A study on the measurement of the profile errors of guide rails in hydrostatic feed tables

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In this paper, we introduce a design and experimental results of the measuring device for the measurement of profile errors of guide rails in hydrostatic feed tables. This measuring device is basically based on the sequential two-point method and the results of the measurements are compared with that using accurate master mirror. Experimental results show that the proposed measuring device is adequate for measuring profiles errors of hydrostatic feed tables.

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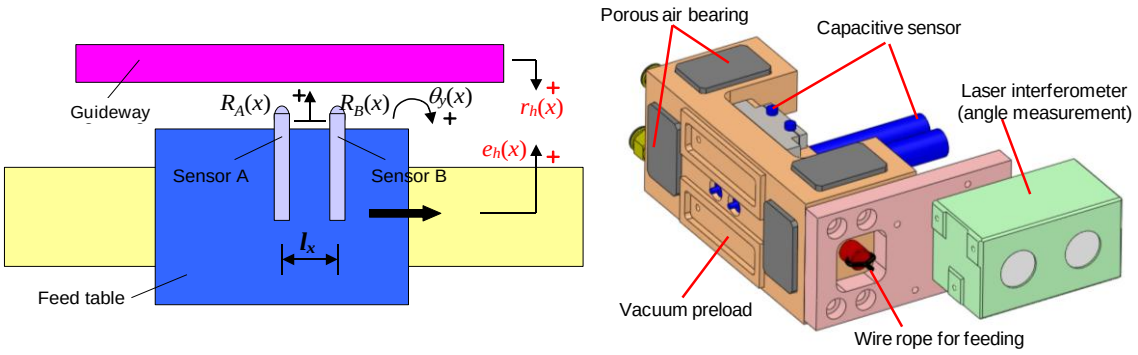
1. Introduction

In a precision feed tables such as aerostatic or hydrostatic tables, 5-DOF motion errors are largely affected by the profile errors of guide rails. To get the target precision of the feed tables, final finishing process such as scrapping or lapping by the skilled workers is normally required and it is time consuming and iterative process. One of the most important tasks to be done in the final finishing process is to measure the profile errors of guide rails precisely and it is not easy owing to limited space in a normal case.

In another point of view, if it is possible to predict the motion errors of the tables from the rail profiles, we can define the allowable tolerance of the rail profile in a design step and also the time for finishing process can be reduced drastically. In a normal hydrostatic bearing table, several bearing pads with same size are placed in a table structure. So, if it is possible to analyze the characteristics of single bearing pad and the spatial arrangement of the bearing pads are known, transfer function method[1,2] can be effectively utilized in the prediction of motion errors. Accurate measurement of profile errors is also necessary to verify the effectiveness of transfer function method.

In this paper, we propose a measuring device for the measurement of profile errors. It is basically based on the sequential two-point method[3] and the measurement results are compared with that using master mirror for verification.

2. Design of Measuring Device



(a) Measurement principle (b) Design of measuring device

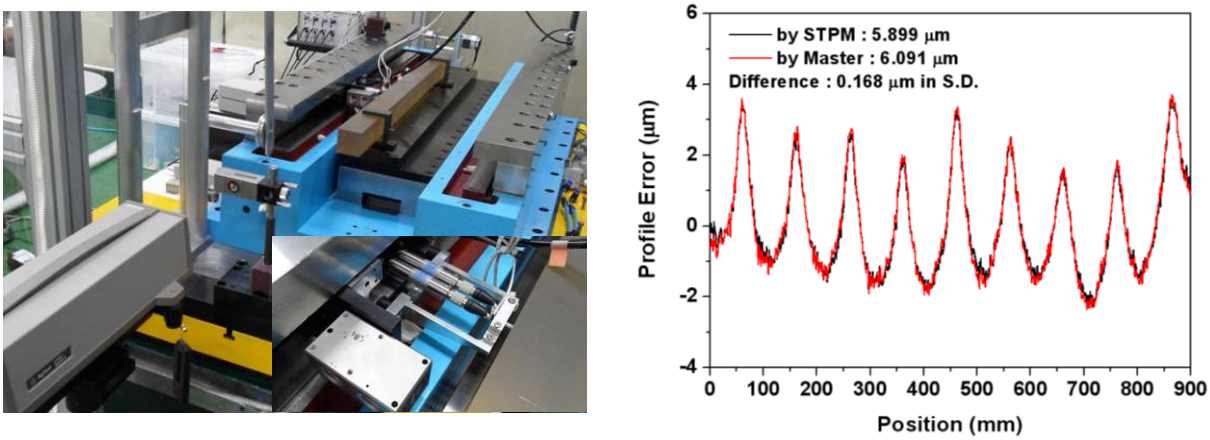
Fig. 1 Measurement principle and design of measuring device

Fig. 1(a) shows the principle of sequential two-point method with angle compensation. $e_h(x)$ is the motion error of the feed table, while $r_h(x)$ is the profile error of guide rail. $\theta_y(x)$ is the yaw error of feed table and l_x is the distance between displacement sensors. Profile error $r_h(x)$ can be expressed as follows,

$$r_h(x_{i+1}) = r_h(x_i) + R_B(x_i) - R_A(x_i) + l_x\theta_y(x_i) \quad (1)$$

Fig. 1(b) shows the design of measuring device. To measure the profile errors of guide rails, two capacitive sensors are installed in horizontal direction, while four capacitive sensors are installed in vertical direction. To feed the measuring device within the guide ways, porous air bearings are used in horizontal and vertical directions. To provide the preload force in a horizontal direction, two vacuum preload pockets are installed in horizontal direction. For angle measurement, angular optics of commercial laser interferometer are used. This measuring device is driven by rotary motor and wire rope.

3. Experimental Results



(a) Experimental setup (b) Results of comparison

Fig. 2 Experimental results

Fig. 2(a) shows the experimental setup. To verify the results of measurement, accurate master mirror and one additional capacitive sensor are used. The length of the master mirror is 1000 mm and the measuring range of capacitive sensors are ± 50 ㎛. Fig. 2(b) shows the results of comparison. Result of profile error measurement by sequential two-point method (5.899 μm in peak to valley) coincides very well with that by master mirror (6.091 μm in peak to valley). Difference of two measurements was 0.168 μm in standard deviation.

4. Conclusions

In this paper, we proposed a design of measuring device for the measurement of profile errors of hydrostatic feed tables. This device follows the surface of guide rails by use of porous air bearings and adopts the principle of sequential two-point method. Measuring device is applied to real hydrostatic table and the measurement result is compared with that by using accurate master mirror. Experimental results show that the proposed measuring device is adequate for measuring profiles errors of hydrostatic feed tables.

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