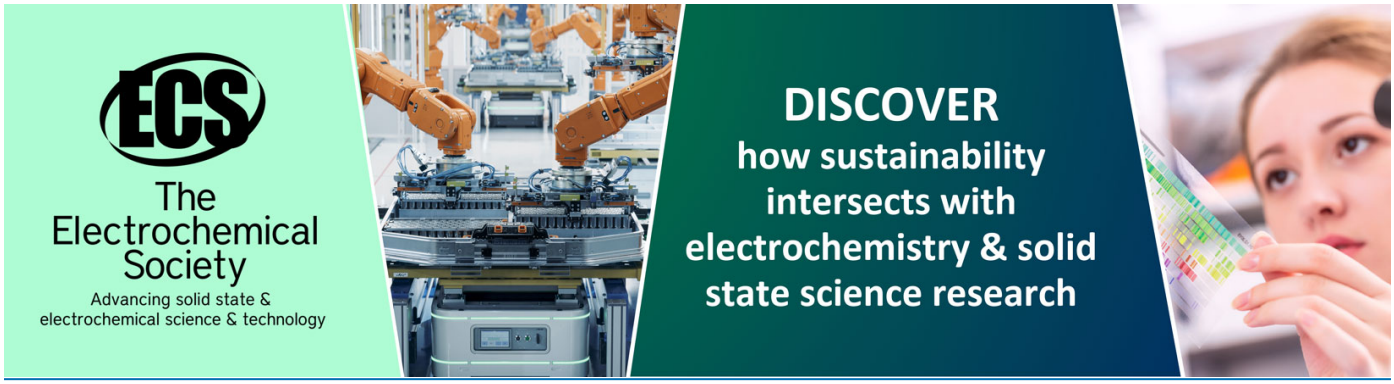
Research of the Spray Curing System of Concrete Based on Fuzzy Control



Research of the Spray Curing System of Concrete Based on Fuzzy Control

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Abstract. In order to improve the efficiency of concrete curing and reduce the generation of cracks, a set of concrete spraying curing device is designed and developed by using computer control technology. The device can monitor the temperature and humidity of concrete in real-time and automatically control the spraying time according to the fuzzy control theory, so as to realize the intelligent curing of concrete. In the application of concrete curing on the side wall of Hanwangling station of Changsha metro line 4, it is verified that the maintenance system has obvious effects of spraying and moisturizing, reducing the generation of cracks and ensuring the construction quality of concrete.

1. Introduction

Concrete pouring and maintenance construction is very important to prevent early cracking and to ensure strength. The inadequate curing, improper control of hydration heat and excessive temperature stress will lead to surface and internal cracks, while the tensile and compressive strength will be reduced. Ultimately, this may affect the normal use of components, shorten the service life of the structure, and cause the huge economic losses. Good maintenance is a necessary condition to ensure good working performance of the concrete structure during the use period and has an important impact on the durability of the concrete [1].

At present, most of the traditional maintenance methods in China adopt manual sprinkler, but the existing maintenance methods have some problems, such as non-standard manual sprinkler, inaccurate control of temperature and humidity, insufficient or excessive water consumption and low maintenance efficiency [2]. In addition, some projects require concrete construction during the winter because of the construction period. At present, these projects mainly use small coal stove heat storage, normal pressure water heating artificial maintenance mode. These projects have low maintenance efficiency and serious pollution problems [3].

In order to solve the above problems, ensure the quality of concrete maintenance and reduce the occurrence of cracks, this paper designs and implements an automatic spray maintenance system based on fuzzy control technology. The system collects and calculates the humidity deviation and its rate of change by real-time data of concrete surface temperature and surface humidity. Then, the spraying water consumption and spraying time are controlled by fuzzy control algorithm, and the surface humidity is accurately controlled. Thus, the smooth release of hydration heat is guided to achieve the purpose of concrete intelligent maintenance.

2. Design and implementation of concrete curing system

2.1. The overall plan of the spray curing system

The automated spray curing system uses a distributed architecture, which can control and complete the automatic spray curing of concrete in many areas at the same time. The system consists of on-site spray maintenance device, remote server and remote-control terminal [4]. The overall block diagram of the system is shown in Figure. 1.

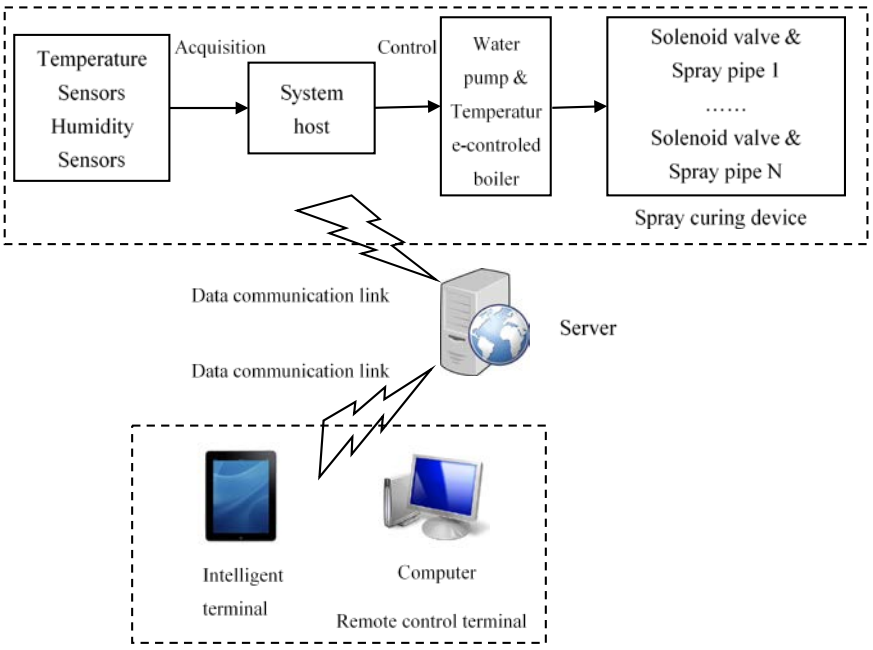

Figure 1. General block diagram of automatic maintenance system.

The on-site spray curing device consists of the spray curing system host, temperature and humidity sensors, water pump, temperature-controlled boiler, solenoid valves and spray pipes. The system host collects temperature and humidity data by installing and embedding temperature and humidity sensors on the concrete surface and inside. According to the fuzzy control strategy, the system host automatically adjusts the spray curing time. If the construction is carried out in winter, the system host is to control the sprinkling temperature by adjusting the temperature of the temperature-controlled boiler, and then control the temperature and humidity of the concrete surface. The surface temperature and humidity can be controlled within a pre-set range, and the heat of hydration can be guided to release smoothly to achieve the purpose of fine maintenance. Meanwhile, data and control parameters in the whole process of maintenance are uploaded and backup to the central server in real time through wireless network. Related managers can view the field data in real time through computers or tablets connected to the Internet, and those with authority can also configure and manage the parameters [4].

2.2. Research on Fuzzy Control Algorithm

There is a coupling relationship between the temperature and humidity of the concrete surface. The change of temperature affects the humidity, and the change of humidity also affects the humidity. In this paper, the main control strategy of concrete surface humidity is adopted [5]. According to the construction time of the side wall maintenance project of Changsha metro line 4 station, considering that the temperature and humidity of the construction site are affected by multiple parameters of the external environment, and the temperature and humidity parameters are coupled to each other, it is impossible to establish a precise mathematical model. Fuzzy control method is adopted to control the humidity of concrete curing surface. The fuzzy controller mainly includes three parts: fuzzification and fuzzy control rules and defuzzification. This paper adopts the form of two-dimensional fuzzy controller with double input and single output. The double input is humidity deviation and humidity

deviation change rate, while the single output is water pump atomizing spray control quantity. Considering the hysteretic nature of the system, the deviation and deviation change rate of concrete humidity in the period of 10 minutes are taken as the system input. In this way, while guaranteeing the real-time control, the interference is largely eliminated. The average humidity around the curing concrete is set as the theoretical domain of the system (85,95), and the humidity value is set as 90%.

Fuzzy reasoning is the core of fuzzy controller, and the basic principle of fuzzy control is to optimize the static and dynamic characteristics of the system output response [6]. When the humidity is too low, and the set value is very different, the spraying quantity should be increased to eliminate the deviation as soon as possible. When the humidity deviation is small to zero, the system is mainly to maintain the stability of the system to prevent overshoot. According to the experience summary, the table of fuzzy control rules is as shown in table 1.

Table 1. Fuzzy rule control table.

U		E						
		NL	NM	NS	ZE	PS	PM	PL
EC	NB	NQ	NQ	NB	NQ	Z	Z	PB
	NS	NQ	NQ	NB	NB	Z	PB	PB
	ZE	NQ	NB	Z	Z	PB	PB	PQ
	PS	NB	NB	Z	NS	NM	NM	PQ
	PB	NB	Z	Z	PQ	PQ	PQ	PQ

In particular, the precise amount of humidity deviation and deviation change rate is fuzzed through the proportion factor Ke and Kec. The fuzzy set U of the output of the fuzzy controller is obtained by querying the fuzzy control table. The precise output U is obtained by the maximum membership degree method. The process of fuzzy control algorithm is shown in Figure 2, including the reading of humidity sampling value, the calculation of humidity deviation e and deviation change rate ec, the limitation of range, the query of control table and the output of fuzzy control quantity. The control effect of the fuzzy controller was simulated by Matlab software and its Simulink toolbox. By comparing the simulation curve with PID (proportional-integral-derivative), the adjustment time is short and the overshoot is not easy to generate.

2.3. Software Design of Spray Curing System

The spray curing system control program is programmed using the VB.net language in the Visual Studio 2015 integrated development environment. First, the system of auto mode gets and loads the corresponding configuration files to initialize the maintenance device. When the device is initialized successfully, the monitoring and control task thread is started, and the data of the sensor is read periodically. According to the fuzzy control Algorithm, the execution condition is satisfied or not and the pump is controlled to open or close. In addition, when the monitoring and control task is started, the polling thread of configuration update is started at the same time to listen whether the maintenance equipment configuration is updated, so as to realize the remote configuration of the device. If the configuration is updated, the system reloads the configuration file and starts monitoring control.

The whole set of server-side programs is developed based on Asp.NET framework, and the server program is deployed to IIS server. The maintenance host communicates with the server via HTTP and requests and returns data in JSON data format. Web data report and management adopts B/S architecture to communicate by HTTP, and data report and management is presented by dynamic page. The database adopts SQLSever2008R2. To avoid performance problems caused by high concurrent data access, the data cache area is added in the server program to reduce data duplication and physical loading, thus improving the reading and writing efficiency. In order to avoid system performance problems caused by high concurrent data access, we added data cache in server program. This reduces data duplication and physical loading, thus improving read-write efficiency.

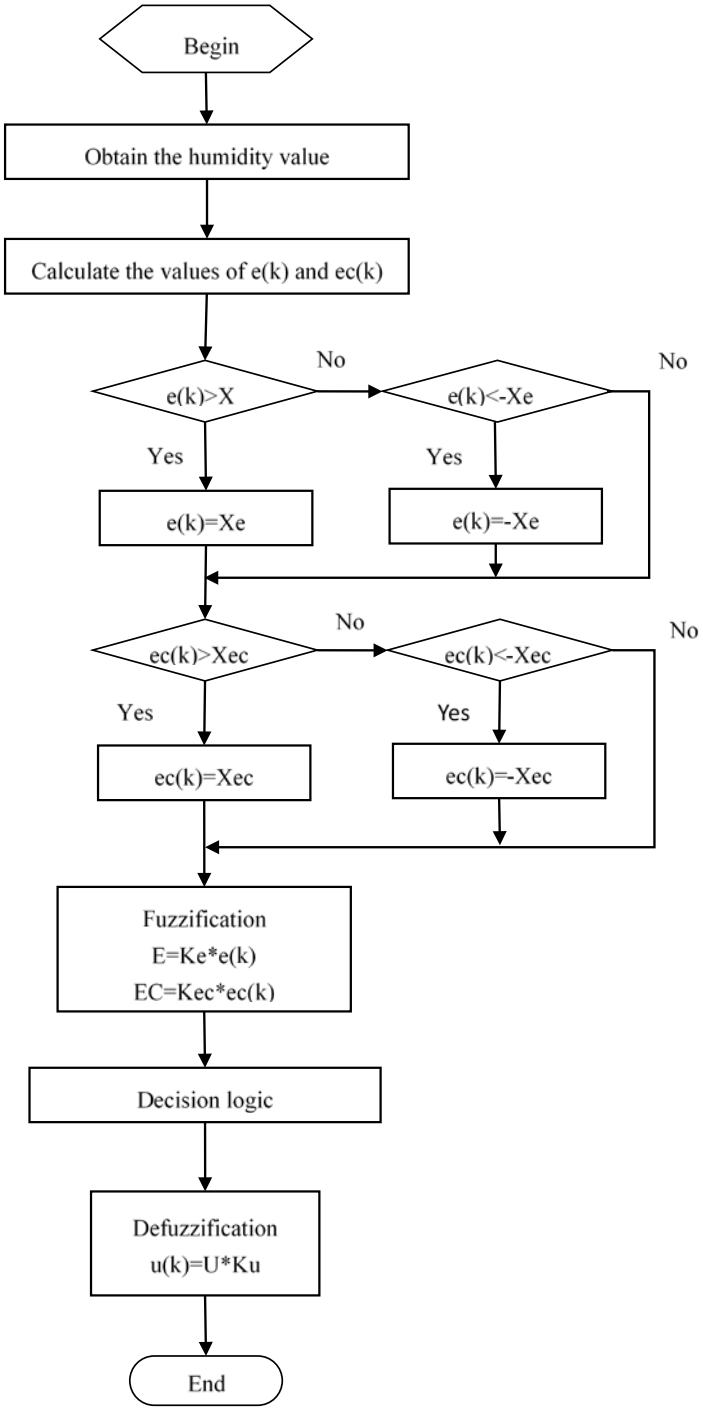

Figure 2. Flow chart of fuzzy control algorithm.

3. FIELD APPLICATION

3.1. Project Overview

The Spray Curing System of Concrete was applied to the side wall maintenance construction of Hanwangling Station of Changsha Rail Transit Line No. 4 in the second half of June 2016. It is mainly used for the maintenance of the side wall concrete after form removal. In the second half of June 2016, the average temperature in Changsha was 26 degrees and the humidity was 76%.

24 hours before the concrete pouring, the internal temperature sensor of the concrete is buried. Two groups of temperature sensors are arranged at 2 meters and 1 meter away from the top of the side wall, one of which was used as a spare measuring point, and each group is arranged inside the side wall, at the center point and outside. The temperature sensors can be used for concrete pouring after the sensor is buried. After the side wall is poured, the surface temperature and humidity sensor, the spray pipe and the intelligent maintenance equipment are installed during the 7-day maintenance period. Spray pipes fixed on the scaffold are divided into two channels with an upper and lower spacing of 2.5m. Each pipe is 18 meters long and the sprinkler head is 1.5 meters apart. The sprinkler head is 1 meter away from the side wall. A set of temperature and humidity sensors are set near the maintenance host to measure atmospheric temperature and humidity. After form removal, intelligent spray curing is carried out according to maintenance standards and indicators. The maintenance cycle is about 14 days. After the host is started, the system initialization parameters are set first, including the spray humidity control value and the maintenance time setting. The system can complete spray maintenance by one-click operation.

3.2. Experimental results

After the maintenance system is put into operation, the internal and atmospheric temperature of the concrete is collected every five minutes. The temperature data curve of each monitoring point in the curing process is shown in Figure 3, and the surface humidity curve is shown in Figure 4. The temperature monitoring data shows that the maximum temperature difference between the center temperature and the surface temperature of the side wall is 3.1 °C, and the maximum difference between the surface and the ambient temperature is 9.4 °C, which meets the requirements of the temperature control specification for mass concrete construction. At the peak of hydration heat release, the surface temperature is up to 38 °C, indicating that the hydration heat has been smoothly released and guided. At the same time, it is found out that the atomized spray has little effect on the concrete surface temperature. Experimental results: the highest curing humidity is 91.6% RH, the minimum curing humidity is 88.2% RH, the average humidity is around 90% RH, and the humidity control accuracy is ±2% RH. The humidity control system has good accuracy and basically meets the control requirements. The maintenance process monitoring data meets the concrete construction temperature and humidity control indicators.

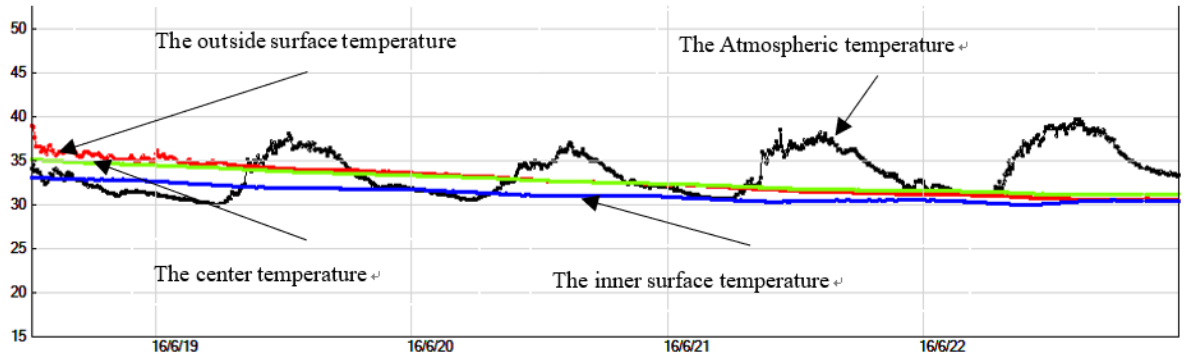

Figure 3. The temperature curve of each monitoring point.

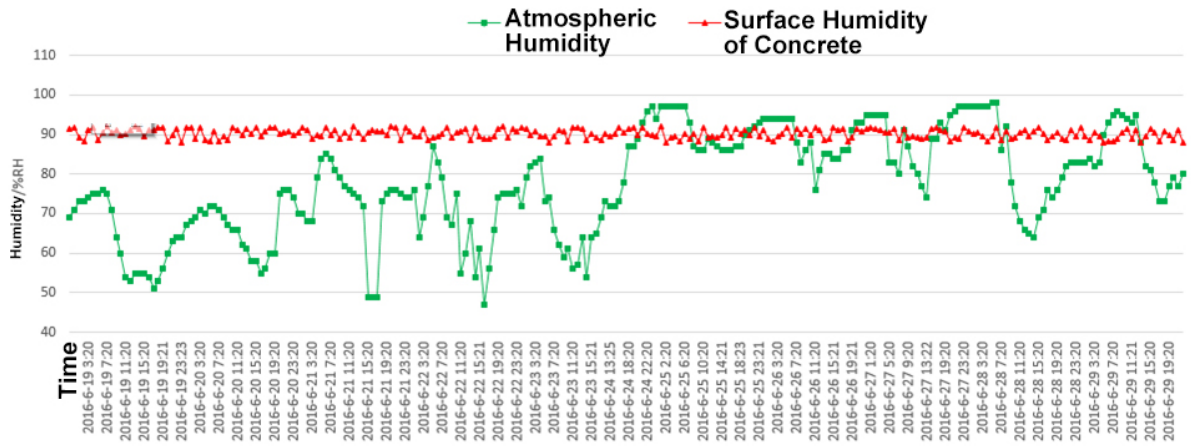

Figure 4. The Variation curve of moisture in maintenance process.

4. Conclusion and Discussion

This system, based on the fuzzy control technology, can guarantee that the concrete structure maintenance humidity is around 90%RH, and the control accuracy is high. Compared with the traditional maintenance, it has obvious effects on the moisturizing effect. Compared with the PID control spray maintenance technology, the adjustment time is shorter, and the overshoot quantity is less. The method greatly reduces the labor intensity, improves the curing efficiency, reduces the occurrence of concrete cracks, and improves the durability of the concrete. The system has been applied to the side wall maintenance project of Hanwangling and Yingwanzhen Station of Changsha Metro Line 4, which has good curing effect and provides technical reference for related engineering applications.

In this paper, the method of surface humidity control during the concrete curing was studied and the fuzzy control method was adopted to improve the surface moisturizing effect of the system during the concrete curing process. The cracks caused by the shrinkage stress were reduced, but there are still many reasons for the formation of cracks in mass concrete. The control technology can be further studied from the three stages of design, material and construction.

References

[1] Yang Jian, Peng Xin, Chen Kangjun, Wang Jinsheng. Concrete intelligent maintenance system [J]. Concrete, 2015, 306 (4): 155-158.
[2] Chen Kangjun.Application Research of Cement Concrete Intelligent Maintenance System in Bridge Engineering[J].Highway.2013,(11):218-220.
[3] Qiao Ji, Li Kefeng, Peng Xin, Chen Kangjun.Study on the Intelligent Spray Maintenance Technology of Concrete in Winter[J].Construction Technology.2015,44(24):52-55.
[4] Tan Lixin, Xu Shangnong, Zhong Ke, et al. Design and application of concrete intelligent maintenance system based on Internet of Things [J]. Engineering Construction and Design. 2017, (1): 75-77.
[5] Wang Jun. Research and design of multivariable temperature and humidity control system based on fuzzy control technology [D]. Shandong: Shandong University, 2015.
[6] Chen Yuechao.Design of temperature and humidity monitoring system for granary based on fuzzy control[J].Journal of Changchun Normal University.2016,35(12):24-28.