3D SYSTEMS

What You Need to Know About

Programming Multi-Task Machines

Multi-task Machines (MTMs)

The term multi-task machine, or MTM, broadly covers a range of machines that, at their most basic level, can do some milling on a turning machine. The machine is sometimes called a millturn or turnmill machine, or a milling lathe, or a turning center with milling function.

NAMES FOR A MULTI-TASK MACHINES

- MTM
- Millturn
- Turnmill
- Milling lathe
- Swissturn
- Swiss-style
- Multi-spindle

A specialized category of multi-task machine is the Swissturn or Swiss-style machine. Yet another is the multi-spindle machine, designed for extreme high-volume production, with multiple spindles and one or two tool stations per spindle. Whatever you call them, the MTM continues to gain in popularity because, bottom line, they are the most efficient machines for making parts that require multiple types of machining functions, typically turning, milling and drilling. In comparison to "standard" lathes and mills, the typical MTM machine is most efficient when alternating turning and milling operations are required to machine a part.

Precision parts, tiny parts, long parts, complex Parts and more parts

Parts made with MTMs are not easily categorized, because they can be parts that could be made on lathes, or mills, or through multiple set-ups switching between lathes and mills. Parts that require both turning and milling are instant candidates for MTMs. High precision parts, complex parts, prismatic parts milled on many sides, and parts that would require complex or expensive set-up on conventional mills are all candidates for MTMs. In addition, high volume production of parts that can be made from bar stock are all candidates for MTMs. For Swiss style machines, we can add tiny parts and long parts.

The benefits: how MTMs are more efficient and more productive

BENEFITS OF MTM MACHINING

- Reduced set-up time
- Reduced errors
- Lower inventories
- Higher accuracy
- Faster throughput

Every shop has its challenges, but none can argue against the value of reducing set-up time, reducing errors, lowering inventories, achieving higher accuracy, getting faster throughput, and making more parts in the same or less time. These are advantages of an MTM over other machines, and all of these, alone or in combinations, increase profits. A brief discussion can explain how these benefits come about.

- **The single greatest benefit of MTM machines is reduced set-up time.** In a single set-up you can go from raw stock to a finished part in far less time than it takes to make a part that would otherwise require multiple set-ups on several machines.

One can do an entire production run with a single set-up, also amortizing set-up time over the production run. The average time-cost per part decreases with each additional part.

- **The single set-up also reduces the opportunity for errors**, which each set-up may add. This is an automatic benefit of the MTM for an entire production run. The only opportunity for errors after initial set-up is changing worn-out tools. Reducing human interaction also reduces the chance for errors.
- **A third benefit from the single set-up is that an inventory of work in process is eliminated.** Every part is completed in that set-up, and it can be shipped and billed. There is no rolling inventory of parts, and the billing period is shortened, both of which increase profitability.
- **Error reduction brings along higher accuracy**, not just for individual parts, but also within the whole part run. Higher accuracy means you gain repeatability, to make the last part like the first. More accuracy also means that you can pursue jobs that require higher precision, or tighter tolerances, which MTM can help achieve.
- **Because higher accuracy allows for making all parts the same, users typically achieve faster throughput.** You need less work in quality control. You have one first-article check for the single set-up, and only one set-up or program to adjust if the first article is bad.
- **Faster throughput allows MTM users to produce more parts, and in many cases, with a smaller workforce.** Typically, one MTM replaces at least one lathe and one mill, which leaves those machines open for other work. This allows taking on more jobs.

All of these benefits make MTMs desirable. As part complexity continues to increase across industries, with a scarcity of skilled machinists and machine operators, MTMs become even more desirable. For some, the machines allow maintaining a level of work.

For others, they enable retaining profitability. For the fortunate, the machines allow increasing the workload and becoming more profitable.

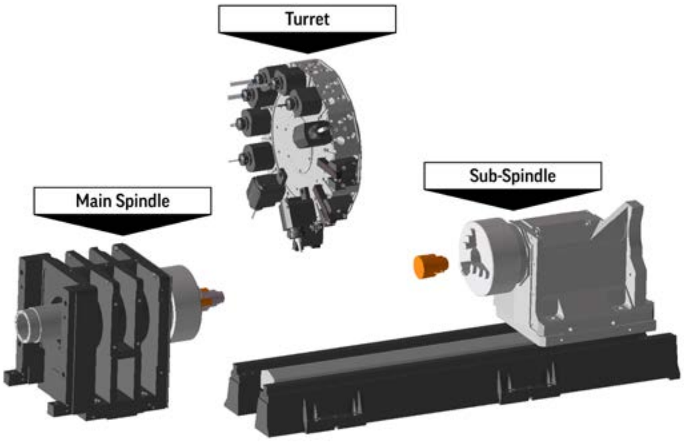
Unfortunately, all the benefits of MTM come at a price beyond the cost of the machine. Some of this involves the knowledge required to operate the machine, and much of this has to do with programming, and can be overcome with software that is geared toward making machines and programmers most efficient.

Terminology

COMMONLY USED TERMS:

- Turret
- Spindle
- Post
- Back post
- Slides
- Tool group
- Subspindle
- Pick-off spindle
- Tailstock

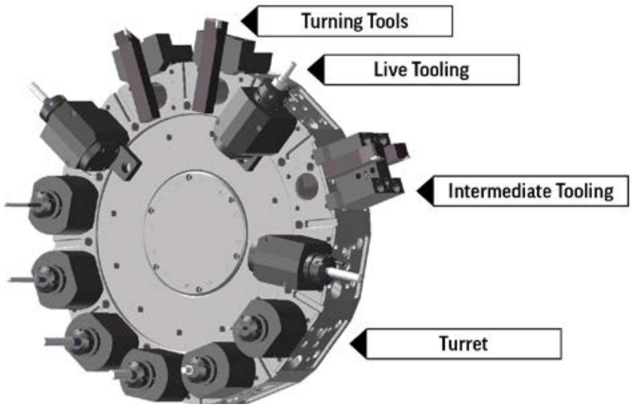
Among machine tool manufacturers, terminology can differ, so a few words about some terms can help you eliminate confusion, before proceeding to Machine Configurations.

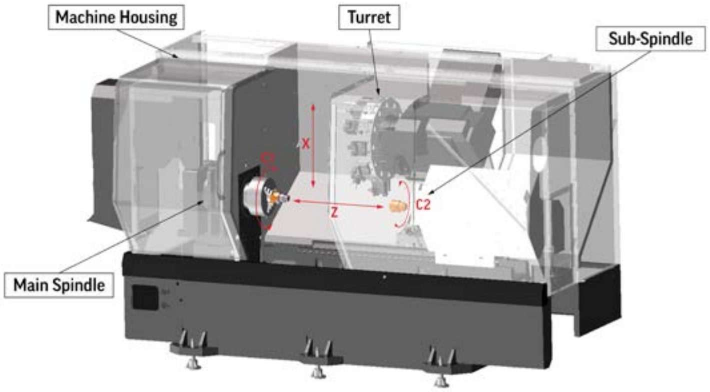


In nearly all configurations of MTM, a tool group is called a "turret." Swiss style machines use a different naming convention: The first group is a turret; the second may be called a "gang" or turret, depending on manufacturer; the third, which is usually a vertical plate with tool holders, the "post" or "back post." Multi-spindle machines use tool holders of one or few tools called "slides." Using the generic "tool group" is convenient because, for programming MTMs, all that matters is that each group has its own CNC program running within the overall program, and that no tool group interfere with the action of another.

If a machine has a second spindle, the second is typically called the "subspindle," and occupies the tailstock position of a lathe. The subspindle is sometimes called the "pick-off spindle." The workpiece is transferred to the subspindle to work "the back side" and finish the part. The two-spindle machine is frequently called a dual-spindle machine. Specialized, high-production machines may have multiple spindles, with multiple tool gangs and no opposing (tailstock) subspindle.

Dual-spindle machines may be equipped with a chuck on each spindle, or with a collet. High production machines, and Swiss style machines use collets because these operate much faster and occupy less space.





A requirement for a turning machine to be considered multi-task is "live tooling." This, of course, means having rotary cutting tools on at least one tool group, or as separate tool group, for milling and drilling.

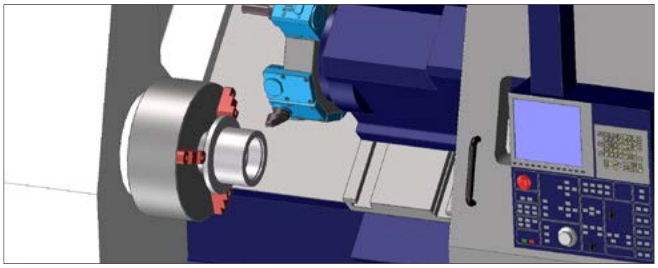
Balanced turning is a cutting operation with two turrets working on diametrically opposed sides of a part, and both tools set at the same depth, with no dwell. The second tool acts mostly as a moving rest when machining long parts.

Pinch turning is a cutting operation with two turrets cutting on diametrically opposed sides of a part, the second tool set to cut just behind and deeper than the first. When the second tool is directly opposed to the first, it also acts as support for long workpieces.

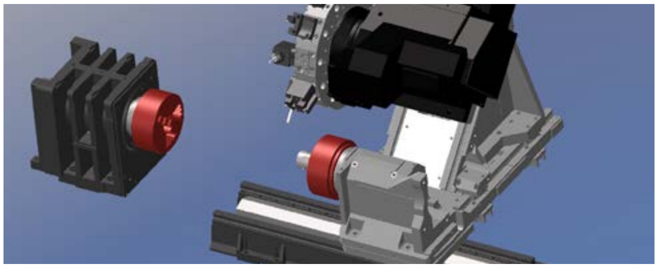
Non-cutting motion on a machine is known as a "utility operation" or "utility process." Bar feeder and subspindle motion for part transfers are the most common of these, but can also include tailstock moves to home or safe position, plus all controls of part catcher, part mover, part loader and unloader, steadyrest positioning, and any other non-cutting motion.

Machine configurations

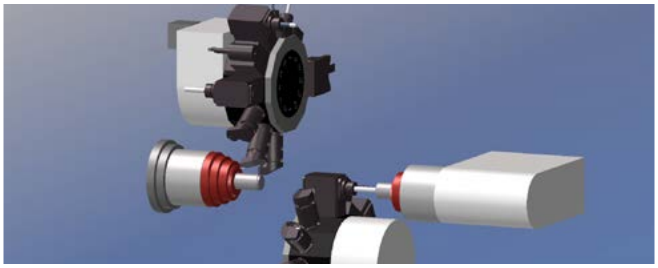
To illustrate, somewhat, the complexity that one is likely to encounter with MTMs, it is worthwhile mentioning some of the more common MTM configurations.



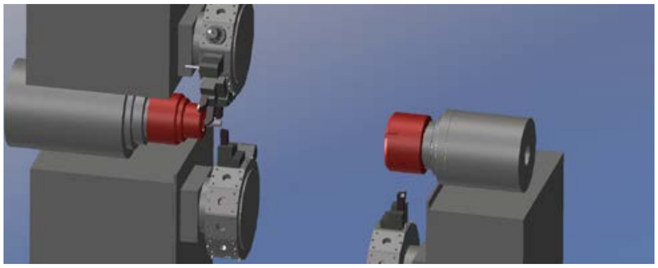
Single Turret, Single Spindle: The simplest MTM has a single spindle, a single tool group, and live tooling, so it can do turning work, and some basic milling, which can involve C-axis rotation to mill flats or do cross drilling. This machine will have up to 4 axes of motion: X, Y, and Z linear on the turret, and the C rotary axis.



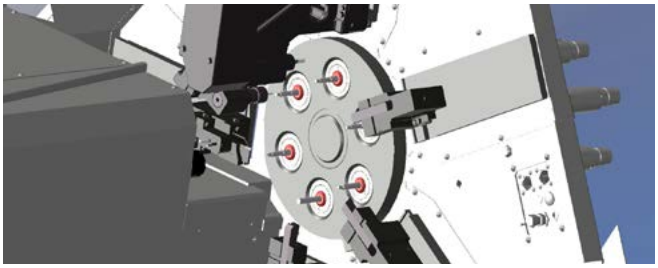
Single Turret, Dual Spindles: This is the basic machine that can make a part and drop it off completed. It may have up to 6 axes of motion: X, Y, and Z linear on the turret, a second Z (or A or W) on the subspindle so it can move to the spindle for handing off the part, and a C rotary axis on each spindle.



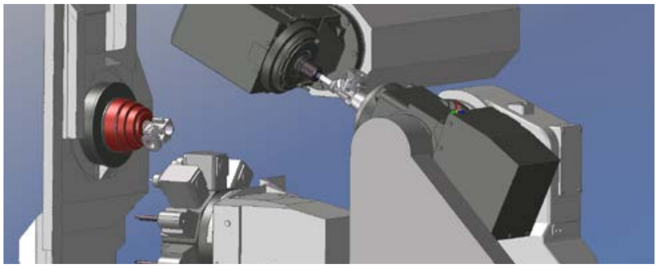
Dual Turrets, Dual Spindles: These machines are typically configured with upper and lower turrets, which enable pinch turning, so roughing operations can be done in half the time. The machine will have up to 8 axes: X, Y and Z on the upper turret, X and Z on the lower, a third Z (or A or W) on the subspindle for part transfer, and C rotary on each spindle.



Three Turrets, Dual Spindles: The obvious benefit is pinch turning, while the third turret works on the subspindle. These machines typically have 12 axes: X, Y and Z on each turret, a C-axis on each spindle, and a Z (or A or W) on the subspindle.



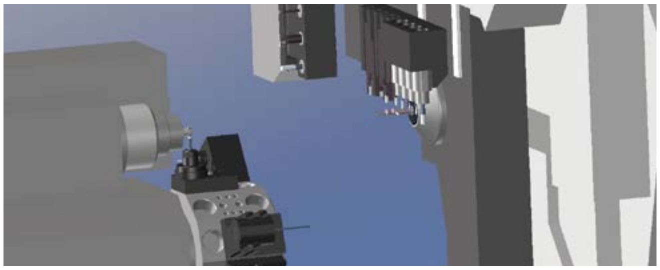
Four Turrets, Dual Spindles: These machines are typically configured with upper and lower turrets dedicated to each spindle, and used for high volume production. They are like a combination of two dual-turret, single-spindle machines in an enclosed machining cell, because each pair of turrets can only work on its own spindle. The exception is when the subspindle moves in to transfer the part, and the first turret cuts it off. These can have up to 13 axes: X, Y and Z on each upper turret, X and Z on each lower turret, rotary C axis on each spindle, plus Z (or A or W) on the subspindle.



B-axis Machines: Any machine can have a B axis, which provides the ability to machine tilted flats, or drill and tap holes at tilted angles not parallel or perpendicular to the centerline of the part. At least one turret is replaced with a rotating milling spindle with tool receptacle, the B axis, and a tool magazine. At the lowest level, a dual-spindle machine will have a B-axis tool spindle instead of a turret. Moving up, a configuration adds one or two turrets.

Until you have a machine with B-axis, you cannot do 5-axis simultaneous machining. Without a B axis, you are still doing a maximum of 4-axis simultaneous: X, Y, and Z linear with C-axis rotary. In 5-axis operation, interpolation is done with X, Y, Z and B, plus the C axis on either spindle.

Swiss-Style (Swissturn) or Sliding Headstock Machines



Originally developed in Switzerland to make tiny, high precision watch parts, the Swiss style machine is the most accurate of the MTM family. It achieves this by maximizing workpiece rigidity as close to the cutting tools as possible, by supporting the piece with a guide bushing. The milling and turning tools are held in a linear configuration in the tool gang, so that the turning tools move up and down in the X axis, while the part moves in Z out of the guide bushing.

The simplest of these has a single spindle and ability to mill flats and drill holes across the part. Increasing capability, there can be a second, lower tool gang or turret to work the main spindle. Increasing complexity, the machine can have a subspindle to finish the part with the second tool group. As tool groups are added, the work envelope gets quite small, increasing the programming challenge. Swiss machines typically have a small footprint, and are equipped with a bar feeder and parts catcher. Small stock diameters allow turning operations at 10,000 RPM. The largest diameter is 32mm, or just over 1.25 inches. The most common spindle sizes run from 8mm to 25mm (approximately 5/16" to 1").

Swiss machines are ideal for two types of parts: the very small, or even tiny parts, and parts that are long and thin (with length-to-diameter ratio of 4 to 1 and higher), because the guide bushing prevents the part from deflecting.

Examples of parts made with 8 mm stock are watch parts. In the mid-range, there are dental implants. With larger, 25 mm stock we have medical parts, and screws for orthopedic implants and restorations. Across the range are long, narrow parts, and all kinds of screws for various industries.

A common, specialized, Swiss style application worth mentioning is thread whirling. Its use is driven by the productivity it offers over traditional thread milling. A thread whirling attachment mounts on a spindle with

C-axis capable of slow rotation. Multiple thread cutting inserts are mounted inside a cutting ring, which turns with the workpiece, but at a different rate. Bar stock feeding through the guide bushing, directly into the cutters, makes thread whirling ideal for long screws. Instead of cutting with a single-point tool that requires relief under the cutting edge, the workload is distributed among multiple inserts. The whirling spindle rotation provides the cutter side clearance. Because the cutters work close to the guide bushing, the piece is well supported for making long screws, with deep threads and multiple-start threads, typically done in a single pass. These characteristics are common features of orthopedic bone screws.

Multi-Spindle Machines

There is another very specialized type of machine, specifically used because its purpose is extremely high volume production, where you may run the same part for months.

This is the multi-spindle machine. The typical configuration is six spindles in a circular barrel, like a Gatling gun, with an equal number of fixed-location tool groups, typically tool slides with only one or two tools, but sometimes more. Machines with this configuration are also known as indexing lathes.

The goal with these is to eliminate tool changes, and minimize X and Y motion. Each spindle has its own bar feeder, which pushes material out through a collet or guide bushing. Limited operations are done at each tool station, then the barrel rotates so the part moves to the next tool group – indexing to the next position – until the part is finished, cut off, and dropped at the 6th station

Ideally, each tool group does the same fraction of work. If each spindle does 1/6 of the work, the cycle time for a part is 1/6 of what it would be on a single-spindle machine.

For example, a part made in 3-minutes (180 seconds) on a single spindle machine, would be dropped every 30 seconds on a 6-spindle machine. There are machines with more spindles and tool groups, with the same principle but more complexity and more tools in motion.

Personnel considerations

Generally speaking, the level of knowledge required to program and operate MTMs is higher than that needed for a straight lathe or mill. The complexity of parts and machine motion has demonstrated that the best programmers for MTMs are people experienced in programming both lathes and mills, especially when the mill programming is for multi-axis machines. Less experienced programmers should take extra care in programming the less familiar functions, and avoid assumptions about the control's "thinking" or corrective capabilities.

After the set-up, the MTM equipped with bar feeder requires little oversight in a production run. In fact, they lend themselves well to lights-out operation. However, for the set-up and for jobs requiring manual loading or unloading of the workpiece, the operator or machinist should have some machine-specific training. Expertise with a brand of lathe or mill control does not guarantee automatic knowledge of a milling lathe or MTM.

Challenges of programming

As can be seen from the few configurations discussed, machine complexity presents a challenge because there can be two or more tools working simultaneously on one or more spindles. This problem is compounded by the small work envelope common to MTMs. The number and motion of tool groups and the length of individual tools become important in avoiding interference and crashes. When high volume production requires shaving seconds from each operation, optimization of the program requires maximizing the number of tools working simultaneously while avoiding waits by tools. Optimization becomes a balancing act.

Part prove-out presents another challenge. Because you never want to prove out the part at the machine, where a small mistake can cause thousands of dollars in damage, you need reliability and accuracy in toolpath verification and simulation of all machine tool motion, including non-cutting motion. A last challenge is achieving efficient, accurate and complete post processing for the precise combination of machine, control, and shop process. Completeness is emphasized because too many shops are accustomed to editing post-processed programs, which takes time and can introduce errors.

CHALLENGES OF MTM MACHINING:

- Machine complexity
- Small work envelope
- Avoiding interference and crashes
- Optimization
- Avoiding waits
- Part prove-out
- Toolpath verification
- Simulation of machine tool motion
- Efficient, accurate, complete post processing

Actual programming

"Proceed with caution" could be an understatement when it comes to programming the MTM. CNC programmers are sometimes misled into believing that programming is "just like programming a lathe and a mill." CAM software vendors who don't have a single interface for doing both turning and milling together, or those with weak linkage between them are the likely purveyors of that idea. In a practical sense – in a shop running real jobs – that description is far from accurate. The following discussion is meant to inform, and to help you implement machines and software successfully and profitably sooner.

Tool groups and flows

The MTM control requires and runs a separate sub-program or "flow" of operations for each tool group of the machine, whether turret, gang, post, or slide. There is one flow per tool group. A machine with two turrets has two flows; three turrets, three flows; and so on. In some controls, flows are called channels, paths, or even "dollar" because the control uses the $ symbol to indicate a flow.

As the control executes each flow, the ideal is to have each tool group working all the time, not having one sit idle while others work. At the same time, you don't want a tool group moving into a position where another is working.

These flows must be synchronized to maximize the amount of simultaneous work being done, but without conflicts or collisions. Additionally, there is non-cutting motion that cannot be ignored. The subspindle may move toward the main spindle for a part transfer, and there can't be tools working while this utility operation is underway. Conflicts and collisions are avoided by using and managing wait codes or "syncs" on each flow, a process done in different ways by different software. Some CAM software may require that the programmer intervene manually, while other software does it automatically, with user guidance.

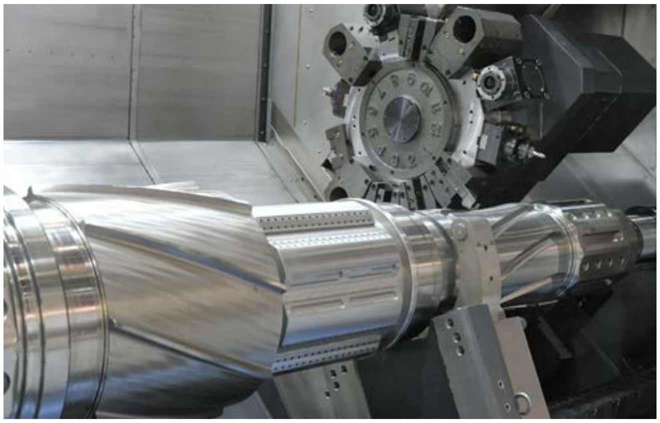
Good software manages syncs simultaneously with optimization. It will show the programmer when one tool group is working while another is doing nothing. It will show gaps in operations in each flow, so the programmer can level the work among tool groups, and machine more parts in less time.

Although not always possible, the goal is to have all tool groups working for the same amount of time, to the fraction of a second. With no tools ever waiting for another tool to finish, a part is finished as fast as possible.

It may be easy to imagine machining with two or three tool groups. Now reconsider some of the machine configurations above, and imagine synchronizing the 6-spindle machine with two tool slides per spindle. You now have 12 flows to manage. Traub Index makes a machine with 6 spindles and 6 subspindles, each with two slides, so you have 24 flows to synchronize.

CAM software considerations

Selecting and using CNC programming software can sometimes frustrate efforts to bring new machine tools on line. This should not happen. What often happens is that software that has been perfectly good for lathe or 3-axis mill work is suddenly required to program a new machine, and it fails.



In searching for good CAM software, one should not assume that it must be complex in operation to program complex functions. Good software is designed to simplify complex tasks, not to add complexity. It should assist the programmer, not impede him or force him to do things its own way.

When a shop is doing work for more than a single customer, it should have CAM software that can accept CAD files from any major CAD system, and not be married to a single CAD package. Also, it should not require file conversion into some CAD package before the CAM software can open it.

Ideally, the CAM software should allow the programmer to work the way he would machine a part. He may need to remove some material by turning, and then milling, then more turning, and so on. If the programmer can proceed

in this fashion, without having to move between screens, the process will be more logical, less prone to errors, and take less time. So if the software works the way a machinist thinks, that's ideal.

For MTM, look for software that has a unified or integrated interface for turning and milling. The user should not need to start up a separate program, or flip from screen to screen and back again, as he alternates between turning and milling. The whole idea behind the MTM machine is to avoid turning on one machine, then milling on another, and going back and forth between machines. CAM software should act likewise, and not flip between software programs.

Also, you need to be able to control motion of all machine components, to move them at the proper time, keep them at a safe home position, and prevent two or more tools from performing conflicting motion. Some CAM software does not control all moving components, but only the cutting motion. Machines can have a subspindle, a bar feeder, a parts catcher, parts loader and unloader, and other accessories that require control through utility operations. The software should have provision for these utility operations, so cutting tools can be stopped before non-cutting motion begins - a subspindle moving to transfer a part, for example.

All utility operations, tool motion, wait codes and optimization can be handled with software that has a sync control manager, so the programmer can visually see if there is wasted idling time, proper wait codes, warnings on conflicting or disallowed motion, and whether tool utilization is optimized for efficiency.

Optimization with a sync manager is a first step in proving out a part. Another useful function to have is toolpath rendering, to visualize the part as machined by the toolpath. Also, depending on part or machine complexity and programmer experience, machine simulation may be necessary, to show if there is interference among tools, tool holders and other moving components.

An important consideration that is sometimes assumed to be available is a proper post processor to convert the CAM file into machine-specific code. The so-called "universal post processors" don't work for multi-task machines. They need to be specific to the machine and control, at minimum, but ideally also specific to a shop's standard. Of all CNC code you don't want to be manually editing, MTM is at the top of the list.

Remember that it is not the programmer's job to make a post processor work. Too many shops have been led to believe it is their responsibility by vendors who are unable to support their own software. To test for a CAM software developer with suitable MTM software, find out how many custom post processors they maintain for customers. A good vendor will have a library of hundreds and hundreds, just for MTMs.

For information on the GibbsCAM solution, visit: www.3dsystems.com/gibbscam

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