International Journal of Mechanical Engineering and Robotics Research

ISSN 2278 – 0149 www.ijmerr.com
Vol. 3, No. 2, April 2014

Review Article

RECENT TRENDS IN ROBOTIC END OF ARM TOOLING (GRIPPER)

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The role of robot end-of-arm tooling has never been more important. With robot users demanding more versatility in their processes, manufacturers are under pressure to deliver flexible, intelligent End-Of-Arm Tooling (EOAT) that adds value to the overall system. From servo grippers and hybrid tooling, to advanced tool changers and control modules, today's EOAT is not only easier to implement and easier to use, it's down right smart. This paper describes about recent trends in robotic gripper and its applications. Application-specific grippers are bringing robotics within arm's length of a broader audience, to new industries and small to midsized businesses that would have considered it out of reach just a year ago. A new breed of anthropomorphic end effector not only plays nice in the lab, it's finding its way onto the shop floor. And a magnetic gripper that's the polar opposite of anything on the market is attracting fans. Pick and place, weld, deburr, apply material, inspect and locate, load/unload—and do it all with one EOAT—robot users are throwing down the gauntlet, and manufacturers are raising their "hands" to the challenge.

Keywords: EOAT, Servo gripper, Adaptive gripper, Flexible gripper

INTRODUCTION

A robot gripper is an end-effector or sometimes called end-of-arm tooling that is used on industrial robots for material handling, e.g., grasping, holding, lifting, moving and controlling materials. Robot grippers are very important tools because without it, industrial robot cannot be used in material handling application. Robot grippers are meant to replace human hands because they are very good for repetitive cycles, handling heavy loads, and operate under extreme temperatures and environments where human hands cannot operate. Since robot grippers are usually custom designed for its particular applications, utmost importance should be given to EOAT while designing. The grippers are generally used for material handling during

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processing, palletizing, etc., where end effectors that can be used as tools serves various purposes. Such as, Spot welding in an assembly, spray painting where uniformity of painting is necessary.Generally, the gripping mechanism is done by the grippers or mechanical fingers. The number of fingers can be two, three or even as high as five.

LATEST TRENDS IN ROBOTIC GRIPPER

Servo Gripper

Flexibility is one of the biggest differentiators and the common denominator in the latest EOAT trends. Robot users are asking for end-of-arm tooling that can handle multiple sizes of similar materials, or end effectors to handle different kinds of materials, or hybrid technologies that tackle multiple tasks with the same EOAT.

Customers want to utilize the same tool for various sized bags without having to use some kind of manual width adjustment. The new Servo Bag Gripper SBG50 (as shown in Figure 1) incorporates a servomotor with a belt and pulley system to automatically adjust on-the-fly between different bag widths.

This tool also provides the ability to operate one robot on two lines with different sized bags. It will adjust the width on-the-fly from one side to the other as customer palletize two different lines at the same time, with one robot and one EOAT.

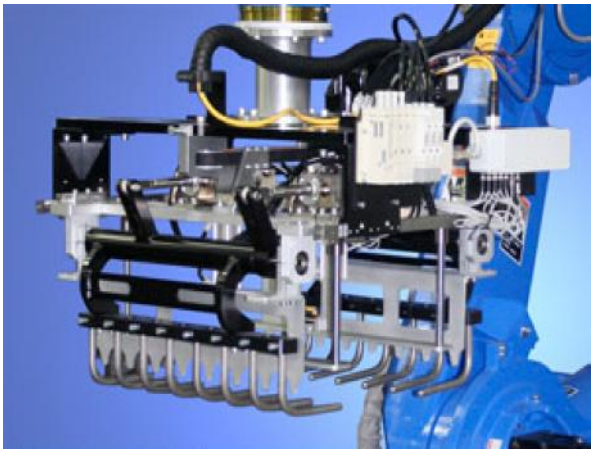
The robot must be preconfigured with a 7th axis controller in order to control a servomotor. It's more user friendly for the teach pendant and programming because the servo-driven EOAT shows up as a 7th axis just like any other axis on the robot. It's more work on robot integrator end, but much more user friendly.

By building the user friendliness right into the equipment, it's also easier on the integrator. There's less programming knowledge involved. If any portion of the project can be simplified, they can install it faster and troubleshoot it easier.

Servo-based grippers are able to adapt to regularities in a part, meaning the robot programmer doesn't have to hit that perfect spot all the time to grip the part. It saves an incredible amount of time. Servo also gives an almost infinite range of options in positioning. Whereas an air cylinder-based clamp is either open or it's closed. One is either grabbing or one is not grabbing. With servo one can engage a part that is slightly irregular or packaged in a slightly irregular way.

In an elecric gripper, or servo-gripper, electric motors control the movement of the jaws using electric input from the robot controller. These robot end-of-arm tools are

Figure 1: New Servomotor Bag Gripper with Automatic, on-the-Fly Adjustment for Bags of Different Sizes (Courtesy of SAS Automation LLC)



now a days appearing more and more in industrial markets.

Advantages of Using Electric Grippers Over Other Types of Robotic Grippers

Control the Position of the Gripper Finger: Using encoded motors and the proper control scheme, the position of the jaw can be defined with an electric gripper. On the contrary, with conventional grippers, you typically have to go full stroke all the time. With electric grippers, you have flexibility to only use the minimum necessary clearance to approach a part, then do a minimum stroke to pick it up. Partial opening and closing helps pick a wider range of part sizes without compromising the cycle time.

Detect Grip: Using encoders, it is possible to determine if a part has been picked up by the gripper. Some electric grippers will relay this information back to the robot controller. For many applications, detecting the grip is mandatory for error-proofing. Doing it at the gripper level avoids putting other sensors in the loop, simplifies integration and can reduce overall cost.

Control the Grip Force and Speed: As the electric motor current is directly proportional to the torque it applies, it is possible to control the grip force applied by the gripper. The same is true for the closing speed. This can be of great help when handling fragile parts for example.

No Air Lines: Save on Power and Maintenance: Many companies are making a move from pneumatic to electric to reduce operating costs. One important aspect of this shift is the cost reduction of the pneumatic hardware and the cost of energy.

Cleaner Grippers: Some applications require a clean environment whereby air leakage could cause contamination. In these cases, electric grippers are the only viable solution to pick up parts.

Modular Vacuum Grippers

End-of-arm tooling designed to handle various kinds of materials in varying shapes and sizes is also trending. Many of end user are looking for lighter-weight tooling, especially when they want the EOAT to handle many different kinds of parts (more flexibility in the EOAT often means more components and more weight) but at same time they still want to use the smallest robot possible.

The above mentioned scenario is especially true in the consumer goods industry where the packaging is changing so often. Customers are asking for tooling that will not only handle their current packaging, but packaging two to three years down the road, but we don't know what it's going to look like in the future.

Schmalz Inc recently launched its large-area vacuum gripping system, the FMP. It is called as "vacuum bars" and are designed to handle various materials such as wood, metal sheet, glass, cardboard, or plastic with different shapes, surfaces and dimensions.

With suction cups, the problem is that the cup has to completely cover a product, if it hits half on a box or pouch, then that suction cup becomes basically meaningless, because it's not generating vacuum and it's just leaking air.

The vacuum bar (as shown in Figure 2) doesn't care where the product is located. It's kind of like a vacuum cleaner in how anything underneath it gets sucked up. But it doesn't

Figure 2: Vacuum Bar Technology Developed by Schmalz Inc. for Handling Different Products

have to perfectly seal around everything that it's gripping. The vacuum bars can handle a lot of different shaped and sized products without having to change the gripper.

If the product is a sheet metal or a glass, or these paver stones (as shown), that stay level or flat, then we can pick those up with an engineered foam and that's usually the best product because it's the most versatile on those kinds of materials.

Figure 3: Large, Engineered-Foam Vacuum Gripping System Hangles Brick Pavers with Ease (Courtesy of Schmalz Inc.)

Advantages of Modular Gripping System

Frequent Product Changes in the Consumer Goods Industry: The product life cycle of products packaged in bags is considerably shorter than for products in bottles or boxes because changing the packaging unit and size for bottles and boxes is more complicated. On average, bag packaging changes its shape, color, packaging material, size or fill level every one to two years. This means that new grippers need to be redesigned every one to two years. So Vacuum End effector gives flexibility in EOAT and avoids redesigning of the EOAT

Time Required: 1 Hour Instead of 13 hrs: The Vacuum End Effectors (VEE) can grip loads weighing up to 2000 g regardless of the product type and, with process accelerations of up to 10 g (100 m/s^2), it meets the speed requirements for the pick and place processes that are typical for the packaging industry. A further advantage: the standard quick-change adapter reduces changeover times for the VEE to a minimum. This makes it well-suited to the consumer goods industry where a large range of products are handled in smaller and smaller batches. Another advantage of the VEE is the hose-free vacuum distribution within the system, which reduces possible leakage and ensures greater efficiency and faster response times.

Schmalz Inc analysis shows that the net time requirement for conventional grippers is approximately 13 hours from definition, design, and manufacture through to assembly. If grippers are manufactured with a clamping function, and thus cannot be adjusted, additional manufacturing capacity must be

scheduled, set up and completely newly manufactured. Depending on how much machine manufacturing companies/system integrators produce internally, delays of a few hours to days can result. In the end this can result in a design and manufacturing period between 1 and 4 weeks. The VEE system; however, reduces gripper definition and assembly work to about an hour.

Saving Gripper Costs: Using the VEE system also reduces the costs of gripper design to a fraction as opposed to conventionally designed grippers.

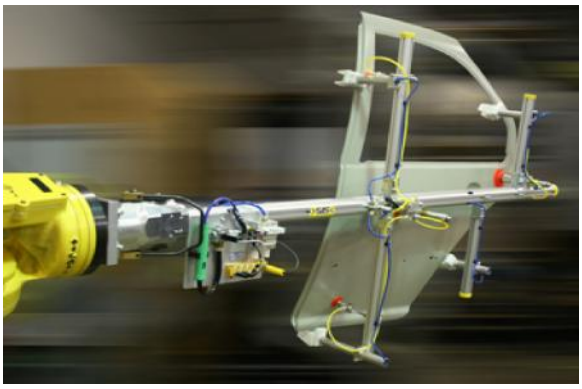
Clean Surfaces: All VEE elements are made of FDA and BfR-compliant polyphenylsulfone (PPSU). The surfaces of the elements are easy to clean and are resistant to alkaline cleaning agents. This makes them suitable not only for the packaging industry generally but especially for use in the food processing industry.

Hybrid EOAT

Another trend in recent EOAT is 'hybrid tooling' that combines multiple gripper technologies in one end-of-arm tool. Many users want one universal gripper for all parts, So that's what EOAT manufacturer try to focus on, is engineering an EOAT that will grip all their products without changing tools. To accomplish that, we sometimes have to use a combination of different technologies all in one tool. For example, part of the tool will have suction. Another part will have a mechanical clamping arm around it.

SAS Automation recently introduced new Hybrid "HX" End Effectors for 5+ Axis Robots, made exclusively with the newly developed SAS HX hybrid frame profiles and modular off

Figure 4: Hybrid End Effector Developed by SAS Automation



the shelf gripper components. This new HX End Effector is specifically designed for increased flexibility, offering an optimal "hybrid" design that includes the benefits of tubular frame adjustability as well as extruded channel frame profile rigidity. Robotic production use includes long reach boom press tending applications or heavy-duty material handling.

Significant features and benefits:

- Direct side channel mounting of standard SAS gripper component hardware, eliminating rotation or twist problems.
- Modular design allows for side mounting or circumference component or connector clamping, offering added compatibility to other brands and types of systems.
- Available with compliant oil resistant vacuum cups with hold down clamps to secure parts even when system fails.
- Available in sizes of 40 mm and 60 mm OD (HX-40/HX-60).
- Center hole can be tapped to accommodate an M8 sized screw for connection of end plates/caps, connectors, etc.

Ideal for high-speed, heavy weight, or press tending applications – especially when gripping from a flat steel stack to load the stamping die to a formed part removal mode.

Advanced Tool Changers

In the growing EOAT market, tool changers have continued to get more flexible, robust and easier to use. But with these advancements come new challenges.

ATI recently introduced its largest tool changer, the QC-1510 Heavy-Duty Tool Changer, which can handle payloads up to 4,080 kg. The modular construction allows integration with applications requiring high-power, coolant, servo, a variety of bus networks, and discrete signal capabilities by incorporating separate modules that can be mounted on any of nine available flats.

Along with the largest, ATI also recently developed its smallest tool changer. The QC-001 Micro Tool Changer weighs less than 122 grams while handling up to 1.4-kg payloads. The micro tool changer was developed in response to robot manufacturers introducing high-speed delta robots.

On the other side of the spectrum, our largest tool changer, which is the largest in the world, was developed in response to a non-robotic application. In addition to the flexibility tool changers provide and the safety aspects of reducing the frequency the operator has to enter the robot cell to change end effectors. One of the primary benefits of tool changers is maintenance. Normally it may take 20 minutes of work for somebody to get it off a robot and get another one back on. A tool changer can do it in 3 to 6 seconds.

Figure 5: The Largest Tool Changer on the Market is Shown in Comparison to One of the Smallest, Lightest Tool Changers (Courtesy of ATI Industrial Automation)

Advantages of Tool Changer

Lines changed in seconds instead of hours.

Operator safety increased by changing tools automatically.

Tools changed in seconds for maintenance and repair.

Increased flexibility of your robots by adding the ability to use more than one end-effector in an application.

Heavy and large multi-tool end-effectors replaced with individual tools that are automatically exchanged.

Superior Fail-Safe Locking: The locking mechanism has a built-in patented fail-safe feature that keeps the Tool plate secured to the Master plate in the event of pneumatic pressure loss. This fail-safe feature eliminates the need for a spring.

High Rigidity: The Quick-Change has a high moment capacity due to the locking piston's large diameter and second taper. The Quick-Change does not rock during high-inertia moves, preventing locking failure or repeatability problems.

Unmatched Repeatability: The piston acts as a large dowel pin, aligning the Master and Tool with remarkable repeatability. Repeatability specifications are based on million-cycle testing.

No-Touch LockingTM Technology: The Quick-Change can lock successfully with a gap between the Master and Tool plates.

Anthropomorphic and Adaptable Finger Grippers

A new breed of anthropomorphic grippers are increasingly strutting their digits on the factory floor. They have grabbed the attention of human collaborative robots designed to work alongside humans in less-structured environments and in small to midsized businesses where robotics is becoming more accessible.

Manufacturers are looking for reliable, rugged, flexible and reusable handling solutions. In past years, manufacturers have seen tool changers as a solution. But costs related to custom tooling design and changeovers made this solution not so attractive for many manufacturers who have to produce parts in low volume.

Figure 6: A Dual-Arm Robot Equipped with 3-Finger, Anthropomorphic Grippers Performs an Assembly Task (Courtesy of Robotiq)

Manufacturers are also looking to automate applications where there is a high mix of parts. Those parts are becoming more complex to handle due to their shape or the material (fragile, brittle) used to build them. So having a flexible handling tool that can grip a wide variety of parts becomes very important. It becomes even more important when manufacturers want to use this same tool for future production processes.

A relatively young company in the end-of-arm tooling arena, Robotiq offers a line of flexible and adaptive industrial robot grippers with what Robert refers to as “mechanical intelligence” designed to handle a wide variety of part shapes, sizes and composite materials. The idea is that by using a single robot gripper, the user saves on tooling costs and can improve process efficiencies.

Robotiq’s electric, servo-driven 2-finger and 3-finger grippers enable the user to control grasping factors such as the opening/closing speed of the fingers, force applied on the object being handled, and precise control of the fingers to enable partial open and close for fast cycle times.

The adaptive 2-finger grippers are designed for day-to-day manufacturing where engineers want to automate labor-intensive processes with high part variability. Robert says the typical cell has to handle 5 to 20 different parts, and instead of using a tool changer with many different end effectors, a single robot gripper represents time saved on changeovers and reduced tooling costs.

The 3-finger gripper is designed for advanced manufacturing and research. According to Robotiq, it combines the flexibility of anthropomorphic functionality with the reliability of manufacturing EOAT, and reduces programming complexity while providing more gripping options. Another relative newcomer to the robotic EOAT stage is attracting attention with a magnetic personality.

Switchable Magnetic Technology

A magnetic technology originally hailing from Down Under is creating buzz in the automation world. Switchable permanent magnets emerged from a five-year strategic R&D program funded by the Australian government.

This patented technology uses opposing magnetic fields to effectively turn on and off a magnet, or collapse the magnetic field. Commercialization of the technology was launched by Magswitch Technology from its headquarters in Colorado, where all Magswitch products were designed and tested, most notably a new line of magnetic robot grippers like no other.

Figure 7: Patented End Effector Design Uses Multiple Switchable Magnets to Create a Shallow Magnetic Field for Destacking Sheet Metal (Courtesy of Magswitch Technology Inc.)

Other end effectors in the market use high air pressure to rip a magnet away from the material, which causes impact stress on the magnet and results in shorter service.

Unlike electromagnets, Magswitch end effectors will remain in the on position if the system loses electric input or air. Blanchard also notes that electromagnets require battery backup and expensive cabling that must be replaced every year.

Our magnets are much lighter, stronger and easier to turn on and off than any other magnetic switches. Our smallest tool weighs 0.2 lb and has a maximum holding force of 55 lbf. Mechanical grippers are inherently heavy pieces of equipment on the order of three to five times the weight of a Magswitch. Now you can use a robot that is 20 to 35% smaller.

The Magswitch automation line has five product areas. The three primary gripper models include the M-Series, which is a small, single housing designed for flat surfaces. The AR-Series grippers are designed for irregular shapes and come with removable, customizable pole shoes, which Blanchard says customers can cut to fit their particular part configuration.

The AY-Series shown in the photo is a patented design by magswitch that uses multiple magnets with different magnetic fields to create a very shallow depth of field to destack sheet material.

Right now, a small amount of air is required to turn the magnets on and off. The largest consumable cost in most production lines is the generation of vacuum. By using magswitch technology, there is reduction the consumption of air by around 90%.

Application-Specific Grippers

In order to differentiate themselves and meet demands of an ever-increasing number of industries and applications implementing automation, EOAT manufacturers are exploring specialized solutions for unique or extreme applications.

Figure 8: Specialized Needle Grippers are Used in Depanning Muffins and Other Baked Goods (Courtesy of SAS Automation LLC)

SAS Automation designed and developed specialized needle grippers used for removing muffins, cupcakes and other baked goods from baking pans, a process called 'depanning.' Designed for high-volume, low maintenance depanning, the SAS Muffin Depanner has custom stainless steel needle grippers, each using 4 curved needles to depan 144 muffins from 2 moving baking pans on an oven conveyor.

SAS' engineering manager says the small-diameter needles leave limited evidence of penetration. This application also involves hygienic design with stainless steels and food-grade-type polymers, so that everything can be washed down and cleaned. We've also used this style of gripper to handle vinyl for automotive applications.

IPR Robotics custom-designed an end-of-arm tool for handling aluminum die cast automotive engine blocks. The pneumatic-driven EOAT is two-sided for loading/unloading the mold, with the die cast part (as shown) on one side. The other side incorporates 3-jaw grippers, 4 in a row, for loading sleeve inserts into the mold prior to casting the part.

The end-of-arm tool has to be very precise in order to properly insert the liner sleeves into the molds before loading the part. It also has to be robust to withstand extreme temperatures.

From dual-duty grippers to intelligent communication modules, the scope of end-of-arm tooling is reaching broader and aiming higher to make the entire robotic system more effective and efficient.

CONCLUSION

It can be seen that main objective of recent grippers is to add flebility in gripper system. It not only saves on the change over time but also saves capital cost on procurement of different customized EOAT. These recent types of EOAT are designed to handle objects of different shapes, sizes and material. Hence EOAT is an very important tool in the robotic system and due importance should be given while designing and selecting the technology used in EOAT.

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