2023-01-1007 Published 07 Mar 2023

Modernization of Equipment in Aerospace Nondestructive Inspection

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Citation: Elrod, J., Waterman, M., and Parker, D., "Modernization of Equipment in Aerospace Nondestructive Inspection," SAE Technical Paper 2023-01-1007, 2023, doi:10.4271/2023-01-1007.

Received: 1 Dec 2022 Revised: 3 Jan 2023 Accepted: 3 Jan 2023

Abstract

Equipment used in aerospace non-destructive inspection presents opportunity for modernization. Many inspection cells in production operate using a widely available control system software that is suitable for most inspection applications with minimal customization. The size and complex geometry of airframe components demand more application-specific system design to ensure the reliability and cycle time required for an aerospace production schedule.

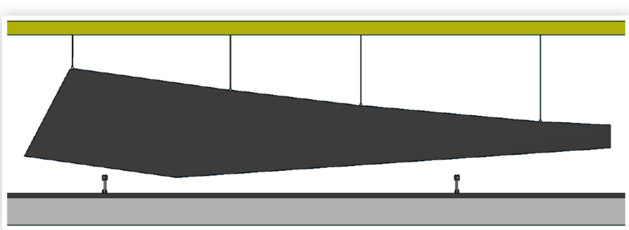
Ordinary inspection systems require manual teaching for program generation and lack datum-finding systems required to rerun programs without modification. Integration of offline programming software and machine vision instruments can save inspection technicians hours or shifts per part by eliminating the need for program retraining due to variation in part delivery position. Modernized inspection cells will reduce labor burden on technicians and provide reliable cycle time information to production planners.

Introduction

The control system of a robotic ultrasonic inspection system commissioned in 2016 is being overhauled at a widebody airframe factory. The existing cell operates using a proven control system with integrated data collection that is widely used in aerospace inspection systems.

The size and complex shape of a wing panel creates technical challenges that often require application-specific solutions rather than standard products. While the antecedent control system can collect the data required to pass inspection, the time required to inspect the parts is not predictable enough for the demands of the production schedule. Leveraging experience with complex aerospace manufacturing, an equipment designer might identify two predominant inadequacies typical of inspection systems that have been responsible for production delays in this aerospace application.

FIGURE 1 Panel inspection orientation.



Inspection Program Generation

Modern equipment used in aerospace manufacturing is fast and accurate. Fastening and carbon fiber layup machines are almost always programmed offline because of the many axes required to execute operations on the complex and curved parts of an airframe.

Inspection systems do not require the same level of accuracy or speed to generate imagery required for inspection. Also, these systems provide flexibility for certified technicians to direct how the part is inspected. In manufacturing, the machine executes a process and continues with the programmed operations. Inspection equipment is different, because it may be used to inspect the same area multiple times using different settings or to revisit an area manually so that a technician may analyze a possible defect. As such, inspection programs are generated by inspection technicians while manufacturing programs are generated by NC programmers.

In the 2016 panel cell and many like it, inspection programs are taught manually. Using the robot pendant, the technician angles the end of arm tool roughly normal to the aircraft skin and jogs the probe into contact at several points to be connected into a line or area scan. For large areas, the software has an algorithm that can automatically generate points in a raster using four points to define a rectangle. However, the algorithm does not allow for more complex geometry.

FIGURE 2 Teach point examples for line and area scan.

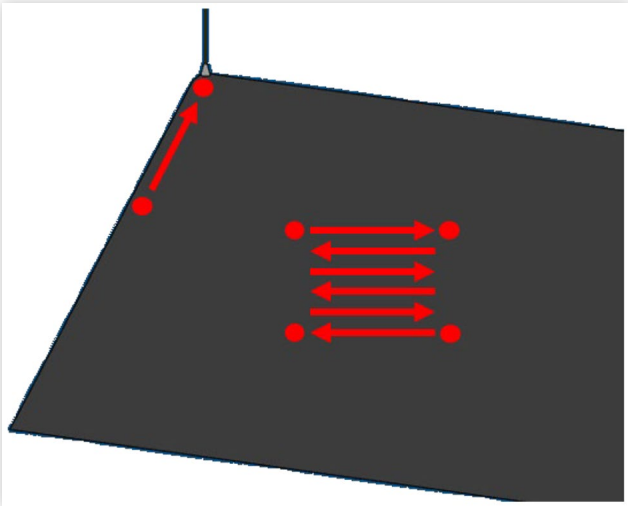
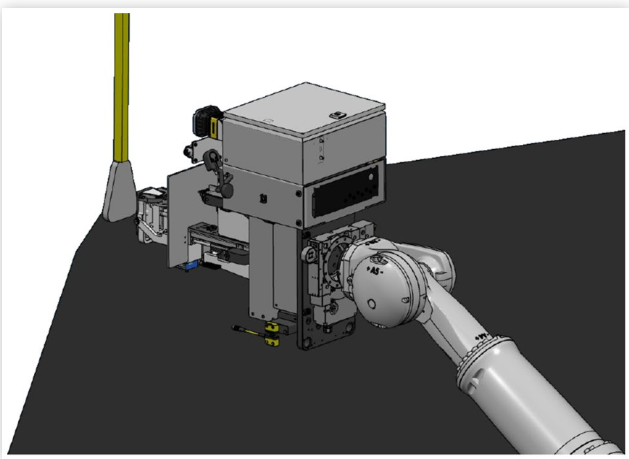


FIGURE 3 Teach point near collision obstacle.



On parts with simple edge contours line generation point-by-point is not overly time consuming. However, a wing panel is huge with curvature in multiple axes. Line scans near edges and collision obstacles are more like splines, requiring many teach points. Additionally the top of the part is seven meters off the factory floor, which means technicians must use a lift to teach scan paths to ensure full-coverage inspection while avoiding collision obstacles.

Manually taught programs do not maintain normality or tool point distance to the part. For lines and areas of high curvature it is necessary to break segments up even further, requiring many more manually taught points.

These manual programming methods can work effectively on reasonably sized parts with simple edge contours and low-curvature areas. However, a wing panel does not meet these criteria and teaching such a large program can be tedious. Even so, after a manual program is taught it ostensibly should not need to be retaught.

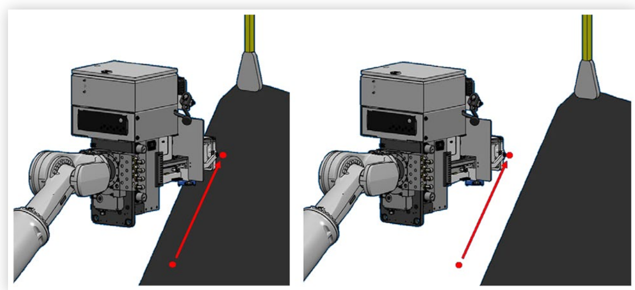
As each scan path is executed, data is tabulated according to the position of the robot when it was collected and can be stitched together into an image file for inspectors to analyze.

Indeterminate Part Positioning

Cells like the 2016 panel cell lack any implement to repeatably position each part in the robot coordinate frame. That means after the tedium of manual program teaching is complete for one part, inspection techs cannot guarantee that the program can be successfully executed on subsequent parts. That's because as the robot executes a program, it repeats the same coordinates that it was taught on the first part, even if the next part arrives in the cell in a different position. As such, if the cell is programmed to scan the part for full coverage and the part arrives out of position, the scan probe may run off the part near an edge or collide with an obstacle in another location.

Repositioning activities due to inaccurate part delivery can cost nondestructive inspection technicians hours per panel. If the technicians are unable to position the part accurately enough to rerun the manually taught programs, reteaching the problematic scan paths can cost multiple shifts per panel.

FIGURE 4 Manually-taught line scan failure due to panel placement error.



Machine Vision Datum Finding

The most egregious limitation of these systems can be eliminated by a datum finding system. Machine vision has been used for datum finding in aerospace manufacturing equipment for decades. As such, the 2016 panel cell retrofit includes installation of a standalone vision system for this purpose. Because the technicians encountered collisions most commonly with the fittings used to hang the part in the cell, the fitting outline was used as a training target.

When the robot locates the target, a relative offset between the target's actual coordinates and nominal coordinates is calculated. The offset is then applied to the reference frame for the scanning robot. This datum finding system has enabled inspection technicians to successfully execute their manually taught programs without modification.

FIGURE 5 Machine vision datum finding.

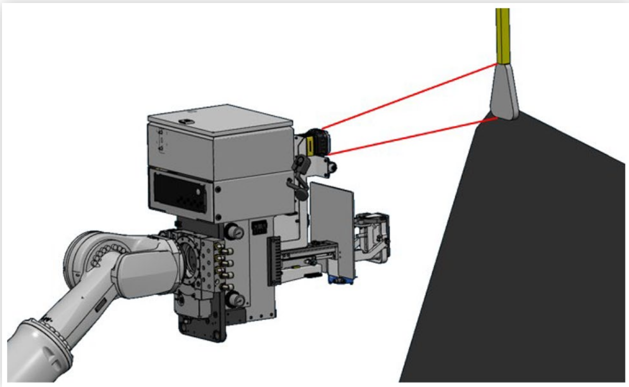


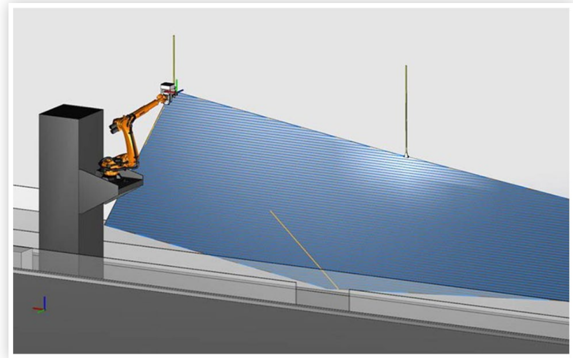
FIGURE 6 Vision system target acquisition.

Offline Programming

Panel scan process change can result in long periods of cell downtime during scan program reteach. Installation of an offline programming package moves programming activities outside of the cell so that equipment remains free for production activity. Compared to manual program generation, offline program generation is faster, more automated, and enables larger scan programs because of tool point normality and offset control.

Instead of manually training points from a lift, inspection technicians can generate scan programs automatically at a desk. The software can follow part edges, create areas, and avoid obstacles loaded into the programming environment. Approach and safe retract moves can also be simulated taking some guesswork out of program try-out.

FIGURE 7 Offline aera scan program generation.



Generated paths are stored as a collection of operations assigned to a given inspection task or part. The technician can put every task in one program to be run all at once or post many programs containing select operations and whatever specific inspection settings are required each operation.

Conclusion

The largest and most complex manufacturing challenges almost always require specialized equipment. The 2016 panel cell is an example of a conventional tool upsized to inspect parts outside the system's capacity.

Shifts worth of uptime can be lost to part reposition and program reteach if a part arrives out of position. For inspection equipment to meet commercial aerospace production schedule requirements, cycle time must be predictable. This means that cell downtime for repeat labor must be eliminated.

Aerospace manufacturing equipment designers have the experience and tools to improve automation in nondestructive testing by introducing industry standard functionality. Offline programming software and reliable part location improves automation, reduces downtime, and brings more predicable processing times to inspection cells

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ISSN 0148-7191