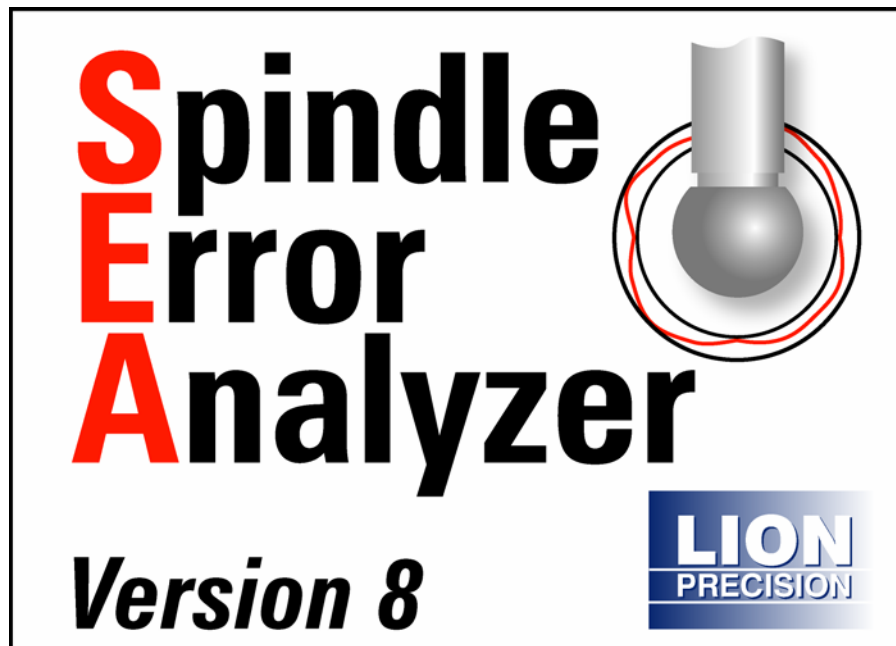


**INSTRUCTION
MANUAL**

***Advanced
Spindle Error Analyzer
Version 8.2***



This instruction manual details the operation of the Lion Precision Spindle Error Analyzer Version 8. Please contact us if you have any questions or suggestions on how we can be of greater service to you.

**Lion Precision
651-484-6544
info@lionprecision.com
www.spindleanalysis.com
www.lionprecision.com**

Software Version: 8.2
Manual Version: 004

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Introduction

The Spindle Error Analyzer System is a hardware and software package for measuring and analyzing the accuracy of spindles on machine tools, hard-disk drives etc.

Fundamental Concepts

SEA uses noncontact, capacitive sensing to measure error motions as changes in position of precision master targets installed and rotating in the machine spindle. The sensors have a typical range of 250 μ m with a resolution of 15nm RMS. Actual values may vary depending on the specifics of the system ordered.

The measurements are collected and analyzed by the SEA software. The results of the active measurement or archived measurement file are presented on polar or linear plots with calculated values of error motion measurements.

Tests Performed by SEA

SEA performs the following tests as described in ISO and ANSI/ASME standards:

- Radial rotating sensitive direction
- Radial fixed sensitive direction
- Tilt fixed sensitive direction
- Axial error motion
- Thermal stability
- Temperature variation error
- Shift vs. RPM

Additional Capabilities of SEA

- FFT Analysis
- Oscilloscope display
- Analog meter display
- Donaldson reversal test
- File overlay
- Automated Test Sequencing

Standards and References

- ANSI/ASME Standard B5.54-2005, *Methods for Performance Evaluation of CNC Machining Centers*
- ISO230 Part 3 (2001), *Test Conditions for Metal Cutting Machine Tools, Evaluation of Thermal Effects*
- ISO230 Part 7 (2005), *Geometric Accuracy of Axes of Rotation*
- ANSI/ASME B5.57-1998, *Methods for Performance Evaluation of CNC Turning Centers*
- ANSI/ASME B89.3.4, *Axes of Rotation, Methods for specifying and testing*

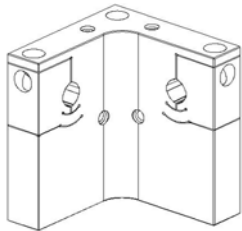
Assistance

For assistance with the installation and operation of the SEA 8 system, please visit our web site at: www.spindleanalysis.com or contact us at:

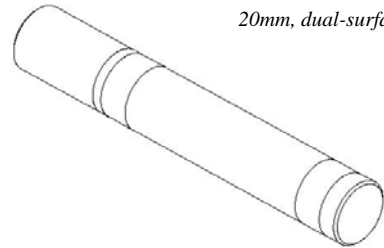
Lion Precision
563 Shoreview Park Road
St. Paul, MN 55126
support@lionprecision.com
651-484-6544
www.lionprecision.com
www.spindleanalysis.com

Parts ID

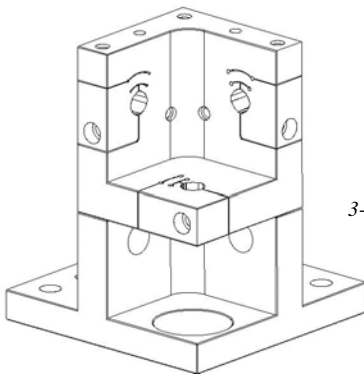
Drawings below identify some of the mechanical components included in the SEA system.



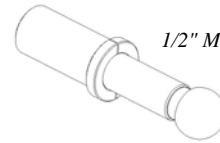
5-Probe Nest Adaptor



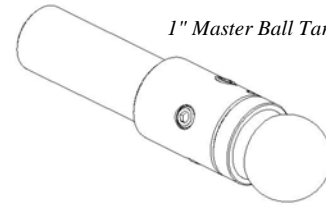
20mm, dual-surface gage pin



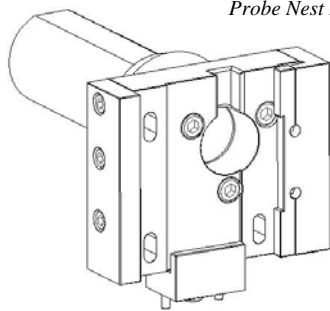
3-Probe Nest



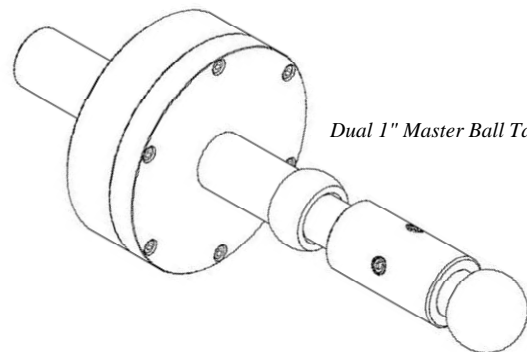
1/2" Master Ball Target



1" Master Ball Target



Probe Nest Lathe Adaptor



Dual 1" Master Ball Target

Installation

SEA Software

Install all software before installing the data acquisition device. The SEA software installation includes installation of all required National Instruments driver software.

Do not install any software from National Instruments disks included with the National Instruments data acquisition hardware.

Minimum Requirements

Windows 2000 or XP

1GB (desktop) 1.5GB (laptop)

1GB Free Disk Space (minimum)

1 GHz Processor

1 Available USB port (or PCMCIA Slot if using PCMCIA card)

1024 x 768 Minimum Screen Resolution

Procedure

The SEA installation program installs all necessary hardware drivers. Do not install National Instruments software separately. The SEA program is installed in the PROGRAM FILES\SEA8 directory on your hard disk. If you install the SEA software a second time using the same subdirectory, you will be prompted to confirm the overwrite of the previous installation.. The installation program also creates the subdirectory PROGRAM FILES\SEA8\DATA where measurement data will be stored unless redirected in the configuration settings.

To use the SEA CD-ROM:

1. Insert the CD and wait for the autorun program to load the welcome screen, then select install.
2. If Autorun is disabled on your computer or if the CD fails to autorun for any reason, click on the "My Computer" icon. Then choose the CD-ROM drive. Double click on the program Install.bat.
3. Follow the directions of the installation programs:
4. Once the installation has copied all files from the installation disk, restart the computer.
5. After restarting, run the program by selecting the icon on the desktop, or by selecting **Start > Programs > SEA**.

The data directory, "Program Files\SEA 8\DATA" contains several demonstration data files.

The installation CD also contains valuable documents related to spindle measurement and improving machine part quality.

Data Acquisition Hardware

SEA requires a USB6251 (preferred) or PCMCIA E-series data acquisition card from National Instruments. PCMCIA cards are not recommended.

After the SEA software is installed (which includes National Instruments drivers), install the DAQ device according to National Instruments instructions, and restart the computer.

All National Instruments software was installed with the SEA8 installation. Do not install any National Instruments software from National Instruments CDs.

Security Key (Dongle)

The security key **MUST** be attached to a USB port on the computer to perform measurements and collect data. The security key is not required to view or print saved data files.

If upgrading from SEA 7 to SEA8, either the USB or parallel port key may be used.

Software Basics

Select Mode of Operation

When the program is launched (**Start > SEA8 > SEA8**), a dialog box appears requiring mode of operation selections as follows:

Measurement System Model

The newer Elite Series sensors provide TEDS (transducer electronic data sheets) information to the SEA system. Older CB-7 style sensors do not provide TEDS and require the installation of VTEDS files (p. 13). Use the photographs to help you select your measurement system. If the software key is not connected to the computer, these buttons will be grayed out.

Select DAQ Source

The first time the program is run, you must select the source of DAQ information. Normally, there is only one to choose from. The installed DAQ devices are listed as: DEV1, DEV2.... After selecting a device, a description of the device will be displayed.

View Files Only/Simulator Mode

As of this revision, these buttons function essentially the same. Selecting either will put the system in Simulation mode; no data will be collected from the DAQ device. These are the only modes available if the software key is not attached to the computer.

Retry

The Retry button only appears when the software key is not connected. Clicking the Retry button after connecting the software key will restart the software with full functionality.

Setting Notepad and Acrobat Paths

Windows Notepad is used for Comments in SEA. For Comments to function, SEA must know the path to the Notepad application.

Adobe Acrobat is used for viewing the pdf manual from the Help menu. SEA must know the path to the Acrobat application.

These paths are entered in the **Main Menu > Configuration > General** screen.

These are typical paths to the files, but it may be different on your computer:

Notepad: C:\Windows\notepad.exe

Acrobat: C:\Program Files\Adobe\Acrobat 8.0\Acrobat\acrobat.exe

Each new version of Acrobat will be placed in a new directory. If you install a new version of Acrobat, this path must be modified.

Basic Navigation

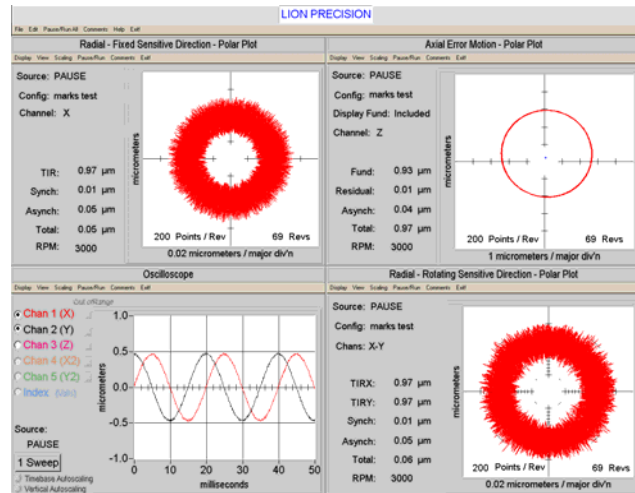
The SEA software uses several simple conventions that make the software easy to use.

- *Menus display lists of selectable options.*
- *Buttons execute or gain access to features.*
- *Panels display fields of information.*

Quadrant Displays

SEA starts with four different display panels in four quadrants on your screen. Each quadrant displays a selected view of the current data. The current data may be live data from the sensors, saved data from a previous measurement, or simulated data for training and experimentation.

Each quadrant has a menu bar which begins with **Display**. Use the display menu to select which panel to display in that quadrant.



Logo Screen (Information Quadrant)

Screen prints are often used to document spindle tests. It is helpful to have test information displayed on the screen when the screen is printed.

To display an information quadrant, select **Display > Logo Screen** in a quadrant.

Information can be entered into fields in the quadrant. To change the displayed image, select **View > Select Graphic** from logo screen's tool bar.

Maximizing Displays to Full Screen

Initially, each display uses one quarter of the screen (quadrant). Maximize the quadrant display to fill the entire screen by selecting **View > Maximum Size** or double click the right mouse button over the display to be maximized.

Minimizing Displays to a Quadrant

Return a maximized display to its quadrant by selecting the **View > Normal Size** or double click the right mouse button over the display.

Choosing a Language

To select a language other than English:

1. In any quadrant, select **Display > Configuration Displays > General Configuration**
2. Select the desired language from the **Language** drop down menu
3. Exit and restart the SEA Software

Language choice will remain until another is selected.

SEA Configuration

For proper operation, the SEA software must be properly configured. There are four types of configuration information:

Indicators: These display information acquired from the system.

Automatic Inputs: These are required input settings which are automatically acquired from the system.

Manual Inputs: These may be required or optional input settings that must be manually entered by the user.

Calculated Values: These are indicators whose values are calculated from other input settings in the configuration. They have cyan colored backgrounds.

Configuration settings can be saved with **File > Save > Configuration** in the top menu bar.

The complete configuration consists of data from several different configuration windows. The configuration windows are accessed through the **Main Menu > Configuration** or the individual quadrant **Display > Configuration > [Selected Configuration Window]**.

General Configuration

Field	Type	Notes
Language	Required Manual Input	
Comment Editor	Optional Manual Input	This is the path to Windows Notepad. Only required to enter test notes and to view some help files.
PDF Viewer	Optional Manual Input	This is the path to Adobe Acrobat. Must be entered correctly to view the onscreen manual.
Display Units	Required Manual Input	
Date Format	Required Manual Input	

DAQ Configuration

These configuration settings determine the operation of the data acquisition board and are critical to the operation of the system. The RPM Range possible with the current settings is displayed in this panel and is updated when the settings are changed. Settings in Analysis Configuration also affect the RPM Range.

Field	Type	Notes
DAQ Board	Required Manual Input	Default = DEV1. Only applies when there are more than one data acquisition boards in the system
Active DAQ Channels	Required Manual Input	Setting the DAQ board to access only the channels to be used in upcoming measurements increases the maximum sampling rate of the system.
DAQ Gain	Required Manual Input	Default = Minimum (½ or 1). Must be adjusted for a ±10V input range. For more information click the “DAQ Gain Help” button.
DAQ Sample Clock	Required Manual Input	Default = Internal Clock. DAQ board sample triggering can also be controlled by a spindle encoder. When using an encoder for triggering or for RPM measurement, the number of encoder pulses per revolution must be entered here.
Rotation Angle Detector	Required Manual Input	Default = Target Eccentricity Ch. X Target eccentricity is used to determine the angular location of the spindle. Alternatively, an index pulse from a spindle encoder or other “once around” sensor can be used.

Analysis Configuration

There is a relationship between the Sample Rate (samp/ch/sec) in the DAQ Configuration screen, the Data Points Displayed per Revolution, Data Points Displayed per Revolution and the maximum RPM. The RPM Range possible with the current settings is displayed in this panel and is updated when the settings are changed. Settings in DAQ Configuration also affect the RPM Range. For more detailed information, click the Help button on the DAQ Configuration Panel.

Field	Type	Notes
Revolutions for Display and Calculations	Required Manual Input	Default = 30. The number of revolutions acquired which form the data from which values are calculated. This number, along with Data Points Displayed, and sample rate in the DAQ Configuration affects the maximum RPM. Click the green Sample Rate Help button for details.
Data Points Displayed per Revolution	Required Manual Input	Default = 150. The number of measurements acquired during one revolution of the spindle. This number, along with Revolutions for Display, and sample rate in the DAQ Configuration affects the maximum RPM. Click the green Sample Rate Help button for details.

Machine Information

Optional, machine-specific information can be entered here including spindle position information on six axes.

Field	Type	Notes
Name	Optional Manual Input	Value is displayed as part of “time stamp”
Machine ID	Optional Manual Input	Value is displayed as part of “time stamp”
Position/Units	Optional Manual Input	Position settings in six axes can be entered here and units selected. Three of the six axes can be displayed in degrees as well as inches or meters
Graphic File	Optional Manual Input	Click the existing image to load a photo or drawing to represent the machine under test. Possible graphic file types: bmp, pcx, wmf.

Target Configuration

The size, shape, and accuracy of the targets affect the measurement results. For maximum accuracy, the details of the target must be entered here. Each channel of measurement can have separate values.

Field	Type	Notes
Roundness Error	Required Manual Input	Default = 0.0 μm . Roundness error specification from target calibration information. This can be entered in either microns or micro-inches. This value is for reference only and is not used in calculations.
Target Shape	Required Manual Input	Default = Sphere
Target Dimension	Required Manual Input	Default = 25.4mm. Diameter of a round target.
Target Multiplier	Required Manual/Automatic Input	Sensors are calibrated to flat targets. When the probes are measuring a cylindrical or spherical target, a correction multiplier is required for accurate measurements. When "Auto" is checked, the multiplier is automatically calculated for the selected target shape, size, and calibrated range. Auto values are only available for "C" size probes (C23-C). If an unlisted target or other probe size is used, a manual multiplier can be entered by unchecking the Auto check box.
Target Model	Optional Manual Input	Target Model such as "1" Dual Ball"
Target Serial	Optional Manual Input	Target serial number
Last Cal.	Optional Manual Input	Last calibration date of the target
Next Cal.	Optional Manual Input	Target calibration due date
Length X to X2	Required Manual Input	Default = 76.2mm. Required for Tilt measurements. This is the distance between the X and X2 probes when measuring tilt. Standard 5-probe nest distance is 76.2mm.

Calibration Configuration

Calibration information is acquired through TEDS (Elite Systems) or VTEDS (older sensor systems). This is automated and these values should not be changed except in the rarest of circumstances.

The Low/High Sensitivity switch is used to change a sensing channels sensitivity remotely. The Sensitivity switches on the driver front panel are disabled when the sensing system is connected to the SEA data acquisition system. The sensitivity switch is only applicable to CPL290 and DMT22 drivers.

Field	Type	Notes
Sensitivity Switch	Required Manual Input	Only works with CPL290 and DMT22 drivers.
Near Gap	Indicator	The minimum calibrated distance from probe face to target, listed in dimensional units and corresponding output voltage.
Far Gap	Indicator	The maximum calibrated distance from probe face to target, listed in dimensional units and corresponding output voltage.
Sensitivity	Calculated Indicator	The amount of output voltage change for a given change in probe/target gap. This is calculated from the Near and Far Gap information.
DAQ Card Range and Resolution	Calculated Indicator	These display the actual near and far gaps after allowing for DAQ Gain setting. For example, a DAQ Gain of 10 will give higher resolution, but input voltage range (and therefore the measurement range) will be limited to less than the calibrated range of the sensors.

Calibration Data

This panel displays the calibration information for all of the sensor channels in the sensor system. The panels will appear slightly different for Elite Series sensor systems than they do for older model modular systems.

See the TEDS and VTEDS section below for important, detailed information on the functional differences in the two system types.

Field	Type	Notes
Reload	Button	Re-acquires the calibration information from the TEDS or VTEDS source.
Chassis	Indicator	Only visible when connected to an Elite Series system.
Available Slots	Indicator	Number of slots available in the system enclosure
VTEDS Filename	Required Manual Input Non-Elite systems only	Default filenames follow SEA conventions and should not require changing. Should a different filename be necessary, click each filename to specify the desired VTEDS file.
Columnar Data	Indicators	A column for each slot indicates the vital statistics of the sensing channel.
More	Button	The “More” button will open a dialog box with indicators detailing calibration information acquired from TEDS or VTEDS. It is possible to change these values but this should only be done in the rarest of circumstances and with assistance from Lion Precision. Any manual changes made here will be lost when the SEA 8 program is closed.

TEDS and VTEDS

TEDS (Transducer Electronic Data Sheet) is technology which enables measurement systems to acquire a wealth of calibration information directly from the sensor. SEA 8 depends heavily on TEDS for configuration information.

The Elite Series of sensors are TEDS compliant and provide this configuration information to SEA 8 when the software is launched. Older systems (black and gray enclosures) are not TEDS compliant and do not provide the configuration data directly. When SEA 8 is used with older sensing systems, the required TEDS data is provided through VTEDS files (Virtual TEDS). These files are provided on a CD and contain specific calibration information for the system being used.

It is critical that the correct VTEDS files be used with corresponding sensing system.

The VTEDS CD includes an installation program which will install the files in the appropriate folder of the SEA 8 system, provided SEA 8 was installed in default directories. The VTEDS files must be located in the “VTEDS Files” subdirectory of the SEA 8 directory.

Making Measurements and Reading Plots

Understanding and Interacting with Plots

Adjusting Plot Displays

Scaling

Use the Scaling menu to select Auto or Manual scaling. Auto adjusts to provide the best view of the existing data. Select **Scaling > Manual > Increase** or **Decrease**, or use Page Up and Page Down keys to adjust scaling manually.

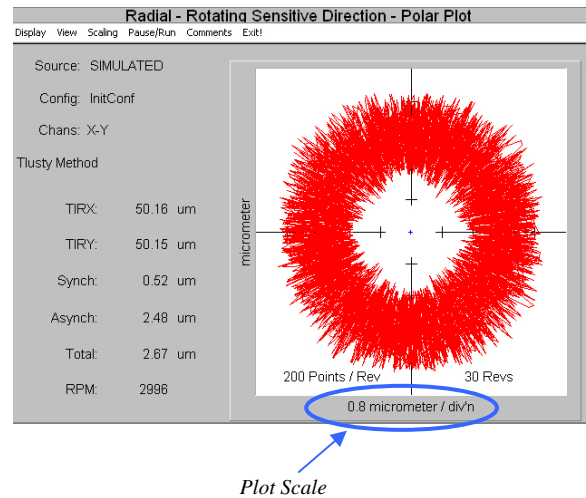
Polar plots

Polar plots chart measurements at successive angular locations of the spindle. By default, all acquired rotations are displayed simultaneously.

The plot scale is listed at the bottom of the plot.

The center of the plot does not represent zero if the axes do not cross (see example at right). This allows sufficient display resolution of small spindle motions, which would be off screen if the center were zero.

Calculated values are to the left of the plot. Definitions of the calculated values are in the glossary in this manual and in Help.



Calculated Circles

Circles can be displayed on the plots to assist in measuring and viewing some important calculated values. To enable circle displays, select **View > Circles**.

Total – Displays two blue circles. The origin of the circles is at the center of the plot. The inner circle is the largest diameter possible *inside* of the data points (maximum inscribed circle). The outer circle is the smallest diameter possible *outside* the data points (minimum circumscribed circle). The distance between the circumferences of these circles is the total error motion.

Average – The average circle is not actually a circle. This green curve is generated by placing a data point at each angular location. The position of the point is equal to the average of the measurements of all the acquired revolutions at that angular location.

Least Squares – Displays a black circle based on a best-fit, least squares calculation of all the displayed data points.

To find the center of polar plot data, SEA uses the MLS (Modified Least Squares) method describe in *A Few Methods for Fitting Circles to Data* by Umback and Jones (IEEE Transactions on Instrumentation and Measurement, V52, I6, December 2003).

Setup for Making Measurements

Configuration

The SEA 8 software must be properly configured. Much of the configuration information is accessed directly from the sensing system.

Some configuration information must be entered by the user. This information must be properly entered for accurate measurements.

See the configuration section of this manual for details.

Connection to PC

Connect a 68 pin, high-density cable between the rear panel of the capacitive sensing system and the National Instruments data acquisition system. If the National Instruments USB6251 Data Acquisition Module is used, it is necessary to connect a USB cable between the Module and a USB V2.0 (high speed) port on the PC. The USB V2.0 (high speed) port is necessary due to the high data transfer rates required.

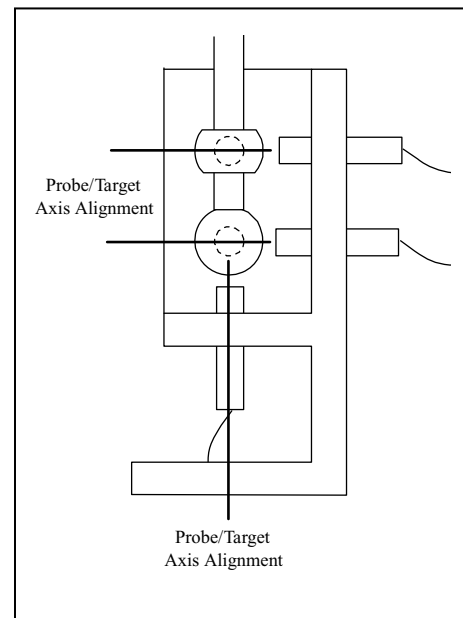
Mechanical

There are five goals in the mechanical setup:

- Probes never make contact with target during rotation (incidental contact during setup while the spindle is stationary is safe)
- Master ball target axes are aligned with probe axes (balls are centered on the probes)
- Probes are adjusted to the center of their measurement ranges
- Target eccentricity is adjusted to be greater than the expected error motions (25 μ m is typical)
- Probes stay in range during the full rotation of the spindle

Target Installation

Targets are installed in the tool/part holder of the spindle to be tested.



Axis/Channel Relationships

Default settings in the SEA software assume Axis/Channel relationships as listed in the table below. Individual tests allow the assignment of other Axis/Channel relationships. This flexibility allows a three-channel system to make measurements normally requiring five channels, such as using the Z probe temporarily in the X2-axis to make a Tilt measurement.

Default Axis/Channel Relationships	
Axis	Channel
X	1
Y	2
Z	3
X2 (X-axis probe near spindle nose in 5 probe setups)	4
Y2 (Y-axis probe near spindle nose in 5 probe setups)	5

Probe Nest

Loosen the clamp screws if necessary and install the probes in the nest. Tighten the probe clamps such that the probes are held in place but can still be repositioned by hand.

Mount the probe nest such that the rotating target can be moved into range of the probes in the nest. It is critical to firmly clamp the probe nest to the machine tool table.

Positioning Spindle/Targets and Probes

Each probe must be precisely centered on the spherical surfaces of the targets. Target centers are located and positioned by using the probes and Probe Meter to find the high-spot as the target is repositioned in front of the probe. Center the targets on the probe with a process such as this:

1. In any quadrant, select **Display > Probe Meter**.
2. Maximize the Probe Meter (double right-click on the panel)
3. Move the spindle/target into the probe nest and approximately center it on the Z-axis probe in the bottom of the probe nest and on the X- and Y-axis probes.
4. Select the Z-axis channel on the Probe Meter (usually channel 3).
5. Physically adjust the Z-axis probe position until the Near/Far indicator on the driver is in the center position.
6. While observing the Probe Meter adjust the spindle X-axis position until the high-spot (maximum positive indication) is indicated on the Probe Meter.
7. While observing the Probe Meter adjust the spindle Y-axis position until the high-spot (maximum positive indication) is indicated on the Probe Meter.
8. The target is now centered over the Z-axis probe.
9. Loosen and move the Z-axis probe away from the spindle so it will not be touched during the following steps.
10. Physically adjust the X-axis probe position until the Near/Far indicator on the respective driver is in the center position.

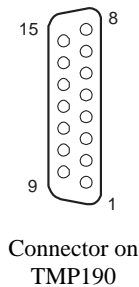
11. Select the X channel on the Probe Meter and use the driver ZERO adjustments to adjust the X-axis sensor output to near 0 as indicated on the Probe Meter.
12. Adjust the spindle Z-axis position until the high-spot (maximum positive indication) is indicated on the Probe Meter.

Measuring/Adjusting Target Eccentricity

13. On the Probe Meter select an X- or Y-axis probe. (If using a dual-ball target and five-probe nest, first select a probe for the ball nearest the spindle nose).
14. Click Refresh TIR on the Probe Meter.
15. Turn the spindle by hand one rotation.
16. The distance between the TIR markers (sticky needles) is the eccentricity of the target
17. If eccentricity is incorrect, adjust the target eccentricity according to TechNote LT05-0023 included with the system and available in the Technical Library at www.lionprecision.com.
18. When the eccentricity is correct, move all probes into range center as indicated by Near/Far indicators on the drivers.
19. Rotate the spindle again and monitor the Near/Far indicators on all sensor channels. If any channel goes out of range (a red light turns on) during the rotation, slightly reposition that channel's probe and retry until all probes remain in range during the rotation.
20. Tighten all probe clamps.
21. Rotate spindle again to confirm all probes remain in range.

Temperature Probes

Place temperature probes as desired on the machine under test. SEA 8 temperature channels T1 – T7 are related to TMP190 sensors as shown in the table below.



Pin Numbers	Connection	Pin Numbers	Connection
1, 9	Probe 1 (T1)	5, 13	Probe 5 (T5)
2, 10	Probe 2 (T2)	6, 14	Probe 6 (T6)
3, 11	Probe 3 (T3)	7, 15	Probe 7 (T7)
4, 12	Probe 4 (T4)	8	No connection

Encoder/Index Connections

Refer to the TMP190 manual for connection details. Spindles without encoders may still use an Index pulse by using an external sensing source such as a mark and an optical sensor.

Running Tests

To view live test data while a spindle is being measured, select **File > Load > Live Display** from the SEA 8 top menu bar.

To view data from saved measurement data, select **File > Load > Test File**.

Reading and interacting with the test plots and panels in general is covered above. The following sections give specific, unique information about the specific tests.

The default channel(s) is listed first in the Possible Channel Combinations table.

Basic Tests

Radial: Rotating Sensitive Direction

Number of Sensors Used	2
Axes Measured	{X, Y}
Possible Channel Combinations	{1, 2} or {4, 5}

X and Y axis measurements are used to create a polar plot using one of two possible methods:

B89.3.4 (r-theta) or

Trusty

The method is selected by **View > Method**. See the appendix for details on the two methods of calculation.

Radial: Fixed Sensitive Direction

Number of Sensors Used	1
Axes Measured	{X} or {Y}
Possible Channel Combinations	{1} or {2} or {3} or {4} or {5}

X or Y axis measurements are acquired and presented in a polar plot or a linear plot with angular position on the linear plot's X-axis.

Select the plot type with **View > Polar Plot** or **Linear Plot**.

Axial Error Motion

Number of Sensors Used	1
Axis Measured	{Z}
Possible Channel Combinations	{3} or {1} or {2} or {4} or {5}

Measures spindle motions in the Z-axis using the probe mounted in the bottom of the probe nest.

Polar and linear plots are available (**View > Polar** or **Linear**).

Select **View > Display** to choose one of three different display options are available for the plots:

- **Total with Fundamental** – includes error motions at the rotational frequency of the spindle.

- **Total without Fundamental** – error motions at the rotational frequency of the spindle are removed from the data before plotting.
- **Asynchronous Only** – error motions at the fundamental or harmonics of the rotational frequency are removed before plotting.

The calculated values are not affected by display choice. See the glossary for more information on these display modes.

Tilt: Fixed Sensitive Direction

Number of Sensors Used	2
Axes Measured	{X, X2} or {Y, Y2}
Possible Channel Combinations	{1, 4} or {2, 5} or {1, 2} or {1, 3} or {2, 3}

Measurements from both X and X2 (or Y and Y2) channels provide measurements of the synchronous and asynchronous changes in the tilt of the spindle at different angular locations. A standard polar plot (tilt angle in μ radians) or a 3D plot are available.

Three channel systems can make Tilt measurements by moving the Z axis probe into the X2 or Y2 position.

Plot type is selected with **View > Polar** or **3D**.

RPM Shift

Number of Sensors Used	1-5
Axes Measured	Any
Possible Channel Combinations	All single channels or tilt combinations

The axis of rotation of the spindle may change with changes in RPM. The test charts changes in the position of the axis of rotation of the spindle against RPM. The operator adjusts RPM and clicks the Save Point button to plot a point.

The first time Save Point is clicked, measurements of the spindle in all axes are set as the reference for future measurements. Successive clicks of Save Point will plot the position change of the spindle at the measured RPM.

Clicking the channel buttons will enable/disable the display of that channel.

Measurements can be taken as the RPM is increased and retaken as the RPM is decreased to display any hysteresis the RPM/Spindle Position relationship.

FFT Frequency Analysis

Number of Sensors Used	1
Axes Measured	Any
Possible Channel Combinations	Any single channel

Used to analyze frequency distributions in error motions. The FFT analysis test acquires sampled amplitude data from a single probe in the *time domain* and converts the data into the *frequency domain*. A graph of amplitude vs. frequency is produced. The graph is updated once per second, showing the FFT results on the most recent data set.

*FFT Views (from **View** menu):*

Bar Graph – Bar (column) graph display

Line Graph – Continuous line connecting measurements

Ping – Plots the results of a triggering event such as a hammer ping.

*Window(from **View** menu):*

Selects the type of mathematical windowing technique for displaying the FFT. Hanning or rectangular are typical choices.

Scaling

Scaling and axis unit options are available in the **Scaling** menu.

Cursor

A cursor (**View > Show Cursor Values**) can be used display values at any point on the charts X-axis (frequency). Click and drag the mouse pointer to reposition the cursor or use keyboard arrow keys. For fine adjustment, hold the shift key while using arrow keys.

Donaldson Reversal (Target Reversal)

Donaldson Reversal displays data from two Radial – Fixed Sensitive test runs combined in such a way that form errors in the target (out of roundness) are separated from the synchronous error motion of the spindle. The Radial – Fixed Sensitive display must be active in another quadrant during Donaldson Reversal functions.

Performing the test:

1. Display the Donaldson Reversal panel in one quadrant.
2. Display Radial – Fixed Sensitive panel in another quadrant.
3. Perform a Radial – Fixed Sensitive measurement.
4. Click **Store A** to store the current Radial – Fixed Sensitive plot in the Donaldson Reversal display.
5. Stop the spindle.
6. Move the probe to a position 180° around the spindle from its original position.
7. Remove and replace the target 180° from its original position in the spindle.
8. Perform another Radial – Fixed Sensitive measurement (do not change any settings).
9. Click **Store B** to store the new Radial – Fixed Sensitive plot in the Donaldson Reversal display.
10. Click **Calculate**.
11. The synchronous error motion of the target and the spindle are plotted independently.
12. Use the display buttons to turn individual plots on and off.

Thermal

Number of Sensors Used	1-5
Possible Channel Combinations	Any single channel or tilt combinations (up to seven temperature sensors)

The two thermal tests listed in international standards are ETVE (Environmental Temperature Variation Error) and Thermal Drift. The display and basic operation of the panel remains the same for both tests. Only the time of the test, the channels used, and the rotation of the spindle are changed.

The thermal test setup parameters are accessed by clicking **Setup!** on the Thermal menu bar.

Measurements are acquired from all channels enabled in the DAQ configuration.

Clicking sensor buttons enables/disables the display of the channel on the chart. When clicked, the X2 and Y2 buttons rotate through Drift/Tilt/Disabled options. Redraw button must be clicked to display new enable/disable selections.

The value displayed on the buttons is the Range (max-min) for that channel.

A valid filename must be specified for the thermal data.

Custom Temperature Channel Names

Right-click on a temperature channel display button to enter a custom name such as “ambient” or “spindle.”

ETVE (Environmental Temperature Variation Error)

Tests the growth and movement a nonrotating spindle due to changes in ambient temperature.

Standard TVE values:	
Interval 1 Duration	2 minutes
Interval 1 Sample Frequency	5 seconds
Interval 2 Duration	24 hours
Interval 2 Sample Frequency	5 minutes

Thermal Drift

Tests the growth and movement of a rotating spindle due to changes in the temperature distribution caused by heat generated by the spindle motor and/or bearings.

Standard Thermal Drift values:	
Interval 1 Duration	2 minutes
Interval 1 Sample Frequency	3 seconds
Interval 2 Duration	58 minutes
Interval 2 Sample Frequency	10 seconds

Automated Measurement

Automated Measurements is useful for testing time- or speed-related changes in spindle performance. Test results can be directly linked to a Microsoft Excel file.

Automated Measurement repeatedly runs axial or radial tests at a specified time interval or at selected speeds. When testing at predetermined time intervals, each run of the test is called a **Trial** and fills one row in the spreadsheet. Multiple trials can be grouped. A **Group** consists of 1 to 1000 trials. Time intervals between Trials and Groups can be set independently. Test runs can include 1 to 1000 Groups. Use caution with large Trial and Group sizes as the spreadsheet file size can become very large. If the Link to Excel option is used, the Excel sheet is limited to 65,356 rows (trials).

When testing at pre-determined speeds, a test will be performed when the selected speed is reached and is stable for a selected **Dwell** time.

Click **Setup!** on the menu bar to configure the test.

Setup

Test Type selects the type of measurement to be performed. The selected test type must be active and configured in another quadrant. The options are:

- Rotating Radial

- Fixed Radial
- Axial

Trials/Group and the number of **Groups** each have a minimum of 1 and a maximum of 1000.

Trial Delay sets the seconds of delay between individual trials within a group.

Group Delay sets the seconds of delay between groups.

File Select selects the filename and location for test results to be stored. A file must be specified before the test can be run.

Link to Excel when checked places the acquired data in an Excel spreadsheet with a graph. Excel must be installed on the computer.

- **X Axis Parameter** selects time or individual trials as the source for the Excel graph's X-axis..
- **Y Axis Parameter** selects which value to chart on the graph's Y-axis. Any calculated value can be charted.
- **Save**
Summary file contains only the resultant data as recorded in the table.
SEA and Summary includes resultant data and the individual samples for later viewing in the SEA quadrants. The **SEA and Summary** selection will generate very large files.

Data Check Limits

The Data Check Limits function will prevent data skewing where this is a concern such as in high-speed spindle measurement where the processor demands are particularly heavy.

Under some circumstances, values reported by SEA, especially RPM, may momentarily report aberrant values such as 0 or 1 RPM. This is due to system limitations. In normal operation, the operator rarely notices these quick, momentary values, but should it occur while the Automated Measurements is collecting data, the resulting data would be skewed.

To use the Data Check Limits function click **Data Check Setup**. In the dialog box, check the parameters to be monitored and set minimum and maximum values. Automated Measurements will verify that all checked values are within limits before capturing the data. If any checked values are outside the limits, the system will wait until all return to acceptable values. While waiting, the system will display a red **Beyond Limits** message in the table.

Done button saves all settings and closes the setup display

When all selections have been made, click **START Test**. The test will run until the selected number of trials and groups have been completed. The test can be paused or ended before completion by clicking the appropriate button.

View > Automated Test File loads a previously saved test file for viewing.

File Overlay

File Overlay simultaneously displays two sets of color-coded measurement data on the same plot. One use for file overlay is to compare the data from a current test on a machine to the data from a baseline test on the same machine.

To use File Overlay:

1. Select the source of the data with the **Select Source** drop down.

2. Use another quadrant to display the selected type of data.
3. Load a stored data file.
4. Adjust the display of the data.
5. Click **Store A** in File Overlay quadrant
6. Load a second file or use live data for comparison.
7. Adjust the display of the data.
8. Click **Store B** in File Overlay quadrant
9. Use **View > Revolutions** options to view all revolutions or view them one at a time.
10. Use the **A** and **B** display selectors to display one or both data sets.

Scaling for the File Overlay display is derived from the source displays, so the scale for those displays should be the same when captured to the File Overlay panel.

Utilities

Probe Meter

The Probe Meter is a utility display that emulates an analog meter indicating the current probe/target gap of the selected probe.

The Probe Meter is best used maximized to full screen.

Any one of the five probe channels can be displayed. Use the mouse or the up or down keyboard arrows to select a different channel.

If the measurement is out of range, red “overrange” text will appear on the meter.

Maximum and minimum indicators retain the maximum and minimum positions of the meter needle. These values are shown digitally below the meter. Click the **Reset TIR** button to reset the maximum and minimum indicators to the current meter indication.

Oscilloscope

The Oscilloscope is a utility display that emulates a basic oscilloscope, allowing a time based view of the data acquired on any of the five probe channels.

Use the View menu to select DC/AC Coupling and multi-trace or multi-scope mode. Multi-scope mode is only available when the panel is maximized to full screen.

Data File Structure

Critical files for SEA must be located in appropriate subdirectories. These files are placed in the correct locations during the installation process. This structure is provided in case new files need to be added or to assist in troubleshooting.

***base* = C:\Program Files\SEA8**

Contains all program files

***base* \DATA**

Default directory for data files.

All sample data files

***base* \SETUP**

All configuration files

***base* \DOCS**

All Help files

SEA 8.0 Manual

Related documents and text files

***base* \VTEDS Files**

VTEDS files must be in this subdirectory to be used by SEA 8

***base* \Language**

Text files with labels and phrases used in SEA 8, translated to the language of the name of the file, e.g. english.txt contains the English labels and phrases.

Appendices

Menu item descriptions

Main Menu Bar

File

File > Load > Live Display purges all data buffers then starts or restarts the Data Acquisition card, and begins to display data from the card in each of the four quadrants. The source indicator in each quadrant changes to indicate **Live Data**.

File > Load > Simulated Display provides internally generated random data to be read by the system for the purpose of testing, demonstrating, and experimenting with the software. A complete waveform simulator is displayed in the first quadrant.

A typical setup simulating common input conditions:

- All Switch Positions: Simulate
- Waveform X: Sine
- Waveform Y: Cosine
- Amplitude (All): 1

File > Load > [Test Files] displays data from a file stored during an earlier test. The default source directory is PROGRAM FILES\SEA8\DATA. Three different file types can be viewed

- Test Data File (*.lda) – Data is displayed in all radial and axial panels
- Thermal data files (*.lts) – Data is displayed in the Thermal panel only
- Donaldson reversal files (*.trv) – Data is displayed in the Donaldson reversal panel only
- Automated Test File (*.lsq) – Data is displayed in the Automated Test panel only
- Shift vs. RPM (*.shr) – Data is displayed in Shift vs. RPM panel only

Viewing stored data loads the original configuration file. The configuration settings cannot be changed.

File > Load > Configuration loads a saved set of configuration settings.

File > Save saves the current rotating data for later printing and review. File names should use the .lda extension (default). Data files are quite large, from 1 to 20MB depending on the data acquisition rate and other factors. The time to save a file can range from 15 seconds to 4 minutes.

Thermal, Shift vs. RPM, Automated Test Summary, and Donaldson reversal data files can only be saved from the View menu in their associated quadrants.

File > Print > Print Full Screen prints the full SEA screen, including menus.

View > BMP to Clipboard copies a bitmap (.bmp) image of the quadrant to the Windows clipboard from which it can be pasted in other documents.

To print individual quadrants, choose the **View > Print Panel** selection on the quadrant menu.

Configuration

Configuration > Show Configuration displays configuration panels in all four quadrants. Select **Display > Return to Test Displays** in any quadrant to close all configuration panels and show test displays.

Configuration > Save Configuration saves the current configuration

Configuration > Save Configuration As... saves the current configuration as a new file

Configuration > Load Configuration loads a saved configuration

Pause/Run

Pause/Run > Pause will pause the displays in all quadrants.

Pause/Run > Run will resume real-time data display in all quadrants.

Help

Help > Manual starts Windows Help with an electronic copy of this manual.

Help > Typical Setups displays a photo of a typical setup for the selected machine type.

Help > Lion Precision Support lists contact information for Lion Precision technical support

Help > About gives version information for SEA 8

Exit!

Closes the program.

Quadrant Menus

Display

Lists all possible quadrant displays. All Test and Configuration displays can be accessed through this menu. Whether the quadrant is currently a Test or Configuration display changes the groupings in this menu.

View

View > Maximum Size enlarges a quadrant panel to full screen.

View > Normal Size reduces a full-screen panel to a quadrant.

View > Polar Plot provides a polar plot of the error motion.

View > Linear Plot provides a linear plot of the error motion with degrees of rotation as the chart's X-axis and error as the chart's Y-axis.

View > Display > Total displays the synchronous plus asynchronous error.

View > Display > Total with Fundamental displays all spindle motions including motions occurring at the rotational speed of the spindle (includes eccentricity).

View > Display > Total without Fundamental removes motions occurring at the rotational speed of the spindle.

View > Display > Asynchronous Only displays the asynchronous error only.

View > Circles > Total [F3] draws the maximum and minimum value circles on the graph at the next update.

View > Circles > Average [F4] draws the average value plot on the graph at the next update.

View > Circles > Least Squares [F5] draws the least squares circle on the graph at the next update.

View > Revolutions > Individual [F6] causes the display to pause the current data and display the first revolution. While the display is paused, changes in the live data will not be seen on the display. Subsequent selections of this menu item will display subsequent revolutions. The displayed revolution number is indicated in the lower right of the graph.

View > Revolutions > Choice [F10] selects up to three revolutions for display. This allows non-consecutive revolutions to be displayed simultaneously in three different colors.

View > Revolutions > All [ESC] displays all the revolutions. The display is still paused and the revolutions displayed are the same as those shown in the individual selections.

View > Channel allows the selection of X, Y, Z, X2, or Y2. X is the default. Selecting other channels is only meaningful if probes are connected to those channels and channels are enabled in DAQ Configuration.

View > Print Panel immediately prints the quadrant to the default printer.

View > BMP to Clipboard copies a bitmap (.bmp) image of the quadrant to the Windows clipboard from which it can be pasted in other documents.

View > Print Report loads a previously saved file and opens the Print Report dialog box.

Setup!

Some tests require specific setup information not included in the configuration screens. Clicking the Setup! menu item immediately displays a dialog box for setting test parameters.

Scaling

Scaling > Rescale [Enter] when in manual scaling mode scales the current data to fit the plot area.

Scaling > Auto [End] monitors the data and changes the scale so that the data is always within 40% to 90% of the scale. Auto-scaling can also be activated by clicking the END key while the quadrant is active.

Scaling > Manual > Increase [PgUp] or Decrease [PgDn] deactivates auto-scaling and increases or decreases the graph scale.

Pause/Run

Pause/Run > Run [Ctrl+R] restarts paused quadrant. Each quadrant's pause/run function applies only to that quadrant.

Pause/Run > Pause [Ctrl+P] stops updating the quadrant's display.

Supported DAQ Hardware

The following National Instrument Data Acquisition hardware has been tested with SEA v8.0 and higher

Model	Resolution (bits)	Advertised Max Scan Rate (kS/s)	Useable Max Scan Rate (kS/s)
USB-6251*	16	1250	1000
DAQCard-6036E (not supported in Windows Vista)	16	200	100
DAQCard-6062E (not supported in Windows Vista)	12	500	250

*Recommended hardware for ease of use and performance.

SEA 8.2 uses DAQmx and can query the DAQ module for gain and sample rate information. Many other DAQ modules do not support these functions. As a result, many other DAQ modules may work but are not guaranteed by Lion Precision.

CAUTION: The user must confirm the accuracy of data acquired with any other card.

If requested scan rates exceed hardware maximums, the scan rate will be adjusted to the maximum scan rate the hardware can support, and a message will be displayed stating the change in rate.

When a board fails to start

Confirm that the correct Device Name is entered in the "DAQ Board" entry in the DAQ Setup screen. Only available module names will appear on the pull-down menu for the "DAQ Board" control. When a device is selected, its model name will appear below the control. Confirm that the model name matches the expected name.

If problems persist;

1. Start National Instruments "Measurement and Automation Explorer".
2. Select "NI-DAQmx Devices".
3. An entry similar to "NI USB-6251: "Dev1" will appear.
4. The value in quote marks in this example "Dev1" is the device name for your board. If you have multiple boards installed each board will appear with its own device name. Select the device name for the board you wish to use.

If problems still persist, start by entering a very low scan rate such as 1000 to verify basic functionality.

If problems continue, confirm that the board and NI-DAQ are functioning.

1. Exit SEA so that SEA and NI-DAQ do not conflict for the board.
2. Start National Instruments "Measurement and Automation Explorer".
3. Select "NI-DAQmx Devices".
4. On the left side of the screen, under "Configuration" highlight the board name. If the board name does not appear, refer to National Instruments documentation. There may be a conflict within your computer or the board and/or NI_DAQ may not be installed correctly.
5. Press the "Test Panels" button on the right top of the panel.
6. The test display should show the signal on probe channel 1 (NI chan 0 is Probe chan 1). Rotate your spindle or change the gap to probe 1 in some other way. If the display is a flat line or does not show the expected signal, refer to National Instruments documentation for help in troubleshooting the problem.

Glossary

Asynchronous error motion - the portion of the total error motion that occurs at frequencies other than integer multiples of the rotation frequency. Asynchronous error motion comprises those components of error motion that are: (a) not periodic (b) periodic but occur at frequencies other than the spindle rotational frequency and its integer multiples, (c) periodic at frequencies that are subharmonics of the spindle rotational frequency.

Asynchronous error motion value - the maximum scaled width of the asynchronous error motion polar plot, measured along a radial line through polar profile center.

Axial error motion - error motion coaxial with the Z reference axis. Axial slip, end-camming, pistoning and drunkenness are common but inexact terms for axial error motion.

Axial thermal drift - applicable when the displacement is parallel to the Z reference axis.

Axis average line - a line segment passing through two axially separated radial motion polar profile centers. The axis average line is used to describe the location of an axis of rotation with respect to the reference coordinate axes, or changes in the location, for example, in response to changes in load, temperature or speed.

Axis of rotation - a line segment about which rotation occurs

Axis shift - a change in position of the axis average line. Causes of axis shift include thermal drift, load changes, and speed changes.

Bearing - an element of a spindle that supports the rotor and allows rotation between the rotor and the stator.

Displacement indicator - a device that measures displacement between two specified objects.

Error motion - changes in position, relative to a calculated axis of rotation. This motion may be measured as motions of the surface of a perfect work piece (a master ball or an optical flat) with its centerline coincident with the axis of rotation.

Face error motion - error motion parallel to the Z reference axis at a specified radial location. Face error motion is a combination of axial and tilt error motions. The term "face runout" has an accepted meaning analogous to "radial runout" and hence is not equivalent to face error motion.

Face thermal drift - applicable to a combination of axial and tilt displacement measured at a specified radial location.

Fixed sensitive direction - the workpiece is rotated by the spindle and the point of machining or measurement is fixed. A lathe has a fixed sensitive direction

Fundamental axial and face error motion - that portion of the total error motion that occurs at the rotational frequency of the spindle. Fundamental axial and fundamental face motions are error motions and cause flatness errors on parts. However, fundamental error motion will create a part with the property of circular flatness: The surface is flat and will provide a "sealing surface" at any given radius. This unique property is important to the plumbing industry.

Fundamental axial error motion value - twice the scaled distance between the PC center and a specified polar profile center of the synchronous error motion polar plot. Alternatively defined as the amplitude of the rotational frequency component. There is no fundamental radial error motion value - in the radial direction, motion that occurs at the rotational frequency is caused by an off-center reference target and is not a property of the axis of rotation.

Least squares circle (LSC) center - the center of a circle which minimizes the sum of the squares of a sufficient number of equally spaced radial deviations measured from it to the error motion polar plot.

Nonsensitive direction - is any direction perpendicular to the sensitive direction.

Perfect spindle - a spindle having no motion of its axis of rotation relative to the reference coordinate axes or the calculated center.

Perfect workpiece - a rigid body having a perfect surface of revolution about a center line

Radial error motion - error motion in a direction perpendicular to the Z reference axis and at a specified axial location.

The term "radial runout" has an accepted meaning which includes errors due to centering and workpiece out-of-roundness and hence is not equivalent to radial error motion.

Radial thermal drift - applicable when the displacement is perpendicular to the Z reference axis.

Residual synchronous error motion - the portion of the axial and face synchronous error motion that occurs at integer multiples of the rotation frequency other than the fundamental. Residual synchronous and synchronous error motions are mathematically identical. These type of errors cause flatness errors on the face of turned parts.

Residual synchronous error motion value-the scaled difference in radii of two concentric circles from a specified error motion center just sufficient to contain the residual synchronous error motion polar plot.

Rotating sensitive direction - the workpiece is fixed and the point of machining or measurement rotates with the rotor. A boring machine has a rotating sensitive direction.

Rotor - the rotating element of a spindle.

Runout - the total displacement measured by a displacement indicator sensing against a moving surface or moved with respect to a fixed surface. The terms "T.I.R." (total indicator reading) and "F.I.M." (full indicator movement) are equivalent to runout.

Sensitive direction - the sensitive direction is perpendicular to the perfect workpiece surface through the instantaneous point of machining or measurement

Spindle - a device which provides an axis of rotation.

Stator - the stationary element of a spindle.

Stator to rotor error motion - error motion measured between the stator and rotor.

Structural error motion - error motion due to internal or external excitation and affected by elasticity, mass, and damping of the structural loop as a function of angle of rotation.

Structural loop - the assembly of components which maintain the relative position between two specified objects.

Synchronous error motion - the portion of the total error motion that occurs at integer multiples of the rotation frequency. The term average error motion is equivalent but no longer preferred. The method of averaging described in B89.3.4 Fig A11 remains acceptable for the determination of synchronous error motion.

Synchronous error motion value - the scaled difference in radii of two concentric circles from a specified error motion center just sufficient to contain the synchronous error motion polar plot.

Thermal drift - a changing distance between two objects, associated with a changing temperature distribution within the structural loop due to internal or external sources.

Thermal drift plot - a time-based record of thermal drift.

Thermal drift value - the difference between the maximum and minimum values over a specified period of time, at a specified speed (or speeds) and with a measured temperature change.

Tilt error motion - error motion in an angular direction relative to the Z reference axis. Coning, wobble, swash, tumbling and towering errors are common but inexact terms for tilt error motion.

Tilt thermal drift - applicable to a tilt displacement relative to the Z reference axis.

Total error motion - the complete error motion as recorded.

Total error motion value - the scaled difference in radii of two concentric circles from a specified error motion center just sufficient to contain the total error motion polar plot.

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