Design and Analysis of Universal Gripper for Robotics Applications

Balaji A*, Mithil J1, Jason Gousanal J1

1Department of Mechatronics Engineering, Kongu Engineering College, Erode – 638060. Tamilnadu India.

E-mail: bala2009mct@gmail.com

Abstract: A universal gripper is a component that consists of fine dust material enclosed in fine rubbery membrane for holding and assembly. The gripper is especially applied for quickly gripping and discharging large number of objects having complex geometries in wide applications. The objects which are in various shapes and different geometries are difficult to grasp which confirms that it is not suitable for apply in various pick and place operations. In this project, a low cost modular gripper is implemented with suitable mechanical design, structural analysis and real time analysis. In this association, the designed gripper can hold many parts and place it at once while sustaining relative distance and relative coordination at their state. The universal gripper acts as a vacuum tube to grip the object it needs to relocate. This universal gripper can hold various objects such as eggs, grocery items, industrial components, heavy objects etc., therefore, a selected experimental setup has been developed with the composition of shapeless gripper and perform simulation in holding of the different items. Results of the tests and experiments shows the proposed Universal Gripper are validated with feasibility options.

Keywords: Gripper, Granules, Silicon Rubber, Vacuum Chamber, Gripping Mechanism

1. Introduction

The effective end user, an end effector or gripper is the momentous module in the robotic manipulator. It assists the robot’s end effector in the effective manner and allows the robot to deploy objects [1]. In recent times, the end effector pay more attention in diverse tasks in various fields such as automation, medical and food processing industries [2]. In manipulators, end effector has major role in grasping actions i.e. to pick and place the object from one location to another location respectively which is a tedious process for all grippers for different geometries [3]. In order to overcome this problem, soft grippers have been manufactured for gripping indulgent kind of geometric objects Soft grippers used in industries are designed to grip the objects which are having minimum tension [4].

Universal grippers are proposed to replace the soft grippers which are able to grip irregular shape of geometric object [5]. It will be used for minimum as well as maximum tension objects, even that object having minimum thickness. This kind of grippers are recently identified by the researches and analysis of its parameters for effective utilization in industries like Food processing industries is done [6]. Universal grippers are standard grippers which may be used in industrial manipulators for
gripping industrial objects. The design, modeling and fabrication of Universal Gripper is analyzed to reduce complication while handling soft materials [7].

To execute different operations of end effectors, the tools such as spray guns, hammer can be utilized which are similar to tools used for industrial robots. End effectors are usually designed for the task that has to be carried out as a mechanized material handling which involves the linkage of work piece with the required places. The connected region is the place where the potential of the machine is fully utilized. There are two variety of components available for the wrist attachment: namely grippers and tools [8].

Using the gripper as interface is fundamentally a point-to-point process in which the working of machine is carried out. The construction of manipulator consists of several job-related classifications it might be essential to exchange the end effectors by the instrument itself in the industrial operations. For example, in on-site construction process, grippers are mostly employed in handling the glass based materials [8]. Grippers are those which are used for holding an object and placing an object in the work space. The path defining for the end effector movement is basically a point to point movement process [9, 10]. The construction of manipulator purely based on the end effector utilization in the required application of industrial process[11]. For example, in on-site construction process, grippers are mostly employed in handling the glass based materials [12]. This work introduces the detailed idea about universal gripper and its basic mechanism. In fact it describes the design of universal gripper using solid works based on the selection of rubber and granular materials [11]. The process also explains the working of universal gripper and the geometric gripping method with granular material as coffee powder and thermocol balls [13]. From this work, the analysis of gripper material and comparison of stress, strain and displacement for various varying loads can be established. The main novelty involved in the work is an effective as well as exclusive universal gripper is introduced with different granular materials for industry handling applications.

2. Materials and Methods

For various applications, the grippers are classified as follows: Mechanical grippers, Magnetic grippers, Vacuum grippers. Using grippers for mechanical clamping of objects with the required mechanisms is the common tasks in various places, where hydraulic or pneumatic operated devices are used to grip the objects. The different types of mechanism available in the industry are parallel jaws, finger crossed mechanisms, contraction and retraction type, Anthropomorphic type of hands etc., among these the parallel jaws mechanism grippers are widely applied to hold the object using the direction controlled surfaces [14]. These devices have one or more moving fingers where the different objects can hold but it is not suitable for soft materials. Finger based grippers will hold the component in the tip of the jaws. Anthropomorphic types require three finger where the object with definite structure can be picked and placed. This type of gripper works as same as the human hand but it is available in the research laboratory for further execution. However the end effector with provision of varieties of objects handling type are highly demanded in the industry to compensate for action of different objects [15]. Electromagnetism is the basic principle employed in magnetic grippers to hold the ferrous components. This type of gripper can be suitable for the magnetic materials not applicable for variety of objects [16].

The most common gripper named vacuum grippers where the suction cups is positioned to do the grasping actions of defined bodies, where the vacuum is produced by a vacuum ejector through the pump. It is mainly used for roofs, interior lightings and outer wall assembly, door, and windows assembly. Vacuum grippers are used for a wide range of applications from cases like soft flexible packaging to soft material handling operations, but most commonly seen handling objects are smooth, flat, and solid. This kind of gripper uses soft rubber, plastic, or elastic suction (vacuum) cups for
picking objects so that there is no damage to the product being handled [17]. The soft material handling of irregular shape and size are difficult in the existing scenario. The main principle behind universal gripper is jamming the object and will transform the shape associated with the object using the granular materials. The rubber pouch filled with granular materials is the holder part of the gripper. The rubber material bag is filled with a sand like porous material [13]. The compressed air is allowed to the rubber bag to soften its action. Then the ball is pushed to the opposite direction of the target. The transition will made on the target based on the geometry by compressing the ball. This method leads the attention gripping forces to hold the objects. The present study utilizes a real time experimental setup to analysis the gripping force variation in the universal gripper with respect to various granular materials. The flow chart as shown in figure illustrates the process involved in the analysis. The methodology of the project is designed as follows Figure.1.

![Methodology of the Work](image)

**Figure 1. Methodology of the Work**

### 2.1 Selection of Vacuum Cup

In order to handle the workpiece safely the force required to produce by suction cups is calculated theoretically. The atmospheric conditions and the application of the gripper is taken into consideration.

The factors required for selection of cups are

- Application
- Material
- Surface
- Shape
- Interior volume
- Materials
- Environment

The comparison of vacuum pressure and atmospheric pressure are discussed in table 1.
| % of vacuum | mm of Hg | Bar | Psi  |
|------------|---------|-----|------|
| 10         | 76.92   | 0.1 | 1.47 |
| 20         | 153.85  | 0.2 | 2.84 |
| 30         | 230.77  | 0.3 | 4.41 |
| 40         | 307.69  | 0.4 | 5.88 |
| 50         | 384.62  | 0.5 | 7.35 |
| 60         | 461.54  | 0.6 | 8.82 |
| 70         | 538.46  | 0.7 | 10.29|
| 80         | 615.38  | 0.8 | 11.76|
| 90         | 692.31  | 0.9 | 13.23|
| 100        | 769.23  | 1   | 14.70|

2.2 Design of Gripper Using Solid works

The gripper is designed using solid works software shown in Fig. 2, and the stress strain analysis is done for various loads. The holder is designed with ABS plastic material and the gripper bladder is designed using natural rubber and latex rubber. The various analysis were carried out to exhibit the result of the design & analysis of gripper in all aspects.

3. Experimentation

Universal gripper is working based on the process of "congestion". When a granulated resource like coffee powder is compressed into the rubber material bag forms, it becomes very rigid as shown in the figure. The contact between porous particle decreases as the pressure increases. This helps to hold the work piece. This is observed during the handling of eggs and soft materials. A vacuum crammed bag of coffee granules is made tighten as much as for transition and the stamp ruins unaffected. When replacing coarse coffee grains with fine grains of powder will have chance to break the bag while applying pressure. It was also tested with fine porous materials such as nuts, cereals, rice, etc. The experimentation was carried out by using the industrial manipulator ABB IRB 1410 for testing the universal gripper model with vacuum cup as shown in Figure. 3. The pressure is controlled...
using the pressure regulator which is attached with FRL unit of the compressor line for ABB IRB1410 end effector.

A latex rubber material bag is filled with coffee grounds as shown in figure and attached to an air hose. On applying minimum pressure the material inside the bag gets positioned accordingly. On pressing the material bag against the workpiece, the porous materials move and form a particular structure. The compression of grounds hold the object and the rubber material bag also helps to holding the object. The rubber holder is filled with coarse coffee ground grains which is attached to the wrist part of the manipulator. The funnel is inserted into the other end. Then minimum amount of porous material is poured into the material bag. The bag is partially inflated on removing the funnel, permits the grounds to come down to the bottom of the bag.

![Figure 3. Experimentation of Universal Gripper](image1)

![Figure 4. Form of Gripper While Handling Objects][13]
Figure 5. a) Stress at 10 N/m^2

Figure 5. b) Strain at 10 N/m^2

Figure 5. c) Displacement at 10 N/m^2

Figure 5. d) Displacement at 20 N/m^2

Figure 5. Simulation of Gripper

Stress, strain and displacement analysis were made to check the stability of the gripper and its deformation on different loading conditions such as 10 N/m^2, 20 N/m^2, 30 N/m^2 as shown in Figure 5. After the air is backed out slowly the porous material will remain trapped inside the material bag. The process is further repeated on adding coffee granules after inserting the funnel. The size of the funnel is checked periodically where the rubber bag stick with an inch of the funnel to perform the actions. If the coffee grounds in the rubber material bag is enough then the rubber material bag is removed from the tube and the coffee grounds stay inside the rubber material bag. A rough filter in the form of a small piece of fabric is placed to avoid the granules from falling out. A fabric that is good is used for moving air in and out. Then inflate the rubber partially. The grains are then loosened and it gets positioned accordingly. Then gently press down the rubber material bag on the surface of the object. Now the air is sucked out from the rubber material bag to holding the object. With maximum pressing on the object will deform the rubber material bag as shown in Figure 4.

Figure 6. Gripping Mechanism[13]
The rubber material bag shrinking itself when applying the suction to hold the object. The rubber material deteriorates the object when releasing the suction. This is the principle followed in the pick and place applications as shown in Figure 6. If the vacuum is compacted, the object will be tapped firmly with the vacuum bag. The placing can be achieved through the gradual releasing of suction pressure. Then the object will be placed and detached in the gripper. If the air is blown forcefully get into the rubber material bag then the gripper will forcefully eject the object as shown in Figure. 7 (a) & (b) which is examples of gripper actions while handling water bottle and bottle cap.

Figure 7(a). Gripper handling water bottle  
Figure 7(b). Gripper handling bottle cap

4. Conclusion

In this paper, the universal gripper was designed and fabricated which will be used to hold and move various materials. The vacuum induced gripper with jamming and unjamming role in the transition enables the actions of handling various geometrics of objects. It has been identified that the performance will get increased while using suitable granular and rubber materials has been chosen. Reliability also exposed by this method of gripping actions. The gripper with air locked construction provide the required potential for different environment of material handling. The future of robotics is depend on the composition of end effector with flexible handling options as well as more accessible objects. Regardless with shape, the universal gripper cab be used to hold different objects. This innovation pays the more attention in various domains such as food processing, defense industry, material handling, home and commercial places etc. The major task of the designed gripper is achieved in the grasping various objects. Thus the productivity, cost and performance of the industry is effectively decreased.

References

[1] Tahir A M, Zoppi M and Naselli G A 2018 PASCAV Gripper: a Pneumatically Actuated Soft Cubical Vacuum Gripper. In: 2018 International Conference on Reconfigurable Mechanisms and Robots (ReMAR): IEEE) pp 1-6

[2] Tai K, El-Sayed A-R, Shahriari M, Biglarbegian M and Mahmud S 2016 State of the art robotic grippers and applications Robotics 5 11
[3] Manti M, Hassan T, Passetti G, D’Elia N, Laschi C and Cianchetti M 2015 A bioinspired soft robotic gripper for adaptable and effective grasping Soft Robotics 2 107-16
[4] Zhong G, Hou Y and Dou W 2019 A soft pneumatic dexterous gripper with convertible grasping modes International Journal of Mechanical Sciences 153 445-56
[5] Lin K-Y and Gupta S K 2017 Soft fingers with controllable compliance to enable realization of low cost grippers. In: Conference on Biomimetic and Biohybrid Systems: Springer) pp 544-50
[6] Bogue R 2016 Flexible and soft robotic grippers: the key to new markets? Industrial Robot: An International Journal
[7] Park W, Seo S and Bae J 2018 Development of a Hybrid Gripper with Soft Material and Rigid Structures. In: 2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS): IEEE) pp 5930-5
[8] Hao Y, Wang T, Ren Z, Gong Z, Wang H, Yang X, Guan S and Wen L 2017 Modeling and experiments of a soft robotic gripper in amphibious environments International Journal of Advanced Robotic Systems 14 1729881417707148
[9] Pilfan T, Sulaiman N, Soltani S, Marhaban M and Ramli R 2011 An adaptive sliding surface slope adjustment in PD sliding mode fuzzy control for robot manipulator International Journal of Control and Automation 4 65-76
[10] Yang G J and Choi B W 2013 Smooth trajectory planning along Bezier curve for mobile robots with velocity constraints International Journal of Control and Automation 6 225-34
[11] Fantoni G, Capifjerri S and Tilli J 2014 Method for supporting the selection of robot grippers Procedia CIRP 21 330-5
[12] Mehmet S G, John E and Wan Nurshazwani Wan Z 1970 Vision based Object Recognition of E-Puck Mobile Robot for Warehouse Application International Journal of Integrated Engineering 6
[13] Brown E, Rodenberg N, Amend J, Mozeika A, Steltz E, Zakin M R, Lipson H and Jaeger H M 2010 Universal robotic gripper based on the jamming of granular material Proceedings of the National Academy of Sciences 107 18809-14
[14] Hisyam Abdul R, Nur Amirah Mohamad H, Mohd Hafiz A J Z, Dirman H, Babul Salam Ksm Kader I, Muhamad Saiful H and Siti Nor Zawani A 2020 Force Control for One Degree of Freedom Haptic Device using PID Controller International Journal of Integrated Engineering 12
[15] Amend J R, Brown E, Rodenberg N, Jaeger H M and Lipson H 2012 A positive pressure universal gripper based on the jamming of granular material IEEE transactions on robotics 28 341-50
[16] Xu Q, Kan J, Chen S and Yan S 2014 Fuzzy PID based trajectory tracking control of mobile robot and its simulation in Simulink International journal of control and automation 7 233-44
[17] Wiseman Y 2017 Safety mechanism for SkyTran tracks International Journal of Control and Automation 10 51-60