A Flexible Development System for Automated Aircraft Assembly

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This paper was given at the 1996 SAE Aerofast Conference in Bellevue, Washington

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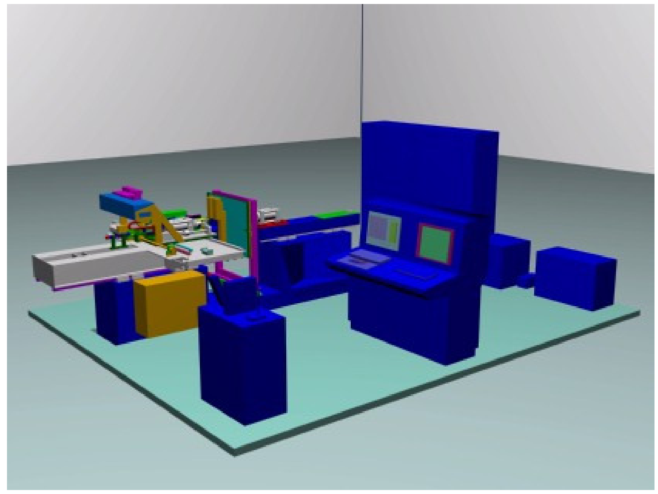


Rendered image of the AFAS Test Bench

ABSTRACT

McDonnell Douglas Aircraft in St. Louis, MO manufacturers various transport and fighter military aircraft such as the C-17 and the F/A-18. With shrinking military budgets and increased competition, market forces demand high quality parts at lower cost and shorter lead times. Currently, a large number of different fastener types which include both solid rivets and interference bolts are used to fasten these assemblies. The majority of these fasteners are installed by hand or by using manually operated C-Frame riveters. MDA engineers recognized that in order to reach their goals they would be required to rethink all phases of the assembly system, which includes fastener selection, part fixturing and fastener installation methods.

Phase 1 of this program is to identify and to develop fastener installation processes which will provide the required flexibility. The EMR fastening process provides this flexibility. While EMR is currently used in production on a number of aircraft programs around the world, it has only been qualified for limited use within MDA. In conjunction with MDA engineers, Electroimpact designed and built an automated EMR development system. The test bench system has complete automated riveting and Lockbolt insertion capability. The test bench platform provides the means to optimize, validate and prequalify the fastener installation process prior to delivery of the full production system. After production implementation, the test bench can be utilized for the development of new processes or for investigating production problems off-line.

The reduction of variability and cost in the assembly stage of military and commercial aircraft manufacturing will be required by any manufacturer who intends to remain competitive in the future. Highly automated, flexible, multitask systems with adaptive controls for real time automated decision making will be enabling technology for improving both cost and variability.

The implementation of automated assembly addresses the three goals of reduced cost, reduce cycle-time and variability and improved product quality. Contributing factors that effect these

goals include: expensive, single task tooling, detailed assembly and part geometry variability and reliance on operator skills and tribal knowledge to overcome systemic weaknesses in manufacturing plans.

A comprehensive evaluation of current and proposed assembly machines was conducted by a multi-disciplinary implementation team. Systems were evaluated for return on investment and the ability to be adaptable to a multitude of dissimilar assemblies and processes. This ability to process a multitude of assemblies is critical to MDC due to low production rates and variable work packages. Additionally, processes that lend themselves to aircraft structural improvements were heavily weighted in the team’s evaluation. The Electroimpact yoke production system was chosen by the team that best met or exceed MDC’s requirements.

The targeted areas for automation included C-17 and F/A-18 E/F assemblies. Bulkheads, ribs, inner /outer wings and control surfaces were selected for initial implementation. These assemblies, both flat and highly contoured, consist of composite and metallic components in various configurations with both solid rivets and two-piece fastening systems. Assembly envelopes varied from 8 sq. ft to in excess of 200 sq. ft.

The engineering requirements to process these assemblies included: high speed drilling, hole probing, sealing, proper fastener selection, controlled fastener installation, and post installation inspection. These processes must be robust and repeatable.

To reduce process risk, enhance development and to accelerate time required to release the system to production, the McDonnell Douglas team procured an engineering process and manufacturing development system. A study revealed that a test bench would expedite machine release 25 weeks sooner to production, accruing at 1500 man-hour savings per week. The system would continue to be used for off-line development of new process and techniques thus eliminating disruptions to production. Additionally, the system would be used to replicate production problem conditions, identify the problem source, design a solution and expedite the solution into production.

PROCESS DEVELOPMENT

AFAS Test Bench - Cell as installed in St. Louis:

The development system was delivered and installed in the MDC manufacturing research and development facility in St. Louis in January of 1996 and released for development activities in April of 1996. Two full-time engineers and various manufacturing, engineering and testing personnel support all development activities. Development activities are directed and facilitated by both military and commercial programs.

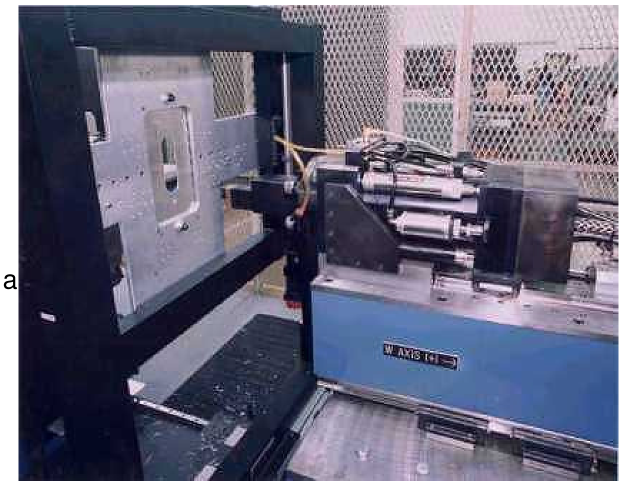
The parameters to install solid rivets and lockbolts have been developed by the St. Louis and Electroimpact engineering staffs. The results have been better than expected and additional processing tools have been budgeted for integration. These additional processes include an additional high-speed drill spindle, an electronic hole probing system and additional fastener feeding modules.

GENERAL DESCRIPTION

The Automated Flexible Assembly System (AFAS) is a machine concept designed to allow a single machine cell to fasten and assemble a wide variety geometrically similar aircraft parts. Originally patterned around the McDonnell-Douglas C-17 “Globemaster III” program, the AFAS machine design utilizes quick-change tooling and a seven tool shuttle table to install solid rivets and interference lockbolts for bulkheads, door panels, and large control surfaces. The AFAS Test Bench is the first stage in implementing the Automated Flexible Assembly System.

MACHINE LAYOUT

Stringer Side EMR with Rivet Tooling:



The AFAS Test Bench is a welded steel structure approximately eleven feet long, four feet tall and two feet wide. Mounted on top of the bench are two steel clamp tables. A test coupon is clamped between these tables as they move toward one another. The skin-side clamp table is designated “Z”. The Z clamp table has a seven position shuttle table holding process tools: a BUCA probe, an Electroimpact drill spindle, a sealant inserter, a pneumatic bolt inserter, and an electromagnetic riveter (EMR). The W-side clamp table is narrow to allow access to the stringer-side of aircraft parts. The W clamp table has only one tool mounted to it, a rivet/bolt EMR. A two-axis coupon positioner facilitates the processing of rivet and lockbolt test panels.

The operator interface, including two button panels, the Fanuc 15-MB CNC monitor and the maintenance PC a mounted in the operator console. Near the operator console is a small cabinet outfitted with fastener feed equipment: five drop tubes, a two-slot fastener magazine rack, and 3/16 automatic collar escapement. The entire test bench work area has a plywood raised floor to place the test bench tools at a comfortable working height.

MACHINE CONTROLS

Since the AFAS Test Bench is designed to be a research tool, the control system employs an entirely different philosophy from that of common production equipment. Typically, in production, the details of assembling parts and installing fasteners are predetermined. A CNC programmer takes geometric information from the aircraft designers and generates a part program. That program specifies what types of fasteners are to be installed, where, and in what order. The exact process used to install a fastener is qualified and tested by engineers and then “locked away” in the machines memory. An operator has very few adjustments at his disposal.

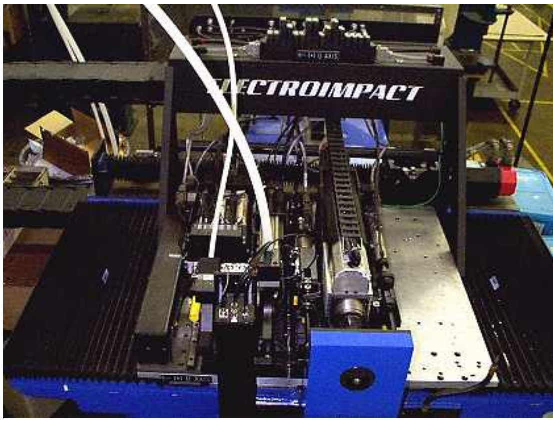
In contrast, the Test Bench is designed to allow the operator to perform any number of tests and experiments. Many of these experiments may involve unusual cycle sequences or machine settings. To support this type of testing, the AFAS Test Bench employs several Miscellaneous Function Codes (M-Codes) which control nearly every facet of the machine. To build machine cycles (to put in a rivet for example) the M-Codes are combined in Macros. Macros, in turn, can be called from part programs similar to those that a production machine might use. The fundamental difference between this research tool and a production machine is the ease which an operator (typically an engineer) can change settings and reconfigure the machine operation.

SHUTTLE TABLE

Process Tool Shuttle Table:

From Left - EMR, Bolt Inserter, Sealant Inserter, Drill Spindle, and Panel Probe.

Spare Tool Slots are to the right.



The shuttle table is located above the Z clamp table. The shuttle table is a precision ground aluminum plate. Below the shuttle table are linear bearings that allow the table to move to the several tool positions. Inset into the table are round and diamond dowel pins for tool alignment, and steel inserts into which screw the individual tool mounting bolts. The shuttle table was aligned by Electroimpact personnel when the Test Bench was installed. No alignment should be required by MDA personnel.

CONCLUSION

The AFAS test bench approach provides a means for the low risk introduction of new technologies into a production environment. The system is designed for maximum flexibility to allow process development engineers to optimize the process parameters prior to production implementation. A number of new technologies, such as the smart bolt inserter and the servoed EMR, provide increased process control and improved product quality.