Design of Durability Testing System for Motorcycle Engine ECU
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ABSTRACT

According to the durability testing principle, an open, high intelligent and practical durability testing system was designed. In this system, various sensor signals and executive loads of the engine are provided to simulate the on-line environment of a real vehicle for ECU. Though the CAN based communication network, the monitor card sends the testing data to the management software, and the durability testing report is automatically generated for developers. This system greatly reduces the testing cost and shortens the development cycle.

Keywords: Durability testing, Electronic Control Unit, Motorcycle, CAN-Bus

1. INTRODUCTION

For the new emission standard of motorcycle to be implanted greatly increases restrictions on gas emission in China, it is foreseeable that electronic fuel injection (EFI) will replace conventional mechanical hydraulic control system in the early future. As the core component of EFI system, electronic control unit (ECU) plays a significant role in improving the fuel economy, exhaust emission and dynamic properties of motorcycle engine. It fine-tunes the engine air-fuel ratio according to different working conditions.

Motorcycle engine ECU works in harsh conditions with high speed and pulling torque, so there are high requirements to the performance of waterproof, dustproof and shockproof. The quality of the new designed ECU module is related to the conditions of design, manufacture, materials and quality management etc. If a major change is carried out in the development or production process, durability testing should be taken to find out the potential problems.

Durability testing is the last and most important process in the development of ECU, as well as a very expensive one if some cost-effective methods were not taken. The existing key technologies at present are handled in several famous international companies, such as Germany’s Bosch, United States’ Delphi and Visteon. Nowadays the domestic companies and universities have begun to pay more and more attentions to the study of durability testing technologies. Durability test specification is the basis of durability testing. However, the design and test technology of ECU abroad is highly trade secret, and in our country there is no relevant durability testing standard for the engine ECU yet. So the deep meaning of this research is to establish durability test specification with independent intellectual property by theory analysis and experimental results.

For complicated ECU strategies, a large number of very precise and dynamically synchronized input stimulus is required to simulate all inputs and outputs of the device. So it is almost unavailable to test the designed ECU in real vehicle for the highly time and money costs. The final goal of this research is to establish a system to simulate the working environment of the real vehicle for ECU, so the durability testing could be carried out in laboratory.

2. ECU DURABILITY TESTING PRINCIPLE

ECU module in EFI system collects the engine sensor signals, such as crankshaft position signal (CKP), vehicle speed signals (VSS), throttle position signals (TPS) etc. According to these input signals, it calculates the fuel pump pressure and amount of fuel to inject to get closed to ideal air-fuel ratio, so that the engine could operate in excellent fuel
economy and dynamic properties. ECU durability testing is carried out to predict or verify the weak and dangerous parts of the designed ECU. The testing result will provide data support for developers to update the ECU design.

During the testing process, different working conditions are provided by the simulated engine to maximum inspire the ECU internal defects with minimum time and capital costs. Module durability code (MDC) is software that runs in the ECU. When power is applied to the ECU module, the test software awaits for a command to determine whether to enter MDC. Whenever it is available, the MDC/ECU interacts with the durability testing system (DTP) which provides dynamic and static stimulus for inputs and loads for outputs to control and monitor its normal and specific operation.

The testing principle is shown in Figure 1 and Figure 2 shows a typical 24 hours durability testing cycle.

![Figure 1: ECU durability testing principle](image1)

![Figure 2: One 24 hours durability testing cycle](image2)

### 3. DESIGN OF THE ECU DURABILITY TESTING SYSTEM

Based on the principles of durability testing, an open, high intelligent and practical durability testing system is designed as shown in Figure 3. The simulation platform consists of signal generator, multi-load box, monitor card and environment box. The parameters such as temperature, humidity and voltage are controlled by the testing management software running on the industrial computer.

![Figure 3: System overview](image3)
3.1 Signal generator

For different motorcycle ECU modules, various input signals with different amplitude and frequency are required. Traditional signal generator only could produce fundamental signals such as sine, square, triangle waveforms, and the amplitude and frequency of them are uncontrollable as well. To solve these problems, direct digital frequency synthesis (DDS) method is applied in the design of signal generator, which is structured by ARM micro-controller and CPLD chip to provide special sensor signals for ECU, such as crankshaft position signal (CPS), throttle position signal (TPS) and air charge temperature (ACT) signal, etc.

The circuit diagram is shown as in Figure 4.

![Diagram of generating CPS signal based on DDS technology](image)

As the core part of DDS technology, phase accumulator is realized by a chip of CPLD chip Isp1048E to generate arbitrary waveforms. Isp1048E is controlled by ARM to generate address signals to read the waveform data pre-saved in the EEPROM periodically. Assuming that the bit of phase accumulator is $N$, the frequency control word is $K$, the system clock frequency is $f_{clk}$, then the output signal frequency is $f_{out} = f_{clk} \times K / 2^N$.

Through the management software, the signal amplitude and frequency are controllable by changing frequency control word $K$. Taking CPS signal for example, the engineer could control the system to generate 36-1, 60-1 and 36-2 signal to test different ECU modules. Fig.2 shows the generated waveform of 36-1 CPS signal.

![Waveform of 36-1 CPS signal](image)

3.2 Multi-load box

In this paper, multi-load box is designed to simulate the executive device on motorcycle engine, such as ignition coil and fuel injector. Due to the inductive and resistive characteristic of different devices, the multi-load box is represented in the
form of inductance and resistances to simulate. Based on the comprehensive analysis of general and special characteristics of executive loads, 8 types of load cards are designed and they could be divided into general load card and special load card.

Between ECU and muti-load box, a relay switch matrix is designed for expansion. To different testing strategies, the management software controls the relay switch to make different combinations, so different types of ECU modules could be tested.

3.3 Monitor card

During the durability testing, the output signals of ECU, such as injection signal and ignition signal, are monitored by the monitor card which is implemented by ARM micro-controller and CPLD chip. By comparing the timing and phase, the monitor card judges whether the output signals and the connection of load box are corrected. The error of ECU output signal is recorded as ‘ECUError’ and the error of load card connection as ‘LOADError’. If any type of the errors is detected, the monitor card sends it to the management software to generate the error report.

Fuel injection and ignition signal directly affects the motorcycle operating conditions. So it is particular important to monitor the cycle and timing of them and the monitoring process is as follows:

1) Converting the CKP to sync signal PIP by square wave conversion, and then sending it to monitor card as the input reference signal.
2) Converting the ECU output signals to TTL level, and then sending it to monitor card as well.
3) The CPLD chip on monitor card, which has been programmed already, takes the PIP as the reference signal and analyses the cycle, phase and timing of the output signals. The monitoring results are packaged into CAN data frame.
4) The monitor card accepts commends and sends the results to the management software through CAN bus communication network.

3.4 Communication network

In ECU durability testing system, various control commands and testing data are translated in communication network. It is difficult for traditional communication system to achieve strict time and reliability requirement of this system. According to field bus control theory and communication characteristics of this testing system, a real time, reliable and flexible communication network is designed based on CAN bus. As Figure 6 shows, this communication network includes some communication subnets, such as Kline, GPIB and RS485 as well.

During the test, signal generator is controlled by parameters which are sent through CAN0 subnet to generate signals with different amplitude and frequency, and the generated signals will input to ECU module. The CAN-KLINE conversion interface is designed on signal generator, so it is easily to test ECU modules with different communication interface. The monitor card monitors the operating state of the system and the testing data are translated through CAN1 subnet to management software. They are divided into ‘ECUError’ and ‘LOADError’ to record. By expanding the CAN subnet, it is easily to test several ECU modules at the same time.

GPIB bus is mainly used for the host computer to control the high-power DC power supply to simulate motorcycle battery and generator. Through the RS485 communication bus, the temperature box is controlled by the industrial computer which sends the parameters of environment box such as temperature and humidity to simulate the extreme running conditions of motorcycle ECU.

3.5 Management software

The management software is designed based on the testing specification to control the durability testing system, and its structure is shown as Figure 7.
According to different ECU modules and durability test requirement, dozens of expert testing strategies are preset in the management software. They consist of different environmental parameters such as power voltage, humidity and temperature to control the environment box to simulate the real operating conditions. Meanwhile, it is also available for the developer to customize strategies to achieve special testing requirement.

The management software constantly reads the state of ECU module and simulation platform with high frequency. These large amounts of test data are the basis of durability test. An effective data base is designed to solve the problem of high-speed data storage, backup and query. Based on this structure, the management software provides accurate, comprehensive and multiple forms of testing reports for developers to improve the design of ECU module.

And also, friendly user interface is designed in this management software. It is convenient for developers to choose testing strategies and monitor the whole test process, just as show in Figure 8.

4. CONCLUSIONS

To simulate the operating environment of motorcycle engine ECU, in this paper, a simulation platform together with an intelligent management software are established by applying ARM, DDS and CAN technologies in the durability testing system. When the durability testing is carried out, the working condition of ECU is monitored to check whether it meets the relevant standards. This system has the characteristics of versatility and scalability, and thus it is convenient to test
different ECU modules under different test strategies. By the expansion of CAN subnets, it is realized to test 12 ECU modules at the same time, which can greatly reduce the developing cost and improve the testing efficiency.

REFERENCES