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Aerospace robotics extends reach to the inside

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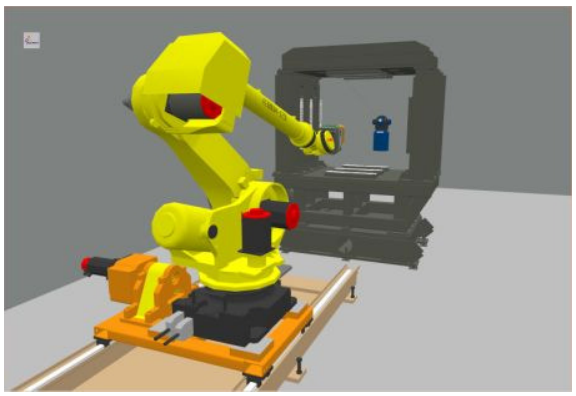

Variation Reduction Solutions is using a DELMIA robotics solution to test the feasibility of using a robot to perform the inlet duct drilling for the F-35 JSF. (Brown Aerospace)

Robots are ideal for replacing manual labor in dangerous or tedious operations. This is not always possible, however, due to technical limitations in robotic movements and accuracy.

Robotic capability is growing, though, and robots can be expected to take over more awkward and dangerous tasks. A case in point is a project in which robots will someday replace drilling in a place any human would find awkward at best: inside the air inlet duct of the F-35 Lightning II. It is a space that measures only 20 in wide at the widest over its 9-ft length. Claustrophobics need not apply.

To prove that automation can do the job, the **U.S. Air Force Research Laboratory** (AFRL) Manufacturing Technology Division (ManTech) has launched a small-business innovative research (SBIR) project, "Guided Robots and Robotic Applications in Confined Spaces." **Variation Reduction Solutions** Inc. (VRSI), the prime contractor, is just concluding the feasibility stage that proved that robots could indeed reach inside a tight space to accurately drill and countersink holes. Subcontractors to VRSI include **Comau North America** as integrator, **Brown Aerospace**, **Precorp**, and the **DELMIA** group of **Dassault Systèmes**. **Northrop Grumman** Corp., the prime contractor for the center fuselage, provided advice and technical input.

The air inlet duct integrates with the fuselage through aluminum frames attached via mechanical fasteners. Manually drilling and countersinking the 800 holes needed per duct requires workers to physically enter the space. They use a drill template to accurately place the holes and countersinks. Speed and ergonomics were the guiding motivations for the project, not dealing with claustrophobia.

"AFRL knew they had to automate this operation," said Joe O'Brien, Aerospace Program Specialist for Comau North America, noting that the planned build schedule is one airplane a day.

The only feasible automation tool was a six-axis articulated-arm robot, commonly used in material-handling, welding, and painting applications. Robots excel in these repetitive tasks, for which accuracy requirements are less stringent compared to drilling. The typical six-axis robot is more mechanically complex than the gantry machines ordinarily used in aerospace drilling.

To fit into the inlet duct at all 800 drilling positions, a long-arm, small-wrist robot was required, the project team decided. While versatile, these robots are less accurate than larger, stiffer models, according to VRSI. Drilling positions of each hole and countersink required accuracy better than 0.030 in, according to Brett Bordyn, Director of Technical Development at VRSI. Such accuracy required a strategy for accurately positioning the drill that the robot would be wielding. Robot users measure accuracy in two ways: absolute accuracy and repeatability. Both are important, but in this case the absolute accuracy (how well the robot moves the first time to its drill position) was key. Although absolute robot accuracy through in-factory calibration has come a long way, the team decided that an external metrology system was the only solution.

That system consists of two robots—one reaching in to drill and another reaching in from the opposite end of the inlet duct to measure its position. A vision-guided, uncalibrated **Fanuc** Series 2000/125L robot drills the holes. A **Faro** CMM X V2 automatic distance measurement laser head on the end of a Comau robot measures the position of the drill head. Three custom spherical measurement reflectors (SMRs) mounted on the drill head act as targets for the laser. **PLX** manufactured the SMRs based on designs by VRSI. The Fanuc drilling robot controller uses the position information fed to it through a complex set of algorithms developed by VRSI.

For the laser to know its own absolute position in space, it calibrates itself to known fixed fiducial marks on the perimeter of the work cell. An inspection head using a laser-triangulation sensor aligns the robot relative to the inlet duct and coordinates the position of the drill relative to holes prior to drilling. It then measures the position and size of holes after drilling, said VRSI's Bordyn. "Using this system, we have guided the robot to drill within 0.0055 in."

Said Comau's O'Brien: "The technology advancement that made this possible is the metrology equipment." VRSI selected a time-of-flight measurement system as more robust than other techniques.

"Circuitry to measure the speed and distance of the beam have advanced recently to provide the accuracy needed," said Bordyn. VRSI supplied the advanced mathematical algorithms to match the coordinate systems of robot, part, tracker, drill head, and work cell.

Robotic simulation software plays its part too, both for efficient offline programming and in-process collision avoidance. Working with **TechniGraphics**, a DELMIA channel partner, VRSI selected the DELMIA robotics solution for its cable simulation, GSL script language, and offline programming capabilities. Using the CAD model of the inlet duct in Catia V5 format, it creates multiple collision and near-miss queues to ensure collision-free robot trajectories.

The next phase after successful completion of the current SBIR is a production cell. Comau's O'Brien envisions using two robots and a rotating platform for the drill and inspection heads. In this configuration, each robot would perform both drilling and laser tracking for the other. The drill heads and trackers (instead of the inlet duct) would rotate.

The future for using robots to perform such drilling looks bright, according to O'Brien. "Approximately 60% of all assembly work in aerospace is fasteners," he noted. Using robots coupled with offline programming means that the same work cell could be reprogrammed within a few days to a few weeks to operate on new parts, depending on the complexity of the part. There is a limit to what six-axis, articulated-arm robots can do—as there is for most manufacturing tools. However, the advances demonstrated by this project extend the reach of robots in new ways.

For those aerospace workers who might suffer from claustrophobia, it is good news as well.

Bruce Morey

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