ISSN (online): 2250-141X
Vol. 7 Issue 1, February 2017

VACUUM GRIPPER- AN IMPORTANT MATERIAL HANDLING TOOL

A. K. Jaiswal[1] and B. Kumar[2]

1 M. Tech. Scholar, Maharishi Markandeshwar University, Mullana, Ambala, Haryana, India

2 Professor, Mechanical, Maharishi Markandeshwar University, Mullana, Ambala, Haryana,

ABSTRACT

Varieties of robotic grippers are developed with high flexibility and multi-functional approaches. In this paper, the study is an innovative approach of a gripper for handling variable size, shape and weight of unpacked food products i.e. 'Vacuum Gripper of Robots' which is working on Bernoulli Principle for generating a high-speed flow between the gripper plate and product surface thereby creating vacuum. Feasibility observations are studied to demonstrate and obtain an overall understanding on the capability and limitations of the vacuum gripper. The main objective of this report is to highlights the importance of vacuum gripper in industrial applications.

The end-effectors like vacuum gripper are designed for the specific application. This paper describes a gripping technology and loading approaches. The system comprises of the gripping mechanism itself as well as its supporting environment.

Key Words: *Robot, Vacuum Cup, Gripper, Shape, Material Handling*

1. INTRODUCTION

Varieties of robotic grippers are developed with high flexibility and multi-functional approaches. Particularly, humanoid robot technology in this area attracts high attention of public interest. Robotic end effectors i.e. vacuum gripper can be used in many materials handling applications. Vacuum gripper is an essential component of a robotic manipulator which serves as the robot's hand and allows the robot to manipulate objects for proper gripping safely and applicable for various kinds of material handling system in various fields. Vacuum grippers are those devices that actually grip an object for moving or placing. End-effectors are usually specifically designed for their particular task, because the highest workload of on-site construction that consists of handling and assembly operations.

2. AREA OF RESEARCH

The robots are used for grasping the non-ferrous objects and packets *where* vacuum cups are preferred as gripping device as shown in

Fig. 2. that provides good handling if the objects are smooth, flat, and clean and stored in cartoons. Only one surface of the object is used for gripping. For smooth handling, the pores surfaces are restricted for gripping the objects.

Fig. 2. Vacuum Cups

The researchers had worked on vacuum type

ISSN (online): 2250-141X
Vol. 7 Issue 1, February 2017

gripper as listed below:
Shimoga et al. [1996] have designed for assembling robot grasp synthesis algorithms. Pham et al. [1998] have developed a knowledge based system related robot vacuum gripper selection criteria and choosing vacuum gripping. Bicci et al. [2000] have presented robotic grasping and different contour for contact. Choi et al. [2006] have elaborated design and feasibility gripper based on inflatable rubber pockets. Sam et al. [2009] have developed a design approach of robotic gripper for reducing cost for handling food products.

Brown et al. [2010] have developed universal vacuum gripper based on granular materials. Kragten et al. [2011] have elaborated vacuum gripper under actuated hands: fundamentals performance analysis and design. Whereas, Rodenberg et al. [2012] developed transactions gripper. Eizicovits et al. [2012] have presented efficient sensory grounded grasp pose quality mapping for vacuum gripper. Ullrich et al. [2015] have developed actuated and guided vacuum gripper for medical application.

Suction cups are used to hold horizontal flat or vertical flat objects using strong suction cups to lift an item. The "vacuum" is used to lift large, flat, smooth sheets of material like wood paneling, metal, plastic and glass. A vacuum gripper of the robot arm as shown in Fig.2 shows the position and securely plants one or more airtight suction cups to the material. The vacuum requires less power than either of the other designs, but is also more prone to mishaps due to misaligned suction cups that fail to achieve an airtight seal. The suction pads are normally selected on the following basis:

Operating conditions: The operating conditions (single or multiple shift operation, expected lifetime, aggressive surroundings, temperature etc.) at the point of use are decisive for the selection of the suction pads.
Materials: For the selection of the vacuum pad material in relation to the type of work piece to handle.
Surface: depending on the surface of the handled work pieces, certain suction-pad versions may be more suitable.
Product: The product range includes flat and bellows suction pads.

3. VACUUM CUP

The objects are generally work parts that are to be moved by the robot. These part-handling applications include machine loading and unloading, picking parts from a conveyor, and arranging parts onto a pallet. In addition to work parts, other objects handled by robot grippers include cartons, bottles, raw materials, and tools. The Single gripper is only one grasping device is mounted on the robot's wrist. A double gripper has two gripping devices attached to the wrist and is used to handle two separate objects. The two grasping devices can be actuated independently for single object. Grippers grasp and manipulate objects during the work cycle. Typically, the objects grasped are work parts that need to be loaded or unloaded from one station to another. Grippers may be custom-designed to suit the physical specifications of the work parts they have to grasp.

Vacuum-grippers become in suction cups, the suctions cups is made of rubber. The suction cups are connected through tubes with under pressure devices for picking up items and for releasing items air is pumped out into the suction cups. The vacuum pressure can be created with the following devices:

- Vacuum pumps
- Ejectors
- Suction bellows
- Pneumatic cylinders

The vacuum grippers use suction cups (vacuum cups) as pick up devices. There are different types of suction cups and the cups are generally made of polyurethane or rubber and can be used at temperatures between -50^{0}C and 200°C. The suction cup can be categorized into four different types; universal suction cups, flat suction cups with bars, suction cups with bellow and depth suction cups.

ISSN (online): 2250-141X
Vol. 7 Issue 1, February 2017

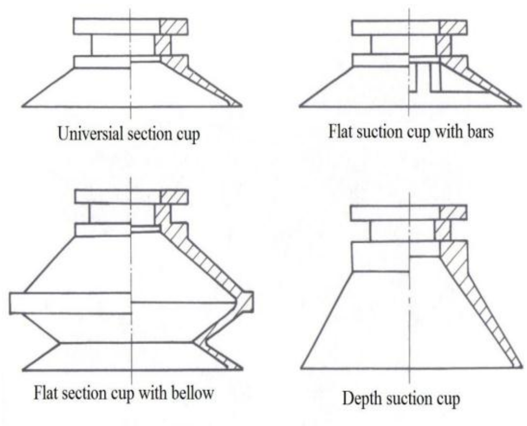


Fig.3.a: Different shape of cup

The universal suction cups are used for flat or slightly arched surfaces. Universal suction cups are one of the cheapest suction cups in the market but there are several disadvantages with this type of suction cups. When the under pressure is too high, the suction cup decreases a lot which leads to a greater wear.

The flat suction cups as shown in Fig.3.a or 3.b with bars are suitable for flat or flexible items that need assistance when lifted. These types of suction cups provides a small movement under load and maintains the area that the under pressure is acting on it which reduces the wear of the flat suction cup with bars and this leads to a faster and safer movement. Suction cups with bellows are usually used for curved surfaces. It is used for example when separation is needed or when a smaller item is being gripped and needs a shorter movement. This type of suction cups can be used in several areas but they allow a lot of movement at gripping and low stability with small under pressure. The depth suction cup can be used for surfaces that are very irregular and curved or when an item needs to be lifted over an edge. Item used as vacuum gripper with rough surfaces (surface roughness ≤ 5 µm) for some types of suction cups or items that are made of porous material. An item with holes, slots and gaps on the surfaces is not recommended to be handled with vacuum grippers.

Fig.3.b: Transparent Vacuum Gripper

a. Problems with varied surface types

- Curvy and sharp angled surfaces might not have sufficient flat surface contact to have enough of the cup exerting the required force on the contact surface.
- Porous or corrugated surface can prevent proper gripping, repeatable suction.
- Dirty surface can clog the airlines circuit.
- Such items are placed on plane platform to activate the work of handling with vacuum grippers.

b. Vacuum grippers can leave marks on some surfaces

In some cases like thick glass or mirror may get impression of gripping marks, these marks will need an additional step of packaging the items in the manufacturing process, increasing cost and manufacturing time. Gripping can affect mark on surface of contact on the body.

c. Vacuum grippers are compliant

This can prevent the robot from applying a sufficiently strong contact between the part being held and the work-piece or decrease the repeatability.

d. Structure of Vacuum grippers

To support different cups, it may need to come up with a custom end-effecter usually made of metal extrusion. If the part is complex, the design of the end-effecter can require a fair amount of trial and error. If different parts are available, or parts that evolve during the

ISSN (online): 2250-141X
Vol. 7 Issue 1, February 2017

process (think banded sheet metal), the design of these end-effectors can be costly and unpredictable. To handle such items need many vacuum cups located at different location for safe handling as shown in Fig.3.d.i and 3.d.ii for working action to create vacuum.

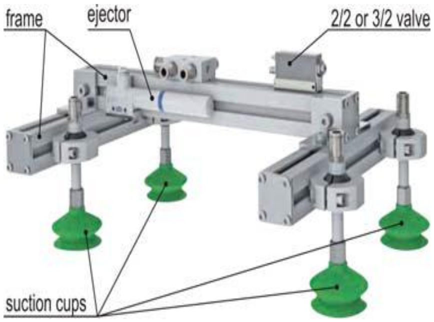


Fig.3.d.i & ii: Heavy Duty application of Vacuum Cup

e. VACUUM SWITCHES

Vacuum switches and pressure gauges are normally selected on the basis of the functions required in the application and on the switching frequency.

The following functions are available:

- adjustable switching point
- fixed or adjustable hysteresis
- digital and/or analog output signal
- status LED
- display with keypad
- connection with Female thread, Male flange or plug-in tube

f. Weight Estimations

It is an important to know the mass of the work-piece to be handled.

Work-piece weight can be estimated as follows:

(i) Suction Pad Mass m [kg]: m = L x B x H x ρ

L = length [m]
B = width [m]
H = height [m]
ρ = density [kg/m3]
Example: m = 2.5 x 1.25 x 0.0025 x 7850
Workpiece mass, m = 61.33 kg
Load case I: horizontal suction pads, vertical force against the workpiece load
FTH = Force for theoretical holding [N]
m = mass [kg]
g = acceleration due to gravitational force [9.81 m/s^2]
a = system acceleration [m/s^2] (remember to include the "emergency off" situation!)
S = safety factor (minimum value 1.5; for critical inhomogeneous or porous materials or rough surfaces 2.0 or higher)

The suction pads are placed on a horizontal with work piece which is to be moved sideways.

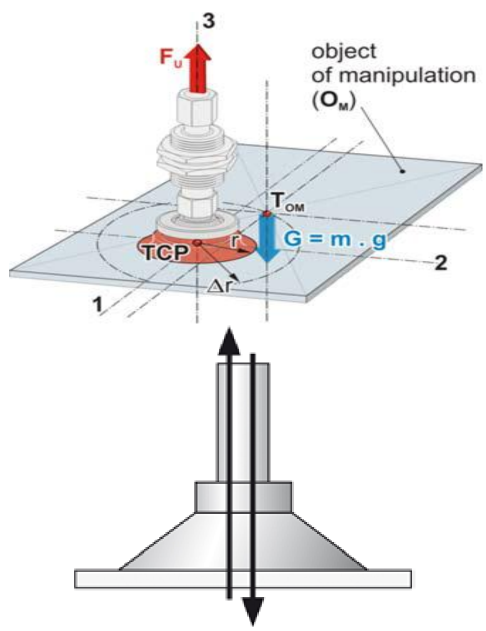


Fig 3.f.i: Suction Pads

ISSN (online): 2250-141X
Vol. 7 Issue 1, February 2017

The theoretical suction force (Fig.3.f.i) is the force acting perpendicular to the surface.
The specifications in the catalog are calculated values in Newton

Example:
Force for theoretical holding,

FTH =m x (g +a) x Factor of safety i.e. 61.33 x (9.81 +5) x 1.5
FTH = 1363 N and for rough surface = 66.33 x (9.81 + 5) x 2 = 1817 N

Comparison:

A comparison of the figures for load cases I and II results, in this example, in a maximum value for FTH =1817 N in load case II, and this value is therefore used for further design calculations.

Load case I: horizontal suction pads, horizontal force

FTH = Theoretical holding force [N]
F_a = mass x acceleration = m a
m = mass [kg]
g = acceleration due to gravity [9.81 m/s^2]
a = system acceleration [m/s^2] (remember to include the "emergency off' situation!)
μ= Coefficient of friction = 0.1 for oily surfaces
= 0.2 ...0.3 for wet surfaces
= 0.5 for wood, metal, glass, stones,
= 0.6 for rough surfaces
S = safety factor (minimum value 1.5 for critical inhomogeneous or porous materials or rough surfaces 2.0 or higher)

The suction pads are placed on a horizontal with work piece which can be moved sideways and the suction pads are placed on a vertical work-piece which is to be moved upwards or downwards (Fig.3.f.ii) where cup feels shear force on the vacuum cup. Shear force is working tangentially to the surface of contacts of the object. The specifications in the catalog are measured values in Newton.

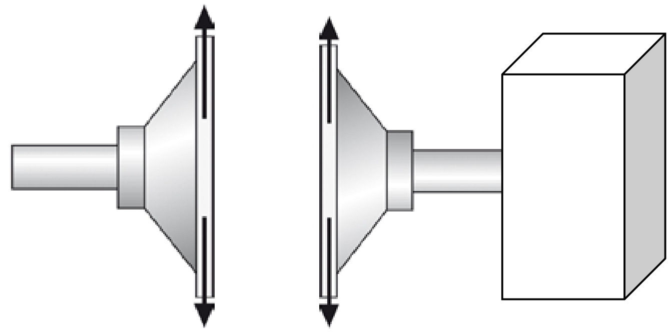


Fig 3.f.ii: Shear Force acting on the Cup pairs

Example.

Force theoretical holding , FTH = m x ((g +a)/μ) x S
Load case II: vertical suction pads, vertical force
FTH = (m/μ) x (g +a) x S

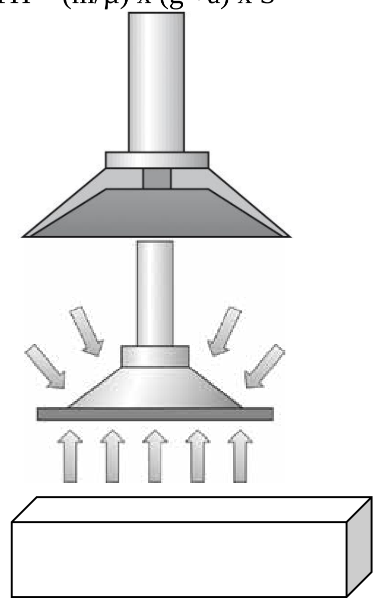


Fig 3.f.iv Inner volume & Pressure

The coefficients of friction shown above are average values.

The actual values for the work piece to be handled must be determined by testing. For the example used for this description, load case III can be ignored, since the work pieces are to be handled only in a horizontal orientation.

This pressure difference is achieved by connecting the suction cup to a vacuum generator, which evacuates the air from the

ISSN (online): 2250-141X
Vol. 7 Issue 1, February 2017

space between the cup and the work-piece. If the suction cup is in contact with the surface of the work-piece, no air can enter it from the sides and a vacuum is generated. The holding force (Fig.3.f.iv) of the suction cups increases proportionally with the difference between the ambient pressure and the pressure inside the cup

The holding force of a suction cup is calculated as below:

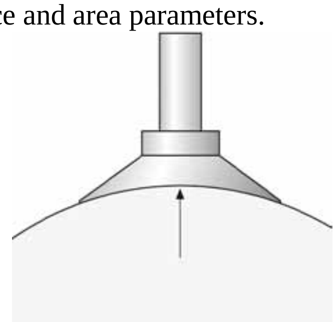
F = p x A

F = Holding force, Newton

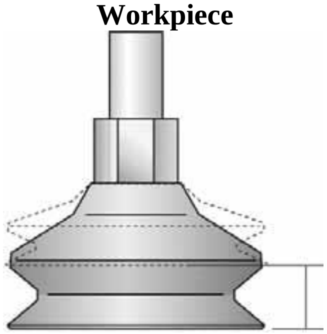
p = Intensity of pressure inside the cup, Kg/m^2

A = Effective suction area, m^2 (the effective area of a suction cup under vacuum)

This means the holding force is proportional to the pressure difference and the suction area. The greater the difference between ambient pressure and pressure in the suction cup or the larger the effective suction area, the greater the holding force (**Fig. 3.f. v & VI)**. The force can vary depending on a change of the pressure difference and area parameters.



(v) Minimum radius of curvature of Workpiece



(vi) Suction cup stroke

Fig. 3.f. v & vi

4. APPLICITION OF VACUUM GRIPPER

- Wide range of applications for material handling,
- Handling technology and process engineering.
- Broad application in industry and research.
- Used for precision processes industry.
- Part feeding systems in the automotive industry.
- Packaging industry.
- Industrial robot applications in all sectors.
- Process engineering.
- Transportation of liquids and bulk material.
- Automated palletizing, depalletizing.
- Commissioning and sorting of many different types of goods in various sizes with a single gripper or multiple grippers.
- Handling of workpieces made of many different materials, such as cardboard, wood, sheet metal (dry) and plastic, with or without apertures.
- Modular design permits the combination of several vacuum gripper systems to form an overall system which is perfectly matched to the intended handling tasks.

5. ADVANTAGES OF VACUUM GRIPPER

- Improves considerably the safety of the company and human beings
- A robot can perform some activities that are dangerous for the human like handle potentially hazardous products, manipulate heavy loads, etc.
- Allows the possibility of doing many different activities related to shipments
- This increases his profitability and faster rate of work performance
- Allows the realization of optimum quality jobs
- The level of incidents is very small
- Less maintenance of the robots

ISSN (online): 2250-141X
Vol. 7 Issue 1, February 2017

vacuum gripper to keep them running smoothly
- Increases the productivity of the company
- The efficiency of the company increases higher
- Over travel forces reduces.

6. DESIGN PARAMETERS

Components should not be damaged during assembly i.e. plastic deformation should not occur when a sapphire sphere with a 1 mm diameter is placed on a planar aluminum. The functional requirements lead to the following specifications for the new gripper design:

- the components are gripped and fixated using suction
- the total positional deviation introduced by the gripper should be less than 5 micrometers
- the equivalent mass which is rigidly connected to the component should be less than 1.4 gram
- the stiffness of the gripper in axial direction should be less than 2.5 N/mm
- the axial position of the needle is constrained using a mechanical type gripper

The bellow is also used to prevent rotation of the needle around its axis. As a result the needle is constrained in 6 degrees of freedom (DOF) during movement of the assembler. During a pickup operation the assembler positions the gripper to make contact with the component to be picked up. When the gripper collides with the component the needle moves in axial direction into the gripper housing.

7. ASSUMPTIONS FOR OF VACUUM GRIPPER

The design of vacuum gripper are having various factors to be considered and some of the factors are considered as an assumptions like shape of object to be handled, weight of items for three types of load, distance to be moved is fixed distance, the medium used to create the vacuum for gripping are pneumatic and hydraulics, size of the object is limited due to lack of source availability, types of materials to be selected for the design of vacuum gripper may be rubber and synthetic materials, properties of the selected materials for their stability for sustaining the load as mentioned in book's data, surrounding environment e.g. air pressure, temperatures like Haryana regions, etc. Assuming some of the factors as mentioned above, some of the critical factors would be taken care of for the design of vacuum gripper considering the object safety and work satisfactory.

9. CONCLUSION

In this paper, vacuum gripper in industrial robot applications has been discussed exclusively with gripping of different variety of materials/parts comparing with other various types of vacuum grippers. The end effectors must typically be designed for the specific application. By comparison to the human hand, a robot's vacuum gripper is very limited in terms of its mechanical complexity, practical utility and general applications.

Vacuum gripper is fruitful for the, objects of very different shape, weight, and fragility can be gripped, and multiple objects can be gripped at once while maintaining their relative distance and orientation. This diversity of Abilities may make the gripper well suited for use in unstructured domains for variable industrial tasks, such as food handling and others. The gripper's airtight construction also provides the potential for use in wet or volatile environments and permits easy cleaning.

The prime interest of this paper is to explore the utilities and advantages of vacuum gripper with its applications for different product type manufacturing robot application's industries. So, the industry performance can be increased and which would decrease the cost of the product effectively. Optimal performance of a vacuum gripper is maintained by resetting the gripper to a neutral state between gripping tasks.

REFERENCE:

I. Bicci A. And Kumar V. (2000), Robotic grasping and contact: A review, in 618 *Proc. IEEE Int. Conf. Robot. Autom.* Apr., pp. 348–353.

II. Choi H. And Koc M. (2006), Design and feasibility tests of a flexible gripper based on inflatable rubber pockets, Int. *J. Mach. Tools Manuf.*, Oct.,vol. 46, pp. 1350–1361.

III. Sam R. and Nefti S. (2009), a new design approach of robotic gripper for reducing cost for handling food products IR3, *Cybernetics Intelligent Systems 8th IEEE International Conference on*, ISBN: 978-960-474-157-1.

IV. Brown E., Rodenberg N., Amend J., Mozeika A., Steltz E., Zakin M., Lipson H., and Jaeger H. (2010), Universal robotic gripper based on the jamming of granular material, *Proc. Nat. Acad. Sci.* vol. 107, pp. 18809–18814.

V. Kragten G. A. (2011), Underactuated hands: fundamentals, performance analysis and design. John R. Amend, Jr., *StudentMember, IEEE*, Eric Brown, Nicholas Rodenberg, Heinrich M. Jaeger, and Hod Lipson, *Member, IEEE* TRANSACTIONS ON ROBOTICS, VOL. 28.

VI. Eizicovits D., Berman S., (2014), efficient sensory-grounded grasp pose quality mapping for gripper.Robot. Auton. Syst.62, 1208–1219.

VII. Ullrich F., Dheman K. S., Schuerle S., Nelson B. J. (2015), magnetically actuated and guided milli-gripper for medical applications. In Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), Seattle,WA, USA, 26–30.

VIII. Jaiswal A. K. , Kumar B. (2016), Design Constraints of Vacuum Gripper of Robots- As A Pick and Place Operating Tool, International Journal of Science & Technology, ISSN (online): 2250-141X, Vol. 6 Issue 4, PP.26-34