Wheel Truing Technology Development and Innovations

Simmons Machine Tool Corporation
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Albany, New York, USA | smtgroup.com
A Need For Innovation

Computer Hard Drive Cost Per Gigabyte Of Storage (2014)

Source: http://www.mkomo.com/cost-per-gigabyte-update
A Need
For Innovation

(millions of revenue ton-miles per mile of railroad)

'M80 '82 '84 '86 '88 '90 '92 '94 '96 '98 '00 '02 '04 '06 '08 '10 '12

Miles = route-miles owned  Data are for Class I railroads.  Source: AAR
Much of railway industry leveraging new technologies to improve production, efficiency, and safety:
- Positive train control
- Autonomous operation
- Automatic track and rolling stock inspection
- Digital wheel profile and defect detection

Wheel reprofiling has largely languished for several decades without significant production increases

To keep pace with the rest of the industry, innovation is critical.
What Is Wheel Reprofiling?

• Machining process to remove defects from a wheel to return the 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
Wheel Reprofiling: Turning

- Cutting tool is stationary
- Workpiece (wheel) rotates rapidly
- Single point machining
Wheel Reprofiling: Turning

- Carbide Insert for Tread
- Carbide Insert for Flange
- Tool Holder
Milling and Turning Technologies

• Presentation focuses on innovations to milling process but first lets point out some details about turning
Milling and Turning Technologies

Downside of Turning?

- Turning has reached its full potential with the available materials.
- Rotating wheel faster decreases maximum depth of cut and creates more risk of damaging tool, particularly with wheel defects.
- Decreasing speed allows greater depth of cut, but results in “stringers” and longer cycle times.
Milling and Turning Technologies

Other turning difficulties?

- With turning, the only proven way to increase productivity is by adding machines
- High cost
- Increases required square footage

4 Lathes
Milling and Turning Technologies

Why milling?

- With turning, cut depth and feed rate must decrease to prevent tool breakage. With milling, this is not the case.
Milling and Turning Technologies

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 rotational speed produces stable machining process
- Easy to set-up, operate and maintain
- Milling process creates small chips – easy to handle and safer to clean up
## Tooling Cost Comparison

**Minimal Wear (“Good Wheels”)**

<table>
<thead>
<tr>
<th></th>
<th>Underfloor Wheel Lathe</th>
<th>Stanray TN-84C Underfloor Wheel Truing Machine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tread Insert</td>
<td>Flange Insert</td>
</tr>
<tr>
<td>Wheel Sets Per Index</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Wheel Sets Per Insert</td>
<td>8</td>
<td>48</td>
</tr>
<tr>
<td>Insert Costs (USD)</td>
<td>$150</td>
<td>$110</td>
</tr>
<tr>
<td>Insert Cost Per Wheel Set</td>
<td>$18.75</td>
<td>$2.29</td>
</tr>
<tr>
<td>Labor To Index Tooling (minutes)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Labor To Index Per Wheel Set (minutes)</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>Labor Cost Per Wheel Set ($30/hour)</td>
<td>$1.50</td>
<td>$0.25</td>
</tr>
<tr>
<td>Total Cost Per Wheel Set (USD)</td>
<td></td>
<td>$22.79</td>
</tr>
</tbody>
</table>
Wheel Truing: History and Application

- First underfloor machine installed in 1949
- Installed in freight and commuter maintenance facilities throughout North America
- Underfloor type installation historically the only application of milling technology
- Machine #2 installed in 1951 at Norfolk Southern’s Enola shop
- Replaced 55 years later (2016) with remanufactured Stanray TN-84C
Designed, manufactured, and assembled in Albany, NY, USA
Wheel Truing Cutter
Wheel Truing Cutter

- Original milling cutter design conceived before computer-aided design and modern manufacturing practices possible
- Largely the same since initial design
- Cycle time stagnant despite decades of use: ~40 minutes (normal wheel wear conditions)
Wheel Truing Measurement

• Using manual tools: AAR finger gage
• Measurement results can vary between operators
Wheel Truing Clamping

- Wheel set held rigidly on centers
- Requires access to axle center holes
- Increases required machine mass
Updated Wheel Truing Technology
Updated Milling Cutter
Updated Milling Cutter

- Changes to cutter design
  - Increased productivity:
    - New design has two effective flutes
    - Twice as much material per revolution removed compared to current single flute design
Updated Milling Cutter

• Changes to cutter design
  • Better surface finish:
    • Enhanced insert geometry as well as modern computer solid modeling lay-out tools produce a more optimal wheel surface finish especially in throat of flange
Updated Milling Cutter

• Changes to cutter design
  • Easier wheel profile exchange:
    • Current cutter body assemblies weigh ~300 lbs
    • Can take an hour or more to exchange
    • New cutters are smaller, 60% lighter, and utilize a quick change coupling
Updated Milling Cutter

• **Changes to cutter design**
  • Increased tool life:
    • New design places indexable carbide inserts directly onto cutter body
    • Creates stiffer, stronger tool holder - extending insert life
# Updated Milling Cutter

<table>
<thead>
<tr>
<th></th>
<th>Current Cutter Design</th>
<th>Smaller Diameter and Two Effective Flute Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (inches)</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Number of Effective Flutes</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Cutter RPM</td>
<td>239</td>
<td>358</td>
</tr>
<tr>
<td>Feed Rate (in/min)</td>
<td>4.8</td>
<td>14.3</td>
</tr>
<tr>
<td>Machining Cycle Time (min)</td>
<td>23.7</td>
<td>14.22</td>
</tr>
<tr>
<td>Projected Machining Cycle Time Reduction</td>
<td>0%</td>
<td>40%</td>
</tr>
</tbody>
</table>
Updated Milling Cutter

- **Changes to cutter design**
  - Modern computer-aided design and digital manufacturing practices (e.g. 5 Axis CNC machining and automated CMM inspection) enable double effective flute cutter design
  - New design supports improved productivity
  - Less time for vehicle maintenance, more time in revenue service
# Tooling Cost Comparison

## Minimal Wear ("Good Wheels")

<table>
<thead>
<tr>
<th></th>
<th>Underfloor Wheel Lathe</th>
<th>Current Underfloor Wheel Truing Machine</th>
<th>Updated Wheel Truing Machine (Projected)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tread Insert</td>
<td>Flange Insert</td>
<td>Cylindrical Insert</td>
</tr>
<tr>
<td>Wheel Sets Per Index</td>
<td>1</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>Wheel Sets Per Insert</td>
<td>8</td>
<td>48</td>
<td>72</td>
</tr>
<tr>
<td>Insert Costs (USD)</td>
<td>$150</td>
<td>$110</td>
<td>$1500</td>
</tr>
<tr>
<td>Insert Cost Per Wheel Set</td>
<td>$18.75</td>
<td>$2.29</td>
<td>$20.83</td>
</tr>
<tr>
<td>Labor To Index Tooling (minutes)</td>
<td>3</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>Labor To Index Per Wheel Set (minutes)</td>
<td>3</td>
<td>0.5</td>
<td>1.67</td>
</tr>
<tr>
<td>Labor Cost Per Wheel Set ($30/hour)</td>
<td>$1.50</td>
<td>$0.25</td>
<td>$0.83</td>
</tr>
<tr>
<td>Total Cost Per Wheel Set (USD)</td>
<td>$22.79</td>
<td>$21.67</td>
<td>≤$21.67</td>
</tr>
</tbody>
</table>
### Productivity Updated Cutter Machining Cycle Time (minutes)

<table>
<thead>
<tr>
<th></th>
<th>Underfloor Wheel Turning M/C or Lathe</th>
<th>Smaller Diameter/Two Effective Flute Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Good Wheels (w/o defects, worn profile only)</strong></td>
<td>20.27 min</td>
<td>14.22 min</td>
</tr>
<tr>
<td><strong>Bad Wheels (flat spots, shelling, out of round)</strong></td>
<td>40-42 min</td>
<td>14.22 min</td>
</tr>
</tbody>
</table>

**Updated Milling Cutter is 40% more Productive and Reliable**
Current milling and turning machines force wheel set center line to be held at exactly the same place in space resulting in an expensive and complex operation.
Fundamental Shift

- New wheel truing machine design allows wheel set center line to move

- New following probe monitors wheel set center line and relies on closed loop servo system to keep cutter at correct radius

- New integrated probing system finds initial location of axle center line with respect to cutter position

- If centerline moves, cutter moves with it, maintaining a constant diameter
Fundamental Shift

Bringing the cutter to the wheel

Control
Keep cutter at constant distance from centerline

Measure
Track movement of wheel set centerline

Axle centerline
Cutter centerline
Drive Roller
Cutter
Drive Roller
Fundamental Shift

• **Clamping**
  • New design is therefore centerless and completely independent of the condition (roundness) of incoming wheels (*system is patent pending*)
• 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)

• 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
Applications New Wheel Truing Technology

M1: Above-Floor Machine
For Loose Wheel Sets and Bogies

M2: Underfloor Machine
For Light Rail Vehicles (20 Ton Max Axle Load)

M5: Above-Floor “Portal” Machine
For Wheel Set Production
Questions?