The benefits of integrated collision checking in CAM systems

▶ *What is collision checking?*

The primary requirement for collision checking is detection of interference between the tool holder, the machine tool itself and the workpiece. However, a comprehensive integrated collision checking program can go much further than this.

Because the algorithms are integrated with the CAM system they have bi-directional access to far more information than just the CNC code, tooling and the part model. The additional benefits can include:

- Real time collision avoidance
- Suggestions for alternative toolpaths
- Information about the minimum tool length required to finish the job
- Identification of areas of the job, which cannot be reached, and which will need further machining or alternative processes to complete
- Knowledge of where the excess material is located to avoid shock loading of the tool
- Ability to edit the toolpath during programming, saving the time required to recalculate a collided toolpath
- Consideration of machine tool specific axis limitations
- Optimisation of feeds and rapid movements to shorten cycle times
- Ability to check the completed part against the original model.

▶ *Benefits of collision checking*

Clearly the main advantage of collision checking is to avoid damage to the tooling, the machine tool and to the job. All of these can be very costly in terms of time lost, repair or replacement of equipment, and customer dissatisfaction. Integrated collision checking meets these basic requirements but also provides some valuable additional benefits:

- Helps to get more or all of the job completed in one operation
- Promotes the use of the shortest and most rigid cutters possible
- Enables 3+2 axis and 5-axis machining to be done with confidence
- Minimizes the shock loading of the tools and increases tool life
- Reduces programming times
- Intelligently modifies the toolpath to make programming simple and reliable
- Maximizes the utilisation of the full capabilities of a machine tool
- Shortens cycle times
- Manufacture the part right first time
- No additional training is required to operate the software.

▶ *Stand-alone collision checking programs*

The main benefit of these is that they check the CNC code, so do not rely on the internal calculations of a CAM system, and are intended to mimic the machine tool control. For certain applications this belt and braces approach is valuable, but it is a considerable overhead, which is unnecessary for the majority of jobs and is justified on the assumption that the internal collision checking of a CAM system is either non-existent or unreliable.

The same logic can be applied to a stand-alone verification system – how well does it simulate the machine, and how accurately does it interpret the CNC code? Rechecking a toolpath which has already gone through an integrated CAM system collision check will obviously reduce the chance of an undetected error, but was there a risk in the first place?

Modern CAM systems are, in general, very reliable. WorkNC in particular has an enviable record of reliability, defaulting to safe toolpaths, and fully considering the machine tool's kinematics.

The disadvantages of adding a stand-alone verification system will be the extra training and skills required for its operation, the extra time required to program it – an extra step in the production process, and the cost of investment. Choosing a CAM system like WorkNC which has comprehensive integrated collision checking, and a reputation for reliability is clearly a better solution.

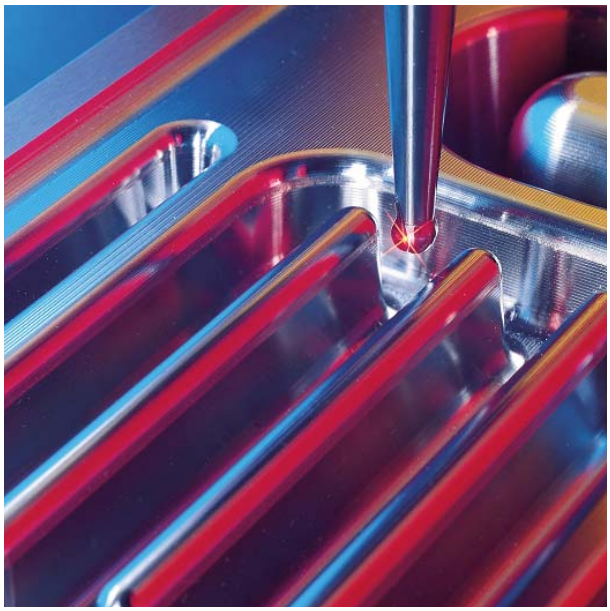
▶ *Interference detection*

This is the main purpose of a collision checking system. Integrated and stand-alone systems both complete this basic function. In WorkNC, the user can set up a proximity allowance in addition to the stock allowance, so that the system will detect movements which are within these limits. Additionally, the user can define the tool, its holder, and part of the spindle, so that all these elements will be checked against the workpiece, clamps, and any surfaces which are not to be machined.

For more complex 3+2 or 5-axis verification the complete machine can be modelled so that any interference with other parts of the machine tool can also be detected. To speed up the process, WorkNC allows the user to view and check only the relevant parts of the toolpath. For example, a large job may have one small, intricate cavity, and the programmer already knows that this is the area which may produce a collision. The software allows him to examine just the cavity, making it unnecessary to view all the other areas which he knows are working perfectly.

Over travel on the machine's limits can be a serious problem, especially in 5-axis applications. Each machine has its own peculiarities, especially on rotary axes. For example, the Auerbach IA 5 B machine has a tilt angle limit of -95° to +95° while the DMG DMC 75V machine has a tilt angle limit of -110° to +9.5°. WorkNC is able to consider these so that unwind or flip movements can be added before the limits are reached, enabling machining to continue uninterrupted.

There are many benefits to this technology. Some companies may use trial cutting to ensure that the program is correct. This uses up valuable machining time, and reduces the available capacity, adding directly to the cost of parts. A reliable programming system with integrated collision checking makes this completely unnecessary.



Confidence in the toolpath produced will build on the competence of the machine operators, enabling them to get the maximum productivity from the machine tools. Unreliable programs cause serious disruption to the production process. Not only are there direct costs for broken tooling and damaged machinery, but also the hidden costs of delays to the production schedule; disruption of other work; potential injury to personnel; scrapped parts; reworking of parts; delays due to excessive program correction times; downtime while awaiting machine tool repairs or new tooling; slower machining due to an over cautious machine operator; and dissatisfied customers, which can have an impact on future business.

Choosing a reliable CAM system like WorkNC with integrated collision checking will enable companies to avoid all these problems and produce optimized programs so that CNC machining becomes the smooth and trouble free operation that it should be.

Simon Doleman, Manufacturing Manager for Expert Tooling & Automation says, "WorkNC is of paramount importance to us and we are very pleased with it. What used to be a source of problems has now become a routine exercise, which gives us absolute confidence in the results that WorkNC produces. We are also delighted with the support we get from Sescoi. Their engineers helped us at our customer's sites, making sure the 5-axis programs we supplied worked perfectly on their machines."

▶ *Collision avoidance*

This function is only possible in a CAM system with integrated collision detection, because any interference between the tool holder and the workpiece needs to be fed back into the toolpath calculations, so that a new safe solution can be computed as programming continues.

A stand-alone system can only work with the generated CNC code or CL data (cutter location), so if a collision is detected, the programmer has to go back into the CAM system, find the error, correct it and then recalculate the toolpath – sometimes this can be very time consuming.

WorkNC computes collision avoidance paths automatically for both its roughing and Auto 5 5-axis toolpaths. For the roughing toolpaths it generates only uncollided paths, and updates the stock model to show where material is still left. The programmer can then clearly see that extra semi-finishing operations are required. This may involve a different tool, tipping the job for 3+2-axis cutting, or 5-axis machining.

For finishing operations which, by definition, only require a small amount of material to be removed, WorkNC can calculate the toolpath and split it into uncollided and collided sections. For the collided section, the system recommends a new tool length for safe machining. The programmer can either accept this or he can choose to reach these parts of the job by other means. In either case, the rest model clearly shows any unmachined areas. Where machining is impossible, the engineer can use the rest model to see exactly what needs to be done to finish the part, and can then produce the fine detail by spark eroding, for example.

Programming in 5-axis definitely requires some sort of verification and collision checking. Not only is there a higher chance of the tool and its holder crashing into the job, but there is also a greater likelihood of the machine's rotational limits being exceeded. WorkNC's Auto 5 module dynamically solves these problems and simplifies programming in one easy step.

Easy 5-axis programming is achieved by preparing the toolpath in 3 or 3+2 axis as normal, using any of the roughing and finishing strategies available in WorkNC. The result is then run through the Auto 5 module, which automatically changes the cutterpath to full, continuous 5-axis. Auto 5 offers nine options for controlling how the 5-axis moves are generated, enabling the programmer to choose the best solution for the surface topology.

The most popular Auto 5 options are:

- Vertical - where the tool is kept vertical as much as possible, and only tipped where necessary to reach an awkward area
- Constant to axis - where the tool is kept at a constant angle to the vertical wherever possible
- Normal to surface - here the tool is perpendicular to the surface being cut, and is best suited to smooth shapes
- No change - here the cutter stays at the same angle as much as possible, the benefit of this is that too many rotational movements will seriously slow down the machine tool, so keeping the angle constant until it is absolutely necessary to change it, will greatly reduce machining times.

As the 5-axis toolpaths are being generated, the software is continually checking for holder collisions and for the machine limits of the individual machine tool. When the limits are approached, WorkNC automatically introduces flip and unwind moves to the rotary axes. This keeps the machine running continuously and allows more of the part to be finished in one setting. If this checking is left until after the job has been postprocessed it is very likely to produce a collision when run through a stand-alone verification system. The programmer will then have to go back into the CAM system, find the axis overrun, correct it, then re-postprocess the job, and finally verify the path again. Clearly, it is better to avoid the collisions in the first place, as WorkNC does, by checking interferences and limits during programming.

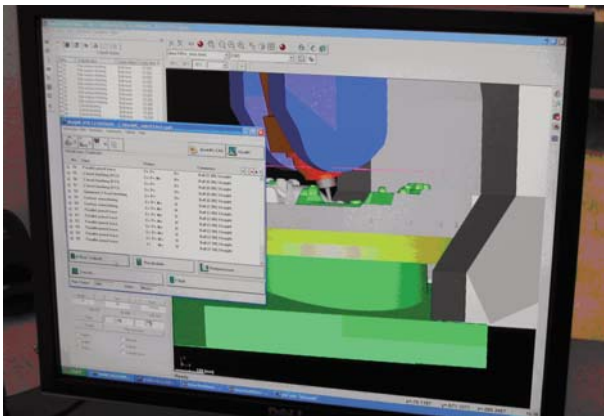
Drazen Vincekovic of Adelaide Pattern Tooling & Design explained the use of WorkNC Auto 5, which automatically changes 3-axis toolpaths into 5-axis. "Generally, we start with a 40mm face cutter and High Torque Roughing, then we re-rough with a 16mm tipped cutter and a 10mm carbide, working our way down to 1mm with WorkNC's Contour Re-machining and Parallel Pencil Trace operations. We run all the toolpaths through Auto 5, which allows us to pick out walls 70-80mm high using the shortest possible cutters, tipping the tool in 5-axis to reach otherwise inaccessible areas of the job. We don't use any EDM tools now. Previously we would have used 10 or 20 electrodes on each pattern. This has resulted in a 40% time saving."

Visualising the complete machine

Both stand-alone and CAM integrated collision checking systems can do this. It is generally only necessary for 5-axis programs and, even for these, it can be restricted to obvious potential problem areas such as cavities or large upstands.

WorkNC uses a module VisuNC, where the user can model the complete machine tool and all its axis limits. By running the 5-axis program through VisuNC the programmer can identify problem areas and then edit the toolpath where necessary. VisuNC will automatically highlight collisions or near misses, and allow the programmer to carry out functions such as cutting out part of the toolpath, smoothing it or adding extra points at the beginning or end.

Machinists will find this mostly useful for the standard 5-axis toolpaths in WorkNC such as tube machining, impeller machining or rolling toolpaths – Auto 5 avoids collisions as it calculates. For these, more specialist, applications, the advantage is being able to carry out the checking in the same environment as the programming, and alter toolpaths as programming progresses. Stand-alone systems will achieve the same results, but from postprocessed data, meaning that the engineer has to go back to the CAM system to make the corrections, which is both time consuming and more complex.



Jon Ingleby from Gordon Murray Design, which is developing the T.25 City Car says, "We have never had a problem with WorkNC so we can leave it to cut overnight with absolute confidence in the results, while we get on with other tasks."

▶ *Optimising the toolpath*

To shorten cycle times, machinists want to minimize air cutting, reduce the number of retract and feed in movements, shorten rapid movement paths and keep the tool in the material as much as possible. Additionally, they need to keep cutter loads steady and low, produce smooth tool trajectories, and eliminate sudden direction changes.

As well as shortening machining times, implementing these principles will increase tool life, reduce wear and tear on the machine, and improve the quality of the finished part.

Stand-alone verification systems sometimes have the capability of optimising the toolpath in this way, linking toolpaths, optimising feedrates and eliminating air cutting.

WorkNC already includes these functions in its strategies. Trochoidal moves are introduced where appropriate, corner smoothing eliminates sudden direction changes, new algorithms have reduced the number of retract movements, and stock and rest models ensure that air cutting is kept to a minimum. Furthermore, knowledge of the location and depth of material to be cut allows the software to keep cutter loads constant, greatly reducing the chances of tool breakage, even in hard to machine materials.

To take the optimisation to the nth degree, Sescoi can offer NCSpeed, which works on the postprocessed data and uses volumetric calculations to fine tune feedrates. This extra step can be especially useful for long thin cutters and for hard materials, improving cutting conditions and further reducing cycle times.

▶ *Simplicity, speed and productivity*

Being able to check for collisions within the CAM system provides some major benefits to programmers. Having one system to learn eliminates the confusion of having to operate multiple software packages. WorkNC has been particularly designed for ease of use. This has many advantages, including the ability to program on the shop floor; the ability to have more people as operators, which improves staff flexibility; a shorter learning curve; higher utilisation levels for the software; and reliable CNC programs.

Speed of programming will be significantly quicker on an integrated system as it does the programming and the collision checking at the same time. Collision avoidance goes even further, modifying the toolpath in advance, rather than correcting it afterwards – the latter being the only way this can be achieved by stand-alone verification systems working from CNC code.

Built in collision checking will raise productivity levels. Shorter and more rigid tools can be used as well as 5-axis techniques, which will enable parts to be completed in one operation and to a higher quality. Operators and managers will have confidence in the reliable toolpaths produced, which will raise the efficiency of each machine tool and enable unmanned operation out of normal working hours.

CERPI has been successful in the aerospace industry with help from WorkNC. Louis Ristic from the company explained, "The advent of 5-axis machining in WorkNC has been a great step forward for us because we now have all the functionality to enable us to create high performance 5-axis machining programs. Because it is so easy to use we have cut programming times by a factor of 4 or 5. Furthermore, we are able to model part geometry and machining center kinematics to simulate and validate our programs on the screen before manufacture. This provides increased security, renders testing unnecessary, and lets us run machines unsupervised throughout the night, which is especially useful for jobs with long cycle times, such as those for Airbus."

▶ *Conclusion*

Stand-alone toolpath verification and collision checking programs have their place but, for the majority of applications, CAM systems such as WorkNC which have integrated collision checking, do exactly the same job yet have some significant advantages in ease of use, more advanced functionality, interactive operation, speed, and simplicity of use.

The most important benefit of integrated systems is the collision avoidance, which is not available on stand-alone verification systems. This corrects the toolpath as programming progresses, removing the need to find and correct errors after the job has been postprocessed. Collision avoidance produces a cutterpath that is efficient, safe, and fast.

In the past, CAM systems were less reliable, but modern systems like WorkNC have been proved to be failsafe in their operation. Many of its users regularly carry out 'lights out' machining with absolute confidence, so repeating the verification step on a stand-alone system is unnecessary, time consuming and expensive. By implementing WorkNC with its integrated collision checking, companies will get a system which optimizes the machining process for maximum productivity and profitability.