CNC Machine Calibration Test & Machine Accuracy Adjustment

Power By :

RENISHAW®
Renishaw QC20-W wireless ballbar for machine tool performance diagnosis

Check machine positioning performance and diagnose machine errors automatically
Why do I need to perform a Ballbar test?

- A typical three-axis machine tool is subject to twenty-one degrees of freedom which include linear positioning, pitch, yaw, straightness, roll and squareness to the other axes.

- Each of these degrees of freedom can have a detrimental effect on the machine’s overall positioning accuracy and the accuracy of machined parts. Furthermore, the potential for problems increases significantly with the additional dynamic effects of machine movement.

- The Ballbar final diagnosis result and data will help out end user to decide:
  - Weather to go for final Laser calibration and compensation of the error.
  - Recond or repair the machine accurately.

- In theory, if a CNC machine’s positioning performance was perfect, a circle traced out by the machine would exactly match its programmed circular path.
However, in practice, any of the errors listed below can potentially cause the machine to deviate from the programmed circle path:

- backlash;
- reversal spikes;
- lateral play;
- cyclic error;
- straightness;
- scale error;
- servo mismatch;
- squareness.

<table>
<thead>
<tr>
<th>Potential errors on an axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backlash</td>
</tr>
<tr>
<td>Reversal spikes</td>
</tr>
<tr>
<td>Lateral play</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Potential errors between axes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servo mismatch</td>
</tr>
</tbody>
</table>

By accurately measuring with Ballbar and comparing the circular path of the machine with the programmed circular path, it is possible to determine the machine’s positional accuracy.

**Testing Capacity**

From 50, 100, 150, 250, 300, 400, 450, 550 or 600 mm radius. With additional extensions it is possible to perform tests up to 1350 mm.
## System specification

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor resolution</td>
<td>0.1 μm (4 μin)</td>
</tr>
<tr>
<td>Ballbar sensor accuracy</td>
<td>±0.5 μm (at 20 °C) / ±20 μin (at 68 °F)</td>
</tr>
<tr>
<td>Maximum sample rate</td>
<td>1000 values per second</td>
</tr>
<tr>
<td>Data transmission</td>
<td>Bluetooth, Class 2 (10 m typical)</td>
</tr>
<tr>
<td>Extension bars</td>
<td>50 mm, 150 mm, 300 mm</td>
</tr>
<tr>
<td>Operating range</td>
<td>0 °C - 40 °C (32 °F - 104 °F)</td>
</tr>
<tr>
<td>Calibrator accuracies (at 20 °C)</td>
<td>±1 μm (50 mm)</td>
</tr>
<tr>
<td></td>
<td>±1 μm (100 mm)</td>
</tr>
<tr>
<td></td>
<td>±1 μm (150 mm)</td>
</tr>
<tr>
<td></td>
<td>±1.5 μm (300 mm)</td>
</tr>
</tbody>
</table>
Axes Measurement

+Z

XY plane
CW direction

360°

YZ plane

CW direction
220°

XZ plane
CW direction
220°
Sample of Analysing Results of The Ballbar Test

**Ballbar diagnostics (%)**

*XY 360deg 100mm Calibrated 20100331-132430*

- **34% Squareness**: 49.6µm/m
- **20% Reversal spikes X**: 2.0µm, 3.0µm
- **15% Reversal spikes Y**: 2.2µm, 2.3µm
- **7% Lateral play X**: 1.0µm, 1.0µm
- **7% Lateral play Y**: 1.5µm, 0.0µm

**Positional tolerance**: 21.0µm

**Best fit radius**: 100.0009mm

**Circularity**: 8.4µm

Machine: Volumetric examples
QC20-W: 9A2870, Last calibrated: 2010-02-11
Ballbar diagnostics (μm)

XY 360deg 100mm Calibrated 20100331-132430

Operator: admin
Date: 2010-Mar-31 13:24:30

- Backlash (μm):
  - X: ±0.1 ±0.2
  - Y: ±0.2 ±0.2

- Reversal spikes (μm):
  - X: ±2.8 ±3.0
  - Y: ±2.2 ±2.0

- Lateral play (μm):
  - X: ±1.0 ±1.0
  - Y: ±1.5 ±0.0

- Cyclic error (μm):
  - X: ±0.4 ±0.2
  - Y: ±0.2 ±0.2

- Other features:
  - Servo mismatch: -0.01ms
  - Squareness: 49.6μm/m
  - Straightness X: 0.3μm
  - Straightness Y: 0.1μm
  - Scaling error X: 13.8μm
  - Scaling error Y: 4.2μm

Positional tolerance: 21.0μm
Best fit radius: 100.0009mm
Circularity: 8.4μm

Run 1, Run 2, Fit 1, Fit 2
1.0μm/div
Set-up and run a ballbar test

### Ballbar diagnostics table

**XY 360deg 100mm Calibrated 20100331-132430**

<table>
<thead>
<tr>
<th>Error</th>
<th>Magnitude</th>
<th>Independent circularity</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backlash X</td>
<td>±0.1</td>
<td>±0.2µm</td>
<td>0.3µm</td>
</tr>
<tr>
<td>Backlash Y</td>
<td>±0.2</td>
<td>±0.2µm</td>
<td>0.2µm</td>
</tr>
<tr>
<td>Reversal spikes X</td>
<td>±2.6</td>
<td>±3.0µm</td>
<td>3.0µm</td>
</tr>
<tr>
<td>Reversal spikes Y</td>
<td>±2.2</td>
<td>±2.3µm</td>
<td>2.3µm</td>
</tr>
<tr>
<td>Lateral play X</td>
<td>±1.0</td>
<td>±1.0µm</td>
<td>1.0µm</td>
</tr>
<tr>
<td>Lateral play Y</td>
<td>±1.5</td>
<td>±0.0µm</td>
<td>1.0µm</td>
</tr>
<tr>
<td>Cyclic error X</td>
<td>±0.4</td>
<td>±0.2µm</td>
<td>0.4µm</td>
</tr>
<tr>
<td>Cyclic error Y</td>
<td>±0.2</td>
<td>±0.2µm</td>
<td>0.2µm</td>
</tr>
<tr>
<td>Servo mismatch</td>
<td>±0.01ms</td>
<td>0.3µm</td>
<td>0.3µm</td>
</tr>
<tr>
<td>Squaredness</td>
<td>49.6µm/m</td>
<td>5.0µm</td>
<td>5.0µm</td>
</tr>
<tr>
<td>Straightness X</td>
<td>±0.3µm</td>
<td>±0.1µm</td>
<td>0.1µm</td>
</tr>
<tr>
<td>Straightness Y</td>
<td>±0.4µm</td>
<td>±0.1µm</td>
<td>0.1µm</td>
</tr>
<tr>
<td>Scaling error X</td>
<td>±13.6ppm</td>
<td>1997.2mm/min</td>
<td>5.6µm</td>
</tr>
<tr>
<td>Scaling error Y</td>
<td>±4.2ppm</td>
<td>1997.2mm/min</td>
<td>5.6µm</td>
</tr>
<tr>
<td>Cyclic pitch X</td>
<td>±2.5400mm</td>
<td></td>
<td>5.6µm</td>
</tr>
<tr>
<td>Cyclic pitch Y</td>
<td>±0.5000mm</td>
<td></td>
<td>5.6µm</td>
</tr>
<tr>
<td>Calculated feedrate</td>
<td>1997.2mm/min</td>
<td></td>
<td>5.6µm</td>
</tr>
<tr>
<td>Centre offset X</td>
<td>±5.6µm</td>
<td></td>
<td>5.6µm</td>
</tr>
<tr>
<td>Centre offset Y</td>
<td>±13.2µm</td>
<td></td>
<td>5.6µm</td>
</tr>
</tbody>
</table>
Set-up and run a ballbar test

Test conditions

XY 360deg 100mm Calibrated 20100331-132430

Operator: admin
Date: 2010-Mar-31 13:24:30

Test parameters

Test specification: XY 360deg 100mm Calibrated
Plane under test: XY
Ballbar length: 100.0000mm
Feedrate: 2000.0mm/min
Test position
NC Program ID: 1
Ballbar length calibrated: Yes
Machine expansion coefficient: 11.7ppm/°C
Spindle number: 1
Start angle: 45°
End angle: 45°
Overshoot angle: 45°
Sample rate: 76.923Hz

Run 1
Run direction: CCW
Machine temperature: 20.0°C

Run 2
Run direction: CW
Machine temperature: 20.0°C
Renishaw Laser Measurement and Calibration System

The ultimate metrology tool for traceable machine tool and motion system analysis
Laser Measurement & Calibration System Configuration

![Diagram of Laser Measurement & Calibration System Configuration](image-url)
## Equipment Specification

### Sensor performance

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material temperature</td>
<td>0 °C – 55 °C</td>
<td>±0.1 °C</td>
</tr>
<tr>
<td>Air temperature</td>
<td>0 °C – 40 °C</td>
<td>±0.2 °C</td>
</tr>
<tr>
<td>Air pressure</td>
<td>650 mbar – 1150 mbar</td>
<td>±1 mbar</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>0% - 95% Non-condensing</td>
<td>±6% RH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>±0.5 ppm</td>
<td>certified linear measurement accuracy over the full range of environmental operating conditions 1 nm linear resolution (even at max. velocity)</td>
</tr>
<tr>
<td>4 m/s</td>
<td>maximum travel velocity</td>
</tr>
<tr>
<td>7 seconds</td>
<td>between each automatically updated environmental compensation</td>
</tr>
<tr>
<td>50 kHz</td>
<td>dynamic capture rate</td>
</tr>
<tr>
<td>80 m</td>
<td>linear range as standard</td>
</tr>
</tbody>
</table>
Capability of Laser XL-80 Measure

- Linear
- Angular
- **Straightness**
- Squareness
- Flatness
- Rotary

At the moment, we can provide the Laser measuring service for Linear & Straightness range of 1m to 30m.
- How a laser is used to check for machine tool errors.
- Factors effecting the accuracy of a machine tool.
Dynamic Measurement - QuickViewXL software

Linear displacement

Machine vibration

Velocity versus time

Acceleration versus time
Renishaw Analysis - Linear

Machine: Linear Example
Serial No: 15345/Lin
Date: 09:00 Sep 2 '97
By: R.T.S.

Axis: X
Location: Mid Position
Filename: errocomp.rtl
Bidirectional, 5 Runs

Accuracy: 0.0153
Pos-Dir Rep.: 0.0052
Rev-Dir Rep.: 0.0057
Bi-Dir Rep.: 0.0105
Error Compensate Table

RENISHAW CALIBRATION INTERFEROMETER SYSTEM
ERROR COMPENSATION TABLE

Machine: Serial No:
Date: 09:16 Sep 19 2008  By:
Axis: Location:
TITLE: Filename: XSDFG.RTL

Table type: Separate forward and reverse tables
Compensation type: Incremental
Compensation resolution: 1 μm
Sign convention: As errors
Reference position: -560.0000 mm
Compensation start: -560.0000 mm
Compensation end: -20.0000 mm
Compensation spacing: 20.0000 mm

<table>
<thead>
<tr>
<th>No.</th>
<th>Axis position (mm)</th>
<th>Forward direction (1 μm)</th>
<th>Reverse direction (1 μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-560.0000</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>2</td>
<td>-540.0000</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>-520.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>-500.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>-480.0000</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>-460.0000</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>-440.0000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>-420.0000</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>-400.0000</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>10</td>
<td>-380.0000</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Complementary Products

Ballbar and laser, working together for maximum benefit

The Renishaw ballbar system is internationally recognised as the ideal solution to quickly check machine tool performance and benchmark in between scheduled laser calibrations.
XL-80 laser measurement system