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Development and Investigation of a Minimum Power Non- Contact Swirl Vane Gripper

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***Abstract-* The automated production processes grasping devices and method play a crucial role in the handling of many parts, components and products. There will be different type of grasping as well as releasing principles are used by the grippers. This includes the experimental study of a new contactless gripper. It generates air flow to create an upward lifting force. This force can be used to pick up a work piece placed underneath the gripper without any contact. In comparison with conventional pneumatic noncontact grippers, the uniqueness of the swirl gripper lies in that it is electrically (rather than pneumatically) activated. Study is being carried out for clarifying the mechanism of the gripper. The swirl gripper is under investigation considered and a better model is being generated for creating a better lift. The rpm is being considered as a major factor of study. The variation of pressure distribution according to rpm change is considered. The characteristics of the pressure distribution, based on experimental analysis on the swirling flow is conducted.**

I. INTRODUCTION

End-effector of a robot interacts with the environment. The exact nature of end effector depends on the application of the robot. The end effector comes in contact with the object to be handled. Handling of food using contact end effectors leads to contamination. Preventing the end effector to come in contact with the food to be handled improves the hygiene standards. In semiconductor industry, wafer comes in contact with the end effector repeatedly which lead to defective product. Surface scratching and static electricity is another disadvantage of contact gripper which is the reason for introduction of non-contact end effectors as robotic arms. Pneumatic levitation is the use of flowing air to lift an object.It generates lesser heat. In this, air is used to create negative pressure, which creates an upward lifting force. The maintenance of a pneumatic gripper is lesser when compared to other grippers. Bernoulli gripper, the first and widely used pneumatic non-contact gripper works on Bernoulli principle.

A work piece is normally brought into contact with a handling device while it is picked up and moved. Such forms of contact are often accompanied by surface scratching and static electricity. In the semiconductor manufacturing process, in particular, each wafer is handled frequently during repeated loading and unloading. Therefore, the inherent disadvantages of contact handling often lead to defective products. In the manufacturing processes of some foods and medicines, contact is undesirable because it may cause damage and contamination. For these reasons, many non-contact handling approaches have been proposed and proven effective . Among them, the use of air flow as the medium to apply a lifting force to pickup and grip a work-piece is a common approach, because air flow is free from magnetism and generates little heat. Hence, various pneumatic noncontact grippers are widely employed in practical applications (semiconductor wafer handling, food handling, etc.). Bernoulli gripper, based upon the Bernoulli principle, is the most typical of these implements . Recently developed vortex gripper is the other one, which takes advantage of vortex flow to achieve non-contact handling . However, given that these non-contact grippers are based on pneumatic methods, they require compressed air supplies and thus have an inherent disadvantage, large energy consumption. In a compressed air supply system ,a compressor consumes electrical power to compress air to a high pressure, and then the compressed air is transmitted through a number of component(dehumidifier, pipes, elbows, valves, etc.)and is depressurized to operation pressure of pneumatic grippers, during which there exist mechanical energy loss in the compressor, thermal energy loss due to heat transfers when air being compressed, energy loss due to viscous friction and turbulence in the transmission and pressurization. Because the energy source is electrical energy, these unavoidable energy losses make the total electrical energy of pneumatic grippers rather large.

This project includes the experimental study of a new contactless gripper. It generates air flow to create an upward lifting force. This force can be used to pick up a work piece placed underneath the gripper without any contact. In comparison with conventional pneumatic noncontact grippers, the uniqueness of the new gripper lies in that it is electrically (rather than pneumatically) activated. Therefore, it fundamentally avoids energy losses and there by reduces the total electrical energy consumption drastically in comparison with present pneumatic grippers . For example , our proposed swirl gripper only needs less than 2W for a 0.2 N lifting force (the voltage is 24 V and the current is 0.08 A). Study is being carried out for clarifying the mechanism of the gripper. The swirl gripper is under investigation considered and a better model is being generated for creating a better lift. The rpm is being considered as a major factor of study. The variation of pressure distribution according to rpm change is considered. The study investigate the characteristics of the pressure distribution and lifting force based on experimental analysis on the swirling flow is conducted.

2. MECHANISM AND DESIGN

It mainly consists of a motor , a set of swirl vanes, and a circular swirl chamber. With the exception of a number of air inlets, the top of the chamber, to which the motor is fixed, is closed. The swirl vanes, each of which is characterized by a curved shape , are installed on the motor shaft and arrayed vertically and symmetrically. Rotation of the motor along the curved direction of the vanes causes the air in the chamber to swirl. The centrifugal force due to this swirling pulls the air from the center to the periphery of the chamber , and creates negative pressure in the central area. Thus, when a work piece is placed under the gripper, a lifting force acts on the work-piece and picks it up. Simultaneously, the curved , rotating vanes suck air from outside the chamber through the upper air inlets , and discharge air via the base of the chamber. Therefore, as shown by the blue arrows in Fig.1, the work piece must maintain a clearance from the gripper while being lifted, in order that air can be discharged. In other words, the swirl gripper achieves non -contact handling.

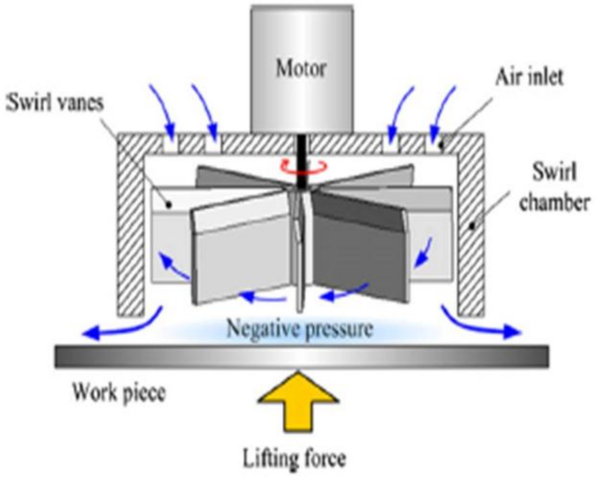

Figure 1: Schematic of the proposed swirl gripper.

Fig 6, shows a photograph of the trial swirl gripper used for the experiments, along with the dimensions of its components. Some qualitative design principles are given here, as the optimization of the design parameters is beyond the scope of the present work. The selected motor can reach a maximum speed of up to 10000 rpm. The swirl vanes are

fabricated by fused deposition modelling (FDM), which involves the extrusion of the semi-liquid plastic material acrylonitrile butadiene styrene (ABS) used to fill the cross section of the swirl vanes. Eight vane pieces are arrayed vertically and symmetrically about the shaft of the motor. Their curved shapes give the swirling air a downward velocity component so that air is sucked from the air inlets into the swirl chamber and then discharged via the base of the chamber. In theory, this function can be achieved by any curve angle in the range of 10-90 degree. Considering the limited space between the vanes, each piece is curved by about 10 degree. The swirl vanes are located inside the swirl chamber, which is composed of a cover board and a cylinder. Eight air inlets, each with a diameter of 1.5 mm, are arranged symmetrically on the cover board. The diameter of the air inlets is an important factor in determining how much air will be sucked into the chamber. Enlarging the size would increase the flow rate sucked into the swirl chamber. Furthermore, the position of the air inlets also has a certain effect on the suction flow rate. As will be discussed in next section, the maximum negative pressure appears in the central area. Therefore, setting the air inlets close to the center of the swirl chamber would increase the suction flow rate because of the pressure difference. The suction flow is very important for keeping a clearance between the gripper and the work piece, while too much suction flow would destroy/disturb the swirling flow and weaken the negative pressure distribution and lifting force.

2.1. Contactless gripper body

The material used for initial design is ABS (Acrylonitrile Butadiene Styrene).The dimensions considered are given below in fig-2,fig3

- Outer diameter: 60mm
- Inner diameter: 50 mm
- Height: 13mm

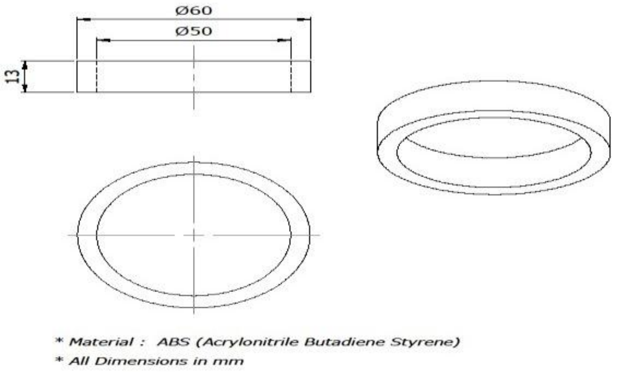

Figure 2: Contact less end effector body

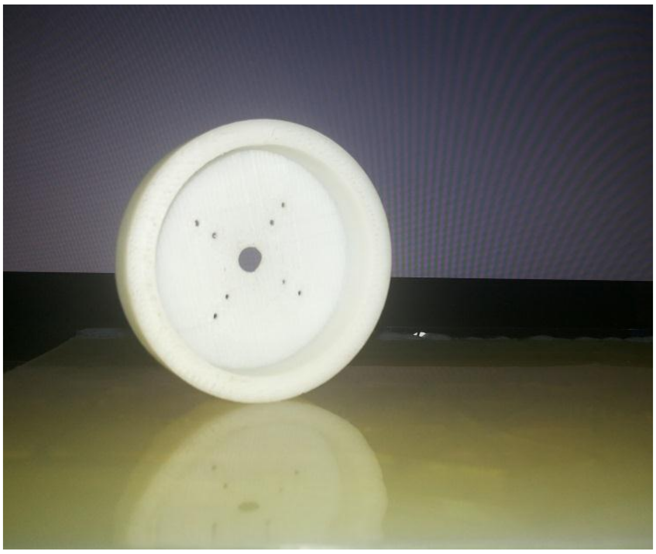

Figure 3: photograph of the trial end effector body

2.2. *Contactless gripper vane*

Air is sucked in with the aid of rotating vanes inside the body and cover. Initial design values are considered and are modified in successive analysis. Blade is made up of acrylonitrile butadiene styrene. fig-4. ,fig-5.

- Outer diameter: 48mm
- Blade thickness 0.7mm
- Vane angle 10 degree

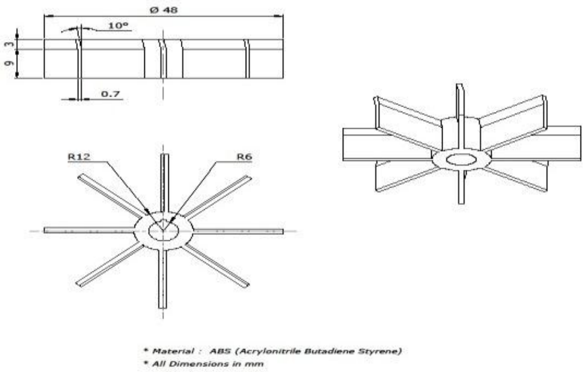

Figure 4: Contact less end effector vane

Figure 5: photograph of the trial end effector vane

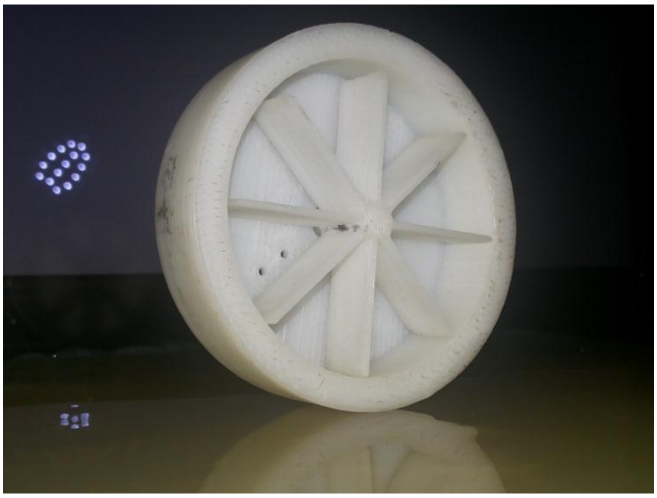

Figure 6: photograph of the trial swirl gripper

3. DESIGN OF THE EXPERIMENT

3.1Experimental setup to measure pressure distribution

Measuring the pressure distribution is an intuitive and valid way of understanding the grippers swirling flow and resulting properties, because the flow phenomenon is generally reflected by the pressure variation. In the experiments, pressure would be measured while the clearance distance between the work piece and the gripper being fixed. We note that, the clearance distance is very small (normally in the range of several hundred micro-meters).Therefore, setting the clearance distance is conducted very carefully by using the experimental setup shown in Fig. 7, and following these steps .

- Insert a steel sheet of known thickness between the gripper and the measurement table.
- Set down three pins andmake sure that their tips touch the top of the swirl chamber.
- Lock the clamps to hold the pins tightly.
- Release the spring, such that the gripper is being pulled towards the upper base.
- Remove the steel sheet.

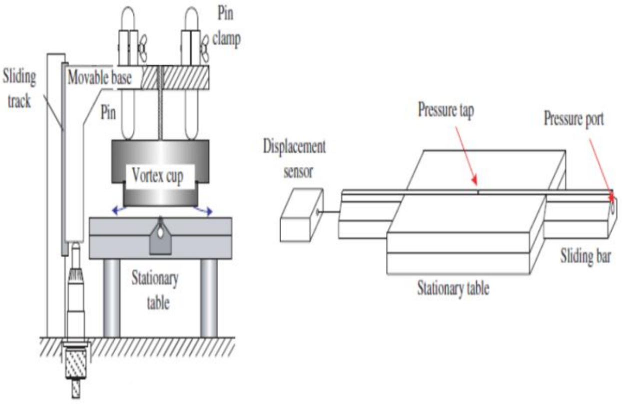

Figure 7: Pressure distribution measurement apparatus.

Thus, the gripper maintains a clearance away from the measurement table equal to the thickness of the steel sheet. By these means, the pressure distribution measurement can be conducted for any clearance setting by changing the thickness of the steel sheet. A sliding bar containing a small tap hole and an internal connecting perforation is inserted through the middle of the measurement table . A wire displacement sensor is placed at one end of the bar to record the location of the bar. At the other end, a pressure sensor is connected to the pressure tap to detect the pressure signal through the internal perforation. In this way, the pressure distribution on the upper surface of the measurement table can be measured by continuously recording the pressure and the position while slowly moving the sliding bar.

Figure 8: Pressure distribution measurement apparatus.

4.RESULTS AND DISCUSSION

Fig 9. Shows the CFD result for a constant clearance distance of 0.2 mm and rotation speeds of 7000,8000 and 9000rpm. Fig. 10, is an experimental result for a constant clearance distance of 0.2 mm and rotation speeds of 7000,8000, and 9000 rpm. The result shows that the parabolic pressure distribution inside the chamber is dependent on the rotation speed. The faster the motor rotates, the stronger is the centrifugal force hence ,the central pressure decreases further .CFD results shows the influence of rotation speed changes by a good agreement with all three sets of experimental results .In contrast , increasing the speed of the motor increases the amount of air sucked in through the air inlets, and thus , more air must be discharged through the narrow gap between the gripper and the work-piece. This would certainly lead to larger pressure loss in the gap. As a result , an increase in the rotation speed shifts the pressure distribution in the gap slightly upward.

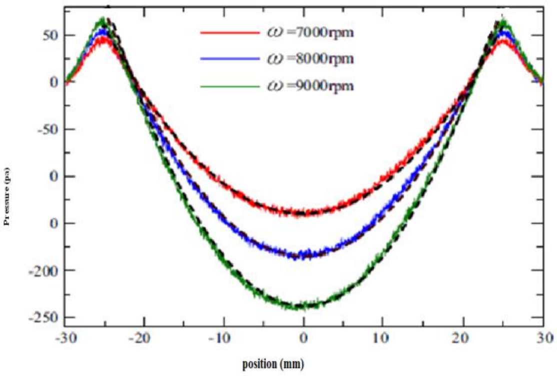

Figure 9: CFD Pressure distribution at different rotation speeds (h=0.2 mm)..

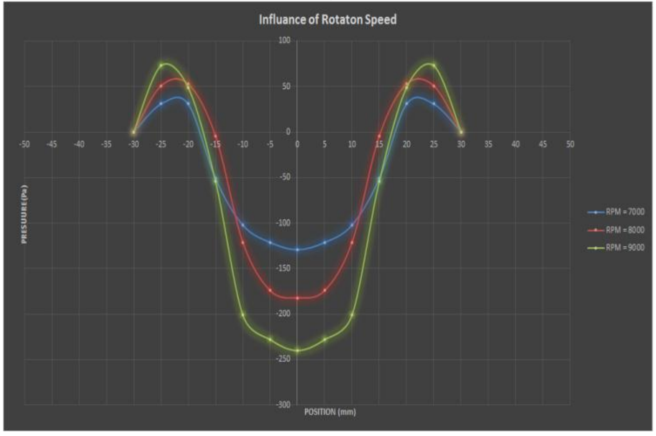

Figure 10: Experimental result for Pressure distribution at different rotation speeds (h=0.2mm)..

4.1Influence of the clearance distance

The next investigation is about the influence of the clearance distance on the pressure distribution. Fig 11 shows the CFD result for various clearance distance at 8000 rpm. Fig. 12 shows the experimental result of pressure distributions at different clearance settings and at a constant rotation speed of 8000 rpm. As the clearance is enlarged from 0.06 mm to 0.4 mm, the pressure distribution in the gap is highly sensitive to changes in clearance. This is because the viscous impedance of the gap is determined by the clearance as well as the suction flow rate. The larger the clearance, the weaker is the viscous impedance hence, less pressure is lost when air flows through the gap. As a result, the entire pressure distribution in the gap falls to atmospheric pressure gradually as the clearance is increased from 0.06 to 0.40 mm. In contrast, the pressure distribution inside the chamber shifts downward but maintains a nearly unchanged shape regardless of the clearance. As is well known,the distribution shape reflects the flow state. Obviously, when the rotation speed of the motor is kept constant, the state of the swirling flow should be identical despite changes in the annular gap. Thus, the swirl gripper maintains the same distribution shape inside the swirl chamber. Nevertheless, as the clearance is enlarged further to1.0,and 3.0,the pressure distribution shows a different tendency. The pressure in the gap is hardly affected by the clearance enlargement because the clearance distance becomes too large to raise significant viscous impedance in the gap. Moreover, it can be seen that the pressure inside the swirl chamber generally returns to wards atmospheric pressure accompanied by obvious pressure fluctuations.

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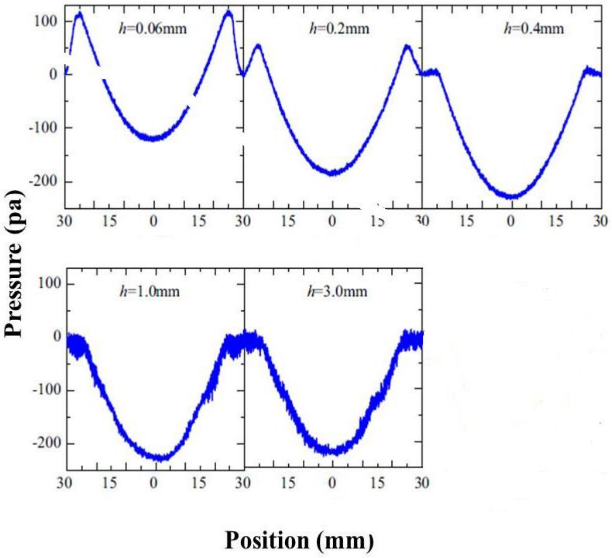

Figure 11: CFD Pressure distributions at different clearance distance settings(w=8000 rpm).

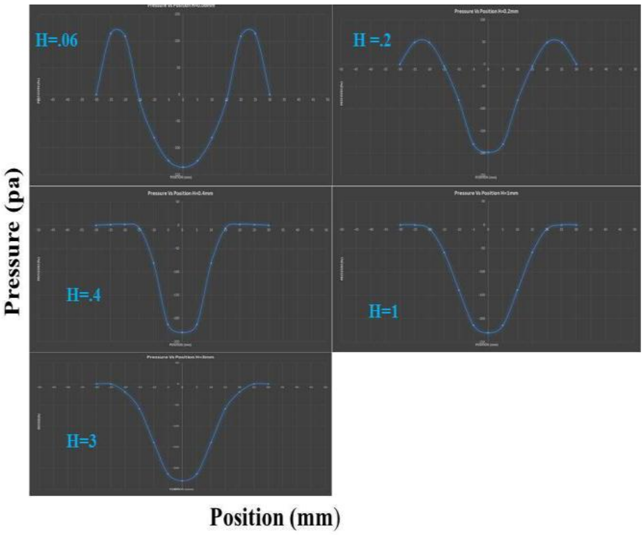

Figure 6.6: Experimental result for Pressure distributions at different clearance distance settings(w=8000 rpm).

5. CONCLUSION

In this paper, we proposed a new noncontact gripper called as swirl gripper. It generates swirling air flow to create an upward lifting force. This force can be used to pick up a work piece placed underneath the swirl gripper without any contact. In comparison with conventional pneumatic noncontact grippers, the unique- ness of the new gripper lies in that it is electrically (rather than pneumatically) activated. We carried out this study for clarifying the mechanism of the swirl gripper. First, we showed the design of the swirl gripper and briefly illustrated the mechanism by which it forms a negative pressure to create a lifting force. Then, we investigated the characteristics of the pressure distribution experimentally and theoretically. It is known that the centrifugal force of swirling air flow gives rise of parabolic negative pressure distribution and the pressure distribution depends upon the clearance between the work piece and the gripper as well as the rotation speed.

- Pressure distribution inside the chamber is dependent on the rotation speed, faster the motor rotates ,stronger is the centrifugal force.

- The clearance is enlarged from 0.06 mm to 0.4 mm, the pressure distribution in the gap is highly sensitive to changes in clearance.

REFERENCES

[1] Xin Li, Ph.D.1; Shouichiro Iio, Ph.D.2; Kenji Kawashima,Ph.D.3;andToshiharuKagawa,Ph.D.4.,\"ComputationaFluidDynamics Study of a Noncontact Handling Device Using Air-Swirling Flow, IEEE Rev Biomed Eng., Volume 6, Pages 47-62,January 2011.

[2] Xin Li, Toshiharu Kagawa, Development of a new noncontact gripper using swirl vanes,Robotics and computer-integrated manufacturing, volume 38, issue 4, pages 63-370, 3September 2012.

[3] G X meng,\Development of a non-contact end e_ector for robotic handling of non-rigid materials", Materials Today, Volume 16, Issue 12, Pages 496-504, December 2010.

[4] Xin Li, Toshiharu Kagawa, Kenji kawshima , Analysis of vortex levitation, Robotics and computer- integrated manufacturing, volume 26, issue 5, page 490-499, march2008.

[5] Vincent Vandaele, Pierre Lambert, Alain Delchambre \ Non-contact handling in mi-croassembly: Acoustical levitation" precesion engineering, volume 29 , issue 4, october-2005..

[6] S. Davis, J.O. Gray, Darwin G. Caldwell \An ende ector based on the Bernoulliprinciple for handling sliced fruit and vegetables" robotics and computer –integrated manufacturing , volume 24 ,issue 5 , november 2006.

[7] Giacomo Mantriota,\Theoretical model of the grasp with vacuum gripper", Mechanism and Machine Theory, Volume 37, Issue 15, Pages 3107-3116, may 2006.

[8] G. Reinhart , J. Hoeppner,\Non-Contact Handling Using High-Intensity Ultrasonics",Mechanism and Machine Theory, Volume 7, Pages 907920, January 2000.

[9] Konstantinos Salonitis.,\Modular design for increasing assembly automation", Manu-facturing Technology, Volume 101, no. 7, Pages 12331242, june 2014

[10] DonghunLee \Robotsintheshipbuildingindustry", RoboticsandComputer-IntegratedManufacturing Volume 21, Pages 1-4, januvary 2014.

[11] Hua Lina,,1, Paul M. Taylora,2, Steve J. Bullb., \Modelling of contact deformation for a pinch gripper in automated material handlings", mathematical and computer modelling, Volume 19, no. 1, ISSN 1517-7076, May 2014.

[12] H. Lin a,, S.J. Bull b, P.M. Taylor a,\Simulation of the deformation and stress dis-tribution within a exible material pressed by a pinch gripper", material processing ,
Volume 26, Pages 5632-5639, 2005.

[13] Z.W. Zhong, C.K. Yeong,\Development of a gripper using SMA wire", Sensors and Actuators, Volume 367, Issue 15, Pages 1993-2009, May 2005.

[14] Dalibor Petkovic, Nenad D. Pavlovic, Zarko C ojbaic , Nenad T. Pavlovic.,\Adaptive neuro fuzzy estimation of underactuated robotic gripper contact forces", Journal of material science: materials in medicine, Volume 1, Pages 201-209, June 2003.

[15] Gualtiero Fantoni a,*, Marco Santochi a, Gino Dini a, Kirsten Tracht b,.,\Grasping devices and methods in automated production processes", Manufacturing Technology.,Volume 17, Issue 11, Pages 1241-1268, June 2014.