

Use of Synchronized Parallel Grippers in Fastener Injection Systems

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Abstract

A new style of rivet injector is in production use on a variety of fastening machines used by major aircraft manufacturers. In this injector the opposing sides of the rivet guide blocks are attached to the arms of a parallel gripper.

We have implemented the parallel gripper in both vertical axis and horizontal axis riveting applications. It is equally effective in both orientations. We have implemented the parallel gripper rivet injector on headed rivets, threaded bolts, ribbed swage bolts and unheaded (slug) rivets.

General Description

In this rivet injector the opposing sides of the rivet guide blocks are attached to the arms of a parallel gripper. The parallel gripper performs three functions:

1. One injector feeds three diameter rivets due to the synchronized motion of the parallel gripper. The guide chutes open up to the required diameter but still remain centered on the fingers. We only change the feed tube.
2. The closing action of the gripper closes the guide chutes to squeeze on the rivet and control its position. Air pressure actuates the gripper closed. By adjusting the air pressure the squeeze on the rivet can be adjusted. The squeeze prevents the rivet from "flying through".
3. Reversing the air pressure on the gripper opens the arms of the injector and allows a convenient purge function. We use a parallel gripper with a 25mm stroke to provide a generous gap for purge.

The rivet guide chutes are tailored to the shape of the fastener. For example, an index head would use a different guide chute from a 100 degree bolt head. We use 3D printing to manufacture the guide chutes. This is the least expensive and most flexible way to

manufacture these parts. We are using commercially low cost and readily available parallel grippers produced for the robotics automation industries.

We have implemented the parallel gripper in both vertical axis and horizontal axis riveting applications. It is equally effective in both orientations. We have implemented the parallel gripper rivet injector on headed rivets, threaded bolts, ribbed swage bolts and unheaded (slug) rivets.

Vertical Inject Version

The injector concept discussed in this paper was originally developed for an injector to meet the needs of a horizontal axis wing fastening system. It bolts to the U side (skin side) process shuttle table directly under the driver, and accepts incoming fasteners through six different feed tubes using six different injector tools. The injector tools are changed out when the machine switches between fasteners, such that the correct feed tube is attached to the correct injector tool. Once the fastener is shot into the injector tool at speeds in excess of 40 mph, the injector pushes it through the guide chute into the finger assembly. The finger assembly is held by the driver socket and drives forward to insert the fastener into the panel.

The use of a synchronized parallel gripper to hold the fastener guide blocks improves the function and reliability of the injector over similar predecessors. The guide chute must remain symmetrical due to the internal rack and pinion system in the parallel gripper, ensuring that the fastener remains centered as the plunger pushes it through the guide chute into the fingers. Additionally, the gripper is easily reversed for a convenient purge function.

The unification of different fastener types in the same injector assemblies holds significant advantages in reducing part count and minimizing difficulty in changing between fastener types during production.



Figure 1. Wing fastening system running with parallel gripper injector

Fastener Delivery and Deceleration

The aerospace automation industry places great importance on the cycle time of fastening machines. At Electroimpact we do everything we can to speed up our machines and deliver better performance to our customers.

The delivery of fasteners from fastener storage locations to the injector takes place through plastic feed tubes. When the machine asks for a particular fastener, it is dropped into its feed tube and shot up to the injector with a powerful air blast. Depending on the machine, this travel between the feed racks and the process head can be between 2 and 15 meters. It is critical that the time between the machine requesting a fastener and delivery into the driver fingers is minimized. To this end, the fasteners are shot through the feed tubes at speeds upward of 40 mph.

This high speed delivery of fasteners requires that they be decelerated before they can enter the injector guide chute and be pushed into the finger assembly. Shooting the fasteners directly into the blocks that form the chute geometry causes them to wear quite quickly. The end of the feed tube is therefore terminated with a urethane stopper that absorbs the speeding fastener's energy. After the fastener dissipates its energy into the stopper, the pusher assembly retracts and allows the fastener to enter the guide chute.

When the fastener bounces off the stopper and back down the feed tube, the continued air blast pushes it back down onto the stopper. During this bounce back, fasteners with sharp, countersunk heads tend to scrape the side of the feed tube. To prevent this, the feed tubes are terminated with easily replaceable, durable inserts. These tube ends slow the wear caused by violent bounce back, and are easy to swap out when they get worn down.

Guide Chute Geometry

After being decelerated, the fastener settles into the guide chute. For headed rivets and bolts, the guide chute geometry indexes the fastener vertically using the head feature. After pausing to ensure that the fastener is fully seated in the guide chute, the pusher is actuated forward, pushing the fastener through the guide chute into the finger assembly, opening the chute in the process.

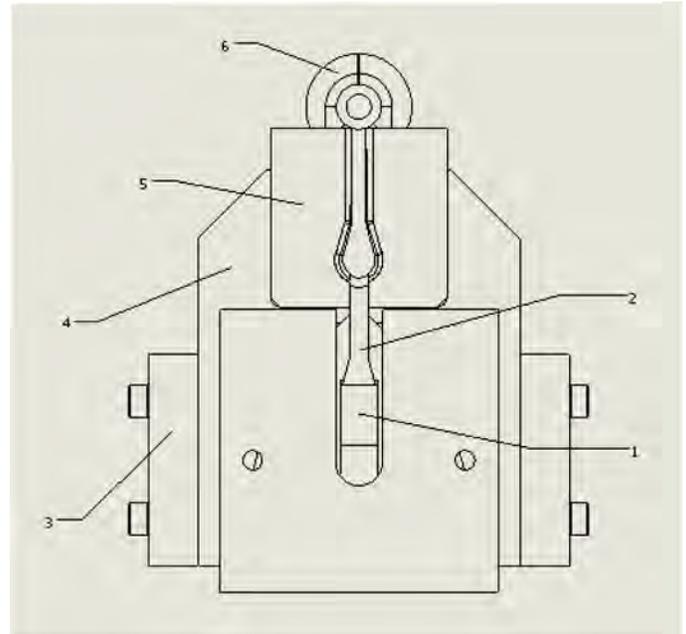


Figure 2. A labeled cutaway picture of an injector.

The guide blocks, labeled #5 in Figure 2, are 3D printed. This allows for quick prototyping and iteration, as well as the ability to create complicated geometries easily. They attach with one socket head cap screw each to the guide block holders (4), which are in turn attached to the outputs of the parallel gripper (3). When the pusher (2) is extended, the stopper (1) is lined up at the termination of the feed tube. After the fastener arrives and the pusher retracts, the guide blocks form a receiving hole for the incoming fastener. Then, as the pusher comes forward, the fastener is forced down the guide chute into the finger assembly (6).

The guide chute has a small lead-in to ensure that fasteners travel down it correctly even if they seat slightly high vertically. This feature is easy to observe in Figure 3, as is the stepped geometry that indexes the head feature and sets the seat position.

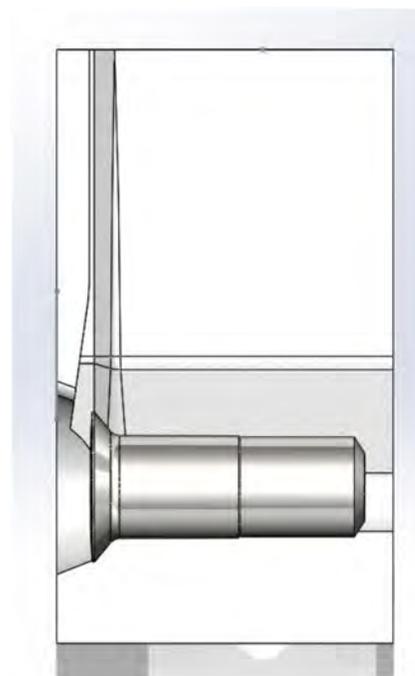


Figure 3. A guide block with fastener.

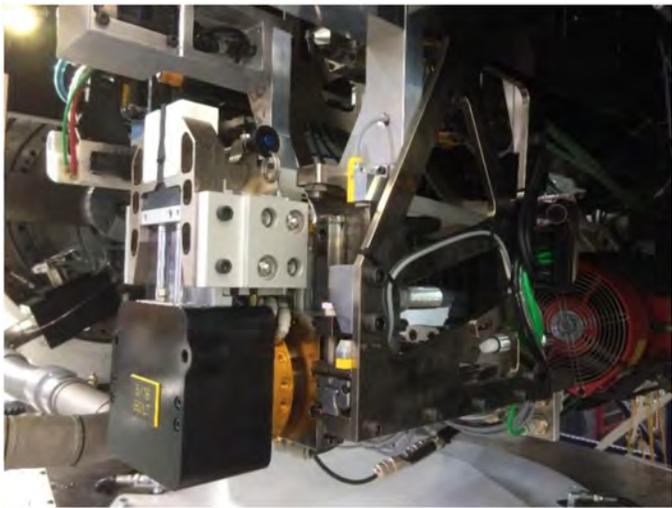


Figure 4. Vertical inject fastener injector

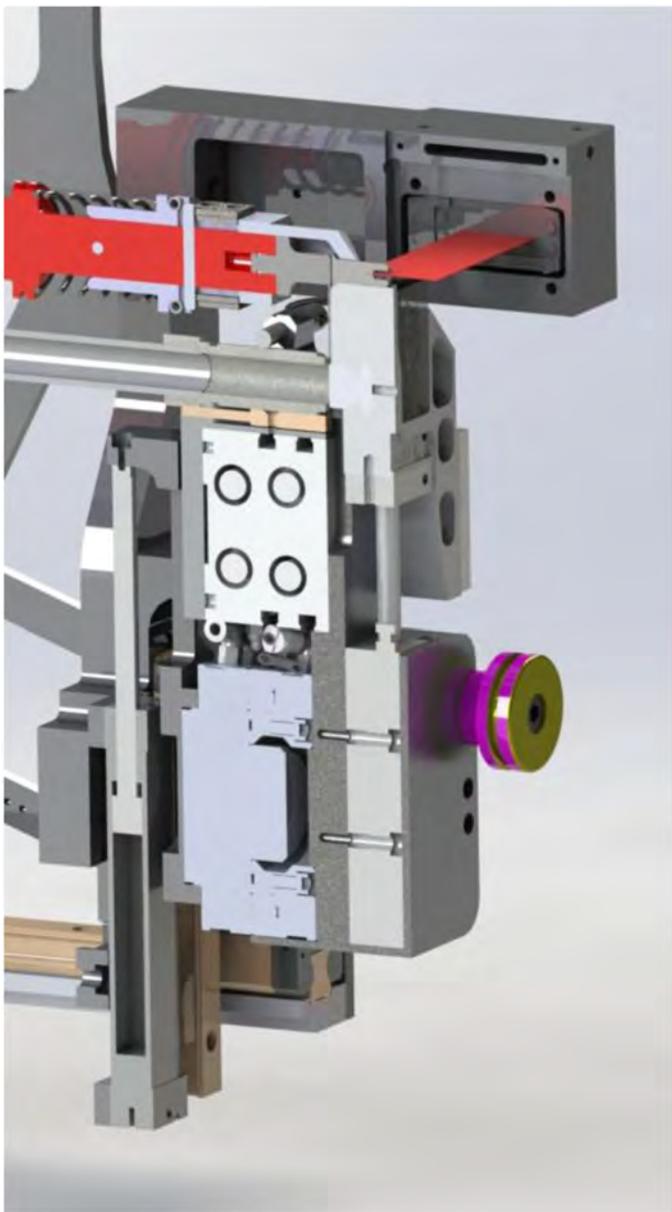


Figure 5. Full vertical inject injector assembly cutaway view.

Purge Functions

As discussed in the previous section, when the parallel gripper is actuated closed, the guide blocks form a space for the fastener to seat into, shown clearly in [Figure 3](#). If there is some problem with the injection, such as the wrong fastener being called, a fastener being fed backwards, or some other malfunction, the injector can use its purge function to clear the feed tube and guide chute of jams.

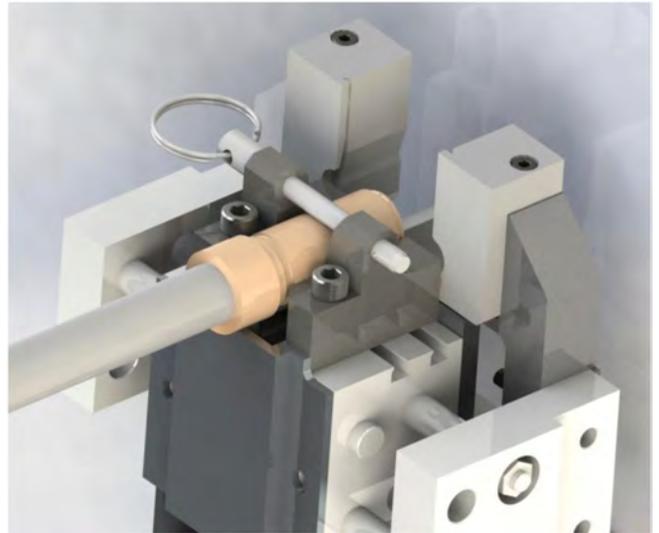


Figure 6. Injector tool in purge position.

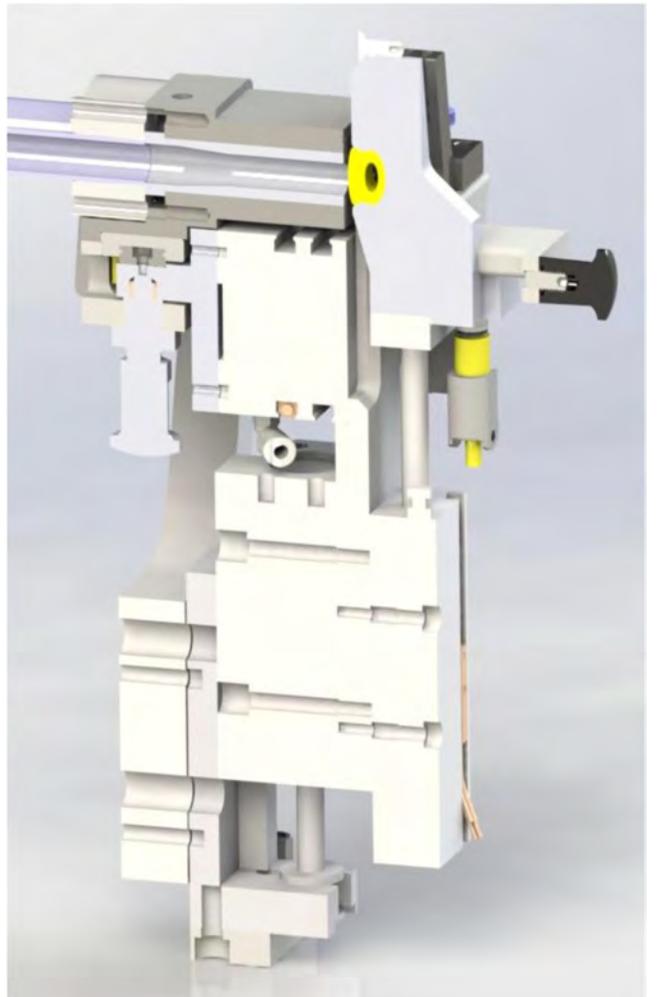


Figure 7. Another vertical inject injector cutaway view

Figure 6 shows an injector tool in purge position. The parallel gripper has been opened, thereby opening the guide blocks and creating a clear path for purge.

Some consideration must be made to prevent the purged fasteners from rocketing into the aircraft panel or otherwise finding their way into places they should not be. The injector purges with the injector positioned in front of the headstone, so purged fasteners contact the headstone before falling harmlessly to the floor. With good injector reliability, purge functions will only be used in extremely rare cases.

Unheaded Fasteners

The position of the fastener in the guide chute in the three injectors discussed already is set by the fastener head. The use of a parallel gripper has also been successfully implemented for use in injecting unheaded fasteners. In this situation, since no head feature is available to index the fastener, the fasteners must be indexed off of their tails.

Figure 8 shows a cutaway view of the unheaded rivet injector. The fasteners exit the tube at speed and bounce off the stopper until they settle into the guide chute with their tail pressed against the stopper. There are three different stopper sizes, which index the tails of the fastener in different spots depending on the fastener grip range being fed.

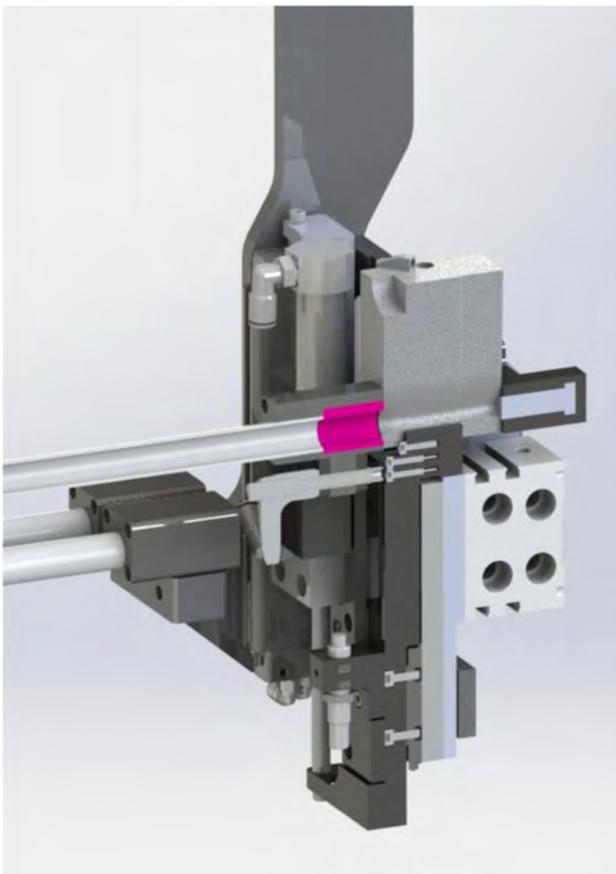


Figure 8. Unheaded rivet vertical inject injector cutaway view

Another challenge of feeding different diameters of fastener with the same hardware is pushing the fastener the proper distance into the feed nose. To make sure that the proper diameter fastener gets pushed the proper distance, the tube end fittings double as a hard stop for the

pusher's up position. When using the tube dedicated to a certain diameter, the pusher's forward stroke is set by that tube's end fitting, ensuring that the proper hard stop is used for the proper fastener. This can be seen by looking closely at figure 8.



Figure 9. Unheaded injector urethane stop pins

Horizontal Inject Version

The parallel gripper injector is implemented in vertical axis riveting machines. In Figure 10 you can see that the designer chose a rotary version of the parallel gripper to make the system more compact. You can see where a replaceable urethane catcher's mitt is incorporated into the track. This feature is easily replaced. Multiple grips and diameters can be fed down the same injector. Due to the synchronized motion the fastener is guided to the center of the fingers. By reversing the air as shown in Figure 10 the guide chutes are opened wide to allow any fasteners or FOD to fall free of the machine and be captured by a reject removal component.

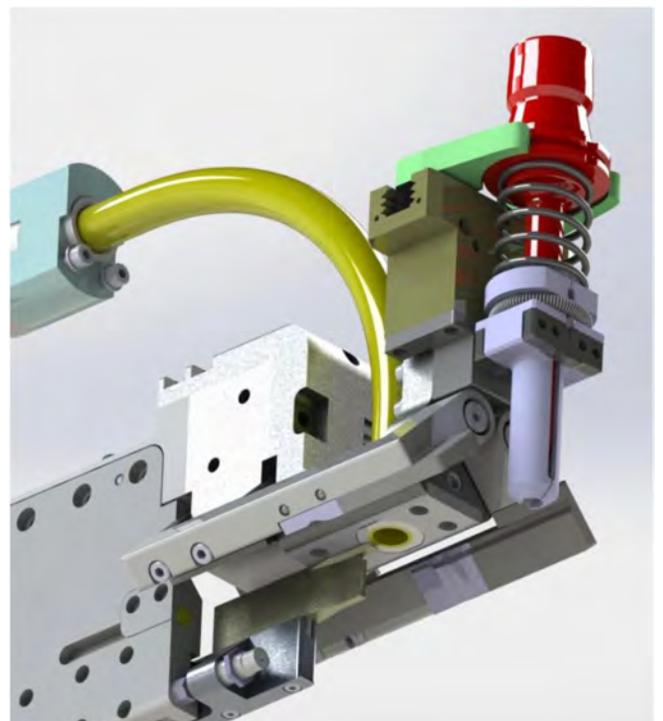


Figure 10. Horizontal inject injector in purge position

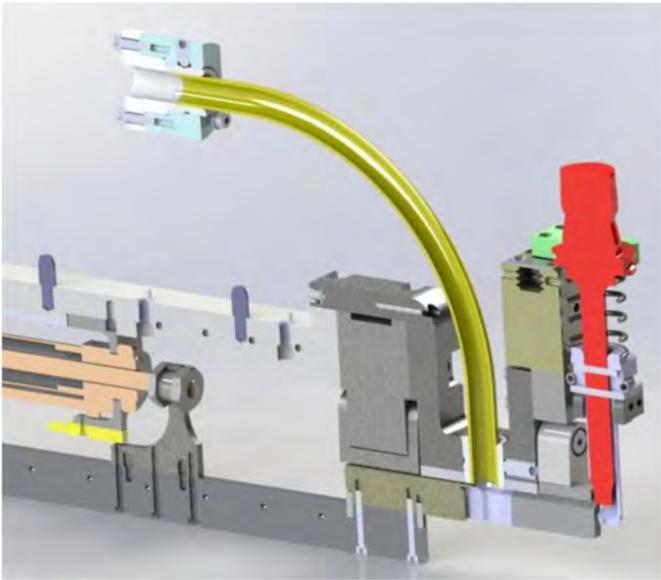


Figure 11. Horizontal inject injector cutaway view

Summary/Conclusions

This new style of rivet injector is in production use on a variety of fastening machines used by major aircraft manufacturers. We have implemented the parallel gripper in both vertical axis and horizontal axis riveting applications. It is equally effective in both orientations. We have implemented the parallel gripper rivet injector on headed rivets, threaded bolts, ribbed swage bolts and unheaded (slug) rivets.

The use of the parallel gripper to constrain and control the injector guide chute enables the feeding of multiple fastener types through the same guide geometry while minimizing jam opportunities and providing a built in purge function. It enables reliable injection of a wide range of fastener types with minimal hardware reconfiguration between types.

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The Engineering Meetings Board has approved this paper for publication. It has successfully completed SAE's peer review process under the supervision of the session organizer. The process requires a minimum of three (3) reviews by industry experts.

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