SpinBOT KIT THE NEW GENERATION OF ROBOTS – ANALYSIS OF OPERATING CHARACTERISTICS

JURAJ SMRCEK[1], PETER SMERINGAI[1], ANNA SMERINGAIOVA[2]

[1] Spinbotics s.r.o., Kosice, Slovakia

[2] Technical University of Kosice, Faculty of Manufacturing Technologies with the seat in Presov, Slovakia

DOI: 10.17973/MMSJ.2022_12_2022010

e-mail: anna.smeringaiova@tuke.sk

The reconfigurable robotic system SpinBOT Kit represents a new generation of robotic technology designed to solve the automation and robotization of production, non-production processes and service processes, with wide use in various sectors of industrial and non-industrial sectors and in municipal services. This paper presents an analysis of the parameters and characteristics of this reconfigurable robotic system. The system enables configuration of the robotic arm, manipulator or robotic peripherals with different kinematics and with different number of degrees of freedom.

KEYWORDS

intelligent robotic system, collaborative robots, modularity, flexibility, safety, operating characteristics, reconfiguration

1 INTRODUCTION

The dynamic penetration of robotization into all processes in the industrial and non-industrial area, as well as into human activities and human life currently brings new requirements for the properties and functions of robotic technology [Trojanova 2021]. This reality is also reflected in current trends in the development of robots. According to [Bozek 2021] and [Kalamkar 2021], properties such as modularity, flexibility, collaborativeness, intelligence, ease of installation, commissioning, programming, safety are priority requirements for modern designs of industrial robots (PR). These requirements are particularly pronounced with the current advent of collaborative robots (Cobots) which are characterized by lower operating costs, operational flexibility and safety, simple operation, quick integration and connectivity. This favors them especially for production, where small series of individualized products are produced. In such establishments, according to [Smrcek 2007], there is a need to automate sub-processes running concurrently with work performed by humans. [Dyadyura 2021] also states the requirement for agility and flexibility in the automation of various processes. Such manufacturers need quick solutions for automating their production in a limited space and without the need to hire a highly specialized worker - a roboticist.

2 ROBOT CHARACTERISTICS

Robotics already has established standards [ISO 8373 2021], which define and delineate the interpretation of the industrial robot and its relational contexts. Deployment of PR in a robotic workplace (RTP) for the implementation of manipulation or technological operations, requires, according to [Tolnay 2012], in addition to a systemic approach to the design and implementation of RTP and the compatibility of its subsystems, also to ensure the safety of RTP operation in relation to the operator of the workplace (human). The solution is that the PR handling zone is defined by protective elements. In Fig. 1 is an example [Daily Automation 2022] of increased protection that meets the strict safety standards specified in [ISO 10218-1 2011, ISO 10218-2 2011]. In addition to the protective cover, the workplace is equipped with an externally connectable hardware module based on a safety PLC, which increases the safety functions of the robot. The overall application can be imagined as a robot which workspace is limited by, e.g., light scanners. These scanners define the zones in which the operator can move. When entering the first zone, the robot will slow down to a predefined speed. After crossing the zone closer to the robot, the robot will stop.

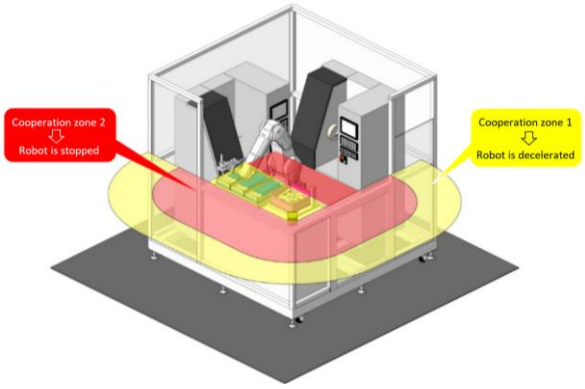

Figure 1. Workplace with MELFA SafePlus safety module [Daily Automation 2022]

Unlike standard industrial robots, Collaborative Robots (COBOTS) are designed in such a way that they are able to work closely with humans and share a common space with them [Vysocky 2016, Vicentini 2020]. The requirements for a COBOT cooperating with a human are determined by the technical specification [ISO/TS 15066 2016], which complements the requirements and instructions for the implementation of COBOTs specified in the standards [ISO 10218-1 and ISO 10218-2]. These documents describe the following techniques for collaborative operation of COBOT with a human:

- monitored safety stop,
- manual guidance of the robot,
- speed and separation monitoring,
- limiting power and strength.

Safety of operation of PR or COBOT in the mentioned contexts is given by the concept of the solution and the design and operational characteristics of the given robot. In order to assess the parameters, properties and capabilities of industrial robots, a generalized set of construction-operational characteristics and technical parameters of the robot, arranged according to relative and functional dependence for determining the properties and capabilities of the robot for the specified task, was introduced [Smrcek 1981, Palko 2010, Smrcek 2013]. List in Tab. 1 represents the basis from which a selection of specific parameters is compiled for assessing the robot's properties for a specific application or for a specific assessment.

Table 1. Robot characteristics

Robot characteristics		
Group	Subgroup	Parameter
Geometric	Workspace	–location, shape, limits, –work zones, –work paths, ...

	Geometric Accuracy	– straightness of movement direction, – perpendicularity of the movement direction,...
	Working Accuracy	– positioning accuracy and repeatability, – path accuracy and repeatability, – peak deviations, – distance accuracy and repeatability,...
Static	Static Accuracy	– static stability, – positional stability,...
	Static Stiffness	– static stiffness, – flexion of the shoulder,...
Kinematic	Kinematic Structure	– num. of degrees of freedom, – kinematic structure, – ranges and limits of movement,...
	Movement Parameters	– track speed, – accuracy and repeatability of track speed, – acceleration of movement, – time courses of movement, – uniformity of movement,...
Dynamic	Dynamic Stiffness	– dynamic stiffness, – position stabilization time, – position drift, – natural frequency, – acceleration extremes,...
	Strength Parameters	– axial forces, – impact forces, – supplementary moments, – driving forces of the movement unit,...
Power	Load	– load capacity, maximum load, – load limitations / motion parameters,...
	Power Parameters	– electric input, power, – engagement torque,...
Operating	Operating parameters	– number and level of inputs/outputs, – machine cycle (progr. length), – reconfiguration time, – maintenance coefficient, – operating costs,...
	Safety of operation	–degree of ingress protection –noise, –interference immunity, –blocking / function of safety circuits, –limits, –central stop function, –safety functions, –safety monitored stop, –manual guidance, –limitation of power and strength, –speed and distance monitoring,...
	Operating restrictions	–climate-technological resistance, ...
Reliability	Reliability	–indicators according to STN,
	Service Life	–indicators according to STN.

3 SpinBOT Kit - ROBOTS OF NEW GENERATION

SpinBOT Kit in Fig. 2 is a reconfigurable robotic system that, thanks to a unique combination of hardware modules with SW and Cloud services, allows user to configure and assemble robotic devices tailored to a specific application.

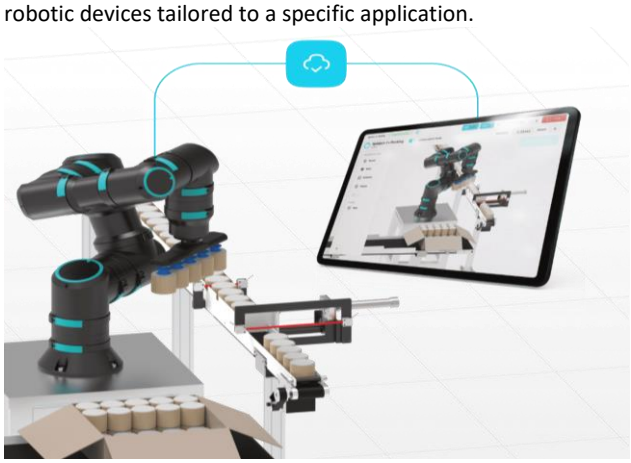

Figure 2. SpinBOT Kit for Modular Automation [Spinbotics 2022]

Table 2. Technical information [Spinbotics 2022]

SpinBOT Configurations	
Payload	up to 20 kg
Reach	up to 1500 mm
Degrees of Freedom	1 to 7
Working Range Possibility	n x 360°
Maximum Speed	± 120 to ± 225°/Sec
Maximum Linear Velocity	up to 1,5 m/s
Repeatability	less then ±0.1 mm
IP Classification	IP54
Noise Level	Comparatively silent
Robot Mounting	Any orientation
Mounting Flange	ISO 9409-1-50-4-M6
Materials	Aluminium / ABS
Ambient Temperature Range	0 - 50 °C

The system makes it possible to create a configuration of the robotic arm, manipulator or robotic peripherals with different kinematics and with different degrees of freedom. Using a reconfigurable mechatronic system, it is possible to assemble, for example, articulated robotic arms with 4 to 7 degrees of freedom (see Fig. 3).

Figure 3. Examples of robotic arm configurations

The concept of their construction is based on rotational movements in the main (positioning) movement system of the action mechanism and rotational movements in the secondary (orientation) movement system. The structure of the robotic

arm is composed of a basic base (Base Connector), a main arm composed of active (Drive Unit) and passive modules (Angled Connector, Straight Connector, Tool Connector), see Fig. 4. Described principle makes it possible to configure multiple kinematics of the robotic arm thanks to the available module base. A characteristic feature of the construction arrangement is the application of the integrated DriveBOT rotary actuator in the joints of the robot mechanism (it is characterized by the integration of the electric motor into the gear block, which are together with the sensing technology, electromagnetic safety brake, controller, processing and distribution of data and power, included into one compact functional unit).

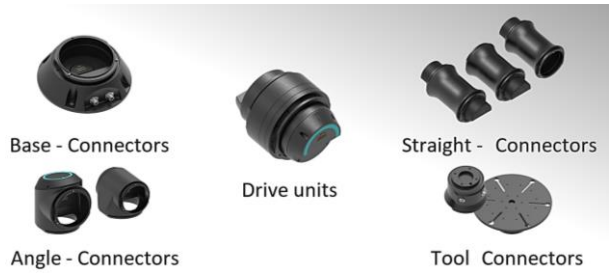

Figure 4. Basic SpinBOT Kit Modules

The SpinBOT Kit reconfigurable system platform composed from five sets of system-arranged modules (see Fig. 4), creates a sufficient system and technical base of components, based on the principles of modular architecture, for assembling robots / cobots that meet the requirements of the application (flexible construction concept).

Characteristic features of this system are:

- *Internal modularity*, built into the internal structure of the modules, enabling the assembly of several module modifications, the modifications represent different performance and parametric lines and designs.
- *External modularity,* built into the external design of the modules, allowing each module to be used for assembling (connecting the modules to each other by rigid connection) of higher functional assemblies of robotic devices of various configurations and kinematic structures.
- *Configuration and reconfiguration of robots,* enables by simply interconnecting the specified modules to assemble an organized functional configuration of the robot according to the requirement. Enables by simply disconnecting such an assembly and changing the interconnection and arrangement of its own modules to assemble a new robot configuration with the possibility of exchanging modules for other types. This feature of the system is unique (current types of robots do not have this option).
- *Broad SW support*, built on the basis of a modular structure and programming, the support structure (modules – installation / configuration / initialisation, security configuration, programming, operation monitoring) is built on the principles of distributed control with the possibility of connecting control systems to local networks, fulfills the requirements for discrete, combined continuous - discrete and logical control.

The mentioned characteristics and their features allow SpinBOT Kit to be classified as a new generation tool for solving the automation and robotization of production, non-production and service processes. The SpinBOT Kit system makes it possible to assemble industrial and at the same time collaborative robots according to the needs of the deployment project, i.e. the kinematic structure and morphological structure of the robot that directly corresponds to requirements of its operational use.

4 ANALYSIS OF OPERATING CHARACTERISTICS OF SPINBOT KIT ROBOTIC ARM

The novelty of the concept and solution of the robot assembled from the SpinBOT Kit reconfigurable robotic system is clearly reflected in its operating characteristics. Significant benefits from the point of view of its applications in production automation or handling processes are:

- Fully digital integration and deployment process.
- Remote control and maintenance.
- Adaptable end-to-end turnkey solutions and robotic devices.
- Cloud-based analytics, interfaces and features.
- Zero lines of code.

Regarding configured robotic device deployment and fulfillment of its technical requirements for the safety of its operation in the project deployment. Using the set of characteristics and parameters listed in Tab. 1. assessment of the suitability of the robotic device configured using the SpinBOT Kit robotic system can be undertaken.

The technical and performance characteristics of the robot are determined by the chosen concept and principles of solving its mechanical part, as well as the concept of solving its control and programming [Boborovsky 2012]. The reconfigurable conformation concept of the SpinBOT Kit system modules (drive, structural, connection, control) creates a sufficient base of components with a capability for simple mechanical and control/signal connection and disconnection in various kinematic structures (kinematic characteristics, number of degrees of freedom, ranges and limits of movements...). The design of the connector connections of the modules (unified element) guarantees the unambiguity of the connection and together with the system of conducting / connecting power and signal distributions, guarantees the reliability, strength and durability of the connection and transmission of energies and signals (characteristics of stiffness, working accuracy...). The drive module (Drive Unit) with the integrated DriveBOT rotary actuator has minimal dimensions and weight due to DriveBOT solution and internal arrangement (variable links). The construction of building and connection modules also contributes to the minimization of their dimensions and weight, which is positively demonstrated in geometric (spatial layout, working precision...), kinematic (speed, acceleration...), dynamic (stiffness, movement forces...), and power (energy distribution in motion modules, efficiency, engagement torques...) characteristics of the robot. The reconfigurable concept of the hardware modules of the SpinBOT Kit system supplemented by a distributed control system ensuring control, programming, data processing and other software support, guarantee simple and comfortable tending and operation of the robot (control characteristics).

Software modules with a user-friendly interface provide the end user with the tools for:

- configuration of the optimal robotic structure with respect to its project use,
- correct assembly and initialization of the robotic device at its place of operation,
- simple programming (graphical programming system),
- data storage, data analysis and planning of maintenance or further reconfiguration of the device (solution through Cloud or On Premise services).

The operational characteristics of the robot are based on the concept and solution of its mechanical part and the application of SW tools and cloud services in the entire process of configuring the robotic device, its initialization, programming, control and monitoring of its operation. The reconfigurable construction concept of the mechanical part

gives the possibility of quick, simple and unambiguous disassembly, assembly (replacement and exchange of modules) of the operating assembly. The built-in visualization of the module operational status gives the operator direct information about its operability. Initialisation procedure and programming procedure, with their simplicity and comfort for the operator, shortens the execution time of the related modes in the operation of the robot. Thanks to analytical tools, it is possible to plan maintenance and the use of modules or entire robotic devices. Built-in safety systems are developed in accordance with applicable standards. The mentioned features guarantee that the indicators of these characteristics (maintainability, repairability, diagnosability, reconfiguration flexibility,...) of robotic arms configured from the SpinBOT Kit system are at the level of current types of cobots and that some indicators (flexibility, reconfigurability, promptness,...) exceed this level thanks to their reconfigurable concept.

5 CONCLUSIONS

It is appropriate to understand the assessment of robots / cobots in such a way that it is not an assessment of the execution of specified tasks by a robot in the same way as a human, but rather the achievement of the same result of the robot's activity together with the guarantee of the safety of mutual cooperation [Smrcek 1998, Ranz 2017].

The operation of robots / cobots, according to current trends, should in any case be more flexible, easier to program with simple operation and maintenance and with the possibility of synchronizing the activity of robots with other types of devices and the possibility of connecting them to central control. The framework of this trend predetermines the need for the development of robots of a new concept, which will fit into the trends of the development of production systems and their operation.

The reconfigurable robotic system SpinBOT Kit represents a new generation of robotic technology designed to solve the automation and robotization of production and non-production processes and tending processes, with wide use in various sectors of industrial and non-industrial sectors and in municipal services. The analysis of the parameters and characteristics of this system presented in the article confirms that robotic devices assembled from this reconfigurable system are at the level of current types of cobots and in some parameters and indicators they exceed this level, respectively they are unique (configuration and reconfiguration).

ACKNOWLEDGMENTS

Authors thank for supporting this research by grant VEGA 1/0823/21 of Agency of Ministry of Education, Science, Research and Sport of the Slovak Republic and by the Slovak Research and Development Agency under contract No. APVV-18-0316.

REFERENCES

[Boborovsky 2012] Boborovsky, Z., et al. Self-Reconfigurable Modular Robotic System. Acta Mechanica Slovaca, 2012, Vol. 16, No. 3, pp. 6-10. ISSN 1335-2393.

[Bozek 2021] Bozek, P., Krenicky, T., Nikitin, Y. Editorial for Special Issue Automation and Robotics: Latest Achievements, Challenges and Prospects. Applied Sci., 2021, Vol. 11, 12039.

[Daily Automation 2022] Podolan, L. Mitsubishi electric industrial robots. Daily Automation, 2022. [online] Available from <https://www.dailyautomation.sk>.

[Dyadyura 2021] Dyadyura, K., et al. Modeling of the Manufacturing Systems State in the Conditions of the Lean Production. MM Science J., 2021, Vol. June, pp. 4408-4413.

[ISO8373 2021] ISO 8373. Robotics – Vocabulary, 2021.

[ISO10218-1 2011] ISO10218–1. Robots and robotic devices - Safety requirements for industrial robots - Part 1: Robots, 2011.

[ISO10218-2 2011] ISO10218–2. Robots and robotic devices - Safety requirements for industrial robots - Part 2. Robot systems and integration, 2011.

[ISO/TS 15066 2016] ISO/TS 15066. Robots and robotic devices — Collaborative robots, 2016.

[Kalamkar 2021] Kalamkar, V. R. and Monkova, K. Advances in Mechanical Engineering. Singapore: Springer Nature, 2021. ISBN 978-981-15-3638-0.

[Palko 2010] Palko, A., et al. Robotics: technical means for automation of production processes: design, construction, solution examples. Presov: 2010. p. 384. ISBN 978-80-7165-807-8. (in Slovak)

[Ranz 2017] Ranz, F. et al. Capability-based task allocation in human-robot collaboration. Procedia Manufacturing, 2017, Vol. 9, pp. 182-189.

[Smrcek 1981] Smrcek, J. and Soltys, V. Basic characteristics of industrial robots and manipulators. In: Proc. of NC technology and precision parts. 1981, pp. 185-194.

[Smrcek 1998] Smrcek, J., et al. Performance Monitoring and Testing of Industrial Robots, Selection for Different Applications. In: Proceedings of INES 98 - Intelligent Engineering Systems. Vienna, 1998, pp. 451-455.

[Smrcek 2007] Smrcek, J. Metamorphic robots, theoretical and constructive approach to the solution. Acta Mechanica Slovaca. Kosice, 2007, Vol. 11, No. 3S/2007. pp. 135-144. ISSN 1335-2393. (in Slovak)

[Smrcek 2013] Smrcek, J. Robotics: methodology for deploying service robots. Kosice: TU, 2013. p. 203. ISBN 978-80-553-1523-2. (in Slovak)

[Spinbotics 2022] Spinbotics. [online] [2022-10-25]. Available from <https://spinbotics.com>.

[Tolnay 2012] Tolnay, J., et al. Production systems operation. Bratislava: STU, 2012. ISBN 978-80-227-3709-8.

[Trojanova 2021] Trojanova, M., et al. Estimation of Grey-Box Dynamic Model of 2-DOF Pneumatic Actuator Robotic Arm Using Gravity Tests. Applied Sciences, 2021, Vol. 11, No. 10, Art. No. 4490.

[Vicentini 2020] Vicentini, F. Terminology in safety of collaborative robotics. Robotics and Computer-Integrated Manufacturing, 2020, Vol. 63, 101921.

[Vysocky 2016] Vysocky, A. and Novak, P. Human – Robot Collaboration in Industry. MM Science J., 2016, Vol. June, pp. 903-906.

CONTACTS:

prof. Ing. Juraj Smrcek, PhD.
Ing. Peter Smeringai, PhD. MBA
Spinbotics s.r.o., Juzna trieda 82/A, 040 17 Kosice, Slovakia
+421 948 938 186, https://spinbotics.com
smrcek@spinbotics.com, smeringai@spinbotics.com

Ing. Anna Smeringaiova, PhD.
Technical University of Kosice
Faculty of Manufacturing Technologies with the seat in Presov
Bayerova 1, 08001 Prešov, Slovakia
+421 55 602 6313, anna.smeringaiova@tuke.sk