

Study on the Automatic Detection Method and System of Multifunctional Hydrocephalus Shunt

Xuan Sun, Guangzhen Wang, Quancheng Dong, Yuzhong Li

School of Mechanical Engineering, University of Jinan, Jinan, China, 250022

377094468@qq.com, 1907268702@qq.com

Abstract. Aiming to the difficulty of micro pressure detection and the difficulty of micro flow control in the testing process of hydrocephalus shunt, the principle of the shunt performance detection was analyzed. In this study, the author analyzed the principle of several items of shunt performance detection, and used advanced micro pressure sensor and micro flow peristaltic pump to overcome the micro pressure detection and micro flow control technology. At the same time, this study also put many common experimental projects integrated, and successfully developed the automatic detection system for a shunt performance detection function, to achieve a test with high precision, high efficiency and automation.

1. Introduction

The utility model relates to a hydrocephalus shunt, which is a one-way hydraulic valve which can be implanted into a patient's intracranial for a long time. The main structure of the interior is adjustable spring and ball core valve, it can control the opening and closing pressure of the valve. Hydrocephalus shunt performance test is very strict. The inspection of the quality of the hydrocephalus shunt related works start late domestic, almost no reference can be consulted. Now, we still use laboratory common equipments for testing, which has low efficiency, poor accuracy and large workload. It is an urgent need that developing a automatic, high efficiency and high precision multifunctional hydrocephalus shunt performance detection system. Through the analysis of the detection principle of physical characteristics of several common shunts, and integration completes the assignment.

2. System composition and principle

2.1. Structure and working principle of hydrocephalus shunt

As shown in the Figure 1, hydrocephalus shunt was a spring type hydraulic one-way valve, special equipment pre adjustment the shunt of the opening and closing pressure after the end of the hose to the water hose parts of intracranial, terminal patients in abdominal cavity. In this way, when the patient's intracranial pressure exceeds the preset pressure value of the shunt, it can automatically open, and the hydrocephalus is drained into the patient's abdominal cavity through the shunt to achieve the purpose of intracranial decompression[1].

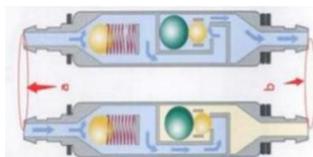


Figure 1. Shunt structure of hydrocephalus



2.2. Artificial test system analysis hardware composition

The physical characteristics of the diverter detected include: the detection pressure value of the opening and closing, the flow-pressure characteristic test, the test of the long-term stability and characteristics and the test of flow-pressure characteristics. As shown from figure 2 to Figure 4, the schematic diagram of the test system for the manual testing of the four test items.

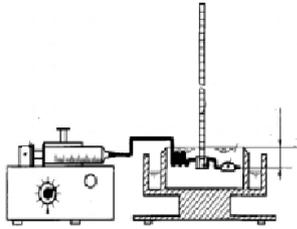


Figure 2. Open pressure, pressure flow characteristics test system

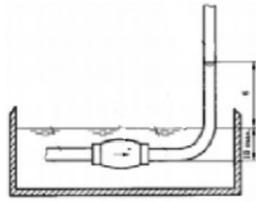


Figure 3. Back flow characteristic test system

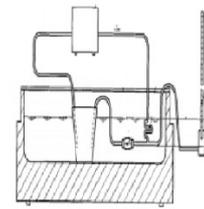


Figure 4. Long term stability test system

To analyze the constituent elements of the test system of four test items, it was not difficult to find that the following test conditions in common with test system for the four test items: (1) To test the flow in the 5-60mL/h adjustable flow range; (2) To detect read shunt entrance or exit test of hydraulic pressure. The accuracy of 0.5mm water column; (3) To maintain the temperature in constant temperature water bath $37 \pm 2^\circ\text{C}$. Therefore, in considering the detection precision, efficiency and automation and other factors, development of hydrocephalus shunts by precision pressure sensor, data acquisition, data processor, controllable precision test flow pump was a main component of the automatic detection system.

3. The hardware configuration of the automatic detection system for diverter

3.1. Hardware composition

The hardware structure of the automatic detection system for hydrocephalus shunts was shown as Figure 5, which consists of a pressure sensor, a controllable flow pump, a data acquisition card and a data processing computer. According to the function, it can be divided into two parts: data acquisition and data processing.

3.1.1. Data acquisition section. The micro pressure sensor for detecting bottom piezoelectric film, because the test fluid bring weak stress can cause slight changes in the film shape, using the piezoelectric effect of the films will convert the pressure into electric signals, through the transmission circuit, voltage signal was converted to 0-5v. The 6 sensor signal lines were connected to the 6 input channels of the A/D module of the data acquisition card. Acquired by industrial computer, the corresponding pressure. The data acquisition system was composed of pressure sensor and data acquisition card.

3.1.2. Data processing. As the core equipment of the IPC controlling input and output data processing, internal PCI interface data acquisition card will install the pressure data measured by sensors to CPU, by supporting the development of data acquisition and processing software test project four. There are parameter setting options on the operating interface, the user can adjust the parameters according to the different experiments and different experimental samples. The software also had the function of automatic analysis and calculation of test data, real-time display, production test curve, test report, print, historical data record and query.

3.2. Design of the main hardware

3.2.1. Pressure senso. Pressure detection using the Japanese MTO-39 micro pressure sensor [2-3], the ideal measurement accuracy can reach 0.25%.

3.2.2. Data acquisition card. Data acquisition using PCI1716L multi-function data acquisition card, installed in the host computer motherboard, exchange and IPC data through PCI interface, this card is a 16 bit high precision and multifunction analog input and output data acquisition card. It comes with a 250K/s 16 bit A/D converter that provides either a single ended analog input or a differential analog input of the 8 channels, or a combination of the inputs of the. It comes with 2 bit D/A output channels, a 16 bit digital input / output channel and a channel with 1 16 bit counters.

3.2.3. Data processor. Using Advantech IPC 610L, internal PCI and ISA interface for convenient expansion, and can satisfy the requirement that long-term stability of experimental project 28 days continuous operation without stopping .

3.2.4. Controllable flow pump. Flow control using Trevor peristaltic pump ^[4-5], the flow range of 1mL/h-100mL flow, the accuracy of 1%FS.

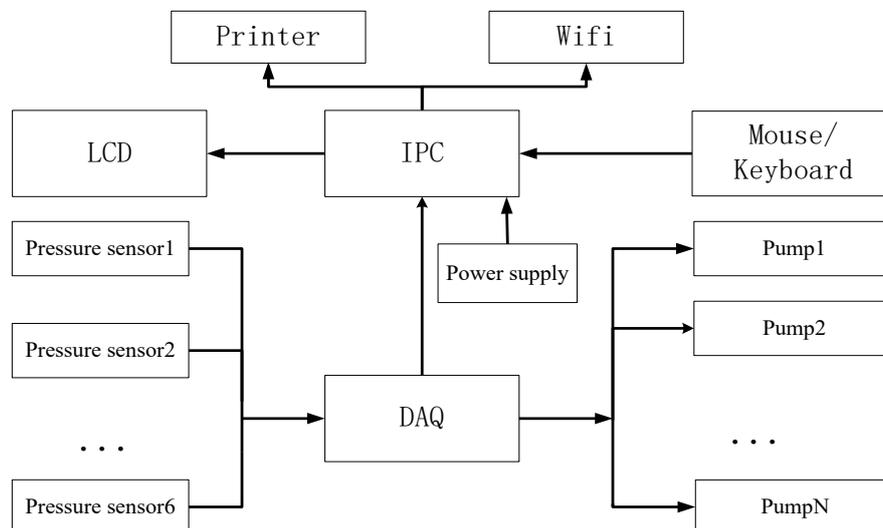


Figure 5. Hardware structure of detection system

4. Test of the system function and performance

4.1. Opening and closing pressure test

As shown in Figure 6 and Figure 7, taken a splitter for the same time for 6 consecutive experimental data and analysis reports. From the table 1 data, the opening pressure value was stable at 45-50mmH₂O pressure, the closing pressure was stable at 25-30 mmH₂O, slightly lower than the opening pressure, in line with the shunt of the opening and closing pressure characteristics. The system automatically calculated the average value, maximum value, minimum value and standard deviation according to the experimental data, was convenient for collecting data to determine the opening pressure and closing pressure of a specific design of the valve manufacturers; in addition, as a type of validation, it can verify the opening and closing pressure valve.

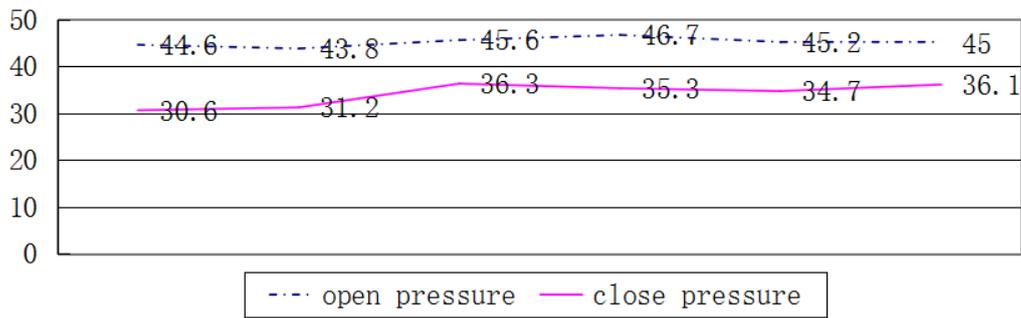


Figure 6. The real time data of opening and closing pressure test

Conclusion: The automatic detection system can satisfy the need of opening and closing pressure test, and reduce the workload.

4.2. The characteristic test of the flow-Pressure

The purpose of the flow-pressure characteristic experiment was to investigate the resistance of the diverter valve at different flow rates. By adjusting the flow pump, made the pressure transmitter to zero, and then, increased the flow of the pressure on the test piece by 50ml/h, 45ml/h, 40ml/h, 35ml/h and so on, until to 5ml/h decline. According to the experimental data, the pressure data obtained at different flow rates were consistent with the flow characteristics of the shunt. Peristaltic pump can meet the requirements of the minimum 5ml/h accuracy required by the experiment, and can easily control the flow rate adjustment from 5ml/h to 50ml/h.

Conclusion: The using of the pump to drive multiple pump head of the peristaltic pump for micro flow control can not only meet the flow - pressure test project accuracy requirements, and multi-channel at the same time to improve the detection efficiency.

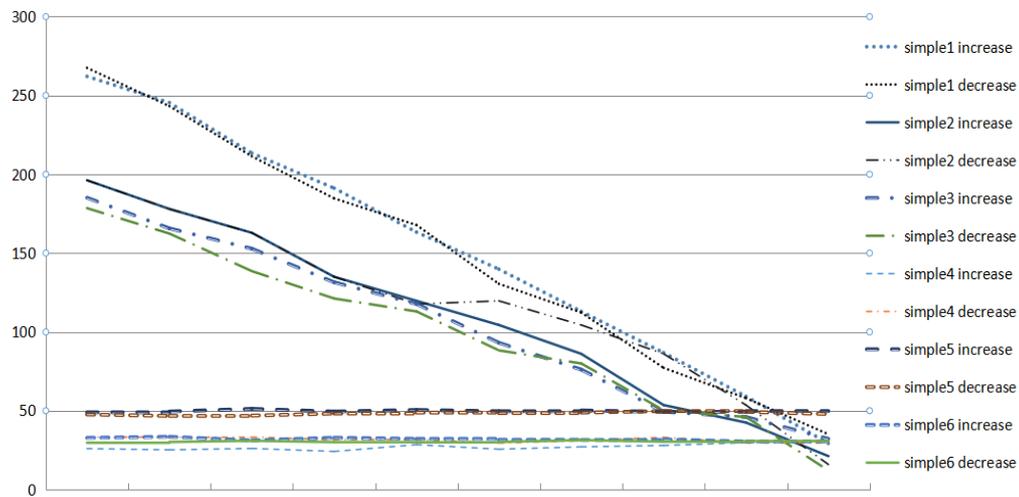


Figure 7. The characteristic test of the flow-Pressure

4.3. Test of the back flow

Using a pump, having three channels, taking 3 pieces of shunt, at the same time, does the experiment. As shown in the table 1, the back-flow pressure value was measured, found from the data obtained, the reverse pressure up to 500mmH₂O, back-flow numerical value only 0.02mL can be regarded as the reverse closure, all test pressure values were in line with the characteristics of reverse flow diverter, and detected the reverse flow of artificial observation was difficult to find the micro pressure detection system can detect 0.02mL, project flow characteristics can meet the requirement of automatic verification.

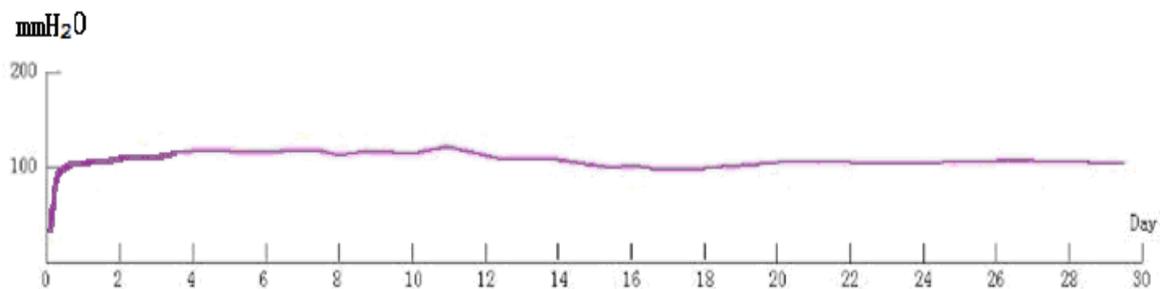
Table 1. Test of the back-flow

Simple Number	Static Pressure			Unit
	10	50	100	
				Pressure: mmH ₂ O
1	0	0	0	
2	0	0.02	0.02	Back -flow: mL
3	0	0.01	0.01	

Conclusion: In the experiment, the micro pressure sensor not only meets the needs of the experiment, but also goes beyond the traditional detection accuracy.

4.4. Long term stability test

By 20mL/h flow, did a long term stability test. Record pressure versus time curve. As shown in the figure, within 30 days of the measured time, the pressure was stable, the work was normal, the actual test showed that the system can complete the long-term stability of the experimental task, and achieve automatic and efficient detection requirements.

**Figure 8.** Long term stability test

5. Research summary

By testing, it is proved that automatic inspection system for hydrocephalus shunt well realize four test tasks. In terms of micro flow control, the accuracy can reach at least 5mL/h. And in terms of the micro pressure detection, the accuracy can up to 0.01mmH₂O. With the help of computer detection technology, the system can achieve the requirements that automation detection, multi-function, high efficiency and high precision.

Reference

- [1] Zhenan Zou, Dengbin Zhang, Hongyuan Guan. Application of hydrocephalus shunt to lateral ventricle, Treatment of hydrocephalus with skin cavity shunt[J]. Journal of Mudanjiang Medical College, 2012, (02): 41-42.
- [2] Shengguo Wan. Study on the control system of high pressure micro flow constant current pump[D]. Nanjing University of Aeronautics and Astronautics. 2012.
- [3] Jiangtao Pang, Changqing Zhan, Zhimin Tan. Journal of functional materials and devices[J]. 2016, (02): 30-33.
- [4] Qian ying Sun, The application of peristaltic pump[J]. Nursing Journal, 2016, (08): 35.
- [5] Xianjun Liu, The principle and application of peristaltic pump[J], Fluid machinery, 2015, (12): 38-40.