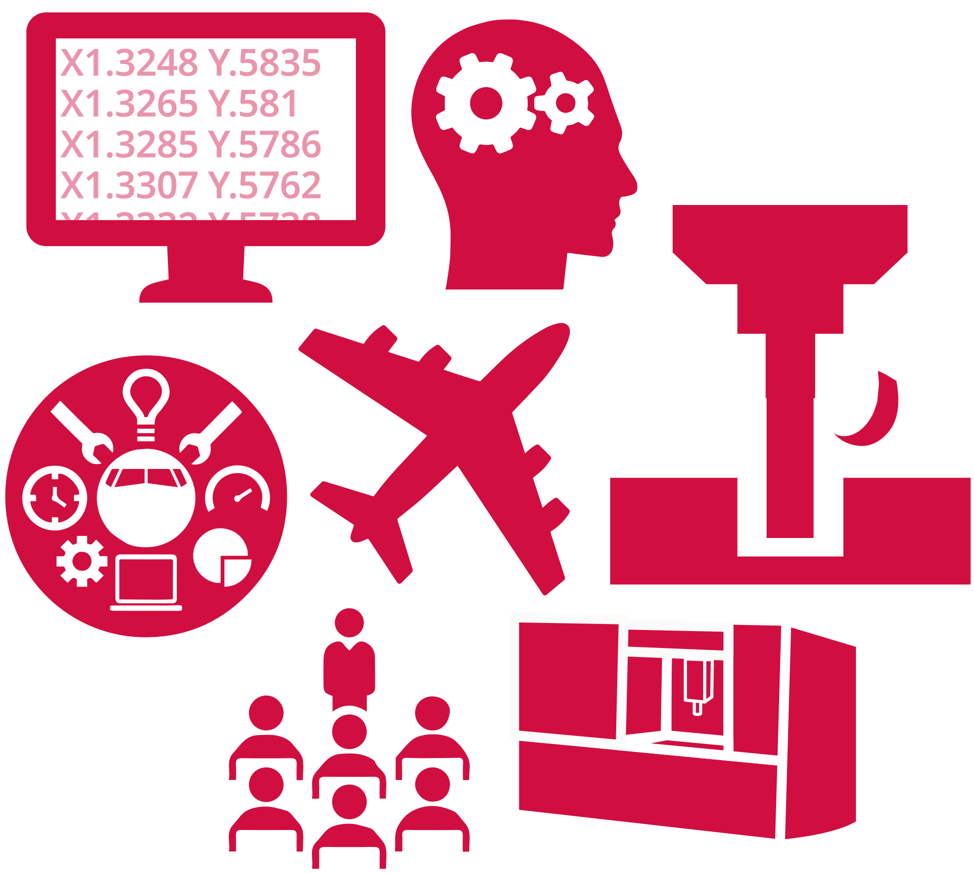
Mastercam® | INDUSTRY SPOTLIGHT

Meeting the Challenge: Changes in Aerospace Manufacturing

An overview of how today's CAD/CAM helps you succeed in the increasingly competitive aircraft component manufacturing space.



This white paper uses Mastercam as a primary example of CAM software. However, the same concepts can be applied to any shop using any of a variety of up-to-date CAM software implementations.

Advances in CAD/CAM Software Meet Challenges in Aircraft Component Manufacturing

Innovation in the aerospace industry is experiencing a resurgence of sorts, with the idea of tourist flights into space becoming more of a reality with the new technologies coming out of Blue Origin, SpaceX, and Virgin Galactic. From space-age materials to tiny, tight-tolerance components to cutting-edge engine and propulsion technologies, aerospace manufacturers have always been the visionaries of innovative design. Innovative design brings with it, however, the need for innovative manufacturing practices.

A design is no good unless it can be turned into an actual part. Machining technology has evolved ten-fold since that first rocket ship was built as has the computer-aided manufacturing (CAM) software to power those machines. Here, we shall discuss the latest innovations in CAM software and how the new functionality helps push the machines to their full potential, yielding parts never-before imaginable in record time.

Commercial Aviation Industry: Current Industry Snapshot

As of January 2020, the global commercial aviation industry, with a market value of nearly $5 trillion, was expected to grow slowly but steadily thanks to soaring travel demand, increasing globalization, rising gross domestic product, liberalization of air transport, and urbanization. However, the COVID-19 Pandemic and the resulting disruption to the global economy have led to a "wait and see" approach to determine the full impact on aerospace manufacturing and whether or not it will make an already highly competitive situation even more so. While order backlogs decreased slightly with the reduction in fleets, it remains to be seen as to whether these orders will be filled in the near-term.[1] Deliveries remained solid at Airbus in late 2019, with demand for its wide-bodied A33 NEO passenger jet keeping production stable.[2] By the end of 2019, Airbus received 768 new orders, with 7,482 back orders needing to be filled. Of those, 863 aircraft were delivered to customers.[3] Boeing, however, suffered its worst loss ever with the grounding of the 737 MAX in 2019. Prior to the grounding order, the company delivered 127 of these aircraft to customers, contributing to the 380 total deliveries by end of year. Still, production remained robust while the company continued to fulfill backlogged orders and complete its Defense, Space, and Security commitments.[4]

[1] Deloitte Consulting, LLP "Deloitte 2020 Global Aerospace & Defense Industry Outlook
[2] Reuters Report 1/15/2020
[3] Airbus Commercial Aircraft Orders & Deliveries 2019
[4] Boeing

While the temporary halt of the MAX has had a significant impact, the industry was still vigorously producing aircraft until March, 2020. According to a report compiled by the International Civil Aviation Organization (ICAO), by October 2019, world passenger traffic grew by 3.4 percent, mostly in the Asia/Pacific and European regions. And, it is not expected to slow down anytime soon. Air traffic is forecast to double in the next 15 years. Airbus predicts a demand for 39,210 passenger and freight aircraft over the next 20 years, with 36 percent of them as replacement aircraft.

By the time the current backlog of commercial aircraft is exhausted, Airbus and Boeing will be touting the next generation of narrow-body jets that will enter service around 2030 and kick off the next major order cycle in the industry. For now, the aerospace industry is contending with the fallout of the COVID-19 crisis and adjusting as necessary.

Air traffic is forecast to double in the next 15 years.

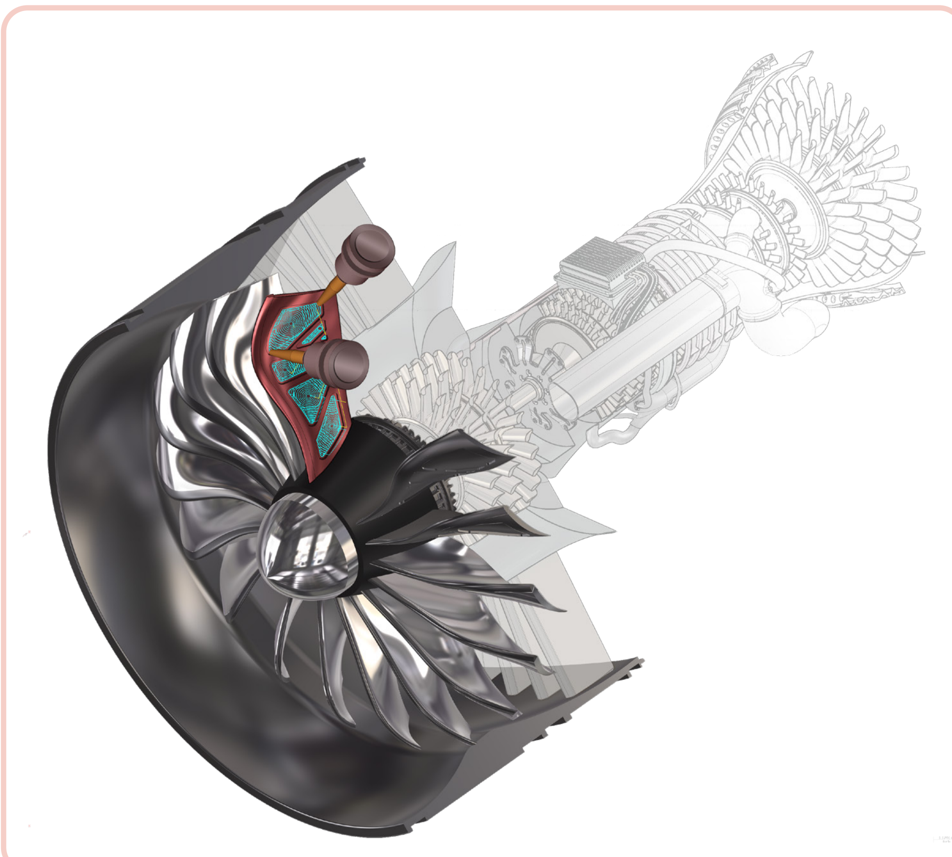
Industry Challenges: Aircraft Component Supply

Aerospace component manufacturing is one of the most demanding industries and will be for the foreseeable future. Part design and development innovations have exploded since the order boom first began about 10 years ago. New materials and effective, profitable production processes have also followed suit. However, despite the fact that aerospace component manufacturing is more high-tech than ever, the pressure is still on for quick turnaround times to meet high delivery rates. Although the current statistics show a slowdown in orders, the production and delivery backlogs are still very real.

The average aircraft possesses up to 3 million components, while wide body aircraft require even more. Aerospace companies must account for every one of these parts, ensuring they meet the strict delivery and manufacturing requirements set in place. OEMs have been seeking to identify high-quality suppliers to meet the demand for all of these parts; however, many operate in different industries and are not certified to produce and sell aerospace parts. Many of these companies are only certified to ISO 9001. Although that is a strong indicator of excellence, it is not advanced enough for aerospace guidelines. The one to secure for this industry is AS9100. It is achievable by upgrading the existing standard. There is talk of an additional standard relevant to data security that is likely to be required as well.

There is a lot more to entering an unfamiliar market than simply acquiring the right credentials. Even if the supplier has the machines, materials, and means to adjust its processes and workflows, there is still a lot to understand to navigate the landscape smartly to ensure success. With that being said, hundreds of subcontract shops have entered the aerospace market successfully, and many have also made substantial investment in capital equipment to do so. Not every machine tool can produce precision parts made of tough aerospace alloys and titanium grades for the hot engine components required. Methodical, objective, technology education is necessary to understand how engine and structural parts need to be cut effectively and efficiently for a profitable endeavor.

Generally speaking, the supplier must take a systematic approach with the optimal CNC machine tools, spindles, fixtures, cutting tools, coolant systems, controls, and software. A starting point might be to simply ask the major aerospace OEMs what they suggest. What are they using successfully in their production operations? It would follow that they would be comfortable working with subcontract companies that are using the very manufacturing systems and strategies that they themselves have researched thoroughly and proved out over the last several years. Also, the organizations that assist and consult surrounding quality standards, such as for AS9100, can be instrumental assets for networking, referrals, and knowledge sharing.



How CAD/CAM Software Can Benefit Aircraft Component Manufacturing

Focusing on one aspect of the system, CAD/CAM software, is one area of opportunity for improved aircraft component production. One might not initially think that it is a vital aspect of success in making aircraft components. However, it is an important behind-the-scenes player in producing the complex parts specified by aerospace manufacturers. Here are some of the ways CAD/CAM is a significant contributor to an effective and efficient manufacturing system:

CAD/CAM Integration

Considering what is often the first step in the digital aspects of part production, the ability of the CAM software to seamlessly work with a variety of CAD files is vitally important. Predominant CAD programs used by aerospace engineers include CATIA, NX CAD, PTC Creo (formerly Pro/Engineer), SOLIDWORKS®, and AutoCAD®. An effective CAM program should be able to import most, if not all, of these.

The importance of being able to import CAD files seamlessly goes a bit deeper than merely securing jobs with aircraft manufacturers. The CAM system must be able to take CAD data in any form. While most components are designed using solids, there could be some legacy data in the file created using wireframe or surface modeling geometries. The system must also be able to work with a hybrid model composed of surface solids technology and mesh. Keeping the model in its original format ensures that design integrity remains unchanged during the transfer process which is crucial to the successful and safe operation of aircraft.

Model Editing and Preparation Tools

Aerospace work is among the most tightly controlled, following a strict set of standards and regulations. Not only does this mean that shops need to accept the native file provided by the customer, but there are heavy restrictions on any type of model modification. However, there are times where a minor tweak is necessary for accurate machining, which can lead to time-consuming back and forth with design engineers.

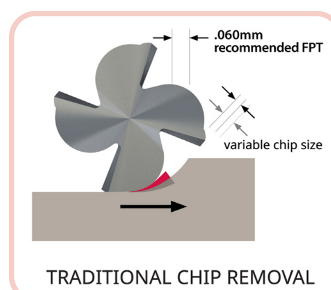
Within the last decade, CAM software developers began incorporating functions allowing programmers to directly edit a solid model immediately in order to easily prep for machining. These design tools are a mix of temporary and permanent options, with the temporary editing tools the most widely used in aerospace. The latter provide a specific adjustment to the part that does not change the design integrity of the model and can easily be reverted to the original model later.

Examples include quickly filling holes for better precision and aesthetics on complex surfaces and identifying and suppressing features to allow easier programming. In both cases, the temporary edits can be switched off for project completion without violating the integrity of the original model.

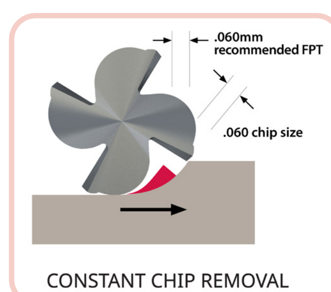
Software can also enable programmers to "push and pull" the solid model at will, offset faces or edges into fillets, and move or copy faces. They can split a solid face into multiple faces in either wireframe or flowline formats and can break parts into several segments to use different toolpath strategies for each segment for easier machining of complex parts. While shops may not use some of these more permanent tools on the part itself, they can also make fixturing for complex projects easily and cost-effectively by being able to design and manufacture the fixtures in one program.

Advanced Machining Strategies for Constant Chip Loading

Machining strategies based in radial chip thinning have made a dramatic impact in how aerospace components are manufactured as of late. Commonly referred to as constant chip loading, this toolpath technology allows for fewer stepdowns, increased tool life, and the ability to cut hard materials — such as the Inconel, copper, and titanium so often found in aerospace components — faster and more easily. And, as designs and specifications are becoming increasingly more complex and precise, CAM software is keeping up with the challenges.



Traditional milling produces widely varying chips as the tool follows "offset" part boundaries.



By looking ahead and changing the tool motion based on upcoming material, the tool can maintain a consistent chip load throughout the cut.

Proprietary algorithms programmed into the software evaluate the motion of the tool in relation to the chip load the tool is bearing, and constantly adjust the cutter path so that the engagement stays as consistent as possible throughout the entire cut. Unlike standard "offset" toolpaths that essentially mirror a part's shape as the tool moves along the project, the engine does not work solely off of the model's boundaries. Instead it uses that information, along with the knowledge of what has been cut and what remains, to ensure that the motion itself is the most efficient and safest possible, evaluating the conditions and adjusting accordingly.

In optimal cases, the entire tool flute length is engaged with the material, minimizing stepovers, stepdowns, and air cuts, easing stresses on the tool, the part, and the machine as feeds and speeds increase.

Thin-walled, tight-tolerance parts, such as those that make up the honeycomb core inside an airplane wall, can be machined easily by harnessing the full capabilities of a 5-axis machining center and the right tooling. Tool angles can be programmed into the toolpaths to ensure precise cutting of the sharp edges that make up the predetermined shape of the honeycomb parts, allowing the machines to automatically do the tool switching instead of manually stopping the machine to make a change interrupting the machining process, potentially leading to compromises in uniformity and quality. Of particular concern are foreign debris or materials that can be caused by frequent stepovers and air cutting.

Importantly, this technique also helps dramatically with heat management. Heat is often the enemy of the part, the tooling, and even the machine. Unchecked cutting heat can warp parts out of tolerance and damage a variety of components. By maintaining a chip load on the tool that is both consistent and adherent to the tool's optimal cutting condition, the heat is safely pulled away in the chips themselves.

As shops have become more comfortable with high speed toolpaths, they have begun to explore more aggressive cutting strategies. These include stepping down three or even four times the tool diameter. In many cases that is achievable. However, cutting around corners can be troublesome because the cutting tool tends to want to grab that edge, then of course the metal can grab the tool, and the metal can bend. This happens because as the tool moves through relatively small inside arcs, the perimeter of the tool is moving through the material faster than the center of the tool. When the cutter moves through outside arcs, the perimeter of the cutter is moving through the material slower than the center of the tool, which results in a decreased chip load on the tool. Some CAD/CAM software packages include the option to choose a Max ID decrease or a Max OD increase value, and will adjust the feed rate for inside arcs and increase the feed rate for outside arcs by using the current motion's arc radius and the cutter size to calculate the proper feed rate.

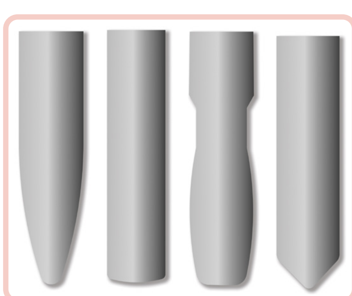
The Partnership Between Software and Tooling

For some time, cutting tool manufacturers and CAM vendors have worked together to dramatically reduce machine cycle times when using solid carbide tools for roughing. Inserts used for roughing need to have a stronger edge and tougher coating than those used for finishing. They must also be more rigid. For those parts with hard-to-reach pockets and angles, smaller inserts or long, thin tools are optimal. With so many tools available, it is a daunting task to select the right ones.

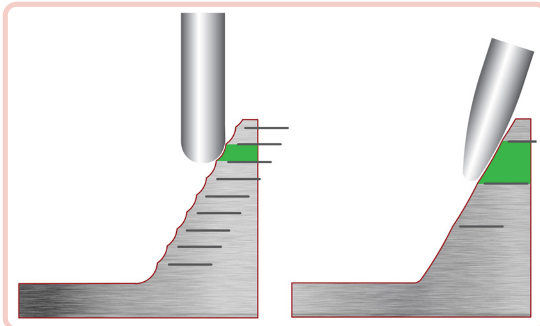
The collaboration between cutting tool manufacturers and CAM vendors has resulted in Tool Libraries or the cloud-based Machining Cloud, where hundreds of cutting tools from numerous vendors are featured along with their recommended feeds and speeds, updated geometry details, and other information specific to that tool. Programmers can review 3D models, build digital tooling assemblies on the fly, and package everything up into a single-source, readable file format. Toolpath quality, productivity, and recommended machine performance strategies are also included in these libraries and on the Machining Cloud.

Shaped Tools for High-Precision Cutting, Superior Finishes, and Fast Turnaround

Aerospace specifications, more often than not, call for smooth, precise finishes, most of which require some sort of secondary finishing or polishing process to achieve desired results. The challenge, especially if the finishing process needs to be outsourced, is keeping the original specifications intact while additional work is done on the parts. This is especially true in the case of jet engine or transmission parts that have extremely tight tolerances and yet need to fit together perfectly.



It is smart to program toolpaths capable of performing both the primary and secondary cutting and finishing operations without removing the part from the machine. In the case of turbine components, especially blisks, components need to be machined exactly as designed. This can be challenging when parts are made from heat-resistant superalloys that transfer heat to the cutting tool. Composites, which are often created by layering different materials — including metals — and exhibit higher stresses, melting, and deformation during high speed machining applications, also pose a challenge. Selecting the correct toolpath/tool combination for each individual cutting operation is paramount to reducing scrap and extending tool life.



Properly used, circle segment tools deliver the finish and speed of machining with a much larger ball end mill.

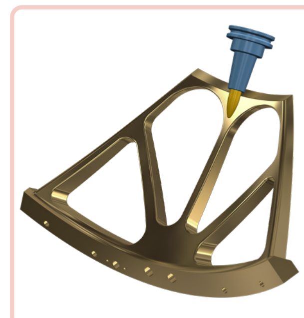
The CAM software/tool vendor partnerships have expanded into finish passes where automated CAM toolpaths are driving innovative cutting tool geometry and vice versa. One such example is the support of the new circle segment cutting tools found in finish toolpaths. In many cases, this new tool support can dramatically reduce finish cycle times verses the use of more traditional ball end mills. Where these tools and automated cutting strategies can be applied, cycle time reductions ranging from 50% to better than 80% are being achieved routinely and with superior surface finishes.

Circle segment cutting tools can dramatically reduce finish cycle times.

To refine this advanced finishing strategy, the circle segment tools and CAM software need to work in sync to coordinate tool definitions and toolpath behaviors, particularly in the 3+2 and simultaneous 5-axis machining modes. Circle segment tools can be used within both 3- and 5-axis finishing toolpaths with which the users are already familiar.

The programmer needs only to load the tool definition into the software from the downloadable libraries. Then the machining operation applies the appropriate tool compensation for ultra-high efficiency finishing. Proficient multiaxis programmers can also fine-tune parameters to make a good finishing toolpath even more efficient for specific surface requirements.

Ball end mills are the traditional go-to cutting tools for surface finishing because of their ability to effectively minimize cusps with tighter and tighter stepovers. However, this advantage can become a limitation on large surfaces or surfaces that require tight finishes. Think wing parts, door frames, and parts for jumbo aircraft. To compensate for this potential staircase effect and achieve the desired surface finish, a proportionally small stepover or stepdown, (e.g. typically 3-5% of the tool's diameter) must be used. This improves the surface finish, but it reduces the amount of surface area engaged by the tool. Thus, the tool must take many passes to achieve the desired finish. And this takes a lot of time.



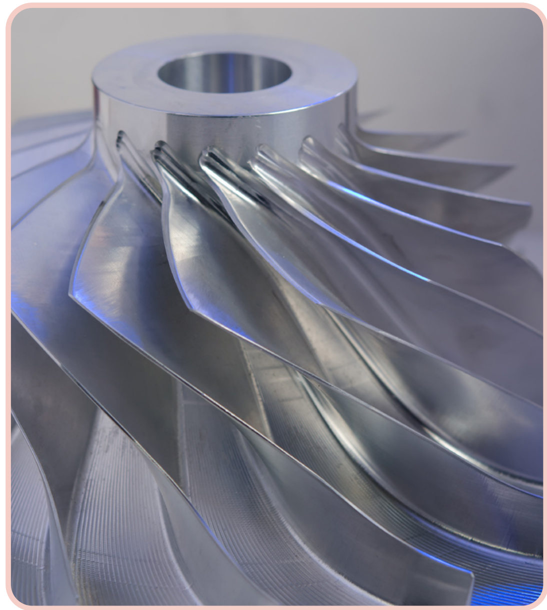
Circle segment cutting tools are designed to allow a small diameter tool to have a large effective cutting radius — many times greater than that allowed by the ball end mill. This design reduces the number of finish passes and the depth of the cusps in the material, for a substantially better surface finish while achieving shorter cycle times. The tools may be used with 3-axis CNC machines, but great care must be taken in defining tool planes to assure accurate finishing results and to ensure the tool is contacting the part in a proper manner. Far better machine cycles are obtained with multiaxis equipment, particularly machines capable of continuous 5-axis machining. When utilizing a machine capable of 3+2 indexing, the ability to apply circle segment tooling vastly improves. Moving to a machine capable of continuous 5-axis machining and the applications for applying this technology broadens even further. Fast, responsive controllers with advanced features like high speed look-ahead are also advantageous.

Specialized Options in CAD/CAM Software for Tough-to-Machine Parts

Intuitive Cutting for Intricate Aerospace Blade Applications

The intricacies of cutting blades for impellers, fans, and turbines can add time to the machining process, requiring multiple cutting operations and separate toolpaths for different configurations. When working with multiblade parts, things get even more complicated and time consuming. Manufacturers have used 3+2 programming in which the part is rotated to a new angle and a 3-axis program is used to clear out as much material as possible from that orientation. The part is then moved to a new position and more material is cleared. These programs take considerable time to write and machine due to the many overlaps where the tool is doing nothing but air cutting. More air cutting can result in higher incidents of tool breakage and the resulting cost to replace the tools. There are blade manufacturers who have opted to manufacture blade segments and assemble them into a special manifold, but they are essentially trading one problem for another — machining hard to access material is substituted for the challenge of aligning and balancing blade assembly. The margin for error, as far as meeting specifications laid out by engineering, is increased.

Add-On programs streamline the multistep, multiaxis process to finish an unlimited number of blade configurations.

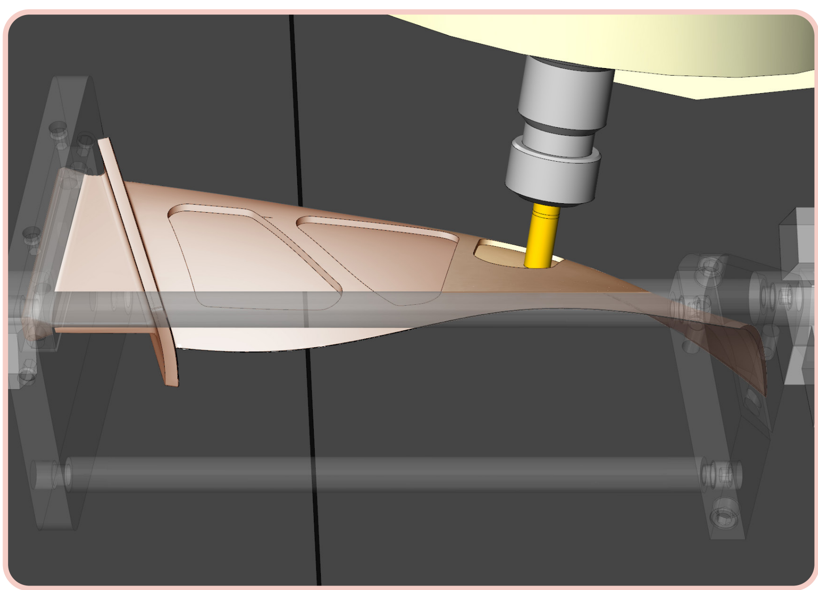


No matter what the differences are in shapes and size, all multiblade parts are manufactured in much the same way: Rough out excess material between the blades, semi-finish the blades, finish the blades, and finish the base. CAM software packages are available with Add-On programs developed to streamline the multistep, multiaxis programming process, allowing the programmer to define blade and hub sections to generate toolpaths in order to remove material from in between the blades. After transferring the blade model from the CAD program, the programmer is prompted for information about how they prefer the 5-axis blade manufacturing process to function. By using the standard interface followed by the software's multiaxis toolpaths, these Add-Ons can finish an unlimited number of blades, splitters, or sub-splitters gouge free, in all types of blade configurations.

Simulation for Verifying Successful Cutting Operations

All CAM software developers have incorporated simulation tools into their software offerings. Everything from testing the viability of a toolpath to designing and manufacturing fixtures can be performed virtually before the machine is turned on. Most importantly, however, is the ability to simulate high speed machining operations to ensure parts are cut to spec with no errant moves by the tool, without crashes. Some of the more advanced CAM software programs allow verification for tight tolerance runs down to 0.001”, made easier with the ability to specify the exact tool(s) to be used in the cutting operation from the tool library or Machining Cloud. Many aerospace manufacturers require renderings of the simulation process prior to signing off on parts to ensure they meet ISO 9000 standards for aerospace applications and that the parts are manufactured according to specification.

Toolpaths programmed to machine difficult-to-cut materials — often expensive and exhibiting high Rockwell hardness ratings — can be simulated and verified using the software’s simulation tools. The high dynamic shear strength of commonly used nickel-based alloys, such as Inconel 718 and Waspalloy, can cause potential problems when the tool begins cutting the material — think material cracking and tool breakage. When machining thin-walled or thin-floor components such as those found in airframe components, maintaining the tolerances of a part become even more difficult as the tool attempts to move through the material. Preventing collisions, chatter, and vibration is of utmost importance. Demonstrating the potential success of the entire cutting operation goes a long way toward securing lucrative aerospace contracts.

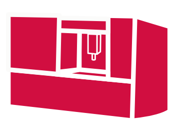


Moving Forward — Considerations for Optimizing Aerospace Manufacturing Operations

Suppliers to aerospace OEMs are faced with quick turnarounds for components with increasingly complex geometries, space age materials, and tight tolerances. The component manufacturers who have succeeded in landing — and keeping — lucrative aerospace contracts are the ones who invest, adapt, and educate. Their strategies are simple, yet many shops are resistant to follow, instead choosing to turn down complex jobs or not compete at all. For those suppliers choosing to invest the time and capital to jump into aerospace, here are some tips:

1

Invest in the most capable machining centers with 3- to 5-axis capabilities and lathes with live tooling for the most efficient cutting operations possible.

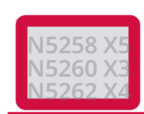


Moving Forward

2

Select a powerful CAD/CAM software package to push your machining centers as fast and as far as they can go. Invest in at least a few seats to keep jobs running. The software should be able to:

- Work with all CAD software programs, especially CATIA, to seamlessly integrate part geometry with exact design parameters as specified by the aerospace manufacturer.
- Allow the programmer to keep 100% part integrity while providing CAD tools that speed machine preparation.
- Provide the programmer with the ability to create toolpaths ranging from the most basic to the highest speeds possible with the shop's machines.
- Hold tool libraries created by the programmer or access a cloud-based tool library whereby the programmer can investigate the proper tools for complex jobs in real-time and drop them into a virtual machining operation for the most precise simulation.
- Allow the programmer to simulate an entire machining operation, replicating the tools, fixtures, materials, and other aspects on the computer screen to ensure constant chip load, minimal stepovers and stepdowns, and accurate machining of the tightest tolerances.
- Have the flexibility to work with many different tools for secondary finishing operations to cut valuable time from machining operations.
- Work with software Add-Ons that help facilitate faster and more accurate machining of complex parts such as turbine blades.



Moving Forward

3

Adapt with manufacturing technology, upgrading machines and software as necessary, to work with innovations in material development and tool design.

4

Educate workers on the best machining technologies available, and empower them with opportunities to learn.

- Embrace education initiatives offered by the software developers in the form of carefully designed curriculum that is downloadable from the developer's website, created through a collaboration with a Third Party Partner company, or taught on-site at a local Reseller, school that works with the Reseller, or your own shop.
- Purchase CAD/CAM software from developers who listen to customer needs and upgrade program offerings to meet them.
- Work with software Resellers that are locally based and can help find solutions to challenging jobs either on-site or remotely based on their knowledge and experience with the software, the machines, and your shop.

About Us

CNC Software, Inc. provides state-of-the-art software for CAD/CAM markets. Our single focus is to provide superior solutions based on our users' needs to solve simple to complex design and manufacturing problems.

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