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DEVELOPMENT OF A DISTRIBUTION SYSTEM FOR MEASURING NOZZLE INTEGRATIVE PARAMETER

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ABSTRACT – The experimental system used in this study was equipped with sensors and computer-controlled processing technology. This system was used in the measurement of major performance parameters such as pressure, flux, spray angle, spray distribution character of the nozzle and its integrative performance parameter. It could also achieve precise and synchronous measurements and process multi parameters. Measuring position of a single nozzle was also available for three-dimensional adjustment by nozzle transmission frame. The boom could achieve two-dimensional precision adjustment. Fluid power supply system could ensure the accurate measurement of nozzle flow between 50~15000ml/min. The control system consisted of a PC, a CCD image acquisition system, data acquisition cards, sensors, and single chip microcomputer. The spray angle was measured by image processing technique. Data fusion technology was used to improve the precise measurement of spray angle. Neural network technology was used to improve the precision and speed of the system. The results showed that it is promising for using this system for measuring nozzle integrative parameter.

Keywords: Nozzle, performance test, image processing, and neural network

INTRODUCTION

In plant protection, research on overall nozzle performance aims to improve atomization of nozzle in order to more effectively manage agricultural chemicals and reduce environmental pollution. The effect of atomization is determined by droplet distribution uniformity, drifting and spray coverage. Droplet distribution uniformity refers to the level of droplets being evenly distributed on the target, and is generally expressed with the distribution coefficient of variation. Drifting refers to the tendency of droplets deviation from the target, and is expressed with the number of droplets on a unit of sprayed area. Spray coverage refers to the area on the target sprayed with the droplets, and is expressed with the number of droplets per unit area. A testing system is required for studying overall nozzle performance. The objective of this study was to develop a distribution system which follows the ISO standard and precisely test the overall nozzle performance.

This system would provide a means of quality testing for nozzle manufacturers and related organizations of plant protection machinery research and atomization technology.

SYSTEM PARAMETERS

The distribution system was to measure parameters, such as pressure, total flow, flow distribution, temperature, humidity and spray angle (Table 1) The nozzle was mounted onto a nozzle transmission frame with three-dimension adjustment so that the spray effect of different nozzle positions could be observed. This system could also be used to test single and multiple nozzle cluster performance of flow distribution. Space between nozzles could be easily adjusted. Table 1. System parameters

No.	Name	Model	Scope of work	Note
1	Nozzle working pressure	KYT-10MPa、KYT-1.0MPa	0～5.0MPa	
2	Total flow	MUT550+MC308 DN3 MUT550+MC308 DN6 MF-11511181210 DN15	0.1～20L	
3	Divided flow	SH-A4	0.5L	
4	Spray angle	IXUS-500	150°	
5	Uniform spray distribution	SH-A4	/	Calculated
6	fluid distribution in progress	SH-A4	/	Calculated
7	Pump working pressure	Y-100	0～10MPa	
8	Lab Temperature	DS18B20	-55～125℃	
9	Lab Humidity	MQ-M3	20～95%rh	

SYSTEM COMPOSITION

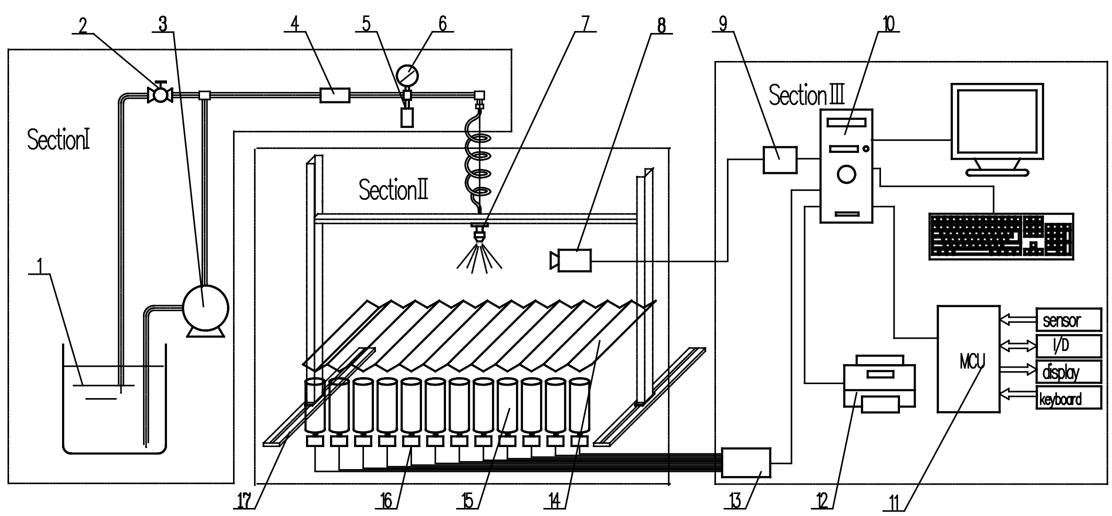
Hydraulic system

The hydraulic system is the most important part of the distribution system (Figure 1). Pump selection and design of pipelines directly influence test accuracy. Two sets of hydraulic pumps were used to provide a large range of pressures and flows. Proper pipeline length was selected to reduce pulsation. Electric valves were used to adjust pressure. Three electromagnetic flow meters, DN3, DN6 and DN15 were used to measure the accurate flow between the 50 ~ 15000 ml/min.

Mechanical system

The mechanical system consisted of the groove and the movable gantry. The groove was a receiver which measured the distribution uniformity of the nozzle by divided flows. Following the structural requirements of ISO 5682-1, the groove in this study was designed to be 3 m long and 1.5 m wide. The distance between two consecutive ridges was 5 cm. Sixty glasses were put at the end of the corresponding grooves to collect the flows. Each glass was connected with a weight senor. A waved plate was designed and used which could be turned to guide the flows into the corresponding glasses or stop the flows. The waved plate worked only when the hydraulic system ran steadily.

The movable gantry was designed so that the two posts could move forward and backward on the rails; the cross girder could move up and down on the posts and the single nozzle boss could move right and left on the girder. All the moveable parts were driven by cylinders. This three-direction movement could help measure the distribution at different positions and replace nozzles easily.



1. tank 2. electric control valve 3. pump 4. flow sensor 5. pressure sensor 6. manometer 7. nozzle

8. camera 9. image capture card 10. host PC 11. MCU 12. printer 13. data acquisition card

14. groove 15. cup 16. r 17. nozzle drive rack

Section I: Hydraulic spray system

Section II: Groove and Nozzle Mechanical system   Section III: Control system

Figure. 1 Diagram of the distribution system

Control system

Hardware

As Figure 2 shows, the control system consisted of a host computer, a CCD image acquisition system, a single chip microcomputer (MCU) and a number of data acquisition cards. The host computer was an ordinary PC. Data acquisition cards were 16-Bit RM 410 capture cards. Each RM 410 card had 14 channels. Five RM 410 cards collected the data provided by the 60 weight sensors. These RM 410 cards were connected by an RS 485 bus and formed a signal acquisition network, and the signal acquisition network was connected by the single chip microcomputer. An RM 4018 card was used to receive the pressure signal from the hydraulic system. A digital cameras and a video camera were used to record spray images. The image data was then transmitted to the computer through the IEEE 1394. The MCU was a 16-bit MSP430F149 with two serial ports; one was connected with the acquisition network and the other connected with the host computer. The MCU could not only complete all the control functions independently, but also work with the host computer. Figure 2 below provides the information about the MCU.

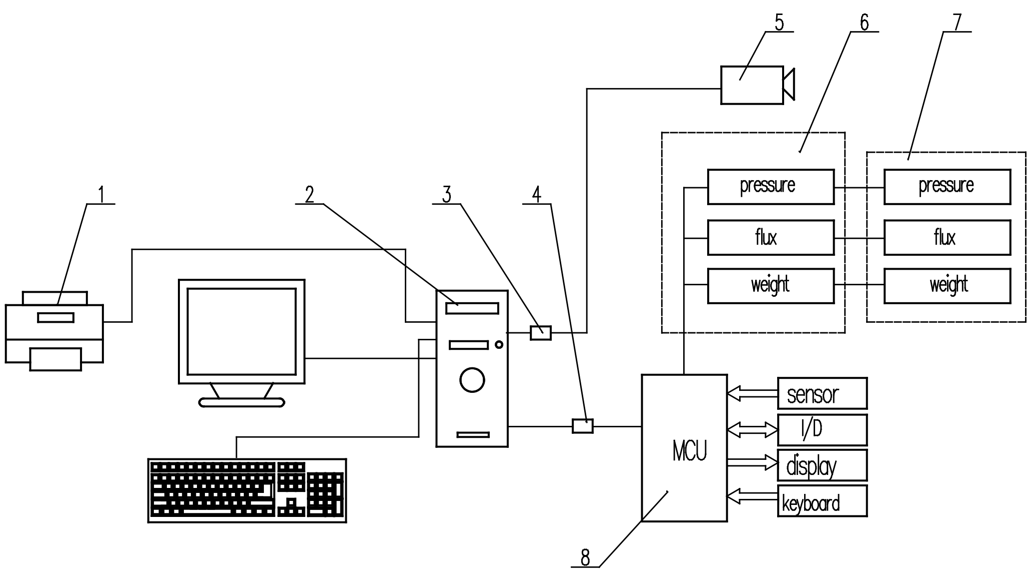
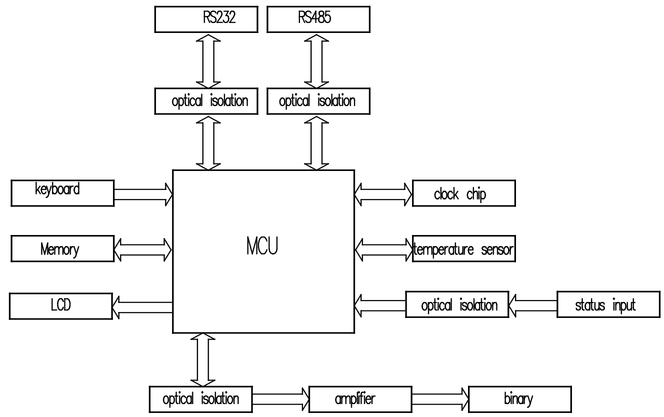


Figure 2. Diagram of control system

1. host com

The hardware system must be stable and reliable, for which a watchdog circuit was



necessary.

Figure 3. The structure of the single chip microcomputer system ***Software***

The software system included a host computer management and control system, an image processing section, a data acquisition and processing section, and an MCU control system.

Management

The management system had the following functions: automatic data collection by the host computer, real-time processing and displaying of spray angle, distribution, flow and other parameters, drawing curves and charts of the processed data, and producing a printed report of testing. This system also had a graphical user interface to operate the whole system through a mouse.

Image processing

The pray angle was measured by image processing. Traditional photo method and calculation method were used. The photo method was to photograph the spray angle and measure it following the ISO5681:1992. The calculation method was to calculate the angle by measuring the spray width and height.

We collected the spray images by the CCD and transmitted the images into the computer on which we enhanced, sharpened and filtered the images, and detected the edges in order to identify the significantly straight parts of the curved edges of the images. The accuracy of straight edge identification determined the accuracy of spray angle measurement. Spray shapes from different nozzles and under different pressures varied greatly and caused great difficulties in determining the straight edge of spray with an evident boundary. The static images were analyzed and a formula was summarized to calculate the angle of spray. However, dynamic spray variation caused errors in calculating the spray angle, and we also analyzed several dynamically photographed images and took the average of the calculations as the value of spray angle which could be more precise.

Data collection and processing

The data to be collected and processed here included temperature, total flow, divided flow and spray angle. The data acquisition cards were used to collect data provided by the pressure sensors, the small-scale weight sensors and the temperature-humidity sensors. These data were entered into the computer to be processed. The small-scale weight sensors used for measuring the distribution of the system were quite reliable. Since they could be cleared, the errors caused by the residual fluid were eliminated.

The data collected by the acquisition cards might still not be accurate enough due to the error-causing factors, e.g. temperature drift, non-linear error and zero drift, etc. Therefore, we employed a neural network calculation to improve the accuracy of the data collection. The neural network is an information processing technique which is based on the structure and function of human brain. It is able to automatically adjust parameters of the network and produce expected output according to the given input by training in self-instructing, self-organizing and self-adapting. The neural network technique used in this study was the BP neural network which is currently the most widely used multi-layer feedforward network and possesses a strong nonlinear mapping and generalization ability. We adopted the method of multilayer sub-approximation to make each section of the data correspond to the weights and bias values of one group of neural networks so as to guarantee the preciseness of network approximation, to enhance the accuracy of data collection and to increase the speed of operation.

The single chip microcomputer

The MCU part of the distribution system performed the following tasks: carrying out the instructions issued by the MCU and the host computer; displaying the working status and the setting condition of the distribution system and transmitting the status data from the distribution system to the host computer; initializing the temperature sensors and correctly reading the temperature values. To make sure that the software was reliable, especially in accident of interference, the MCU part was designed to automatically recover the preceding running state. Before booting, it would perform itself-inspection after initialization.

CONCLUSIONS

Our distribution system went through operation and a large amount of data collection test. The results proved the system to be reliable with all the indices meeting the designed requirements.

The system provided the following testing programs: real-time test for single and multiple-nozzle cluster pressure, flux, spray angle, and distribution properties of single and multiple-nozzle cluster. This system possessed a function of precisely synchronous multi-parameter measurement because it was designed with advanced sensor technology, automatic measurement technology, and computer controlled and processing technology.

The system possessed the following technical properties:

- The specification of the part to test the distribution of the nozzle was in strict accordance with structural requirements of ISO 5682-1 standard.
- Single nozzle testing could be performed by three-dimensional movement of the nozzle on the transmission device, and multiple-nozzle cluster testing by two-dimensional movement of the nozzles on the device.
- Accurate measurement of spray distribution could be achieved by using 60 small-scale weight sensors.
- Real-time display of the parameters of spray angle, pressure, flow, temperature, humidity, and so on could be achieved.
- The connected computer would automatically collect and process measurement data, draw characteristic curves, establish a mathematical model of nozzle performance, and print a report of tables and figures.
- The hardware control was extensible with a design of combined modules, and the software control system was upgradable with a design of configuration software.
- The overall measurement produced by the distribution system was of high accuracy because the data input and output were performed by trained neural networks which established the function between the input and the output and reduced the cumulative measurement errors.

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