

Adaptive Manufacturing System

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ABSTRACT

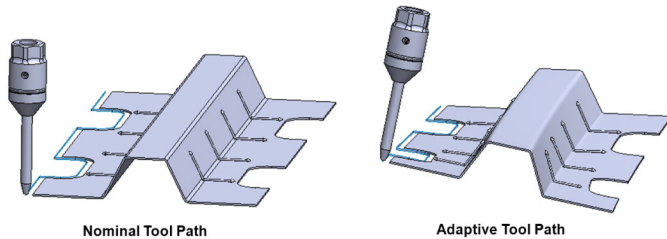
The ever increasing use of composites for aircraft components presents opportunities for new ways to process these parts. There are myriad benefits for use of composites in achieving aircraft performance goals. However, composites come with unique challenges as well. Some of these challenges impact the ability to produce accurate parts. Traditionally, such parts have been trimmed only while clamped in dedicated rigid tools that secure the part in the nominal shape. This results in significant investment in tooling design, production, maintenance, storage and, handling. As an alternative, PaR has developed its Adaptive Manufacturing System that incorporates a Robotic Fixture and Precision Motion Machine with an Integrated Process Head. The Robotic Fixture allows the entire family of parts to be managed with one fixture that remains within the machine footprint. The fixture is programmed to command 38 individual robots to assume appropriate poses and end effector configurations to accommodate over 400 different parts in the family that range in length from 0.5 to 20 meters. Once the part(s) is loaded in the fixture, the system automatically scans the part to determine the actual location and contour, as presented to the machine. The actual measurements are compared against reference data, which defines the nominal condition. This allows the machine to automatically develop adaptive tool paths that trim the part, so that the part will be the right size when constrained to its nominal condition. Trimming is done with abrasive waterjet, using multiple different catchers to accommodate different accessibility conditions. A spindle is also integrated into the same head as the waterjet and laser scanners, to accommodate hole drilling and edge chamfering. After the trimming operations are complete, the system washes and dries the part. A subsequent geometric inspection is performed using either a probe in the spindle, or the laser scanners. The inspection uses DMIS programming and results in an inspection report to go with the completed part. This paper will further describe the challenges and technology implemented in the development of this system.

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Adaptive Manufacturing System

INTRODUCTION



Nominal and Warp Part Configurations

The Adaptive Manufacturing System was developed to address some of the significant challenges of producing composite parts for aerospace. These challenges include a high diversity of parts, even within a family of "similar" parts, and the tendency of the parts to be outside of a perfectly nominal contour due to spring back from the layup tools unless rigidly constrained. These two challenges traditionally mean a large investment in unique tooling custom to each part with vacuum tools that constrain the part over 100% of its surface. This results in a large number of tools that must be designed, produced, handled, stored, maintained, and updated for engineering changes. The Adaptive Manufacturing System eliminates the need for dedicated tooling in favor of a Robotic Fixture. For this to be successful a number of related system capabilities must be employed. First, the Robotic Fixture does not hold the parts to contour, implying that some means must be provided to identify the location and contour of the part as presented on the Robotic Fixture. Second, a trimming method is required that works within the holding capability of the fixture. Lastly, a means must be provided to measure the trimmed part to verify the process.

OPERATIONAL SCENARIO

The following operations complete the processing of a part in the Adaptive Manufacturing System.

1. Operator bar codes part number for subject part.
2. System processes part number and executes the program to configure the Robotic Fixture.
 - a. Each robot sets its end effector to adjust for the cross section of the part local to that robot
 - b. Robot moves to its pose ready to accept the part
3. System moves into position above the location of the first part and projects the laser scanner line where the tooling hole should be.
4. Operator manually loads the part, roughly aligning the center of the tooling hole under the projected line. Proceeding to each robot, the operator presses the lighted vacuum button on each end effector to secure the part.
5. If multiple parts are being processed, steps 1-4 repeat for each part.
6. With the part(s) loaded and the access doors secure, the system begins the automatic operations by using the laser scanner and moving along the part, periodically capturing images of the actual local contour. The images are processed to create a local coordinate frame at each location.
7. The system compares each captured frame with a reference frame from the part program, creating a local transformation matrix.
8. The system then moves to the tool rack and automatically picks up the waterjet catcher to trim the longitudinal sides of the part.
9. Trimming proceeds along the part and along multiple parts that utilize this catcher configuration. When all trimming with this configuration is complete, the catcher is returned to the tool rack.
10. At the tool rack, the side trimming catcher is exchanged for the end trimming catcher. The part(s) are processed and the end trim catcher is returned to the tool rack.
11. If the part(s) require spindle operations, the system moves to cutter section of the tool rack and picks up a cutter with the spindle. The cutter is then moved to the tool check station to confirm it is the proper diameter and length before proceeding to the part(s).
12. Spindle operations proceed for drilling operations with automatic tool changes for different diameters.
13. The chamfer tool is also loaded in the spindle to process edges where required.
14. With trimming operations complete, the process continues with the machine using water spray nozzles to wash from end to end. The return stroke uses an air knife to dry the part(s).
15. The system proceeds to inspect the part to validate the trimmed geometry. The inspection programs are DMIS based and can utilize either a touch probe, in the spindle, or the second laser profilometer.
16. Inspection proceeds with the system executing the DMIS script and collecting the appropriate data for point or edge data.
17. The collected data is processed by the CAPPS-NC software and a report is generated.
18. With inspection complete, the cell access doors are released and the operator is able to enter and remove the parts. The next set of parts is loaded and the cycle repeats from step 1.

EQUIPMENT DESCRIPTION

Robotic Fixture

Fixture design begins with an analysis of the targeted family of parts. These parts, while all similar in function, proved to be widely diverse: Lengths ranged from 0.5 to 20 meters. Cross section shape varies in height, width, and angularity. The longitudinal contour variations include X, Y, Z and yaw, pitch and roll. There are over 400 unique parts per ship set for a single aircraft variant. The analysis concluded that a series of supports spaced nominally 0.5 meters apart could support the