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# Development of a VG10 Electric Vacuum Gripper for Collaborative Robots

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***Abstract:*** *In recent few years grippers are widely used for various tasks/jobs in different fields. A gripper is a device which allows the holding of an object to be manipulated according to the requirement of application (machine tending, food processing or packaging, assembly, Etc).Gripper operates with the cobots for handling and manipulating the objects from one place to another place. Robot integrated manufacturing has turned out to be the future of manufacturing and automation technology. Operator assisting robots can perform simultaneous operation including machining, assembly, inspection, material handling etc. and in some case multiple operations in the same system at a faster and precise rate. Collaborative robotsi.e., cobots are human and computer-controlled material handling device which facilitates the concept of shared workplace. This project focuses on the design of cobotic grippers for pick and place application, the different concepts compared a suitable design is chosen. The gripper moves according to the signals received from the cobot, sensors and PLC control system.*

**Keywords*:*** Gripper; Collaborative robots; types of grippers; Design of vacuum cups, design of Vg10 electric vacuum gripper

## I. INTRODUCTION

Cobot are robot arm which is capable of learning the multiple tasks so it can operate as assistant to operator/humans. This cobots are hard coded to perform the repeatedly tasks and so it can work independently and without any human interruption. Cobots are typically used in applications working alongside humans or operators.

Gripper is a part of the cobotic hand and it enables the holding, pick and place of objects. The gripper can define in simple term as a human hand. Just like human hand it allows holding, handling and pick/place and releasing of an object. The grippers available in the market can't detect if object is lifted or not, if the object falls during the gripping and also,they don't have vision system. A gripper allows cobot to pick up objects and put them back down somewhere else. There are many different types of grippers that are suitable for a variety of tasks. These include finger grippers, vacuum grippers, mechanical grippers, electric grippers and magnetic grippers. Each gripper is suitable for different tasks. For example, soft grippers are suitable for foods that are fragile and should not be broken, and vacuum grippers can be used to pick up boxes. Each gripper has its own specifications such as payload, gripping width and gripping force.

The purpose of this particular project was to develop a "VG10 Electric Vacuum Gripper" with the ability to alter its applied vacuum force in a controlled manner. It was seen that being an appropriate extension to the capabilities of a conventional robot gripper, giving it the ability to handle a wide variety of objects requiring a range of gripping forces. The ultimate aim was to achieve this variability in gripping.

There are many various designs of cobot arms available in market like claw-type, end-effectors type to choose from. Industrial claws use the pneumatic actuators and have powerful grip but less displacement for a very specific operation. These pneumatic actuators made from metal and are quite heavy in weight, which makes them unsuitable for the current cobot's arms.

VG10 Electric Vacuum Gripper comes with dual gripping functionality, tool changer and variety of vacuum cups. It has the built in vacuum pump so it doesn't require a compressor or air supply. It is compact in size and easy to move around, which brings flexibility on production line and also it saves the maintenance cost of the gripper. Its arms are flexible and it has adjustable vacuum enabling the vg10 to handle a variety of objects in different sizes. It has dual gripping functionality means we can control its both arms i.e.,it's right and left side arms independently of each other which further increases efficiency on the production line. Additionally, there are many third-party vacuum cups available in market to fit every application. Also, we can integrate it with cobot of our choice.

## II. OBJECTIVE

To design a VG10 Electric Vacuum robotic gripper and select the necessary components, parts and sensors required for the use in machine tending, material handling and retail application.

Fig1: Collaborative Robots

### 2.1 Problem Statement

Cobots are designed to work with people and not to replace people. Dirty, unsafe, boring, monotonous or repetitive tasks can be performed by the cobot with the help of the grippers so that employees can concentrate on other tasks. In industries there are many places where it is not possible to maintain safe working environment for humans/employees there at those places **grippers** can be used under such working environments.

Fig 2. Existing grippers in market

### 2.2 Gripper Specifications and requirements

The specifications and requirements for gripper are set by doing customer survey and also it depends on what type of work is to be done. Also, it depends on their use cases and other grippers available in the market. The following requirements are set for the grippers

- Type of actuation- Integrated BLDC motor
- Gripper can reach - 32 to 358 MM
- Payload Capacity -10Kgs
- Used with -Universal and Techman Robots
- Gripper mechanism used-Rack and pinion.
- Features - object centre alignment, object pick and fall detection, gripping feedback and to accommodate a camera, dual grip, UR cap integrated software, built in vacuum pump

### 2.3 Tools and Accessories

**Compute box:** it is a device used in grippers for communication between robot tools and controllers.

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**Angle brackets: -** this bracket enables the user to attach different tools at different angles (45, 90 degree) to the robot flange.

**Suction cups: -**these are very important tool for vacuum grippers, used to improve the ability of gripper to handle material.

**Controller: -** controller is the heart of system used for the controlling the actions of gripper and also to adjust gripper according to the requirement.

**Quick changers: -** there are three types of the quick changer available in market. Namely single quick changer, double quick changer and hex-h quick changer. Quick-changer enables robot arm to install grippers. It is necessary for the connecting the grippers.

**Adaptor plates: -** this are required to be installed between cobot arm and quick changer. It comes with some robot only. It is required in some cases only.

## III. WORKING OF VG10 ELECTRIC VACUUM GRIPPER

Fig3: Electrical connections of gripper

The electrical connections for the working of the vg10 gripper are as per the fig shown above. It consists of the controller and compute box for the controlling and communication purpose. The compute box used for the communication between the robot tools and robot. First connection of a data cable to a selected quick-changer is done, then from quick changer the data cable is connected to compute box and this cable is secured with the strips on the cobot arm. Internet cable is connected to the compute box and controller for the internet supply. The power cable is connected to compute box. Then DIP switch setting on the compute box is set for adjusting the controller's output to gripper. Any device controller can communicate to robot tools with the simple I/O interface via the compute box and controller.

## IV. DESIGN

The main criteria in designing a gripper are gripping force and payload. In order to hold an object, there is need of sufficient gripping force to be produced by the gripper. The gripping force required to pick an object is calculated as follows. Gripping force required by the gripper to carry to a payload is given below.

### 4.1 Gripping Force calculations:

Gripping force = $F_g = m \times (g+a) \times s/\mu \times n$

Where, $F_g$ = gripping force

m = mass of object

g = acceleration due to gravity      s = factor of safety

$\mu$ = coefficient of friction

n = number of vacuum cups

$F_g = 3X\ (9.8+1)X3/0.64X2$

### 4.2 Motor selection:

The required gripping force in a gripper is generated by the actuation mechanism, which is an integrated BLDC motor in this case. Selecting the motor with appropriate torque and power for appropriate application is very important as the

gripping force is dependent on it. The torque required is calculated as shown below.
Torque = T = F x R F – gripping force
R – Radial distance

**4.3 Positioning the vg10 arms and channels: -**

The arms of vg1o can be easily folded to the desired position simply by pulling the arms. The torque of 6N/m is required to overcome the friction in between the rotational joints of the arm to ensure that the arms movement is avoided when handling the 10 kg or more than 10kg payloads.

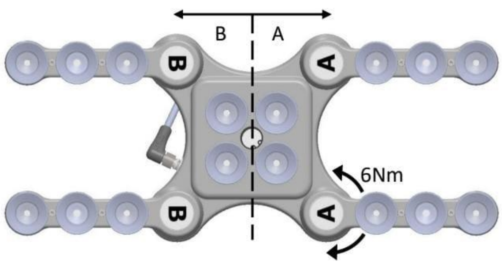


Fig 4: -Independent vacuum zones A and B

When grippers arms are adjusted to desired angles, it is recommended to add the arrow stickers on them. This enables easy realignment and exchanging between different works.

Fig 5: - Alignment marking on joints

**4.4 Vacuum cup design and fitting:**

Selecting the right vacuum cups for your application is very important. This vg10 gripper commonly comes with 15,30 and 40 mm(with gripping area of 29,200 and 450mm$^2$ respectively) silicone vacuum cups and this are good for holding hard and flat surfaces, but not good for the uneven surfaces.

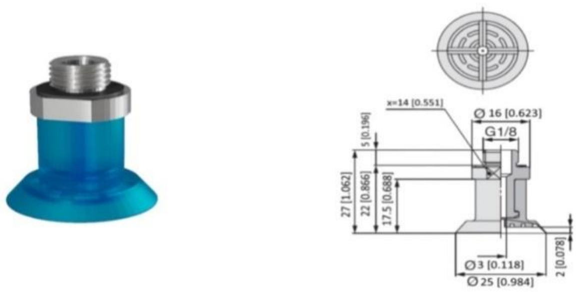


Fig 6: Design of vacuum cups

For non-porous materials suction cups are highly recommended. Some of the nonporous materials are as listed below:

- Plastic
- High/low density paper
- High/low density cardboards
- Metals
- Glass

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- Composites
- Fabrics
- Varnished wood

Number of cups needed for a particular application is dependingupon the payload and vacuum: -

Number of cups= $\frac{m.a}{fcup} = \frac{(kg).\left[\frac{m}{S2}\right]}{N} = \frac{10.2.9.81}{12.2}$

$= 16$Vacuum cups

$Amount_{Cups} * Area_{Cups} = 14700\frac{\text{Payload (kg)}}{\text{Vacuum (kpa)}}$ mm

For specific materials specific type of suction cups are required. See the below table:

| Woking surface | Vacuum cup shape | Vacuum cup material |
|---|---|---|
| Hard and flat surface | Normal or dual lip | Silicone |
| Soft plastic or plastic bag | Dual lip | Special plastic bag type |
| Hard but curved or uneven | Thin dual lip | Silicone or soft NBR |
| Varying heights | 1.5 or more levels | Any type from above |

It is possible to change this vacuum cups easily just by pulling them off the fittings. Unused holes can be blinded using a blind screw and each of this fitting can be changed to different type to match desired cup.

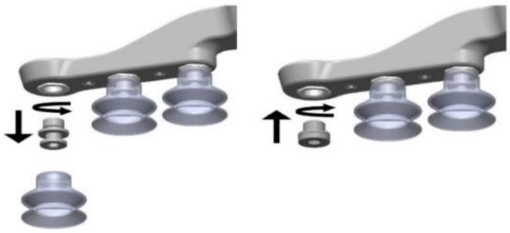

Fig 7: - vacuum cups fitting

**4.5 Vacuum**

It is defined as percentage of absolute achieved vacuum relative to atmospheric pressure. i.e.

| % VACUUM | BAR | KPA | INHG | TYPICALLY USED FOR |
|---|---|---|---|---|
| 0% | 1.01ABS | 101.3ABS | 29.9ABS | NO LIFTING CAPACITY |
| 20% | 0.81ABS | 81.1ABS | 23.9ABS | CARDBOARD & THIN PLASTIC |
| 40% | 0.61ABS | 60.8ABS | 18.0ABS | LIGHT WORKPIECE |
| 60% | 0.41ABS | 40.1ABS | 12.0ABS | HEAVY WORKPIECE |
| 80% | 0.20ABS | 81ABS | 6.0ABS | NOT RECOMMENDED |

The vacuum in kPa setting is the desired vacuum. The pump will run at full speed until the target vacuum is achieved, then run at lower necessary speed to maintain desired value of vacuum.

**4.6 AIR FLOW-**

Air flow is the amount of air that to be pumped to maintain the desired vacuum. Completely tight system will not have any air flow, whereas real life applications have some smaller amount of air leakages from two different sources:

- Leaking vacuum cup lips
- Leaking work pieces

The smallest leak under a vacuum cup can be hard to find as shown below –

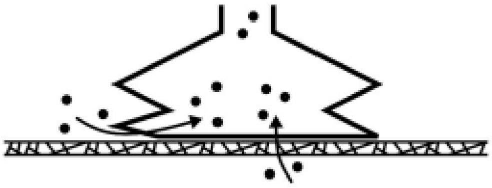

Fig 8. Leaking vacuum cups

Leaking work pieces can be even difficult to identify. Things that look completely tight might not be tight at all. A typical example is coarse cardboard boxes. The thin outer layer is often requiring a lot of air flow to create a pressure difference over it –

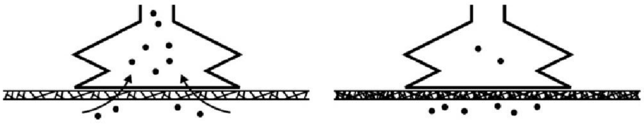

Fig 9. Leaking work pieces

VG10 grippers are not suitable for most uncoated, coarse cardboard boxes. Extra attention to be taken for leakages, e.g., vacuum cup shape and surface roughness the air flow capability of a VG grippers is shown in the graph below:

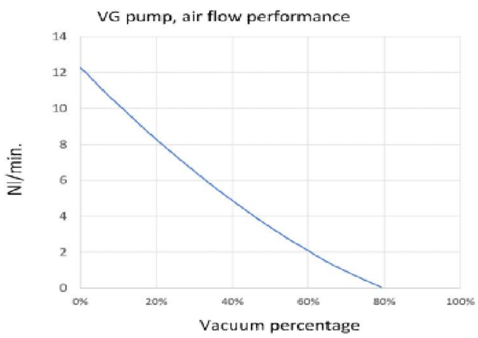


Fig 10. Vacuum VS air flow

### 4.7 Suction area:

Larger the suction area, the higher lifting capacity. The actual suction area is smaller than the outer diameter of the vacuum cups, as the vacuum cup libs forms around the work piece; the actual suction area is reduced.

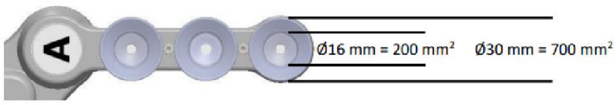


Fig11: - Available suction cup area for the standard Ø30 mm cups.

With a typical vacuum of 60% and one vacuum cup with a 200 mm2 suction area, the lifting force is:

$Fcup = p \cdot A = [\Delta Pa] \cdot [m^2]$

$= 60\% \cdot 101.3kPa \cdot 10^3 \cdot 200\ mm^2 \cdot 10^{-6}$

$= 12.2\ N$

With this force per vacuum cup, to lift 10 kg and accelerate with 2g’s, this many vacuum cups are needed:

Number of cups= $\frac{m.a}{fcup} = \frac{(kg).[\frac{m}{S2}]}{N} = \frac{10.2.9.81}{12.2}$

$= 16$Vacuum cups

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## V. DESIGN OF VG10 ELECTRIC VACUUM GRIPPER

Design for the required industrial applications like machine tending, material handling, palletizing, processing and packaging etc.

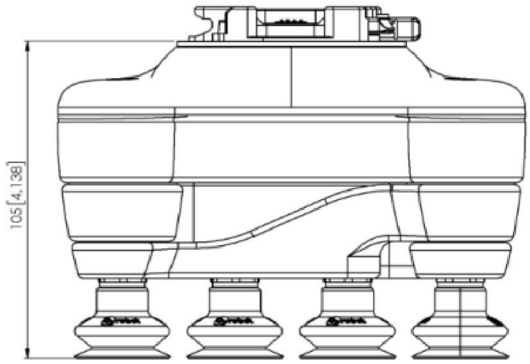


Fig 12.Side view of vg10 gripper

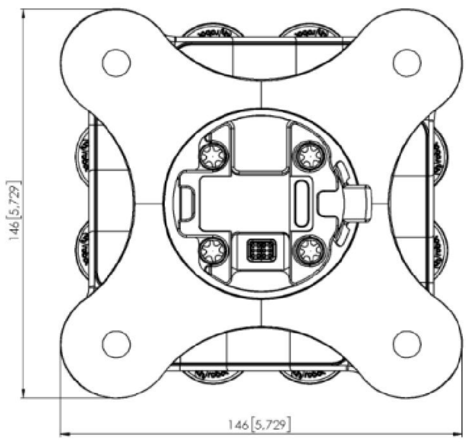


Fig 13.Top view of vg10 gripper

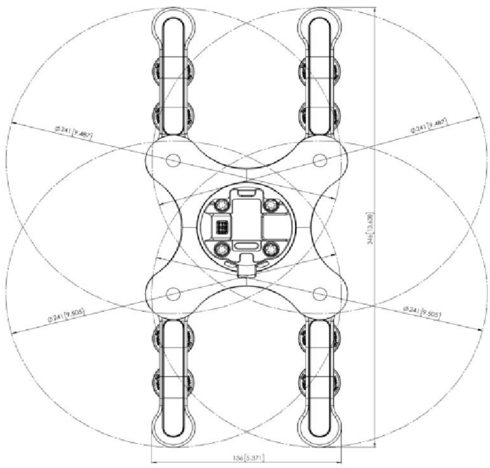

Fig 14. Top view with open arms


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## VI. METHODOLOGY

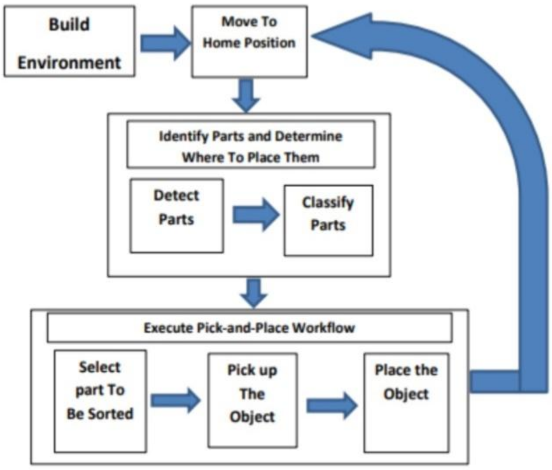


Fig 15. Methodology of vg10 gripper

## VII. FLOWCHART

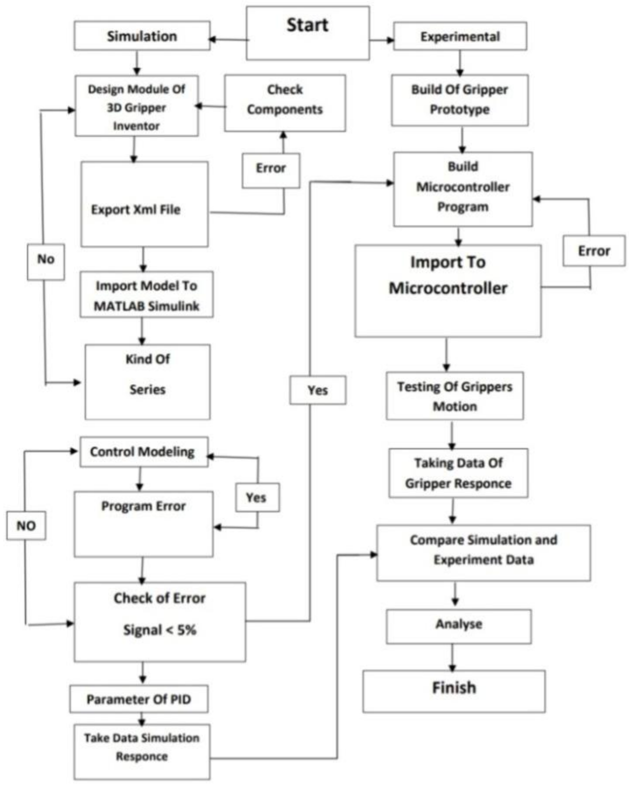


Fig 16. Flowchart of VG10 gripper


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Various sensors have been accommodated in the gripper to provide various feedbacks and make the gripper smart and hence achieve high efficiency in machine tending and retail applications. The following sensors have been integrated in the gripper.

1. Force feedback sensor to give the gripping force.
2. Time of flight IR sensor to sense the offset distance before grasping the object and to know whether the object is picked up or not.
3. IR range sensor to make the object centred to the gripper fingers, to detect if object is picked and to detect if the object falls during the cycle.
4. Camera to get the visual feed of the object and align accordingly

## VIII. SIMULATION AND RESULTS

Simulation for the vg10 gripper is not possible till date today. As the vg10 is not available in tool box of MATLAB, so instead of vg10, we had created the simulation for two finger grippers as a reference for vg10 gripper. For the understanding the operation of vg10, assume that two finger grippers as vg10. The entire operation of both the grippers is same as shown in simulation. And the gripping time, releasing time, hold time and gripping distance can be changed simply by the changing the values in the program. The results obtained from this are as shown below:

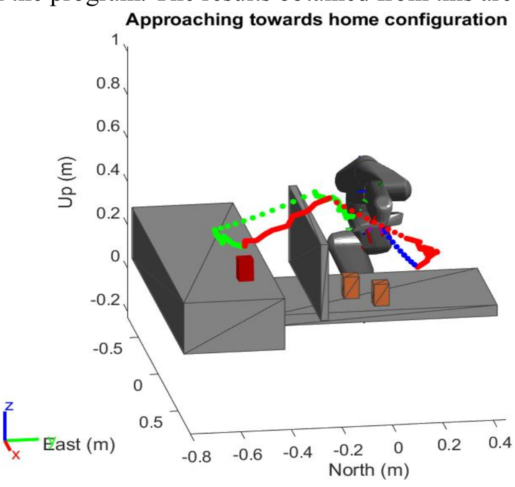


Fig 17: -Cobot approaching towards object

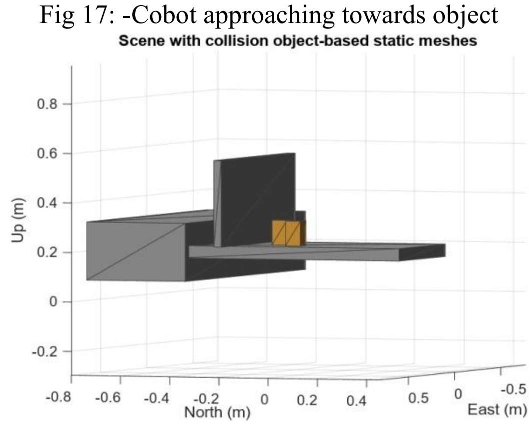


Fig 18: -Scene with collision object


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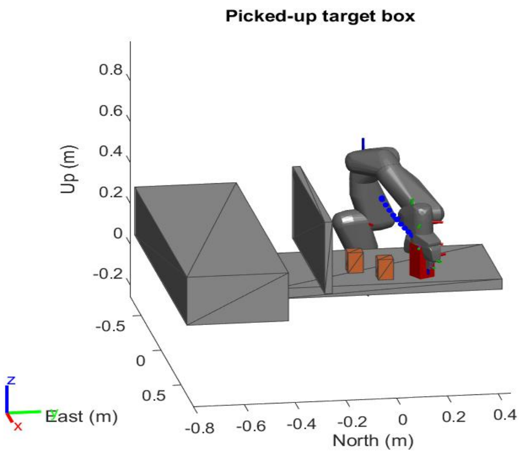

Fig 19: - Object picked up form workplace

## IX. CONCLUSION

The customized design of the new robotic gripper will improve productivity and efficiency of robots in production and material handling applications in industries. The gripper is robust in design and will be manufactured and tested for the same. Further the gripper will be implemented with optical navigation sensor to detect slips and apply adaptive grasping.

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