Hydraulic pump automatic test system based on C/S structure

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Abstract. In order to meet the automation production and testing needs of modern enterprises, this paper takes the hydraulic vane pump test bench as an example, and builds a set of hydraulic automatic measurement and control system based on C/S framework, which can meet the requirements of single/double pump test simultaneously. Among them, the client software is developed based on LabVIEW, the server is built based on FTP protocol and MYSQL database, and the test bench is successfully connected to the internal production management system of the enterprise through the local area network, realizing the integration of product model management, process control, automatic testing, result uploading and other functions. At the same time, the PID closed-loop control strategy was improved in the acceleration and loading stages to shorten the test time and reduce the system overshoot. Finally, the automatic run-in, efficiency verification and low-speed pressure-holding test of vane pump have been completed.

1. Introduction
For large-scale manufacturing enterprises, workshop automation and assembly line technology have an important impact on their production and testing efficiency[1]. The traditional hydraulic test bench often only focuses on the single test results, but ignores the requirements of enterprises for fast, convenient and automatic testing. In this paper, according to the requirements of a foreign-funded enterprise for the automatic testing and management of hydraulic pump, the traditional test bed is upgraded and transformed, and the hydraulic automatic measurement and control system with C/S structure is designed and built. Online query of test parameters and upload and update of test results are realized through database technology, and the local test report is synchronized to the specified server using FTP file transfer protocol. This method of separation of test software and data overcomes the risk of loss caused by the data only stored in the field computer, and is convenient for the back-end management personnel to organize the data, and the C/S architecture can better guarantee the security of data.

2. Design of hydraulic system
As shown in Figure 1, the hydraulic principle of the vane pump test bench consists of two main loading loops, which are respectively used for pressure and flow testing before and after the double pump. To ensure the safety of the test system, a safety relief valve is provided on each loading circuit, and the safety pressure can be adjusted by a remote handle. At the same time, in order to ensure that the oil cleanliness reaches the standard, the system is equipped with a multi-stage filter device, and the backup filter element can be switched directly and quickly to ensure the continuous operation of the system. In order to meet the requirement of oil temperature test, the system adopts circulating water cooling and external heater to control the temperature. Try to ensure that lines are no thinner than 0.25 point.
3. Design of electric control system

The measurement and control system mainly includes upper computer, signal I/O module, sensor, PLC module, remote server and so on. Its structure block diagram is shown in Figure 2. Advantech integrated industrial computer is selected as the upper unit, and Advantech PCI-1716 multi-channel data acquisition card is selected to complete the data acquisition and transmission of the upper and lower units. Mitsubishi FX series PLC is adopted as the circuit control unit, and the communication between the PLC and upper unit is established through VISA serial port protocol[2]. The remote server and the local client are networked via TCP/IP protocol, and database and FTP connections are established.

The software of upper unit is developed based on the LabView11.0 platform of NI (National Instruments) Company. It has a good man-machine interaction interface, rich function library and strong signal processing ability, and according to the idea of virtual instrument modular and hierarchical structure design[3]. The whole automatic testing process can be divided into 5 parts: model identification, parameter reading, starting the test (automatic acceleration, displacement verification, efficiency verification, graded loading, pressure oscillation check), report generation, and data upload.
4. Building and access of server-side

4.1. MySQL Database
MySQL, a fully networked, cross-platform relational database system developed by MySQL AB of Sweden \[^4\]. To facilitate the management of test parameters and statistical results associated with each test product, the system introduces a MySQL database. All important test information is stored in the server-side data table, which has the advantage of effectively avoiding data loss caused by damaged or dead computers in the field and facilitating unified online changes to the test parameters of a batch of products at a later stage.

A new database and related data tables for external access are created on the server and authorized to the client (test bench). As shown in Figure 3, the client connects to the server by ODBC (Open Database Connectivity) data source. Since there are many test products and different models in the assembly line, this system adopts the input method of scanning gun to identify the product information. As shown in Figure 4, LabVIEW indexes the relevant product models in the server database through SQL statements and imports the corresponding test parameters, such as rated speed, loading pressure, flow range, test time, etc. In addition, for the duplex pump, it is necessary to separate and splice the strings according to the total product model code and then identify them in turn to obtain the specific test parameters of the single pump body.

4.2. FTP site
FTP (File Transfer Protocol) is one of the protocols in the TCP/IP protocol group. Because FTP transfer is very efficient, this protocol is generally used when transferring large files over the network \[^5\]. Meanwhile, considering the problems of server network connection and security in the active (FTP Port) mode, the system adopts the passive (FTP Passive) mode for file transfer.

Firstly, FTP service and IIS (Internet Information Services) management console are enabled on the server side. A new FTP site for remote connection is created using the IIS management console, and disk space is allocated as the storage address for sending and receiving data. At the end of each test, the program first generates an Excel report file on the client according to the date and model, then indexes...
whether the file already exists according to the specified file path, and pops up a prompt box if it does not exist, and uploads a copy of the file to the corresponding path in the server through the program as shown in Figure 5.

Fig. 5. FTP transfer program block diagram

5. Test method and results

5.1. Control algorithms
In order to accurately measure the test parameters, the system speed, pressure and other signals need to be accurately closed-loop control. PID control is widely used in industrial control because of its simple and practical structure, good intuitiveness, high reliability and high cost performance[6].

The system uses interpolation and PID adjustment method for rapid acceleration and loading to save time in the run-in and low-speed pressure-holding test. The interpolation method can calculate the required control signal value by the function relationship between the control signal and the speed/pressure, and then use PID closed-loop control for precise adjustment after the output is stabilized, so that the speed/pressure is finally stabilized within the error range. The advantage is to make up for the problems of long adjustment time, large overshoot and difficult adjustment of PID parameters when the controlled object has variable parameters, nonlinearity and large hysteresis.

As shown in Figure 6, when the system detects that the deviation of the controlled quantity exceeds the allowable value, the PID closed-loop correction is activated. Among them, the PID gains and the allowable error values are originated from the server side, and these parameters can be changed online according to the different products under test, so as to achieve custom settings between regulation time and control accuracy. At the same time, the PID control program is encapsulated into sub-VIs, which can be easily called by the main program at any time.

Fig. 6. PID control program block diagram

5.2. Test results
The run-in and low-speed pressure-holding test curve is shown in Figure 7. The red curve indicates the pressure and the yellow curve indicates the speed. The above control method can significantly reduce the adjustment time and avoid the influence of system overshoot, making the curve look more smooth. When the pressure adjustment is completed, the system performs the holding operation for the
corresponding time and checks the pressure oscillation value during the holding time of each pressure section. Finally, the test result is judged by comparing with the standard value of the model in the database.

Fig. 7. Run-in and low-speed pressure-holding test curve

The efficiency-load characteristic test curve is shown in Figure 8. In order to avoid the influence of dynamic effect on the fluctuation of efficiency value during the loading process, the system adopts the tracing point method to record the steady-state efficiency data at each pressure point, and finally carries out B-sample fitting to get the corresponding curve. It can be seen from the figure that the model vane pump at 25MPa volumetric efficiency is about 86%, the total efficiency is about 78%. The result can meet the test standard compared with the standard value in the database.

Fig. 8. Efficiency-load characteristic test curve

According to the actual data comparison at the test site from Table 1, the use of the new fully automated test system can significantly improve the test efficiency. Among them, the data preparation before the test and the result processing after the test reduce a lot of time by simplifying the operation process and improve the production and shipment of enterprises.

Table 1. Table of test flow comparison before and after update

|                | Model select | Data input | Control method     | Results Processing     |
|----------------|--------------|------------|--------------------|------------------------|
| Original       | Manual       | Manual     | Closed loop control| Local Reports          |
|                |              |            |                    | Copy Manually          |
| Time/s         | 15           | 20         | 80                 | 100                    |
| Now            | Scan         | Online     | PID                | Database， FTP          |
| Time/s         | 2            | 1          | 60                 | 3                      |
6. Conclusion
This paper builds a testing system based on C/S architecture on the basis of traditional hydraulic testing, which not only meets the automation requirements of traditional testing, but also realizes the separation of client software and server data. Among them, the client software is developed based on LabVIEW and connected to the server FTP site and SQL database through programming. It effectively reduces the cost of test data management and lowers the difficulty of manual operation and learning cost. The parameters such as pressure/flow rate of test demand are automatically adjusted by PID, which effectively shortens the test duration. The results show that the automatic test system designed and developed in this paper greatly improves the testing and management efficiency and achieves the expected results.

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