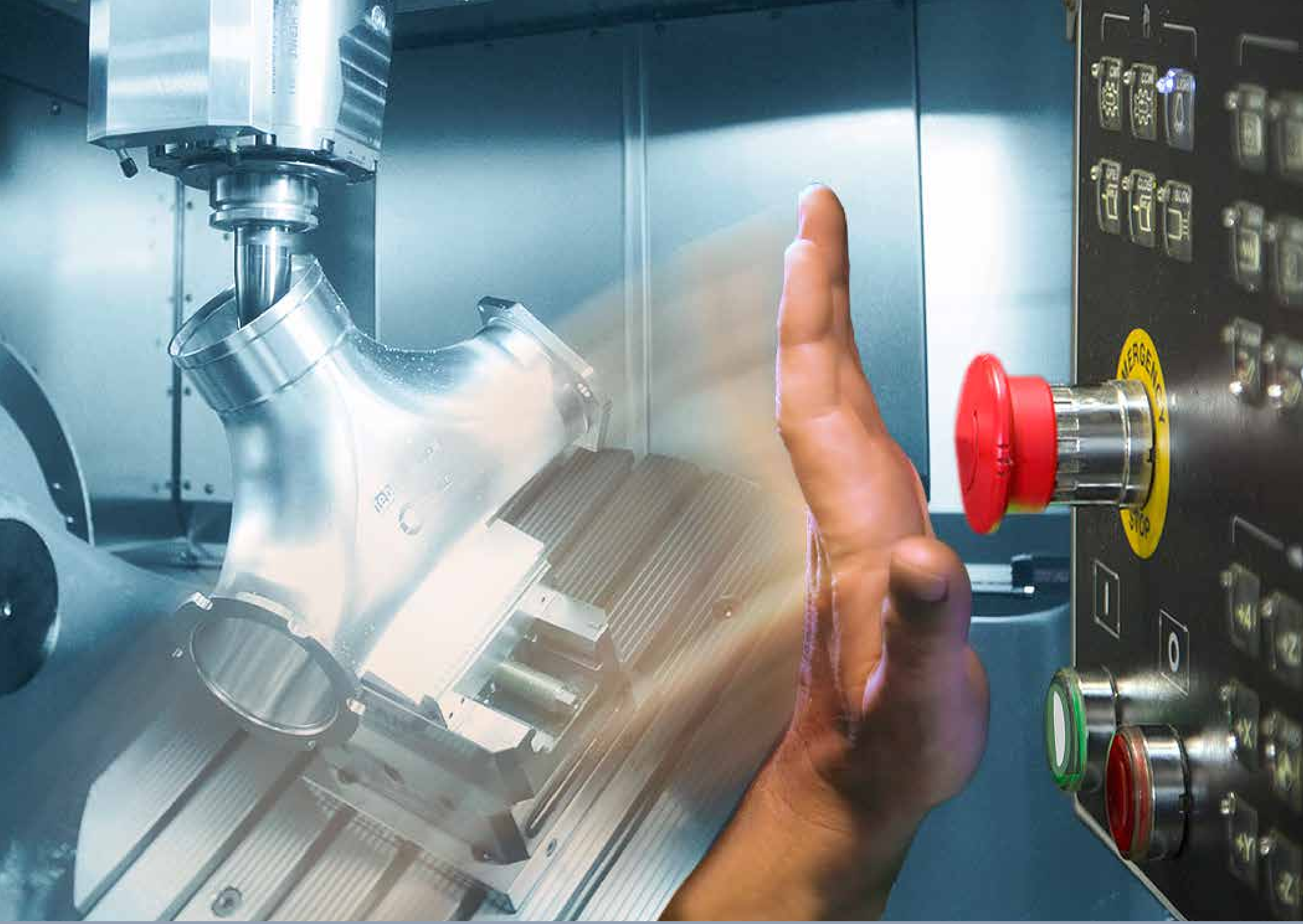

Detecting and preventing collisions: The earlier the better

CAD/CAM MES
Software & Services

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A collision between machine head and part, tool and clamping device or spindle and machine table can be an expensive mistake. There are various approaches for detecting and avoiding collisions and machine damage in advance. If the right method is used, unnecessary down-times can be avoided.

This article shows different methods for detecting and avoiding collisions and compares their advantages and disadvantages.

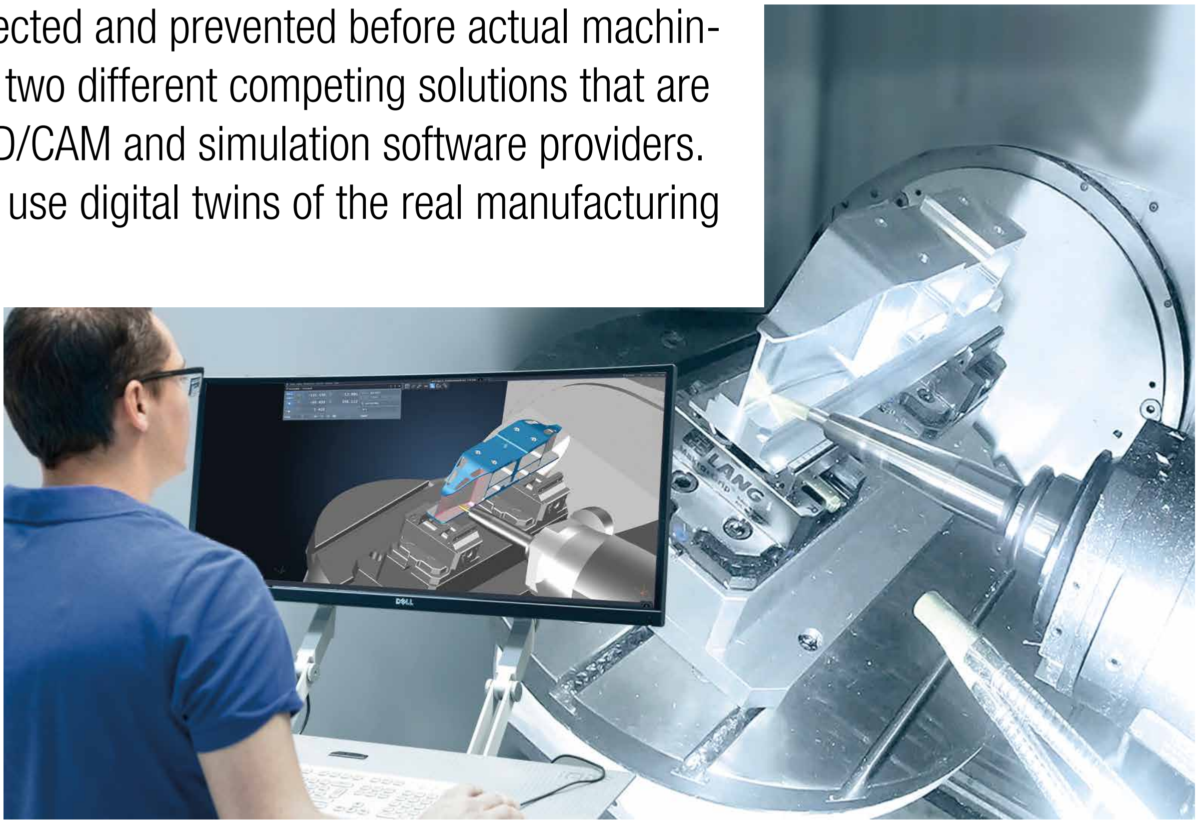
It also presents the possibilities for identifying and preventing collisions in the virtual CAD/CAM environment:

- Interactive planning
- CAM programming with automated collision avoidance strategies from NC templates
- Verifying the calculated toolpaths for the entire machine

A collision between machine head and part, tool and clamping device or spindle and machine table can be an expensive mistake. There are various approaches for detecting and avoiding collisions and machine damage in advance. If the right method is used, unnecessary downtimes can be avoided.

On simpler machines, an attentive machine operator can usually detect potential collisions visually and press the emergency stop button in time. However, fast and complex movements make it impossible to manually interrupt machining on modern high-performance machines like turning-milling centers or simultaneous 5-axis machines. These machines are automatically stopped by integrated protective mechanisms in the event of a collision risk. But stopping the machine manually or automatically have the same result: The machine is sitting idle.

To avoid machine downtimes and crashes, collisions should be detected and prevented before actual machining. There are two different competing solutions that are offered by CAD/CAM and simulation software providers. Both methods use digital twins of the real manufacturing environment.

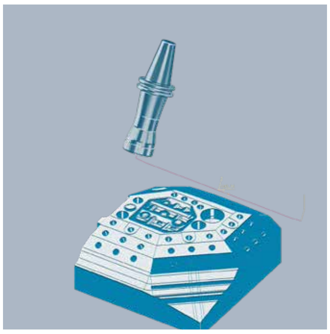


Detecting and avoiding collisions before machining: Comparison of methods

Key differences: In Method 1, NC programming in the CAM system is initially performed independently from the components that are used in machining – such as the machine, machining tools and clamping devices. The toolpaths are then verified by **additional** simulation software. Method 2 integrates the digital twins of these components in the CAM programming. The toolpaths are verified right in the CAM system **without** additional simulation software.

Method 1:

NC programming in the CAM system and verification of the toolpaths with additional simulation software.



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Method 2:

NC programming with integrated verification of the toolpaths in the CAD/CAM system.

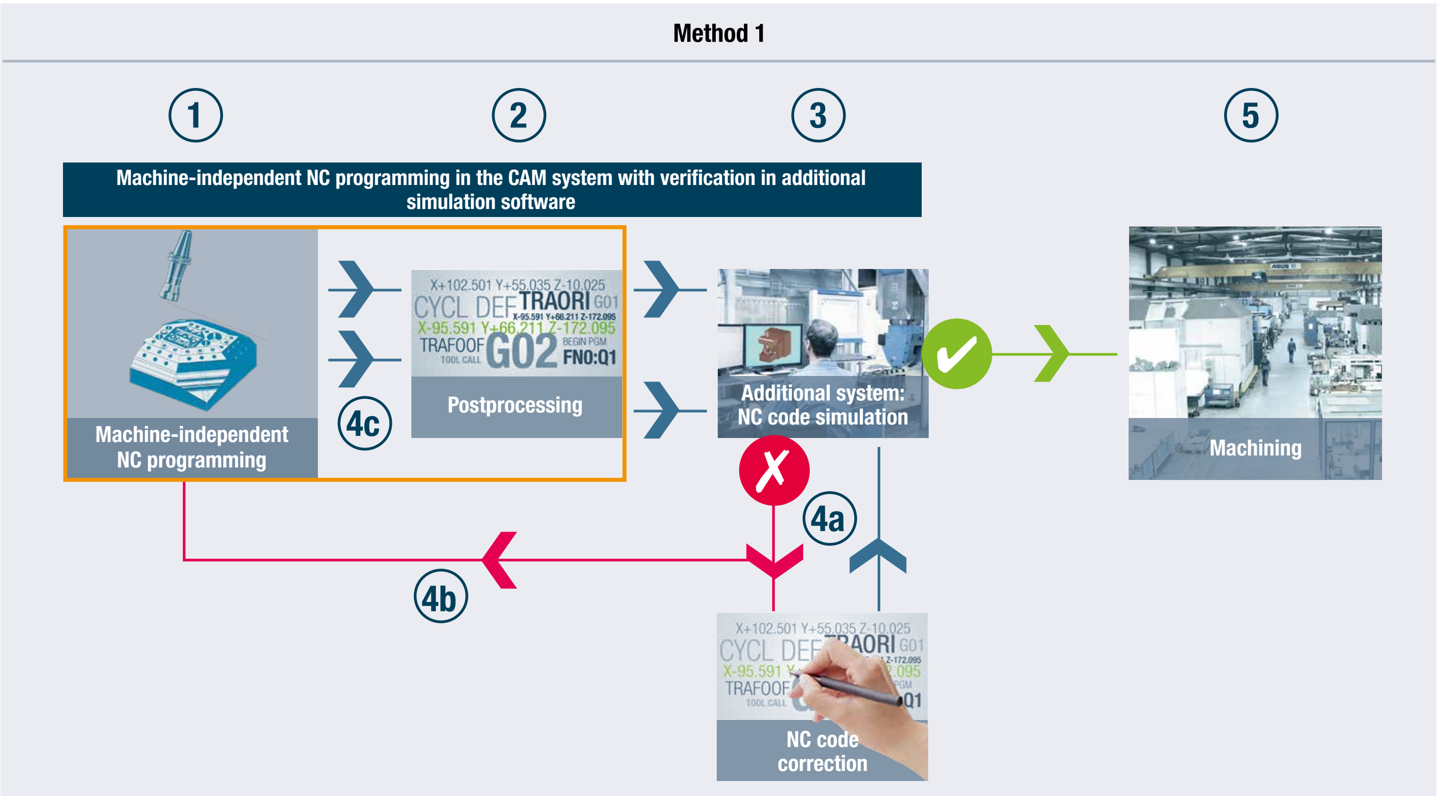
How these methods are used in the manufacturing process

Method 1: Machine-independent NC programming in the CAM system and verification of the NC code with additional simulation software

In this approach, the NC program is first generated in the CAM environment – independent of the machine, tool and clamping device models (digital twins) (1). The data is then supplemented with the machine, tool and clamping device information – either before or after NC output depending on the system (2). Then, the CAM programmer or the machine operator use additional simulation software to verify the NC code.

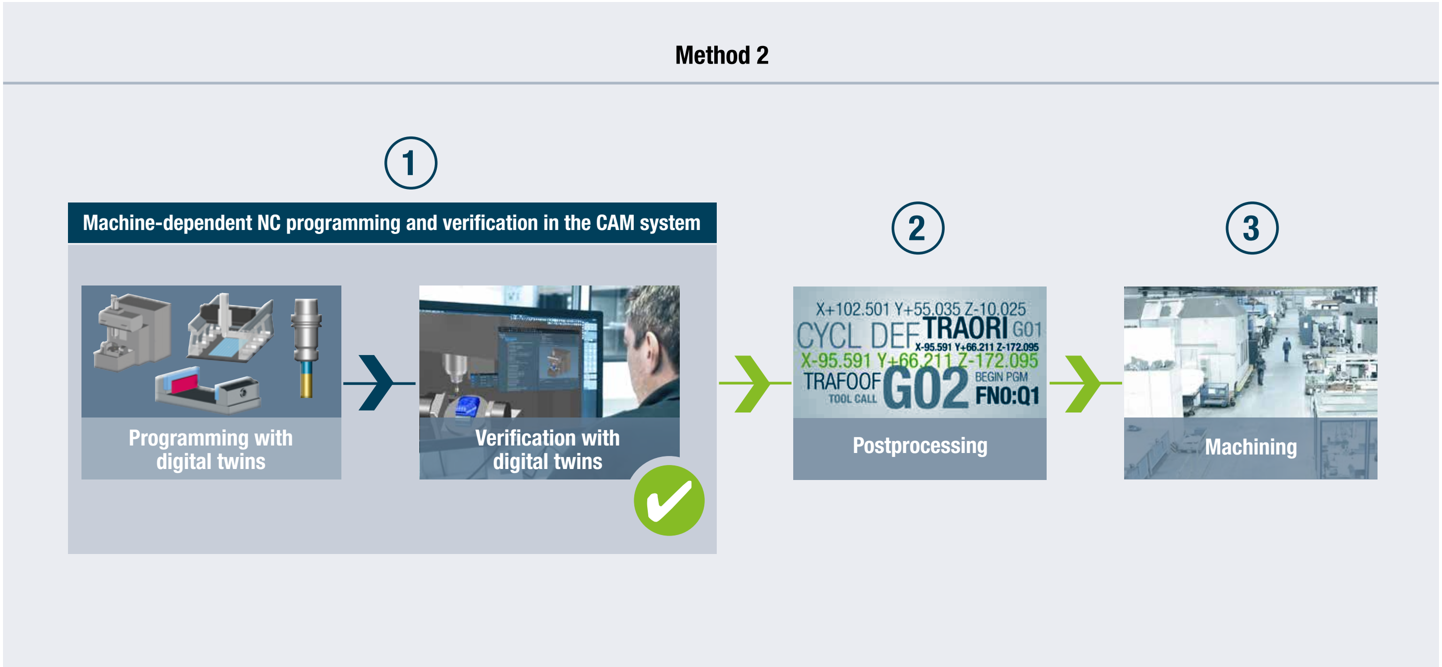
If no collisions are identified, the part proceeds to manufacturing (5).

In the event of collisions or other issues, there are two possibilities: The NC code is corrected manually and then simulated again (if the NC program is regenerated later, such as due to changes in parts, it must be corrected and simulated again) (4a). Larger corrections are done in the CAM environment (4b). The updated NC program must also be verified with the simulation software to ensure that the correction was successful (4c).



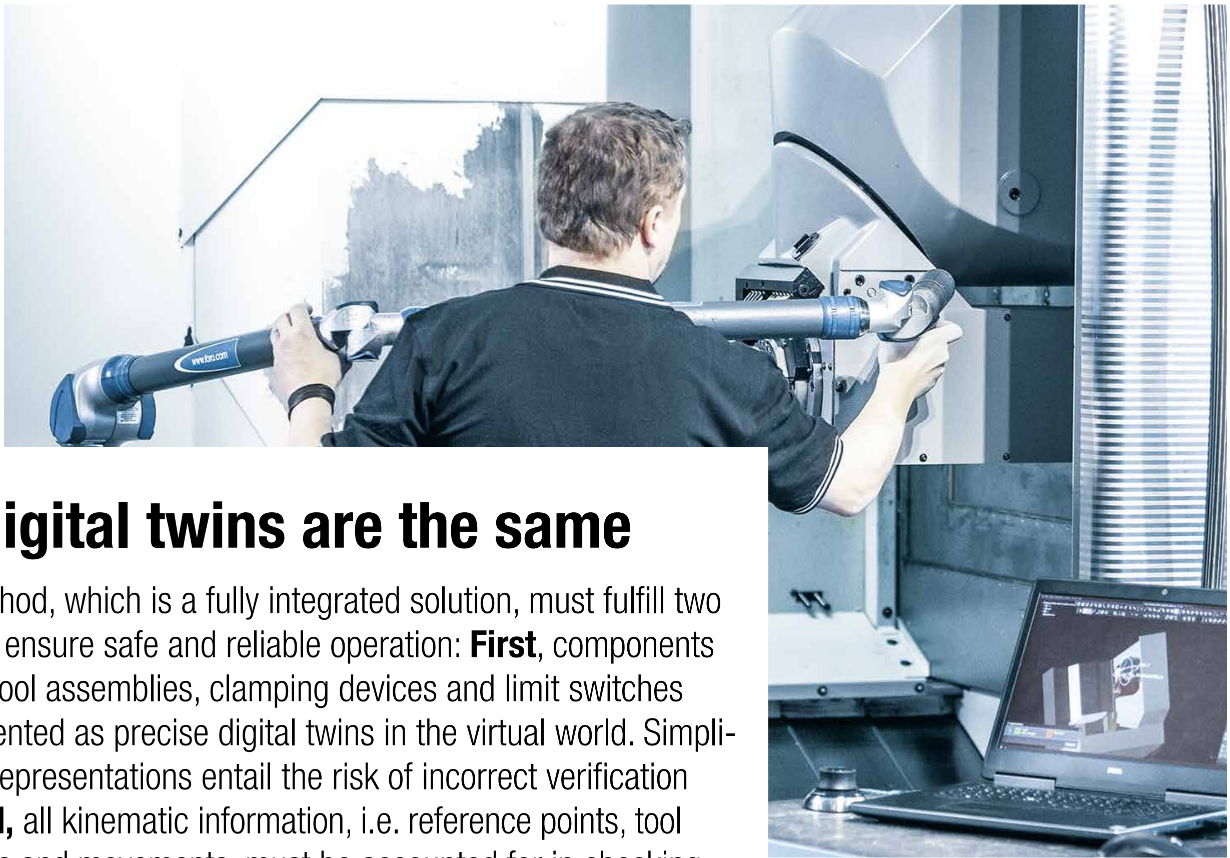
Method 2: Machine-dependent NC programming and toolpath verification in the CAD/CAM system

In the second approach, planning, programming and verification are performed in the CAM environment with digital twins of the real production environment: The CAM programmer uses all manufacturing-related data from the machines and tools used, checks the machining for collisions in the system and corrects any errors (1). This means that the output programs are completely collision-checked (2). The NC code is then sent to manufacturing for machining of the part (3).



Comparing the two methods shows that the second approach – integrated simulation and collision checking – has many advantages:

- Interface iterations and correction loops are reduced.
- Planning is easier, because the CAM programmer has access to all the virtual manufacturing components that are represented in virtual process libraries.
- The process is simple and the CAM programmer doesn't need any special knowledge of machine code or additional simulation software.
- Manual corrections to the NC code are not necessary that could place process safety at risk.
- All corrections automatically flow back into the CAM environment, so errors are never repeated.
- The digital twins are managed only in the CAM environment instead of both in the CAM environment and the simulation software.



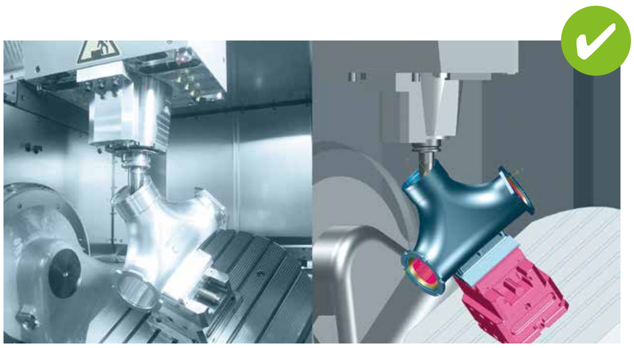
Precise measurement of the real machines by a specialist.

Not all digital twins are the same

The second method, which is a fully integrated solution, must fulfill two prerequisites to ensure safe and reliable operation: **First**, components like machines, tool assemblies, clamping devices and limit switches must be represented as precise digital twins in the virtual world. Simplified geometric representations entail the risk of incorrect verification results. **Second,** all kinematic information, i.e. reference points, tool change positions and movements, must be accounted for in checking. The CAD/CAM provider must be able to fulfill both requirements with no compromises.

Particularly, complex machines and machines with special equipment should be measured with all properties and transferred to the CAD/CAM system. This enables precise virtual reproduction of the real machining situation.

While designed machine heads only permit simulation of head movements ...

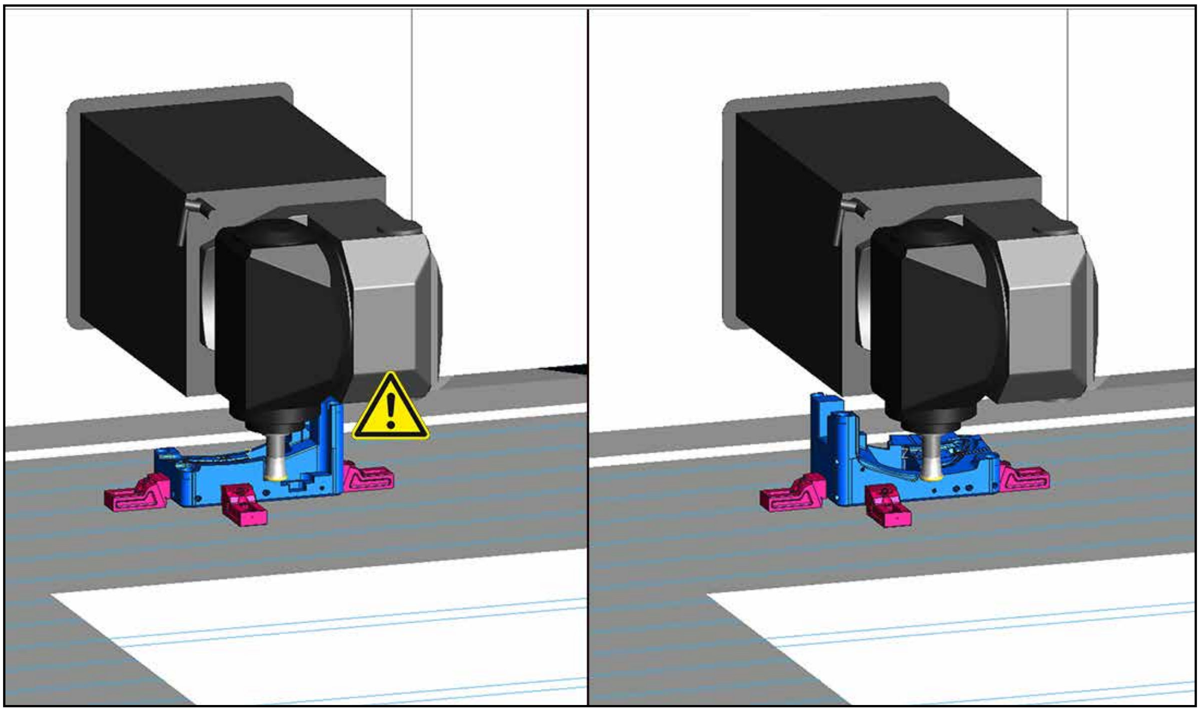


... the virtual machine enables precise simulation of the real kinematics.

Planning setups in the virtual environment

Another advantage of the fully integrated solution: The CAM programmer has several options for identifying and preventing potential collisions and limit switch problems in planning, i.e. before CAM programming and toolpath verification. This is possible because they have access to all virtual components at their workstation that are used in real production. Errors can be corrected before they become a problem.

The programmer manually moves the virtual machine with the tool in the holder to the positions that could be critical. They can graphically and interactively specify tool lengths and the clamping position. If the clamping situation turns out to be to be impractical due to the head geometry, the table or the part is rotated by 180 degrees.

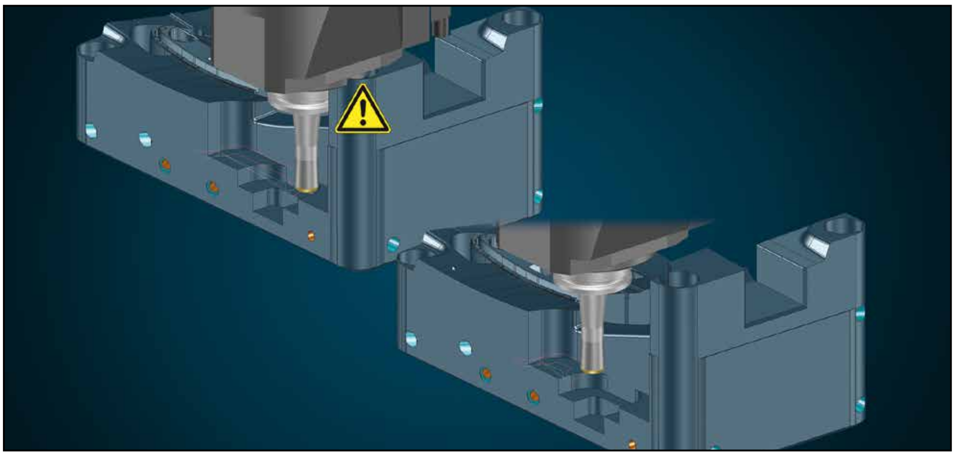


The clamping situation can be optimized early, during work preparation. In this example, the part is rotated by 180 degrees.

CAM programming with intelligent collision avoidance strategies

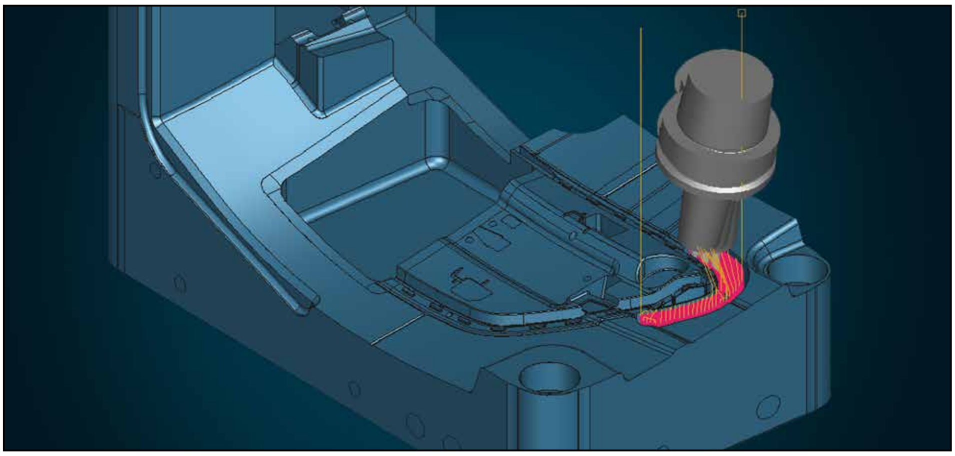
Collisions detected by the CAM program can be avoided with automated collision avoidance strategies that are integrated in NC templates. The most appropriate strategy depends primarily on the specific part geometry, the machining task and especially the available machine. This knowledge should be stored in NC templates. This means that the CAM programmer only has to select the machine and machining elements. The appropriate collision avoidance strategy – with area reduction, simultaneous 5-axis avoidance milling or indexed machining – is automatically assigned.

Automatic area reduction is generally used in 3-axis roughing: Milling areas that can't be machined with the tool in use – because of a collision with the machine head, for example – are automatically deactivated.



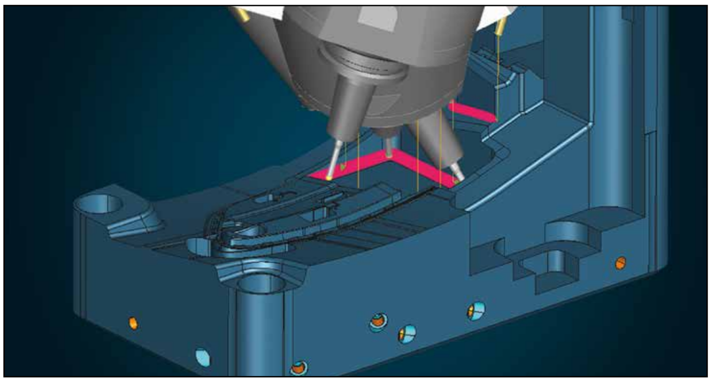
In 3-axis roughing, optimally short tools with high cutting values are used, whereas longer tools are only used for areas with a collision risk.

For optimum surface quality in **finishing,** it's best to use a short tool as long as possible. If the machine kinematics permit, **5-axis simultaneous avoidance milling** is a good collision-avoidance strategy.



In 5-axis simultaneous avoidance milling, programs for simultaneous 5-axis milling are generated automatically from 3+2-axis NC programs with fixed positionable axes.

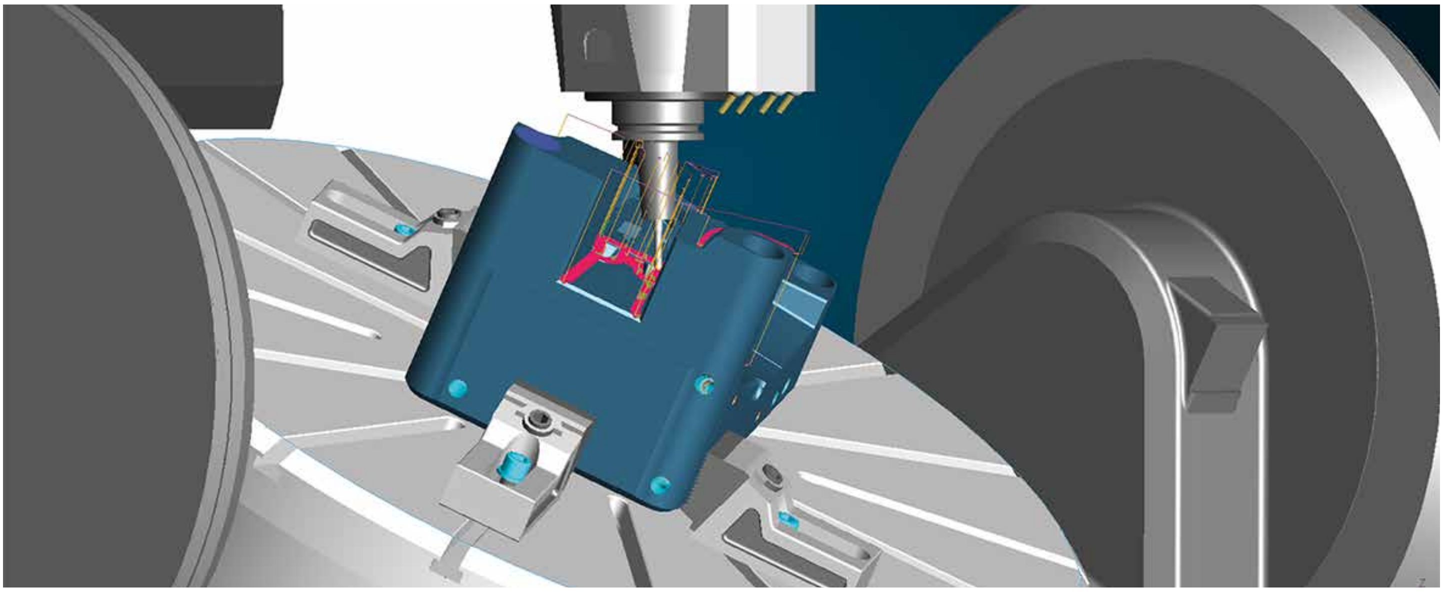
Residual stock area machining is often **indexed**. For example, indexed collision avoidance is recommended for multi-axis machines that are unsuitable for 5-axis simultaneous machining because of their dynamics. In some cases, machining performance and surface quality are even better than when 5-axis avoidance milling is used.



In indexed machining, milling areas that can be machined collision-free at the same tilt direction are automatically detected and combined.
The tilt direction is also automatically calculated.

Simulation of the entire machining area

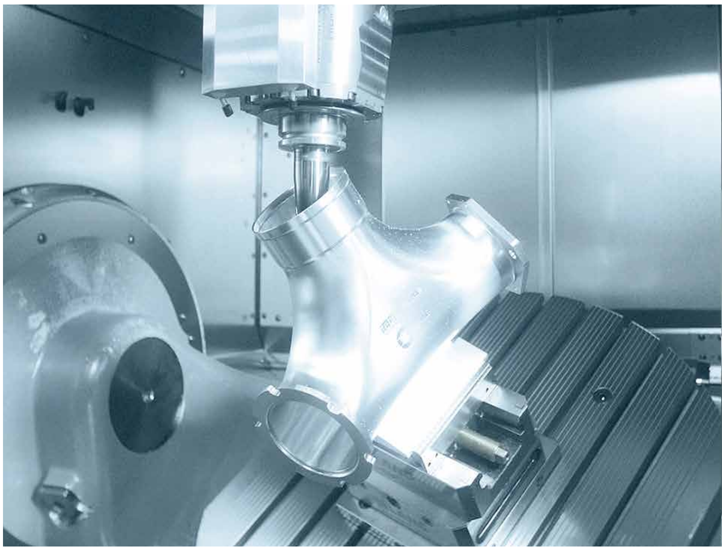
As a further benefit, the manufacturing process can be fully tested with the entire machining area in batch mode once all strategies have been calculated. Retract movements can also be individually modified.

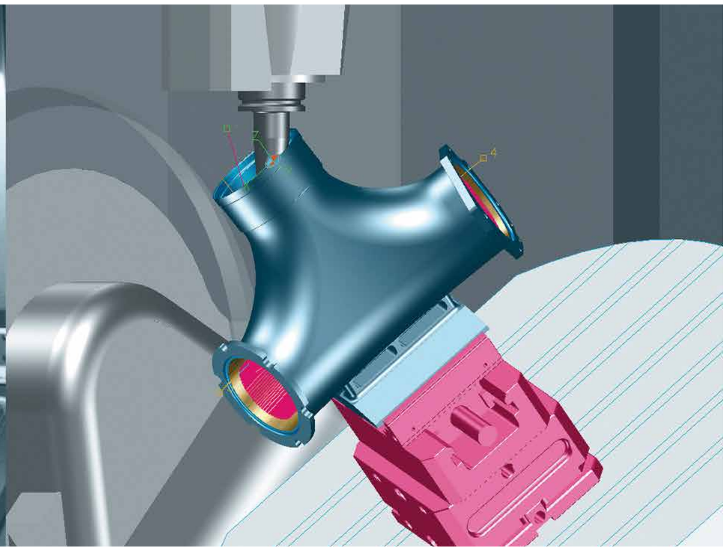


Integrated simulation accounts for all tilt directions, tool components and the entire machine including movements and tool changes. This ensures collision-free machining for each clamping situation.

Conclusion

The sooner collisions are prevented in the process chain, the better. All virtual components must be precise replicas of their real twins. This enables the optimal utilization of all options for collision avoidance in the CAD/CAM environment – from planning and CAM programming to simulation.





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