AUTOMATED DISASSEMBLING AND ITS POSITION IN THE PROCESS OF PRODUCT RECYCLING

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Abstract: *Disassembling, together with assembling technology, creates sizeable part of manufacturing technologies in the area of manufacturing and post-manufacturing processes in industry. A large number of manual activities, that are needed to be gradually automated, prevail in disassembling technology. Topic of disassembling the machines and devices plays important role at present time due to the requirements of non-wasting economy and disposal of these devices after their lifetime is finished.*
Key words: *disassembly, automation of disassembly, product recycling*

1. INTRODUCTION

Products manufacture is often represented by complicated process under the frame of which the gradual change of raw materials, materials and semi-products to final product is performed. Product is influenced by less or more advanced system of manufacturing technologies. Manufacturing technologies reach high level in most areas at present time, what is also supported by good science-research activity developed mainly in the area of technologies of change of dimensions, shape and properties of products, which are exploited in realization of parts in production. But, product is rarely represented by one part, mostly; it is complex of parts that are mutually and functionally connected, realized by assembling technology, which task is to ensure the change of components relations. In the comparison with named manufacturing technologies, assembling is not such completely developed; its level falls behind the level of other technologies, but as a closing technology from the manufacture technological complex, by which the products flow, determines the final quality and deadline of final product manufacture and thus it is very important. The same importance is necessary to put to disassembling technology, which is equally demanding and its importance raises mainly with the effort to ensure and operate non-waste technologies [6, 9].

2. DISASSEMBLING AS A PART OF PRODUCT´S PRODUCTION CYCLE

The relation between design of new product and conception of disassembling system is comparable to the relation between design of new product and conception of manufacturing and assembling system. But, there is a time period between design of new product and finishing of its lifetime during which it is possible to develop disassembling technologies. It is rarely taken into account easy disassembling in designing present products, therefore the costs of their disassembling will be rapidly higher than it is needed [10].

Development of disassembling systems related to environment raises on value. Using the disassembling will enable reuse of assembling semi-groups, parts and materials and the disassembling is understood as an important part of recycling from this point of view. Used product is generally subjected to various effects and influences, which cause various signs of damage. This damage has important impact to product dismount ability. Products assembled from parts with different materials are necessary to be disassembled before their recycling or reusing. Change of product respectively material properties during their life cycle is shown in Fig. 1. High elaborateness is a weak property of disassembling. Common disassembling operations are mostly performed manually and only few numbers of them are performed automatically. Sizeable disassembling factories are very rare, since the processes such as disassembling of car require a lot of manual labor, supported by manual manipulation with tools. This work is physically demanding, dirty and sometime dangerous. Therefore, it is necessary to create organized, productive, highly mechanized and partially automated disassembling workplaces.

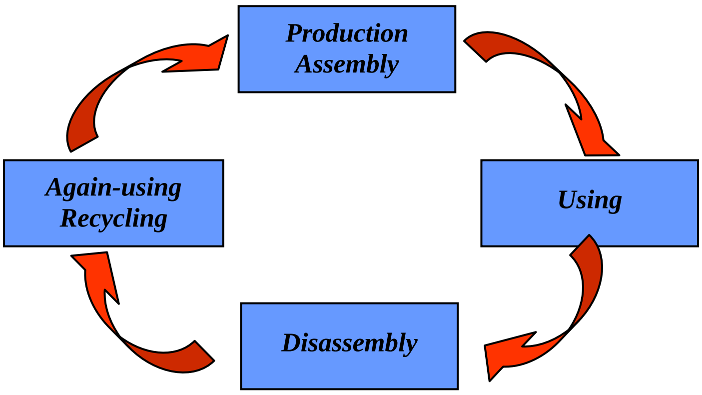

Fig. 1 Change of product properties in time of its lifecycle

A complex of consumer technical products such as cars, or household appliances is immediately disposed or demounted (crushed) at present time. Present methods of scrapping allow reusing of only several metals, which are prevailingly contaminated by fragments of other materials that results their failure to be certified in desired quality standards. High quality steel loses its value, what is often resulting in reusing it only as a building iron, since it contains a lot of impurities.

Non-metallic materials are often expensively disposed under special conditions without any material impurities. Disassembling of worn products, opposite to their disposing, can help to decrease their degree of damage and to return the materials, or complete assembly groups and subgroups back to manufacturing process simultaneously.

Prevailing use of nondestructive disassembling methods is necessary condition for valuable recycling of whole products. It puts high demands to intelligence of automated system, which has to react to different variants of products as well as to the product changes caused by its using (for example maintenance, emergency, contamination). The need of large quantity of specialized tools for removing, respectively destructions of assembling components and for performing many operations is typical for majority of nondestructive disassembling methods. Functional integration is required with regard to avoid frequent tool changes and thus to decrease total time of disassembling.

3. SPECIFICS OF AUTOMATED ASSEMBLING AND DISASSEMBLING

Manufacturers have to shorten their innovation cycles and manufacturing times in order to be able to keep and to increase the competitiveness of their products and under the frame of this to shorten the time of products assembling. It is often not possible to be ensured by improving the manual assembling organization and using the tools and fixtures, but it is necessary to automate assembling workplaces.

At present time, it is necessary to deal with the topic of products disassembling mainly with respect to responsibility of producers to ensure full product life time cycle in the frame of which it is necessary to solve also their disposal and re-circulation of products parts. This responsibility is also legislatively fixed in advanced industrial countries [3]. Efficiency of disassembling operations is conditional to assuring the assumptions for automated disassembling as similar as to assembling. At the same time, disassembling problems are in many aspects more difficult as assembling. It is necessary to take into account that disassembled products can be worn, corroded, damaged; their shape can be changed etc, which all influences the organization and used ways of disassembling. Automation of assembling and disassembling is most frequently assured by two basic ways [2]:

- exploitation of automated assembling and disassembling machines, which, if necessary, can be grouped to automatically controlled workplaces, and that are able to assembly or disassembly the groups of products,
- exploitation of flexible assembling, respectively disassembling devices.

Increasing the degree of automation and flexibility of assembling and disassembling workplaces is hard to realize without the use of robotic and manipulation devices. Industrial robots and manipulators enable to perform assembling and disassembling operations more safely and efficiently as a man performing manual assembling and disassembling. Important aspect of robots and manipulators use is that they simultaneously enable efficient realization of other manipulating and technological operations together with individual assembling and disassembling operations [4].

End-effectors of industrial robots and manipulators, assuring compact and safe object gripping respectively realizing technological operation during assembling or disassembling cycle, are their important parts from individual assembling and disassembling operations realization point of view in assembling and disassembling technological processes. Used end effectors of robots and manipulators are characterized by high assortment composition with large number of types, shapes and sizes. End effectors enable to realize also special technological operations during assembling and disassembling, for example screwing, drilling, thread cutting, covering by sealing films, riveting, soldering, welding, flame cutting etc. Selection of concrete end effectors of assembling respectively disassembling robot depends on application type, object mass and geometry. Conventional end effectors of these robots and manipulators are as follows:

- grippers and technological heads,
- special assembling and disassembling heads,
- systems of automated gripper and technological head exchange.

Using denoted conventional end-effectors discovers a set of insufficiencies and problems [5]:

- grippers of assembling and disassembling robots have to be specially constructed for assembled or disassembled objects in most of the cases,
- technological heads, which substitute grippers in realization of individual assembling and disassembling operations are also specially constructed and similarly as grippers equipped with own pneumatic, hydraulic, or electric drive,
- it is necessary to use the systems of automated effectors exchange in relation to large number of gripping and technological effectors during performing assembling and disassembling operations.

Non-conventional and universal end-effectors of robots and manipulators, which geometrically and functionally imitate human hand and are also known as biomechanical robot grippers, seem to be efficient tools removing the above-mentioned insufficiencies that are able to manipulate with parts of various shapes without the necessity to be specially set up in technological pallets, they manipulate and perform operations with common tools such as screw-drivers, fastening spanners, riveting jaws, welding torches, manual drills etc.

4. BIOMECHANICAL GRIPPERS IN ASSEMBLING AND DISASSEMBLING

Biomechanical grippers can perform either force operations in manipulating with parts and tools of higher masses, or soft operations, which are necessary mainly in assembling and disassembling the products. On the base of the analyses of human hand gripping activities as shown in Fig. 2, it is possible to define the requirements to activities onto the technical analogue of human hand – biomechanical gripper, which has to include mainly following types of tasks:

- soft gripping of manipulated object by clamping and manipulation,
- power gripping of manipulated object by clamping and manipulation,
- gripping of spherical object type and its manipulation,
- gripping of object by ends of fingers and its manipulation,
- gripping of object by function of type "jaws" and manipulation,
- gripping by "pen/pencil" function,
- free holding of objects by "loop" function,
- locking (prying) by finger of gripper,
- interaction with cooperating object of "keyboard" type

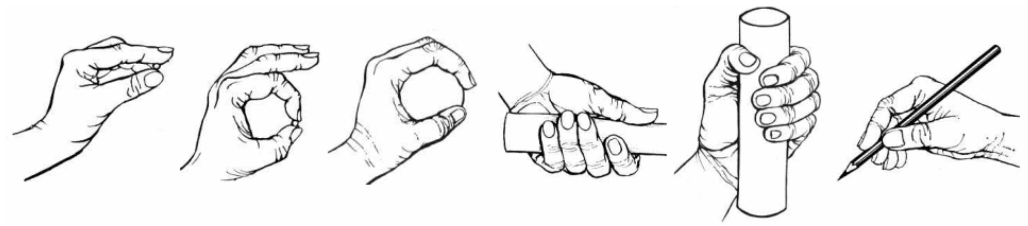

Fig. 2 Different types of gripping by human hand

Efforts to construct robotic biomechanical grippers start in beginning of 80 years of previous century. In 1982, two still most known constructions of robotic biomechanical grippers have been introduced, Salisbury hand developed by K. Salisbury in Stanford University (USA) and Utah/MIT smart hand developed by collective of workers of University of Utah and Massachusetts Institute of Technology under leadership of S. C. Jacobsen. Similar biomechanical grippers, in constructions of whose the human hand was taken as a model, have been gradually developed in Japan by workers of Hitachi (1984), in Italy on University of Bologna (1988) and Politecnico di Torino (1989), in Beograd (Yugoslavia) etc.

In Slovakia, three fingers gripper has been designed and made in Bratislava; it is based on materials with shape memory and has 11 degrees of freedom and compressive force 1N at the end of fingers determined for manipulation of the objects with dimensions from 15 to 40 mm. In 1994, TU Košice collective under leadership of J. Novák-Marcinčin has developed first version of biomechanical gripper (Fig.3a), based on similar principle as Torino hand, pneumatically driven with loading capacity up to 1,5 kg that manipulated with objects of diameter from 10 to 90 mm. It consists from three parallel fingers with three knuckles and one opposite thumb with one joint. Fingers and thumb are mounted to flat hand, which is made form aluminum alloy similarly as other subsections of fingers. Moves of individual knuckles are driven by four pneumatic linear motors placed in upper section of gripper. Second version of biomechanical gripper was developed in 1996 (Fig. 3b), it contains four parallel fingers and one opposite thumb with one joint. All sections of gripper are made from aluminum alloy and rubber "glove" coats construction. Simultaneous movement of finger group and thumb is driven by one electromotor placed in forearm of gripper, supplied by accumulators also placed in forearm. Maximal carrying capacity of biomechanical gripper second version is 2 kg, its width is 100 mm, its altitude is 85 mm and length 300 mm. Weight of gripper is 4 kg.

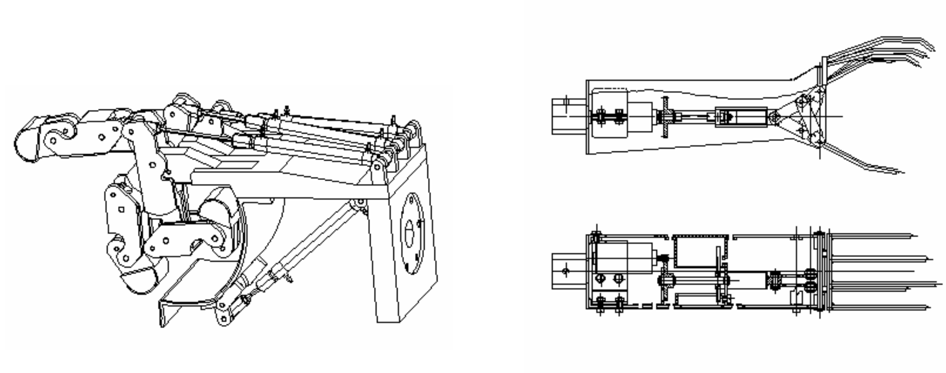

Fig. 3 Scheme of biomechanical gripper - version I a II

It is possible to use biomechanical grippers for the manipulation with parts of various shapes in the area of assembling and disassembling operations. Similarly, it is possible to use biomechanical grippers for manipulating and operating various tools and technological devices in the area of automated assembling and disassembling. Examples of manipulation of the biomechanical gripper with screwdriver, nut spanner and hammer are shown in Fig. 4.

Assembling and disassembling robotic biomechanical grippers enable to grasp and manipulate the objects of various shapes usually by three or more flexible fingers. These grippers are complex with difficult construction and financially demanding from the design point of view. Grippers designed on the base of knowledge about skeleton and functions of human hand are able to grasp, hold in flat hand and manipulate the objects such as for example electric handle driller, riveting pliers, and simultaneously to move and control their activity by button in accordance with requirements. These grippers are frequently very good equipped by sensors, and often work on the base of data acquired by visual systems [10].

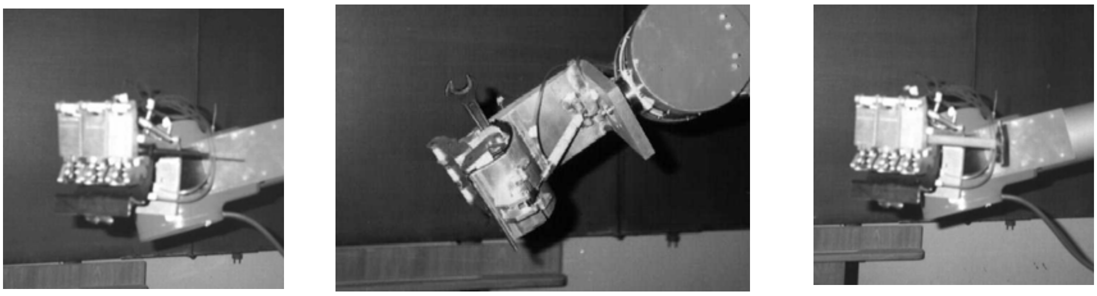

Fig. 4 Examples of manipulation with different types of tools

5. CONCLUSION

Complex automation of manufacturing processes is not possible without the realization of automated assembling and disassembling the products. It is defined individual part – computer aided assembly (CAA - Computer Aided Assembly) under the frame of CIM (Computer Integrated Manufacturing) [8]. It is possible to schedule assembly operations, simulate the process of automated assembling of parts to final product assembly, and also control automated assembling devices such as assembly machines, assembly robots and manipulators, transport routes etc by means of computer technique. Similarly, it is possible to define CADA systems (Computer Aided Disassembly), which are aimed to the area of products automated disassembly, what ensures environmentally suitable disposal after the end of their lifetime. The paper was created under the frame of solution of research task VEGA No.1/0405/03 „Computer Aided Technological Preparation of Production in the area of Disassembling Processes “.

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