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A TWO TOWER RIVETING MACHINE WITH A TRUE Z AXIS

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ABSTRACT

The A380 aircraft is the largest passenger aircraft ever built and an appropriate machine was required to accomplish the fastening of the wing plank to stringer and buttstrap joints. The lower wing panels are curved along the length and move 1.42m out of plane. All previous E4000 machines had clampup heads that would extend and retract whatever distance was required to contact the wing panel. To improve toolpoint alignment, Electroimpact added a Z-axis that moves the yoke in order to reduce the necessary travel envelope of the clamp table axes and to cause them to clamp in the same plane regardless of panel position along the Z-axis.

INTRODUCTION

A new design of gantry riveting machine is implemented for A380 which allows operation on panels with severe curvature. It is named the E4380. The target application is the A380 wing panels both upper and lower surfaces. Airbus UK has purchased eight of these machines. Four have been in production since April 2003. Two more machines are about to ship.

All of the E4000 machines feature a yoke that straddles over the wing panel passively gimbaled to one leg on the skin side and one leg on the stringer side. For previous versions of the machine when the wing panel moved away from the yoke centerline the opposing clampup tables would travel the necessary distance to contact the surface.

Functionally the new design E4380 machine shifts the overhand yoke in the Z axis such that clampup is always achieved at the same plane of the yoke. This improves machine maintainability since alignment is only required at one plane of the yoke. The machine can access a very large work zone of 4m vertically, 1.67m horizontal and 175m long as well as +/-15 degrees in both the A and B axes with a limited clamp up table stroke of only 25mm panel and 1m on the stringer side.

BASIC MACHINE CONCEPT

The machine gantry consists of two towers with a slideable arrangement between. Each tower is independently driven in the long X axis. See Figure 1. The yoke is trunnion mounted such that one side of the yoke is mounted to one tower and the other side is mounted to the other tower. By differential motion between the towers the B axis is created. In order to create this improvement the machine was redesigned with the yoke mounted on and sliding across the face of the towers.

Figure 1 Two tower riveting machine

There is also a Y axis on each tower sliding along the face. The yoke can be raised up and down four meters on these dual linear axes. By differential motion between the two sides in Y the yoke is tipped in the A axis. Note in Figure 4 that the Z axes on each tower do not remain collinear but stay parallel. In Figure 4 you can see the Z axis ballscrew that can shift the yoke 1.67m in Z. The Z ballscrew is ground, 63mm diameter. All axes on the machine have an absolute Heidenhein LC491F scale for secondary feedback except for the dual tandem X axis which uses dual Renishaw RG2 tape scales.

The wing fixture is in the center, vertically arranged. The yoke straddles the wing panel in order to access the fastener locations. Particularly the lower wing panel surface is not flat. The wing panel moves in and out of plane along the Z axis. On the ends of the yoke arms are the two clampup tables, the U axis on the skin side and the V axis on the stringer side. These clampup tables are driven towards and away from the skin and they meet each other at the skin surface in order to create the clampup condition. For the thicker sections the clampup pressure, loadcell controlled, can be programmed up to 3000 lbs. This clampup keeps the skin and stringer well clamped together and prevents interlaminar burs during drilling.

The opposing heads approach each other in order to create the clampup force. In previous designs of machines the opposing heads would meet at different planes across the width of the yoke. This is illustrated in Figure 3. Very precision alignment is required between the heads for LGP collar installation and in the PREVIOUS METHOD this had to be achieved over the entire range of U/V stroke. In NEW METHOD it is much easier to align the yoke at one clampup plane with the U axis always at the same position and the V axis position only varying by the stack range of the panel, 10mm – 60mm.

The A4380 machine has many superlative features. It weighs 160 tons. The machine fills much of a 10m cube. The machine installs rivets of all sizes between 0.25” and 0.5" diameter. The machine installs all sizes of LGP lockbolts in sizes between 0.25” and .5625" diameter. The yoke which the machines moves about so effortlessly weighs 15 tons.

MULTI-AXIS MOVES UNDER TRACER CONTROL

A unique feature of the E4000 family of machines is that they are fully programmed in six axes for all of the fasteners that they need to install. This means that the machine can be run fully automatically without sensors or tracers. Often the customer prefers the use of sensors and tracers to accommodate the build tolerances of the parts.

The E4380 machine tool is a dual 5 axis tool point with a C axis on one side. Due to the yoke the machine only requires eight axes (X,I,Y,J,Z,U,V,C) to achieve this configuration. The part programmer must only provide the five axes positions (X,Y,Z,A,B) for the skin side of the panel and the orientation of the C axis on the stringer side. The C axis typically is either 0 or 180 degrees, depending on which side of the stringer the fasteners are being installed. Of the six programmable toolpoint axes up to five may be constrained by the use of sensors on the skin side and also by a set of tracers used on the stringer side of the panel. Although the use of sensors and tracers is not unique to the E4380 nor to Electroimpact machinery the implementation and performance achieved is unique. When considering how to achieve normality with the addition of the new pure Z axis it was soon realized that the use of manual handle pulses to manipulate the toolpoint would not be possible due to the fact that there are only four manual handle axes available. With the addition of Z we would actually have to drive five to order to achieve normality and the desired offset from the work surface. Because of this fact, control of the toolpoint under normality control precluded the use of the standard G-code interface.

The normality sequence is as follows:

1. Sensors come on

2. U axis (skin side clamp table) comes forward to achieve the programmed panel offset (If the sensors touch the panel, Z is moved such that motion in U is cancelled and the tool point appears to remain fixed in space, meanwhile V (the stringer side clamp table), if extended, is moved to cancel the motion in Z).

4. Once the U position is established, the machine moves to achieve normality by moving the linear axes X, I, Y, J and Z. When normality is completed, the U side clamp pad will be at a programmed distance from the panel (typically 20mm), which will match the U-axis position, and the machine will be normal to the work surface. Note: if V is extended, any moves of Z during normality are cancelled by motion of V to insure that unintended collisions do not occur.

The tracer sequence is as follows (turn on both Y and V at the same time):

1. Once the tracers are extended and resting on the stringer the machine control achieves an edge distance from the stringer web (very loosely referred to as the Y axis but is orthogonal to the toolpoint vector) and an offset from the stringer parallel to the toolpoint vector is established.

The G1 style motion with sensors and tracers on:

1. The machine given a move command while constrained in four of five axes begins motion by commanding a segment based on the Acc/Dec, feedrate, latency of the HSSB/DNC hand shake, and position uncertainty. When the toolpoint approaches the endpoint of this segment (but before deceleration begins to occur) the sensors and tracers are evaluated:

2. The toolpoint A, B, Z, Y and V errors are determined

3. The rate of change of A, B, Z, Y and V are also determined.

4. Based on the above steps a new segment is commanded but now with the information from above we can take out the absolute error and make a good guess

based on the rate of change as to where the panel will be at the end of the segment.

5. As the tool point approaches the programmed position the target endpoint for X is commanded. Before the machine finishes deceleration the last check of sensors is completed and the last possible move without delaying the machine is commanded.

6. After all machine motion is complete one last check of the sensors is completed, if the sensors are not in the desired position, more moves are commanded…however this event is rare and normality is typically completed in the above step.

In the G1 style motion we are able to achieve normality, a programmed offset from the panel, edge distance from the stringer and backside tool offset as well as the target X position in the same amount of time that a normal five axis move block would take to execute. Normality and tracer control comes at no cost in time. Further normality and tracer control is much more accurate than on previous machines. Normality is controlled within .020 degrees and the other sensors are held to within .015" during motion and .005" when arriving at the end point.

In order to carry out the above algorithms it was necessary to change the method in which we controlled the machine. On the FANUC 15i we use a piece of hardware called the HSSB (High Speed Serial Buss). The HSSB allows the controls engineer to view and manipulate both the memory of the CNC and the PMC (or ladder) as well as DNC (or tape mode) functionality. The interpolation, normalization and all machine kinematics are run from a PC front end that drip feeds motion blocks over the HSSB to the FANUC 15i which is responsible for motion control and logic control. The NC programming continues to program in the simple X, Y, Z, A, B (+C) wing coordinate system, and the PC reads the part program, performs the reverse kinematics and sends enough G1 moves to the 15i (now in pure machine coordinates X, I, Y, J, Z, U, V, C) to provide adequate toolpoint path and feed rate control. This way Electroimpact is able to present a custom front end that matches the tool point of the part being built, a custom G-code style programming language which is much more flexible and readable than the G-code and custom macro combination typically used on other machine tools. Most importantly since the PC has 8ms access to the entire PMC map and 35ms access to the DNC buffer, precise fast and efficient control of the machine tool point under sensor control is achieved. Also, since the 15i is being sent very small G1 block segments from the PC, near perfect tool point path (under .0005" theoretically) and feed rates are achieved which is impossible using the standard G-code and custom macro functions.

CURRENT USE OF THE E4380 MACHINE

The E4380 is used in Broughton facility of Airbus UK. It is used in the new West factory built for the A380. There are four lines, two for upper panel (port and starboard) and two for lower panel (port and starboard). The lower panel lines are 175 meters long and the upper panel lines are 156 meters long (off to the right). The wing panel is split up into planks width wise. On each line are three panel fixtures. Panel 1 and 2 each have their own fixtures and panels 3 and 4 are fastened together in one fixture. So far the machines have produced six shipsets.

CONCLUSION

Due to the addition of the Z axis prior to the A and B gimbals the E4380 is able to achieve much better toolpoint alignment on panels featuring more curvature and depth than previous machines had to accomodate. The Z axis caused Electroimpact controls engineers to move away from the standard G code/macro program approach for controlling the machine toolpoint. Auxiliary benefits include a higher speed normality solution, an improved interface as well as improved toolpoint control.

CONTACT

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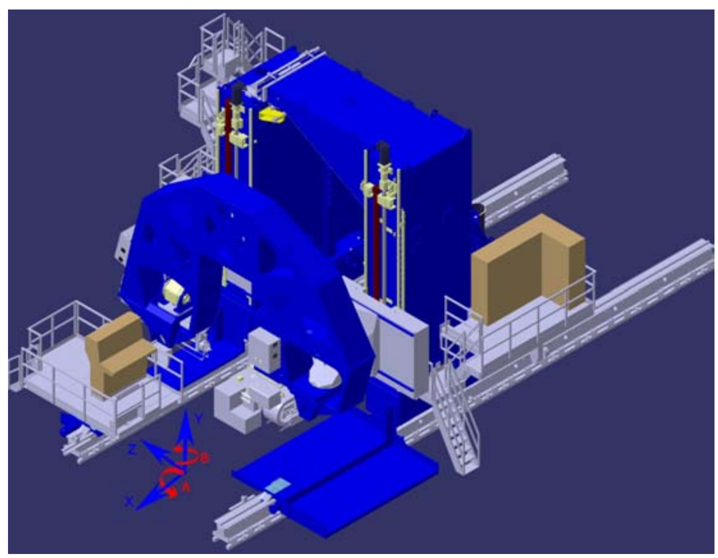
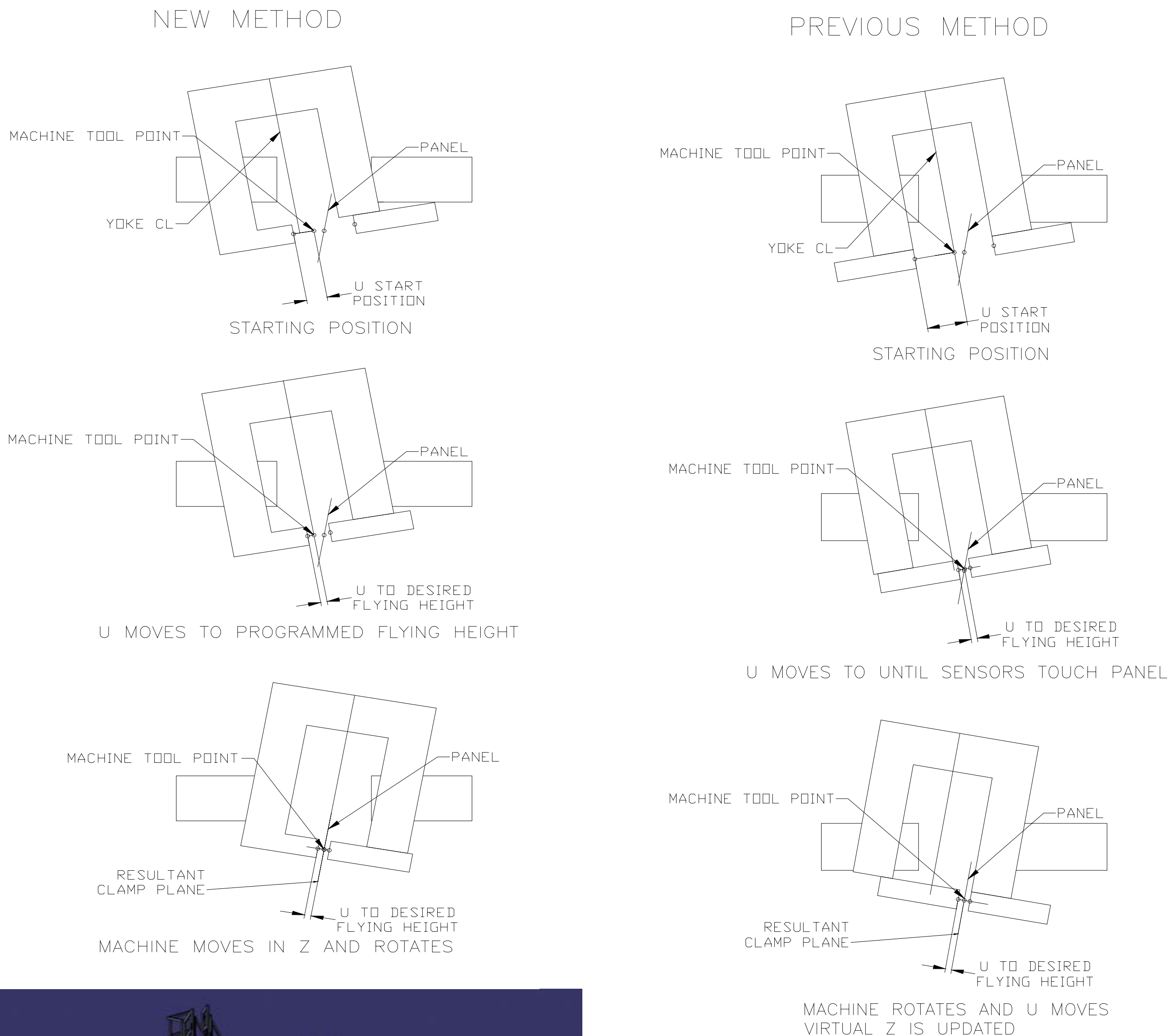


Figure 2 Yoke in the A=B=0 position

Figure 3 Yoke motions for normality in the new E4380 and the previous



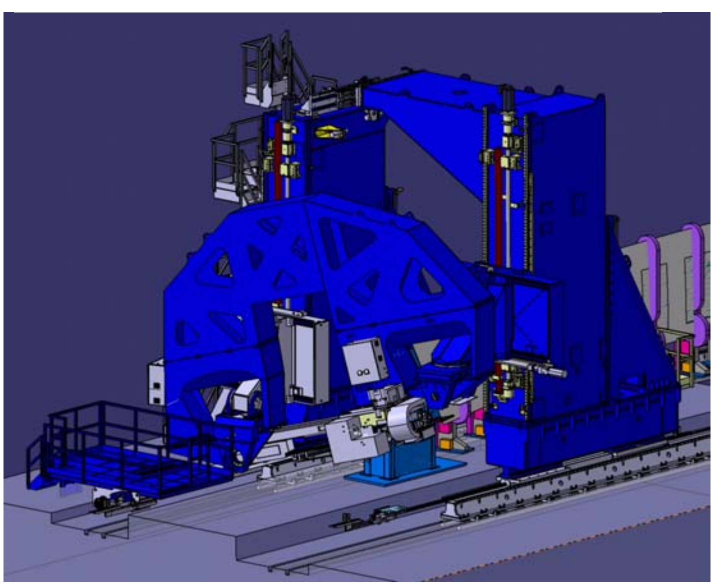


Figure 4 Machine rotated with A=B=15 degrees