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厦门大学

硕　士　学　位　论　文

光学元件精密磨削加工的表面检测及评价

Measurement and Evaluation of Optical Surface after Precision Grinding

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摘　要

随着光学技术的发展，各种精密光学元件被广泛地应用于工农业生产，国防军事建设，航空航天科技等。为保证元件的加工精度，检测技术已成为先进光学元件制造的关键。合理的检测方法对评价元件表面特性以及指导元件的精密加工有着很大的帮助。

本文根据精密磨削加工的要求，从宏观角度对光学元件的表面形状进行检测；从微观角度对元件的表面粗糙度、微形貌等表面质量进行检测；以及对元件的亚表面损伤进行检测，从而为加工提供指导思想，实现高精度、高效率、低缺陷的磨削加工。本文具体研究内容如下：

1. 设计了一套光学元件面形精度的在位检测系统，包括硬件系统的搭建和软件系统的开发，并对检测轨迹进行了规划，分析了不同检测路径的优缺点及适用范围。完成了光学元件面形检测的数据处理方案，提出了加权均值滤波算法对数据进行预处理，并对测量误差进行了补偿，实现了面形的拟合算法。最后，通过测量实验和误差补偿实验证实了此检测系统的有效性和精确性。

2. 采用多种方法检测元件磨削加工后的表面质量，分析了不同加工参数对表面质量的影响。检测实验表明采用平行磨削方式加工、提高砂轮转速、降低工件进给速度、减小磨削深度、减少砂轮面形误差，可以提高元件表面质量。

3. 搭建了一套光学元件亚表面损伤的检测装置，测定了元件在各种不同加工参数下产生的亚表面裂纹的深度，并对不同深度的亚表面形貌及分布进行了分析。通过实验证实了所设计的改进型磁流变抛光法是精确有效的。同时，研究还表明：对亚表面裂纹深度影响最大的是砂轮磨料的粒度，粒度越大裂纹越深。其余参数影响较小，但减小磨削深度、降低进给速度、提高砂轮转速也有利于减小亚表面裂纹深度。

以上研究，均为精密磨削及后续的抛光加工提供了指导。

关键词：面形检测；数据处理；表面质量；亚表面损伤

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Abstract

With the development of optical design and manufacturing technology, more and more optical components have been widely used in industrial and agricultural production, national defense, space navigation and so on. Because of the requirement of the accuracy, the measuring technology has become a key point of the manufacture of optical components. The reasonable measuring method is paling an important role in evaluating the surface quality of lens and guiding the precision machining.

According to the requirement of precision grinding, this research measured the surface shape of the optical components through macroscopic perspective, measured the surface quality of the optical components through microscopic perspective, and measured the subsurface damage of the optical components with advanced instrument. All of these provide direction for the precision machining, which helps to improve the grinding technology with high accuracy, high efficiency and low damage. The main work can be described as follows:

1. The paper presents an on-machine measuring system for the shape accuracy of the optical surface, including the construction of the hardware system and the design of the software system. The measuring paths for different kinds of optical surface have been planed. Through large amounts of experiments, the paths have been compared and estimated from different aspects including measuring efficiency, application situations and etc.. Thereafter, a data processing method has been put forward, which included the algorithm of Two-dimensional weighted average filtering, error compensation and the curve fitting based on Gauss-Newton least-square method. At last, the validity and accuracy of this measuring system have been proved by the measuring experiment and compensation experiment.

2. The paper introduces several ways to measure the surface quality of the optical components after grinding, and analyzes the surface quality influenced by different machining parameters. The measuring experiment indicates that using parallel

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grinding, increasing the speed of grinding wheel, decreasing the feed speed, decreasing grinding depth, and decreasing shape error of grinding wheel can improve the surface quality of optical components.

3. Based on the Magnetorheological Finishing technology, this paper puts forward a measuring system for subsurface damage. It has measured the depth of subsurface damage under different grinding parameters, and analyzed the distribution of the subsurface damage in different depth. At last, the experiment has proved that the measuring system was accurate. Moreover, the research indicates that the granularity of the grinding wheel has a great influence on subsurface damage, and other machining parameters have less influence. Deceasing the size of the abrasive particle, deceasing the grinding depth, decreasing the feed speed and increasing the speed of grinding wheel can reduce the subsurface damage.

The research above has provided direction for the precision grinding and the subsequent polishing.

Keywords: Shape measurement; Data processing; Surface quality; Subsurface damage

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