

Errormap Rotation Point

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Errormap Rotation Point

Purpose

This article describes the significance of the position selected as the rotation point for a coordinate measuring machine compensation errormap. Recently an example was found that highlighted problems as a result of selecting a mathematical rotation point at a location different than the mechanical rotation point. The effect was clear on the linear data from the compensation map.

The ideal position for the rotation point is always the same as the mechanical rotation point the the axis of a CMM. One example where placing the rotation point inside the volume of the CMM is desired is when the goal is to have all the parameters collected then built into a compensation map in one step. This is more a case where the advantage of having the ability to collect all the data then building the map in one step outweighs the disadvantages of not having the rotation point at the mechanical origin.

Software Error Correction

The error compensation used by coordinate measuring machines does not change the physical characteristics of the machine. The correction is applied in such a way that the position of the probe stylus is always known based on the described errors in the machine from the compensation error table.

Using software to correct machine errors is actually very thorough. Most machines will have and use the standard 18 compensation parameters.

Practically all manufacturers deal with machine compensation in the same way despite any claims to the contrary. There can be subtle differences in some cases and one of the areas that does vary quite a bit is the choice for the placement of the math rotation point for interpreting the compensation data.

Example With X Axis Roll

The easiest way to describe the effect is to show a practical example of the problem. This example shows the effect of the X axis roll error (RXX) on the horizontal straightness of the X axis of a CMM. The X axis roll affects the straightness in the Y axis of the CMM.

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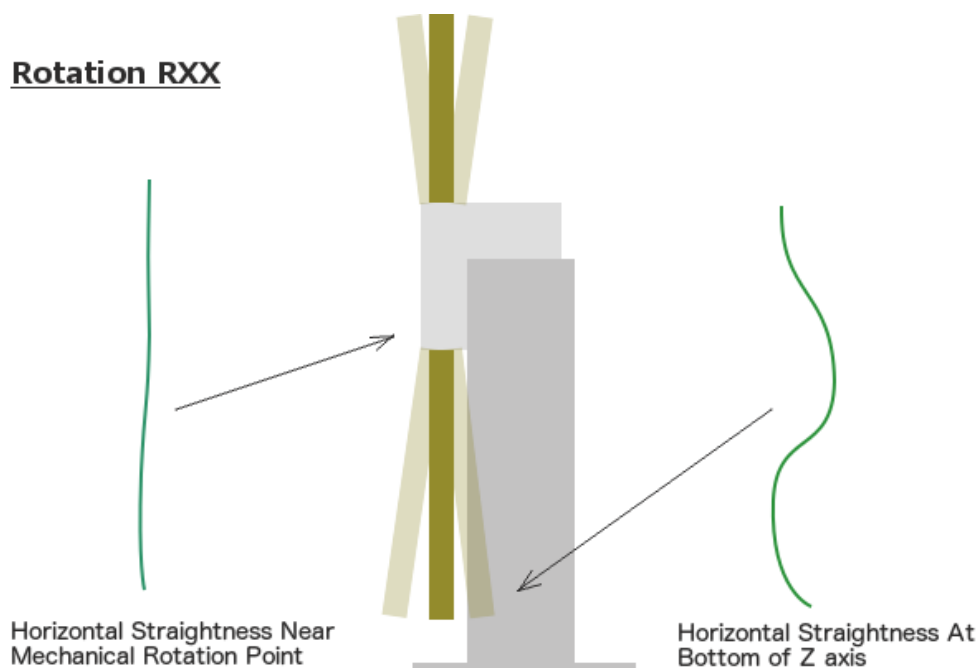


Illustration 1: Example of the effect of rotation error RXX at different points in the X axis affecting the Y axis straightness.

As the X axis moves from one side of the machine to the other the X axis roll changes the direction of the Z axis. The effect of the rotation is the primary source of the horizontal straightness error at the bottom of the Z axis when the machine is not correcting for this angular error. The horizontal straightness is not affected from the angular roll at the location of the mechanical rotation point.

Case 1: Mechanical and Compensation Point Identical

When the mechanical and software rotation points are the same the calculated correction matches the physical error of the machine axis. An example showing the calculation for parameter RXX is shown in illustration 2.

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Rotation RXX



Illustration 2: Calculation of machine error from parameter RXX performed from the position of the mechanical rotation point.

When applied this way the result is that the straightness error, which was previously measurable with no compensation for the angular error RXX, will no longer appear to exist. The machine cannot physically remove the error but knowing where the bottom of the Z axis is located the position of the machine will be offset by the calculated effect of the angular parameter. The straightness error seen at the bottom of the machine will be identical to what existed at the position of the mechanical rotation point which is zero in this example.

Case 2: Mechanical and Compensation Point Not Identical

When the mechanical and software rotation points are not the same the calculated correction does not match the physical error of the machine axis. This mismatch creates a straightness error which is identical to what was previously seen at the bottom of the Z axis. An example showing the effect of the calculation for the correction of parameter RXX from the bottom of the Z axis is shown in illustration 3.

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Rotation RXX

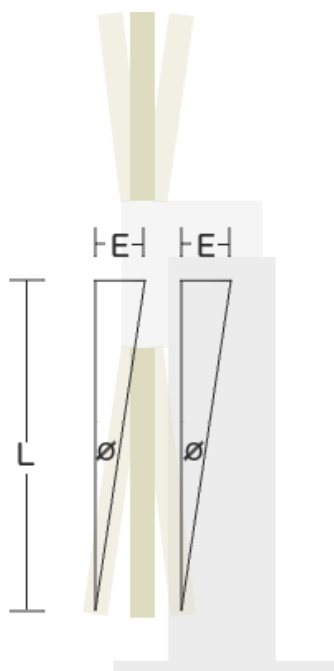


Illustration 3: Calculation of machine error from parameter RXX performed from the bottom of the Z axis. The start of the angular correction is at the moving end of the axis which creates a straightness error at the other end of the axis.

At the bottom of the Z axis the largest horizontal straightness error exists as a result of the X axis roll error. The correction length at the bottom of the Z is zero so no compensation at this point is applied. At the top of the Z axis, near the mechanical rotation point of the machine, the maximum amount of correction is performed. The end result is that the straightness error that existed at the bottom of the Z prior to compensation now exists at the top of the Z as well.

The horizontal straightness error at the top and bottom of the Z axis are identical once the angular RXX data is applied. The straightness error of the X axis in the Y direction of the machine will be identical to what was measured at the bottom of the Z axis without the RXX compensation applied.

Simulation of Straightness Errors

The effect of using the wrong end of a CMM axis for the angular correction point can be simulated. A machine with the dimensions of 1000x1000x1000 (positive Z axis) was created for the simulation. The angular data for RXX was input with the following expression:

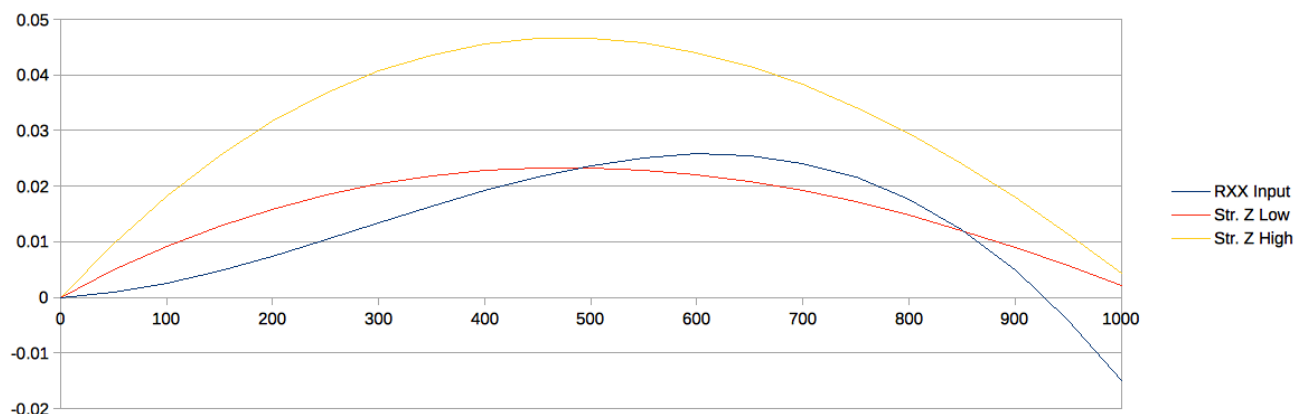
$$R_{XX}=0.010*L+0.127*L^2-0.200*L^3$$

Where:

L = length in meters.

Two measurements were performed in the X axis of the CMM; one at the top of Z and the other at the bottom. The rotation point was set for the top of the axis and the mechanical rotation is set to the bottom of Z.

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The straightness at the bottom of the Z axis is as predicted and is a result of the physical rotation of the Z axis around the X. The straightness at the top of the Z axis is significantly larger than that of the bottom which, with compensation applied, will be identical to that at the bottom of the Z axis.

The data was created with the CMM Error Simulator. Version 1.1 or higher is required to perform tests against the mechanical rotation points.

Real World Example

An example of this problem was found from an actual machine compensation map downloaded randomly from the internet. This compensation map was generated with software that is known to use bottom of the Z axis as the reference starting point for all rotational calculations. The machine kinematic is YXZ and describes a (rather large) bridge machine. The following images shows a good example of this problem from this setup:

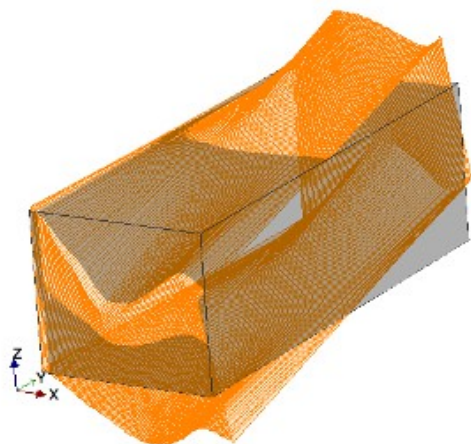


Illustration 4: Graphical view of rotation error RXX

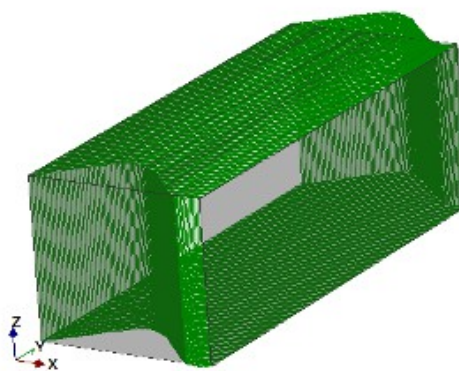


Illustration 5: Graphical view of straightness error LXY

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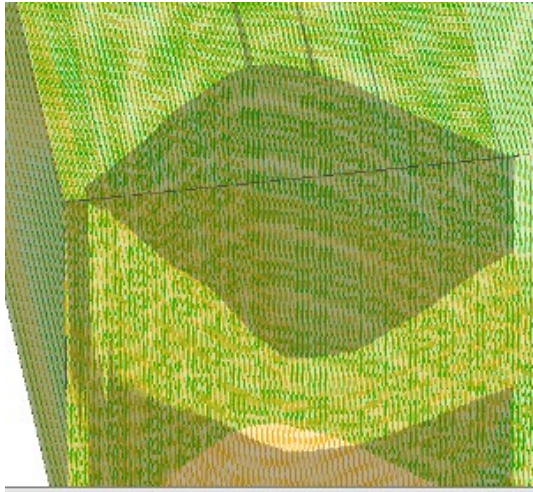


Illustration 6: Direct comparison of the angular RXX to the straightness LXY

The straightness error in this example file is clearly associated with the angular roll data. With the math rotation point identical to the mechanical rotation point this kind of relationship would not exist at all.

As an unrelated comment the data in this particular map looks quite decent. There are certain characteristics that are looked at when deciding the qualify of a compensation map and this data appears to be quite good. This is not a comment about the size of the errors contained in the map but the believability of how well the data describes the actual errors of the machine.

This problem does not affect the accuracy of the machine. It only adds characteristics to the compensation map data that should not normally exist. The correction becomes larger than what is necessary.

The comparison images was created using the compensation viewer program.

Known Issues from Non-Mechanical Rotation Points

The following is a list of known problems from using a non-mechanical rotation point:

- Routines that estimate straightness errors of an axis are no longer reliable without far more information than is commonly available.
- The correction in the machine error map table ends up larger than what it is needed to be. As the errors increase the uncertainty may increase as well.
- Straightness errors may not be updated with changes in angular parameters in some cases. Frequently the angular parameters are checked and updated but less often for straightness parameters depending on the calibration service provider (Note: Select Calibration Incorporated measures and updates all compensation parameters from a compensation map).
- Some compensation maps have very poor control over the limits of the map. If using the end point from one of these maps the corrections will be far worse than simply using the wrong end of the axis.

Compensation Map Conversion

One observation is that compensation maps may be converted from one format to another format without proper consideration of the effects from the conversion. An example of this would be where a machine is purchased that includes a compensation table collected at the factory but converted into a format that the target inspection software requires. If the two types of compensation data are interpreted differently then the linear data will simply be wrong.

It is theoretically possible to convert the data into different compensation formats if the rotation points are different but this requires a very thorough understanding of how to interpret the compensation data. It is a very error prone approach. Using the method of simply copying the data from one compensation map format into another should always be avoided.

Due to the proprietary nature of most CMM vendors no access to detailed information about the interpretation of the compensation map data will be available. This can further complicate conversion of compensation map from one vendor to another.

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Revision History

<i>Revision</i>	<i>Date</i>	<i>Reason</i>
1	Aug 6, 2016	Initial Release
2	Aug 7, 2016	Added real world example section.