



*Junebug Clark, photographer, Cessna Aircraft*

Workers on Cessna Aircraft's Citation CJ production line employ various styles of aerospace fasteners.

# Keeping It Together

**cover story**

By Bill Kennedy,  
Contributing Editor

Fasteners for jets and spacecraft must be superstrong and supersafe. Here's how they get that way.

Huge wing spars, giant bulkheads and massive turbine blades get most of the attention in discussions of aerospace part making. However, those parts would simply sit on the hangar floor if no one showed up with the nuts and bolts required to fasten them together into an airplane or spacecraft.

A January 2008 Associated Press report about a production delay of Boeing's 787 Dreamliner vividly illustrated the crucial role fasteners play in aerospace manufacturing. Among the causes of the delay, the report said, was "a shortage of small parts

and the tiny fasteners that hold pieces of the plane together." Most of the same metallurgical, production planning and documentation issues dealt with by makers of large aerospace components also affect the makers of fasteners.

One manufacturer dealing with those issues is United Titanium Inc., Wooster, Ohio. The company serves customers in the medical, fluid handling and aerospace industries, producing fasteners and other components from numerous metals, including titanium, nickel, zirconium and cobalt.

**Learn more  
about fasteners**



Read more commentary on fasteners by visiting Bill Kennedy's Web log in the CTE Community section online at [www.ctemag.com](http://www.ctemag.com). The Web site features a range of Interactive Reports, a virtual product showcase, daily industry news and editors' blogs at CTE Community.

Sales Manager Charlie Gray said about 50 percent of United Titanium's business is in fasteners. Aerospace accounts for about 5 percent of its fastener business, primarily space vehicles. Production runs range from tens of thousands to one or two that might cost \$5,000 apiece.

"However, you don't actually run one bolt," said Fred Weekley, manufacturing engineer for United Titanium. "When you build one bolt, you have to test 17 of

them." He added that manufacturing of aerospace fasteners is characterized by a focus on complete reliability and related testing and documentation.

According to Weekley, most aerospace fasteners have threads that are rolled rather than cut. In roll threading, a die pushes against a fastener blank and forms the threads by displacing the metal. The result, Weekley said, is "a higher quality thread, a stronger thread," because the

part's grain structure is rearranged and compressed. Compared with their cut counterparts, rolled threads can show as much as 20 to 25 percent greater tensile and shear strength. Additionally, the die's burnishing effect generally produces a finer surface finish than what is achieved with a cutting tool.

### Like Cutting Wood

A metal bar has a grain pattern similar to the grain in wood, running parallel to the bar's axis. "When you machine it, you cut through those grains," Weekley said. On the other hand, the roll-threading process bends the grains to the shape of the thread and they remain unbroken,

*Most of the same metallurgical, production planning and documentation issues dealt with by makers of large aerospace components also affect the makers of fasteners.*

increasing the thread's strength and failure resistance. Workhardening of the fastener material adds strength as well.

Brian Shook, engineering manager at threading tooling provider ATI Landis Threading, Waynesboro, Pa., pointed out that many high-tensile aerospace bolts require UNJ thread forms, which have a higher root diameter and a larger root radius to produce a strong thread. Roll threading is usually specified when making UNJ threads.

Dies used to thread difficult aerospace materials tend to be made from higher grade tool steels that can withstand heavy pressure, said Shook. He noted that a rolling machine's hydraulic system may need to produce 25 to 35 percent more pressure to roll exotic materials compared with more common stock (see sidebar on page 48). One aerospace partmaker using this type of Landis die is J.D. Ott Co., Seattle. Bill Cook, vice president and general manager, said his company is one of the biggest thread rollers in the North-

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west. J.D. Ott makes fasteners and bolts mostly from heat-treated 15-5 stainless steel, using both two- and three-die thread rolls on machines from Tsugami and Reed. "We run a few hundred at a time," Cook said, "and the majority of them are used in the construction and assembly of aircraft."

Maintaining a precise blank diameter is a critical element in thread rolling. "It's like you're filling a mold in each roll," Cook said. "If you have too little material there, you don't get a complete thread. If you have too much, it overfills the rolls and has a tendency to break them, because you are mashing the threads with 20 tons of pressure."



J.D. Ott

Gaging a thread pitch at J.D. Ott.

As a result, J.D. Ott grinds fastener stock "to within a couple ten-thousandths tolerance," Cook said. The stock is ground to the thread's basic pitch diameter, halfway between the major and minor diameters. "What you press in has to go somewhere," Cook said. "You start out in the middle of the pitch diameter, roll the thread, and the same amount of material comes up that goes down. You end up with a bigger diameter when you are done."

The thread rolling process offers advantages in terms of material savings and speed. While those cost-savings are important in the manufacture of high-volume commodity fasteners, they are not as vital when making aerospace fasteners. United Titanium's Gray said: "Cost is not the essence. We do thread rolling for the properties it puts into the fastener. If you are going to get into the space shuttle, you would probably like to have the highest reliability possible in each component."

ing rule of thumb. United Titanium does occasionally cut certain fasteners. Gray said, "Without getting into proprietary techniques, the use of the fastener may indicate that having those parallel grains is really not going to cause detrimental properties in the fastener." And certain factors, such as fastener size or quantity, may make machining more cost-effective than thread rolling. For example, a very short, small fastener is more apt to be

machined than a 1½"-dia. part because "If you did form it, it might be so small you couldn't control the dimensions and you would have to machine it anyway," Gray said.

Some of United Titanium's threading operations are CNC and some are not. CNC programs for the company's screw machines are downloaded to the shop floor via a distributed numeric control (DNC) system. The reason, Weekley said,

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### Exceptions to the Roll

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## Sizing up materials for roll threading

**NOT ALL MATERIALS** are good candidates for roll threading. The reason is that successful roll threading depends on a material's ductility, the material's ability to flow into the shape of the die. Ductility is measured by the percentage of elongation a material will endure before it breaks, said Brian Shook of ATI Landis Threading. "There is sort of a magic figure of 12 percent" regarding elongation. If a material can't handle at least 12 percent elongation, rolling it will likely be difficult. "You know when you reach the limit, because the thread will crack," Shook said.

He offered a rule of thumb: "If the material is not so good for thread cutting, it's probably a pretty good material for rolling." For example, the minimal ductility of cast iron makes it unsuitable for thread rolling. Conversely, a gummy material that produces unmanageable chips when cut may react well to being rolled.

Some materials, however, are on the fence. Titanium is known as a difficult-to-cut material as it is subject to built-up edge, seizing, galling and abrasion when cutting threads. But that doesn't make titanium an excellent material for thread rolling. Fred Weekley of United Titanium said the Ti6Al4V alloy commonly used in aerospace fasteners possesses just about 12 percent elongation capability and as such has barely enough elongation for effective roll threading.

When roll threading workhardening materials, such as stainless steel and titanium, "get the material moving and keep it moving," Shook said. "You don't want to penetrate with your dies at a slow rate. You want to approach it as quickly as possible and then let the material dictate how it's going to be displaced."

While some threading machines feed at a constant velocity, more sophisticated ones use feedback systems that slow the feed as the dies reach greater depth and displace the largest amount of material. "That's the best approach because you get your best die life and part control," Shook said.

Threads are rolled using various techniques and equipment. Rotating or stationary heads and other threading attachments can permit thread rolling on CNC lathes. The rolls plunge into a blank tangentially from the side, or a blank can be fed through the rolls and threaded axially. Shook said most threading of high-tensile aerospace materials is done "not using attachments or heads, but on dedicated thread rolling machines with two or three die assemblies used specifically for thread rolling because the loads are generally too high to thread roll aerospace materials on CNC lathes with acceptable tool life.

Weekley said the thread rolling method has to be chosen based on the thread's diameter and length and the workpiece material. United Titanium modifies commercially available roll threading machines to fit its specific needs. Flat dies, applied axially to the fastener, are the preferred approach, he said.

For dies used to thread difficult-to-cut aerospace materials, Shook added: "You generally don't use plain, run-of-the-mill tool steels, like D-2. They work fine for a lot of applications. But when you get into the high-tensile applications, you need to go a little higher up the tool-steel food chain. That gets you into the M series of high-speed steels or more exotic materials."

—B. Kennedy

is the company wants its threading operations to run exactly as written and does not want operators to edit CNC programs on the shop floor.

United Titanium thread-rolling machines are run manually. "There probably are some roll threaders that are computer controlled, but we don't do that," Weekley said. "We have a stable setup that produces very little variability in the part. With any of these high-reliability parts, an awful lot depends on having a process that is the same every time." Because the operations do not change, there is no need for CNC.

Minimal variability helps United



B. Kennedy

A 1¼-8 proprietary titanium bolt is thread rolled at United Titanium.

*Aerospace customer requirements for strength and reliability may require that a fastener be formed on a hot press instead of a cold-heading machine.*

Titanium meet tolerance requirements for aerospace fasteners, which vary according to their application. "We hold  $\pm 0.0001$ " on some fastener shoulders," Weekley said.

### Cellular Efficiency

GS Aerospace, Anaheim, Calif., is a subsidiary of B&B Specialties Inc., which manufactures high-quality socket products and fasteners. B&B maintains what it claims is the largest socket inventory in the industry.

Tom Rutan, general manager for GS Aerospace, said the company doesn't cur-

rently handle products for commercial aircraft, but focuses on making military parts for companies like Lockheed, Boeing and Pratt & Whitney, and fasteners for space vehicles produced by manufacturers such as JPL and Loral. The F35 and F22 fighters, the space shuttle and the Mars Rover feature GS Aerospace products. Fastener runs for aircraft engines are typically 1,000 pieces or less, while parts run for military applications can approach 100,000 pieces. The fasteners generally

are threaded, and work materials include titanium and nickel-base alloys.

To economically maintain its large inventory, B&B maximizes manufacturing efficiency. Rutan said that almost all B&B products, including those sold by GS Aerospace, are formed via the cold-heading process, which involves applying force with a punch to the end of a metal blank contained in a die.

Different-size products require different cold-heading machines. Previously,

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the machines were grouped in a separate department. "You get some benefit of scale by doing that," Rutan said, but he added that the arrangement limited the amount of knowledge and input operators could have regarding a part's ultimate quality and throughput.

The company improved its cold-heading operations by adopting a cellular approach. Each cell consists of a cold-heading machine and a thread-rolling machine. A toolmaker supports the cell, which is

run by a heading operator and a rolling operator. "They talk to each other about how the part is being run, and they are allowed to modify the product minimally, obviously within print," Rutan said.

The cellular configuration reduces the distance parts must travel between manufacturing steps and minimizes problems that arise when one step in a process is done far ahead of the next. Rutan said: "The cellular setup makes it easier to adapt to production runs of different sizes. It's a

lot easier if you've got two large runs to do and a couple small ones. You can run a large one, and while it's running, you can get the small ones done." The company makes fasteners from 0.051" to 1¼" in diameter. "It's a lot different trying to handle a 1¼"-dia. by 8"- or 9"-long fastener than it is to handle one that is 0.051"-dia. and ¾" long," Rutan said.

Because GS Aerospace fasteners are usually much more complex than those made by the B&B side of the company, "the GS routers (production flow sheets) are much longer," Rutan said. A typi-

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K.L. Steven

K.L. Steven Co. produces these 17-4 PH stainless steel fasteners for an aircraft engine subcontractor. They feature a 3 UNJ thread and a full-depth knurl held to a 0.002" tolerance.

cal B&B process involves cold heading, knurling and thread rolling, described in an eight- to 10-line router. A GS Aerospace router, on the other hand, may list 35 steps, typically including grinding, pointing and secondary machining operations, a drilling operation, and two or three separate heat treatments.

Aerospace customer requirements for strength and reliability may require that a fastener be formed on a hot press instead of a cold-heading machine, and GS Aerospace has improved its hot-pressing operations. Until recently, the hot-pressing process was precise but low-tech. An operator put each fastener individually into a heating coil and, when the part reached a specified temperature, used tongs to put it into the press. The press was then activated to form the fastener head. Depending on the operator's speed and skill, the method produced 50 to 75 pieces an hour.

GS Aerospace has replaced that system with a new CNC hot press from Impact

## Part and people shortages

**LOW SUPPLIES OF STOCK** material have been associated with recent delays in some aerospace programs, but the manufacturers contacted for this article said that while lead times for materials often were long in mid-2007, they have eased somewhat since then.

"Material is not much of an issue anymore," said Tom Rutan of GS Aerospace. "It was for a while, but it seems to have ironed itself out. The problem we have right now, in California especially, is that there are not enough skilled tradesmen to go around." He said he is surprised there hasn't been an influx of workers from Midwest fastener companies that have gone out of business. "Out in this area, they can make a pretty good living; these guys can make what a lot of college graduates would like to make," he said.

Rutan said GS Aerospace is trying to use technology to overcome the labor

shortage. CNC machines create conditions where part programs are preset and controlled and the volumes are controlled. Advanced equipment removes some of the need for an experienced operator, said Rutan.

He added that the shortage also exists on the engineering side. "Engineers don't want to be fastener engineers. They want to work with computers and go where the

glitz is," said Rutan. "I can't blame them. But there is a void. I don't think they let us retire out of the fastener industry anymore. You'd be surprised how many 'gray hairs' are still here because they've been requested to be here. In a lot of cases, there is no one to replace them." (For more information on the metalworking worker shortage, see article on page 72 of this issue.)

—B. Kennedy

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Global Machinery Inc., Mississauga, Ontario, Canada. The automatic system is hopper fed and can handle part diameters from 0.190" to 0.760." "I believe we are the first company in this country to use one of these on the aerospace side. We can go up to about 300 pieces an hour, and the consistency is there," Rutan said.



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## Matching Processes to Demand

In addition to meeting strict performance requirements for their products, fastener makers are developing ways to increase operational flexibility due to changing market demands.

K.L. Steven Co., Rio Rancho, N.M., produces a family of 17-4 PH stainless steel fasteners for a subcontractor to an aircraft engine manufacturer. The parts are molded into plastic panels to form attachment points. The fastener features a 3 UNJ thread and a knurl that has to be held to a 0.002" tolerance. A full-depth knurl, pointed at both top and bottom and normally not an industry standard, is a customer requirement.

"Knurling is still kind of an art," said Steve Weitz, president and owner of K.L. Steven. "When you go with diametral pitch knurls, you have to work with the right preknurl diameter, and certain speeds tend to work better to avoid any harmonic vibration. You have to play with it and just get it right." K.L. Steven knurls with tools from Form Roll, Worcester, Mass. "We also put a controlled chamfer on the edge," Weitz said. "We start out with a square-edge knurl, and we chamfer them here. We add a chamfer because when we knurl into the part, we lead with that chamfer and run across the knurled area. Then the knurl runs over it again to polish it."

Weitz said the family of fasteners used to be a high-volume job, but that has changed. "We used to run them by the hundreds of thousands, but now we run them in batches. We are lucky if we get a thousand or two." A number of factors contributed to the change, including movement of some production overseas and the slowing of production of new aircraft engines. "They are doing more rebuilding than they are making new ones," Weitz said.



B. Kennedy

Lead thread roller Bob Bonowitz displays a 3/8-8 proprietary titanium bolt produced via thread rolling at United Titanium.



When volumes were large, K.L. Steven produced the fasteners on cam-controlled Brown & Sharpe screw machines that were quick but difficult to changeover and maintain. The company now makes the parts on a Daewoo CNC lathe with a bar feeder. While cycle time is slightly higher, the lathe produces a more consistent product with less waste and is easier to maintain than a screw machine.



B. Kennedy

Stages in the production of a 1¼-8 proprietary titanium bolt at United Titanium include, from left, raw forging, machined blank and thread-rolled fastener.

Weitz said he machines the parts at conservative feeds and speeds to preserve the integrity of the material and hold size and finish. "Cosmetics are extremely important in the aerospace business. Some of the end users, in particular those in Japan, want to see the parts looking perfect. I guess if I were flying on [the plane], I'd want it to look really good too!"

### Critical Inspections

Because K.L. Steven is an aerospace partmaker, Weitz has a large installed base of inspection equipment. He also has a full-time worker filling out QC forms that apply before and after the jobs. K.L. Steven inspects 100 percent of its parts on the machine. "They don't go to the next station if they are not good. If it's going on an aircraft, it's got to be right," Weitz concluded. CTE



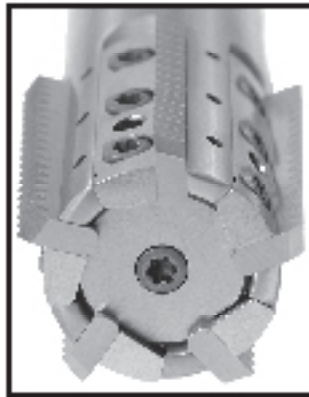
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