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Development of an Adaptive Gripper with Fin-Ray effect.

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Abstract

This paper presents the development of a flexible adaptive robotic gripper with a single actuation. An adaptive gripper with a fin-ray effect can give great flexibility and a multi-choice option for grasping the product of various shapes and sizes. The fin-ray effect is developed from fish's tail fin which is structured as two flexible surfaces come to one end and the middle section is filled with several cross-beams. In this research, the gripper system has two fin-ray fingers and an actuator for linear drive controlled by a motor driver module. With the inclination of the crossbeams relative to the base, the deformation of the fin-ray finger is increased compared to the no inclination formation for the same amount of force of the actuator. Thus, the contact surface of the gripper finger is increased with the object hence developed a good grasping as well as giving better adaptivity and flexibility of grasping various shapes.

Keywords: Adaptive gripper, Fin-ray Effect, Linear actuator, Inclined crossbeam.

1. Introduction

In the manufacturing industries, various tasks have been automated to improve productivity and product quality by using industrial robots. Industrial robots generally comprise a manipulator and an end effector. For the grasping tasks, the end effectors are classified into two types: grippers and multi-fingered robot hands. Grippers have a simple mechanical structure with lower degrees of freedom (DOF) [1]. Thus, they have been mainly used in actual production lines because of the simplicity of control and economic efficiency. However, grippers are not universal; they are used only for grasping a specific object with a dedicated design [2]. Thus, the adaptive gripper plays an important role in increasing the adaptivity and flexibility of gripping action. The adaptive gripper can be in various forms like fully rigid parts with the help of some mechanism, semi-rigid like human skin and skeleton and flexible forms. But most of the adaptive grippers are complex to design as it needs a lot of motor pulley or tendon drive or several servo motors. Thus, the main focus is based on simplifying the design through using flexible material and few actuation systems without considering adaptivity, flexibility or multi-choice option. The fin-ray effect would ensure great adaptivity and flexibility. It is inspired by the fishtail fin

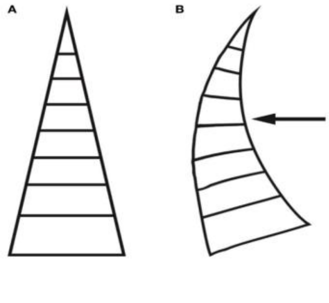

Fig. 1. Fin-ray Effect

which is discovered by biologist Leif Kniese of Evologics while fishing and is based on the deformation of fish fins [3]. The structure of the fish fin is composed of two bones arranged in a V shape with connective tissue in between as shown by Fig. 1. Pulling on one side of the V causes the fin to deform. This was adapted by Kniese into an A-frame structure with crossbeams spaced between the tip and Applying a force to the structure causes the structure to bend. Later, Whitney Crooks, et al. developed a model of fin-ray gripper based on the flexible surfaces and rigid cross-beams [4]. As shown by Fig. 2, the pulling force was generated to the inner base through using the motor tendon drive. Moreover, a decision had been made that the inclined cross-beams gave higher deformation. From the results, it is found that the designed gripper can lift the object of 300-350g.

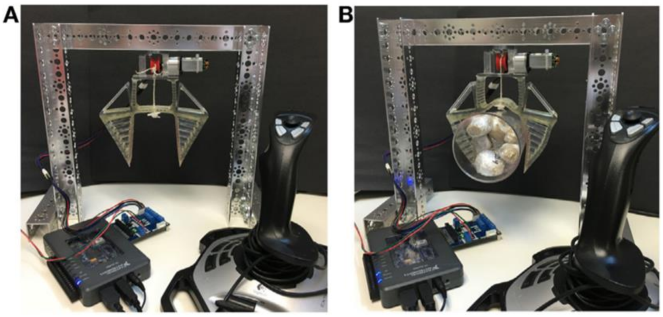

Fig. 2. Fin gripper through tendon drive to the inner base

In the next year, again the same author worked on increasing the workspace as well as load capacity through using passive gripping action [5]. The passive action had been made through connecting the motor tendon drive to the outer port as shown by Fig. 3. The gripper was tested for both vertical and horizontal to the ground formation. The horizontal formation was able to carry about 300g while the vertical formation could carry about 500g.

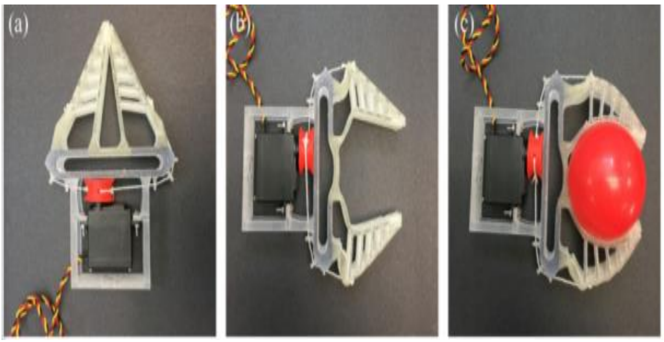

Fig. 3. Fin gripper through tendon drive to the outer-port of the finger [3]

Moreover, C.I. Basson and G. Bright published a paper based on the simulated results of the different geometry of the crossbeams as shown by Fig. 4 [6]. It is found that the inclined crossbeams along with the base give more displacement than the other three geometric patterns. Also, the repeatability was tested and again the inclined shaped crossbeams show a higher value.

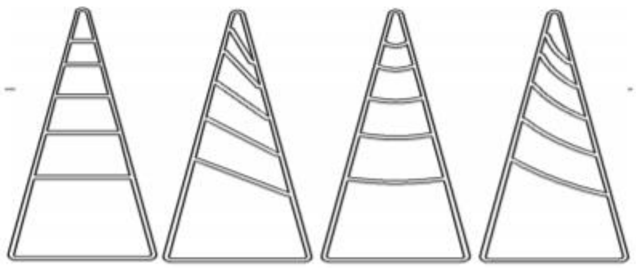

Fig. 4. Analysis of different geometric configuration [4]

Therefore, from the previous researches, it is demonstrated that there is a limitation of working range and also high stress is generated at the flexible connection of the base and fingers. The high stress can cause permanent deformation through repetitive usage of gripper which is not desirable for the industrial purpose.

Thus, this research focuses on constructing the fin-ray finger with single flexible material through 3D printing and the utilization of single material will reduce the printing time as well as the complexity of fabrication. Also, the single actuation system with stepper motor will ensure easy handling and the high load capacity of the gripper.

2. Gripping and Releasing Mechanism

The gripper system is based on the combination of the linear driving system and flexible fin-ray finger. The linear driving system is constructed with the stepper motor coupling with a lead screw. As for stepper motor, the NEMA 17 is chosen due to required ratings and it needs a driver for controlling the step, speed and rotational direction. Thus an A3967 micro-stepping driver is chosen which has a current control limit under 150mA/phase to 750mA/phase. The driver is controlled with the help of the Arduino UNO microcontroller through programming.

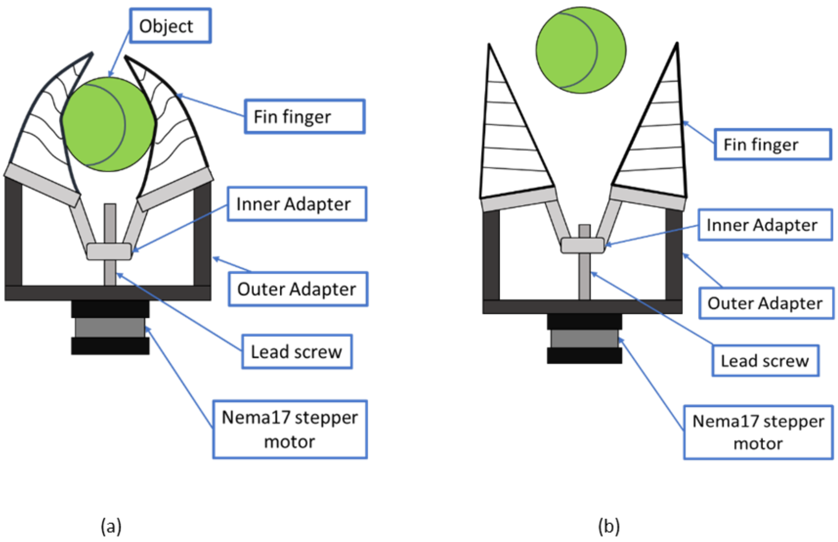

Fig. 5. (a) Grasping operation; (b) Releasing operation

As presented in Fig. 5 (a), when the gripper reaches its destination the grasping operation can be done through 4 complete rotation towards clockwise direction so that the inner adapter moves downward. For good grasping capacity, the complete rotation or the steps can be increased but it will increase the time of gripping action. Thus, it is desired to set the steps of the stepper motor to its optimum value for better working and reducing the time consumption. Again from Fig. 5 (b), when releasing the load, the driver rotates anti-clockwise and it opens the gripper through moving the inner adapter upward and it takes 2 complete rotation for the desired workspace but the workspace can be increased through increasing the number of complete rotation but not more than 4 in this case. In this system, the only moving adapter is the inner one the outer adapter is fixed with a motor. The adaptive finger is made of flexible filament through a 3D printer. Therefore, when the two fingers act against each other due to their downward movement they adjust the shape of the object.

3. Design and Fabrication of Fin-ray Finger

The flexible fin-ray finger is complex to design. Thus, based on the reference model of the previous paper along with some assumptions, it is possible to model and analyze it through the finite element method. The CAD modeling is done by Solidworks and then analyzing the model with simulation software Abaqus. Some assumptions of the modeling were considered as explained in the following part.

In the model, the width of the base is fixed to the value of 40mm and also the spacing between the cross beams is fixed at 20mm. The only variable is the inclination angle of the cross beams. Here the analysis is made between the two inclination angles such as 0-degree inclination or no inclination and the 5-degree inclination.

As presented by Fig. 6, the fabrication of the fin-ray finger is done with the 3D printer using the material TPU which is the composite of elastic and plastic material. The modulus of elasticity of the material is 20MPa and Poisson's ratio about 0.48.

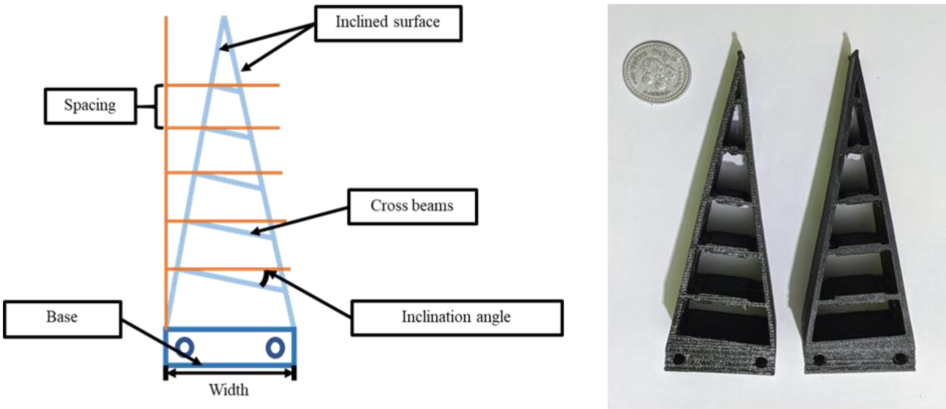

Fig. 6. Fin-ray finger

4. Results

Static deflection analysis of fin-ray finger

The simulation is done in the Abaqus for two inclination angles (0-degree and 5-degree) where the base is fixed and a load about 10N is applied to the 61mm of the one inclined surface. As presented in Fig. 7, the whole system looks like a one end fix and one end free beam.

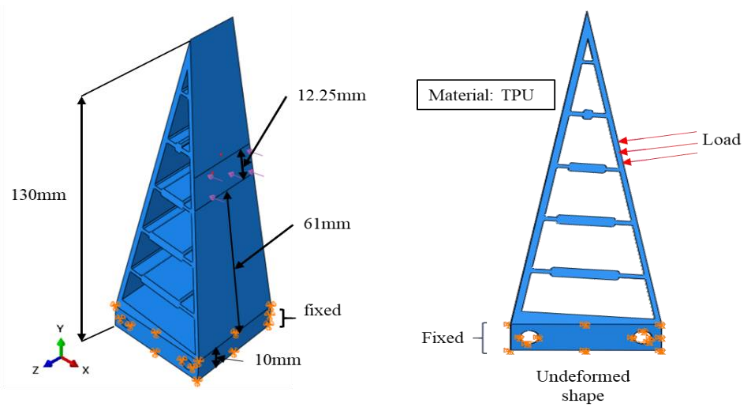

Fig. 7. The system and the material of the gripper analysis

In Fig. 8, a comparison is made between the 0-degree inclination and 5-degree inclination of cross-beams.

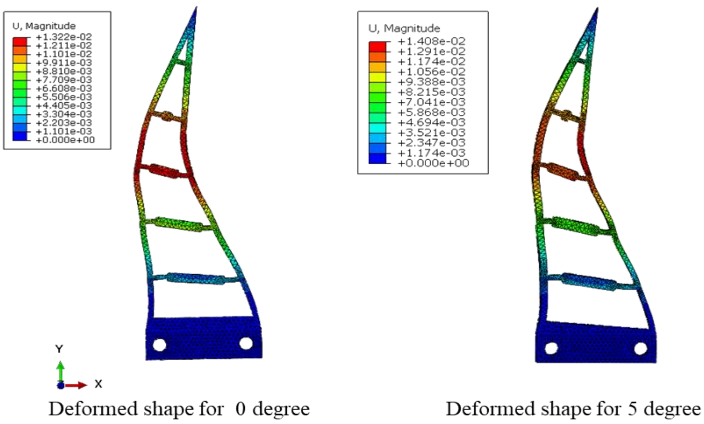

Fig. 8. Simulated result of Displacement along the inclined surface

It is seen from the simulated results of displacement that zero degree inclination has maximum deformation of about 13.22mm, whereas the 5-degree inclination has 14.08mm maximum deformation. Therefore, it has been decided that the increase in inclination angle gives more displacement from its original form to the same amount of applied load.
Moreover, from Fig. 9, it is seen that the increase in inclination angle can give more curvature, hence more adaptivity of the shape of the object to a constant applied force.

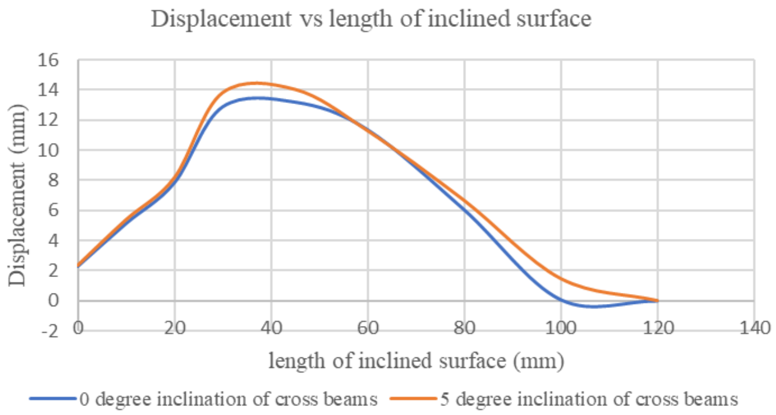

Fig. 9. Displacement of the fin-ray finger along the inclined surface

Gripper load capacity

Gripper load capacity is determined experimentally through lifting a hollow cylindrical container as presented in Fig. 10. The hollow cylindrical container is filled up with different masses. At first, the small amount of mass is given and when the gripper can hold the container for 10 seconds along with three successful trials, then the value of the mass is recorded. After successfully holding that small mass, the value of the mass is increased until the gripper is unable to hold the object for 10 seconds and one unsuccessful trial. Thus, the maximum load capacity is recorded based on the experiment.

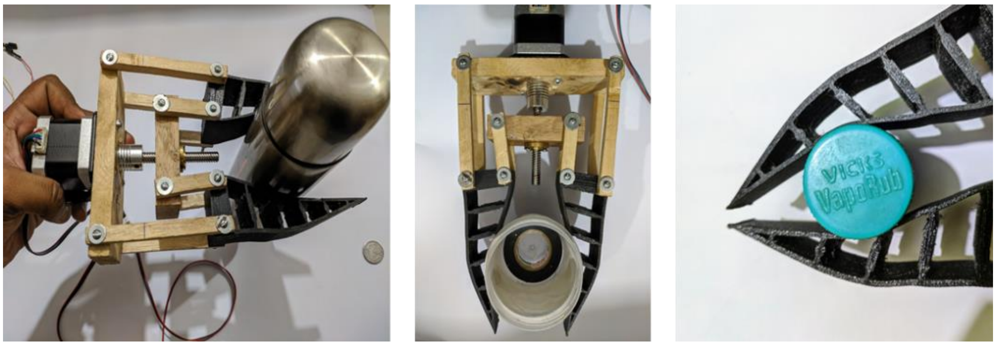

Fig. 10. Grasping of a cylindrical container

From the experiment, it is seen that the horizontal orientation can lift as much load as the vertical one. For both orientations, the maximum load capacity is about 550g.

5. Conclusion

The adaptive gripper with the fin-ray effect can ensure the good adaptivity of handling products of various shapes. The inclination of the crossbeam results in more displacement of the fin-finger which is analyzed through finite element analysis. Thus, generating more contact surface for grasping object which is tested experimentally when gripping the object. Moreover, the single actuation would give a simple control system and also reduce the cost of fabrication. More capacity can be gained by placing higher torque stepper motor. Moreover, the material of the fin-ray finger plays an important role in adaptivity and it is thought that the reduction of the thickness of the inclined surface and the change of geometry of the cross beams would increase the adaptivity of the gripper which creates an opportunity for the future work.

6.References

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