스텝대각오차 측정법의 오차 보정

Testing the new equation for Step-diagonal Measurement Method

*부이바친 [1], #황주호 [2], 박천홍 [2], 이찬홍 [2]
* B.C.Bui (bbchinh@kimm.re.kr)[1], #J.H. Hwang[2] (Jooho@kimm.re.kr), C.H. Park[2] , C.H. Lee[2]
[1] 과학기술연합대학원 나노메카트로닉스학과, [2] 한국기계연구원 초정밀시스템연구실

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1. Introduction

To ensure the motion accuracy of entire three-dimensional workspace such as machine tool or coordinate-measuring machine, all the volumetric errors including three linear displacement errors, six straightness errors and three perpendicular errors are needed to evaluate. However, measuring all of these errors with direct use of laser interferometer and other equipments is very complicated and time consuming.

Recently, a vector method developed by Wang can overcome the disadvantage of conventional diagonal method and provide linear accuracy, straightness and perpendicular of X, Y, Z from only 4 step-diagonals data [1]. However, this method still has many limitations as identified by Chapman that errors in the alignment of flat mirror and laser beam will introduce additional errors that cannot be separated from linear displacement errors in the axes of the machine [2].

Therefore, in this paper, a new equation for step-diagonal measurement method is introduced in three-dimensional case to overcome the limitations [3]. In this method, the Optodyne equipments are used to get the four step-diagonal data and three linear errors, thanks to the new equation all straightness errors of each axis and perpendicular errors can be distinguished without the limitations of the conventional method. To evaluate the new equation for step-diagonal measurement method, all straightness errors are directly measured to compare with assuming errors.

2. The conventional equation and limitations.

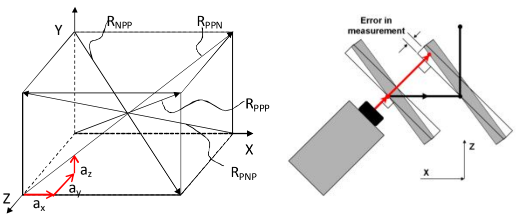

Fig. 1 The principle of step-diagonal method and limitation

To measure the errors, four step-diagonals shown in Fig.1 are used to collect all the errors such as the linear, straightness and angular errors every step of face diagonal movement [1]. Hence, this method seems to be a fast check for 3D positioning error. However, Chapman shows that estimated errors can be influenced by setup error of flat mirror and laser direction [3]. To solve these issues, new equation will be addressed in the next part.

3. A new equation for step-diagonal measurement method.

When four linear errors are known, by solving Eq.1 [3] we can have six straightness errors as Fig. 2, Fig. 3, and Fig. 4:
Where a_x, a_y ,a_z length of measurement steps

$$\begin{bmatrix}\alpha_{x,ppp} & \alpha_{y,ppp} & \alpha_{y,ppp}\end{bmatrix} = \frac{1}{\|a\|}\left[a_x, a_y, a_z\right]$$

$$\|a\| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

Three linear errors $\Delta e_x(x(k)), \Delta e_y(y(k)), \Delta e_z(z(k)$

Step-diagonal data at the k[th] step measurement

$$R_{x,ppp}(k), R_{y,ppp}(k), R_{z,ppp}(k), R_{x,pnp}(k)$$

$$R_{y,pnp}(k), R_{z,pnp}(k) R_{x,npp}(k), R_{y,npp}(k), R_{z,npp}(k)$$

Six straightness errors

$$\left[\Delta e_y(x(k)); \Delta e_z(x(k)); \Delta e_x(y(k)); \Delta e_z(y(k)); \Delta e_x(z(k)); \Delta e_y(z(k))\right]^T$$

$$\begin{bmatrix} \alpha_{y,ppp} & \alpha_{z,ppp} & \alpha_{x,ppp} & \alpha_{z,ppp} & \alpha_{x,ppp} & \alpha_{y,ppp} \\ -\alpha_{y,npp} & -\alpha_{z,npp} & \alpha_{x,npp} & \alpha_{z,npp} & \alpha_{x,npp} & \alpha_{y,npp} \\ \alpha_{y,pnp} & \alpha_{z,pnp} & -\alpha_{x,pnp} & -\alpha_{z,pnp} & \alpha_{x,pnp} & \alpha_{y,pnp} \\ \alpha_{y,pnp} & \alpha_{z,pnp} & 0 & 0 & 0 & 0 \\ 0 & 0 & \alpha_{x,ppp} & \alpha_{z,ppp} & 0 & 0 \\ 0 & 0 & 0 & 0 & \alpha_{x,ppp} & \alpha_{y,ppp} \end{bmatrix} \begin{bmatrix} \Delta e_y(x(k)) \\ \Delta e_z(x(k)) \\ \Delta e_x(y(k)) \\ \Delta e_z(y(k)) \\ \Delta e_x(z(k)) \\ \Delta e_y(z(k)) \end{bmatrix} =$$

$$= \begin{bmatrix} (R_{x,ppp}(k)+R_{y,ppp}(k)+R_{z,ppp}(k))-(a_x+a_y+a_z)-(\Delta e_x(x(k))+\Delta e_y(y(k))+\Delta e_z(z(k))) \\ (R_{x,npp}(N-k+1)+R_{y,npp}(k)+R_{z,npp}(k))-(a_x+a_y+a_z)-(\Delta e_x(x(k))+\Delta e_y(y(k))+\Delta e_z(z(k))) \\ (R_{x,pnp}(k)+R_{y,pnp}(N-k+1)+R_{z,pnp}(k))-(a_x+a_y+a_z)-(\Delta e_x(x(k))+\Delta e_y(y(k))+\Delta e_z(z(k))) \\ R_{x,pnp}(k)-a_x-\Delta e_x(x(k)) \\ R_{y,ppp}(k)-a_y-\Delta e_y(y(k)) \\ R_{z,ppp}(k)-a_z-\Delta e_z(z(k)) \end{bmatrix} \quad (1)$$

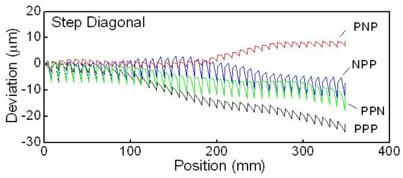

Fig. 2 Four step-diagonal data

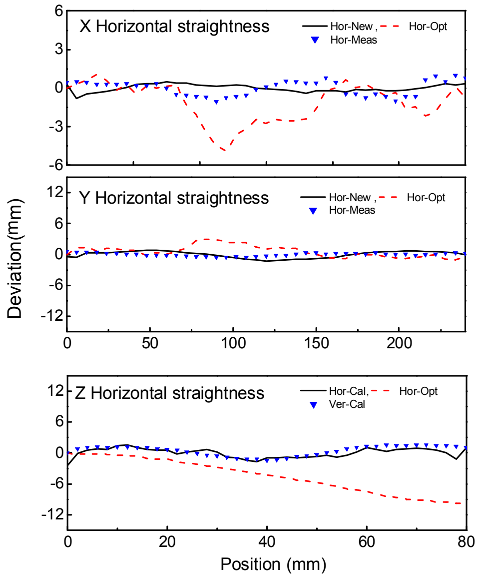

Fig. 3 Horizontal straightness comparison

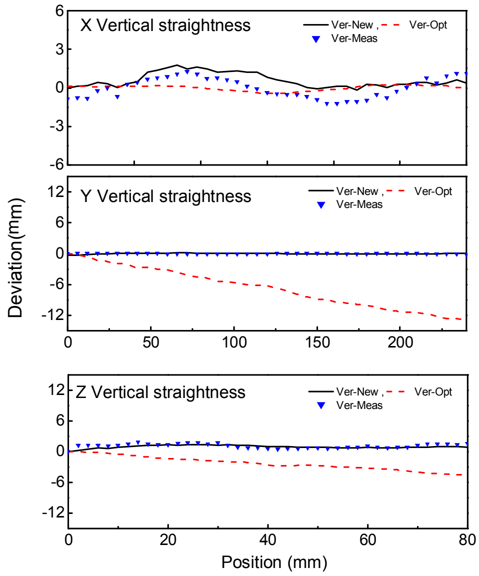

Fig. 4 Vertical straightness comparison

REFERENCES

1. Wang C., Laser vector measurement technique for the determination and compensation of volumetric positioning errors, Part 1. Basic theory. Review of Scientific Instruments, 71 (10) (2000).
2. Chapman M.A.V, Limitations of laser diagonal measurements. Precision Engineering 27 (2003) 401–406.
3. S. Ibaraki, T. Hata, “A new formulation of laser step-diagonal measurement-Three-dimensional case” Precision Engineering, 34 (2010) 516-525.