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大口径光学元件检测平台综合误差
数学建模及试验研究

**Comprehensive Error Model and Experimental Research of
Large Aperture Optics Measurement Platform**

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摘要

大口径高精度光学元件,特别是非球面光学元件,已经广泛应用于航空航天、天文及惯性约束聚变(ICF)激光装置等国家重大工程中,特殊的工作环境对光学元件的面形精度和表面质量均提出了很高的要求。在制造过程中,为了达到各项技术参数的要求,非球面光学元件必须经过反复检测,并将检测得到的面形精度信息反馈到加工系统中,以指导下一步加工工序的修正和补偿。为了使大口径光学元件检测平台的测量信息能够准确地指导加工,对大口径光学元件检测平台的精度提出了更高的要求。

本文以所在课题组自行研发设计的“大口径光学元件检测平台”为研究对象,围绕检测平台综合误差分析等关键问题,采取理论与试验相结合的方式进行研究。主要研究内容如下:

对大口径光学元件检测平台的误差源及其特性进行分析,根据检测平台的结构特征及各直线轴间的运动关系,综合考虑检测平台直线轴各项误差的耦合关系,提出一种检测平台综合误差建模方法。借助激光干涉仪、激光位移传感器对大口径光学元件检测平台的定位误差、直线度误差、俯仰偏摆角误差进行测量,借助球杆仪测得检测平台各直线轴的轴间垂直度误差,并对测得的数据进行拟合,分析其变化规律。基于测得的误差并结合检测平台的综合误差模型可计算的综合误差在 x 、 y 、 z 三个方向的误差分量。球杆仪测量同时对检测平台的二维平面联动误差进行综合测量,对球杆仪平面联动误差结果进行误差溯源分析,分析圆偏差的影响因素及各因素所占比例,合理有效评价检测平台的测量精度。

同时为了验证本文中所提的检测平台综合误差数学建模方法的正确性,利用检测平台对泰勒霍普森 Form Talysurf PGI 1240 轮廓仪的校准半球进行空间曲面的测量。获取检测平台 z 方向的误差分量,分析相应位置的误差分量,并与检测平台误差建模的计算值进行对比,验证了本文所提的检测平台综合误差计算模型的正确性与有效性。

综上,本文建立的检测平台综合误差模型为大口径光学元件检测平台的误差

补偿提供了理论指导，能有效提高检测平台的测量精度，使检测结果能够更准确地指导补偿加工，具有较好的学术价值和应用意义。

关键词：大口径光学元件；检测平台；几何误差；综合误差

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Abstract

Large aperture high accuracy optics, especially the aspheric optics have been widely used in many national important engineering, such as aeronautics, telescope and the inertial confinement fusion(ICF) laser driver, etc. Because of the special working environment of optics, the requirement for optical precision and optics surfaces quality is becoming higher.

In order to meet the requirement of technical parameters, the aspheric optics must be repeated measured in the manufacturing process, the measurements information of optical precision and optics surfaces quality are fed back to the processing system to guide the correction and compensation of next processing step. In order to ensure the correctness of the measurement information of large-aperture optics measurement platform can accurately guide the processing of optics, the accuracy of large aperture optical element detection platform have put forward higher requirements.

The large-aperture optics measurement platform of research group was researched by the combination of theoretical and experimental methods in this paper, and the analysis and compensation of measurement platform comprehensive error were the main contents. The main contents are as follows:

The error source and characteristics of the measurement platform are analyzed, and a method modeling its comprehensive error is proposed based on the relationship between the structure characters and axes motions together with considering the couple relationship of all errors of all axes. Positioning error, straightness error, rotation error and perpendicularity error are measured using the laser interferometer and laser displacement sensor, perpendicularity errors between each linear axis are tested through using double ball bar. Based on the measured error, error components in x , y , z directions are calculated combining the comprehensive error model. When using double ball bar measure the measurement platform, and two-dimensional plane

linkage errors are also measured at the meantime. Impact factors of the circle deviation are analyzed depending on the linkage error results. And the weightiness of these factors is also analyzed to help evaluate the measurement accuracy of this platform effectively.

At the meantime, the measurement experiment on the calibration hemisphere part of Form Talysurf PGI 1240 is conducted to verify the accuracy of the mathematical error model of this testing platform. Error components in z direction is extracted and used to analyze error components of the corresponding positions. Comparison between the measurement results and the calculation results based on the error model proves that the error model proposed in this paper can be used to calculate the comprehensive error of the measurement platform accurately and effectively.

In summary, the comprehensive error model of measurement platform was used in the error compensation of measurement platform, which improve the measurement accuracy of measurement platform, and make the measurements data more accurately guide the compensation processing, have a better academic value and application significance.

Keywords: Large apertureoptics; Measurement platform; Geometric error; Comprehensive error

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