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Engineering precisely what you value

Blisk milling – from components to machine design

The 18th Israeli Symposium on Jet Engines and Gas Turbines, Technion, Haifa

Nov. 28th, 2019

Solutions for
Aerospace
Energy
Transportation
Industrial

Rorschacherberg, 15/12/2019

Business philosophy

The Starrag Group is the leading solution provider for the complete process of machining components with an unmatched portfolio.

In Aerospace & Energy applications, the Starrag Group is a solution provider concerning

- machine
- software
- process
- tools
- fixtures
- automation

Starrag's innovation focus is on giving its customer a competitive edge.

PRODUCTIVITY QUALITY RELIABILITY ERGONOMICS

Production System

Starrag AG
Rorschacherberg

Starrag Technology GmbH
Mönchengladbach

Starrag Vuadens SA
Vuadens

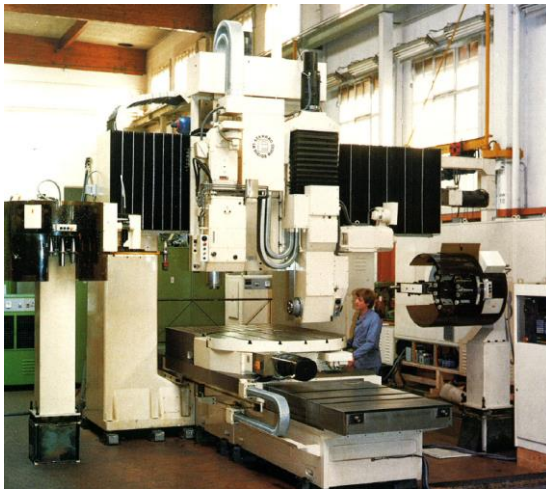
Starrag Technology GmbH
Bielefeld

Starrag SAS
St.Etienne

Starrag GmbH
Chemnitz

From machine focus to application focus

- Unique Selling Point
  - 1980
    - Technical solution, with which a certain complex component could be machined
    - Difference in the machine tool, through knowledge and experiences in production, construction, control, etc.
    - Core competences: mechanics, hydraulics, electronics, production
  - Today
    - Machine tools are commodities which can be bought at very low prices around the world
    - Very high requirements concerning quality, availability, service, production safety
    - Difference in total solution: «Cost per part» including process, software, tools, machine,…
    - Core competences: intelligence (sensors + software), tools, fixtures
- Increased, global competition
- Very cyclic market

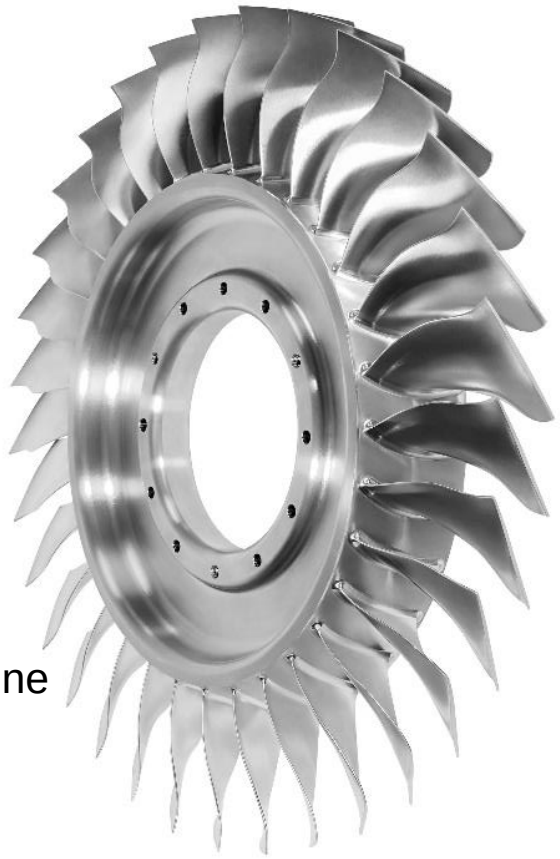


Video

Application focus for machine tool design

The process how to machine a Blisk is in the center

- Compressor Blisks (from Titanium or Nickel-based alloy)
- From solid or linear friction welded



What to achieve

- Lowest production cost per part
- Highest production safety (reliable output)

What you need

- Complete process know-how (strategies, tooling, CAM, fixtures, etc.)

Then it is easy

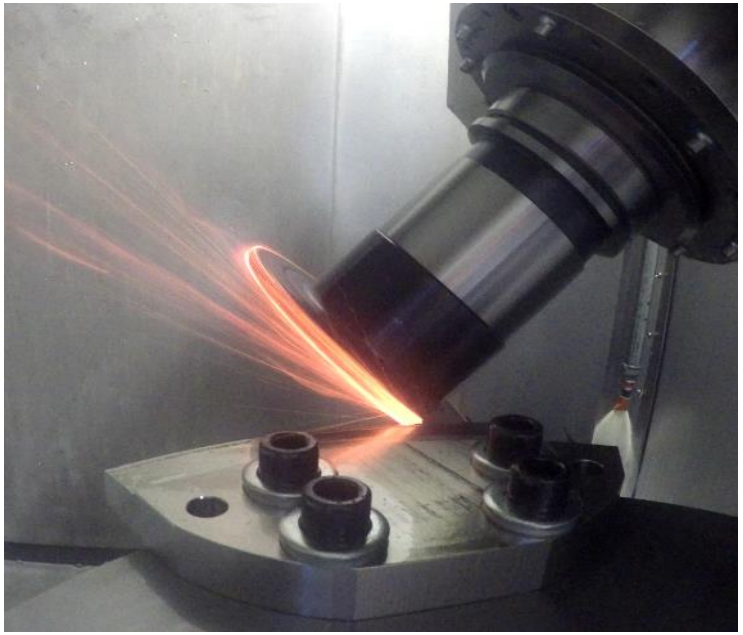
- The optimal machining strategies should be implemented on the machine tool without compromise

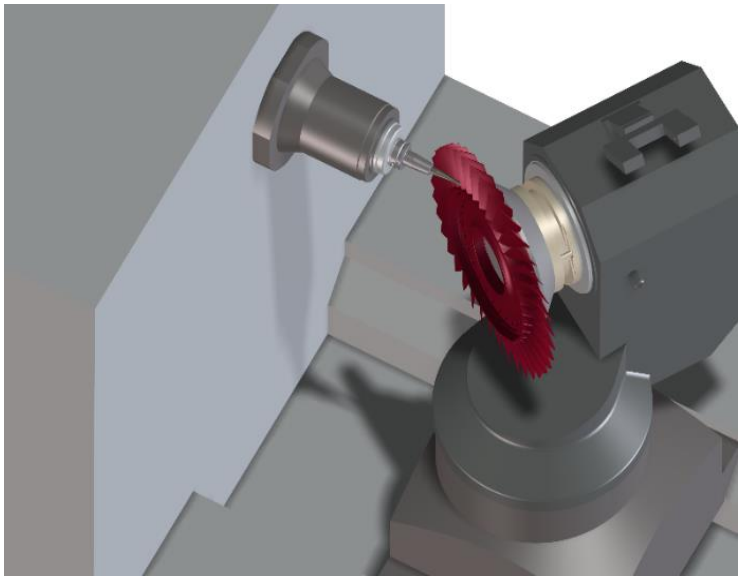
Necessary aspects to understand for the machine tool per strategy

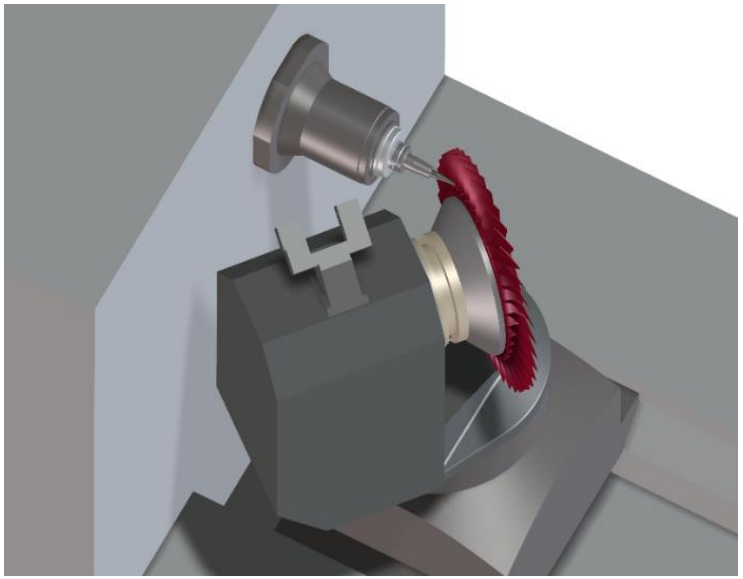
- Accessibility to the part
- Required roughing stability
- Dynamic behavior of the machine components and effect of machine time

Simulation of the optimal strategies

- A lot of process knowledge goes into defining and benchmarking strategies, identifying the optimal one, including new developments
- Identifying accessibility is then standard
- Defining of required machine parameters such as spindle speed and torque or machine feed rates is easy too







Identifying limitations

Chatter free surfaces

- Section of the **optimal tool design** through tap testing
  - the dynamic behavior of tool and workpiece can be balanced out
  - geometrical factors like diameter, number of cutting edges can be optimized
- Determination of the **optimal tool pitch variation** for highest stability
  - pitch variation avoids periodic excitation
  - the optimal pitch variation can be calculated by Starrag engineers
- **Optimization of stock material** distribution before finishing
  - stock distribution affects the stability of the blade
  - an optimal distribution can be calculated via FEM, e. g. tapered offset
- **Test cuts** in order to prove out

Identifying limitations

Dynamic accuracy

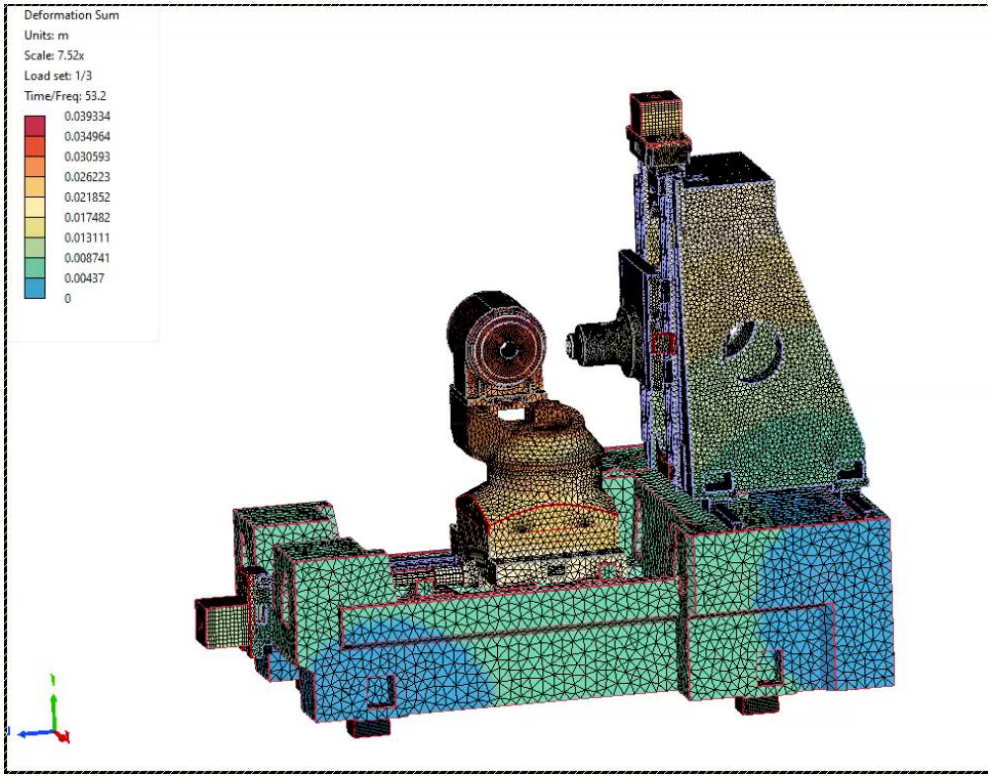
Understanding the dynamic accuracy behavior of the machine is critical, because it will ultimately determine the surface quality and the production time of the Blisk.

Due to acceleration loads, the machine will

- Lag behind or Overshoot in motion direction
- Move in cross directions to the programmed motion (cross-talk)

To come to optimal results, machine and control must be included in the simulation in order to optimize

- Mechanical build-up
- Dynamic control settings (acc., jerk, filters, …)
- CAM path generation



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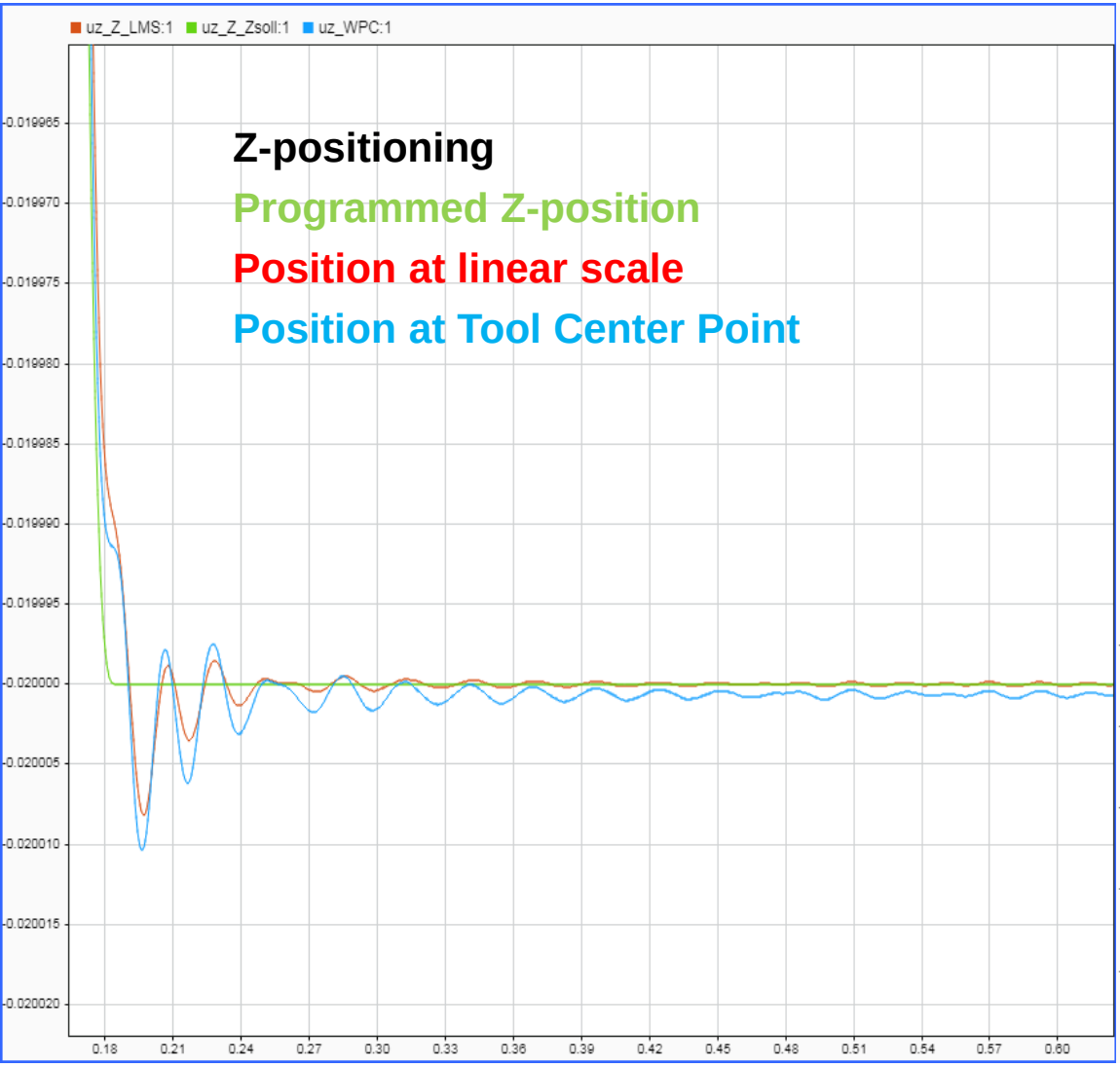
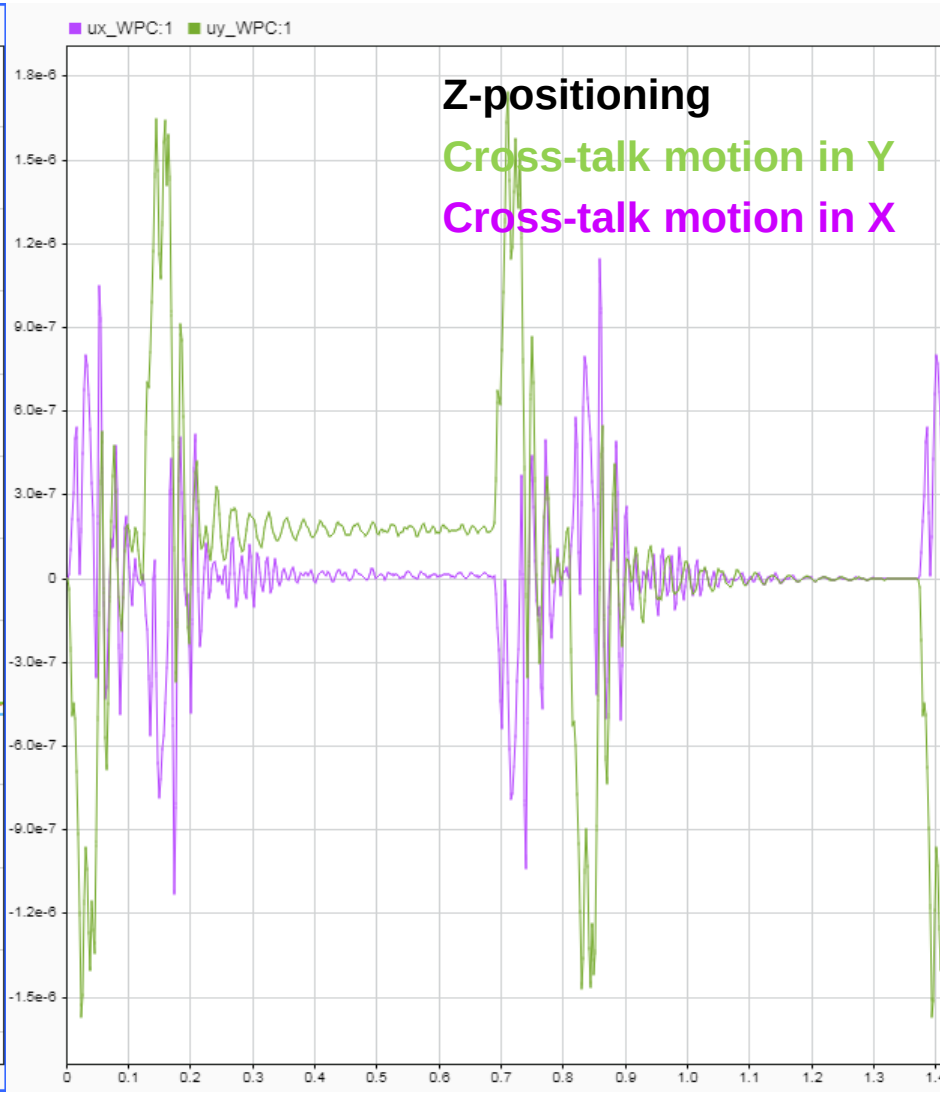
Simulation results, basis for optimization



Time [s]



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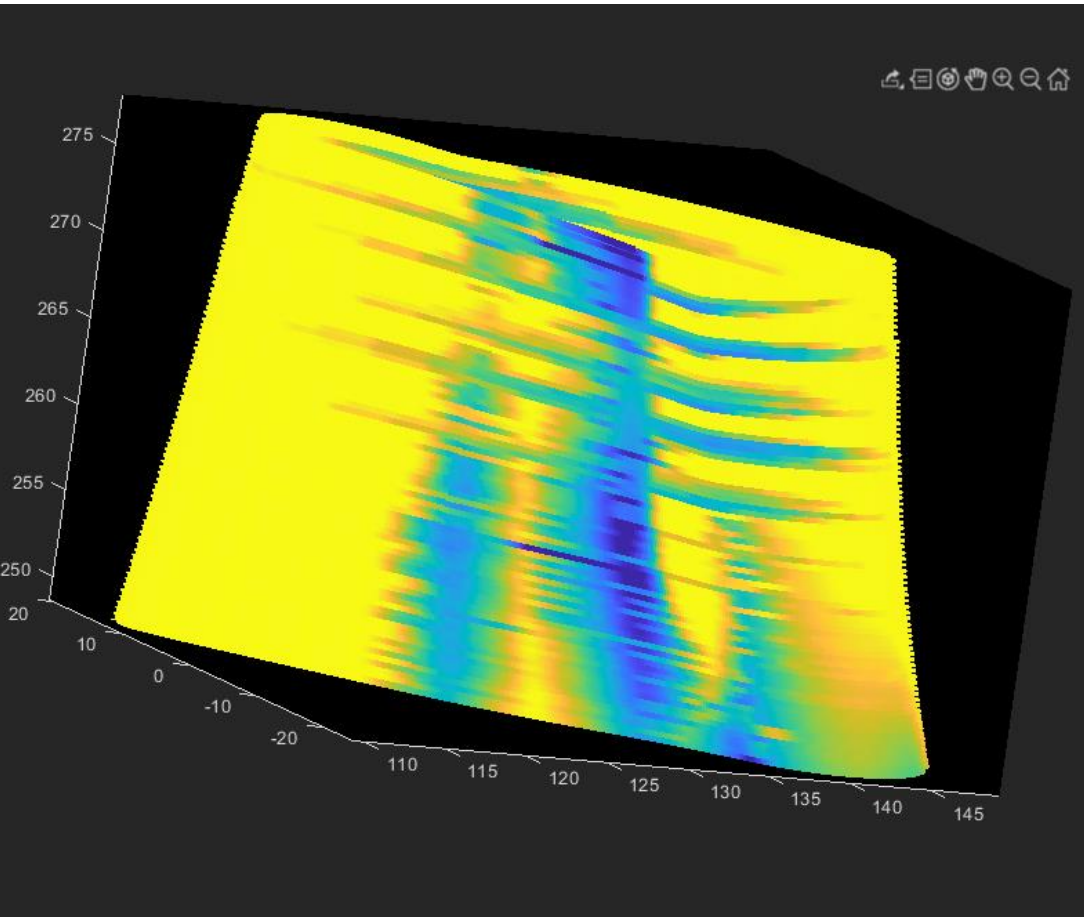
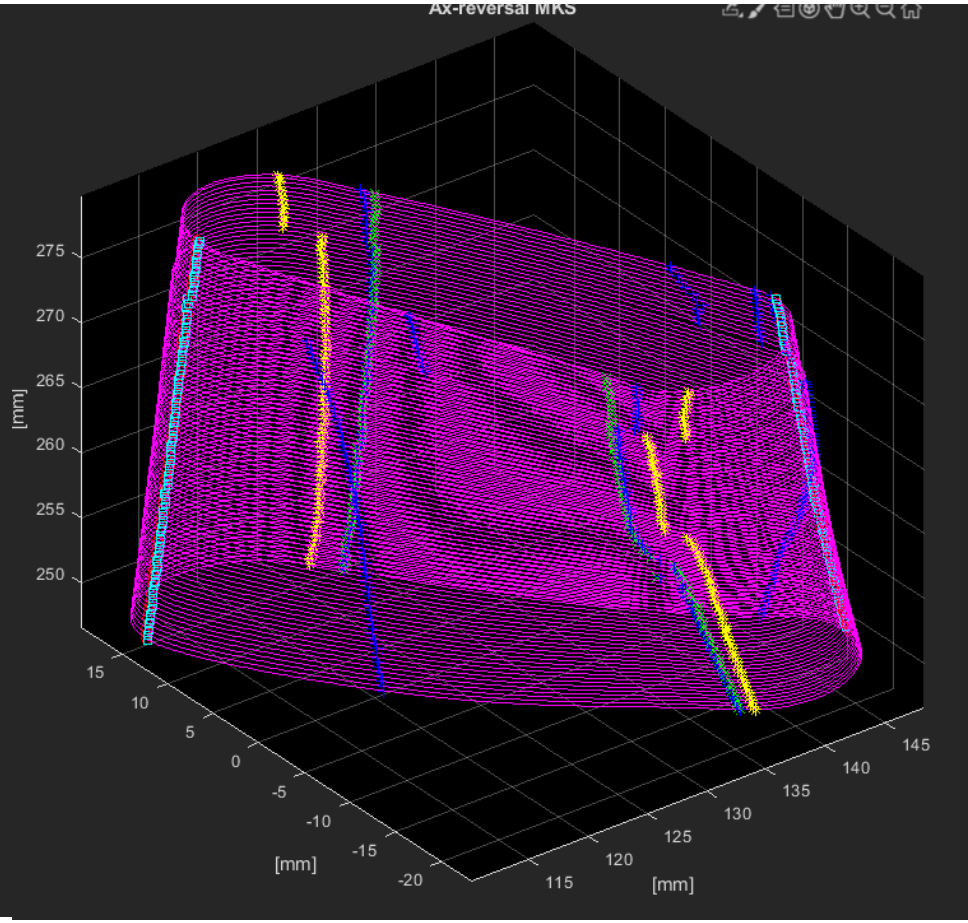
Direct access to control

Analysis of real cutting program on real NC (in simulation environment or on real machine)



Examples: non-optimal feed rate on real Blisk airfoil



axis reversal points on real Blisk airfoil

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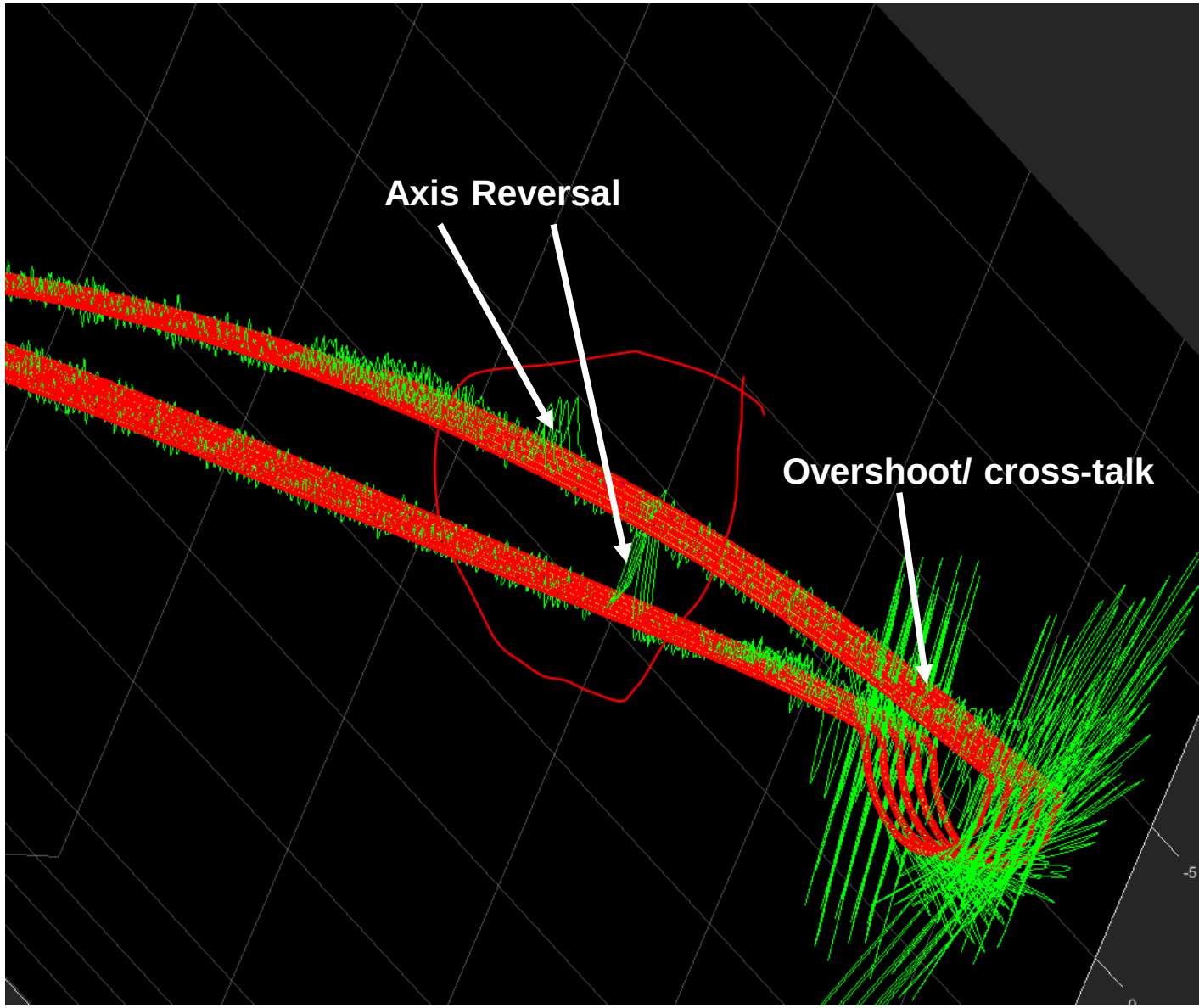
Test results on real machine

Read-out from machine scales from machining (green) vs. nominal machine path /red



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Conclusion

For high end machining solution e. g. for Blisks, in order to be competitive, the starting point for development has to change from machine tool construction to application know-how!

Critical issues

- #1 is applications know-how! Going to a better strategy, better tools and so on can change the production time and cost by factors!
- Designing the machine tool for this strategy can reduce the number of setups by better accessibility, reduce roughing (potential 50% time and cost saving) and finishing (potential 20% time and cost saving) effort
- To realize this potential, extensive process experience must be available. For the machine tool design, clear performance parameters are deducted from the process. Through simulation and test results, these performance parameters can be optimized.