

E7000 ARJ – Manual Flexible Tooling for Horizontal Riveting System

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Abstract

Electroimpact has designed and manufactured a flexible tooling system for the E7000-ARJ horizontal panel riveter. This tooling design accommodates panel sizes from 3.5m to 10m long, with a variety of straight and tapered curvatures. The tooling is re-configured manually and utilizes removable index plates that can be adapted to accommodate new panel types.

This type of tooling is ideal for value-conscious applications where a single machine must process a large range of panel styles. Electroimpact is currently using this system to tool 17 different styles of pre-tacked panels on a single E7000-ARJ machine. This flexible system does not require large removable form boards or custom frames that index one type of panel. Instead it uses 4 form boards that are permanently mounted to the picture frame by linear rails, allowing them to index anywhere along the 10m working envelope. Each form board holds several rail mounted surface indexes that are adjusted to accommodate different panel curvatures.

All index locations on the form boards and the sliding indexes are set by lightweight, removable, aluminum index plates. This allows for new index locations to be quickly added without the use of lifting equipment, and reduces storage area required for additional indexes.

The simplicity of the tooling and its ability to quickly adapt to new panel types allow this system to provide a large amount of flexibility at a low cost. This is an ideal solution for value-conscious applications where various panel types need to be indexed on a single machine.

Introduction

In 2013 Electroimpact was tasked with building a horizontal fuselage riveting machine for the COMAC ARJ-21. This regional jet is currently being built in China at the Xian Aircraft Company (XAC) factory with an almost completely manual process. With an emphasis on improving rivet quality and increasing rate, XAC ordered an E7000 Horizontal Riveting Machine and asked EI to develop a full tooling solution for all 17 panels of the ARJ Forward, Mid, Aft and Tail fuselage panels.

Tooling Concepts

To address the tooling challenge, Electroimpact looked towards previous solutions for this style of machine. It was decided that dedicated tooling frames (specific to each panel style) would require too many high cost welded/machined aluminum frames, as well as storage for these large frames. A concept using individual form boards that could be directly mounted to the part holding fixture was also explored. These form boards would be specific to panel curvatures, not individual panel styles, and would have movable edge clamps to accommodate different panel widths. For straight panels, this concept worked very well. However, with the complexity of tapered aft and tail panels and their unique curvatures, it was calculated that 50+ different form boards would be required. Again storage for these form boards became a concern, as well as the time it would take to re-configure the tooling for a new panel style. Because of their required size, these form boards would have to be loaded via crane or special lifting equipment.

Electroimpact decided to pursue a flexible tooling solution that could index any panel style, and would be easily and quickly reconfigured without the use of lifting equipment. EI currently utilizes this panel indexing style in semi-automated and fully automated “flex fixtures” used for indexing wing panels vertically in stage 0 cells. It was decided that a fully manual tooling solution for ARJ-21 would be developed, and the challenges specific to indexing a fuselage panel in a horizontal riveter would be addressed.

Machine Structure

The general machine structure of the E7000 is shown in [Figure 1: Machine Structure](#). The machine can be broken into 2 main sections: the gantry structure houses the X, Y and V axes, and the part positioner houses the rigid “picture frame” and the Z1, Z2 and A axes. The B axis is a simulated axis, and is adjusted

by varying the height in the Z1 and Z2 axes.

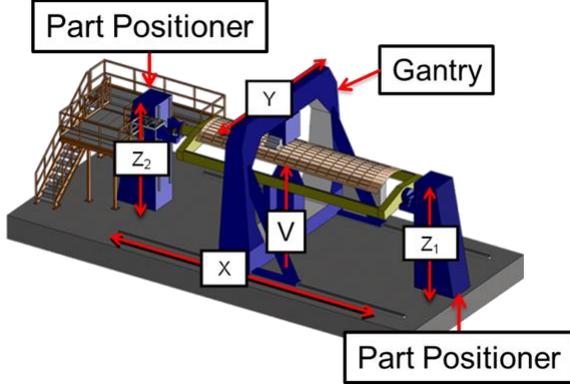


Figure 1: Machine Structure

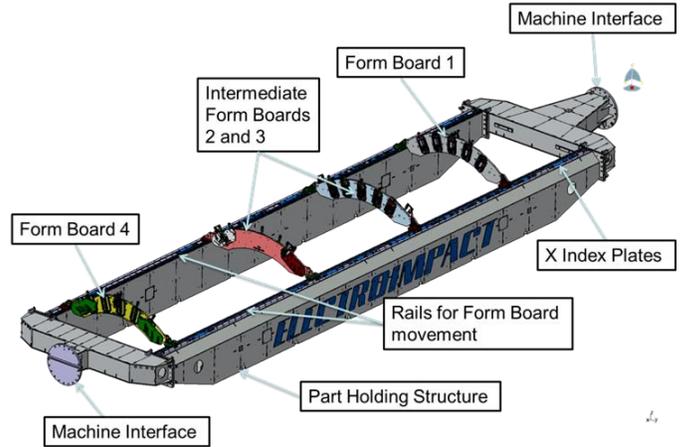


Figure 3: Picture Frame Components

Picture Frame Structure

The picture frame structure sits between the two part positioner towers and maintains the part's orientation during moves and drilling/riveting operations. The picture frame on the E7000 utilizes a large cross section and low weight construction to decrease deflection and increase natural frequency. These are both important factors in a horizontal riveting machine as the deflection of the part can lead to increased move and re-sync time, and low natural frequency increases the settling time of the part.



Figure 2: Picture Frame Structure

Rails that run the entire 10m of the working envelope of the Picture Frame are mounted directly to the structure. In addition, there are index holes drilled into the structure that are used to locate several aluminum index plates.

Adjustable/Flexible Tooling

The tooling for the E7000-ARJ flexible tooling is comprised of 3 main components that work together to index, hold and maintain a panel's curvature. These components are:

- Form Boards and X Location Plates
- Slider Indexes
- Panel Edge Clamps

To maintain flexibility, all indexed locations are set by removable aluminum index plates with pinoff bushings. Because of the quantity of different panel styles required to be tooled (x17), this was a key feature in being able to reach customer requirements. In addition, this style of indexing allows for new styles of panels to be indexed by making new aluminum index plates and replacing old ones.

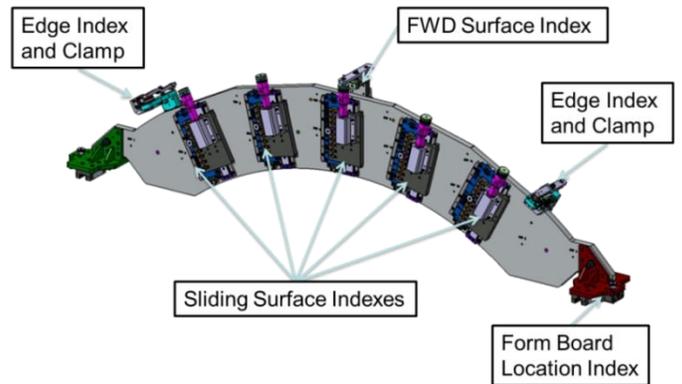


Figure 4: Form Board Components

Another key feature of the tooling is that all major components of the tooling stay permanently mounted to the picture frame. Once assembled, no large form boards or indexing frames need to be removed to tool new styles of panels. Only the small aluminum indexing plates need to be changed. The largest plate weighs in at approximately (3kg) or (6.6lbs).

Form Boards and X Location Plates

There are 4 re-configurable form boards that ride along linear rails mounted to the picture frame structure. These form boards are located in the X direction by removable aluminum plates with pin bushings that index directly to the picture frame structure. These form boards hold the slider indexes and edge

clamps.

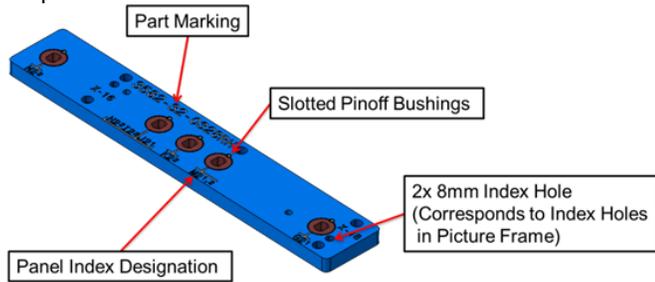


Figure 5: X Location Plate

Slider Indexes

Each form board is equipped with 5 sliding surface indexes that also move along linear rails, and index to removable aluminum plates with pins and bushings. These surface indexes are spherical and allow up to 4 degrees of angular adjustment. The contact spheres themselves are made of Delrin to prevent marring of the panels they index, and can be removed to accept a 1.5" SMR for tool setting. See [Figure 6: Slider Index](#)

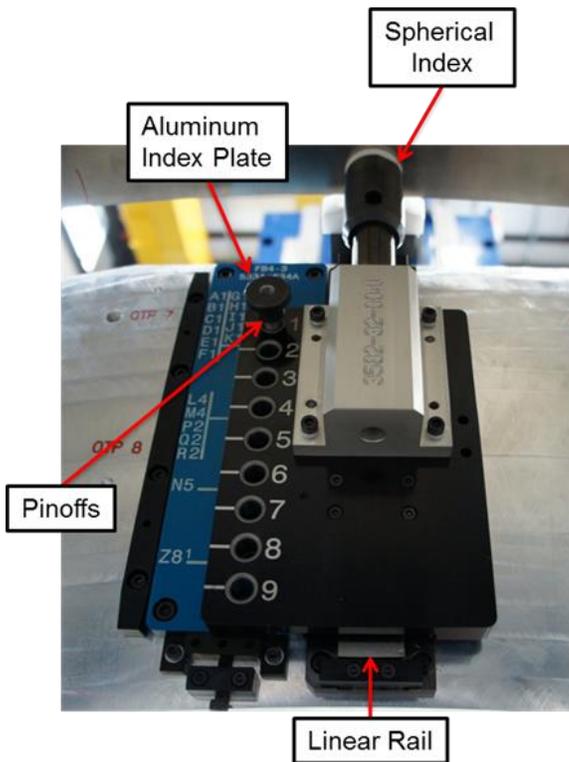


Figure 6: Slider Index

Because of the variance of locating positions for each surface index, a special system of variable pinoff positions is utilized. Each slider plate has 9 different pinoff locations that have a set 20mm spacing. The aluminum index plates allow any position along their 250mm length to be indexed to several locations on the slider plate. This allows the slider to use a very easy and fast pinoff system to index the surface index within a large range, to a high degree of accuracy. The difference between some of these positions on the E7000 is (0.1mm) or (0.0039in).

Panel Edge Clamps

In addition to the 5 slider indexes on each form board, there are also 2 edge clamps that feature both a surface index and a clamping arm. This ensures that at each form board location, the panel is being held firmly to its intended profile. These edge clamps are also located by removable aluminum plates using pins and bushings, and new index locations can be added by replacing the plates.

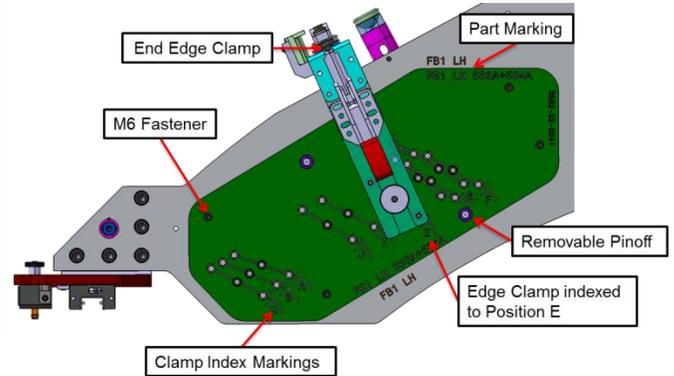


Figure 7: Indexed Panel Edge Clamp

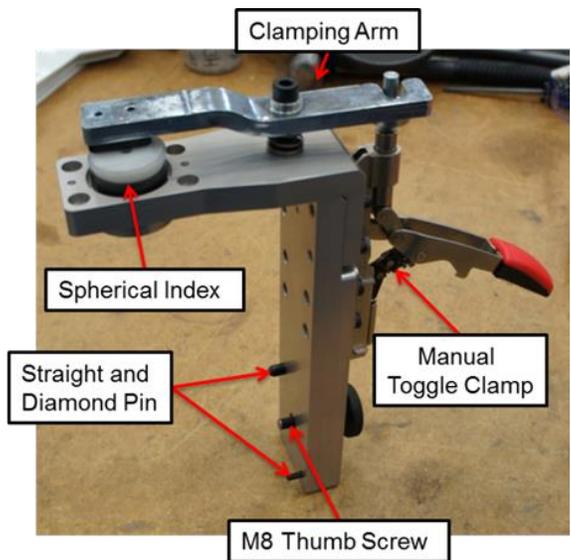


Figure 8: Panel Edge Clamp

Intermediate Form Boards

It is important to note that there are some minor differences between some of the form boards, their surface indexes and their edge clamps. This is due to the fact that the outer form boards (1 and 4) hold the ends of the panels, while the Intermediate Form Boards (2 and 3) hold the center of the panels.

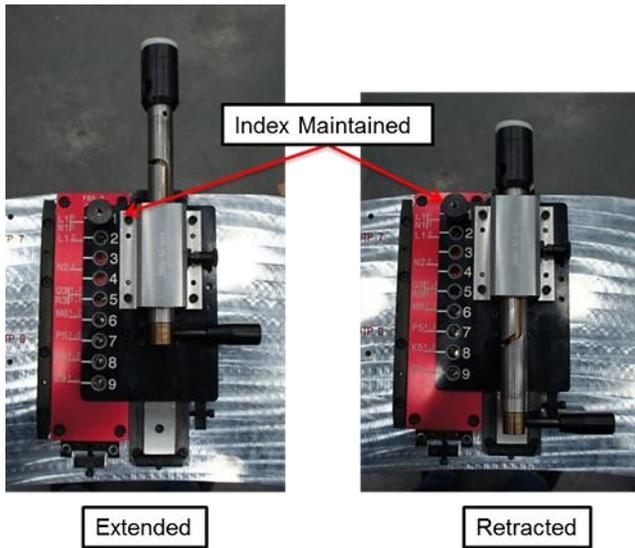


Figure 9: Intermediate Slider Index

Because they block panel fastener locations, the intermediate form boards are required to re-index between drilling cycles. As a result, they have several differences in design including:

- **Intermediate Form Boards have 2 Index Locations:** To allow the machine to access all parts of the panel, these form boards move to access two locations and re-index the panel.
- **Intermediate Form Boards are smaller:** To avoid stringers and shear ties when moving from one index position to another, these form boards have a smaller profile.
- **All Surface Indexes have a Retract Feature:** To allow for safer movement during re-indexing, all Surface Indexes on intermediate form boards have a retracting feature that allows them to retract (120mm) (~5in) from their index location, while maintaining a repeatable position. See [Figure 9: Intermediate Slider Index](#)

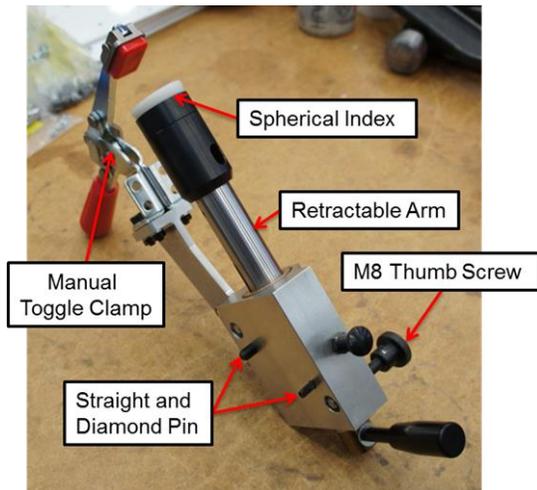


Figure 10: Intermediate Panel Edge Clamp

Benefits

The central focus of the E7000-ARJ tooling is value. This value not only stems from the reduced cost of the tooling, but also from:

- **Reduced re-configuration time:** Because all indexing relies on dedicated pinoff positions and easily removable aluminum plates, tooling changes are very fast and easy to complete. This reduced re-configure time is also tied to the simplicity and ease of use of the tooling.
- **Increase machine utilization:** By having a single machine index 17 different styles of panels, machine utilization can be greatly enhanced. The machine does not have to wait for a specific panel style to be ready for riveting; it can load any panel available.
- **Simple mechanical design:** Because the tooling is completely mechanical, and requires only re-pinning of indexes and manual toggle clamps, it is easy to use.
- **Increased maintainability over similar automated systems:** Along with the simple mechanical design and use comes simple maintainability. Any breakdowns and issues can be quickly diagnosed and fixed, in most cases without specialized personnel.
- **Reduced storage facilities for unused tooling:** As opposed to having multiple form boards or aluminum frames, the only storage required for this system is for small aluminum index plates. The largest one is (250mm x 550mm) (10in x 21in) and weighs (3kg) (6.6lbs). This also reduces the need for special equipment to remove or replace new index locations e.g. overhead cranes or special lifting equipment.
- **Adaptability for use with future panels:** The other added benefit of using small, removable aluminum index plates is adaptability. Because these small plates are easy to make, they are also easy to replace, adding new panel styles for the machine to process.
- **Use of common parts and assemblies:** Great emphasis was placed on using common assemblies. This means that only a limited number of spare parts need to be kept on hand in order to repair any damaged indexes.

Summary/Conclusions

The E7000-ARJ Flexible Tooling provides a simple yet elegant tooling solution for horizontal panel riveting machines. By focusing on ease of use, adaptability and maintainability Electroimpact has built a system that is not only capable of tooling a wide variety of panel styles, but will also reduce downtime and increase machine productivity.

References

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