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High-precision Detecting Device for the Performance of the Tap

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Abstract. The conventional tap flow and sensitivity detecting devices have low precision, poor stability and poor repeatability. In order to improve the detection performance of tap flow and sensitivity, a high-precision detection device for the flow and sensitivity performance of the tap is designed in this paper. The industrial computer is used as the upper computer, which is mainly responsible for the collection of key data, the control of the servo and the detection of tap angle. The Siemens PLC is used as the lower machine to realize the control of the water supply system. At the same time, the innovative introduction of the CMOS camera is used to handle the tap angle. The experimental results show that the system stability and measurement accuracy of the device is significantly improved.

1.Introduction

Ceramic cartridge taps were introduced to China since the mid-1990s. Compared to traditional spiral lift taps, ceramic cartridge taps had accounted for more than 80% of the market for its outstanding performance. However, the results of the inspection of ceramic cartridge taps by the State Administration of Quality Supervision in recent years indicate that the product failure rate is high[1][2], which is related to the poor measurement performance of the companies' testing equipment[3]. Flow and sensitivity are two important indicators to measure the performance of taps[4]. How to accurately measure the flow and sensitivity of the tap becomes a difficult problem for the companies.

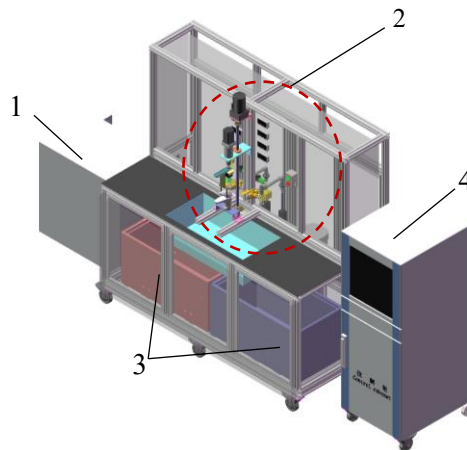
The existing tap flow and sensitivity detecting devices in the market have problems of poor system stability and poor measurement accuracy, mainly because of the fact that the handle rotation speed and angle are completely equal to the servo that controls taps rotation, which cannot meet the indicator requirements of GB18145-2014 "Ceramic Cartridge Taps"[4]. This paper designs a tap flow and sensitivity detection device based on industrial computer. It adopts the combined control system of Advantech industrial computer and Siemens PLC. Simultaneously, it introduces the CMOS camera for the handle angle of the tap. Experiments show that the measurement accuracy and stability of the device are significantly improved.

2.System design and implementation

The device uses Advantech industrial computer as the upper computer to realize the collection and analysis of key data, image processing and servo motor control. Siemens PLC is used as the lower machine to control the water temperature of hot and cold water tank, two frequency converters and several pipeline valves. The system design diagram is shown in figure 1.



The device is mainly composed of two parts: the control unit and the water supply unit. The control unit achieves the hardware control, data processing and human-computer interaction of the whole system, including the rotation control system of the water tap. The control unit is mainly composed of the industrial computer and the PLC, and the two parts realize information corresponding through Modbus-RTU serial communication. The water supply unit realizes constant temperature and constant pressure water supply and field data collection.



1- refrigerator 2- rotation control system 3- water supply system 4- control cabinet

Figure 1. Design diagram of whole system

2.1. Control unit

The control unit of the device is mainly composed of Advantech IPC-900 industrial computer and Siemens S7-200smart PLC, and the structure of control unit is shown in figure 2.

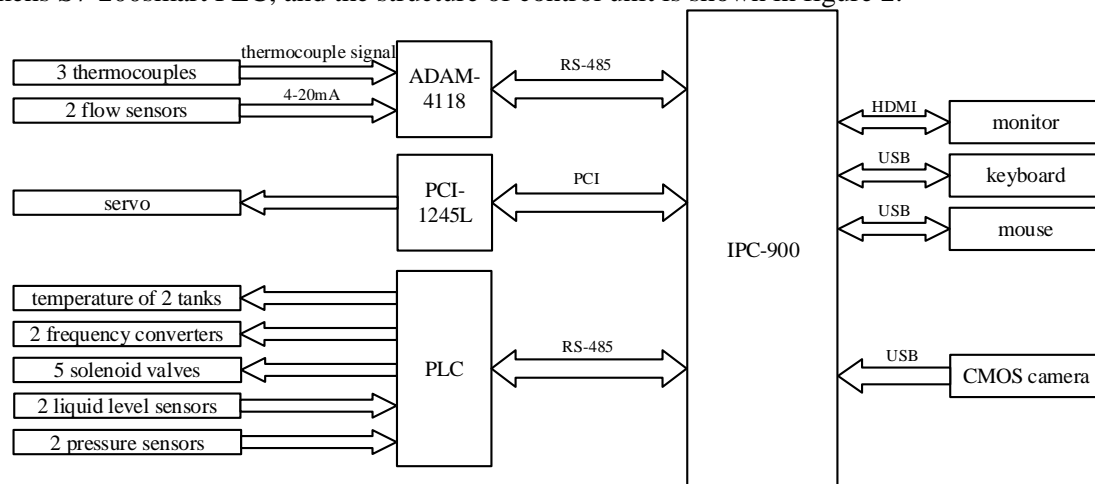
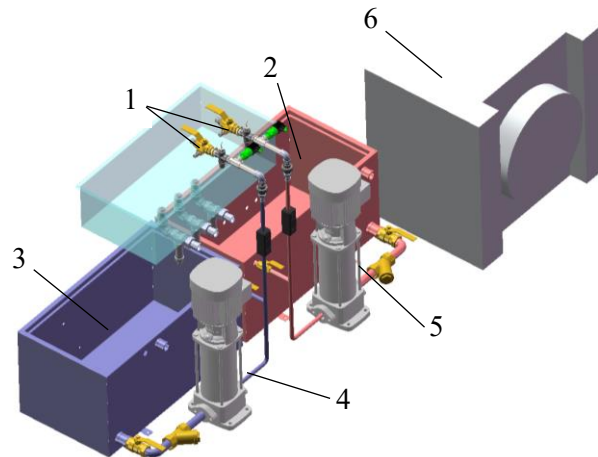


Figure 2. Schematic diagram of the system control structure

Industrial computer as the upper computer of the whole system, connects externally an Advantech ADAM-4118 analog acquisition module, an Advantech PCI-1245L pulse-type motion control card and a CMOS camera. Among then, Advantech ADAM-4118 module realizes the collection of water temperature at the tap outlet and the flow of hot and cold pipelines, Advantech PCI-1245L motion control card realizes the control of the servo that controls the rotation of the tap, CMOS camera realizes tap angle acquisition. The accuracy of the tap rotation speed is improved by the combination of servo and CMOS camera.

2.2. Water supply unit

The water supply unit is mainly composed of hot and cold water tanks, two water pumps, two frequency converters, heating tubes, a refrigerator, various field data acquisition sensors, pipelines and solenoid valves. The schematic diagram of the water supply unit is shown in figure 3.



1- cold and hot water supply port 2-hot water tank 3-cold water tank 4-cold water pump
5- heat water pump 6-refrigerator

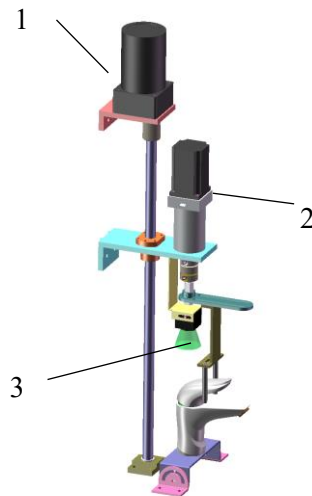
Figure 3. Structure diagram of water supply unit

GB18145-2014 "Ceramic Cartridge Taps" requirements for the tap flow test is the water temperature of the cold water pipe is 10~15°C, the pressure is 0.1 ± 0.01 MPa, the water temperature of the hot water pipe is 60~65°C, the pressure is 0.1 ± 0.01 MPa, and the temperature of cold and hot water does not exceed $\pm 1^\circ\text{C}$. The sensitivity test is similar to the flow test, and the pressure rises to $0.3_0^{+0.02}$ MPa. The whole water supply system collects the pipeline temperature and pressure value by PLC in real time, and the water pump controls the rotation speed by the frequency converter to achieve constant pressure water supply. Since the requirements for the standard temperature is the water temperature in the pipe, the pipe water temperature must be collected as feedback point. The device adds a loop pipe to the pipeline portion between the pipe thermocouple and the water outlet[4], which achieves water circulation in pipes and tanks, and then achieves constant temperature water supply. The switch of the loop pipe is controlled by solenoid valves, which can be selected according to the test item when the test condition is reached. It has been verified that the temperature stability of the whole water supply system is $\pm 0.5^\circ\text{C}$ and the pressure stability is ± 0.005 MPa.

3. Rotation control system

3.1. Fundamental

In the test process, the traditional tap sensitivity test device considers the motor feedback angle as the handle stroke angle. However, there is a certain deviation between the motor shaft center and the rotation center of the tap, which causes the test records to deviate significantly from the actual results. The device introduces CMOS camera innovatively, and applies the image processing technology to process the calculation of the rotation angle of the tap, which cooperates with the servo to realize the requirement of the tap speed of the tap in the sensitivity test. The structure of the rotation control system is shown in figure 4.



1- lift motor 2- rotation control servo motor 3- CMOS camera

Figure 4. Schematic diagram of the tap handle rotation control system

The basic principle of rotation can be expressed as follow.

$$v_m = \frac{\theta_m}{\theta_c/v_0} \quad (1)$$

In equation (1), v_m is the actual motor rotational speed; θ_m is the angle of the motor encoder feedback corresponding to the total stroke angle of the tap handle; θ_c is the rotation angle of the tap handle measured by the CMOS camera; $v_0=0.5^\circ/\text{s}$.

After obtaining the actual rotational speed of the motor by this method, the servo can be controlled by calling the relevant function of the Advantech motion control card.

3.2. Rotating control system

The rotation control system of this device is composed of Advantech PCI-1245L pulse-type motion control card and Panasonic MINAS A6 servo. The physical map is shown in figure 5.

Advantech PCI-1245L is a PCI bus-based four-axis pulse-type motion control card, which can be directly connected to the PCI bus slot IPC, and provides a rich API interface library, and it can be very convenient to control most of the market servo. The Panasonic MINAS A6 series servo is the latest servo with high precision, high performance and easy operation. And because the rotation control system of the present devices is low speed, in order to ensure accuracy, a reducer with a reduction ratio of 1:10 is added. The motion control card and the servo drive are connected by the PCL-10153PA5 cable provided by Advantech. The structure of the rotation control system is shown in figure 6.



(a) Advantech PCI-1245L motion control card



(b) Panasonic A6 servo

Figure 5. The servo and motion control card physical map

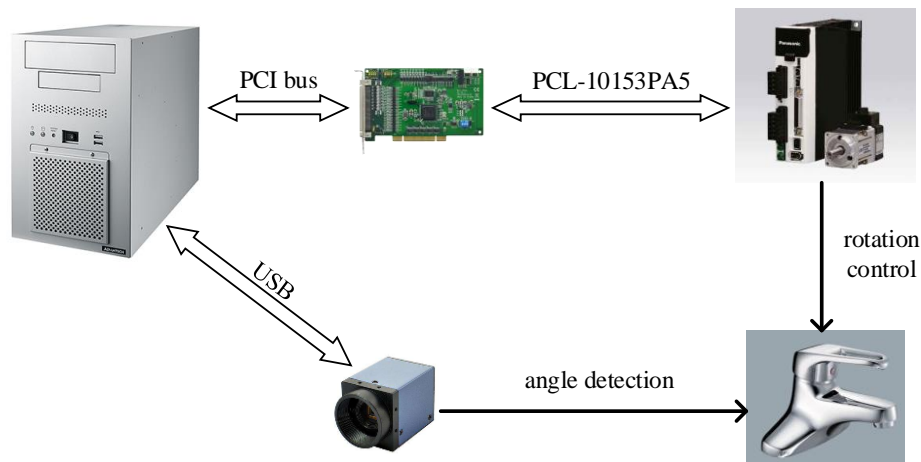


Figure 6. Schematic diagram of the rotation control system

The parameters of the motion control card and servo are set identically. The control mode of servo is position control mode, and the parameter Pr0.08 which described as the pulses of per rotation set to 10000. The reduction ratio of the reducer is 1:10, therefore the actual rotation of servo requires 100000 pulses by PCI-1245L each cycle. The actual control accuracy of the rotation control system can reach 0.0036°/pulse. The angle of the motor encoder feedback and the actual angle measured by the camera are obtained by rotating the tap handle before the test. The actual rotation speed of the servo is calculated by equation (1). In the test process, the relevant API functions of the board is called to achieve the rotation control of the tap.

4. Experiment analysis

The stability of the whole device is verified through testing the flow and sensitivity of several taps on the market. The flow and sensitivity test data of two taps are shown in table 1 and table 2.

Table 1. Flow test data of 2 taps

tap	Flow rate (L/min)		
	1	2	3
tap 1(common type)	6.18	6.14	6.14
tap 2(water saving type)	3.12	3.08	3.11

Table 2. Sensitivity test data of 2 taps

tap	Sensitivity (°)		
	1	2	3
tap 1(common type)	10.35	10.33	10.44
tap 2(water saving type)	10.52	10.28	10.37

The experimental results show that the device has high repeatability for the flow and sensitivity detection results of several taps, and the detection stability is obviously improved.

5. Conclusion

Flow and sensitivity are two important indicators to measure the performance of the tap. The high-precision tap detection device based on the industrial computer designed in this paper improved the temperature stability of the device through the redesigned pipeline. Furthermore, a new rotation control system is designed to meet the requirements of the sensitivity test for the rotation of the tap, which innovatively introduced the CMOS camera to realize the measurement of the tap rotation angle and improve the rotation speed accuracy of the tap. The experimental results show that the stability and accuracy of the device are significantly improved, which solves the problem of measuring the flow, especially the sensitivity of the tap for companies, and it has high application value.

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