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Design and Implementation of Strain-strengthening Automatic Control System in Hydrate Production Process

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Abstract. In this article we had built up a strain-strengthening automatic control system based on visualizing man-machine interface built by configuration software of upper computer, field control by PLC and data collection accomplished by A/D converter to meet the technological requirements of the strain-strengthening process. The system can realize many functions such as controllable program loading, data collection, dynamic link in database, testing process monitoring and storage of test data. In addition, our system added a weighing module and a dynamic perimeter measuring module to measure residual deformation rate in the hydrate production process.

Keywords: strain strengthening, automation control system, austenitic stainless steel pressure vessels

1. Introduction

With the development of technology and growing energy demand, cryogenic pressure vessels have become an increasingly important and an effective way for transporting energy [1]. Cryogenic vessels are commonly applied in many fields such as petrochemical industry, aerospace industry, nuclear power industry and medical treatment, playing an essential role in the national economy development [2].

On the other hand, strain-strengthening technique, which can enhance the yield strength of austenitic stainless steel and reduce the thickness and weight of stainless steel cryogenic vessels (the wall thickness is about 30%-50% lower compared to the conventional ones), is commonly used in the manufacturing process of pressure vessels extensively [3].

Compared to traditional manual strain-strengthening process, strain-strengthening automatic control system, which involves visualizing man-machine interface built by configuration software, field control system by PLC and data collection system accomplished by A/D converter, has a positive role in ensuring product quality, promoting production efficiency and realizing the scientific management in the strain-strengthening process[4].

2. Hardware design of the automatic control system

The hardware of the automatic control system is consists of three main parts: IPC (industrial personal computer), Mitsubishi PLC and field instruments. Siemens SIMATIC IPC is applied as the upper computer of the strain-strengthening automatic control system. It has a rugged design and powerful functionality and provides PROFIBUS DP/MPI interface and Ethernet interface which is convenient to connect management

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or operation level applications and to internet [5]. Besides, configuration software-Kingview 6.01is used to design the monitoring system and realize the communication between the lower computer (PLC) and the upper computer (SIMATIC IPC). On the other hand, Mitsubishi PLC FX2N-32MR-001 equipped with expanding module FX2N-4AD and FX2N-4DA is adopted as the lower computer. Generally, this kind of PLC can adapt to the use of various automation control occasions, especially in manufacturing occasions.

The weight sensors, pressure sensors and perimeter module gather on-the-spot signals and A/D converter converts analog signals into digital signals. Accordingly, electromagnetic valves are controlled through PLC to take normal on-off action and the output of frequency converter is adjusted by D/A converter to control pump operation.

The structure of the automatic control system is shown in Fig.1.

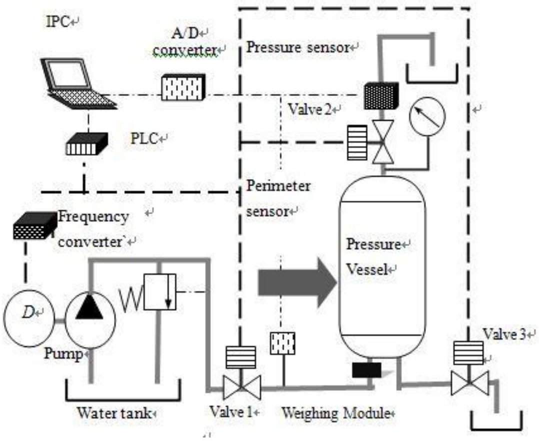

Fig.1: Structure of automatic control system

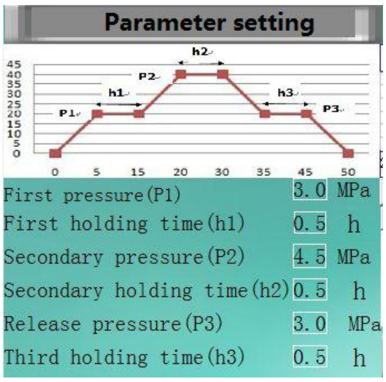

Fig.2: Parameter setting interface

3. Software design of the automatic control system

3.1 Monitor interface design

The strain-strengthening automatic control system adopts configuration software-Kingview 6.01 to design and establish monitoring interface of the upper computer. Based on a windows-based platform, configuration software-Kingview 6.01 can construct and generate PC monitoring system rapidly. The Kingview software combines animation, process control, data acquisition, device control and output, network data transmission, engineering reports, data and curve and many other powerful features in one and provides users with a development platform and complete solutions for solving practical problems.

According to customer requirements, monitor interface includes parameter setting interface, monitoring main screen, real-time curves, history curves and report window.

3.1.1 Parameter setting interface

Parameter setting interface is built in the configuration software-Kingview 6.01.As it is shown in Fig.2, user can enter parameters in the input box manually according to the processing requirements. Key parameters such as First pressure(P1),First holding time(h1),Secondary pressure(P2),Secondary holding time (h2),release pressure(P3) and Third holding time(h3) will be written into data registers in the PLC after inputting processing parameters.

3.1.2 Monitoring main screen

Monitoring main screen can provide real-time monitoring of strain-strengthening process for pressure vessels. As shown in Fig.3, in addition to the dynamic changes in pressure, circumference, weight and frequency and other parameters, the right side of the main screen also displays the operating status of the valves and pump. Meanwhile, the left side of the main screen not only can show the important parameters such as strain strengthening rate and pressure change rate but also can adjust the operating frequency of the pump. Besides, monitoring main screen provides toggle buttons which can switch to the pressure curve, weigh curve, perimeter curve and report form at any time.

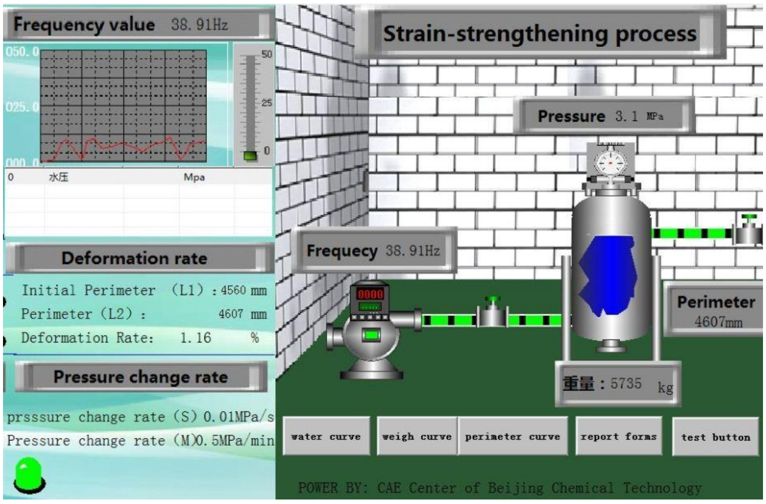

Fig.3: Monitor main screen

3.1.3 Real-time and history curve

Real-time curve displays the trend of parameters dynamically; for instance, the pressure-time curve can display the pressure variation with the time. Similarly, the history curve is helpful for users to look over the history and the change of some specific parameters.

3.2 PLC program design

PLC controls actual devices such as valves, pumps and other devices through the PLC programs and different PLC has its own programming software.GX DEVELOPER is a standard software package for Mitsubishi PLC programming and its basic functions are as follows: setting up and managing projects, assigning parameters for hardware, communicating with A/D converters and D/A converters [6]. In this article, GX DEVELOPER software is employed to establish the program of PLC and implement all the strain-strengthening process. In order to reduce the difficulties of programming, the program is divided into three separate sections: the main program, A/D acquisition program and data exchange program. The basic flow of the main program is as follows:

(1) Starting the system, opening the pump, valve1 and valve2 and injecting water into the pressure vessel to exhaust air.
(2) Closing valve 2 and valve 3 after removing the air completely, increasing the water pressure through the pump and recording the real-time data on pressure, weight, strain rate and other parameters.

(3) Turning off the pump and valve 1 until the strain rate achieves the set value (P1).Maintaining the pressure for at least half an hour.
(4) Turning on the Valve 3 when the holding time is up then turn off the valve 3 until the pressure achieves the set value (P3). Maintaining the pressure for another half an hour.
(5) Turning off the valve 3 and relieving the pressure until the pressure drops to zero.
(6) Shutting down the system.

Fig.5 provides parts of the PLC program code.

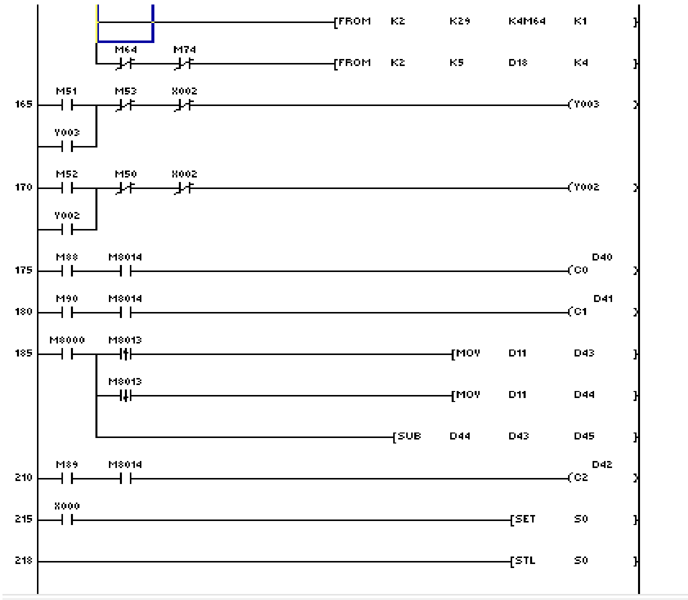

Fig.5: parts of the PLC program code.

3.3 Automatic system debugging

In order to guarantee the stain-strengthening automatic system can be used securely and normally, it must be debugged and run it after the design and installation of the automatic system.

(1) The data acquisition program should be confirmed and debugged. The data acquisition part plays an important role in the whole system. The A/D date collected from sensors by FX2N-4AD converter is transferred to Mitsubishi PLC FX2N-32MR-001 to get vertical filtering and the filtering adopts the mean algorithm to eliminate interference. According to the testing results, the errors seem to be full-precision errors and the accuracy of the A/D converter is less than 1%.

(2) The pressure adjusting part is also very essential and it is regarded as a close loop system. The signal of feedback unit is the pressure value collected by FX2N-4AD converter and the actuator is the pump controlled by the frequency converter.

(3) Checking all the mistakes then correcting them through the trail operations of the system. Several problems have been found during the trail operation process. For example, the electromagnetic valve doesn't work, the main monitoring system provides inaccurate data in some situations, connection errors occurs between the upper computer (SIMATIC IPC) and the lower computer (FX2N-32MR-001PLC), etc.

At last, the automatic control system has completed the debug procession after multiple trail operations.

4. Conclusions

After commissioning, the strain-strengthening tests were conducted to verify the stability and reliability of the automatic system and to improve the system functions and control accuracy gradually. Trial operation shows that according to the combination of hardware and software and the PLC control program, the strain-strengthening automatic control system can replace traditional manual strain-strengthening process and meet different requirements of the actual production process.

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6. References

[1] Zheng, J.Y., Li, Y.X., Xu, P., Ma, L., Influence Factors of Mechanical Property for Strain Strengthening Austenitic Stainless Steel, J. of PLA University of Science and Technology (Natural Science Edition), 2011, 12(5): 512-518.

[2] Peterkin J.S. Cold Stretched Austenitic Stainless Steel Pressure Vessels[C]. Symposiumon Stress Analysis for Mechanical Design 1981: Preprints of Papers 1981. 96-98.

[3] Huifang Li, Zhenbei Wang, Xiaoju.Sun, Caifu Qian. Experimental investigation of the strain-strengthen effect on the existed Ⅰ+Ⅱ mixed mode fatigue crack transformation propagation in an austenite stainless steel. ASME 2013 Pressure Vessels and Piping Conference. 2013.

[4] Cunjian Miao .Fatigue Testing Machine for Cryogenic Enviroment and Fatigue Properties of Cold Stretched Austenitic Stainless Steel [D]. Zhejiang university, 2012.

[5] Cui Jian. Siemens Industrial Network Communications Guide [M].Beijing, Machinery Industry Press.2004.9

[6] Mitsubishi electric automation (Shanghai) Co., LTD.Training materials of Mitsubishi programmable logic controller. Shanghai: Mitsubishi electric automation(Shanghai) Co., LTD. Mitsubishi electric FA center in Shanghai, 2005.