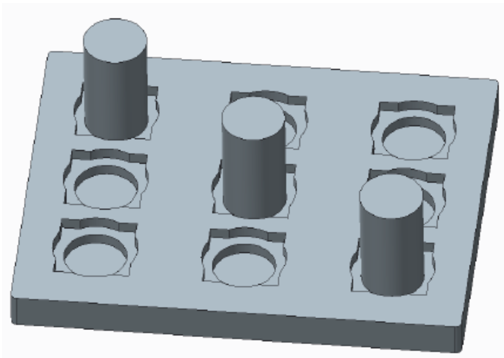

Fig. 4. Pallet with rotating parts

From the three simulation proposals, a proposal was selected and subsequently implemented, which included the use of a robot, both conveyors and a palletizer.

The MotoSim environment does not include the ability to create a "pick and place" function, which is necessary to develop the chosen simulation. It is also not possible to simulate the movement of uploaded CAD models. Exchange of effectors in the MotoSim program is not visually possible, but programmatically feasible [8]. For this reason, it was necessary to create a simulation differently. For this, the "Model script manager" function was used, through which it was possible to create a visual simulation of the design by hiding and displaying objects. For this reason, extra models of workplace equipment, pallets and cylinders were created. The SEE, HID and ACT functions were used in the created scripts. The SEE function is used to display the models, the HID function serves to hide the models, the ACT function moves the models in the direction of the selected axis by the selected length [9]. The RESET function is used to create a workplace model for the start of the line start-up. Models of the palletizer with a pallet at maximum height, an empty pallet on a belt conveyor, as well as hiding a loaded pallet on the conveyor and an empty pallet in the end position of the belt conveyor will be displayed. For the sake of testing the simulation, the other models of pallets and cylinders were also hidden.

Programming was done using a virtual pendant in the MotoSim program, robot movement points and script execution were written into it. The program was tested using a simplified version of the pendant called "Simple pendant". With a simplified pendant, it is possible to record robot movement points and run a program simulation. The virtual pendant, which fulfills the same functions as a real pendant, includes all the properties of a simplified pendant and allows adding functions, macros to the program, modifying the properties of the robot, conveyors and effectors.

In fig. 5 shows a view of the robotic workplace in the MotoSim environment, where the location of the robot, effector, belt conveyor and depalletizer is visible. At the same time, a simplified version of the pendant with the created program is shown on the left side of the picture.

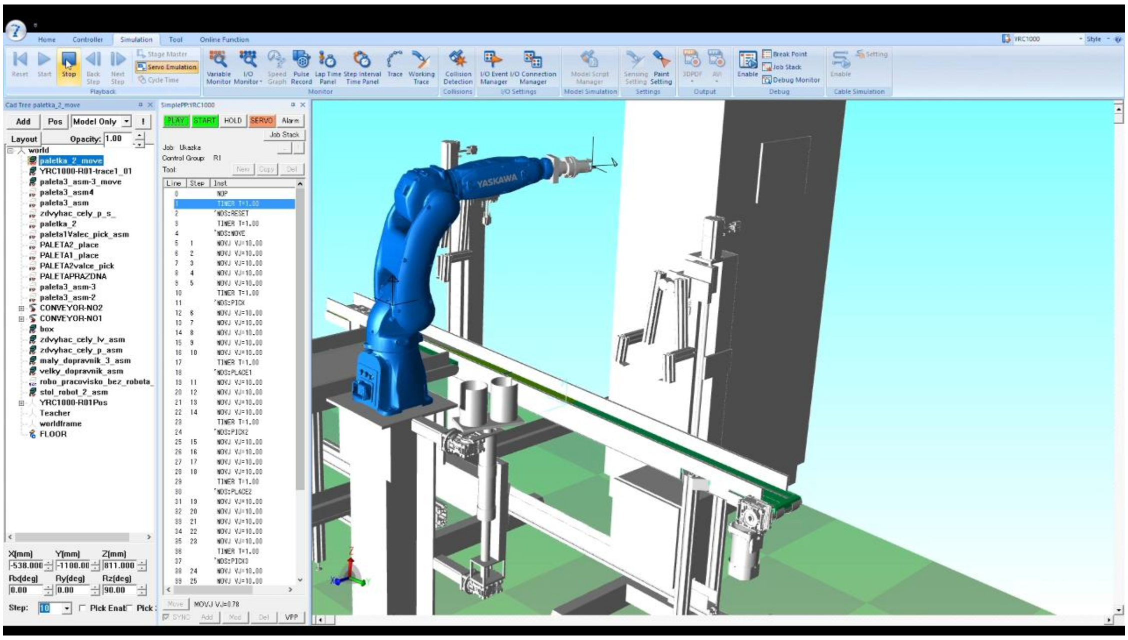

Fig. 5. A robotic workplace in the MotoSim environment

A view of a real robotic workplace equipped with a Yaskawa GP8 industrial robot, where the created program was verified in the MotoSim environment, is shown in Fig. 6.

Fig. 6. A view of a real robotic workplace

Conclusions. The problem solved was focused on creating a virtual robotic workplace in the MotoSim environment according to a real model. The goal of the work was to analyze the current state of the workplace, create its 3D model and then create a program for simulating the functionality of this environment. Due to the limitations of the MotoSim program in the area of creating 3D models, the workplace model was created in the CAD program Creo PTC. Off-line programming in the MotoSim environment is not the same as programming on a real robot. Manipulation functions cannot be simulated with the same program that would be created for real robot operations. Therefore, the created simulation could not be used for a real application, but it was necessary to modify the program so it could be imported into a real robot. After modifying the program, the proposed simulation was verified at a real workplace.

The proposed robotic workplace solution met the basic goal of a functional educational workplace for working with the Yaskawa robot, where it is possible to carry out teaching (training) online at the workplace, or offline from a computer room equipped with licenses for the MotoSim environment.

Acknowledgements

This article was created thanks to the KEGA project support: 020TUKE-4/2022 Development and implementation of new approaches in teaching industrial and collaborative robotics and project VEGA: 1/0215/23 Research and development of robotic workplaces equipped with industrial and collaborative robots.

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Отримано 18.09.2024

УДК 621.8

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ДИЗАЙН РОБОТИЗОВАНОГО НАВЧАЛЬНОГО РОБОЧОГО МІСЦЯ В ОФЛАЙН-СЕРЕДОВИЩІ З YASKAWA ROBOT

У статті йдеться про створення 3D моделей окремих частин роботизованого робочого місця в середовищі Creo Parametric. Роботизоване робоче місце складалося з двох реверсивних конвеєрів, палетизатора, депалетизатора та системи автоматичної зміни інструменту. У лотку для інструментів було два пневматичних захвати від SMC і Parker Kuroda, здатні захоплювати як обертові, так і неповоротні частини за допомогою пальців, створених на 3D-принтері з матеріалом PLA. Система автоматичної заміни інструментів від компанії SMC забезпечувала пневматично кероване від'єднання фланців окремих захватів, а також передачу сигналів на датчики кінцевих положень окремих ефекторів. Створені моделі компонентів робочого місця були згодом імпортовані в офлайн-середовище MotoSim, де вони були зібрані у тому вигляді, в якому вони знаходяться на реальному робочому місці. У подальшому було реалізовано проєктування трьох варіантів технологічного рішення монтажу з використанням б/в пневмозахватів. При виконанні моделювання в середовищі MotoSim в основному використовувалися об'єкти ротаційної форми розміром ф20x50 мм, що зберігалися на технологічних піддонах. Оскільки середовище MotoSim не містить функції «вибери та розмісти», необхідно було створити симуляцію за допомогою функції «Менеджер сценаріїв моделі». В якості робота використовувався промисловий робот компанії Yaskawa під назвою GP8, оснащений системою управління YRC 1000, здатний переносити вантаж на відстань 727 мм з максимальною вагою 8 кг. Обраний варіант з використанням палетайзера для штабелювання технологічних піддонів згодом був імпортований на реальне робоче місце, де був налагоджений та протестований. Мета пропозиції полягала в тому, щоб створити освітнє робоче місце, де можна було б проводити викладання або навчання онлайн безпосередньо за допомогою підвіски на роботі Yaskawa GP8 або офлайн в освітньому середовищі MotoSim EG-VRC.

Ключові слова: *офлайн середовище; Yaskawa GP8; MotoSim; навчальне робоче місце; Creo PTC.*
Рис.: 6. Бібл.: 12.

Kovaluk, D., Semjon, J., Sabol, M., Hrabcak, M. (2024). Design of robotized educational workplace in off-line environment with Yaskawa robot. *Technical sciences and technologies*, (3(37)), 101-107.