Aerospace: Comply or Die

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How quality assurance and regulatory issues influence aerospace part manufacturing

Success in aerospace machining requires more than the ability to hold tight tolerances in difficult materials. It also requires the ability to prove that you did so in compliance with a pile of specific guidelines, with reports that likewise must follow a specific format. Let's consider how these quality assurance (QA) and regulatory burdens influence aerospace manufacturing, and explore some new tools that ease the burden.

Aerospace machining often requires specialized machine tools, such as this X10000 from Mitsui Seiki. Tier 1 suppliers often look to the machine builder to share in the creation of a manufacturing process, which allows the owner of a new machine to better understand the latest technical features and how to use them.

In order to meet the quality management requirements of the Federal Aviation Administration (FAA), U.S. Department of Defense (DoD), and National Aeronautics and Space Administration (NASA), the aerospace industry built on the ISO 9001 quality management system to create the AS9100 standard. AS9100, in addition to any number of project or manufacturer specific requirements, is what governs much of what happens in the field, particularly since original equipment manufacturers (OEMs) and higher Tier suppliers are increasingly pushing these requirements down through the supply chain.

This creates some pain. First, manufacturers must absorb the cost of complying with these quality management systems, and the means to do so are not always viewed as value added. Second, the cost and difficulty of changing an approved process inhibits making improvements. Happily, there are a number of excellent solutions that address both problems.

Software to the Rescue

The software that will help navigate this maze fall into three broad categories: Product Lifecycle Management (PLM), which focuses on product development and managing all the document revisions that occur in that process; Enterprise Resource Planning (ERP), which is primarily concerned with inventory management and supply chain efficiencies; and Quality Management Systems (QMS), which deals with corrective and preventive actions, quality audits, and process improvement. The products often overlap, so don't concern yourself with the umbrella terms as much as the individual features needed to run a business.

For Elite Aerospace Group, an aircraft component design, engineering, and manufacturing company based in Irvine, Calif., an acquisition was the impetus to get into PLM. As Stuart Weiler, director of CAD/PLM explained, Elite started as a low-complexity, high-volume manufacturer and then acquired

a company that was a low-quantity, high-complexity manufacturer. The RFQ processes didn't mesh, plus the company had people in five different states working on projects, increasing the risk that something would fall through the cracks.

Elite Aerospace opted for Windchill PLM from PTC, Boston, which includes ERP and Customer Relationship Management (CRM) components. Using Windchill, Elite follows a well-defined process, regardless of where the RFQ originates or its format, everything from "a job shop with a request for 50 widgets and paper print, to a 50-page RFQ from an OEM with a zillion requirements," said Weiler. "Windchill allows us to create an item and then attach all of the other relevant information, such as the drawings, the specs, the processes. Now when you look up that item number, everything's collected together and you don't have to go searching. Everything is linked nicely to make it a lot easier and more accountable."

Weiler also made the point that requests to change a part are handled like a new RFQ, which is logical because any change will likely result in a change in the cost. "In the past, we weren't always doing that," said Weiler. "Now, because we're using the system to do that same review, all the right people oversee the process and we eliminate the risk of someone deciding that a change is 'no big deal' without fully understanding the implications."

Weiler added that one of the biggest wins in moving to a PLM system is finding you can "reuse an existing design rather than designing the same thing a second time. People have a very hard time keeping track of what they already have, including the designs from five or ten years ago. Inventory gets out of control. You wind up with identical parts that have different part numbers. And, because they are being ordered at different quantities, the parts cost different amounts. With better organization, you have just one part number, you're ordering a higher quantity of that item, and you don't have all of the inventory costs of keeping multiple items in stock." The converse is that the system enables you to keep track of many more items, so designing ever-more customized components "is no longer as consequential as it used to be," observed Weiler. This fits well with the advent of additive manufacturing and a "build it when you need it" approach.

Quality Management, Quality Improvement

Paul Van Metre was an aerospace manufacturer for 17 years, during which his company created ProShop ERP software for its own use. He ultimately sold the manufacturing company in favor of founding ProShop USA, Bellingham, Wash., to focus on bringing the software to others. In addition to ERP functions, ProShop features a QMS system, so "it's particularly good for manufacturing complex products in a regulated space," Van Metre explained.

"Before we entered the market, most packages we saw were primarily accounting-based ERP systems that had little to no quality management and manufacturing execution ability. We are just as much a quality management solution as we are ERP software, and we get deeply onto the shop floor, making it paperless, and making all the shop employees just as much a part of the system as the office employees," he said.

The software covers everything from part-specific work instructions to documentation of all current and past jobs—with digital sign-offs at each process step—to inspection reports, corrective action reports, and all the records needed for a quality audit. That includes the AS9102 forms typically required for quality reporting under AS9100. Van Metre said there are still many companies that attempt to comply with AS9100 and related guidelines using a collection of ad hoc MS Word documents, Excel spreadsheets, and the like, but it's "exceedingly tedious to update, keep current, and control." In fact, making changes in such a system is so difficult that "people don't use it to improve their business process nearly as much as they should. They stick with inefficient methods because the cost of change is too great," he said.

In contrast, QMS software brings all the critical information into a single database, with a documented process for each activity, tied to individual job roles.

The right software can both help your shop make good parts and help your QA team prove compliance with aerospace requirements.

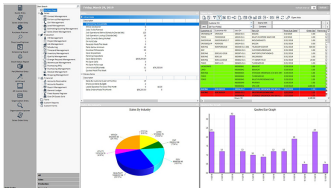
Van Metre cited the example of a work instruction, with responsibility assigned to six people. "Any one of those six people can spawn a draft in the background, make edits, and get feedback. Once they decide it's right, they can check off a single box to release it for approval. That automatically notifies the approvers that there's a new revision in draft state, asking for their approval. Once they all approve it, the software automatically archives the old version, notifies all six people that the new official version is released, and replaces the latest revision with the new one. The new one becomes the only thing users can access unless they look in the archive." And because it's so much faster and easier, Van Metre observed, "people are incentivized to make changes. And auditors love this, as opposed to visiting your company and finding all of your documents still at Revision A. Because a key purpose of ISO and AS is to continuously improve your service to your customers." With ProShop and similar products, "the quality management system becomes an effective tool for continuous improvement, whereas before, it was an obstacle."

David Isaacson, senior director of product marketing for ETQ LLC, Burlington, Mass., pointed to Sikorsky Aircraft's experience with its Reliance QMS product. "Sikorsky had a problem with foreign objects left in their helicopters. But by using Reliance to centrally record every incident in which extra bolts or a wrench or any component was left in an aircraft, they were able to put a global foreign object prevention program in place, tracking trends and solving the problem location by location. The incidences of foreign objects being left in an aircraft have gone way down."

In the same way, if another problem occurs, Sikorsky can quickly understand if that condition is likely to occur at another location and apply the same solution there. As Isaacson sees it, having data often serves as "a proof point to force change. If the data identifies a consistent problem in my processes, then I know I need to find a solution, and having the right tools can hep implement that change."

Isaacson also underscored the challenge that larger aerospace manufacturers face in managing their supply chains. "They're not dealing with half a dozen or even a few hundred suppliers. They're dealing with thousands, and there's no way to manage the quality of all parts coming in without some

sort of automated system. For example, during first article testing, when a new part shows up on the dock, how could a manufacturer report back corrective actions and non-conformances without the supplier's information being in a system, without access to the workflow history, and without exchanging information in real-time? There's just no way to manage these critical quality processes efficiently in e-mail and spreadsheets." A manufacturer needs an automated system that gives it the ability to query the status of each supplier and the expected products from that supplier.



The start-page for the M1 ERP package at Horberg Industries shows open jobs and critical statistics at a glance.

Bob Leety, president of Horberg Industries Inc., Bridgeport, Conn., offered a perspective from the other end of the size spectrum. Horberg specializes in manufacturing small dowel pins, taper pins, and precision shafts to extremely tight tolerances, generally in the high-chrome, high-nickel, high-cobalt materials that are used in high-temperature aerospace applications. With only 15 employees, Horberg was still faced with the need to document compliance with AS9100 plus a number of other onerous requirements, like being able to prove it didn't use "conflict minerals" (tin, tantalum, tungsten and gold mined in or smelted in the Democratic Republic of Congo or adjoining countries). Managing this with such a small staff drove Horberg to adopt the M1 ERP package from ECI Software Solutions Inc., Fort Worth, Texas, more than 15 years ago. Leety credited M1 with making it manageable, though he added that "the people implementing it need to understand what compliance looks like in order to reach the end game. M1 makes it possible. It doesn't make it painless."

Leety also lauded M1's ability to search for things like all the non-conformances and group them by the root cause. "If you see a pattern, like a lack of training, then you know you need to set aside resources to better train people. Or if it's a particular vendor, you know you need to put them on notice or find another one. It really helps focus your efforts." Leety said Horberg also bar codes all of its gages and records each use in M1. So, if later it finds a gage had a problem it can trace every single job on which it was used and quarantine the affected parts.

"We also use a feature that automatically generates e-mails to alert the proper staff on what jobs are due to be released and what jobs or inputs are overdue. It gives you the data you need right on your desk instead of having to dig for it." Horberg also customized the product to track and alert the qualification status of its suppliers so it isn't caught depending on a company that lacks the right credentials. Leety also observed that dealing with outside vendors that don't use ERP can be frustrating. "It's usually much slower to get information back, and you're not apt to get equally accurate information."

One of the sweetest rewards of a good QMS is a short and successful quality audit. Leety said Horberg's audits typically run two to three days. "We have a computer set up with a projector and a big screen and we're looking at M1 through the whole audit."

Elite Aerospace puts their software driven resource planning right onto the shop floor.

At ProShop, Van Metre said customers can reduce the time and cost of audits by 75 percent and he's seen planned two-day audits "finish by lunchtime the first day." ProShop offers another aid for the quality journey: A "Flying Start" package that comes pre-filled with all the business processes a company needs to start a documented quality program compliant to AS9100. Surprisingly, Van Metre said even certified companies get the package because they realize that switching from their old system to ProShop's paperless workflow would require "totally re-doing their business processes. With the Flying Start option, they just follow the processes we created and once they have a month or two of records to prove to an auditor that's how they're doing it, they could pass an audit. And that is much faster than developing it themselves from scratch."

In general, Van Metre fully expects ProShop software to deliver a return on investment of at least 100 percent in the first year and "we've seen customers have 200 or 300 percent in the first year." The AS9102 forms alone can be a huge help. For example, one company spent hours a day preparing the documents that shipped with its products only to experience a 60 percent rejection rate with one customer—not on the products themselves, but on the paperwork. "If an 'i' wasn't dotted or a 't' wasn't crossed, their customer would reject the whole shipment and send it back. I spoke with them six months after they got ProShop and they hadn't had a single rejection since."

Defining and Measuring Processes

Mitsui Seiki USA, Franklin Lakes, N.J., has been a major machine tool supplier to leading aerospace companies for decades. Scott Walker, chairman, noted that OEMs define their own manufacturing processes and generally don't share that information with machine builders. Instead, they issue highly detailed RFQs with specifications like excitation frequencies, component bending moments, and software compatibility protocols to meet data acquisition and distribution requirements.

Tier 1 suppliers do look to the machine builder to share in the creation of a manufacturing process, which allows the new machine owner to better understand the latest technical features and how to use them in order to meet the OEM's requirements. Tier 1 companies want a complete turnkey solution. However, there aren't requirements to deliver a particular process. Rather, the machine simply needs to deliver parts that are in tolerance without changing the material properties of the workpiece.

Besides measuring finished parts, one critical element in ensuring process control is making sure what you're measuring and what you're machining agree, said Walker. "That's the fundamental driver of all these software QC programs. You need to make sure the data going in is verifiable to some kind of hard artifact." For example, Boeing Portland ensures its machines are qualified to its measurement systems by using a 12×6" (305-152 mm) artifact, or "coupon," affectionately called R2D2. "They qualify R2D2 in their CMM, put it in the machining center and measure it with probes,

and then measure it back in the CMM to make sure the coupon, the software that drives the CMM, and the positioning mechanism in the machine tool are all in compliance.” This process is repeated periodically to determine if the machine has changed, either due to wear or a crash. Another artifact is machined and the surface finish inspected to determine if servo tuning is needed.

So how do OEMs create their manufacturing processes? And does the red tape that goes with quality management hinder change? Van Metre said it’s logical to assume that the efficiencies created by modern QMS software are contributing to a greater willingness to modify processes throughout the supply chain. As always, necessity is the mother of invention and OEMs are willing to make radical changes in methods when the incentives are high enough. These efforts start in R&D departments and move to testing under production conditions as they progress, finally defining the new production and inspection process.

A portable Novator orbital drilling machine and a close-up view of the drill jig and bushings to which the machine is clamped for each hole. RFID tags in the drill plate and machine ensure only the correct hole is drilled.

The introduction of orbital drilling to the production of the Boeing 787 Dreamliner offers an excellent example. As Hans-Petter Andersson, CEO of Novator AB, Spanga, Sweden, explained, carbon fiber composites make up half the aircraft structure and most of that is stacked with aluminum, titanium, or both. Drilling these components with conventional methods is a nightmare and Boeing quickly realized that making the 787 efficiently called for “more tools in the tool box,” as Andersson put it. Luckily, Eric Whinnem, a now-retired associate technical fellow at Boeing’s Long Beach research center, had already identified the potential in orbital drilling. And Novator, then a tiny Swedish start-up, had been working on just such technology.

Orbital drilling rotates the cutting tool around both its own axis and about a principal axis while feeding through the material. (The tool diameter is smaller than the hole diameter and because the tool cuts axially and radially, it’s technically a spiral milling cutter rather than a drill.) Whinnem explained that because of this and the intermittent tooth engagement, chips have room to be evacuated, avoiding the overheating, excessive tool wear, and composite delamination that occurs with the conventional method. But creating a production-ready solution required many design iterations in both the orbital drilling machine and the cutting tools. Based on feedback from Whinnem, Novator further refined the machine and Sonic Tools, Ashland, Va., optimized the cutting tools. Whinnem said both partners delivered the kind of creativity and responsiveness needed for timely development, not to mention friendly pricing—attributes he didn’t always experience with larger vendors. (Walker echoed that OEM R&D departments never have enough money.)

Ultimately, Whinnem’s team created a process that differed in almost every respect from the conventional drilling process, which used Quackenbush motors and “guys up on step ladders stretching to reach the highest points,” as he recalled. “We needed to address every part of the workcell, including properly configured vacuum systems, correctly programmed lubrication systems, and optimal locations for the mechanics, control boxes and motors within the workspace,” said Whinnem. “We ended up improving the ergonomics and were able to reduce the drilling time to about

one-third of the conventional approach. And with no mistakes, which was what they really liked about it.” One reason for that last advantage was the introduction of an RFID system that ensures the Novator machine is in the correct position in the jig before permitting it to drill the hole.

The first implementation was on small areas of the wings and body joints and they’ve moved step-by-step through other areas of the 787. According to Andersson, the approach has proven so successful that it’s now being applied to other aircraft and even influencing design decisions. “Right now it’s mainly a technology for relatively large holes in deep stacks where you have enough access for the machines to fit,” he said. “But for the 777X they moved the holes for the upper side of the wings and the body joint in order to get our machines in. That’s pretty cool, isn’t it?”