GRIPPER'S QUALITY ESTIMATION APPROACH

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ABSTRACT

The main objective of this study is to obtain the quality importance of robotic vacuum cup gripper in industry for gripping of different variety of packed materials/parts by using vacuum cup gripper. Feasibility studies to demonstrate the capability and limitations of the 'Vacuum Cup Gripper'. In this study, an experimental approach is considered for handling variable sizes, shapes and weights of packed food products by Vacuum Cup Gripper. The gripper operates on Bernoulli Principle for generating high-speed fluid flow between the gripper plate and packed product surface thereby creating vacuum to lift the packed products. The gripper must typically be designed for the specific application to realize the full potential of future robotics technology with vacuum cup system.

KEYWORDS: Vacuum Cup, Areas, Shapes, Vacuum Gauge, Material's Packing, Gripping Approaches

Vacuum cup grippers are designed with high flexibility that are having single and multi-functional approaches. Vacuum cup grippers are those devices that actually grip an object for moving or placing it within the working range of system. The study aims to highlights all the factors which are influenced in case of vacuum cup type gripping system. Different shape of vacuum cup gripper is available in which some existing vacuum cup grippers with feasible mechanism in the literatures review have been described. Vacuum cup gripper which is called the end-effectors is usually specifically designed for their particular task. The highest workload onsite construction that consists of handling and assembly operations are performed by the vacuum cup gripper. Modern vacuum cup grippers are used for handling in assembling system for light, medium and heavy work in industry considering human safety.

VACUUM CUP GRIPPER'S WORKING

Vacuum cup gripper's working is shown in Figure 1 that actually grip an object for moving or placing it within the working range. The task cannot be completed satisfactorily, if the end-effectors are not properly designed.

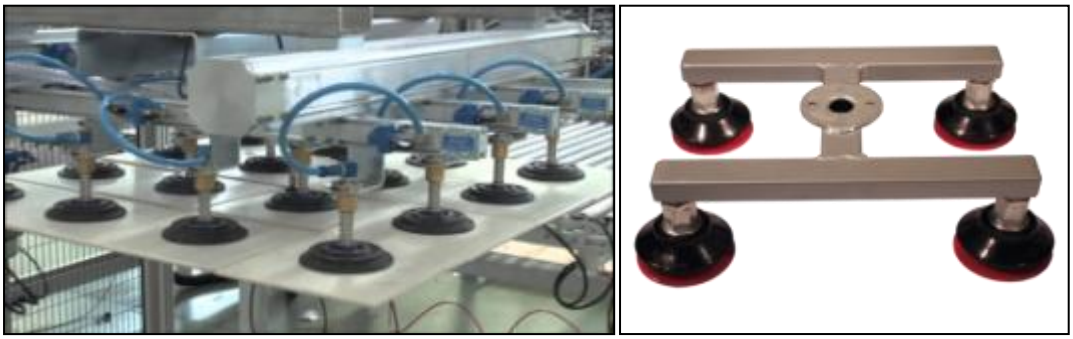

Figure 1: Vacuum cup gripper for handling Materials

Vacuum cup grippers are used in applications like automated assembly lines, modern industrial robotic arms, for grasping the non-ferrous objects and packets.

RESEARCH WORK CARRIEDOUT

Some of the researchers have worked on gripping technology with vacuum cup grippers and some of them have worked on vacuum cup shape and size and gripping process. Whereas some of them have worked on its control devices and some of them have worked on application of gripping from are sides as per requirements.

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

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Materials

Some researchers have worked considering the type of materials used in vacuum cup design for handling the items.

Surface

The nature of gripping surface plays an important role for holding the items which are observed by some of the researchers.

Product

The products are of various natures which should be handled carefully. Some of the researchers have worked on it considering safety and approaches for gripping the items.

Mostly, the items are handled from one place to another with application of safe gripping technology for loading and unloading the materials it must have economical designed safe to grasp the work part to handle with cares.[2] It would be very fruitful to handle such items in a box for small items case and large sized items should be handled with specific design of vacuum cup to grasp the items rigidly.

Figure 2: Transparent Vacuum cup Gripper

The suctions cups are made of transparent plastics or rubber as Figure 2. The vacuum cups which are linked throw hose pipes to act as system to develop vacuum pressure inside the system with application of vacuum pump.[9] The components used in this working system mentioned below:

- Pump to develop vacuum
- Ejector
- Bellow
- Cylinder (Double acting)

Figure 3: Different shape of cup for vacuum cup Gripper

The different shape of cups for gripping the items is mentioned in F.3. It is suitable for flat surfaced items and flexible items. It can sustain more vacuum pressure for lifting the items of heavy weight. It can be suitable to lift in case of curved surfaces of items.[10] The depth of suction cup can be used for vacuum suction cup areas that are very irregular and curved. Sometimes it may be suitable for lifting the items which are placed on an edge. If the part is complex, the design of the end-effecter can require a fair amount of trial and error.

APPLICATION

- Applicable for handling technology and process engineering.
- Broad application in industry and research.
- Used for precision processes industry.
- Part feeding systems in the automotive industry.
- Transportation of liquids and bulk material.
- Automated palletizing, de-palletizing.

VACUUM CUP GRIPPER'S ADVANTAGES

- Less maintenance to keep them running smoothly.

- Increases the productivity of the company.
- The efficiency of the company increases higher.
- Improves considerably the safety of the company and human beings
- A robot can perform some activities that are dangerous for the human beings.
- This increases his profitability and faster rate of work performance

LITERATURE REVIEW

The relevant literature had been observed which are categorized for studies in this chapter as discussed below. The literature review is presented in chronological order, tracing the developments in the field of vacuum cup gripping technology. The review shows that further work is needed to better understand the certain aspect of convergent divergent of vacuum cup gripping technology and their performance.

Choi and Koc; 2006 have elaborated design and feasibility gripper based on inflatable rubber pockets. Jain et al; 2014 have presented interpretation of multi-axial gripper force sensors. Jaiswal and Kumar; 2016 have design construction of vacuum cup gripper or robot- as a pick and place operating tool. Jaiswal and Kumar; 2017 have discussed on design constraints of vacuum cup gripper an important material handling tool for vacuum cup gripper and again presented on material composition affects vacuum system in gripping technology.

Jaiswal and Kumar; 2017 have submitted the application of vacuum cup grippers for material handling in industry. Lovell; 2006 has discussed optimized vacuum cup system improves productivity. Mantriota; 2007 has developed the theoretical model to grasp the object with vacuum cup gripper. Sam R. and Nefti S.; 2009 have developed an approach for reducing cost for handling the products.

MODEL DEVELOPMENT

The design of the vacuum cup gripper must be based on the functional requirements. Vacuum cup gripper is useful to handle the varieties of applications to pickup and place at a fixed location of materials.

- The components are gripped and fixated using suction head inside the cups.
- The total positional deviation should be minimum than 5 micrometers.
- The gripping attachment which is rigidly connected to the component should be less than 2 grams.
- The stiffness of the vacuum cup gripper in axial direction should be less than 2 N/mm
- To prevent rotation of the needle around its axis, bellows are used.

DESIGN AND CALCULATION

Find the weight of Suction Pad

Weight of work piece = w

Let Suction Pad Mass = m kg

Length of Suction Pad = L metre = 1.5 m

Width of Suction pad = B metre = 0.002 m

Height of suction pad = H metre = 8500 m

Density of suction pad material = ρ kg/m3 = 5 kg/m^3

Now, mass of suction pad, m = ρ x volume of suction cup

= ρ x L x B x H

e.g. m = 5 x 1.5 x 0.002 x 8500

Suction Pad Mass, m = 127.5 kg

Load case I

Suction pads (Horizontal) where the workpiece load exerts vertical forces

Theoretical Holding Force = F_h

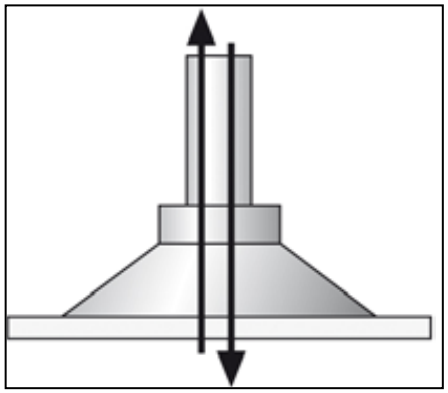
Mass = m kg

Gravitational force = g = 9.81 meter per square second

Acceleration = a meter per square second

Factor of safety = S = 1.5, min value

= 2.0, for critical case like in homogeneous items or porous items or rough surfaces



Figigure 4: Suction Cups

The theoretical suction force (Fig. 4) is the force acting perpendicular to the surface.

Load case II

Theoretical Holding Force with acceleration **= F_{ha}**

F_{ha} = m x (g +a) x Factor of safety

i.e. 127.5 x (9.81 + 5) x 1.5

F_{ha} = 2832.41 N and for rough surface = 127.5 x (9.81 + 5) x 2 = 3776.54 N

Comparison

It is observed that on comparison load cases I and II results, the II case has maximum F_{ha} = 3776.54 N, which should be considered for further design.

Load case III

Horizontal suction pads,

The horizontal forces are acting for gripping on both sides to raise the item.

Let, Holding force in shear on cup surface, = $F_s = 2 \times F_a$

Force, F_a = mass x acceleration = μ x m x (g + a) = 0.1 x 127.5 x (9.81 +5) = 2408.86 N in oily surfaces, similarly other surfaces situation can be estimated.

Where, Mass = m kg

Gravitational force, g = 9.81 m/s^2

Horizontal acceleration of vacuum cup pads = a m/s^2

Coeff. of friction, μ = 0.1 (oily surfaces) μ = 0.2 ...0.3 (wet surfaces)

μ = 0.5 (wood, metal, glass, stones,)

μ = 0.6 (rough surfaces)

Factor of safety, S = 1.5(minimum value) - critical inhomogeneous/ porous materials / rough surfaces 2.0 or higher)

SETUP DECLARATIONS

Arrangements and Observation

The setup (Fig. 5) was developed and observations were recorded in Table 1 to study the vacuum cup gripper applications to lift the items. A single vacuum cup and/or multi vacuum cups are used along with by changing the different sizes of vacuum cup in consideration to varying weight lifting capacities. Graph 1 is plotted to observe the pattern of head vs weight. The graph indicates that the vacuum head is decreasing and load lifting capacity is increasing.

Table 1: Plastic Suction cup (0.09m)

Head (mm) Hg	Vacuum head (Hg) mm	Vacuum Air head (M)	Weight (Load Lifted) (Kg)
16.4-5.7	10.7	0.1435	0.5
16.3-6.2	10.1	0.01373	1
16.0-6.5	9.5	0.01292	2
15.8-6.4	9.4	0.1278	2.5
15.4-6.2	9.2	0.1011	3

Consideration: Nozzle Diameter -0.007M & Vacuum cup area =0.0063m^2

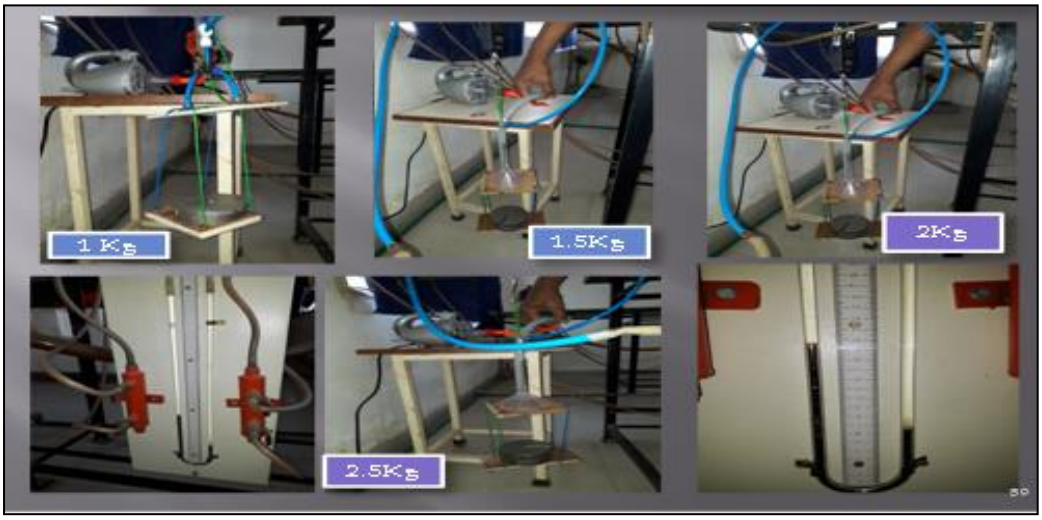
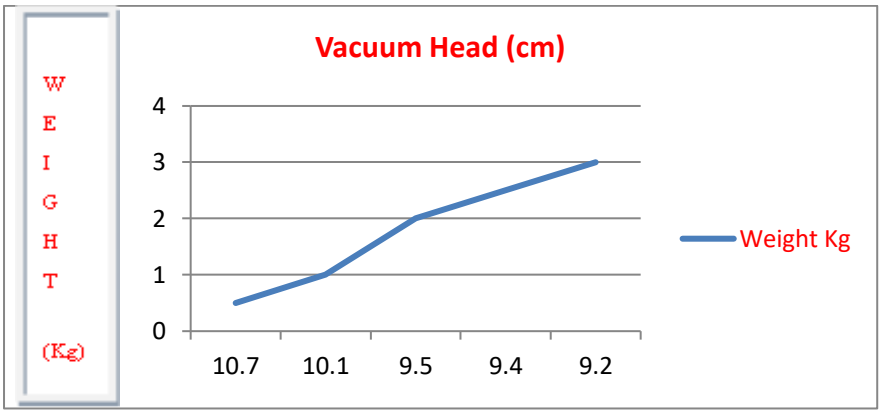
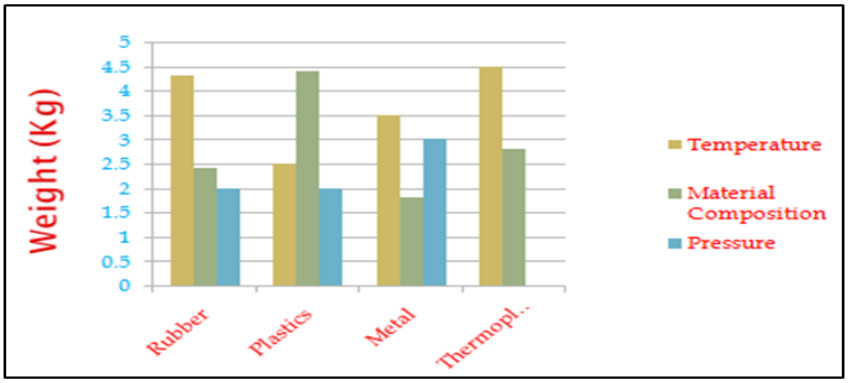


Figure 5: Different modules of experiment with Vacuum on Cup Gripper



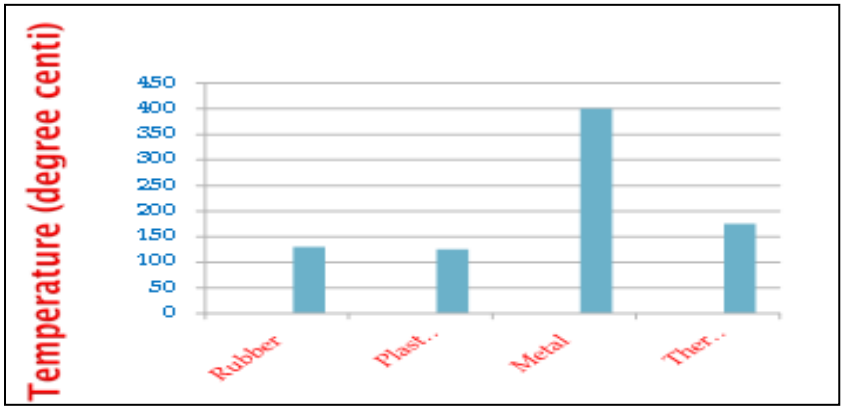
Graph 1: Head Vs Weight

Graph 2 is shown for types of materials vs Temperature dependent parameter which indicate that rubber and thermoplastics are more suitable to carry higher load in comparison to plastics and metal vacuum cup. Also thermoplastic material composition is more sustainable to take more loads in compare to other three. But metal body vacuum cum having more sustainable for pressure to carry load more than the others type of materials.



Graph 2: Vacuum cup material vs weight (Kg)

Graph.3 is plotted between types of material and temperature ranges. It can be observed that metal body vacuum cup can sustain more temperature in comparison to other type of materials.

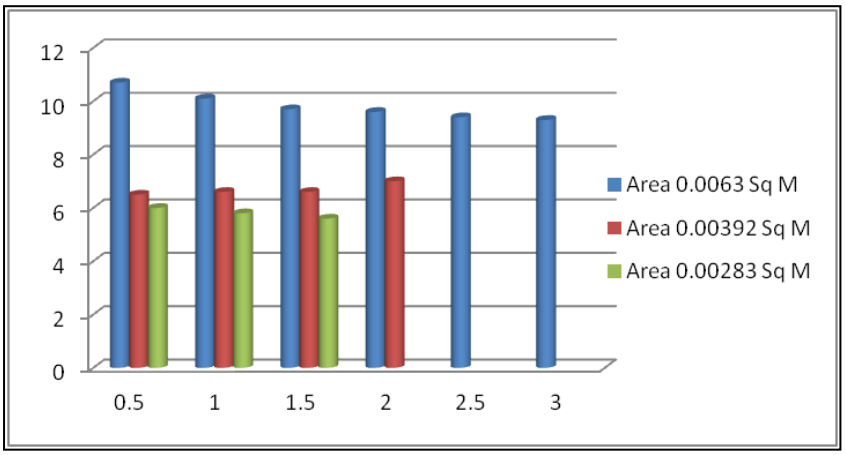


Graph 2: Vacuum cup material vs temperature

Table 2: Vacuum Air Head Developed with variation of gripping areas in a constant load

Weight (Kg)	9-Areas = 0.00636 m^2, Air Head Developed (M)	2x5-Areas = 0.003927 m^2, Air Head Developed (M)	6-Areas = 0.002827 m^2, Air Head Developed (M)
0.5	0.01455	0.0883	0.0816
1.0	0.01373	0.0925	0.0789
1.5	0.0140	0.0952	0.0816
2.0	0.0130	-	-
2.5	0.0129	-	-
3.0	0.0127	-	-

Graph 4 is plotted based on T.2 to understand the characteristics of load lifting capacity. For same load lifting by reducing the gripping areas, air column is increasing i.e. air head column is indirectly proportional to gripping areas of vacuum cup. It can be observed that when contact areas decreases, the air column head increases for same load i.e. in column 2 and column 4. If the number of vacuum cup is increases for increasing the areas of vacuum cup as in column 3, the air column head developed very high for same load. For larger diameter of vacuum cup having more load lifting capacity as indicated by graph 4 i.e. it can be effective for more than 3 kg load.



Graph 4: Weight (Kg) Vs Height in Hg head (mm)

RESULT ANALYSIS

The design of the vacuum cup gripper must have many considerations as stated earlier to fulfill the functional requirements as pick and place for handling items from one location to desired locations within robotics ranges. It is mentioned that a vacuum cup gripper is useful to pickup and fixate a wide variety of material size of the object.[10] The types of materials are to be selected for the design of vacuum cup gripper may be rubber and synthetic materials which must be based on properties of the selected materials for their stability for sustaining the load as mentioned in discussions, etc.

Some assuming factors and some of the critical factors must be taken care of for the design. The Design consideration parameter should have easy cleaning factors and cost economic approaches based on industry applications.

CONCLUSION

The vacuum cup gripping approaches has been discussed in details with factors influencing the design parameter used for industrial robot. Experimental setup has been discussed considering verities of vacuum cup shapes and sizes along with different materials comparing the load carrying parameters with other different types of vacuum cup which are suitable for industries. The vacuum cup may be suitably designed for special considerations based on types of items to be handled.

Vacuum cup grippers are very fruitful for the use of varying shapes, sizes, weights, which may be rigidly gripped. Multiple objects also can be handled with maintaining their safety, relative distances and orientations.

The researcher's interest is to highlights the utilities and various key factors with advantages of vacuum cup gripper. The modern gripping technologies with its applications have been highlighted for different product assembly line, production system, gripping applications and safe handling system in industries.

FUTURE RUN

Various considerations had been accounted during studies with many assumptions were noted during experiments due to lack of resources and environment. The researcher may have the facility to change the environment and to change the coefficient of friction between vacuum cup and the items to be picked up to know the vacuum pressure head during load carrying.

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