АНАЛІЗ ДОЦІЛЬНОСТІ ВИКОРИСТАННЯ КОЛАБОРАТИВНИХ РОБОТІВ У ВИРОБНИЦТВІ КОМПОНЕНТІВ ВІДНОВЛЮВАНИХ ДЖЕРЕЛ ЕНЕРГІЇ

Гурін Д.В.
Харківський національний університет радіоелектроніки,
Україна, 61166, Харків, пр. Науки 14
E-mail:dmytro.gurin@nure.ua

Анотація: розглянуто сучасні можливості застосування колаборативних роботів у виробничих процесах, пов’язаних із виготовленням компонентів систем відновлюваної енергетики. Проаналізовано особливості колаборативної робототехніки та визначено основні типи роботизованих систем, потенційно придатних для використання у відповідних виробничих операціях. Окрему увагу приділено можливим сценаріям застосування колаборативних роботів під час виготовлення сонячних панелей, компонентів вітроенергетичних установок та акумуляторних систем. Розглянуто переваги роботизації з погляду підвищення продуктивності, якості та безпеки виробництва, а також зменшення впливу людського чинника й оптимізації використання енергетичних і матеріальних ресурсів. Обґрунтовано перспективність подальшого розвитку колаборативної робототехніки на основі технологій машинного зору, штучного інтелекту та сенсорного злиття даних.

Ключові слова: колаборативна робототехніка, колаборативний робот, кобот, промислові роботи, людино-машинна взаємодія, відновлювані джерела енергії, виробництво компонентів відновлюваної енергетики.

ANALYSIS OF THE FEASIBILITY OF USING COLLABORATIVE ROBOTS IN THE MANUFACTURING OF RENEWABLE ENERGY COMPONENTS

Gurin D.V.
Kharkiv National University of Radio Electronics
Ukraine, 61166, Kharkiv, Nauky av., 14
E-mail: dmytro.gurin@nure.ua

Abstract: considered the modern possibilities of using collaborative robots in production processes related to the manufacture of components of renewable energy systems. The features of collaborative robotics were analyzed and the main types of robotic systems potentially suitable for use in relevant production operations were identified. Special attention was paid to possible scenarios for using collaborative robots in the manufacture of solar panels, components of wind power plants and battery systems. The advantages of robotics in terms of increasing productivity, quality and safety of production, as well as reducing the impact of the human factor and optimizing the use of energy and material resources were considered. The prospects for further development of collaborative robotics based on machine vision, artificial intelligence and sensor data fusion technologies were substantiated.

Keywords: collaborative robotics, collaborative robot, cobot, industrial robots, human-machine interaction, renewable energy sources, renewable energy component manufacturing.

Collaborative robotics is one of the promising areas of modern robotics, which is increasingly being integrated into industrial production processes. Unlike traditional industrial robots, which usually operate in isolated robotic cells, collaborative robots are focused on direct interaction with humans within a shared workspace.

The development of this area is due to the need to increase production efficiency, reduce costs, reduce the number of monotonous and physically complex operations, and increase the level of worker safety. According to forecasts, collaborative robots should occupy an increasingly large share of the global market for robotic systems.

The use of collaborative robotics is especially relevant for the production of renewable energy components. The renewable energy industry is demonstrating significant growth rates, with solar and wind energy remaining among the most common areas. The expansion of relevant production requires increasing the productivity of technological processes, stable product quality, and optimization of resource use.

The use of collaborative robots in such conditions can become one of the means of automating individual production operations. At the same time, unlike fully automated robotic complexes, cobots allow combining the capabilities of automated equipment with the experience and flexibility of a human operator.

The purpose of this work is to analyze the prospects for using collaborative robots in the production processes of components for renewable energy sources and to determine the main areas of their potential application as an alternative or addition to traditional forms of labor automation.

The scope of application of cobots is quite wide. In industry, they can perform operations of moving and positioning parts, assembling products, quality control, packaging and servicing equipment. In agriculture, robotic systems can be used for planting plants, harvesting and sorting products. In medicine, promising areas are assistance in patient care and performing certain physiotherapy procedures. In the food industry, cobots can be used for packaging, sorting and controlling products.

Depending on the design, kinematic scheme and purpose, collaborative robotic systems can be conditionally divided into several main groups.

Cartesian robots move the working body along three mutually perpendicular linear axes. Such a kinematic scheme provides high positioning accuracy and is well suited for performing operations with a given geometry of movements.

This group includes, in particular:

– Cartesian robots with three linear axes and a rotating working body, which can be used for drilling, grinding, welding and other technological operations;

– gantry robots, in which the working mechanism moves along guides. This design provides a significant working area and can be used to move heavy loads or large components.

Articulated robots have several kinematic links and a significant number of degrees of freedom, which provides a wide range of movements of the working body. This makes them suitable for operations that require high flexibility and precision, such as component handling and assembly.

SCARA (Selective Compliance Articulated Robot Arm) are articulated manipulator robots with selective compliance. They are characterized by high movement speed and stability during repetitive operations, which makes them particularly suitable for high-precision assembly.

Related robotic systems include industrial manipulators and coordinate machines with numerical program control, including small-sized milling machines, engraving machines and 3D printers.

Mobile cobots are able to move independently within the work area. Their main areas of use are internal logistics, material transportation, loading and unloading operations and maintenance of production areas.

Depending on the method of operation, they can be divided into:

– hybrid robotic systems capable of operating both autonomously and under the control of an operator;

– robots designed for operation in open space;

– robots for use in rooms and confined work areas.

A separate group consists of robotic systems directly focused on the joint performance of production operations by a person and a robot. Such systems make it possible to distribute technological operations between the operator and the robot in accordance with their functional capabilities and use a common workspace.

This direction includes robotic exoskeletons and autonomous guided vehicles (AGV). In the production of renewable energy components, such systems can be useful during assembly, quality control, transportation and packaging of components.

Two-armed robots are equipped with two actuators, the work of which can be coordinated for simultaneous or sequential execution of technological operations. This design expands the functional capabilities of the robotic system and allows you to perform tasks that require coordinated actions of two manipulators.

Among the possible areas of application, welding and painting, machine tool maintenance, machining of parts and assembly of components can be distinguished.

Delta robots have a parallel kinematic structure formed by three levers connected to a common base. Unlike sequential articulated manipulators, a delta robot has several kinematic chains connecting the base to the working body.

Such robots can be classified by load capacity and radius of the working area. The main advantage of delta robots is the ability to perform high-speed and high-precision operations. Therefore, they can be used for sorting and positioning components, as well as for loading and unloading operations.

Therefore, the choice of a specific type of collaborative robot should be determined by the nature of the technological operation, the required accuracy, load capacity, working area and requirements for interaction with the operator.

One of the most promising areas of use of cobots is logistics and warehouse operations. Robotic systems can perform operations of order picking, material movement, inventory management, packaging and preparation of products for shipment. Automation of such operations makes it possible to reduce the duration of production and logistics processes, increase the accuracy of task performance and reduce the risk of injury to workers.

Another potential area is the construction industry. Cobots can be used for preparing work sites, performing loading and unloading operations and welding. Involving robotic systems in physically complex operations potentially allows simultaneously to increase productivity and the level of safety of workers.

In the transport sector, collaborative robotic systems can be used to load and unload cargo, navigate vehicles, and perform individual maintenance operations.

Other areas of use also remain promising. In the educational process, robotic systems can perform auxiliary functions related to the control of learning outcomes and monitoring of success. In the entertainment sector, cobots can be used to create interactive systems, robotic performances, and other forms of interaction with the audience.

Thus, the potential of collaborative robotics is not limited to individual production operations. Further development of technologies expands the list of tasks that can be transferred to robotic systems.

The production of components for renewable energy is one of the promising areas of integration of collaborative robotics. The use of cobots makes it possible to automate individual technological operations, while maintaining the possibility of direct human participation in the production process.

During the production of solar panels, robotic systems can be involved in the operations of material processing, cutting and assembling structural elements of panels. The use of robots in such operations contributes to the stability of the implementation of repetitive technological procedures and can increase the reproducibility of results.

In the production of wind turbines, cobots can perform machining operations, drilling and welding of components, as well as participate in the assembly and testing of finished assemblies.

A separate direction is the production of battery systems designed to accumulate energy from renewable sources. Here, collaborative robots can be used to move materials, assemble battery components and control quality. In addition, robotics makes it possible to automate the sorting, packaging and labeling of battery cells.

An important advantage of robotic systems is the possibility of their use when working with potentially hazardous materials and in production environments where there are increased risks for personnel. Using robots to perform relevant operations can reduce direct contact of workers with toxic or flammable substances and, accordingly, increase the level of industrial safety.

Another area of application of cobots is automated quality control of renewable energy components. Robotic systems can perform programmed inspections and tests of finished products, ensuring their compliance with established standards and technical specifications. This makes it possible to reduce the likelihood of defects and increase the reliability of finished components.

The use of robotic systems can also contribute to reducing the carbon footprint of production processes. Program control of technological operations makes it possible to optimize energy consumption and reduce the amount of production waste. As a result, robotics can ro be seen not only as a means of increasing productivity, but also as one of the tools for increasing the environmental efficiency of production.

CONCLUSIONS. The analysis shows that collaborative robotics has significant potential for application in the production of renewable energy components. The use of cobots makes it possible to automate repetitive, physically complex and potentially dangerous operations, while maintaining the possibility of interaction between the robotic system and the worker.

The use of collaborative robots in the production of solar panels, wind turbine components and battery systems potentially contributes to increasing productivity, stability of technological processes and quality of finished products. Additional advantages are a reduction in the risk of industrial injuries, a reduction in the impact of the human factor and optimization of the use of material and energy resources.

An important aspect is the possibility of using cobots in clean production facilities and during operations requiring high accuracy. This makes it possible to reduce the likelihood of contamination of components and errors associated with the human factor, as well as to ensure more stable compliance with established technical requirements.

Collaborative robots can also partially compensate for the shortage of production personnel by taking over monotonous and physically complex operations. At the same time, their use does not mean the complete elimination of humans from the production process: the most effective model is one in which the robotic system performs standardized and repetitive operations, and the worker focuses on tasks that require decision-making, control, and professional experience.

However, there are certain limitations. The need to ensure safe interaction with a person may lead to a decrease in the speed of the cobot's work while the operator is in its work area. Therefore, when designing a robotic production area, it is necessary to take into account the compromise between productivity and safety requirements.

Further improvement of machine vision and artificial intelligence technologies can significantly expand the functional capabilities of collaborative robots. The use of lidars, 3D cameras, and sensor fusion technologies allows you to increase the ability of robotic systems to perceive the environment, recognize objects, and respond to obstacles or unpredictable movements of workers..

LITERATURE

1. Keshvarparast, A., Battini, D., Battaia, O. *et al.* Collaborative robots in manufacturing and assembly systems: literature review and future research agenda. *J Intell Manuf* **35**, 2065–2118 (2024). https://doi.org/10.1007/s10845-023-02137-w.

2. Borboni, A., Reddy, K.V.V., Elamvazuthi, I., Al-Quraishi, M.S., Natarajan, E. and Azhar Ali, S.S. (2023), "The expanding role of artificial intelligence in collaborative robots for industrial

applications: A systematic review of recent works", Machines, Vol. 11, No. 1, Article 111. DOI: https://doi.org/10.3390/machines11010111

3. Yevsieiev V. Development of a model for constructing the optimal trajectory of the gripping device of a collaborative robot-manipulator taking into account the influence of the cargo mass and energy consumption / V. Yevsieiev, D. Gurin // Відкриті інформаційні та комп'ютерні інтегровані технології. – 2026. - № 107. – С. 224-240. - https://doi.org/10.32620/oikit.2026.107.15..

4. Abdous, M. A., Delorme, X., Battini, D., & Berger-Douce, S. (2022). Multi-objective collaborative assembly line design problem with the optimisation of ergonomics and economics. International Journal of Production Research. https://doi.org/10.1080/00207543.2022.2153185

5. Yevsieiev V. Development of a model for constructing the optimal trajectory of the gripping device of a collaborative robot-manipulator taking into account the influence of the cargo mass and energy consumption / V. Yevsieiev, D. Gurin // Відкриті інформаційні та комп'ютерні інтегровані технології. – 2026. - № 107. – С. 224-240. - https://doi.org/10.32620/oikit.2026.107.15.

6. Yevsieiev, V., Gurin, D., Kulish, S., & Voloshyn, Y. (2025). Development of a partially supervised Markov decision-making model for a 3-link collaborative robot-manipulator. Radioelectronic and Computer Systems, 2025(4), 83-94. https://doi.org/10.32620/reks.2025.4.06.

7. Attar, H., Abu-Jassar, A. T., Yevsieiev, V., Lyashenko, V., Nevliudov, I., & Luhach, A. K. (2022). Zoomorphic mobile robot development for vertical movement based on the geometrical family caterpillar. Computational intelligence and neuroscience, 2022(1), 3046116.

8. Abu-Jassar, A. T., Attar, H., Amer, A., Lyashenko, V., Yevsieiev, V., & Solyman, A. (2025). Development and investigation of vision system for a small-sized mobile humanoid robot in a smart environment. International Journal of Crowd Science, 9(1), 29-43. https://doi.org/10.26599/IJCS.2023.9100018

9. Gurin, D., Yevsieiev, V., Maksymova, S., & Abu-Jassar, A. (2024). Effect of Frame Processing Frequency on Object Identification Using MobileNetV2 Neural Network for a Mobile Robot. Multidisciplinary Journal of Science and Technology, 4(8), 36-44.

10. Hamdan, M., Abu-Jassar, A., Essa, M. A. B., Maksymova, S., Yevsieiev, V., & Lyashenko, V. (2026, April). Hybrid Navigation Model of a Mobile Manipulator Robot: Combination of Global Planning and Local Dynamic Optimization. In 2026 International Conference on Artificial Intelligence for Sustainable Engineering and Innovation (AISEI) (pp. 518-524). IEEE. https://doi.org/10.1109/AISEI68628.2026.11572980

11. Yevsieiev V. Digital Twin in Modeling and Control of Collaborative Robots: Analysis, Comparison and Application Recommendations / V. Yevsieiev, S. Starikova // Computer-integrated technologies, automation and robotics 2026 : Proceedings of III st All-Ukrainian Conference, May 14-15, 2026. - Kharkiv .: [electronic version], 2026. - P. 89-92.

12. Hamdan, M., Ababneh, J., Hafez, M., Abu-Jassar, A., Yevsieiev, V., & Lyashenko, V. (2025, December). Collaborative Manipulator Adaptive Path Planning with Human Presence and Comfort Zone Consideration. In 2025 Asian Conference on Communication and Networks (ASIANComNet) (pp. 1-8). IEEE. https://doi.org/10.1109/ASIANComNet68615.2025.11579621

13. Attar, H., Abu-Jassar, A., Hamdan, M., Hafez, M., Yevsieiev, V., & Lyashenko, V. (2025, December). Stochastic Model of Collaborative Robot Interaction in a Manufacturing Environment. In 2025 Asian Conference on Communication and Networks (ASIANComNet) (pp. 1-6). IEEE. https://doi.org/10.1109/ASIANComNet68615.2025.11579675

14. Abu-Jassar, A., Attar, H., Hafez, M., Hamdan, M., Yevsieiev, V., & Lyashenko, V. (2025, December). Adaptive System for Constructing a Mobile Robot Trajectory Using Neural Network and Stochastic Optimizer. In 2025 26th International Arab Conference on Information Technology (ACIT) (pp. 422-428). IEEE. https://doi.org/10.1109/ACIT68900.2025.11510567

15. Nevliudov I. Sh., Yevsieiev V. V., Jabrayilzade E. A. Intelligent Motion Planning of a Collaborative Mobile Robot in a Dynamic Environment Based on VFH+ and Semantic Processing of LIDAR and Video Data // Visnykof Kherson Nationaltechnical University. 2026. 2(97). P. 295-309. https://doi.org/10.35546/kntu2078-4481.2026.2.36