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ABSTRACT

The introduction of a new derivative to an existing aircraft model poses many decisions regarding old versus new. In the case of the introduction of the extended range 767 (the 767-400ER), an entirely new wing design prompted the examination of the then current assembly processes and tooling. The hesitation to build new drill templates for use in the traditional method of second stage wing spar assembly inspired Tool Engineering Management to request the investigation of a low cost automated drilling apparatus. As a result, the Boeing Automated Tools Group and Advanced Integration Technology, Inc. (AIT) developed and implemented mobile numerically controlled mini-drilling machines for post-ASAT I assembly-drilling operations. This paper presents the NC automated mini-driller as a viable alternative to conventional assembly drilling and provides the technical description of a cost effective design which results in flexibility, time and cost savings, consistency in results and improved shop-floor ergonomics.

INTRODUCTION

As background, this paper will describe Boeing's conventional post-ASAT I assembly drilling processes together with the benefits Boeing and AIT hoped to realize through the automation of that process. It will then give a technical description of the automated NC mini-driller together with an overview of the machine's operation and capabilities. Finally, it will compare conventional second stage wing spar drilling methods with the automated mini-driller, highlighting the automated machines benefits and advantages.

BACKGROUND

CONVENTIONAL SECOND STAGE WING SPAR DRILLING – Many large-scale assembly designs incorporate a first stage, fully automated assembly process followed by subsequent manual or semi-automatic operations. While the ability to modify the automated portions of the assembly process is relatively easy and cost-effective, the cost and time expended changing hard tooling associated with the manual and semi-automatic operations can make a significant difference in overall profitability. This was true with the 767-wing assembly line.

While the initial first stage of the 767 wing spar assembly was accomplished using an automated spar assembly tool, the second stage operations utilized large drill plates to assist the operator in locating and drilling the fastener holes for additional component assemblies. The drill plates were specific to each assembly configuration along the length of the spar. Multiple drill plates were needed for each airplane derivative and each forward/aft - left/right spar combination.

The use of the drill plates necessitated the use of hand held drilling equipment. Though the drill operation incorporated semi-automatic devices, each fastener location had to be drilled individually. The equipment was heavy and had to be manually moved between hole positions.

The major problems associated with the conventional second stage drilling became evident with the introduction of the 767-400ER. Because fastener locations were different on the new spar and the same base fixtures would be used for both spar models, a new set of drill templates would have to be designed and manufactured. If the new fastener locations were to again change before the new drill plates were fully completed, additional costs would be incurred in the rework or remake of the plates. In order to reduce the possibility of additional tooling expense and delays, the requirement for a positional flexible second stage drilling system was realized. Thereafter, Boeing identified the functional requirements of such a system, and with AIT as prime contractor, the mini-driller was designed, fabricated, and installed within a compressed schedule of only 7 months.

GOALS OF AUTOMATED DRILLING – With an understanding of the problems associated with conventional second stage spar drilling, Boeing and AIT sought to achieve the following goals in the mini-driller.

Flexibility – One of the major expectations of the mini-driller was the ability to operate the machine in various locations along the entire length of the spar. Additionally the mini-driller was to be able to conform to various spar configurations regardless of program model or spar hand. The mini-driller was also to incorporate the adaptability to reconfigure changing drill positions and sequence, all within a reasonably short period of time, and without additional tooling costs.

Size – In efforts to maximize work areas and minimize tooling costs, the mini-driller was not to be a permanent structure attached to the main holding fixture. Instead it was to be attached to the main fixture for use and then removed and stored when idle.. Storage space for the mini-driller was limited in non-use periods, and therefore it needed the capability of being rolled around without the assistance of any additional equipment.

Accuracy – The traditional second stage wing spar drill method using drill plates produced sufficient accuracy, but the mini-driller would need to increase the speed of hole to hole sequencing and thus reduce overall cycle time. The addition of a numerically controlled positioner would improve process throughput and consistency while maintaining required accuracy.

Speed – The use of drill templates allowed multiple production personnel to drill the spar concurrently. In order to be cost effective, the automated process would be required to incorporate multiple drill heads to be competitive with the manual process.

Ergonomics – Due to safety concerns associated with repetitive, high impact manual operations, ergonomic considerations became an integral part of the mini-driller design. ?Requirements were to be implemented for weight reductions in operator lifting. Additional requirements for proper body positioning, and improved accessibility of manually operated components were also to be adopted.

TECHNICAL DESCRIPTION OF AUTOMATED MINI-DRILLER

To fully understand the benefits of the automated mini-driller, it is important to understand the machine's technical aspects. The following is a brief technical description of the pieces and parts of the mini-driller along with the control system that makes it work.

PHYSICAL SYSTEM LAYOUT – The mini-driller is composed of the following major components:

- Frame assembly
- Control system cabinet
- Pendant
- Spindle assembly

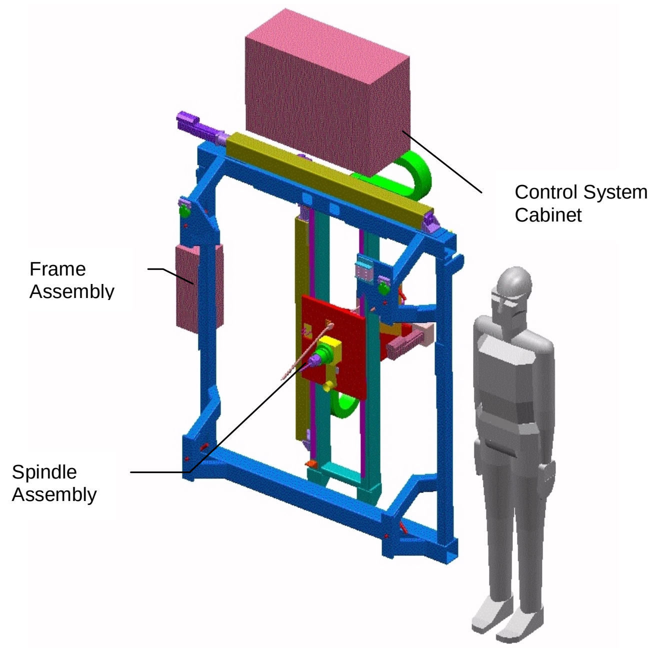

Figure 1. Mini-Driller Machine

Frame Assembly – The frame assembly is the primary support structure for the mini-driller and it's components; parts such as the axis carriages, the spindle, and the control system cabinet. The frame assembly is compact and portable so that the entire machine may be stowed when not in use.

Control System Cabinet – Each mini-driller has its own control system cabinet located on the frame assembly. This cabinet is the primary power distribution unit for the system and it houses the servo motion controller or real-time controller (RTC), fuses and terminal blocks, master control relays, and digital I/O rack and servo amplifiers.

Spindle Assembly – The spindle assembly is positioned by X and Y motors. The spindle drive directly turns the drill bit at commanded speed and direction. The spindle assembly feed drive (Z-axis) controls the rate at which the drill enters the spar. A lubrication system provides coolant to the drill bit during drill. A vacuum system is used to remove chips generated during drilling.

Pendant – The operator interface pendant is a mobile touch-screen computer that serves as the operator interface for the system. It is mounted in a carrying case to allow mobility near drill location and portability with the mini-driller. Plugging the pendant into the system connects the pendant into the ethernet network so that it can interface with the RTC.

Figure 2. Operator Pendant

The operator interface is made intuitive by graphical representations of the structure and status of the mini-driller as shown below. The screens are touch-screen interactive: functions and tasks are activated by simply touching the appropriate field or button.

Whereas most NC drilling machines display process in a textual MCD format, the mini-driller displays process parameters graphically so that the user is not required to have any NC machine experience. The illustration below shows the typical user interface where the NC interface is available in a pop-up window, but the main user interface is graphical.

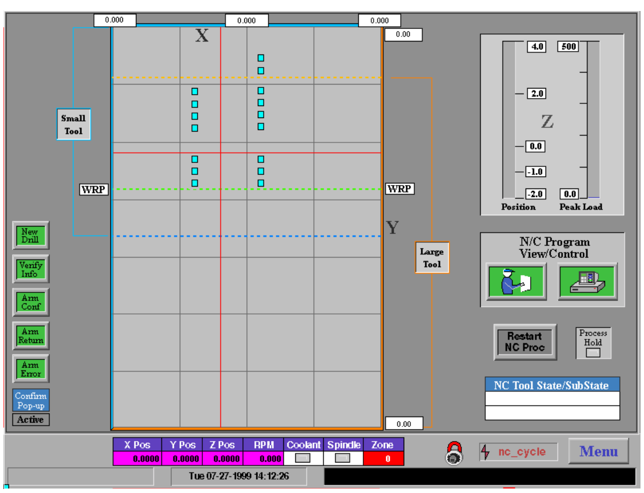

Figure 3. Graphical Display of Process Status

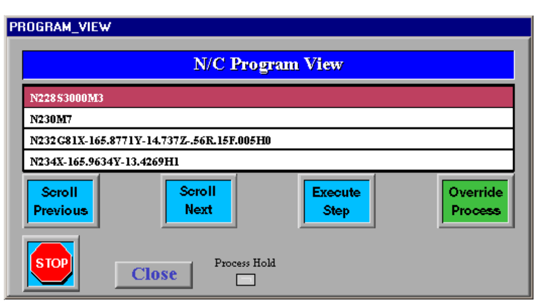

Figure 4. Textual Display of M&G Codes

SYSTEM OPERATION AND CAPABILITIES – In use, the mini-driller is indexed to either the assembly to be drilled or to the assembly's holding fixture. If necessary, the user enters the airplane model or configuration through the machine's graphical user interface (GUI). If the machine is drilling a zone of a large assembly, it is instructed (or optionally it can sense) which zone of the assembly is to be drilled. Using this assembly and zone identification information, the machine then downloads the appropriate NC part program data via a wireless LAN. The user then initiates the automatic drill and countersink operation. Once the drilling is complete, the machine can be used on a different zone of the same assembly or on another fixture.

The mini-driller includes various modes of operation: Fully-automatic NC mode; Single-Step NC mode; and Manual Mode.

Fully Automatic Mode – When the mini-driller is in fully automatic mode, the machine will progress through all steps in a NC program and drill all holes in that program without operator input or prompting.

Single-Step Mode – If the mini-driller is in single-step mode, the operator is required to approve each command block throught the GUI before the machine completes each step in the process. In the Single-Step mode, any of the drilling parameters can be overridden. Such a feature allows the user to tweak process parameters as the process is being proven.

Manual Mode – Manual mode is the default for the system. When in manual mode, the mini-driller is not actively working through an NC program, and its manual functionality is available for use. In manual mode, an operator can command the mini-driller to actuate any axis or spindle move.

OTHER CAPABILITIES

Verification of Drill Size – The mini-driller can automatically verify that the correct drill bit is in the spindle. The system performs the verification while displaying the information to the operator on the pendant GUI.

Monitoring Drill Process – A GUI screen is designed to assist the operator in monitoring the status of the drill program while the program is in progress. The screen displays the current pattern and uses colored icons to indicate the drilled/not-drilled status of each hole in a given program.

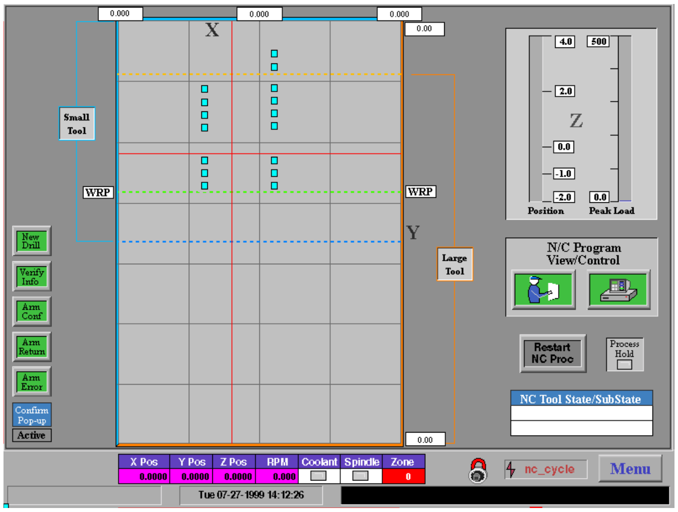

Figure 5. Drill Monitoring Screen

BENEFITS OF THE MINI-DRILLER

MINI-DRILLER VS. CONVENTIONAL DRILL TEMPLATES

Cost Savings – Normally, drill templates or plates are used to locate fastener holes. The mini-driller obviates the need for fixed drill templates saving money associated with their design, fabrication, and maintenance

Labor and Space Savings – Usually, multiple drill templates are required for different zones and aircraft variants. Storing and managing this array of drill templates requires space and labor resources. By replacing the drill template, the mini-driller produces labor and space savings.

Flexibility – With the mini-driller, tool set-up for the introduction of a reengineered or different assembly is effortless and requires little time. The operator simply enters the model number of the assembly to be drilled into the systems GUI. The system then downloads the NC program identified with that reengineered or new assembly and drilling can begin.

Shortened Lead Time for Variant or Configuration Change – When engineering changes are made to an existing model, or a new variant is introduced, drill templates must be modified and fabricated. While engineering changes can be made instantly to aircraft assembly drawings and machined parts' NC programs, the drill templates require design and fabrication which increases the lead time associated with engineering changes.

Reduced Cycle Time and Increased Quality – The mini-driller drills faster than manual operations. Additionally, the mini-driller controls variables such as drill speed and pressure. The result is more consistent holes that are more accurately placed.

Ergonomic Improvement – The mini-driller obviates the need for the movement of heavy power feed drills from hole to hole. Movement of heavy drill plates is also eliminated.

MINI-DRILLER VS. MONOLITHIC NC DRILLING FIXTURES

Reduced Cycle Time – The mini-driller is a stand-alone machine, so multiple mini-drillers can be used at the same time on the same assembly. Consequently, multiple spindles can be drilling at the same time, increasing jig capacity.

Lower Investment Costs – With the mini-driller, assembly capacity can be added in small increments rather than in large steps, which allows it to more closely follow production requirements.

CONCLUSION

Technology is allowing the Boeing Automated Tools Group to accomplish their manufacturing objective of flexible second stage wing spar drilling. The automated NC mini-driller, actuated through an intuitive graphical user interface, is able to conform to various spar configurations regardless of program model or spar hand. Additional benefits of this enabling technology are time, cost and space savings, reduced lead and cycle time and better shop floor ergonomics.

DEFINITIONS, ACRONYMS, ABBREVIATIONS

GUI: Graphical User Interface
I/O: Control System Electrical Inputs and Outputs
RTC: Real-time Controller