Narrow Fixture Improves One-Up Panel Assembly

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Abstract

The use of a narrow profile posts or Skinny Fixture increases build speed and flexibility while improving quality of aluminum aircraft panels fastened in one-up assembly cells. Aluminum aircraft panels are made up of an outer skin and a series of stringers. The components must be held in accurate relative positions while preliminary fasteners are installed. By using narrow fixture posts in conjunction with deep drop stringer side machine tools, the fastening machine can apply fasteners at tighter initial spacing. The spacing is gained by providing clearances that allows the centerline of the fastening system to work closer to the post than previously achieved with deep fixture posts and short stringer side tooling.

At one time the standard process was to hold the parts in manual tack cells and after tacking the panels are moved to a separate automated fastening cell. One-up assembly fixtures improve the process by reducing manual processes while minimizing component handling. A typical one--up fixture has large tooling posts that interfere with the automated fastening process. The Skinny Fixture uses contoured posts fully indexing the skins and stringers. The parts come in as individual components and are held to within ⌖0.25mm. No manual tacks or temporary fasteners are required.

Narrow profile posts fully integrated with the fastening machine allow customers and programmers to final fasten up to 80% of a panel without moving posts or pulsing a panel. To access the remaining fasteners the Skinny Fixture can be used as part of a pulse line or as a single cell with moving posts. Full fastener coverage is gained either by pulsing the panel to a mating line or moving each post during the process. With a pulse line, the second position posts would be configured to hold the panel in the previously fastened zone. When moving posts, clearance is instead gained by translating the posts in X by a sufficient distance to clear the unfastened region.

Introduction

In automated aerospace fastening there is always a push for improved product accuracy and speed. Electroimpact's Skinny Fixtures help achieve this by increasing a machines access to the panel resulting in an increase in the number of fasteners installed prior to post or panel move. Speed is increased by holding the panels in the tooled position for the whole process allowing the machine to run at higher speeds. Accuracy is improved with tighter tack spacing to each side of the posts ensuring stringers do not move once the indexes are removed.

Narrow post dimensions are based on rigorous analysis of the interaction between the fastening machine, fixture, and the aircraft parts. By designing around all three components, the most flexible and highest performing system is produced. The added flexibility in programming also allows for load balancing when using multiple positions, increasing time between tool changes.

Skinny Fixtures grant additional process improvements by reducing manual interactions. This is aided by permanently attaching many locating tools that have previously been applied manually and necessitate removal to complete the fastening process. Manually applied tools increase the chance of a machine crash and require machine stoppages for application or removal.

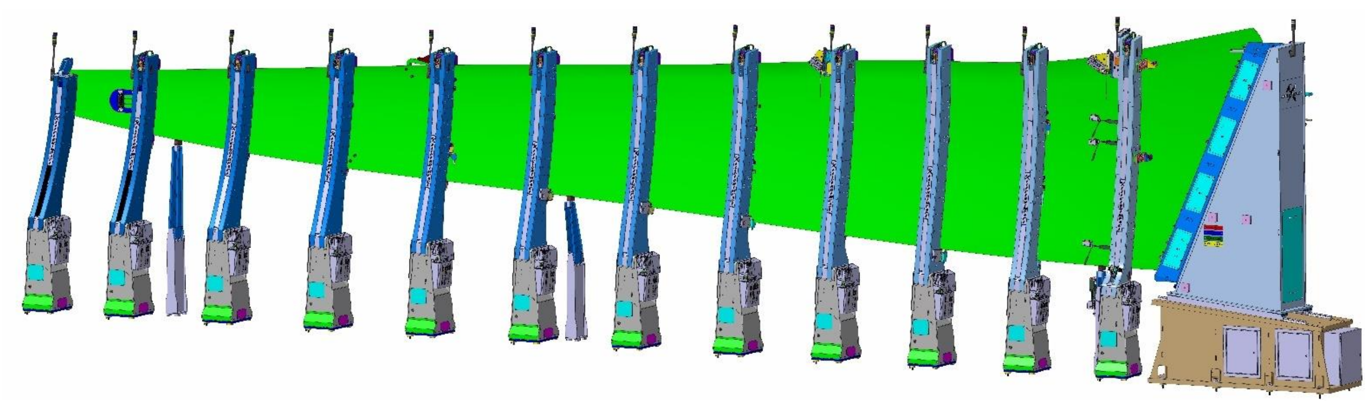

Figure 1 – Overview of the Skinny Fixture: Posts, Endgate, and Trailing Edge Indexes Shown

Maximum Fastener access in primary build position

The Skinny Fixture allows for up to 80% of the final fasteners to be installed while the aircraft part is held in the primary build position. Fixture posts are designed and built so that both faces of the board follow the contour of the panel at each location. This ensures that the machine can approach and fasten much closer to the fixture than previous panel build fixtures. Where the spanwise curvature is high the posts are also angled to follow the curvature.

Fully contoured narrow posts are coupled with a deep-drop machine tool to achieve a fully integrated cell. This allows the machine C-axis bearing to overlap the back of the post while drilling. The combined narrow profile, shallow contour, and deep-drop tools are what set this fixture apart.

To achieve the optimal integration the fixture and machine are designed and evaluated in concert. A single supplier source for both the machine and fixture allows for the highest level of integration. The skinny fixture goes beyond simple stay-out zones that are fixed at the start of a project. The communication and clash checking are conducted throughout the design process.

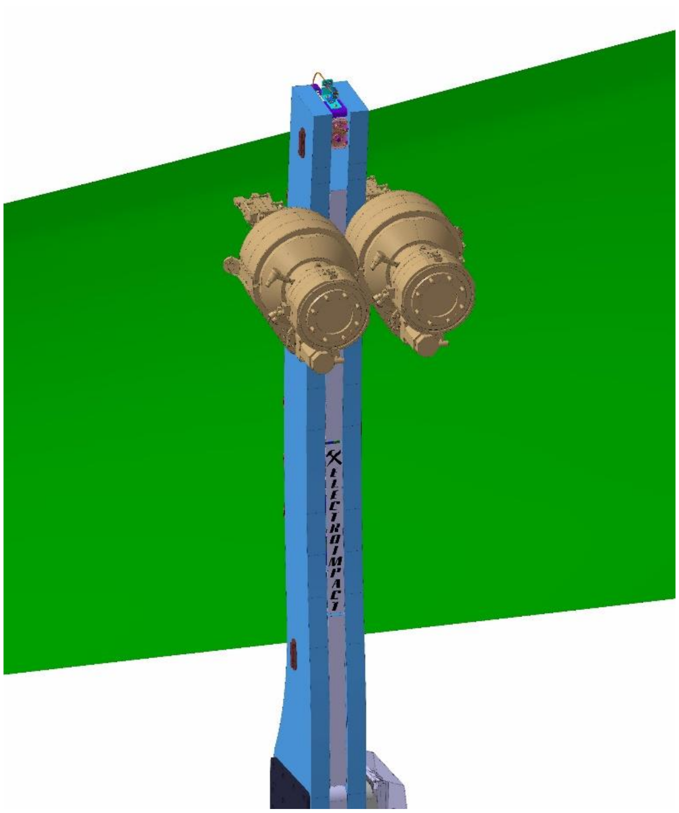

Figure 2 Skinny fixture post shown with representative panel and Stringer side machine head overlapping post on inboard and outboard side.

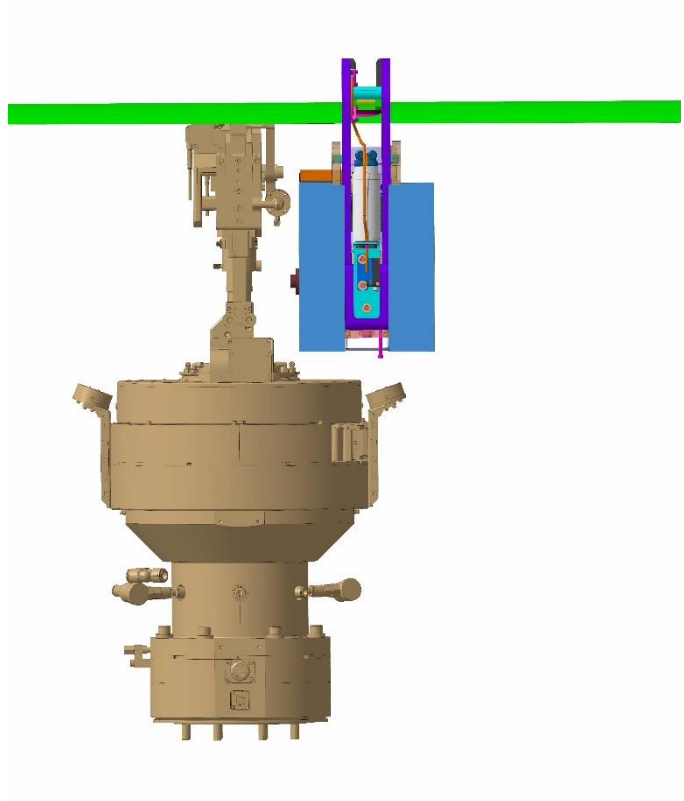

Figure 3 Top view of post shown with deep drop machine tooling fully overlapping back of post.

Field of Fasteners

Flexibility in programming and fastening is improved with the Skinny Fixture by increasing the field of fasteners accessible in the primary build position. In both pulse and moving post configurations performance is gained by maintaining large open areas. The large open areas allow the machine to reach many of the same fasteners in the primary build position, and in the subsequent positions or configurations.

When the factory is setup with fixed bases in a pulse line load balancing is possible. Load balancing allows the programmers to balance the workload between cells. Balancing ensures that production in any cell is never waiting for upstream or downstream cells. Balancing can be achieved because there are large numbers of fasteners that can be installed in either cell. In previous build lines many fasteners could only be installed in one configuration which reduces flexibility.

The improved fastener access of the skinny fixture allows for a pulse configuration. In the fully tooled position, all fasteners can be installed in the areas blocked by the second position. The second position fixture does not have the requirement to index the stringers as the stringers are tacked prior to the panel being removed from position one. Therefore, the second position can be made up of half as many posts. These posts are located in areas that can be fully fastened in the first position. The posts in the second position are located on the panel in areas between position one posts 1 and 3, 4 and 5, and so on. The combination of the reduced number of posts and the location of the posts in areas that are fully fastened allows for minimal interference between the fixture and the machine.

In a moving post configuration, the benefit of the skinny post is in the large field of fasteners allows for maximum run time prior to necessitating moving posts.

Speed

The fastening speed of the machine is maximized by reducing the obstructions of the fixture. Leaving large areas unobstructed by the fixture allows the machine to move quickly; limiting the number of large moves around the fixture posts. Going from one side of a post to the other can be time consuming. Reducing hops over the post helps overall machine fastening time. The depth of the post shortens the time required to complete the retract and translation around a post.

Increasing the accessible areas for any one configuration reduces the number of tool changes. Every reduction in number of tool changes results in a shorter total part runtime.

Tack Spacing

Prior to running the main fastening cycles a preliminary tack pass program is run to ensure the components do not move during the primary fastening pass. Ideally the tack fasteners will be evenly spaced and placed in areas that ensure part stability. The Skinny Fixture posts allow for tack spacings that are much closer together than conventional fixtures around a post. For the Skinny Fixture typical maximum tack spacing around a post is 380mm center to center. Whereas the tack spacing on previous fixtures with deep posts is greater due to the fact that the ram for the stringer side tooling must nest in next to the post to reach the stringers. The tack spacing on the previous fixtures is 760mm.

Reducing the tack spacing has the advantage of more accurately holding the components once the components are separated from the indexing features when pulsing or moving posts. Maintaining accurate predictable part locations improves part quality. It also improves downstream assembly quality and speed.

Another benefit of tight tack spacing is a reduced machine fastener cycle time. The tighter tack spacing means that components are located closer to their programmed location. When components are more predictable it allows for faster machine approach speeds and less corrections needed prior to machine clamp up stemming from better confidence in part location and form.

Pulse (Multi Fixture) vs Moving Posts

Two different factory layouts are possible with the Skinny Fixture. The Moving Post Configuration incorporates a bi-directional post translation. The translations move the post off the tooled location to gain access to previously blocked fasteners. The Pulse Cell instead uses a primary fixed build fixture and a secondary minimal part holding fixture. Each cell has a dedicated fixture and the part is moved with a crane from the first fixture to the second.

The advantage of a Pulse Cell is that the fixtures are simpler because neither position is required to move. The load time in the First cell includes loading all of the skins and stringers. The load time in the second position is greatly reduced as only one partially fastened panel is loaded. This allocates more time to fastening. With half the posts, there are less large machine moves and more clear space for continuous fastening. A balanced Pulse Cell will put about 40% of the fasteners in the first position and around 60% of the fasteners in the second position. The difference in fastener count is due to different load times, and the reduction of large machine moves around posts in the second position.

When using a Moving Post Configuration, minimizing floor space and minimizing part movement is prioritized instead. Any fastener can be installed at any time. The moving posts can be controlled by the CNC allowing for minimal operator interaction.

Applied Tool Elimination

The Skinny Fixture uses fixed locating tools in most locations where applied tools were previously used. In previous fixtures, applied tools were used to support the stringers where they ended in a location that was not adjacent to the post. Using fixed tooling in these locations decreases the probability of a machine fixture crash because the indexes are always in a predictable location. Replacing applied tools with fixed tools also decreases operator interaction with the tool reducing machine interruptions for applying and removing tools. The biggest advantage is reducing machine crashes which can cause damage to the tool, machine, or aircraft parts.

Aircraft parts can also be mis-indexed when the wrong applied tool is used in a location. Fixing the applied tools to the post minimizes that risk. The flexibility in fastener application mentioned previously is what allows use fixed tools where it is not normally possible on other fixtures.

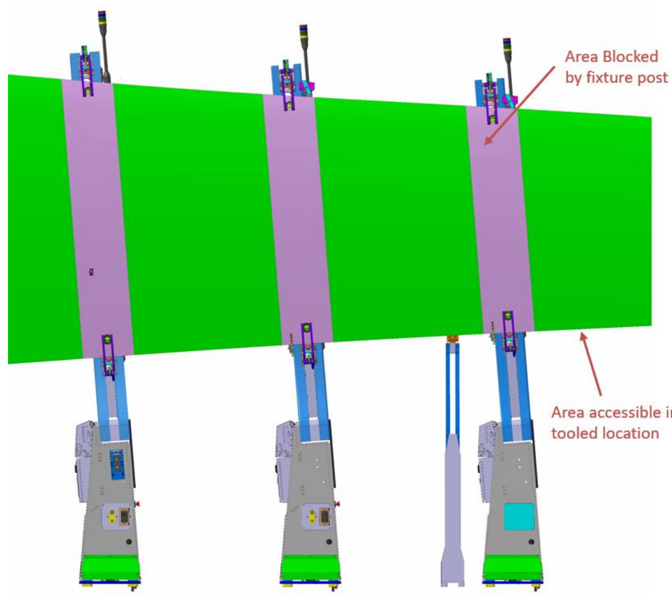

Figure 4 Fastener Access

Post Construction

The construction of the posts is based on a pair of machined aluminum contour boards sandwiching the stringer indexes all built on a steel base. The aluminum boards contain all the index and clamping features. These locations are machined into the posts. The indexes each have two dowel holes that match up to two holes in the board to allow for determinate assembly. The holes in the components are tightly tolerance to eliminate the risk of mis-locating the parts. The main advantage to the customer of determinate assembly is that index assemblies can be replaced without the need to reshoot the tool. The boards and indexes are machined and inspected to very tight tolerances to ensure replaceability of the indexes.

The sandwich construction allows for the smallest cross-section. The indexes are made of aluminum blocks that fit precisely between the contour boards. The stack is through bolted in a way that shear forces can be transferred through the index block. This arrangement gives us maximum stiffness with a minimal volume.

Assembly

Each post is constructed at the supplier facility and is shipped as a complete unit. Each index location is inspected for dimensional accuracy to the post prior to shipping. All of the controls for each post are contained within the steel base allowing for complete functional testing and documented inspection at the supplier facility.

Once complete and inspected, the components are packaged for shipping with little to no disassembly. The level of completion when the components reach the customer site reduces risk and schedule by ensuring minimal setup on site.

Customer Site Setup

On the customer site, the posts are positioned to a reference system. Setting can be done with three tooling holes on the side of the contour board. Final measurement and qualification are done by measuring each index block and recording the location.

Recertifications can then be done by verifying the tooling hole locations as the indexes are in a fixed position relative to the tooling holes.

Thermal and fastener Growth

As an aircraft panel is built up the length and height will change due to the installation of interference fasteners and thermal changes. In the vertical direction there is a parting plane across all of the tool features between steel and aluminum. Having a consistent parting plane with all components ensures the components grow at the same rate. Above the steel parting plane, the growth is driven by aluminum components matching the growth of the aluminum aircraft parts. The machine uses a resync target on the end gate to find the relation between the fixture and machine.

The parting plane does not address fastener growth. Fastener growth is experienced mostly after tacking. In the skinny fixture the vertical growth of the panel due to fasteners is allowed in two ways. The first is that the clamps have a limited force that will allow the stringers to push off the index. For any vertical indexes that are opposed to the other indexes a spring is used. The spring holds the index against a hard stop to ensure proper indexing until the time at which the growth loads the index significantly. The primary goal of the spring is to mitigate the possibility of jig locking or damaging stringers due to overloading.

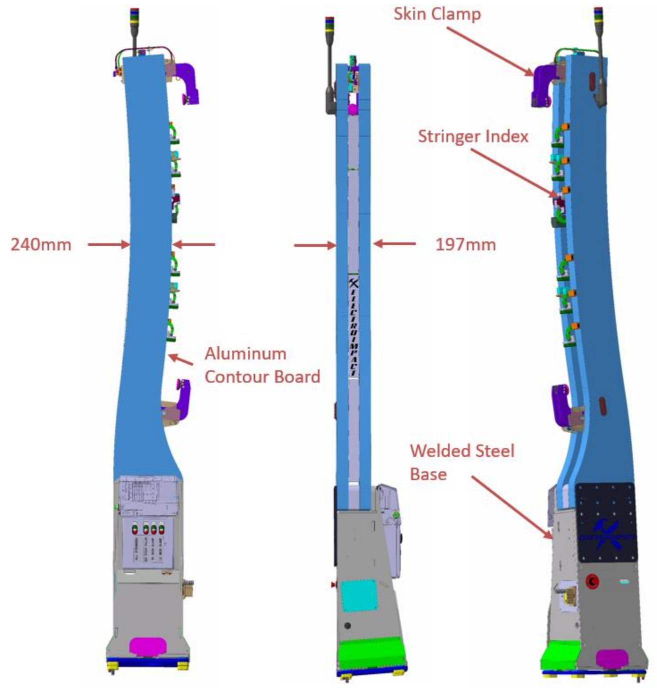

Figure 2 Fixture post constructionqmst

The growth along the length of the fixture will be greater than the vertical direction. Older fixtures have used aluminum beds and bases or linear rail to manage this growth. There are limitations and challenges with using those solutions to growth. Aluminum bases theoretically expand at the same rate as the panel, however the temperature variation near or below the floor and the elevated panel can be great. This temperature variation between the components negates the advantage of using the same materials. Using fixed bases on a steel bed requires a different way to manage lengthwise growth. Using linear rail adds complication and the rails can seize up if they are not cycled regularly.

For these fixtures the aircraft components are anchored at the root end of the fixture and then allowed to slip lengthwise through the Y and Z indexes and clamps. Analysis and testing was done to verify the correct index and clamp materials to reduce forces induced to the tool or aircraft components. This arrangement simplifies the fixture and provides robust allowance for growth. The hardened indexes are machined to very smooth surface finishes to protect the aircraft parts from damage when slippage occurs. The clamp components are made of plastics which do not mark the components.

The same considerations for growth could be used on any aircraft panel materials. To maintain the most accurate indexing with variable materials it would be recommended to maintain a consistent factory temperature.

Summary/Conclusions

The use of fully contoured fixture structure improves the fastening process of aircraft parts. Fully integrating the fixture, machine, and aircraft component results in many improvements to the production process. Improvements are found in tack spacing, tool changes, and reduced operator interaction.

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Definitions/Abbreviations

C-axis Rotary axis on stringer side tool. Allows rotation of the stringer side tooling to reach above or below the stringer webs.

One Up Assembly process where the parts can be fully fastened without the need to separate for deburr.

Determinate Assembly Dowel holes between two components allowing for assembly that defines relative position without adjustment.

Tack Fastening Initial fastening pass to ensure accurate positioning of stringers to skins before the primary (full density) fastening pass.

Pulse A multi fixture configuration where the Aircraft part is moved from one fixture to another after certain portions of the build cycle are complete.