國立臺北科技大學

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碩士學位論文

線性移動台之體積誤差建模與量測

Volumetric Error Modeling and Measurement of Linear Stages

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中華民國 一百一十二 年 七 月

摘要

任一運動軸由於元件製造與組裝誤差，都存在六種自由度的幾何誤差。傳統對精密機器的幾何誤差測量方法都是逐項一一量測，不僅費時費力，價格也昂貴。本論文自行開發五自由度測量系統，結合了四自由度幾何誤差測量系統與 LDDI 雷射都卜勒位移器，並藉由精心設計過的光學組件相互搭配，實現同時對測量目標的五個自由度幾何誤差進行量測，包含了定位誤差、水平與垂直兩個方向的直線度誤差以及偏擺和俯仰兩個角度誤差，且只使用穩頻氦氖雷射管作為單光束雷射源。

本五自由度誤差量測系統具有結構簡單容易安裝、成本低以及高精度等優點，也因使用 60 MHz 的調頻光，具有高速度的特性，且可以進行長距離的實時測量，其直線度誤差測量精度為±1 μm、角度誤差測量精度為±1 arc-sec，定位誤差測量精度為 2 ppm。而在光軸與移動軸的校準上，透過可調式的折射鏡可快速地進行雷射光軸的對齊校準。

本論文並基於阿貝原則與布萊恩原則推導體積誤差公式，用五自由度誤差量測系統對 AOI 機台進行測量，再透過公式計算可得知機台的定位誤差。

關鍵詞：五自由度測量系統、阿貝原則、布萊恩原則、體積誤差

ABSTRACT

This article introduces a self-developed five-degree-of-freedom measurement system for geometric errors in precision machinery components. Traditional methods of measuring geometric errors in precision machinery involve time-consuming and expensive individual measurements of each error component. This article introduces a system that combines a four-degree-of-freedom geometric error measurement system with an LDDI (Laser Doppler Differential Instrument) laser displacement sensor. Through carefully designed optical components, this system can simultaneously measure five degrees of freedom of geometric errors in the measurement target. These include positioning errors, linear straightness errors in horizontal and vertical directions, as well as pitch and yaw angle errors. The system uses a stabilized frequency helium-neon laser as a single-beam laser source.

The five-degree-of-freedom error measurement system offers advantages such as simple structure, easy installation, low cost, and high precision. It operates at a high speed due to its use of a 60 MHz modulated light source and can perform real-time measurements over long distances. The precision of linear straightness error measurement is ±1 μm, angle error measurement is ±1 arc-sec, and positioning error measurement accuracy is 2 ppm. For alignment calibration between optical axis and moving axis, an adjustable reflecting mirror is used to quickly align the laser beam.

By deriving volume error formulas based on Abbe's and Brien's principles, the system measures an Automated Optical Inspection (AOI) machine and calculates its positioning error using the derived formulas.

Keywords: 5 DOF measuring system, Abbé principle, Bryan principle, Volumetric error