Milling for Smoothness, Milling for Profit

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People and Planning

The first step towards achieving a smooth milling job occurs way before the construction process begins. Everyone involved in the milling process contributes to the overall smoothness of the job, including:

• a. Mill operators
• b. Ground person
• c. Truck drivers
• d. Clean up.
Do I have what I need?

Do I have all the correct safety equipment
Do I have enough teeth to get through the day?
Do we have a Game Plan for a Productive day?

It is important to understand the job. Cutting it once and Correctly is by far the most economical way for the Company.
Choose the proper equipment
Where Do We Start?
Tracking

Watch to see how the machine is tracking. You may be keeping a good line with front tracks but if your tracking is off then you will have several problems.

Again the deeper you are the more this is critical.

You are looking for marking in the pavement as shown below.
Keeping a straight line

The deeper the cut the more that a straight line is important.

Side loading the cutter will reduce bearing life
End ring wear.
If you are not paying attention you will be into the holders very quick.
Cross hairs in the cut

Look for a cross hatch pattern in the cut.

a. You should be seeing a up and down cut pattern.
b. If the pattern is only going in one direction then this is what you are trying to avoid.
c. You may need to wipe the fines clean before you can see this pattern.
Cross hairs in the cut
2 Types of Smoothness

• Longitudinal Smoothness (Ride)
  – How to achieve
  – Factors on Ride

• Surface Smoothness
  – How to achieve
    • Factors on surface texture
      – Drum maintenance
      – Speed (of what?)
      – Drum pattern
  – Impacts on Production
Grade & Slope Controls
Endgate Averaging
Grade & Slope Controls
Averaging System
Grade & Slope Controls
3D Grade System

Trim Grade based on Position
Checking 0

Be sure you know where to check 0

This is what you want
0 is 0
Keep it Clean

How can you mill with this. If you have this to work with you will never achieve grade.

Why?
No really, clean up your mess

Oh that Pile.
Our shovel is on the water truck.
The automatics will take that out...
Clean up your mess

Clean up after you pick up.
What will happen when you set back down.
Instead of taking the time to clean this up I
Will just guess how thick this is.
Speed and Slope
Continuous Milling

There are a lot of forces generated during milling. When you stop so do the forces. Plus all of the teeth now cut in one spot, no longer spread out.
2 Types of Smoothness

• Longitudinal Smoothness (Ride)
  – How to achieve
  – Factors on Ride

• Surface Smoothness
  – How to achieve
    • Factors on surface texture
      – Drum maintenance
      – Speed (of what?)
      – Drum pattern
  – Impacts on Production
Surface Texture
Quick Change Drum Tooling

- Tungsten Carbide
- Cutting Tooth (Bit)
- Tooth Holder (Sleeve or Insert)
- Base
- Flighting (Pedestal)
Cutter Drum
Proper Maintenance
Tool Wear Characteristics

At Stage 3
Tool has lost 0.365 “ [9.3 mm] of gage height

0.15 in²
0.433” (11.0 mm)

287% Increase in Surface Area

0.43 in²
0.634” (16.0 mm)
0.744” (19.0 mm)
Production Tradeoff

![Graph showing the relationship between Advance Rate (fpm) and Milling Depth (inch) for RX-900 New Teeth.]
Production Tradeoff

![Graph showing production tradeoff between advance rate (mpm or fpm) and milling depth (cm or inch) for RX-900 New Teeth and RX-900 Stage 4 Teeth with Wear.]
New holders have been spotted in in various places. The wear shown here is not common to all the holders on the drum, some are worn more, some are worn less. This cutter does not leave a very good looking pattern.

90% of the holders on this drum are worn like this. New holders are 2” from seat to face.
Caliper set at EXACTLY 2”
Same holder in previous picture turned 180 degrees
The tooth tip should be centered on the blue line.

The red line shows the misalignment of the tooling due to the face wear on the tooth holder.
Proper Maintenance
Proper Maintenance
Proper Maintenance
The Math of Milling

The 4 Main Factors that Affect Surface Texture
1. Line Spacing
2. Forward Speed
3. Drum RPM
4. Lacing Pattern
Triple Wrap, Off Set Flighting

Triple Wrap

Off Set Flighting
Line Spacing

5/8”
Standard Drum
5/8” Line Spacing

Profiling Drum
3/8” Line Spacing
Micro-Milling Pattern
0.2” Line Spacing
Line Spacing and Texture

Each cutter pattern is determined by the number of carbide teeth installed on the mandrel. More teeth produce fine patterns such as Profiling and Micro-Milling, but production rates remain low. Excavating and Traditional patterns allow for higher production rates but produce a coarser surface.

Milling Machine Cutter Drum Patterns
5/8” (16mm) Triple Wrap Lacing Pattern
5/8” (16mm) Triple Wrap Lacing Pattern
5/8" (16 mm) Triple Wrap at 30 fpm
2/10” (5mm) Triple Wrap Lacing Pattern
2/10” (5mm) Triple Wrap Lacing Pattern
2/10” (5mm) Triple Wrap Lacing Pattern
# Amount of Tools

<table>
<thead>
<tr>
<th>Line Spacing</th>
<th># of Teeth</th>
<th>Cost of Teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/8” (16 mm)</td>
<td>268</td>
<td>$1340</td>
</tr>
<tr>
<td>3/8” (9 mm)</td>
<td>406</td>
<td>$2030</td>
</tr>
<tr>
<td>0.2” (5 mm)</td>
<td>770</td>
<td>$3850</td>
</tr>
</tbody>
</table>

Nearly 3 times more teeth  
Nearly 5 times the cost  
No more quick change holders
Production Tradeoff

Advance Rate (fpm) vs. Milling Depth (inch) for RX-900 12'6"
Production Tradeoff

![Graph showing production tradeoff between advance rate (fpm) and milling depth (inch) for RX-900 12'6" and RX-900 12'6" Micro models.]
The Math of Milling

The 4 Main Factors that Affect Surface Texture
1. Line Spacing
2. Forward Speed
3. Drum RPM
4. Lacing Pattern
Continuous Milling

There are a lot of forces generated during milling. When you stop so do the forces. Plus all of the teeth now cut in one spot, no longer spread out.
Forward Speed
“Out running the drum”

Tooth Strikes Line Up in Straight Lines
Tooth Strikes in One Drum Rotation
Machine Speeds Up Pattern Spreads Out
Straight Line Pattern
Advance Rate = 30 fpm
Drum Diameter = 46”
Drum Speed = 100 rpm

Machine
Advance
3.6”

0.071”
30 fpm
Advance Rate = 60 fpm

Drum Diameter = 46"
Drum Speed = 100 rpm

Machine Advance
7.2”

0.28”
60 fpm
Advance Rate = 90 fpm
Drum Diameter = 46”
Drum Speed = 100 rpm
90 fpm
Advance Rate = 120 fpm
Drum Diameter = 46”
Drum Speed = 100 rpm
120 fpm
30 fpm vs. 120 fpm

2.3 miles in a day vs. 9.1 miles in a day
Sand Patch Test
ASTM E965
Indiana Glass Bead Test (ITM 812)

The 4 Main Factors that Affect Surface Texture
1. Line Spacing
2. Forward Speed
3. Drum RPM
4. Lacing Pattern
## Drum Speed

### RX-900 Drum Speeds

<table>
<thead>
<tr>
<th>Engine Speed</th>
<th>Top Sheave Diameter (in)</th>
<th>Bottom Sheave Diameter (in)</th>
<th>Gear Ratios 20:1</th>
<th>Gear Ratios 24:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>2100rpm</td>
<td>16</td>
<td>14</td>
<td>120rpm</td>
<td>100rpm</td>
</tr>
<tr>
<td>2100rpm</td>
<td>16</td>
<td>15</td>
<td>112rpm</td>
<td>93rpm</td>
</tr>
<tr>
<td>2100rpm</td>
<td>14</td>
<td>15</td>
<td>98rpm</td>
<td>82rpm</td>
</tr>
<tr>
<td>2100rpm</td>
<td>14</td>
<td>16</td>
<td>92rpm</td>
<td>77rpm</td>
</tr>
</tbody>
</table>
Advance Rate = 120 fpm
Drum Diameter = 46”
Drum Speed = 120 rpm
Advance Rate = 120 fpm
Drum Diameter = 46"
Drum Speed = 100 rpm
The Math of Milling

The 4 Main Factors that Affect Surface Texture
1. Line Spacing
2. Forward Speed
3. Drum RPM
4. Lacing Pattern
Triple Wrap, Off Set Flighting

Triple Wrap

Off Set Flighting
Drum Lacings
Scroll Start Comparisons

Triple Wrap

Double Hit
Quad Wrap
Double Hit Drums

Above
Double hit Quad wrap drum

Standard triple wrap drum
Below
Pattern Comparisons

Single Hit Triple Wrap

1 7/8” (48 mm) spacing per flight
Equals
5/8” (16 mm) spacing

Double Hit Quad Wrap

1 ¼” (32 mm) spacing per flight
Equals
5/8” (16 mm) spacing
Advance Rate = 120 fpm
Drum Diameter = 46”
Drum Speed = 100 rpm

20% to 15% less time in cut
OR
20% less Tooth Consumption

Diagram showing the impact of advance rate on tooth consumption.
Pattern Comparison

5/8” Triple Wrap at 100 FPM

7/8” DHQW at 100 FPM
## Same Speed Comparison

<table>
<thead>
<tr>
<th>Single Hit Profiling Drum</th>
<th>Double Hit Profiling Drum</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 fpm</td>
<td>100 fpm</td>
</tr>
<tr>
<td>8 hr shift/7 hr milling = 56,000 sq yd/day</td>
<td>8 hr shift/7 hr milling = 56,000 sq yd/day</td>
</tr>
<tr>
<td>Crew cost (operator and ground man) = $720 for the day</td>
<td>Crew cost (operator and ground man) = $720 for the day</td>
</tr>
<tr>
<td>Let’s say 250 Teeth per day</td>
<td>20% less Teeth = 200</td>
</tr>
<tr>
<td>@ $5 per Tooth = $1250</td>
<td>@ $5 per Tooth = $1000</td>
</tr>
<tr>
<td>Fuel Usage = 25 gph</td>
<td>Fuel Usage = 25 gph</td>
</tr>
<tr>
<td>– 200 gal/day</td>
<td>– 200 gal/day</td>
</tr>
<tr>
<td>– $700 @ $3.50 /gal</td>
<td>– $700 @ $3.50 /gal</td>
</tr>
</tbody>
</table>

$0.05 per sq yd $0.04 per sq yd

From sand patch tests course milled surface can use 4 times more material to fill than a fine milled surface

This relates to about 25 tons per lane mile
The Point of Breakout
Same Texture – Very Different Production

Full Lane 8mm (0.3”) standard at 45 FPM

½ spaced DHQW at 140 FPM
# Same Texture Comparison

<table>
<thead>
<tr>
<th>Single Hit Profiling Drum</th>
<th>Double Hit Profiling Drum</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 45 fpm</td>
<td>• 140 fpm ( \approx 3 \times ) production</td>
</tr>
<tr>
<td>• 8 hr shift/7 hr milling = 25,200 sq yd/day</td>
<td>• 8 hr shift/7 hr milling = 78,400 sq yd/day</td>
</tr>
<tr>
<td>• Crew cost (operator and ground man) = $720 for the day</td>
<td>• Crew cost (operator and ground man) = $720 for the day</td>
</tr>
<tr>
<td>• Let’s say 160 Teeth for the day</td>
<td>• 20% less = 497 w/ production gain</td>
</tr>
<tr>
<td>• @ $5 per Tooth = $800</td>
<td>• @ $5 per Tooth = $2485</td>
</tr>
<tr>
<td>• Fuel Usage = 20 gph</td>
<td>• Fuel Usage = 25 gph</td>
</tr>
<tr>
<td>– 160 gal/day</td>
<td>– 200 gal/day</td>
</tr>
<tr>
<td>– $560 ( \times ) $3.50 /gal</td>
<td>– $700 ( \times ) $3.50 /gal</td>
</tr>
</tbody>
</table>

$0.08 per sq yd

$0.03 per sq yd
Apples to Apples

3/8” spaced Single Hit “Profiling” Drum at 120 FPM

½” spaced Double Hit Drum at 140 FPM
Micro-mill surface at 65 FPM
Production Tradeoff

[Graph showing the relationship between advance rate (fpm) and milling depth (inch) for different models of milling equipment, including RX-900 12'6", RX-900 12'6" Standard DHQW, RX-900 12'6" Fine DHQW, and RX-900 12'6" Micro.]
### Amount of Tools

**12’6” (3.5 m) (Full Lane Drum)**

<table>
<thead>
<tr>
<th>Spacing</th>
<th># of Tools</th>
<th>Cost of Drum</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/8” (16 mm) SH</td>
<td>268</td>
<td>$1340</td>
</tr>
<tr>
<td>Standard DHQW</td>
<td>343</td>
<td>$1715</td>
</tr>
<tr>
<td>Profile DHQW</td>
<td>440</td>
<td>$2200</td>
</tr>
<tr>
<td>0.2” (5 mm) SH</td>
<td>770</td>
<td>$3850</td>
</tr>
</tbody>
</table>

Fewer teeth
Less cost
Still quick change holders
Questions?