Design of a Robotic Workstation in the Company

Peter Malega [1], Naqib Daneshjo [2], Peter Korba [3], Simona Balaščáková [2]

[1] *Technical University of Kosice, Faculty of Mechanical Engineering, Letná 9, 042 00 Košice, Slovak Republic*
[2] *University of Economics in Bratislava, Faculty of Commerce, Dolonozemská cesta 1, 852 35 Bratislava, Slovak Republic*
[3] *Technical University of Kosice, Faculty of Mechanical Aeronautics, Rampová 7, 041 21 Košice, Slovak Republic*

Abstract **– Robotic process automation is utilized across various domains of human activity to introduce faster and safer processes through the reduction of risks or errors, as well as increasing productivity. The increase in its use and importance requires more and more effective methods of solving this problem. Robotic workstations serve as a means to achieve high reliability, efficiency, production precision, and short cycle times. Their undeniable advantage lies in performing tasks that are physically or ergonomically demanding for humans. A well-designed robotic workstation leads to reduced production costs, shortened production times, and rapid return on invested resources.**

Keywords **– Robotic workstation, robot, gripper, technical parameters, layout.**

DOI: 10.18421/TEM141-09
https://doi.org/10.18421/TEM141-09

Corresponding author: Naqib Daneshjo,
University of Economics in Bratislava, Faculty of Commerce, Dolonozemská cesta 1, 852 35 Bratislava, Slovak Republic.
Email: daneshjo47@gmail.com

Received: 18 June 2024.
Revised: 20 September 2024.
Accepted: 02 December 2024.
Published: 27 February 2025.

1. Introduction

Producers are driven by market forces to scale and optimize their production processes in order to fully meet market demands. Currently, the primary means of streamlining production is transitioning to "Industry 4.0," which entails the incorporation of information technologies and automated or robotic workstations into the production process. Robotic workstations serve as a means to achieve high reliability, efficiency, production precision, and short cycle times [7], [10]. Their undeniable advantage lies in performing tasks that are physically or ergonomically demanding for humans. Well-designed robotic workstations lead to reduced production costs, shortened production times, and rapid return on invested resources [1], [6].

Robotic process automation (RPA) is a new solution for automating work processes, similar to data processing [13], [11]. This technology is one of the significant trends of Industry 4.0 and is already implemented in many areas such as accounting, finance, insurance, human resources, banking, and logistics. It emerged as an enhancement of simple macros, which evolved into multifunctional and multi-application macros, enabling users to communicate with multiple systems and incorporate decision variables [3], [4]. RPA can be defined as a technology that enables the automation of repetitive tasks through robots created by software tools capable of performing "sequences of fine interactions with web and desktop applications," mimicking human behaviour.

2. Design of a Robotic Workstation in the Selected Company

The proposal is to install an industrial robot from ABB at the workstation next to the Laeis 2000 hydraulic press. Throughout the year, various moulds for different types of chamotte and magnesite bricks are replaced on the hydraulic press [5], [9]. The installation of the industrial robot for operation is associated with a change in the layout concept within the company, aiming to save one worker [8]. Before the installation of the ABB industrial robot, a pair of workers, known as press operators, where one operated the hydraulic press, operated the hydraulic press and the other worker removed the pressed bricks from the press and manually placed them on a kiln car. Thus, it involved physically demanding and monotonous work [15], [14]. In the Laeis 2000 press, the material compaction operation takes place, where there is a storage bin above the press with prepared material, which is automatically dosed into the mould cavity with each compaction cycle.

The compaction of the upper and lower mould assemblies into the mould cavity occurs under high pressure using hydraulic pistons [2], [12].

3. Proposal for Computer Visualization

In the first phase of the project, computer visualization will be implemented to show the placement of the industrial robot and its manipulation with the moulds. The workstation is designed based on approximate specifications provided by selected company. Images of extraction and loading plans provided by ABB are illustrative, demonstrating the conceptual solution of the industrial robot project.

The operator using a stretching chain (Figure 1) will bring the kiln car under the robot ramp. After starting the workstation, the retention mechanism will secure the kiln car and bring it into the loading position for the robot to load the first half of the kiln car (Figure 2). After loading the first half, the kiln car will be moved to a position where the robot will load the second row of moulds (Figure 3). A motor with feedback for setting the desired position controls the retention mechanism.

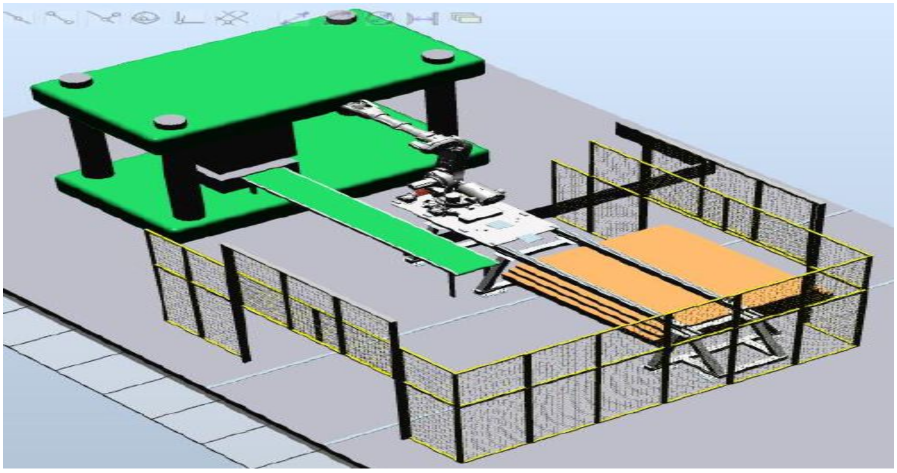


Figure 1. Implementation of the kiln car

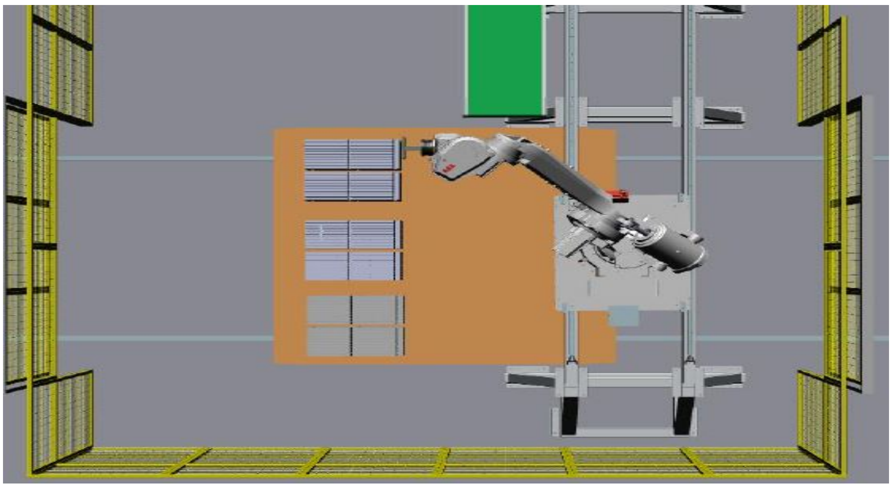


Figure 2. Loading the first half of the kiln car

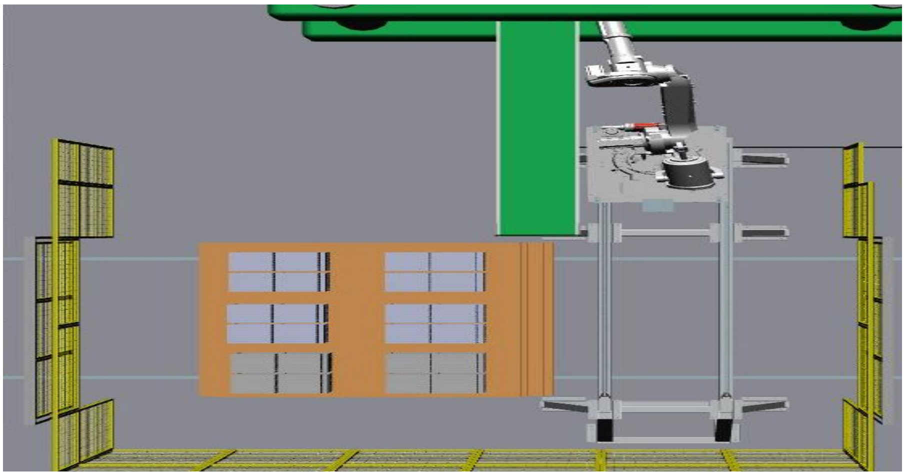


Figure 3. Loading the second half of the kiln car

The robot is positioned on a platform located above the kiln car. To enable the robot to load the bricks according to a universal plan allowing loading the kiln car from various directions, it is mounted on a movable carriage.

The carriage allows the robot to move so that it reaches the furthest point of the kiln car and also to access the press for mould cleaning purposes (Figure 4).

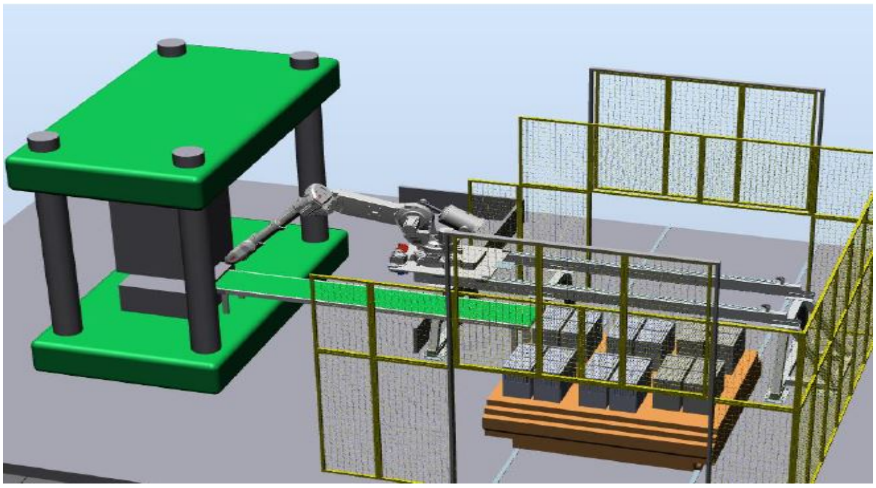


Figure 4. The position of the robot in the press

4. Versions of the Robot Layout Proposal

During the creation of the proposal, various methods of robot placement were explored in accordance with peripherals, etc. For clarity, some examples are provided to illustrate the diverse situations that may arise.

When using a robot positioned in a single location (Figure 5), it is not possible to accommodate a furnace car measuring 2.9 m x 2.8 m.

Additionally, when using a robot with a large reach, there arises a challenge in placing fixtures within the area near the robot. Moreover, a fundamental obstacle encountered in utilizing a robot from a single position is the placement of fixtures with differing attachment directions.

While the orientation of certain fixtures can be adjusted directly upon removal, some types may only be removed from an unsuitable side, thereby necessitating subsequent rotation or tilting of the fixture.

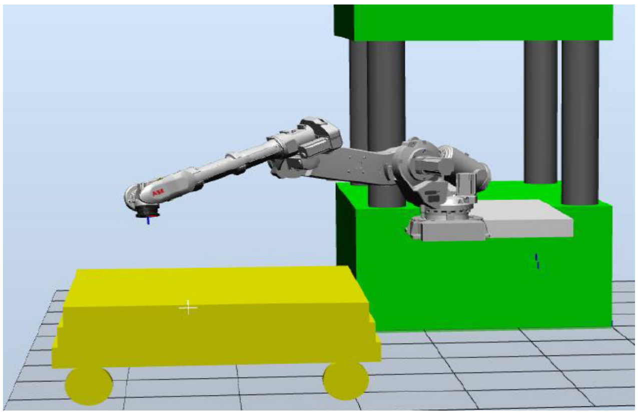


Figure 5. Illustrative picture for the robot with a reach of 3.2 m

In the case of using a robot with a carriage shift or a robot shift, a similar scenario arises where, in the event of the need for side unloading of fixtures, a significantly larger reach of the robot is required. This promptly leads to a problem with reaching the area near the robot. In Figure 6 below, the red area illustrates the region where the robot is outside the furnace car, while the blue area depicts the region where the robot is depositing "below itself."

5. Proposal of a Pneumatic Gripper

The device consists of a pneumatic gripper with interchangeable jaws (Figure 6), which serves as a replaceable working tool on the robot arm for transferring bricks. Technical parameters are displayed in Table 1.

Table 1. Technical parameters of the gripper

Title	**Pneumatic gripper**
Type	17ABB RMS
Serial number	001/2017
Year of production	2017
Coverage	IP54
Compressed air	6 bar
Dimensions (W x L x D)	200 x 300 x 580 mm
Weight	27.5 kg

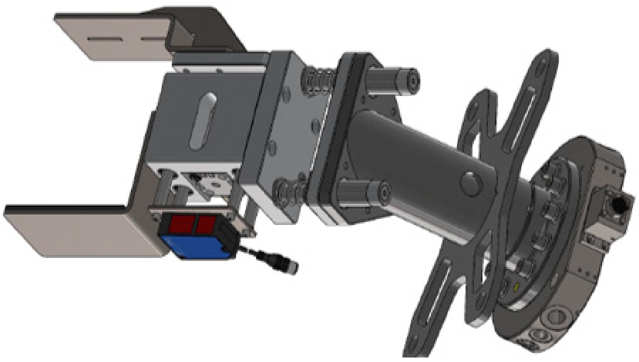
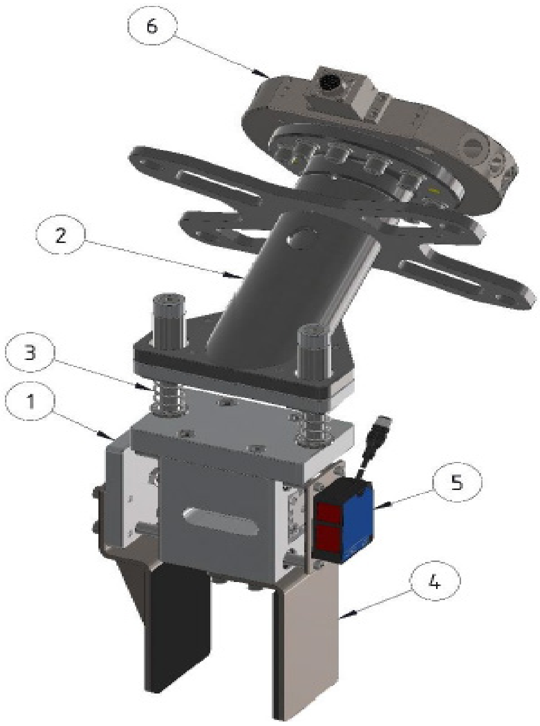


Figure 6. Pneumatic gripper for the robot

The gripper (Figure 7) consists of three main components:

- Gripper body – equipped with a pneumatic piston that provides the force necessary to grip bricks between the gripper jaws.
- Interchangeable jaws – the jaws are fastened to the gripper body using screws. A fixed jaw (L-shaped) is attached to the fixed part of the gripper, and a shaped jaw is attached to the movable part. Depending on the type of bricks being handled, a specific pair of jaws is used.
- Holder – on one side of the holder, the gripper body is attached, and on the other side, there is a tool changer, which connects the gripper to the robot arm and also connects the gripper to the energy system. The holder is equipped with a mounting plate, which is used to store the gripper in the holder when the gripper is not in use.



1- Gripper body, 2- Holder, 3- Flexible connection, 4- Interchangeable jaws, 5- Distance sensor, 6- Tool Changer - connection to the robot

Figure 7. Main parts of the gripper

6. Vacuum Gripper

The robot is equipped with a vacuum gripper designed for the retrieval of a specific type of fixture. This entails the need to interchange and replace the suction cup for different shapes. ABB supplies 2 pieces of shaped suction cups. As precise alignment of the fixture onto the conveyor from the press cannot be guaranteed, and ensuring an accurate retrieval position (trapezoidal shapes can vary in orientation), measurement precision is addressed by a camera system. Fixtures are retrieved from the press by a mechanism where precise alignment upon retrieval in various directions is not guaranteed. This displacement may lead to unsatisfactory situations during retrieval, such as when the fixture has been shifted to the left side, but the unloading surface is on the right side, resulting in an excessively high unloading height and potential fixture fall.

This primarily concerns narrow fixtures built on the edge. The camera system targets the fixture and sends this information to the robot.

Additionally, upon unloading, the robot measures the unloading position height using gripper sensors. The unloading position height, considering fixture tolerance of ±3 mm and variable height dispersion of the furnace car, varies. Therefore, it is necessary to measure this height, and based on the sensor data, the robot adjusts the unloading height. For ease of manipulation, the robot utilizes a Toolchanger Master (fixed part located on the robot flange) and Toolchanger Slave located on the detachable part of the gripper (Figure 8).

During unit replacement, the robot places the gripper in a storage station and retrieves the second unit (spreading, or optionally, cleaning). This solution prevents collisions between mechanisms, hoses, and wiring with the press or other parts.

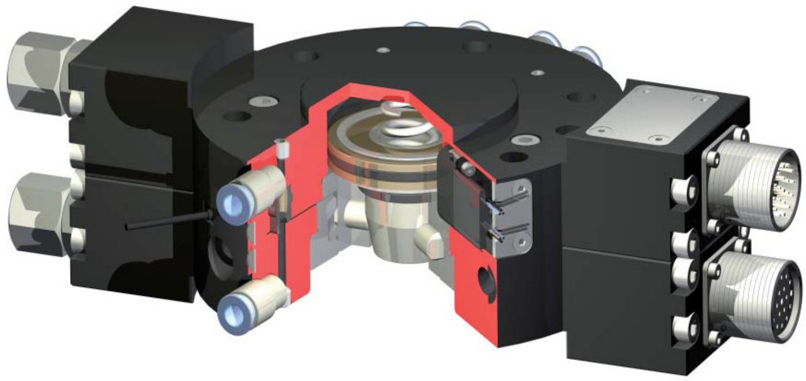


Figure 8. Master – the fixed part on the robot, and Slave – the detachable part of the gripper

The spreading unit will be placed in the storage position. After loading the first layer of the first half of the load, the robot will move to position and pick up the spreading unit. Subsequently, it will move over the fixtures and initiate dispensing. The sand/sawdust hopper will have a capacity of 100 kg. The dispenser is a rotary drum. The amount of spreading material is adjustable by the speed of the robot's movement and the rotation speed of the pick-up cylinder. The overall cycle of operation is as follows:

1. The operator selects the processed type. They place an empty furnace car in the defined location, close the doors, and initiate the workstation. The furnace car is automatically moved to the loading position.
2. The robot waits for a signal from the press to retrieve the fixture. Communication interface between the press and the robot is via digital signals: start press, stop press, press error, part fraction.
3. Upon the start signal from the press, the robot retrieves the part based on the created stacking plan.
4. The precision of the retrieval position is corrected by the robot offset obtained from the camera system. The part is retrieved from the defined side. The robot transfers the fixture over the furnace car and places it according to the stacking plan. The fixture can be unloaded from various sides. The robot measures the unloading height before depositing the fixture.
5. After releasing the vacuum, the robot returns to retrieve additional fixtures until it completes the cycle, then waits for the next press cycle. If the robot completes loading one layer, it moves to the parking station for the spreading unit and spreads the layer with sand or sawdust. It then returns the unit to the parking station and continues the cycle.
6. If the robot needs to clean the rails, it takes a dry ice cleaning nozzle, performs cleaning and surface blasting of the rails. After returning the cleaning unit to the parking station, it continues the cycle. During cleaning, the robot sends information to the press to suspend the cycle.

7. Once the first row of fixtures is loaded with the desired combination of layers, the furnace car is moved to the second position so that the robot can load the second layer of fixtures. After loading is completed, the output doors are opened, and the operator can push out the furnace car with a chain conveyor to proceed with the next cycle.
8. The workspace is enclosed to prevent workplace accidents. Opening the doors disconnects the safety circuits, and the workstation is in a safe state. Safety circuits of the press and robotic workstation will be interconnected as described below.

The workstation can operate in two modes:

1. Automatic operation: The robot operates in automatic mode. In case of door interruption or activation of the central stop, the entire workstation including the press transitions goes to a central stop state, as the safety of the new workstation and press will be interconnected.
2. Manual operation mode: The robot is in safe disconnect mode, and the press operates in its original mode without changing the conveyor. The operator in manual mode operates with the same (original) conveyor as when working with the robot. The operator can use a manual nozzle for dry ice blasting to clean the mould.

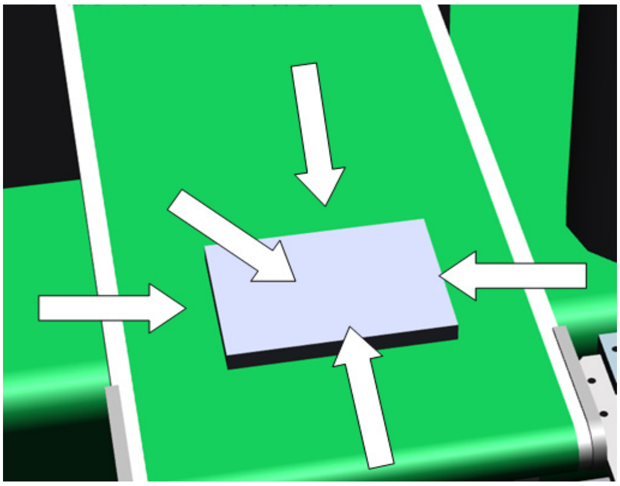


Figure 9. Possible ways of retrieving fixtures

Arrows in Figure 9 indicate possible directions for retrieving fixtures from the conveyor belt using the robot. Figure 10 shows arrows indicating possible ways of unloading fixtures onto the furnace car.

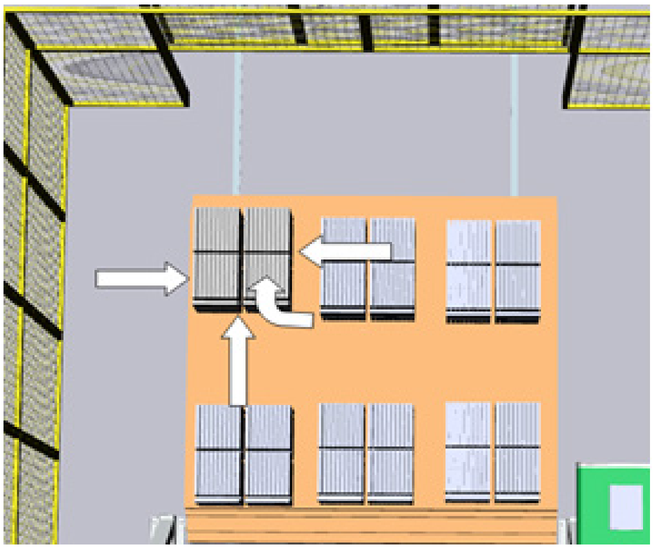


Figure 10. Possible methods of unloading fixtures onto the furnace car

The cycle time depends on the type of fixture:

1. For the production of 1 or 2 fixtures, it is assumed that these fixtures are large and placed on the narrow side, hence it is necessary to handle them carefully during unloading. Therefore, the length of pressing, typically more than 30 seconds defines the cycle time.
2. For the production of 3 or more fixtures, the cycle time will be 10 seconds for the furthest fixture. If the fixtures are placed closer to the robot, the cycle time will be shorter.
3. Since the specific methods of exiting fixtures from the press and placing them on the furnace car are not precisely defined in the task, a longer loading time may be required for a specific type if positioning is needed. The exact cycle time will be defined after the system is deployed and optimized based on real conditions and requirements.

The device (Figure 11) serves to position the tunnel car inside the robotic workstation, onto which the robot places the products. The base of the device consists of a welded steel frame. The frame comprises a track for the carriage with a pair of pneumatic pistons used for clamping the tunnel car. The carriage with pistons is attached to a chain driven by an electric gearbox with a brake and an incremental position sensor. Table 2 displays the technical parameters of the carriage movement.

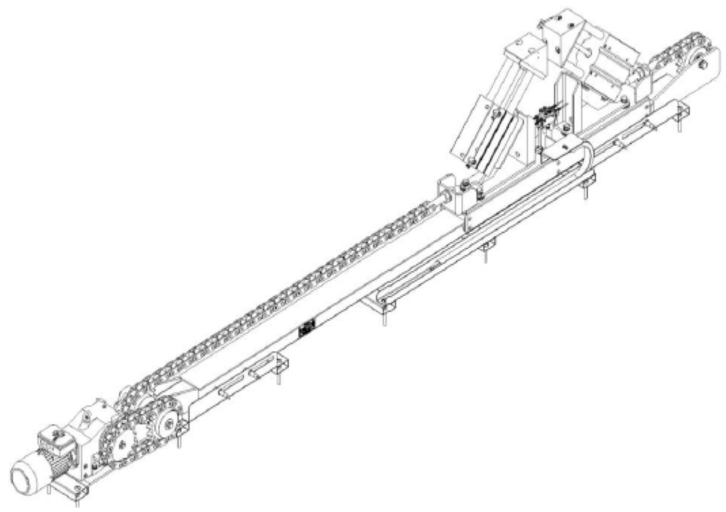


Figure 11. The carriage movement

Table 2. Technical parameters for the carriage movement

Carriage movement	
Type	DOPNE-0003
Serial number	OP-2017-039*001 to 002
Device length	1784 mm
Device width	323 mm
Device height	780 mm
Device weight	400 kg
Drive type	NORD SK9022.1-80LH/4BRE10 IG
Drive power	0,75 kW
Drive speed	14 rpm
Drive torque	501 Nm
Brake voltage	230 V
Engine cover	IP 66
Movement speed	8 m/min

The structure (Figure 12) serves as a vehicle for an industrial robot. Linear guides and a toothed rack are mounted on the welded steel structure. The pedestal with the robot is positioned within the guides.

The platform is driven by an ABB MU 400 servo motor with a NORD SK 92772.1 AD-IEC112 gearbox via a toothed rack and wheel mechanism. This arrangement enables the movement of the platform with the robot along the track. Technical parameters for the robot vehicle are illustrated in table 3.

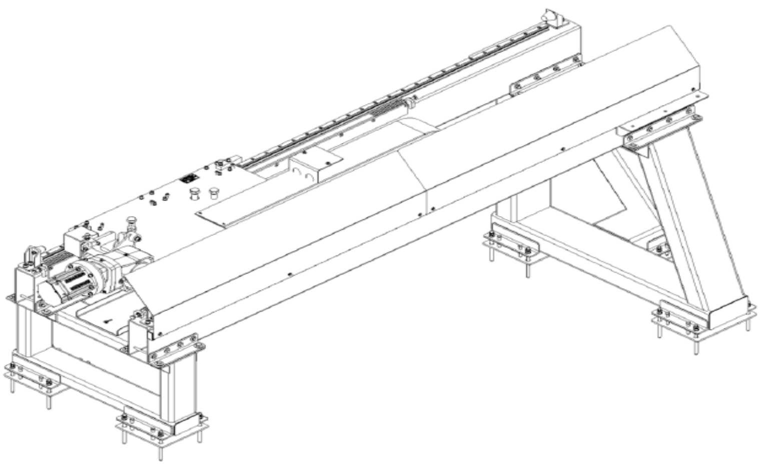


Figure 12. The vehicle for a robot

Table 3. Technical parameters of vehicle for the robot

The vehicle for a robot	
Type	KOLAJ-0016
Serial number	OP-2017-039*001
Device length	4576 mm
Device width	1685 mm
Device height	2052 mm
Device weight	1800 kg
Vehicle type	
Servo motor	ABB MU 400
Gearbox	NORD SK 92772.1 AD-IEC112
Gear ratio	11,28
Drive speed	203,9 rpm
Vehicle travel speed	53,8 m/min

The device (Figure 13) is used for safely storing the currently unused tool. The basic frame is welded from carbon steel profiles. Guide pins are placed at the top for storing two tools: one is the gripper extension and the other is the spreading tool. The spreading tool is used to spread a layer of products before loading the next one.

It is mounted on the frame made of steel profiles. The frame with the spreading tool is attached to the industrial robot using a flange equipped with a quick tool change system. Technical parameters for the tool stand are illustrated in Table 4.

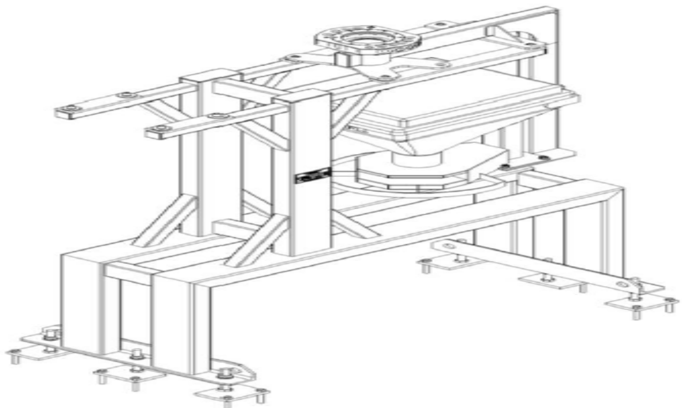


Figure 13. Tool stand

Table 4. Technical parameters of the tool stand

Tool stand	
Type	STOJA-0087
Serial number	OP-2017-039*001 to 002
Device length	1300 mm
Device width	630 mm
Belt conveyor height	1700 mm
Roller conveyor height	850 mm
Device weight	110 kg
Capacity of the device	200 kg
Power of the spreader motor	0,17 kW
Spreader power supply	12 V
Tank volume	40 l
Frame width	1 ÷ 12 m

The conveyor (Figure 14) serves to transport products from the press to the track with the robot. The base of the conveyor consists of a welded frame made of steel profiles.

Adjustable legs and tensioning brackets with a return and drive roller are attached to it. A gearbox drives the conveyor belt. At the end of the conveyor, there is a height-adjustable stop.

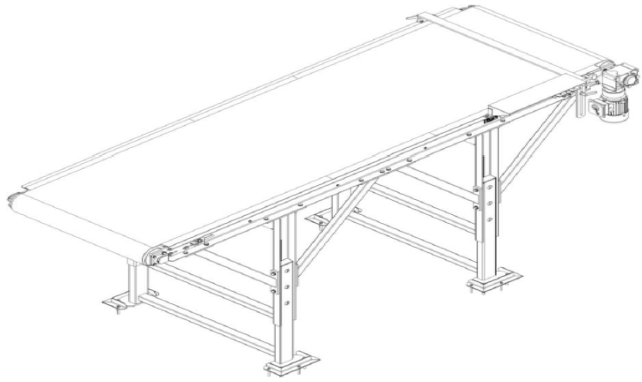


Figure 14. Belt conveyor

Technical parameters of the belt conveyor are illustrated in Table 5.

Table 5. Technical parameters of the belt conveyor

Belt conveyor	
Type	DPHLD-0176
Serial number	OP-2017-039*001
Device length	3600 mm
Device width	1000 mm
Device height	1500 mm
Device weight	480 mm
Capacity of the device	200 kg
Drive type	NORD SK 1SI63DH-IEC80-80L/4
Drive power	0,75 kW
Drive speed	57 ot/min
Drive torque	96 Nm
Transport speed	26,7 m/min
Engine cover	IP 66

7. Program for Creating Stacking Plans, Retrieval Plans, and New Bricks

Initiating a new plan (Figure 15) begins by pressing the "New Plan" button on the stacking plans screen. This action will display a top-down view of the furnace car on the screen. In this view, sections can be created from pre-defined chimneys. Since no chimneys have been created yet, the plan remains empty. Clicking on the "Chimneys" button will navigate to chimney creation. This section is also empty, therefore, it is necessary to create layers by clicking the "Layers" button. Here, all the layers to be used in the plan are created.

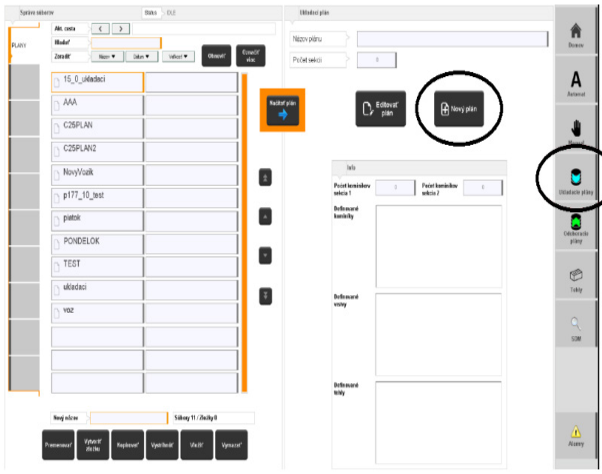


Figure 15. Creating a New Stacking Plan

The process of creating a layer is as follows:

1. Select the type of brick to be used in the layer by pressing the "New Type" button. To return to the layer creation screen, press the "Stacking Plan" button (above the selected bricks) after selecting the desired brick.
2. Press the "Add Brick" button to add individual bricks. Bricks can be added by clicking on the screen at the desired location for the brick. The brick will appear at the designated location. End brick addition by pressing the "Add Brick" button again.
3. By pressing the "Add Multiple" button, multiple bricks can be added at once. A window will appear, allowing the brick addition options to be set.
4. After adding bricks, they can be adjusted to the desired position and orientation.
5. Choose a gripping point for the robot. This point is the same for all bricks in the layer.
6. After completing the layer creation, save it by pressing the "Save" button. The layer name is automatically generated based on the sequential number of the layer and the type of brick used.
7. Once all the necessary layers have been created (Figure 16), chimneys can be created from them. Chimneys are created on the chimney screen (Figure 17).

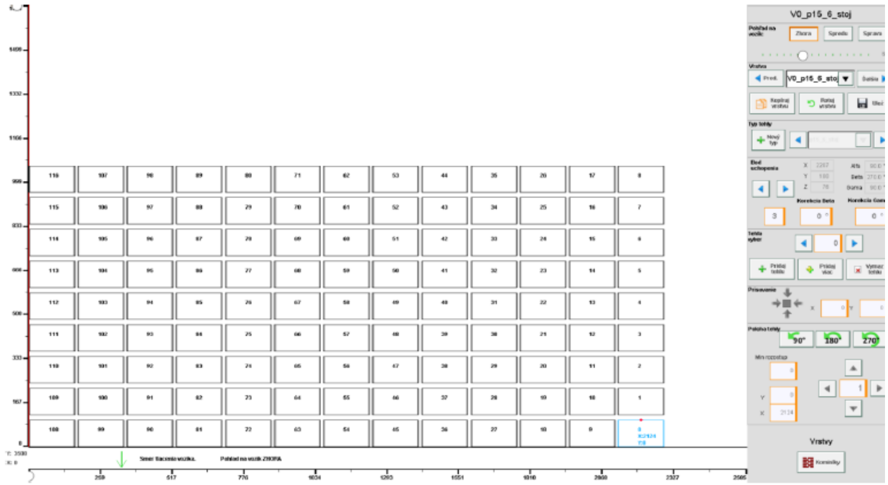


Figure 16. Example of a created layer, top view of the layer

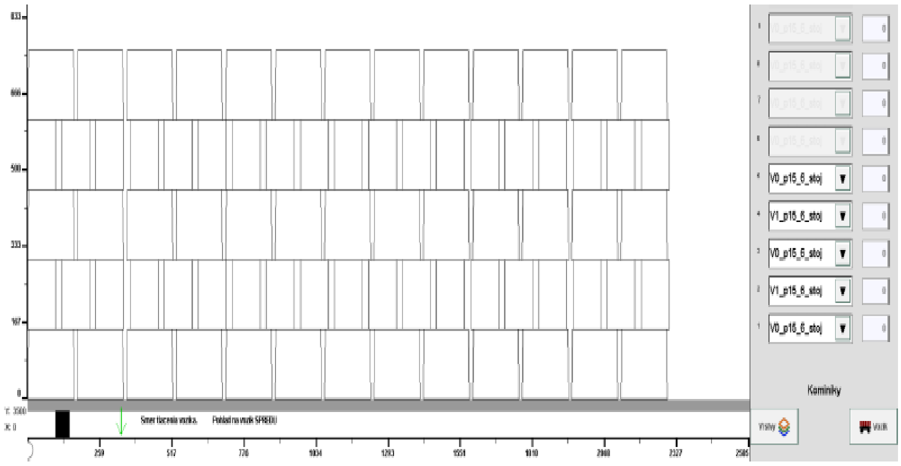


Figure 17. Example of a created chimney, view of the furnace car from the right

Procedure for creating chimneys:

1. Specify the number of layers the chimney should contain (Figure 18).
2. Select the types of layers.
3. Choose the vertical offset of the layers (up/down shift).
4. Save the created chimney.
5. After creating all the chimneys, proceed to creating sections by pressing the "Sections" button.

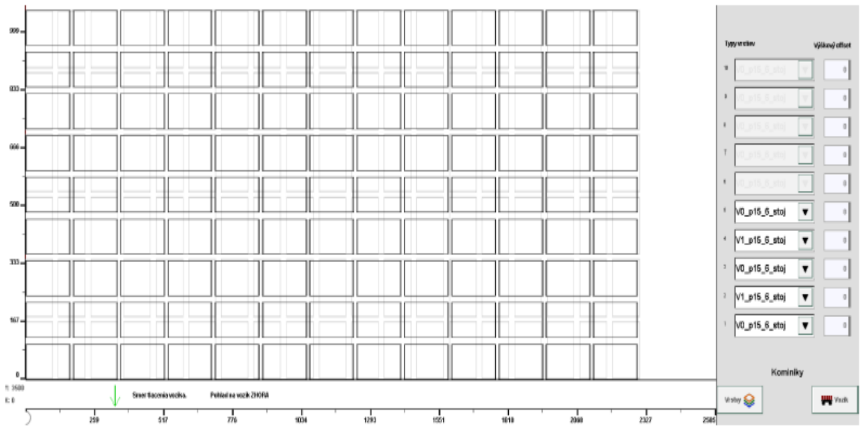


Figure 18. Top view - displaying the highest and second-to-last layer

The procedure for creating sections is as follows:

1. Enter the name of the carriage (the name of the storage plan).
2. Select whether a spreader is to be used for the selected plan or not.
3. Choose the gripper to be used for the given plan.
8. Select the section to be edited (Section).
9. Choose the number of bins in the respective section (Number of bins).
10. Select the index of the bin to be edited (Bin selection).
11. Choose the type of bin to be used - from the created bins (type).
12. Choose the position of the bin - the position is specified in the coordinate system of the carriage.
13. Similarly, proceed with the second section, or copy sections.
14. Save the created plan (Figure 19).

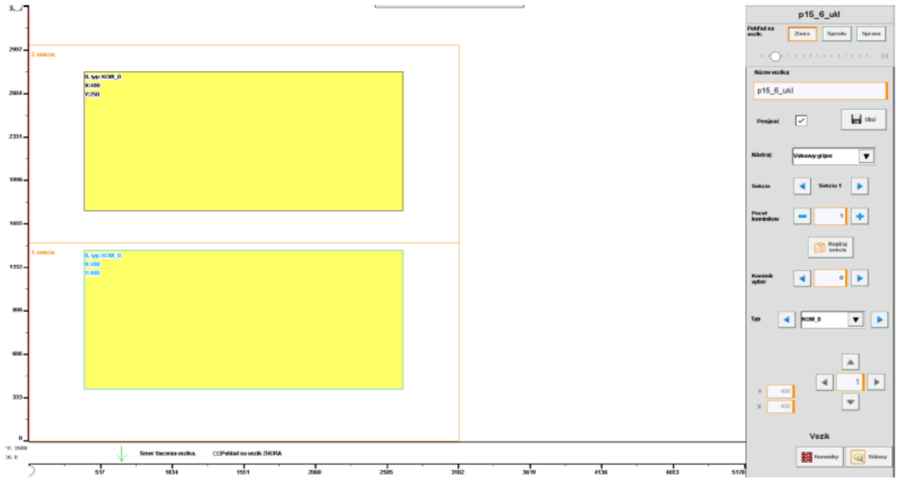


Figure 19. Sample of a created plan

The retrieval plan (Figure 20) represents the arrangement of bricks exiting the press onto the conveyor and the method of their retrieval. The gripping point of the brick chosen in the retrieval plan must be identical to the gripping point of the brick in the storage plan. The only variation permitted is in the method of brick storage.

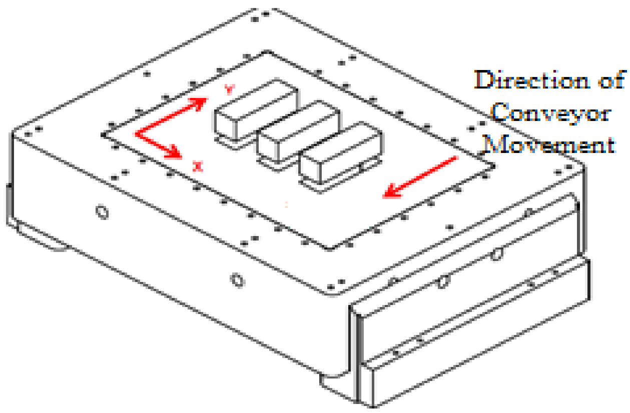


Figure 20. Coordinate system of the retrieval plan

Creating a New Retrieval Plan (Figure 21) begins by pressing the "New Plan" button on the retrieval plans screen. This action displays a top-down view of the outgoing conveyor.

On this screen, the desired bricks will be added in the arrangement they come out of the press onto the conveyor.

Additionally, the gripping point from which the robot will retrieve the brick will be selected.

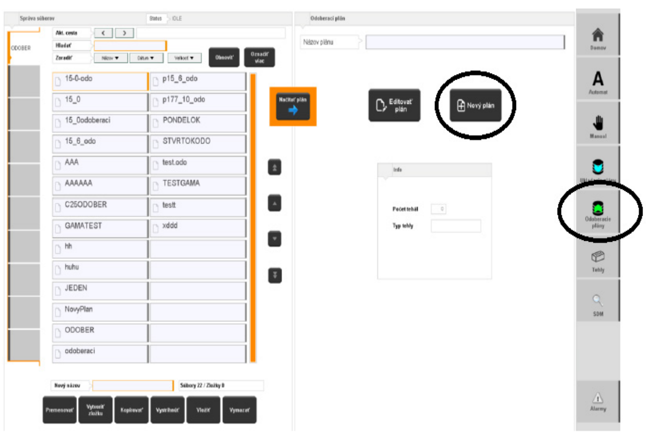


Figure 21. Creating a New Retrieval Plan

The process of creating a retrieval plan is as follows:

1. Select the type of brick to be used in the retrieval plan by pressing the "New type" button. To return to the plan creation screen, press the "Retrieval plan" button (above the selected bricks) after selecting the desired brick.

2. By pressing the "Add brick" button, individual bricks can be added. Bricks can be added in this way by clicking on the screen at the desired location for the brick. The brick will be displayed at that location. End the process of adding bricks by pressing the "Add brick" button again.
3. By pressing the "Add multiple" button, multiple bricks can be added at once. A window will appear with options for adding bricks.
4. After adding the bricks, they can be adjusted to the desired position and orientation.
5. It is necessary to select a gripping point for the robot. This point may be different for each brick in the layer.
6. After finishing the plan creation (Figures 22 and 23), it must be saved.

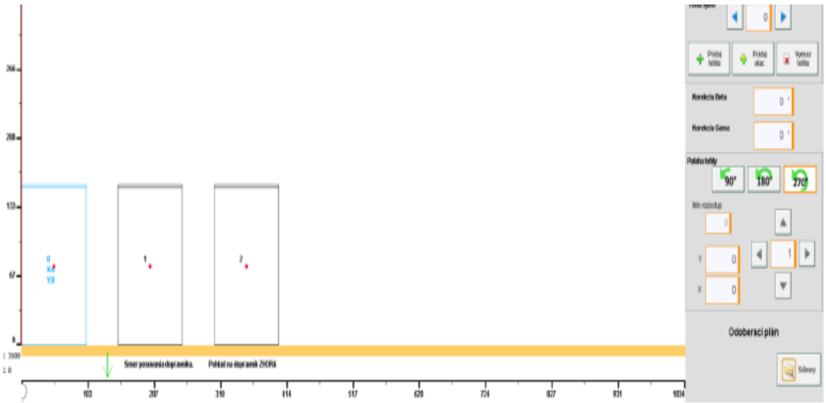


Figure 22. Example of the created retrieval plan – top view

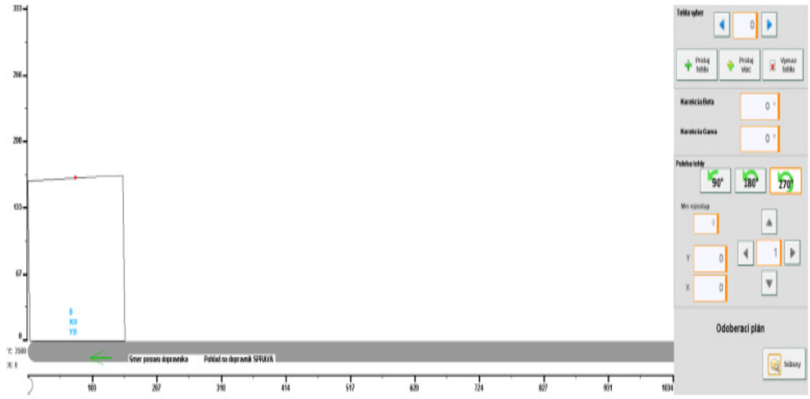


Figure 23. Example of the created retrieval plan – right view

New brick types (Figure 24) can be created on the screen under the column 'Bricks'.

This screen contains a list of created brick types on the left side and a button for creating new brick types on the right side.

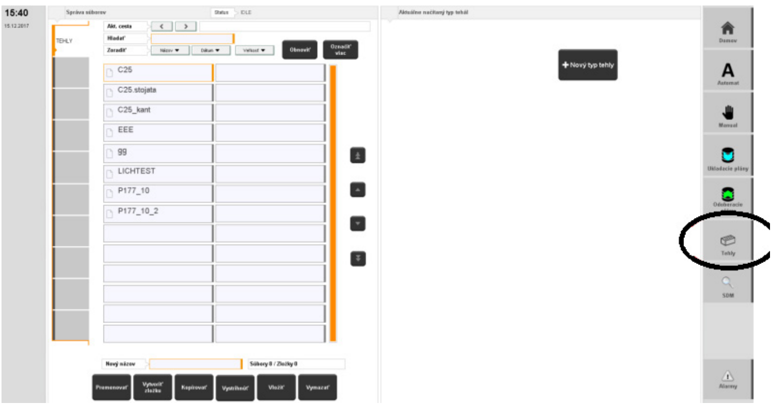


Figure 24. Creating a new brick

8. Evaluation of Solution Benefits

Since the primary incentive for the investment is to relieve the worker in the press shop from physically demanding and monotonous work, and to save costs for labour at the press shop workstation, the payback period depends on the savings in labour costs.

$$PP = \frac{PCI\ (EUR)}{SLC\ (EUR/ROK)} \quad (1)$$

Where:

PP- Payback period
PCI- Procurement costs for the investment
SLC- Savings in labour costs

1. To determine the payback period, the following calculation procedure is used: Procurement costs for the investment (PCI). It is the sum of all one-time costs associated with implementation. The company calculated these costs for one proposed technical solution.
2. Savings in labour costs for the operator (SLCO). This is the annual labour costs of operators, which will be saved in the workplace thanks to the exchange of operators with industrial robots.
3. Labour costs for industrial robot service (LCIRS). Considering the need to service industrial robots, it is necessary to determine the annual labour costs of external service technicians. Part of these costs is travel costs for technicians.
4. Labour costs for the maintenance of an industrial robot (LCMIR). In addition to the labour costs of the service technician, it is necessary for the company to determine the labour costs of the maintenance worker. The calculation of these costs was based on information about the maintenance of the industrial robot IRB 6700, which the selected company has.
5. Savings in labour costs (SLC). Labour cost savings are the operator labour cost savings minus the labour costs of service technicians and maintenance workers.
6. Payback period (PP). This is the ratio of items No. 1 and No. 5. Based on this procedure, the payback period of implementation at the workplace is calculated.

9. Conclusion

The long-standing challenging situation in the labour market coupled with rising inflation, which will force businesses to increase labour costs, will stimulate growing customer demand for automation and robotization in production, with expected higher returns on invested capital and higher margins for offered goods.

It is estimated that currently only 5% of distribution centres are automated and robotized. Advanced automation solutions are most cost-effective in large warehouses with higher operational heights than in smaller storage units.

The pace of technological advancement in the field of automation and robotics is rapidly accelerating, and automated systems are becoming more affordable. In the current era, characterized by robust economic conditions in many nations, companies are increasingly embracing innovative solutions. This trend is not limited to the automotive industry; automation and robotics are gradually permeating into other sectors where the deployment of such systems was not previously the norm.

Acknowledgements

This work has been supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic (Project KEGA 030EU- 4/2022, VEGA 1/0064/23, KEGA 019TUKE-4/2022 and KEGA 003TUKE-4/2024).

References:

[1]. Ayed, M. B., Zouari, L., & Abid, M. (2017). Software in the loop simulation for robot manipulators. *Engineering, Technology & Applied Science Research*, *7*(5).

[2]. Andronas, D. et al. (2020). Design of human robot collaboration workstations–two automotive case studies. *Procedia Manufacturing*, *52*, 283-288.

[3]. Delang, K. et al. (2017). Evaluation and selection of workstations for an application of Human-Robot-Interaction (HRI) in manufacturing. *Workshop Human-Robot Interaction in Collaborative Manufacturing Environment, IEEE/RSJ International Conference on Intelligent Robots and Systems IROS*, Vancouver, Canada, 1-6.

[4]. Daneshjo, N. et al. (2022). Implementation of Simulation in the Design of Robotic Production Systems. *TEM Journal*, *11*(1), 179.

[5]. Daneshjo, N. et al. (2020). Methods and Procedures Applied to Design of Production Processes and Systems. *TEM Journal*, *9*(4).

[6]. Gui, W. (2022). Gui, W. (2022, February). Simulation design of welding robot workstation based on RobotStudio. In *ISMSEE 2022; The 2nd International Symposium on Mechanical Systems and Electronic Engineering*, 1-5.

[7]. Gradim, B., & Teixeira, L. (2022). Robotic Process Automation as an enabler of Industry 4.0 to eliminate the eighth waste: A study on better usage of human talent. *Procedia Computer Science*, *204*, 643-651.

[8]. Husnain, S., & Abdulkader, R. (2023). Fractional Order Modeling and Control of an Articulated Robotic Arm. *Engineering, Technology & Applied Science Research*, *13*(6), 12026-12032.

[9]. Medjoubi, H., Yassine, A., & Abdelouahab, H. (2021). Design and study of an adaptive fuzzy logic-based controller for wheeled mobile robots implemented in the leader-follower formation approach. *Engineering, Technology & Applied Science Research*, *11*(2), 6935-6942.

[10]. Ore, F., Jiménez Sánchez, J. L., Wiktorsson, M., & Hanson, L. (2020). Design method of human–industrial robot collaborative workstation with industrial application. *International Journal of Computer Integrated Manufacturing*, *33*(9), 911-924.

[11]. Okamoto, H., & Deuchi, K. (2000). Design of a robotic workstation for automated organic synthesis. *Laboratory Robotics and Automation*, *12*(1), 2-11.

[12]. Sobaszek, Ł., Gola, A., & Varga, J. (2016). Virtual designing of robotic workstations. *Applied Mechanics and Materials*, *844*, 31-37.

[13]. Siderska, J. (2020). Robotic Process Automation—a driver of digital transformation?. *Engineering Management in Production and Services*, *12*(2), 21-31.

[14]. Velíšek, K. et al. (2017). Design of a robotized workstation making use of the integration of CAD models and Robotic Simulation software as way of pairing and comparing real and virtual environments. *MATEC Web of Conferences, 94*, 05008.

[15]. Xu, Y. et al. (2016). Design of palletizing algorithm based on palletizing robot workstation". *IEEE International Conference on Real-time Computing and Robotics (RCAR),* Angkor Wat, Cambodia, 609-613.