Pergamon

Int. J. Mach. Tools Manufact. Vol. 37, No. 5, pp. 579–590, 1997

0890–6955/97$17.00 + .00

PII: S0890–6955(96)00078-8

CCD-BASED CMM GEOMETRICAL ERROR MEASUREMENT USING FOURIER PHASE SHIFT ALGORITHM

CHIEN CHOU,†‡ LING-YU CHOU,§ CHIH-KUANG PENG,¶ YEU-CHUEN HUANG¶ and KUANG-CHAO FAN§

(*Received* 24 *May* 1996; *in final form* 21 *August* 1996)

Abstract—A precision multi-degree-of-freedom measuring (MDFM) system based on CCD has been developed and implemented for the simultaneous measurement of straightness, pitch, yaw and roll errors of the moving axis of CMM. The Fourier phase shift algorithm (FPS) in conjunction with two-dimensional CCD replaces the quadrant photo-diode used in position sensing detector (PSD)-based MDFM which was proposed by Ni *et al.* (*ASME J. Engng Ind.* **114**, 362, 1992 [1]). The submicron and subarcsec accuracy of the CCD-based MDFM system was achieved experimentally. In comparison with the PSD-based MDFM, the proposed CCD-based MDFM shows the advantages of a longer working distance, better background noise resistance and a simpler configuration. © 1997 Elsevier Science Ltd. All rights reserved.

1. INTRODUCTION

The adoption of a multi-degree-of-freedom measuring system (MDFM) in order to correct the geometrical error of coordinate measuring machine (CMM) is an extremely important area of research. This will improve the measurement accuracy of CMM in the increasing demand for a higher quality product manufacturing system [1–4]. A laser-based system which contains an autocollimator, beam expander and position sensitive detectors (PSD) which senses the location of the laser-beam spot and then calculates 5 d.f. geometrical errors was proposed by in Refs [1, 2]. The laser beam was reflected by the moving retroreflectors which are attached to the moving head during the measurement. The autocollimator was introduced in this MDFM in order to increase the angular resolution of the system. The beam expander was used so that the beam divergent angle can be reduced. Hence, the drift of the position of the beam spot caused by thermal agitation can also be reduced [1, 2].

The conventional methods which have been commonly used are based on the laser heterodyne interferometer such as HP5529 [4] and LDDM III [5]. Significant improvement was successfully achieved by enhancing the multifunction capability of the PSD-based MDFM in the areas of geometrical error investigation and simplified implementation [1, 2]. However, the performance of the PSD was limited by a higher detection noise and the spatial nonlinearity of the detector [6]. By introducing actively designed electronics, the detection noise can be improved. However, the poorer spatial response of PSD limits the useful performance of the detection to a small detective area; moreover, PSD has to be used with a nulling detection technique [1, 2, 6].

A two-dimensional CCD is then recommended to replace PSD in order to meet the requirement of a wider measuring range of the CMM. However, the array structure of the detector (of which the pixel size is about 13 μm) presents a low resolution of the position sensing ability. This discourages the idea of using CCD directly to replace PSD in the MFDM system, although CCD presents the advantages of lower noise, faster response

†School of Medical Technology, National Yang Ming University, Shi-Pai, Taipei, 112 Taiwan, Republic of China.

‡Author to whom correspondence should be addressed.

§Department of Mechanical Engineering, National Taiwan University, Taipei, Taiwan, Republic of China.

¶Department of Mechanical Engineering, Chuan Yuan Christian University, Chung Li, 320 Taiwan, Republic of China.