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Rivet and Bolt Injector with Bomb Bay Ejection Doors

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ABSTRACT

Electroimpact's newest riveting machine features a track-style injector with Bomb Bay Ejection Doors. The Bomb Bay Ejection Doors are a robust way to eject fasteners from track style injector. Track style injectors are commonly used by Electroimpact and others in the industry. Using the Bomb Bay Doors for fastener ejection consists of opening the tracks allowing very solid clearing of an injector when ejecting a fastener translating to a more reliable fastener delivery system. Examples of when fastener ejection is needed are when a fastener is sent backwards, when there are two in the tube, or when a machine operator stops or resets the machine during a fastening cycle. This method allows fasteners to be cleared in nearly every situation when ejecting a fastener is required. Additional feature of Electroimpact's new injection system is integrated anvil tool change. Anvils with fingers are parked on each Injector and an indexing system automatically changes tools for different fastener diameter. Fundamentally, this track-style Injector has only one moving part, the Pusher, used in every fastening cycle. With the Bomb Bay Door ejection system and the integrated automatic tool change, this injection system is very flexible, and is likely one of the fastest in the industry with injection times of under a second. In addition to speed, the new eject system is a robust way to recover from common errors, adding to machine reliability. Overall the new injection system featured on Electroimpact's new riveting machines is a fast, flexible, and robust new system for fastener delivery.

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INTRODUCTION

The Injector discussed in this paper was developed to meet the demands of new riveting machines made by Electroimpact. The applications require the ability to automatically feed multiple diameters and multiple types of fasteners in addition to fully automatic tool change. The Injector design was inspired by the typical track-style injector found on older machines in the industry. This design goes further however, and features unprecedented ejection capabilities. Additionally, the Injector facilitates automatic change between fastener types and automatic upper anvil tools. The Injector can easily handle fastener speed in excess of 70mph and supports fastener staging to contribute to very fast cycle times. The Injector uses Bomb Bay Ejection Doors (patent pending) to provide reliable clearing of the Injector and can recover automatically from basically any misfeed scenario. At any point when the fastener is in the tube or in the Injector, the Bomb Bay Ejection Doors can open up to discard the fastener and reset the injection process. This proves to be very solid method of clearing the system and contributes to increased machine reliability. Overall, the new Injector is a fast, flexible, and reliable system that contributes to the speed and reliability of the riveting machines as well as reducing operator intervention with fully automatic Anvil tool change.

MACHINE OVERVIEW

The overall layout of the typical riveting machine consists of a d-frame gantry with upper and lower heads, see Figure 1. The gantry and the two heads move in the X and Y directions while part holding towers (not shown) manipulate the workpiece (airframe section) in the Z, A and B directions.

The fastener delivery system on an Electroimpact riveting machine starts at a Fastener Feed Cabinet, also shown in Figure 1. The fastener path goes from the cabinet to the Upper Head through flexible plastic tubing called “feed tube”. The Upper Head and Lower Head work together to provide clamping to the part. The Upper Head drills and inserts fasteners. The Lower Head forms the rivet using a servo-driven ballscrew. In the case of bolts, the Lower Head

provides back-up force for inserting interference fit bolts. The Injector resides on the Upper Head, see Figure 2.

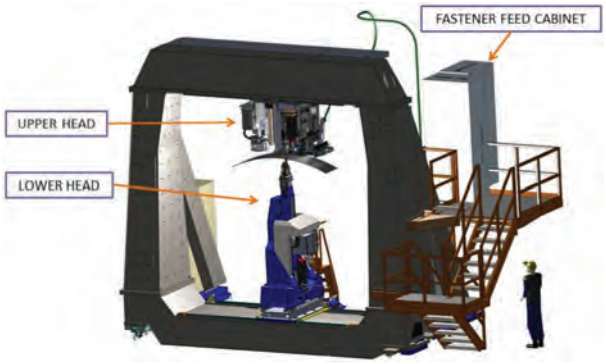


Figure 1. Machine Overview

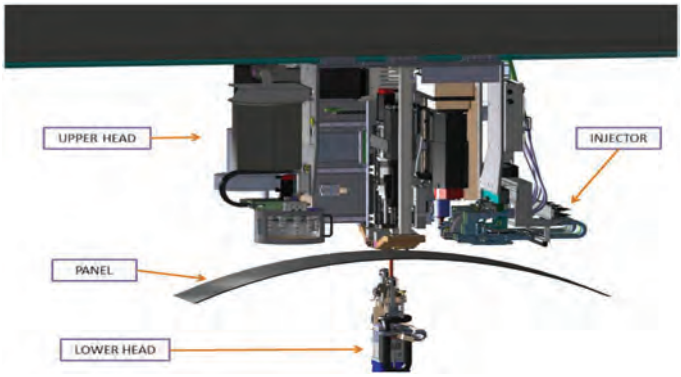


Figure 2. Machine Major Components

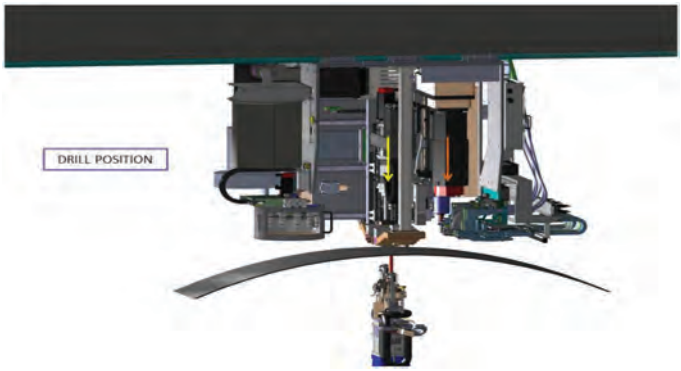


Figure 3. Shuttle Table in Drill Position

The X position of the machine is set by the entire gantry moving on linear ways. The Y position is set with moving the Upper and Lower Heads. The main motion inside the Upper Head is that of the Shuttle Table. The Shuttle Table moves the Drill Spindle and the Rivet Driver tools such that in one position, the Spindle is concentric the Headstone, and in the other position, the River Driver is concentric to the Headstone. The Headstone is the part that applies clamping pressure to the workpiece and has a hole through which the drilling and fastener insertion takes place. Figure 3 shows the Shuttle Table in Drill Position. Note that the Spindle has a feed system which extends and retracts to form drilled and countersunk holes in the workpiece through the Headstone.

Figure 4 shows the Shuttle Table in fastener insertion position or rivet "Buck" position. Note that the Driver can be extended and retracted to insert fasteners into the drilled holes.

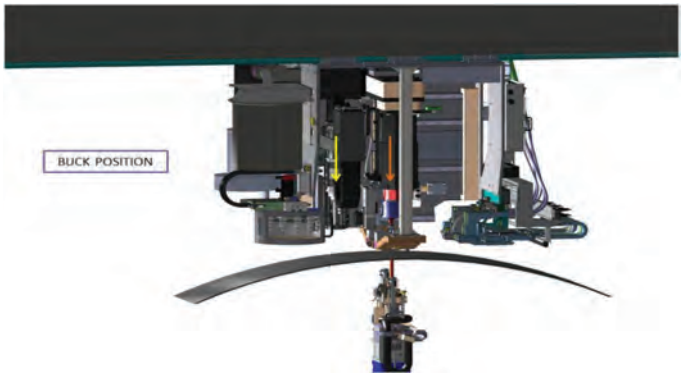


Figure 4. Shuttle Table in Rivet Buck Position

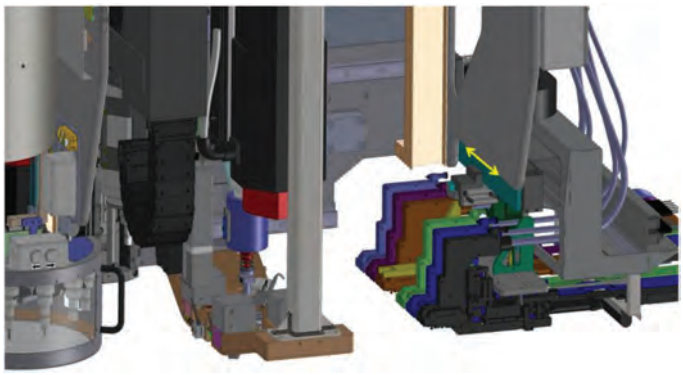


Figure 5. Injector Index in Center Position (Modules Retracted)

The riveting machine can drill holes for and install a variety of fastener types and diameters. The Injector is made up of several Injector Modules, which each serve specific types of fasteners, typically differing by diameter and head geometry. To accommodate for the different types in operation, the Injector moves the Modules along an indexing axis which centers the appropriate Injector Module with the Rivet Driver. The Injector has an Index Pusher mechanism that pushes the centered Injector Module out, extending it right up to the Fingers on the Rivet Driver. The Fingers are a spring-loaded clam-shell design which are commonly used for holding the fastener in front of the rivet-driving Anvil. The Injector Module stays in this position throughout the time the machine is setup to use the fastener types associated with that Module. The Injector Modules are normally held back with springs and only extend out to the Driver when the Index Pusher mechanism is actuated. Figure 5 shows the

Injector centered with no Module extended forward. Figure 6 shows the injector in its farthest left index position with the leftmost Module extended. Figure 7 shows the injector is its farthest right position with the rightmost Module extended.

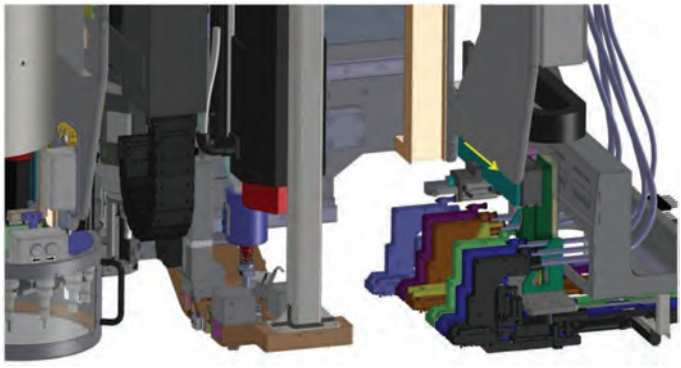


Figure 6. Injector Index in Far Left Position

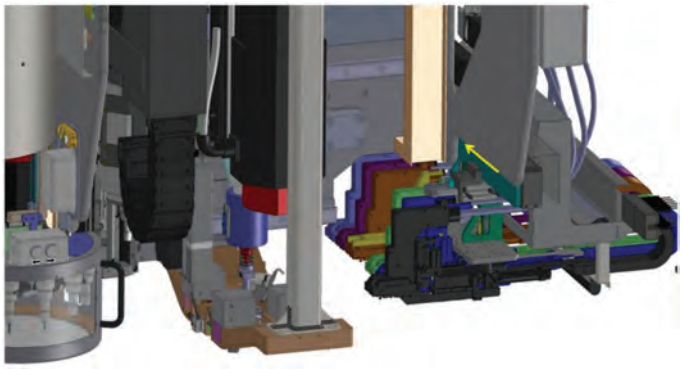


Figure 7. Injector Index in Far Right Position

The injection process happens when the machine is in Drill Position. In this position, the Rivet Driver is to the right of the Headstone, see Figure 8, and the extended Injector Module is extended out to meet the Driver. The Module stays in this position until fasteners from another Module are required.

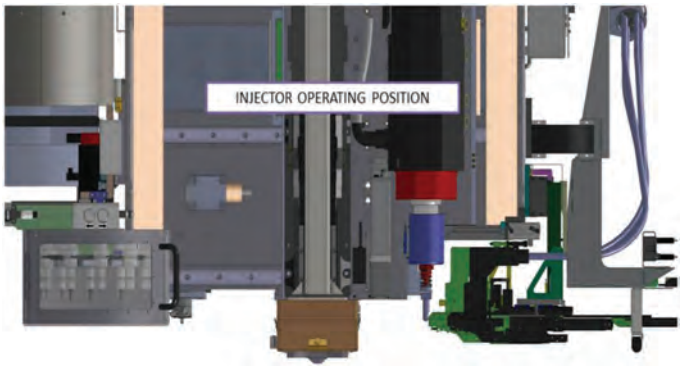


Figure 8. Operating Position for Injection (Drilling Position)

THE FASTENER DELIVERY PROCESS

The riveting machine is controlled by a CNC and NC programs developed for the particular aircraft structure being built.

For a given line in the program calling for a drilled and fastened hole, the machine moves all of its axes to achieve the correct programmed position for the hole. At this point, the Lower Head and the Upper Head converge on the part and clamp the layers together. During "clamp-up" the thickness of the materials, or "stack", is measured, see Figure 9

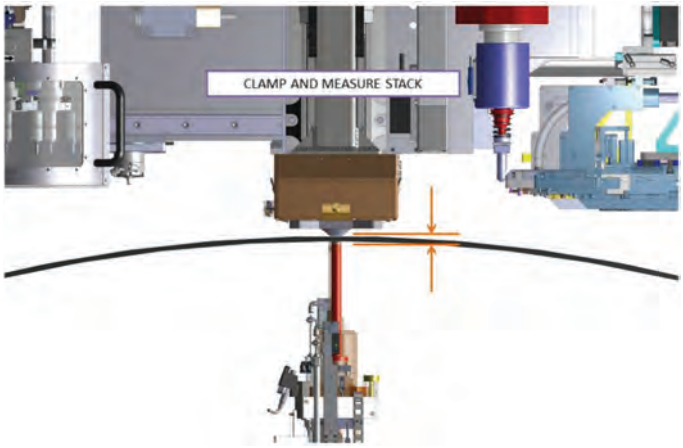


Figure 9. Machine Clamp and Stack Measurement

With the stack thickness measured, the drilling can proceeds. Simultaneously, the CNC calls the appropriate sized fastener to be sent to the Injector. The fastener type, diameter, and length information is relayed to the Fastener Feed cabinet (in this case made by F_2C_2) and it deposits one fastener into the feed tube.

Alternatively, the machine can be set to look ahead in the program and feed fasteners based on the programmed stack value instead of the measured stack. With this method, the feed system does not need to wait for stack measurement and faster cycle times can be achieved. However, when using this method a discrepancy can arise in the required fastener grip length. In this case a fast and reliable ejection system is very valuable.

Once the fastener is deposited into the feed tube, the fastener is propelled through the feed tube with a device called a "Blast Valve", see Figure 10. The Blast Valve provides high pressure air behind the fastener and sends it through the feed tube at very high speeds.

Feed tube is routed on the machine from the Fastener Feed cabinet to the Upper Head where the Injector resides. The Blast Valve blows the fastener through the feed tube to the Injector Module, see Figure 11.

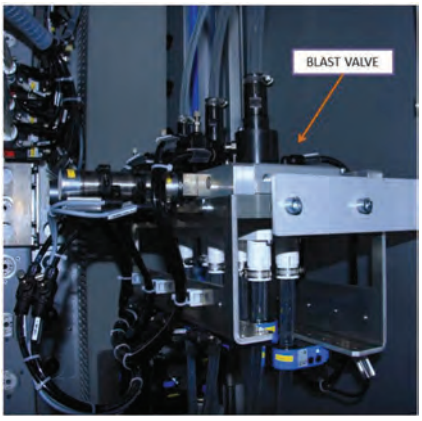


Figure 10. Blast Valve in Fastener Cabinet Propels Fastener

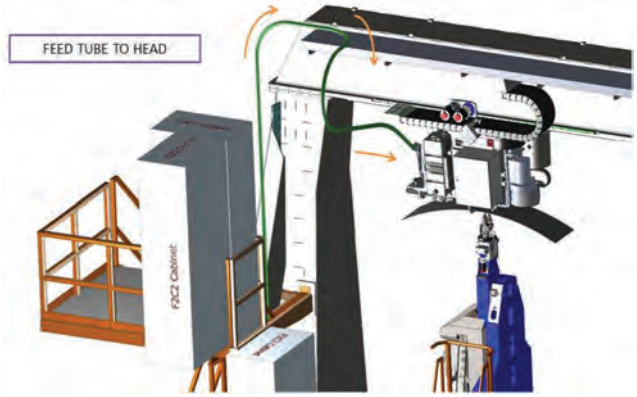


Figure 11. Feed Tube Path for Fastener from Cabinet to Head (Injector)

At this point in time, the Driver and Injector Module are in position for injection because the drilling is taking place and the machine is in Drill Position. Figure 12 shows the Injector and front end of the Rivet Driver in this operating position.

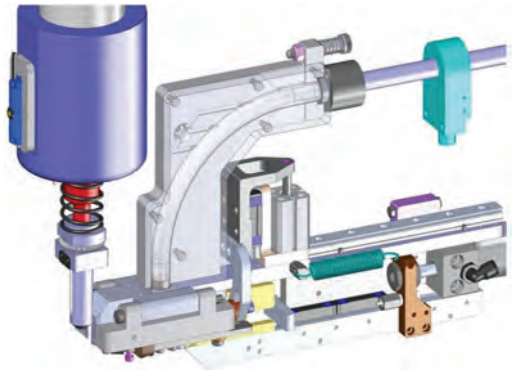


Figure 12. Operating Position for Injection (Close-Up)

As the fastener reaches the end of the Feed Tube, it passes a sensor attached to the tube, and signals to the CNC that it has arrived at the Injector. Then it enters a curved tube section of the Injector called the "Chamber", see Figure 13.

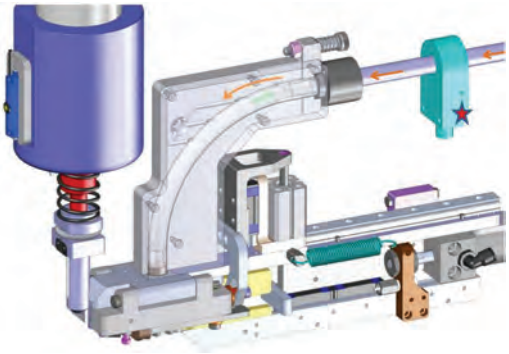


Figure 13. Fastener Trips Tube Sensor and Enters Chamber

Continuing through the Chamber the fastener approaches the track. The track consists of two parts which are spaced wide enough to allow the tail of the fastener through, but not the head. The tops of the two half-track parts are shaped to conform to the countersunk head such that the fastener stops in a consistent position. In addition, the track also has "Catch Blocks" which are extensions of the half-track parts, taking on similar form and function; however they give the tail of the fastener no degree of freedom to move when seated. These Catch Blocks move out of the way later to let the fastener pass through along the track.

Figure 14 shows the fastener approaching the track.

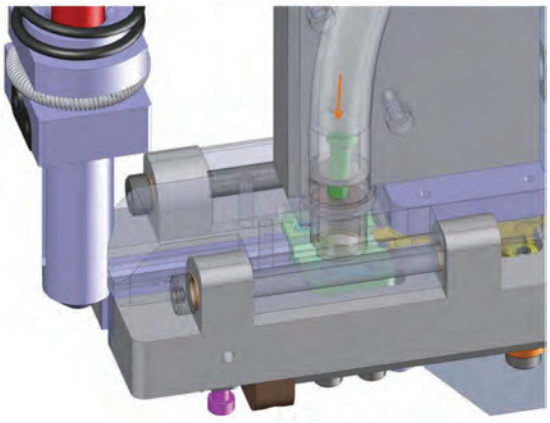


Figure 14. Fastener Approaches Track (Catch Blocks)

The fastener stops when it reaches the Catch Blocks. The fastener is stopped on the angled features of the part that conform to the countersunk head while the tail can pass through, see Figure 15. Note that the Blast Valve is still on which pushes the fastener to this destination.

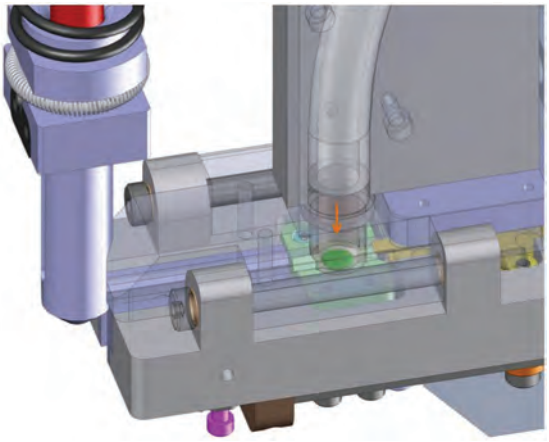


Figure 15. Fastener Lands in Track (Catch Blocks)

The CNC allows a brief pause, via a timer, to let the fastener reach the Catch Blocks and settle. The timer starts when the tube sensor trips and its duration is a fraction of a second. With the fastener seated, next, the Pusher begins to extend and engages the fastener, see Figure 16. The Pusher (not to be confused with the Index Pusher) is the blade-like part of the Injector that pushes the rivet down the track. Note that the Pusher also has a "cap" feature which prevents the rivet from riding up in the track.

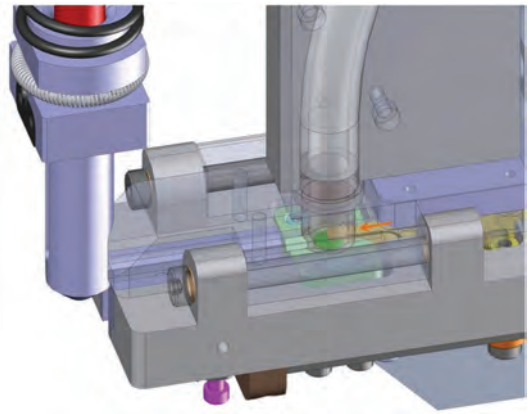


Figure 16. Pusher Begins Extending and Engages Fastener

As the Pusher extends, the fastener is pushed out of the Catch Blocks and down the track, see Figure 17.

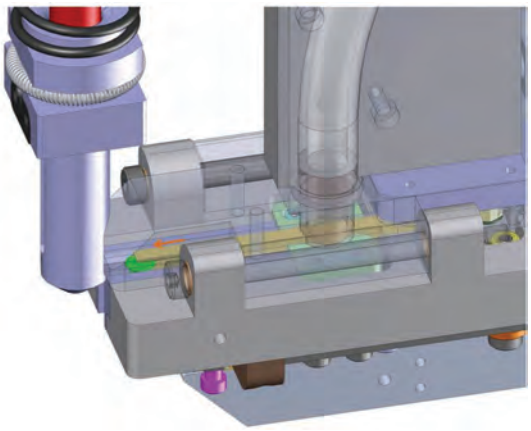


Figure 17. Pusher Moves Fastener down the Track

The Pusher continues and pushes the fastener all the way down the track until the fastener is "injected" into the Fingers, see Figure 18. The spring-loaded Fingers are forced open by the fastener being pushed in, and they close by spring force to hold the fastener securely once the fastener reaches the center of the fingers.

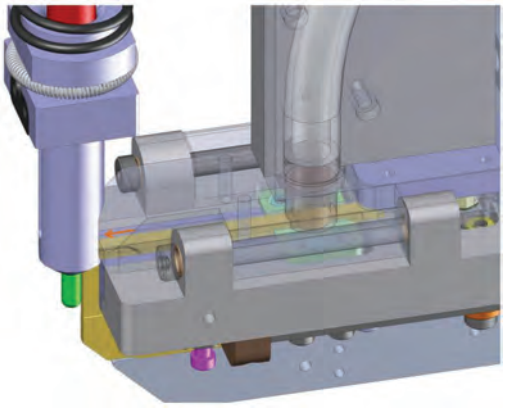


Figure 18. Fastener Injected into Fingers

Now, the Pusher retracts fully leaving the fastener in the Fingers, see Figure 19. At this point, the Injector is back in its starting position and the injection cycle is effectively complete. In this position fastener length is measured using an optical micrometer (not shown).

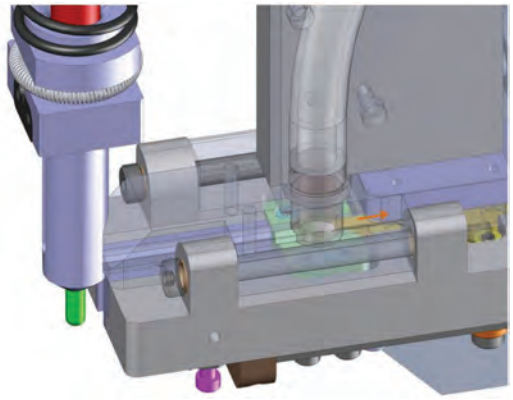


Figure 19. Pusher Retracts, Injection Cycle Complete

Once the Spindle is finished drilling the hole and with the fastener delivered into the Fingers, the Shuttle Table now moves toward the "Buck" position, see Figure 20. Once the Shuttle Table has moved to Buck position, the Driver extends and inserts the fastener into the drilled hole. From here the rest of the programmed cycle completes and the machine moves to the next location where a fastener is to be installed.

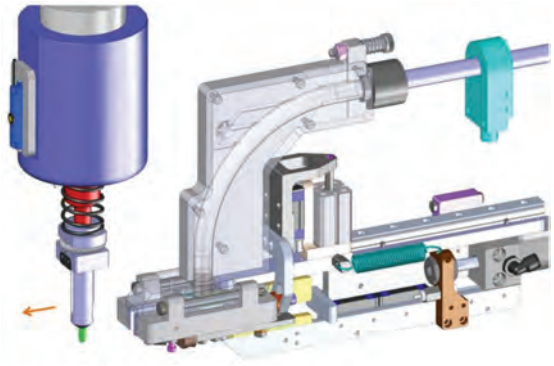


Figure 20. Shuttle Table Moves Driver to Rivet Buck Position

USING BOMB BAY EJECTION DOORS FOR FASTENER EJECTION

The Bomb Bay Ejection Doors are useful in multiple different scenarios in which a fastener needs to be cleared from the Injector. The fastener may be located in the feed tube or the Injector or there may be multiple fasteners that need to be cleared. Some common examples are a backwards fastener being sent through the tube or two fasteners in the tube. Also, if the Injector is pre-fed before clamp measurement (for increased fastening rate) and the predicted stack is wrong, the pre-fed fastener will need to be ejected so the correct fastener can be fed. The Bomb Bay Ejection Doors handle all of these scenarios and almost every other type of jam. The following example illustrates how the mechanism works.

Backwards Fastener Example

The fastener travels to the Upper Head through the Feed Tube via blast air from the Fastener Feed cabinet's Blast Valve, as before. The fastener, this time traveling backwards (head first), passes the tube sensor which signals to the CNC that it has arrived at the Upper Head and it then enters the Chamber, See Figure 21.

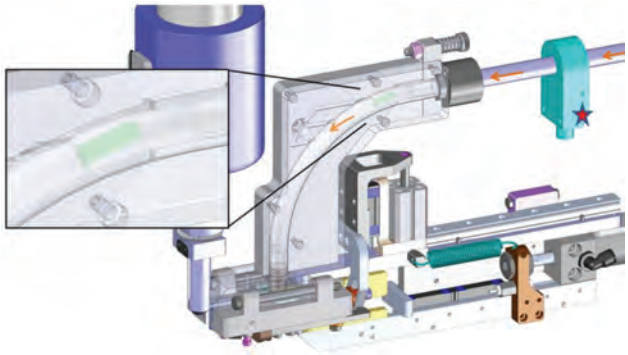


Figure 21. Backwards Fastener Trips Tube Sensor and Enters Chamber

Continuing via blast air, the backwards fastener passes the Air Brake, being slowed slightly and approaches the track at the end of the Chamber, see Figure 22.

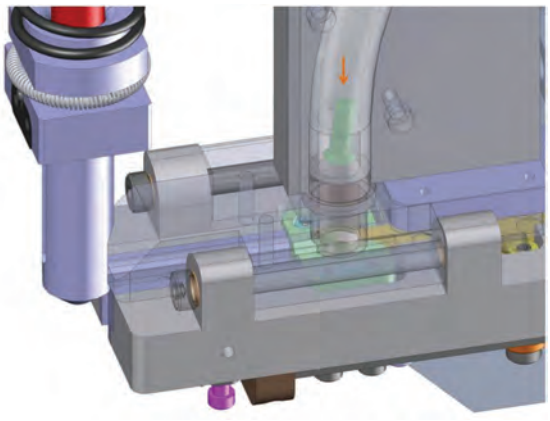


Figure 22. Backwards Fastener Approaches Track (Catch Blocks)

The fastener continues and impacts the Catch Blocks and comes to a stop, see Figure 23. Note that in this backwards fastener example, the tail of the fastener does not pass through the Catch Blocks. Remember that the track, including the Catch Blocks, are spaced apart wide enough to let the tail of the fastener pass through but not the head. When fed backwards, the tail of the fastener is left pointing up into the Chamber with only the head of the fastener in the Catch Blocks.

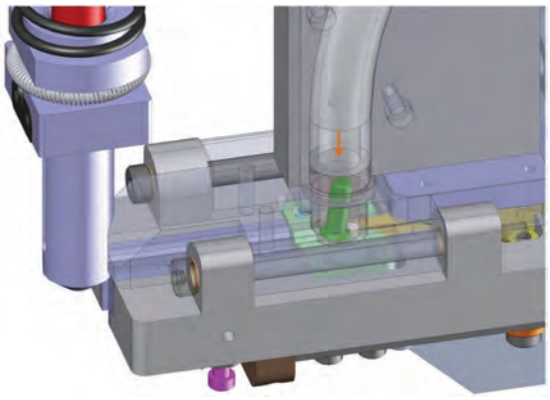


Figure 23. Backwards Fastener Lands on Track (Catch Blocks)

After a brief pause the Pusher is commanded to extend by the CNC. Because the tail of the fastener is up in the Chamber instead of down in the Catch Block, the Pusher jams and is not able to extend forward, see Figure 24. The Pusher is actuated with a pneumatic cylinder and its force is limited so the resulting jam doesn't damage any components, however, its motion is stopped by the backwards fastener.

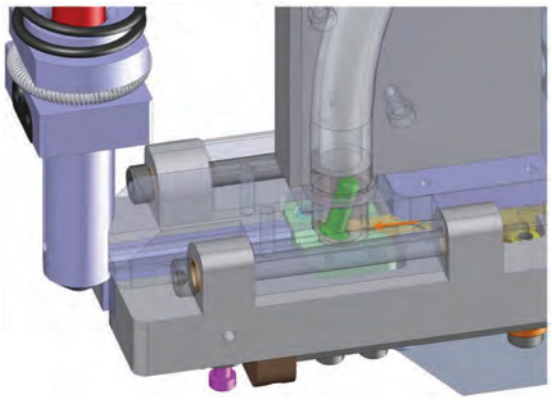


Figure 24. Pusher Extends and Jams on Backwards Fastener

The CNC expects to see a proximity switch indicating the Pusher has fully extended; however, it does not, and instead a timer indicates a time-out and the CNC enters an eject sequence to eject any fasteners and start the delivery process over again. On the first step of the eject sequence, the Pusher retracts, see Figure 25.

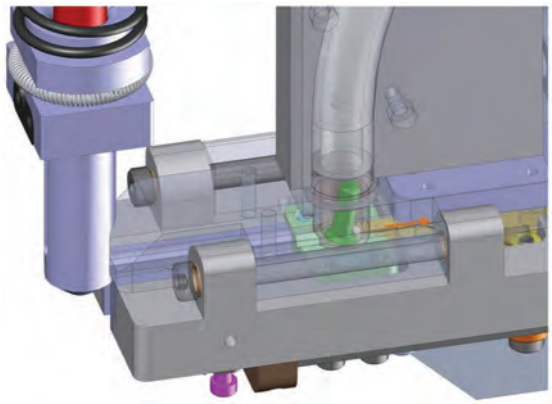


Figure 25. Eject Sequence: Pusher Retracts

Next, the Bomb Bay Ejection Doors are actuated and they open separating the track such that the fastener can fall or be blown out of the Injector, see Figure 26.

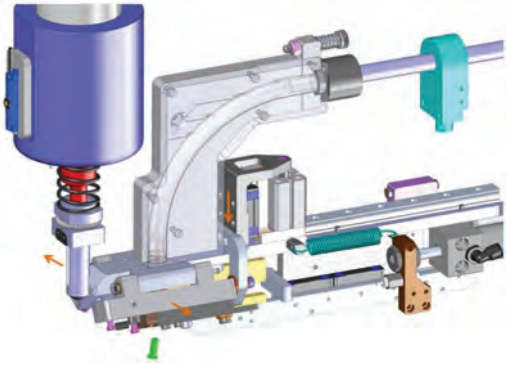


Figure 26. Eject Sequence: Bomb Bay Ejection Doors Open

Once the Bomb Bay Doors are open, the fastener is blown out via blast air or falls out by gravity, see Figure 27. Note that the Bomb Bay doors when open leave no place for the fastener to get stuck. This method shows to be a very reliable way to eject fasteners from the Injector, and is useful, not only for the backwards fastener example, but almost any situation when clearing the Injector is required.

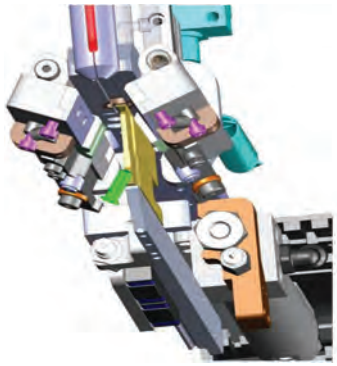


Figure 27. Bomb Bay Doors: Underside View

To complete the eject sequence, the Bomb Bay Doors close, see Figure 28, leaving the track empty and ready to restart the fastener delivery process.

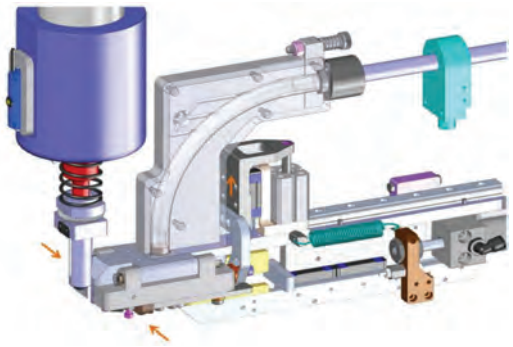


Figure 28. Eject Sequence: Bomb Bay Ejection Doors Close

This example shows how the Bomb Bay Ejection Doors easily clear jams associated with common misfeeds like a backwards fastener. In this example, and many others, at any point with the fastener(s) in the tube or in the Injector, the ejection mechanism can open up to clear the tube and the Injector such that the fastener delivery process can be restarted. This device proves to be a very solid method for clearing the feed system and contributes to increased machine reliability.

AUTOMATIC UPPER ANVIL TOOL CHANGE

With this injector design, automatic tool changing of the upper anvils is also possible. Changing anvils is required because the fingers and the anvil tip geometry change by fastener diameter and type (protruding heads vs. flush head for example). Tool changing is done automatically using the Injector Module as a parking spot for its corresponding anvil when it is not in use. To drop off an Anvil, the gripper on the front of the Injector grabs the anvil. Then the Rivet Driver retracts and the anvil comes out of its socket, overcoming the retaining force of the ball detents that hold it in the socket. To pick up an Anvil, the Driver extends down onto the Anvil as it is held by the gripper until it engages the ball detents. Then, the gripper opens to allow normal operation.

Figure 29 shows the Driver and Injectors in a normal operating position. The Anvil associated with the center Module is held in the Driver's socket by the ball detents. The gripper jaws are open so the Anvil can shuttle in and out during each fastening cycle (recall the shuttle move direction from Figure 20). The Injector Module in use is held forward by the Index Pusher (not shown) for normal operation. In this state, it is concentric with the Driver when the Shuttle Table is in Drill Position.

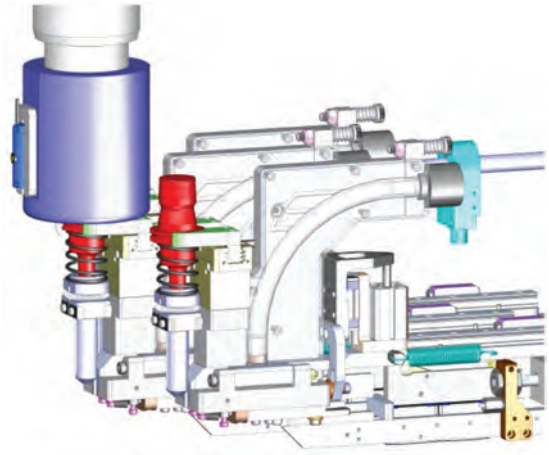


Figure 29. Anvil ATC Normal Operating Position

To start the ATC process, first, the gripper is activated to grip the anvil. This is shown in Figure 30 although the small distance the gripper moves is not easily apparent.

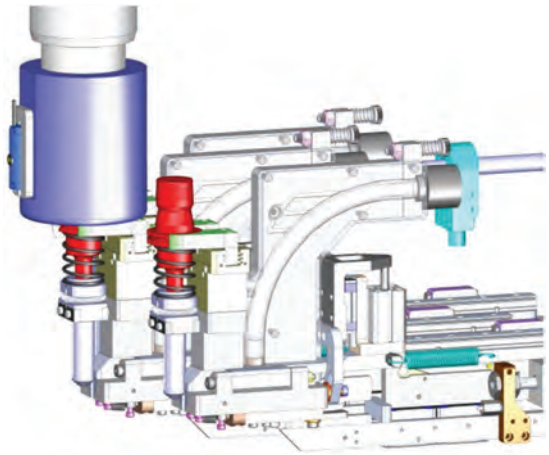
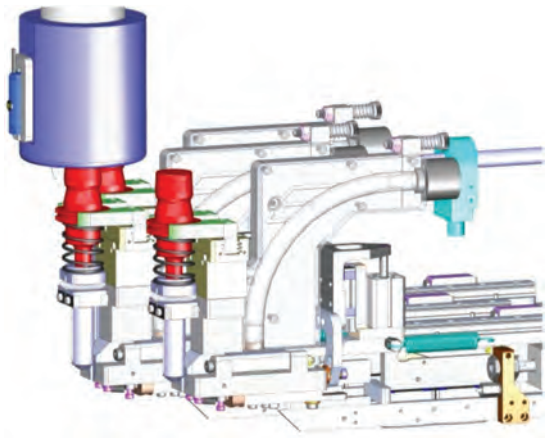


Figure 30. Anvil Gripper Grips Anvil



With the gripper holding the Anvil securely, the Driver retracts. The force that holds the anvil in the socket is overcome and the Anvil is left being held only by the gripper, see Figure 31. The gripper is sprung closed and opened pneumatically, so the Anvil is not dropped in the event of a loss of air pressure.

Next the Injector Module retracts carrying the Anvil, see Figure 32. This is accomplished by retracting the Index Pusher and a spring pulling the Module back (not shown).

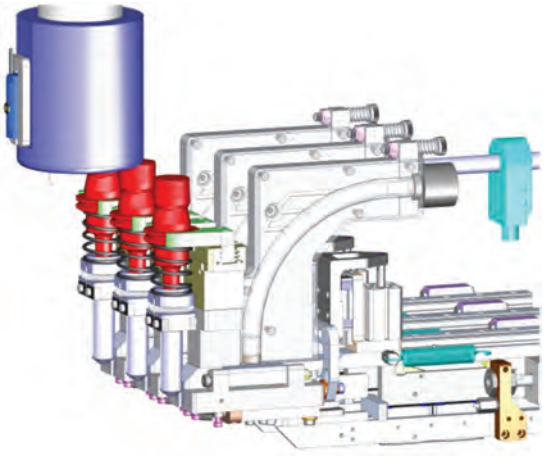


Figure 32. Module Retracts

Next, the Injector indexing axis moves to align another Injector Module with the centerline of the Driver (recall Figures 5, 6, 7). See Figure 33.

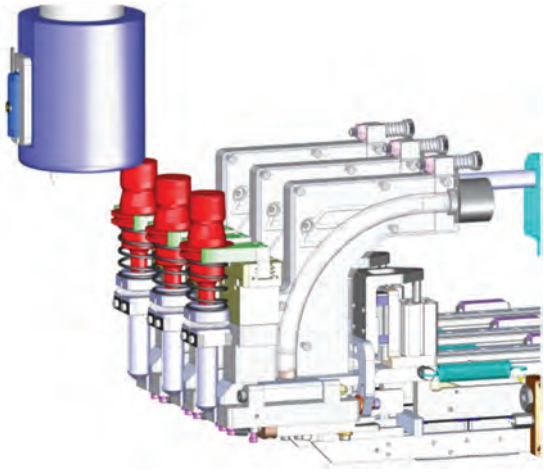


Figure 33. Index Axis Moves to New Injector

The new Injector Module is pushed out to bring the new Anvil to be concentric with the Driver, see Figure 34.

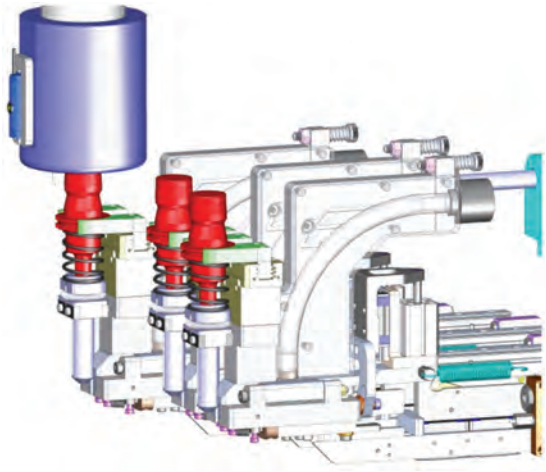


Figure 34. Injector is Pushed Forward

Next, the Driver is actuated down to engage the new Anvil with the ball detent socket, see Figure 35. Because the Driver is capable of delivering extremely high forces, the Injector is protected with a crash slide mechanism to prevent damage to the machine. The mechanism will give way and signal the machine to stop in the event of misalignment or debris preventing correct engagement of the Anvil.

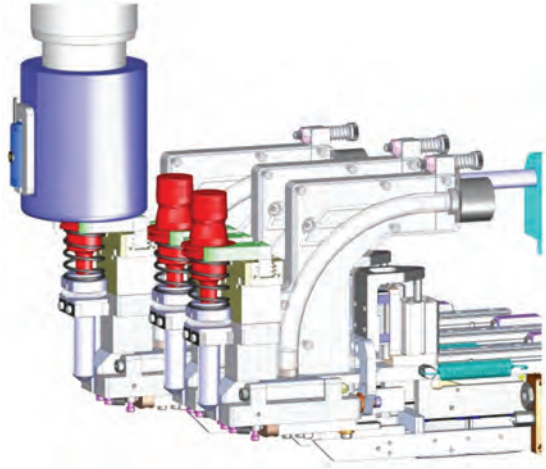


Figure 35. Driver Socket Engages Anvil

To complete the tool change, the gripper associated with the new Anvil opens allowing the Anvil to shuttle in and out between the events of injection into the Fingers and insertion of the fastener into the panel. See Figure 36.

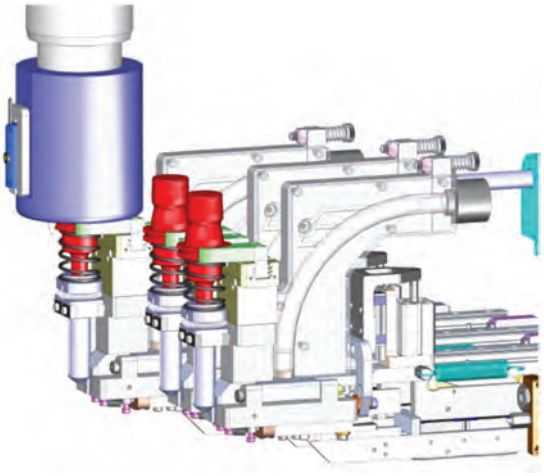


Figure 36. Gripper Opens, Returning to Normal Operating Position

SUMMARY/CONCLUSIONS

This summarizes the new Rivet and Bolt Injector with Bomb Bay Ejection Doors. The Injector was designed for Electroimpact's new riveting machines to meet the challenges of new applications in automated aerospace assembly.

The Injector is a track-style Injector which is found commonly in the industry, however, the new Injector features a number of technological advances which set it apart from previous designs.

The Injector features patent pending Bomb Bay Ejection Doors which enable the machine to recover automatically from almost any misfeed scenario. The ejection capabilities contribute to overall machine reliability as well as facilitating look-ahead fastener staging for increased cycle times. The Injector also features Catch Blocks which enable it to catch fasteners traveling at extremely high speeds.

The Injector is divided into several Injector Modules, with each serving a specific fastener type or diameter. An indexing axis automatically moves Injector Modules during tool change. Additionally, the Anvils are held on each Module with a gripper. These combine with the rivet Driver to create and automatic anvil tool change system.

Overall, the new Injector provides the primary benefits of increased machine speed and reliability. The system is very flexible, with the ability to handle many different fastener types, and reduces operator intervention through fully automatic tool changing.

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