How To Read and Interpret A Gear Inspection Report

AGMA Webinar
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The Three Parts of Gears

• The Form
• The Tooth
• The Teeth
The Three Parts of Gears

• The Form
The Three Parts of Gears

• The Form
• The Tooth
The Three Parts of Gears

- The Form
- The Tooth
- The Teeth
Definition of an Involute

\[ V = r_1 \omega_1 = r_2 \omega_2 \]

Base circle

Involute

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Base Circle

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Involute Helicoid

- Paper Cut as Parallelogram Shape
Involute Helicoid
Involute Helicoid

- Paper Cut as Parallelogram Shape
- Wrapped Around Base Cylinder
Involute Helicoid

Helix

Tangent

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Involute Helicoid

- Paper Cut as Parallelogram Shape
- Wrapped Around Base Cylinder
- Unwrapped as to Generate Involute
- Paper Edge Defines Involute Helicoid
Involute Helicoid
Involute Helicoid
So What Are We Trying To Do Here

• Determine the amount of deviation from a perfect gear tooth form, both;
  – Profile (tooth form tip to root)
  – Lead (tooth face one end to the other)

• Compare ‘actual’ form to required form as defined by standard;
  – AGMA
  – ISO
  – Etc.
Line of Action and Transmission Error

Point of Contact Between Driver and Driven As They Roll Through Mesh
Issues Caused By TE

• This ‘off-axis’ motion causes vibration as it tries to accelerate / decelerate the load

• This manifests itself as;
  – Vibration, which becomes ‘noise’
  – Parasitic losses / inefficiencies
  – This ‘lost energy’ goes into the lubricant and structure as heat
  – And finally it is one of the main sources of wear
Polling Question #1

- What causes transmission error?
  - A. Tooth form (profile) deviations
  - B. Lead variations
  - C. Surface finish (worse than required by quality standards)
  - D. Lubricant failure (oxidation, debris entrainment, etc.)
  - E. All of the above
Involute Measurement

- Measure of Gear Tooth Profile
- Rolling Gear on Base Circle
- Produces Contact Traces of Profile
- Relation Between Roll Angle / Profile
- Variations in Tooth Geometry
  - Deviations from Straight Line on Chart
- Run Out / Gear Wobble Effect Trace
- Measure at Several Axial Positions
Involute Chart
Involute Chart
Red Liner

- Double Flank Tester
- Master Gear
Red Liner
Schematic of Gear Rolling Device
Red Liner

• Double Flank Tester
• Master Gear

• Motion of Center of Test Gear
  – Recorded (Trace)
  – During Roll with Master
Red Liner
Typical Chart
Red Liner

• Double Flank Tester
• Master Gear
• Motion of Center of Test Gear
  – Recorded (Trace)
  – During Roll with Master
• Measures Variation of Test Gear
  – Composite Test & Master Gear Error
  – Master Variation Assumed to be Negligible
Red Liner Data

- Total Composite Error
Red Liner
Typical Chart
Red Liner Data

• Total Composite Error

• Tooth to Tooth Composite Error

• Tooth to Tooth Error
Red Liner
Typical Chart
Red Liner Data

- Total Composite Error
- Tooth to Tooth Composite Error
- Tooth to Tooth Error
- Run-out
Red Liner
Typical Chart
Red Liner Limitations

- Test Run with Zero Backlash
  - Not at Operating Pitch Diameter
- Test Run with No-Load
- Both Flanks are Engaged
- Can Not Differentiate Between
  - Involute Errors
  - Lead Errors
  - Profile Modification Errors
  - Combination of Errors
Single Flank Gear Tester

• Measures Similar Parameters
  – With Backlash
  – On Operating Pitch Diameters
Single Flank Gear Tester
Schematic
Single Flank Gear Tester

- Measures Similar Parameters
  - With Backlash
  - On Operating Pitch Diameters
- Measures Transmission Error
- More Accurate Representation of Error
Polling Question #2

- Which measurement system predicts a more accurate representation of ‘real-world’ operation?
  - A. Red-liner (Double flank tester)
  - B. Single flank
  - C. No difference between the two
CMM: Coordinate Measurement Machine
GMM: Gear Measurement Machine

• Index Variation
• Lead Variation
• Involute Variation
• Topological Plots
• Generates Surface of Actual Tooth Form
Charts: Profile Inspection
Charts: Profile Inspection

- Profile inspection is a view of the tooth from root to tip (or tip to root)
- A straight vertical line indicates a perfect involute
  - As defined and ‘old school’ measure by the profile check
Profile Chart: General Information

- Which part of the chart you are reviewing
- Client data
- Remarks specific to the job (i.e. orientation)
- Inspection machine / system used
- Inspection operator
Profile Chart: General Information

Job specific data (i.e. gear tooth profile, etc.)
Profile Chart: General Information

- Type of measure profile (i.e. external or internal)
- Units of measure
- Type and size of probe used
Profile Chart: General Information

- Diametral position of probe (referenced to tooth diameter)
- Ratio between horizontal and vertical measurements
- Axial grid measure (linear / chordal measure across tooth)
- Chart magnification factor
Profile Chart: General Information

Side of tooth being inspected
Profile Chart: Tooth Height

Root to Tip
Profile Chart: Active Profile

Start of Active Profile (SAP) to End of Active Profile (EAP)
OR;
Length / Area of Tooth of Interest
Profile Chart: Measured / Inspected Teeth

Specific teeth designated for identification purposes
Either specifically designated by the client
Or selected equally spaced (typically) around the shaft
Profile Chart: Measured / Inspected Quantities

**Measurement Results:**

- $F_a$ is the composite error of both angular and form deviations
- $f_{fa}$ is the form error or essentially the waviness of the line
- $f_{Ha}$ is the angular error or the deviation of the assumed straight line from vertical
Profile Chart: Deviation from True Involute

**Measurement Results:**

\[ f_{fa} \] is the form error or essentially the waviness of the line.
Profile Chart: Deviation from True Involute

**Measurement Results:**

$f_{a}$ is the form error or essentially the waviness of the line.
Profile Chart: Deviation from True Involute

**Measurement Results:**
\[ f_{fa} \] is the form error or essentially the waviness of the line.
Measurement Results:

$f_{H_a}$ is the angular error or the deviation of the assumed straight line from vertical.
Profile Chart: Deviation from Tooth Form Position

**Measurement Results:**

$f_{H_a}$ is the angular error or the deviation of the assumed straight line from vertical.
Profile Chart: Composite View of Total Error

**Measurement Results:**

\( F_a \) is the composite error of both angular and form deviations
Profile Chart: Composite View of Total Error

**Measurement Results:**

\( F_a \) is the composite error of both angular and form deviations.
Profile Chart: Results Relative to Quality Number
Polling Question #3

• This is an extension question; meaning, we did not specifically cover it in the preceding material, but let’s expand our thinking a bit . . .

• What is the ‘non-measured’ attribute that also must be taken into consideration and can be seen on the previous charts?
  – A. Waviness
  – B. Tooth spacing (relative position of one tooth to the next)
  – C. Consistency (or lack thereof) in error / deviation
Lead on a Helical Gear

Note: Spur gear is the degenerate form of a helical gear, with a helix angle of: 0.00°
Charts: Lead Check
Lead Chart: General Information

- Diametral position of probe (referenced to top of tooth)
- Ratio between horizontal and vertical measurements
- Axial grid measure (linear / chordal measure across tooth)
- Chart magnification factor
Lead Chart: General Information

Side of tooth being inspected
Lead Chart: Tooth Height

Root to Tip
Lead Chart: Active Profile

Length of tooth face to be inspected
Or of interest
Lead Chart: Measured / Inspected Quantities

**Measurement Results:**

- $F_B$ is the composite error of both lead curvature and form deviations
- $f_{fb}$ is the form error or essentially the waviness of the line
- $f_{H_B}$ is the lead curvature error or the deviation of the assumed straight line from vertical
Lead Chart: Deviation from True Lead

**Measurement Results:**

$ff_B$ is the form error or essentially the waviness of the line.
Lead Chart: Deviation from True Lead

**Measurement Results:**

$f_f_B$ is the form error or essentially the waviness of the line.
Lead Chart: Deviation from True Lead

**Measurement Results:**

\[ f_{B} \] is the form error or essentially the waviness of the line.
Lead Chart: Deviation or Curvature of Lead

**Measurement Results:**

$f_{H_B}$ is the lead curvature error or the deviation of the assumed straight line from vertical.
Lead Chart: Deviation or Curvature of Lead

**Measurement Results:**

$f_{HB}$ is the lead curvature error or the deviation of the assumed straight line from vertical.
Lead Chart: Composite View of Total Error

**Measurement Results:**

$F_B$ is the composite error of both lead curvature and form deviations.
Lead Chart: Composite View of Total Error

**Measurement Results:**

$F_B$ is the composite error of both lead curvature and form deviations
Lead Chart: Results Relative to Quality Number
Charts: Pitch Inspection
Pitch Chart: General Information

Scale used on chart
Pitch Chart: General Information

Side of tooth being inspected
Pitch Chart: Measured / Inspected Quantities

**Measurement Results:**

- $f_p$ is the composite tooth to tooth spacing error
- $f_u$ is the single highest deviation of pitch spacing
- $f_{up}$ is the individual tooth to tooth spacing error
Charts: Run-Out Inspection
Run-Out Chart: General Information

Scale and side of tooth being measured (right)
Scale and side of tooth being measured (left)
Scale and composite measurement of tooth
Charts: Run-Out Inspection

Perfect Circles
Charts: Run-Out Inspection

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Reference List

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Reference List – URL Information

1. http://www.flying-pig.co.uk/mechanisms/pages/crank.htm
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