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AUTOMATION OF ASSEMBLY OPERATION BASED ON DUAL-ARM ROBOT

Urgency of the research. Automation as a whole, together with increasing of demands from customer push companies at all levels to the implementation of new and innovative solutions of robotic devices. This reason we consider as sufficient for realization of special customized solution for deployment at assembly operations.

Target setting. Purpose of article is to give an example how to increase a level of automation based on specific requirements that consists from assembly area.

Actual scientific researches and issues analysis. Actual research is nowadays focused at such problematics, because return of investments based on robotic devices seems to be reliable and people at workplace can realize and focus to another type of tasks.

Uninvestigated parts of general matters defining. Specific automated solution based on dual arm robot implementation into the assembly process brings us a new possibility for assembly flow realization together with required assembly sequence for whole operation.

The research objective. The aim of article is to provide an idea how to automate such manual assembly tasks with focus to robotic devices implementation.

The statement of basic materials. For realization of automated solutions is good to have a suitable material how to solve assembly sequence and assembly process.

Conclusions. Published article presents an innovative idea for dual arm robot implementation into the assembly process. Proposed assembly sequence based on human – robot cooperation at this specific workplace gives an example and view how automation of assembly processes can be solved.

Keywords: automation; assembly operation; dual arm robot.

Fig.: 4. **References:** 8.

Introduction. The emerging needs for automation in the increasingly wider range of applications in conjunction with planning in term of both: short and medium future points out to the investing and developing of dual arm collaborative robot technology as a means for top level of robotic technology. Dual arm collaborative robots are implemented into operation mainly due to increasing requirements for process automation, services or ergonomically unsuitable workplace conditions [1]. In workspace of an ergonomically improper workplace, there is a high risk of damage at assembled parts of the finished component as a whole by operators themselves. So, collaborative robots appear to be suitable innovative equipment, which has met with great acclaim especially in automotive companies. In order to ensure safe operation of this robotic equipment, it is not necessary to enclose a complete collaborative arm into a work cage. It can work safely right next to a human without causing any injury [2]. This is one of the first solutions presented regarding to the concept “Industry 4.0”.

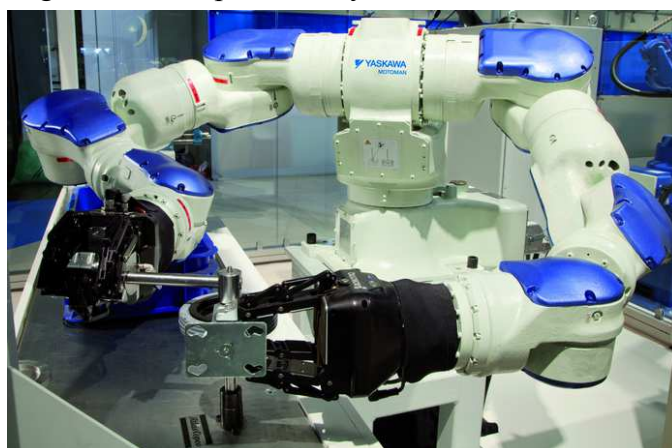


Fig. 1. Assembly operation using dual arm robot

Kinematics structure of this type of robot is ideally suited for assembly, setting or inspection operations depending on customer needs. They have an almost unlimited working space and thanks to their construction they occupy a small, space-saving area. Integration of drives and sensing technology directly into the interior of robotic arm prevents the risk of collision,

capturing of objects and humans. Reasons for deploying two-arm collaborative robots are summarized in the following points:

- Decreasing company operating costs thanks to the benefit in form of advanced robotic automation without usual additional costs associated with standard programming and adjusting work zones.
- Average payback period is within one year (typically about 195 days).
- Replacement of human operators in environments not suitable for them or dangerous (explosive, contaminated, etc.)
- Removing of monotonous operations and reducing accidents, this on exertion and repetitive movement threatens to the operator.
- Increasing of production capacity, quality, accuracy and production speed. Using of a robotic arm in a new assembly process automates every small-lot production operation with sufficient flexibility.
- Collaborative robotic arm is space-saving and can be quickly reprogrammed for cooperation with various machines. Extension of robots with additional peripherals can be individually adapted to installation requirements.

The assembly activities often require a collaborative robotic arm to accurately locate and grip of individual parts. Often is necessary to handle small parts of different shapes and sizes. In case that these devices taking on repetitive simple and monotonous repetitive tasks, they release operator for more creation of demanding and creative tasks.

Automated assembly of selected equipment. As a suitable example for realization of two-handed automation by a collaborative robot we choose a specific gearbox that is assembled into motorcycles, which is sold in several types. Gearbox is produced in series by company LIFAN, Fig. 2. Automation of such assembly activity requires determination of a stable components position and design of a suitable worktable for the both robotic arms [3].



Fig. 2. LIFAN 110CC gearbox

Systematic approach for achieving of optimum assembly activity range starting from initial planning of collaborative assembly as a whole, through determination of individual sequential handling operations, selection of peripheral devices, spatial layout, process decomposition into programmable sections, installation of collaborative workplace equipment for operation up to maintenance is presented in Table 1.

Table 1

Methodology for proposing of assembly sequence

1.	Determination of goals to be achieved with aim of collaborative robots.
2.	Strategic decisions about transformations in assembly - handling process.
3.	Analysis of assembly process and conditions for assembly - transport procedures.
4.	Selection of equipment into the collaborative workplace with regard to compatibility with working environment.
5.	Design of structure and spatial layout for individual parts of assembled object.
6.	Determination of input requirements for assembly process.
7.	Ensuring of links with working environment.

TECHNICAL SCIENCES AND TECHNOLOGIES

The responsible selection of optimal weighted decision matrix is based on design of assembly structure for assembly object, including known knowledge and methodologies for designing of such assembly activities or systematic approaches, as well as design and operation knowledge of similar collaborative applications [4]. Method should be used as a strong decision-making tool in cases where solution requires emphasis on each of considered criteria, usually of unequal weighted significance. Principle of method consists of evaluating weight (importance) for each criterion to be scored on a scale from 1 up to 10, so that grade 1 is assigned as lowest weight and grade 10 as largest. Same scale is used also as evaluation the fact that three variants of proposed solution by us meet selected criteria (mentioned above), i.e. level "1" - does not meet up to "10" - suits ideally. Table 2 shows resulting decision matrix for choosing optimal assembly process for assembled object.

Table 2

Weight decision matrix for choose of optimal assembly process for assembled object

Criteria	Weight	Evaluation of individual variant		
		Variant 1	Variant 2	Variant 3
Number of changes in position and orientation of assembled object	8	9	7.5	6
Assembly time	9	9	8	8.5
Number of tools and implements	6	7	6.5	7
Complexity of assembly process	4	9.5	5.5	8
Weighted sum		233	193	198.5
Rank		1	3	2

Individual variants of assembly process for assembled object were assessed on the basis of results of decision matrix, which shows that variant 1 is considered as best, it has highest score. The following criteria were considered:

- Number of changes in position and orientation of assembled object.
- Assembly time.
- Number of tools and implements.
- Complexity of assembly process.

In initial phase of creation and selection of suitable criteria to assess, it was necessary to develop a philosophy that optimizes conditions of this assembly process with respect to changes in position and orientation of individual parts for assembled object during time of process. Next phase involved selection of criteria for assessing the assembly process feasibility as proof that realisation exists. Suitable criteria that support this idea are e.g. experimental tests, measurement of assembly time and more [5]. The last stage during selection of assessed criteria was possibilities and ways for using simulation of automated projection systems in the form of CAD / CAM technology, enabling creation of an assembly scenario, so as to approximate as closely as possible to the structure of assembly workplace, Fig. 3.

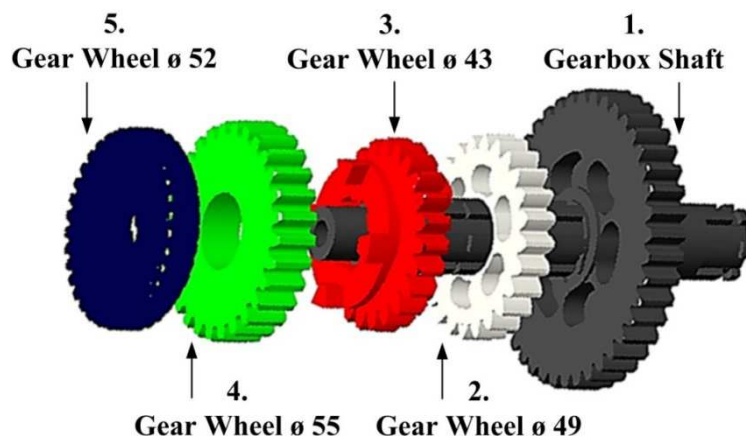


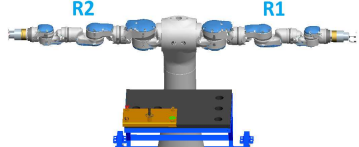

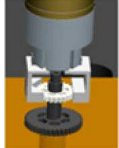
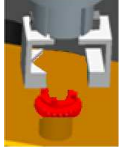
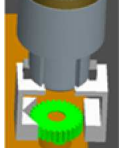
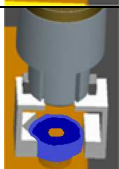


Fig. 3. Optimal composition of LIFAN 110 CC assembling

Assembly sequence for dual arm robot. It should be considered that creation of assembly scenario is a complex and important process of a wider problem - planning of collaborative assembly as a whole, which is mostly solved by partial tasks methods. Therefore, creation of assembly scenario is often carried out by IT software packages capable of generating, simulating and analysing of individual sequences for proposed assembly scenario according to the predefined conditions (assembly time, product quality, etc.). Assembly scenario of selected object is divided into 6 successive elementary steps, see Table 3.

Table 3

Assembly sequence for chosen equipment

Step	 Human activity	 Robot activity	Position
1.	Operator gives a command for starting of assembly sequence.	Robot is going to the initialising position for configuration before gripping of objects.	
2.	Operator prepares white gear wheel 2.	Robotic arm R2 takes a shaft 1. and inserts them into specific position at working table for next assembly process. Robotic arm R1 moves for white gear wheel 2.	
3.	Operator prepares red gear wheel 3.	Robotic arm R1 inserting white gear wheel 2.0 into position. Robotic arm R2 moves to position for taking of red gear wheel 3.	
4.	Operator prepares green gear wheel 4.	Robotic arm R1 inserts red gear wheel 3. Robotic arm R2 moves to position for green gear wheel 4.	
5.	Operator prepares blue gear wheel 5.	Robotic arm R1 inserting green gear wheel 4. Robotic arm R2 moves to position for blue gear wheel 5.	
6.	Operator completing of assembly process.	Robotic arm R1 inserts blue gear wheel 5. Robotic arm R2 moves to initial position.	

Sequence of assembly for collaborative application is divided between human and robot. Operator activities are focused on implementation of preparatory activities, resp. on inserting of individual parts selected assembled object, i.e. gearbox LIFAN 110 CC. Activity of dual-arm robot is directed mainly towards to the main activities, thus facilitating work for operator and accelerating overall assembly cycle time. For safety reasons, robot stops during operator storing of individual parts gearbox near robot's workspace as well as waiting for operator confirmation commands to continue mounting via control panel [6].

Used equipment for automated assembly. Assembly automation should be a substitute for single-purpose applications where greater flexibility is required. Wide possibilities for automation of assembly processes assume mastering of design solution based on modular principle, which enables realization of several variant dispositions, where basis of this entire concept is advanced intelligent control system [7].

Dual-arm robot

Main element for automation that is involved into the assembly process is dual-arm robot from company MOTOMAN SDA10F. Its main application area is assembly processes, packaging and handling [8]. The characteristic of its properties can be seen in Table 4. Robot workplace and dimensions see at Fig. 4.

Table 4

Main properties of dual arm robot

Number of robot axes	15 (7 per arm and 1 for base rotation)	
Payload	10 kg (per arm)	
Max. reachability	Horizontal direction: 720 mm Vertical direction: 1400 mm	
Repeatability	± 0.1 mm	
Maximal range of movements	rotation of waist	± 170°
	stroke	± 180°
	forearm	± 110°
	elbow	± 170°
	upper arm	± 135°
	rotation upper arm	± 180°
	stroke of forearm	± 110°
Maximal speed	rotation of waist	130 °/s
	stroke	170 °/s
	forearm	170 °/s
	elbow	170 °/s
	upper arm	170 °/s
	rotation upper arm	200 °/s
	stroke of forearm	200 °/s
weight	220 kg	
Max. permissible inertial moments	rotation of forearm	1 kg. m ²
	stroke of forearm	1 kg. m ²
	rotation of elbow	0.4 kg. m ²

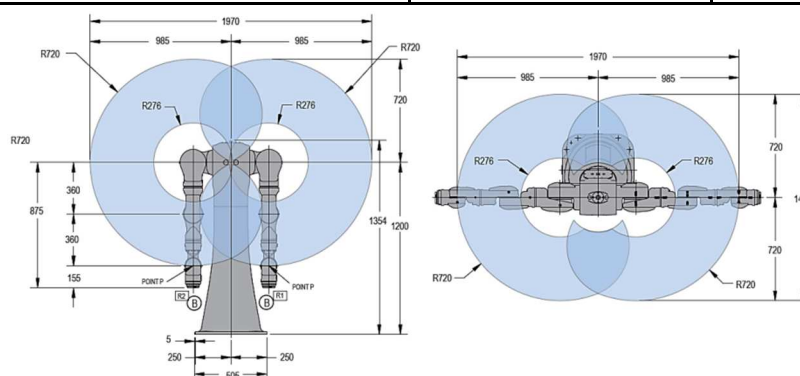


Fig. 4. Working envelope and dimensions of dual arm robot

Conclusions. Deployment of a dual-arm robot in order to automate assembly process and its suitable application into suitable solutions requires perfect preparation in design and also in the field of software equipment. His postulate for cooperative and synchronized movement among the arms and torso with full support of open control architecture will increase level of automation as a whole. In our case, task for dual-arm robot is primarily storing and positioning operations, thus they facilitating work of operator and thus is possible acceleration of overall assembly cycle time.

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АВТОМАТИЗАЦІЯ ЗБІРНИХ РОБІТ НА ОСНОВІ ДВОРУКОГО РОБОТА

Актуальність теми дослідження. Автоматизація взагалі, а також підвищення вимог компаній-замовників на всіх рівнях сприяє впровадженню нових та інноваційних рішень роботизованих пристроїв. Ця причина є достатньою для застосування на виробництві спеціального індивідуального рішення на операціях складання.

Постановка проблеми. Мета – навести приклад того, як підвищити рівень автоматизації на основі конкретних вимог, що висуваються на складальних операціях.

Аналіз останніх досліджень і публікацій. На сьогодні фактичні дослідження орієнтовані на проблему автоматизації процесу складання. У результаті впровадження роботизованих пристроїв працівники можуть зосередитись на інших видах роботи.

Виділення недосліджених частин загальної проблеми. Конкретне автоматизоване рішення, засноване на впровадженні дворукого робота в процес складання, дає можливість реалізації процесу складання в необхідній послідовності для всіх операцій.

Мета роботи. Мета статті – дати уявлення про те, як автоматизувати ручне складання з впровадженням роботизованих пристроїв.

Виклад основного матеріалу. Для реалізації автоматизованих рішень потрібно мати інформацію про послідовність та сам процес складання.

Висновки відповідно до статті. Опублікована стаття представляє інноваційну ідею багатозадачності робота в процесі складання. Запропонована послідовність складання, що базується на співпраці людини та робота на конкретному робочому місці, наведено приклад, як можна здійснити автоматизацію процесу складання.

Ключові слова: автоматизація; операція складання; дворукий робот.

Рис.: 4. Бібл.: 8.

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