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Manufacturing the F/A-22

Building the next-generation superfighter

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For the Boeing sections of the F/A-22, most of the parts are being made by GKN Aerospace's St. Louis, MO manufacturing facility. Programs currently in the St. Louis portfolio include: the F-15, the C-17 Globemaster (a cargo carrier), F/A-18 (the Navy's replacement for the F-14), the F/A-22 Raptor, and the T-45 Goshawk trainer.

The site was initially founded by the United States Navy in 1939 and post-WWII became a part of the McDonnell Aircraft Corporation. It was home to the Phantom series of jet fighter aircraft and the AV-8B Harrier combat aircraft. McDonnell-Douglas Corp. merged with Boeing in 1997. On January 8, 2001 GKN Aerospace acquired the operation. It is now a Tier One supplier for Boeing IDS and other companies.

When contracts were awarded for the F/A-22, GKN Aerospace was faced with the challenge of bringing the metal structures operation up to the standards required for the new generation of aircraft. They had to develop the ability to rapidly machine titanium, work with large complex parts never before made, improve accuracy, and minimize scrap.

The improvements came in two forms:

First was working with existing machines. The shop had 54 Cincinnati Milacron gantry machines, some over 30 years old. Each is being evaluated for the company's gantry rebuild program. So far, six have been reworked and plans are in place to complete an additional 18 gantries.

Second, because of the complexity and precision required for other parts, the purchase of new equipment was necessary. This major investment included three Henri Line' high-speed profiling machines and three five-axis Mazak e-1060V Integrex machining centers.

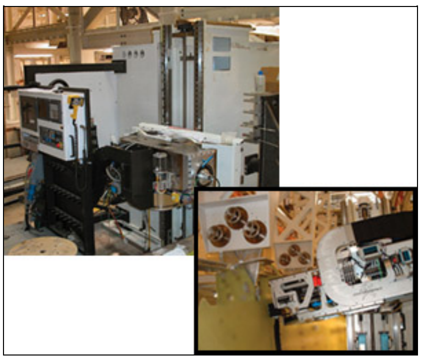
Company engineers worked to improve a number of specific areas:

Titanium machining. One of the major features of the F/A-22's design is extensive use of titanium. The weight, stress, and survivability requirements made it a necessary element of the structure. Therefore, learning to machine titanium quickly and accurately became a prime requirement for the manufacturers. Essentially they achieved the speed and accuracy required by applying the same processes that gained them the ability to machine aluminum at high speeds. This was done by blending several elements: new cutters and cutter coatings, minimizing runout, and advanced programming techniques.

One particular challenge is cutting thin sections. In these cuts the designers try to avoid placing backup elements since that takes much more setup time, particularly with the large parts they work with. Instead they have derived a program that uses a combination of DOC, tool speeds, and feeds that allows the forming of sections less than 0.030" (0.8-mm) thick. The trick is to keep solid material around the pocket as much as possible.

Working with titanium not only means more rapid cutting but at the same time requiring greater accuracy. This is necessary because specifications demand it and because the cost of scrapped parts is very high.

With titanium roughing, it was found that cutter-tool selection and operating specs were concerns. These were addressed by adapting new programming techniques that influence the DOC, cutting feeds and speeds, and cutter size.



For finishing passes the main issue was the need to understand the impact of runout. It became understood that a bad pass with too much runout could easily ruin a part–or at least require extensive rework.

Spindles were reworked and toolholding methods were developed, including the use of shrink-fit on high-precision parts. In addition, they used smaller axial and radial DOC. This produced an overall runout of 0.001" (0.03 mm) TIR measured from the cutting tool. Once runout is minimized it's possible to do more aggressive cutting, yet still hold tool life.

Training programs were necessary. The new and refurbished equipment requires a competent workforce. To ensure the availability of skilled operators, GKN Aerospace has linked with a local junior college which has a machinist training program.

They have a close relation with the school which is a potential source of not only machinists but maintenance personnel as well. There is a cooperative interchange between GKN Aerospace and the school faculty to ensure that course work matches the company's needs.

Deburring is essential for both ease of assembly and ensuring proper air flow over external mold-line surfaces. At GKN it's done in a vibratory media system. A recent addition is a unit that can take larger parts such as a wing spar measuring 8" X 12" X 20' (203 mm X 305 mm X 6 m). Part areas with very critical dimensions are masked to prevent dimensional changes.

Machine tools. The key machine is the Cincinnati Milacron (Cincinnati, OH) five-axis gantry. A gantry is the optimum machine to use for many of the F/A-22 parts.

These machines are undergoing a major refurbishing to bring them up to the standards needed for F/A-22 part production. All parts related to accuracy were reworked or rebuilt. Changes include the replacement of the original control with GE Fanuc 150i units, new drives and servos, and a full rebuild of the gearboxes, transmissions, and the 3600-rpm spindle packs. In the reworked machines quality, has improved 30% and there has been a 70% reduction in maintenance problems. The production C_{pk} is now averaging 1.3. The current goal is a runout of 0.0001" (0.003 mm).

This is an ongoing program. There is still a lot of older equipment to evaluate to see if it fits the core competency. The evaluation is expected to take another two years.

Among the newer machines are three units supplied by Henri Line' (Granby, Quebec, Canada). That company has supplied two vertical and one horizontal milling machine.

Mazak (Florence, KY) machines using their Integrex spindles are one of the more recent equipment additions. They have improved both manufacturing speed and part quality. An Integrex head allows access to more areas of the parts, which means more can be done in a single setup.

Before production begins, GKN Aerospace engineers have to match the part to be made to a particular machine. Most of the simple cuts are made on a five-axis gantry that cut multiple parts in one setup. However, the gantry is limited to cutting angles of 20º. For more complex shapes, the parts are machined on a single-spindle machine with a 40° cutting angle such as the Mazak or Henri Line' units.

The Henri Line' machines have 90-hp (67.5-kW) spindles operating at 24,000 rpm. With a 110º *B* axis they can really crawl over a part, and do five sides of a complex part in a single setup. When necessary, a proprietary version of shrink-fit toolholding is used.

Flood cooling is used in about 99% of the operations. It's preferred over other cooling because of the need for chip evacuation. Dry and mist lubrication is not currently used. In some cases access slots are milled in the parts to ensure complete chip removal.

Assembly required simplification. One of the benefits from increased accuracy by the GKN Aerospace operations has been to simplify assembly by the customer. In the past, setup jigs and fixtures were used to position parts for assembly, or to perform some drilling and machining to accommodate the assembly. These preassembly operations are no longer needed because of the accuracy of the GKN Aerospace detail parts.

Waterjet cutting provides two savings. First, there are no heat affected zones (HAZ). If the part were cut by other means, the HAZ had to be machined off. Also, there is a saving in metal. Parts can be nested more closely so there is less excess material. Normally, these parts are made to near net shape and a finished machining cut is required. Company engineers are looking for other opportunities to integrate this process.

Finish and match. Finish is an important issue on the wind-swept parts because the aircraft operates at supersonic speeds. Both the surface finish and the blends (joints between parts) are critical. To avoid mismatches, the finished surface of one part is feature probed and the data recorded. Those data are used to modify the toolpath when machining the adjoining piece. That way any tolerance buildup that might influence fit is eliminated.

Cutting tools. Monitoring is a big feature that helps ensure accuracy. Each tool carries a bar code that gives the tool's description and operating history (i.e. how much it was used, its expected life). This helps ensure that the proper tool is automatically selected for a given job.

Many of the tools are of an earlier McDonnell Douglas design that uses a special carbide alloy. It's a proprietary carbide material developed several years ago, but which still outperforms some newer materials. Virtually no inserts are used. Cutters are chiefly carbides and steel, some with specialized coatings.

Part holding. One way GKN Aerospace has found to minimize fixture problems is to make tapped holes in sections of the part that will later be cut away. These holes are used to bolt the part to the worktable. Since the bolt comes from behind the part, there is nothing on the part's surface to block the spindle's path. The cutter can reach five sides of the part, and only a single setup is needed.

In analyzing error GKN Aerospace engineers found wrong diameter cutters, wrong cutter radius, and wrong set length. These problems have been virtually eliminated by a three-step program.

First, the tools and checking gages needed for a particular job are positioned near the machines where they will be used. In addition, the operator has a card for each tool to simplify the checking of tool type and sequence of use.

Second, before the tool begins to cut it is programmed to make a pass around an aluminum test post. If the diameter, radius, or set length is off, the tool will hit the post and stop the machine.

Third, a Blum laser-checking system is used on Line' machines. It checks the size and position of the tool, and shuts down the machine if an error is found. This laser system is being considered for use on all machines.

F/A-22 Background

The F/A-22 is to be a replacement for the F-15 Eagle, which was first built in 1974. The plane had its first flight on Sept. 7, 1997. Currently, some 72 aircraft have been built or are under construction. The first squadron is scheduled to be ready by the end of this year. Initial plans were for building 770 of the single-seat F/A-22's by 2013. But several reviews have pared that number to 339 and it could be dropped further. By contrast, over 1500 F-15s have been built.

Key features of the F/A-22 design are extensive use of titanium, very advanced avionics, stealth shielding, and the ability to cruise at supersonic speeds. Other fighters could operate at these speeds only intermittently chiefly by using afterburners. This high-speed capability is known as supercruise.

To ensure stealth capability, there is a smooth blending of all surfaces. There is more welding and less bolting and riveting than on earlier designs. Any breaks cause energy to be reflected back. Horizontal fins are angled for extra maneuverability, and act as heat shields for the engine. Vertical fins are also configured to reduce radar signals as are the engine inlets and exhausts.

The plane's mission is to quickly sense, reach, and destroy a target. This might be enemy fighters or ground targets. A two-seat bomber version, the FB-22, is being considered.

Power comes from two Pratt and Whitney F119-PW-100 engines, each delivering 35,000 lb of thrust for a top speed of Mach 2.5. Range is 1600 miles (2575 km) and it can operate from sea level to 50,000' (15,240 m).

Lockheed Martin is the overall program manager. Boeing is responsible for the aft fuselage, main wing structure, power generation units, and some main fuselage elements. Lockheed Marietta is building the fins, flaps, ailerons, and forward fuselage. Lockheed Fort Worth has the main fuselage or midsection. By weight, the aircraft is 67% titanium, 22% aluminum, and 11% composite.

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