

Enhanced Robotic Automated Fiber Placement with Accurate Robot Technology and Modular Fiber Placement Head

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ABSTRACT

The process of robotic automated fiber placement has been enhanced by combining the technologies of an accurate articulated robotic system with a modular Automated Fiber Placement (AFP) head. The accurate robotic system is comprised of an off-the-shelf 6-axis KUKA Titan KR1000L750 riding on a linear axis with an option for an additional part rotator axis. Each of the robot axes is enhanced with secondary position encoders. The modular fiber placement head features a robotic tool changer which allows quick-change of the process heads and an onboard creel. The quick-change fiber placement head and simplified tow path yields terrific process reliability and flexibility while allowing head preparations to occur offline. The system is controlled by a Siemens 840Dsl CNC which handles all process functions, robot motion, and executes software technologies developed by Electroimpact for superior positional accuracy including enhanced kinematics utilizing a high-order kinematic model. Part programming and simulation are performed offline using CGTech VERICUT Composite Programming and VERICUT Composite Simulation. This combination of technologies results in a system that has high path accuracy and process flexibility at a lower cost than traditional fiber placement machines.

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INTRODUCTION

Electroimpact has developed accurate robotic technologies and modular automated fiber placement end effectors over a period of many years. Each of these technologies has reached maturity through use in multiple production applications. Recently Electroimpact combined their patent pending accurate robotic technology with their modular automated fiber placement head technology. This unique combination results in a low cost automated fiber placement solution that can be used for a wide variety of CFRP parts.

MAIN SECTION

Accurate Robotics

Industrial robots are used in many applications that require moderate levels of accuracy and repeatability. These applications include pick and place, light assembly, and welding. Traditionally the lower accuracy of articulated industrial robots has precluded their use in many aerospace applications due to the requirements for high positioning

accuracy. Electroimpact developed a line of accurate industrial robots for use in aerospace applications. Most of the applications for accurate robotics have involved drilling and fastening of aerospace structures.

To achieve higher accuracy Electroimpact mounted optical encoders to each robot rotary axis near the output. The encoder signal is input into an industrial CNC (Siemens 840Dsl) which is capable of controlling each axis based on optical scale secondary feedback rather than the primary feedback on the servo motor.

Electroimpact also developed a high-order kinematic model to enable high precision compensation of the toolpoint position. This kinematic compensation software is also executed on the Siemens 840Dsl CNC. This combination of optical encoders and software kinematic compensation allows correction of position inaccuracies due to drivetrain deflections, drivetrain backlash, deflection due to payload, and deflection due to process force inputs. The secondary feedback also effectively stiffens the robot as it allows the CNC to react to positional inaccuracies whether due to statically applied forces or dynamically applied forces during path motion.

The improvement in toolpoint positioning accuracy was demonstrated by analyzing patterns of holes drilled by an accurate robotic end effector on representative work pieces. The radial position deviation of the hole parallel to the surface was examined. A standard industrial robot (non-accurate, without secondary feedback) was used to drill a pattern of 56 holes over an area of 3240×220 mm (0.71 square meters). The system demonstrated a 3-sigma hole pattern accuracy of ± 0.45 mm. Then an accurate robot (with secondary feedback) was used to drill a pattern of 64 holes in an area of 1400×840 mm (1.18 square meters). The resulting 3-sigma accuracy was ± 0.08 mm, conclusively demonstrating the toolpoint positioning accuracy improvement when using the accurate robot technology (see Figure 1) [8].

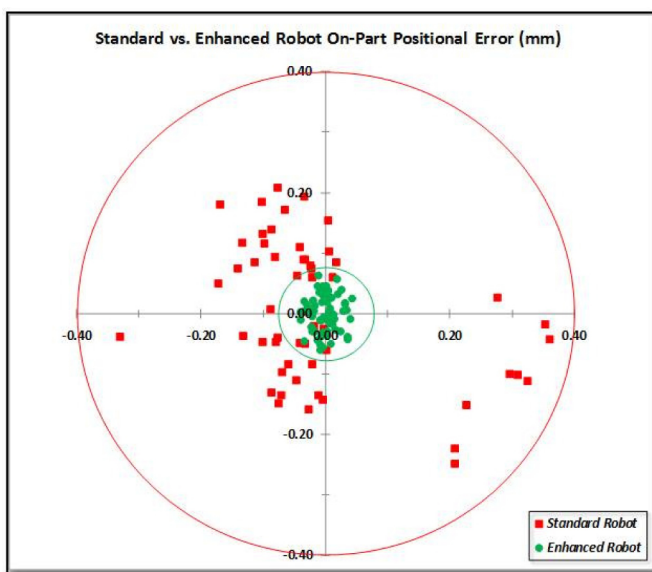


Figure 1. Accuracy comparison of standard robot vs. accurate (enhanced) robot.

For robotic automated fiber placement systems the KUKA KR1000L750 was chosen (see Figure 2). This robot provides a high payload rating (750 kg) and long reach (3602 mm). The robot arm utilizes large section steel castings. These characteristics of the robot arm result in good dynamic stiffness which helps maintain toolpoint positional accuracy while in motion on a path.

Path positioning errors in AFP result in course to course gap, course overlaps, and tow end placement errors. Note that high speeds and accelerations are required to traverse a moderately contoured part while maintaining normality. Inability to maintain path accuracy while traversing a contoured path will result in lower quality AFP layup or force a reduction in path speed, thereby reducing productivity. Utilizing the high payload robot with accurate robot technologies allows AFP layups that rival the speed, accuracy, and productivity of any non-robotic AFP machine.



Figure 2. Accurate Robot (KUKA KR1000L750) with optical scale secondary feedback installed.

Modular Automated Fiber Placement (AFP) Heads

Electroimpact began development of AFP heads in 2004 for use in CFRP structure production for commercial aerospace. Several unique developments were made that improved the performance and reliability of automated fiber placement. Electroimpact AFP heads have been used in commercial aircraft production and have demonstrated high rate, high quality production. Some of the key characteristics of the AFP heads include:

- Robotic tool changer on the AFP head. This provides a quick-change interface allowing the entire head and creel to be moved offline. Typically a production cell will be paired with a set of "transfer stands" that allows AFP heads to be swapped in roughly 90 seconds. This enables the robot/machine to maintain production while an AFP head is moved offline for cleaning and/or material loading. This interface also allows a quick-change of material forms, for instance, a single motion platform can utilize 1/8", 1/4", and 1/2" tow AFP heads. Additional processes can also be introduced into the cell using this interface including ultrasonic cutting, automated tape laying (ATL), wide fabric handling, etc.