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Robotics System Design for Assembly and Disassembly Process

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***Abstract*—**In this paper is described a new conception of the Cartesian robot for automated assembly and also disassembly process. The advantage of this conception is the utilization the Cartesian assembly robot with its all peripheral automated devices for assembly of the assembled product. The assembly product in the end of the lifecycle can be disassembled with the same Cartesian disassembly robot with the use of the same peripheral automated devices and equipment. It is a new approach to problematic solving and development of the automated assembly systems with respect to lifecycle management of the assembly product and also assembly system with Cartesian robot. It is also important to develop the methodical process for design of automated assembly and disassembly system with Cartesian robot. Assembly and disassembly system use the same Cartesian robot input and output devices, assembly and disassembly units in one workplace with different application. Result of design methodology is the verification and proposition of real automated assembly and disassembly workplace with Cartesian robot for known verified model of assembled actuator.

***Keywords*—**Cartesian robot, design methodology, assembly, disassembly, pneumatic

I. Introduction

AUTOMATED assembly and disassembly process is the actual trend of machine industry. The assembly process and also disassembly process in automation improvement is developed in the lower degree opposite to other industrial technological processes [1]. Environment is in present day constantly menaced by huge technological progress. This progress also has some consequences. For example one of them is that there is huge number of products with various shapes, dimensions, kinds or product ranges. The problematic questions are, what we will do after finishing of its life cycle, or what we will do with damaged or rusty product? In these days people are also talking about huge economic lucrative possibilities, which gives to us disassembly or recycle process of rusty or used product. To the end of life management strategies belongs reusing, reutilization and recycling. Before these end of life strategies we have to disassemble the product.

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For this will be used the same Cartesian robot for assembly process designed with respect to use for disassembly of the same product. Therefore it is important to rely on the developed tool for the design of the Cartesian assembly and disassembly robot with all requested peripheral devices and also the control of this equipment. The design methodology takes into the account the assembly and also disassembly process individual and both together in the conclusion. The advantage of the design of the automated assembly device also as disassembly device for same assembled product is the utilization of the same robot with devices for two processes of the same product.

II. Design Methodology of Automated Robotics System for Assembly and Disassembly

Each automated device consists of several building units such as suspension frame, manipulating equipment, working equipment, helping equipment, or control equipment [2]. The same building units have to be designed and created by design of automated assembly and disassembly device with robot. The bases for realization of design methodology are theoretical knowledge in the projecting of automated systems and in the automation, assembly, disassembly area and also practise realization of automated devices. The design methodologies are developed only for automated assembly and disassembly process. Automated assembly device can assemble final assembly product from the parts [3]. Disassembly process is defined as on reverse process of assembly. By proposition of the Cartesian robot conception it is required to detail analyze assembly process, disassembly process, control of processes and also assembled and disassembled product by design of assembly method [7]. Also it is needed to recognize and resolve automation process and the using of automation equipment. Assembly and disassembly automation suggests the various technical hardware using for automatically realization of assembly and also disassembly process individual sectors or complete on the ground of created control program. Selected and defined automation hardware is integrated to control system with control, coordinate and automate functions. Assembly and disassembly process control system is known as combined system integration of mechanical, sensor, actuating and control system.

III. Design of the Assembly System with Robot

Before the design of the assembly and disassembly equipment in workspace of the Cartesian robot is very important to realize the analysis of the assembled and disassembled product. Very important element in disassembly problematic is product life cycle. The disassembly process is nearly connected with the product life cycle. In the first time is the design of the product, assembling of the product. We can say that product life cycle is created by several parts, or

sections: creation section, maintenance section and end of life section (Fig. 1).

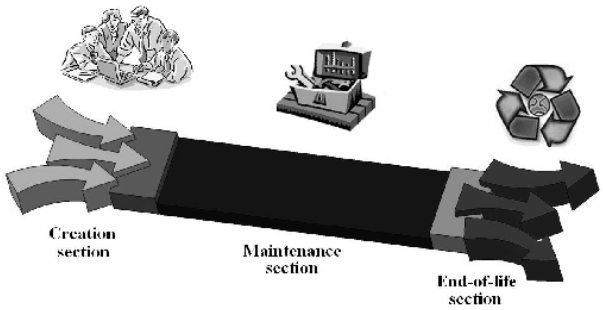

Fig. 1 Product life cycle

One of the specific characters of assembly process is often modification of assembled product shape and dimension and device have to adjust to it. Other specification of assembly is the increase of assembling parts quantity during assembly process [4]. Tendency of design methodology proposal is to standardize some procedures by design and realization of the automated assembly devices and machines. This standardized proceeding includes four basic levels (Fig. 2). Design methodology proceeds from analytical partition with using of known analytic methods through basic concept planning and concept solutions till to detail designing of assembling workplace and individual devices. Last level of methodology is the design of automated devices considering to before designed solutions of assembly devices in workspace.

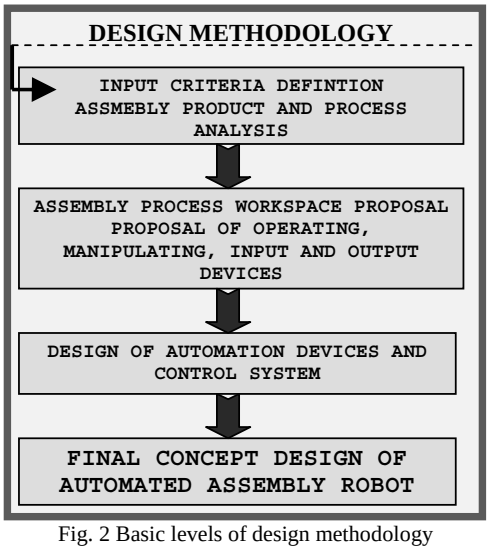

Fig. 2 Basic levels of design methodology

A. Input analysis of assembled process and product

Before design of equipment of automated assembly device with robot it is important to detail analyze assembled part in various terms. On the ground of parts basic analyze of assembled product, assembling advance, and choosing of assembly process structure is possible to create the proposition of automated assembly device design by using of design methodology.

The analyze of assembly group is possible to divide to this categories in a general (Fig. 3).

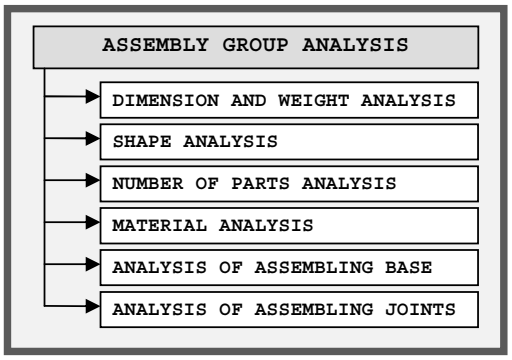

Fig. 3 Partial analysis of assembly group

B. Proposition of the assembly robot units

Second level of design methodology is a project part includes individual proposals of assembly devices and units that generate automated assembly system and provide for assembly process realization. (Fig. 4) This level also includes analysis and assembly sequence. On the basic of the first level of methodology, analysis of assembly group, is possible to define some parameters of automated assembly device. In a general is able to determine basic shape, dimension and complexity of final device. On the ground of analyzed parameters summary definition is able to define full parameters that are become a background for design of automated assembly device.

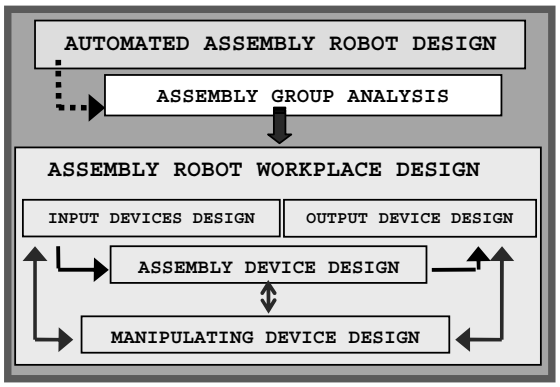

Fig. 4 Design methodology of assembly workspace

C. Input and output devices designing

Assembly process is characteristic by input devices quantity that provided for interaction connections between assembled parts. As a result of interconnections of input parts is assembled product. Input devices quantity depends on assembled parts quantity. For every to assembly process imputed part is necessary to propose design of device that included device for part delivery, separating, orientation, clamping and feeding (Fig. 5).

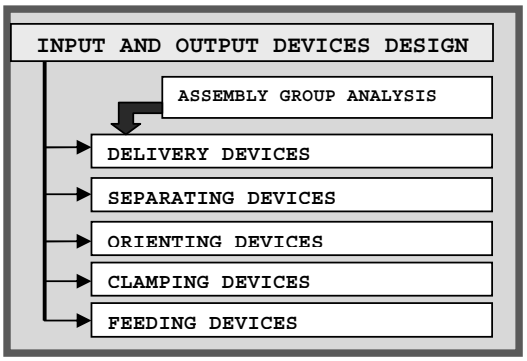

Fig. 5 Methodology of input and output devices design

Assembled product, assembly method and technological process have to be designed for simply assembly by help of automation equipment. This is the main condition for designing and generation of automated assembly device and automated assembly process realization. After fist level of method and analysis of assembly joints, assembly operations and creation of assembly sequence is possible to design the character and number of assembling devices.

D.Assembly units and devices designing

Assembly operation devices perform joints between parts term assembly. Before assembly operation units design has to be define the character and method of automated assembly process. Process of automation assembly can be various; continuous, linear or discontinuous. According to process type is chosen the type of assembly devices, manipulating devices and totally workplace of automated assembly device. If are the assembling operations dimensional and shaped similar then is able to use universal devices for assembly and manipulation. This type of device can realize all assembly operations. In the second case the assembly operations are standard different and then it is necessary to use individual assembly stations that are realized all assembly. Assembled product is sequentially moved to assembly station to next assembly part. Through integration of all assembly, input and output devices generates workplace for the manipulating device operated in.

E. Manipulating robot designing

Automated assembly device is produced by complex of workstations, input and output devices, assembly units worked in various work modes and various level of automation. For provision of automation assembly is required to provide automated interoperable manipulation between operation units in relation to specified assembly and technical sequence. Manipulating device as robot is characteristic as connecting element [6]. On the ground of assembly process analysis and assembly character is able to design the manipulating method. It is important to note to several parameters by choose of manipulating type. First aspect of note is assembly group analysis; concrete the dimension of imputed parts. A second criterion is number of manipulating stand. Manipulating stand is the place of manipulating device position. In this position it is necessary to stop in this position operate manipulating with parts, assembled product or assembling individual parts. This stop positions are exactly input, output, assembly or control units of automated assembly device. Manipulating device is characteristic as system of technical equipment with individual function and integral unite. Technical equipment of manipulating device is able to class into the individual function groups. There through is possible to design sequentially individual function parts and after that to configurate into one manipulating device by standards of design methodology (Fig. 6).

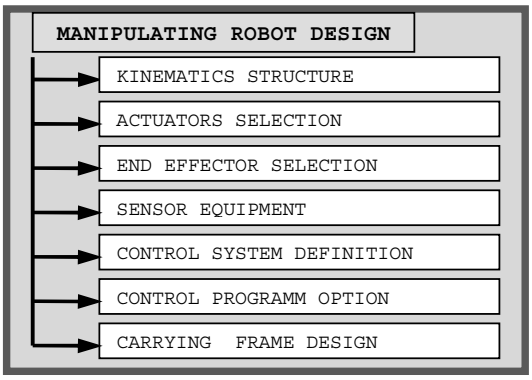

Fig. 6 Methodology of manipulating robot design

F. Design of the automation equipment and control system

Next level of design methodology is the proposal of automation devices and control system (Fig. 7).

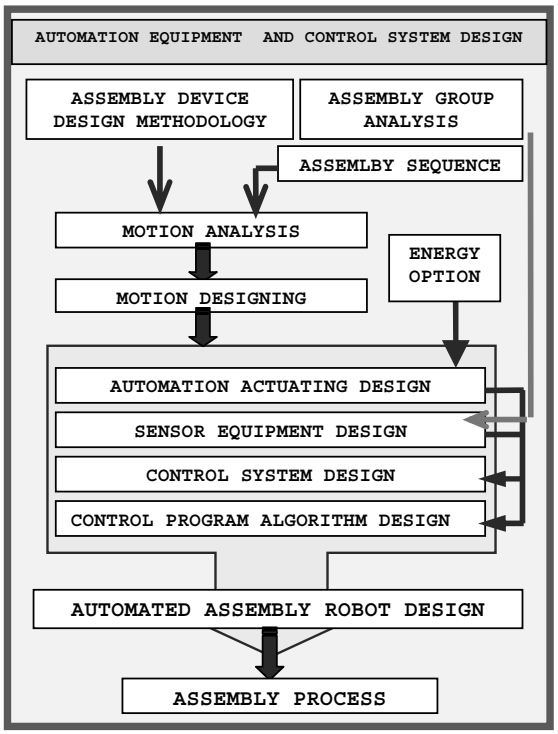

Fig. 7 Schematic chart of automated devices and control system design

These devices and equipment provide for automated assembly process performance. Technical equipment is defined and designed on the basic of before projecting and

projecting phase of design methodology and generation of assembly devices proposition. Consistent and depth assembly process and objects analysis provides for rational proposal of automated devices. It is existed a lot of technical devices of automation for automated assembly process realization. On the ground of experience and using of automated devices is chosen the type of automation equipment. In a general has to be design actuating parts, sensory parts, communicating elements and control system by design methodology in sequence. In the second level is able to design the control mechanism for assembly process monitoring and also emergency devices. On the ground of motion analysis is designed rational advantageous control mode of automation. Design methodology includes the definition and design of technical automation equipment with regard to assembly sequence and assembly character.

G.Disassembled product analysis

There is also very important to realize analysis of disassembled product before design of automated disassembly device. All information getting from this disassembled product analysis can be used for creation of proper disassembly method. In the first phase of disassembly method creation is important to focus on all movements which are realized during disassembly process. This way created disassembly method has to be supplemented by other information. With help of this information, there will be possible to create internal structure of disassembly method, or other alternatives of whole disassembly process. Ending of first analytical phase, which is used for disassembly method creation, is creation of disassembly method in form of disassembly combine procession diagram. In the other phase is methodology for design of automated disassembly device dealing about the choose of proper automation instruments. These choose is realized regarding to the created disassembly method and also regarding to the techniques of assembly joints destruction. Following to the choose of proper automation instrument, there is needed other one choose of building components of whole automated device. Last activity, which is really important for creating process of whole device, is choose of proper control system. These choose is partially given by kind of chosen automated instrument. This activity is also that one, which creates single steps of control, or whole control method
Input of most manufacturing of assembly technologies is analysis of manufactured or assembled product.

Disassembled product analysis is analyzing product from many views. Also design of disassembly device needs product analysis, which will look to the product from many valuation views. The number of valuation views can be different; usually the number depends on complexity or largeness of whole disassembled block. Valuation views which are valuated disassembled product can be divided in the five groups: disassembled element analysis according to the recycling kinds of single building products, disassembled elements analysis according to its influence to the environment, disassembled elements analysis according to the design materials of disassembled products, disassembled elements analysis according to the using assembly joints or according to the used assembly technologies and dimension and shape analysis of single products, which are used during the whole assembly process. Information which comes from these analyses is then used for identification of parameters which are limiting the following disassembly process.

H.Disassembly process design

For proper disassembly process design is necessary to know, the process which was used by its assembly. From that reason we use, as an input for disassembly process design, assembly processes and other assembly documentation and materials. It is important to suppose disassembly process all documentation prepares before the design of the assembly process. So, it is important to design both processes together.

I. Design of automated disassembly device

Methodology solves the automated disassembly device design in several levels, which are influencing one to another. First two solution levels are the design of elements which are creating the working space of whole device and design of disassembly device manipulation device. We have to use the same devices for the assembly process. Design methodology solves the character of manipulating and working places. For the manipulating and also input supply it is used the same devices that are designed for the assembly process. It saves time and costs in generally. Design process of manipulating device deals about design of power unit, design of clamping units, design process of clamping jaws. During the design process of manipulating unit, it is very important to focus on parameters such as load, dimensions, power, performance, manipulating repeatability, clamping dimensions and so on. For definition of these parameters the methodology it can be used the parameters from the design methodology of the assembly process. The next one activity which is realized in the design methodology is design of control unit. This activity includes the design of control elements, design of processing elements, design of storage elements, design of control elements and design of signal elements. It is the only one element of the disassembly robot which has to be design independently. Main area of this activity is focused on the design of control algorithm of automated disassembly device, which will be realized in three steps. These steps are creating of step diagram, creating of progress table and creating of normalized tool called Grafcet. With connection of these three parts the design of whole automated disassembly device is can be realized.

IV. Design Application of the Design Methodologies to Verification of the Assembly and Disassembly Device with Robot

Proposition and generation of automated assembly and disassembly robotics system is a complex problematic that includes and makes provision for problematic of automated device generation and continuous connects with problematic of assembly and disassembly device design. Design process of automated assembly device requires tool for automation assembly and also disassembly device problematic. Result of

design methodology is the verification and proposition of real automated device for known verified model of assembled actuator.

A. Verified product analysis

Pneumatic actuator model consists of four basic parts in three various modifications (shape, dimension, material) and assembly process is realized by various methods [9]. On the basic of design methodology is important to make analysis of assembled product and process and thereafter to realize assembly sequence. The tool which can be used for such input data creation is for example step diagram, which is added by information taken from assembly product joints analysis and is showed on Fig. 8 [8].

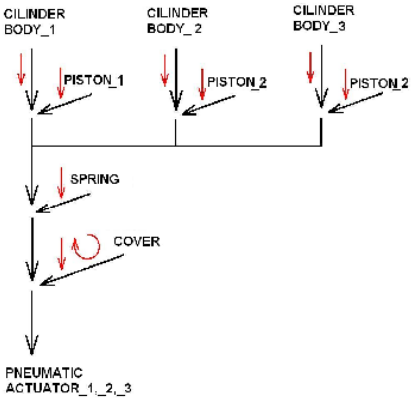

Fig. 8 Step diagram for assembly of pneumatic actuator

This way created assembly process can be later reworked by process of creating of reverse step diagram (Zvolenský et al, 2008). In case of more complicated design, not only reverse step diagram can be used. This solution needs, because of complicated and large design, the creation of internal structure, which wills simple whole this kind created diagram. Diagram doesn't include logical branching and conditions, which are needed for effective disassembly process. From this reason the reversed step diagram have to be supplemented by conditions and rules, which are presented by Petri net theory. This way created diagram is a combination of two kinds of disassembly process designs. This way created scheme offers more information which can be used for design of automated disassembly device. Using of logical functions is necessary. This way created diagram also deals about need of sensors equipment, which will be used for realization of disassembly device. On the other hand this scheme also shows basic movements which are needed for whole disassembly process and it's also shows need of movement actuators which will be needed for realization of whole disassembly device. Diagram of this type was specially designed and created for needs of automated disassembly devices design methodology and is also combined by automated devices design problematic [8].

B. Design of the supply devices for verified product

The projecting phase of design methodology included proposals of devices that are important in automated assembly and disassembly process. In this solution level are designed devices that generated workplace of automated device with robot. Assembly and disassembly device constitutes output device for final assembled or disassembled product delivery, input device for actuator body, spring, piston and cover, or assembled product and assembly or disassembly clamping device. Through the use of supply devices and workplaces integration is generated workplace for the manipulating device in that is operated (Fig. 9). It has to use the same devices for assembly and disassembly process.

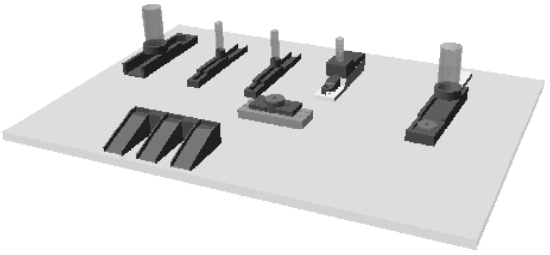

Fig. 9 Expected character of proposal devices workplace

C. Design of the Cartesian robot for verified product

The connecting device between all devices is the automated manipulating device. Basic concept of manipulator is its Cartesian kinematics and manipulating space is cubic. Manipulating device has to operate all devices and workplace positions on the ground of designed assembly devices. It means that manipulator axes have to provide for exact positions in all points. Manipulating device of this type is designed as Cartesian robot with three linear kinematics axes. It is possible to provide all positions of the workplace and all operations. On the ground of the analysis of the processes it is important to provide that the axes have to stay in exact positions in all points. This information increases the requirement to the design of the axes and its control. On the Fig. 11 is showed the proposal of the Cartesian robot axes. Rotary axis provides for the assembly or disassembly process.Also is important to design the end effector of manipulator that is universal for all parts grasping. The end effector provides for assembly and disassembly process.

Thereafter it is necessary to automate the assembly and disassembly process by help of next created technical control system. Control system provides for automated assembly or disassembly process realization. Design of automated devices is generated on ground of all motions analysis by assembly sequence and designed assembly devices. The automation equipment is used also for disassembly process. As a work medium for actuators is chosen compressed air. On the basic of motion analysis are generated pneumatic actuators that provide for automatic motion sequence (Fig. 12.). Control of the axes X and Y has to provide two proportional servo pneumatic valves because in this zone has to be operated all supply and assembly devices. The pneumatic servo axes have also measure system that provides the feedback to control system. Z axis is normally double operated pneumatic actuator.

Important element of device is sensor equipment that is generated on the ground of design methodology in three levels; actuators end positions checking, part in process detection and position and travel of manipulator axes [4].

Control algorithm as last part of system is the base for generation of control system and program. For design of control program are used methods: motions short entry, step diagram, sequence table and Grafcet [5]. All devices have to be mounted on the basic frame e.g. Activities such as working space character and manipulating device will have influence to the design of main frame and to the control unit design of Cartesian robot for assembly and disassembly process. The end of whole Cartesian robot design process is characterized by activity called collision analysis. This analysis defines single zones created in the working space of the device such as manipulating zone, working zone, non-usable zone, and so on. This activity defines the intersections of these zones and analyses possible collision stays. Final design of automated assembly device is showed on Fig. 10.

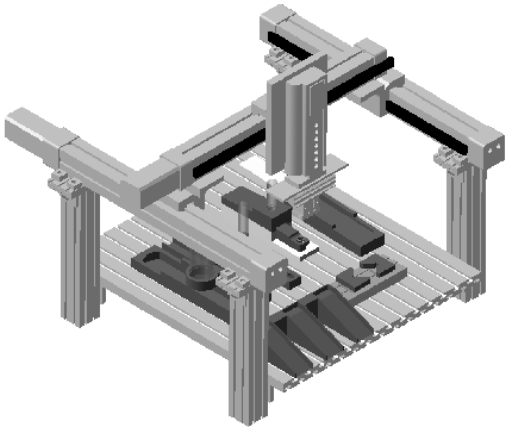

Fig. 10 Design of Cartesian robot for assembly and disassembly process

Cartesian robot for assembly and disassembly process is developed at our Institute laboratories. Cartesian robot consists of pneumatic servo axes and all support devices are also controlled by compressed air. On the Fig. 11 is whole model of the Cartesian robot.

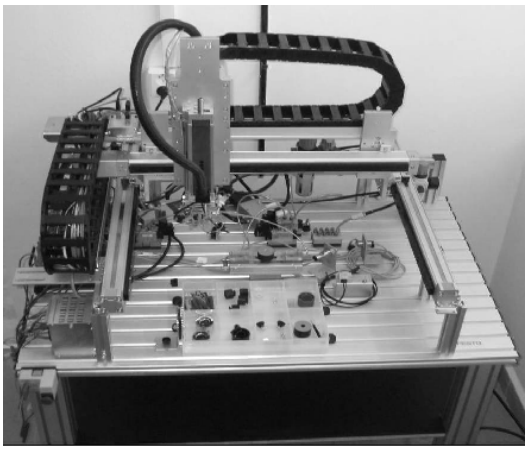

Fig. 11 Model of Cartesian robot for assembly and disassembly process

Manipulating, assembly and disassembly process provides the same Cartesian robot. Input delivery of the main actuator body or assembled product provides the same input device. It is important to produce input devices for assembled parts that are no required for disassembly. Assembly and disassembly process provides the same automated assembly device. For output delivery of the assembled product or disassembled parts is used the same output device.

V. Conclusion

Main contribution of the methodical compilation is a complex design methodology for generation of automated assembly Cartesian robot for assembly and disassembly of the same product. Methodology includes requisite analytic and proposal methods and procedures that are developed and modified for problematic about automated assembly and disassembly devices generation. By connecting of updated well known methods and specialized newly created methods a new methodology is created, and it is able to create working automated Cartesian robot for assembly and disassembly process. It can be defined characteristics of the advantage to design the disassembly device regarding to the same assembly process: save time to the design of the disassembly device, save costs for producers, save the environment and save the error rate of the assembly process, the product disassembly possibility in the assembly process.

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