The Fuselage Automated Upright Build (FAUB) robotic system by KUKA Systems automates most riveting for future Boeing 777 aircraft, installing up to 60,000 fasteners per fuselage with great precision.

Aerospace Automation Stretches Beyond Drilling and Filling

Automation expands deeper into aircraft production, speeding deliveries and helping to reduce order backlogs

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Faced with ballooning order backlogs, aerospace builders and automation suppliers are exploring new ways to automate a broader range of aircraft manufacturing processes. The goal is to deliver higher-volume commercial aircraft like the Boeing 737 and 777 more quickly to customers, but also to improve the consistency and safety of the final product. To pick up the production pace, manufacturers and their suppliers are refining the automation systems used for drilling, filling and fastening operations and finding new opportunities for automation.

In recent years, the aerospace and defense industry has adopted many of the high-volume automation practices of the automobile industry with some success given the much lower volumes of aircraft manufacturing. Some examples include high-precision robotic drilling and riveting of holes on airframes. Other key automation improvements have been made in painting, coating, and sealing, trimming of composite components, and machining aircraft engine turbine blades.
Greater use of automated guided vehicles (AGV) for transporting very heavy and unwieldy airframe structures to drilling or machining cells has also enabled reductions in the time-consuming use of large cranes traditionally deployed in aircraft factories, leading to faster production, lowered costs and more optimized factory floor space.

Integrating Airframe Automation

A new robotic pulse production line developed by KUKA Systems North America (Sterling Heights, MI, and Augsburg, Germany) for the Boeing 777X program aims to speed up production of Boeing’s latest wide-body 777X commercial jetliner. Last September KUKA Systems unveiled the new robotic riveting system for the 777, called the Fuselage Automated Upright Build (FAUB), that will be the baseline manufacturing process on the twin-aisle 777X aircraft as well as current 777 models. This pulse line uses KUKA robots with special end effectors from a KUKA company, Alema Automation, for performing riveting operations currently done by hand. The robotic line will install up to 60,000 fasteners in the forward and aft sections of the 777 fuselages.

“Aerospace manufacturers are improving manufacturing processes and using automation to make the assembly process less costly. The less touch labor you have on an assembly, the less it costs to produce,” said Jeff Camphous, senior account manager, KUKA Systems Aerospace Group. “We will never automate aircraft assembly in the same ways we do in our automotive business, mainly because of the volumes of production. Specific processes such as drilling and fastening, which is very high volume in aircraft manufacturing, can be automated to reduce cost and improve quality.”

The FAUB system, one of the largest projects undertaken by KUKA Systems in the aerospace sector, was preassembled and integrated at KUKA Systems’ Sterling Heights headquarters. The system is undergoing final-phase tests before being installed at a Boeing facility in Anacortes, WA. “The end effectors for this project are the standard Multi-Function End Effector used on most of our robotic drilling and fastening systems,” said Camphous. “The unique aspect of this end effector is the ‘Gatling Gun’ service module. This allows us to install multiple modules in the end effector to perform different manufacturing tasks while maintaining clamp-up pressure on the structure.

“Some of the most common modules we use are Drilling, Vision, Quality, Insertion, Fastening and Sealant,” Camphous said. Multiple metrology systems are employed in the FAUB system, with KUKA’s metrology partner, Variation Reduction
Solutions Inc. (VRSI, Plymouth, MI), supplying vision systems and laser trackers. “Systems are in place to aid in the alignment of the equipment, global positioning of the robots, and local registration of the robot to the product,” Camphous said. “The end result of these metrology components allows us to place holes in a very accurate location. Some of our systems have the capability to position a hole to a true position diameter of 0.007” [0.1778 mm].

Drilling and fastening no longer rank as the top problems of aerospace builders, but they’re still the most requested, Camphous added. “Most systems of aircraft assembly require drilling and fastening. It is also the highest-volume activity when it comes to aircraft structure manufacturing, which in turn, allows for the easiest return on investment,” he said. “Fay and fillet sealing are most likely the next challenge in the industry.”

Mimicking Automotive

Making aerospace production faster necessitates some adaptation of best practices used to great advantage by the auto industry. “What’s happening in the aerospace industry, both in the jet engine side and in the aero structure side, is as these aircraft rates go up, the aerospace industry is starting to look at building airplanes like cars,” said Scott Walker, president, Mitsui Seiki USA Inc. (Franklin Lakes, NJ).

Using higher-rate production with automation is the key to bringing the aerospace industry closer to automotive automation levels, Walker noted. An example is the highly automated machining cells used for producing jet engine turbine blades, blisks or other aircraft components in high volumes. Machine builder Mitsui Seiki supplies its customers with five-axis machining centers for producing precision aerospace components from hard metals including titanium and stain-
less. Mitsui Seiki’s aerospace customers include Sikorsky Aircraft Corp. (Stratford, CT) and other aircraft builders that use the company’s automated machining systems equipped with large pallet pools in the Flexible Manufacturing System (FMS) developed by Fastems LLC (West Chester, OH), which frequently partners with Mitsui Seiki in automating aircraft component production.

“If you go into a car plant, you’ll see a block line, you’ll see a transmission line, you’ll see lots of automation, parts coming off one after another,” Walker said. “The just-in-time environment is very critical to automotive, and aerospace has not been like that.” In aerospace production, the mantra has been more like “these are more expensive components, they require more hands-on,” Walker said. “But as the technology changes and the demand for aircraft goes up, really the only way to meet the rate is to automate how parts are manufactured, based on the demand and the scheduling of the aircraft.”

At a recent installation, Mitsui Seiki automated the machining of landing-gear components for a commercial aircraft builder with a system employing seven Mitsui Seiki machining
centers equipped with 630-size pallet systems, Walker said. Featuring about 100 pallets, the system aimed to supply enough components to help double the builder’s monthly production to 60 planes a month.

“Typically in automotive, they’ve got these terms like Cpk and Six Sigma, and the aerospace guys are also going in that direction,” Walker said. “They need to develop the process so that the parts can be made with very little human intervention. It’s not making it faster necessarily, it’s making it very consistent and that helps a lot when you’re in an automated system. Number two, it allows you to be able to have very clear, definitive deliverables.”

A key benefit to this type of automation, involving systems with long machining times on very hard materials, is obtaining greater spindle uptime, Walker added. With an FMS automation system like those from Fastems, a builder can boost spindle uptime on these machining operations to at least 60%, up to even 80%, Walker said, which is close to approaching world-class spindle uptime levels.

At Sikorsky Aircraft, Mitsui Seiki five-axis HMCs perform high-precision machining of 66” (1.7-m) diameter titanium main rotor hubs for the Sikorsky CH-53K heavy-lift cargo helicopter under development for the US Marine Corps. “For the Sikorsky rotor hub, we take a block of metal that weighs nearly seven tons down to about 400 lb [180 kg],” Walker said. The system uses two large-envelope, five-axis HMCs that hold 0.002” (0.051 mm) on diameters and true positions of 0.005” (0.13 mm), with “zero” setup capabilities via dedicated part load/unload stations that are tied to the FMS pallet transfer station.

Innovating with Automation

Many aerospace customers are looking for new ways of thinking for solving throughput issues in building the machined components and composite parts needed for their aircraft programs. “We are seeing new creative ideas for integration of different processes into a
complete manufacturing cell. We are able to help aerospace customers complete entire processes to achieve a completed product,” said Michael Bell, Fastems director, operations.

As an example, Bell offered the case of a major aerospace contractor currently manufacturing 20-m long carbon-fiber components that need to be layered by hand, then moved to a machining process before going through an automated measurement process. After machining, the parts have some secondary profiles added to the machined workpiece, then go through a wash cycle and back to automated measurement without being removed from the machining pallet. “This was unheard of even five years ago,” Bell said. “Now these types of operations take place on most new system designs.”

Many of Fastems aerospace customers are looking for help solving problems in hard metal machining automation for large components, Bell said. “Fastems can integrate machining centers no matter how large the raw materials and workpieces. Another challenge we are solving is multi-process machining without removal from fixtures, helping customers maintain proprietary processes without handling the machined components between operations.”

**Moving Massive Parts**

Making aircraft production rates also means eliminating some of the large monument fixtures and minimizing the time-consuming crane moves often required with large airframes. With the latest automated guided vehicles (AGV) from automation developer Fori Automation Inc. (Shelby Township, MI), aircraft builders can lower costs associated with delays for crane moves, while gaining precision positioning with new servo-controlled AGVs, which also include auto-leveling technology that helps ensure accuracy.

“What they’re really looking for is flexible automation,” said Martin Erni, director, business development, Fori Automation. “For drill and fill, there’s been super-large fixed cells, but in the future, it’ll be more a flexible line. Whoever builds the drill and fill equipment will have to either be flexible or get out of the way.”

With its flexible AGVs, Fori typically handles transportation of the drill units. “Instead of the monuments, they’re now switching to autonomous vehicles,” Erni said. “It is very practical to move the robot along the wing.”

Robots mounted on Fori’s AGVs are able to hold the high precision required on drilling applications, said Paul Meloche, Fori’s vice president, sales. “It’s better to move the equipment to the part, just because of precision,” Meloche said. These AGVs have locking and docking anchors, and are equipped with Fori’s precision motion control using the company’s controls and encoders with its drive and steer systems, he added. “We can be accurate to ±3 mm,” he said, “with a 40–50’ [12.2–15.2-m] workpiece.”

With increased requirements for positioning, the AGVs have floor bushings that increase the accuracy to 0.005” (0.127 mm) and allow auto-leveling the platform, Erni said. The company has provided such systems for Brown Aerospace, supplying aircraft built by Spirit AeroSystems. These systems transport large workpieces weighing as much as 110,000 lb (49,500 kg), moving it between stages of manufacturing including to and from autoclaves. “Prior to using this, it would have been a very time-consuming process with an overhead crane,” Erni said.

**Forging Better Blades**

A new forging cell developed by Schuler Inc. (Canton, MI) and Schuler Pressen (Weingarten, Germany) features
the company’s ServoDirect Technology in its SDT Upsetter and Screw Press. This automated robotic system employs two robots in two cells feeding new exotic metal material that is heated in ovens before going into the forging machine that produces near-net-shape turbine blades.

Under development for about two years, the prototype forging cell is currently undergoing testing at the Advanced Forming Research Center of the University of Strathclyde in Glasgow, Scotland. Schuler’s SDT Upsetter employs a two-servomotor design that enables high production output rates and sets the forming parameters to the specific forming requirements of the material. The system’s press force is 2100-2600 kN, and it includes ovens, robotic automation and die lubrication. The resulting turbine blades will require minimal machining, and the new forging system will increase output, said Klaus Berglar-Bartsch, sales manager, Forging Technology, Schuler Pressen. “It’s a bidirectional machine that clamps the material and then you upset it,” Berglar-Bartsch said. “If the upsetting material [speed and pressure] is too high, you crack the material and it falls apart, so you need to control the speed.”

This system enables much more efficient forging of the metal alloys used in mission-critical turbine blades. “Safety is the No. 1 priority in manufacturing aerospace parts,” he added. “This is a fully controllable process, with controlled deformation of the part.”

Sealing the Deal

Another area of opportunity for automation in aerospace is the sealing of joined components on airframes. “I would say drilling is still No. 1, but there are other opportunities that are
sneaking up, especially in the sealing of long joints in the wing box,” said Chris Blanchette, national account manager, aerospace and assembly, FANUC America Corp. (Rochester Hills, MI). “They do that by hand right now, and it has to be sealed because of the fuel in the wing. From an ergonomic perspective, coatings is probably the next big one.

“What they’re trying to do is use more automation and robotics for the ergonomically difficult tasks, and to use the real estate that they have,” Blanchette added, noting the difficulty of speeding up production on predominantly manual operations. “Robotics can increase it significantly. You can push people to work faster, but they make mistakes.”

In the past year, FANUC has worked on many aircraft painting and sealing applications, most of which require “activating” the surface of the airframe through sanding or other operations. “A lot of the challenges with the newer planes are the materials, where they’re using a lot of carbon fiber,” Blanchette said.

Newer methods of automating these types of operations robotically include using FANUC’s Force Control. “You’re going to be contacting the entire surface with a robot. They’re looking at ways to control the force while scuffing or sanding, doing surface activation,” Blanchette said, “and one is using our Force Control option, which is sort of like touch sensing. Those are being evaluated, and we’re getting into the phase now where there’s a lot of research going on.”

Another issue for aerospace builders is processing a large variation of parts with new composite materials, he added. In trimming applications, there are many variations and shapes of stringers that make it more difficult to machine than with traditional materials. “When they manufacture with the composites, they don’t have great control of dimensions when it comes out of the autoclave, and they have to trim the part,” Blanchette said. “It’s very difficult to machine carbon fiber.”
Robots for Workholding

For a recent trimming application, aerospace supplier PaR Systems Inc. (Shoreview, MN) developed an overhead gantry-based KMT waterjet cutting workcell that used 37 FANUC LR Mate 200iD Series robots functioning as flexible fixtures precisely holding a 40–50’ (12.2–15.2-m) long composite airframe component. “In the past, they’d typically have a fixture or a pogo to hold the part, and the pogos are much more expensive,” Blanchette said. “The beauty of the robot is it has six axes of articulation, and you’ve added flexibility at a significant reduction in cost. It’s also able to do more with the range of part variation. There are a lot of features of the robot that are enablers, such as the force control sensor that allows them to be able to do complex geometric shapes, with great repeatability.

“We’re also working with Nordson Sealant Equipment [Plymouth, MI] to develop new tools and applications software to be able to dispense sealers,” he said. These systems could be used for fay and filleting, which are sealing terms that relate to the shape of the sealer, similar to caulking, he added. “In a lot of ways, it’s a lot more difficult. They’re doing it all by hand now and there’s an art to it. It’s difficult to get access to the areas that need sealing, you have to control the bead. The shape has a tolerance, you have to be able to inspect it, and there’s got to be enough volume to it. It’s a very, very difficult process, and it’s also very time-consuming. If they’re going to increase throughput, it’s a bottleneck.”

Aerospace builders continue to show broad interest in automating aerospace operations, said Joe Campbell, vice president, marketing, Güdel Inc. (Ann Arbor, MI). “The applications are very traditional—material handling, machine loading, assembly including drilling and riveting, surface prep and paint, sealant dispensing, etc. Gantry robots are a natural fit due to the heavy payload capacity and large work envelopes. Where the dexterity of a six-axis robot is preferred, floor and overhead robot tracks deliver the work envelopes required.” Teach pendant programming is economically difficult for low-volume, high-mix manufacturing, he noted. “Aerospace manufacturers have been aggressive in adopting CAM principles for machining,” he said. “They want to apply the same offline processing and programming to robot applications. This is all good, but building large work envelope systems with sufficient accuracy [versus taught point repeatability] is a challenge. In many applications, high-resolution sensors such as machine vision are delivering the required precision.”

Güdel is developing large-scale robot positioning systems to support automation of the largest aerospace parts and frames. “We see considerable interest in painting,” he said. “The economic drivers are significant, from the cost and weight of the material being applied, typically over applied, to the dangerous and dirty working conditions.”

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