Improving the Performance of Your 5-Axis Milling Machine

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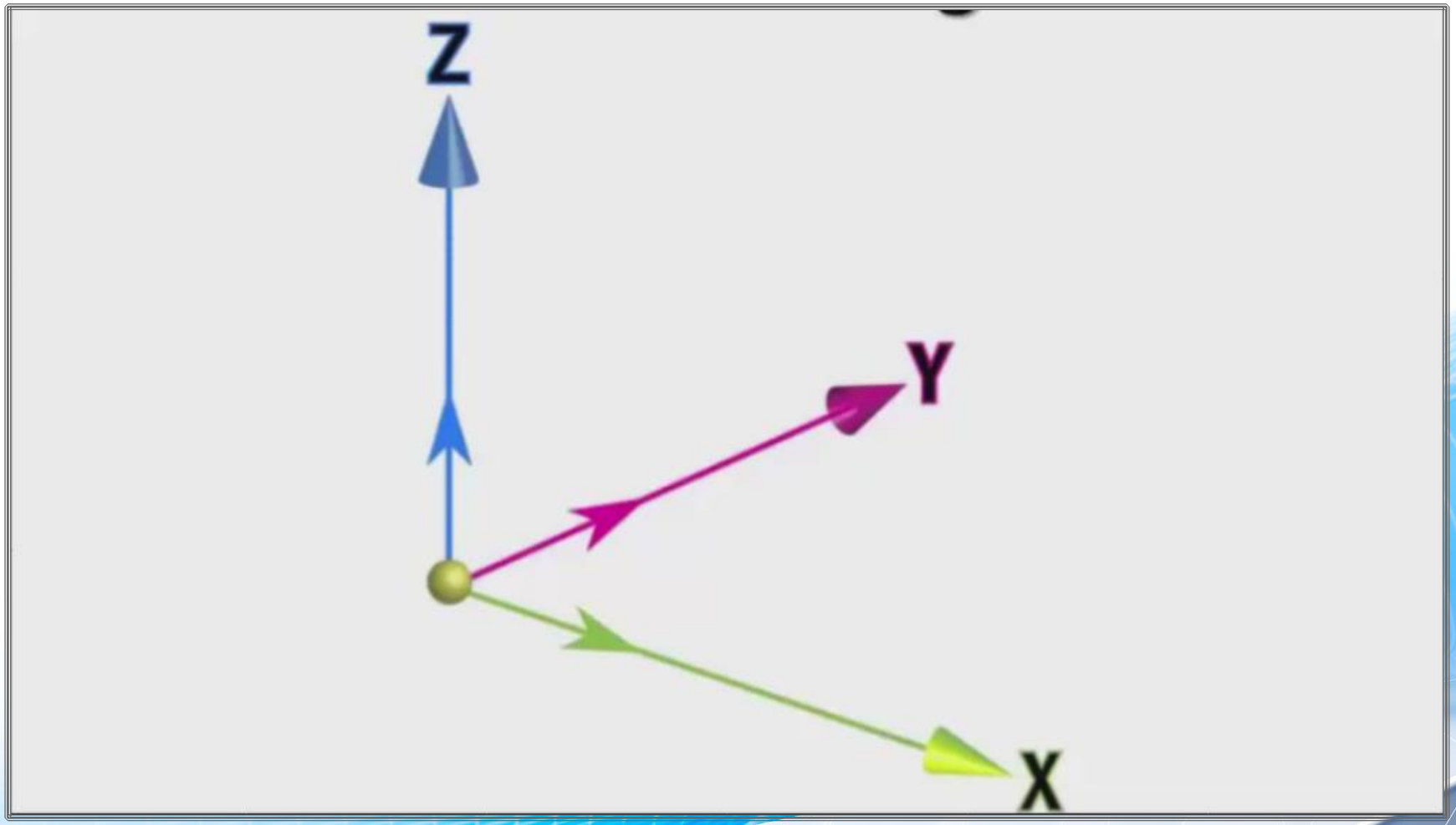
5 Axis Machining: Why?

- Fewer setups
- Shorter, more rigid tools
- Reduced cycle time

“5 Axis” What does that mean?



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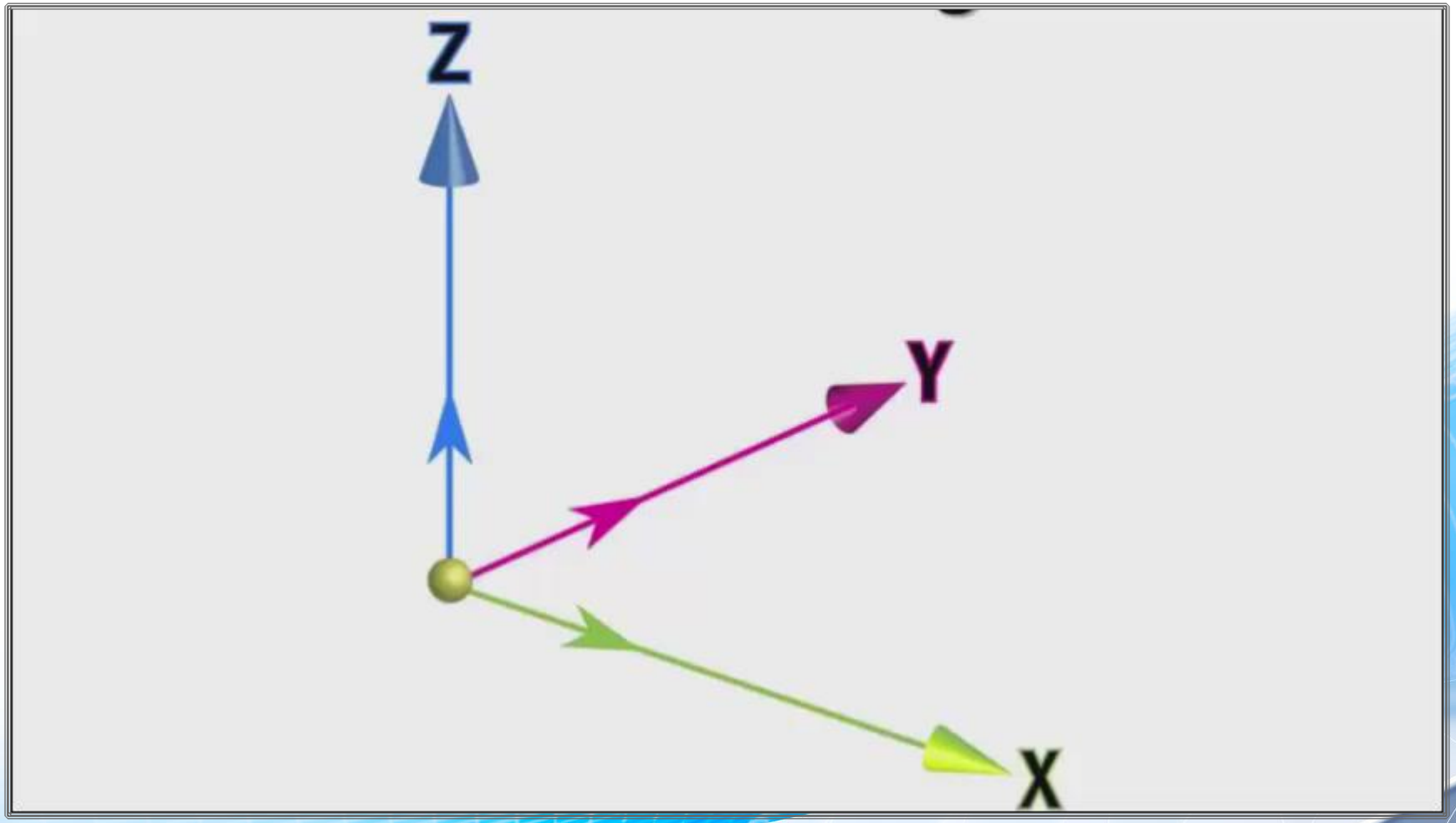

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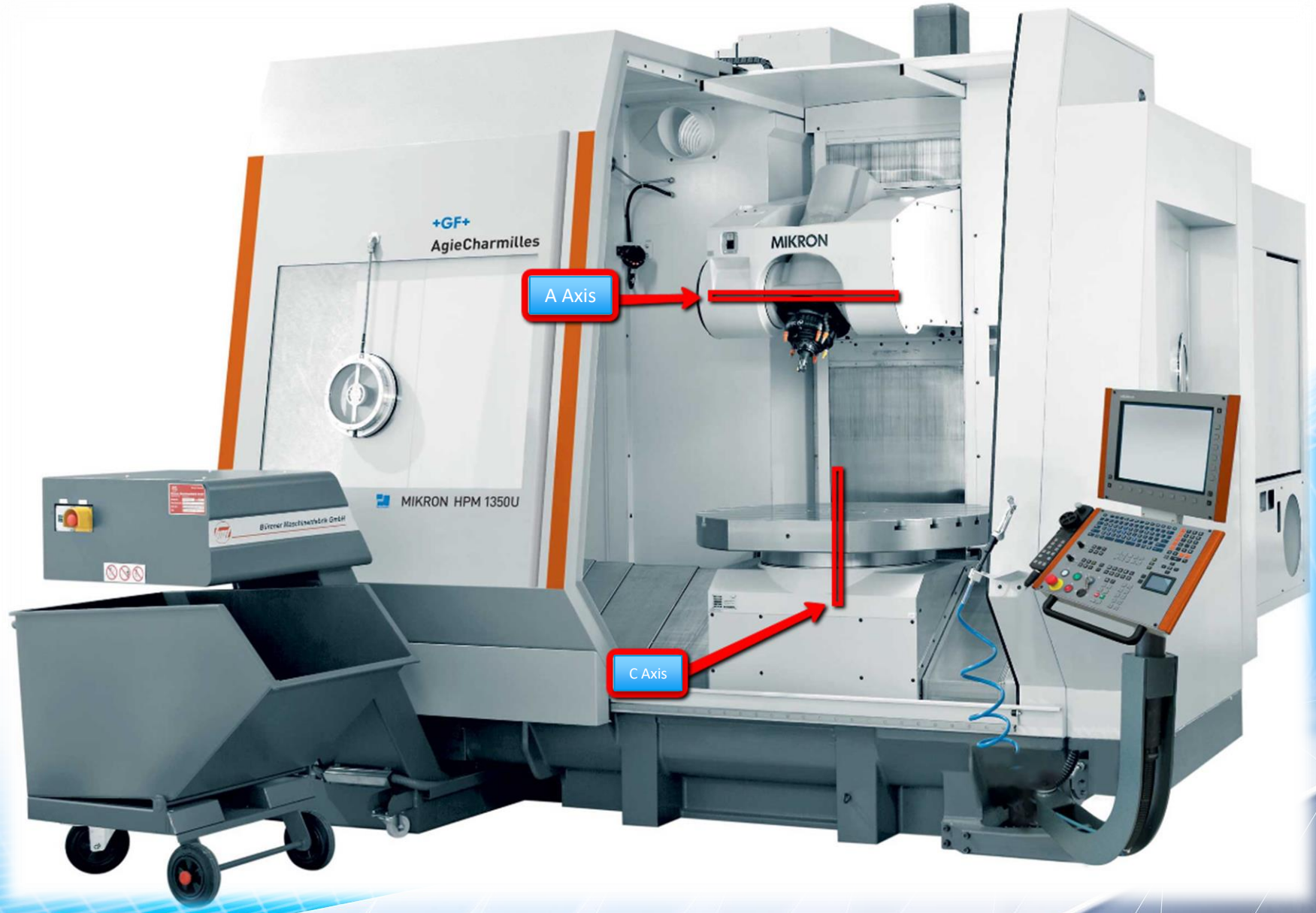

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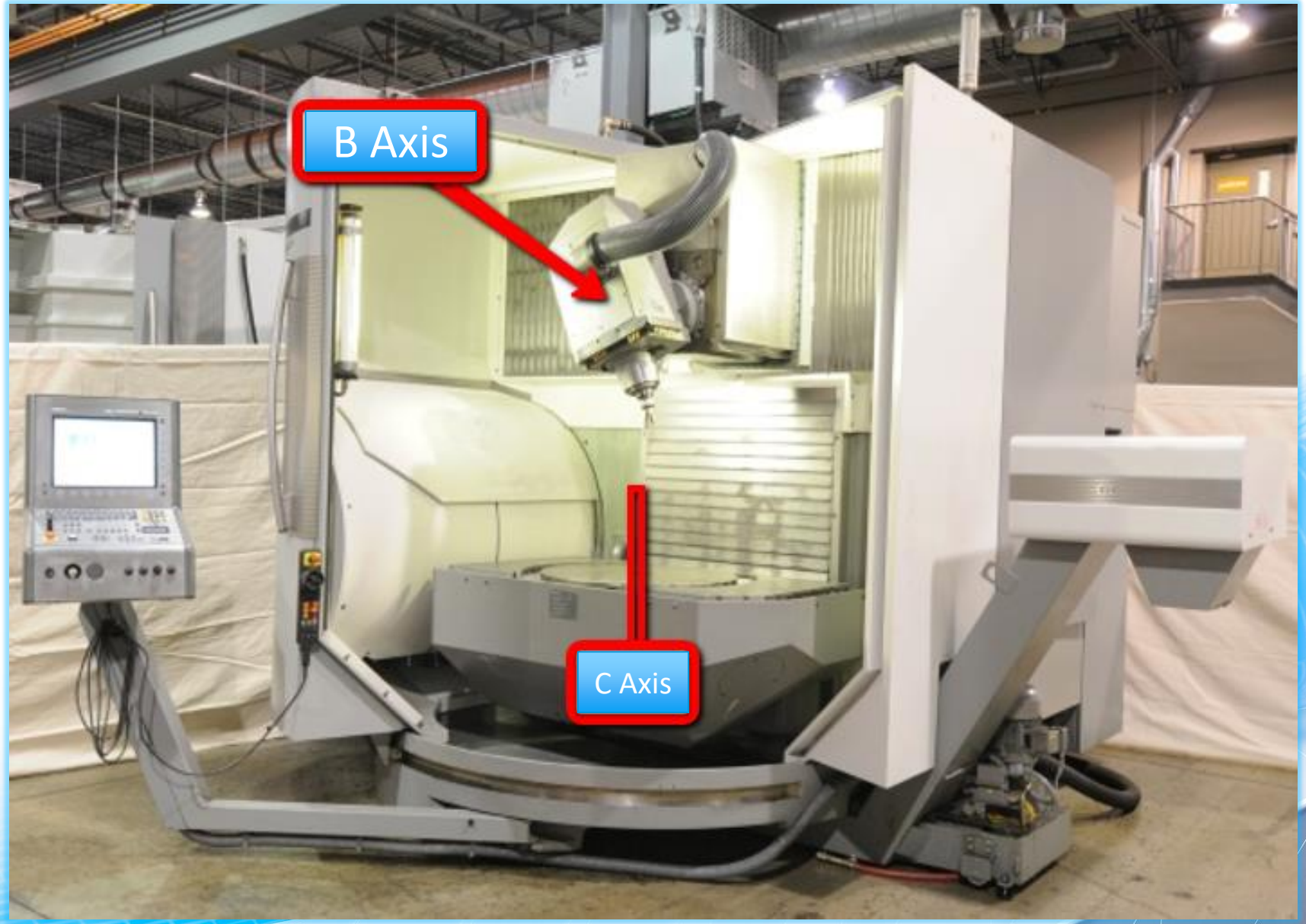
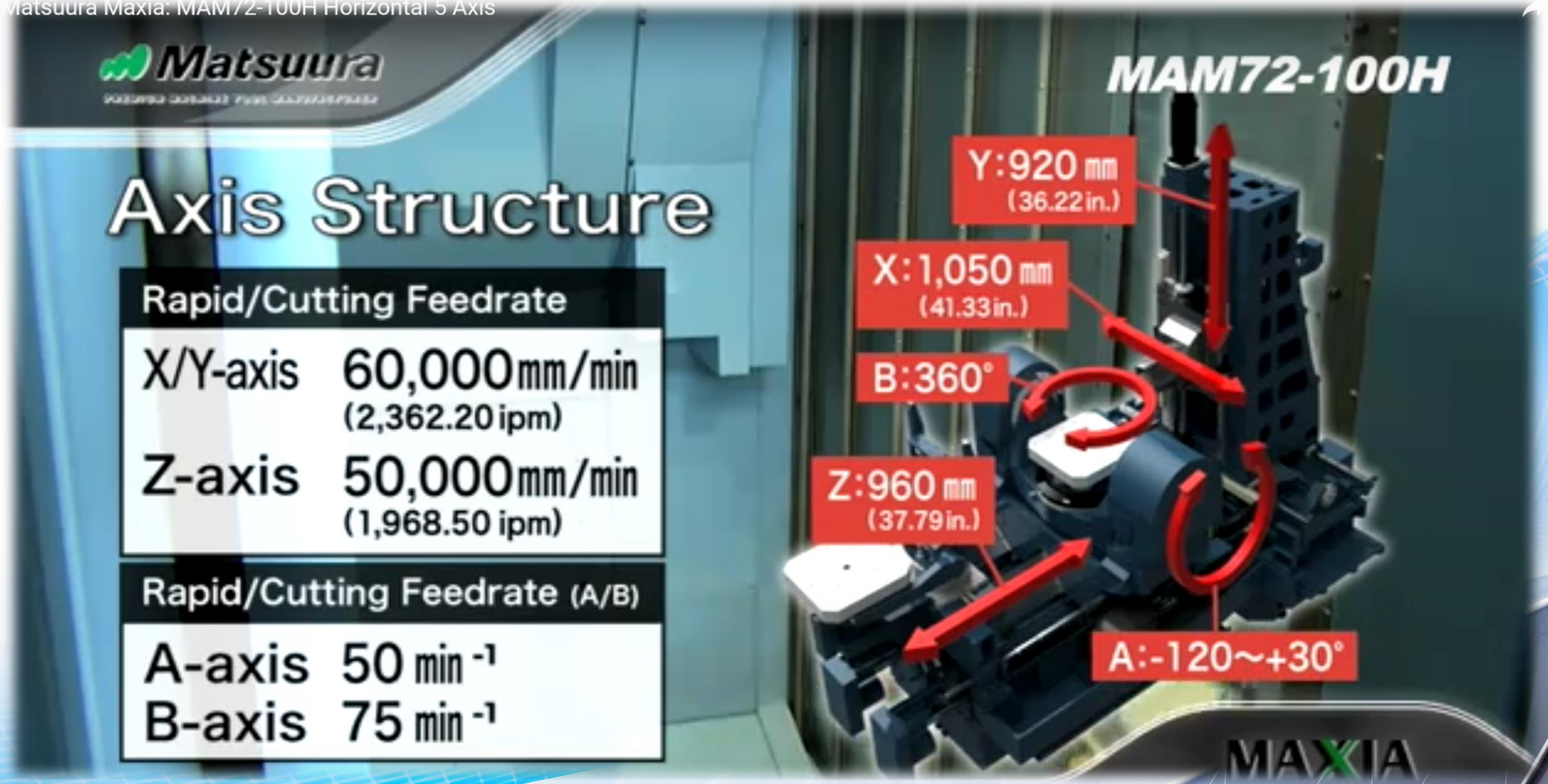


“5 Axis” What does that mean?



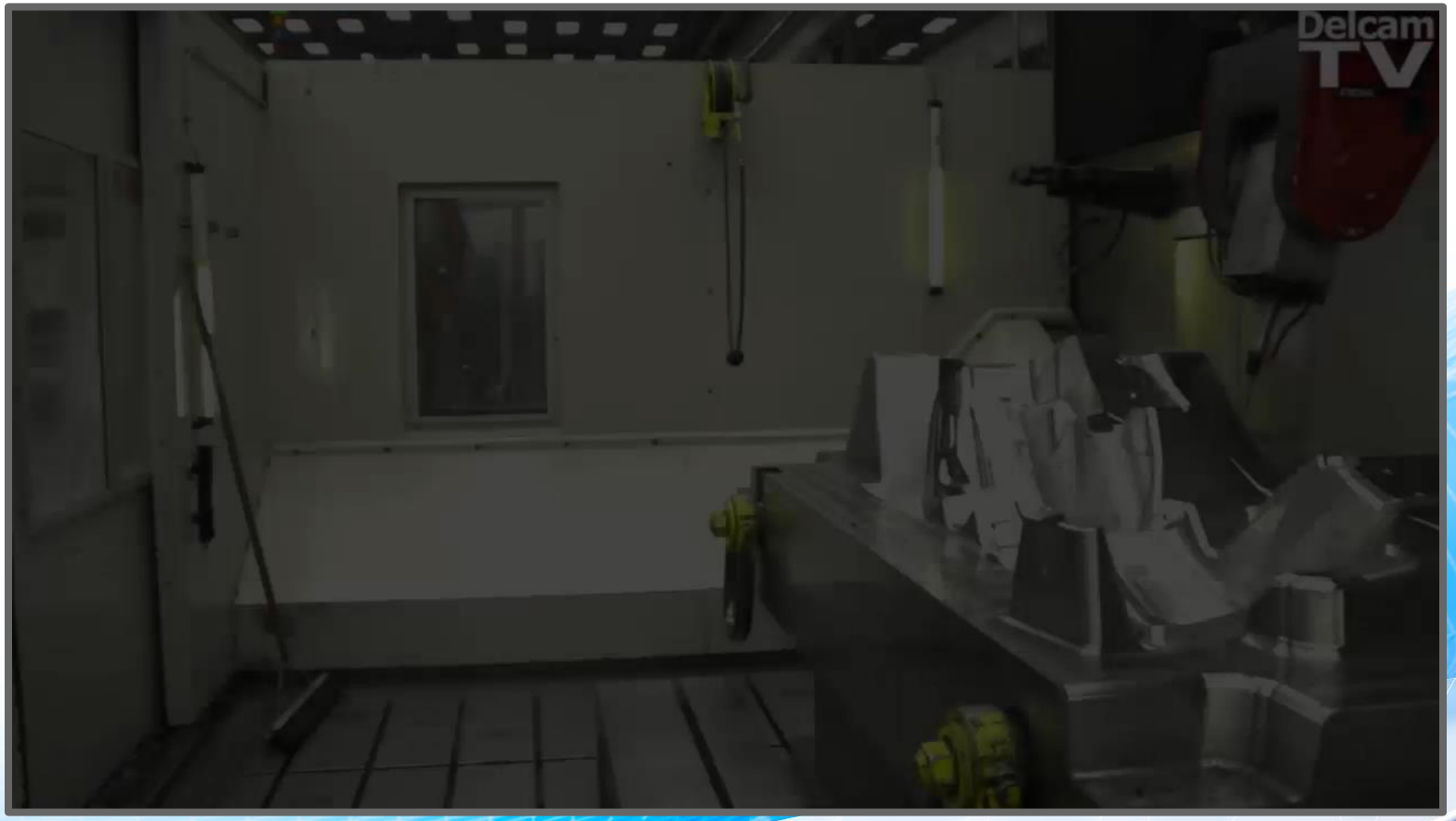
So, is 5 axis machining for me?

Common beliefs…

- Aerospace

Common beliefs…

- Injection Molds



Common beliefs…

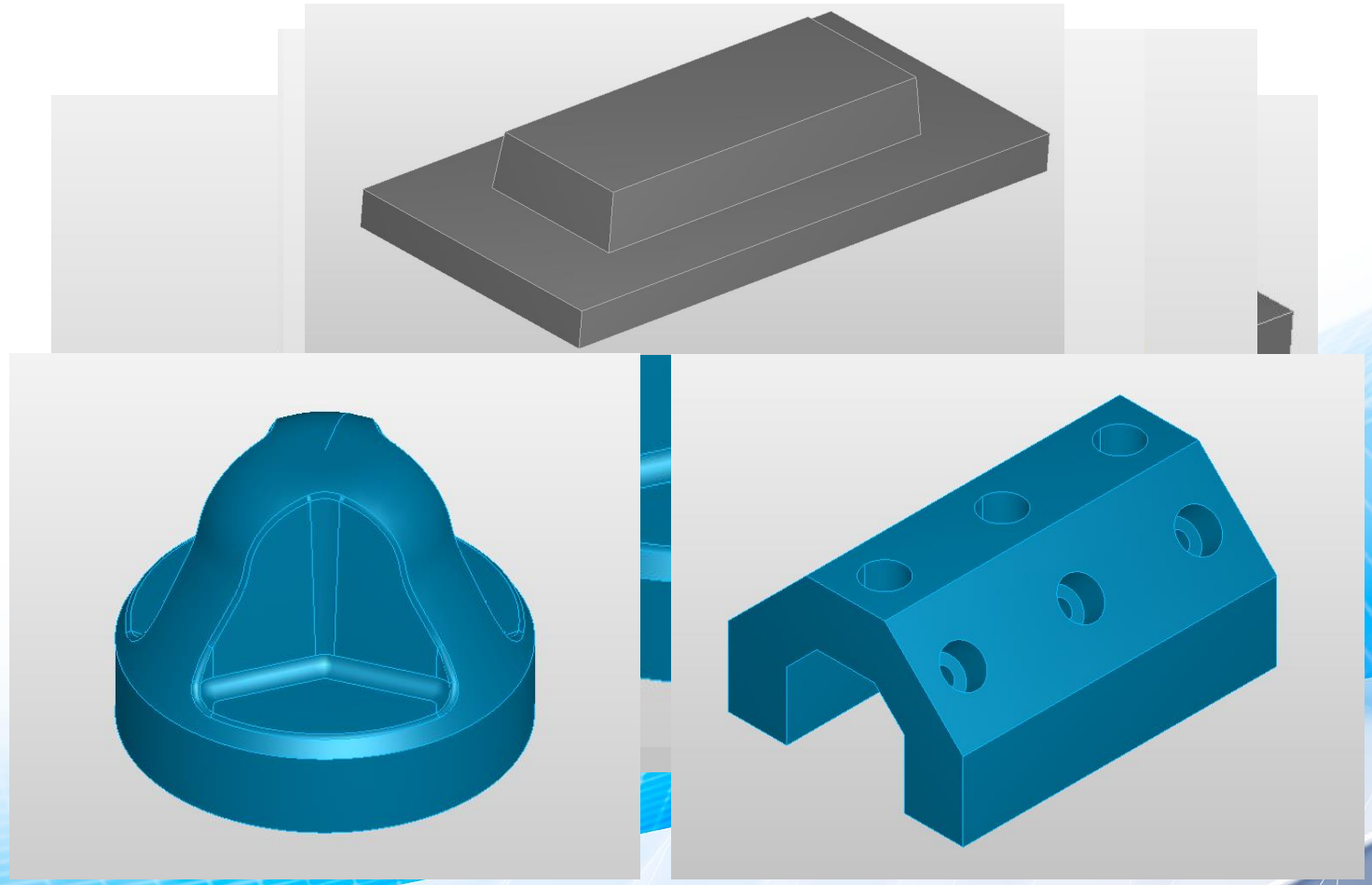
- Military and Defense

Common beliefs…

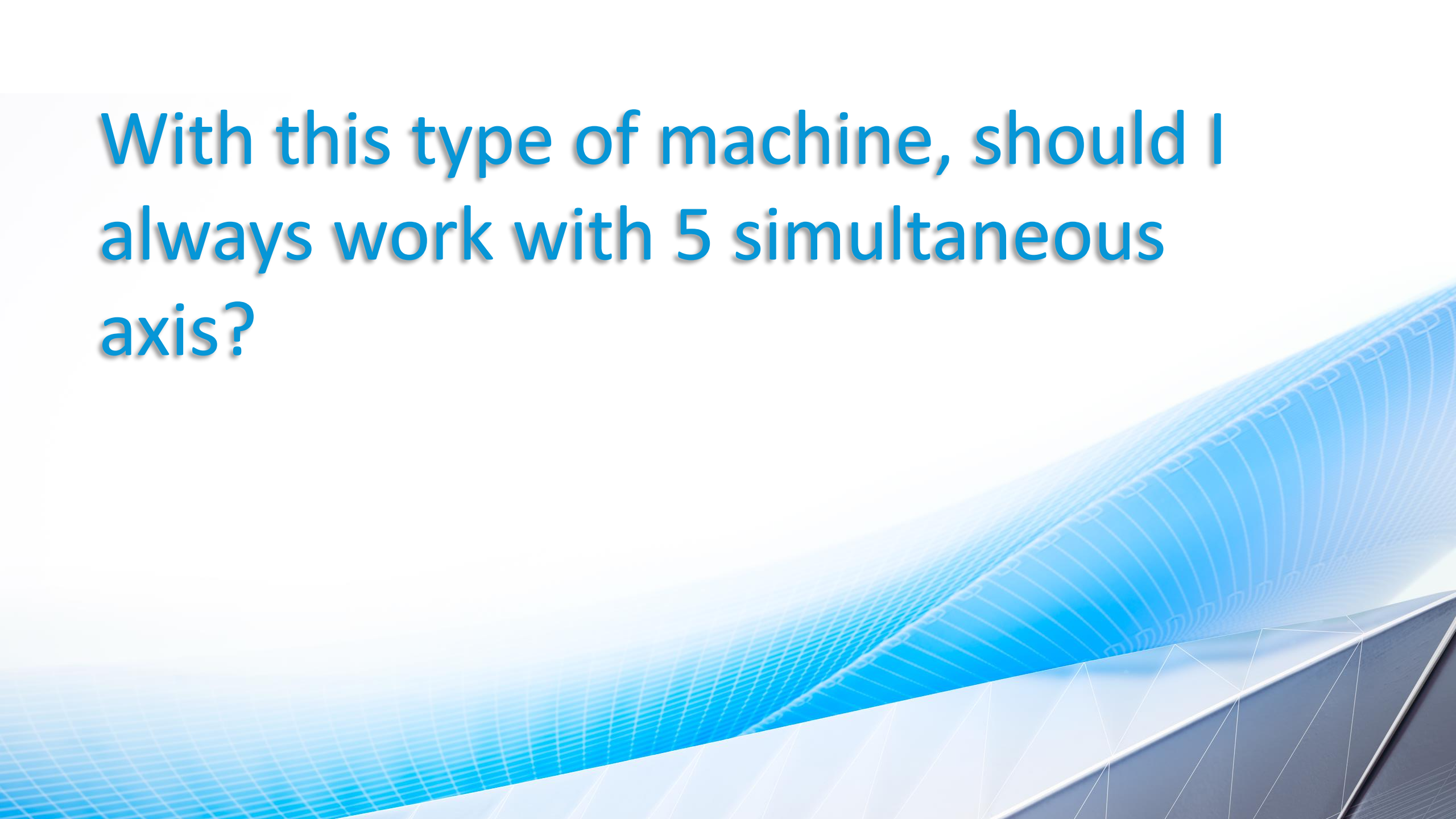
- Think again!

Common beliefs…

- 5 axis machining is also for everyday simple parts.



With this type of machine, should I always work with 5 simultaneous axis?

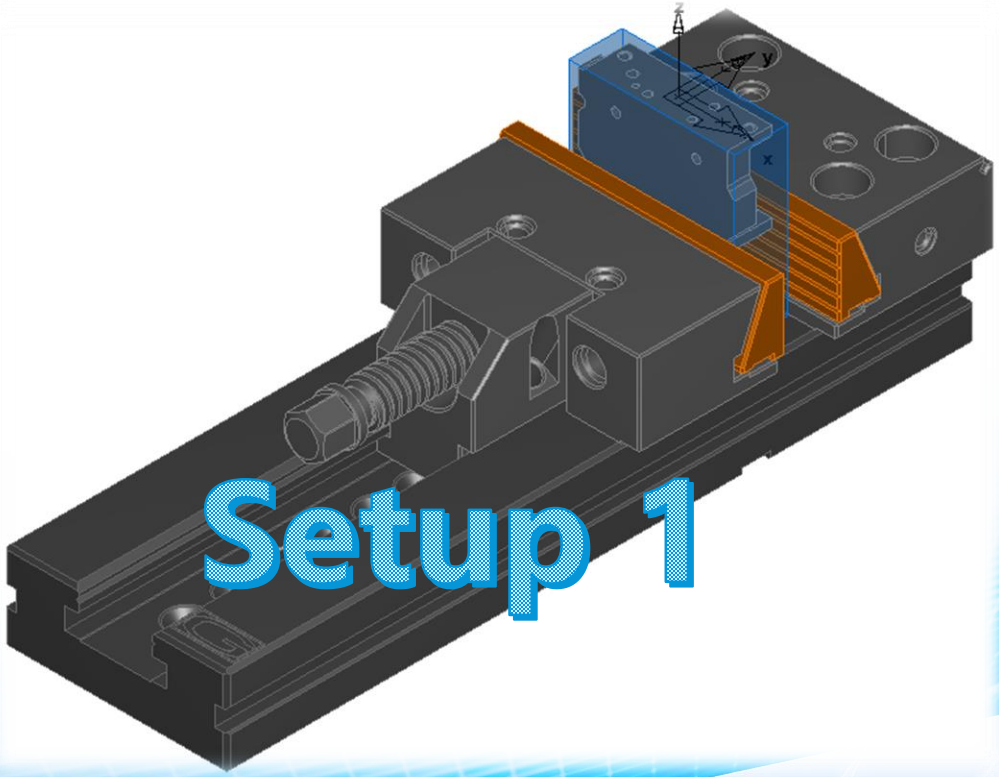


Of course not!

- 5-axis machines are mostly used for 3 and 3+2 axis machining
  - Simple to program
  - Predictable motion
  - Predictable surface finish
- 3+2 axis machining is often faster than simultaneous machining
  - No large rotary moves over short distances
- Some “5-axis” machines do not support simultaneous machining

3+2 axis Vs 3 axis

- 3+2 axis machining can reduce the number of Setups required for part manufacture



3+2 axis Vs 3 axis

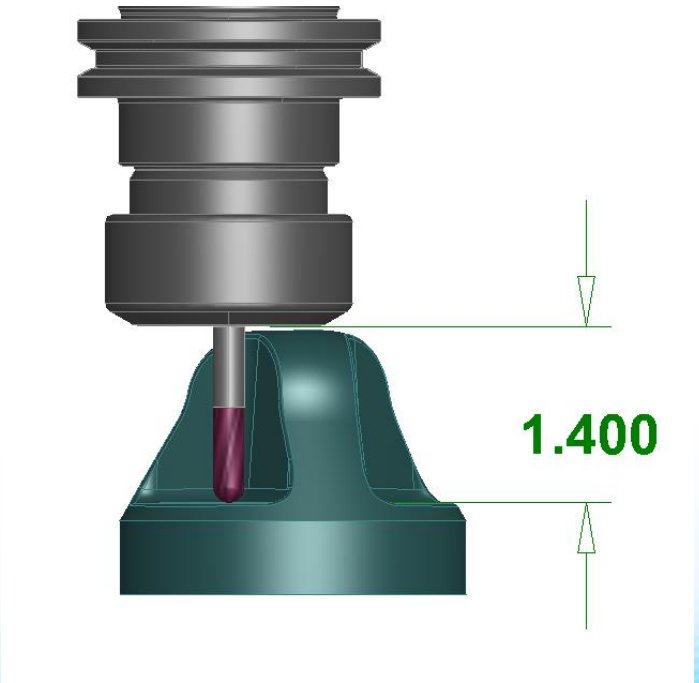
- Increase the precision of machining by reducing the number of setups

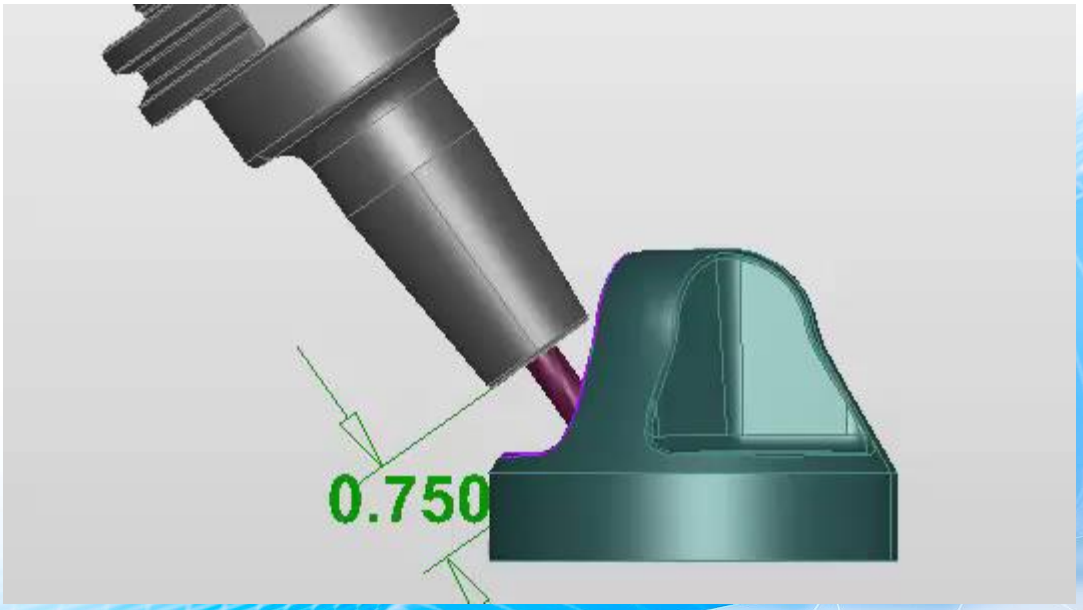
3+2 axis Vs 3 axis

- Minimize tool changes

3+2 axis Vs 3 axis

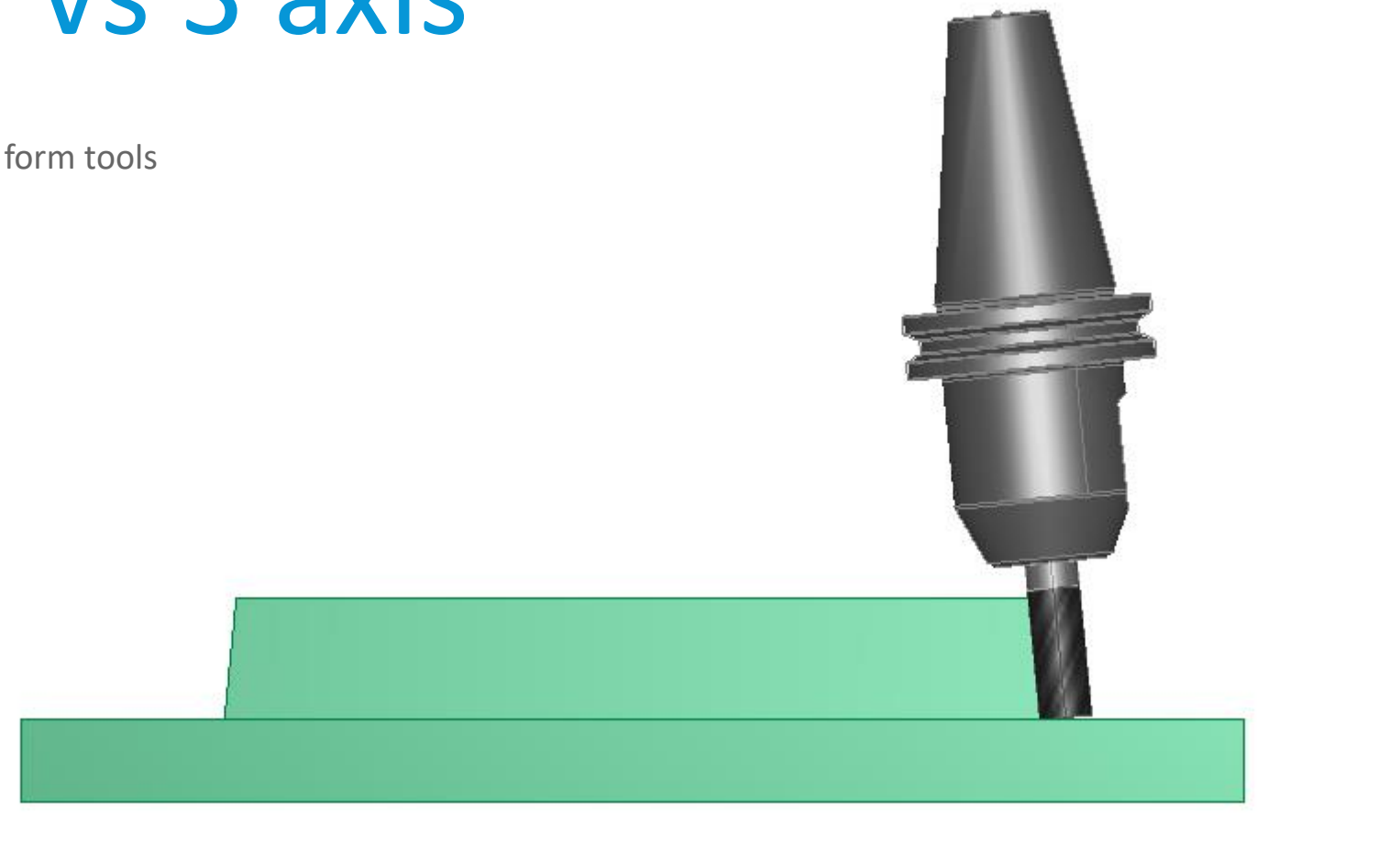
- Use of shorter tools



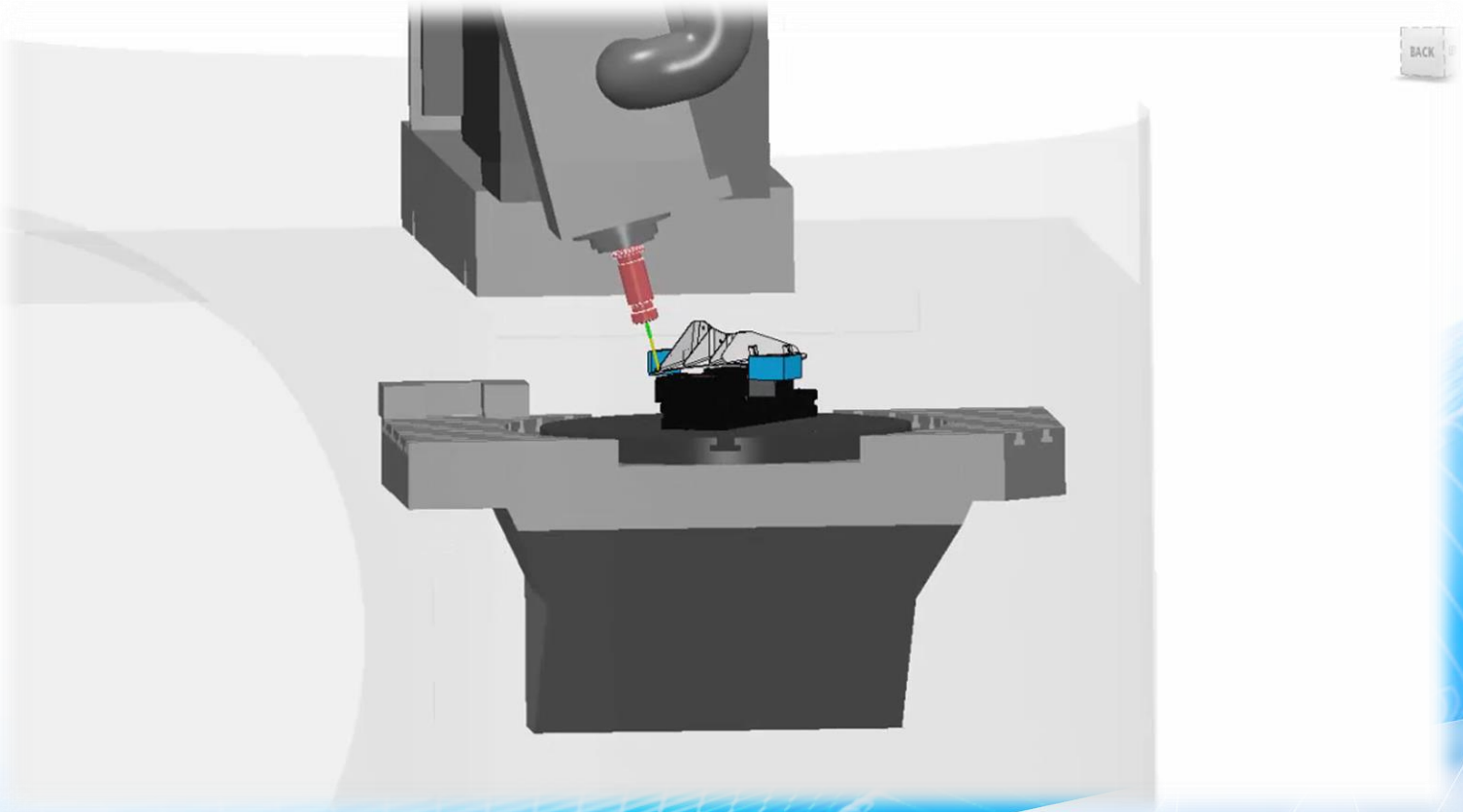


3+2 axis Vs 3 axis

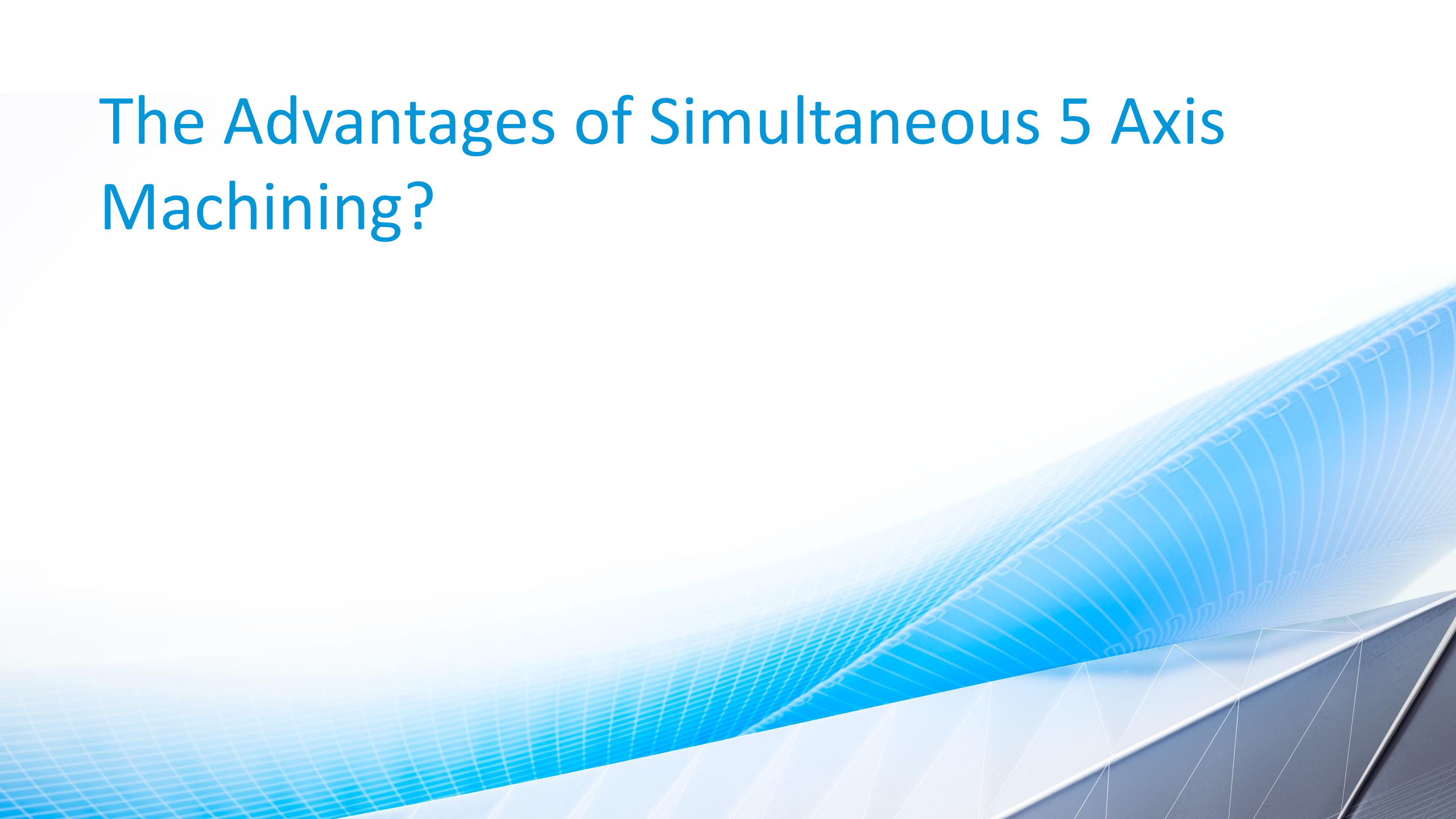
- Avoid the purchase of form tools



3+2 axis Machining



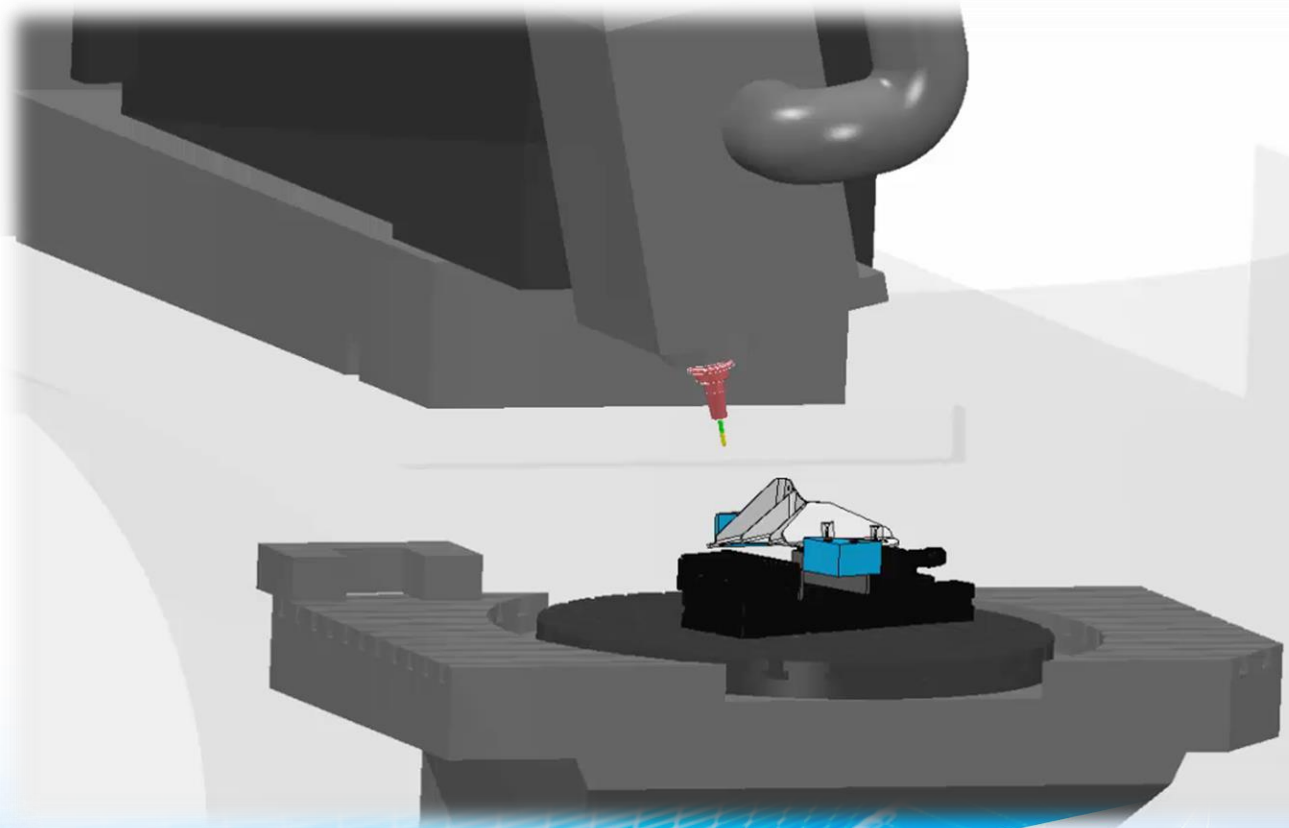
The Advantages of Simultaneous 5 Axis Machining?



A quick explanation of simultaneous 5 axis

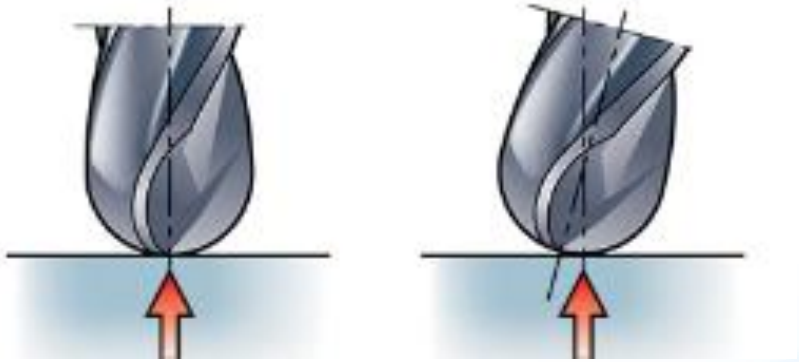
- Up to 5 Simultaneous axes:
  - Rotations will be applied throughout the machining
  - The lines of machining code will contain the axes of rotation in addition to the linear axes
  - More advanced programming
  - More complex machine tool motion

Simultaneous 5 axis



Simultaneous 5 axis Vs 3+2 axis

- Check the contact point on the tool



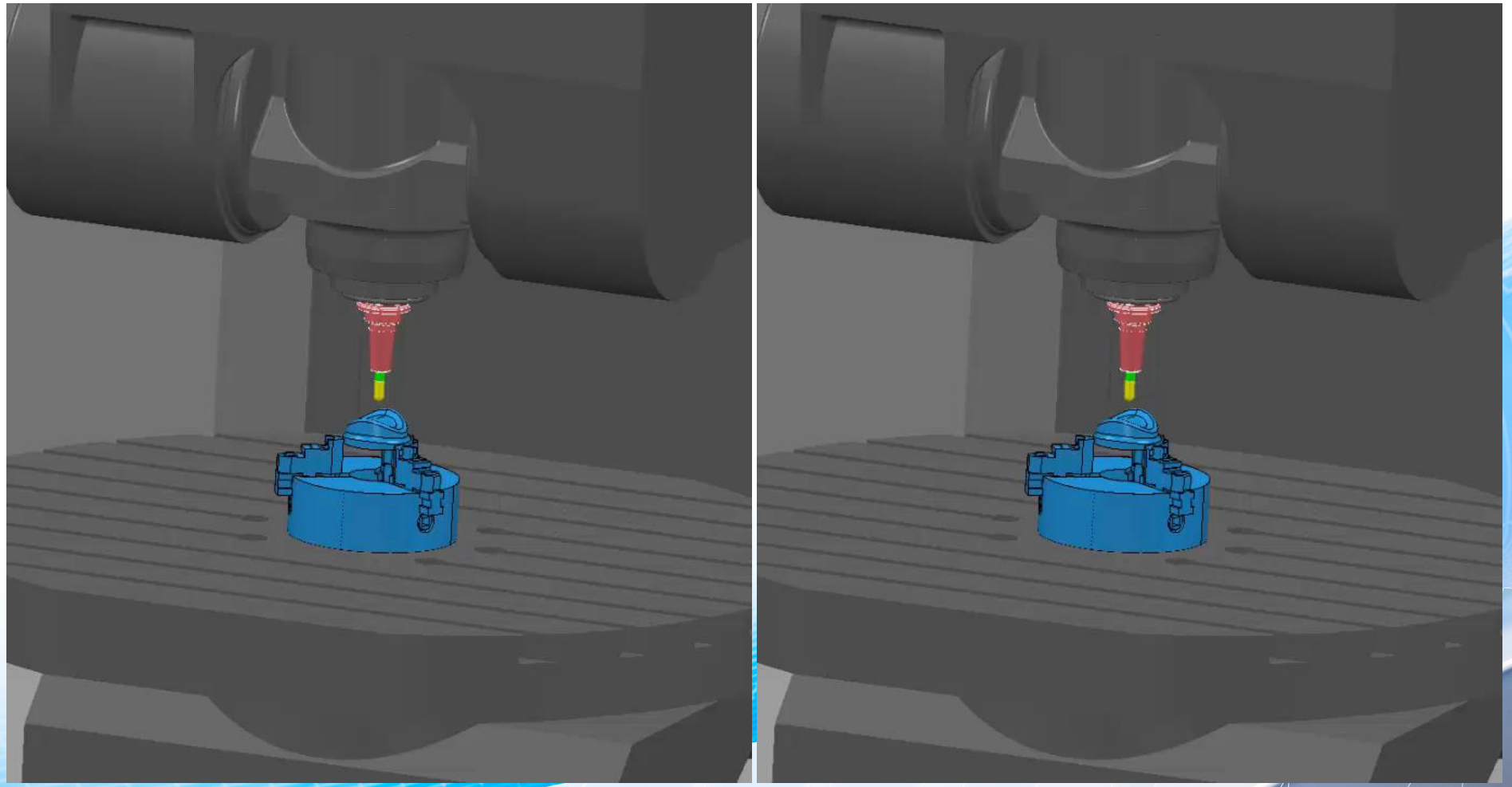
Simultaneous 5 axis Vs 3+2 axis

- Check the contact point on the tool

Operation	Non-tilted cutter	Tilted cutter (10°)
• **Semi-finishing a_p – 2 mm** The speed can be further increased by approx. 75% due to the shallow cut and short engagement time: **v_c – 300 m/min** Feed per tooth, f_z, is the same for both the non-tilted and the tilted cutter, but the effective No of edges, z_c, differs near the centre as described on the previous page.	D_c = 10 mm D_{cap} = 8 mm v_c = 300 m/min n = 11 940 rpm h_{ex} = 0.08 mm f_z = 0.12 mm/tooth z_c = 2 f_n = 0.24 mm/r v_f = 2 860 mm/min	D_c = 10 mm D_{cap} = 8.9 mm v_c = 300 m/min n = 10 700 rpm h_{ex} = 0.08 mm f_z = 0.12 mm/tooth z_c = 4 f_n = 0.48 mm/r v_f = 5 100 mm/min
• **Super-finishing a_e – 0.1 mm** The cutting speed can be increased by the factor 3-5 due to the extremely short contact time: **v_c – 5 x 170 – 850 m/min** ***Note:*** In super-finishing a two teeth cutter z_n = 2, should be used to minimize the run-out. With this extremely small a_p, the f_z will be limited by the surface finish demands. Therefore, h_{ex} must be disregarded. A good rule of thumb in super-finishing is to use approx. the same f_z as the a_e. **f_z – 0.12 mm/r**	A non-tilted cutter is not recommended for super- finishing	D_c = 10 mm D_{cap} = 4.4 mm v_c = 850 m/min n = 61 100 rpm h_{ex} = 0.02 mm f_z = 0.12 mm/tooth z_c = 2 f_n = 0.24 mm/r v_f = 14 600 mm/min

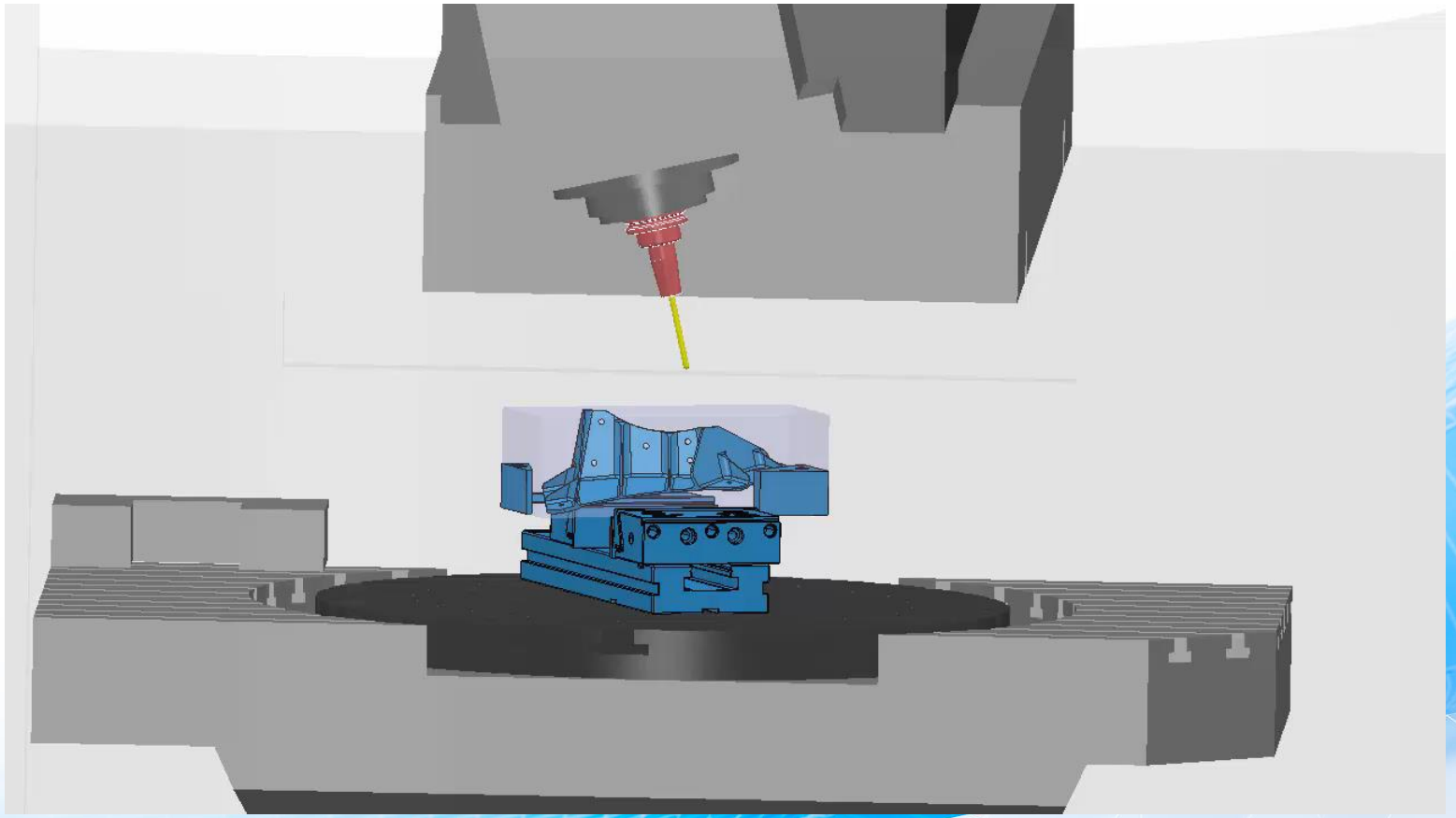
Simultaneous 5 axis Vs 3+2 axis

- Check the contact point on the tool



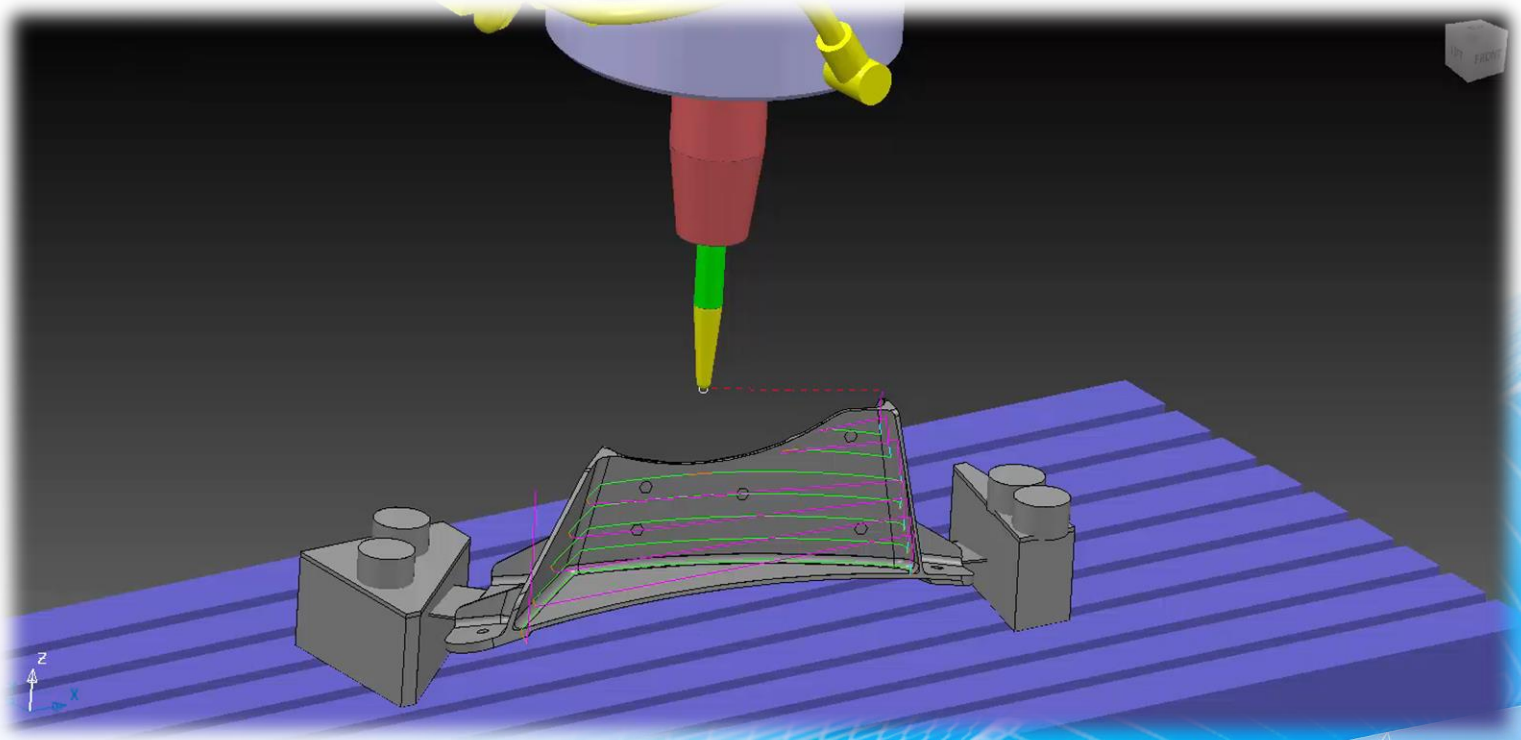
Simultaneous 5 axis Vs 3+2 axis

- Check the contact point on the tool



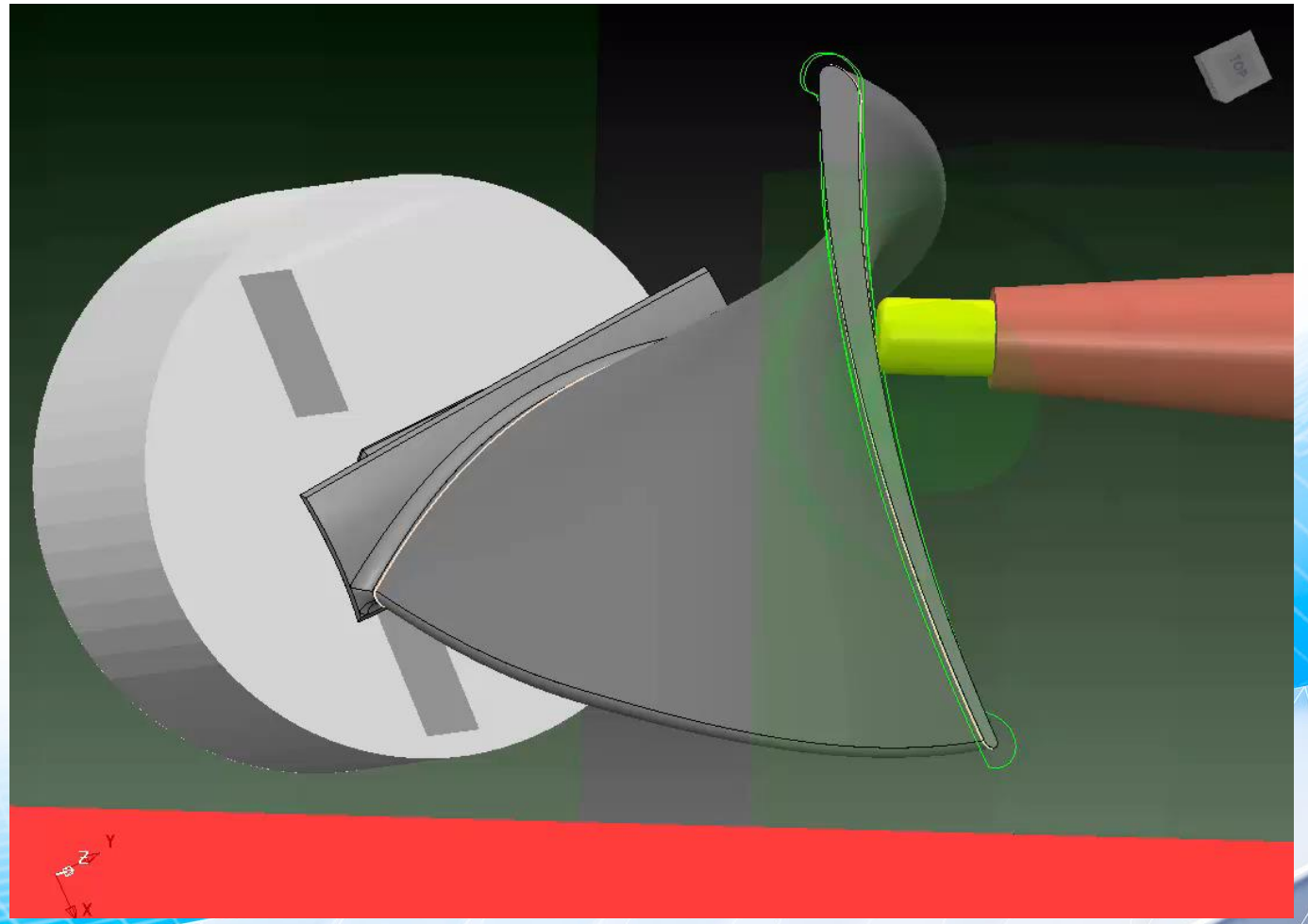
Simultaneous 5 axis Vs 3+2 axis

- Check the contact point on the tool
- This tapered tool enables the lower fillet to be machined whilst increasing the rigidity of the tool



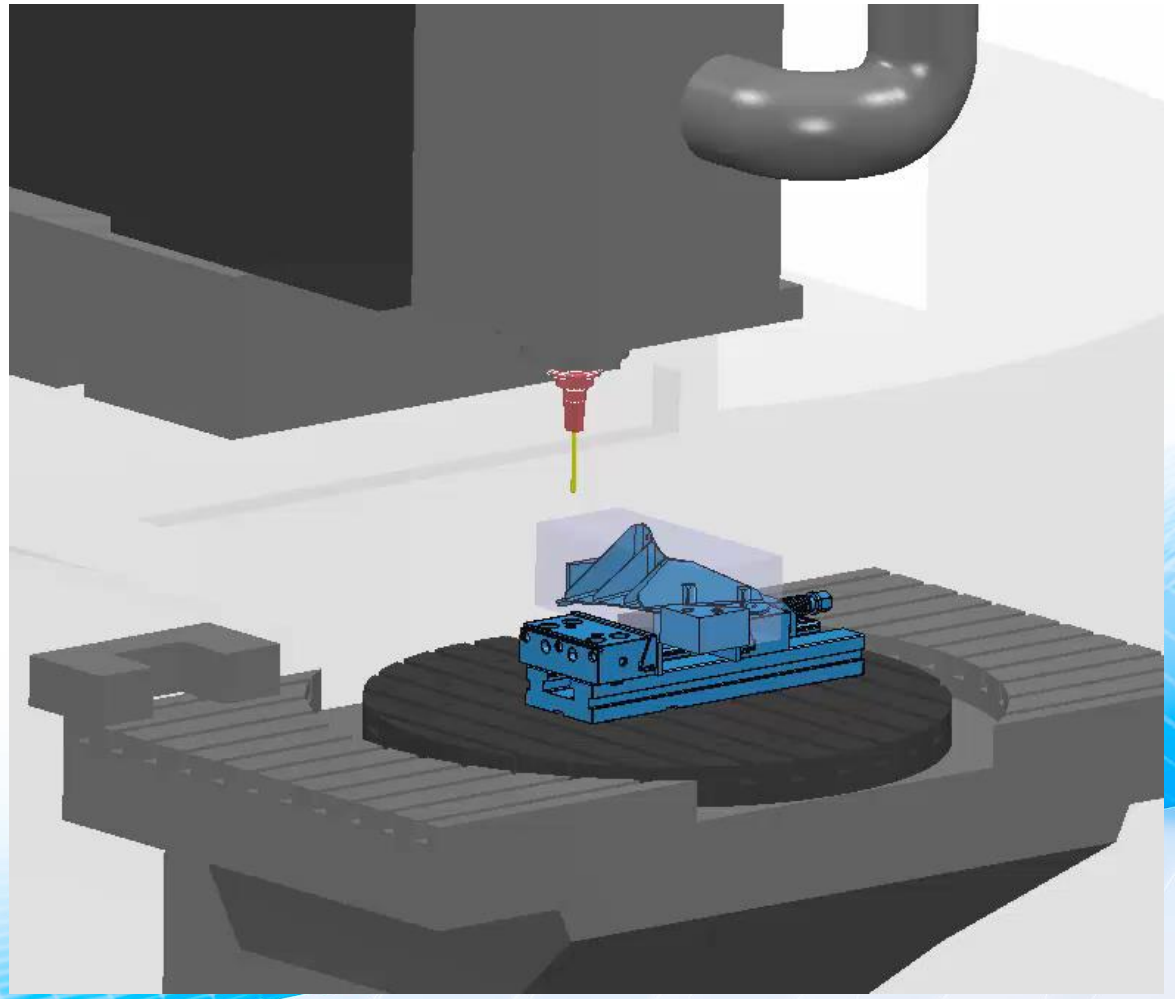
Simultaneous 5 axis Vs 3+2 axis

- Check the contact point on the tool
- This tip radiused, flat bottomed tool machines very efficiently when maintaining a controlled lead angle



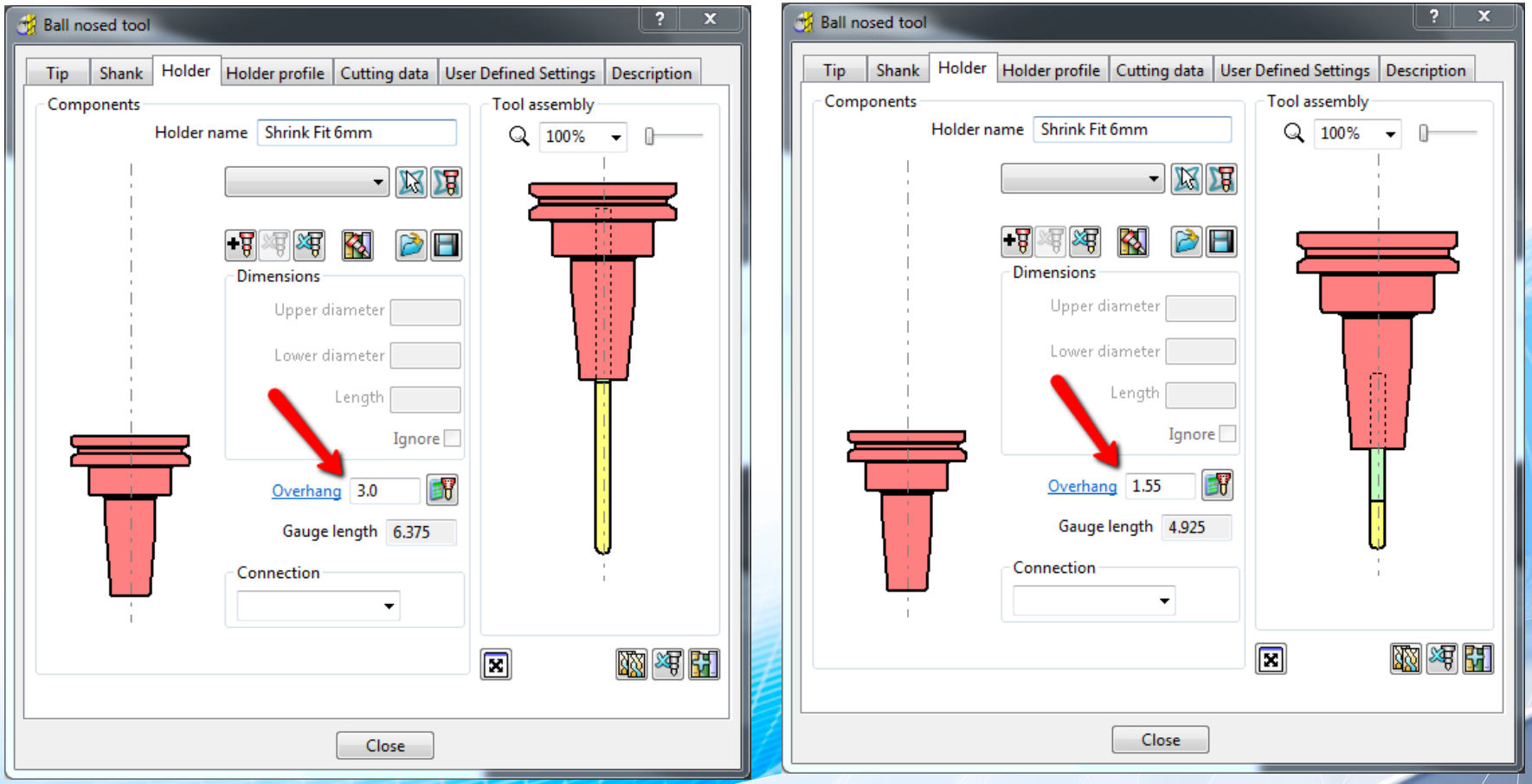
Simultaneous 5 axis Vs 3+2 axis

- Reduced stickout length

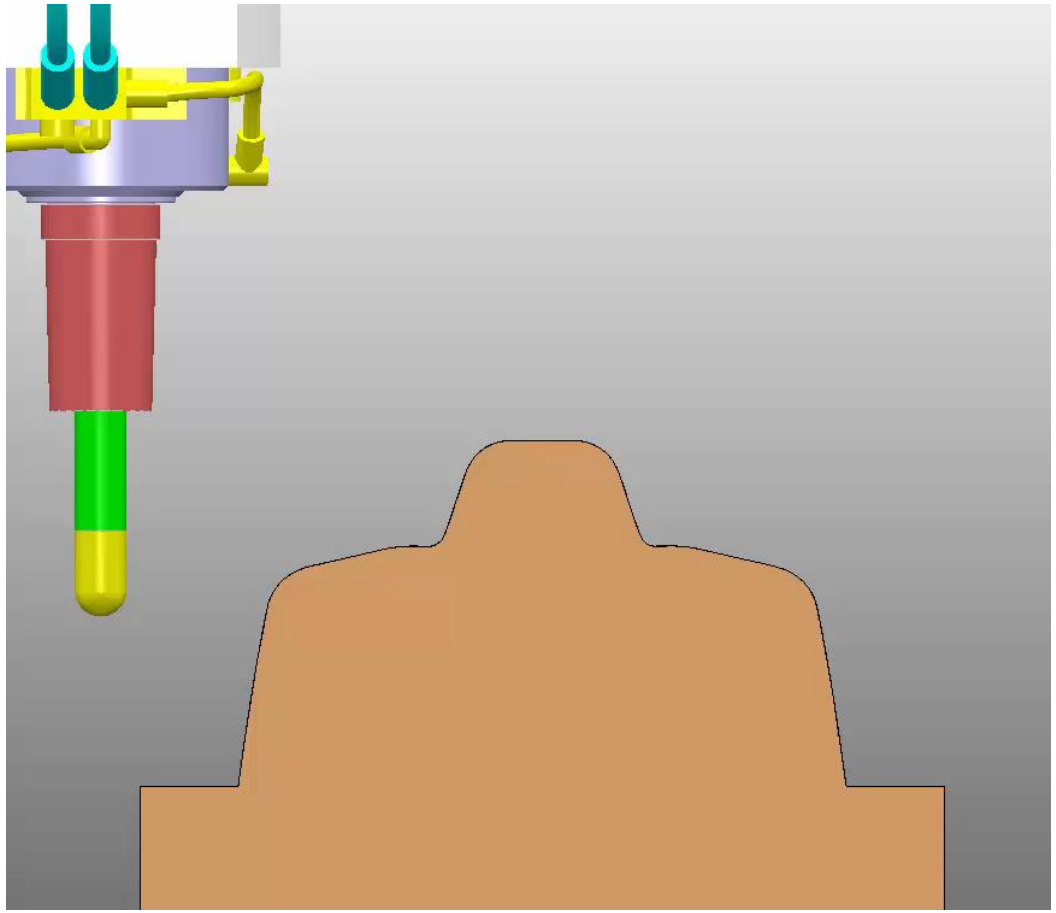


Simultaneous 5 axis Vs 3+2 axis

- Reduced tool stickout



Problems Caused by Excessive Stickout?



3 Axis Machining

- Greater tool deflection?
  - Poor tolerances
  - Increased probability of chatter
    - Poor surface finish
    - Reduced tool life

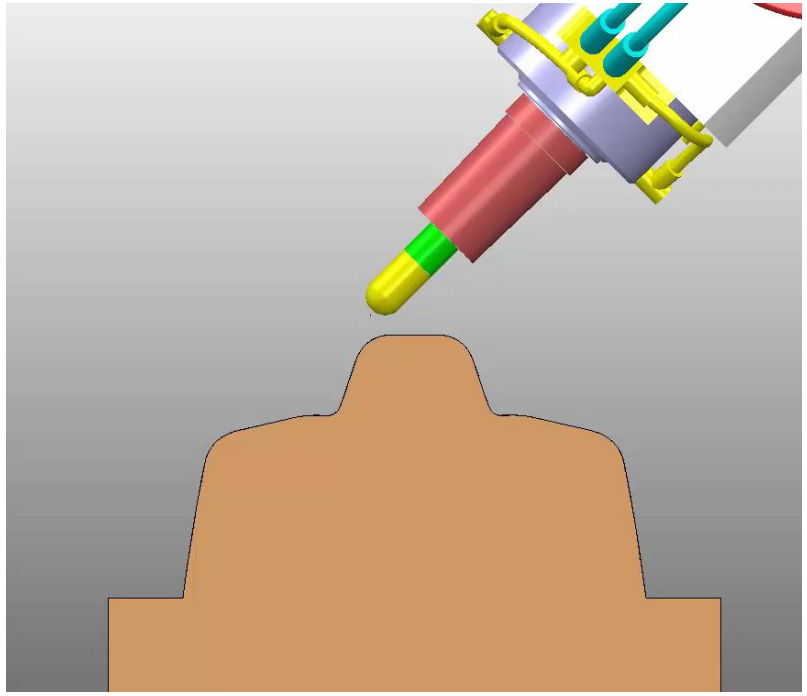
CNCCOOKBOOK.COM

Rigidity increases as the 3rd power of stickout.

Reducing stickout from 1.25″ to 0.75″ buys us 4.63x more rigidity…

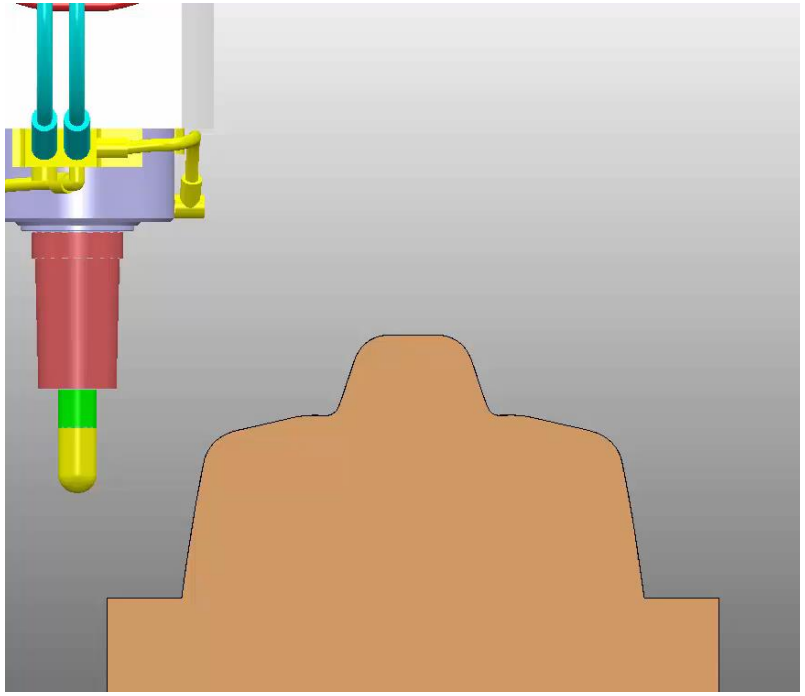
https://www.cnccookbook.com/afraid-tool-deflection/

3 Different ways to use your 5 axis machine tool



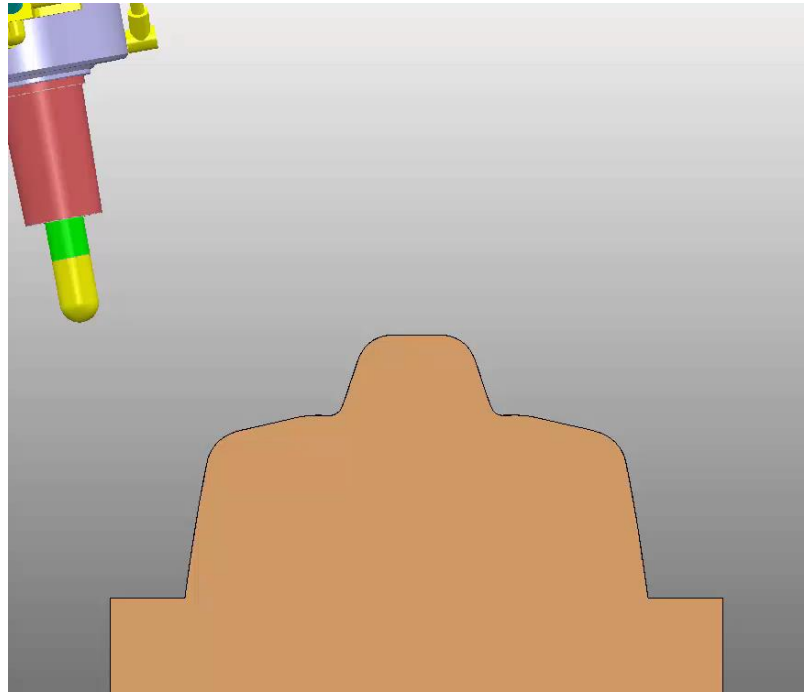
3+2 axis Machining

- Cutting has no simultaneous rotary axis cutting motion. Predictable results
- Increased programming time on complex, feature rich parts
- More manual polishing to blend between individual toolpaths



4 Axis Machining
(Locking one rotary axis)

- Locking the C axis can improve the surface finish as there are no axis reversals or rapid C axis accelerations
- Not suitable for more complex, feature rich geometry

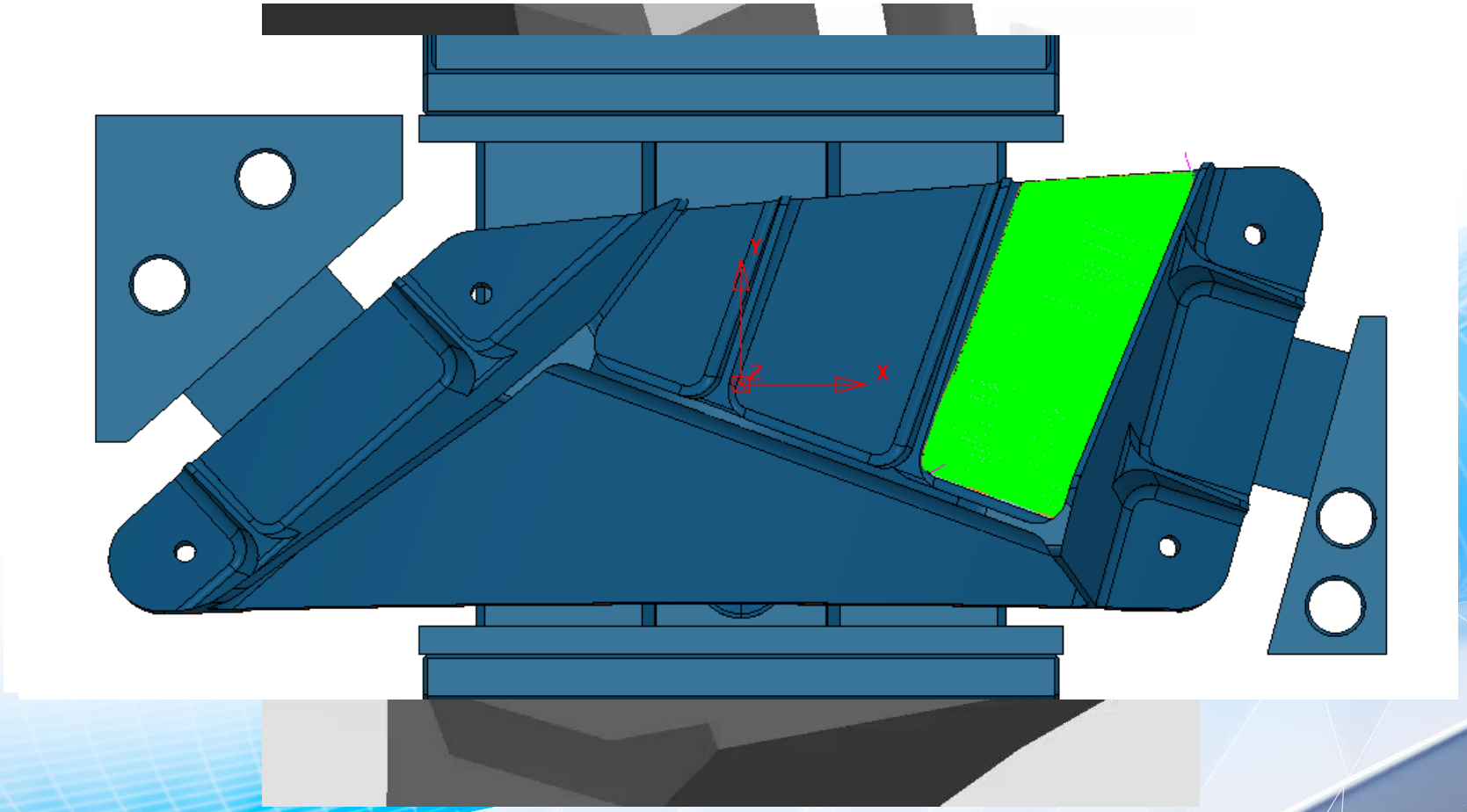


5 Axis Machining

- A single toolpath can cut the whole part. No ‘patchwork’ required
- Shortest possible tool stickout
- 2 simultaneous rotary axis can degrade the surface finish during sudden axis reversals or changes in acceleration

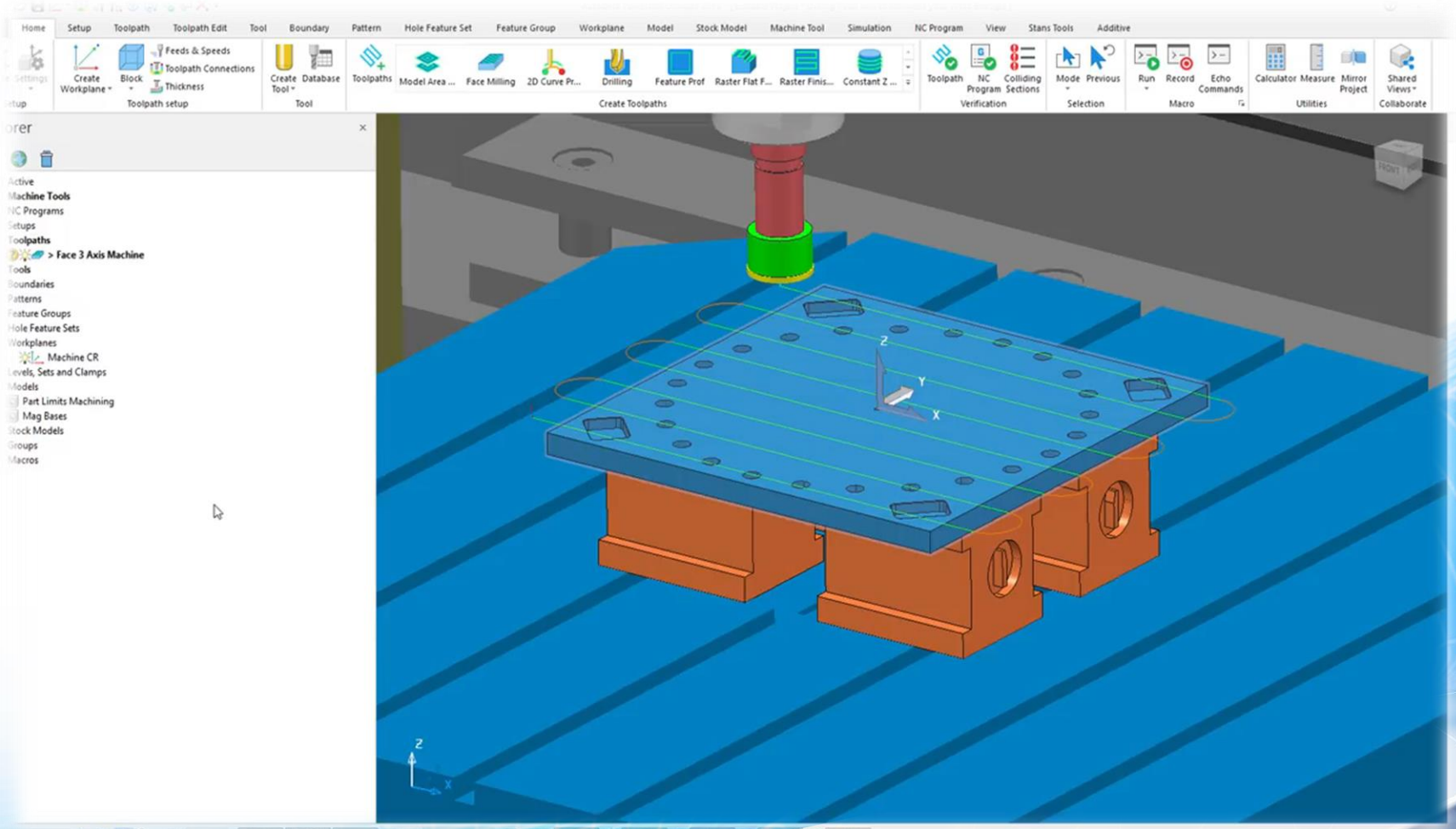
Simultaneous 5 axis Vs 3+2 axis

- Machine regions that are difficult to access. For example, undercuts.



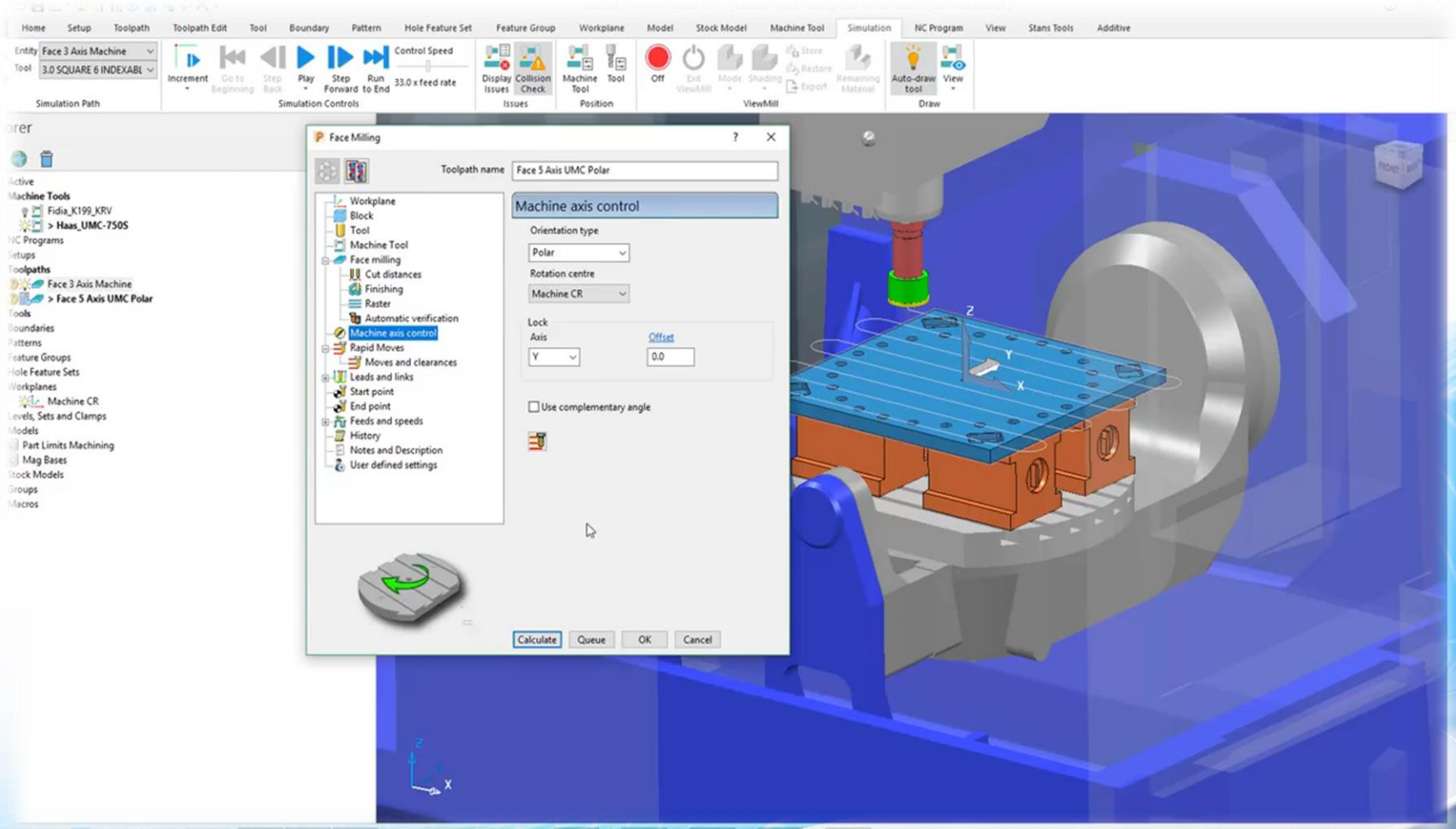
Common 5 axis problems

- Problem? Toolpath exceeds the Y axis range



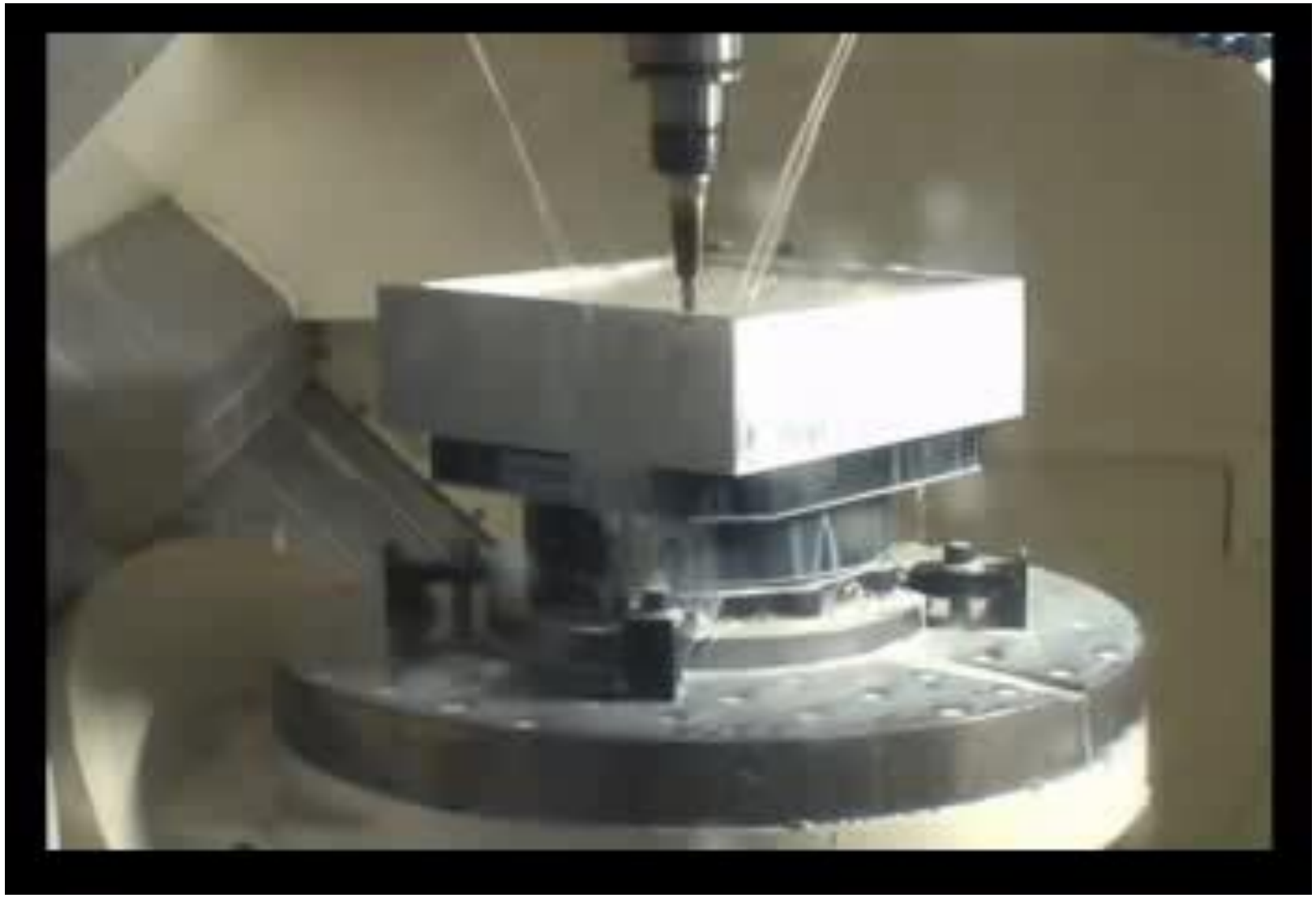
Common 5 axis problems

- Solution? Fix the Y axis and replace it with the C axis (Polar Milling)



Common 5 axis problems

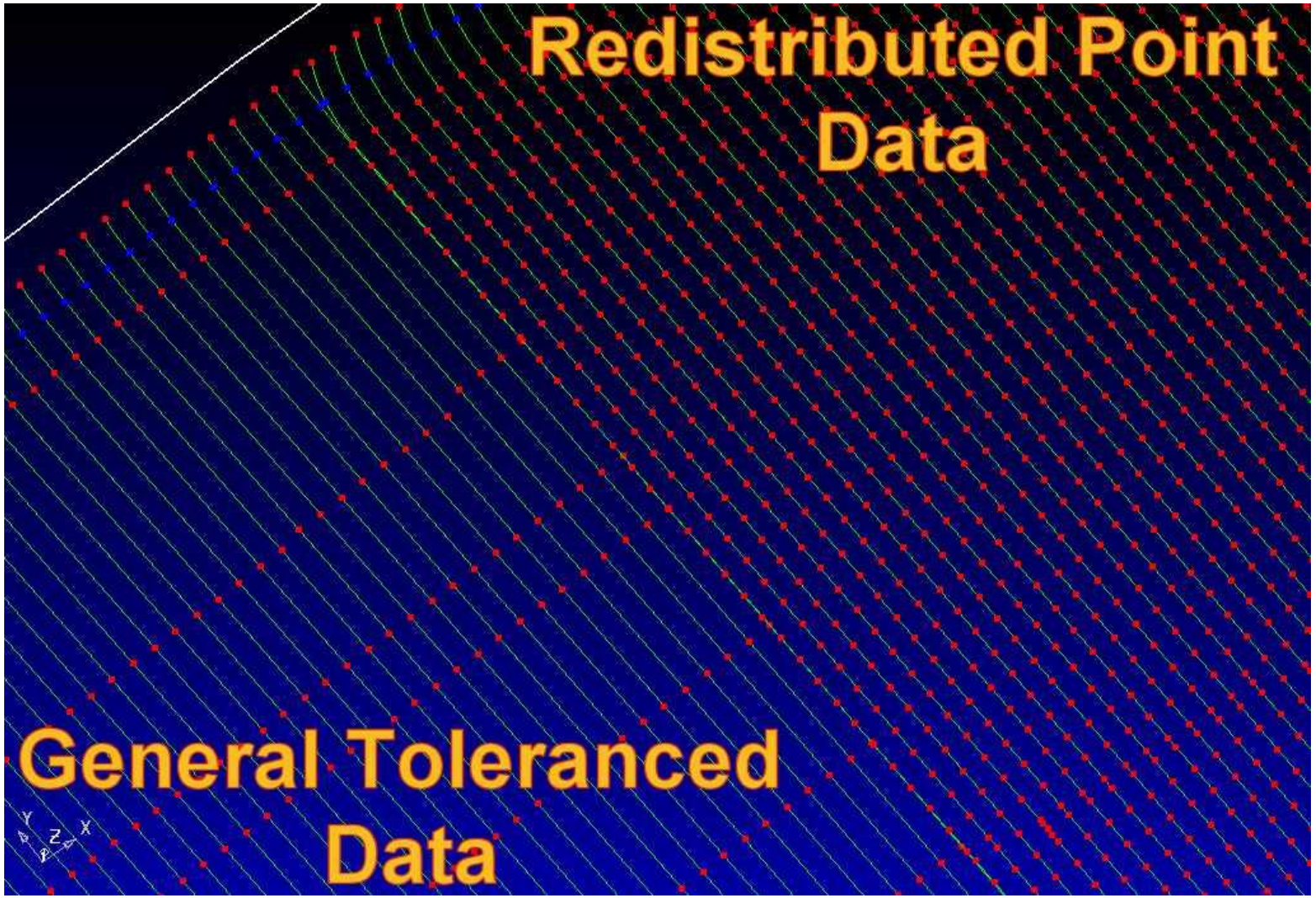
- Problem? Jerky Tool Motion



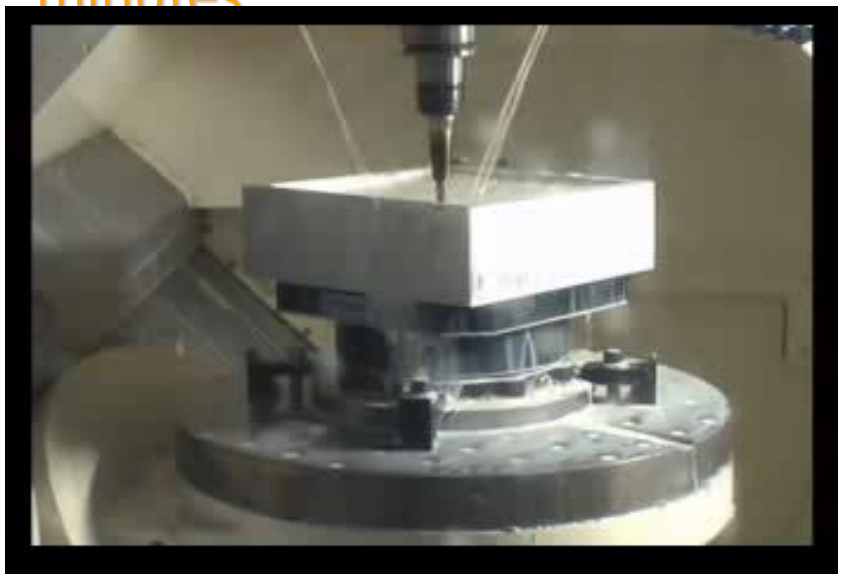
HuronKX8-Five
Siemens 840D
Feedrate:
7500mm/min

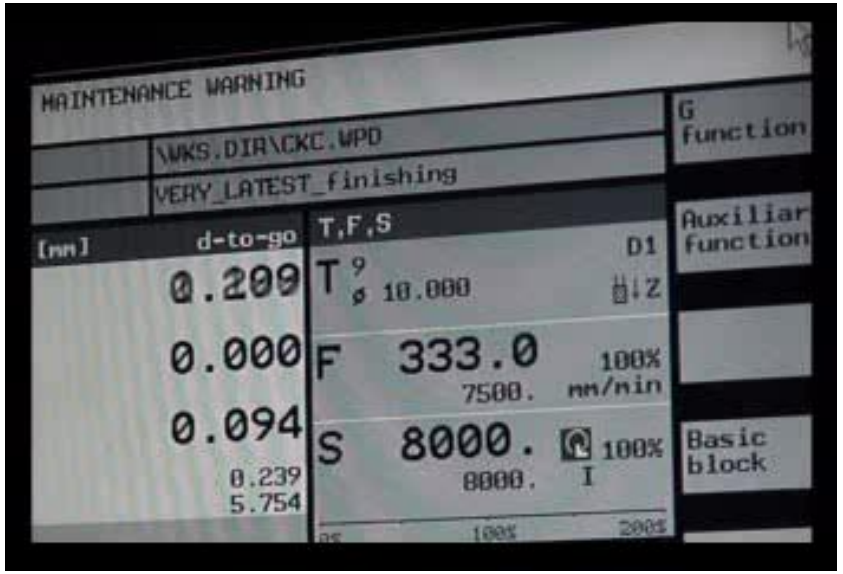
Common 5 axis problems

- Common Solution? Evenly space the points on the toolpath. This enables the CNC control to process the toolpath faster and more smoothly

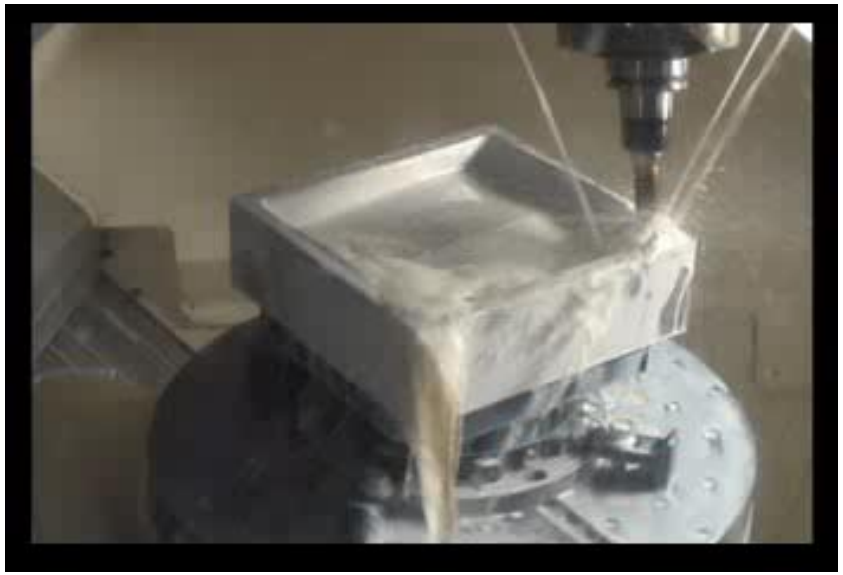


Standard Tolerance @Feedrate 7500 mm/min + CYCLE832. Machining time: 82 minutes





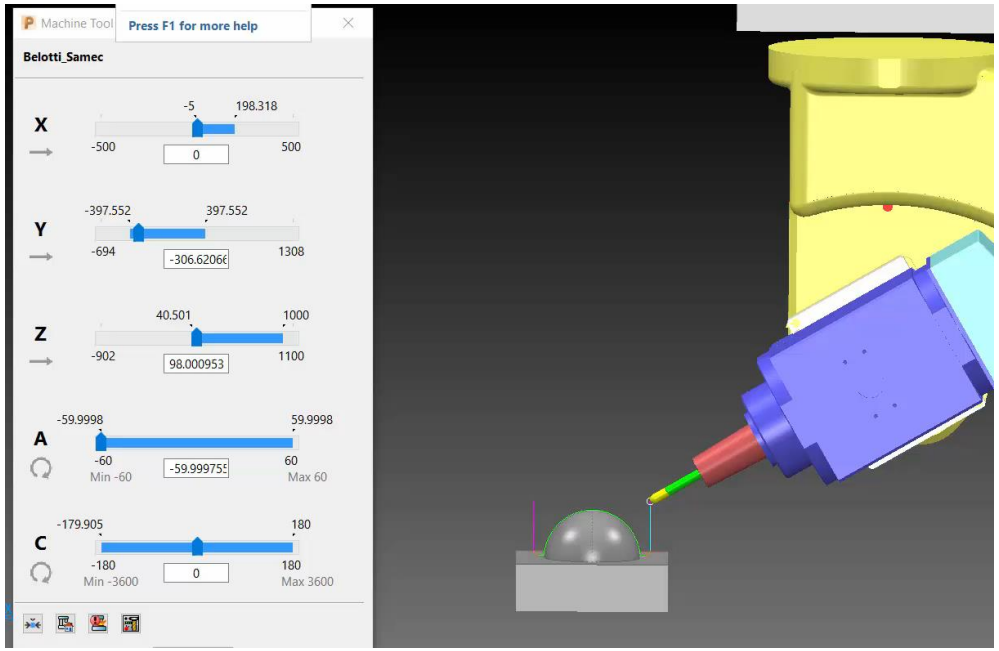
Redistributed Points @Feedrate 7500 mm/min + CYCLE832. Machining time: 50 minutes

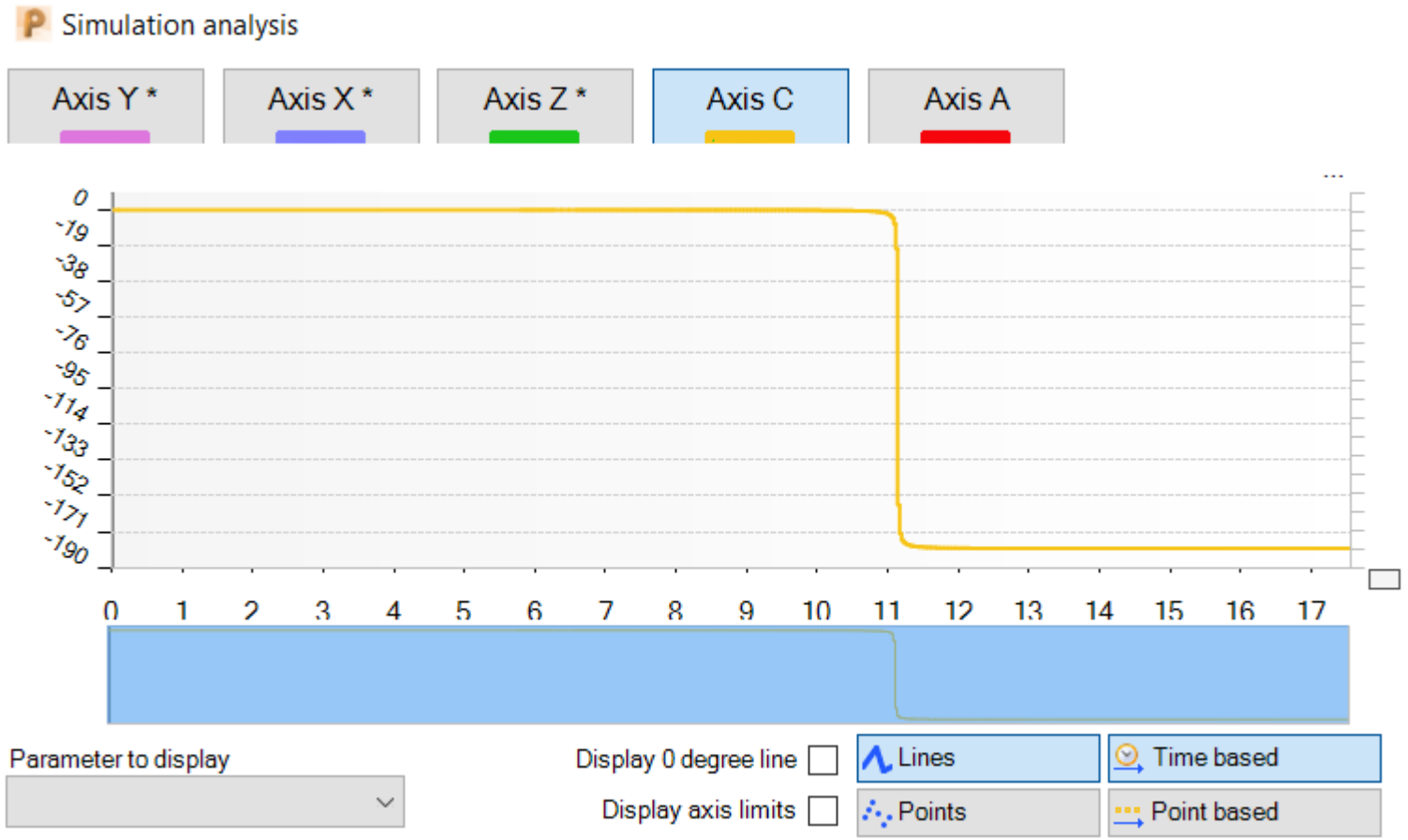


39% cycle time saved by utilizing evenly spaced point distribution

Common 5 axis problems

- Problem: Rapid rotary axis acceleration. Typically occurs when the tool axis is close, but not through the machines singularity (The machines singularity commonly = the Z axis)



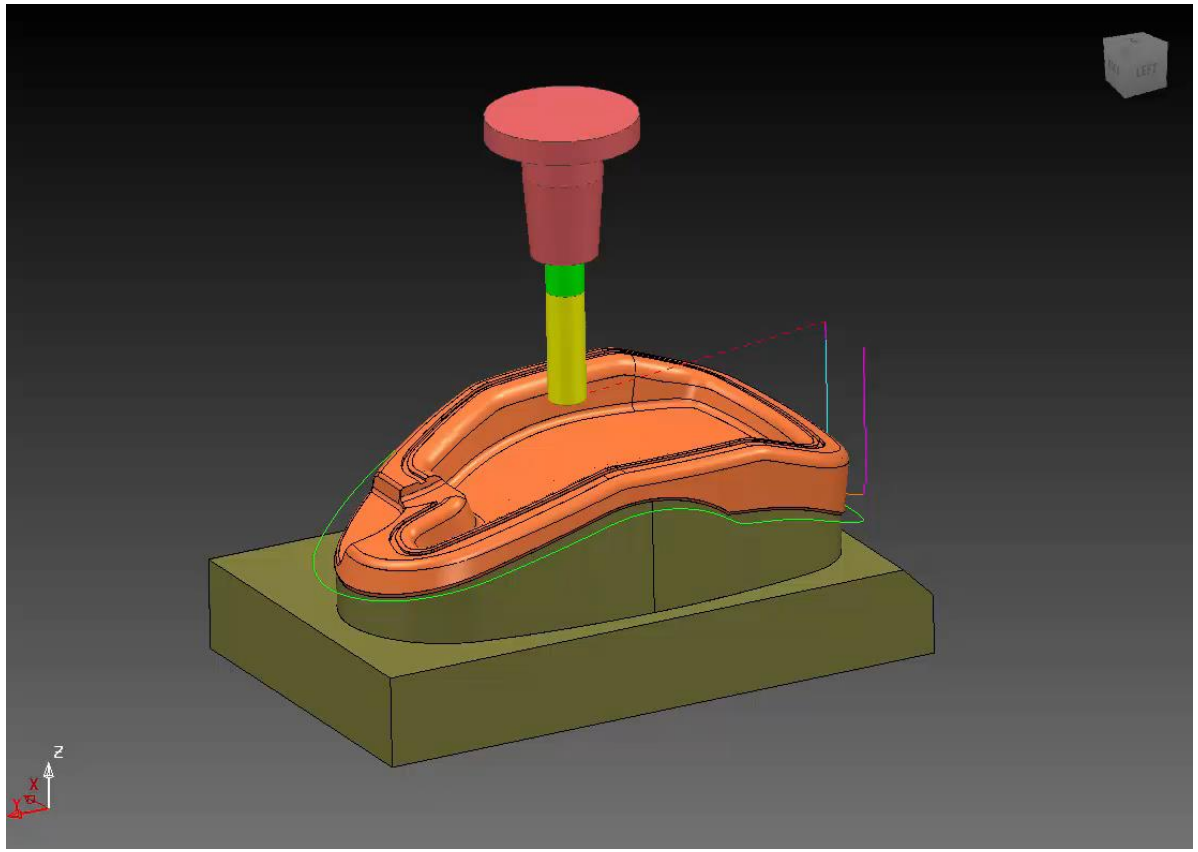


Tool axis pointing towards spherical center, passing directly over the center point at X0

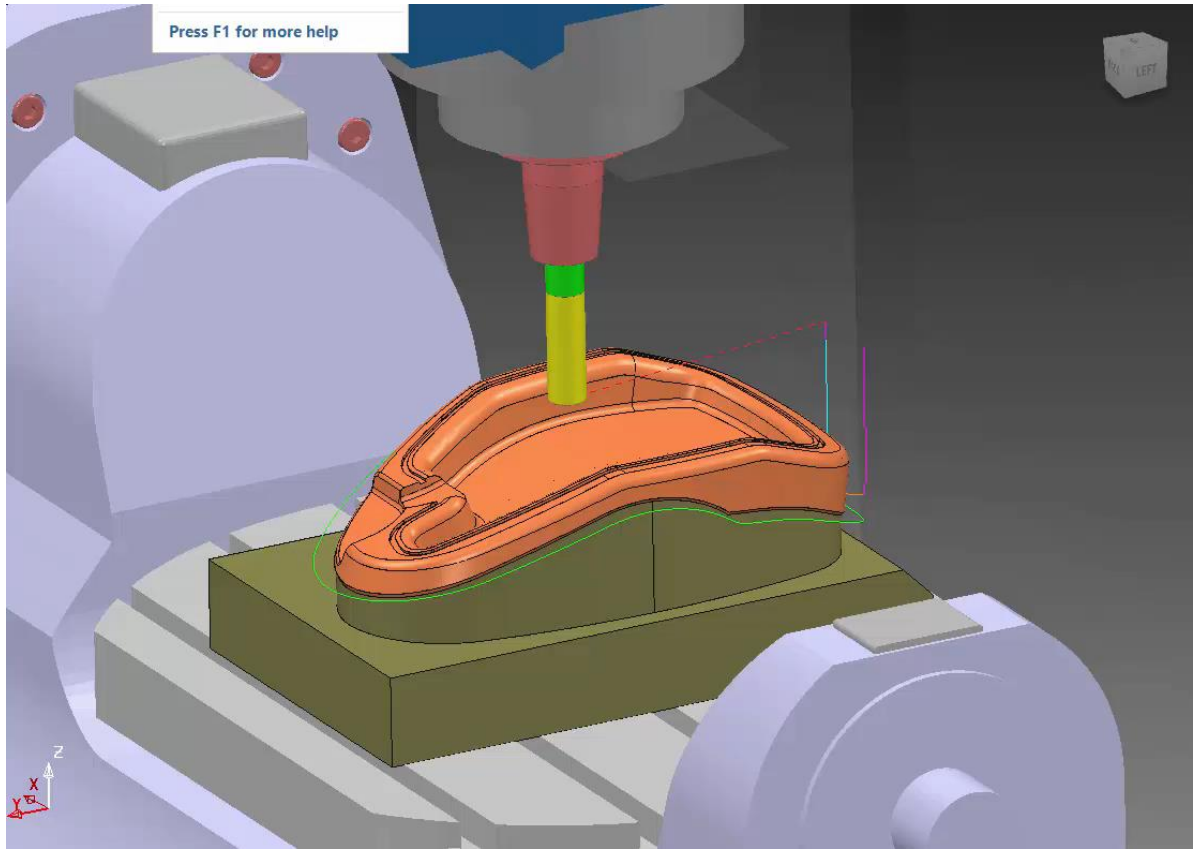
Tool axis pointing towards spherical center, offset in X by 0.01mm

Common 5 axis problems

- Problem: Rapid rotary axis acceleration. Typically occurs when the tool axis is close to the machines singularity (The machines singularity commonly = the Z axis)



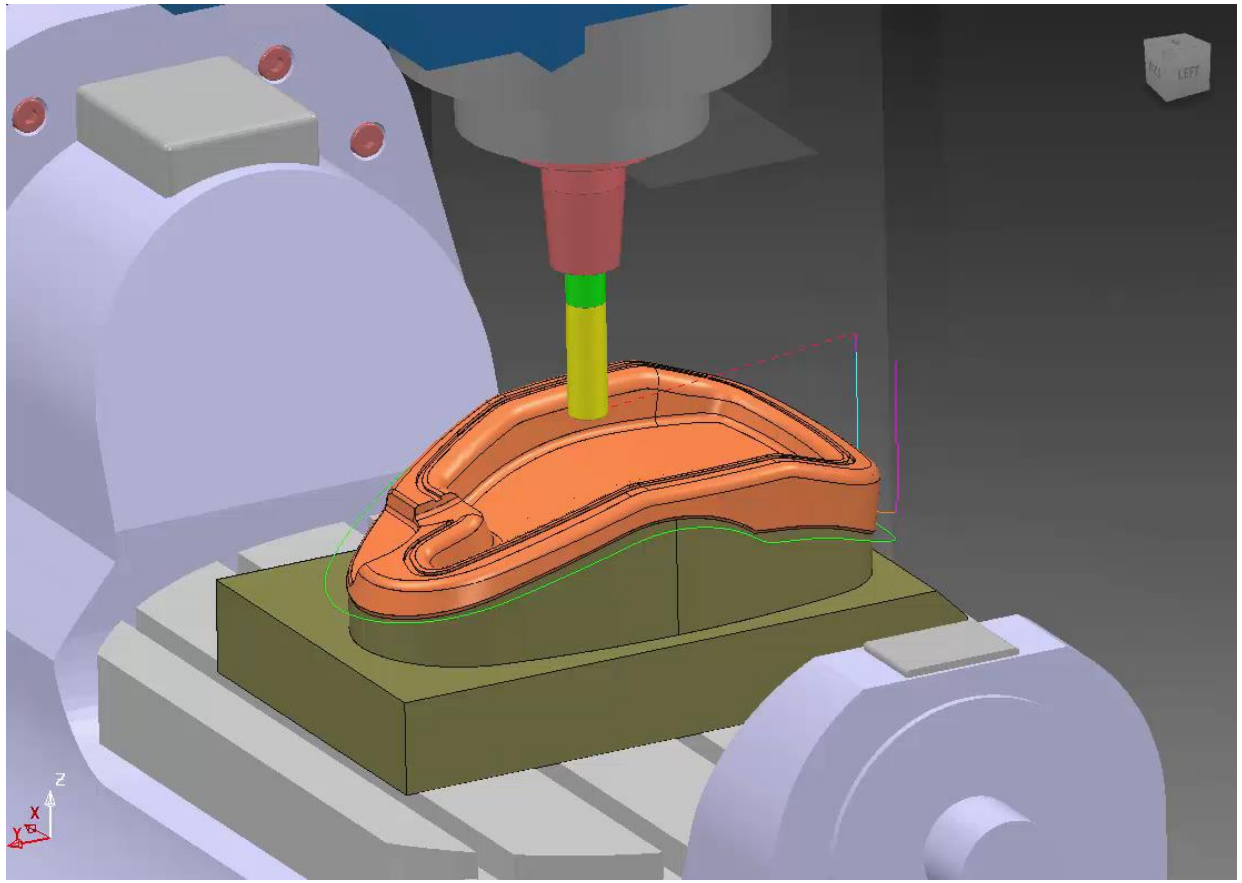
Is the machine motion smooth?



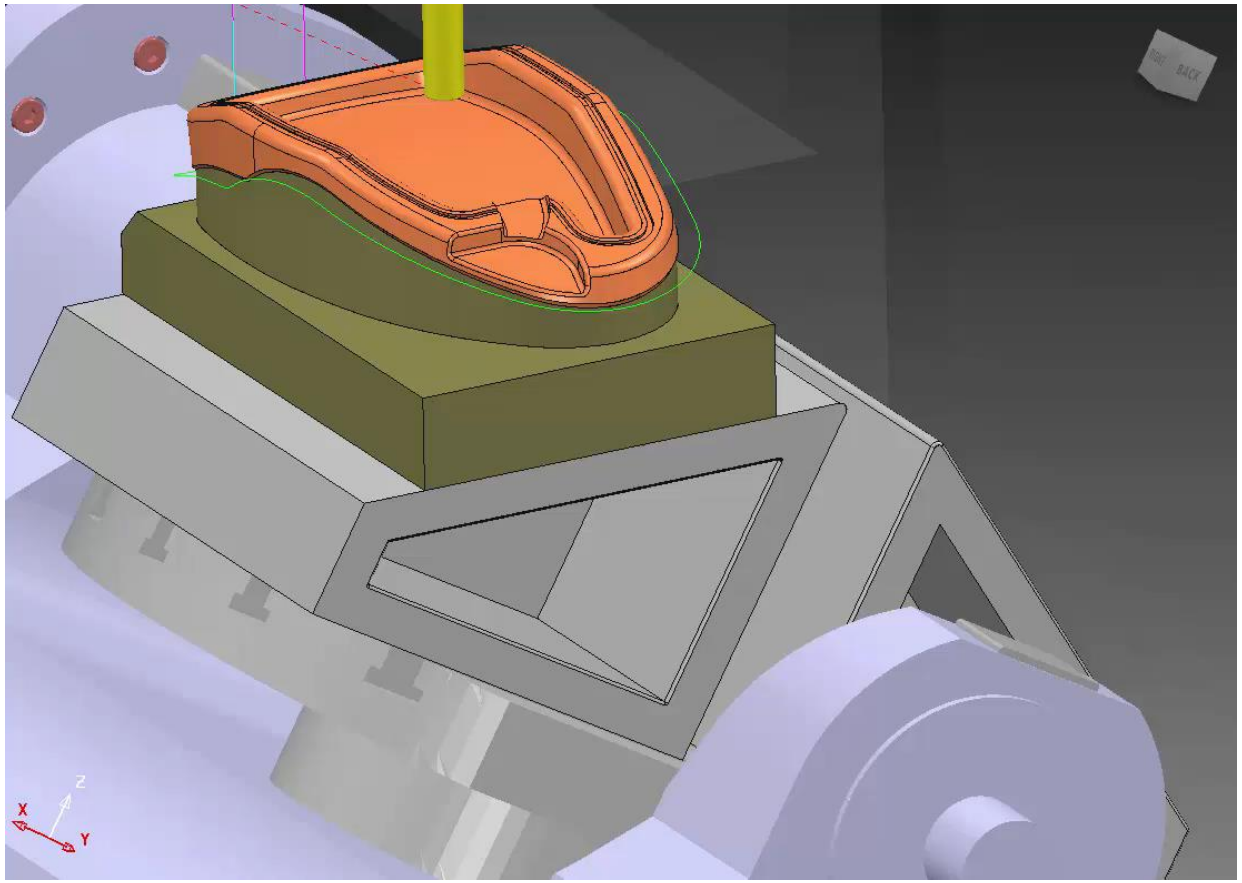
No! There are 2 rapid C axis accelerations.

Common 5 axis problems

- Solution 1: Move the tool axis away from the singularity by mounting the part on an angled fixture



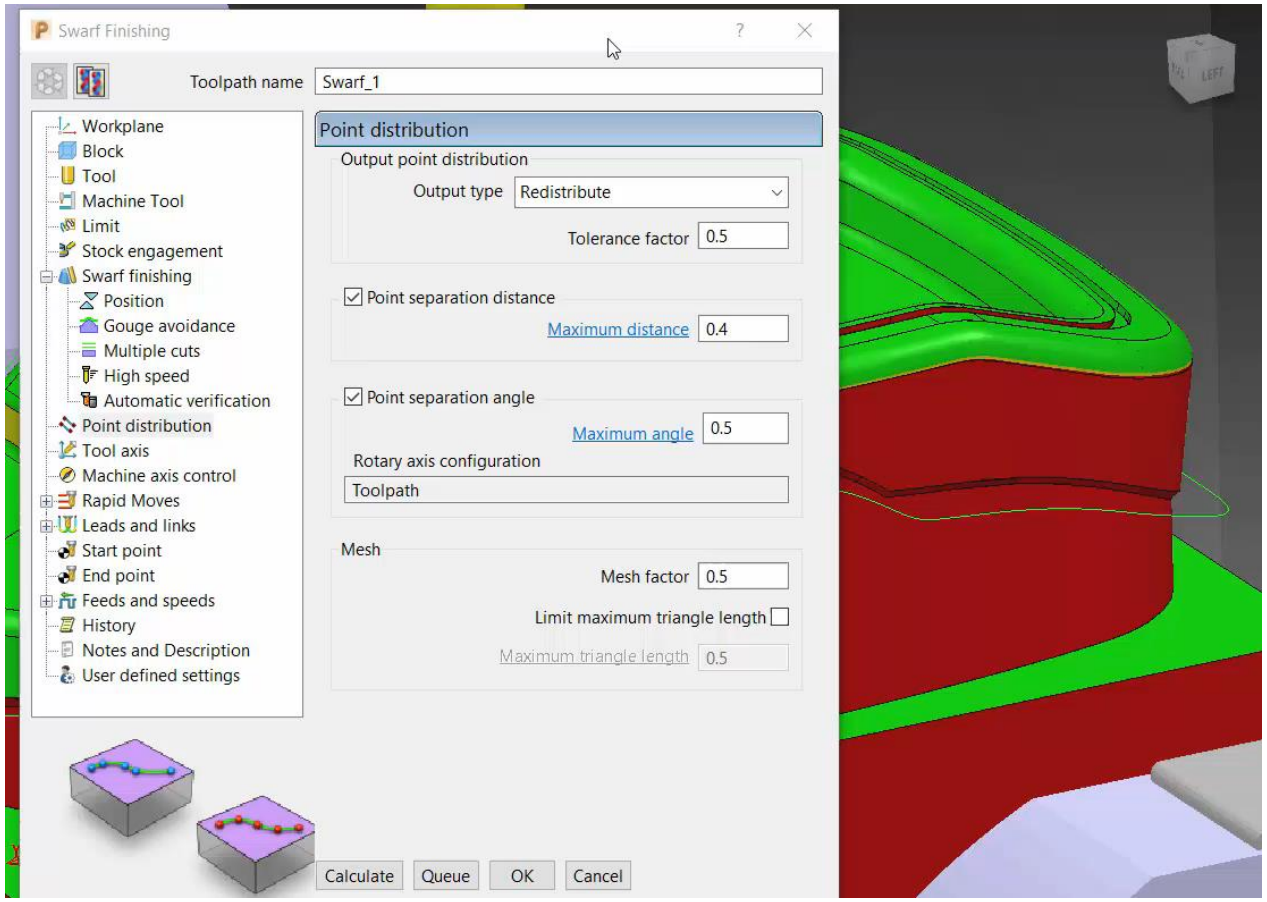
The problem: Large C axis move.
This is caused by the toolaxis moving from a +ve to a –ve draft angle, close to the singularity



The same toolpath on the same machine tool now runs smoothly. The fixture has moved the tool axis away from the singularity (Z Axis).

Common 5 axis problems

- Solution 2: Add more points in the region where excessive rotary action occurs

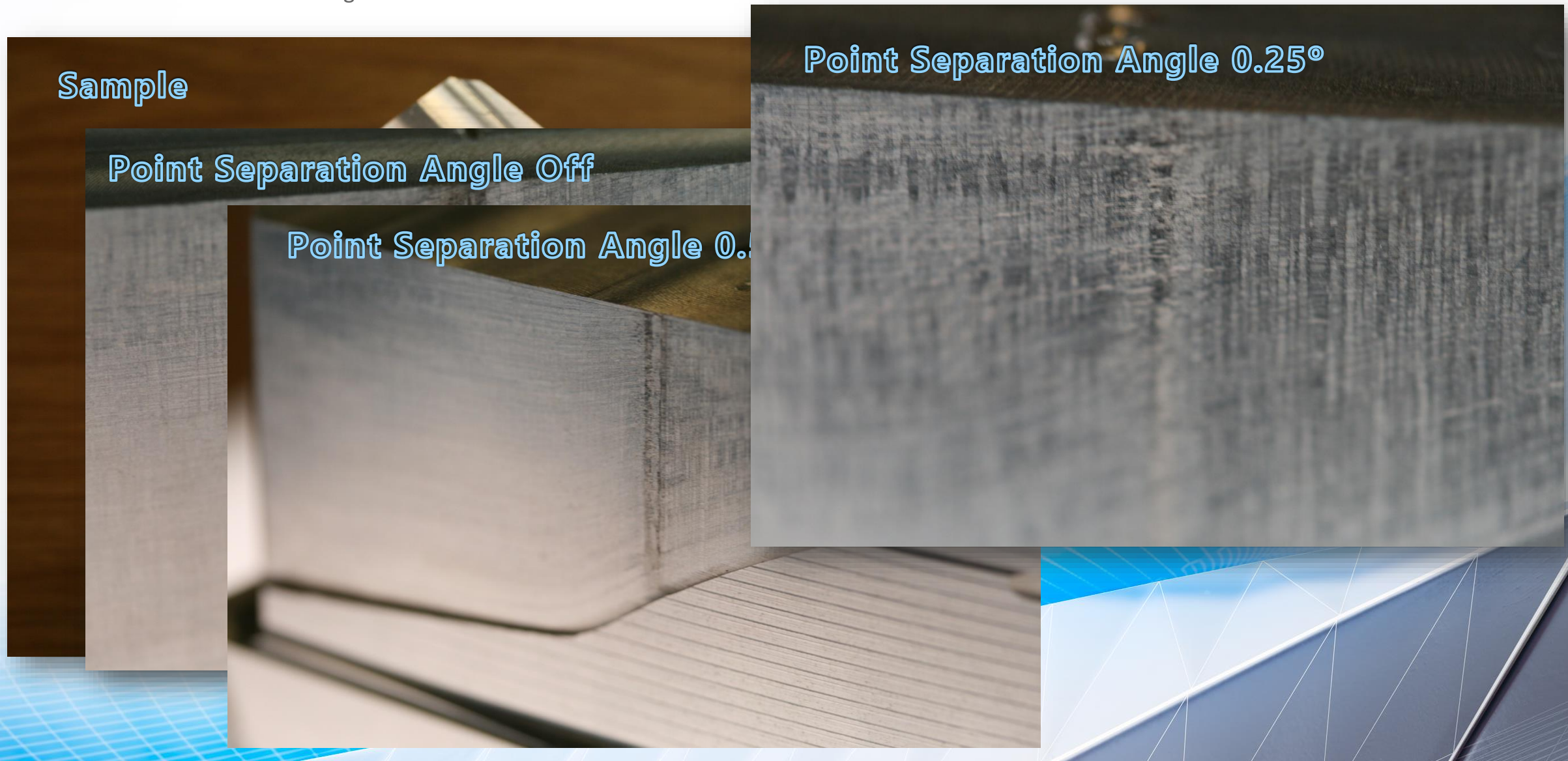


We can reduce the impact of the problem by adding additional points into the toolpath when simultaneous 5 axis machining close to the machine tools singularity.

This solution is not as effective as fixturing the part away from the singularity, but it is an easier and cheaper method of reducing the negative effects of this problem.

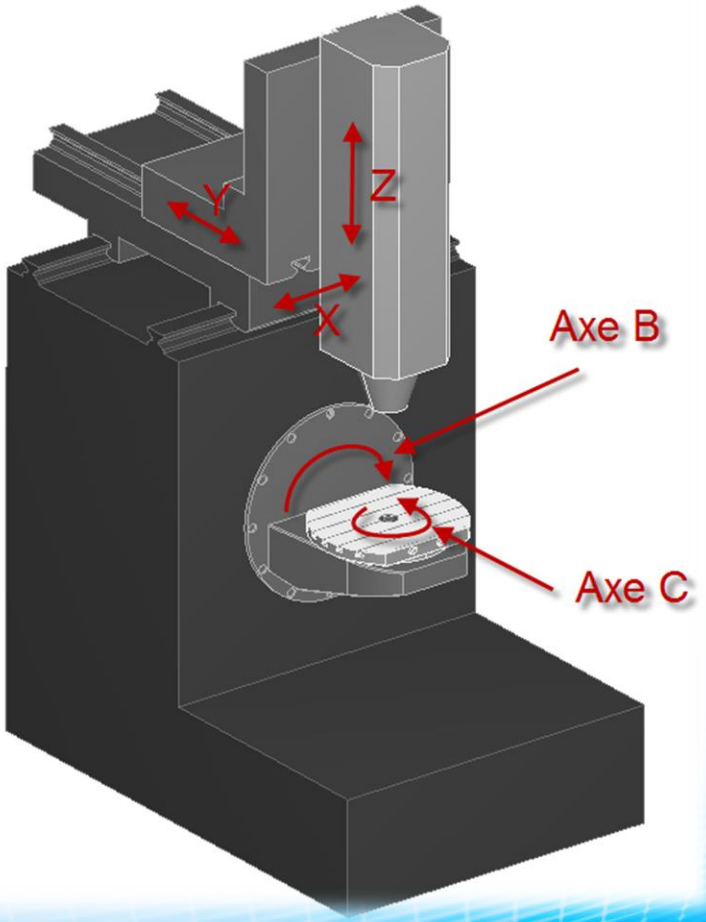
Results

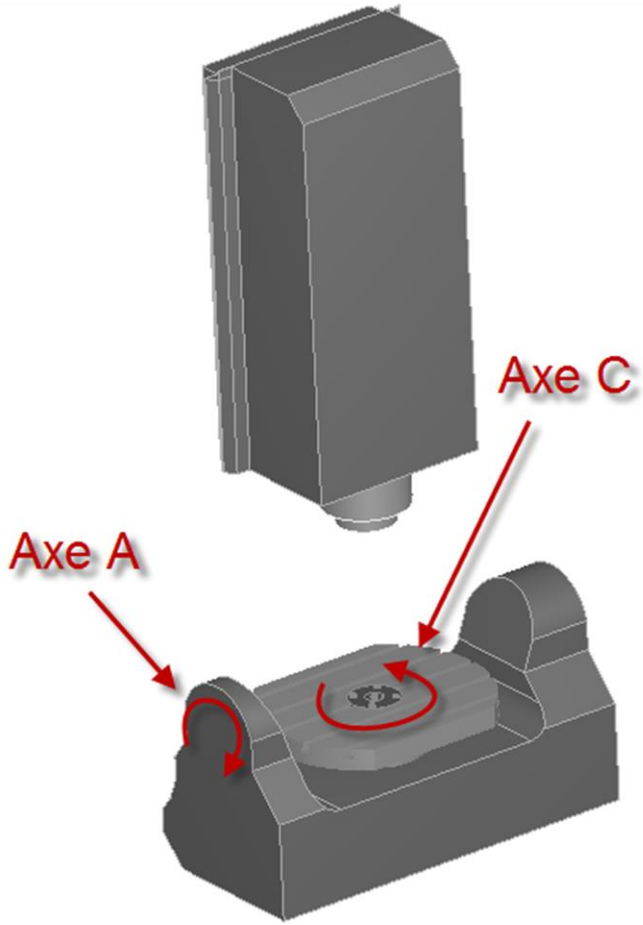
- Huron KX200 Head-Head configuration



Types of 5 axis Machine

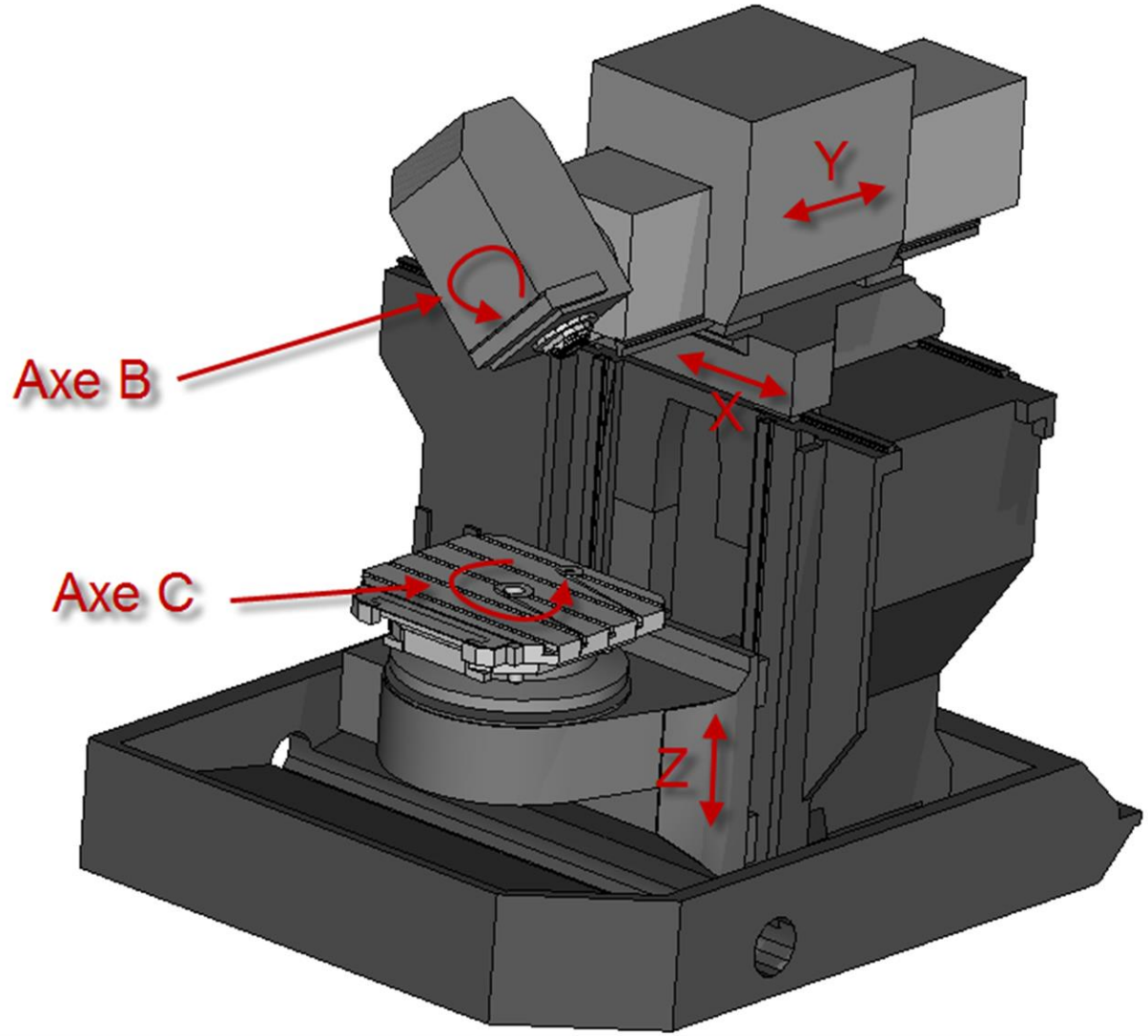
- Table/Table





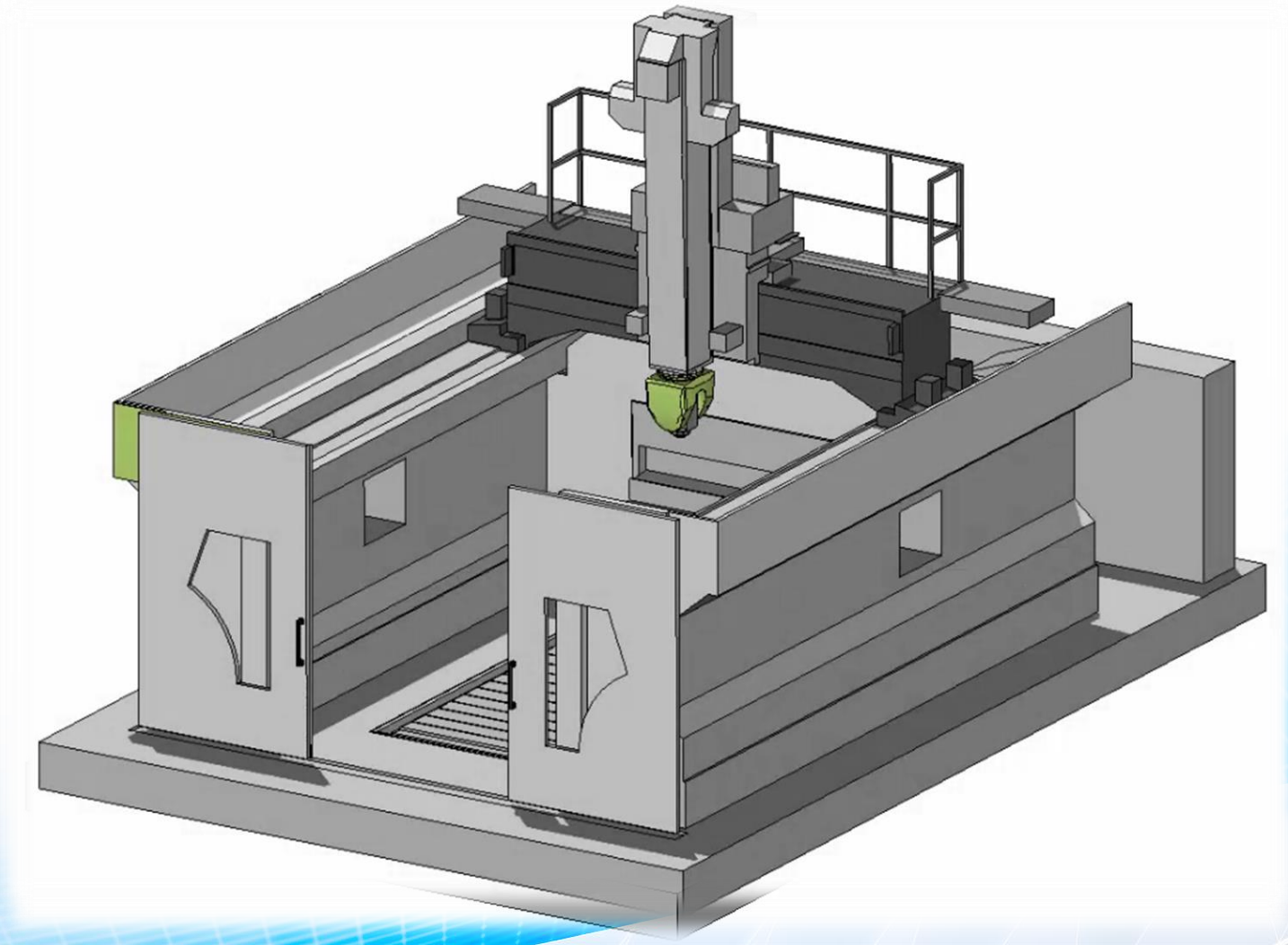
Types of 5 axis Machine

- Head/Table



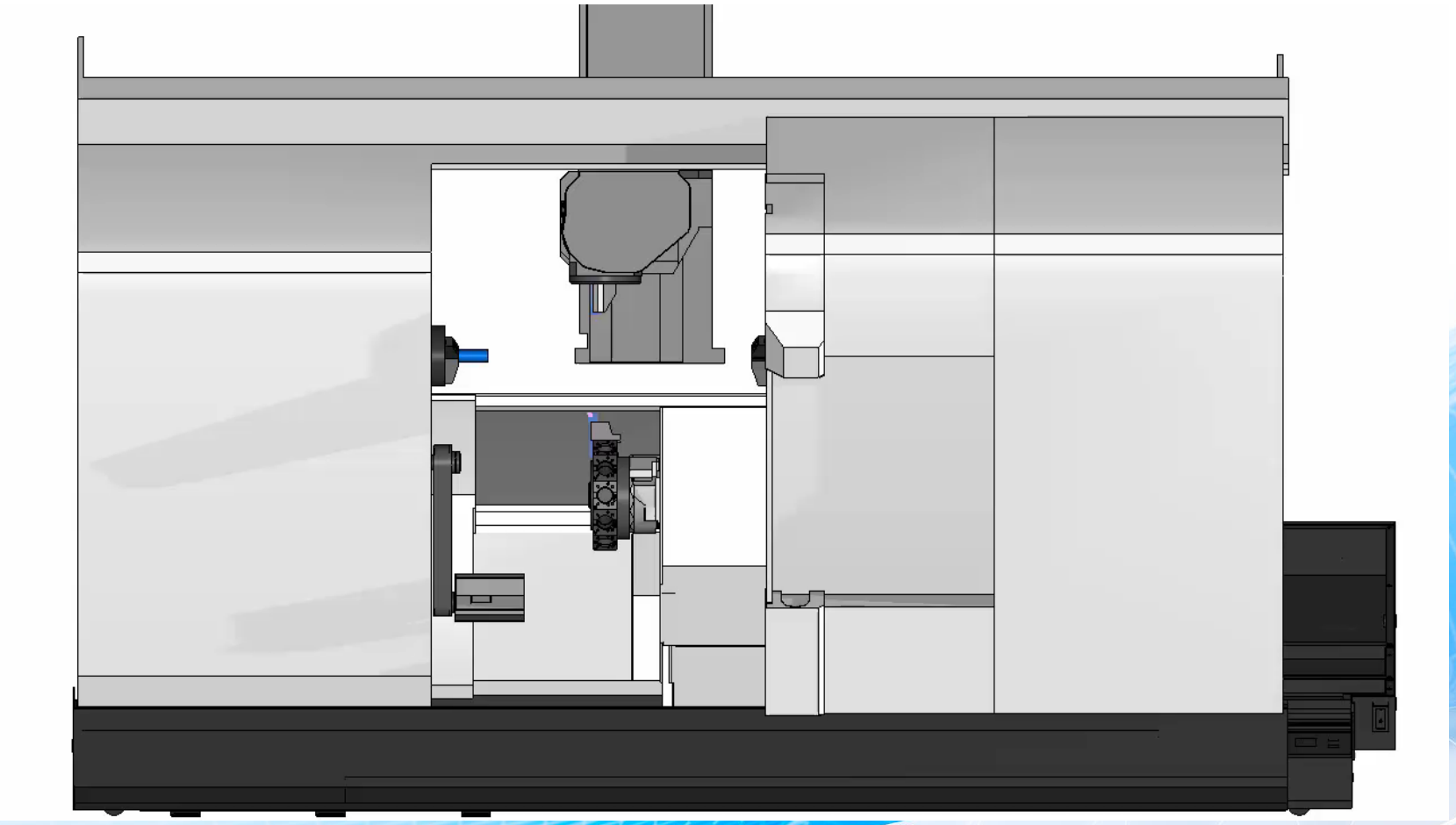
Types of 5 axis Machine

- Head/Head



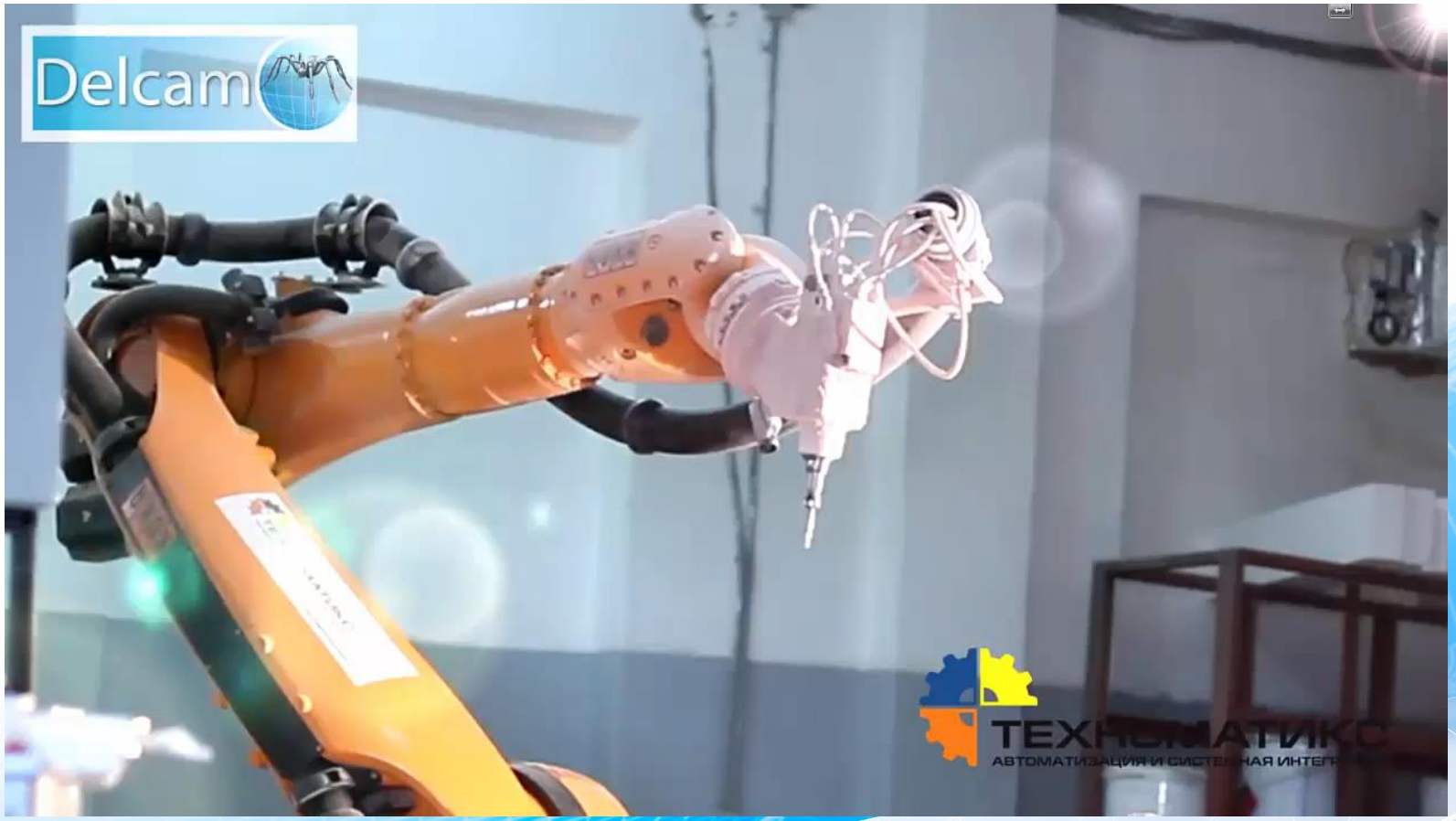
Types of 5 axis Machine

- TurnMill



Types of 5 axis Machine

- Robots



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