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Electroimpact Automatic Fan Cowl Riveter

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Abstract

The Electroimpact Automatic Fan Cowl Riveter exhibits new and unique design features and automated process capabilities that address and overcome three primary technical challenges. The first challenge is satisfying the customer-driven requirement to access the entire fastening area of the fan cowl doors. This necessitates a unique machine design which is capable of fitting 'inside' a fan cowl door radius. The second challenge is determining drill geometry and drill process parameters which can produce consistent and high-quality countersunk holes in varying mixed-metal stack-up combinations consisting of aluminum, titanium, and stainless steel. The third challenge is providing the capability of fully automatic wet installation of hollow-ended titanium rivets. This requires an IML-side countersinking operation, depositing sealant throughout the OML and IML countersinks and the hole, automatically feeding and inserting a rivet which is only 5mm long and 6mm in head diameter and flaring the rivet tail to a 'sub-flush' condition.

Introduction

A recent project required designing, testing, and installing a new fastening machine capable of positioning, drilling, and automatically installing fasteners into fan cowl doors. Many aspects of this machine's functionality had been previously proven on other automated production platforms. However, there were several requirements within this project that presented new technical challenges. These challenges were addressed throughout the design and testing phases of the project and required close customer collaboration and buy-off throughout all phases.

The result today is an automatic fastening platform that is uniquely capable and highly specialized, but also employs designs and processes that are transferrable to other applications with similar or shared technical challenges.

This paper primarily focuses on each of these challenges and the corresponding solutions that were implemented on this project.

FIGURE 1 Fan cowl riveter performing real-world testing at Electroimpact's facility in Mukilteo, WA. Three out of four fan cowls are loaded onto the positioner in this photo.

Fan Cowl Fastening Access and Machine Shape

The most apparent feature of the Fan Cowl Riveter upon first observation is its unique shape, in particular – it's profile. A 'barge' or 'picture-frame' part positioner (as shown in Figures 1 and 2) was implemented due to customer requirements to protect for future capability of fastening different types of aircraft parts. Customer requirements also necessitated that the positioning system exhibited the capability of holding an entire shipset (4x fan cowl doors) at once.

An extensive part access study was employed early in the project (see Figure 3). This access study was used to design the machine structure around the aircraft parts. It was also used to inform the customer of specific access location details to facilitate both upstream and downstream production adjustments based on machine capability.

FIGURE 2 Unique machine shape enables the lower half of the machine to fit inside the curvature of the fan cowls at a variety of different angles.

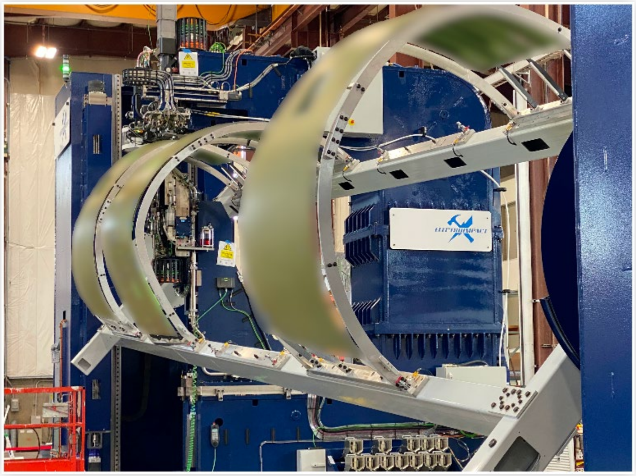
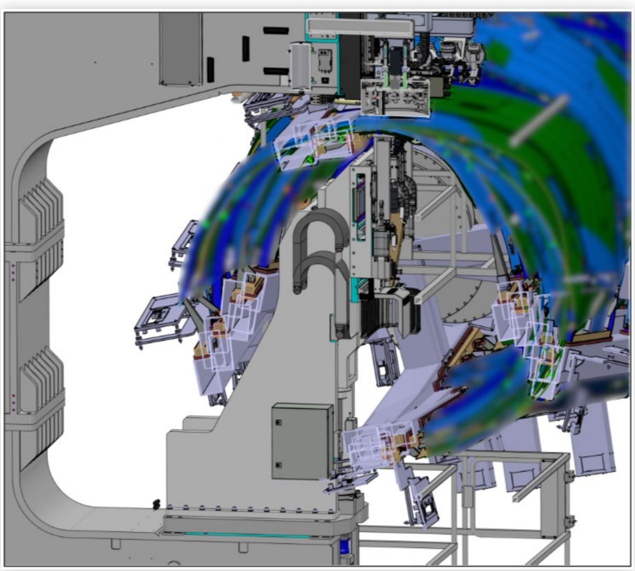


FIGURE 3 Machine Design Phase Access Study - Panel positioner was overlayed in CAD in many different positions to form a "design constraint cloud" which informed the shape of the lower portion of the fastening machine.



Additionally, it was also determined that in order to achieve full part access on the fan cowls (which have nearly 180deg curvature) the machine would either need to exhibit a rotating lower portion, or the fan cowls would need to be produced in two separate production setups, and the panels would need to be "flipped" approximately halfway through production. The latter was chosen as a more cost-effective solution. A special lifting jig was designed to lift the fan cowls and is used in both loading, unloading, and flipping the individual panels (this is shown in Figure 4).

FIGURE 4 Full part access requires flipping the fan cowls individually after about 50% of the panel is fastened.

Drilling Process Development

The second technical challenge encountered during this project was determining material drilling parameters and developing cutter design. The fan cowls consist of varying multi-material stacks, and the holes drilled by the fastening machine are held to aerospace tolerances and quality/consistency standards. The three stack composition types were (from OML to IML):

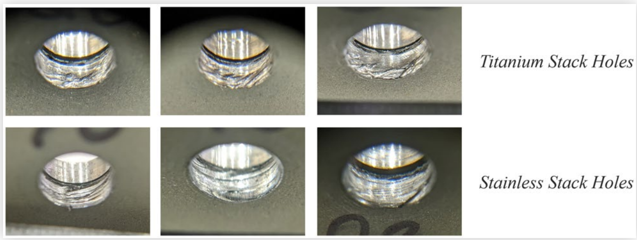
- Aluminum (OML) – Fiberglass – Aluminum (IML)
- Aluminum (OML) – Fiberglass – Stainless Steel (IML)
- Aluminum (OML) – Fiberglass – Titanium (IML)

The holes to be drilled in these stacks are intended for countersunk-headed solid rivets, double-flush hollow tailed rivets, and bolts. Additionally, customer-driven cycle time requirements prevented the possibility of a two-step drill/ream process. To satisfy these cycle time requirements, a "one shot" drilling process was necessary for all stacks, whereby a single cutter needs to drill holes to a satisfactory tolerance throughout the stack consistently without a subsequent reaming operation.

This challenge was addressed by developing cutter design and process parameters in very close collaboration with the cutter manufacturer. A drilling test bench was used throughout the project to facilitate this process and to allow for offline development to occur as much as possible.

The most significant challenge regarding drill/process development was the presence of 'retract-rifling' and/or poor surface finish in the aluminum OML layer after drilling through stacks that included stainless or Titanium as an IML layer (Figure 5). This was identified early in the development process. It was identified that excessive heat could result in material "buildup" on the cutting surfaces,

FIGURE 5 Poor surface finish identified early in the project in the aluminum OML layer in mixed-metal stacks (before the majority of cutter testing and development occurred).



and that process parameters that resulted in heavier chip loads were likely the reason(s) for these results.

Cutter development efforts were primarily targeted at this issue during early stages of this project. Through extensive testing, it was determined that a combination of the following three elements could produce consistent hole quality well within tolerance in the required stacks (see Figure 6):

1. A "piloted" cutter design (as opposed to single diameter)
2. A layered drilling process whereby feeds and speeds are adjusted throughout the stack depending on the individual layer being drilled.
3. Sufficient "pecking" amount and frequency allows for the cutter to be re-lubricated and allows heat to dissipate.

An additional challenge that was tackled next was achieving consistent exit burrs in the stainless-steel stacks. The ductility of the IML material resulted in exit burrs that were consistently out of tolerance. The solution to this problem was to use an IML-side cutter employed on this machine to remove the exit burrs immediately after they are formed (see Figure 7). The primary purpose of this IML-side cutting capability was for tail-side countersinking (see Figure 10), but burr removal in mixed-metal stacks was identified early as an additional benefit.

The final challenge with cutter development was increasing the speed of the drilling process to achieve customer-driven cycle-time requirements. It was identified that consistent hole quality was achievable with very

FIGURE 6 Typical hole quality in mixed-metal stacks after cutter testing and development efforts.

FIGURE 7 Exit burrs are automatically removed by the fastening machine using an IML-side cutter. The machine is programmed such that the cutter barely makes contact with the material in this process.

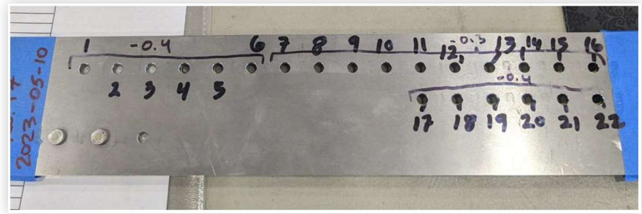
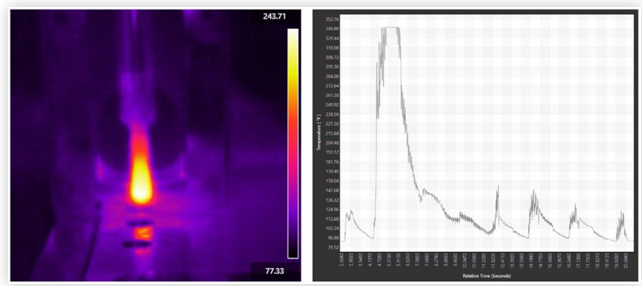


FIGURE 8 A thermal imaging camera was used in later stages of drill process development to inform how much pecking could be reduced. The graph shows temperature vs. time in a typical mixed-metal stack process. Each peak in the graph is a single peck.



frequent pecking and re-lubrication, but this also slowed the process down considerably. To overcome this, a thermal imaging camera was utilized to collect data, which informed where and how pecking could be reduced while keeping cutter temperature(s) as low as possible.

Wet Installation and Feeding of Small Hollow-Ended Titanium Rivets

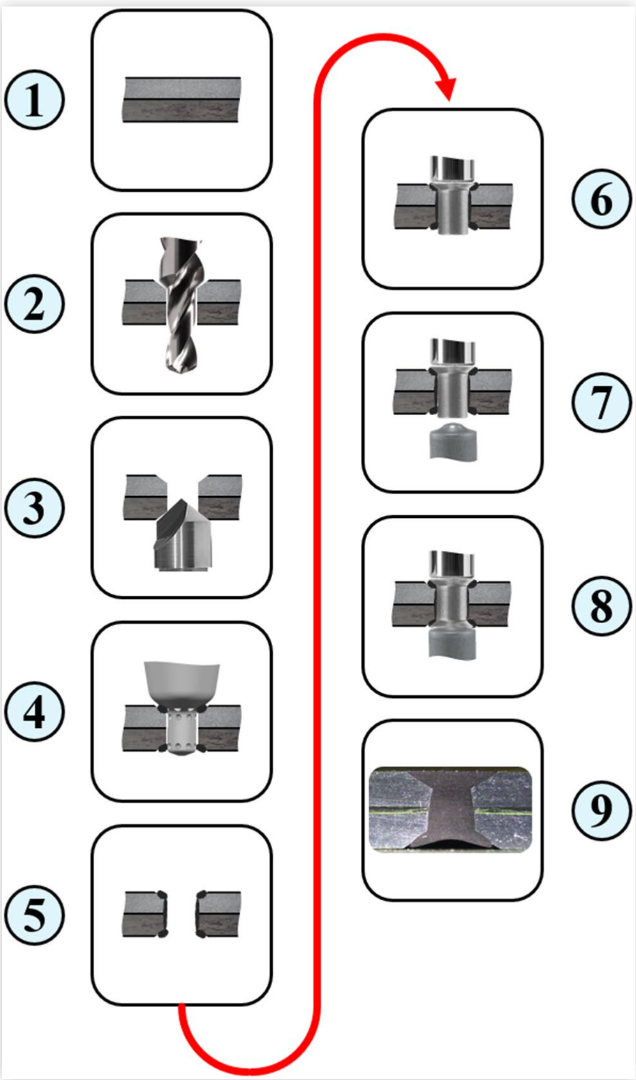
The third and final primary technical challenge solved during this project was the wet installation of small hollow-ended titanium rivets (Figure 9).

The installation process for the hollow-ended rivets is described below (depicted in Figure 10):

1. The machine clamps up on the part from both sides using pneumatic cylinders (not depicted in figure 10 for clarity). This clamped up state is maintained throughout the rest of the process.
2. The upper spindle of the machine drills through the stack from the OML side of the part and forms an OML-side countersink.
3. The lower spindle of the machine forms an IML-side countersink in the part.

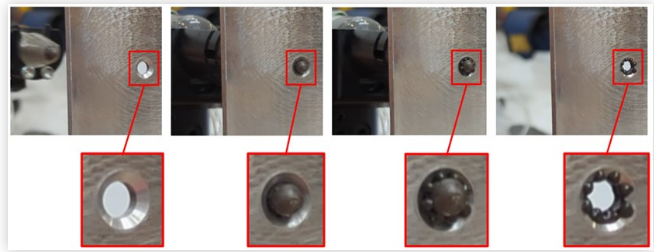
FIGURE 9 Small hollow-ended titanium rivets

FIGURE 10 Schematic depiction of installation process for hollow-ended rivets.



4. A specially designed sealant applicator nozzle applies sealant from the OML side of the part to both the OML-side countersink and the IML-side countersink (Figure 11).
5. Sealant coverage is throughout both countersinks and the hole. The machine operator can choose to implement a special 'sealant check' step at this point in the process to confirm full coverage.
6. The rivet is inserted into the panel via a set of fingers on the OML-side of the machine.
7. The lower bucking ram on the IML-side of the machine approaches the panel. A specially shaped die is used for flaring the rivet tail.
8. The rivet rail is flared to fill the lower countersink. The tolerance for installation is "sub-flush" with the IML surface to within a few thousands of an inch.
9. The rivet tail is fully formed. Sealant "squeeze out" must be continuous around both the head and the tail of the fastener.

FIGURE 11 Sealant nozzle applies sealant from the OML side of the part to both the OML-side countersink and the IML-side countersink.



In addition to automating the wet installation process, new hardware needed to be designed to enable these rivets to be fed reliably. These rivets are extremely small, both in head diameter (6mm) and overall length (5mm), so orienting them, feeding them and inserting them into the panel was a difficult series of design challenges.

A custom rotary drum hopper design (Figure 12) was prototyped and implemented as the first step in the automatic feed path. The hopper can orient the fasteners

FIGURE 12 Rotary drum hopper assembly

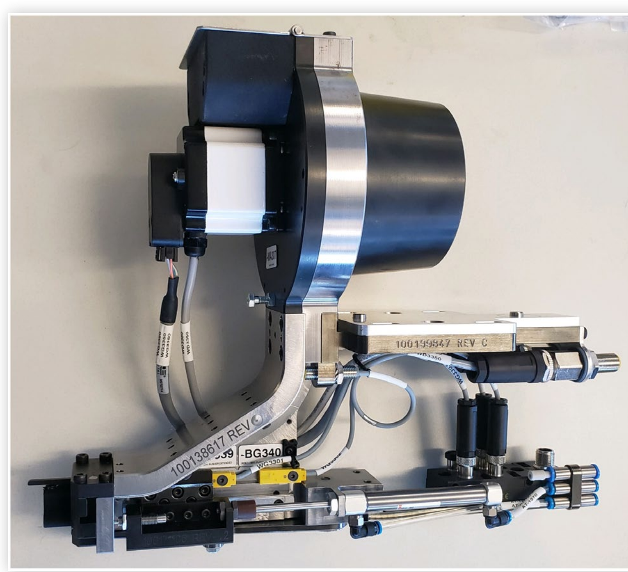
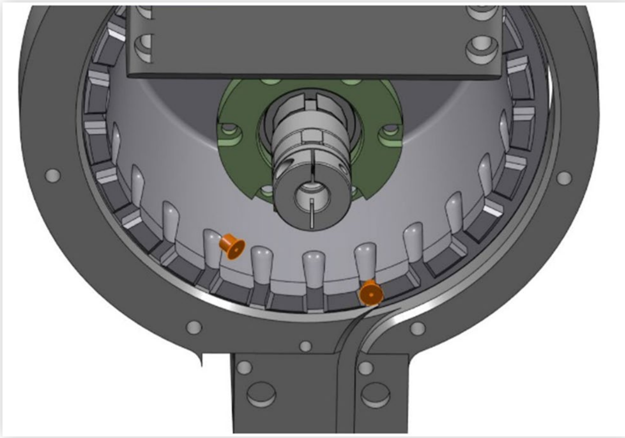


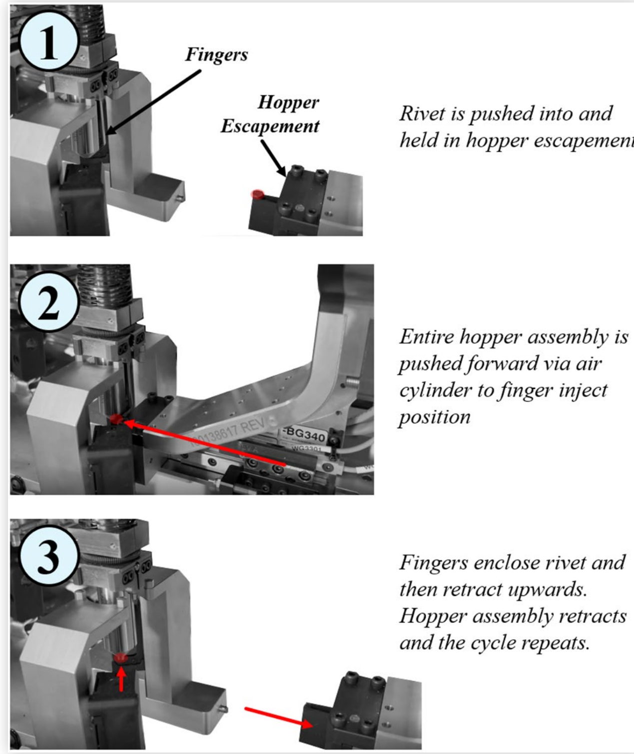
FIGURE 13 Internal drum geometry prevents fasteners from being fed in the incorrect orientation



reliably without jamming by using a mechanical poka-yoke gate (Figure 13) that does not allow the fasteners to escape the drum unless they are in the correct orientation. Once the fasteners leave the drum, they are fed into a small buffer rack. A sensor on the buffer rack triggers the control system to rotate the drum to refill it when necessary. The entire assembly is mounted directly on the OML process head of the machine, so the fasteners do not need to be fed in tubes.

From the buffer rack, the fasteners are pushed one at a time into an escapement assembly where they are subsequently picked up by the fingers (Figure 14) which insert them into the panel.

FIGURE 14 Hollow tailed rivets are injected from hoppers into fingers



Summary/Conclusions

The three primary technical challenges outlined in this paper resulted in several original innovations that were brought from conceptual design to successful implementation over the lifespan of a single project. The overall result is a machine that is capable of automatic wet installation of hollow-ended rivets, drilling high quality holes consistently through mixed-metal stacks to aerospace tolerances using a "one shot" drilling process, and providing a means to automatically fasten the entirety of a high curvature fan cowl door panel area.

Each of these solutions and the information that was acquired when reaching them have the potential to be transferred or adapted to other automated fastening applications. Any application involving automatically feeding and inserting extremely small rivets, flaring hollow ended rivet tails, drilling through mixed metal stacks involving hard and soft metals, or fastening extremely high curvature parts would be well suited to drawing on the technical solutions that were developed on this project.

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