더블 볼바를 이용한 다축 공작기계의 오차요인 지정

Trace pattern of double ball bar test from designated error origin on five-axis machine tools

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1. Introduction

It is worth noting that the issues of five-axis machine tools are not a straight extension from the three-axis machine areas. Introduction of rotary axes fundamentally alters the machine's kinematic structure, thus limiting the application of analytical methods developed for three-axis machines to five-axis machine tools. The overall accuracy is determined by the interaction of a number of error terms in the kinematic chain of a five-axis machine. But the influence of the major components is still difficult to reveal.

Based on the view of a machine tool as a kinematic composition of different linear and rotary axes, we can describe geometric performance of machine tools. The geometric errors of the different axes cause relative displacements between tool and workpiece. How the different errors add up depends on the kinematic buildup of the machine tool.

Then a kinematic model of the machine is essential. Here, the objective of the model is to employ a unique formula to relate cutter location (CL) data and machine control coordinate (MCC) that can be easily customized for a specific kinematic chain. Figure 1 illustrates the construction of axes kinematic function for motion on a tilting rotary table five-axis machine.

The general ballbar test method for any combination of linear and rotary axes begins with the analysis of the work space created by the two tested axes. Then, a test circle on the work space is defined as the test path and the corresponding axial driving signals for the circular path are derived through backward kinematic transformation. Sensitivity analysis helps to optimize the test parameters. Finally, an error diagnosis can be done based on the simulated trace patterns of different error origins as reference.

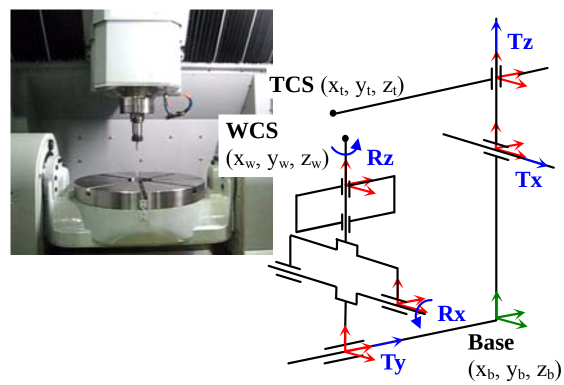

Fig. 1 Kinematic modeling of Five-axis machine with tilting rotary table type

2. Geometrical based kinematic model

An entire machine tool structure can be decomposed into a series of HTMs, starting at the tool tip and progressing around the machine. In this way, a machine with N rigid bodies can be connected in series [1]. The representation of the workpiece coordinate system in base frame is obtained from Figure 1 by series multiplication of the homogeneous transformation matrices (HTM) as:

$$H_w^b = T_y(y,0,0) \cdot R_x(X_a, \theta_a) \cdot R_z(Z_c, \theta_c) \quad (1)$$

T_y as HTM 4x4 matrix for translation motion with relative distance about y from the origin (based) in y axis direction. And R_i for rotation round i-axis where

$\theta_a = a$, $\theta_c = c$ are rotation angle of the A and C drives. The tool frame is represented similarly as:

$$H_t^b = T_x(x,0,0) \cdot T_z(z,0,0) \tag{2}$$

For realistic manner, the model take into account the fact that no axis purely act single motion. It can have positional error due to straightness of linear axis or due to shift of center of rotational axis. The HTMs associated with the error can be formulated by multiplying the related matrices containing the error terms. If, for example, there is a center shift of C axis from A in Y axis direction (δ_{yCA}), the HTMs for workpiece frame can be rewrite as:

$$\begin{aligned} H_w^b = & T_y(y,0,0) \cdot R_x(X_a,\theta_a) \\ & \cdot T_{\delta Y}(\delta_{yCA},0,0) \cdot R_z(Z_c,\theta_c) \end{aligned} \tag{3}$$

3. Trace pattern of different error origin

These are deviations particular to five-axis machining centers but not in the conventional three-axis machine [2]. Tsusumi plot the trace pattern of DBB test related with a particular error. One of it is positional deviations (δx_{AY}) of A axis respect to Y axis in X axis direction. By multiplying related HTM matrices containing the error terms in to the model, we can regenerate the plot of DBB test as shown by Tsusumi.

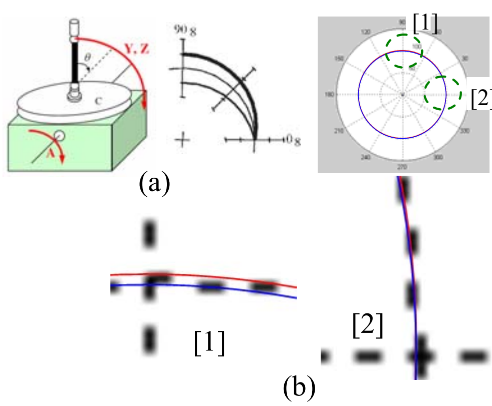

Fig. 2 (a) DBB test setup and trace pattern of single δx_{AY} error by Tsutsumi. (b) Redraw by the model.

The algorithm of above example is describe in figure 3. By taking advantage from NC command of DBB test, we can get error based trace pattern that can be used as reference for further error diagnosis.

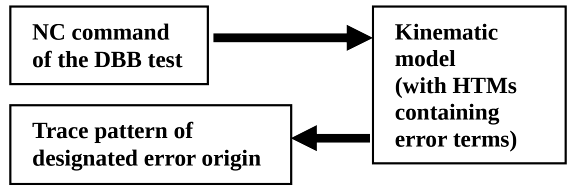

Fig. 3 Algorithm for generating trace pattern from a DBB test

Due to the limited length of DBB test equipment, changing initial value of the model HTMs can be used also as sensitivity analysis. By this way, we can evaluated also the most significant factors other than well-known geometric errors for feasible new DBB calibration path.

4. Acknowledgment

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5. Conclusion

A geometrical based kinematic model that can be easily customized for a specific kinematic chain can be used to describe machine performance. The trace patterns of DBB test from different error origins are simulated and used as a reference for error diagnosis. The plot of new feasible DBB test path will be shown in the conference.

References

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