Review on grippers used in remote handling applications

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ABSTRACT

Various Remote Handling applications require a gripper for either a simple pick and place operation or a complex operation like the replacement of plasma-facing components inside a tokamak. Grippers require a high level of dexterity and performance. Presented review work deals with the review of the grippers used for the said operations along with a brief classification of grippers. The ability of the gripper to work under normal and challenging conditions is the main focus of the paper. This paper also discusses the grippers used in a vacuum environment, grippers used in fusion applications, Impactive grippers, adaptive grippers, and complaint grippers.

1. Introduction

Remote Handling finds its usefulness at a place where the work to be carried out is not safe for a human. We use remote handling in places where the task is not feasible for a human worker to carry out. In places such as fusion reactors like a tokamak, it is not safe for a person to go in and inspect the reactor after a cycle. In such cases, we use Remote handling. The environment having high temperatures, vacuum, radiation, etc. is unsuitable for humans. Remote Handling is made for such cases. In some cases, contact with the workpiece is not desirable for a human. Thus, the gripper attached to the robot manipulates the workpiece.

Remote Handling means mainly controlling a robot remotely using Virtual Reality and other suitable technologies. One of them is master/slave technology also known as primary/replica technology. As the name suggests that the movement of a robot is controlled remotely via a master robot which is in turn controlled by a human operator. The master robot's every movement is replicated by the slave robot. The sensors placed at both the robots and the VR as well as cameras placed on the slave robot will give the view and the feel of the environment inside of the place where the work is to be done. Generally, the slave robot consists of an articulated arm which is manipulated using a serial manipulator or a parallel manipulator depending upon the environment and task. The robot contains an End -effector for doing various operations. This end-effector might be a gripper or a tool used for a specific task. Sometimes the gripper is used to hold the tool and then the work is carried out using the gripper-tool assemblage. The grippers are designed mainly for a specific task rather than for multiple tasks. Gripper design is based on many factors which are also responsible for its working and performance.

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Section 1 consists of introduction while section 2 has general information about grippers like the classification of grippers and gripping methods. Section 3 shows the various applications of grippers in different fields. Section 4 discusses miscellaneous grippers. Finally, a conclusion is made.

2. Grippers

Grippers are the end-effectors of a robotic arm. Grippers are used mainly for pick and place operation. This operation might be in an environment with a normal working condition or it might be in an environment having extreme conditions such as high temperature, radioactive materials, vacuum, etc.

The grippers must be able to perform the task for which it is designed while considering its working environment.

2.1. Classification of grippers

The grippers are classified into four categories when referring to the robotic prehension (grasping) type.

1. Impactive Grippers – Grippers use jaws or claws to grasp an object which creates a physical impact on jaws and objects. Thus, they are named Impactive grippers.
2. Ingressive Grippers – Needles or pins are used to penetrate the object. So, it uses a penetration tool for the grasping of the object. There are known as Ingressive grippers.
3. Astrictive Grippers – These grippers do not have direct contact with the object but instead they use suction forces such as vacuum force. This force is applied only in one direction.
4. Contigutive Grippers – The force is produced using chemical adhesion, thermal adhesion, or surface tension for the grasping of the object. They make direct contact with the object. These grippers can only be used if the object material is not be affected by the chemical adhesion.

Grippers can also be categorized based on the following

1. According to the number of fingers

- 2 – Jaw Grippers – These grippers contain two jaws which are placed parallel or at an angle to each other. The force is applied in the opposite direction towards the object from both sides. Thus, the object is grasped.
- 3 – Jaw Grippers – These grippers contain three jaws or fingers at an angle of 120° to each other. They encompass the object from its centre. These are highly used when the object is of round or cylindrical shape.
- Anthropomorphic Hands – The gripper is of a shape similar to that of a human hand. These are the most advanced grippers which are very complex as well as expensive.

2. According to the type of actuation used

- Vacuum Grippers – They are actuated using vacuum pumps. The vacuum pump/generator starts when the suction cup comes in contact with the surface of the object. The system is expensive but the response obtained is fast with great accuracy.
- Magnetic Grippers – They are actuated by the means of magnetism. These cannot be used where the workpiece is made of metal.
- Hydraulic Grippers – Gripper jaws are actuated using piston directly connected to them. The piston is moved using hydraulic forces. There is always a chance of leak or spill in hydraulic actuators. But the gripping force obtained at the jaws is very high.
- Pneumatic Grippers – They contain piston inside a micro-pneumatic cylinder which actuates the gripper using compressed air. The actuators are very expensive. Though the response is very fast as well as very accurate and precise.
- Electric Grippers – Electric motors, mainly servo or stepper motors, are used to actuate the motion of the gripper. As the motors are programmed as per the task, the grippers are very accurate and precise. They are cheap compared to other actuation systems and no leakage problems which is beneficial in conditions where it is not suitable to have leakage.

3. According to the mode of gripping

- Internal Grippers – The gripping is done on the internal surface of the object. Thus, they are known as Internal Grippers. They are used when the gripping is to be done for a hollow object like pipes.
- External Grippers – The external gripper grasps the object from its external surfaces with the help of jaws or fingers.

2.2. Type of gripping methods

There are four types of gripping methods used for gripping an object or workpiece.

- Encompassing Grip – The fingers of the griper encompass around the center of the object which requires less force compared to the parallel grip. This method is used mostly by multi-fingered grippers.
- Parallel Grip – The jaws of the gripper remain parallel when the gripper holds or grips the object. This is the most used method in two jawed grippers.
- Force – Fit Gripping – The gripping is done by applying force in a particular area or a point

on the objects. This method is generally used in traditional grippers.

- Form-Fit Gripping – Fingers adapt to the shape of the object and require less force. This method is the base for the adaptive grippers.

3. Gripper Applications

The grippers available in the market are made and used for a specific task only. Grippers are generally designed based on many factors. One of the factors or as one would say the first step in the design procedure for a gripper will be understanding the task for which the gripper is to be developed. The understanding of the task can be interpreted as an understanding of the workspace in which the gripper is to be used. Also, the working environment of the gripper is considered. There are industrial applications of a gripper as well as there are applications where the remote handling is a must. The industrial environment for a gripper is generally considered as a normal environment while remote handling applications of gripper generally comes under the extreme or challenging conditions domain of applications.

3.1. Industrial applications

Grippers are mostly used for industrial applications. The reason behind the creation of the grippers is its use in industry. Grippers are equipment used for mostly pick and place operation. Grippers are attached or mounted on a robot that is placed on a fixed platform or a revolving base. The industrial applications can be divided into two types namely Grippers working in the Known environment and Grippers working in Unknown environment as explained by Mohammadali Shahriari et al., in (Shahriari, Tai, El-Sayed, Boglarbegian, & Mahmud, 2006).

As explained in (Shahriari, Tai, El-Sayed, Boglarbegian, & Mahmud, 2006) the grippers used in known environments have an easier task as the orientation and position of the station is fixed and known. The packaging industry is using robot automation for the packaging of various products. The grippers used for such applications must be fast, dexterous, accurate, and have very repeatability.

In unknown environments, the pick and place operation is hard as the environment is unknown so are its governing parameters. The automation is trusted to carry out such tasks. The feedback systems having sensors like proximity sensors, force sensors, temperature sensors, etc. are used to gather information, and the work is done accordingly.

Normally, impactive robotic grippers are used for the industrial tasks but industry such as the soft drinks industry uses the Astrictive grippers for the packaging operation. The automobile industry generally uses automation for the assembly of various components of an automobile. The traditional grippers are mounted on the robotic manipulators of the system. (Shahriari, Tai, El-Sayed, Boglarbegian, & Mahmud, 2006) The grippers are most used by the multi-national companies where everything is done using automation. The grippers can also hold soft objects with ease without causing any harm to the objects. In short, wherever there is automation, there is an application of gripper.

3.2. Fusion applications

The need for remote handling and dexterous manipulation in the field of fusion is more due to the highly radioactive materials in the reactor. The main purpose of the remote handling and dexterous manipulation is nothing but to keep away or separate the human from the hazardous environment such as fusion reactor. The gripper was suggested for this purpose in 1997 by A Dutta et al., was successful in handling a weight of 2.5 kg (excluding the weight of gripper) with the maximum gripper opening of 80 mm. It had various sensors for the determination of slippage and grasping force (Dutta, et al., 1997). As figure 1 shows, the gripper uses a parallelogram link structure which is one of the best link assemblage configurations. It was proved by Anna Maria Gil Fuster in her thesis with various

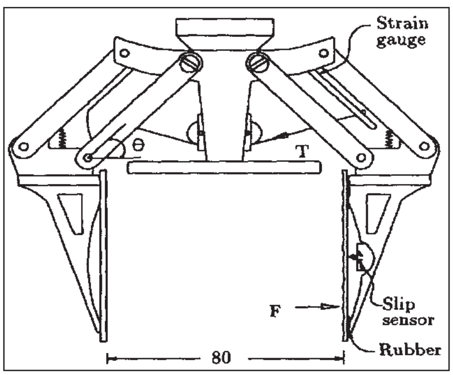

Fig. 1. Schematic diagram of a dexterous gripper (Dutta, et al., 1997).

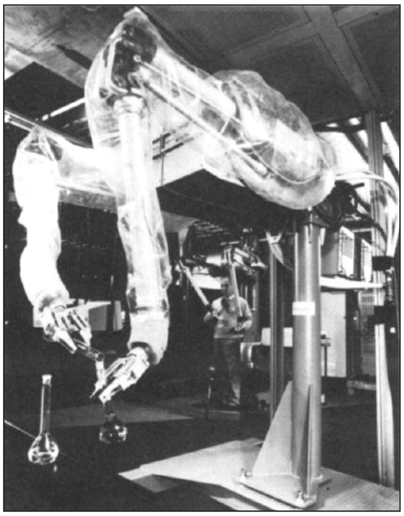

Fig. 2. Mascot Ⅳ (Ramondi, 1989).

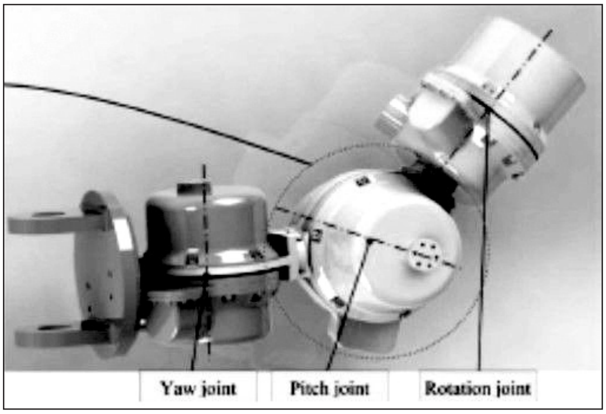

Fig. 3. Arm Joints (Hongtao, et al., 2018).

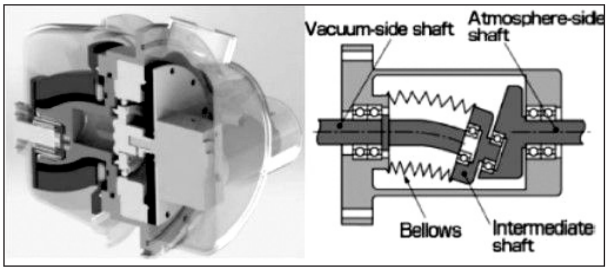

Fig. 4. Bellows sealing mechanism (Hongtao, et al., 2018).

experimentation. The parallelogram mechanism was found to have required less actuating force (Fuster, 2015).

One of the major applications of the gripper in the field of fusion was in the MASCOT manipulator used in JET. MASCOT manipulator is a dual-arm manipulator with two grippers attached as an end effector as shown in figure2. The MASCOT Ⅳ was fully operational in 1997. The MASCOT was used to change the Plasma Facing Components of the tokamak. One of the arms of MASCOT Ⅳ has a gripper at its end which holds the plasma-facing component down on the wall while the other gripper containing arm places the captive bolt on the plasma-facing component with the help of bolt runner. The lifting capacity of MASCOT is around 20 Kg per arm as shown by A C Rofle in (Rofle, 1999). The MASCOT is controlled by a single operator using master/slave technology. The operator is assisted by sensors placed on the MASCOT Ⅳ, cameras with the view of the operation done using the grippers and Virtual Reality to understand the current position of MASCOT Ⅳ. The dexterity of the MASCOT gripper was very high. The accuracy of the gripper is also extremely high. The efficiency of the work done by the MASCOT and its gripper during the shutdown period was around 98% which is considered as very high (Ramondi, 1989).

3.3. Vacuum applications

A 3 DOF gripper was used for changing Plasma Facing Components inside the East Vacuum vessel. The Degrees of Freedom of the gripper used were Pitch, Yaw, and Rotation as shown in figure 3. One of the technical problems faced while working in a vacuum environment is the contamination of the vacuum which is not desirable. Hongtao Pan et al proposed the solution by designing a bellow which seals the output shaft from the normal environment. The flexibility with high robustness is used in the ultra-vacuum environment. The mechanism used for sealing is shown in figure 3 (Hongtao, et al., 2018).]

The gripper used for this environment has a payload capacity of 2 Kg. Various sensors like laser guide finder, Torque sensor, cameras, etc. are used for the replacements of Plasma Facing Components. The designed claw uses rope – pulley mechanism, screw-driven unit and parallelogram linkage for the transmits of the motor force to the jaws. Gripper holds the plasma-facing components and the second hand of the manipulator with a bolt runner will bolt the component to its position as shown in figure 5. A Finger adapter is mounted on the gripper to facilitate the holding of the component for the bolting process. The main feature of this gripper is the ability of the gripper to work in Ultra High Vacuum (UHV) environment with high accuracy and repeatability (Hongtao, et al., 2018).

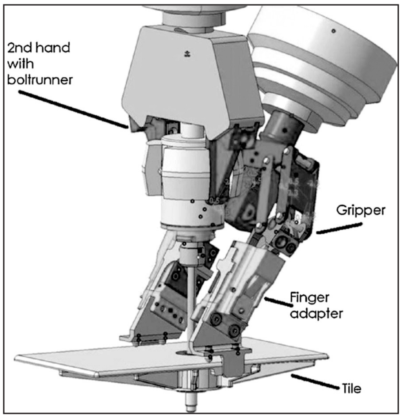

Fig. 5. Tile Handling in the JET (Hongtao, et al., 2018).

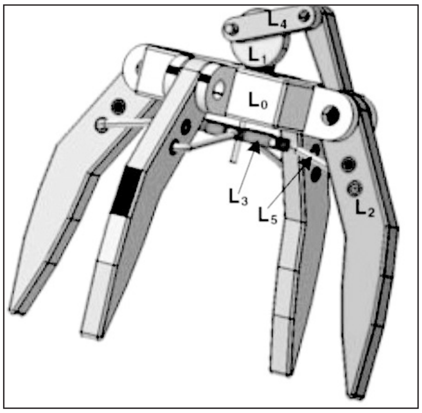

Fig. 6. Gripper with single DOF (Hassan & Abomoharam, 2014).

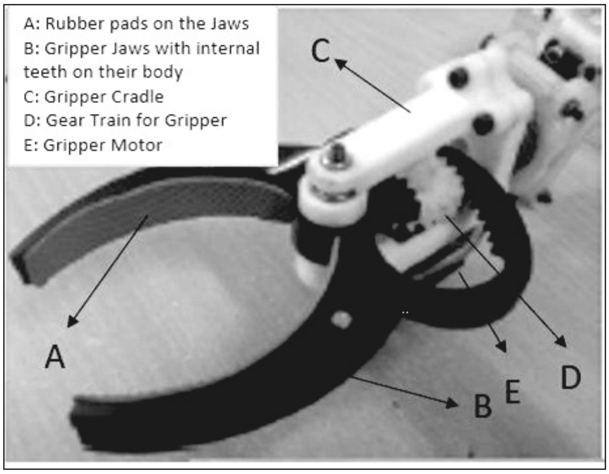

Fig. 7. Gripper with gear train used for transmission of motor power into grasping force (Roy, Pandit, Chothe, & Atpadkar, 2018).

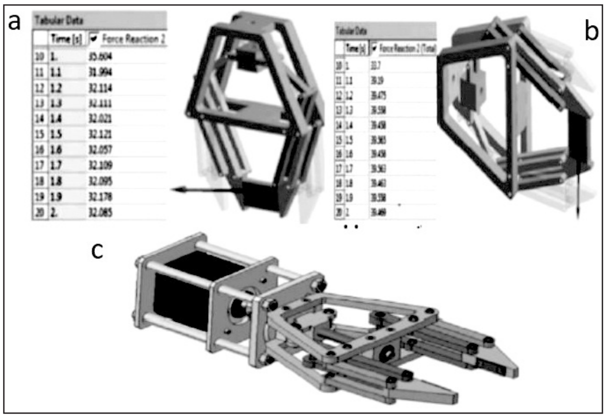

Fig. 8. (a). Gripper lifting the object in a vertical configuration, (b). Gripper lifting the object in horizontal configuration and (c). Gripper with a screw-driven mechanism using a parallelogram linkage structure (Raval, Gotewal, Stephen, & Patel, 2016).

4. Miscellaneous Grippers

There are grippers made using various materials, mechanisms, and technology for various purposes. Ala Hassan made a gripper by using a combination of two well-known mechanisms namely four-bar chain mechanisms and slider-crank mechanism. This was controlled by a cam and follower arrangement. One finger was moved by using the slider-crank mechanism. The movement was then transmitted to all the other fingers by the means of the four-bar chain. The gripper had 1 DOF. The gripper was easy to understand for any beginner. The gripper is shown in figure 6 (Hassan & Abomoharam, 2014).

Debanik Roy et al., developed a gripper to reduce the system trembling in real-time. The fingers of the grippers used the gears for the transmission of the motion. As shown in figure 7, each finger of the gripper is driven via an individual gear. Both the gears are connected on the same shaft. The jaw base has internal teeth. While the other jaw base has teeth in its outer periphery. Both the jaw base mesh with the intermediate gear. This is shown in the form of a gear train in figure 7. An electric motor was used for the actuation of the gripper (Roy, Pandit, Chothe, & Atpadkar, 2018).

Samir Raval et al., have presented a gripper having a payload capacity of 1 kg with a maximum opening of 50mm. The gripper uses a screw-driven mechanism for the transmission of motion. The actuation used is an electric motor as the other systems were not feasible due to the working environment of the gripper. The linkage structure used in this gripper is the parallelogram linkage structure. As shown in figure 8(a), the maximum gripping force for the lifting of the object in the vertical configuration is 32.03 N. While for horizontal configuration is 39.469 N as shown in figure 8(b). Figure 8(c). shows the assembly of the gripper (Raval, Gotewal, Stephen, & Patel, 2016).

4.1. Adaptive grippers

One of the advancements in the field of robotic grippers was the introduction of the flexible fingered or otherwise known as an adaptive gripper. The word adaptive suggests that the adaptive finger will adapt to the shape of the object. First adaptive grippers were based on Fin Ray Effect. Fin Ray Effect is the effect that occurs in the fin when coming in contact with anything. (Crooks, O'Sullivan, Vukasin, Messner, & Rogers, 2016). The change of the shape of the gripper occurs by the deformation of the fingers. The object is encompassed at the centre of the gripper. The Fin Ray inspired FESTO's Multichoice gripper was one such gripper. The gripper has a minimum of two fingers. The slots provided on the body of the gripper enables the gripper to have a maximum of 6 fingers. The gripper is actuated by a pneumatic actuation system having a pneumatic micro-cylinder. The material used for the flexible framing was silicone (Festo Multichoice Gripper, 2015). The design of the traditional fin ray gripper was changed by Crooks Whitney. The addition of nails and asymmetric fingers increased by the holding capacity of gripper by 40%. The material used for the adaptive fingers was Silicone (soft). Where as the ribs or cross components were made by a harder material Acrylonitrile butadiene styrene (ABS) (Crooks, O'Sullivan, Vukasin, Messner, & Rogers, 2016). Further changes were done by C I Basson et al in the orientation of the ribs of the traditional Fin Ray gripper. Figure 9 shows the changes in the rib orientation. Geometry 4 having curved as well as slanted ribs showed to have maximum mass holding capacity and maximum deformation of fingers (Basson, Wright, & Walker, May 2018).

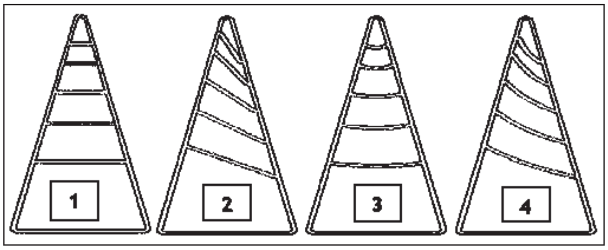

Fig. 9. Rib orientation of the gripper's finger (Basson, Wright, & Walker, May 2018).

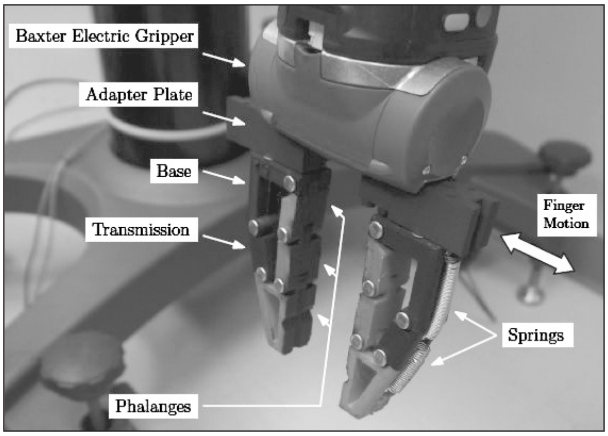

Fig. 10. Underactuated Gripper (Birglen, February 2019).

4.2. Smart material-based grippers

Some special types of smart-material based grippers are still in the realm of development. The gripper is mainly replaced by a vacuum cup or material like granular material also known as particle jamming. In (Amend, Rown, Rodenberg, Jaegar, & Lipson, 2012), John R amends et al., has developed a positive jamming granular gripper. A ball made of granular material is attached at the end of the gripper body in place of fingers. The granular ball will grasp the object by the means of static friction. It is difficult to attach them to a normal robot. The applications of such grippers are limited as the gripping force obtained is not very high. If the gripping force is increased as well as the difficulty in applying to the robot is reduced, then they can be of much use in the field of robotics.

4.3. Underactuated compliant grippers

Underactuated Grippers use the natural dynamics of the system to obtain a greater performance in terms of handling, accuracy, and repeatability. Lionel Birglen designed an underactuated self-adaptive gripper. The under actuation allows the gripper to conform itself to the shape of the object making it adaptive. Baxter electric motor provides the actuation to the system. The gripper consists of five phalanges held in place with the help of springs during no contact. All the phalanges are connected using revolute joints. This acts as a passive component. The reverse motion of the joints is blocked with the help of mechanical stoppers. Precision grasping occurs due to the blocking of the reverse motion of joints. The under actuation helps the gripper in adapting to the shape of the object. Figure 10 shows the underactuated gripper. The precision and power grasping of the gripper is shown in figure 11 (Birglen, February 2019).

Atushi Kakogawa et al., (2016) proposed a gripper with a pull in a mechanism. The concept of under actuation is used here. The gripper finger

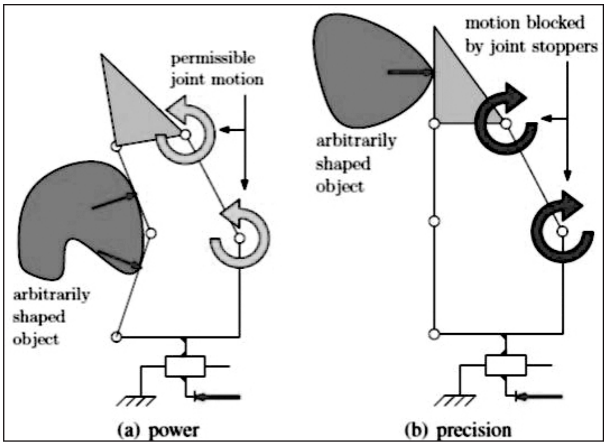

Fig. 11. Power and Precision grasping of the collaborative gripper (Birglen, February 2019).

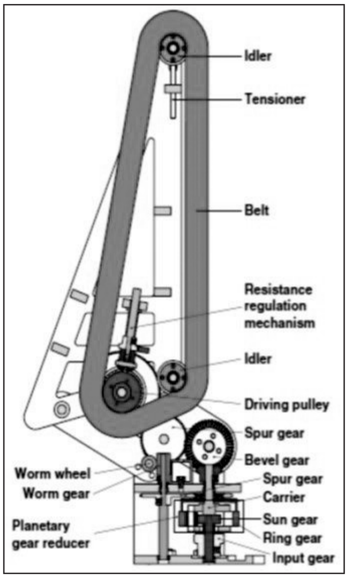

Fig. 12. Finger module of the gripper with pull-in mechanism (Kakogawa, Nishimura, & Ma, 2016).

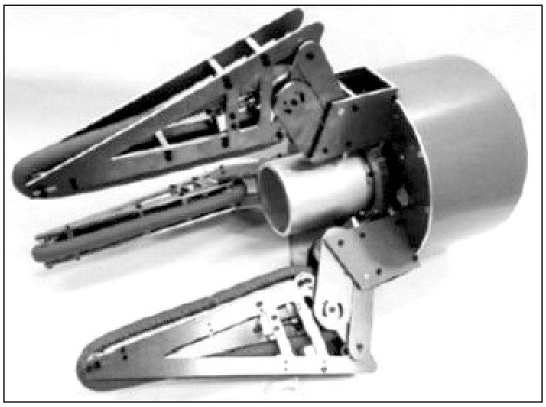

Fig. 13. Gripper with a pull in mechanism. (Kakogawa, Nishimura, & Ma, 2016).

has a gear train which actuates the mechanism. The finger encompasses the object. The finger has a belt made up of silicone which pulls in the object to grasp. The pulley system is used for the movement of the belt. The preference is given to the fingers coming in the contact first before the belt pulls the object. A single finger module is shown in figure 12. Figure 13 shows the complete gripper with a pull-in mechanism (Kakogawa, Nishimura, & Ma, 2016).

5. Conclusion

End Effectors such as Grippers, welding torch, tool changers, sensors, cameras, etc. play one of the major roles in the robotic ecosystem. Classification of grippers and different types of gripping methods was done in this paper. This paper also presented different types of grippers along with their applications in different fields. Furthermore, the summarization of different research work in the field of various grippers was done, especially of adaptive grippers. The observations made during the literature survey of the existing papers show that the dexterity of the gripper is based on the grasping ability of the gripper which in turn relies on the type of actuation, the mechanism used for transmission of motion, number of fingers and also on the grasping force. This will be useful in the design and development of the combination of the traditional impactive grippers and the adaptive grippers.

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Disclaimer

The views and opinions expressed here in do not necessarily reflect those of the Institute for Plasma Research, Gandhinagar.

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