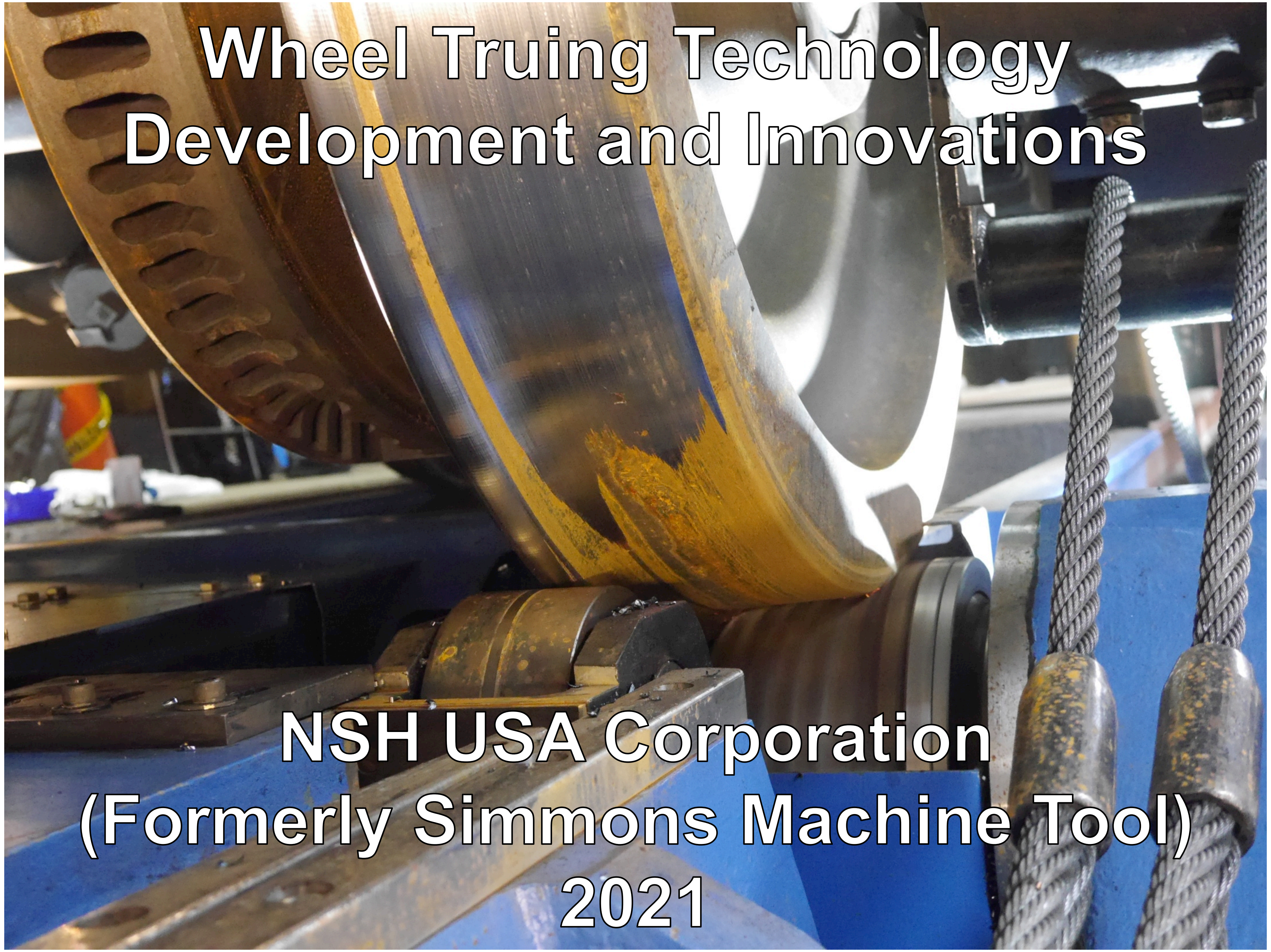
Wheel Truing Technology Development and Innovations



NSH USA Corporation
(Formerly Simmons Machine Tool)
2021

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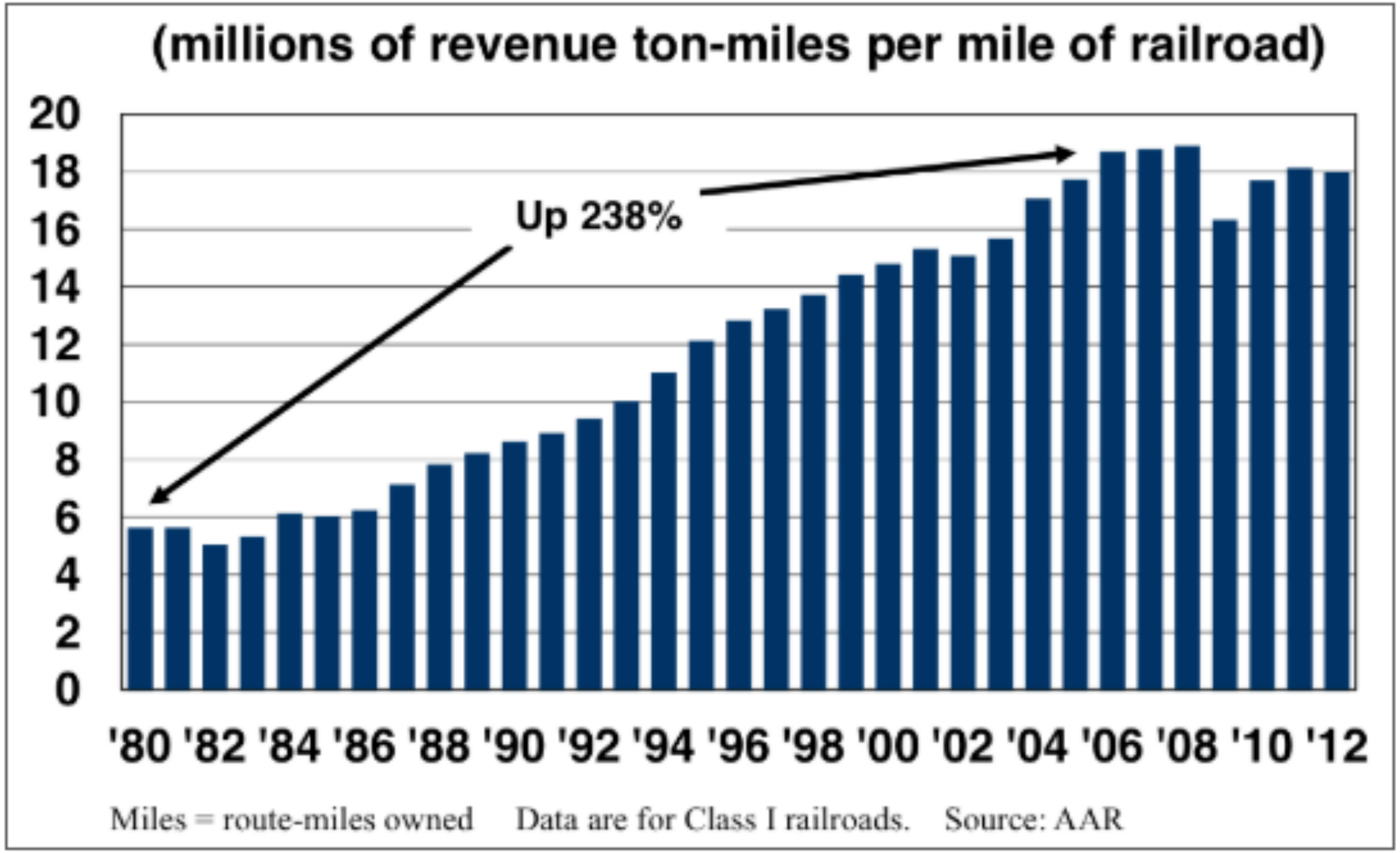
A Need For Innovation



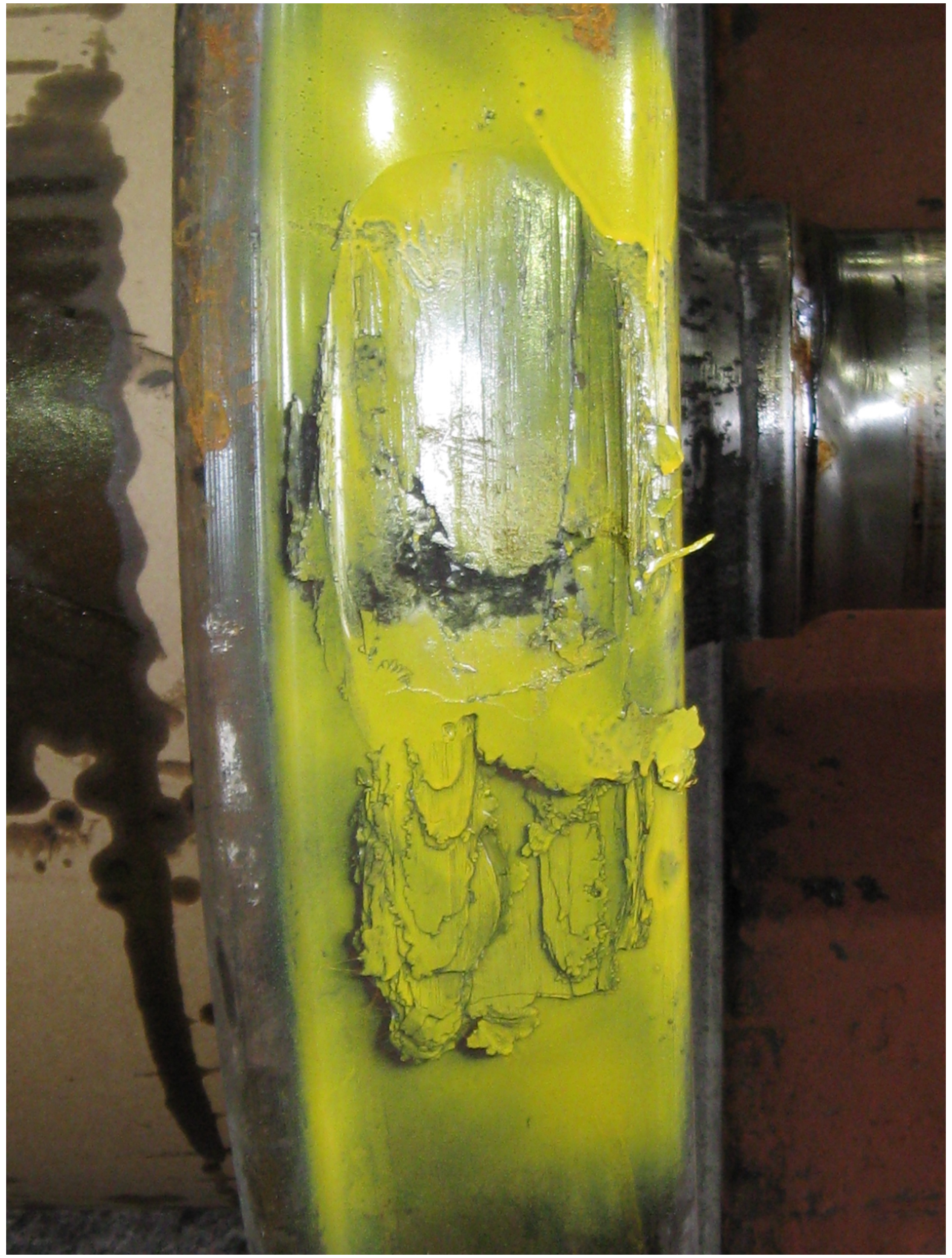
A Need For Wheel Truing Innovation

- Much of railway industry leveraging new technologies to improve production, efficiency, and safety:
  - PTC
  - Autonomous locomotive operation
  - Computer assisted track and rolling stock inspection
  - Digital wheel profile and defect detection
  - Carbon emission decrease and other green initiatives

- Wheel reprofiling largely remained stagnant for several decades without significant production increases

To keep pace with the rest of the industry, innovation is critical.

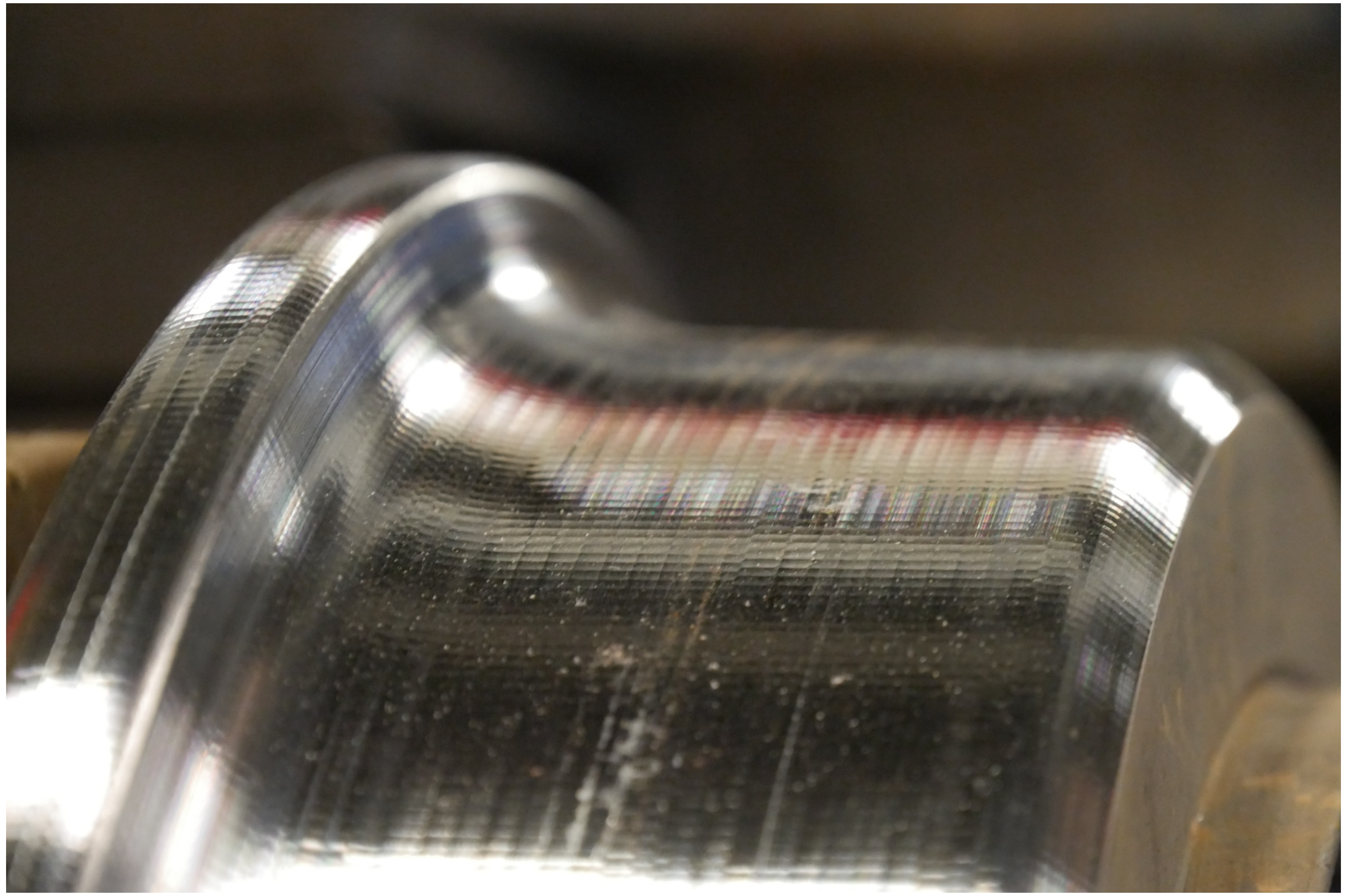
How Are Defects Removed From Worn Wheels?



How Are Defects Removed From Worn Wheels?

- Reprofiling: a machining process to remove defects from wheel to return profile to its optimal shape

- Can be one of two machining processes:
  - Milling (wheel truing machine)
  - Turning (lathe)



Wheel Reprofiling: Milling

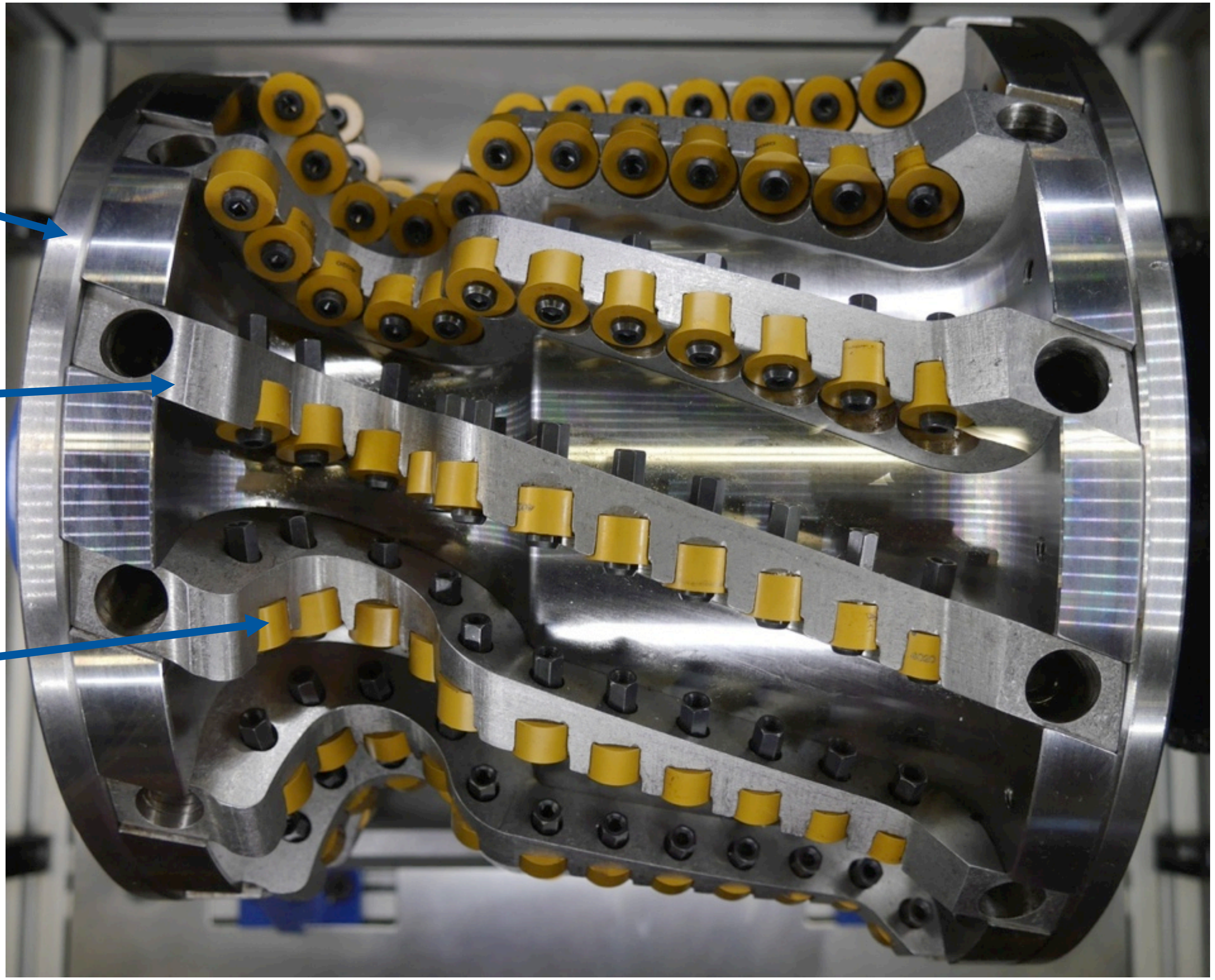
- Cutting tool rotates rapidly
- Workpiece (wheel) rotates slowly
- Multi-point machining

Wheel Reprofiling: Milling

Cutter Body

Removeable Blade

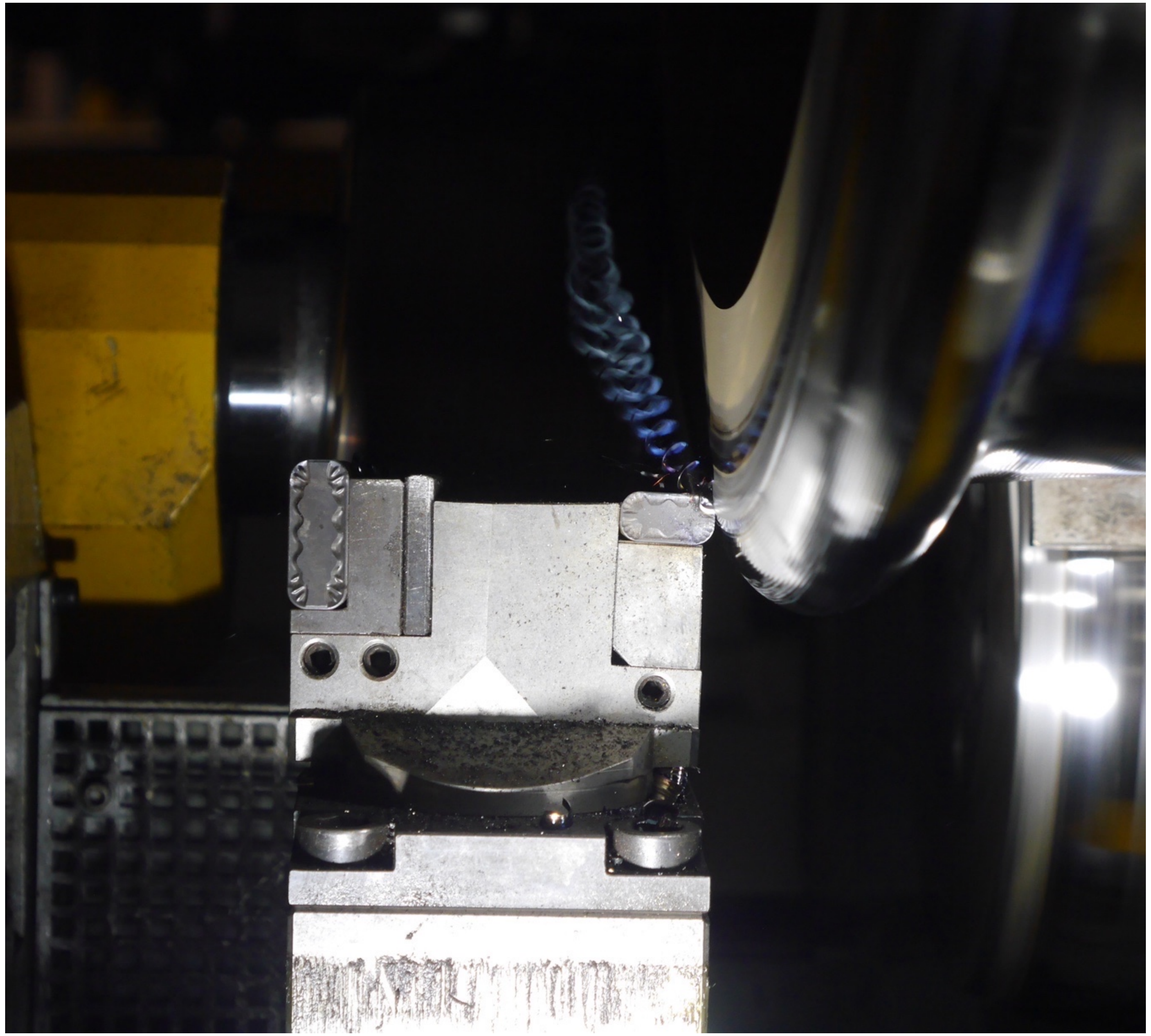
Carbide Insert



Traditional Milling Cutter Design

Wheel Reprofiling: Turning

- Cutting tool moves slowly along the profile
- Workpiece (wheel) rotates rapidly
- Single point machining

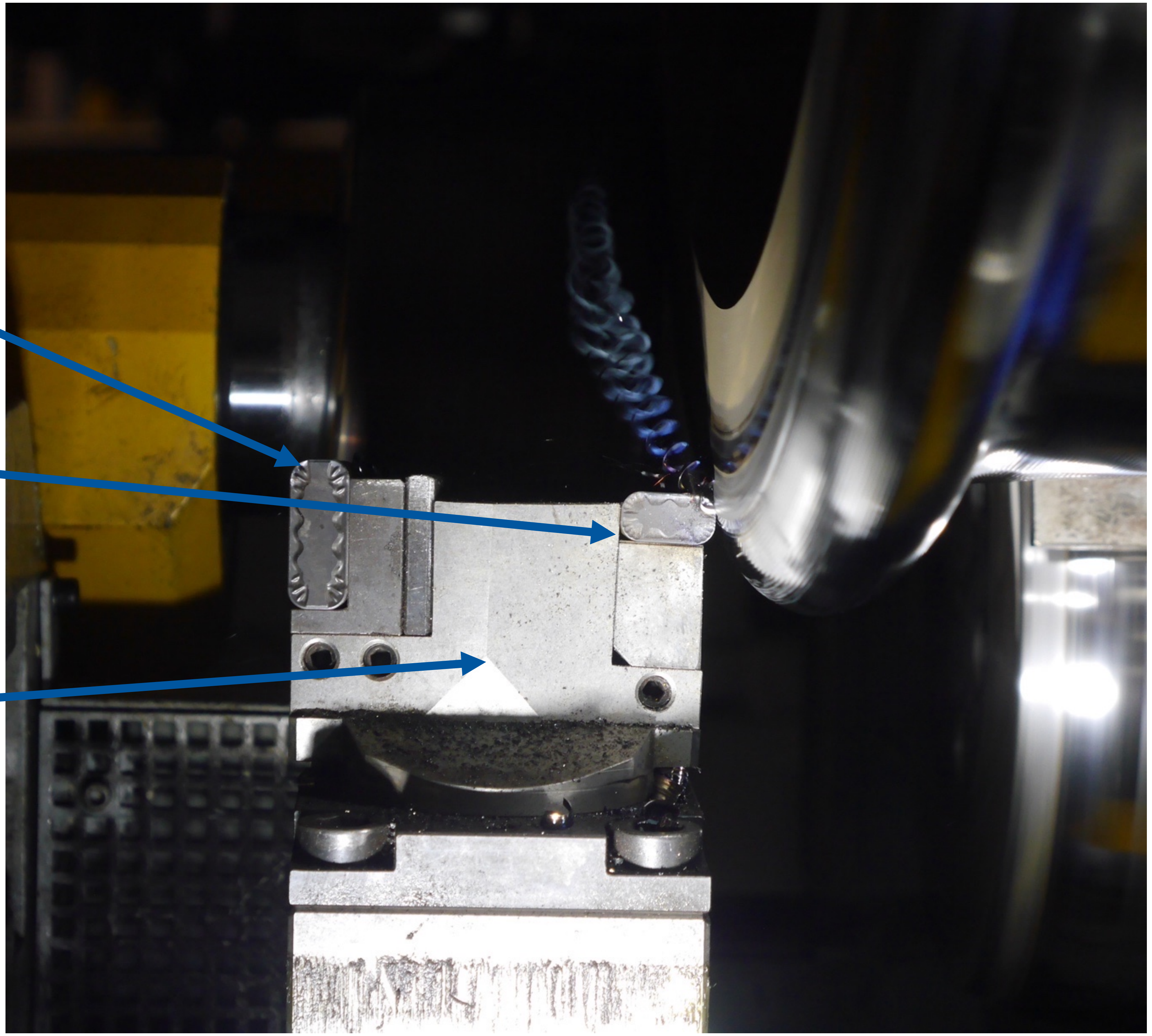


Wheel Reprofiling: Turning

Carbide Insert for Tread

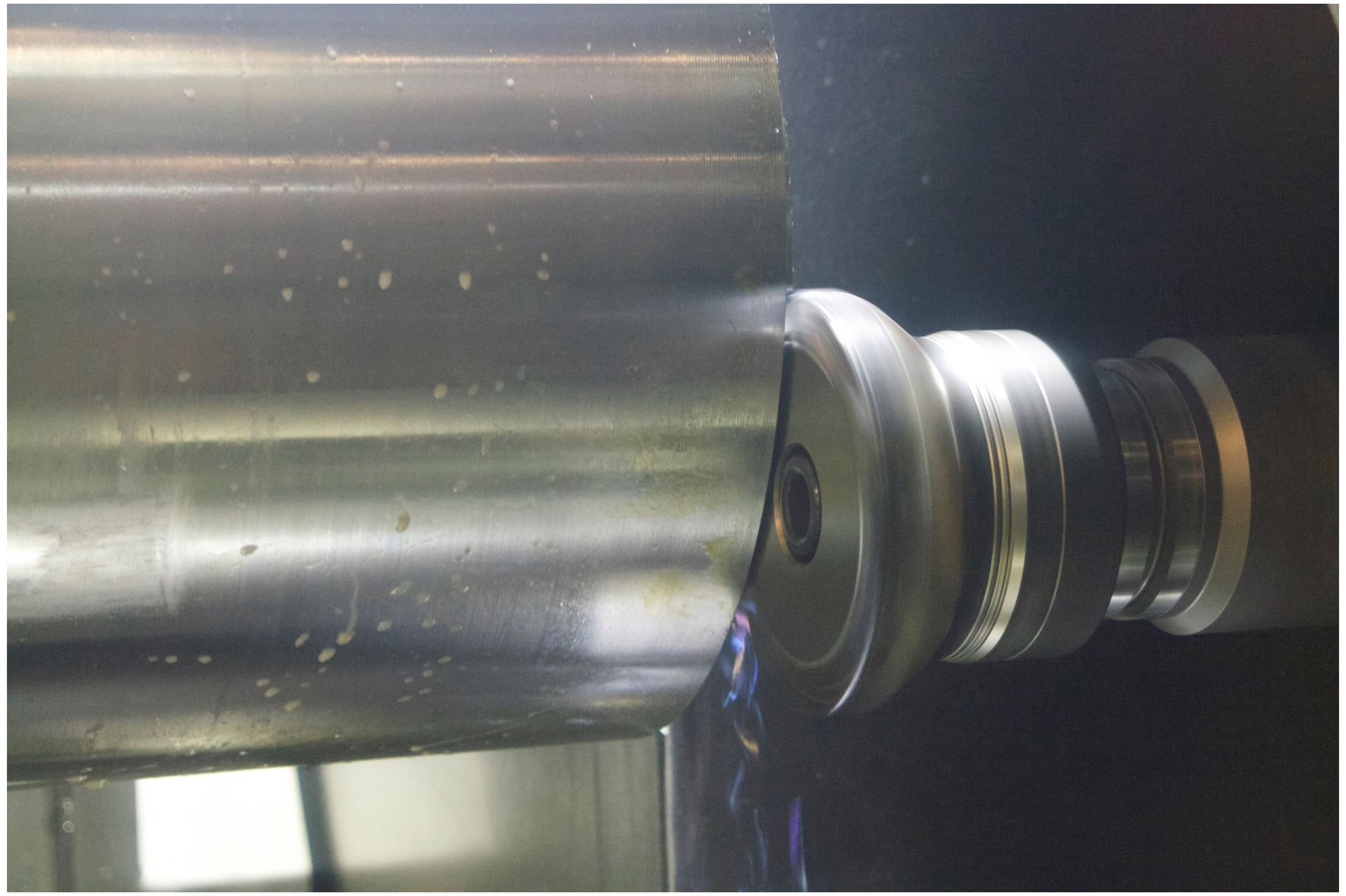
Carbide Insert for Flange

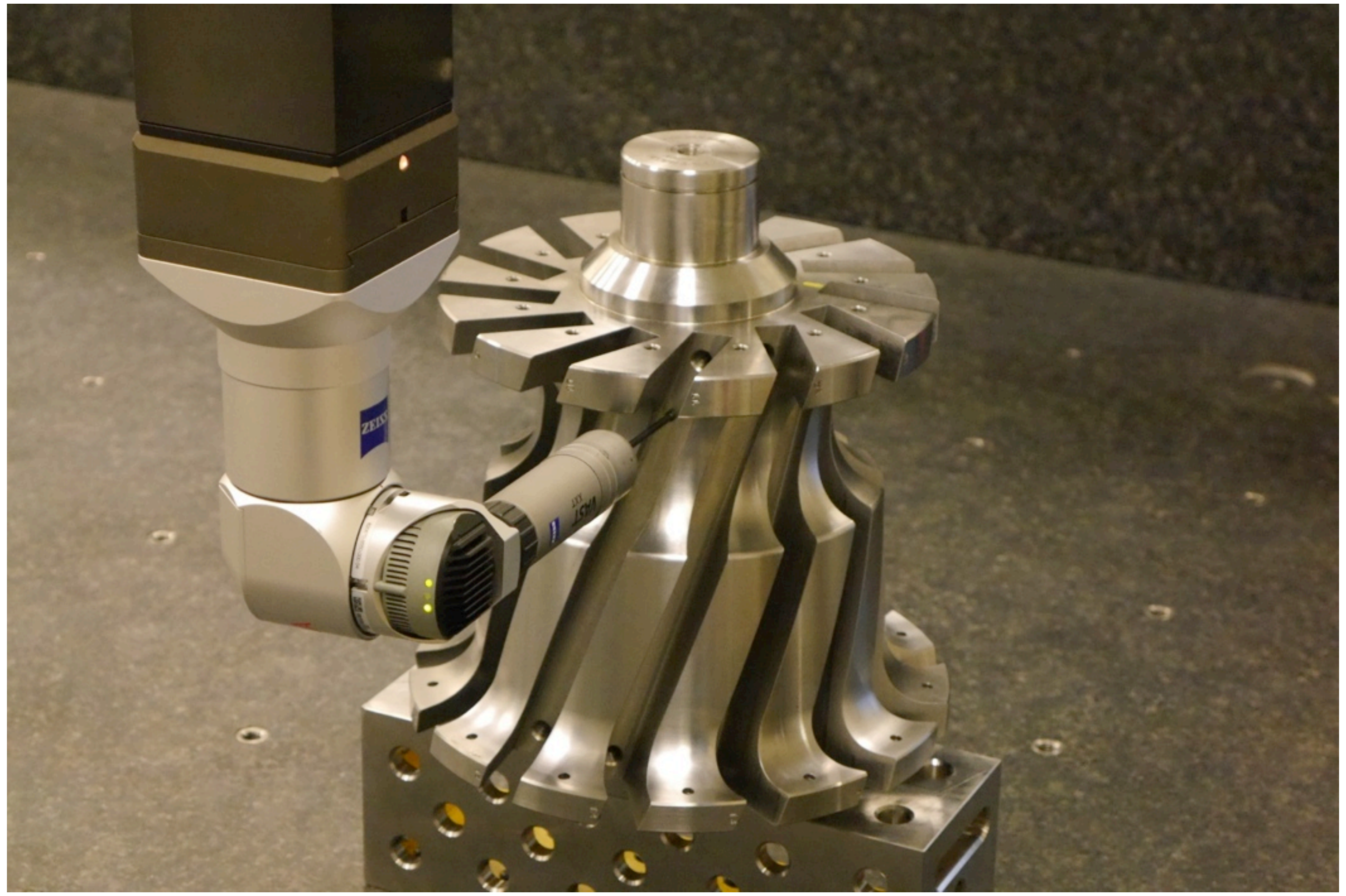
Tool Holder



Milling and Turning Technologies

- We have concluded that milling (“wheel truing”) offers the most potential for radical innovation + production gains
- Based on NSH USA’s extensive history and experience in the design, manufacture, and support of both technologies





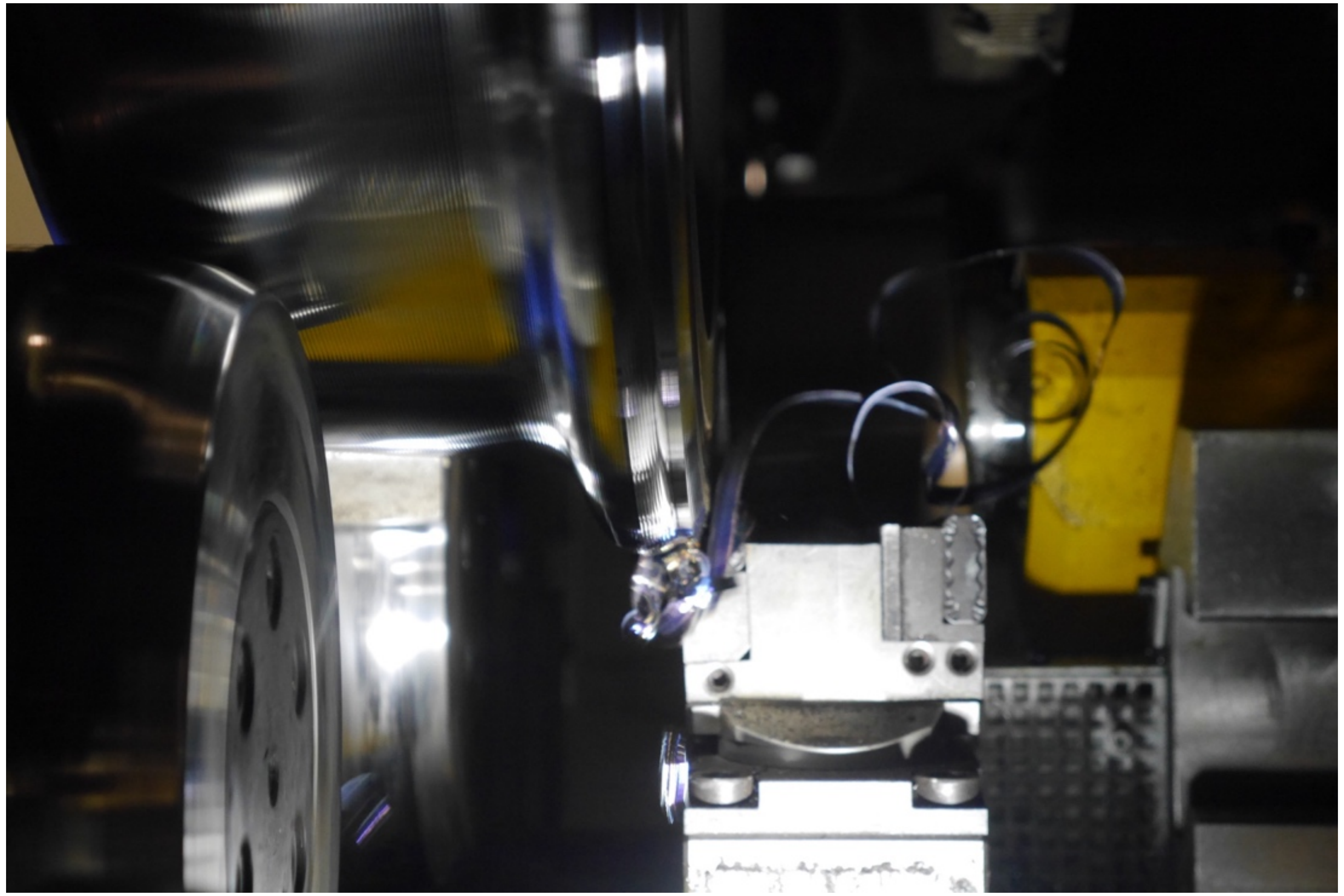
Milling and Turning Technologies

Milling Versus Turning
From Continuous Improvement Perspective

- Turning has reached its full potential with available resources

- Rotating wheel faster decreases maximum depth of cut; also creates more risk of damaging tool, particularly with wheel defects

- Decreasing speed improves insert life, permits more cut depth, but results in “stringers” and longer cycle times

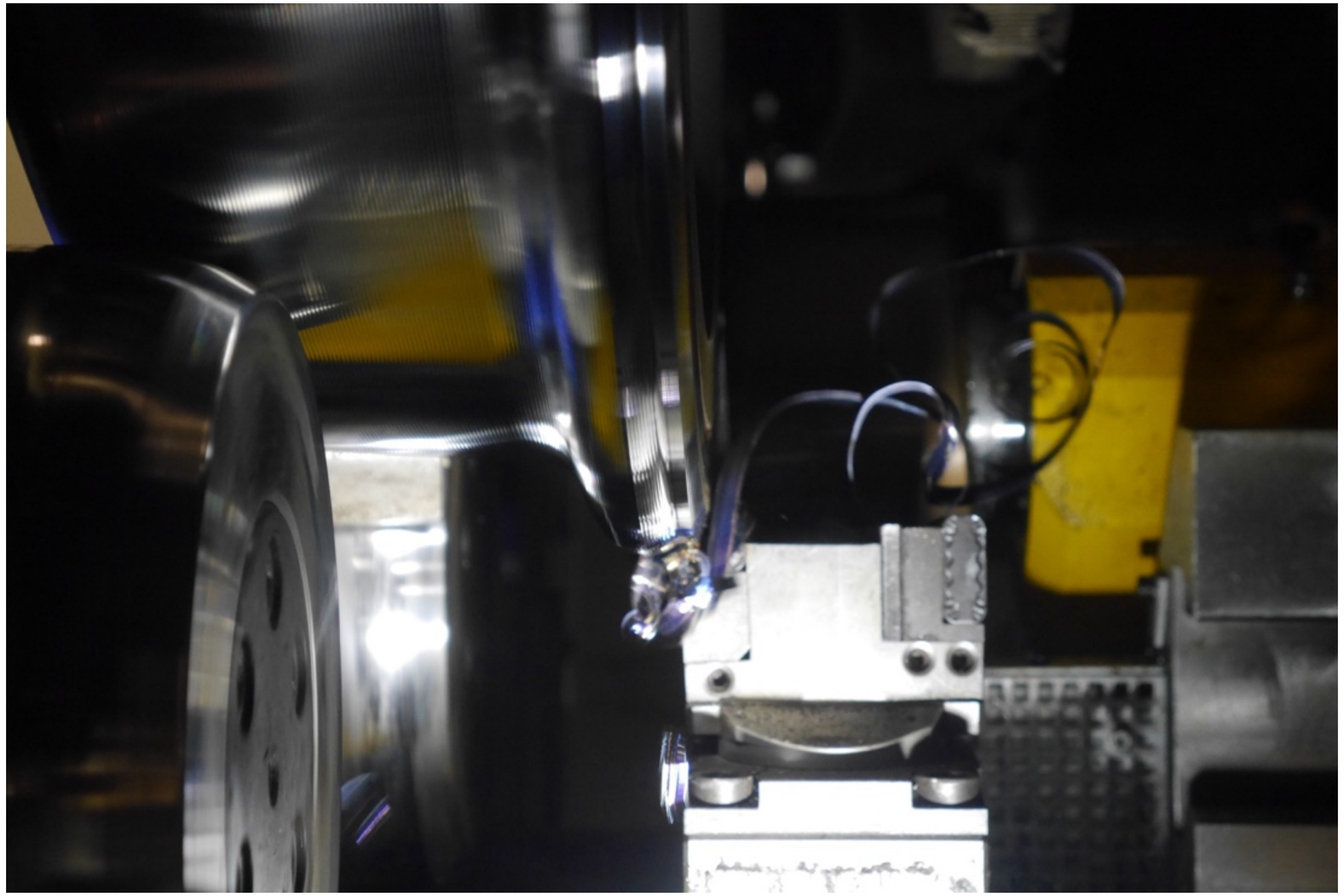


Milling and Turning Technologies

Milling Versus Turning
From Continuous Improvement Perspective

- When reprofiling surface defects such as hard spots with a lathe, increased tool pressure can fracture inserts unless the operator cuts under the defect, removing additional material

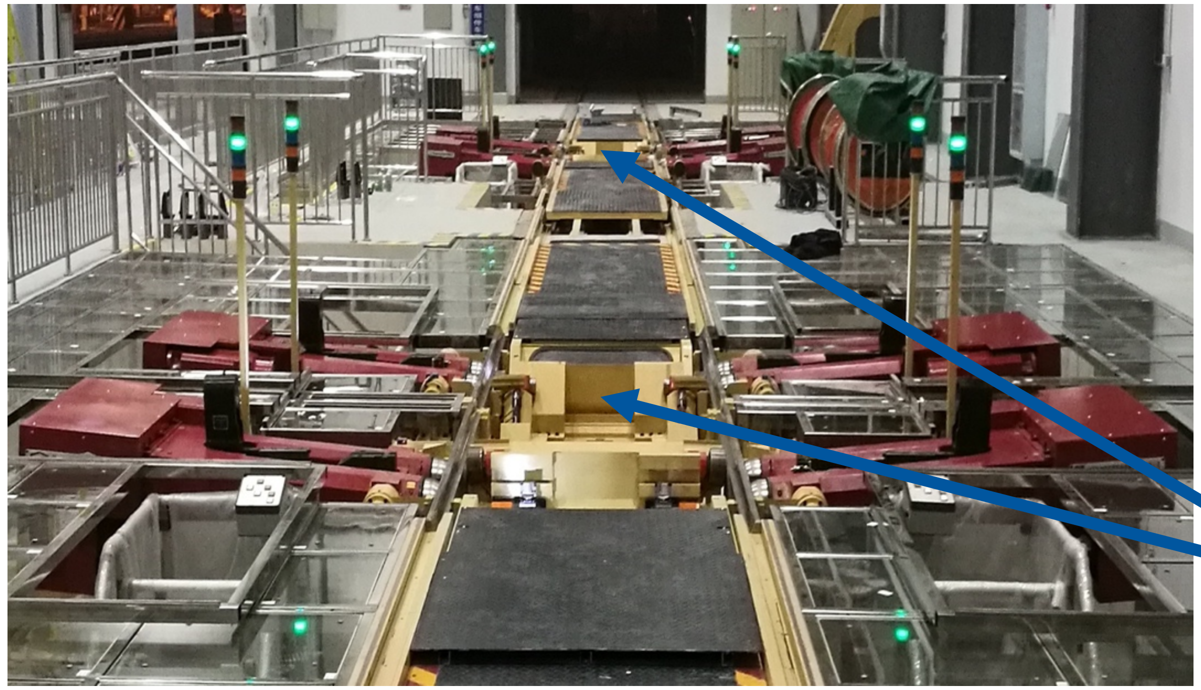
- During the turning process, cutting inserts spend all their time in the cut, generating very high temperatures and degrading the life of the insert



Milling and Turning Technologies

Milling Versus Turning
From Continuous Improvement Perspective

- With turning, the only proven way to increase productivity is by adding machines
- Costly venture that increases required square footage as well as operation and maintenance staff



4 Lathes

Milling and Turning Technologies

So, Why Milling?

- Full-profile milling manages wheel wear conditions without operator intervention while cutting
- Cuts through wheel defects (flat spots, shelling) without changing spindle speed or cut depth
- Undercutting of flat spots not necessary
- Slow workpiece rotation creates stable machining process
- Milling process creates small chips – easy to handle and safer to clean up

Milling and Turning Technologies

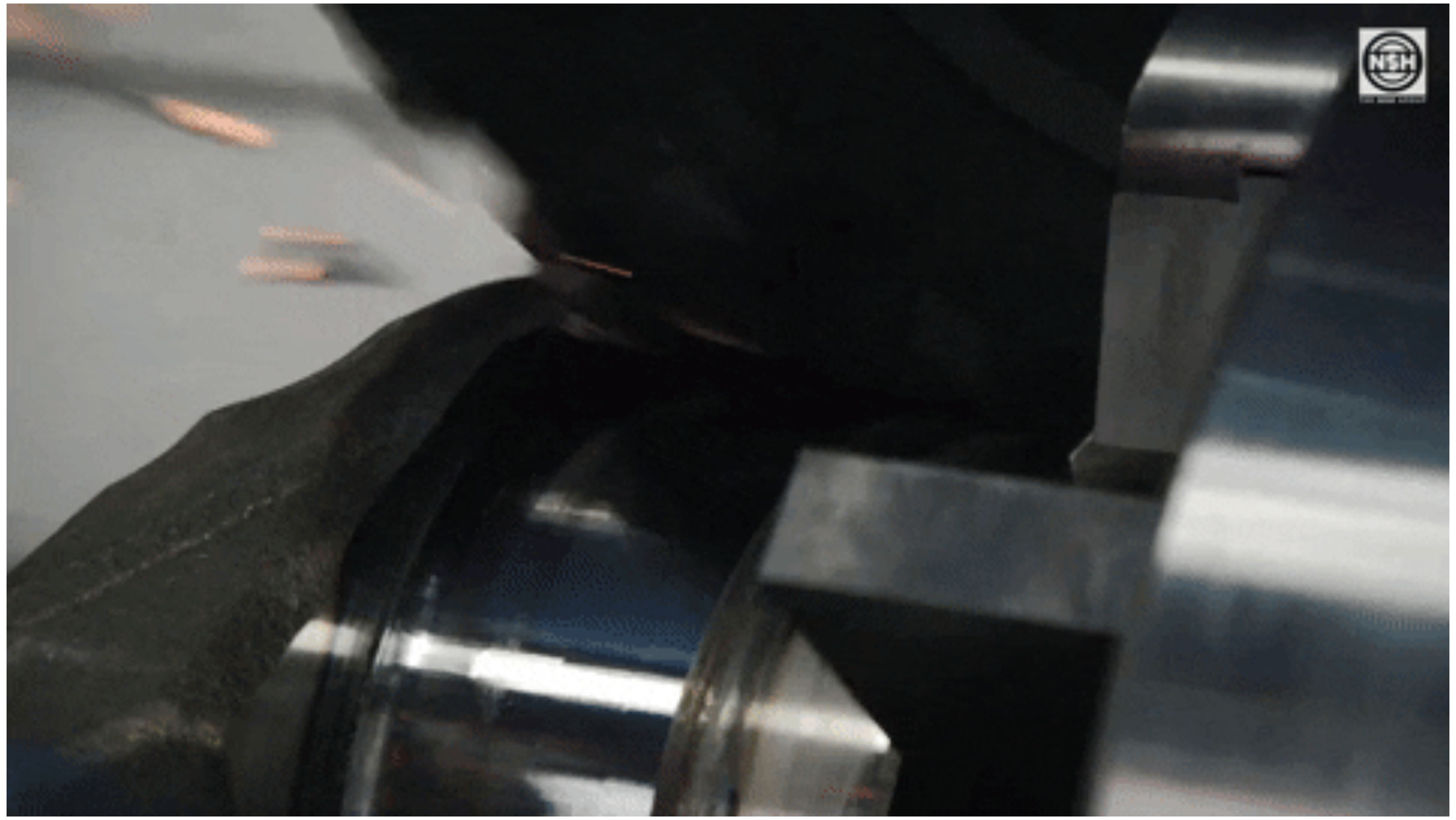
So, Why Milling?

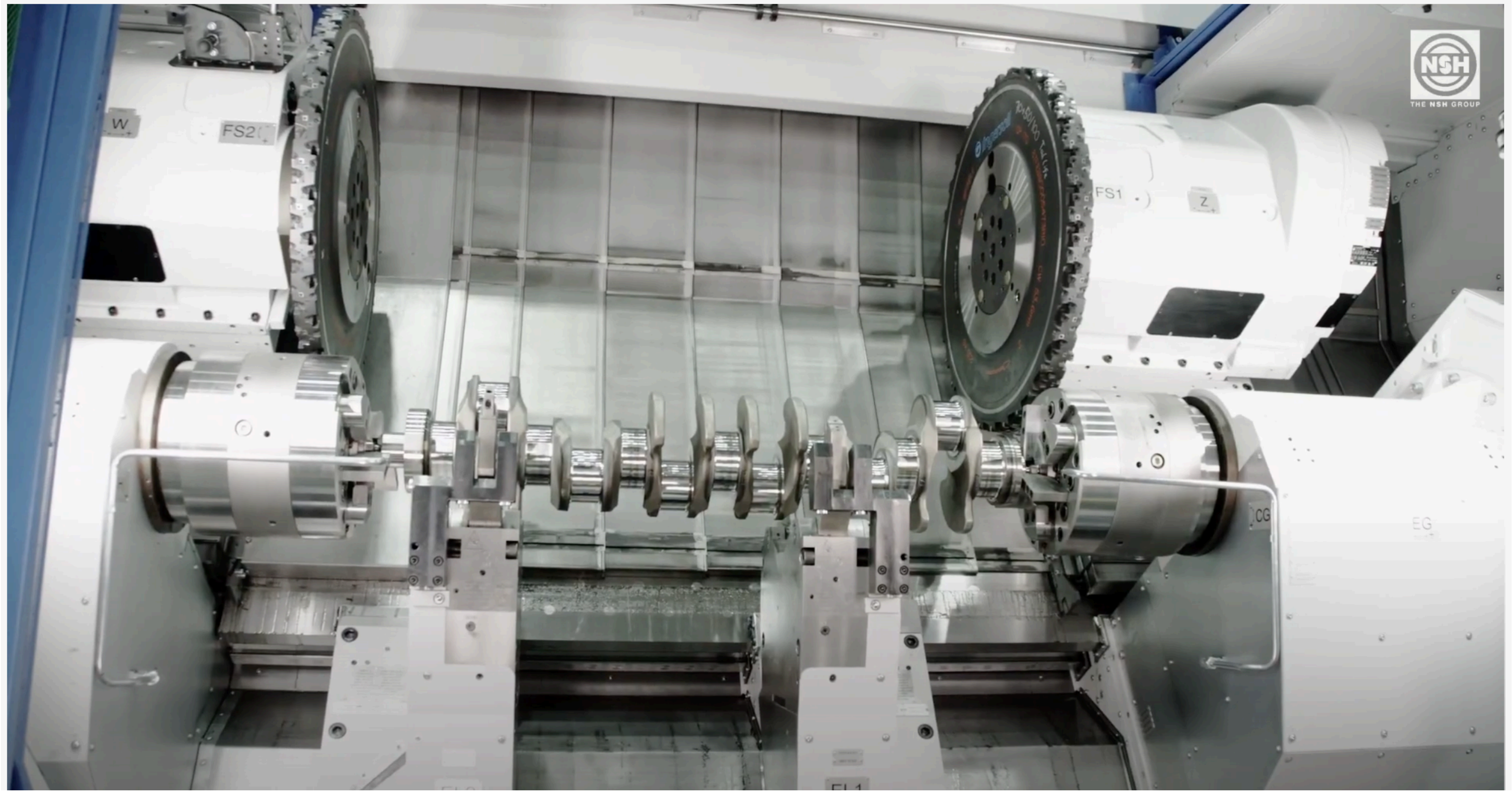
- Easier to control known and consistent spindle carriage than more massive and varying work piece
- Multiple cutting inserts better distributes heat and force during cutting process
- Tool life/consumption is comparable to turning
- Profile generation is a constant and not operator dependent
- Better platform due to drastic reduction in chances for operator error
- With the lathe, the wheel profile is the responsibility of the machine operator; with milling, the cutter is responsible for the generation of the wheel profile

Milling and Turning Technologies

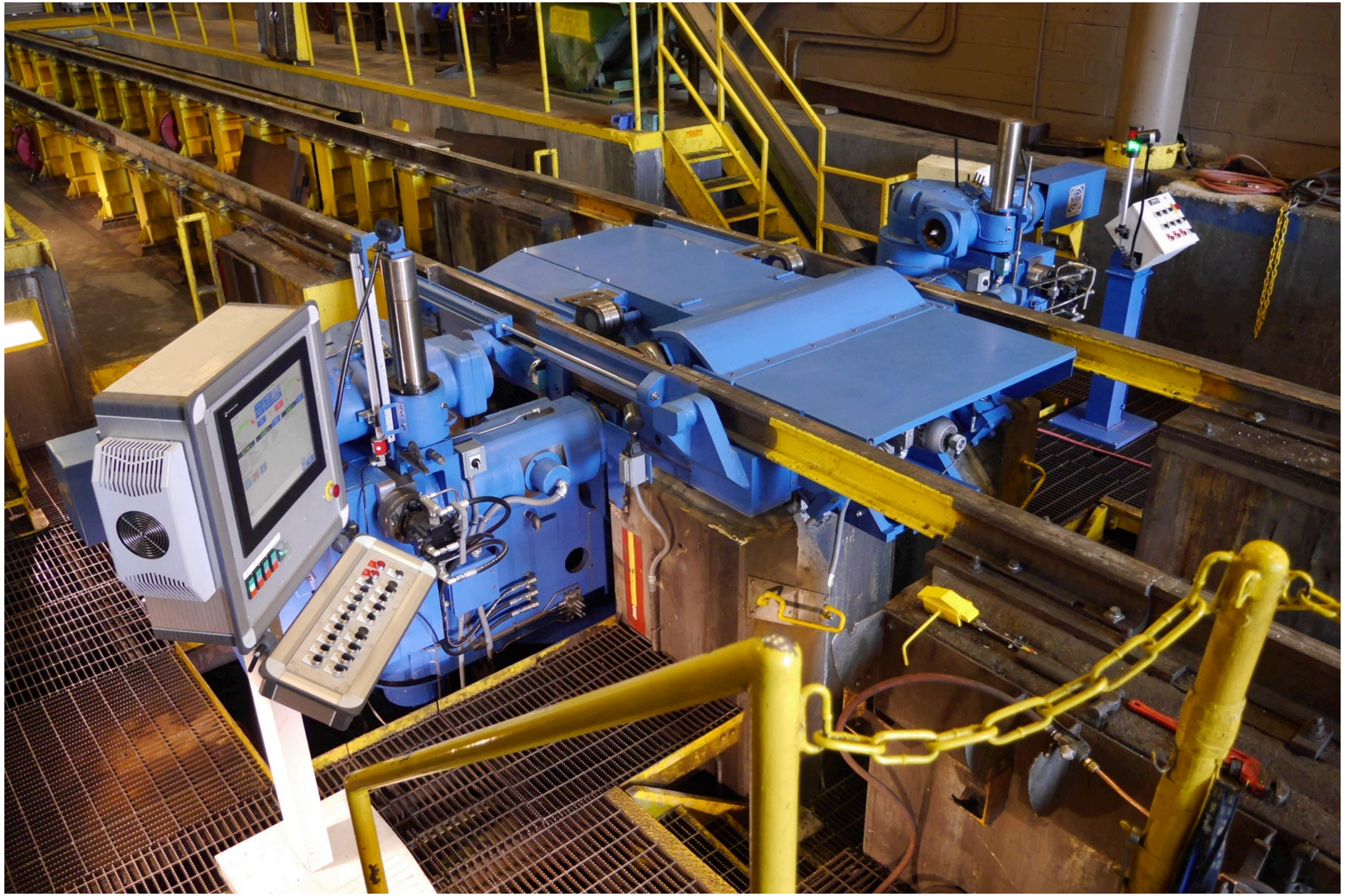
So, Why Milling?

- Looking to the general purpose machine tool world, the innovations are coming from adding milling capability to turning and/or boring centers





Underfloor Wheel Truing Machine



Wheel Truing: History and Application

- First underfloor wheel truing machine installed in 1949
- Installed in freight and heavy commuter maintenance facilities throughout North America
- Underfloor type installation historically only application of milling technology

Wheel Truing Machine #002

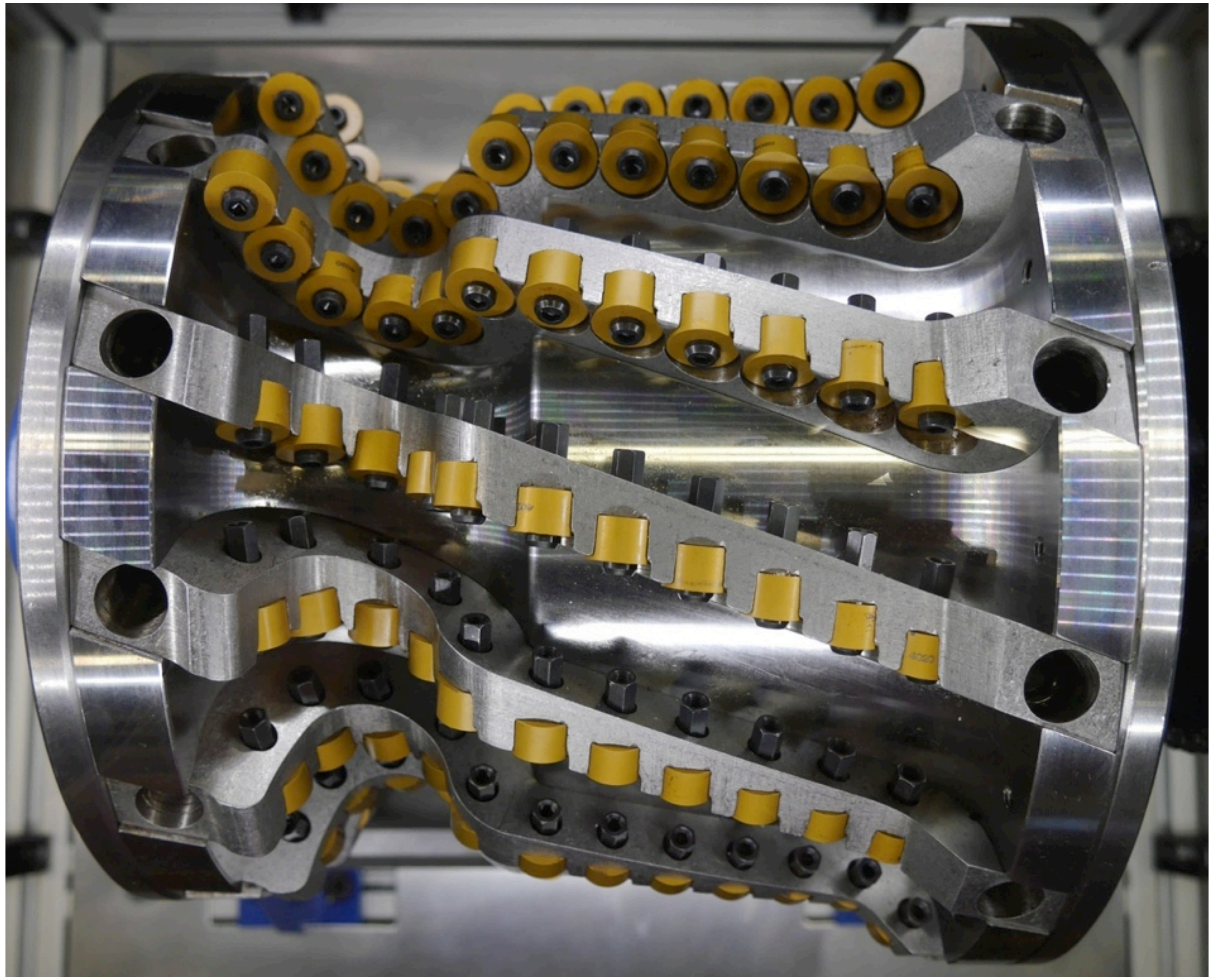
- Installed in 1951 at Pennsylvania Railroad
- Replaced 65 years later (2016) with remanufactured underfloor wheel truing machine

Wheel Truing: Traditional Cutter

- Traditional milling cutter design conceived before computer-aided design and modern manufacturing practices possible

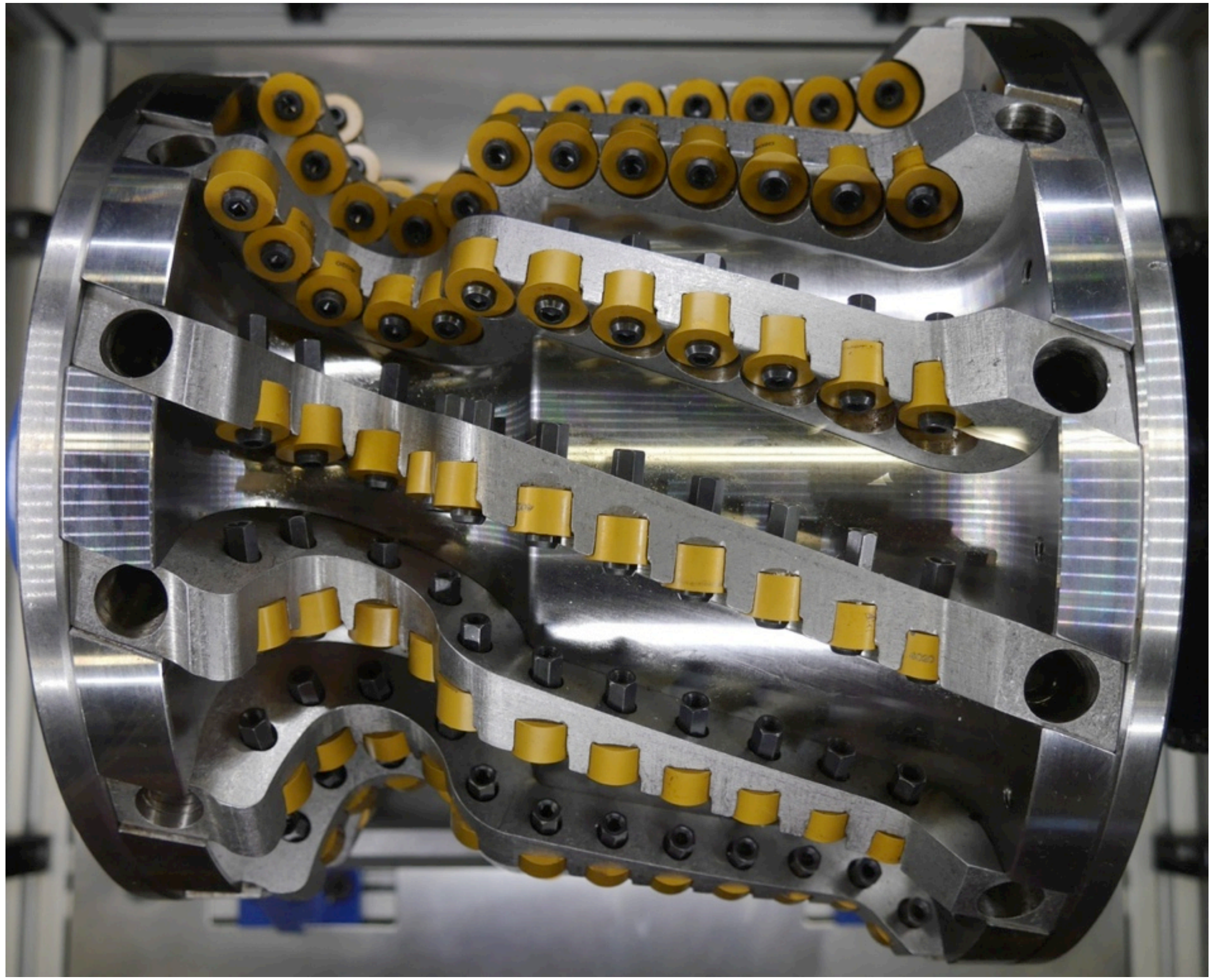
- Largely the same since initial design

- Cycle time unchanged despite decades of use: ~40 minutes (normal wheel wear)



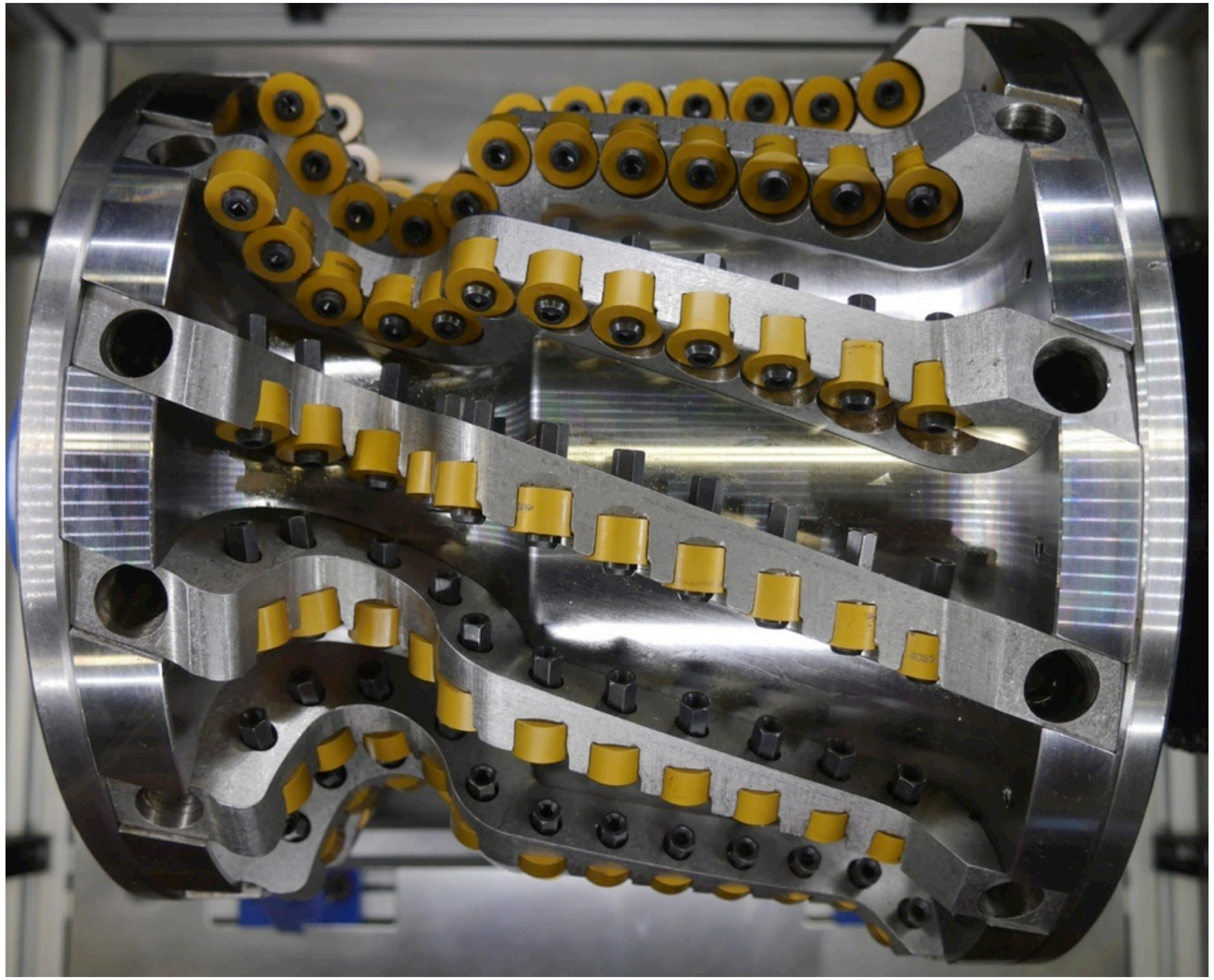
Wheel Truing: Traditional Cutter

- Traditional milling cutter consists of two options:
  - Tapered inserts: 13 blades with 12 inserts (156 inserts total)
  - Cylindrical inserts: 13 blades with 11 inserts (143 inserts total)
- In both designs, inserts and blades are identical / interchangeable



Wheel Truing: Traditional Cutter

- Single effective flute design
- It takes one full cutter revolution to generate complete wheel profile
- 2-3 inserts fully engaged in cut at any one time during machining process

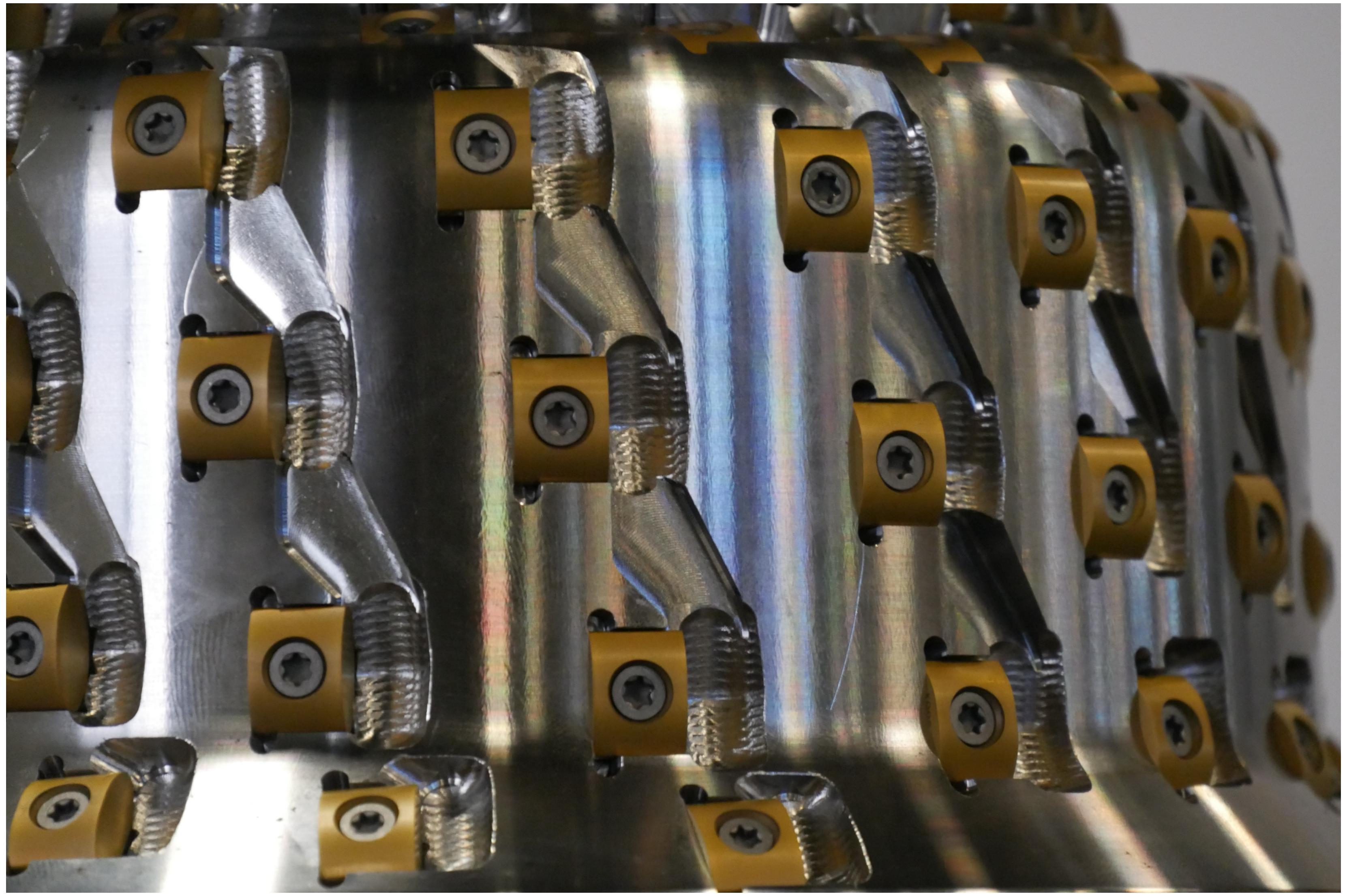


Wheel Truing: Traditional Cutter

- Single effective flute design
- It takes one full cutter revolution to generate complete wheel profile
- 2-3 inserts fully engaged in cut at any one time during machining process

Wheel Truing: Updated Cutter

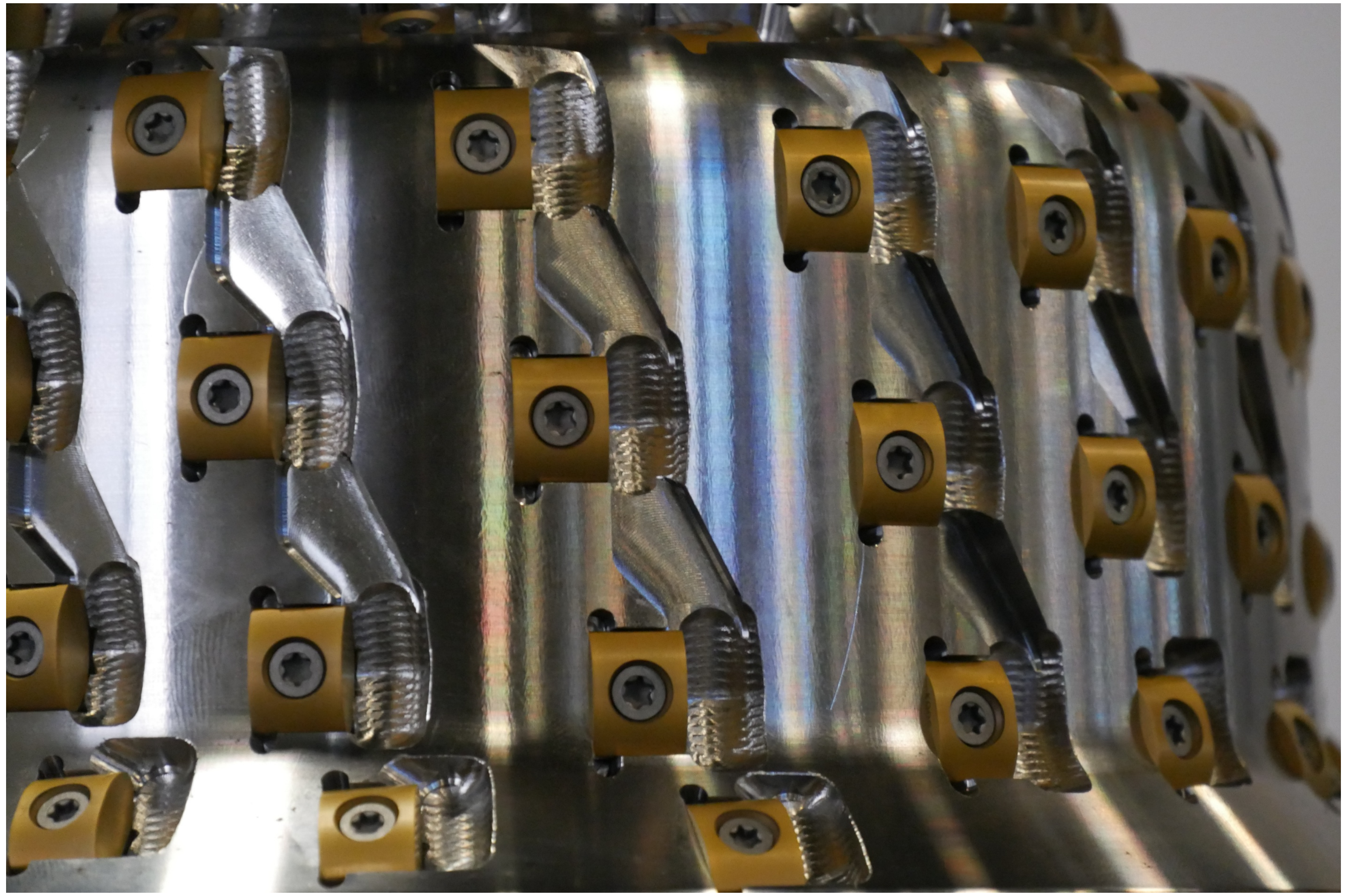
- **Cutter redesign focused on following goals:**
  - Optimal surface finish, particularly in the throat
  - Decreased cycle times without decreased production
  - Smaller/lighter cutter with improved tool clamp for easier exchange



Updated Wheel Truing Machine Cutter

Updated Wheel Truing Machine Cutter

- **Changes to Cutter Design**
  - Modern 5-Axis CNC machining and automated CMM inspection enable increased accuracy of two effective flute cutter design
  - Updated design supports improved productivity
  - Less time for vehicle maintenance, more time in revenue service



Updated Wheel Truing Machine Cutter

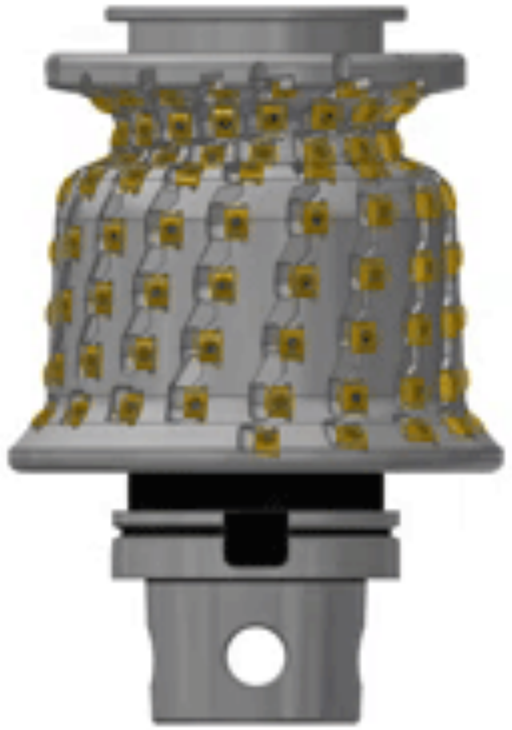
- **Two Effective Flute Design**
  - New design has two effective flutes
  - Twice as much material per revolution removed compared to current single flute design

One Flute

Two Flutes

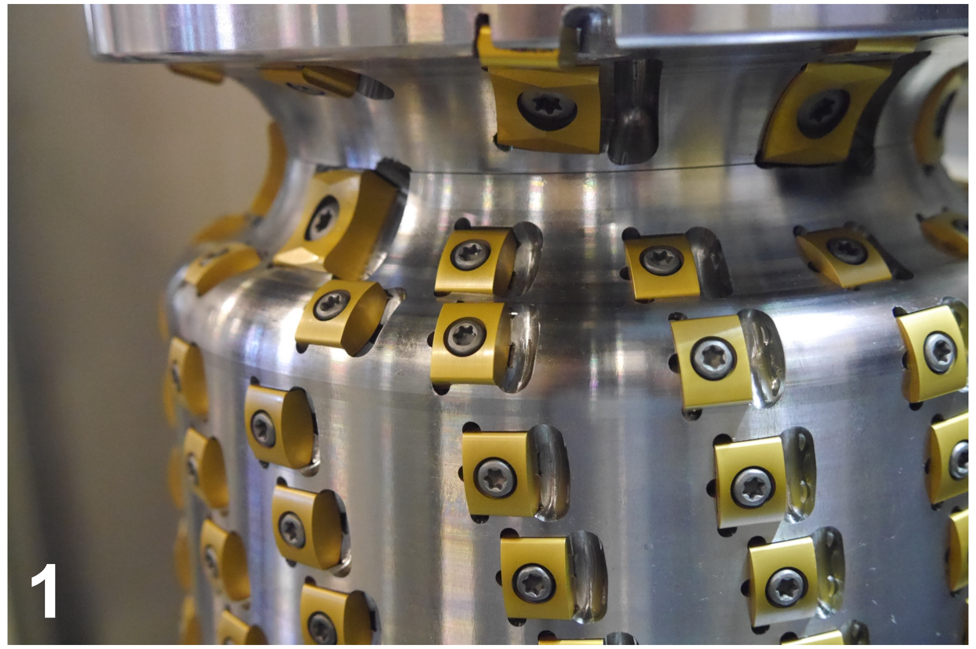
Updated Wheel Truing Machine Cutter

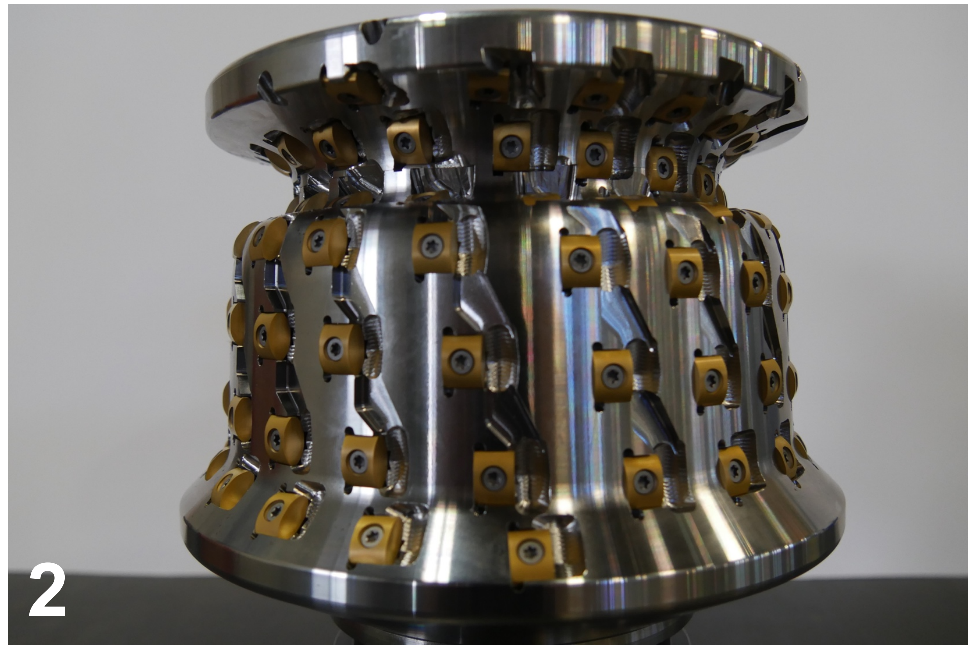
- Two Effective Flute Design



Updated Wheel Truing Machine Cutter

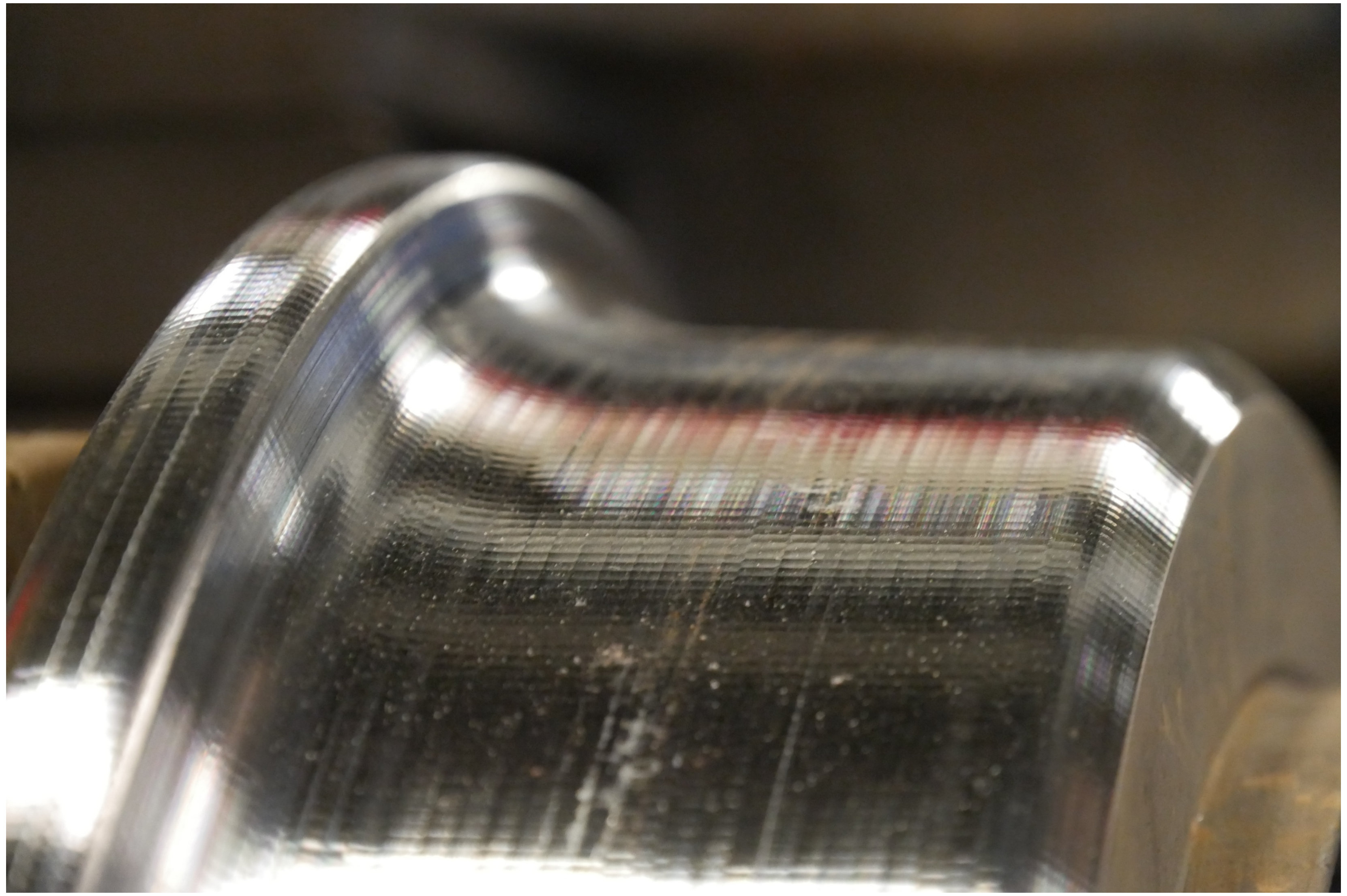
- **Continued Design Optimization**
  - First iteration of new cutter had no gullets for chip evacuation
  - Second iteration incorporates necessary gullets
  - Tread insert has also changed
  - First iteration had three different insert geometries
  - Second iteration has changed to just one, which is easier to design and should perform better





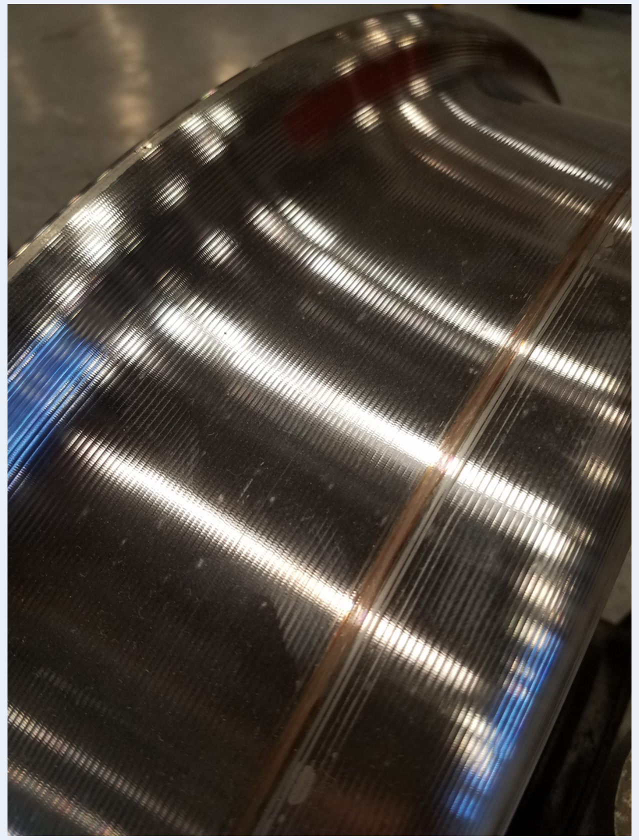
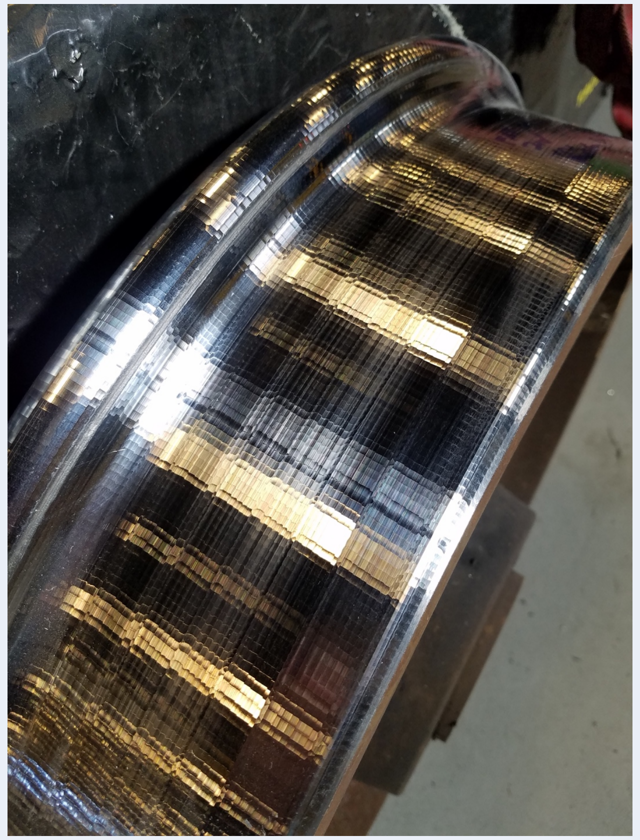
Updated Wheel Truing Machine Cutter

- **Increased Focus on Surface Finish**
  - Enhanced insert geometry as well as modern computer solid modeling lay-out tools produce more optimal wheel surface finish – particularly in flange throat
  - Flange throat area targeted for improvement



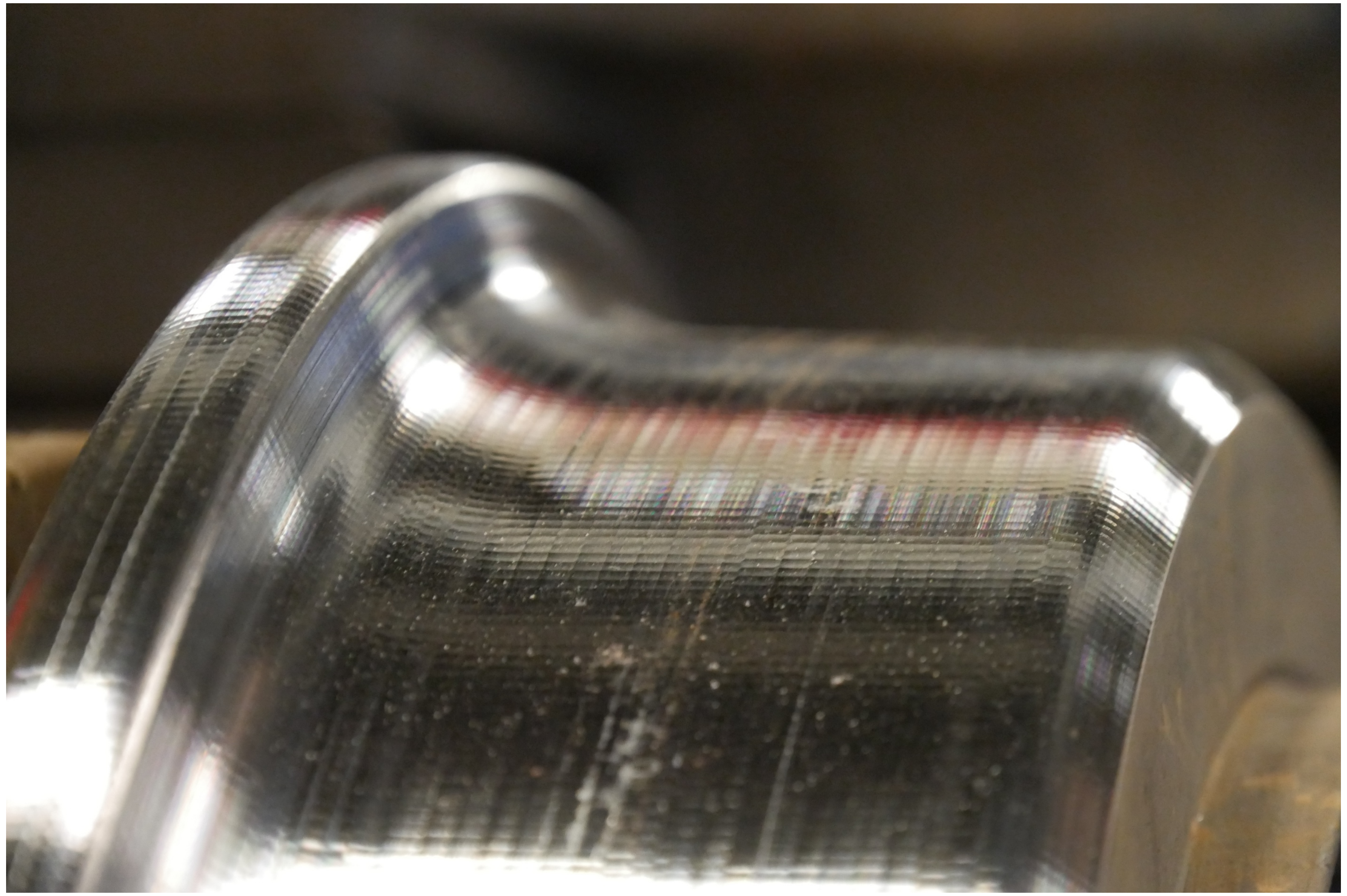
Updated Wheel Truing Machine Cutter

- **Increased Focus on Surface Finish**
  - Turning and milling profile machining produce very different visual effects

Turned Underfloor Wheel Lathe	Milled Traditional Wheel Truing Machine	Milled Updated Wheel Truing Machine
		

Updated Wheel Truing Machine Cutter

- **Increased Focus on Surface Finish**
  - Very different visual effect
  - However, surface finish (Ra) achieved by turning and milling are typically equivalent
  - Advances in milling cutter design now producing substantially better surface finish with the updated wheel truing machine than are typically produced by turning



Updated Wheel Truing Machine Cutter

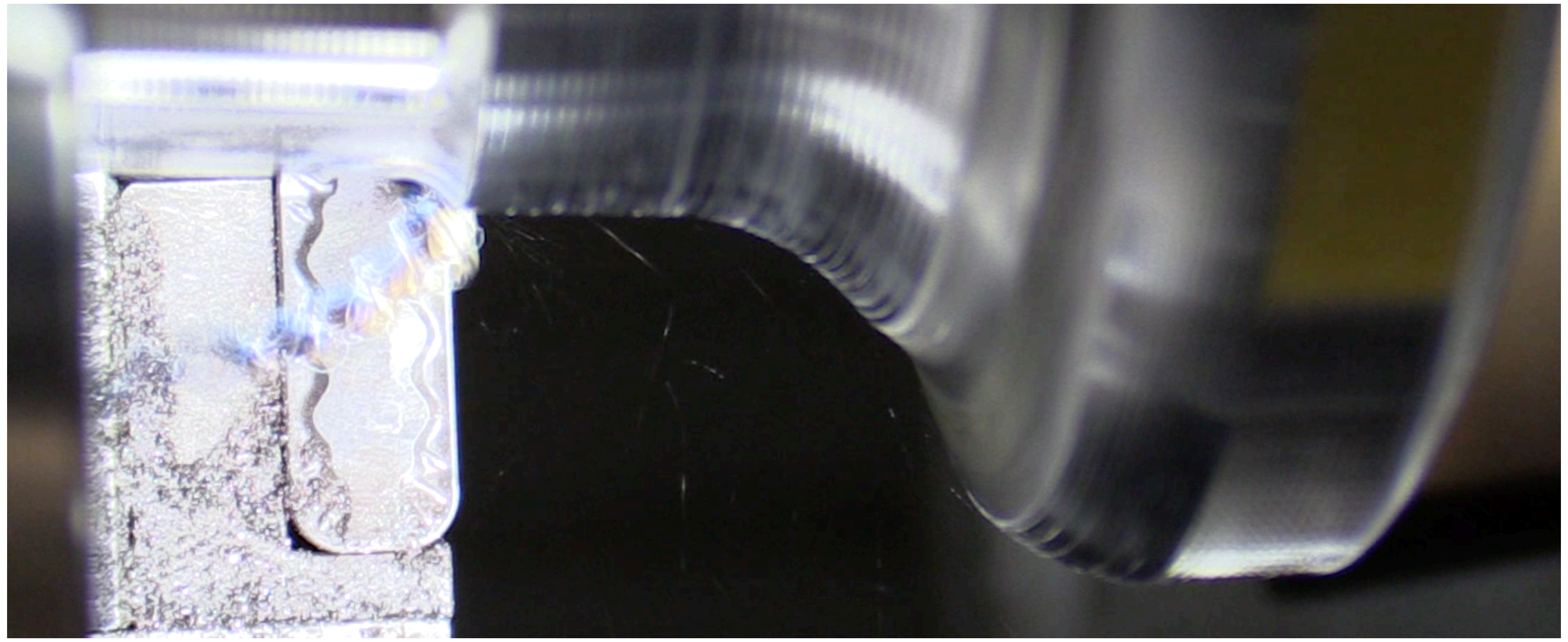
- **Increased Focus on Surface Finish**
  - Measured average roughness (Ra)

	Product Specification	Actual[1] Wheels[2]
Underfloor Wheel Lathe	≤ 472 µin Ra	157 µ-in. Ra [2]
Traditional Underfloor Wheel Truing Machine	≤ 200 µin Ra	141 µ-in. Ra [2]
Updated Wheel Truing Machine	≤ 200 µin Ra	54 µ-in. Ra [4]

- 1. Measured on tread surface in axial direction with Mahr Pocket Surf stylus-type profilometer (.195” stroke, 5 subgroups)
- 2. Number of wheels sampled based on in-house availability Feb. 2021

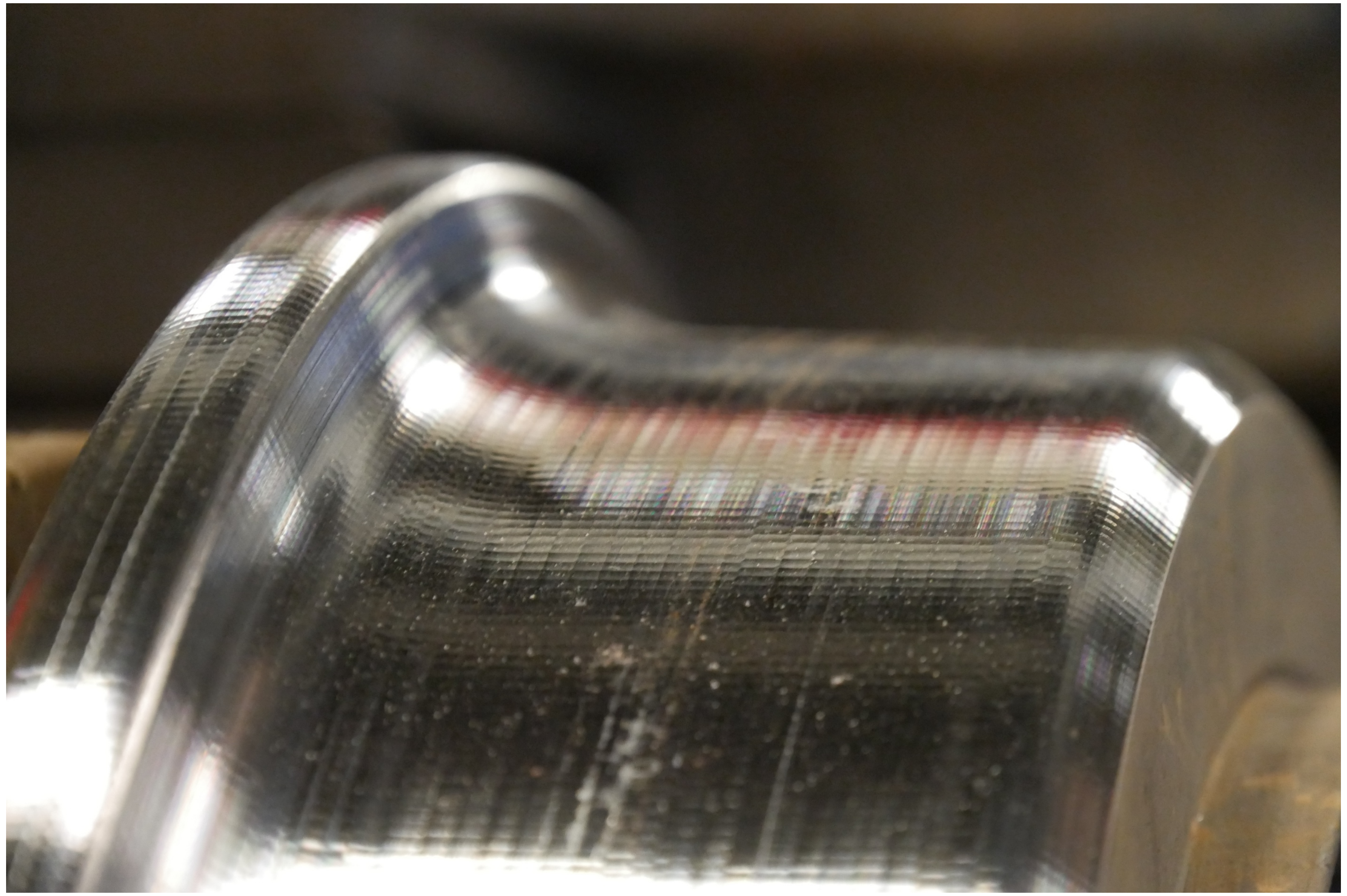
Updated Wheel Truing Machine Cutter

- **Increased Focus on Surface Finish**
  - Turning
    - Due to wiping affect of shallow angle of cutting edge, finish will be rougher on throat/flange area than tread
    - Improving finish on lathe requires slower feed rate = longer cycle time



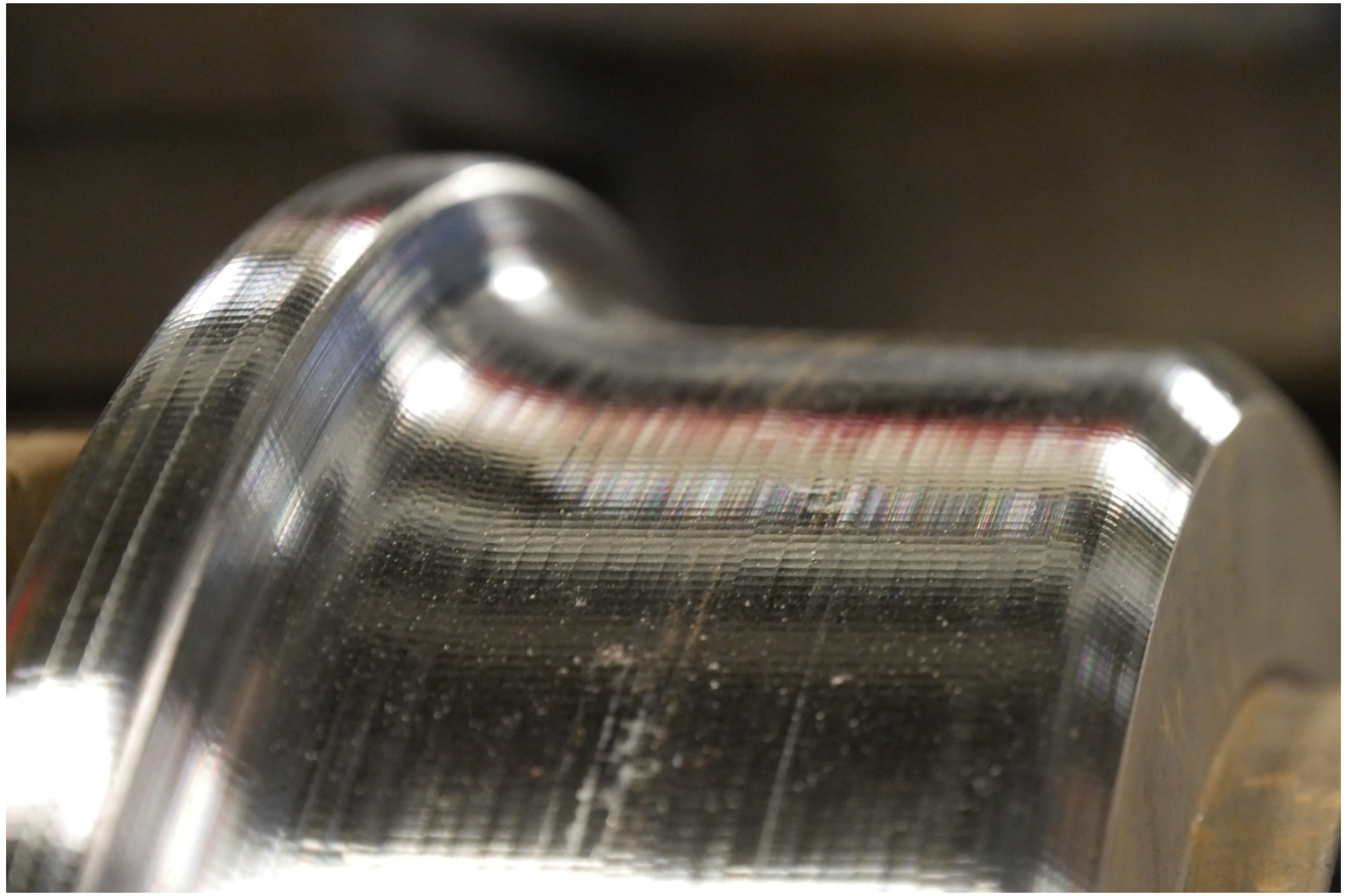
Updated Wheel Truing Machine Cutter

- **Increased Focus on Surface Finish**
  - Milling
    - Innovative patent-pending carbide insert design permits selective finish optimization while reducing cycle time
    - Finish in the throat/flange area will be better than what is measured on the tread
    - With new single insert geometry, surface finish on the tread should be similar to the throat



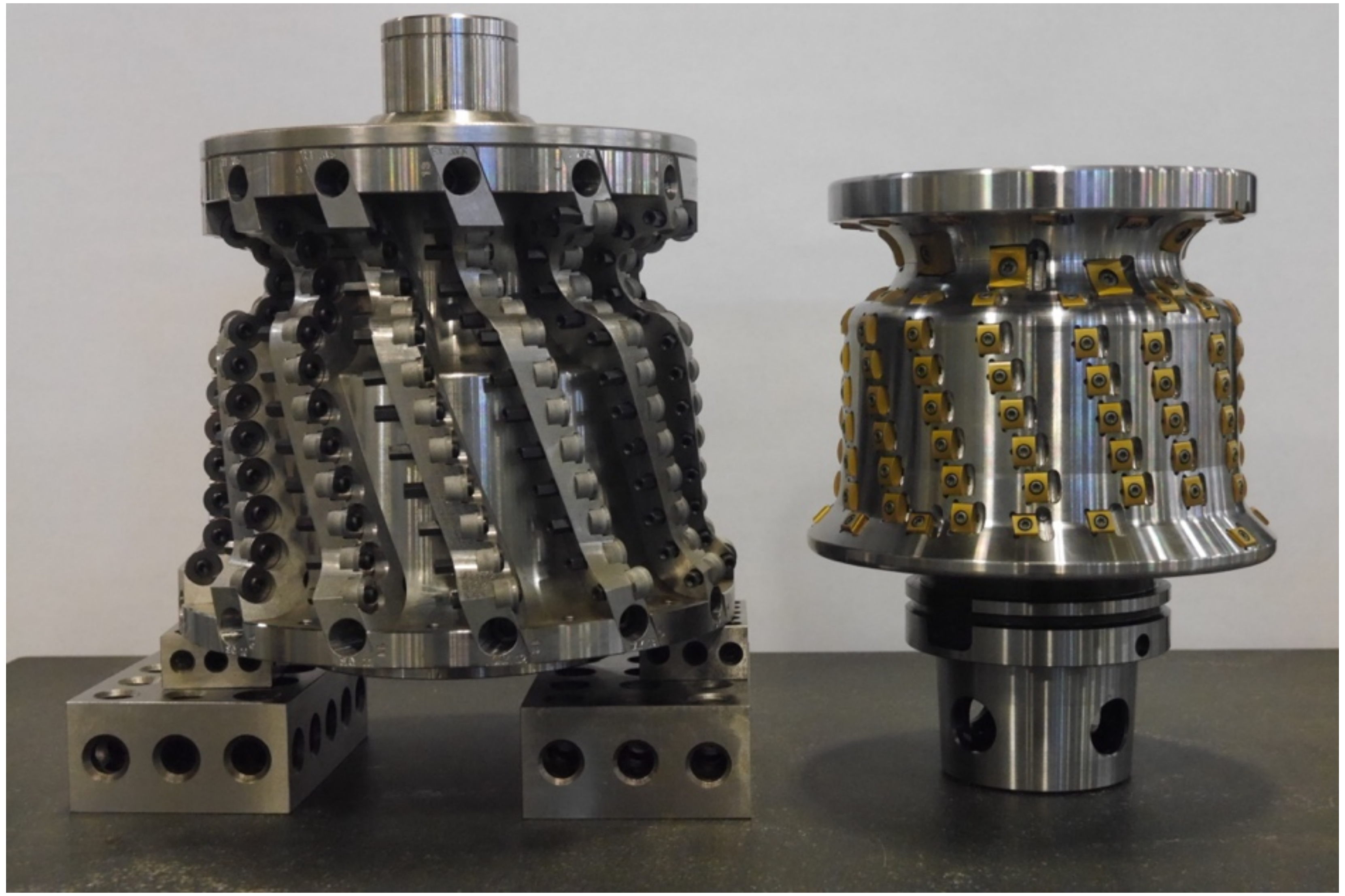
Updated Wheel Truing Machine Cutter

- **Increased Focus on Surface Finish**
  - Continued research into surface finish is hindered by currently inadequate measurement procedures



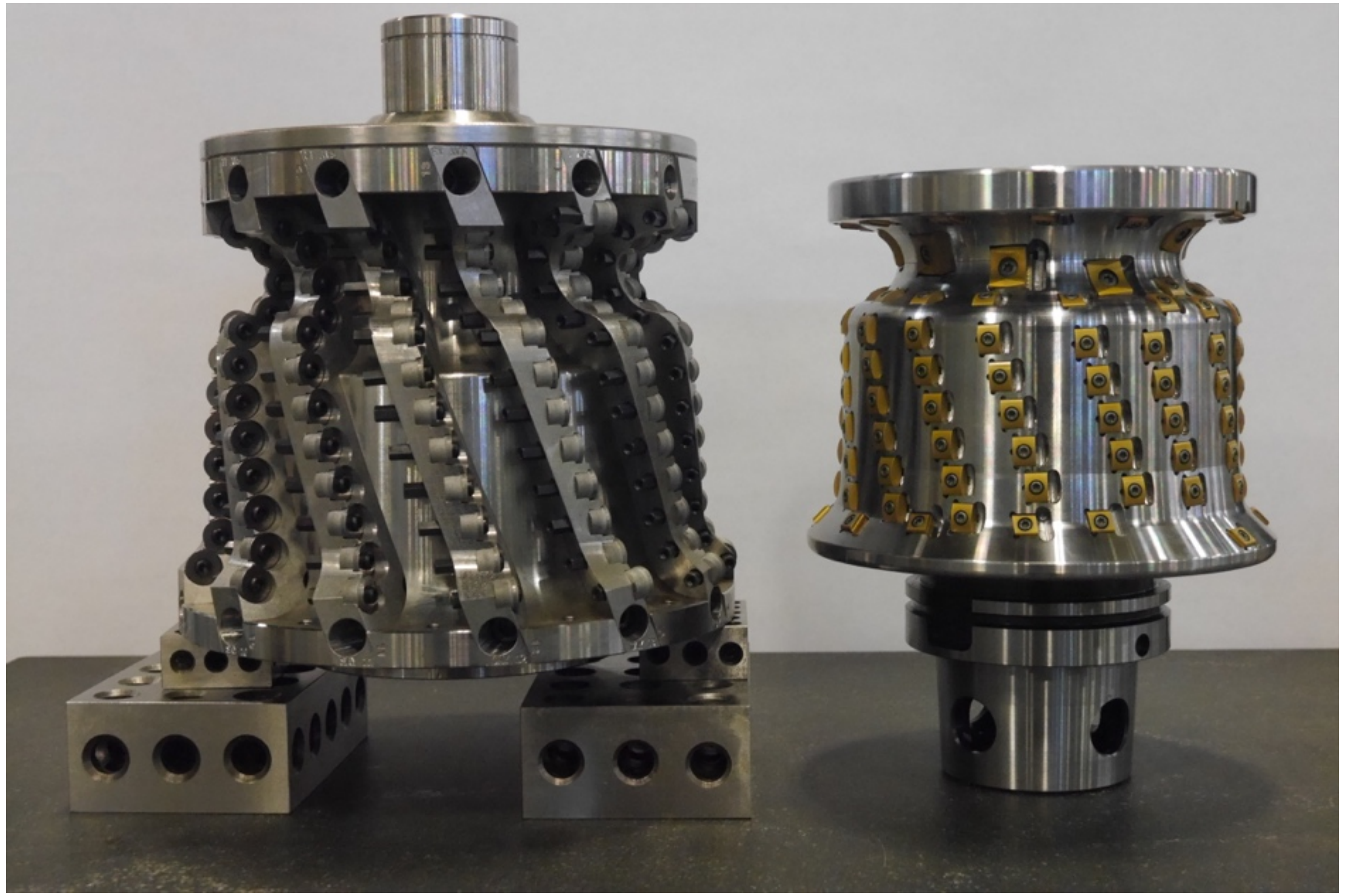
Updated Wheel Truing Machine Cutter

- **Smaller Diameter Cutter**
  - Traditional cutter body assemblies weigh ~300 lbs.
  - Can take an hour or more to exchange
  - Updated cutters are smaller, 60% lighter, and utilize quick change coupling
  - Up to two times increased wheel speed (feed rate) while achieving better surface finish



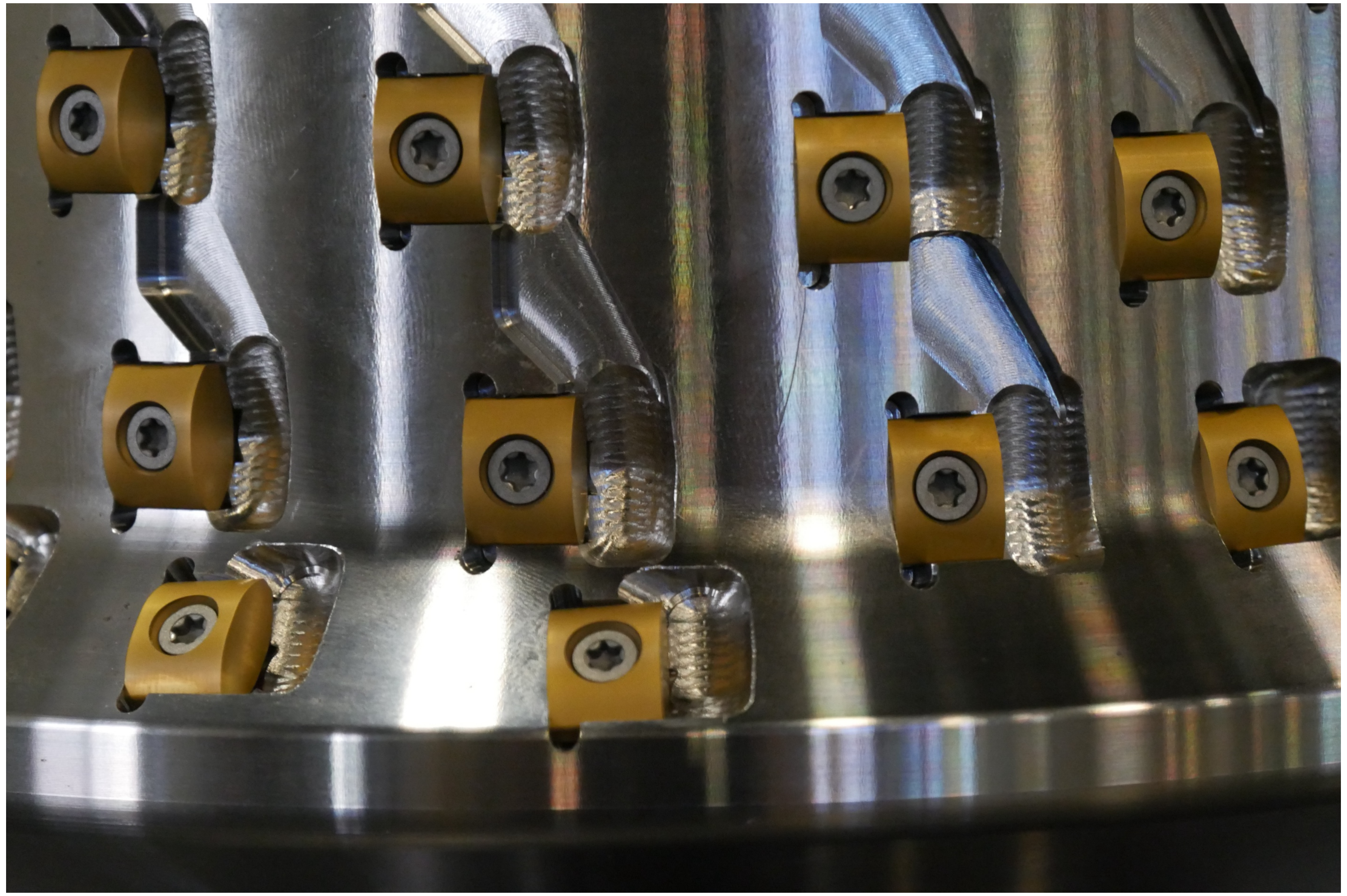
Updated Wheel Truing Machine Cutter

- **Smaller Diameter Cutter**
  - Fits between closer drive rollers needed to accommodate smaller wheel diameters
  - Allows for 40-80% increase in feed rate



Updated Wheel Truing Machine Cutter

- **Extended Tool Life**
  - Updated design places indexable carbide inserts directly onto cutter body
  - Creates stiffer, stronger tool holder – decreasing vibration and extending insert life



Updated Wheel Truing Machine Cutter

	Traditional Cutter Design	Smaller Diameter and Two Effective Flute Design
Diameter (inches)	12	8
Number of Effective Flutes	1	2
Cutter RPM	200	300
Feed Rate (in/min)	18	33
Machining Cycle Time (min)	23.7	14.22
Projected Machining Cycle Time Reduction	**0%**	**40%**

Productivity Updated Cutter Machining Cycle Time (minutes)

	Underfloor Wheel Lathe	Updated Wheel Truing Machine
Good Wheels (w/o defects, worn profile only)	20.27 min	14.22 min
Bad Wheels (flat spots, shelling, out of round)	40-42 min	19.22 min

Updated Milling Cutter
Is More Productive and Reliable

Updated Wheel Truing Machine Measurement

Updated Wheel Truing Machine Measurement

- **Measuring Pre- and Post-Machining**
  - Wheel location and diameter for cutter alignment
  - Wheel width
  - Profile – worn and reprofiled
  - Back-to-back
  - Radial runout (each wheel)
  - Axial runout (each wheel)

Updated Wheel Truing Machine Measurement

- **Measuring Pre- and Post-Machining**
  - Less chance for operator error
  - Better pre-machining measurement data = more precise machining process and less service metal removed
  - Measurement data can be stored and evaluated

Updated Wheel Truing Technology

Next Steps

- Better methods for measuring surface finish on wheel, as current methods are flawed
- Continue collecting data
  - Machining cycle times
  - Cutting insert livelihood
  - Wheel defect machining differences between milling and turning

Questions?