Pitch and Yaw Angular Error Measurement Using a MCV-500 Laser Calibration System

I. What is the problem

The MCV-500 laser calibration system with the SD-500 sequential step diagonal measurement option can be used to measure the 3 linear displacement errors, 6 straightness errors and 3 squareness errors. However, for many machines, the pitch and yaw angular errors may be large and need to be measured. Instead of using another laser calibration system such as MCV-2002, or add another laser head such as MCV-5000, the existing MCV-500 laser calibration system can be used to measure the pitch and yaw angular errors by repeated measurements with different Abbe offsets and data processing software.

II. How to solve this problem

Using a dual-beam laser head(MCV-2002) or two laser heads(MCV-5000), the pitch and yaw angular errors of the machine can be measured. For a single laser head(MCV-500), if the machine is repeatable, the angular errors can be determine by 2 or 3 separate measurements along the same axis but at different Abbe offsets [see Ref 1].

For example, for 3 measurements along X-axis at 3 different locations with known Abbe offsets m1, p1; m2, p2; and m3, p3, the measured results, DX1, DX2 and DX3 can be expressed as the followings.

DX1 = Dx(x) + m1*Ay(x) + p1*Az(x)
DX2 = Dx(x) + m2*Ay(x) + p2*Az(x)
DX3 = Dx(x) + m3*Ay(x) + p3*Az(x)

Where Dx(x) is the linear displacement error, Ay(x) and Az(x) are pitch and yaw angular errors respectively.

There are 3 sets of data DX1, DX2 and DX3 and 3 unknowns Dx(x), Ay(x) and Az(x). The solutions are,

Ay(x) = [(m3-m1)*(DX2-DX1)-(m2-m1)*(DX3-DX1)] / [(m3-m1)*(p2-P1) -(m2-m1)*(p3-p1)]
Az(x) = [(p3-p1)*(DX2-DX1)-(p2-p1)*(DX3-DX1)] / [(m3-m1)*(p2-P1) -(m2-m1)*(p3-p1)]
Dx(x) = DX1*(m2*p3-m3*p2)+DX2*(m3*p1-m1*p3)+DX3*(m1*p2 -m2*p1) / [(m3-m1)*(p2-p1)-(m2-m1)-(p3-p1)].

Similarly for the Y- and Z-axis, Ax(y), Az(y), Dy(y), Ax(z), Ay(z), and Dz(z) can all be determined.

Of course, the accuracy of the measurement is limited by the repeatabililty of the machine and the Abbe offset. For example, for a machine with repeatability of 0.0001”(2.5 µm) and the Abbe offset of 20”(500 mm), the accuracy of the angular measurement is 0.0001/20 = 0.000005 rad, or 1 arcsec which is good enough for most of the machines.

III. How it works

Same as a linear displacement measurement of an axis, here the position of the laser head (or laser beam) is recorded in the setup screen as shown in Fig. 1.

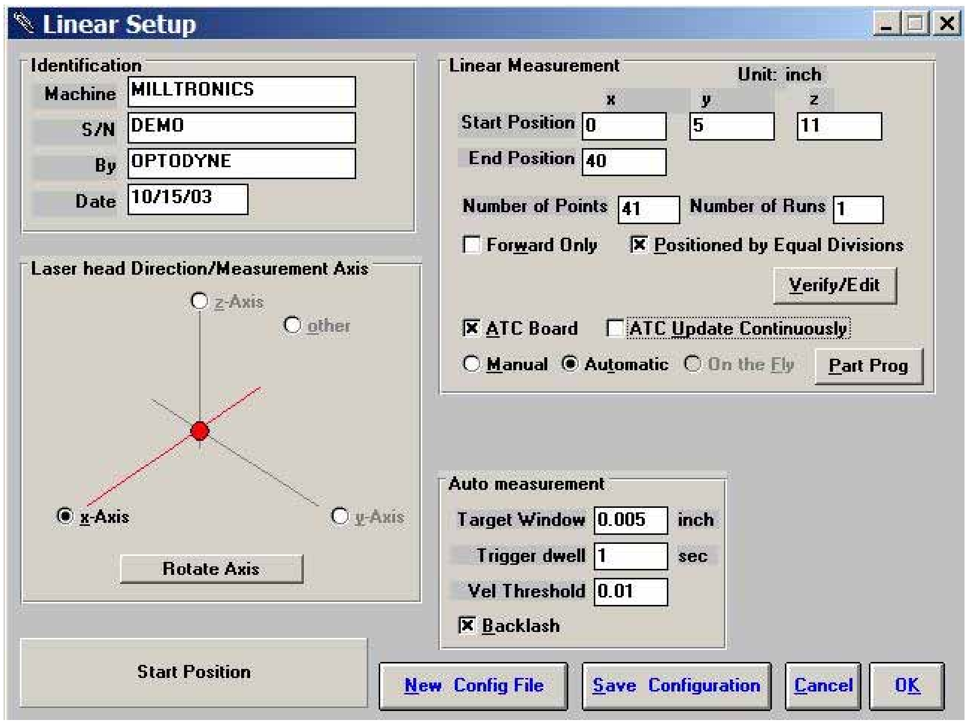

Fig. 1, A popup screen for user to enter the location of the laser beam.

Pushing the Part program button on the set up screen, you can have the ISO part program to move the machine by sub sequential steps in order to measure positioning error.
load the program in the CNC .
Aligning the laser beam parallel to the X axis movement. Take the first measurement positioning the machine at starting point and collect it pushing START button on the PC screen. Start the positioning program, the machine will move to the next point and stops for few seconds, the point will be collected automatically, the same as the sub sequential points. At the end of the measurement save the data .

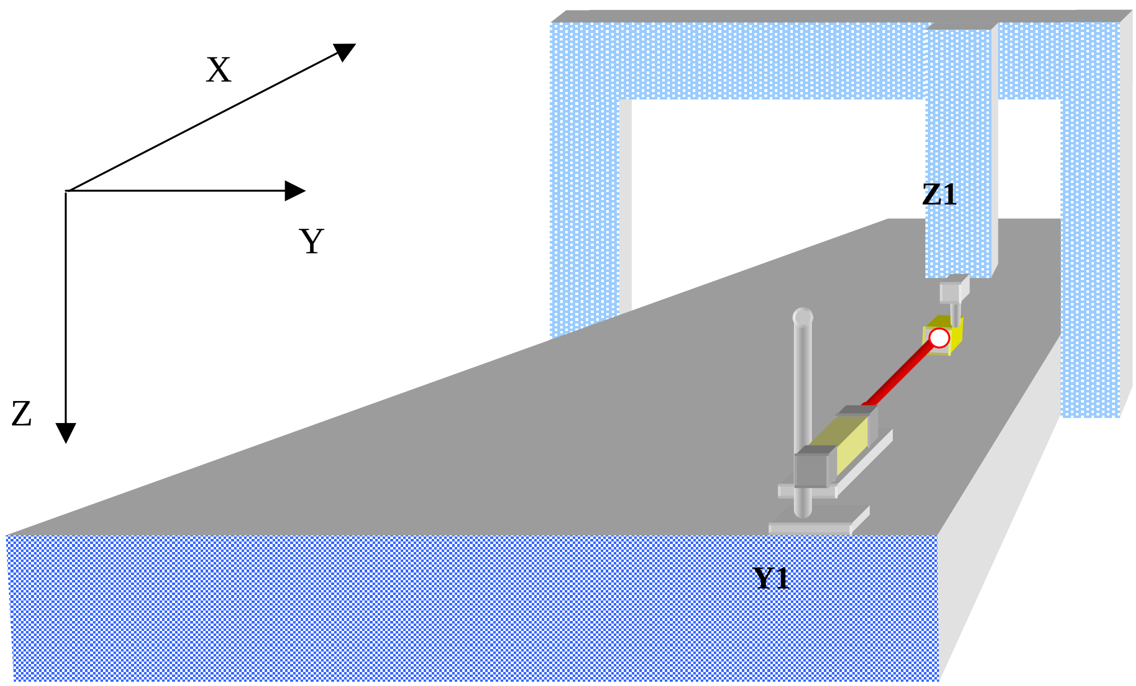

Fig2 Example of laser position at the first measurement

Then relocate the laser head
in a new location with
different Abbe offset in
in the horizontal direction.

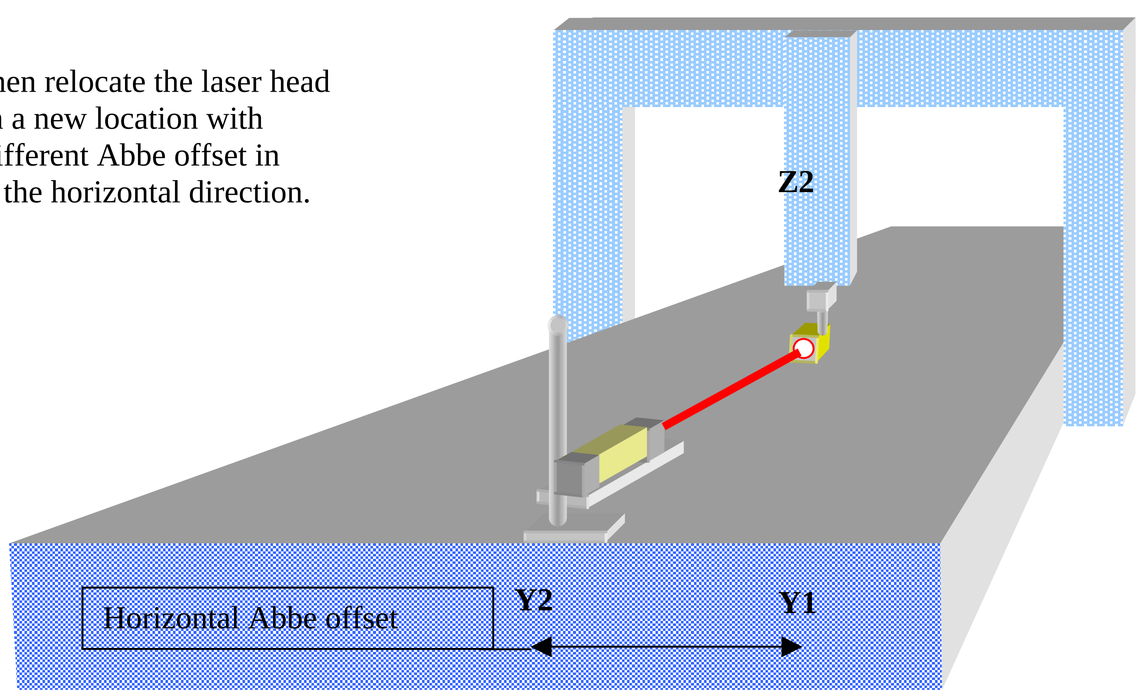

Fig3 Example of laser position at the second measurement

and again another location with different Abbe offset in the vertical direction.

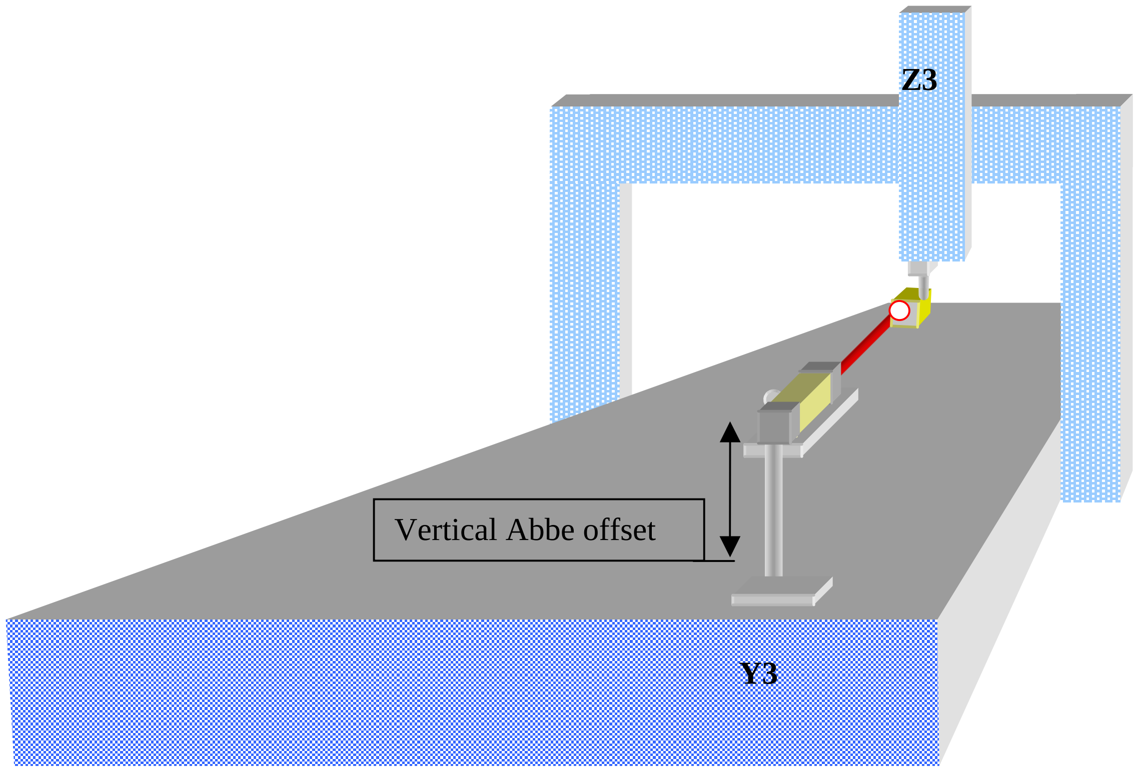

Fig4 Example of laser position at the third measurement

A software is available to calculate the pitch & yaw angular errors based on three linear displacement data. Click on “Data Analysis”, “File” and “Convert 3 Linear Files”, a popup screen as shown in Fig. 2 , allow user to enter 3 linear files & coordinates.

Enter 3 linear files of the same axis, same starting and ending position and same number of points. The first coordinate and second coordinate are the two Abbe offsets at vertical and horizontal directions respectively. User needs to enter the output file names. The first file is equivalent to the linear displacement measured at the reference (both Abbe offsets are zero). The second file is equivalent to pitch angular errors with an offset equal to the vertical distance from the reference (user input the value). The third file is equivalent to yaw angular errors with an offset equal to the horizontal distance from the reference (user input the value). The angular errors can be analyzed by click on the “Straightness” button or open the straightness file.

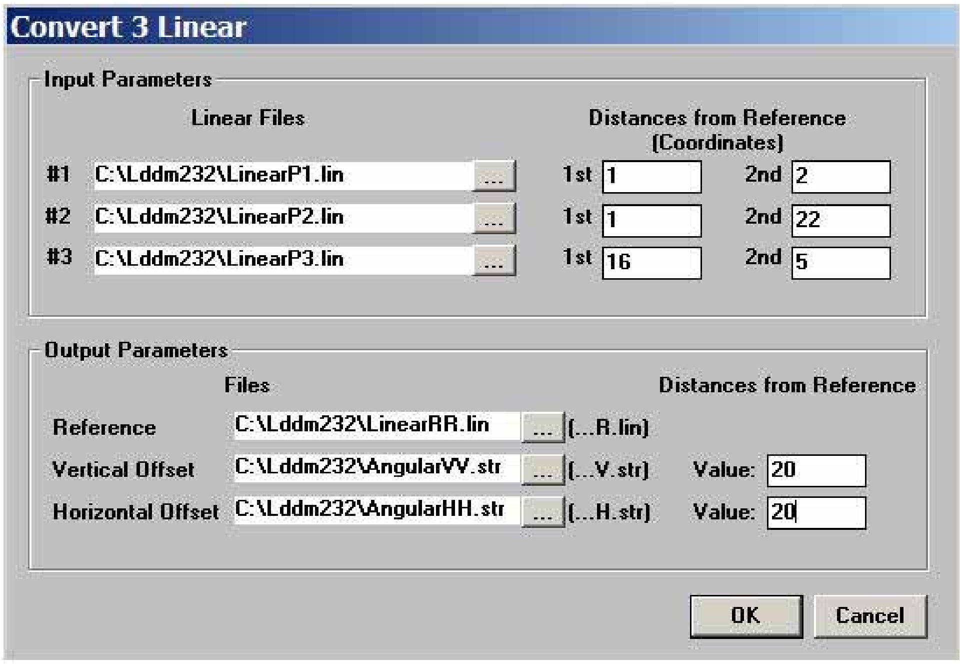

Fig. 5, A Popup Screen for User to Enter 3 Linear Displacement Files with Different Abbe Offsets and 3 Output File Names with 2 Different Abbe Offsets

Fig. 6, A vertical straightness analyzed and calculated by LDDM software

IV. References

[1] C. Wang & G. Liotto, "A theoretical analysis of a body diagonal displacement measurement and sequential step diagonal measurement" in proceedings of the LAMDAMAP Conference, Huddersfield, England, July 4, 2003.

V. Need more information

Call Optodyne at 310-635-7481 or your local representative.