Technical Developments in the Measurement of Commutator Profiles

Carbone of America

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WMEA
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Dedicated Innovation, Dedicated Partner
Content

1. Tools and Methods of Measuring Commutator Profiles (9)

2. Commutator Profile Examples and their Analysis (11)

3. Basics of Armature Windings and how they effect Commutator Profiles (10)

4. High Speed non-contact profiling with the ‘ComPro 2000’
Profile Measuring Instruments

- Contact Probes
  - Dial Indicator
  - Pundicator
  - Feinpruf – Analogue (1986)

- Non-Contact Probes
## Units of Measurement

<table>
<thead>
<tr>
<th>m/s</th>
<th>ft/min</th>
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<tr>
<td>5</td>
<td>984</td>
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<tr>
<td>10</td>
<td>1968</td>
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<tr>
<td>15</td>
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<tr>
<td>20</td>
<td>3936</td>
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<td>50</td>
<td>9840</td>
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<tr>
<td>60</td>
<td>11808</td>
</tr>
<tr>
<td>70</td>
<td>13776</td>
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<table>
<thead>
<tr>
<th>MICRONS</th>
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<tr>
<td>3.175</td>
<td>0.125</td>
</tr>
<tr>
<td>6.35</td>
<td>0.250</td>
</tr>
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<td>12.7</td>
<td>0.500</td>
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<td>25.4</td>
<td>1.000</td>
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<td>50.8</td>
<td>2.000</td>
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<td>101.6</td>
<td>4.000</td>
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<td>127</td>
<td>5.000</td>
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<td>203.2</td>
<td>8.000</td>
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<tr>
<td>254</td>
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<tr>
<td>508</td>
<td>20.000</td>
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<tr>
<td>762</td>
<td>30.000</td>
</tr>
<tr>
<td>1016</td>
<td>40.000</td>
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**Typical modern DC Motor/Generator Operating Parameters**
## Typical Run-out and Bar to Bar Criteria

<table>
<thead>
<tr>
<th>Situation</th>
<th>Runout (TIR)</th>
<th>Bar - Bar Variance</th>
<th>Undercut Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>Less Than .0015</td>
<td>Less Than .0002</td>
<td>.050 or more</td>
</tr>
<tr>
<td>In Service</td>
<td>Less Than .003</td>
<td>Less Than .0003</td>
<td>.020 or more</td>
</tr>
<tr>
<td>Needs Repair</td>
<td>More Than .003</td>
<td>More Than .0003</td>
<td>.010 or less</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Situation</th>
<th>Runout (TIR)</th>
<th>Bar - Bar Variance</th>
<th>Undercut Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>38 um</td>
<td>5 um</td>
<td>1,4 mm</td>
</tr>
<tr>
<td>In Service</td>
<td>76 um</td>
<td>8 um</td>
<td>1,4 mm</td>
</tr>
<tr>
<td>Needs Repair</td>
<td>76 um</td>
<td>8 um</td>
<td>0,25 mm</td>
</tr>
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</table>
Measuring Commutator Profiles

Methods of Rotating the Machine

• Lathe

• By Hand (Uncoupled)

• Overhead Crane

• Barring Gear

• Low Voltage Supply (Welder)

• Another Motor (flat belt)

• Sun-gear Removal (Wheel Motors)
Methods of Rotating Armatures

- Hydraulic or Pneumatic Jack for Traction Motors.
- Overhead Crane & Lever
Contact Probe Positioning

Expanding clamp in the brush holder
Commutator Profile Measurement
MMS vs Feinpruf

• MMS 6000 Probe
  • Digital Output

• Feinpruf Probe
  • Analogue Output
- Feinpruf fitted with a Ruby-tip Probe
- Can measure profiles with machine energized and running at low speed
- Unmistakable signs of commutator deformation
- Narrowing of brush tracks
Non-Contact Probe Positioning

- Magnetic Base and Adjustable Arm with Fine adjustment
- Inductive Probe located approximately 20/1000” from commutator
1. **Tools and Methods of Measuring Commutator Profiles (9)**

2. **Commutator Profile Examples and their Analysis (11)**

3. **Basics of Armature Windings and how they effect Commutator Profiles (10)**

4. **High Speed non-contact profiling with the ‘ComPro 2000’**
A Carbon Brush Can Only Perform As Well As the Surface Condition on Which It Runs!

TYPICAL EXAMPLE.

1500 RPM

16 inch Diameter Commutator with 250 segments.

Speed = 6,284 ft/min

or 31 m/s.

Segment ‘X’ will pass under each brush 25 times per second!
Commutator Profile Deterioration. (Exponential Curve)

<table>
<thead>
<tr>
<th>Time</th>
<th>Commutator Total Indicated Run-out</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 year</td>
<td>3/1000 (100 microns)</td>
</tr>
<tr>
<td>2 years</td>
<td></td>
</tr>
</tbody>
</table>

Danger of failure.

Big $$$ !!!
Be careful of the ‘Y’-axis Scale

All profiles depicted in this presentation are done wherever possible on a +4 to -4 mil scale

Doing this gives one a ‘feel’ for the profile

Most instruments produce a profile to fit the screen

Profiles shown depict 1 revolution of the commutator.

This profile is of a commutator that has just been cut!
The ‘Y’-axis scale is 0 to 1.0 mils
A perfectly good commutator!!
Dragline # 126 – Hoist Motor #3 Track #2.

Fig 10.

Fig 11.

Note the scale, it is twice that of the other profiles.

Fig 12.

Note the shiny surface on the brush as a result of brush bounce.
Commutator Appearance

- Dark bars – Low bars
- Bright bars – High bars
- Burnt bars – Flat spots

(Commutator profile shown on next slide)
Analyzing a Profile

- TIR – Total Indicated Run-out
- MBTB – Maximum Bar to Bar
- Change in 6 bars

Trace must be repeatable!
Of interest here is the fact that the 2 tracks exhibit similar patterns of similar magnitude.

<table>
<thead>
<tr>
<th></th>
<th>Outer</th>
<th>Track 3</th>
</tr>
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<tbody>
<tr>
<td>TIR</td>
<td>3.6</td>
<td>4.0</td>
</tr>
<tr>
<td>MBTB</td>
<td>0.6</td>
<td>0.5</td>
</tr>
<tr>
<td>In 6 Bars</td>
<td>1.6</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Machine started with some ovality – 40 microns or 1.6 mils.

There is some evidence of symmetrical ripple.

Again we see similar deformation on different tracks.
Commutator Profile
‘Feinpruf’ compared with ‘Commtest’

- Almost the same starting point
- Same ‘y’-axis scale !! NB
- Not exactly the same point on the brush-track

Digital Profile as compared with an Analogue Profile
MMS6000 Profile – Digital Bars

Commutator Bars in digital format (Square)
Linear vs. Polar Plots

Again the Importance of the ‘Y’-axis Scale. +/- 5 mils or 10 mils! in this case

ComPro Profile – the lowest bar is at 0 mils
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4. High Speed non-contact profiling with the ‘ComPro 2000’
Understanding CPS (Conductors per Slot)

Count the bars
Count the coils
No. of bars/No. of coils = CPS
Arrangement of Conductors in the Armature slot

Wedge

Conductor

Separator

Insulation

5 CPS

3 CPS

Normally 2, 3 or 4 in Industrial DC machines
Equalizing Winding (Every 2nd bar)

Prevents circulating currents by joining points of equal potential in the winding.

Located normally behind the Riser, under the winding overhang.

Lack of space precludes every bar being equalized.
Lap Winding

3 Conductors per slot armature Lap Wound
Therefore if bar-marking exists it will be every 3rd bar
Lap Wound 4-CPS Armature

- Lap Winding has
  - Converging end-connections
  - No. Parallel paths = No. Pairs of Poles
  - Equalizing Windings

- Wave winding has
  - Diverging end-connections
  - 1 Pair of Parallel Paths
  - No Equalizing Winding
4 Similar Traction Motor Profiles

- These 4 traction motors all show the formation of ripple
- Counting the bars gives a 7 bar-ripple
- This armature is a wave-wound 7 cps configuration

This small flat spot was formed as a result of poor undercutting.
Sympathetic Flat Spots

- 150 Bars
- 3 CPS
- Note the 3-bar Ripple
- 4-Pole with 2 major flats and 2 minor flats

Exactly 75 bars between the 2 major flat-spots
4-Pole 4 CPS

Be careful of the ‘Y’-axis scale!

- Every 4th Bar is High !!
- 168 Bars (4 cps)
- 4 Pole

TIR = 3 mils
Commutator Profile Deterioration

After Stone

218 RHS OTER 92/9/22

218 RHS OTER 8/10/92
Removal of 4 mils will take approximately 45 minutes.
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4. High Speed non-contact profiling with the ‘ComPro 2000’ (12)
Introducing the ComPro 2000

ComPro2000™
Portable, high-speed, Commutator Profiler

The new ComPro2000™ from Motor Measurements™ is a portable diagnostic tool for quickly and easily determining the health of your motor’s commutators. The ComPro 2000’s exclusive non-contact method of measurement results in a commutator profile that can take minutes to complete versus hours for typical contact-based methods.

Contact-based profiling systems require you to shut down your process to obtain the measurement. The very nature of this measurement method oftentimes prevents the optimal collection interval necessary as a part of a risk management strategy for DC machinery. With minimal downtime, the ComPro2000™ can gauge your motor’s or generator’s commutator health while it’s in operation. Speed, surface/airborne contamination, temperature, voltage, or current do not affect the ComPro2000™’s non-contact measurement technology. Since the profile can be obtained under normal operating conditions, not only is the static profile measured (the profile that you would obtain with a contact-based measurement) but the dynamic profile is measured as well.

The dynamic profile may reveal abnormal conditions even when the static profile is acceptable. These dynamic situations can be a source of poor commutation, poor commutator life, excessive commutator maintenance, and poor brush life.

The key to the ComPro2000™’s ability to achieve a non-contact profiling is the combination of its unique ability to sense the commutator’s geometry and extract critical measurement information from each individual commutator segment, as well as the commutator as a whole, while the motor or generator is at full speed. Since the ComPro2000™ can sample the commutator surface at a frequency of 1 MHz, the result is that commutator profiles can be obtained at surface speeds greater than 1,500 inches per second. The ComPro2000™ automatically determines the proper sampling frequency without prior knowledge of motor speed or commutator diameter. Additionally, the ComPro2000™ can determine the number of commutator segments that comprise the commutator and the motor speed.
Benefits

- Perform Commutator Profiles on Machines previously inaccessible due to time constraints and the complexity of utilizing traditional methods of profiling.
- Eliminate/confirm potential causes of brush performance issues.....easily, safely & painlessly
- Predictive Maintenance at it’s best
### Motor 57301
Same Settings – 2 Recordings (Comparison) @ 113 RPM

<table>
<thead>
<tr>
<th>Revolutions</th>
<th>TIR</th>
<th>Std. Dev.</th>
<th>MBTB</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.994</td>
<td>0.036</td>
<td>0.113</td>
<td>0.009</td>
</tr>
<tr>
<td>6</td>
<td>1.098</td>
<td>0.044</td>
<td>0.123</td>
<td>0.009</td>
</tr>
</tbody>
</table>
24 x 2500HP Generators measured at speed in 6 hours

- Generators being driven by the Synchronous Induction Motor at 360 RPM
- Field Excitation locked out
- Voltage to ground 5V
• Raw data analysis - typically shows 5 revolutions
• This facility negates the effect of vibration – one typical revolution can be extracted
Feinprüf Profile and Photo of Large Test Armature in the Lathe

Do not lose the history!
Record the profile before and after the commutator is cut or stoned

Note the ‘Y’-axis scale on this trace.
0 – 32 mils
Armature in Lathe – 6 Pole 279 Bars Measured for 50 Seconds (7.4 Rpm)
Polar Plot As Seen in the ‘ComPro 2000’ Software
Note the ‘Y’-axis scale on this trace. 0 – 22 mils
These 8 profiles are all +/- 5 mils i.e. The same ‘Y’-axis scale !!!
### Commutator Profile Table – (mils)

<table>
<thead>
<tr>
<th></th>
<th>Priority</th>
<th>TIR (Total Indicated Run-out) (mils)</th>
<th>MBTB (Maximum bar to bar) (mils)</th>
<th>Change in 7 bars (mils) Point 'X'</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot Strip Mill</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generator #1</td>
<td></td>
<td>2.958</td>
<td>1.062</td>
<td>0.100</td>
<td>Light Stone</td>
</tr>
<tr>
<td>Generator #2</td>
<td></td>
<td>1.254</td>
<td>0.641</td>
<td>0.500</td>
<td>No Action</td>
</tr>
<tr>
<td>Generator #3</td>
<td>2</td>
<td>12.5</td>
<td>9</td>
<td>5.300</td>
<td>Needs Attention</td>
</tr>
<tr>
<td>Generator #4</td>
<td></td>
<td>1.753</td>
<td>0.486</td>
<td>0.500</td>
<td>No Action</td>
</tr>
<tr>
<td>Generator #5</td>
<td>1</td>
<td>5.851</td>
<td>0.705</td>
<td>2.800</td>
<td>Needs Urgent Attention - Grooving</td>
</tr>
<tr>
<td>Generator #6</td>
<td>4</td>
<td>8.118</td>
<td>1.728</td>
<td>5.700</td>
<td>Needs Attention</td>
</tr>
<tr>
<td>East Generator</td>
<td>3</td>
<td>6.669</td>
<td>2.585</td>
<td>5.000</td>
<td>Needs Attention</td>
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<tr>
<td>West Generator</td>
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<td>0.817</td>
<td>0.397</td>
<td>0.300</td>
<td>No Action</td>
</tr>
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</table>
PROFILE ACQUISITION SEQUENCE

Step by step
- Isolate machine
- Fit probe into fixture
- Adjust to 20/1000” (3.8 volts on meter)
- Step back
- Run machine
- Acquire profile
  - 5 Revolutions of a 24” commutator running at 300RPM equals 9.6m/s or (2000 fpm)
  - 5*Circumference/2000 = 1.0 second
- Shut down machine
- Remove probe
- Move on
Requirements for Optimum Performance

- Correct **Grade** at correct current density
- **Sound Mechanical Configuration:**
  - Symmetrical in all respects
  - Correct spring **pressure** (+10% -10% normally 3 or 5 psi)
  - Correct design of brush and associated pressure system
  - Correct axial and circumferential stagger
  - Holder to commutator spacing ( .06 - .125”)
  - **True** commutator (TIR typically within 3 mils)
  - Surface roughness
    - 600 peaks/inch
    - R ave. = 1/16 of a thousandth of an inch

- **Environmental**
  - Suitably treated grade

- **Load**
  - Suitable complement of brushes
In Conclusion

• This talk presented in the interests of all those involved in DC machines.

• Let's keep them running and above all - avoid this!

Thanks for listening!

Questions?