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Wing Assembly System for British Aerospace Airbus for the A320

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ABSTRACT

British Aerospace needed an automated wing riveting system for fastening the A320 wing sections. The E4000 Wing Riveting System was designed and installed at their Airbus factory in Chester, UK and is now in production. It uses a five axis solid yoke with workheads on each end of the yoke. It accurately installs both rivets and lockbolts over the entire wing panel, including offset areas.

INTRODUCTION

The first application of the E4000 yoke assembly machine cell is on the A319/A320/A321 upper wing panels. The machine has built a pair of A320 upper wing panels. A second set is nearly completed as of this writing.

In the E4000 assembly cell detailed parts are loaded into the cell. These detailed parts include seventeen stringers, two skins, a buttstrap and a pylon reinforcement. These parts load into the clamping details of the wing panel holding fixtures, both port and starboard. The E4000 machine then runs across the fixtures, drills critical holes and installs all of the permanent fasteners. When the wing panel is removed from the fixture all of the assembly work is complete.

FACILITY

a. The machines and fixtures sit on a dedicated foundation provided by BAe. The foundation is sixty-six meters long with features for mounting the machine rails and the two fixtures (port and starboard).

b. The facility includes two upper wing panel fixtures, a port and a starboard.

c. There are two parallel sixty meters runs of levelable precision bedrail, fifty-six meters of continuous Renishaw RG2 scale on each bed, IKO precision recirculating roller bearing and ground rack. The bedrails straddle and run along both sides of the fixtures.

d. The E4000 riveting machine runs on the bedrail.

e. There are floor plates surrounding the machine and fixture.

f. There is an offline fastener feed system.

E4000 ASSEMBLY MACHINE KINEMATICS

The E4000 machine is designed to access the entire surface of the wing panel for drilling holes and installing rivets and lockbolts. Each wing panel is fifteen meters long and three meters in width. The width of the panel is the vertical height that the machine must traverse since the panel is placed vertically in the fixture.

The E4000 machine is capable of accurate positioning of the toolpoint. On the E4000 machine the toolpoint is the point where the drill first touches when entering the skin. The E4000 is designed to locate this point within .008" over the work envelope of the machine.

The E4000 machine utilizes a solid yoke that is articulated in five axes. By rotating the solid yoke the alignment between the opposing heads is maintained. Correspondingly, the work axis of the yoke is horizontal. The E4000 machine can rotate the yoke +/-15 degrees in A and B to keep the drilling axis normal to the wing panel surface. Rotation of a solid yoke provides precision alignment between the opposite heads. Alignment within .007” is required for reliable collar loading, and it is achieved. The yoke is employed as the engine of alignment and clampup.

The yoke is connected by two trunnions that attach near to the extreme points of the yoke. By attaching the trunnions near to the extreme points the stability of the yoke is enhanced. Each trunnion features two perpendicular passive rotary axes. One of the rotary axes is for the A axis, the second is for the B axis. The trunnions are supported by the gantry. In addition the trunnion on the stringer side features a passive length change slide.

The gantry has two independent X axes, one on each side of the wing panel. In addition, the gantry features two separate Y saddles that also straddle the wing panel. When the two gantry X axes move in unison the yoke translates in X. When the two gantry X axes move differentially the yoke rotates in B.

The motion is similar for the two Y axes. Parallel motion causes a Y translation of the yoke. Differential motion causes the yoke to rotate in A. A figure is enclosed which illustrates the resulting kinematics.

The servo axes of the E4000 machine are as follows:

AXIS	SIDE	DESCRIPTION	FEEDBACK
Xm	skin	gantry rack tandem master	RG2
Xs	skin	gantry rack tandem slave	tandem
Im	stringer	gantry rack tandem master	RG2
Is	stringer	gantry rack tandem slave	tandem
Ym	skin	vertical ballscrew master	Heidenhein
Ys	skin	vertical ballscrew slave	Heidenhein
Jm	stringer	vertical ballscrew master	Heidenhein
Js	stringer	vertical ballscrew slave	Heidenhein
U	skin	head in/out for 2000 lbs of clampup	Heidenhein and load cell
V	stringer	head in/out for 2000 lbs of clampup	Heidenhein and load cell
C	stringer	anvil rotation	motor encoder
K1	skin	EMR in/out	motor encoder
K2	skin	hole probe in/out	motor encoder
E	skin	shuttle table linear motor, 2m/sec transfer speed	Heidenhein
W1	skin	spindle #1 feed	Heidenhein
W2	skin	spindle #2 feed	Heidenhein

In addition to the above listed real axes, the E4000 also features three virtual axes. These axes respond to motion commands and are displayed on the CNC but are actually the result of calculation.

Table 2: E4000 machine virtual axes

A	yoke A rotation, ARCTAN[(Y-J)/192"]
B	yoke B rotation, ARCTAN[(X-I)/192"]
Z	Z plane of workpoint from yoke center

Table 3: E4000 spindle drives

S1	spindle 1, 13,500 RPM, HSK 50 hydraulic collet with Ott-Jacobs power drawbar
S2	spindle 2, 13,500 RPM, HSK 50 hydraulic collet with Ott-Jacobs power drawbar

As already mentioned, the X axis is 55 meters long. The Y axis is 3.55 meters, although some of this height is sacrificed to allow for A axis rotation.

E4000 WING PANEL HOLDING FIXTURES

Elements of the fixtures include:

a. Fixture bases which can be precision leveled

b. Upper beam on each fixture

c. 14 rotating headers on each fixture

d. Stringer clamps and buttstrap grippers are mounted on the headers

e. Slider for the inboard end

f. Stringer inboard locators are mounted on the slider

g. Slider moves out of the way to permit unloading

h. Skin straps to pull in panels, air motors pull in straps

The fixture is designed so that every location on the panel can be accessed. This is achieved by the rotating headers. As illustrated the stringer side head is 14" wide. The dimension to the inside surface of the rotating header is eight inches. Therefore, coming from either direction the stringer side head can rivet up to the centerline of each rotating header.

E4000 PROCESS TOOLS

As shown in the attached photo the shuttle table on the skin side carries seven tools. All of the tools on the skin side remain permanently attached with the shuttle table, which uses a high speed linear motor to transfer from tool to tool. The shuttle table positions on the skin side are as follows:

a. EMR

b. bolt inserter

c. sealant applicator

d. spindle 1

e. spindle 2

f. hole probe

g. resynch camera

The stringer side has multiple anvil setups. The anvil setups have side tooling to perform the necessary functions. Stringer side tooling is shown in the photo. The various stringer side tools are listed in Table 4. The stringer side anvils attach to a spring loaded crash base which freezes machine motion if the anvils are deflected to the side or outward.

Table 4 E4000 stringer side tooling

ANVIL	FUNCTIONS	SIDE TOOLING
drill only	drill only	V tracer
shallow offset	rivets, 5/16 collars	Y/V tracer, double hit, collar feed
deep offset	1/4 collars	Y/V tracer, collar feed
straight	1/4 and 5/16 collars	Y/V tracer, collar feed

The sequence for installing a rivet is as follows:

a. clampup

b. drill and countersink

c. feed, measure rivet and upset rivet with EMR

d. double hit if required

e. shave

The sequence for installing a lockbolt is as follows:

a. clampup

b. drill and countersink

c. probe hole

d. apply sealant to hole

e. feed and measure bolt

f. feed collar

g. drive bolt

h. swage collar with EMR

MANUFACTURING PROCESS

a. Stringers, buttstrap and pylon reinforcing are loaded into the clamps. All rotating supports are initially closed.

b. Sealant is applied at the rib bays and at the stringer ends.

c. Two skins are loaded in. The lower skin sits on the trailing edge locators and is pushed in by removable pushers. The upper skin is attached to lugs and is slid in and the gap then adjusted. Skin straps press the skins up against the stringers.

d. The E4000 machine runs over the panel and installs rivets and lockbolts to stabilize and hold firm all of the sealed areas. This includes fastening of the buttstrap.

e. Precision 5 axis drilling is performed on the inboard end. Only the U side head is engaged for the inboard hole drilling. The U side head presses the panel up against the fixture. The inboard pattern is employed when the wing panel is attached to the center wing box.

f. After the seal pass is complete the skin straps are removed and the production pass begins. Headers are rotated out of position to create 48” wide bays. The bulk of the rivets and lockbolts are installed.

Some of the fastener locations utilize sensors (there are six sensors, four skin side normality sensors and a two axis stringer side tracer). Some are located under CNC control.

CONCLUSION

The E4000 Wing Riveting System has provided British Aerospace with a flexible automated assembly method which assists in meeting ramped-up Airbus production schedules. Its centerpiece, the five axis solid yoke with workheads on each end of the yoke, accurately and effectively installs both rivets and lockbolts over the entire wing panel surface including offset areas.

ACKNOWLEDGMENTS

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Figure 1: Overall view of cell

Figure 2: Operator view of machine

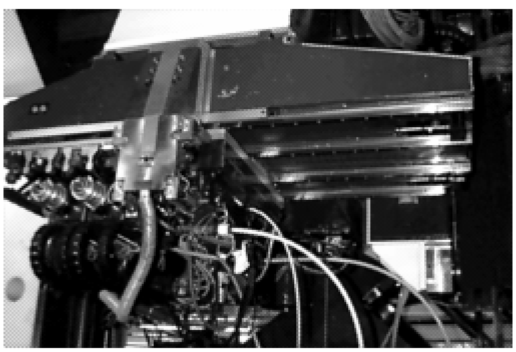

Figure 3: Skin side workhead on panel

Figure 4: View of completed panel

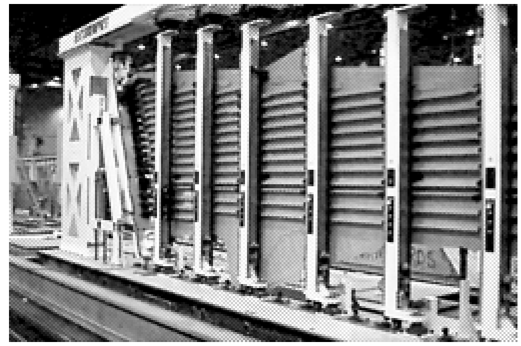

Figure 5: stringer side view

Figure 6: skin side workhead

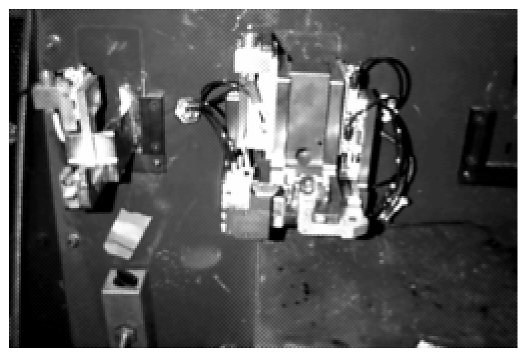

Figure 7:   stringer side anvils

Figure 8: E4000 installs offset fasteners

Figure 9: Cartridge fastener feed system

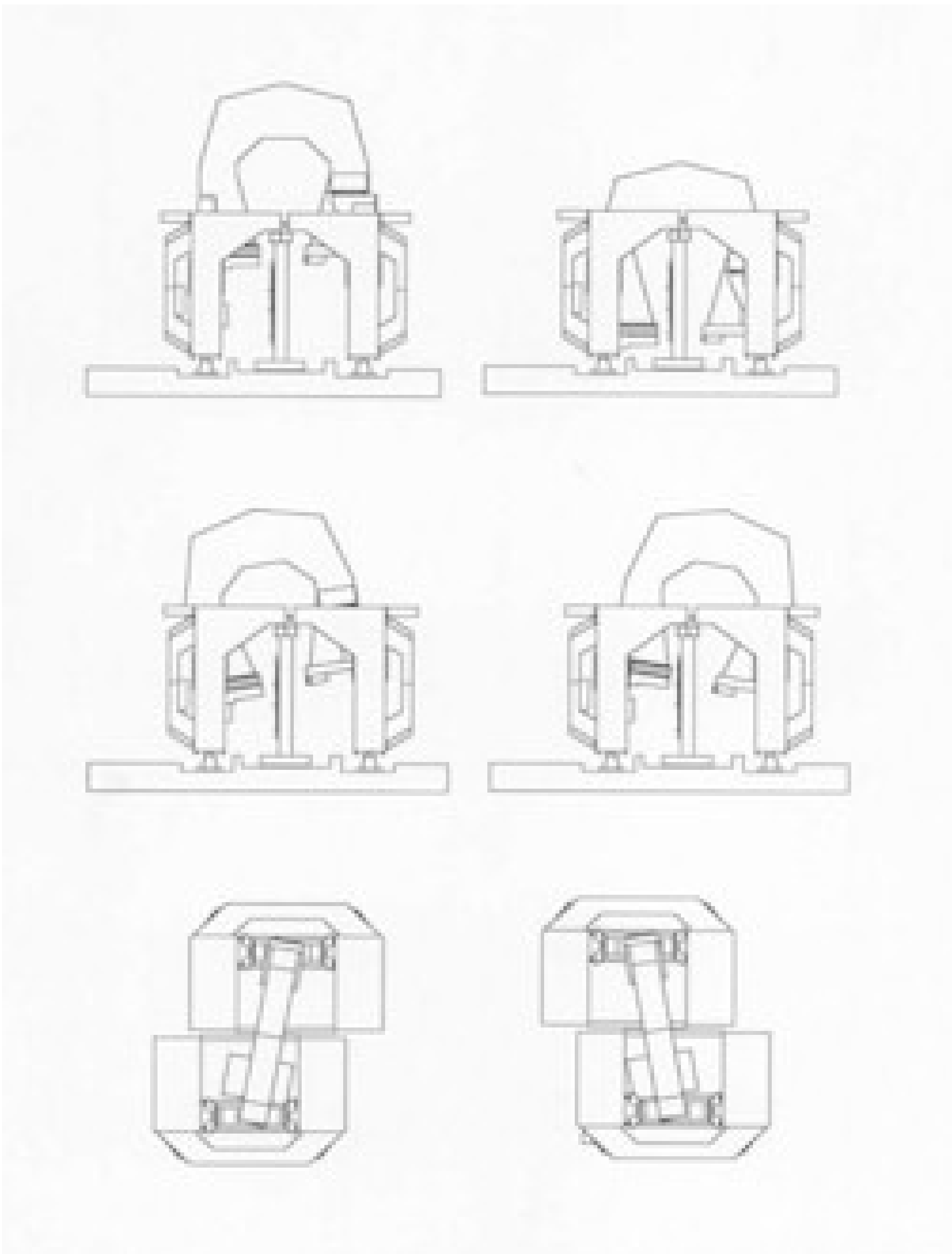

Figure 10: E4000 Machine Kinematics

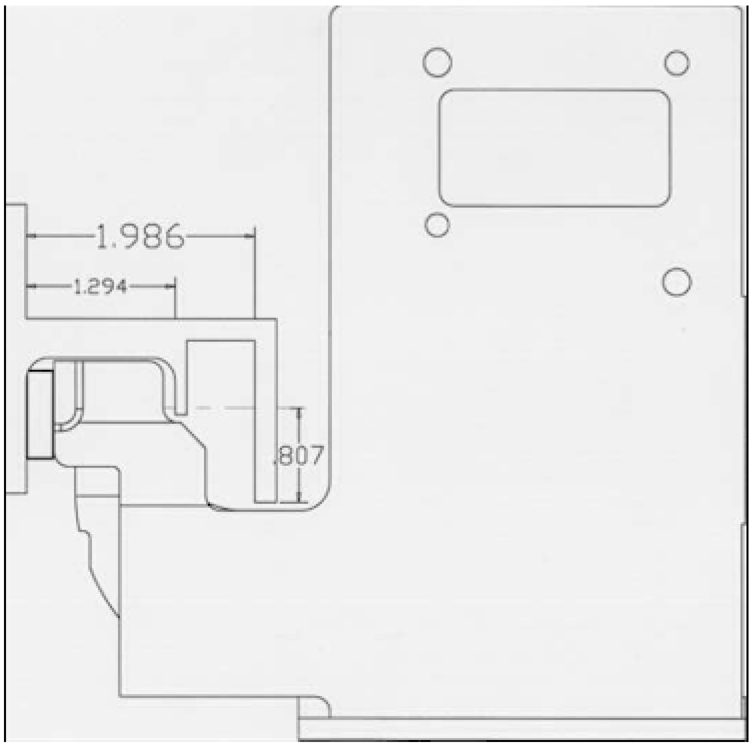

Figure 11: Anvil inside of offset stringer

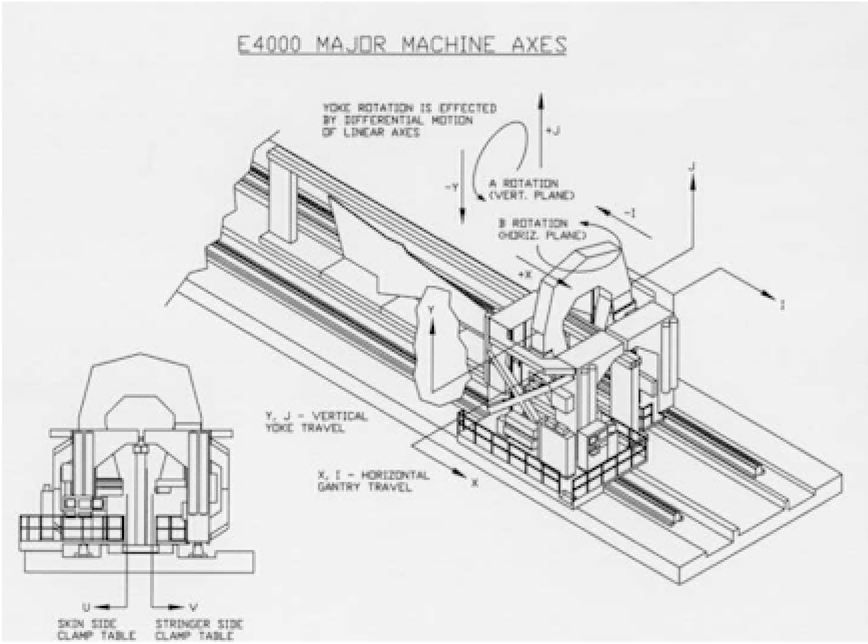

Figure 12: E4000 Machine View

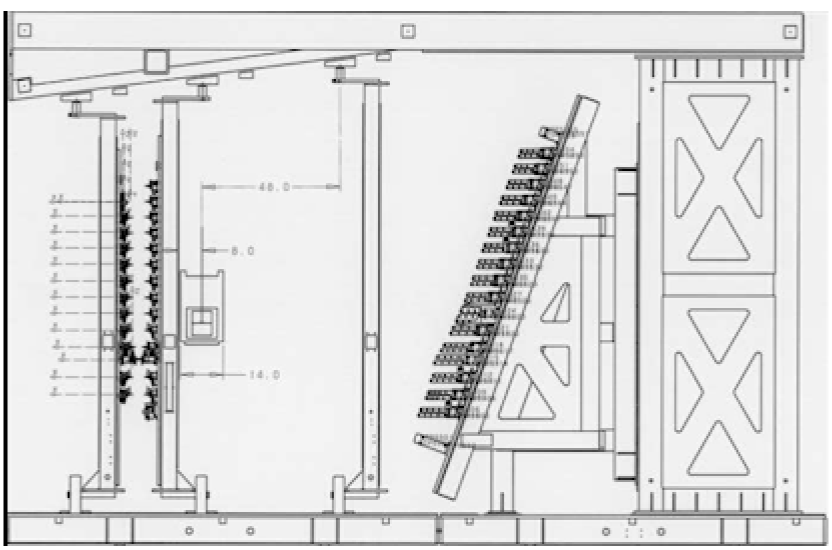

Figure 13: String side head clears the rotating support. Rotating supports provide a 48" wide workbay.

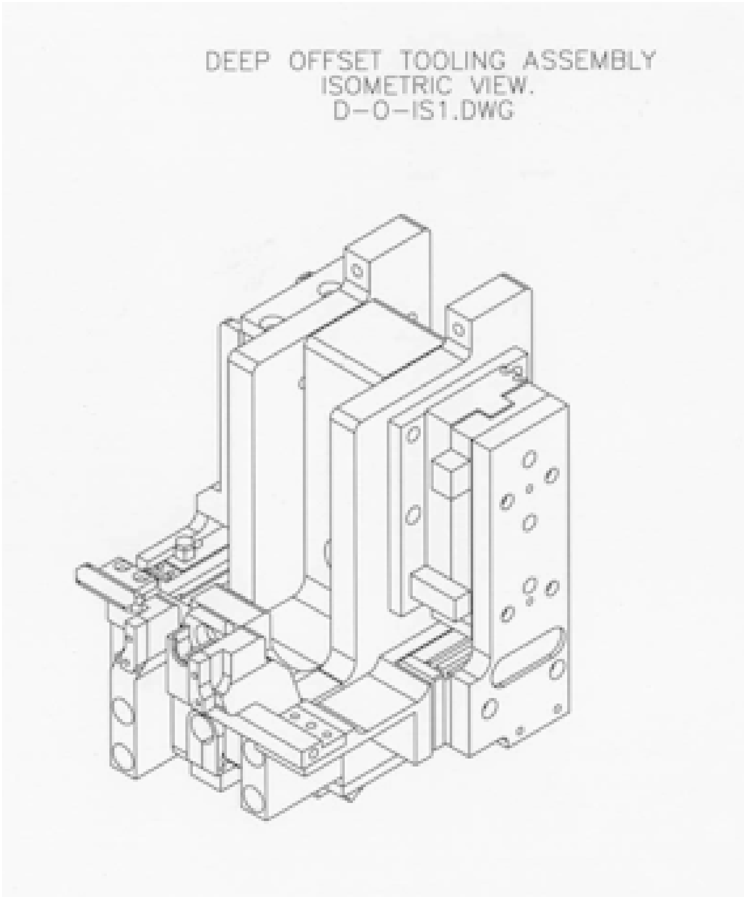

Figure 14: Offset anvil

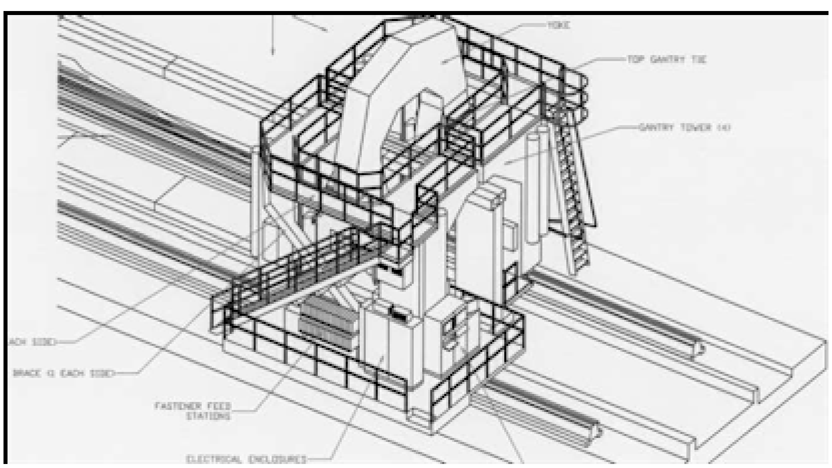

Figure 15: E4000 machine view