Research on MCGS biochar measurement and control system

Kai Zhu¹, Zixin Wang² and Zhixia Zhang³,⁴

¹School of Information and Electrical Engineering, Shenyang Agricultural University, Liaoning Province, China
²Jinzhou Experimental Middle School, Liaoning Province, China
³Tianjin Tianda Qushi Electric Power High Technology Co. Ltd, Tianjin City, China
⁴E-mail: 1327743089@qq.com

Abstract. Biochar is a kind of carbon-rich, highly aromatic and highly stable solid product produced by high temperature thermal cracking of biomass feedstock under complete anaerobic or partial anoxic conditions. It is pyrolyzed at 300~500 °C. Biochar can be prepared from rice straw. Based on the actual needs, this paper proposes a biochar carbonization temperature control technology based on the Internet of Things technology for straw carbonization. The SCADA data monitoring and control system consists of a Modbus-based, Web Access web database and a remote data transmission and local control network. With ADAM-4060 and intermediate relay as the control core, thermocouple, ADAM-4018 data acquisition module, MCGS industrial grade programmable human-machine interface and no Web Access webpage database, remote monitoring of carbonization furnace temperature parameters, and according to the alarm status and warning line alert the manager to control the operation of the blower. The purpose of this paper is to find the optimum carbonization temperature for rice and to control the internal temperature of the carbonization furnace near the optimum temperature.

1. Introduction

As a large agricultural country, China has a large area of rice planting and a large output, but the utilization efficiency of rice straw in China is not high. According to the survey statistics, China's straw volume in 2007-2009 was 735 million tons, of which about 21% was directly incinerated [1, 2]. This not only wastes resources, but also pollutes the atmospheric environment, which directly leads to rapid deterioration of the atmosphere in a short period of time [3]. With the advent of biochar technology, rice straw is pyrolyzed to prepare biochar, and biochar fertilizer is returned to the soil to achieve carbon cycle.

In recent years, some scholars have found that the content and effect of biochar prepared at different temperatures are significantly different. Different biochar prepared at different temperatures and their different additions can also cause differences in soil environmental effects, which make it effective. It is necessary to control the temperature at which rice biochar is prepared.

Yang CY, Chen WF and others believe that the speed of heating, the temperature of the final temperature of carbonization and the length of carbonization will affect the quality of biochar and its internal components. Because the quality of biochar affects its positive effects on soil and crops, how to produce high-quality biochar is also the focus of current research [4, 5].

Lehmann, a professor at Cornell University in the United States, wrote in the journal Nature that plants absorb CO₂ through photosynthesis, synthesize and convert into carbohydrates and store them.
in plants. They can be pyrolyzed under anaerobic or anoxic conditions. The biochar obtained after carbonization can be re-applied and stored in the soil to achieve carbon fixation [6]. Pia et al. believe that biochar is to improve soil fertility and crop yield. Biochar can be used as a tool to mitigate climate change and can capture important role in soil carbon [7].

Through the analysis of the current situation of treatment of agricultural and forestry waste and the research and analysis of biochar technology at home and abroad, it is found that the use of rice straw and other agricultural and forestry wastes to prepare biochar has become an effective method to solve agricultural environmental problems. This project completed the preparation of rice biochar temperature measurement and control system through the research on the preparation of rice biochar at home and abroad and the measurement and control methods applied in the field of industrial production. The temperature measurement system collects the carbonization temperature in the carbonization furnace by connecting the thermocouple to the ADAM-4018 data acquisition module, transmits it to the MCGS touch screen through the 485 bus, and through the network cable to the web access for remote display. The MCGS touch screen is connected with the ADAM-4060 relay to process the collected data to realize the stop and operation of the blower, thereby making the temperature inside the carbonization furnace within the setting range. The purpose of this paper is to find the optimum carbonization temperature for rice and to control the internal temperature of the carbonization furnace near the optimum temperature.

2. System overview and system architecture

2.1. System overview

The biochar remote monitoring system consists of a web access-based system that enables complete monitoring of the carbonization furnace.

System goal: Real-time measurement and acquisition of carbonization temperature data in the carbonization furnace; centralized management of all measurement nodes to realize remote transmission, storage and processing of measurement data.

2.2. System architecture

The three-tier architecture is used to decompose the system into three levels: the sensing layer, the network layer, and the application layer. The three-tier architecture of the system is shown in Figure 1.

![Figure 1. System Level.](image)

2.2.1. Perception layer. This layer is directly in contact with the carbonization furnace. The data collected by the thermocouple is collected by the ADAM-4018 data acquisition module. The temperature inside the carbonization furnace is monitored in real time, and the instructions issued by the node are used to judge whether the data meets the control requirements. When the carbonization
temperature exceeds the set upper and lower limits, the relay activates and turns off the blower, thereby adjusting the temperature parameter in the carbonization furnace, so that the temperature value is stabilized within a reasonable range.

At the sensing level, various sensors monitor the various elements in the carbonization furnace, which is the origin of all the data in the system. The scalability, maintainability and flexibility of the system depend to a large extent on the data provided by this layer. The ADAM-4018 data acquisition module works with the MCGS industrial grade touch screen to improve data accuracy and design stability.

2.2.2. Network layer. This is the middle link of the system. It indirectly transmits the data acquired by the sensor sensing layer to the application layer through different communication means. Different transmission methods can be used depending on the transmission distance.

Currently commonly used short-range communication methods include wired transmission, high-frequency wireless, wireless LAN and wired LAN. Long-distance communication can be accessed by internet, GPRS or SMS. The system adopts the long-distance communication method intervening in the Internet. By establishing a Web Access database, the data on the touch screen is uploaded to the Web Access database via the switch. Users access the database through PC client and mobile client to view and download historical data. The Web Access system architecture is shown in Figure 2.

![Figure 2. Web Access System Architecture.](image)

2.2.3. Application layer. This layer processes the collected and fed back data and provides a level of management control. Its function is mainly reflected in the background server.

The raw data collected by the thermocouple is transmitted remotely through the network layer to the backend server and stored in the Web Access database. The application layer is used to complete the decomposition the data, so that the manager can conveniently and quickly view the parameters in the carbonization furnace, and can download the historical data, and observe and compare the image trend of the data to summarize the suitable growth of the carbonization temperature. The experience gained is used to improve the controller, set the relay action warning line, automatically control the relay to open and close, achieving fine control of the carbonization temperature of rice straw burning.

3. System components

3.1. Sensor node
The sensing node realizes the real-time monitoring of the carbonization temperature data, collects the sample data at equal time intervals, obtains the temperature data of each temperature measuring point in the carbonization furnace, and then performs data processing through the A/D conversion module of
ADAM-4018, and integrates into 32 floating-point data. The floating-point data is transferred to the touch screen display via the 485 bus.

3.2. Gateway node
The gateway node is composed of a Modbus gateway and a switch, and the touch screen is connected to the router through the network cable to upload data to the webpage Web Access database.

3.3. Management node
The management node, the Web Access database backend server. A single management node can manage multiple controllers. Mainly complete the storage and processing of data.

Field data transmission using Modbus gateway, MCGS, TPC in a LAN TCP host to read data can directly read the corresponding address in the "address correspondence table" Modbus address. Long-distance communication uses serial communication technology + host computer + Web Access database technology.

4. System design and implementation

4.1. Hardware

4.1.1. Selection of Sensors. The sensing layer consists of thermocouples. By connecting with MCGS, using serial 485 bus type transmission mode and Modbus protocol, the data collected by the sensor is transmitted to the ADAM-4018 data acquisition module and output digital quantity, and then the digital quantity is in Wop through RS-232 communication mode. Displayed on the touch screen.

In order to obtain the data of the temperature inside the carbonization furnace, two types of thermocouples K type and PT-100 type are selected. The K-type thermocouple can directly measure the surface temperature of liquid vapor and gaseous media and solids in various production ranges from 0°C to 1300°C. The PT-100 temperature sensor is a smart sensor that integrates temperature and humidity collection. The temperature can be collected from -200°C to +850°C. K and PT-100 thermocouple comparison chart is shown in Figure 3.

4.1.2. Data acquisition module. In order to obtain the data sensed by the thermocouple, select the 8-channel thermocouple input module ADAM-4018 designed for the thermocouple. The ADAM-4018 is a 16-bit, 8-channel analog input module with programmable input range on all channels. This module is an extremely economical solution for industrial measurement and monitoring applications. The ADAM-4018 provides signal conditions, A/D conversion, range and RS-485 digital communication capabilities. The ADAM-4018 uses a 16-bit microprocessor-controlled sigma-delta converter to
convert the sensor voltage or current into digital data. Then, the digital data is converted into engineering units. When prompted by the host, the module will send data to the host via the standard RS-485 interface.

4.1.3. Relay control module. The core of the controller is the ADAM-4060 relay output module. The ADAM relay output module is an ideal replacement for SSR modules and is more economical. The ADAM relay output module provides four relay channels, two of which are 2-way A-type and 2-way C-type. This module is ideal for switching control or low voltage switch control applications. It is equipped with the corresponding peripheral interface circuit, just set the action value according to the temperature requirements of the carbonization furnace, write the control code in Web-OP Designer, and the relay will act when the value is satisfied. The system is equipped with a relay interface board. In practical applications, it is only necessary to connect the blower for controlling the carbonization temperature to the module.

4.1.4. Web access web page database design. Web Access provides business intelligence analytics through HTML5-based dashboards. By analyzing charts, this is called a widget, and users can create custom information pages. Users can view data in different browsers, like Explorer, Chrome and Firefox for a seamless viewing experience with computers and smartphones.

The Excel report provided by Web Access implements the requirements of the custom report function. Users can build custom Excel templates to generate daily/weekly/monthly or on-demand reports automatically in Microsoft EXCEL format. In addition, Web Access can automatically configure Web Access Express, SCADA redundancy, support multiple operating systems, real-time database, Google Maps and GPS location tracking trend analysis, network function audio and video, multi-touch structure.

All the above devices that need the network are only provided by 4G to Wi-Fi & network cable router, only one mobile card can be used, so that the carbonization plant does not need to be equipped with another network cable. Network Video is shown in Figure 4 and 4G to Wi-Fi Cable Router is shown in Figure 5.

![Figure 4. Web Camera.](image1)

![Figure 5. 4G to Wi-Fi Cable Router.](image2)

4.2. Software

4.2.1. Fluent model. Biochar incineration involves fluid and heat transfer, so fluent is used to build a carbonization furnace model, using rich physical model with fluent, advanced numerical methods and powerful pre- and post-processing functions, flexible unstructured grids and solution-based adaptive grids. Technology and mature physical models can simulate the flow of heat transfer and phase change, chemical reactions and combustion. Based on its characteristics, the input parameters simulate the temperature distribution around the carbonization furnace, determine the optimal temperature measurement point, and lay the foundation for the next step thermocouple arrangement. The three-dimensional carbonization furnace simulation diagram is shown in Figure 6.
4.2.2. **Touch screen configuration development software.** The development software selects Web-OP Designer development software, which is a powerful and intuitive software that can build a complete solution for Web-OP series human-machine interface products. Multi-language version of menus, alarms, data logging and slave logging for user programming Great convenience. The Web-OP series man-machine interface benefits from the good design of the Web-OP Designer configuration software during operation, ensuring the stability of the system operation. The overall design block diagram of the touch screen interface development software is displayed in Figure 7.

![Figure 7. Touch Screen Software Interface Design.](image)

4.2.3. **Touch screen software design interface.** The computer simulation run screen is exhibited in Figures 8 to 13.

![Figure 8. Boot Interface.](image)
Figure 9. System Homepage.

Figure 10. Real-Time Data.

Figure 11. Historical Data and Historical Trend Display Interface.

Figure 12. Touch Screen Settings.
5. Conclusions
In the design of the IoT biochar temperature monitoring system, it is divided into three parts: hardware design, software design and Web Access database design.

In the hardware design, the best temperature measurement point was simulated according to the fluent carbonization furnace model, and the K-type and PT-100 thermocouple was inserted into the temperature measurement. The touch screen and the relay module are assembled into an electric control box, which is convenient for carrying and summarizing the devices. The connection between the device and the device uses the 485 protocol and the Modbus protocol, and the two protocols ensure the accuracy and stability of data transmission.

The software design mainly uses Web-OP Designer to develop software. In this software, functional modules can be added and output display on the touch screen. The background system adopts Web Access database design, which mainly installs Web Access software on PC, establishes engineering nodes on the webpage, establishes historical trend, establishes real-time trend, data transmission, establishes EXCEL report, records events, and alarms, etc., to achieve the function of data transmission, storage, and metering.

The system adopts a hierarchical construction method to make the carbonization furnace measurement and control system easier to operate and maintain. In the overall design of the system, "MCGS + ADAM-4018 + ADAM-4060" is used to realize node data aggregation and actuator control functions, which can realize streamlined data representation and control relay action.

Acknowledgement
Supported by Project: Improvement and application of precise temperature measurement and control technology for straw charring Project number: 20150316-10.

References
[1] Chen W, Hu XY, Zhang YY, Zhang D and Song JZ 2015 Estimation of carbon sequestration potential of rice straw pyrolyzing to biochar *Environmental Science & Technology* 38(11) 265-270
[2] Wei MG, Wang XY and Xie GH 2012 Field residue of field crops and its temporal distribution among provinces of China *Journal of China Agricultural University* (6) 32-44
[3] Zheng SN, Wang YG, Meng J, Chen WF and Zhang ZZ 2016 Analysis of gaseous carbonized products of straw in Northeast China *Jiangsu Agricultural Science* 44(12) 472-475
[4] Yang YC, Yao JZ, Lu XS, Yang XM and Lin WG 2006 The effect of K~+~ and Ca~(2+)~ on pyrolysis and its mechanism in biomass *Acta Energia Sinica* (05) 496-502
[5] Chen WF, Zhang WM, Meng J and Xu ZJ 2011 Research on biochar application technology *China Engineering Science* 13(02) 83-89
[6] Lehmann J 2007 A handful of carbon *Nature* 447(7141) 143-144
[7] Pia Piroschka, Otte, Jostein, Vik and Jostein 2017 Biochar systems: Developing a socio-technical system framework for biochar production in Norway *Technology in Society* 51