공간오차 저감을 위한 공작기계 구조설계 방법
Machine Tool Configuration Design Method for Volumetric Error Reduction

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1. Introduction

The establishment of the volumetric error (VE) of a machine tool is usually carried out by detecting the individual error components and combining those by means of a mathematical model. It is a system analysis implement, used for prediction and control the total error of a system at the design stage. By using this model, there are different methods that have been studied for improving the volumetric error of machine tools. This paper presents a new method for VE reduction. It is based on the effects of changing single-axis linear motion carriage orientation. Changing orientation of the linear does not affect to accumulated error, but changes the distribution. It leads to change in accuracy of system. By using this property and the modeling method for volumetric machine tool, which was introduced by Donaldson[1], Treib[2], Solocum [3], and Okafor [4], a program is developed for VE simulation to show the changing of the VE corresponding to the different configurations. This application supports the designer in evaluation and selection of suitable configuration.

2. Changing orientation of a single-axis linear motion carriage

As Fig.1 a single-axis linear motion carriage is oriented from A to B.

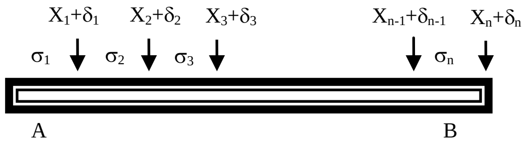


Fig. 1. X axis servo error (AB)

Where, σ_k is a series of errors that occur when axis move from X_{i-1} to X_i position and δ_k is a series of X-axis servo errors (from A to B).

$$\begin{aligned} &\delta_1 = \sigma_1 \\ &\delta_2 = \sigma_1 + \sigma_2 \\ &\delta_3 = \sigma_1 + \sigma_2 + \sigma_3 \\ &\delta_k = \sigma_1 + \sigma_2 + \sigma_3 + ... + \sigma_k = \sum_{i=1}^{k} \sigma_i \end{aligned} \quad (1)$$

As Fig.2 a single-axis linear motion carriage is oriented from B to A.

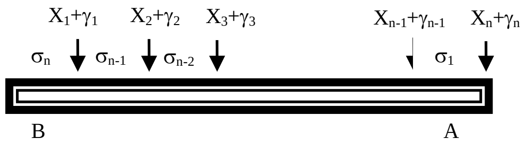


Fig. 2. X axis servo error (BA)

Where, γ_k is a series of X axis servo errors.

$$\begin{aligned} &\gamma_1 = \sigma_n = \sum_{i=1}^{n} \sigma_i - \sum_{i=1}^{n-1} \sigma_i \\ &\gamma_2 = \sigma_n + \sigma_{n-1} = \sum_{i=1}^{n} \sigma_i - \sum_{i=1}^{n-2} \sigma_i \\ &\gamma_3 = \sigma_n + \sigma_{n-1} + \sigma_{n-2} = \sum_{i=1}^{n} \sigma_i - \sum_{i=1}^{n-3} \sigma_i \\ &\gamma_k = \sigma_n + \sigma_{n-1} + \sigma_{n-2} + ... + \sigma_{n-k+1} = \sum_{i=1}^{n} \sigma_i - \sum_{i=1}^{n-k} \sigma_i \end{aligned} \quad (2)$$

Combine (1) and (2), γ_k can be calculated as below:

$$\gamma_k = \delta_n - \delta_{n-k}$$

$$\gamma_n = \delta_n$$

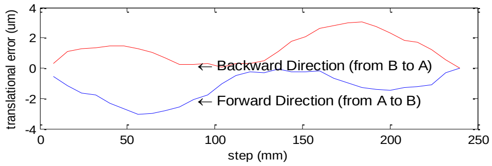


Fig. 3. X axis servo error

Similar, other errors can be presented as below:

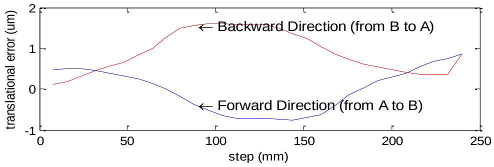


Fig. 4. Horizontal straightness error

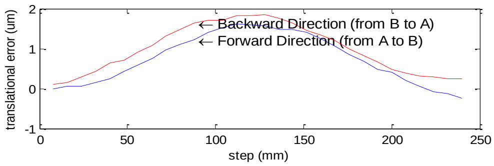


Fig. 5. Vertical straightness error

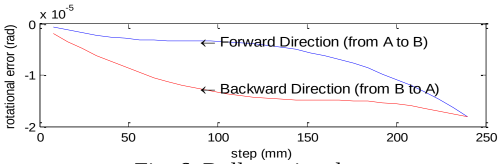


Fig. 6. Roll rotational error

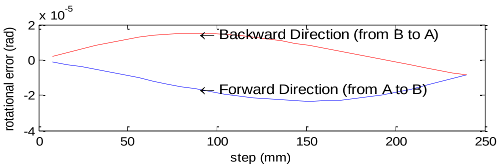


Fig. 7. Pitch rotational error

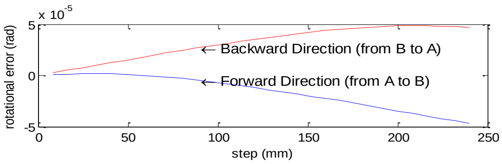
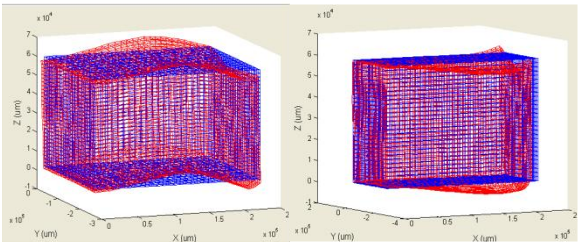


Fig. 8. Yaw rotational error

3. Volumetric Error Reduction Method

By considering the geometric description of machine tool, we realize that changing orientation of the axis leads to change the volumetric error.

Some simulations are performed to illustrate for above mention. In the example, we consider two cases of a 3-axis machine tool. The machine tool includes X-axis and Z-axis in cutting tool group and Y-axis in workpiece group. In the first case in Fig.9a, the X-axis was not rotated, the volumetric error was 10.7 (μm). In the remaining case in Fig.9b, the orientation of X-axis was rotated, the volumetric error was 21.4 (μm). Therefore, we can improve the VE by selection a suitable configuration.



(a) (b)

Figure. 9. Error contours

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