Implementation of the HH550 Electromagnetic Riveter and Multi-Axis Manlift for Wing Panel Pickup

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ABSTRACT

A new wing panel riveting cell capable of replacing tack fasteners and performing small repair jobs has been developed. Using two mobile scissor lift platforms with electromagnetic riveters mounted on each, the operators can access every portion of the wing panel without the use of ladders or platforms. This method minimizes fatigue, allows workers to carry all tools and supplies with them, meets current safety standards and minimizes coldworking of the components.

INTRODUCTION

In 1993, the 767 wing line submitted a request to Facilities to provide a new wing panel riveting cell capable of replacing tack fasteners and performing small repair jobs. These tasks were being worked in the Panel Pickup area, but the pneumatic riveting gun and bucking bar method was very loud and caused an extremely high incidence of wrist and hand injuries. The new cell would need to make significant strides towards noise abatement and reduction of wrist and hand injuries such as carpal tunnel syndrome. Another concern with the existing multi-decked panel pickup cell was the difficulty in accessing the entire panel. Easy access to the entire panel would be a critical design goal.

Boeing looked to Electroimpact to implement their hand held low voltage electromagnetic riveting (LVEMR) technology. This would be the first use of the LVEMR on a Boeing wing panel, so there would be many challenges.

Electroimpact would be responsible for design, fabrication, installation, and implementation support of the new system. The turnkey system would include the LVEMR guns, tooling, and a positioning system that would allow the mechanics to reach all areas of the 767 wing panels. It would need to be safe for both the operators and the Boeing workpiece. Since available space on the factory floor was limited, Electroimpact would need to minimize the amount of space required for such a cell.

DESIGN AND SPECIFICATIONS

A wing riveting cell was required for the replacement of tack rivets on the four 767 wing panels. In the current practice of wing manufacture tack rivets are employed every 18” along stringers. In previous practice tack rivets were replaced in a wing panel pickup station. In the pickup station workers used hand tools to drill up the holes. Temporary fasteners were replaced with permanent using conventional pneumatic riveting tools.

The customer wanted to use the HH550 handheld EMR gun on a motorized mobile platform. The reason for the use of the mobile platform are as follows:

1. The mobile work platform allows workers access to every portion of the wing without changing levels, climbing on platforms and the like.

2. The worker is able to carry all of his tools, fasteners and equipment with him as he works his way down the wing panel.

3. Fixed work platforms require a considerable amount of work at less than optimum posture, including crouching and working overhead.

4. In the previous panel pickup station sliding floor plates were utilized to provide clearance on both sides to the wing panel for manual work and loading. These needed to be improved to meet stiffening safety standards and this requirement provided impetus to explore the manlift concept.

The HH550 is the largest handheld EMR built by Electroimpact. The reason for the desire to use the HH550 are as follows:

1. The HH550 makes less noise than a conventional handheld riveter.

2. Due to the one-shot action use of the HH550 produces less operator fatigue.

3. Plans were developed to eliminate coldworking when the HH550 was utilized. This eliminates a difficult and costly step in the manufacture of wings.

Due to the 240 lb. weight of the HH550 it is not feasible to use it without the lift to provide a counterbalance for the weight.

In addition, all of the HH550 support equipment is carried along on the lift. Due to the large amount of required support equipment the man-lift provides the only practical means to utilize the HH550. Therefore a synergy developed, to produce a man-lift to simplify pickup work which can also carry the HH550.

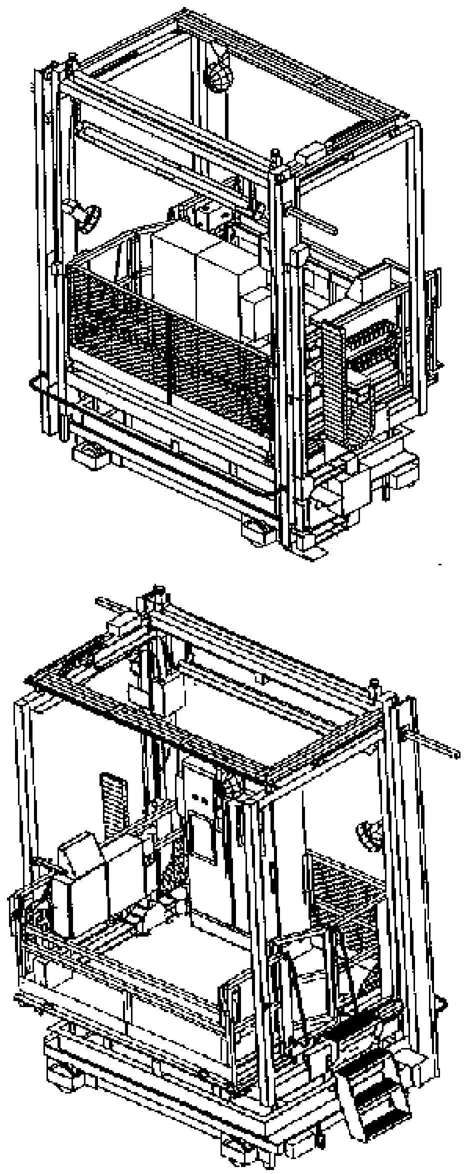
A third project task was presented. A unique wing panel holding fixture was required. To conserve floor space the upper left and lower right wing panels were held in one fixture and the lower left and upper right were held in a second adjacent fixture. The fixture used steel upright posts and the lifts had to be able to jog around them.

DESIGN OF THE LIFT FOR THE 767 WING PANEL

The 767 mobile platforms, which are illustrated in Figure 1, were designed with special components and several features that facilitate their operation. They include a solid drive base, a heavy duty scissors lift table, side mounted anti-sway beams, a floor guided cable track, an extendible work platform, an upper lift table, a manual down valve and an overhead EMR gantry.

Base: A schematic of the base trolley is shown in Figure 2. The base design began with a 4x4 steel tube frame underneath a ¾" hot rolled plate. Flange bearings were bolted to stand-offs below the tube while a drive and idle axle were added to either end of the base. Steel v-wheels provide motion in the x-axis. A squirrel cage motor with a variable frequency drive was used for variable speed travel along the wing panel. The motor drove a hollow shaft reducer which mounted on the axle. A fixed wheel on the panel side of the lift insured that the position relative to the panel would stay fixed, while a floating wheel on the rear of the lift allowed for variations in the rail-to-rail distance. A floating wheel drive mechanism was conceived and tested to permit two-wheel drive, but it proved to be unnecessary, as slight floor height variations were accommodated by flexing in the base.

Figure 1. Front and Rear View of Manlift



Scissors Lift Table: A heavy duty scissors lift was designed and built for vertical motion by Southworth Products of Portland, Maine in conjunction with Electroimpact. A 7-1/2 horsepower squirrel cage motor provided positive power to the hydraulic pump which operated the twin hydraulic cylinders. Velocity fuses (excess flow valves) were mounted directly on the cylinders so that a hydraulic line failure would cause the lift to lock in place at its current height.

Side Mounted Anti-sway Beams: All conventional scissors lifts share a tendency to sway in one axis due to the geometry of the leg sets. This sway increased with the height of the lift and was unacceptable in the application due to the possibility of contact with the wing panel. Sway was also undesirable due to its negative impact on the operators.

Electroimpact's solution to this problem was a vertical anti-sway I-beam mounted on each end of the base (see Figure 3). Two linear bearing cars were bolted to it about two feet apart. A vertical tube was mounted to the upper lift table, and in turn, a linear bearing was mounted on the tube. This arrangement stiffly resisted any tendency to sway even at the full 12-foot vertical extension.

Cable track: Power is provided to the base via a 110' floor mounted cable track guided in a custom trough.

Extendible Work Platform: The application required approximately two feet of platform travel to alternately place the operator up against the wing panel and then jog back and around the fixture posts. Platform motion was provided by a rack and pinion drive mechanism and cam followers, driven by a 1/3 horsepower gear motor. The possibility of collision with the wing panel led to the use of a horizontal ribbon switch along the entire length of the platform, while two vertical switches added to the protection. The platform is conveniently controlled by the operator either from the steering box or from a thumb switch mounted on the HH550 handle.

The platform was designed with the operator in mind. Lift controls are close at hand, lubricated air and dry air outlets are available on the platform, 110 VAC outlets are at the operator's feet, and an overhead light insures good visibility of the work area. A second lamp, mounted near the operator's feet, is used on the stringer side lifts to remove shadows cast by the stringers.

Upper Lift Table: A steel tube frame was bolted to the upper scissors deck, forming the "upper lift table". This frame became a mounting surface for the overhead gantry, overhead lights, junction boxes and conduit, as well as the anti-sway linear rail previously mentioned.

Figure 2. Mobile Lift Base

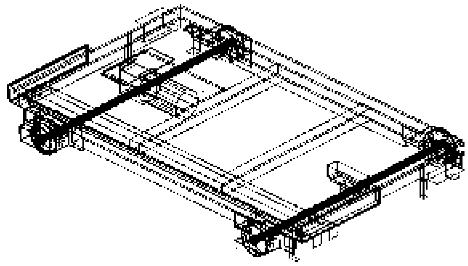
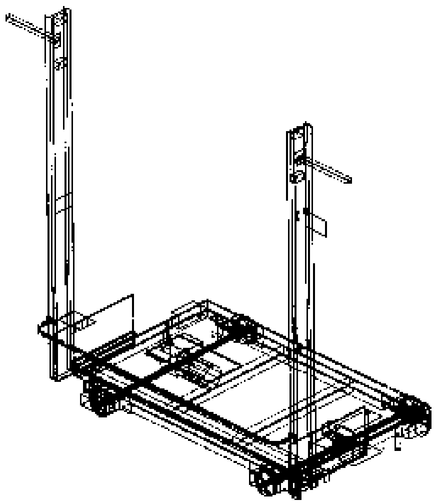


Figure 3. Anti-sway columns mounted on lift base.



Manual Down Valve Above & Below: A manual down valve was provided on the lift base, to aid in maintenance tasks, and a second valve was placed on the upper lift table so that the operator would have a method to descend in the event of a power failure. Overhead EMR Gantry: The lift is topped by an all-aluminum gantry. An I-beam spanned one end of the gantry to support the EMR trolley, an 8' florescent light hung from the other end, and a rack and pinion gear arrangement driven from a single gear motor drove the entire gantry via cam followers. The gantry is jogged toward and away from the wing panel by a thumb switch mounted on the HH550 handle.

HH550 EMR DEVELOPMENT

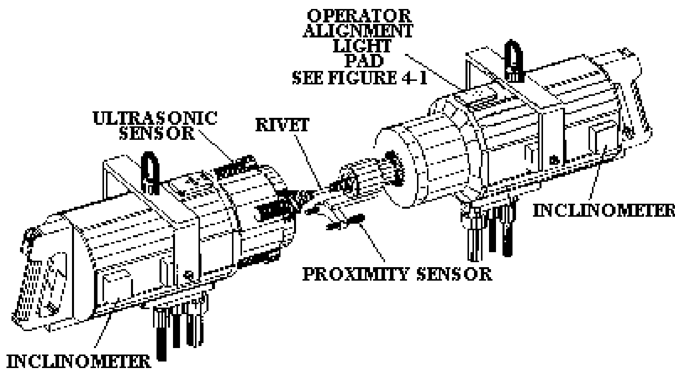
Electroimpact developed the HH500 hand positioned actuator in 1990 to form up to 3/8" 7050 alloy rivets on the 747 Section 11. While this system has been in production since 1992 on flat wing box panels it was apparent that they had limitations that prevented them from being implemented on the 767 wing panels. They did not have an external alignment capability to aid the operators in positioning the actuators normal to the work piece. Because the HH500 system was near its maximum output when forming 3/8" 7050 rivets it would not be able to accept increases in driver mass from external offset anvils. The limited output also excluded the installation of oversize replacement rivets used during panel rework. After reviewing the HH500 shortcomings, we decided to design an updated version of our then largest actuator. Hence, the HH550 concept was born.

The HH550 hand held riveting system was designed to meet several requirements for the 767 wing panel fastener installation. They had to be able to install from 3/16" to 3/8" KE (7050 alloy) rivets within stringent interference limits while producing low operator fatigue. Positioning of the guns and lifts during riveting had to be performed quickly and easily while maintaining normal alignment of the actuators with respect to the outside surface of the wing to within +/-2 degrees. The EMR charging system had to be able to form rivets at a rate of 10 per minute. Finally, protection against discharging the actuators against anywhere on the wing (skin, stringer or adjacent rivet) except the common, in-line rivet was vitally important to the system's implementation.

The increased output requirements of the HH550 necessitated the development of larger, more robust components than those used on the HH500. A 4½" diameter coil was designed to maintain the surface pressure of the 4" coil while producing 25% more formation force. The capacitor bank, which is the engine of all EMR systems, has 16 electrolytic capacitors instead of the 12 used on the HH500. The driver mass was increased from 4 pounds to 8 pounds to help slow the formation rate of the large KE rivet. To reduce the additional recoil from the increased output and heavier ram the weight of the gun body increased from 180 lbs. to 240 lbs. These changes result in a hand positioned actuator with formation force capability in excess of 40,000 lbs.

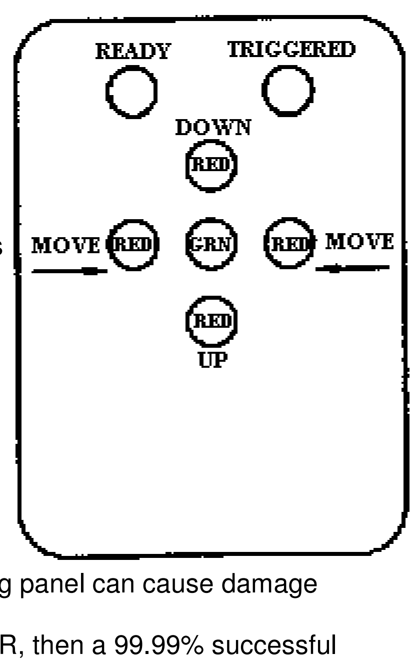
The HH550 control system consists of a 386 industrial personal computer, which handles the operator interface and statistical process control data logging, and three Microdac embedded microcontrollers which handle all EMR control duties and normality sensors. The operator console consists of a keyboard in a lockable cabinet, a 15” monitor for displaying relevant system parameters, a four position joy stick for selecting diameter and grip length values and several momentary push buttons for system power, sensor overrides and emergency stop. Voltage values for selected diameter and grip length fasteners are entered in a password protected table, and are selected by the operator through actuation of the 4-position switch on the EMR control box.

Figure 4. HH550 Alignment Sensor System



Alignment of the HH550 actuator with respect to the wing panel external surface is accomplished by the cooperation of the three sensor systems illustrated in Figure 4. The skin or dry side actuator has three ultrasonic sensors mounted on the front body of the EMR. The sensors are mounted in an equally spaced equilateral triangular formation centered about the rivet die, and are spaced 4” off of the wing surface. These sensors align the pitch and yaw angles of the skin side EMR gun. The sensors are sequenced individually at a frequency of 2 Hz by one of the microcontrollers. The stringer or wet side gun has two inductive proximity sensors that contact the stringer flange and align the actuator’s yaw direction. Stringer side pitch is measured relative to the skin side EMR pitch through analog inclinometers attached to both wet and dry side guns. The operators align the EMR’s rotation angles about the unformed rivet based on the output of a small diamond array of red and green LEDs on a gun mounted light pad (see Figure 4-1).

Figure 4-1. Operator Alignment Light Pad

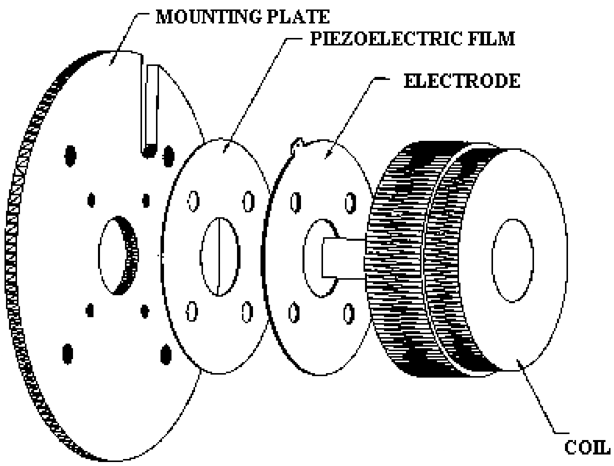


When the EMR is out of position one or more of the red LEDs at the diamond corners are lit and the EMR system is incapable of firing. When the gun is properly aligned normal to the skin panel a green light at the center of the diamond array is lit, thereby informing the operator that he is ready to fire. Both wet and dry side operators must simultaneously produce a green alignment light on their actuators light pad before the system is ready to form a rivet. The normality sensor system is capable of aligning the guns within +/- 1 degree from the axis of the rivet. It is possible to disable each individual alignment sensor if an obstruction blocks its measurement path.

The HH550 alignment system also had to include the capability of detecting whether the two actuators are positioned correctly on the ends of the unformed rivet prior to formation. Since many of the rivet tails are located under stringers and out of direct view of the EMR operator it is possible that the die can slip off of the rivet if he/she is momentarily distracted. Firing the actuator directly into the wing panel can cause damage sufficient enough to scrap the wing panel.
Since the operators install ~1,000 rivets per panel with the EMR, then a 99.99% successful system could produce the unacceptable scrap rate of one part in ten. However, a system that is overly safe and gives too many false negatives reduces cycle rate and operator confidence in the

axial alignment system. The success of the hand held EMR system on expensive production panels depends heavily on a well-tuned axial alignment system.

Figure 5. Coil/Smart Sensor Assembly



Electroimpact has employed an axial alignment system called the 'smart gun'. In the conventional EMR system both EMR guns fire at the instant that both triggers, one on each actuator, are pulled. With the smart gun when both triggers are pulled just the smart capacitor bank on the stringer side fires first. This small, auxiliary capacitor bank, which has about 5% of the output of a main capacitor bank, sends a pulse through the rivet that is just a tap; not nearly enough force to deform the rivet. The pulse takes about 1 millisecond to travel from the transmitting EMR coil, down the driver, through the rivet, and down the second ram to be resolved into the receiving EMR coil. A thin film piezoelectric force transducer is placed behind the EMR coil, as shown in Figure 5. If the force signal that is sensed by this film exceeds an adjustable voltage level then the main EMR capacitor banks are discharged. The resulting delay between the firing of the smart and main capacitor banks is slightly over 1 millisecond and the presence of two force pulses cannot be detected by the operator. If the force signal that is sensed by this film does not exceed the preset voltage level then the main banks will not fire and the operators will feel a small tap rather than the customary large impact of the EMRs. Since the voltage value measured across the film is highest when both actuators are on a common rivet then a predetermined level can be set for each rivet type to ensure that the EMR gun will only fire when these conditions are met.

The combination of normality and smart sensors ensure that the positioning of the EMR guns is repeatable from rivet to rivet. The consistency and reliability of the HH550 puts the quality of a machine installed fastener in the hands of shop mechanics.

DESIGN OF THE FAJ FOR THE 767 WING PANEL PICKUP

Figure 6. 767 Wing Panel Pick-Up Fixture

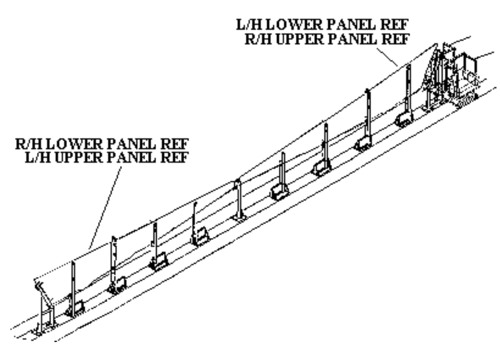


Figure 6 shows the general layout of the two wing panel holding fixtures. Note that there are two fixtures in-line aligned with outboard ends outboard. Electroimpact subcontracted the design work on the wing panel holding fixtures to Nova-Tech Engineering of Edmonds, WA. Once the design was approved by Boeing, Electroimpact fabricated and installed the fixtures. Nova-Tech was able to work with the Boeing CATIA data to design each holding fixture to accommodate two wing panels, one upper left and lower right. The other lower left and upper right.

Note that the HH550 contains features in the gun which are specific to the skin side and the stringer side. Four lifts carrying EMRs were provided. There are two lifts which are always on the skin side of the wing panels and two lifts which are always on the stringer side. Note that the lifts run on tracks and there is adequate space for a parking zone at each end of the cell.

Implementation of this new system was not an easy task and required a huge effort by Operations Technology to get the system qualified to the satisfaction of Boeing Materials Technology. In early 1995, Boeing started utilizing the 767 LVEMR Wing Panel system. It was a major accomplishment in that it was the first time that the LVEMR process was used to install fasteners into a Boeing wing panel.

Although this new system met Boeing's major requirements, it became apparent very early that improvements would be necessary to make the system a success. Some of the areas that required changes/improvements were: the flexible tool fixtures, operator interface, SPC functionality, smart sensor design, X-axis drive system, safety bumpers, and die sleeves. Improving the system has been and will continue to be an ongoing effort as we are constantly looking to improve quality, ease of operation, minimize downtime, and alleviate safety concerns.

Many of the lessons learned with the Everett system have allowed for an improved system currently being implemented in Renton. Although the Renton panels pale in size compared to the 767 panel, the basic concepts still apply and Renton is reaping the benefits of the Everett effort.

As a whole the project has been successful. Boeing got a system that is easier on the mechanics' wrist and hands, noise levels have been reduced in the area, wing panel accessibility is improved, and finally, one could make a convincing argument that the quality of the rivet installation has been greatly improved.

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