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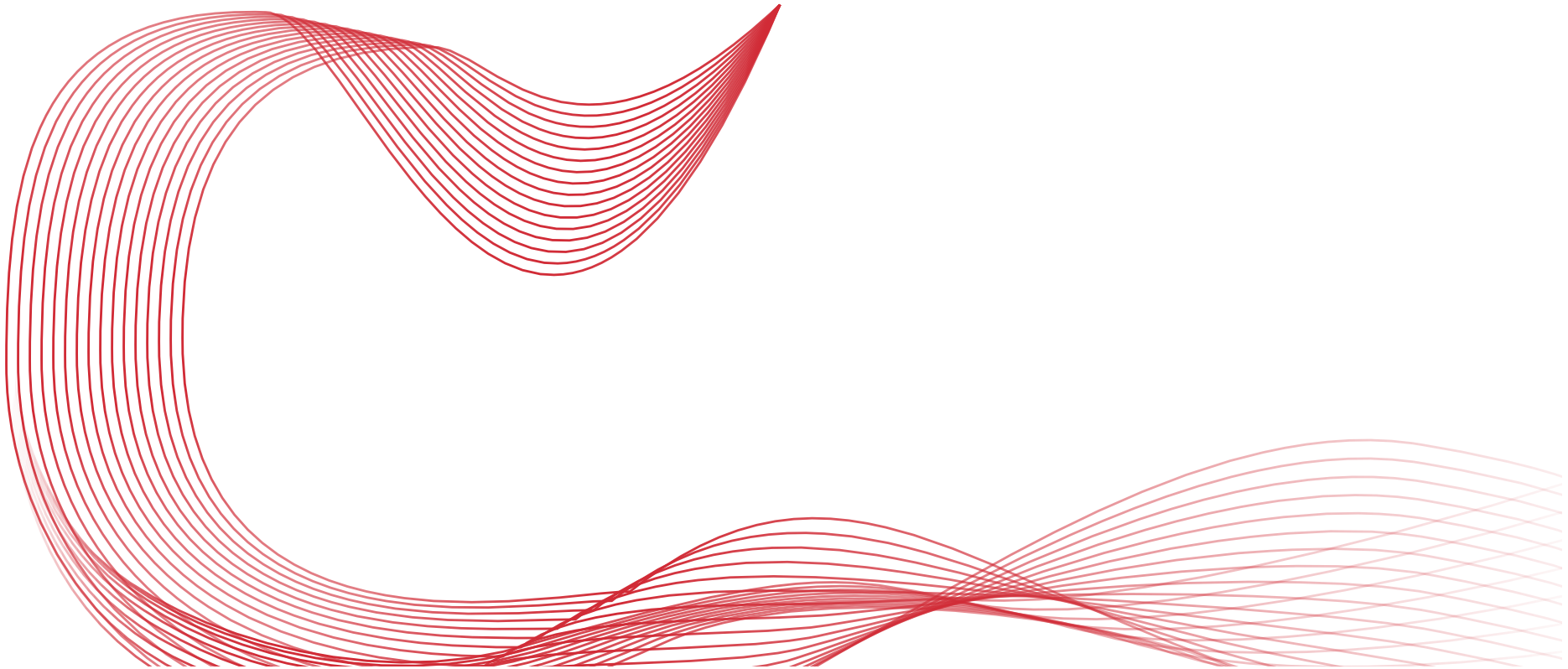
CARTO Compensate



www.renishaw.com/carto

#renishaw

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Legal information

Terms and conditions and warranty

Unless you and Renishaw have agreed and signed a separate written agreement, the equipment and/or software are sold subject to the Renishaw Standard Terms and Conditions supplied with such equipment and/or software, or available on request from your local Renishaw office.

Renishaw warrants its equipment and software for a limited period (as set out in the Standard Terms and Conditions), provided that they are installed and used exactly as defined in associated Renishaw documentation. You should consult these Standard Terms and Conditions to find out the full details of your warranty.

Equipment and/or software purchased by you from a third-party supplier is subject to separate terms and conditions supplied with such equipment and/or software. You should contact your third-party supplier for details.

Safety

Before using the laser system, consult the *XL laser safety* information booklet (Renishaw part no. M-9908-0363) or the *XM laser safety* information booklet (Renishaw part no. M-9921-0202).

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Introduction

This software uses data from the XL-80 laser, XM-60 multi-axis calibrator and XR20 rotary axis calibrator to create error compensation tables for specific machine controllers.

Compensate currently supports the following error compensation options. Use the tabs to navigate to the correct section:

Pitch Error Compensation

- **Renishaw** (Generic output)
- **Siemens 840D**
- **Fanuc 30i series**
- **Heidenhain iTNC 530 and TNC 640**

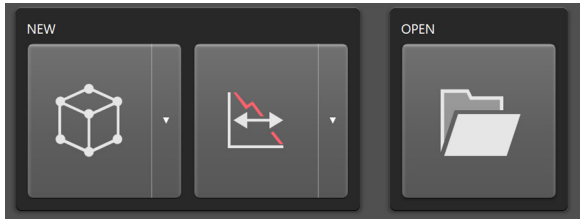
Volumetric Error Compensation

- **Renishaw** (6 DoF Generic output)
- **Siemens 840D** (VCS A3, A5 and A5 Plus)
- **Mitsubishi M800**

Configuration

Home screen

The home screen allows the user to create a new volumetric or pitch error compensation project, create a new compensation project from an existing project or open an existing project. Selecting an existing project will load the machine configuration and axis information from the existing project. To return to the home screen at any point, select the 'Arrow' icon.



Settings

Theme – choose whether Compensate has a 'light' or 'dark' appearance.

Application – Compensate will open the output folder by default after generating the compensation file and will not suppress the warning to overwrite the output file.

Help improve CARTO – choose whether to share technical information to help improve CARTO.

Help – launch help content and user guides.

About – version information for CARTO.

Notifications – software notifications, for example, check for updates.

File format

When generating a compensation file, Compensate creates a file in a controller-specific format which can be transferred directly to the controller.

Volumetric verification

Once the VCS file has been transferred to the machine tool, the compensation must be verified.

This can be done using one of the following methods:

XM-60 – measure three different locations for each axis for a consistent result throughout the machine's volume.

QC20 – capture multiple tests in multiple locations for a consistent result throughout the machine's volume. This test is representative of machine interpolation.

XL-80 – capture body diagonals that pass through the volume of the machine.

Probing – measure different length bars with a machine tool probe. This is the same process as used for verification of CMM error-mapping.

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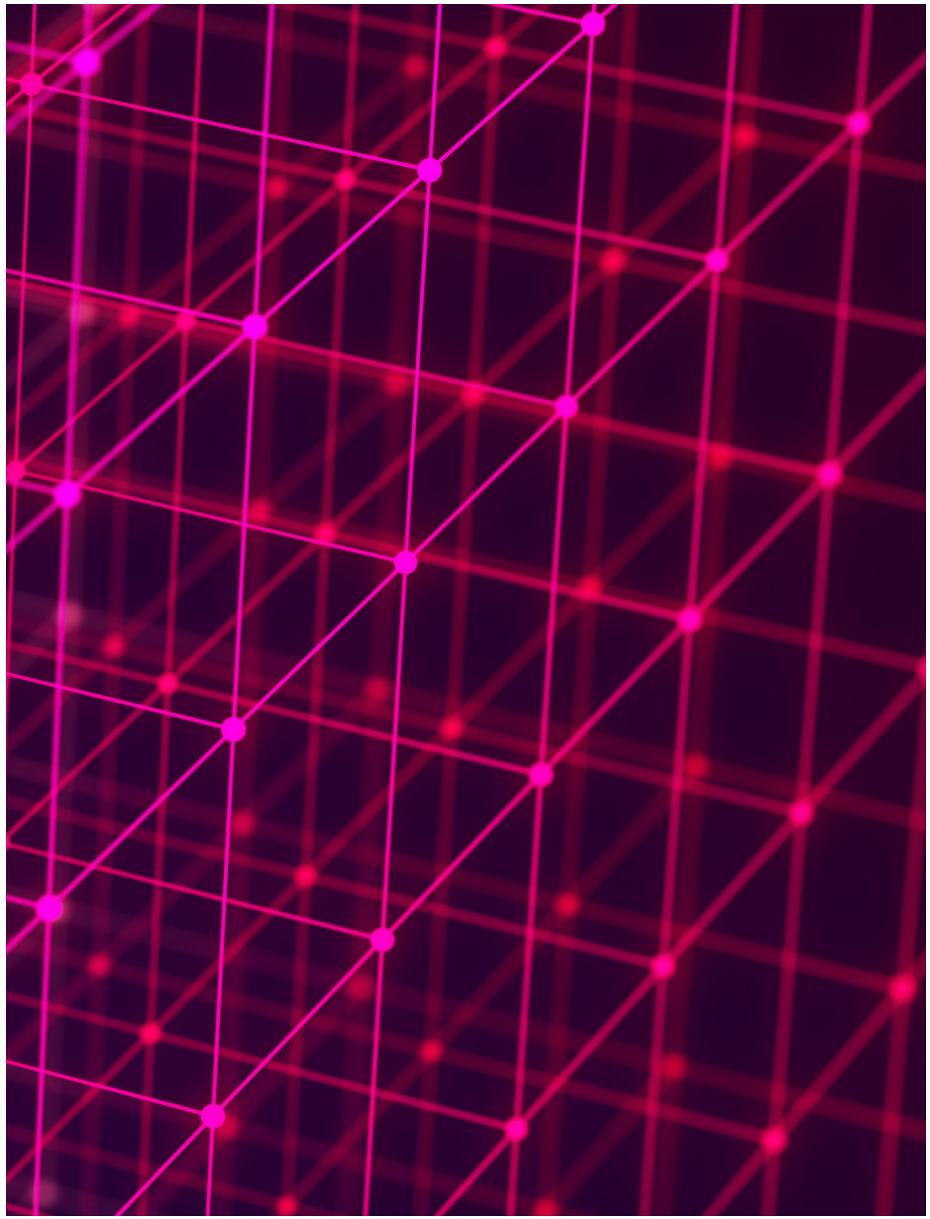
Renishaw

Pitch Error Compensation

Volumetric Error Compensation



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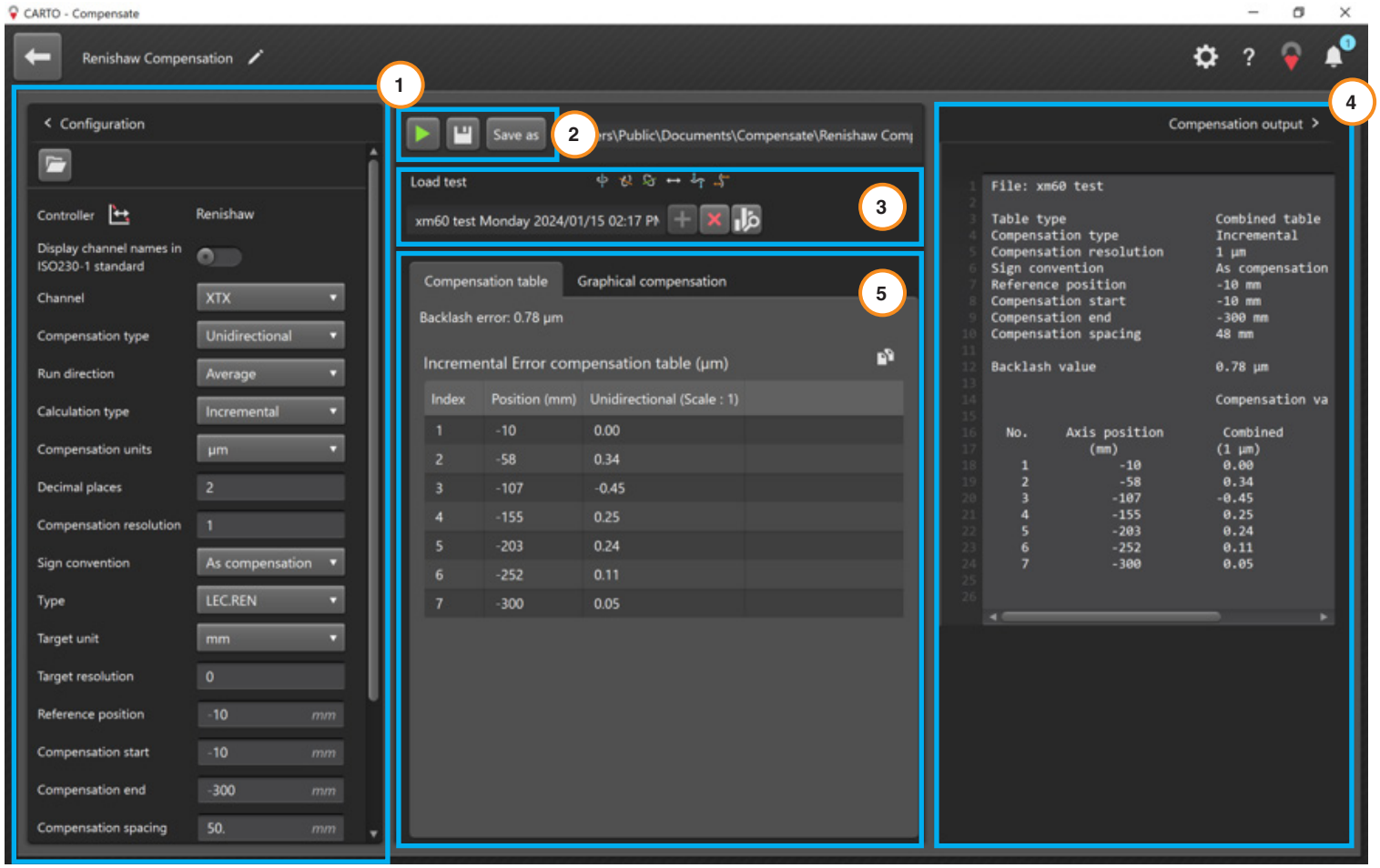
Renishaw pitch error interface

The image below highlights the main features of the Compensate interface.



1	Machine configuration
2	Create and save compensation table
3	CARTO test selection
4	Compensation output
5	Compensation information

Renishaw configuration

- **Type** – choose between LEC.REN and LEC2.REN for the file output format.
- **Use legacy format** – enable or disable the legacy file format.

Pitch error compensation

- **Controller** – type of controller being compensated.
- **Display channel names in ISO 230-1 standard** – switch the displayed error channel names between ISO and VDI standard.
- **Channel** – the machine channel to be compensated.
- **Compensation type** – select either unidirectional or bidirectional compensation.
- **Run direction** – when applying unidirectional compensation, select the forward run, the reverse run, or an average of the two.
- **Calculation type** – choose between incremental and absolute error compensation.
- **Compensation units** – select the compensation units.
- **Length/positional unit** – the length units of the machine tool.
- **Deviation unit and decimal precision** – the number of decimal places displayed for linear and straightness error values.
- **Angular unit and decimal precision** – the number of decimal places displayed for angular error values.
- **Compensation resolution** – set the compensation resolution to be used.
- **Sign convention** – set the sign of the compensation output to ‘as errors’ or ‘as compensation’.
- **Target unit and resolution** – select the target units and resolution to be used.
- **Reference position** – set the compensation reference position.
- **Compensation start** – set the compensation start position.
- **Compensation end** – set the compensation end position.
- **Compensation spacing** – set the compensation spacing to be used.
- **Number of compensation points** – adjust the number of compensation points to be used.
- **Add file** – add a measurement file directly from the Explore database.
- **Delete file** – remove a measurement file from the Compensate project.
- **Analyse** – select the ‘Analyse’ icon to open Explore with the data from the selected test. For more detail on using Explore, refer to the *CARTO Explore* user guide (Renishaw part no. F-9930-1008).
- **Select rotary mode** – choose between linear and rotary compensation.

Renishaw pitch error compensation process

Machine preparation

Machine	Take an archive of the current machine state
Machine	Disable all compensation
Machine	Check that no compensation is active

Software configuration

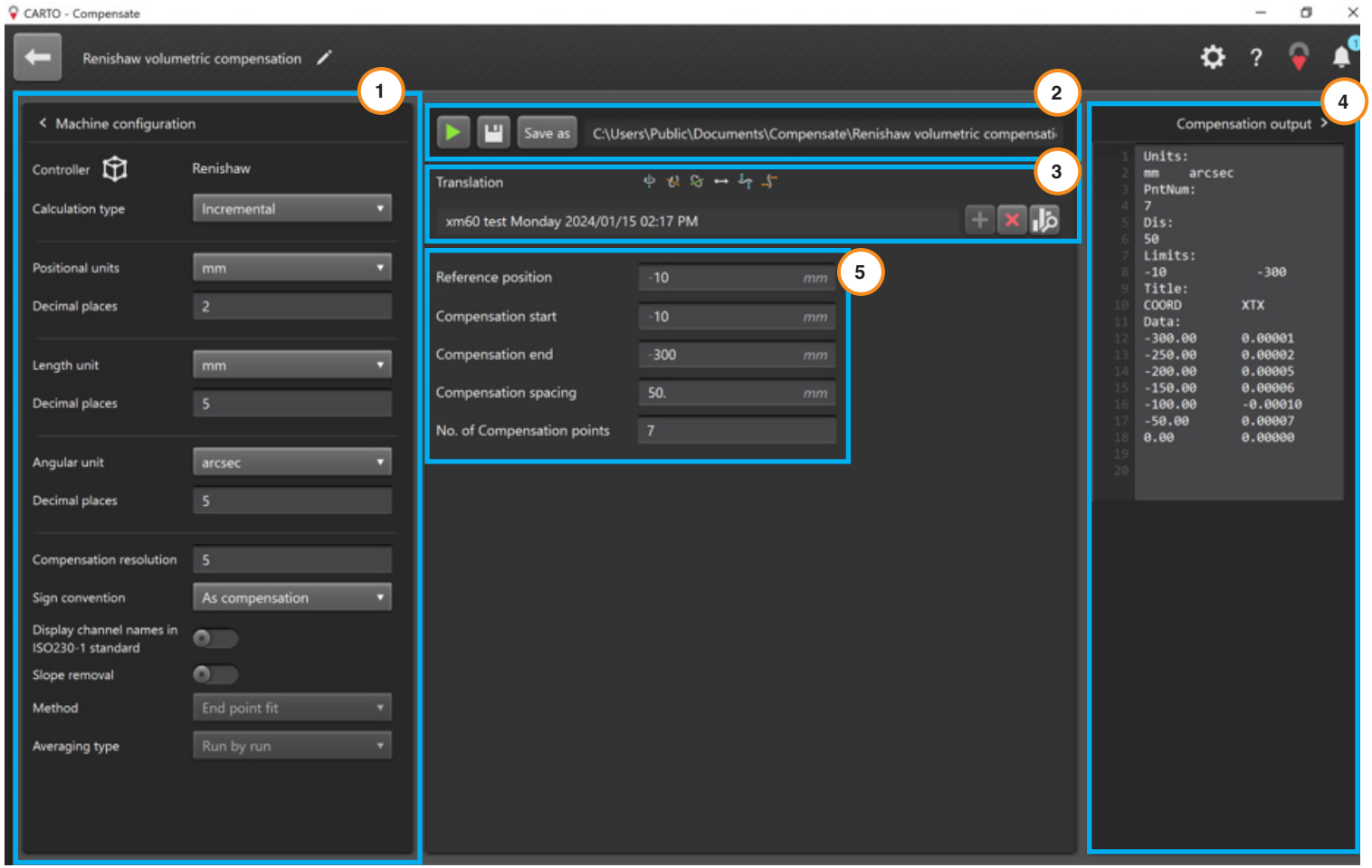
Compensate	Open Compensate
Compensate	Create or open a project
Compensate	Complete the machine configuration as defined by the machine parameters

Mount and align hardware

Laser	Set up and align the XL-80 or XM-60 to measure the axis
CARTO	Measure the axis
Compensate	Generate and save the compensation file
Machine	Load and enable compensation on the CNC
CARTO	Measure and verify the axis

Renishaw volumetric error interface

The image below highlights the main features of the Compensate interface.



1	Machine configuration
2	Create and save compensation table
3	CARTO test selection
4	Compensation output
5	Compensation configuration

Volumetric error compensation

- **Kinematic chain** – this describes the kinematic chain from the workpiece to the tool.

  Examples:

  - **FXYZ**: The workpiece is fixed to the frame and the kinematic chain to the tool tip is X-Y-Z (MCS-UCS).
  - **YFXZ**: The Y axis moves the workpiece and the X-Z axes move the tool.

- **Averaging mode** – this allows the user to switch between two compensation types:
  - **Averaging on, Unidirectional** – one table of compensation values with a backlash value.
  - **Averaging off, Bidirectional** – separate values for forward and reverse directions.
  - **Channel** – the axis channel. Only used on multi-channel machine tools.
- **Squareness is positive** – this keyword selects the definition of the squareness angles:
  - **RIGHT_HANDED xwz > 0**: The angle between X and Z is smaller than 90°.
  - **LARGER_THAN_90 xwz > 0**: The angle between X and Z is greater than 90°.

Renishaw 6 degrees of freedom compensation process

Machine preparation

Machine	Take an archive of the current machine state
Machine	Disable all compensation
Machine	Check that no compensation is active

Software configuration

Compensate	Open Compensate
Compensate	Create or open a project
Compensate	Fill out the optional fields with test information
Compensate	Complete the machine configuration as defined by the machine parameters

Mount and align hardware (XM)

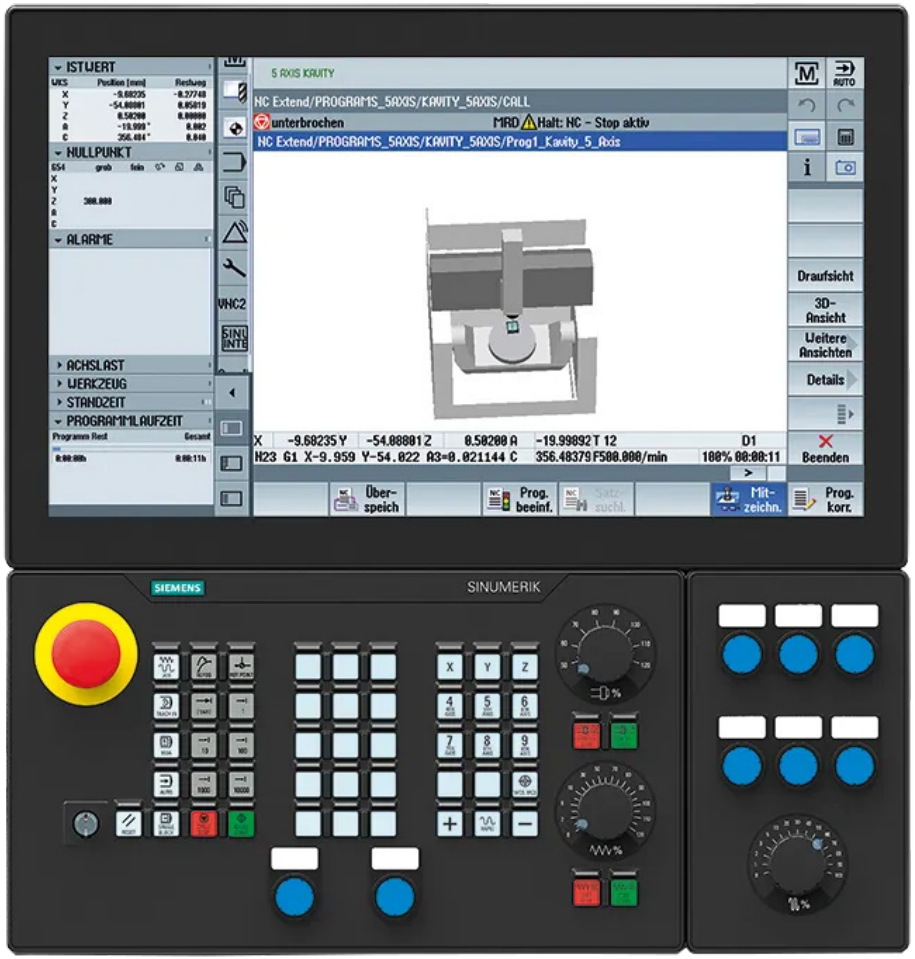
Laser	Set up and align the XM-60 to measure the axis
CARTO	Measure the axis
Compensate	Generate and save the compensation file
Machine	Load and enable compensation on the CNC
CARTO	Measure and verify the axis

Siemens 840D

Pitch Error Compensation

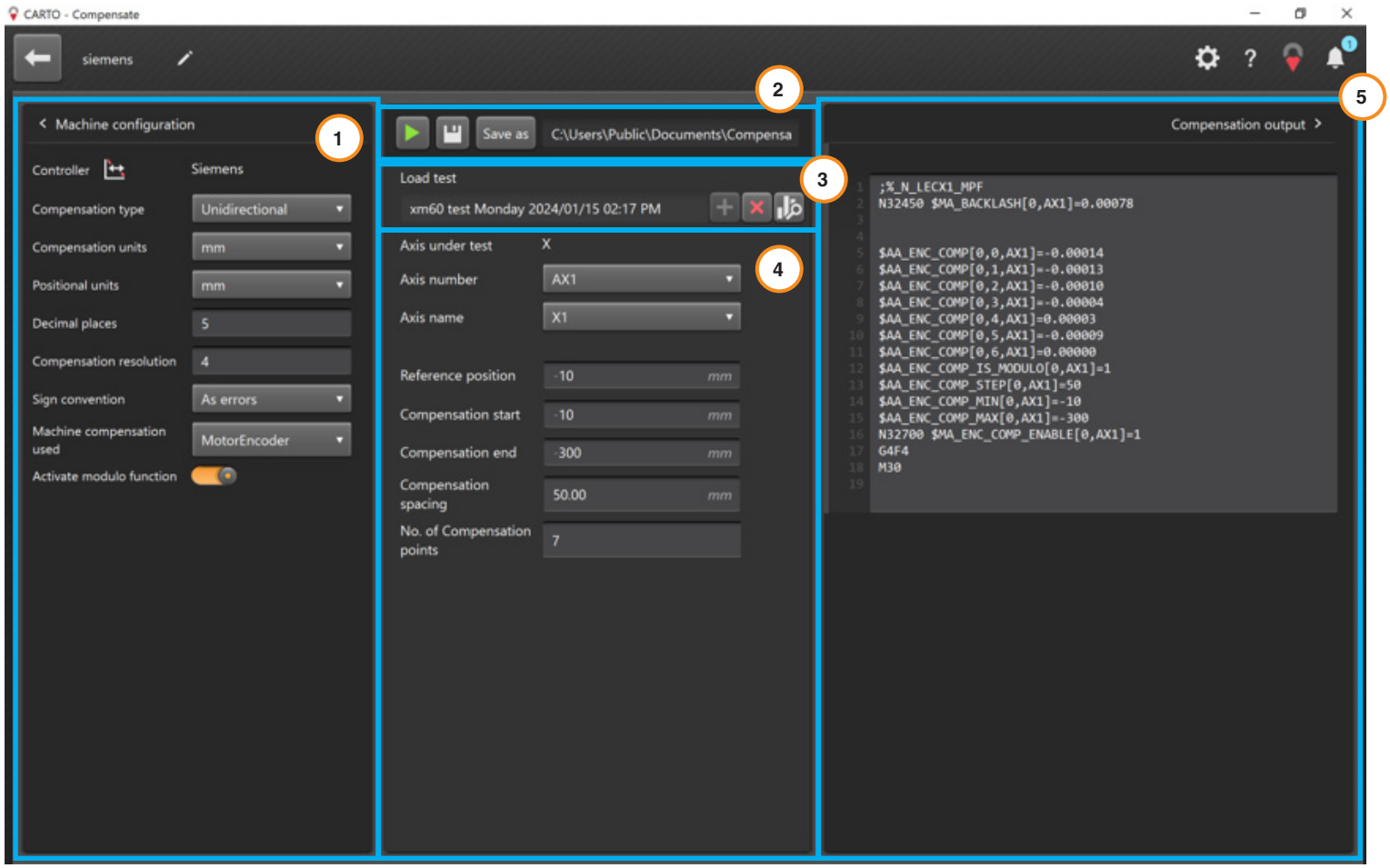
Volumetric Error Compensation

(VCS, A3 and A5)



Siemens pitch error interface

The image below highlights the main features of the Compensate interface.



1	Machine configuration
2	Create and save Compensation table
3	CARTO test selection
4	Axis configuration
5	Compensation output information

Siemens interface configuration

Pitch error compensation

- **Machine compensation used** – select whether to use Scale or Drive Encoder for the applied compensation.
- **Active modulo function** – enable or disable the modulo function on the controller.

Siemens pitch error compensation process

Machine preparation

Machine	Take an archive of the current machine state
Machine	Disable all compensation
Machine	Check that no compensation is active

Software configuration

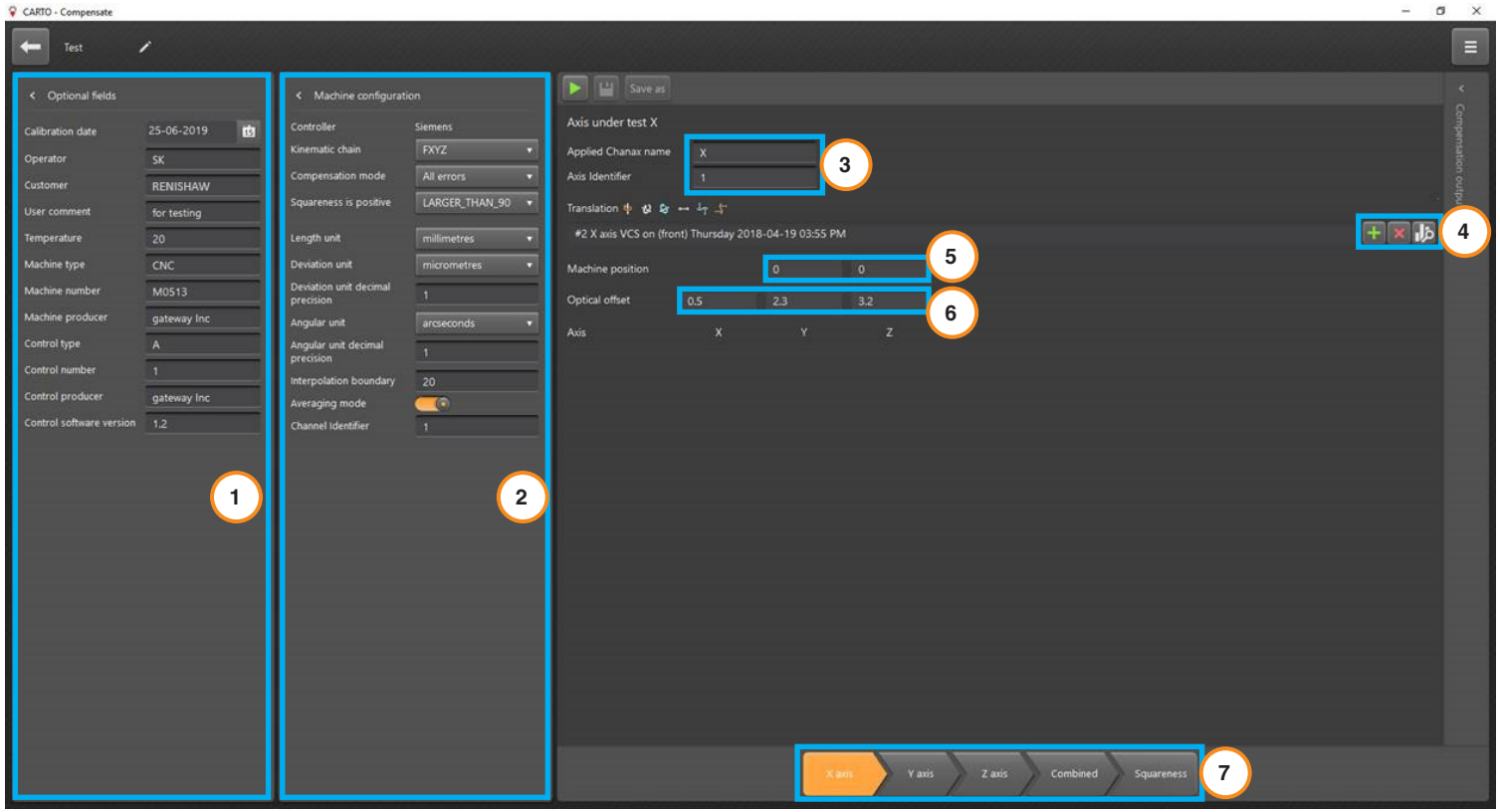
Compensate	Open Compensate
Compensate	Create or open a project
Compensate	Complete the machine configuration as defined by the machine parameters

Mount and align hardware

Laser	Set up and align the XL-80 or XM-60 to measure the axis
CARTO	Measure the axis
Compensate	Generate and save the compensation file
Machine	Run the generated MPF file on the the CNC
CARTO	Measure and verify the axis

Siemens volumetric error interface

The image below highlights the main features of the Compensate interface.



1	Optional fields
2	Machine configuration
3	Axis information
4	CARTO test selection
5	Machine position of XM-60 test (volumetric only)
6	Optical (PSD) offset volumetric only)
7	Axis selection/squareness values

Siemens interface configuration

Volumetric error compensation

- **Compensation mode** – Compensate only supports capture mode ‘All errors’. (Compensate uses the ‘All errors’ method which allows the user to capture all the laser measurements before any 3D compensation is applied. This method relies on the user accurately measuring the position of the optics and non-moving axes for each set-up).
- **Interpolation boundary** – Volumetric Compensation Software (VCS) can apply two VCS files; for example, measured at different ambient temperatures or with tools having different weights. The user provides the actual temperature or weight between the two interpolation boundary values.
- **Channel identifier** – the machine channel to be compensated. This value is also used to generate the VCS file name.
- **Applied Chanax name** – optional keyword; by default, VCS compensates the three geometry axes. If this is not required, the considered axes must be specified using these keywords. The values on the right side of the assignment must be valid names of the channel axes; that is, elements in the machine data 20080 AXCONF_CHANAX_NAME_TAB.
- **Axis identifier** – number associated with the specified axis. This number is also used to generate the VCS file name.
- **Machine position** – the machine position for the two stationary axes when the measurement is captured.
- **Optical offset** – the distance (±10 mm) from the Position Sensitive Device (PSD) in the receiver back to the spindle gauge line (**see diagram of optical offset for sign convention – Appendix D**) in the direction of the machine co-ordinates.
- **Axis** – the axis (X,Y, Z) for the machine position and optical offset.

Combined test

- **Select the axis for combined compensation** – the compensation output can be created at any time during the measurement process. This means that the VCS file can be tested with data from one, two or three axes. This is useful if there is a need to verify each axis after it has been measured.

Squareness

The squareness measurement can be taken using any of the following products:

- QC20 ballbar
- XK10 alignment laser
- XL-80 laser interferometer
- Granite square

The squareness values are entered manually into Compensate. If using the QC20 ballbar and ‘LARGER_THAN_90’, the values shown in the Ballbar 20 software are the correct sign convention to be entered into Compensate.

Siemens volumetric compensation process

Machine preparation

Machine	Take an archive of the current machine state
Machine	Disable all compensation
Machine	Check that no compensation is active

Software configuration

Compensate	Open Compensate
Compensate	Create or open a project
Compensate	Fill out the optional fields with test information
Compensate	Complete the machine configuration as defined by the machine parameters

Mount and align hardware (XM)

XM-60	Set up and align the XM-60 to measure the axis
Machine	Measure the optical offset (from PSD to gauge line of spindle)
Machine	Ensure active tool is set to zero offset
Compensate	Enter the machine position and optical offset for the measured axis
Compensate	Enter the Chanax details for the measured axis
CARTO	Measure the axis
CARTO	Repeat for all axes

Create and load compensation file (without squareness)

Compensate	For each axis in turn, browse to each axis measured
Compensate	Create a combined compensation file
Machine	Transfer the combined VCS file to the controller
Machine	Load and enable the VCS file
Machine	Check that the VCS file is enabled

Squareness measurement

Machine	Set up the ballbar test
Machine	Activate and enter the correct tool offset before running each test
Ballbar 20	Measure each plane XY, YZ, ZX
Compensate	Enter the squareness value measured into the Compensate software
Compensate	When using Ballbar, select LARGER_THAN_90 to enter the values as shown

Create and load VCS compensation with squareness values

Compensate	Generate the complete VCS file in Compensate
Machine	Transfer the file onto the machine controller
Machine	Load and enable the VCS file
Machine	Check that the VCS file is enabled
Machine	Measure the optical offset (from PSD to gauge line of spindle)
Machine	Enter the optical offset into the tool offset page on the machine controller
CARTO	Set up the XM-60 and measure each axis to verify that VCS compensation is enabled

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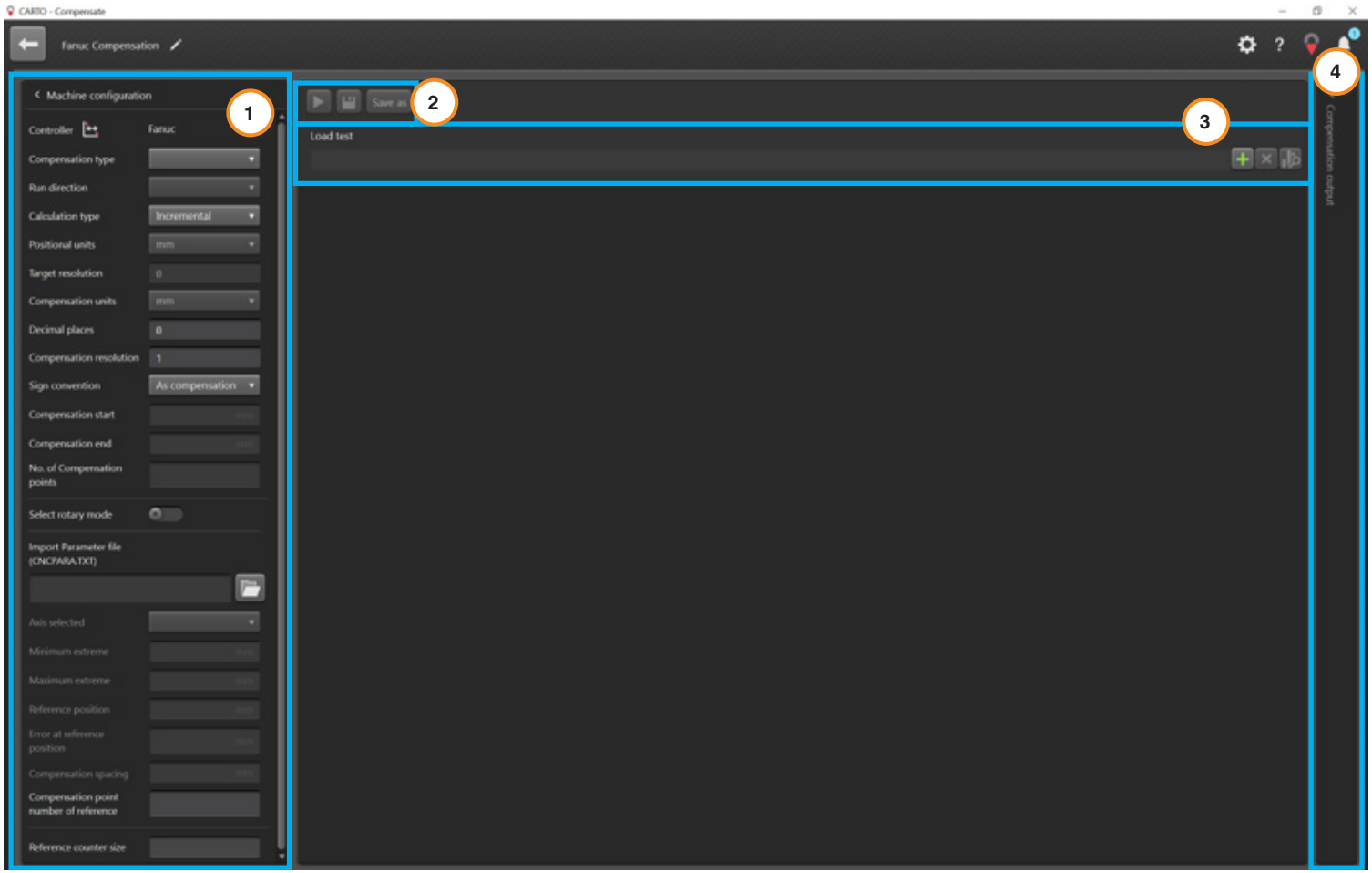
Fanuc 30i

Pitch Error Compensation

Fanuc interface

The image below highlights the main features of the Compensate interface.



1	Machine configuration
2	Create and save Compensation table
3	CARTO test selection
4	Compensation output information

Fanuc pitch error compensation

- **Import parameter file (CNCPARA.txt)** – browse and import the CNC parameter file from the machine controller that is being compensated.
- **Axis selected** – the axis to be compensated.
- **Minimum extreme** – the physical negative extreme position of the machine.
- **Maximum extreme** – the physical positive extreme position of the machine.
- **Error at reference position** – set the error at the reference position.
- **Compensation point number of negative extreme** – these parameters specify the register positions in the pitch error table where the compensation values will be stored. The negative extremes should be chosen such that all compensation points can be stored in a register position between 0 and 1535.
- **Reference counter size** – this can be identified by taking a back-up of the pitch error table and opening it in a text viewer. The reference counter size can be identified by looking at the number between N and Q on the first line of the table. An example is shown below:

  N10000Q0PO

  In this case, the default reference counter size is 10000 for all Fanuc 30i series controllers. This is defined by the machine builder and should not be changed.

Fanuc pitch error compensation process

Machine preparation

Machine	Take an archive of the current machine state
Machine	Disable all compensation
Machine	Check that no compensation is active

Software configuration

Compensate	Open Compensate
Compensate	Create or open a project
Compensate	Complete the machine configuration as defined by the machine parameters
Compensate	Load CNC Para file into Compensate software

Mount and align hardware

Laser	Set up and align the XL-80 or XM-60 to measure the axis
CARTO	Measure the axis
Compensate	Generate and save the compensation file
Machine	Load and enable compensation on the CNC
CARTO	Measure and verify the axis

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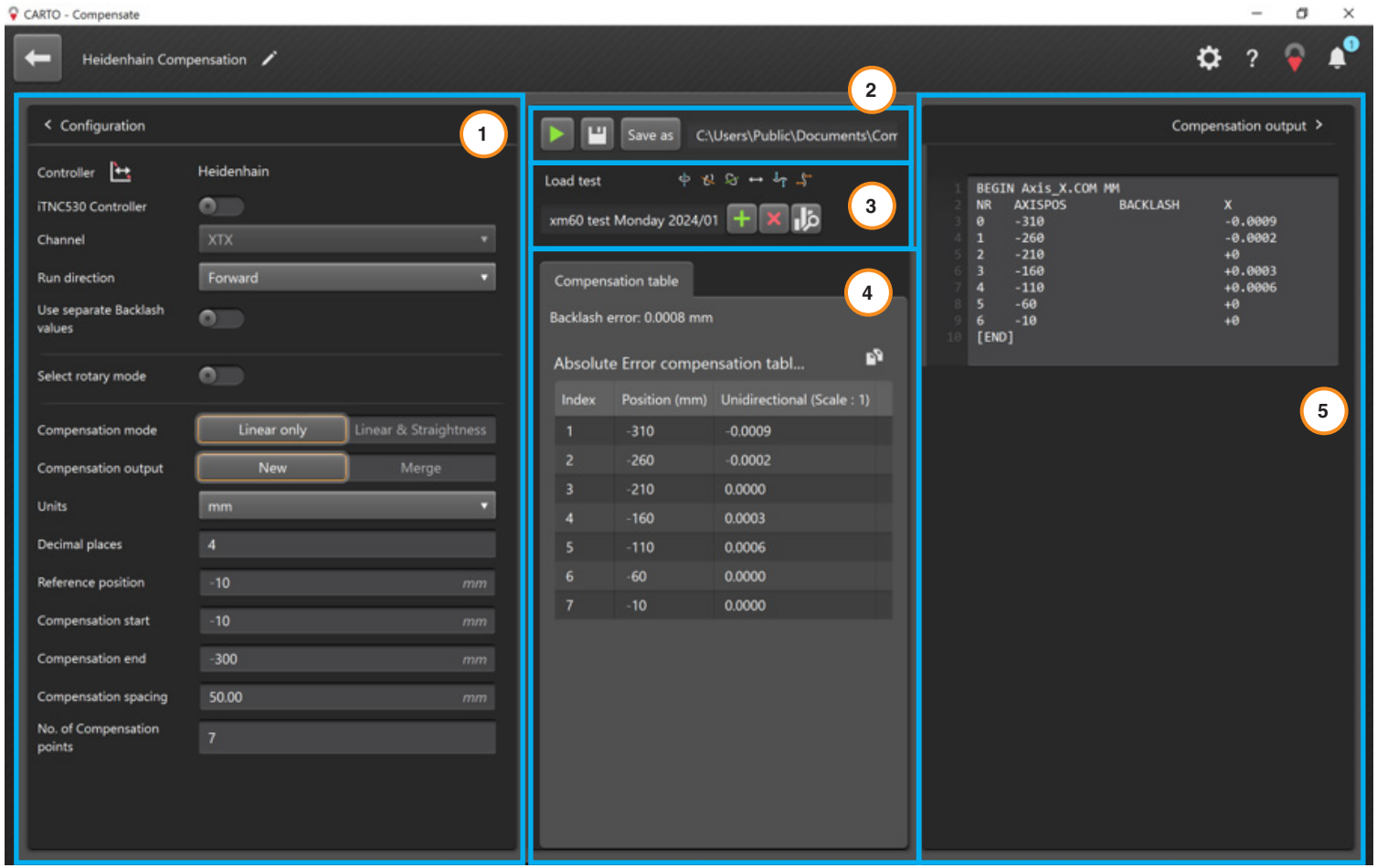
Heidenhein iTNC 530 and TNC 640

Pitch Error Compensation

Heidenhein interface

The image below highlights the main features of the Compensate interface.



1	Machine configuration
2	Create and save Compensation table
3	CARTO test selection
4	Compensation output information
5	Compensation table

Heidenhain pitch error compensation

- **Separate backlash values** – select whether the calculated backlash values are included in the compensation output file.
- **Compensation mode** – for XM-60 tests, choose linear only or linear and straightness compensation.
- **Compensation output** – select whether to generate a new compensation file or merge the linear data with an existing compensation file.

Heidenhein pitch error compensation process

Machine preparation

Machine	Take an archive of the current machine state
Machine	Disable all compensation
Machine	Check that no compensation is active

Software configuration

Compensate	Open Compensate
Compensate	Create or open a project
Compensate	Complete the machine configuration as defined by the machine parameters

Mount and align hardware

Laser	Set up and align the XL-80 or XM-60 to measure the axis
CARTO	Measure the axis
Compensate	Generate and save the compensation file
Machine	Load and enable compensation on the CNC
CARTO	Measure and verify the axis

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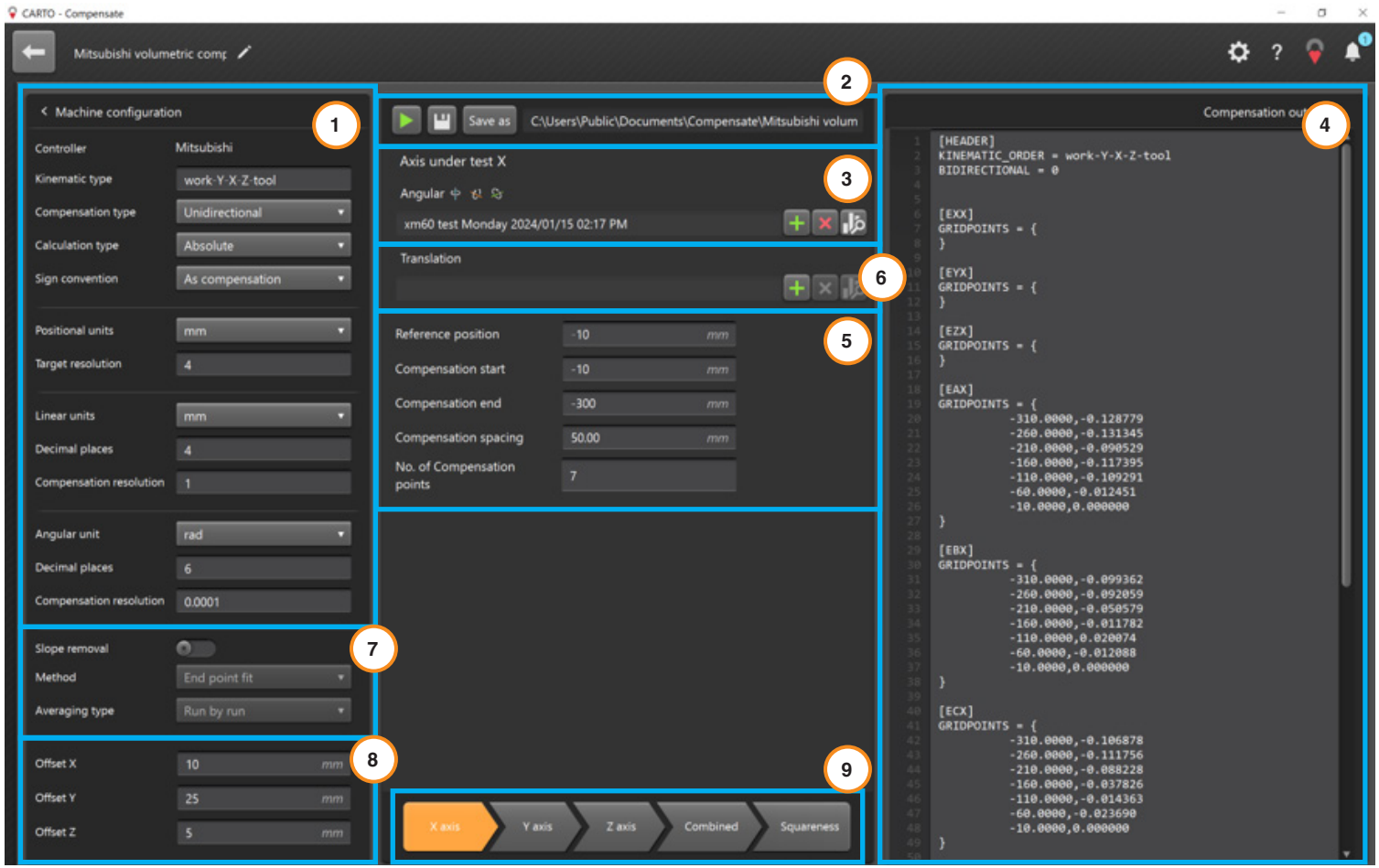
Mitsubishi M800

Volumetric Error Compensation

Mitsubishi interface

The image below highlights the main features of the Compensate interface.



1	Machine configuration
2	Create and save Compensation table
3	CARTO test selection
4	Compensation output information
5	Compensation configuration
6	Translation
7	Test configuration
8	Optical offset
9	Navigation tabs

Mitsubishi volumetric error configuration

- Controller – type of controller being compensated.
- Compensation type – select either unidirectional or bidirectional compensation.
- Calculation type – choose between incremental and absolute error compensation.
- Length/positional unit – the length units of the machine tool.
- Deviation unit and decimal precision – the number of decimal places displayed for linear and straightness error values.
- Angular unit and decimal precision – the number of decimal places displayed for angular error values.
- Compensation resolution – set the compensation resolution to be used.
- Sign convention – set the sign of the compensation output to ‘as errors’ or ‘as compensation’.
- Target unit and resolution – select the target units and resolution to be used.
- Reference position – set the compensation reference position.
- Compensation start – set the compensation start position.
- Compensation end – set the compensation end position.
- Compensation spacing – set the compensation spacing to be used.
- Number of compensation points – adjust the number of compensation points to be used.
- Add file – add a measurement file directly from the Explore database.
- Delete file – remove a measurement file from the Compensate project.
- Analyse – select the ‘Analyse’ icon to open Explore with the data from the selected test. For more detail on using Explore, refer to the CARTO Explore user guide (Renishaw part no. F-9930-1008).
- Select rotary mode – choose between linear and rotary compensation.
- Kinematic type – this describes the kinematic chain from the workpiece to the tool.
- Positional units – units used to position the machine tool.
- Linear units – units used for the linear measurement.
- Decimal places – the number of decimal places displayed.
- Slope removal – turn on and off slope removal.
- Method – method used for slope removal (end point fit or least squares fit).
- Averaging type – run by run, average all run, average run per direction.

Mitsubishi volumetric error compensation process

Machine preparation

Machine	Take an archive of the current machine state
Machine	Disable all compensation
Machine	Check that no compensation is active

Software configuration

Compensate	Open Compensate
Compensate	Create or open a project
Compensate	Fill out the optional fields with test information
Compensate	Complete the machine configuration as defined by the machine parameters

Mount and align hardware (XM)

XM-60	Set up and align the XM-60 to measure the axis
Compensate	Generate compensation for angular errors
Machine	Enable compensation and re-measure
Compensate	Generate compensation for translation errors
CARTO	Repeat for all axes

Squareness measurement

Machine	Activate compensation
Machine	Set up the Ballbar test
Ballbar 20	Measure each plane, XY, YZ, ZX
Machine	Enter the squareness value measured into the machine controller

Create and load VCS compensation with squareness values

Compensate	Generate the complete VCS file in Compensate
Machine	Transfer the file onto the machine controller
Machine	Load and enable the VCS file
Machine	Check that the VCS file is enabled
Machine	Measure the optical offset (from PSD to gauge line of spindle)
Machine	Enter the optical offset into the tool offset page on the machine controller
CARTO	Set up the XM-60 and measure each axis to verify that VCS compensation is enabled

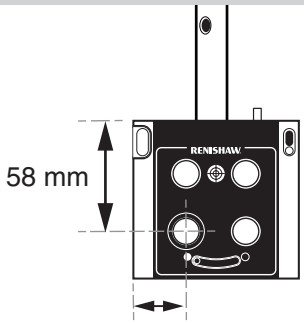
Appendix A: Optical offset

Optical offset is the distance measured *from the PSD* to the *gauge line and centre line* of the machine tool spindle.

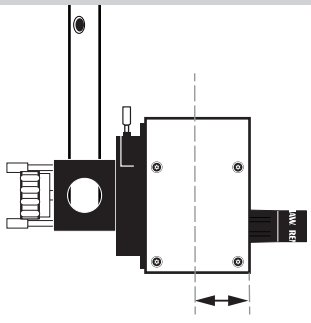
For each measured axis there will be three offset distances and associated sign conventions. Optical offset is critical for knowing the placement of the hardware when the test was carried out and these offsets are applied to the volumetric compensation table.

Receiver reference position

The PSD location is the reference point on the XM-60 receiver from which all measurements must be taken.



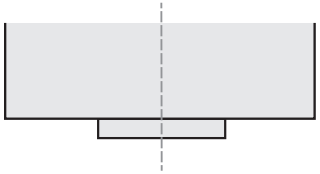
When looking at the front face of the receiver, the reference is the centre of the PSD aperture, located bottom left.



When looking at the side of the receiver, the PSD location is 39 mm from the front face.

Machine reference position

Optical offsets must be measured to these spindle locations.

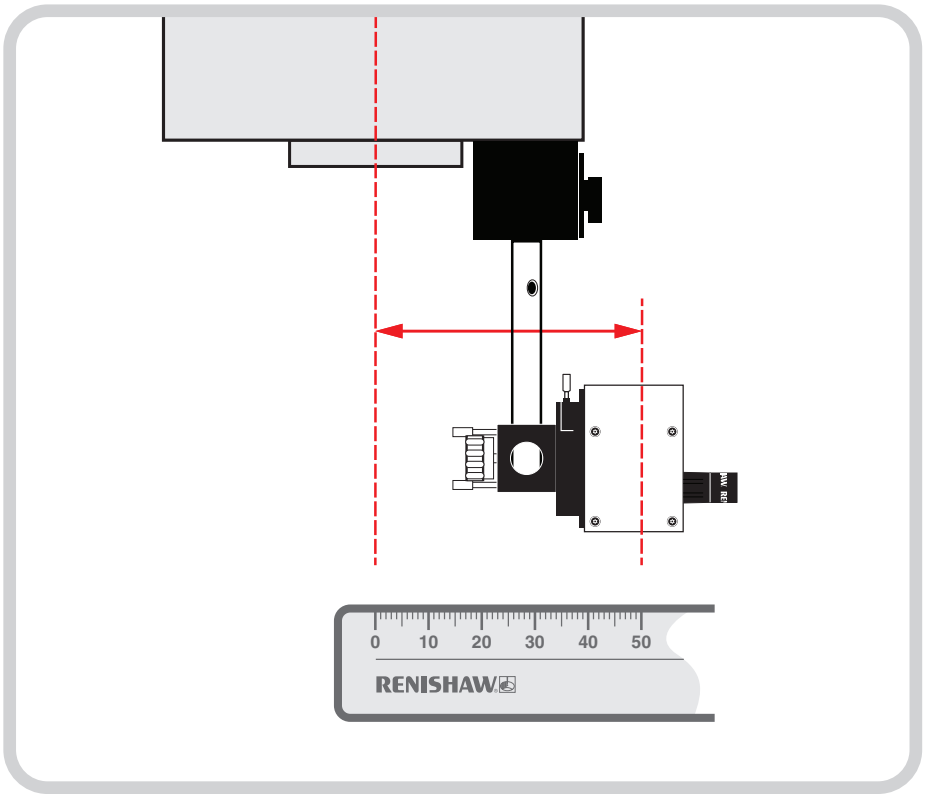


The spindle centre line is the reference for all horizontal offsets.

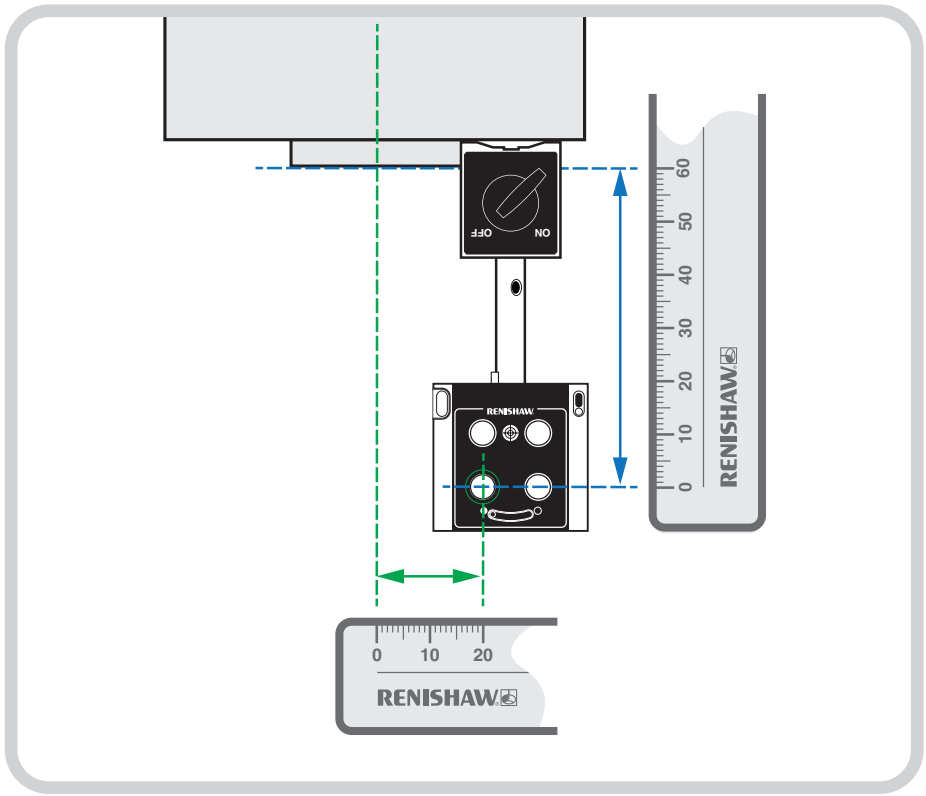
The spindle gauge line is the reference for all vertical offsets.

Appendix B: Measuring the optical offset

In the example set-up below there are three clear offsets from the PSD location to the spindle centre line and spindle gauge line.
The offset distances can be measured using a ruler.



The receiver has a horizontal offset from the *spindle centre line*.
In the example, the offset distance is 50 mm.

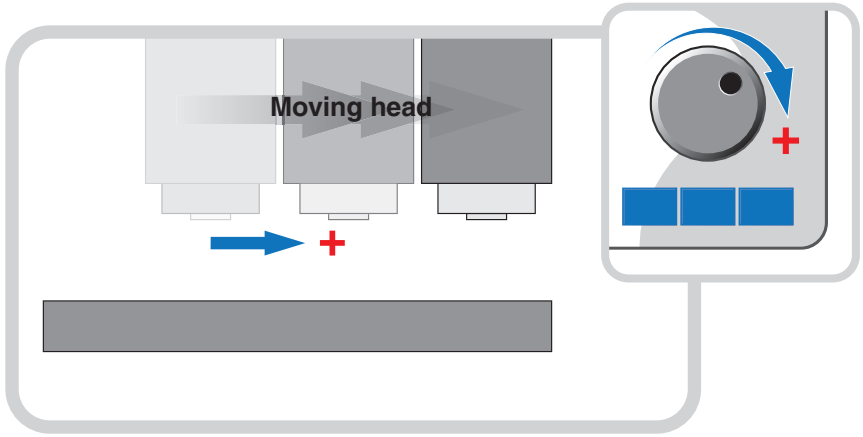


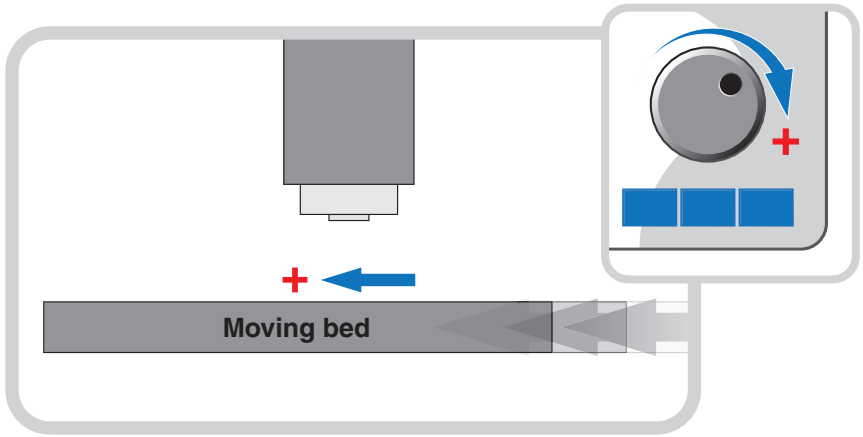
The receiver has a horizontal offset from the *spindle centre line*.
In the example, the offset distance is 20 mm.

There is also a vertical offset from the *spindle gauge line*.
In the example, the offset distance is 60 mm.

Appendix C: Machine sign convention

To ensure correct sign convention for optical offset, you must understand the machine sign convention. The two machine variants below appear to perform differently. When the handwheel is driven in a positive direction, the moving elements are in opposite directions.

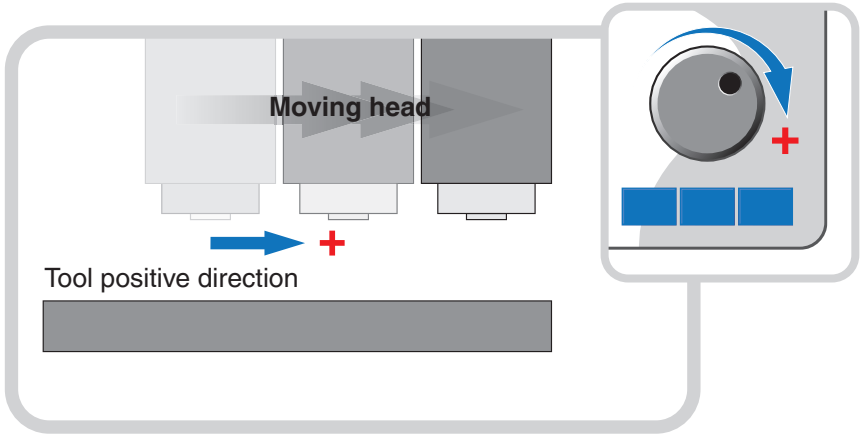


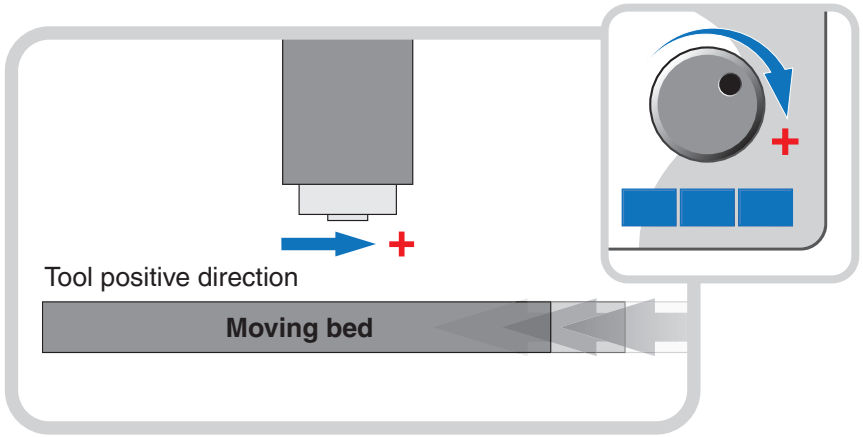


On closer inspection, the machines are actually the same.

The machine sign convention is determined by the direction the tool travels in relation to the workpiece (denoted below as ‘tool positive direction’).

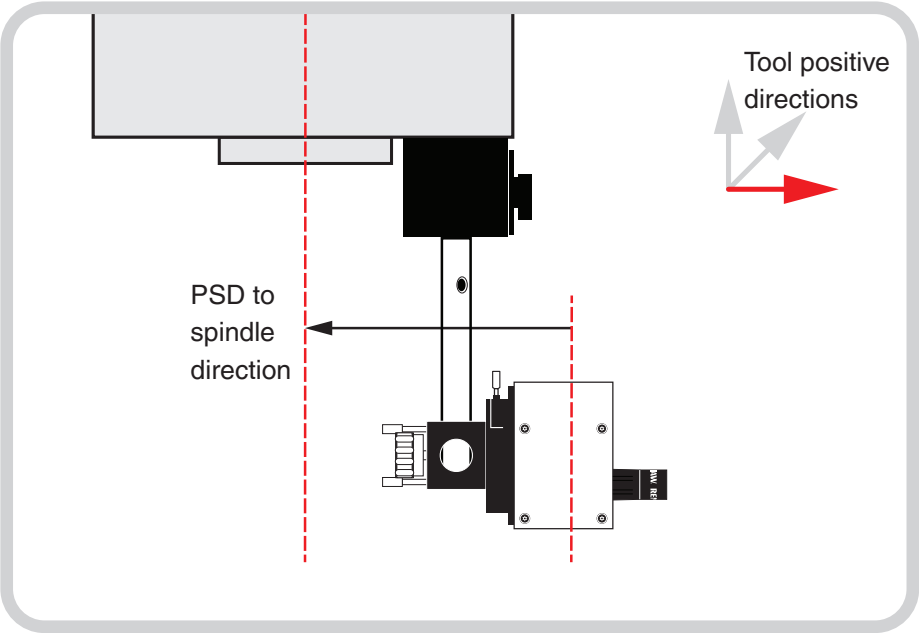
Tool positive direction is required to determine optical offset sign convention.

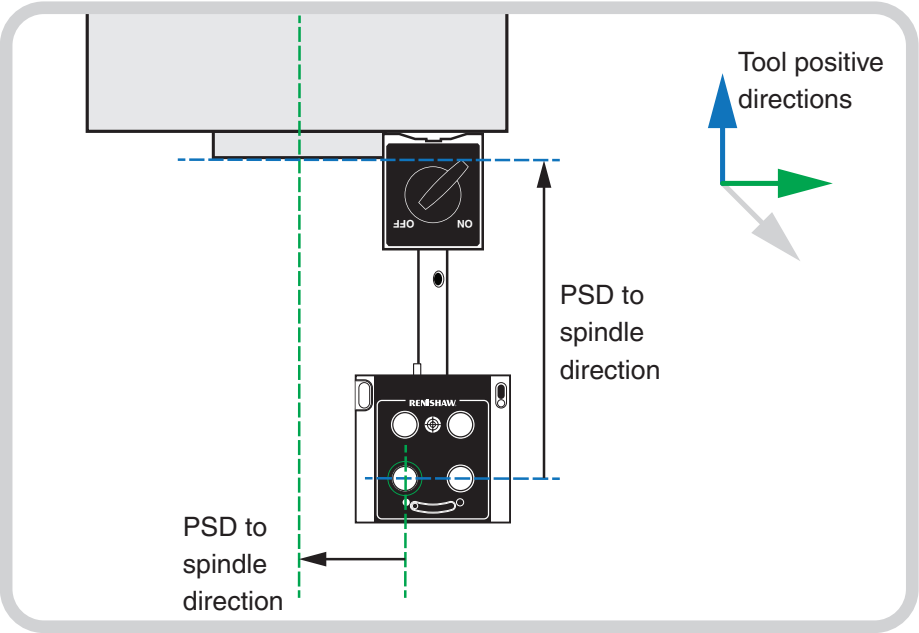




Appendix D: Optical offset sign convention

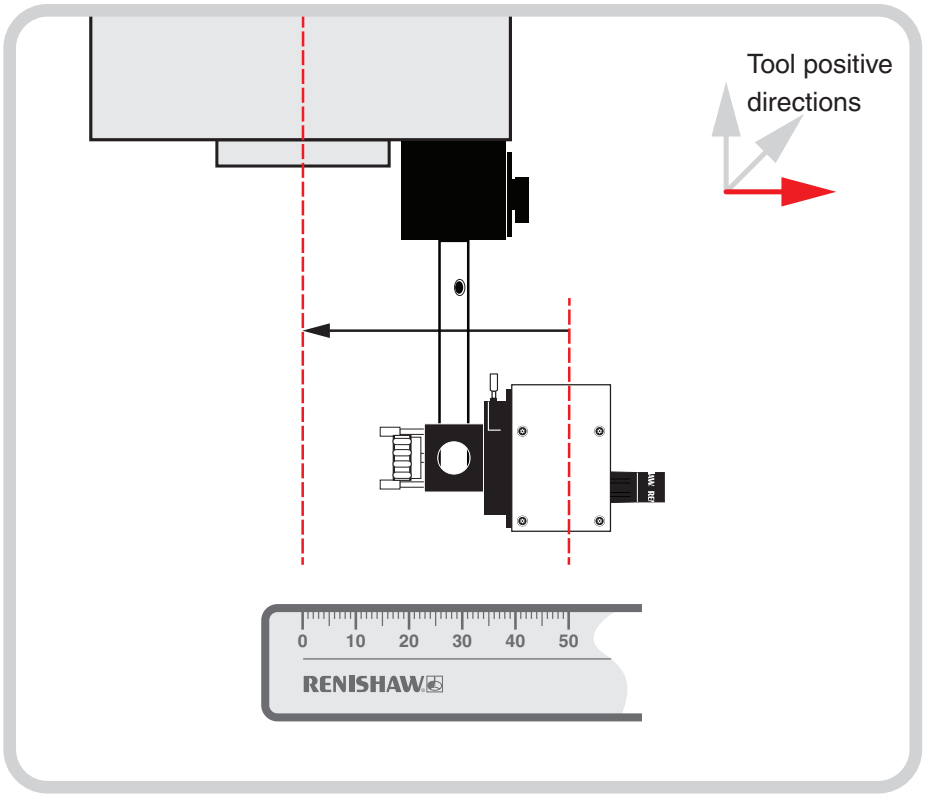
The optical offset sign convention must be entered into the software with the offset distance.
Optical offset sign convention is the direction from the **PSD to the spindle** compared to the tool positive direction.



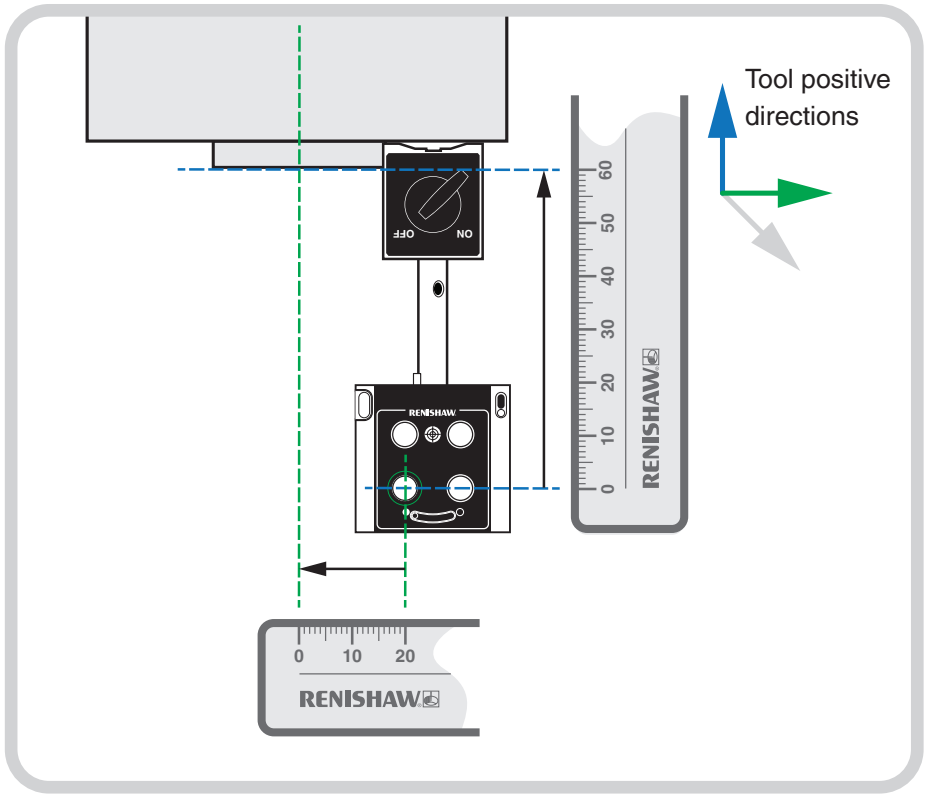


PSD to spindle direction	Optical offset sign convention
If the **PSD to spindle direction** is the same as the **tool positive direction**	Offset has a **positive** offset sign
If the **PSD to spindle direction** is opposite to the **tool positive direction**	Offset has a **negative** offset sign

The example below shows the measured optical offset distances and sign conventions.



Linear offset – the 'PSD to spindle direction' is **opposite** to the 'tool positive direction'. The optical offset is **–50 mm**.



Horizontal offset – the 'PSD to spindle direction' is **opposite** to the 'tool positive direction'. The optical offset is **–20 mm**.

Vertical offset – the 'PSD to spindle direction' is **the same** as the 'tool positive direction'. The optical offset is **+60 mm**.

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