GRIPPERS FOR INDUSTRIAL ROBOTS

Peter KOŠTÁL
Jarmila ORAVCOVÁ
Miriam MATÚŠOVÁ

Abstract: The industrial robots are characterized as electro-mechanical system by higher level of integrated electronic. They realize predefined actions by flexible acting and information exchanging with environment. Its connection to manufacturing devices is used for workpiece loading and unloading to these devices. One of the most important part of industrial robots from view of its usability is its gripper system

Key words: grippers, robots, manufacturing, assembly

1. INTRODUCTION

The assembly has a specific state in manufacturing process, because assembly imply major portion of high toilsome and manual work in a term of their portion in production total time. For their technical differentness and heterogeneousness, actual assembly is make manual too, because of automation assembly lag in higher manipulating ability requirement for assembly devices by joining parts. Often some assembly operation, which are requested very complicated and very expensive device. This problem may be partially solved by designing parts especially for automated assembly.

The industrial robots are able to take, move, machine and assemble workpiece. They are universal automated devices realizing movements similar as a human arm. Industrial robot are defined as a programmable, multifunction manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks. The industrial robots has a follow base characteristics and differ from other industrial devices by these characteristic:
- target oriented,
- flexibility,
- programmability,
- automated working,
- information exchange between a robot and its environment,
- acting to environment.

On base of today trends at a field of robotics was added a new characteristics too:
- possibility to robot working in case of environment changing to unknowable state,
- structure of robot have some intelligence and is possible use this intelligence to activities planning and realizing.

2. ROBOTIZED ASSEMBLY SYSTEM

A Considerable feature of assembly process realization is flexibility of assembly system. There is the ability of assembly system to adapt to changed requirements of assembly (maybe modified article or new type of article). Systems flexibility illustrates measure of versatility of these systems. Flexible assembly systems are available to perform other assembly operations. Versatility of industrial robot can achieve provide for ability reprogramming and automated exchange of gripper, or technological head, which can use for technological operations.

The diffusion of assembly automation towards applications characterized by increasing complexity levels and reduced product lifetimes requires solutions which, besides high performances, guarantee high flexibility and reconfigurability levels.

There are many industrial situations in which this approach shows interesting application perspectives, for example assembly processes which involve many component insertion directions. In this case, employing a robot as a general fixture allows for the elimination of complex orienting and fixing devices, dedicated to a specified product, and using skilled robots which present a preferential direction of insertion (i.e. Scara) for the assembly of components. Such assembly cells are very beneficial when small lots of many products have to be assembled using a limited number of components. Example of assembly robot for screwing is at Fig. 1. Example of robotized assembly cell is shown at Fig. 2.

Fig. 1. Assembly robot for screwing (laboratory usage)

The Industrial robot, which are able perform complicated operation sequence, sense environment by sensors and make a decision according to actual state we call as industrial robot with adaptive behavior. Adaptive industrial robot is defined as an industrial robot with
higher level of control, which are able change their behavior during their running in order to condition quality of operating all production system satisfied. Behavior exchange is realizing for a consideration exchange state parameters of environment. Monitoring of these exchanges state parameters are realized by sensors, which are part of adaptive robot.

![Fig. 2. Robotized assembly cell](image)

General structures of robotized assembly systems can be divided into three main groups:
- Assembly systems, in which robots performs only manipulation
- Assembly systems represents assembly center, in which on the one place are performed manipulate, assembly and assistant operations
- Assembly systems, in which assembly robot of higher generation perform manipulate and assembly operations

![Fig. 3. Gripper exchange system (example)](image)

### 3. GRIPERS IN ROBOTIZED ASSEMBLY

The end effectors of industrial robots as an interactive part of robots design realize some very important functions derived from base of robots using at concrete case. One of end effectors function is manipulation tasks realizing in technological process.

In this case the end effectors realize not only workpiece moving, but often realize the workpiece positioning and orientation at technological device workspace. (Fig. 3, Fig. 4)

The other different function of end effectors may be technological process realization in workpiece (milling, drilling, screwing,...). End effectors can be design to realize the measurement and quality control too.

Robotic technologies becomes to huge range of applications so we can find spread spectrum of special end effectors design. These special end effectors can use in medicine, space applications, army and so much other fields.

End effectors can divide by its function to:
- gripping end effectors – gripers,
- technological end effectors,
- measuring end effectors,
- control end effectors,
- combined end effectors,
- special end effectors.

![Fig. 4. Gripper changing system from SMC](image)

A part of complex automated assembly process is an automation of process control, automated transportation, handling, feeding, interchange of workpieces and tools. There are many technological sites existing, which match given requirements. Besides obvious computer techniques for controlling the manufacturing machines, automatically working bins, loaders, conveyors, manipulators and industrial robots are implemented step by step. As industrial production is growing constantly, besides implementing of the classical automated means, which were mentioned above, manufacturing systems with intelligent control are being installed.

Exploitation of automated manufacturing systems is conditional by effectiveness of all subsystems, from which is the automated manufacturing system created. All subsystems are often developed together with certain automated system, not to decrease parameters of whole system.

### 4. CALCULATION OF GRIPPER FORCE

The shape and mass of manipulated part has influence to gripping method. In case of mechanical grippers the gripping method results from kinematics structure. Optimal conception are combined from partial kinematics schemes. Order of these schemes are designed by needed movements in a frame of gripping positioning, orientation and unlocking operations.
From construction point of view the “M” class gripper structure contain two or more clamping jigs. Shape of these jigs are defined as a base shapes: cone, cylinder, sphere, planar or its combinations. These shapes are used in depending of manipulated part shapes. Principally all of these grippers jig shapes can be use to gripping all manipulated part shapes, but we must qualify these cases by other points of view too. Difference between gripping by individual cases of gripping jig shape will be in level of other criteria achievement. In base of these qualifications will be find the best solution of gripping jigs shape for concrete manipulation and for concrete objects. The goal is design the simples construction of gripper with accent to small mass of end effector and certain functions.

Very important criteria is achieving to high accuracy of gripping. By adjustable range of gripping dimension we can achieve a most flexible gripper. At case of adaptive grippers is very necessary take mind to sensors mounting in design time of grippers.

The grippers act to manipulated objects by clamping forces $F_{ju}$ which has a critical role for they dimensioning in design time. In general hold the follow equation (1):

$$\sum_{j=1}^{n} F_{ju} = k \sum_{i=1}^{m} F_{iz}$$

where:
- $F_{ju}$ – clamping forces,
- $F_{iz}$ – outer forces,
- $k$ – safety constant,

Cumulative safety constant $k$ are calculated by multiplication of partial safety coefficients. These partial coefficients takes head to concrete factors of operation. The cumulative safety constant are calculated by equation (2):

$$k = k_1 k_2 k_3 k_4 k_5 k_6$$

where:
- $k_1$ – coefficient of manipulated objects,
- $k_2$ – coefficient of clamping type,
- $k_3$ – coefficient of manipulated object surface,
- $k_4$ – coefficient of clamping forces drifting
- $k_5$ – coefficient of working cycle dynamics,
- $k_6$ – coefficient of running cases.

The methods of clamping forces calculation are based on critical stability in contact layer in cases of adverse conditions of running. This calculation we can realize by follow equations (3):

$$\sum_{j=1}^{n} F_{ju} = \sum_{m=1}^{n} F_{mv} \eta_{mv} \eta_i \eta_{in}$$

where:
- $F_{mv}$ – forces from actuators,
- $\eta_{mv}$ – actuators effectivity
- $\eta_i$ – gearings effectivity

The next clamping jigs design criteria is a material of manipulated objects. Quality of surface (roughness, hardness and other) are affect to clamping jigs surface type. By modification of clamping jigs active surface we can modify friction between clamping jigs and manipulated objects. This modification are realized by various value of friction coefficient $\mu$.

Clamping force value to cylindrical object longitude centered gripping by planar clamping jigs (Fig. 5) is possible calculate by follow equation (4):

$$F_u = k \cdot m \left[ a_1 + a_2 \left( \frac{1}{\mu} \cdot \cos \varphi \right) + a_3 \left( \frac{1}{\tan \varphi} \right) \right]$$

where:
- $\mu$ – friction coefficient
- $a_1$ – partial gravity and instants accelerations in X, Y, Z axis

Clamping force value to cylindrical object longitude eccentrically gripping by planar clamping jigs (Fig. 6) is possible calculate by follow equation (5):

$$F_u = k \cdot m \left[ a_1 \left( \frac{3l}{b} + \frac{1}{2} \right) + a_2 \left( \frac{1}{\mu} \cdot \cos \varphi \right) + a_3 \left( \frac{6l}{b} \cdot \frac{1}{\tan \varphi} \right) \right]$$

where:
- $l$ – length of gravity center eccentricity,
- $b$ – length of contact line between a jigs and object.
5. CONCLUSION

The assembly has a specific state in manufacturing process, because assembly imply major portion of high toilsome and manual work in term of their portion in production total time. For their technical difficulties and heterogeneousness, actual assembly is make manual too, because assembly has large reserves of automation aided. One of the causes of automation assembly lag is higher manipulating ability requirement for assembly devices by joining parts. Often some assembly operations, which are trouble free realizable by manual, by automation are requested very complicated and very expensive device. Robotized workplaces are used at several industrial branches. Request to competitive and effective manufacturing generate pressure to robotics design centers. The end effector design must take head to lot of special requests apart a common mechanical engineering parts. Trends in this area is a continuous accuracy increasing and develop a new methods to gripper design.

ACKNOWLEDGEMENT

This paper was created thanks to the national grants: VEGA 1/3193/06 - Multi functional manufacturing and assembly cell.

REFERENCES


CORRESPONDENCE

Peter KOŠŤAL,
Assoc. Prof., MSc, Eng., PhD.
Slovak University of Technology
Faculty of Material Science and Technology, Rázusova 2
91724 Trnava, Slovak Republic
peter.kostal@stuba.sk

Jarmila ORAVCOVÁ, MSc, Eng.
Slovak University of Technology
Faculty of Material Science and Technology
Rázusova 2, 91724 Trnava,
Slovak Republic
jarmila.oravcova@stuba.sk

Miriam MATÚŠOVÁ, Ing, PhD.
Slovak University of Technology
Faculty of Materials Science and Technology
Rázusova 2, 917 24 Trnava,
Slovak Republic
miriam.matusova@stuba.sk