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APPLICATION OF THE BIOMECHANICAL ROBOT GRIPPERS IN AUTOMATIZED ASSEMBLY

Abstract: *Biomechanical robot grippers represent endeffectors of robots derived from the structure of biological systems. Devices based on the human hand are capable of either picking up objects and drawing them into a nested grip againts the palm or holding a pistol-like tool, such as an electric drill, and pulling the trigger at the same time. In the paper are described the first and second versions of the Presov Biomechanical Robot Gripper which was developed in 1995 at the Technical University in Presov by workers underlead of Jozef Novak-Marcincin and was applied on industrial robot APR 20 produced by VUKOV Ltd. in Presov. This robot with biomechanical grippers was using in automatized assembly.*

1. INTRODUCTION

Most of products produced in workshops of mechanical-engineering enterprises have to be completed in difficult production process in order to fulfil the requirements onto their shape, functioning and quality. In the frame of production process the raw materials, materials and semi-products are gradually changed to complete product. The product has to be influenced by less or more difficult system of production technologies in order to perform this change of quality.

At present, production technologies reach high level in some areas. This high level is ensured by good-quality science research activity, which is mainly developing in the technologies of changes of the dimensions, shapes and properties of the products. These technologies are mainly used in individual parts manufacturing realisation. But, only in rare cases the final product is represented by single part, in most of cases it is system of mutually functioning connected parts. In comparison with research in the area of the above production technologies the final phase of production represented by assembling is not developing so systematically and thus its technical level is lagging behind the level of other technologies in the mechanical-engineering production. Assembling as final technology in the system of production technologies, through which the products flow, determines the final quality and due date of final product production.

2. AUTOMATED ASSEMBLY AND DISASSEMBLY

Present requirements to improve product competitiveness force individual producers to shorten the innovation cycles. It has influence to necessity of manufacturing time and thus also product assembling time shortening. At certain level, it is not possible to fulfil this requirement only by improving of the manual assembly organisation and using auxiliary devices and fixtures, but it is necessary to automatize assembling working-places.

In the last period, mainly due to duty of the producers to ensure the complete life cycle of their products, in frame of which it is necessary to solve the liquidation and/or recycling of products, the necessity to solve the problems of products disassembling is topical. This duty is already defined by law of progressive industrial countries. Similarly to assembling also the efficiency of disassembling operations is determined by performing of the assumptions for automated disassembling. In many considerations the problems of disassembling are more difficult than problems of assembling. It is necessary to take in, that disassembled products can be worn, corrosive, damaged, their shape could be changed e.t.c. [16].

Automation of assembling and disassembling can be performed in two basic ways [1]:

- using automated machines for assembly and disassembly, these can be arranged to automatically controlled working-places, which are able to assembly or disassembly the groups of products if necessary,
- using flexible assembling or disassembling equipments.

Increasing level of automation and flexibility of assembly and disassembly working-places is difficult to perform without robotized and manipulating equipments enforcement. These allow to perform assembly and disassembly operations with higher safety and efficiency against the man, who these operations performs manually. Important aspect of robots and manipulators exploitation in assembling and disassembling is that besides the manipulating operations realisation allow also to realise the own assembly and disassembly operations directly.

The end effectors, which enable fixed and safe object gripping or realise technological procedures during assembling or disassembling cycle, are important part of robots and manipulators from viewpoint of immediate realisation of assembling and disassembling operations in the processes of assembly and disassembly technology. Used end effectors of robots and manipulators are characterized by wide assortment with large number of types, forms and sizes. They enable to realise also the special technological functions, for example bolting, drilling, boring, thread cutting, seal substances piling, riveting, brazing, welding, fire cutting, e.t.c..

The selection of concrete end effector of assembly and disassembly robot depends on type of application, mass and geometry of the object. The following types of end effectors of these robots and manipulators are included into conventional end effectors:

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

As efficient tools, which remove noticed failures; can manipulate with parts of various shape without necessity of special setup in technological pallets; can manipulate and perform the activities with common tools as screw drivers, wrenches, riveting tongs, welding guns, hand drills, e.t.c. are obviously to be the versatile nonconventional end effectors of robots and manipulators, which imitate by their form and functionity the hand of man and are known under title biomechanical grippers.

3. BIOMECHANICAL GRIPPERS OF INDUSTRIAL ROBOTS

Reading more articles, books and publications on grippers, one may encounter that different authors use different names and nomenclature for grippers. E.g. Ch..Pellerin uses "mechanical hand" [12], Y. Nakano describes "robot hand" [11], G. Vassura writes about "articulated hand" [17], A. Romiti [14] and H. Yoshinada [18] use "multi-fingered robot hand", S. C. Jacobsen [3] in your works deal with "dextrous hand". Besides it is very common to combine its name either with a name of the place where it has been designed, e.g. Stanford/JPL Hand, Hitachi Robot Hand, Utah/MIT Dextrous Hand, Belgrade/UCS Robot Hand, or with initials or author's surname, e.g. U. B. Hand, Salisbury Hand.

For there exists an analogy between the mechanism of such gripper and the human hand (construction and shape), this gripper is a typical example of a biomechanism. So it is very convenient to call it "biomechanical gripper". This name fully reflects the fact of the mechanical analogy of any biological system designed upon biomechanical knowledge.

Biomechanical gripper represents an end-effector of a robot, construction of which is derived from the shape of the human hand. This name is connected to "biomechanical robot", i.e. kind of a robot with a construction simulating moving activities of living organisms. Name "biomechanical gripper" has already been used in several articals given by author of this one [10], having more authors using it recently. This name will be used hereon.

First prototypes of biomechanical artificial hands were for prosthesis applications, e.g. hand of Kato [4] in Waseda, Mori and Yamashita hand, the Belgrade hand [13]. Later on some of them were used in industry for mechanical assembly operations (e.g. the Belgrade hand). Very advantageous properties of biomechanical grippers (light weight, compact and dexterity) make them highly suitable for biomechanical robots. Recently new technologies have started an age of biorobots. Lets describe some of these biomechanical grippers [8].

3.1. The Utah/MIT Dextrous Hand

In 1982 at the University of Utah and the Massachusetts Institute of Technology began development of the Utah/MIT Dextrous Hand. It is one of the better-known dexterous mechanical robot grippers intended to function as a general purpose research tool for the study of machine dexterity. The structure of the Utah/MIT Dextrous Hand is simple. The links and joints of the dextrous hand are roughly anthropomorphic in form. The completed hand includes three four- degree-of-freedom fingers, one four-degree-of- freedom thumb, and a three-degree-of-freedom wrist for spatial orientation of the hand. A four-digit hand configuration was chosen to provide finger redundancy that permits more flexibility in grasping tasks and to minimize reliance on friction during certain manipulations. In order to achieve the desired active and passive performance, antagonistic pneumatic actuators were used in the Version III system. The product of years of development and exhaustive testing, 32 specially designed glass and graphite pneumatic cylinders control tendons via associated jet-pipe valves. Actual forces are transmitted to the hand via high strength polymeric tendons [3].

3.2. The Salisbury Hand

The hand, originally called the Stanford/JPL hand, is a three-finger articulated grasping and manipulation device intended for attachment to a Unimation 560 (PUMA) robot or similar arm. Developer K. Salisbury began working on the hand as part of his doctoral research at Stanford University. In 1982 he formed Salisbury Robotics Inc. and continued to explore control and utilization questions for his own and other types of robotic hand. The Salisbury Hand, driven by 12 motors, is equal in complexity to two robots. Salisbury has been working on a standalone controller based on PC architecture, which he expects to be available at a future date. The Salisbury Hand's multi-jointed fingers each have three degrees of freedom - the minimal configuration capable of imparting arbitrarily directed forces, torques and small motions to object held in the finger tips [12].

3.3. Hitachi Robot Hand

The pull strength effect of Shape Memory Alloy (SMA) used in 1984 by Japan firm Hitachi (Yaskawa Electric Co. in this time) in design of multi-finger robot gripper for assembly named the Hitachi Robot Hand. Gripper is determined for flexible manipulation with objects and it imitates by its shape the human hand. The Hitachi Robot Hand has three fingers, which are sufficient for grasping of most objects. Every finger has four independent joints, which secure sensitive grasping of objects. The gripper has in wrist two joints for vertical and horizontal wave motions. Totally the gripper has 14 inpendent joints, which are activated by driven SMA unit. Gripper bearing capacity is 2 kg, gripper width is 80 mm, height is 50 mm and length is 400 mm. Gripper weighs 4.5 kg [11].

3.4. The U. B. Hand

The first version of the U. B. Hand [17] started working on a test frame in March 1988 at the University of Bologna and has been operative on a IBM 7565 gantry robot. The version I U.B. Hand showing that its kinematic configuration was suitable for whole hand manipulation. The fingers of the version II U. B. Hand are designed according to a biomorphic skeleton and flesh model. The actuation of 11 joints of fingers is obtained through tendons and pulleys. The modular design of the U. B. Hand will allow the synthesis of different configurations, e. g. by varying the relative position of fingers with respect to the palm. The adduction-abduction movements of the upper fingers are independent, so that syncronous lateral movements of both fingers are allowed.

3.5. The Torino Multi-fingered Robot Hand

In 1992 was developed on Dipartimento di Meccanica at Politecnico di Torino multi-fingered robot hand with very simple actuation and control. This articulated hand is based on following principle: the movement of individual phalanxes through single controls is replaced by a single device for each finger, with only one degree of freedom, based on a system of rods connecting the phalanxes together [14].

The hand has four equal fingers parallel to one another, each having three phalanxes alternately interconnected, a thumb with only one movement facing the four fingers and palm - indispensable for positive gripping - obtained as the envelope formed by successive positions assumed by the finger tips during gripping. Actuation is through five double-acting air cylinders, one for the thumb and the other four for the fingers.

3.6. The Komatsu 3-fingered Robot Hand

Using the rubber muscle type actuator, at KOMATSU Ltd. (Japan) there was developed a 3-fingered robot hand for subsea use. To consider the simplification of the hand mechanism and control system, it is not practical to design the hand with the same function as the human hand. Finger 1 of this hand corresponds to the thumb of human hand, finger 2 to the forefinger and finger 3 to the middle finger respectively. The rubber muscle actuators are built in the palm and each joint is driven with the mechanical links. The adduction and abduction joint (CM) of the thumb are driven with muscles as rivalry. Other joints are driven with muscle toward the direction of flection and toward extension the joints are driven with springs. The joint angle is detected to measure this spring force using a miniature load cell (for this purpose CM joint has the dummy return spring) and the force sensor is built in each finger tip to detect the finger force applied to the object [18].

4. THE PRESOV BIOMECHANICAL ROBOT GRIPPER AND ITS APPLICATION IN ASSEMBLY

During 1994-1996 there have been developed first version of biomechanical gripper under leadership of J. N. Marcinčin at Department of Industrial Robotics TU Košice. This gripper version is similarly concepted to Torino Hand, pneumatically driven, with 1.5 kg loading capacity and can manipulate with objects of 10-90 mm diameter. Prešov biomechanical gripper is determined for application on industrial robot APR 20, which is product of VUKOV a.s. Prešov. APR 20 is adaptive industrial spherical robot with 6 degrees of motion freedom, with electrical drives, preferably determined for manipulating with products and for arc welding technology [7, 9].

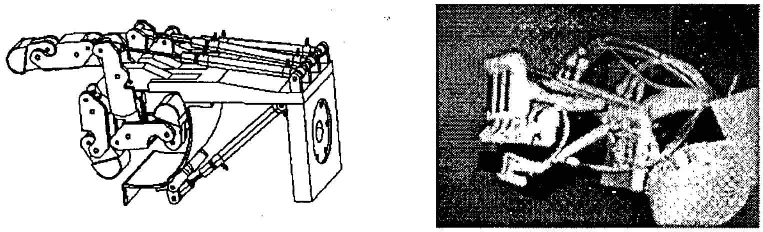

Fig. 1 Prešov biomechanical gripper - version I scheme and photo

Construction of Prešov gripper (Fig.1) is simple. It consists from three parallel fingers with three articles and one opposite thumb with one joint. Fingers and thumb are positioned on palm, which is similarly as other parts of fingers made from aluminium alloy. Motions of individual articles are actuated by four pneumatic linear drives located in upper part of gripper. Motions of fingers and thumb are controlled by RS-4A control system (control system of robot APR 20). Senzor equipments of gripper, in the comparison with biological origin, is considerably simplified. On the tips of all fingers and thumb are located contact senzors only, which provide the information about load gripping safety to the control system. Maximum loading capacity of this version of Prešov biomechanical gripper is 1.5 kg, its width is 100mm, height 100mm and length 300mm. Gripper weighs 4.5 kg.

Form of fingers, their number and arrangement and also the shape of palm enable to grip and manipulate with various shape objects. Gripper can perform both power operations in manipulating with massive parts and devices and soft operations, which are necessary mainly in assembly of products. Allowed configurations of biomechanical gripper fingers in manipulating with various shape products are shown at fig. 2.

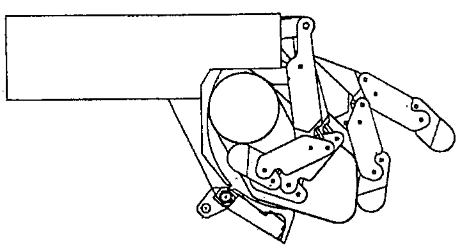

Fig.2 Various types of gripping by biomechanical gripper.

Based on analysis of gripping activity of man hand, it is possible to define the requirements to activities of the technical parallel of man hand - biomechanical gripper, which should perform following types of tasks [6]:

- soft gripping of manipulated object and manipulation,
- power gripping of manipulated object and manipulation,
- gripping of spherical type of object and its manipulation,
- gripping of the object with tips of fingers and its manipulation,
- gripping of the object by function „tongs“ and its manipulation,
- gripping of the object by function „pen/pencil“,
- free holding of the objects by function „loop“,
- breaking out by gripper finger,
- interaction with co-operating object of the „keyboard“ type.

Noticed tasks, which the biomechanical gripper of robot is able to perform in the area of assembling and disassembling is possible to divide according to Fig. 3 [15].

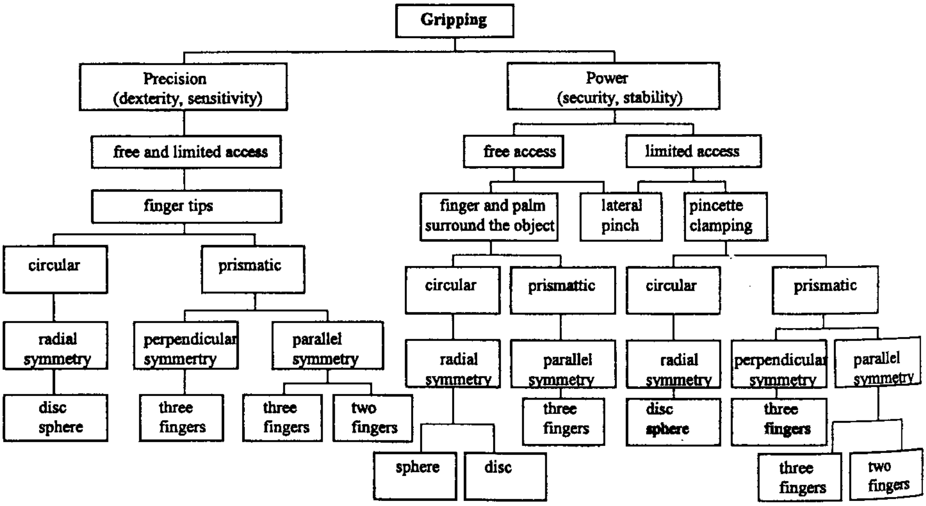

Fig. 3 Standart types of gripping by the biomechanical gripper

Prešov biomechanical gripper is possible to use in the area of assembling and disassembling for manipulating with various shape parts. Biomechanical gripper is shown on fig. 4 in possible soft manipulation with sphere and with piece of sheetmetal.

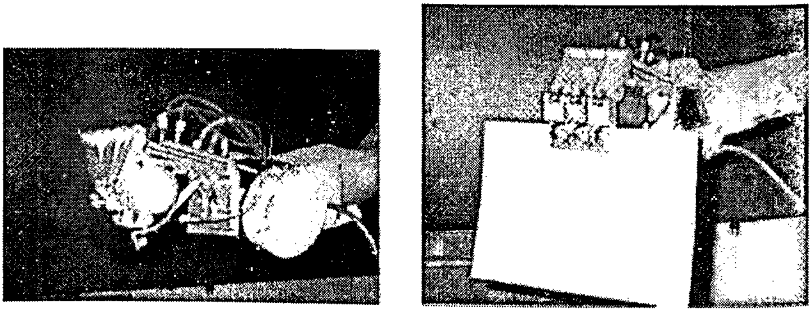

Fig. 4 Examples of soft manipulation with the solids of various shape

Similarly, the biomechanical gripper is possible to use in automated assembly and disassembly for manipulation and moving with various tools and technological devices. Examples of biomechanical gripper manipulating with screw driver, spanner and hammer are shown at fig. 5

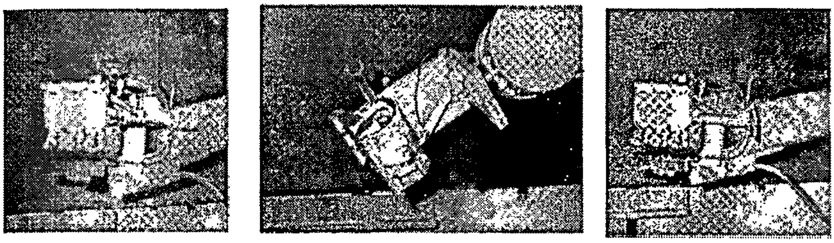

Fig.5 Examples of manipulation with various types of tools

Biomechanical robot grippers usually possess three or more articulated fingers capable of both holding any awkwardly shaped objects and also manipulating them. Obviously, such grippers are complex, difficult and expensive to construct. Devices based on the human hand are capable of either picking up objects and drawing them into a nested grip againts the palm or holding a pistol-like tool, such as an electric drill, and pulling the trigger at the same time. They should be equipped with tactile sensors. In some cases, kinematic redundancy is deliberately introduced to maximize dexterity and minimize reliance on friction for stable grasping.

5. CONCLUSION

Full automation of production processes is not possible without realisation of the automated assembling of the products. In the frame of computer integrated manufacuring (CIM) there is defined independent section - computer aided assembly CAA. Using devices of computer technology it is possible to schedule assembly operations, simulate the procedure of automated assembly of the parts to final assembly of the product, and also control automated assembling devices such as automated assembling machines, assembling robots and manipulators, trasports e.t.c.. Similarly, it is possible to define the CADA systems (Computer Aided Disassembly), which are aimed at the area of automated disassembling of the products. Thus the ecologically suitable liquidation is ensured after product life time guarantee ends. The paper was created in the frame of solution of research task VEGA no. 1/4367/97.

6. ACKNOWLEDGEMENTS

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