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USING THE SIMULATION PROGRAM FOR THE DESIGN AND OPTIMIZATION OF THE PRODUCTION LINE

Urgency of the research. *Increasing productivity while maintaining sufficient production quality is one of the main criteria for maintaining competitiveness. An appropriate way is to automate and robotize the production process. In order for robotization to succeed, all design steps need to undergo in-depth research.*

Target setting. *The aim is to design a robotic device (robotic line) capable of increasing the production of components in a smaller workspace from 91,000 to 160,000 per year for each of the 7 types of components.*

Actual scientific researches and issues analysis. *The introduction of robotic devices into production systems is devoted to a large part of the publication. In general, it is possible to state that the robot deployment is specific and depends on the particular manufacturing process. For this reason, it is necessary to carry out a new analysis of the suitability of the robot for each manufacturing process, supported by off-line simulation.*

Uninvestigated parts of general matters defining. *This article focuses on a specific workplace solution that uses one type of robot delivered by a parent company. The use of a different robot type with more appropriate parameters was not feasible in financial terms.*

The research objective. *The aim is to design the most suitable placement of production machines against the position of the industrial robot. Then analyse all the robot's working moves so that it can be manipulated by one of the 7 types of component on the line, with a production increase of 483.000 pieces per year.*

The statement of basic materials. *Simulating the production workspace in the offline environment allows you to optimize your design before it is actually created on the selected desktop. This reduces the development costs and saves the total time when the work is completed.*

Conclusions. *The article describes the problems of design, optimization and simulation of a robot equipped workplace. For optimizing workplace was precisely defined robot type when, which limited the use of the robot from better parameters. Using the robot can increase workplace productivity while reducing the work area. With the implementation of the proposal, the target was achieved to increase workplace output by 483.000 components/year.*

Keywords: *robot; simulation; program; optimization.*
Fig.: 5. Table: 1. References: 5.

Problem definition. At present, high demands are placed on car manufacturers and their subcontractors. Higher production, lowering costs, reducing staffing and, in particular, lowering product prices. Due to high demands, they are forced to come up with new technologies and solutions to make production processes more efficient. Because people's performance can only be increased to a certain extent, it is necessary to automate production and replace human activity with robots, thereby greatly reducing costs. The aim of the article is to automate the production process that will be used to process castings. Castings are components for the automatic transmission. The designed robotic workstation will handle 7 types of components. The role of the robot will, in the first step, be to take out half-finished products with input conveyors. Subsequently, they will be stored in production machines located within the robot range. After machining the respective surfaces, the robot's job is to remove the finished parts and store them on the output conveyors. The following steps are described in the simplified form. Firstly, an optimal layout of machines, devices, and industrial robots is proposed. Once the placement design has been completed, simulation will proceed. The Fanuc Roboguide simulation program is used to verify the required robot position, which makes it possible to clearly determine whether a given machines and equipment layout is required in place. In the simulation environment, individual work cycles are checked and the solution is judged to be sufficient for both current and increased production. A solution that suits it is considered to be a standard, according to which the 3D assembly of the production line is drawn with the relevant drawing documentation. The designed 3D assembly of the production line will consist of the main base under the robot and its control unit, protective fencing, conveyors and attachment brackets for individual machines and devices [1; 2].

Environment and components description. The environment in which the production process is located is the section of machining of aluminium alloy castings cast in the foundry operation.

The components that will be the resultant product of this process are one of the components of the automatic gearbox, Fig. 1, which is used to transmit a high torque of up to 3500 Nm for heavy goods vehicles.

In total, seven different types of parts are machined. The current production has been set at 91.000 components per year of each type. Currently, production is planned for 160.000 components per year of each type, so the automated line will be designed to produce 160.000 components.

These are components of Deckel 217, 218, 219, Bremsdeckel 222, Kolben 018, 025, and Pumpendeckel 005, Fig. 1. The technology for each piece is different. Each piece has a precise design, on which devices it will be machined and in what order.

Fig. 1. Machined components in the manufacturing process

Analysis of working space and used machinery and equipment. The area of work space on which production facilities are located is approximately 61.6 m2 with dimensions of 8.4 x 7.33 meters. A new auto line will also be placed on this desktop. Thus, the newly designed workplace must also meet the external dimension condition (max. 8.4 x 7.33 m). The current deployment of machinery and equipment is shown in Fig. 2.

The individual machines and equipment are distributed according to machined parts in four areas. The area 1 operated by one worker is used to work on the four components of Deckel 017, 018, 019 and Kolben 018. The outer periphery of the entire workpiece is machined in this area. In future designs, due to the number of machined parts in this area, it is necessary to deploy machinery and equipment so that machines from area 1 are as close as possible to the chosen robot and the time the robot needs to move as short as possible.

The composition of the machines and equipment in region 2 is the same as in area 1, therefore it is possible to use this area also for machining parts from area 1. This area is intended mainly for the first part of machining, Kolben 025 (267), Bremsdeckel 222 and Pumpendeckel 005, in which also the outer periphery of the whole piece is machined. In the case of the Bremsdeckel 222, one more of the inner dimensions is machined.

These machined components are further machined either in the 3 or 4 region. Thus, either workpieces in areas 2 and 3 or in regions 2 and 4 are machined. A both combinations, one worker works. A second part of the Bremsdeckel 222 and Pumpendeckel 005 is machining work in area 3. Each part is machined on a CNC milling machine as required. In area 4 runs machining in the second part of the component Kolben 025 (267). On the mounting press a small case is first pressed and then tested in the DHP (device for checking the tightness of the moulded case) for its tightness. In the event of an error, is component thrown out.

The workplace is bounded by a walkway designed for employees, storage space and another manufacturing processes. During a 12-hour change, a 3-fold measurement of the outer dimensions and a 1-fold measurement of the contour by means of the Zeiss coordinate measuring device of the area 1, 2 and 3 are performed. One measurement of the outer dimensions takes about 10 minutes and the contour measurement is approximately 30 minutes.

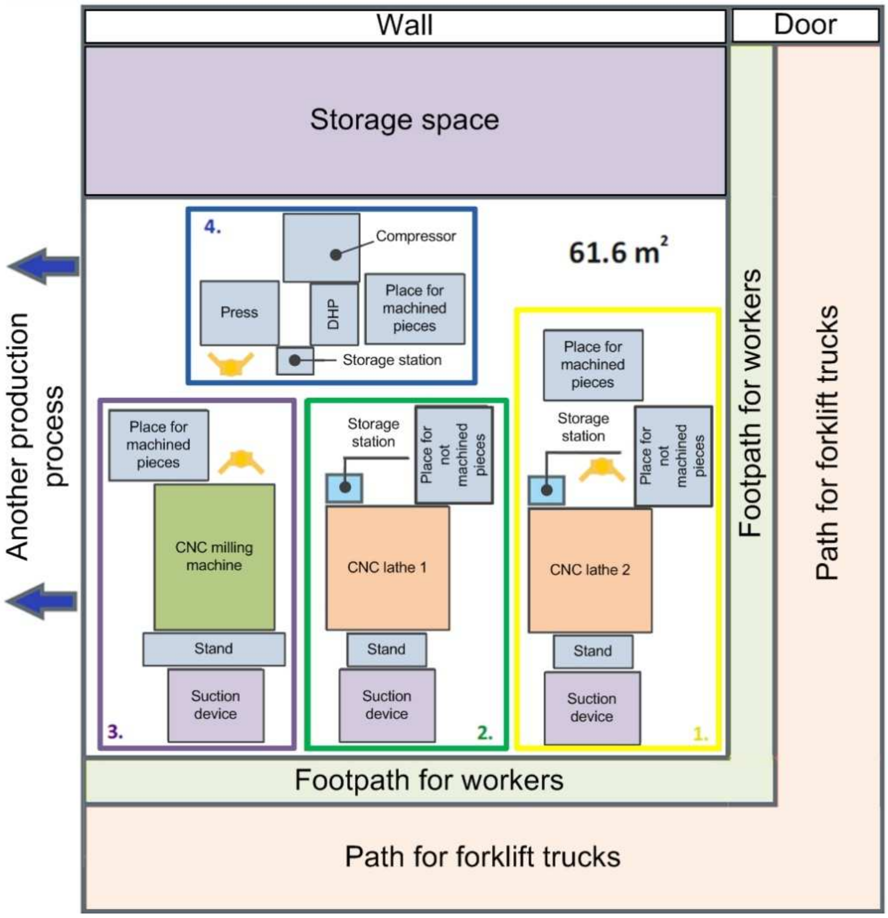

Fig. 2. The current layout of machinery and equipment

Design of robotic cell. The new robotic lines (cell) solutions are designed to produce 160,000 units of each type, that is, a total of 1,120,000 units of all components per year. The design of the workplace must include one Fanuc M-20i / 25 industrial robot with two DMG Mori CL 1500 CNC lathes, the Fanuc a-D21MiB5 ADV CNC milling machine, the DHP, the Kaeser SXC 8 compressor, four belt conveyors, the Sony XC56 camera system, three Ringler RE 201 suction outlets, a transfer station, stands for an external power source and packing boxes.

The use of the selected industrial robot Fanuc M-20i / 25 with the R-30iB control unit is due to his presence in the parent company in Germany. The robot has six degrees of freedom with a maximum load of 25 kg. The maximum range is 1853 mm and the robot accuracy is +/- 0.02 mm [4].

The CNC machines to be used in the designed production line for machining parts are the Lathe DMG Mori CL 1500 CNC and CNC Milling Machine Fanuc α-D21MiB5 ADV. Each of these machines is equipped with an external power supply located on the stand and a Ringler RE 201 suction device for dust and dirt extraction. The press which serves to press the small case and the DHP station that inspect the tightness of the component is the device designed by the parent company Schüle Druckguss in Germany. The Kaeser SXC 8 compressor is required for the DHP station.

Belt conveyors are designed by mk Technology Group according to their own requirements. Because the line will be machining two different parts at once, we need four conveyors. The width of the conveyor belt must be chosen so that all types of parts of different dimensions can be loaded. Two conveyors will serve to move unworked parts into a line and two to transfer finished parts from the line. In order to recognize the position of the incoming parts in the line, an industrial 2D Sony XC56 camera is used.

Design of machinery and equipment placement. The position of the machines and equipment must meet certain requirements such as the size of the built-up area, the availability and effective shifting of the robot to the required positions, common access to conveyors and access for maintenance. By optimizing the initial four proposals, a proposal has been developed that satisfies each defined requirement, Fig. 3.

The size of the built-up area is approximately 44.4 m2. Thus, compared to the currently built area of 61.6 m2, approximately 17 m2 will be saved. The outside dimensions of the production line are 8.39 x 7.31 m. The proposed robotic line under this proposal will fit into the area where the current production process lies. For both CNC lathes, maintenance access is possible from the required side. The robot control unit is located near the entrance door and access to the conveyor is on the same side. From the point of view of the movement of the robot, the positioning of the machines is very good.

When transferring parts from conveyors to CNC lathe 2 or into CNC lathe 1, the robot performs a small movement. The location of the suction devices and stands for the external power source also suits. This proposal is considered final. According to this proposal, the workplace in the Fanuc Roboguide program is simulated and later the construction design of the robotic line is proposed.

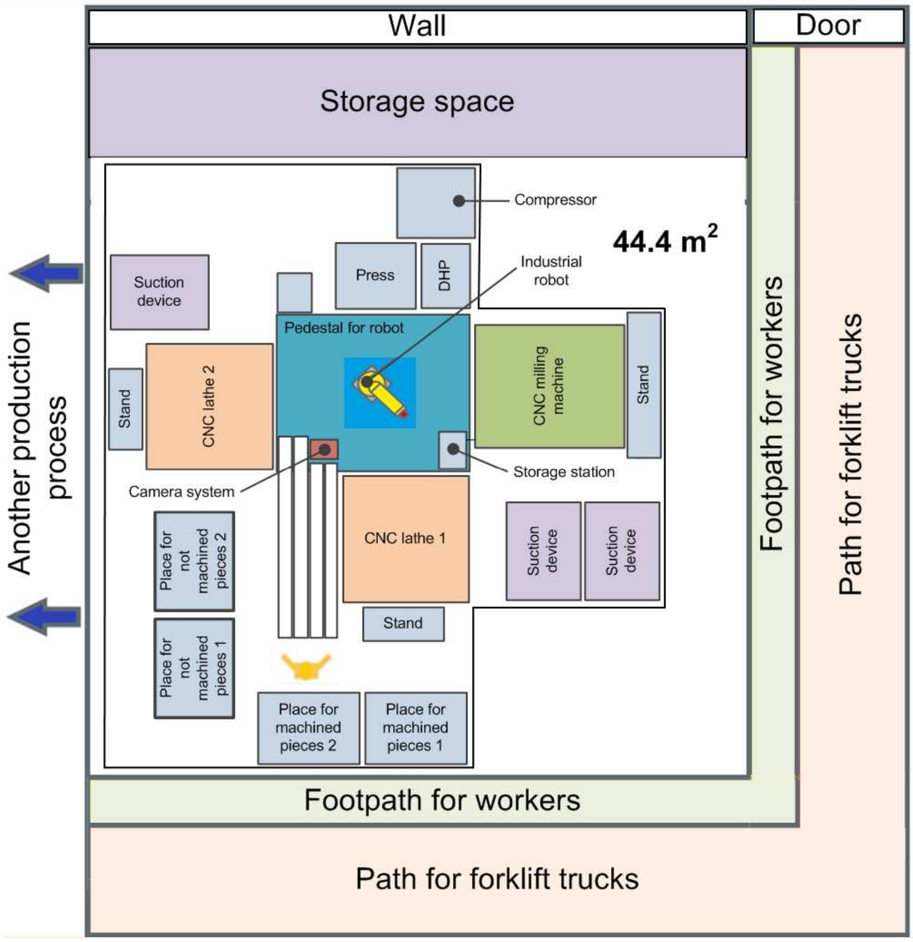

Fig. 3. Final design robotic cell

Workplace simulation in off-line environment. In order to make sure that the layout of the machines according to the final design also suits the robot's reach, and how long the individual process cycles run during operation, the Fanuc Roboguide simulation overwork is used. Once the workspace has been simulated, it will be able to clearly determine whether the robot is able to perform the predicted activity and, at the same time, we will be able to calculate the total production that the robot can perform according to the measured time cycles.

The problem area model is used to describe relationships between objects and properties in the problem area. The automated line model describes the general concept of the problem area without considering the details that are required for the design and implementation of the mechatronic system.

According to the following model, the planned production line could be formulated as follows: Suppose the production line is already ready for machining the exact types of parts. There are defined types of component, machine tools and industrial robots. The operator stores the selected parts on conveyors. Using a camera to identify the position of the parts, the robot grabs the workpiece from the conveyor and, depending on which part of the machining line, knows which machine to insert it into. The line can handle two different types of parts. The robot grasps the workpiece from the conveyor for which the machine tools are free. [4].

In the working environment of the Fanuc Roboguide program, individual machines, equipment and, in particular, the industrial robot are placed according to the final design, Fig. 4. The robot, control unit, machines, conveyors, fencing and boxes are 3D CAD models imported from the Fanuc library. Those machines and equipment which are from another manufacturer must be insert separately, respectively. Models that are not freely available must be modelled separately. These are the DMG Mori CL 1500 CNC lathe, Ringler RE 201 and DHP. Since the robot will handle parts of different dimensions, it is necessary to design a custom end effector [5].

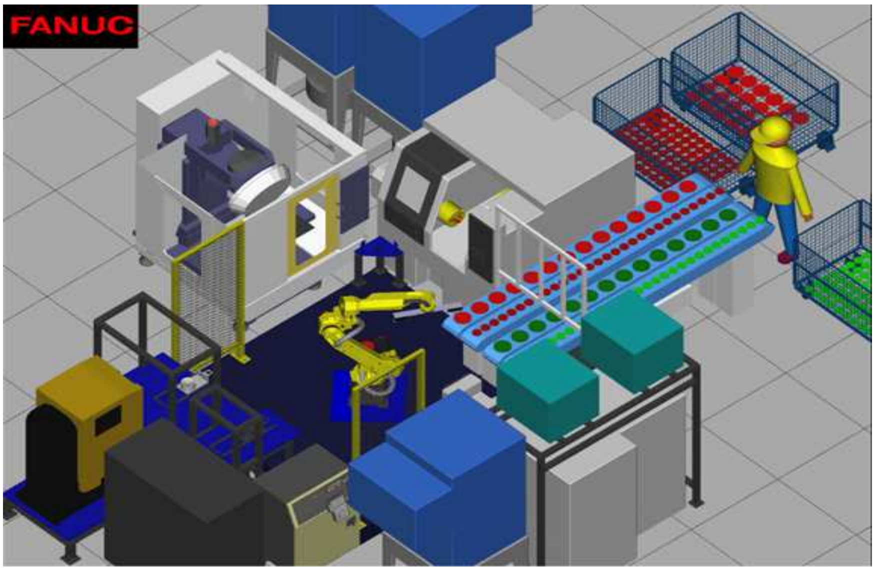

Fig. 4. 3D model of machines and equipment in Roboguide

Verify cycle times after optimization using simulation. Before using the finished program in production, it is necessary to verify that the robot with the program can produce the number of components we assumed. In order to get the highest productivity on the proposed production line, we optimized some work cycle and process values for current state, Table. Verification cycle times is realized in Roboguide simulation. In simulations, we can measure not only the individual cycle times but also the total working cycle for one or more machined parts. If the simulation shows that the production line can produce machined parts according to optimized times, the program can be used.

Table

Optimization of work cycles and processes

Parts	Status	Operation (s)														
		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	Total
Deckel 217	Current	0	0	0	3.8	0	12.2	12.2	0	0	0	0	0	0	13	35
	Optimization	0	0	0	3.6	0	9	9	0	0	0	0	0	0	13	31.6
Deckel 218	Current	0	0	0	0	0	0	0	10	0	0	0	0	0	13	29
	Optimization	0	0	0	0	0	0	0	8	0	0	0	0	0	13	27
Deckel 219	Current	0	0	0	0	0	0	0	0	0	0	0	0	11	13	30
	Optimization	0	0	0	0	0	0	0	0	0	0	0	0	11	13	30
Bremsdeckel 222	Current	0	0	0	21	10	0	0	0	0	0	0	0	0	13	50
	Optimization	0	0	0	21	10	0	0	0	0	0	0	0	0	13	50
Kolben 025 (267)	Current	12.9	0	0	0	0	9	9	0	4.9	3.4	0	0	0	13	49.2
	Optimization	12.9	0	0	0	0	9	9	0	4.9	3.4	0	0	0	13	49.2
Kolben 018	Current	0	30.1	20	0	0	0	0	0	0	0	0	12.1	11.8	13	92.5
	Optimization	0	18.2	9.4	0	0	0	0	0	0	0	0	10	7.5	13	64.1
Pumpendeckel 005	Current	0	0	0	24.3	5.2	0	0	0	0	0	10.3	0	0	13	58.8
	Optimization	0	0	0	21.3	5	0	0	0	0	0	8.2	0	0	13	53.5

The view of the 3D design of the manufacturing robotic line is shown in Fig. 5.

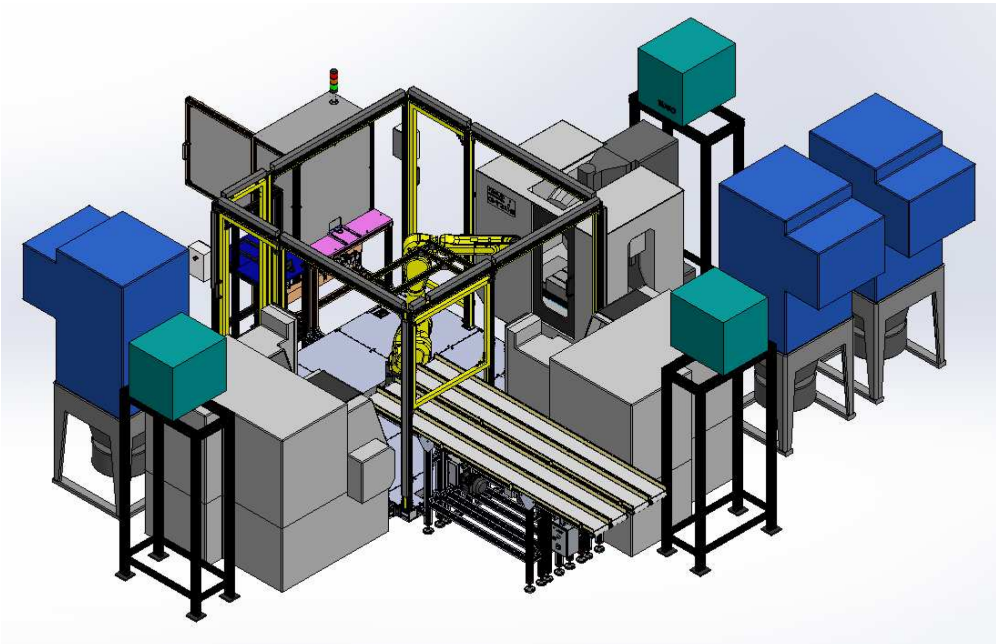

Fig. 5. View of the designed production line in SolidWorks

Conclusions. The article describes the problems of design, optimization and simulation of a robot equipped workplace. For optimizing workplace was precisely defined robot type when, which limited the use of the robot from better parameters. Using the robot can increase workplace productivity while reducing the work area. With the implementation of the proposal, the target was achieved to increase workplace output by 483,000 components / year.

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ВИКОРИСТАННЯ ІМІТАЦІЙНОЇ ПРОГРАМИ ДЛЯ ПРОЕКТУВАННЯ Й ОПТИМІЗАЦІЇ ЛІНІЇ ВИРОБНИЦТВА

Актуальність теми дослідження. *Підвищення продуктивності при збереженні достатньої якості продукції є одним з основних критеріїв підтримки конкурентоспроможності. Це стосується автоматизації й роботизації виробничого процесу. Для того щоб роботизація була успішною, усі етапи проектування повинні пройти поглиблене дослідження.*

Постановка проблеми. *Метою є створення роботизованого пристрою (роботизованої лінії), здатного збільшити виробництво компонентів з 91 000 до 160 000 на рік у меншому робочому просторі для кожного з 7 типів компонентів.*

Аналіз останніх досліджень і публікацій. *Велика частина публікації присвячена впровадженню роботизованих пристроїв у виробничі системи. Загалом, можна зазначити, що розробка робота є специфічною й залежить від конкретного виробничого процесу. З цієї причини необхідно провести новий аналіз придатності робота для кожного виробничого процесу, ґрунтуючись на автономному моделюванні.*

Виділення недосліджених частин загальної проблеми. *У цій статті основна увага приділяється конкретному рішенню на робочому місці, в якому використовується один тип робота, що поставляється компанією-виробником. Використання іншого типу робота з більш підходящими параметрами було неможливе у фінансовому плані.*

Постановка завдання. *Мета полягає в тому, щоб спроектувати найбільш підходяще розміщення виробничих машин навколо положення промислового робота. Проаналізувати всі робочі рухи робота, щоб він міг маніпулювати одним із 7 типів компонентів на лінії зі збільшенням виробництва на 483 000 штук на рік.*

Виклад основного матеріалу. *Моделювання робочої області в автономному режимі дозволяє оптимізувати конструкцію до того, як вона буде створена на обраному робочому місці. Це зменшує витрати на розробку й економить загальний час виконання роботи.*

Висновки відповідно до статті. *У статті описуються проблеми проектування, оптимізації та моделювання робочого місця, обладнаного роботом. Для оптимізації робочого місця був точно визначений тип робота в умовах коли існувало обмеження на використання робота з кращими параметрами. Використання робота може підвищити продуктивність робочого місця та скоротити робочу зону. Із впровадженням цієї пропозиції була досягнута мета збільшення обсягу виробництва на 483 000 компонентів у рік.*

Ключові слова: *робот; моделювання; програма; оптимізація.*

Рис.: 5. Табл.: 1. Бібл.: 5.

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