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ORIGINAL ARTICLE

Design of spline surface vacuum gripper for pick and place robotic arms

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ABSTRACT – The gripper is the most important part in an industrial robot. It is related with the environment around the robot. Today, the industrial robot grippers have to be tuned and custom made for each application by engineers, by searching to get the desired repeatability and behaviour. Vacuum suction is one of the grippers in Watch Case Press Production (WCPP) and a mechanism to improve the efficiency of the manufacturing procedure. Pick and place are the important process for the annealing process. Thus, by implementing vacuum suction gripper, the process of pick and place can be improved. The purpose of vacuum gripper other than design vacuum suction mechanism is to compare the effectiveness of vacuum suction gripper with the conventional pick and place gripper. Vacuum suction gripper is a mechanism to transport part and which later sequencing, eliminating and reducing the activities required to complete the process. Throughout this study, the process pick and place became more effective, the impact on the production of annealing process is faster. The vacuum suction gripper can pick all part at the production which will lower the loss of the productivity. In conclusion, vacuum suction gripper reduces the cycle time about 20%. Vacuum suction gripper can help lower the cycle time of a machine and allow more frequent process in order to increase the production flexibility.

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INTRODUCTION

Robot gripper is end-effector mounted on the wrist enables the robot to realize and perform specified task in an industrial work floor. Various types of gripper are designed for same type of machine to make it more flexible and versatile. Usually the gripper is designed as jaws for grasping and to move objects. Furthermore, it is constructed for opening and closing the jaw like human fingers [1-3]. Nowadays, the evolution of technology delivers the chance to bring the grippers innovation to a next level. Smart grippers functions not only open, close and bringing objects to another position but they are capable of sense different factors around them and react to this. For this interface different sensors and actuators have been added to grippers and can be focused by microcontrollers [4-5].

Currently available gripper is unable to pick up parts with spline curve surface. This due to the limitation of rigid shape finger gripper, and utilizing only surface contact mechanism for pick and place action. Thus, a special design of gripper utilizing vacuum suction mechanism is proposed, where it is assumed that, by utilizing vacuum suction method, the ability for the robotic arm to pick and place parts will be improved whereas the gripper fingers are more flexible due to rubber vacuum suction cup. Designing a flexible smart gripper is a currently essential, due to its benefits for developing several tasks without the need of a human interface or shifting places to save production period [1-5].

The device that is going to be planned in the study is an enhanced smart gripper that contains different sensors. Distinct the other smart grippers, this designed of gripper is tries to reach a widely amount of chores using various types of sensors. The goal of the gripper is to reach a high flexibility using the response of these sensors. So it is being able to improve different manufacturing activities without require someone to change the gripper for another one or change the station. The study is going to propose a gripper design and compared the effectiveness of the designed gripper with the conventional pick-and-place gripper.

METHODOLOGY

There are consist of several procedures in section of the design for a complete system. Besides there are the considerations which will lead the gripper from all the opportunities to the best one that is able to accomplish the objective for which one will be created.

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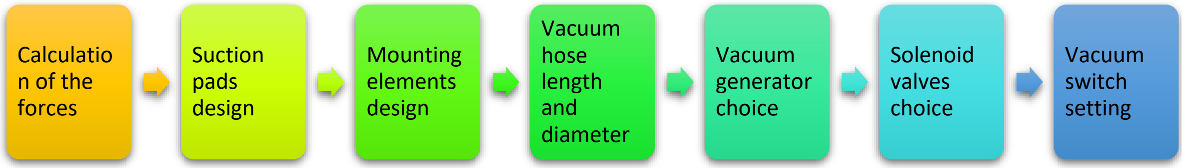

Figure 1: Flowchart of system design

Calculation of the force-dynamic and kinematic theory

The important things to make sure the gripper workable are used a correct sizing of the actuators and other essential parts of the gripper. But this can be comprehended through calculations [. Therefore, dynamical and kinematical design of the gripper be subject to the weight, size, process cycle times and accelerations. This chapter tries to explain and show briefly the formulas and theories behind the gripper's kinematics and dynamics. The holding force is an important factor in the gripper design. As known, it is significant for the gripper to keep the object hold while moving in whole positions. This is because the position of the object can be affected by inertia forces while gripper is in movement. The holding forces are almost directly using direct vacuum suction cup. Therefore, the force is calculated using the suitable method for the actuators. Thus, all techniques consider a safety factor for considering all the impermissible factors during the operation, especially friction. Accordingly, there are also international safety standards to preserve the system safe in the entire condition which means to make sure that the robot can avoid any danger or lose the object. [5-7]

The vacuum lifting device consists of a vacuum generator, load beam with vacuum reservoir and vacuum distributor and suction plates. The vacuum holds the object and a chain host is used to lift the object.

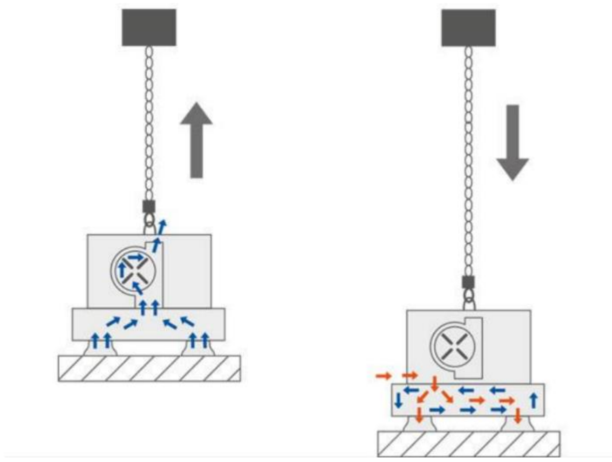

Figure 2: Vacuum suction working mechanism

In dynamic calculations is only exanimated the necessary holding forces for keeping the gripper's versatility. For all succeeding calculations, it is significant to know the mass of the object to be handled. Hence, the suction cups must be capable of handling the acceleration forces which in fully automation system. There are three most important and most frequent load cases are shown graphically and described below due to simplify the calculation. [8] Eq. (1) is required to calculate the mass of object.

$$m = LBH\rho \tag{1}$$

Where;

m: Mass of object [kg]
L: Length of object [m]
B: Width of object [m]
H: Height of object [m]
ρ: Density of object [kg/m^3]

In vacuum suction pick-and-place system, the direction of gravitational acceleration is the main component to be taken in consideration in the design, where there will be 3 load cases to be taken into consideration, which are;

Load case I: Horizontal suction pads with vertical force

If the object is lifted from a pallet, the object will be lifted with an acceleration, as shown in Figure 2, where the theoretical holding force can be calculated as Eq (2).

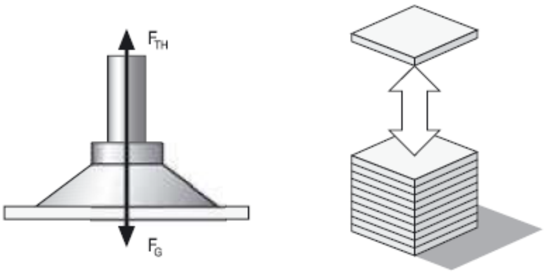

Figure 3: Horizontal suction pads with vertical force schematic diagram

$$F_{TH} = m(g + a)S \tag{2}$$

Where;

F_{TH}: Theoretical holding force [N]
m: Mass of object [kg]
g: Length of object [m]
a: Width of object [m]
S: Height of object [m]

Load case II: Horizontal suction pads with horizontal force

If the object is lifted from a pallet, the object will be lifted with an acceleration, as shown in Figure 2, where the theoretical holding force can be calculated as Eq (3).

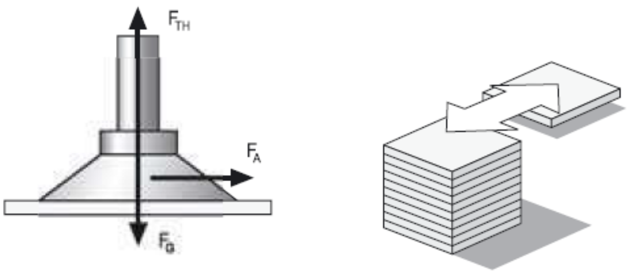

Figure 4: Horizontal suction pads with horizontal force schematic diagram

$$F_{TH} = m(g + a/\mu)S \tag{1}$$

Where;

F_{TH}: Theoretical holding force [N]
m: Mass of object [kg]
g: Length of object [m]
a: Width of object [m]
S: Height of object [m]
μ: Coefficient of friction

Load case III: Vertical suction pads with vertical force

If the object is lifted from a pallet, the object will be lifted with an acceleration, as shown in Figure 2, where the theoretical holding force can be calculated as Eq (4).

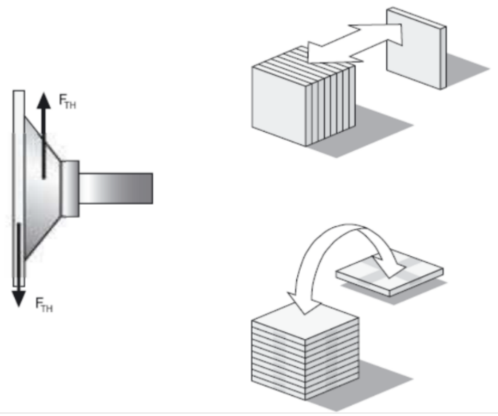

Figure 5: Vertical suction pads with vertical force schematic diagram

$$F_{TH} = \frac{m}{\mu}(g + a)S \tag{2}$$

Where;

F_{TH}: Theoretical holding force (N)
g: Gravitational acceleration (ms^{-2})
a: System acceleration (ms^{-2})
S: Safety factor
m: Mass of the object (kg)
μ: Coefficient of friction

Smart gripper design

The study is proposing a smart and flexible gripper for manufacturing activities. As in operation, the device has to be able to recall information about the situation that surrounds it and send it to the control system which able to process it and respond to the data received, then correct the movements and interrelate with the movement. By flexible it means that it has to be able to work with all shapes and sizes of object without operator to be monitor. From of all of this the gripper has to be simple, try to keep low costs and able to be use for long term without need to change the gripper. Nevertheless, a control system is needed to achieve the objective of the gripper. A computer based control is required for the operation development, an easy application and to create flexibility. Therefore, the control system requires a software that will be the user interface which can be used easily and in a logical way. The vacuum will need vacuum suction cups which is able to hold the object and giving the possibility of using a manual tool.

One of the important parts for developing a gripper is to choose how this one will be. Nowadays, there are various choices for designing robot grippers, such as a magnet or electromagnet, vacuum, balls (Versaball) and fingers. The first step is to choose one of this gripping method due to the magnet and finger are not more suitable for this study. This is because of the limitations about materials of magnets and application of finger for various shape and size of object they can grasp. Hence, a good option for keeping the gripper flexible are the vacuum suction cups. Even there is the opportunity of two, three, four, five or even more. The model would be to use the same amount as the operator hand due to all the objects is formed for being used by operators. As mentioned above the vacuum suction cups can handle 100% of the parts than the finger gripper can handle. This is the greatest option for the study because it is more simple and easier the finger gripper and still has a high percentage of parts that can handle more compared to finger gripper.

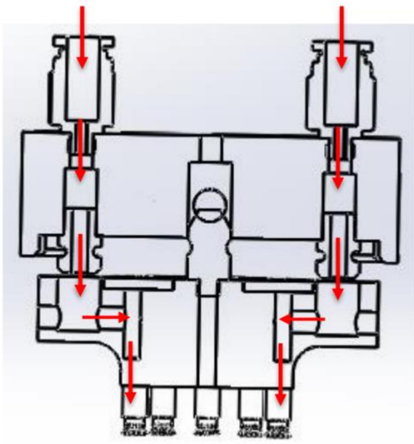

Figure 6: Vacuum suction working mechanism

During the decision for designing vacuum suction gripper has been made, the challenge is which configuration is the most suitable for the study. As shown below is the cross section of vacuum suction gripper that has been designed. The round shape is used to make the gripper more flexible and easy to hold the object from the pallet. In addition, to get high pressure in the vacuum, the space in the vacuum need to be compress as shown. This is because the design is used two supply of air pressure to make sure the air pressure enough and able to be used to hold the object.

Additionally, the dimensions of the vacuum suction design are depending on the dimensions of the objects which run in the production. It is mean that there are several dimensions to be design for small, medium and big of dimension. The main part of this vacuum suction is the suction cup. The types of suction cup need to be used are depending on the surface of the object. If the surface of the object is flat, then the suction cup used also flat. If the surface of the object is spline, then the suction cup used is bellows. This is because the bellows suction cup are more flexible than flat suction cup.

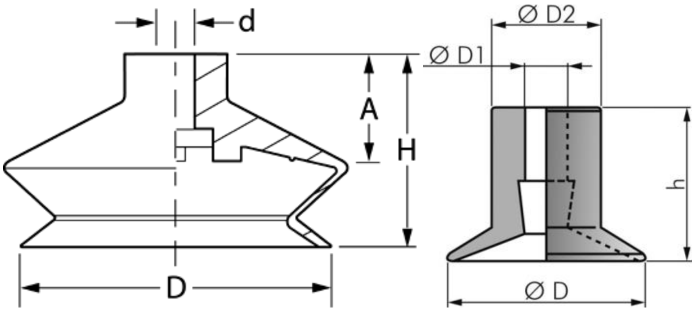

Figure 7: Design choice of suction cup

Vacuum suction testing setup

After finished fabricate the vacuum suction, it is need to pass an effectiveness test. Before start testing the vacuum suction whether it is function or not. The first thing that need to be concern is make sure all hole that can allow air go through it must be closed. This is to avoid the air leakage from the vacuum suction. Normally silicone glue will be used to cover the hole. The reason of effectiveness test for vacuum suction is to make sure that vacuum suction is ready to run in production to help the operator.

Figure 8: The robot pick up the object during effectiveness test

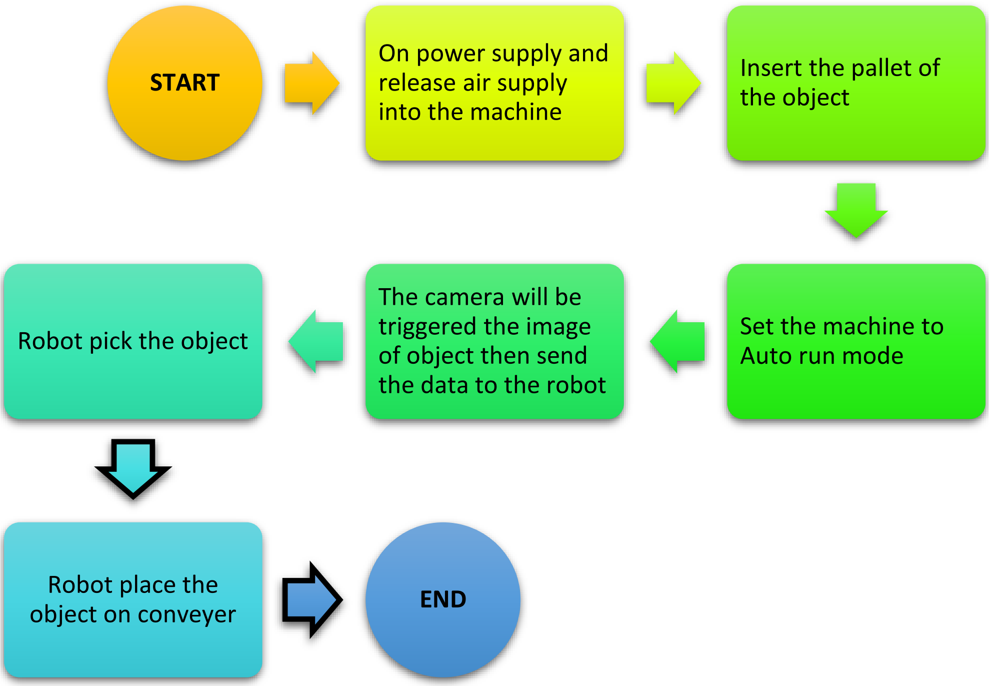

Figure 9: Flowchart of Effectiveness Test

From the effectiveness test, all the failures about the vacuum suction cup can be found out. Therefore, the study of the failures is required before start to do improvement. This is due to avoid any accident happen to the user during they operate the machine. During testing, all sensors at the machine must be function so that they will inform the control system when the component at the machine does not function. From that, user can know where is the failures happen.

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RESULT AND DISCUSSIONS

Vacuum suction testing setup

10 trays which consists of 25 pallets of object have been set up for the effectiveness testing of finger gripper annealing autoloading machine. For this effectiveness testing, there are two types of objects will be test but the object which ring shape only can be test by finger gripper. This finger gripper has limitation which cannot grasp the flat object because it only can grasp the object at the centre of object.

Figure 10: First Set of Object for Effectiveness Test

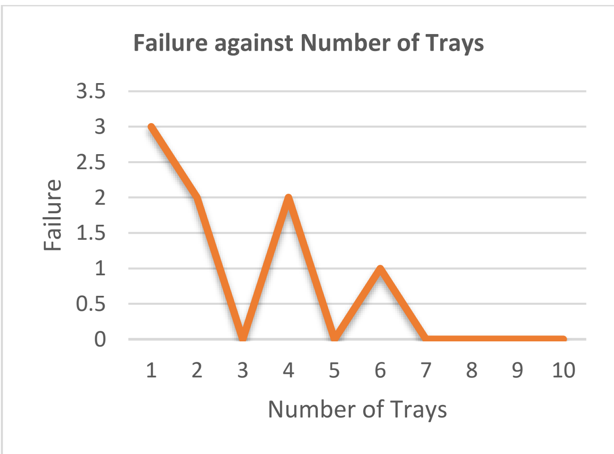

Figure 11: Result of Effectiveness Test for Small Object

During the testing, there were various failures happen and need some improvement to make the machine work more efficiency. Sometimes the finger gripper can pick and place very well but sometimes the gripper will be misplacing the object. There are some data below that shows the figure of the objects used and also the result of the testing. From Figure 11, there are several types failures happen during the starting of operation. The types of failures that normally happen are the finger gripper cannot grasp the object very well when pick the object, camera that used to capture the image cannot have detected the object and finger gripper misplaced the object during placed the object on conveyer. All these problem need to be study then proceed to request some improvement to make sure the failures cannot happen again.

Figure 12: Second Set of Object for Effectiveness Test

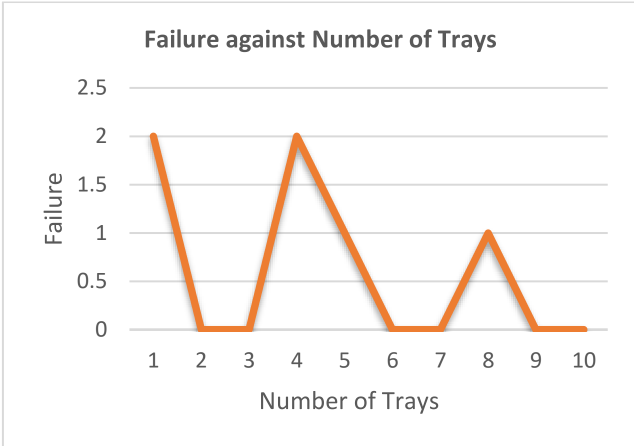

Figure 13: Result of Effectiveness Test for Big Object

The finger gripper does not have so much problem with the bigger object due to the size and also the thickness of object. This is because the bigger object has more thickness than small object. Hence, it makes the finger gripper easier to grasp and place the object correctly. But there are still have some failures due to the camera detection. That's means the camera need some improvements because of the camera is the main point for the robot to detect object and send the data to the control system then tell the robot about coordinate of object.

Effectiveness Test for Vacuum Gripper

Same procedure as effectiveness test for finger gripper, but the test has been done with different object. The test is for two different types of objects which are ring part and flat part. This is due to test whether the vacuum gripper can pick the heavies object and flat object or not. This is because the vacuum gripper does not have any limitations to pick the smallest or biggest object but need to change the size of vacuum based on the dimension of object. Therefore, there is also some failures happen during the testing but it is not as much as finger gripper's failures and the failures are not from the gripper. It is happening due to size of object fit with the pallet and also the setting of camera. Below shows that figure of object that have been testing and also the result after the testing.

Figure 14: The Biggest Object for Effectiveness Test

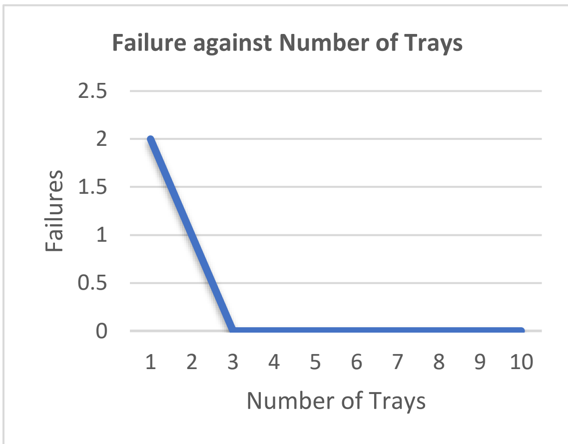

Figure 15: Result of Effectiveness Test for Biggest Object

From the graph above, the failures happen only for the first two trays only and then there is no failures after that. The failures happen due to the object stuck at the pallet which the size of object fit with the pallet and the camera setting which cannot detect the object. It can be avoiding if the operators placed the object correctly with the orientation of pallet. The setting of the camera usually due to the brightness of the light and it cannot detect the actual diameter of the object.

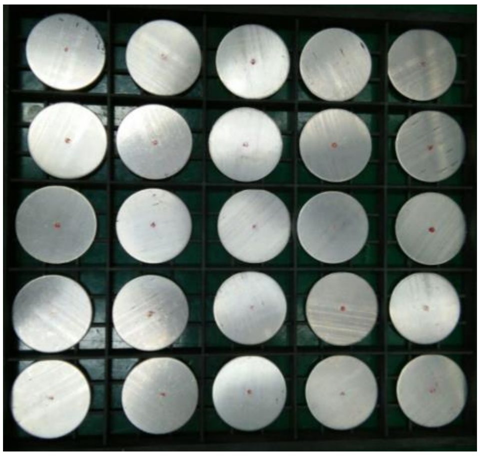

Figure 16: The Flat Object for Effectiveness Test

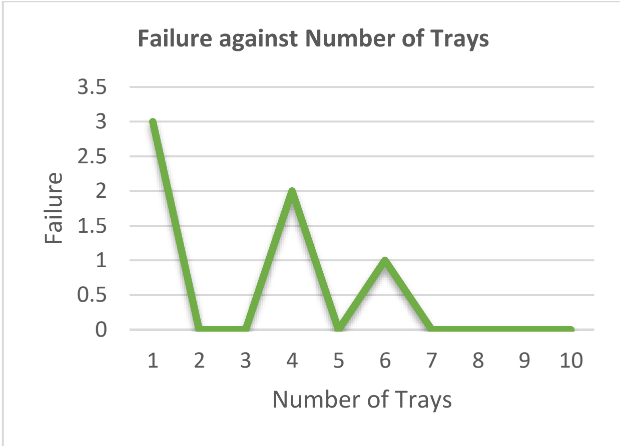

Figure 17: Result of Effectiveness Test for Flat Object

There are few failures happen during the test and this is cause by the setting of the camera. Sometimes if the camera cannot detect the correct diameter of the object or the camera cannot detect because of the lighting then it will send the data to robot which the object is Not Good. If the robot receives that information, then it would not collect the object. Here the function of the camera is more like the eyes of the robot.

CONCLUSION

In the study, the main objectives had been achieved. The vacuum suction gripper can be used in production as the automation for pick and place the watch case and case back of watch. This vacuum gripper also can be implement for unloading automation which will collect the object from conveyer to the tray. The main parts of this project are successfully completed in order to achieve the objective especially the mechanical parts from designing using SolidWorks to assembly process, it needs to consider the distance between vacuum suction and object to make the gripper can move up, hold the object and carry it to the conveyer, to get the best results during operation. Besides, the ability of the camera to detect the object and determine the diameter of the object with the aid of image processing. Furthermore, the camera also needs more light even though it has its own camera flash to detect the position of the object.

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