Research of Measurement and Control System for Hydro-mechanical CVT Test Bench Based on LabVIEW

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Abstract

The performance of measurement and control system plays an important role in the transmission test bench. Based on the test bench of hydro-mechanical CVT (HMCVT), the analyses on the composition of the HMCVT test bed and its measurement and control system have been finished in the paper. By using of LabVIEW graphical programming software, the measurement and control system main control software realizes the function of real-time data acquisition, processing, display, storage and control. Thus, it provides a reference for the measurement and control system design of similar test system.

Keywords: Hydro-Mechanical CVT, Test Bench, Measurement and Control, LabVIEW

1. Introduction

In the process of development and product testing, it is required for the transmission to have a performance bench test, which is artificially imposed by load torque after transmission start running, and makes transmission shifted in different gear at different speed and torque, in other words, working at different conditions to acquire the transmission efficiency, the shift schedule and other relevant performance parameters. With the development of automatic control technology, the requirements for robotized testing and control of the test bench are getting higher and higher recently. So it is highly needed to develop a set of measurement and control system to govern the test bench, and which should have some virtues such as the high reliability, strong real-time, operating simply and with friendly human-computer interface, short development cycle, easy to upgrade [1-2].

As the result of a combination of computer technology and instrument technology, virtual instrumentation technology has broken through the old concept of instrument and will become the artery of test system [3]. By using LabVIEW, the most popular virtual instrument graph software, it will be effectively meet the needs of the test bench system for data acquisition, monitoring, transmission, analysis, processing, display and instrument control. The design of the hardware and software is simple, offers good man-machine interface and the control mode can be adjusted at any time according to different demands [4-7]. Thus, LabVIEW has been chosen as the development platform in the paper, to develop measurement and control system for hydro-mechanical CVT (HMCVT) performance test bench.

2. Framework of HMCVT Test Bench

In the paper, the bench is mainly used for the HMCVT performance test. The system structure of the bench is shown in Figure 1.

The HMCVT test bench is mainly comprised of two parts: mechanical system, measurement and control system. Mechanical system provides the necessary mechanical support for the test-bed, and it mainly consists of engine, torque divider, HMCVT, load resistance simulation...
system, speed-increase gearbox, laboratory support system, etc. The function of measurement and control system is to collect and process the test information of the test system, and coordinate all the moving parts.

The driving force, which is produced by a diesel engine, provides the main source of power for the bench. The power passes through main clutch, speed and torque sensors, torque limiter, then arrives at torque divider, where it is split into two parts, one for the mechanical system of HMCVT, the other for the transmission hydraulic system. At the transmission output end, the two parts of power join together. And then, passing through torque limiter, speed and torque sensors, speed reducer, the power is absorbed by the DC dynamometer, the load resistance simulation device. According to the virtual accelerator pedal signal set by the host computer and the engine energy equation model, the engine controller controls the throttle opening. The auto-shift process of HMCVT is independently completed by its own controller. The load resistance simulation system, which utilizes DC motor as the loader, simulates all the conditions of HMCVT may be encountered in practical work process. And it also absorbs the power transmitted by the transmission system, then feedbacks to the power grid. The sensors collect torque and speed signals, convert them into electrical signals and send them to the data acquisition card. The measurement and control system completes the tasks of signal acquisition, analysis and processing during the trial, and monitors the trial process and working condition of the bench.

3. Hardware Configuration of Measurement and Control System

In the HMCVT performance test, there are many complex tasks for measurement and control system to deal with, such as the input/output rotational speed and torque of HMCVT, the input/output rotational speed of HMCVT hydraulic system, hydraulic oil pressure, hydraulic oil flow, the engine throttle opening, load torque generated by the load resistance simulation system [8-10].

According to the characteristics of the HMCVT performance test, the CYB-803S rotary torque/speed sensor, produced by Beijing Wister AVIC Electromechanical Technology Co., Ltd., has been chosen as the device to measure torque and speed of the transmission. It outputs square wave frequency signal or 4~20mA electric current signal, supplied by a transformer. The sensor has features of strong anti-interference ability, high detecting precision, good stability, and it can work for a long time at high speed. The paper selected the CYB-20S ion beam sputtered thin-film pressure sensor, produced by Beijing Wister AVIC Electromechanical Technology Co., Ltd., as the device to detect the pressure of the transmission hydraulic system. The sensor could work stably and reliably under high temperatures, high pressure. The output signal is 1~5 V standard voltage signal, and it can communicate with the data acquisition card directly.
hydraulic oil flow is measured by the LUGB intelligent vortex flow-meter. This series of sensors output 4~10mA standard current signal, and can be connected to the data acquisition card directly.

NI PCI-6229, M Series of multi-function data acquisition card produced by National Instruments (NI), was selected in the paper. The card is based on the PCI interface, with 32-channel analog inputs at 16 bits, and the sampling frequency could be up to 250kS/s. Each channel has programmable input ranges of ±10V, ±5V, ±1V to ±0.2V. The card has 4 analog outputs at 16 bits, the output rate is up to 833kS/s, and the conversion from the maximum amplitude to the minimum amplitude can be finished in 6µs. It has 48 TTL level digital I/O lines, including 32lines can work at 1MHz (hardware trigger). It offers two counter/timers, 6 DMA channels, which can execute multiple tasks at the same time. And if the card cooperates with NI-DAQmx measurement services software, driver incompatibilities and things like that can be easily solved. NI-MCal calibration technology is applied in the card, which makes it perform well in measurement accuracy.

The paper selected NI PXI-6602 card as the counter/timer. The card has an 8-channel and 32-bit subtraction counter/timer module, 32 digital I/O lines, and the maximum source frequency is up to 80MHz.

4. Principle of Measurement and Control System

The structure of measurement and control system is shown in Figure 2.

The sensors collect field test information, such as accelerator pedal position, engine oil temperature and pressure, cooling water temperature, and transform them into electronic signals for signal conditioning units processing. Then the signals will be delivered to engine controller, which is connected to the host computer via the CAN interface card 1. According to virtual accelerator pedal position set by the host computer and the actual obtained from the sensors, the engine controller controls the throttle opening degree, thus the engine speed will be under control. The transmission control units will independently control the behavior of HMCVT.
according to the test instruction sent by the host computer via the CAN interface card 2. The DC motor of the load resistance simulation system is controlled by the dynamometer controller, which is connected to the host computer via the CAN interface card 3. Some important parameters, such as the transmission input/output speed and torque, the hydraulic system pressure and flow, requires strict and real-time measurement, so they are sharing the CAN interface card 2, which works at high baud rate. Some parameters like temperature and the accelerator pedal position, the real-time requests of which is not high, share the CAN interface card 1, which works at low baud rate, so as to improve the anti-interference ability and the transmission distance. For the dynamometer system, the information needs to be exchanged seamlessly and in real time with the host computer when having quasi-dynamic tests of HMCVT. So it shares the CAN interface card 3 alone. In order to enhance the real-time processing ability of measurement and control system, the card works at high baud rate. As a host, the master adopts the general industrial computer, which takes charge of tasks such as experimental condition setting, coordination and management of subsystems, signal acquisition and data processing, etc.

4.1. Principle of Engine Control

According to the variation of the accelerator pedal set by the host computer, the target value of the engine speed is confirmed. The actual engine output speed is detected by speed sensor. And the speed difference between the reference and measured results will be send to the engine controller. The engine controller regulates the throttle position. In this way, the engine gets controlled. The principle of engine control is shown in Figure 3.

![Figure 3. Block Diagram of Engine Control System](image)

4.2. Principle of HMCVT Control

The control system of HMCVT communicates with the measurement and control system through CAN bus, receives the controlling commands from the latter and transmits the logging data to the host computer. And the automatic shift process of HMCVT is finished by its own control system.

4.3. Principle of Load Resistance Simulation System

In order to guarantee a smooth test system operation, the load resistance simulation system adopts two-variable closed-loop control system: By taking the output of rotating speed adjustor as the input of torque adjustor, then using the output of torque adjustor to control the load module. The concrete implementation process goes like this: The host computer calculates the driving resistance of the vehicle according to the vehicle structure parameters and working conditions set by the operator. Speed sensor detects the actual output rotate speed of dynamometer, with which the current acceleration of dynamometer can be calculated, and then the angular acceleration of the virtual vehicle acceleration at the next moment will be acquired, so does the electrical inertia simulation acceleration resistance, thus the reference resistance torque of dynamometer can be figured out. Compare the reference resistance torque of dynamometer against measurement results, and use the error as the input of DMC predictive controller. Then make use of the results of the DMC predictive controller to control the output torque of dynamometer. By this means, the system simulates resistance load. The principle of load resistance simulation system is shown in Figure 4.

![Figure 4. Block Diagram of Load Resistance Simulation System](image)
5. Design of Measurement and Control System Software

5.1. Selection of Software Development Tools

In the development of virtual instrument system, the combination of different function modules can form different function instruments [11]. In the paper, the measurement and control system software is developed on the software platform of LabVIEW, produced by the United States national instruments (NI) Co., Ltd. LabVIEW has been widely used in data acquisition and control, signal processing and data representation, etc. Different from traditional programming language, it is a graphical programming environment, using powerful graphical language, G language, and graphic symbols to create application programs. The execution sequence of the programs is determined by the data flow among the blocks. And they can process multiple tasks in parallel synchronously [12-13].

The frame diagram of measurement and control system software is shown in Figure 5.

The operation panel of the measurement and control system software serves as a bridge for information communication between operator and test bench. There are a lot of switch buttons and display controls on the panel, as shown in Figure 6, with which the information collected in the trial and working situation of the control system can be easily observed.
In the stepless speed regulation characteristics test of HMCVT, the software front panel, mainly includes the real-time display of rotating speed and torque, pump-motor system oil flow and pressure, as well as temperature monitoring for some essential parts of the bench, test system parameter setting and storage, stepless speed regulation characteristic curve drawing and display, etc. Before the trial, the system will have a self-checking. In the process of testing, the change of main parameters can be directly observed, so do the test results' processing and analyzing. The procedure of data collecting can be interrupted by pushing the “Pause” button at any time. When the test is finished, the testing data and content will be saved by pushing the “Save” button.

5.2. Software of Measurement and Control System

The software of measurement and control system for the test bench is designed with layered software architecture. According to the different objects of functions, it is divided into three main parts, instrument driver software, I/O interface software and user-oriented human-computer interaction main control software.

The instrument driver software is a set of programs for instrument control and communication, each instrument module has its own drivers, it is the link between the host computer and instruments. This part of the software will be provided by the instrument manufacturer in the form of source code, and it can be called directly in the application.

The I/O interface software plays an important role of connecting the slave computer with the host computer. Its main function is to complete the resource addressing, create and modify resources, report incidents, parallel control, etc. It is usually in the form of dynamic link library or static link library for system calls.

By using the technology of human-computer interaction in the development of the measurement and control system software, process control of the test, as well as real-time processing and display of test results can be easily accomplished. For this reason, it was adopted the object-oriented development method in the development of the main control software, and all of the work is finished on LabVIEW. The sketch of measurement and control system main control software is shown in Figure 7.
The measurement and control system main control software mainly consists of five modules: system parameter setting module, system calibration module, performance test module, data processing module and alarm module. Each module is composed of several sub-modules. The main function of the system parameter setting module is to manage hardware configuration of the data acquisition and transmission system, as well as to set the operating mode of engine and dynamometer. System calibration module, manually or automatically compensates for the experimental error caused by the system, adjusts for the offset, converts the electrical signal into a digital value for the computer to interpret and establishes numerical conversion relationship between the direct and indirect measurement. The performance test module selects test items to be carried out. According to the specific test requirements, it uses specific test methods and data acquisition & processing to accomplish the verification test of control strategy and method, stepless speed regulation characteristics, etc. The data processing module integrates many modules for on-line or off-line data analysis, database management, etc., which brings a lot of convenient for the data further processing after the test. The alarm module monitors the test bench system parameter to find whether it is beyond the alarm range during the operation, and makes corresponding response to provide security protection for the test system and the operator.

6. Test Results

In the field testing of measurement and control system for the HMCVT test bench, the operating conditions was set with engine speed of 2000 rpm, dynamometer load torque of 300 Nm, and the speed-ratio (the reciprocal of the transmission ratio) of HMCVT changing steplessly between 0.5~0.75. The output speed of HMCVT is shown in Figure 8, and the torque variation is shown in Figure 9. Figure 8 and Figure 9 show that, in the process of HMCVT stepless speed regulation experiment, the test bench works stable, has no sign of instability or runaway, and is capable to complete tasks set by experiment.
7. Conclusions

In the paper, a set of measurement and control system for HMCVT test bench based on LabVIEW is introduced, test results and theoretic analysis show that it performs well at real-time data acquisition and processing, and can meet the requirements of the test bench for automatic control. The technology of the virtual instrument is adopted in the system development, which simplifies the system structure, shortens the software development cycle and makes it easy to debug and maintain. Therefore, it can be a solution for the construction of HMCVT performance test bench.

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9. References