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Design Study of End Effectors

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***Abstract:** Robots play a vital role in automation of machines.The performance of robotic manipulator is completed by the end effectors.The choice of end effector is depended on the type of task to be performed. For holding the component and pick & place activities to the specified location gripper is selected and for different types of workshop operations various tools are fixed on the manipulator e.g. welding electrode holder,painting spray gun etc.*

***Keywords:** Robot, grippers, end effectors, manipulator, workshop operations*

I. INTRODUCTION

A Czechoslovakian play in early 1920s by Karel Capek called Rossum's Universal Robots, gave rise to the term robot. The Czech word "Robota" means servitude or forced worker and when translated into English, the word became Robot. The story concerns a brilliant scientist named Rossum and his son who develop a chemical substance that is similar to protoplasm. They use the substance to manufacture robots. Their plan is that robots will serve mankind obediently and to all physical labor. Rossum continues to make improvements in the design of the robots, eliminating unnecessary organs and other parts and finally develops a "perfect" being. The plot takes a sour turn when the perfect robots begin to dislike their subservient role and proceed to rebel against their masters, killing all human life. Among science fiction writers, ISAAC Asimov has contributed a number of stories about robot, starting in 1939, and indeed is credited with coining the term "robotics". The picture of a robot that appears in his work is that of a well designed, fail-safe machine that performs according to the three principles. These principles were called the "Three laws of robotics by Asimav and they are:-

1. A robot may not injure a human being or through inaction, allow a human to be harmed.
2. A robot must obey orders given by humans except when conflicts with the first law.
3. A robot must protect its own existence unless that conflicts with the first or second laws.

II. METHODOLGY

An effector is a device that attaches to the wrist of the robot arm enables robot to perform a specific task. The End effector is the part of special – purpose tooling for a robot. Usually, end effectors must be custom engineered for the particular task which is to be performed.

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The two major categories of end effectors are:

1. Grippers
2. Tools

Grippers are end effectors used to graph and hold objects. The objects are generally workparts that are to be moved by robot, Grippers can be classified as single grippers or double grippers. This classification applies best to mechanical grippers. Single grippers is distinguished by the fact that only one grasping device is mounted on robot's wrist. A double gripper has two gripping devices attached to the wrist and is used to handle two separate objects. The two gripping devices can be actuated is especially useful in machine loading and unloading applications. The term multiple grippers is applied in the case where two or more grasping mechanisms are fastened to the wrist. Another way of classifying grippers depends on whether the past is grapsed on its exterior surface as its internal surface, e.g. a ring shaped part. The first type is called an external gripper and second type is called internal grippers.

III. MECHANICAL GRIPPERS

A mechanical gripper is an end effectors that uses mechanical fingersactuated by a mechanism to grasp an object. The fingers are either attached to the mechanisms or in integral part of the mechanisms. If fingers are of attachable type then they can be detached and replaced. The use of replaceable fingers allows for wear and inter changeability. Different sets of fingers for use with same gripper mechanism can be designed to accommodate different part models. The mechanism must be able to open and close the fingers and to exert sufficient force against the part when closed to held it securely. There are two ways of constraining the part in the gripper. The first is by physical constriction of the part within the fingers. In this approach, grippers finger enclose the part to some extent there by constraining the motion of the part. It is usually. Accomplished by designing the contacting surfaces of the fingers to be in approximate shape of the part geometry. The second way of holding the part is by the friction between the fingers and the work part. With this approach fingers must apply a force which fingers must apply a force which is sufficient for friction to retain the past against gravity, acceleration etc.

$W = \mu n F_g$

Where

μ= coefficient of friction of finger contact surface against the part surface.

N= number of contacting fingers

Fg= gripper force

W= weight of the part or object being gripped.

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Engelberger suggests that in high speed handling operation the acceleration or deceleration of the part could exert a force that is twice the weight of part.
Where g factor is supposed to take account of the combined effect of gravity and acceleration. If acceleration is applied in the same direction as the gravity force then g = 3.0. If acceleration is applied in opposite direction, then g = 1.0 (2x weight of part due to acceleration – 1 x the weight of part due to gravity.). If acceleration is applied in a horizontal direction then use g = 2.0
Example (1)
Weight of workpiece = 10 kg
μ = 0.25
Fast work cycle (g) = 3.0
0.25 x 2 Fg = 10 x 3.0
Fg = 60 kg
Gripper force of a 2 finger gripper = 60 kg.
Mechanical grippers can also be classed according to the type f kinematic device used to actuate the finger movement.

1. Linkage actuation
2. Gear and rack actuation.
3. Cam actuation
4. Screw actuation
5. Rope and pulley actuation.
6. Miscellaneous.

The linkage category covers a wide range of design possibilities to actuate the opening and closing of the gripper. The design of linkage determines how input force Fa to the gripper is converted in to gripping force Fg applied by the fingers. The linkage configuration also determines other operational features such as how wide gripper fingers will open and how quickly the gripper will actuate. Gear and each actuation covers the method of actuating the gripper fingers using a gear and rack configuration. The rack gear would be attached to a piston or some other mechanism that would provide a linear motion. Movement of rack would drive two partial pinion gears and these would in term open and close the fingers. Cam actuation covers a cam and follower arrangement using a spring located follows, cam provide the opening and closing action of the grippers. For example, movement of cam in one direction would force the gripper to open, while movement of cam in opposite direction would cause the spring force the gripper to close. The advantage of this arrangement is that spring action would accommodate different sized parts. Screw – Type actuation method has a screw turned by a motor, usually accompanied by a speed reduction mechanism. When screw is rotated in one direction, this causes a threaded block to be translated in one direction. When the screw is translated in opposite direction the threaded block moves in opposite direction. The threaded block is, in turn, connected to the gripper fingers to cause the corresponding opening and closing action. Rope, and pulley mechanisms can be designed to open and close a mechanical grippers. As the nature of these mechanisms, some form of tension mechanisms, some form of tension device must be used to oppose the motion of rope or cording pulley system. E.g. the pulley system might operate in one direction to open the gripper and the tension device would take up the slack in the rope and close the gripper when pulley system operates in opposite direction. Miscellaneous category may include an expandable bladder diaphragm that would be inflated or deflated to actuate the gripper fingers.

IV. GRIPPER FORCE ANALYSIS

The purpose of gripper mechanisms is to convert input power into required motion and force to grasp and hold an object. The analysis that might be used to determine the magnitude of required input power in order to obtain a given gripping force.

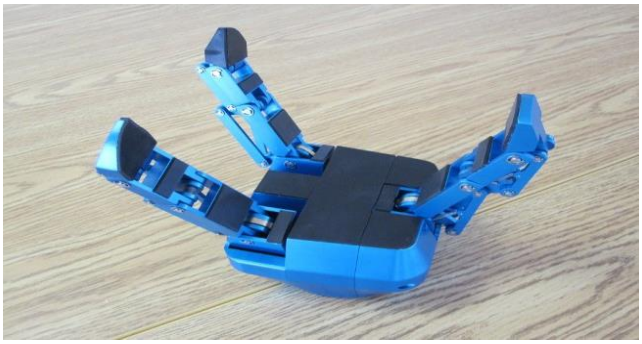
$$FgLg = Fa2a=0$$

$$60 \times 12 - Fa\ 3 = 0$$

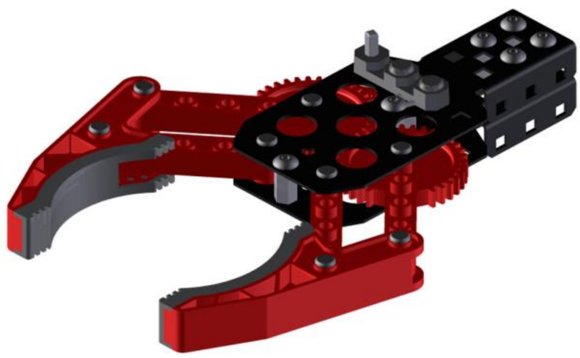
$$Fa = \frac{720}{3} = 240$$

The piston device would have to provide an actuating force of 240 N to close the gripper with a force against a work piece of 60N.

3 FINGERS GRIPPER



2 FINGERS GRIPPER



ROBOTIC VACCUM GRIPER

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ROBOTIC DRILLING

V. OTHER TYPES OF GRIPPERS

1. **VACCUM CUPS**: They are also called suction cups. The usual requirements on the objects to be handeled are that they be flat, smooth and clean condtions necessary to form a satisfactory vaccum between object and suction cup. Suciton pads some in a wide range of material to meet specific application requirements. E.g. nitrile, silicone natural rubbers, fluoroelastomers and polyurethanes.

The co – efficient of friction between workpiece and suction pad is very important.

- Oily sufaces : μ = 0.1
- Moist or wet surfaces : μ = 0.2 to 0.4
- Glass, stone, plastic (dry) : μ = 0.5
- Wood and metal : μ = 0.5
- Rough surface : μ = 0.6
- Sandpaper (dry) : μ =01.1

Holding forces : calculating holding forces can never exceed the theoretical maximums. In practice, many other factors come in to play so, safety factor of 2 is recommended.

Suction paddia : -

With force applied horizontally: -

$D = 1.12 \quad (mS/Pv\ n)^{1/2}$

With force applied vertically

$D= 1.12 \quad (mS/Pv\ n\ \mu)^{1/2}$

Here,

D= suction dia

M= mass of workpiece

Pv = vaccum pressure

N= number of suction pad

S= safety factor

μ = co – efficient of friction.

To determine necessary forces for a suction pad and workpiece.

I. Horizontal suction pads, vertical force In this case suction pads are placed on a horizontal workpiece which is lifted vertically.
F 7 = m (g+a)x 5

II. Horizontal suction pads, horizontal force the suction pads, are placed horizontal workpiece which must was laterally.
F1 = m (g+a/ μ) x 5

III. Vertical suction pads, vertical force. The suction pads move a vertical work piece, as shift a horizontal work piece to another orientations.
F1 = m/u x (g+a) x 5

Where

M= mass of workpiece

G = acceleration due to gravity

A = system acceleration

S = factor of safety

μ = co – efficient of friction between suction pad and work piece.

2. MAGNETIC GIPPERS

Magnetic grippers are very feasible means of handling ferrous materials. The stainless steel plate would not be an appropriate application for magnetic gripper because 18-18 stainless steel is not attracted by a magnet. Other steels would be suitable for this means of handling especially. When materials are handled in the form of sheet or plate.

Advantages of magnetic grippers in 20botic handling application.

- Pick up times are very fast
- Variations in part size can be tolerated. The gripper does not have to be designed for one particulars work part.
- May have ability to handle metal parts with holes.
- They require only one surface for gripping.

Disadvantage with magnetic grippers include the residual magnetism remaining in the workpiece which may cause a problem in subsequent handling and the possible slide slibbage and other errors which limit the precision of this means of handling. The magnetic attractive terms to penetrate beyond the top sheet possibility that more than a single sheet will be lifted by magnet. This problem can be solved. First magnetic grippers can be designed to limit the effective penetration to the desired depth, which would correspond to the thickness of the top of sheet. Second the stacking device used to held the sheets can be designed to separate the sheets for pick up by the robot. Magnetic grippers can be divided into two categories, those using electromagnets and those using permanent magnets. Electromagnetic grippers are easier to control, but require a source of DC Power and an appropriate controller unit.

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As with any other robotic gripping device pan must be released at the end of the handling cycle. This is easier to accomplish with an electromagnet than with a permanent magnet. When a part is to be released, the controller unit reverses the polarity at a reduced power level before switching off the electromagnet. Permanent magnets have the advantage of not requiring an external power source to operate power source to operate the magnet but there is loss of control that accompanies this apparent advantage. Permanent magnets are often considered for handling tasks in hazardous environment requiring explosion proof apparatus, as no electricity is required in its operation.

3. ADHESIVE GRIPPERS

Gripper designs in which an adhesive substance performs the grasping action can be used to handle fabrics and other light weightmaterials, Adhesive material is loaded in the form a continuous ribbon into a feeding mechanism that is attached to the robot wrist.

4. HOOKS, SCOOPS AND OTHER MISCELLANEOUS DEVICES

Hooks can be used as endeffecters to handle containers of parts and to load and unload parts hanging from overhead conveyors. Scoops and labels can be used to handle certain materials in liquid or pointer form. Chemicals in liquid or powder form, food materials granular substances and molten metal sare all examples of materials that can be handled by a robot using this method of holding. Other types of grippers include inflatable devices in which an inflatable bladdlesordiaphragon is expanded to grasp the objects. Checklist of factors in selection and design of grippers.

Factor	Consideration
Part to be handled	Weight and size
	Shape
	Changes in shape during processing
	Tolerances on the part size
	Surface condition, protection of delicate surfaces
Actuation method	Mechanical grasping
	Vacuum cup
	Magnet
	Other methods (adhesives, scoops, etc.)
Power and signa transmission	Pneumatic
	Electrical
	Hydraulic
	Mechanical
Gripper force	Weight of the object
(Mechanical gripper)	Method of holding (physical constriction or friction)
	Coefficent of firction between fingers and object
	Speed and acceleration during motion cycle
Positioning problems	Length of Finger's
	Inherent accuracy and repeatability of robot
	Tolearnaces on the part size
Service conditions	Number of actuations during lifetime of gripper
	Replaceability of wear components (fingers)
	Maintenance and serviceability
Operating environment	Heat and temperature
	Humidity, moisture, dirt, chemicals
Temperature protection	Heat shields
	Long fingers
	Forced cooling (compressed air, water cooling, etc.)
	Use of heat resistant materials
Fabrication materials	Strength, rigidity, durability
	Fatigue strength
	Cost and ease of fabrication
	Friction properties for finger surfaces
	Compatibility with operating environment
Other considerations	Use of interchangeable fingers
	Design standards
	Mounting connections and interfacing with robot
	Risk of product design changes and their effect on the
	Gripper design
	Lead time for design and fabrication
	Spare parts, maintenance, and service
	Tryout of the gripper in production

Tools as End Effector

1. Welding
2. Painting
3. Drilling, Flaming, Tapping
4. Riveting

Welding

Welding gun is used as end effectors. Welding process in which robot is used is of two types.

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1. Spot Welding
2. Continuous Arc Welding

Spot welding – The process of welding in which two similar metal pieces are localized heated by passing a large current through the parts are to be welded. This current results sufficient heat the contact area to fuse the two metals and produces the weld. A end effector to robot's wrist and the robot is programmed to perform a sequence of welds on the product as it arrives at the workstation. Some robot spot welding lines operate with several dozen robots all programmed to perform different welding cycles on the product. The product quality is improved and production rate is quite high.

Continuous Arc welding : Continuous arc welding is used to made long welded joints in which an air tight seal is often required between the two pieces are being joined. Here welding electrode gun is used for making long continous welding joints in an in herent protective gtas atmosphere to preserve the quality of weld. A sequences of steps to be performed are fed in the control unit of robot and its works in the same manners. To guide the welding gun and check the quality of welding done by robot a vision based system is used. A high vision camera is mounted on the robot near the welding gun to view the path and compare the quality of welt made as programmed. Robovision II from Automatic Inc. and west vision from General Electric are examples of commercial vision system in a single pass category. In the automatic system the camera is focused about 4 cm in front of weld. The observed image is analyzed to extract the location of the entire of seam etc.

PAINTING

The commercial industrial painting method are categorized as follows : -

1. Immersion and flow coating method
2. Spray – Coating method.

Immersion and flow coating method – The object is completely dipped in primmer solution. The primmer solution bath is a electrically charged positive and it gets strick to the object. After keeping it for some time the object is removed and died in a furnace for about 2-4 hrs at temp from 200c to 100 c. After the baking of object it comes into atmosphere. All these activities are tone by one or more than one robotic manipulator arm as per the size of object. Then, object is again dipped in liquid paint for some time. As the paint is electrically charged positive it gets tick on the object. After keeping it for some time object gets removed from the bath of paint and again kept in furnace for 1-2 hrs at a temp. 100C to 200 C. So that paint may get tried up. The body / object is quietly inspected for any left over marks and after satisfiying all requirements buffing and polishing of the object take place. Besides visual inspection robotic inspection is also performed and results gets verified with each other.

SPRAY COATING: - A spray gun filled with primmer is attached with the robotic manipulator. SThis primmer is electrically charged positive so, that it get stick with the object. After getting dried a robovision is uses for any left over marks. Apply primmer if necessary. This primer solution provides a base to the uniform spread of paint. Next, the desired paint is filled in the attachment of robotic arm and through feed program it starts performing the action by providing a very fine mist of paint for painting the body. After baking in the furnace for drying of paint. It is allowed to coal in atmosphere. It is closely inspected for any defect with visual inspection and robotic vision camera. Both result are compared re paint if necessary. If every thing is correct then object moves for further action of buffing and polishing final finish.

DRILLING, REAMING, TAPPING

In above operations end effector is a powered spindle attached to the robots wrist. The purpose of robot is to correctly position the rotating tool against the stationary work piece in order to accomplish the desired operation. After getting on the desired position a else is drilled, reamed (finished for accurate size) and tapping (make thread inside the drilled hole).

RIVETTING

In this process end effectors is a fine gripper for holding and fitting the rivets in the desired hole. In this process after placing the rivet the rivet cap is placed from other side and both the ends are compressed from completing the action. The quality of riveting is inspected by Robo-vision immediately. If joint is OK then passed for further operations.

VI. RESULT

The correct choice of end effector is very important and necessary considering the robot manipulator work space limit and type of operations to be performed on the type of works piece. In this study a co-relation and co-ordination of different types of end effectors is shown for completing the desired task completely and satisfactorily.

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