

Expanding the Use of Robotics in Airframe Assembly Via Accurate Robot Technology

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ABSTRACT

Serial link articulated robots applied in aerospace assembly have largely been limited in scope by deficiencies in positional accuracy. The majority of aerospace applications require tolerances of $\pm 0.25\text{mm}$ or less which have historically been far beyond reach of the conventional off-the-shelf robot. The recent development of the accurate robot technology represents a paradigm shift for the use of articulated robotics in airframe assembly. With the addition of secondary feedback, high-order kinematic model, and a fully integrated conventional CNC control, robotic technology can now compete on a performance level with customized high precision motion platforms. As a result, the articulated arm can be applied to a much broader range of assembly applications that were once limited to custom machines, including one-up assembly, two-sided drilling and fastening, material removal, and automated fiber placement.

INTRODUCTION

Assembly tolerances in aircraft structures have driven automation manufacturers to design custom, dedicated equipment that will meet accuracy requirements. Though successful, custom machines are relatively expensive, and for shorter term contracts, are difficult to justify as their scope is typically focused on a single application. Production implementations of articulated arm robots in aerospace have been active for many years with varying degrees of success. Interest in them derives from their successful implementation in automotive manufacturing. Robots offer airframe manufacturers benefits in both cost and application flexibility. Because their mass is relatively low, foundation requirements are minimal and often systems can be installed on top of existing slabs. The articulated arm spans a large working envelope capable of navigating along highly curved surfaces and into tight spaces. Because robots are produced in

high volume their cost is low and reliability is high compared to customized positioners. Within the last 10 years, significant mechanical and control improvements have made robots a viable option for mid-range assembly tolerances ($\pm 0.75\text{mm}$).

Manufacturers commonly give 1/3rd of the overall assembly tolerance to automation systems, and in most cases this overall tolerance is less than $\pm 0.75\text{mm}$, requiring the automation accuracy to be $\pm 0.25\text{mm}$ or better. Existing technologies are available for global accuracy improvement to this level. These include real-time guidance via metrology (laser tracker, indoor gps, camera systems), directly teaching positions, etc. Design changes and variants are common in aircraft structures and the location of assemblies within the automation cells are typically not tightly controlled. Manufacturers therefore require the ability to program systems offline, whereby teaching methods become obsolete as they are inherently time-consuming and unique. Guiding robots real-time via metrology has proven to greatly improve positional accuracy, however, the automation system must include expensive, sensitive equipment. External systems also tend to restrict the working range and suffer from line of sight issues. In some cases these technologies cannot be avoided (e.g. when required global accuracy is at or below 0.15mm), however it is desirable to have an inherently accurate standalone automation system wherever possible.

MAIN

As performance and control of tailored CNC systems are desired with the flexibility and low-cost that articulated robots offer, a combination of these technologies has been developed. The "Accurate Robot" system is controlled via industry standard Siemens 840Dsl CNC which handles all controls requirements and offers a familiar interface to programmers and operators. Drawing from common axis configuration in machine tool design, the robot arm was

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integrated by Electroimpact with secondary position sensors at the output of each axis (figure 1). Repeatability is significantly improved enabling the system to be calibrated to accuracies below $\pm 0.25\text{mm}$ over a large global volume. This patent pending system has broadened the range of applications for unguided industrial robots in the aerospace industry to include high-precision single and dual-sided drilling and fastening, accurate material removal (trimming, milling), and accurate robotic fiber placement.

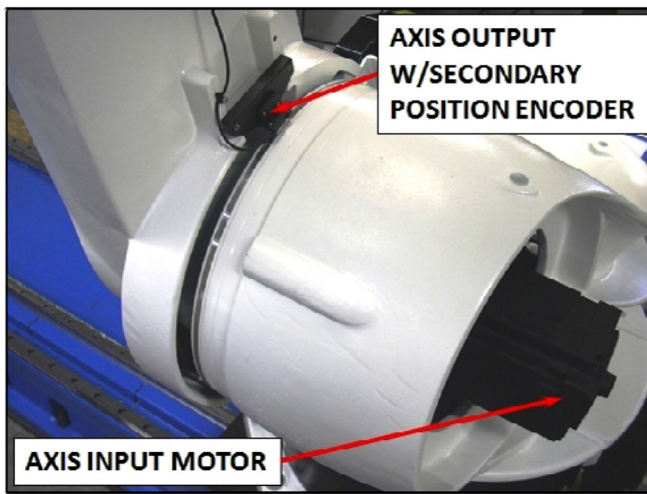


Figure 1. Robot axis with secondary encoder

Identification and Elimination of Inaccuracies

The accuracy in which features are placed via automation is a function of two main criteria; 1) The positional accuracy of the motion platform in free space, and 2) The ability of the motion platform to remain in position or on-path when loads are applied. For a drilling application, this would require the machine to position itself at the programmed hole location and remain stationary when pressure foot and drill thrust forces are applied. For path-related applications such as trimming or fiber placement, the system must be dynamically stable, remain on its programmed trajectory and resist forces induced from cutting, compaction, etc. (figures 2 and 3).

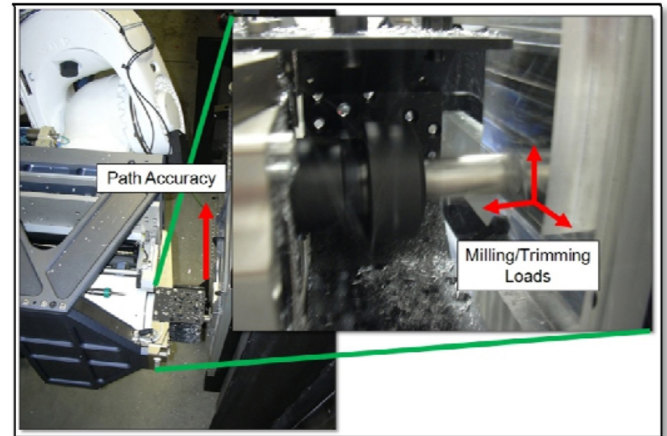


Figure 2. Robotic Milling/Trimming

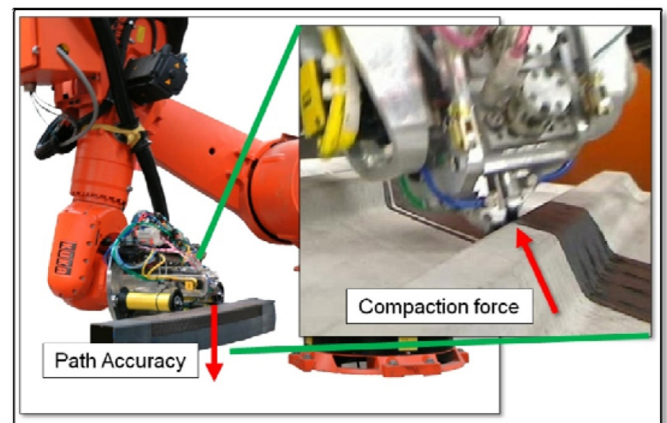


Figure 3. Robotic fiber placement

Although an off-the-shelf robot can perform the required manipulation of the process tooling, it fails to meet the positional accuracy and rigidity required for the majority of aerospace assembly tasks. With dual-sided processes such as bolt and collar installation, the problem is compounded as both systems must align well enough to reliably feed and install a collar on a pin. The error in alignment between heads can be as large as the sum of the accuracies of the two systems (figure 4).