2025-01-0169

Drilling Methods for Controlling Exit Burr Height in CRES Material Stacks

Rich Schultz, Zack Luker, Randy Peterman, Sai Krishna Murakonda
Electroimpact, Inc.

Abstract

The Electroimpact Automatic Fan Cowl Riveter uses two novel drill processes to control exit burr height and achieve the required hole quality in CRES (Corrosion-Resistant Steel, also called stainless steel) material stacks. Both processes use piloted cutters on the OML (Outer Mold Line, referring to the exterior surface of an airframe) side, and two different tools are used in a backside spindle on the IML (Inner Mold Line, referring to the inside surface of an airframe) side of the component. The first process uses a shallow-angle shave tool in the IML spindle to directly control the exit burr height after it is produced by the OML spindle and is called the "burr shave" technique. The second process uses a countersink tool in the IML spindle and produces an "intermediate countersink" after the pilot hole is drilled by the OML spindle, but before the final hole diameter is drilled. These drill processes were able to achieve the required hole quality in a challenging CRES material stack, which allows the machine to be qualified for one-up assembly of the component.

Introduction

Commercial aerospace manufacturing requires the highest levels of consistency and quality to ensure that the final product is held to standards that few other industries face. A recently built C-frame machine, currently used in the production of fan cowls required brand new drilling processes to be developed to achieve that level of consistency and quality. These drill processes were developed through the combined ingenuity and creativity of those involved. As a result, the hole quality and hole consistency in challenging material stack ups can be achieved using only MQL (Minimum-Quantity Lubrication), piloted cutters and a range of spindle process settings, which allow for OUA (One-Up Assembly) process of the aircraft part.

The processes were developed over a period of roughly 12 months of trials. They utilize hardware that is not available on many of our other automated machines, but the lessons learned during development could be applied to other automated equipment with similar use cases.

The goal of this paper is to educate readers about complex, novel drill processes that can be used for automated assembly to achieve the hole quality required in large-scale manufacturing of commercial aircraft.

Development History

The material stack composition for this aircraft part includes combinations of aluminum, fiberglass, titanium and CRES. During initial development of the cutting processes, the most challenging material stack up was aluminum + fiberglass + CRES from OML to IML. During preliminary development, the biggest issue was caused by harder, CRES material chips scratching and gouging the softer aluminum layer as they were formed by the cutter and pulled up and out of the hole.

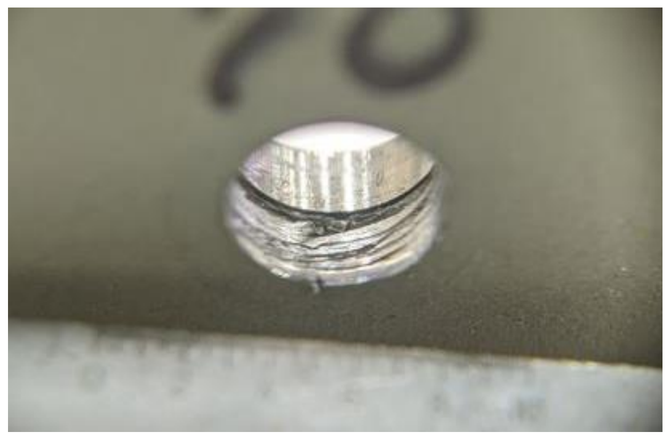

Figure 1: Deep grooves in the aluminum layer from a standard, non-piloted cutter. CRES is on the bottom layer, fiberglass in the middle, and aluminum is on the top layer (closest to the bottom of the image above).

No special cutter geometry was considered in the initial round of test drilling rivet holes. Only standard, single diameter cutters that were optimized for cutting hard metals like Titanium and CRES were used during the preliminary development phase.

Figure 2: A typical cutter for aerospace manufacturing. The cutter pictured above has a single diameter and countersink geometry for drilling rivet holes.

However, one of the processes developed on this machine was for a tight tolerance bolt installation. During the preliminary process development, a stepped drill/reamer style cutter was used and the hole quality observed was significantly better than the rivet holes produced by a standard cutter. This observation, combined with the fact that the single diameter cutters were struggling to produce the required hole quality in aluminum + fiberglass + CRES stacks, led us to the decision to change the cutter geometry to include a pilot tip.

Figure 3: A piloted cutter used for drilling through the aluminum + CRES stack.

Another feature unique to this machine is the inclusion of a backside spindle for drilling countersinks in the IML of the part. This additional spindle is required for installation of double flush, hollow tailed rivets. The existence of this backside spindle allowed the novel drill processes used to control CRES exit burr height to be developed.

Material Specific Challenges

As drill process development progressed, material stacks with CRES on the IML continued to be the biggest challenge. All other material stacks were able to achieve the required bolt and rivet hole quality, but two material stacks with CRES on the IML layer had issues specifically related to exit burr height.

To include these two material stacks as part of the OUA process, rivet holes required a stable exit burr height with minimal tolerance. One material stack was for a flush head rivet and one material stack was for a double flush hollow tail rivet. The requirement to control exit burr height for the double flush rivet applied to the hole *before* drilling the countersink in the IML. This was to ensure that there wasn't any undue stress in the hole wall caused by tear-out or a cutter beyond its' usable life, which are both root causes of excessive exit burr height. However, after multiple conversations with the customer, the exit burr height requirement was increased by roughly 4x prior to any backside operations. This looser tolerance gave us the freedom to develop processes for controlling the exit burr height.

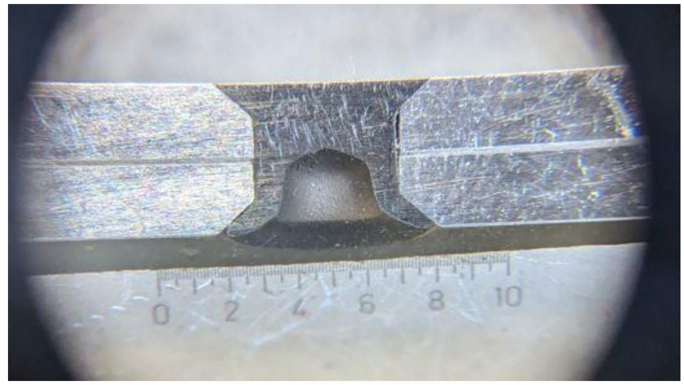

Figure 4: A cross-section of a double flush, hollow tail rivet.

New Processes Developed

Once the process was stable enough to maintain exit burr height after drilling, two separate processes were developed to directly control exit burr height to achieve the required tolerance achieve one-up assembly.

Burr Shave Process

Preliminary development of this process began with the same countersink cutter that is used for double flush rivet installation. However, we quickly determined that exit burrs weren't always cleanly cut by the CSK (shorthand for countersink) cutter. Instead, the cutter would occasionally fold the exit burr over which failed criteria for rivet installation.

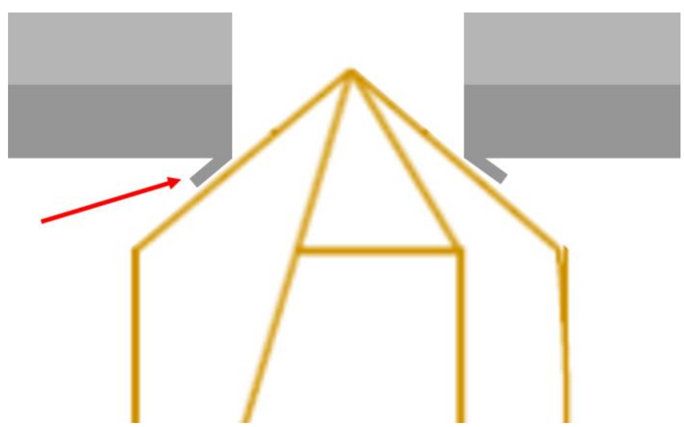

Figure 5: A 100° countersink cutter would sometimes cause exit burrs to fold over, instead of cleanly cutting them.

Development of this process continued by using the CSK cutter to form an edge break at the exit of the hole. This would completely remove the exit burr, but this process came with its' own set of challenges. First, when forming an edge break on a hole for OUA, there is are *minimum* and *maximum* depth requirements that the edge break must meet. In our case that total edge break tolerance is limited to a narrow band. Second, the pilot tip of the CSK cutter was sized for a smaller hole diameter which meant upper to lower spindle alignment was critical to meet a concentricity requirement for edge breaks. Between the narrow tolerance band for edge break depth and the critical alignment requirement of upper and lower spindles, this process was never stable enough to be used for OUA.

Instead, for the CRES material stacks where flush head rivets were installed, a new "burr shave" tool was developed. The tool is similar to an end mill, but it utilizes a shallow-angle to cut the exit burrs cleanly while pushing material away from the center of the hole in case some burr folding occurred during the cut.

The burr shave process follows this basic outline:

1. Upper spindle cutter approaches the panel.
2. Drill + CSK rivet hole.
3. Retract upper spindle and advance the lower spindle.
4. Shave the exit burr with the lower spindle.
5. Hole is complete.

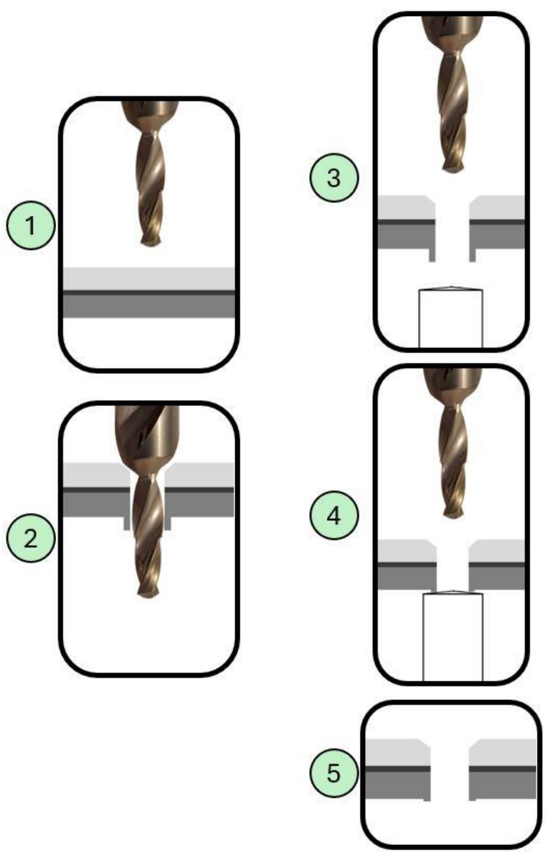

Figure 6: A flow chart of the burr shave process.

Using this process for drilling and finishing flush head rivet holes in CRES material stacks, we were able to maintain them within the OUA scope of work. A summary of the results of burr shaving can be seen below.

Figure 7 shows the exit burr height measurements before implementation of the burr shave process, and Figure 8 shows the exit burr height after burr shaving.

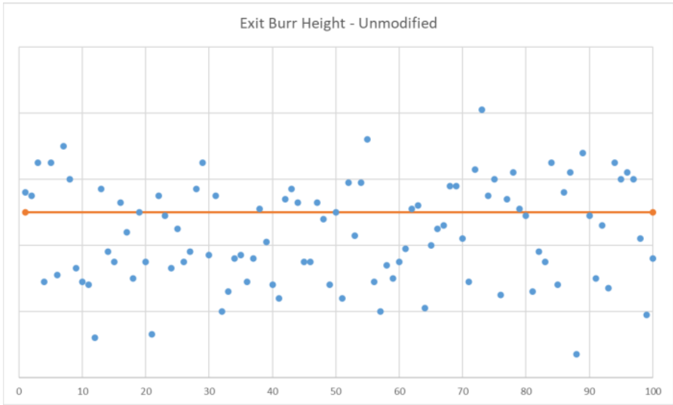

Figure 7: Exit burr height measurements prior to burr shaving.

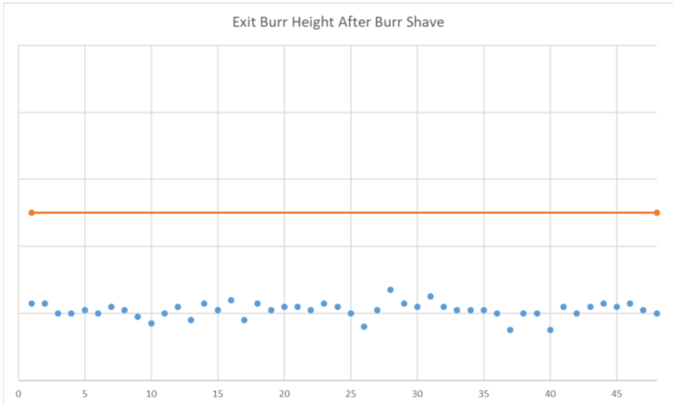

Figure 8: Exit burr height measurements after burr shaving.

Intermediate Edge Break Process

The need to maintain exit burr height for the double flush rivet holes was required because of unique circumstances as part of the OUA process for this component. Some of the double flush rivet holes were drill-only because another component was added manually at a later stage of assembly. The exit burr height requirement for these holes was looser than a typical rivet installation, because they would be manually deburred prior to adding the additional component. However, when forming these drill-only holes, we observed excessive exit burr height. This caused concerns by the end-user because excessive exit burr height can be an indication of unwanted stresses inside of the hole. After discussions with the end-user, a new exit burr height tolerance was identified for these locations, and we needed to develop a process to consistently meet that requirement.

It should be noted that these drill-only holes were intermixed with holes that required a backside countersink and therefore they needed to be completed using the backside CSK tool. These combined requirements dictated the use of the CSK tool to control exit burr height as opposed to using the burr shaving tool.

The decision was made to try removing material from the IML after drilling the pilot hole, but before completing the hole. We believed that the exit burr created by the pilot tip was adding to the exit burr height formed when drilling the final hole diameter. By removing material in advance, the goal was to eliminate the exit burr formed by the pilot tip. An added benefit of removing material in advance is that there was less material near the hole exit to form an exit burr when drilling to the final diameter.

The intermediate countersink process follows this basic outline:

1. Upper spindle cutter approaches the panel.
2. The pilot hole is drilled.
3. The lower CSK cutter approaches the panel.
4. The lower CSK cutter removes the pilot exit burr and forms a small edge break on the IML.
5. The lower spindle retracts.
6. The upper spindle finishes the hole diameter and upper CSK.
7. Both spindles retract, and the hole is complete.

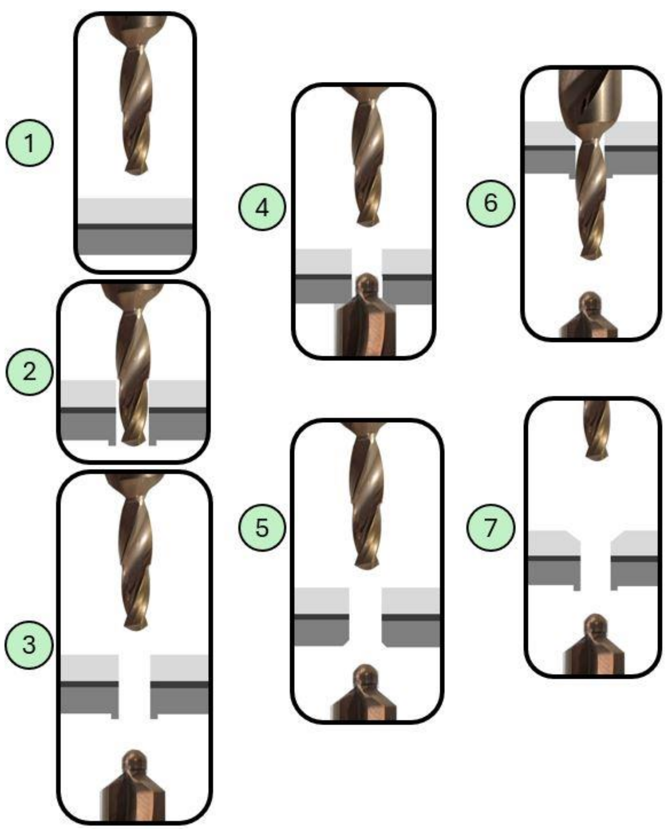

Figure 9: A flow chart of the intermediate edge break process.

Using the CSK tool to make an intermediate edge break on the backside of the part doesn't control exit burrs to the same level of consistency as the burr shaving tool. However, the process met the required exit burr height tolerance and it allowed us to keep the lower CSK tool installed while drilling all of the double flush rivet holes.

A summary of the exit burr height of the drill only holes is shared below. Figure 10 shows the exit burr height measurements prior to intermediate edge breaking and Figure 11 shows the measurements after intermediate edge breaking.

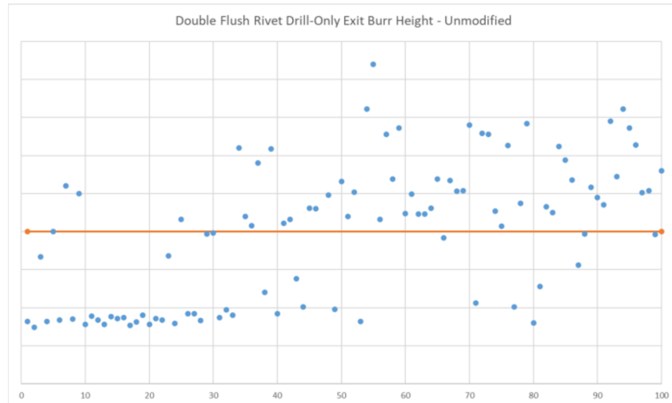

Figure 10: Exit burr height measurements of the drill only holes, prior to intermediate edge breaking.

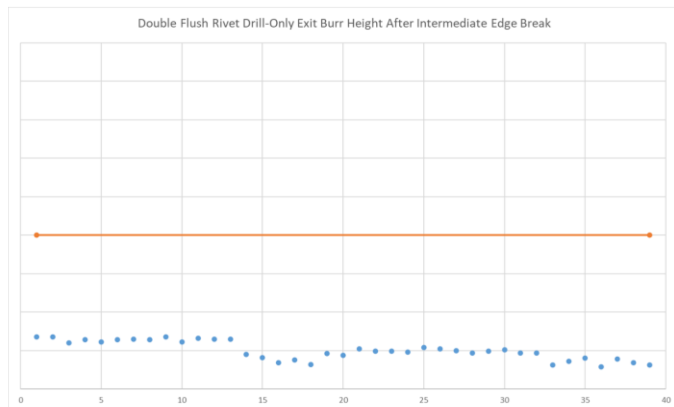

Figure 11: Exit burr height measurements after intermediate edge breaking.

Summary/Conclusions

The two novel drill processes outlined above allowed the CRES material stack holes to remain part of the OUA process for the Automatic Fan Cowl Riveter. The most difficult aspects of finding a solution to the material and hole quality challenges was first – coming up with a unique process unlike any we had previously considered and second – implementing it on an automated machine. Compounded with those challenges was the fact that time was limited due to schedule pressures.

All these factors are part of the unique manufacturing expertise demonstrated by Electroimpact engineers. The result of that creativity, expertise and dedication is what drives large scale assembly automation forward.

Definitions/Abbreviations

CRES	Corrosion-Resistant Steel
CSK	Countersink
IML	Inner Mold Line
OML	Outer Mold Line
OUA	One-Up Assembly
MQL	Minimum-Quantity Lubrication