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Pinch Bolt Injector

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ABSTRACT

This paper will cover the design of the pinch bolt injector used on the A380 panel to stringer joining machines #9 and #10. The bolt injector was designed to decrease bolt insertion cycle time, increase reliability and incorporate a fully automated bolt purge system. This paper will cover how the injector handles bolt diameters from 1/4"-1/2" and how it helped increase the machines' bolt insertion rate from 5.5 bolts per minute to 8 bolts per minute

INTRODUCTION

Airbus assembles the A380 wing in the West Factory in Broughton, Wales. In stage 0, the stringers are fastened to the skin panels. The work is done by ten E4380 Low Voltage Electromagnetic Riveting machines, which install thousands of 1/4"-3/8" Slug rivets and 1/4"-1/2" LGP lockbolts, ASNA threaded bolts, steel slave bolts and pan head bolts.

On E4380 #1 through #8 the bolts are blown through feed tubes from a cartridge auto feed system into the bolt inserter. To prevent damage, the bolts travel through these tubes at relatively low speed. This limits the machines to a rate of 5.5 bolt/min insertion. Airbus wished to increase the insertion rate of machines #9 and #10 to 8 bolt/min to help increase production rate. To achieve this goal, Electroimpact designed a bolt injector that could absorb the high energy of a fast moving bolt and inject it into the bolt inserter. Electroimpact came up with the pinch bolt injector to handle this problem.

MAIN SECTION

INJECTOR DESIGN FEATURES

The injector can feed a variety of bolts from a 1/4"-4 lockbolt to a 1/2" steel slave bolt 63mm long. The injector can automatically purge a bolt in the case of a misfeed. Polyurethane was used throughout the feed path to prevent damage to the delicate features of these fasteners. The injector is made up of four subassemblies: the post, chamber, stop pin and feed tube shifter.

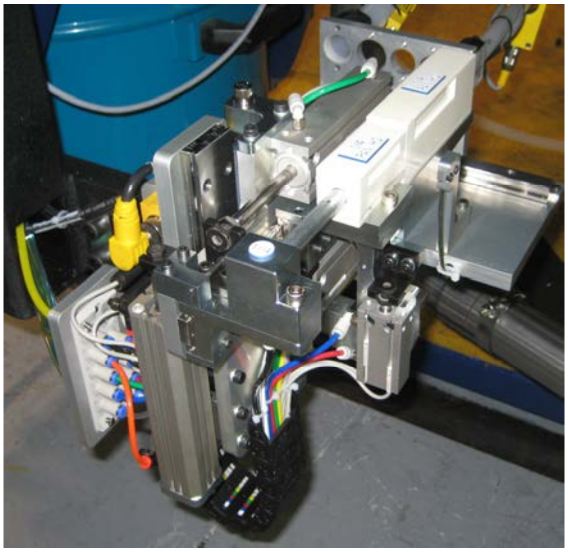

Figure 1- Pinch bolt injector E4380 #9 with 1/4'' feed tooling

The post assembly is the heart of the pinch bolt injector. The post absorbs the energy of the incoming bolt, and then slides back to press the bolt against a stop pin. The post assembly consists of a hollow post, tungsten mass, polyurethane nub and post base. The mass is attached to the polyurethane nub and inserted into the post. Air pressure is applied to the post assembly, which extends the nub and mass past the end of the post to contact the incoming bolt. When the bolt hits the nub it pushes the mass back into the post. This increases the duration of impact event and dissipates the kinetic energy of the bolt. The weight of the mass is calculated based off the largest size bolt for that diameter. An equation for collisions between elastic particles was used to calculate the weight of the mass. The equation was modified using the coefficient of restitution making the equation applicable to inelastic collisions. The post assembly is quickly interchangeable for each bolt diameter.

V_{1f} = Final velocity of bolt after impact

C_R = Coefficient of restitution

M_1 = Mass of bolt

M_2 = Weight of mass

V_1 = Velocity of bolt before impact

V_2 = Velocity of mass before impact

$$V_{1f} = \frac{(C_R+1)M_2V_2+V_1(M_1-C_RM_2)}{M_1+M_2}$$

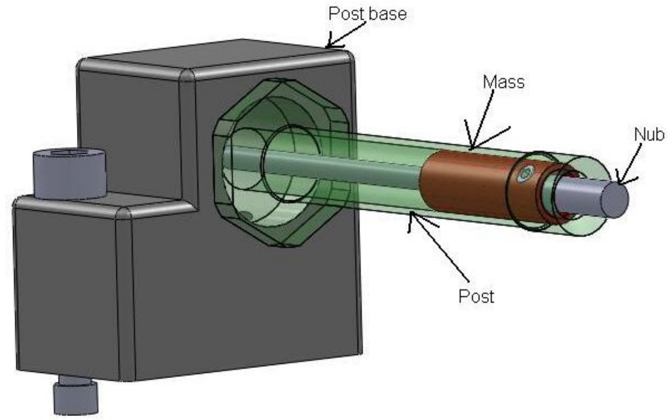

Figure 2 - ¼'' Post Assembly

The chamber assembly is where the bolt is housed before being injected into the bolt inserter. The chamber is a molded polyurethane part. Molding the chamber allowed for color coding and reduced the cost of manufacturing. Extensive material test was done to determine the correct material that would hold up to the tens of thousands of cycles without damaging the bolt. 75D polyurethane was picked as the material. It is a hard polyurethane that is easy to mold and holds its' dimensions after it is pulled out of the mold.

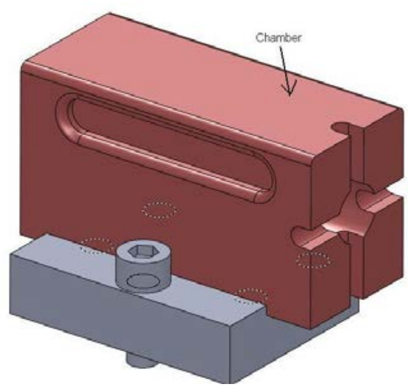

Figure 3 - 1/4'' Chamber Assembly

The stop pin assembly is used to pinch the bolt and keep it from sliding back into the feed tube. The pinching process insures that the bolt is fully constrained and is ready to be injected into the bolt inserter fingers.

The feed tube shifter assembly allows the feed tubes to be changed quickly and easily. Five different feed tube sizes are used on the E4380 machines to accommodate the different bolt diameters. The feed tubes are bolted to a bracket, which is attached to a liner bearing car and rail. To change the feed tube size, the operator simply pulls a pin on the feed tube shifter and slides the assembly to the desired tube size. Three proximity switches are used to confirm that the operator has the correct hardware configuration for the desired diameter set up.

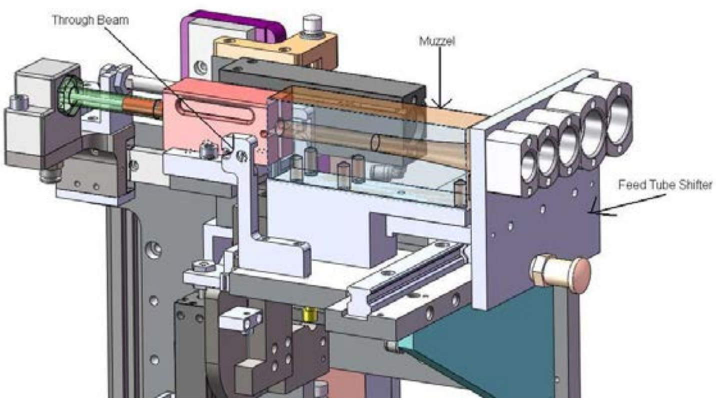

Figure 4 - Muzzle, Through beam and Feed tube shifter

INJECTOR SEQUENCE

The following injection sequence takes place within the span of about two seconds:

Step 1: The bolt is blown down the feed tube at a high velocity: between 35-70 mph depending on bolt size. The velocity was measure using two ring sensor place at the end of the feed tube. The air flow in the feed tubes was set between 35-50 CFM.

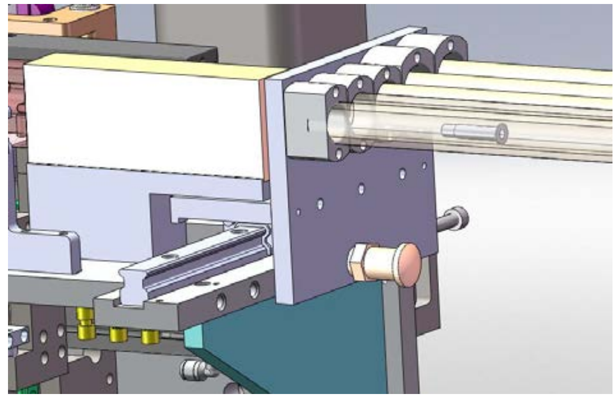

Figure 5 - Bolt in feed tube

Step 2: When the bolt reaches the injector, it first enters the muzzle. The muzzle tapers the bolt feed path down from the feed tube ID to around .010ö larger than the bolt head diameter. This helps constrain the bolt before it enters the chamber.

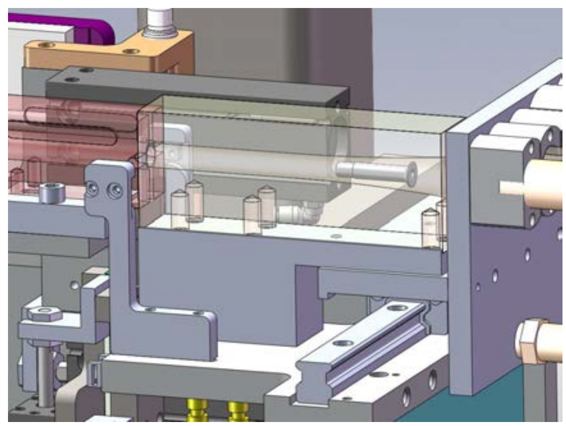

Figure 6 - Bolt going into the muzzle

Step 3: A fiber optic beam is broken when the bolt passes from the muzzle to the chamber. This tells the machine that the bolt has entered the chamber.

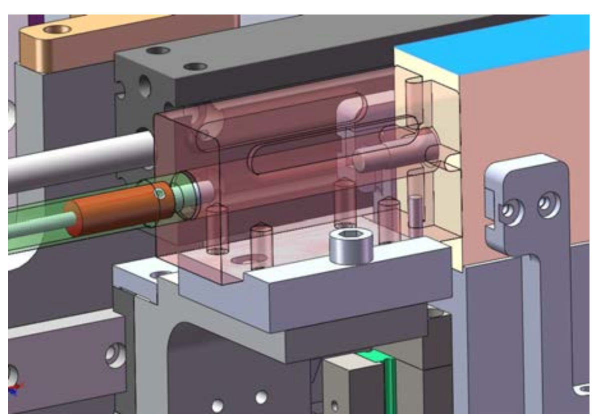

Figure 7 - Bolt breaking fiber optic beam

Step4: The bolt enters the chamber and contacts the nub, transferring the incoming energy into the post assembly.

Step 5: The stop pin extends to keep the bolt from sliding back into the muzzle.

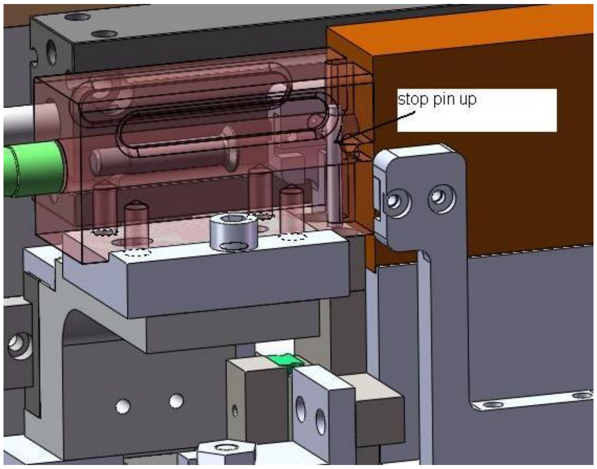

Figure 8 - Stop Pin extended

Step 6: The post assembly retracts on a linear rail pressing the head of the bolt against the stop pin.

Step 7: The chamber extends on a linear rail until it stops against the post assembly. This exposes the bolt head and part of the shank so that it can be injected into the bolt inserter.

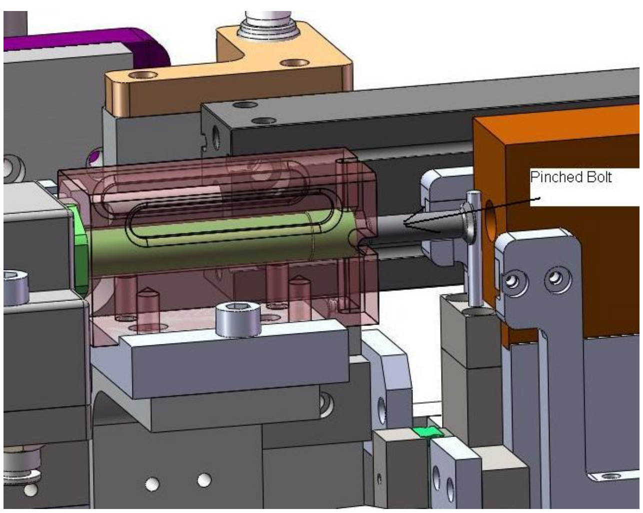

Figure 9 - Chamber extended with a pinched bolt

Step 8: The post, chamber and stopper pin extend upward together, injecting the bolt into the inserter. At this point the bolt is being held by the injector and the inserter.

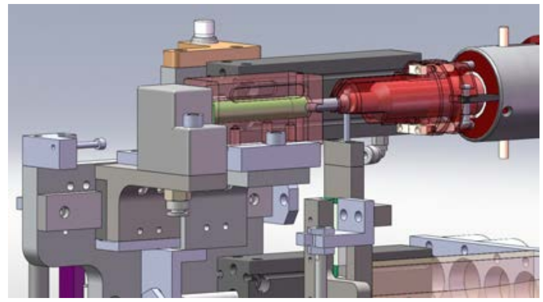

Figure 10 - Bolt injected into bolt inserter fingers

Step 9: The post and chamber extend together, exposing the tail of the bolt. A three position pneumatically controlled set fingers now pull the bolt tight up against the driver anvil.

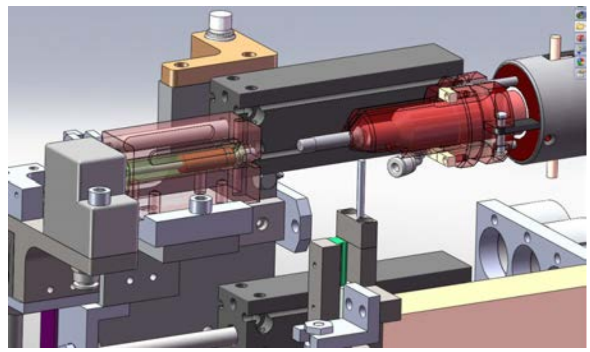

Figure 11 - Bolt held by bolt inserter fingers

Step 10: The post, chamber and stopper pin drop back down, completing the injection cycle. The bolt inserter is now free to put the bolt into the panel.

BOLT PURGE

To reduce downtime, the injector is designed to automatically purge bolts. A purge is necessary when the wrong size bolt is fed; two bolts are fed at once, etc. The purge cycle extends the chamber assembly and turns on the feed tube blast air, clearing all bolts from the feed tube and injector.

CONCLUSION

The pinch bolt injector was a crucial component that allowed Airbus' fastening machines to reach an 8 bolt/min insertion rate. The injector can handle a very large range of fastener diameters, lengths and styles. With the help of the pinch bolt injector the E4380 # 9 & #10 has gone from a cycle time of around 11sec/cycle to around 7sec/cycle. The pinch injector has proven to be very reliable means of feeding bolts quickly and without damage, and has been in production for Airbus since early July 2009. The same style of injector is also proving to be very reliable and robust on Electroimpacts' 787 fuselage fastening machine, which goes into production in the fall of 2009 at Kawasaki Heavy Industries, as well as the E6000 wing riveting machine.

ACKNOWLEDGMENTS

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DEFINITION, ACRONYMS, ABBREVIATIONS

Bolt inserter: process tool that puts bolts into drilled holes

Inserter finger: what holds the bolt when the Bolt inserter puts the bolt into the panel