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

MATERIAL COMPOSITIONS AFFECTS VACUUM SYSTEM IN GRIPPING TECHNOLOGY

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

Some grippers operate using Bernoulli Principle for generating a high-speed flow between the gripper plate and product surface thereby creating vacuum which lifted the product. Most of the robot grippers are not easily applicable due to the food products are often delicate, easily marked or bruised, adhesive and slippery. Feasibility observations are studied to demonstrate and obtain an overall understanding on the capability and limitations of the vacuum gripper. A substantial part of automated material handling and assembly is the interface between machine and work piece. The main objective of this paper is to highlights the importance of Vacuum Gripper in industrial robot applications which will deal exclusively with gripping of different variety of materials/parts by using vacuum gripper.

The design parameter of the vacuum gripper is a critical consideration in the applications of robotics for industrial operations. In order to realize the full potential of future robotics technology, vacuum grippers must be designed more likely as human hand, both in their sensory and control capabilities as well as their anatomical configurations.

This paper describes a gripping technology with vacuum system for large building components, such as two dimensional modules and three-dimensional modules. The system comprises of the gripping mechanism itself as well as its supporting environment.

Key Words: Vacuum Gripper, Material, Composition, and Application.

1. INTRODUCTION

Materials used for vacuum chamber are materials showing very low rate of out gassing in vacuum and where applicable, tolerant to the bake-out temperatures. The materials can produce gas by several mechanisms.[3] Molecules of gases and water can be adsorbed on the material surface (therefore materials with low affinity to water have to be chosen, which eliminates many plastics). Materials may sublimate in vacuum (this excludes some metals and their alloys, most notably cadmium and zinc or the gases can be released from porous materials or from cracks and crevices).[1][3] The gases liberated from the materials not only lower the vacuum quality, but also can be reabsorbed on other surfaces, creating deposits and contaminating the chamber.[10] Traces of lubricants, residues from machining, can be present on the surfaces. A specific risk is out gassing of solvents absorbed in plastics after cleaning.[5] The requirements grow increasingly

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

stringent with the desired degree of vacuum achievable in the vacuum chamber.

Yet another problem is diffusion of gases through the materials themselves. Atmospheric helium can diffuse even through Pyrex glass, even if slowly; this however is usually not an issue. Some materials might also expand or increase in size causing problems in delicate equipment.[4] In addition to the gas-related issues, the materials have to maintain adequate strength through the entire required temperature range (sometimes reaching cryogenic temperatures), maintain their properties (elasticity, plasticity, electrical and thermal conductivity or lack of it, etc.), be possible to machine, and if possible not being overly expensive. Yet another concern is the thermal expansion coefficient match of adjacent parts.

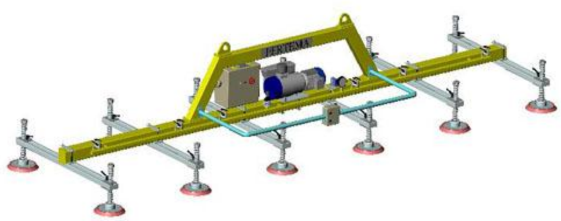

Fig.1: Heavy duty vacuum Gripper

The quality of a partial vacuum refers to how closely it approaches a perfect vacuum as shown in Fig.1. Other things equal, lower gas pressure means higher-quality vacuum. For example, a typical vacuum cleaner produces enough suction to reduce air pressure by around 20%. Much higher-quality vacuums are possible. Ultra-high vacuum chambers, common in chemistry, physics, and engineering, operate below one trillionth (10^{-12}) of atmospheric pressure (100 nPa), and can reach around 100 particles/cm^3. Outer space is an even higher-quality vacuum, with the equivalent of just a few hydrogen atoms per cubic meter on

Materials for use in vacuum system are materials showing very low rate of out gassing in vacuum and where applicable, tolerant to the bake-out temperatures.[3] The requirements grow increasingly stringent with the desired degree of vacuum achievable in the vacuum chamber. The materials can produce gas by several mechanisms.[10] Molecules of gases and water can be adsorbed on the material surface. Therefore, materials with low affinity to water have to be chosen, which eliminates many plastics. Materials may sublimate in vacuum which excludes some metals and their alloys, most notably cadmium and zinc.

2. Research on Vacuum Gripper

Vacuum grippers are used in the robots for grasping the non-ferrous objects and packets. It uses vacuum cups as the gripping device as shown in Fig.2 which is also commonly known as suction cups.

Fig.2: Mechanism of vacuum Gripper

Many researchers have worked on robot grippers related with vacuum type as mentioned below:

Sood et al. [1] have formulated Range image Segmentation with Applications to Robot Bin-Picking using vacuum gripper. Lovel et al.[2] have discussed about a Optimized vacuum system design improves productivity'. Choi et al.

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

[3] have elaborated design and feasibility gripper based on inflatable rubber pockets. Mantriota et al.[4] have also Theoretical model of the grasp with vacuum gripper. Fronz el al.[5] have also Recursive modeling and control of multi-link manipulators with vacuum grippers. Sam et al. [6] have developed a design approach of robotic gripper for reducing cost for handling food products. Laschi el al. [7] have a Design and Development of a soft robotic gripper for manipulation in minimally invasive surgery. Jaiswal et al. [9] have discussed about design construction of vacuum gripper of robots relevant to pick and place operating tool in which merits and demerits of vacuum gripper has been discussed. Jaiswal et al. [10] have a Design Constraints of Vacuum Gripper an important material handling tool. The authors have discussed about the shape, size and temperature effect on vacuum cup gripper.

3. MATERIAL COMPOSITION USED IN VACUUM GRIPPER

Austenitic stainless steels are the most common choice for high vacuum and ultra-high vacuum systems. Not all the alloys are suitable; e.g. the free-machining 303 steel contains sulphur, which tends to outgas. Alloys with good weld ability under argon arc welding are usually chosen.[5]

- **304 stainless steel** is a common choice of a stainless steel.
- **304L stainless steel**, a low-carbon variant of 304 steel, is used for ultra-high vacuum systems.
- **316L stainless steel** a low-carbon and low-magnetic stainless steel, used in accelerator technologies.
- **347 stainless steel** does not accept high polish.
- **321 stainless steel** is chosen when low magnetic permeability is needed.
- Mild steel can be used for moderate vacuums above 10^{-6} torr. Out gassing can be lowered with suitable (e.g. nickel) plating.[7][1] It has high permeability to hydrogen and tendency to rust. For use it should be thoroughly out gassed in vacuum.

- Aluminium and its alloys are another class of frequently used materials which have low out gassing, unless the alloys contain higher proportion of zinc. The parts must not be anodized, as the oxide layer traps (and out gasses) water vapor. Aluminium and its alloys have low strength at high temperatures, distort when being welded, and the copper-containing ones are poorly weldable. Aluminium wire rings can be used as cheap gaskets in demountable seals.[9] Aluminium has high thermal conductivity, good corrosion resistance, and low solubility of hydrogen. Loss of strength at high temperatures limits its use in bakeable applications, but aluminium is advantageous for large-size systems due to its lower weight and lower cost than stainless steel. Use of aluminium is limited by difficulties in its welding and brazing.[3][5] It can be used for x-ray windows.
- Aluminium bronze is a material looking and machining similar to brass. It is not susceptible to galling, which makes it suitable for sliding fits against stainless steel.
- Nickel is widely used in vacuum technology, e.g. as mechanical parts in vacuum tubes. It is relatively low-cost, can be spot welded, can be easily machined, has high melting point and is resistant to many corrosive fluids and atmospheres.[8] Its potential drawback is its ferro-magnetism, which restricts applications that would be influenced by magnetic fields.

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

- Nickel alloys, e.g. cupronickel Beryllium is used primarily for x-ray windows.
- Oxygen-free copper is widely used. It is easily machined and has good corrosion resistance. It is unsuitable for bakeable vacuum envelopes due to its tendency to oxidize and create scales. Copper rings are used in demountable seals. Normal copper is unsuitable for high vacuum as it is difficult to outgas completely. Copper is insensitive to hydrogen and impermeable to hydrogen and helium, has low sensitivity to water vapor, but is attacked by mercury. Its strength falls sharply above 200 °C. Its vapour pressure becomes significant at above 500 °C.
- Brass is suitable for some applications.[6] It has good corrosion resistance. Its zinc content may cause problems; zinc outgassing can be reduced by nickel-plating.
- Indium wire is used as a gasket in demountable seals.
- Gold wire is used as a gasket in demountable seals for ultra-high vacuum.
- Platinum is a highly chemically inert material with high cost and low outgassing.
- Zirconium is corrosion-resistant which has low production of secondary electrons. Hence, it is used as a coating of areas where reducing their production is important and also used for neutron windows. [2] Zirconium is costly and scarce, its uses are therefore limited and are used for guttering.
- Tungsten is often used in high temperature applications as well as for filaments in electron/ion optics. [5] It becomes brittle from work hardening when mechanically deformed, or subjected to very high temperatures.
- Molybdenum and tantalum are useful for high temperature applications.
- Titanium and niobium are good materials.
- Solders are sometimes unavoidable for soft-soldered joints. A better choice for vacuum systems is the tin-silver eutectic, Sn95Ag5; its melting point of 230 °C allows bakeout up to 200 °C.[10] A similar 95-5 alloy, Sn95Sb5, is unsuitable as antimony has similar vapor pressure as lead. Take care to remove flux residues.[4][8]
- Brazing alloys are used for joining materials by brazing. Care has to be taken while choosing the alloys, as some elements tend to outgas. Cadmium and zinc are the worst common offenders. Silver, a common component of brazing alloys, can be problematic at higher temperatures and lower pressures.

3. A. Materials to Avoid

Materials out gassed by three mechanisms:

i) release of absorbed gases

ii) release of absorbed gases

iii) Evaporation of the material itself.

The former can be reduced by a bake out the latter is an intrinsic property of the material.[3][7] Some out gassed materials can deposit on other surfaces, contaminate the vacuum system and be difficult to get rid of.

The most common sources of trouble (out gassing) in vacuum systems are:

- Cadmium, often present in the form of cadmium plating, or in some soldering and brazing alloys

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

- Zinc, problematic for high vacuum and higher temperatures, present in some construction alloys, e.g. brass and some brazing alloys. Tends to poison hot cathodes and form conductive deposits on surfaces.
- Magnesium, PVC, usually in the form of wire insulation (source of virtual leaks too)
- Paints Lead and antimony used in some soft solders and out gassing at higher temperatures.
- Many plastics, namely many plastic tapes (special attention should be paid to adhesives).[3] Fiberglass composites, e.g. Micarta (G-10) and G-30, should be avoided. Even Teflon is sometimes advised against.
- Various residues e.g. flux from soldering and brazing, and lubricants from machining. Thorough cleaning of the parts is important.

3. b. Electromagnetism

In classical electromagnetism, the vacuum of free space, or sometimes just free space or perfect vacuum, is a standard reference medium for electromagnetic effects. Some authors refer to this reference medium as classical vacuum, a terminology intended to separate this concept from QED vacuum or QCD vacuum, where vacuum fluctuations can produce transient virtual particle densities and a relative permittivity and relative permeability that are not identically unity.[3][6]

3. c. Measurement

The quality of a vacuum is indicated by the amount of matter remaining in the system. Vacuum is primarily measured by its absolute pressure, but a complete characterization requires further parameters, such as temperature and chemical composition. One of the most important parameters is the mean free path (MFP) of residual gas, which indicates the average distance that molecules will travel between collisions with each other.[3][9] As the gas density decreases, the MFP increases, and when the MFP is longer than the chamber, pump, spacecraft, or other objects present, the continuum assumptions of fluid mechanics do not apply.[6] The Following terms are used in the vacuum system:

- **Atmospheric pressure** is variable but standardized at 101.325 kPa (760 Torr).
- **Low vacuum**, also called rough vacuum or coarse vacuum, is vacuum that can be achieved or measured with rudimentary equipment such as a vacuum cleaner and a liquid column manometer.
- **Medium vacuum** is the vacuum that can be achieved with a single pump, but the pressure is too low to measure with a liquid or mechanical manometer.[2][5] It can be measured with a McLeod gauge, thermal gauge or a capacitive gauge.
- **High vacuum** is the vacuum where the MFP of residual gases is longer than the size of the chamber or of the object under test.[7][9] High vacuum usually requires multi-stage pumping and ion gauge measurement.
- **Ultra high vacuum** requires baking the chamber to remove trace gases, and other special procedures. [2][8] British and German standards define ultra-high vacuum as pressures below 10^{-6} Pa (10^{-8} Torr).
- **Deep space** is generally much emptier than any artificial vacuum.[5] It may or may not meet the definition of high vacuum above, depending on what region of space and astronomical bodies are being considered.
- **Perfect vacuum** is an ideal state of no particles at all.[7] It cannot be achieved in a laboratory, although there may be small volumes which, for a brief moment, happen to have no particles of matter in them.[4][8]

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

- **Hard vacuum** and **soft vacuum** are terms that are defined with a dividing line defined differently by different sources, such as 1 Torr, or 0.1 Torr, the common denominator being that a hard vacuum is a higher vacuum than a soft one.[7][8]

3. d. Measuring instruments:

Many devices are used to measure the pressure in a vacuum, depending on what range of vacuum is needed. Hydrostatic gauges (such as the mercury column manometer) consist of a vertical column of liquid in a tube whose ends are exposed to different pressures.[4][6] The column will rise or fall until its weight is in equilibrium with the pressure differential between the two ends of the tube.

The simplest design is a closed-end U-shaped tube, one side of which is connected to the region of interest. Any fluid can be used, but mercury is preferred for its high density and low vapour pressure. Simple hydrostatic gauges can measure pressures ranging from 1 torr (100 Pa) to above atmospheric.[1][3] The McLeod gauge can measure vacuums as high as 10^{-6} torr (0.1 mPa), which is the lowest direct measurement of pressure that is possible with current technology.

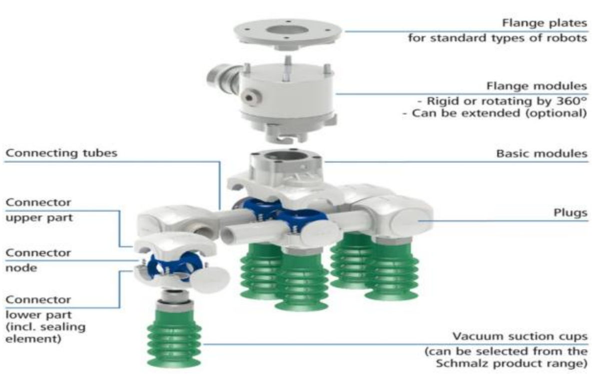

Fig.3: Hydrostatic Vacuum Creator

The kenotometer is a particular type of hydrostatic gauge, typically used in power plants using steam turbines.[2][5] The kenotometer measures the vacuum in the steam space of the condenser, that is, the exhaust of the last stage of the turbine.

Mechanical Gauges depend on a Bourdon tube, diaphragm, or capsule, usually made of metal, which will change shape in response to the pressure of the region in question. A variation on this idea is the **capacitance manometer**, in which the diaphragm makes up a part of a capacitor.[3][7][10] A change in pressure leads to the flexure of the diaphragm, which results in a change in capacitance. These gauges are effective from 10^3 torr to 10^{-4} torr, and beyond.[4][9]

Thermal Conductivity Gauges rely on the fact that the ability of a gas to conduct heat decreases with pressure. In this type of gauge, a wire filament is heated by running current through it. A thermocouple or Resistance Temperature Detector (RTD) can then be used to measure the temperature of the filament.[1][4] This temperature is dependent on the rate at which the filament loses heat to the surrounding gas, and therefore on the thermal conductivity.

A common variant is the Pirani vacuum gauge which uses a single platinum filament as both the heated element and RTD.[2][6] These gauges are accurate from 10 torr to 10^{-3} torr, but they are sensitive to the chemical composition of the gases being measured.

4. UTILITIES OF VACUUM

This is the principle behind chemical vapor deposition, physical vapor deposition, and dry etching which are essential to the fabrication of semiconductors and optical coatings, and to surface science. The reduction of convection provides the thermal insulation of thermos bottles.[3][7] Deep vacuum lowers the boiling point of liquids and promotes low temperature out gassing which is used in freeze drying, adhesive preparation, distillation, metall urgy, and process purging.

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

The chemical inertness produced by a vacuum is also useful for electron beam welding, cold welding, vacuum packing and vacuum frying.[4][8] Ultra-high vacuum is used in the study of atomically clean substrates, as only a very good vacuum preserves atomic-scale clean surfaces for a reasonably long time (on the order of minutes to days). High to ultra-high vacuum removes the obstruction of air, allowing particle beams to deposit or remove materials without contamination.

5. MATERIAL BASED ON THE LOAD FACTORS

a. Capacity planning

Capacity planning is the process of determining the production capacity needed by an organization to meet changing demands for its products. In the context of capacity planning, design capacity is the maximum amount of work that an organization is capable of completing in a given period.[5][9] Effective capacity is the maximum amount of work that an organization is capable of completing in a given period due to constraints such as quality problems, delays, material handling, etc.

Capacity is calculated as (number of machines or workers) × (number of shifts) × (utilization) × (efficiency). The broad classes of capacity planning are lead strategy,[5][9] lag strategy, match strategy, and adjustment strategy.

b. Plastics

It is self-lubricating, a good electrical insulator, tolerant to fairly high temperatures, and has low out-gassing.[2][5] It is not suitable for barrier between vacuum and atmosphere, as it is somewhat permeable for gases. Ceramics is a superior choice, however, Polyethylene is usable but requires thorough out gassing.

Nalgene can be used as a cheaper alternative for Bell jars. Vessel polyimide is very expensive, but a machine well, has good electrical insulator properties and is compatible with ultra-high vacuum.[3][7][9] PVC, despite its high out gassing rate, can be used in limited applications for rough vacuum lines.

- Nylon is self-lubricating but has high out gassing rate and high affinity to water.
- Acrylics have high out gassing rate and high affinity to water.
- Polycarbonates and polystyrene are good electrical insulators with moderate out gassing.
- PEEK (Poly Ether Ether Ketone) has relatively low out-gassing values (0.31% TML, 0.00% CVCM, 0.06% WVR).
- Kapton is a type of polyimide film,[5][7] has very low out gassing. Kapton is discouraged if a ceramic alternative can be used.
- Some elastomers (polymer) have sufficient vacuum properties employed for vacuum o-rings: NBRs, (Nitrile rubber), commonly used for demountable vacuum seals (bakeable only up to 100 °C).
- FKMs (FPMs), (Viton) is used for demountable vacuum seals.[3][5] It is better for lower pressure than nitrile rubber and chemically much more inert. It is bakeable to 200 °C.
- FFKMs (FFPMs) very low out-gassing similar to Teflon and withstands baking temperatures up to 300 °C,[7][9] while chemically one of the most inert sealing elastomers.

c. Glasses and ceramics

- Borosilicate glass is often used for smaller assemblies and for viewports. It can be machined and joined well. Glasses can be joined with metals.

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

- Porcelain and alumina ceramics,[4][7] when fully vitrified and therefore non-porous, are excellent insulators usable up to 1500 °C. Some ceramics can be machined. Ceramics can be joined with metals.
- Macor is a machinable ceramic that is an excellent alternative to alumina, as the firing process of alumina can change the dimensions and tolerances.

d. Lubricants

Lubrication of moving parts is a problem for vacuum.[3][7] Many lubricants have unacceptable outgassing rates, others (e.g. graphite) lose lubricating properties.

Vacuum greases are greases with low outgassing. Ramsay grease is an old composition of paraffin wax, vaseline and natural rubber, usable up to about 25 °C, for low vacuums to about 1 Pa. Krytox is a fluorether-based vacuum grease,[8][9] useful from -75 to over 350 °C, not flammable even in liquid oxygen, and highly resistant to ionizing radiation.

Dry lubricants, can be incorporated in plastics as fillers, as a component of sintered metals, or deposited on metal, ceramic and plastic surfaces.[3][7] Molybdenum disulfide is a dry lubricant usable in vacuum. Tungsten disulfide is another dry lubricant usable in vacuum. It can be used at higher temperatures than MoS_2.[8] Tungsten disulfide used to be significantly more expensive,[9] but rise of prices of molybdenum disulfide brought them to a comparable range.

e. Adhesives

Torre-Seal, or its generic equivalent Hysol-1C, is an epoxy with resin and hardener for use in vacuum environments.[5] It will begin to degrade at high temperatures but otherwise is very stable with very little outgassing.[9] Other vacuum-rated epoxies are also available.

6. FACTOR OF SAFETY

Factors of safety (FS), also known as safety factor (SF), is a term describing the load carrying capacity of a system beyond the expected or actual loads. Essentially, the factor of safety is how much stronger the system is than it usually needs to be for an intended load.

Many systems are purposefully built much stronger than needed for normal usage to allow for emergency situations, unexpected loads, misuse, or degradation.[10]

The difference between the safety factor and design factor (design safety factor) is as follows: The safety factor is how much the designed part actually will be able to withstand.[7] The design factor is what the item is required to be able to withstand.

Design Safety Factor -For a successful design, the Realized Safety Factor must always equal or exceed the Design Safety Factor so the Margin of Safety is greater than or equal to zero.[3] The Margin of Safety is sometimes used as a percentage, i.e., a 0.50 M.S is equivalent to a 50% M.S.

A measure of strength frequently used in Europe is the Reserve Factor (RF).[7] With the strength and applied loads expressed in the same units, the Reserve Factor is defined as:

RF = Proof Strength / Proof Load

RF = Ultimate Strength / Ultimate Load

7. CONCLUSION

In this paper, authors have highlighted the different parameters of materials used for vacuum gripper in industrial robot applications The end effectors must typically be designed for the specific application. 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

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

variable industrial tasks, such as food handling and others. The airtight construction of vacuum grippers 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 industries so that 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 based on material selection as suitable with environment and conditions.

REFERENCE

I. Hujazi E. Sood Al, (1990), A. Range Image Segmentation with Applications to Robot Bin-Picking Using Vacuum Gripper. IEEE Trans. Syst. Man Cybern. 20, 1313–1325.

II. Lovell, A.[2006] Optimized vacuum system design improves productivity. Control Eng. 53, 26–28.

III. 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.

IV. Mantriota, G.[2007],' Theoretical model of the grasp with vacuum gripper', Mech. Mach. Theory, 42, 2–17.

V. Callies, R.; Fronz,[2008] S. Recursive modeling and control of multi-link manipulators with vacuum grippers. Math. Comput. Simul. 79, 906–916.

VI. 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.

VII. Active Robots. Robotiq 2-Finger Adaptive Gripper. [2015] Available online: http://www.active-robots. com/robotiq-2-finger-adaptive-gripper- 200.

VIII. Rateni; Cianchetti, M.; Ciuti, G.; Menciassi, A.; Laschi, C.[2015] Design and Development of a soft robotic gripper for manipulation in minimally invasive surgery: A proof of concept. Mecanica ,V 50, 2855–2863.

IX. Jaiswal A. K. , Kumar B. (2016), Design construction of vacuum gripper of robots-as a pick and place operating tool, International Journal of Science and Technology, ISSN 2250-141X, Vol.6, Issue 4 Oct, P 26-35.

X. Jaiswal A. K. , Kumar B. (2017), Design Constraints of Vacuum Gripper an important material handling tool, International Journal of Science and Technology, ISSN 2250-141X Vol.7, Issue 1 Feb, P 1-8