

A Computer Controlled Test Bench for Automotive Steering System

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Abstract: Test load is important in the test of the automotive steering system which greatly influences the test results. In this paper, different simulation methods for steering load were reviewed, and a new test bench for steering system was introduced, and the emphasis was on the steering load simulation and its control system. An AC servo motor was used as loading motor, which is controlled by a computer. Matlab/Simulink/ Real-Time Windows Target (RTWT) is used to model the system and calculate the steering load, and the control signal is sent to the AC servo motor. The angle signals of the steering wheel and the motor are feed back to the computer. Tests were conducted to verify the performance, and an automotive electric power steering device was tested on the bench. Test results showed the test bench worked well, and the design of control system is high efficient, powerful and easy to use.

Keywords: real-time simulation, steering test, steering test load, Matlab, Real-Time Windows Target

1. Introduction

Steering system is important for automobile because it influences the automotive controllability, stability and safety. Study of the steering system is essential, bench test is necessary due to the good repeatability, safety and low coat. However, test results differ widely from practice if steering load is not suitable. In this paper, some load simulation methods were examined, and then, a new test bench was introduced. The new test bench involves an AC servo motor controlled by a computer. The Matlab/Simulink/Real-Time Windows Target was adopted for data processing, i.e. getting signals of steering wheel angle and the AC motor angle, calculating the steering loading, sending control directions to the AC servo motor which loads the steering system. Due to the computer control, different steering load can be simulated in realtime.

2. Present Status

Several types of test bench for automotive steering system were developed, and each has its own characteristics in the implementation of test loading.

Helical spring is a simple, cheap, reliable loading device. According to publicly available information, such method was firstly adopted in Tsinghua University in China. Reference [1] shows the basic scheme, in which two helical springs load the each end of the rack of a rack and pinion type steering gear. Such load device was also reported in use in Zhejiang University, Tongji University, Jiangsu University, Hefei University of Technology, Chongqing Jiaotong University, et al. This type of test device play an important role in colleges and universities in the study of steering system, but such device is not flexible enough to simulate steering load in various working conditions. For example, in one hand, static steering torque during parking maneuvers is mainly due to the Coulomb friction between tire contact patch across the road surface, and the direction of the Coulomb friction is the opposite of the rotation of the tire, but the simulation force produced by the helical spring always points to its free status. In another hand, aligning torque of a motor vehicle changes with speed, and one or several types of springs can hardly simulate such steering load when speed changes continuously.

Magnetic particle brake is another loading device [2]. Torque of magnetic particle brake is determined by the excitation current, which can be controlled by computer. Theoretically speaking, magnetic particle brake can simulate Coulomb friction ideally, such case is much like parking maneuvers. But Coulomb friction is not all the steering load even if during static steering, because apart from Coulomb friction, steering load includes the torque generated by vertical force moments [3]. As automobile runs, aligning torque duo to the lateral force is also part, even the main part of the steering load, which can not be simulated by magnetic particle brake. In the aligning torque simulation, magnetic particle brake dose even worse than the helical spring.

Static chassis is also a loading device, which use part of the chassis including one or two tires as well as suspension and some counterweigh [4].Such simulation load is quite similar to that during static steering, but just as the magnetic particle brake, such device hardly simulates the aligning torque due to the lateral force.

Hydraulic system is also a common loading device [5]. Hydraulic servomechanism can simulate steering

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load in various conditions, but high cost puts it at a disadvantage.

3. The New Test Bench

A new test bench was developed, as in Fig. 1. The highlight is the loading device which is an AC servo motor controlled by a computer, and the key is the control program. When the steering wheel is turned, the rack and pinion steering gear runs at the same time, and the output end of the rack was loaded by an AC servo motor with a reduction gear and a rack and pinion device. The steering wheel angle and the AC servo motor angle were measured by two incremental photoelectric encoders which feed back to the computer, and the computer, based on the two angle signals and vehicle parameters as well as given working conditions, calculate the steering load, then sent directions to the AC servo motor. The motor can run with 1000Hz response frequency, which is much higher than the human handling of the steering wheel.



Figure 1. The new test bench

Because the rotation speed of the steering wheel is much slower than the rated speed of the AC servo motor while the rated torque of the motor is much less than the steering torque, a reduction gear was used to magnify the motor torque and reduce its speed in according with the working condition of the steering wheel.

Incremental photoelectric encodes were selected for angle measurement because it has no accumulative error, and the number of the pulses per revolution (ppr) determines its precision. The two encodes are the same with 2500ppr, so resolution as high as one ten-thousandth revolution can be obtained if their two — way orthogonal signals, usually named A and B, are quadrupled.

There are two ways for turning the steering wheel, one way is manual, and the other is motor-driven, so subjective and objective evaluation can be conducted. The steering wheel is also driven by an AC servo motor; the AC servo motor has three working modes, i.e. torque mode, speed mode and position mode. Good repeatability is another advantage in the way of motor-driven.

To a large extent, the loading AC servo motor determined the performance of the bench, and the control system determines how the AC servo motor works. Because the main purpose of this test bench is to be used in lab and not in the product line for product testing, the control system must be flexible enough. Moreover, implement of the control algorithm should be accurate and rapid. Nowadays, Windows operating system is widely used, so Windows based software is favorable. In control system design, Matlab and its many toolboxes are very popular, which provide an integrated environment for designers to model, simulate and implement the control strategy. In addition, test data can be collected and visualized in realtime with Matlab.

4. Control System Based on the Real-Time Windows Target

4.1. Principle of the Real-Time Windows Target (RTWT)

RTWT is a Matlab toolbox developed by the Mathworks, Inc. which provides an environment to execute real-time simulation with a single computer as host and target. If added appropriate I/O devices in the computer, the realtime application can exchange information with outside, so such toolbox provides a cheap platform for carrying out real-time simulation [6].

Structure of the RTWT is shown in Fig. 2, the Matlab/Simulink runs on Windows OS, the RTWT runs on the real-time kernel, and they communicate with each other through shared memory. The real-time kernel and the RTWT run at CPU ring zero, and have the highest priority, which enables the target direct access to I/O registers [6, 7]. For simple task, sampling rates exceeding 10 kHz can be achieved on Pentium computers. Besides, the RTWT can be used for teaching concepts and procedures for modeling, simulating, testing real-time systems, and iterating designs.



Figure 2. Structure of the RTWT system

Simulink blocks can be automatically converted into executable code with Real-Time Workshop, Stateflow Coder (optional) and the Open Watcom C/C++ compiler in minutes, which greatly improves efficiency and minimizes errors.

4.2. Frame of the Control System

The core of the control system is an IPC-610 industry computer with one PCL-812PG board and one PCI-1720 board from the Advantech Co., Ltd. The computer use a Intel Pentium 4 2.8 GHz Processor. The PCL-812PG



board fulfills analog signal input, digital signal input and output, and the PCI-1720 board outputs analog signals which include directions for the AC servo motor and other signals for specific steering system, for example, engine rotation speed signal for electric power steering system.

The PCL-812PG board has no special counters for the signals of the two encodes, so additional counters are necessary which count the two — way orthogonal signals, quadruple them and output digital signals to the digital input channels of the PCL-812PG board. In this process, a digital control signal from the board is needed which latches and enables the output signals. After the signals are sent to the PCL-812PG board, the control signal should change its level for the next reading. So, the control signal should change two times in one sample time. Three methods were discussed and the problem was resolved successfully [8].

5. Tests

Currently, the simulation device is in debugging, and a simulation of static steering was conducted. The steering system is electrically powered, and the control system with Simulink model is in Fig. 3. The model send a vehi-

cle speed signal via the second digital output channel of the PCL-812PG board and a engine rotation speed signal via the fourth analog output channel of the PCI-1720 board. Control signal of the counter was from the first digital output channel of the PCL-812PG board, and the result of the counter feed to the digital input channels of the PCL-812PG board. A subsystem AnglePro was designed to process the input angle signals and output control signal to the AC servo motor via the first analog output channel of the PCI-1720 board.

Test of static steering effort of a car was conducted, and the result was shown in Fig. 4. Bench tests were then conducted, and the steering effort without power assistance was shown in Fig. 5 while the steering effort with power assistance was shown in Fig. 6. In the tests, steering wheel was turned manually. Fig. 4. and Fig. 5 are similar, which indicates the bench can simulate static steering to a considerable extent. We will do more to improve the simulation results in the future. Compared with Fig. 5, Fig. 6 shows that power assistance can greatly reduce the steering efforts, which also indicate the vehicle speed signal and engine rotation speed signal are effective. In all the tests, the sample time is 1 ms, and the signals can be visualized on the scope block in real-time.







Figure 5. Test on the test bench without assistance





Figure 6. Test on the test bench with assistance

6. Conclusion

A steering test bench was developed, and the key part focus on the control system based on Real-Time Windows Target. Tests were conducted, and the results show that the device can simulate the steering load to a considerable extent. The tests also indicate that the Real-Time Windows Target is a powerful means in control system design, implement and analysis. Such tools can free designers from the complicate coding; enable it possible that researchers can concentrate on the key problems in the steering system. The ultimate goal of this project is to build hardware in the loop simulation platform for automotive steering system.

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