分类号 _____ 密级_____

UDC _____

学 位 论 文

基于数字锁相放大器的近红外水分测量研究

作 者 姓 名：李宇坤

指 导 教 师：李新光 教授

东北大学信息科学与工程学院

申请学位级别： 硕士 学 科 类 别：工学

学科专业名称： 检测技术与自动化装置

论文提交日期： 2016 年 12 月 论 文 答辩 日 期：2016 年 12 月

学位授予日期： 2017 年 1 月 答辩委员会主席：谢植 教授

评 阅 人： 王玉涛 教授 吴新杰 教授

东 北 大 学

2016 年 12 月

A Thesis in Measuring Technology and Automatic Instruments

Research on Near-infrared Moisture Detection Based on Digital Lock-in Amplifier

By Li Yukun

Supervisor: Professor Li Xinguang

Northeastern University

December 2016

独创性声明

本人声明，所呈交的学位论文是在导师的指导下完成的。论文中取得的研究成果除加以标注和致谢的地方外，不包含其他人已经发表或撰写过的研究成果，也不包括本人为获得其他学位而使用过的材料。与我一同工作的同志对本研究所做的任何贡献均已在论文中作了明确的说明并表示谢意。

学位论文作者签名：

日　　期：

学位论文版权使用授权书

本学位论文作者和指导教师完全了解东北大学有关保留、使用学位论文的规定：即学校有权保留并向国家有关部门或机构送交论文的复印件和磁盘，允许论文被查阅和借阅。本人同意东北大学可以将学位论文的全部或部分内容编入有关数据库进行检索、交流。

作者和导师同意网上交流的时间为作者获得学位后：

半年 □　　一年 □　　一年半 □　　两年 □

学位论文作者签名：　　导师签名：

签字日期：　　签字日期：

摘 要

物质含水量的精确测量对很多工业领域中的过程控制具有重要意义。在众多水分检测方法中，近红外水分检测凭借连续、在线、非接触测量、响应速度快等优点，在很多领域得到了广泛的应用。在烧结生产工艺中，烧结混合料水分是其中一个重要的参数。由于烧结过程中水分检测的干扰因素较多，烧结混合料水分含量的在线检测十分困难。目前，应用较为广泛的烧结混合料水分在线检测的仪器主要是基于近红外吸收光谱的近红外水分仪。这种水分仪通过切光盘对大功率卤素灯光源进行调制，具有功耗大、可动部件多、调制频率受机械转速限制等不足，并对仪器的测量精度、稳定性和使用寿命产生影响。

针对传统的近红外水分仪的不足之处，本文采用一种新型近红外水分检测方案，即用近红外 LED 光源代替传统光源，电调制光信号取代机械调制。然而，由于 LED 光源发光功率低，光电探测器接收到的信号非常微弱，存在难以准确检测的问题。本文在充分了解前人研究工作的基础上，提出采用数字锁相放大技术对光电探测器接收到的信号进行处理。数字锁相放大器不仅极大简化了电路设计，而且有效提高了信噪改善比。本文的研究内容包括以下几个方面：首先，研究水分检测方法和微弱信号检测相关理论，在对数字锁相放大技术进行设计仿真的基础上，设计了近红外水分检测系统的整体方案。其次，分析研究了新型近红外水分检测方案的光学系统并对其进行校准，使光电探测器能够接受到更多的光信号。然后，对前置放大电路、滤波电路等模拟信号处理电路进行了优化，设计了频率可调、电流稳定的光源信号驱动电路和基于 DSP 处理器的信号检测电路。在搭建了近红外水分测量系统硬件平台的同时，编写了基于 DSP 处理器的数字信号处理程序以及串口触摸屏人机交互程序。最后，利用本文研制的近红外水分测量系统进行了一系列验证实验。

在实验室条件下，本文采用干燥法对水分测量系统进行标定。然后对含水量为 3%～8% 的烧结混合料进行了水分测量实验。实验表明，仪器的测量距离为 0～150mm 时，仪器的最大绝对测量误差为 0.32% 水分含量，重复性相对标准偏差最大为 1.91%。

关键词： 数字锁相放大器；近红外；水分检测；LED光源

Abstract

Accurate measurement of material moisture content is important for process control in many industrial fields. In many water detection methods, near-infrared moisture detection by virtue of continuous online, non-contact measurement, fast response and other advantages, has been widely used in many areas. In the sintering production process, sintering mixture moisture is one of the important parameters. On-line measurement of moisture content of sinter mixture is very difficult due to the interference of water content in the sintering process. At present, the application of a wide range of sintering mixture moisture content on-line detection equipment is mainly based on near-infrared absorption spectrum of near-infrared moisture meter. The moisture meter modulate high-power halogen light source by cutting disc, with power consumption, Components, modulation frequency by the mechanical speed limits and other deficiencies, affecting the instrument's measurement accuracy, stability and service life.

Aiming at the shortcomings of the traditional near-infrared moisture meter, a new near-infrared moisture detection scheme is adopted in our research, that is, infrared LED light source instead of the traditional light source, electrical modulation optical signal instead of mechanical modulation. However, due to the low luminous power of the LED light source, the signal received by the Photoelectric detector is weak and there is a problem that it is difficult to detect accurately. Otherwise, based on full understanding of previous research work, the use of digital phase-locked amplifier technology to detect the Photoelectric detector received signal processing. Digital lock-in amplifier not only greatly simplifies the circuit design, but also effectively improve the signal to noise ratio. The research contents are as follows: Firstly, the theory of moisture detection and weak signal detection is studied. Based on the design and simulation of the digital lock-in amplification technology, the overall scheme of near-infrared moisture detection system is designed. Secondly, the optical system of the new near-infrared moisture detection system is analyzed and calibrated, so that the Photoelectric detector can receive more optical signals. Then, the analog signal processing circuit, such as preamplifier circuit and filter circuit, is optimized, and a signal driver circuit based on adjustable frequency and stable current and DSP-based signal detection circuit are designed. At the same time, the digital signal processing program based on DSP processor and the human-computer interaction program of serial-port touch-screen were written at the same time of building the near-infrared moisture measurement system hardware platform. Finally, a series of validation experiments

were carried out using the near-infrared moisture measurement system.

In the laboratory conditions, we use the drying method to calibrate the moisture measurement system. Then the moisture content of 3% to 8% of the sintering mixture for moisture measurement experiments. The experimental results show that the maximum absolute measurement error is 0.32% water content and the relative standard deviation is 1.91% when the measuring distance is 0∼150mm.

Key words: digital lock-in amplifier; near-infrared; moisture detection; LED light source