3D2-2

Proceedings of the 6th JFPS International
Symposium on Fluid Power, TSUKUBA 2005
November 7-10, 2005

Design and Implementation of Lab. Simulator for Vehicle Control

Jeongdai Jo*, Dong-Soo Kim*, Kwang-Young Kim*, and Hyung-Eui Kim**

* Division of Intelligence & Precision Machine Research, IT Machinery Research Center
Korea Institute of Machinery & Materials(KIMM)
#171, Jang-dong, Yuseong-gu, Daejeon, 305-343, Korea
(E-mail: micro@kimm.re.kr)
** Division of System Engineering Research, Mechanical Systems Reliability Research Center
Korea Institute of Machinery & Materials(KIMM)
#171, Jang-dong, Yuseong-gu, Daejeon, 305-343, Korea

ABSTRACT

The Lab. simulator for conducting a performance test and a reliability test on a vehicle and components has been designed and embodied. In order to control non-linear of a vehicle, a fuzzy control algorithm, a running mode tracking algorithm and a vehicle speed control algorithm were applied to the actuator control. The vehicle controller functions were implemented; setup of the actuator, position control, the gear shift control depending upon the vehicle RPM, the serial interface function for data communication and control with the servo controller, and transmitting and receiving data. The servo controller performed the function to drive the actuator by controlling the pneumatic servo valve, and measured data information such as a position, a velocity and an acceleration as obtained through operation by means of the second differentiator and controlled a position precisely. An experimental apparatus was consisted of a dynamometer and a vehicle, and the performance and durability of the controller was verified. The Lab. simulator was mounted onto the vehicle, and the position control test and a LAP mode tracking test were conducted. It was found that the response characteristic, the tracking capability and precision of the position control were so excellent.

KEY WORDS

Lab. simulator, Vehicle controller, Servo controller, LAP mode tracking test

NOMENCLATURE

u *: Output Feedback Control Input*
K_p *: Position Control Gain*
K_v *: Speed Control Gain*
K_a *: Acceleration Control Gain*
x_d *: Object Position Input*
x *: Position Output of Actuator Load Mass*
$\dot{x}$ *: Speed Output of Actuator Load Mass*
$\ddot{x}$ *: Acceleration Output of Actuator Load Mass*
e *: Position Error*

INTRODUCTION

The Technologies used in a vehicle control simulator can be categorized into a servo actuator control technology, a fractional technology of the computer

interface technology, a vehicle control technology and a vehicle-related test system technology pertaining to the system integration technology[1]. The Lab. simulator (comprising a vehicle controller and a servo controller) for conducting a performance test and a reliability test on a vehicle and components has been designed and embodied. In order to control non-linear characteristics of a vehicle, a fuzzy control algorithm, a running mode tracking algorithm and a vehicle speed control algorithm were applied to it[2]. The Lab. simulator comprised a vehicle controller having functions for controlling, obtaining data, receiving vehicle information and processing control signals, a servo controller for controlling an actuator and processing data, a second differentiator for producing a position, a velocity and an acceleration and a serial interface converter[3].
An experimental apparatus was consisted of a chassis dynamometer and a vehicle of 1500cc displacement, and the performance and durability of the controller was verified. The Lab. simulator was mounted onto the vehicle, and a basic control characteristic test and a LAP mode tracking test were conducted[4]. As a result, it was found that the response characteristic, the tracking capability and precision of the position control were so excellent that it would be possible to use it as a vehicle controller. It is thought that the Lab. simulator for controlling a vehicle will be greatly applicable to the whole industry related to vehicle technology as well as the auto pilot system, including development and test of a test system to which it is applied, particularly, the mileage accumulator test, the exhaust gas measurement test, the fuel consumption test, the environment test, the noise measurement test and so on.

DESIGN OF LAB. SIMULATOR

Design of Control Algorithm

The Lab. simulator was designed by means of the fuzzy control algorithm for the vehicle controller, the position and load control algorithm for the servo controller and the interface software. The vehicle controller was designed so that it could be received a vehicle speed from the running mode and the control software, produce a displacement of the actuator according to the situation and further transmit it to the servo controller. The servo controller controlled a position and a load of the actuator, and it was designed so that it could be received an instruction value from the actuator of the vehicle control system and control feedback. Such designed servo control algorithm enables feedback of a position and a velocity and an acceleration as obtained by differentiating it. In order to implement fast response, high precise position control, tracking control performance, the position and load control algorithm, the speed control algorithm and the tracking control algorithm were applied to the actuator control.

The structure of the servo control algorithm is as shown in Figure 1, and the control input for consist of the controller is as in Eq. (1).

$$u = K_p \cdot e - K_v \cdot \dot{x} - K_a \cdot \ddot{x} \tag{1}$$

Wherein,

$$u = [u_1 \; u_2 \; u_3 \; u_4 \; u_5]$$
$$u = [K_{p1} \; K_{p2} \; K_{p3} \; K_{p4} \; K_{p5}]$$
$$u = [K_{v1} \; K_{v2} \; K_{v3} \; K_{v4} \; K_{v5}]$$
$$u = [K_{a1} \; K_{a2} \; K_{a3} \; K_{a4} \; K_{a5}]$$
$$u = [x_{d1} \; x_{d2} \; x_{d3} \; x_{d4} \; x_{d5}]$$
$$u = [x_1 \; x_2 \; x_3 \; x_4 \; x_5]$$
$$u = [u_1 \; u_2 \; u_3 \; u_4 \; u_5]$$
$$e := x_d - x = [e_1 \; e_2 \; e_3 \; e_4 \; e_5]$$
$$\dot{x} = [\dot{x}_1 \; \dot{x}_2 \; \dot{x}_3 \; \dot{x}_4 \; \dot{x}_5]$$
$$\ddot{x} = [\ddot{x}_1 \; \ddot{x}_2 \; \ddot{x}_3 \; \ddot{x}_4 \; \ddot{x}_5]$$

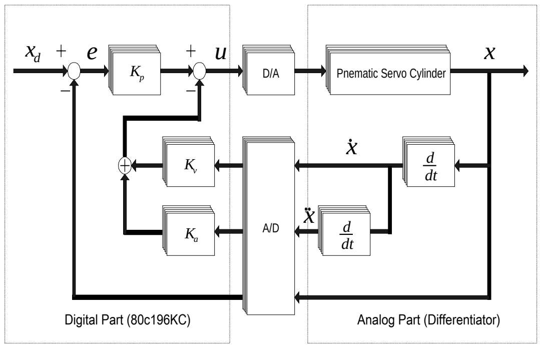


Figure 1 Block diagram of servo control algorithm

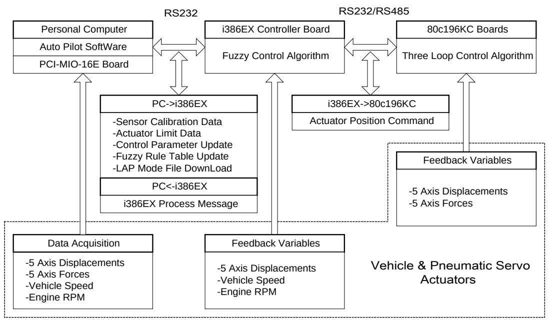


Figure 2 Control block diagram for implementation of the software

The vehicle control software for the Lab. simulator was designed so that it could be had the following functions: manipulation and renewal of system parameters, revision of controller information, real-time system monitoring, download of the running mode file, and saving and output of experimental results. It was designed in consideration of convenience and flexibility for the use so that if any vehicle information is changed, the controller information might be revised only by manipulating control parameters. Figure 2 is a control block diagram for implementation of the software.

Design of Controller

The vehicle controller was designed by means of the i386EX CPU board, and the servo controller was designed by means of the 80C196 CPU board[5][6]. Figure 3 shows a data linkage diagram of the vehicle control system comprising the vehicle controller, the servo controller, the actuator and the sensor. Through the vehicle controller, the following functions were implemented; setup of the actuator, position control, the gear shift control depending upon the vehicle RPM, the serial interface function for data communication and control with the servo controller, and transmitting and receiving data. The servo controller performed the function to drive the actuator by controlling the pneumatic servo valve, and measured data information such as a position, a velocity and an acceleration as obtained through operation by means of the second differentiator and controlled a position precisely.

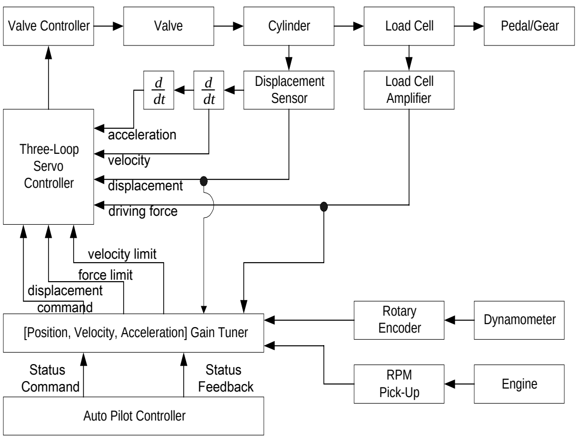


Figure 3 data linkage diagram of the vehicle control system

The serial interface converter(RS232/RS485) performed the bidirectional communication function to transmit an instruction on position and selection of the actuator from the vehicle controller to the servo controller and transmit the actuator status depending upon a position value to the vehicle controller[7]. The second differentiator, which was an analog circuit using an operational amplifier, produced a position, a velocity and an acceleration in consideration of driving characteristics of the actuator and performed the function to enhance the control performance by reducing a load to process data in place of the numerical operational function of the servo controller. Figure 4 is an image of the Lab. simulator comprising the vehicle controller of i386EX board and the servo controller of 80C196 board.

Figure 4 Image of the vehicle controller and the servo controller

EXPERIMENTS AND RESULTS

An experiment was conducted to verify the performance and the position control characteristic of the Lab. simulator for controlling a vehicle, which comprised the vehicle controller, the servo controller, the actuator and the sensor as shown in Figure 5.

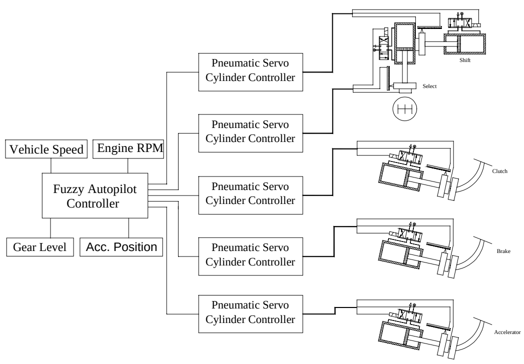


Figure 5 Schematic of Lab. simulator apparatus

The Lab. simulator was applied to the vehicle control system and then a position control experiment was conducted. Since the gear shift actuator requires the point-to-point position control, a step response experiment was conducted as illustrated in Figure 6. And, since the acceleration pedal actuator and the clutch pedal actuator had to tracking in process of time, each tracking control experiment in response to each input of the 0.25 Hz and 1Hz of the lamp wave and the sine wave was conducted as illustrated in Figure 7 and Figure 8. The Lab. simulator satisfied the target specification that any error of its performance and position control precision should be within ±1mm, and its excellent tracking capability was verified.

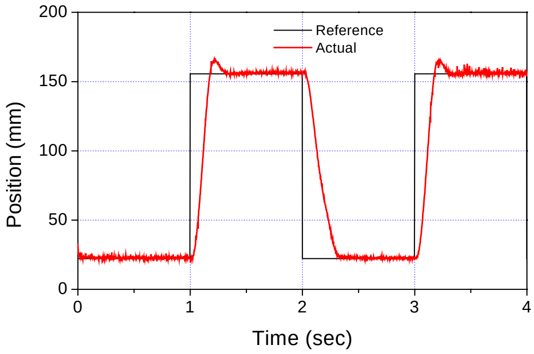
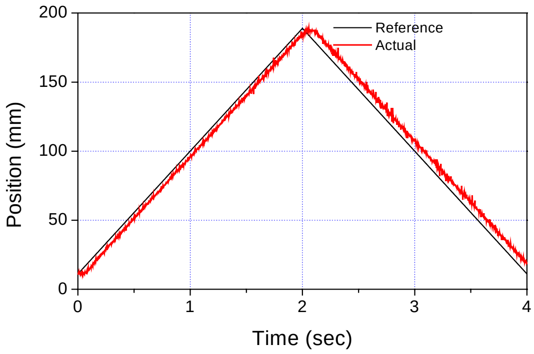
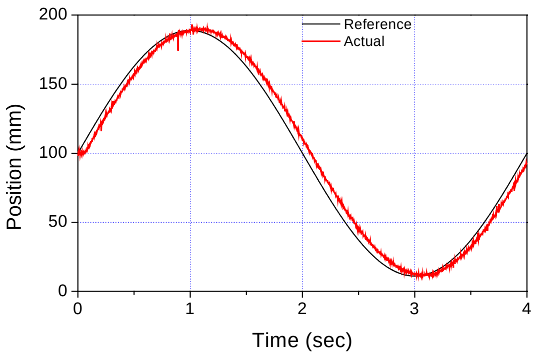


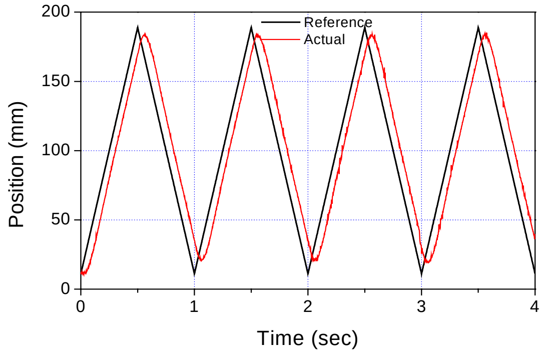
Figure 6 Result of step response test



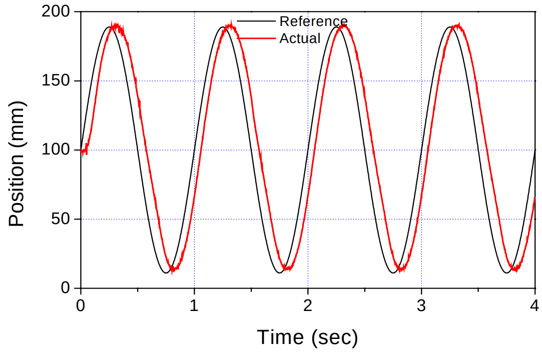
(a) Tracking test of ramp wave signal



(b) Tracking test of sine wave signal
Figure 7 Results of tracking test at input of 0.25Hz



(a) Tracking test of ramp wave signal



(b) Tracking test to sine wave signal
Figure 8 Results of tracking test at input of 1Hz

The vehicle control test was conducted in the running mode, and each result of the tracking control test as conducted in the JPN1015 LAP mode and the CVS test mode was described in Figure 9 and Figure 10. In the JPN1015 LAP mode, the said test was repeatedly and periodically conducted 10 times every 200 seconds, while in the CVS test mode, it was repeatedly and periodically conducted 10 times every 900 seconds. As a result of conducting the test, it could be verified that it was excellent in the tracking performance, durability and stability.

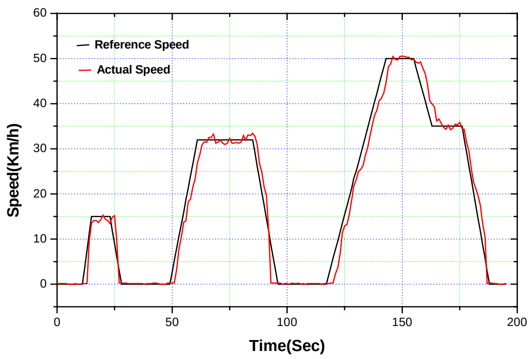


Figure 9 Result of tracking test at JPN1015 LAP mode

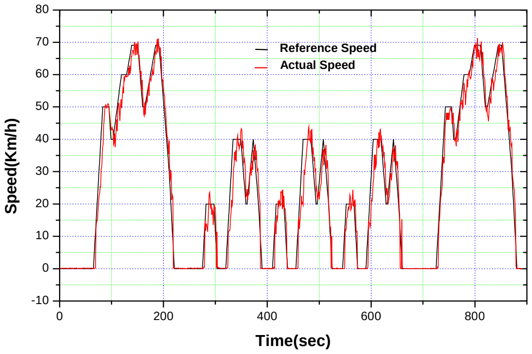


Figure 10 Result of tracking test at CVS test mode

CONCLUSIONS

The Lab. simulator comprising the vehicle controller and the servo controller was designed and embodied, and it was installed in an actual vehicle. Then, its performance and control characteristic experiment was conducted. The results of such experiment could be summarized as follows:

1) The step response experiment, the triangular wave and sine wave experiment and the LAP mode tracking test were conducted by using the Lab. simulator which was designed and embodied as above described, and as a result, its tracking capability and position control precision satisfied the target specification. And, it was verified that it was applicable to the vehicle test.

2) The vehicle controller and the servo controller were applied to the vehicle control system, and then a test was conducted. As a result, its repeatability, precision, control characteristic and stability were excellent.

3) It is thought that the Lab. simulator for controlling a vehicle will be greatly applicable to the whole industry related to vehicle technology as well as the auto pilot system, including development and test of a test system to which it is applied, particularly, the mileage accumulator test, the exhaust gas measurement test, the fuel consumption test, the environment test, the noise measurement test and so on.

REFERENCES

1. Hyung-Eui Kim et al, Develop Report of Auto Pilot Lab. Simulation, MOICE, 2000.
2. Jeongdai Jo et al, The Design of Lab. Simulator, *Proc of KSAE 2002*, pp445-449.
3. Auto Pilot Operation Manual, ATOMAX, 1992.
4. Lap Mode Test Sheet, EPA, 1996.
5. Intel 386EX Embedded Mocroprocessor User's Manual, Intel, 1996.
6. 8XC196Kx Microcontroller Family User's Manual, Intel, 1990.
7. In-Uk Kong et al, Intel 80386EX Microrobot Design, Ohm Inc., 1998.