

LTD Bolt Injection System

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ABSTRACT

Growing use of composite materials in aircraft wing construction requires a new generation of drilling machines. Electroimpact's new LTD drilling machine features a Bolt Injector with improvements for more streamlined operation and less operator intervention. The Bolt Injector "injects" or stages Single Sided Temporary Fasteners (SSTF). It features hands-free automated tool change between three different feed paths for a total of eight different fastener diameters being fed through one set of Bolt Injector hardware. This is accomplished with an indexing system for three feed tubes fed to the machine head, with each feed tube serving more than one diameter. Furthermore the LTD Bolt Injector checks fastener diameter at the machine head and also length in conjunction with Bolt Inserter servo axis. The bolt diameter is checked with an analog sensor attached to a gripping mechanism. The length check is accomplished with a "touch off" pad and the Inserter's servo motor encoder. The LTD Injector is the latest in SSTF bolt feed systems and offers increased functionality and reduced operator involvement contributing to more efficient utilization of the LTD drilling machine.

INTRODUCTION

The origin of the bolt feed system discussed in this paper was developed to address the LTD machine's bolt feed requirements where multiple diameters of bolts were required to be fed automatically. The Bolt Injector is an evolved design stemming from the Confined Spaces Bolt Injector discussed in SAE paper 2010-01-1879 [1] and works with the Bolt Inserter discussed in SAE paper 2010-01-1842 [2]. Bolts required were of diameter ranging from 3/16" to 5/8", constituting a total of eight different diameters with considerable length variation. These were all to be fed fully

automatically. The bolts, SSTF or Single Sided Temporary Fasteners [3], are increasingly replacing more cumbersome manual tools for temporary doweling and clamping of aerospace components during assembly.

This paper will focus on the Bolt Injector, a process tool which take the bolts from feed tube and delivers them to the Bolt Inserter. The LTD Bolt Injector features more streamlined functionality reducing machine operator interaction. The Bolt Injector provides length and diameter checking abilities and the ability to feed 8 diameters of bolts without a tool change operation.

SYSTEM OVERVIEW

An Electroimpact bolt feed system is tasked with delivering fasteners to the machine's head from a loading station some distance away from the end effector. The loading station allows access for resupplying fasteners and typically consists of hopper or Stick-style [4] Fastener Feed system. The fasteners are sent from the Fastener Feed system to the machine's head through plastic feed tube. On the machine's end effector are a Bolt Injector and a Bolt Inserter. These process tools take the bolt from the feed tube and install it in the drilled hole.

Electroimpact's new Lean Technology Drilling Machine (LTD) is pictured in [Figure 1](#). The LTD machine is a highly capable and cost efficient solution for composite wing box drilling. Pictured, the machine's head is at the lower extent of its Y travel where the clamp table extends carrying the different process tools, including the Bolt Injector and Inserter.



Figure 1. Lean Technology Drilling Machine

aligned with the Bolt Inserter, a tool on the shuttle table, when the machine is drilling a hole. With this setup, the bolt is feeding while the machine is drilling, one of many features that maximize machine utilization.

SINGLE SIDED TEMPORARY FASTENERS

Single Sided Slave/Temporary Fasteners are designed to clamp and dowel components for drilling in aerospace applications. They are replacing separate tools used for each of the clamping and the doweling processes. Furthermore, these bolts have been designed with a low profile head such that, after installation, they sit considerably closer to flush to the workpiece than their counterparts. This allows an automated machine to “fly over” them. The bolts can be used in countersunk and non-countersunk holes. The SSTF bolts' relatively small head also allows them to be fed through plastic feed tube. Its “blind” or one-sided capability makes them a fit to be installed by automated machines. With these features, the fasteners reduce the amount of tooling required for assembly and allow them to be installed by machine. [Figure 3 \[3\]](#) shows some of the key features of the SSTF bolts.

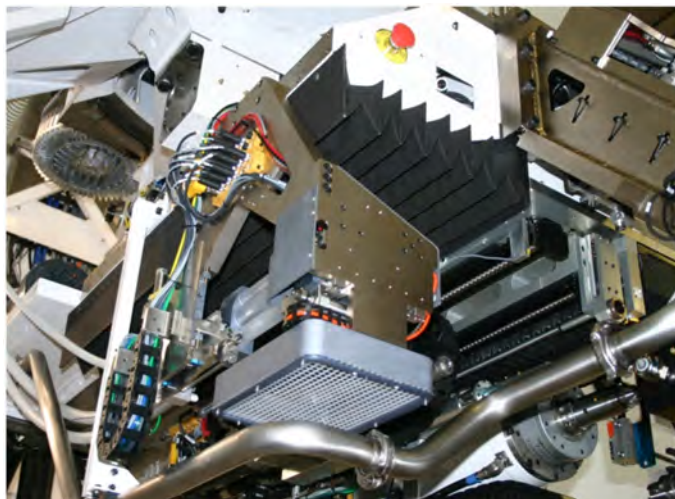


Figure 2. LTD Bolt Injector

The Bolt Injector is a pneumatically actuated tool whose task is to catch the incoming fastener traveling through the feed tube and present it to the Bolt Inserter. The Bolt Inserter is a process tool which resides on the machine's shuttle table and is tasked with picking up a fastener from the Bolt Injector and installing it in the drilled hole. The Bolt Injector resides on the end effector's clamp table ([Figure 2](#)), which is the machine's primary approach axis to the wing panel of fuselage, typically moving in the Z direction. The Bolt Injector is mounted onto the side of the clamp table and it is

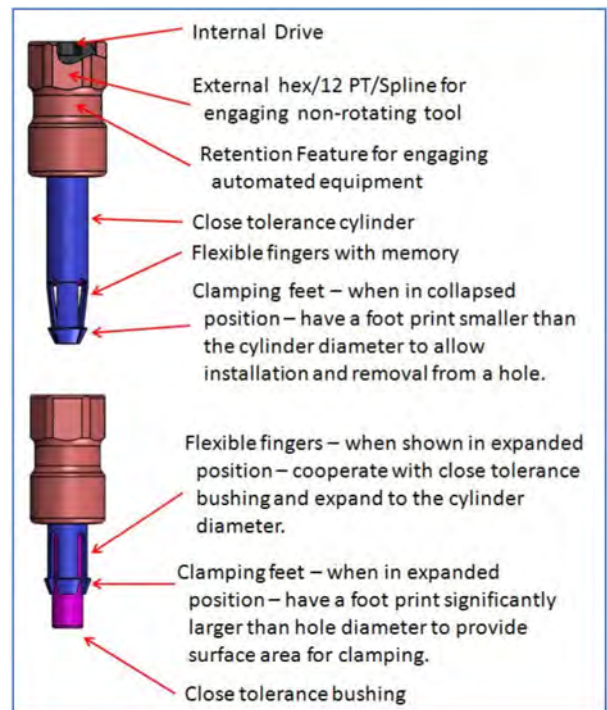


Figure 3. SSTF Bolt Features. Adapted from [3]

FEED TUBE INDEXING SYSTEM

The LTD Bolt Injector uses a feed tube indexing system to toggle between 3 different feed tubes of different size. The smallest feed tube is used with 3/16" and 1/4" diameter bolts.

The next size serves three diameters, 5/16" through 7/16", and the largest tube is used with 1/2" through 5/8" diameter fasteners. The indexing system is actuated by two pneumatic cylinders providing three vertical stop positions. The stop positions line up the appropriate feed tube with the Bolt Injector centerline. This system is fully controlled by the LTD machine's CNC and requires no manual involvement to change between diameters. This is useful further as the operator station is on the opposite side of the end effector where the operator changes cutting tools.



Figure 4. Feed Tube Indexing System

CYCLES OF FUNCTION

The first step in the bolt feed process is the diameter selection. The machine is set to drill one diameter and the drill and reamer are setup in the LTD machine's tool changer. With the diameter input, the CNC commands the feed tube indexing system to the position corresponding to the correct bolt head diameter.

When the machine drills a hole, it uses the diameter and the programmed stack to call a SSTF bolt from the Stick style Fastener Feed system. The bolt is escaped from the Fastener Feed system and blown through plastic feed tube up to the machine head.

From here the injection sequence starts. First, the bolt enters the Bolt Injector's Chamber and impacts the Damping Rod (Figure 5). The Chamber forms the last few inches of the feed tube path. Protruding into the Chamber is the Damping Rod. The Damping Rod is made from a soft material and protects the SSTF bolts from a harsh impact. This soft landing protects the longevity of the bolt and the machine hardware.

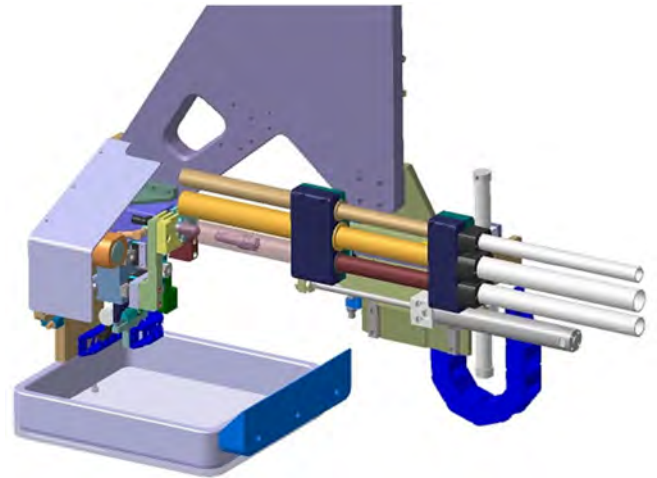


Figure 5. Bolt Enters Chamber

After the bolt's impact, the Damping Rod is retracted. Because the blast air that pushed the bolt through the feed tube is still on, the bolt follows the Damping Rod and becomes registered in the Z-direction, see Figure 6.

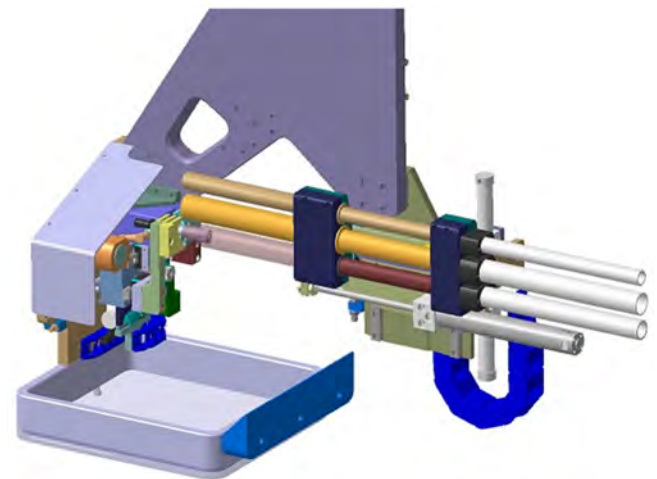


Figure 6. Damper retracts and Bolt follows

At this point, the Bolt Jaws, a parallel gripping mechanism, close and grips the bolt by the forward section of its shank (Figure 7). With an analog 0-10VDC sensor, the diameter is also checked. Diameters are checked to discriminate between bolt diameters in increments of 1/16".

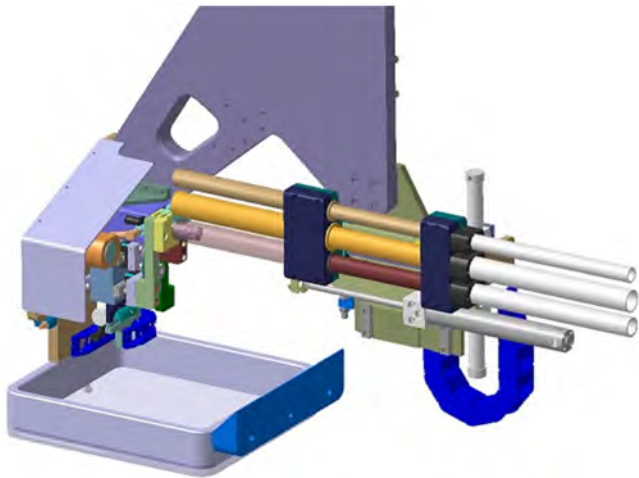


Figure 7. Jaws close on bolt

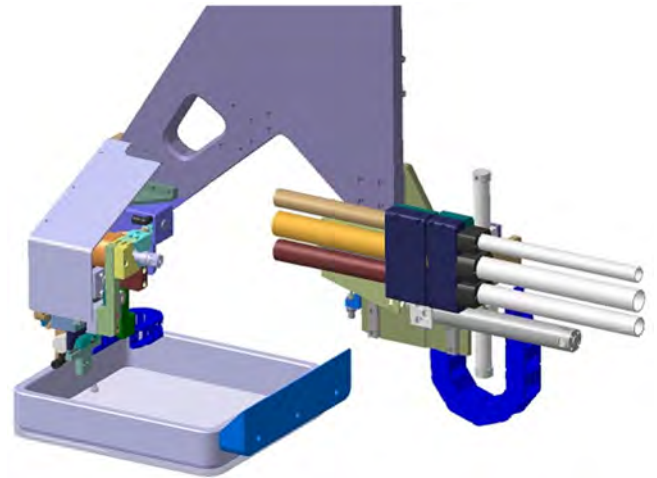


Figure 9. Injector sled extends

Now, the Chamber retracts ([Figure 8](#)). The Chamber is a telescoping device with the ability to retract. This facilitates clearing the bolt's head so it can shuttle sideways. With the bolt held securely by the Jaws, the Chamber is no longer needed to guide or contain the bolt.

[Figure 10](#) shows the Bolt Inserter pictured, previously hidden from view for clarity. The Inserter is retracted and the Bolt Jaws hold the bolt in a staging position ready to be socketed.

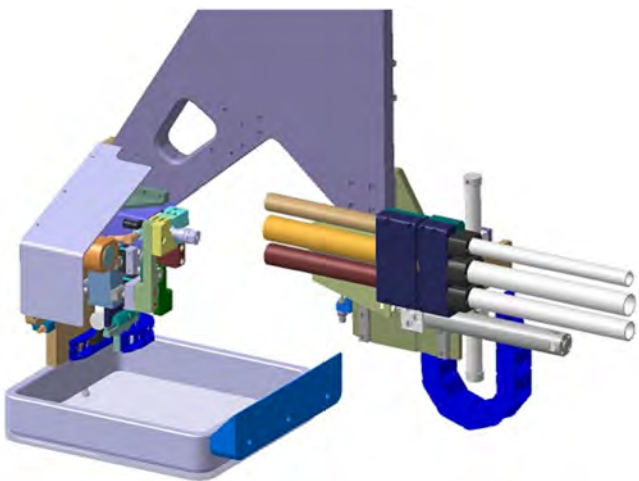


Figure 8. Chamber retracts

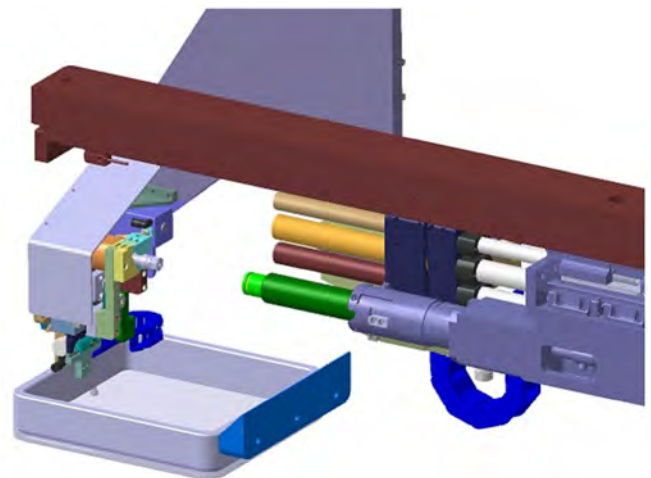


Figure 10. Bolt Inserter in line while machine is drilling

[Figure 9](#) shows the Injector Sled extended which puts the Bolt in line with the Bolt Inserter while the machine is drilling. Because the Inserter resides on the machine's shuttle table, drill position is chosen to be the Injector to Inserter alignment position giving the Injector the time it takes to drill a hole to complete the Injection cycle without adding anytime to the overall cycle time of the machine.

Now the Inserter drives forward, driven by a servo motor and ballscrew, and the bolt head snaps into the socket, see [Figure 11](#). The socket on the Bolt Inserter has spring loaded features for retaining the bolt and teeth which align with wrench flats on the bolt to prevent rotation. Later, upon fastener installation, the Inserter will apply torque to actuate the SSTF bolts and the wrench flats are used to react this torque. Also at this point, the Inserter, which contains an electric nutrunner, will check the bolt to make sure it is fully unwound. A partially actuated SSTF bolt cannot fit into the drilled hole.

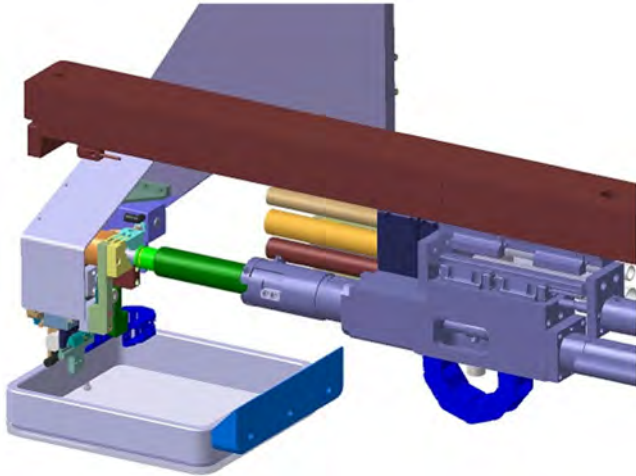


Figure 11. Bolt is captured in socket

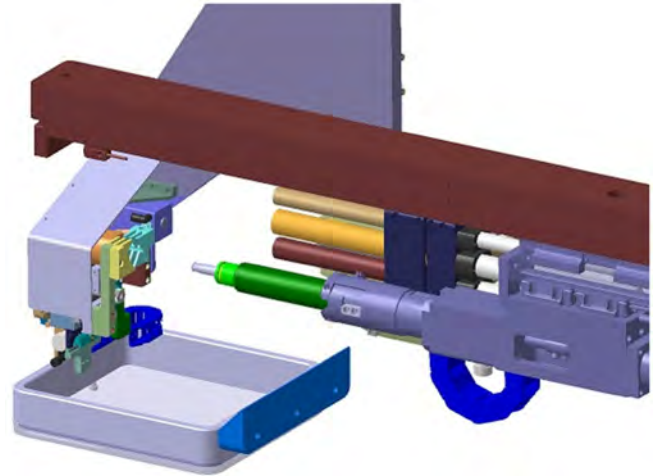


Figure 13. Inserter retracts completing injection cycle

With the bolt not captive in the Inserter's socket, the Jaws open and release the bolt, [Figure 12](#). Behind the Jaws is a spring loaded touch off pad. The touch off pad has a proximity switch embedded which the Bolt Inserter can trip by driving forward and depressing the pad. With this switch and the feedback of the servo motor position, the length of the bolt is calculated and checked against the expected value.

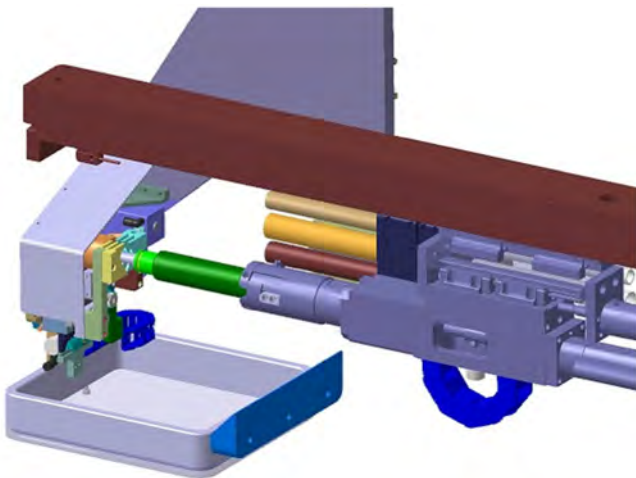


Figure 12. Jaws release bolt

Now the Bolt Inserter retracts with the bolt. The bolt is held captive in the socket and its diameter and length have been checked along with ensuring the fastener is fully unwound. The Injection cycle is now complete and the Inserter is clear move to the drilled hole, via shuttle table move, and install the fastener in the drilled hole, see [Figure 13](#). Upon installation, the Inserter provides a preset amount of torque to the fastener correlating to a clamp force provided. The installed fastener provides clamping and doweling to the aerospace components.

SUMMARY/CONCLUSIONS

This summarizes the new LTD Bolt Injector. This new injector is an evolution from the Confined Spaces Injector [1] similarly featuring no tool change between diameters and provide length and diameter checking of the fed fasteners. The LTD Injector makes advances offering more diameters without any manual tool change operations. A total of eight different SSTF bolt diameters are fed fully automatically with no operator involvement with the Injector. The LTD Injector was developed for another SSTF bolt application. SSTF bolts are being used more and more for temporary doweling and clamping or aerospace components. Overall, the LTD Bolt Injector is a more streamlined and versatile tool allowing great flexibility without additional operator intervention which contributes to high utilization of Electroimpact's new LTD machine.

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DEFINITIONS/ABBREVIATIONS

Bolt Injector

Process tool that catches fastener travelling through feed tube and presents it to Bolt Inserter

Bolt Inserter

Process tool on shuttle table that installs fastener in drilled hole

End Effector

Device or tool connected to the end of robotic arm

Socketed

The state in which the bolt's head has been secured in the Bolt Inserter's socket

SSTF

Temporary fastener that provides clamping and doweling primarily available from Centrix, LLC

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. This process requires a minimum of three (3) reviews by industry experts.

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