Horizontal Arm Deflection

Table of Contents

Purpose

This article describes some of the effects of tower deflection on horizontal arm CMM's. All manufacturers of horizontal arm CMM's have provisions for dealing with tower deflection as this is a common problem for this type of machine.

Horizontal Arm Coordinate Measuring Machine

A horizontal arm coordinate measuring machine consists of a work table, a tower mounted on a base that runs parallel to the table, and an arm that extends from the tower ending with a probe or some other equivalent measurement sensor. The typical kinematic chain for these types of machines is XZY where X is parallel to one side of the table, Z is up / down, and Y is across the table.

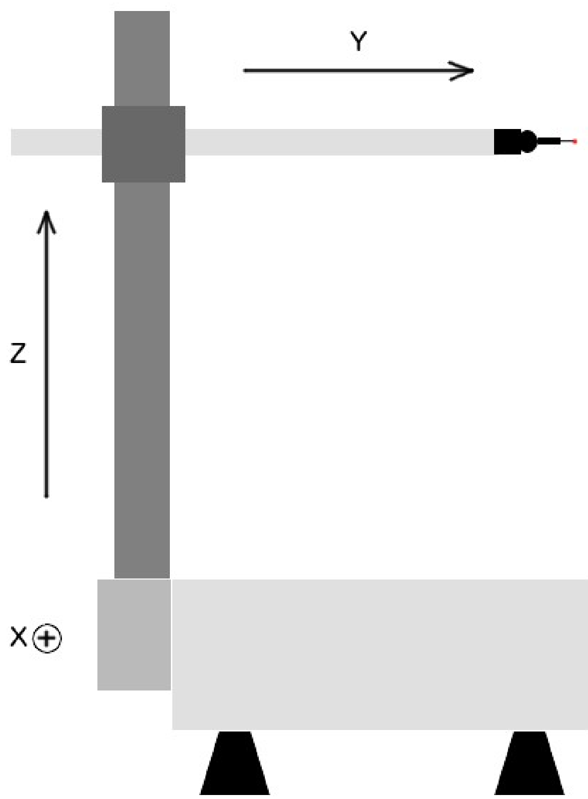

Illustration 1: Typical horizontal arm CMM with a kinematic of XZY.

Deflection

The source of tower deflection of a horizontal arm coordinate measuring machine is primarily from the change in the center of gravity when the arm moves combined with increasing leverage the further away the base of the tower. Deflection is a common problem for this configuration of machine since one side is open and unsupported unlike a typical bridge machine. Deflection may actually be the largest contributing source of errors for this family of CMM's.

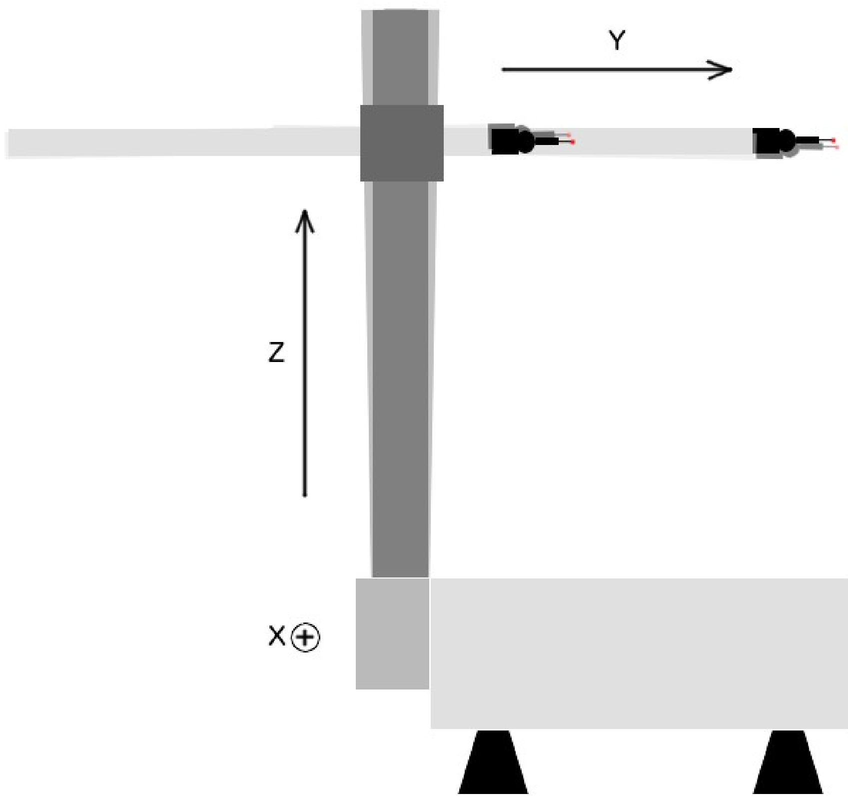

Illustration 2: Deflection when arm is moved from inboard to outboard position.

Common solutions used by manufacturers to deal with this problem include the following:

- Use of air bearings instead of hard roller bearings at the base of the tower. Air bearings are more rigid.
- Addition of an upper bearing support to minimize tower deflection.
- Addition of a counter balance for the Y axis. As the Y axis moves in or out the Y counter balance would also move so that the center of gravity does not change as the position of the Y axis changes.
- Software compensation.

Horizontal Arm Deflection

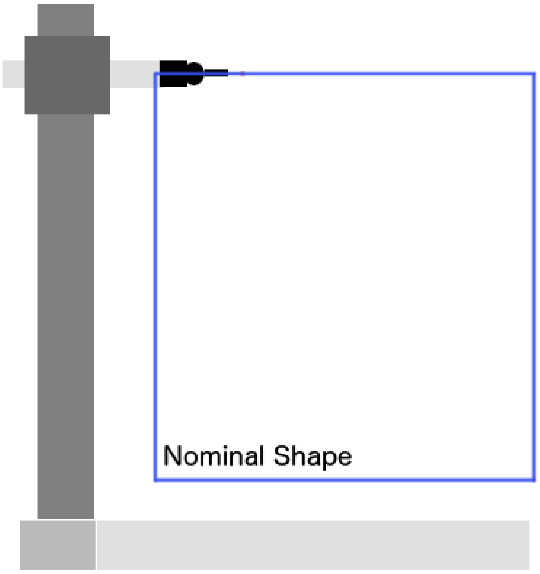

Illustration 3: Shape of YZ axis when no deflection exists.

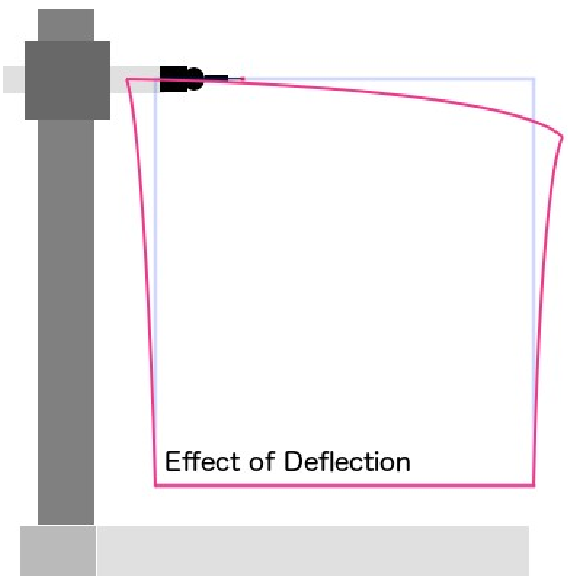

Illustration 4: Shape of YZ with deflection relative to the world.

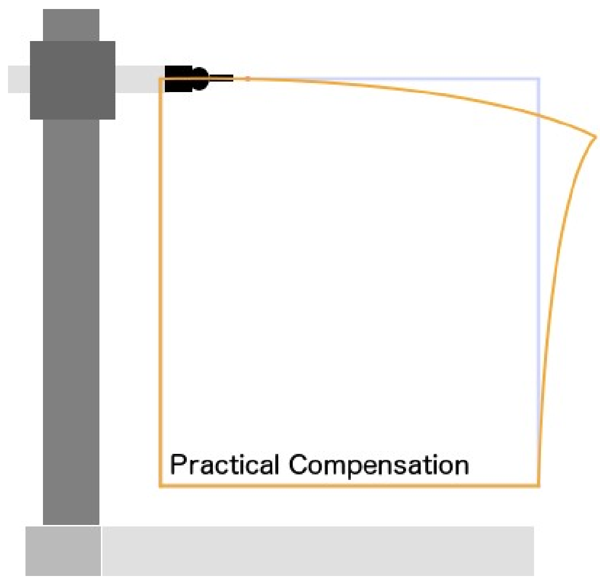

Illustration 5: Shape of practical YZ software compensation relative to frame of machine.

Horizontal Arm Deflection

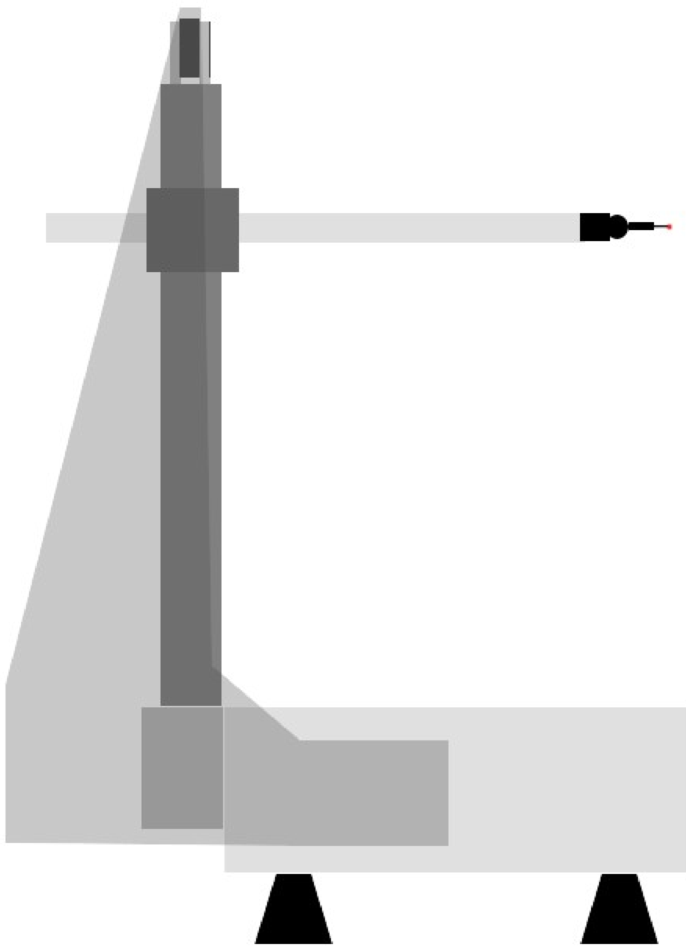

Illustration 6: A horizontal arm coordinate measuring machine with a separate tower supporting structure (bearing surface way) at the top to minimize deflection.

Software Compensation

A typical compensation map consists of eighteen compensation parameters and three for squareness. The standard set of correction parameters cannot deal with the effects of deflection so most manufacturers use supplemental parameters specific for deflection. When dealing with standard compensation parameters the methods are almost universal but this is not true for deflection and everyone seems to use a different method to solve this problem.

A common method to correct for deflection is the use of linear gradients where one gradient would represent the correction in Z and the other gradient would represent the correction in Y as a function of the YZ position. An example of this type of compensation is shown in illustration 7.

The actual error is not linear so a more complete correction would be two curves that mimic the actual shape of the errors in the Y and Z directions. This is most commonly achieved as a fourth axis correction table (a non-linear expression such as $Err = A + Bx + Cx^2$ would also work).

Horizontal Arm Deflection

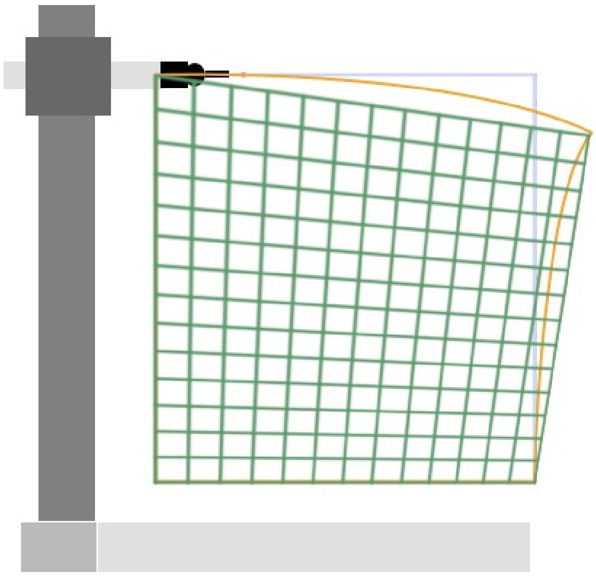

Illustration 7: Basic deflection compensation using gradients.

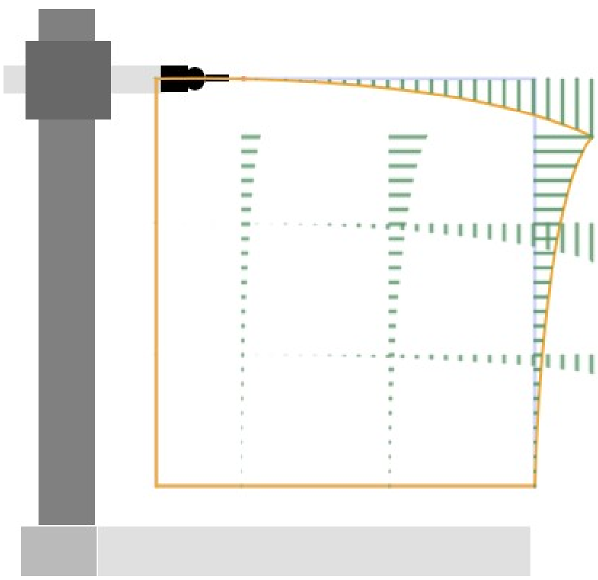

Illustration 8: Deflection compensation using a correction table.

Deflection is functionally repeatable and can be inadvertently affected by simply changing the amount of weight on the end of the arm.

Deflection Angle Measurement

Tower deflection can be checked by placing an electronic level on the base of the Z axis tower and moving the Y axis through its range. This test should be performed with the Y axis at the top of the machine.

Horizontal Arm Deflection

Deflection Effect On Length Measurements

Deflection of the tower will have an effect on the measurement of length in the Y axis at the top of the machine and in the Z axis when the arm is fully extended. Comparing measurements of length in the Y axis top to bottom and Z axis inboard to outboard is a good way to verify deflection compensation is working as expected.

The effect of deflection on the measurements can be used to determine the amount of correction and is a common way to update for this kind of error. Illustration 9 shows an example of a deflection editor that isolates the user from the implementation details of the manufacturer.

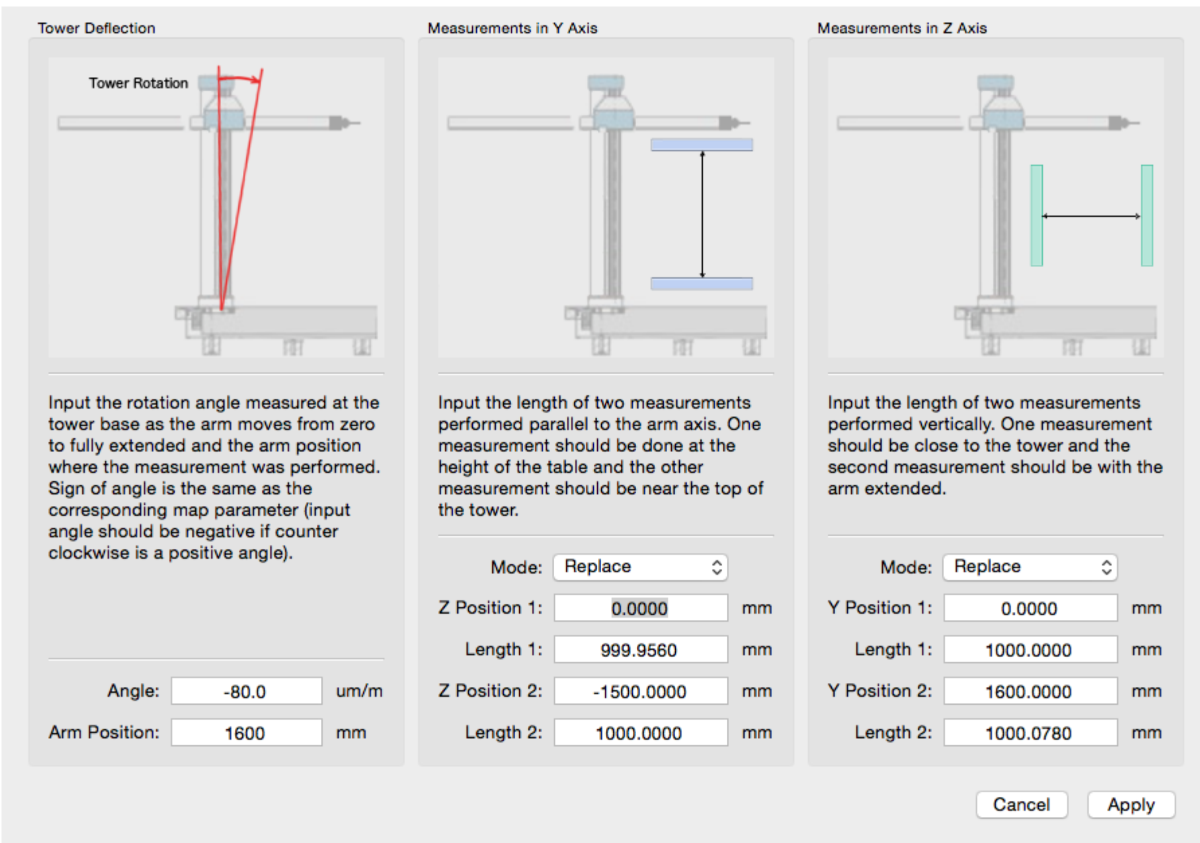

Illustration 9: Generic editor for deflection compensation.

Revision History

Revision	*Date*	*Reason*
1	Sept 20, 2015	Initial Release
2	May 18, 2020	Document Review and Update.