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Evaluation of Control System for Mode Change Clutch of HEV by using Embedded System

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Abstract

Environmental pollution and resources exhaustion are problems of the whole world. Therefore, a lot of vehicle industries try to make a vehicle with high fuel efficiency and an eco-friendly vehicle. Especially HEV (hybrid electric vehicle) is the focus. In this paper, HEV is composed the engine, motor, battery, transmission, HCU (Hybrid Control Unit) and mode change clutch between an engine and a motor. The Bench Tester has a pre-transmission double-shaft torque combination parallel hybrid electric drive train performed as a real HEV. Performance test of Mode Change Clutch, controlled by Embedded System based on 32-bit MPC556 and communicated by FlexRay, is accomplished.

Keywords: HEV (Hybrid Electric Vehicle), control system, transmission, powertrain

1 Introduction

As you know, a LEV (Low Emission Vehicle) is essential not selectivity. Most of vehicle companies have a goal which is a ZEV (Zero Emission Vehicle). A ZEV doesn't exhaust pollution gas. Furthermore, the world best vehicle company TOYOTA has a plan; it is going to make an air cleaning car. The more it runs, the more cleanly the air pollution. And the GM launches out the EV (Electric Vehicle) 'Volt'. That shows us, most of Vehicle Company has enthusiasm of researching an environment-friendly car and a high-efficiency car.

In this paper, a goal is application of HEV (Hybrid Electric Vehicle). HEV is transition of a dream ZEV. The HEV consists of the components such as the engine, motor, battery, transmission, regenerative braking, ECU and HCU (Hybrid Control Unit). We made a Bench tester having a mode change clutch. The mode change clutch is situated between the engine and the motor. The double-shaft torque combination parallel hybrid electric drive train, bench tester copied from a quarter real car, which has a mode change clutch controller based on 32-bit embedded system.

2 Configuration of Bench Tester

A double-shaft torque combination parallel hybrid electric vehicle has the mode change clutch between an engine and a motor. Therefore, it has the advantage which excludes engine loads on the EV mode or regenerative braking. However, while it is changed the mode, the change makes torque shocks or delays of acceleration. While changing the EV mode to the HEV mode, a motor is already running very fast according to vehicle speeds. However, the engine is starting from the idling state. So if the clutch attaches quickly to the engine, the engine can sometimes stop because of speed gaps of clutch before and after. If a time for attach is long, it has a low power efficiency which makes delays of an acceleration.

So developing of a double-shaft torque combination parallel hybrid electric vehicle in a mode change clutch system must need the attaching time of the engine and clutch, an attaching speed and the speed gap of the engine and motor. This situation is required the Bench Tester copying a double-shaft torque combination parallel hybrid electric vehicle. Figure 1 shows the whole structure. And Table.1 shows the parts specifications of each component.

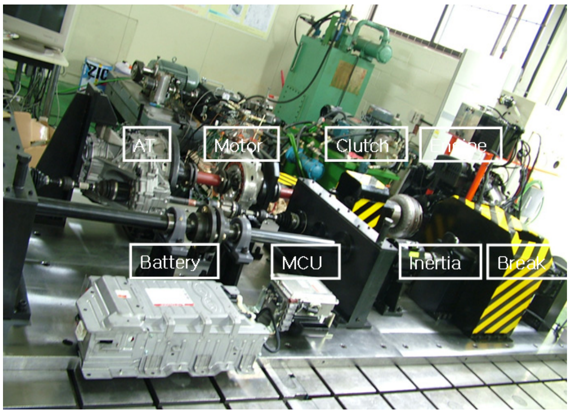

Figure 1: Out view of bench tester

2.1 Engine

The engine of the bench tester is a 1000cc SOHC type. Its maximum power is 61PS/5600rpm, and the maximum torque is 8.8kgf.m/4500rpm. And the ECU (Engine control unit) controls the engine. An amount of throttle opening is controlled by a servo motor. Figure 2 shows the engine part of bench tester.

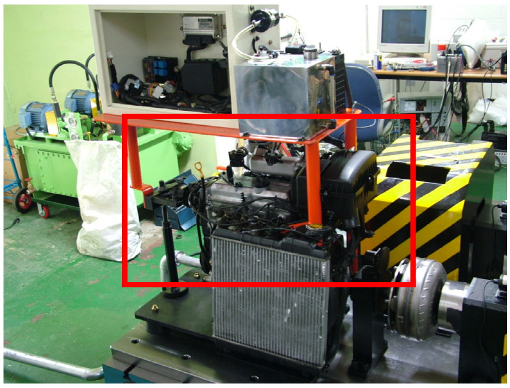

Figure 2: Engine part of bench tester

2.2 Mode Change Clutch

The mode change clutch is made of a torque converter's lock-up clutch. We remove blades in the torque converter. If the state of clutch is lock-up, power is transmitted. The mode change clutch and a torque converter in an automatic transmission are wet-type multiple disk clutches. Figure 3 shows the configuration of the mode change clutch.

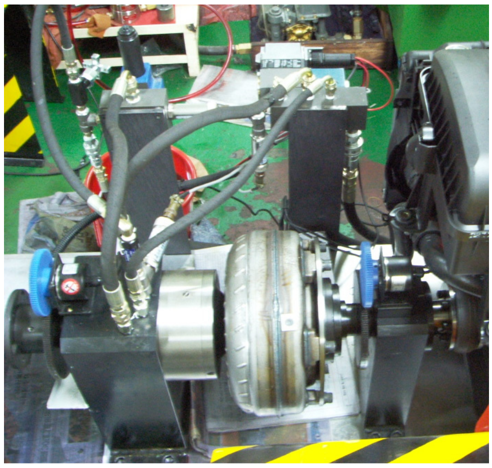

Figure 3: Mode change clutch

Table1: Specifications of Components

	Specification	Controlled Value	Sensor / Actuator
Engine	1000cc SOHC 61PS@6500rpm	Throttle angle	Servo Motor
Mode change Clutch	Torque converter Lock-up clutch	Oil pressure	Input/Output pressure, Servo Valve
Motor	PMSM 12kW	Motor torque	MCU(Motor Control Unit), CAN
Battery	12kW Ni-MH	SOC	BMS(Battery Management system), CAN
Transmission	Small front wheel drive fourth gear auto transmission	Oil pressure	Solenoid Valve pressure, CAN
Driving Load	Inertia:15.625kg·m^2(500kg, 0.25m)	Output torque	Torque sensor

2.3 Motor/Battery System

The role of motor in HEV is a rotational power source on a driving state and a generator on a regenerative braking state or a charging state. The generator charge batteries. The motor has maximum torque, 97Nm on maximum power at 1200 rpm. It is a 12kW PMSM (Permanent Magnet Synchronous Motor). And the motor is controlled by MCU (Motor Control Unit). The battery is a 12kW Ni-MH high-voltage battery. The DC electricity is transformed to 3-phase AC electricity. And AC electricity supply to the motor power. The battery is controlled by BMS (Battery Management System). The left picture of Figure 4 is Motor. Figure 4 shows the motor, MCU and the Battery, BMS.

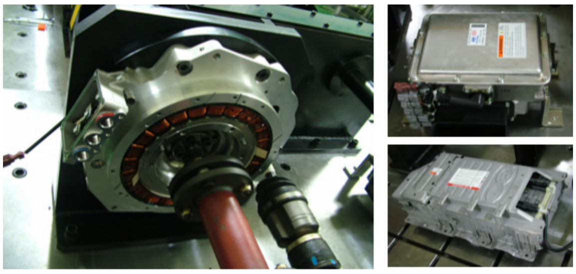

Figure 4: Motor & MCU and battery & BMS

2.4 Automatic Transmission

The transmission of the bench tester is a front wheel drive, 4-speed automatic transmission that constructed of a torque converter and power transfer part (single planetary gear 2 pieces, disk type clutch 3 pieces, disk type brake 1 piece, band brake 1 piece and one-way clutch 1 piece). The changing of planetary gear is controlled by the connection or braking of front/rear construction parts. Figure 5 shows the auto transmission.

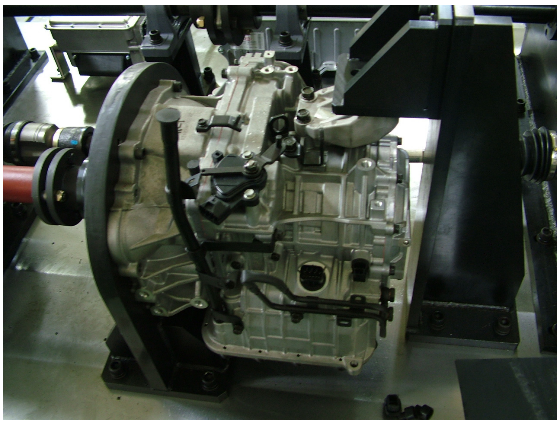

Figure 5: Automatic transmission

2.5 Inertial Load

For simulating the inertia of vehicle, a fly wheel has a mass of 500kg, a radius of 0.25m and the rotational inertia is 15.625kg$\cdot$m^2. It has a brake system using a screw type cylinder. Figure 6 shows the brake system and Figure 7 shows the flywheel.

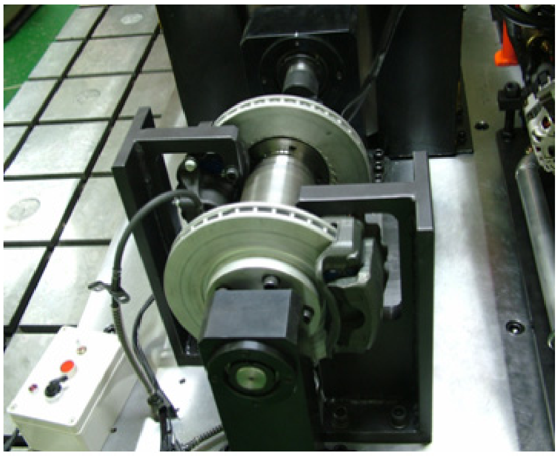

Figure 6: Brake system

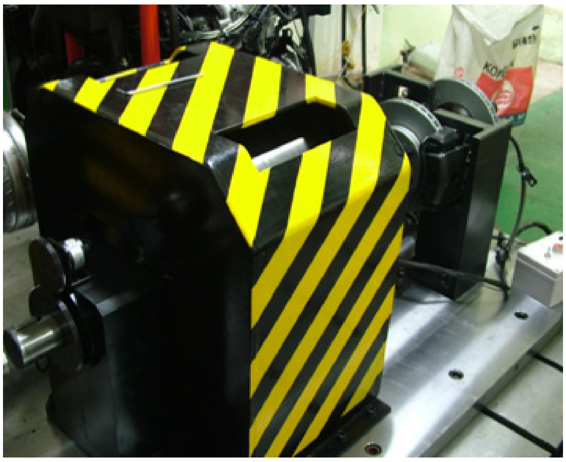

Figure 7: Flywheel

3 Embedded System Environment

3.1 32-Bit Embedded System

The MPC556 with 1Mbyte Flash memory is made by the Motorola Company for vehicle industry. It has a 32-bit embedded processor which is based on a high performance Power PC core for total controls in a vehicle. And it runs 56MHz maximum and it has module which can interact with peripheral devices. The 32-bit high performance embedded system is implemented, because the 32-bit processor will be the main trend of vehicle embedded market even better than a stable 8-bit processor.

3.2 Function of Embedded System

Main function of MPC556 is whole vehicle controller. MPC556 has 40 dual ADC channels and 56 I/O channels. The FlexRay communication of Single/Dual channel is able to communicate in 64 maximum nodes. Figure 8 shows the MPC556 block diagram

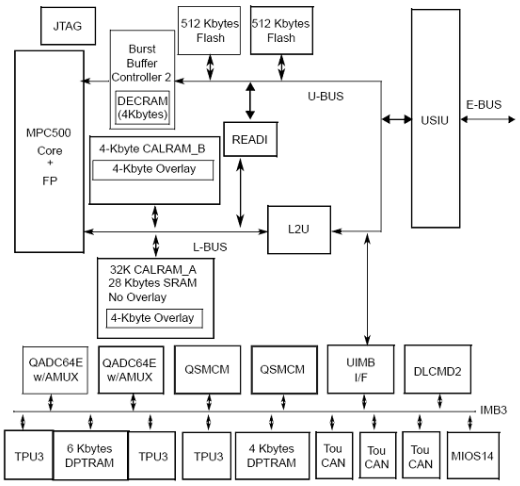

Figure 8: MPC556 block diagram

4 Embedded Control System

4.1 Throttle Position Control

For controlling the throttle position of the engine in bench tester, the embedded board is used. To control the throttle position actuator, the DC servo motor is implemented. This servo motor is controlled by PWM signals of the embedded board. The embedded board compares the front speed of the clutch with the rear speed of the clutch. The inertia simulating a real vehicle speed is a rear position of the clutch. The rear speed of the clutch is a reference of the whole vehicle speed. The front of the clutch is an engine part. If rear speed of the clutch is low, embedded board reduces the front speed of the clutch. If the rear speed of the clutch is high, the controller increases the front speed of the clutch. And then if the front and rear speeds of the clutch is matched in the range of speed, the clutch is attached. Figure 9 shows the prototype of embedded board based on MPC556.

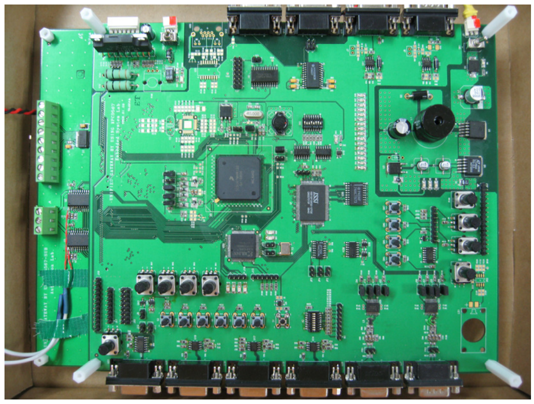

Figure 9: Embedded board based on MPC556

4.2 Mode Change Clutch Control

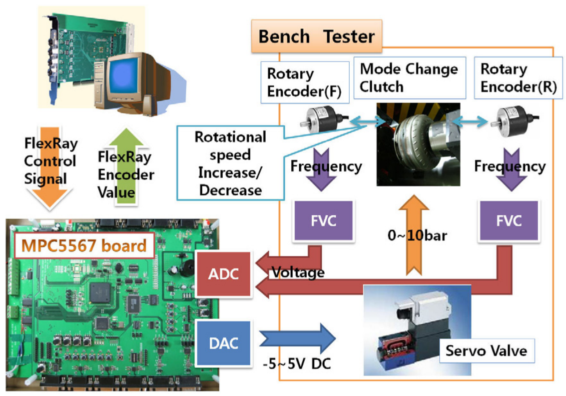

Figure 10: FlexRay communication configuration with MPC556 system

The Figure 10 shows a FlexRay communication configuration with the 32-bit embedded system which is based on the MPC556. The FlexRay communication with a PC and the embedded board can control the servo valve that controls the oil pressure. Then the mode is changed as on/off. The Figure 11 shows that the embedded board communicates each front/back speed of the mode change clutch to the PC. The embedded board receives the speed of automatic transmission output shaft using CAN. The CAN signals changes to FlexRay by the embedded board. The PC for user interface displays the graph of FlexRay communication results (Figure 12). This figure shows that two different signals from encoder and output speed of the automatic transmission are the same.

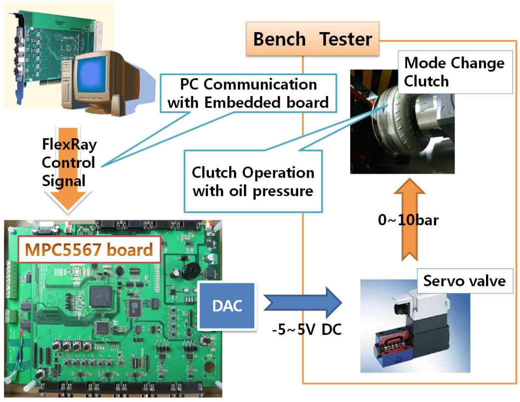

Figure 11: Control signal to actuator

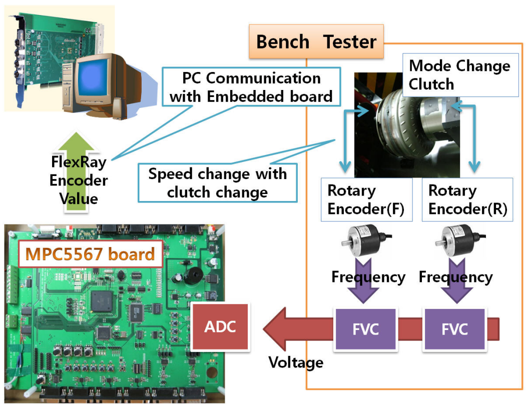

Figure 12: Input signals by sensors

Figure 13 shows the FlexRay monitoring program and experimental results. The left side of Figure13 is a user interface display for setting the FlexRay configuration and the right side shows a experimental results graph. The upper line (Red) is a front rotary encoder speed and the lower line (Blue) is a rear rotary encoder speed. When overlapping the upper line with the lower line, it means that the mode change clutch has been actuated to change the mode. During the mode change process, the embedded board communicates with the PC by FlexRay.

5 Conclusion

The bench tester including an engine, transmission, motor, battery, and mode change clutch is implemented. The mode change clutch plays a role to change the power source between the engine and the motor. The bench tester that has double-shaft torque combination parallel hybrid electric drive train simulates a quarter car. The controller of mode change clutch is implemented based on 32-bit embedded system that can do FlexRay communication. The power mode between the engine and motor could be changed according to the control signal of the embedded board. In addition to, the experimental results show that the CAN signals are converted into the FlexRay signals well. For the future work, the break control unit based on the embedded system will be implemented.

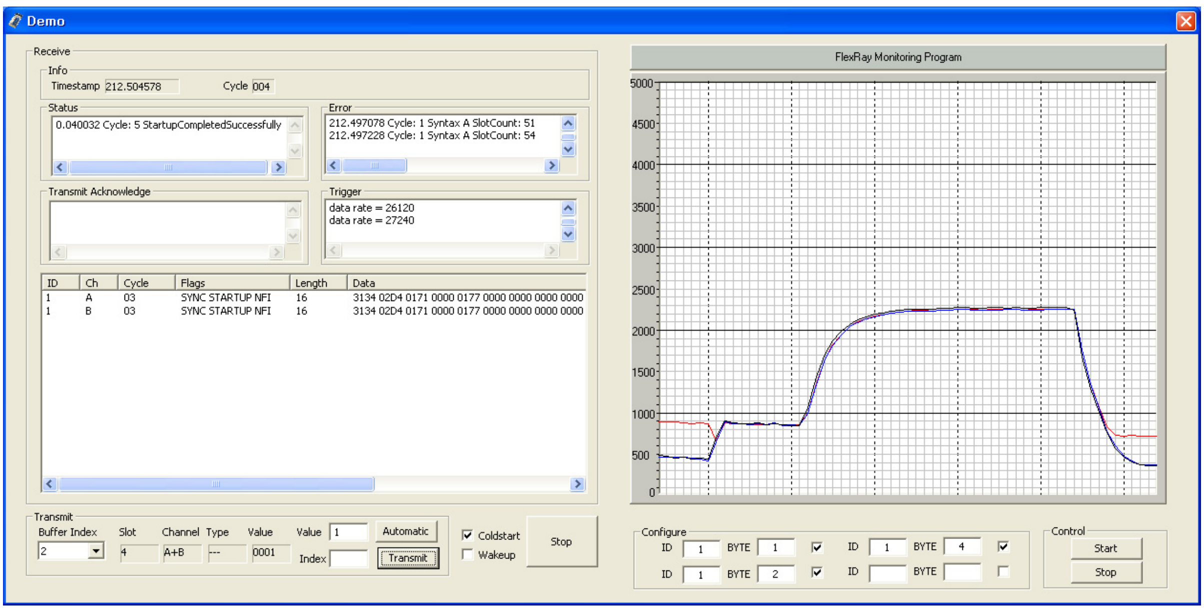

Figure 13: FlexRay monitoring program

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