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RESEARCH ARTICLE OPEN ACCESS

Development of Servo Actuator for Intrusion Simulator

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ABSTRACT
The servo actuator system can be used as a kind of tracking control system. The layout of our system consists of two main parts, pneumatic and hydraulic. Our current main goal is to simulate the piston velocity and acceleration generated by the impact force in the chamber. Our final goal in the future is to develop a simulator for vehicle crash testing through this study. The piston acceleration can be controlled by a hydraulic-operated friction brake system. The servo actuator system is initially transformed into a linear system description, and then a tracking controller is developed. Our system using FPGA-based PID controllers allows about 0.32 seconds of execution time to match our assumptions about the system requirements. The simulation results demonstrated the velocity, and acceleration reactions of the cylinders with nonlinear feedback control system. The simulation results have been shown to be consistent and in good agreement with the test data. The crash test is an important step in verifying a new car design. However, the high cost of the experimental test limits the number of crash tests and as a result, adequate data may not be obtained. In addition to safety assessment tests, vehicle crash simulators will therefore be a very important tool to reduce the time and cost of car development.

Keywords – Actuator, Tracking, Crash, Simulation

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I. INTRODUCTION

Pneumatic and hydraulic systems are very attractive and have advantages in many applications. Pneumatic systems are cheap, light, clean, easy to assemble, have a good force/weight ratio, and hydraulic systems have several major advantages, which are quite efficient at transmitting power[1-3]. For example, by using simple levers and push buttons, operators of hydraulic systems can easily start, stop, speed, and speed down. Fluid power systems can simply and efficiently multiply forces from a fraction of a pound (without cumbersome gears, pulleys, and levers) to hundreds of tons of output. Constant force and torque: only fluid power systems can provide constant torque or force regardless of speed changes. Hydraulic systems typically use fewer moving parts compared to mechanical and electrical systems[4-6]. They are therefore simpler and easier to maintain. This type of system, which is widely used in automobile crash test devices as an actuator. This is because crash test mechanisms require high response time and extreme power to take action. The layout of our system consists of two main parts, pneumatic and hydraulic. Therefore, we can call this system a hybrid actuator. Our main goal is to control the piston acceleration generated by the impact force within the chamber. In this system, the piston acceleration can be controlled by an additional hydraulic brake system. Typically, the hydraulic system uses an electro-hydraulic servo valve, which controls how hydraulic fluid is delivered to the actuator.

The duration of the control for the tracking speed and acceleration of a piston is very small, 0.32 seconds. This very narrow time requirement makes the problem difficult.

Crash experiments are essential elements to determine performance and safety in the manufacturing process of automobiles. However, the problem is that the price of one crash experiment is too high, so many companies and institutions cannot easily experiment. In fact, a significant fee is required to conduct crash experiments on automobiles in automotive parts technology research. In addition, even if the experiment is conducted by paying the amount, it is only one-time, so additional experiments are also difficult.

Therefore, it is necessary to introduce and develop a system capable of conducting a crash experiment that is directly related to the driver's safety several times.

The solution to this problem is the development of a collision simulator. A simulator is a model device that allows you to simulate physical phenomena and predict the results. With this concept, if the same force as the amount of impact generated in the actual collision is applied to the vehicle and the experiment through the simulator, the collision experiment can be avoided and the same effect can be obtained. The advantage of the simulator is that it is not only one-time, but it is possible to conduct a number of experiments, and the amount of impact and effect can be changed depending on the purpose of use in various ways. In addition, it can have a great effect in terms of money.

II. SYSTEM OPERATION PRINCIPLES

When boarding a vehicle, the intrusion of vehicle parts or other objects is one of the most common causes of injury to vehicle occupants in a traffic incident. An example of intrusion is when pressure is applied to a side door by another vehicle or an object in a vehicle collision. The servo actuator for the collision test comprises a cylinder as a pressure chamber, and the volume of the chamber is defined by the piston acting on the test object through the piston rod. Additionally, the device consists of a control device for controlling the braking force during the test run and a piston rod acting on the braking device. The force acting on the piston rod braking device can be operated by hydraulic pressure. Because of the relatively small amount of hydraulic oil, a small flow valve, especially a standard hydraulic valve, is used, which is controlled in real time. A servo valve is used and the valve can be mounted directly on the braking device regardless of the valve type. The valve is primarily designed so that the brake has a full braking effect when the power supply to the device is interrupted. The braking device for hydraulic control of the braking force is connected to the hydraulic unit. The hydraulic power unit is first composed of a pump and a hydraulic accelerator that generate necessary pressure. It can be ensured that it is maintained in case of failure, degradation of the pump, or when pressure is required at any periodic time. Since the hydraulic unit is configured appropriately for acceleration resistance, it can be installed and used on the collision sled. It can also be used as a hydraulic power unit for two or more cylinders. More specifically, the hydraulic unit includes an acceleration sensor to measure the acceleration of the piston rod, and a braking force related to the output value of the acceleration sensor can be adjusted. The signal from the acceleration sensor of the piston rod is monitored in real time with the control device.

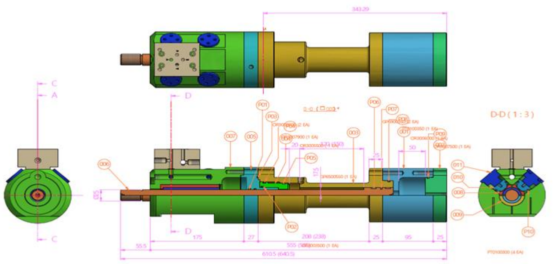

Fig.1 A hybrid hydraulic servo actuator

Fig.1 shows a hybrid hydraulic servo actuator. The hybrid hydraulic servo actuator is a combination of pneumatic and hydraulic pressure. It should be composed of a brake hydraulic device that can sufficiently control with the piston rod, which is momentarily moved forward by the pneumatic pressure of 350 bar. The brake hydraulic device should be able to control the pressure quickly and freely according to the waveform of the piston rod advancing, and since it moves quickly with a high-pressure device, safety design and reproducible design should be given priority.

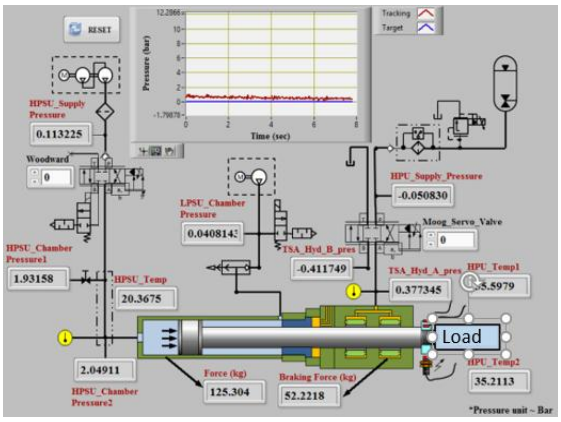

Fig.2 Block diagram of system

Fig. 2 shows a block diagram of a system developed with LabVIEW. By supplying the working fluid to the piston, the desired gas pressure can be generated in the compressed gas container. The hybrid hydraulic servo actuator undergoes a multi-step preparation process after cylinder launch, and repeats it again two to three times when the system identification is applied. First for advancement in the actuator, the position of the cylinder is made into the initial position before launch. When the exhaust solenoid valve is opened and the low pressure air compressor is operated, the position of the cylinder is moved to the initial position. Next, then high-pressure pneumatic compressed air is added, the cylinder moves forward, so the cylinder must be stopped by using a hydraulic brake until the desired high-pressure pneumatic pressure is charged. The amount of flow rate used when the actual brake is operated is not large, but hydraulic fluctuations occur in a short time of 0.32 seconds, and a flow rate of tens of liters must be prepared in the tank. Continuously when the flow supply to the tank is complete, the brake is parked to prevent the movement of the cylinder. The brake is controlled by moving the signal from the hydraulic servo valve. And then, the pressure is increased in the high pressure pneumatic tank, when brake parking is completed. The air pressure varies depending on the target waveform of the load and acceleration.

Prior to advancing the cylinder, set up the collision waveform when a vehicle collision occurs or profile input data for system identification. The cylinder is moved forward by controlling brake parking or release by changing the port of the hydraulic servo valve. The cylinder also receives data from the acceleration sensor at the same time as the cylinder starts to move forward. Quickly change the port of the hydraulic servo valve, control brake parking or release, and control the movement of the cylinder as it moves forward. The collision situation ends after 0.32 seconds after the start of a piston rod, so if it is not controlled, a collision occurs in the end position. Strong collisions cause damage to the simulator, so the brake parking is arbitrarily operated to prevent this. When the piston rod stops, compare the acceleration of the target waveform with the waveform of the measured acceleration. All control ends in this way.

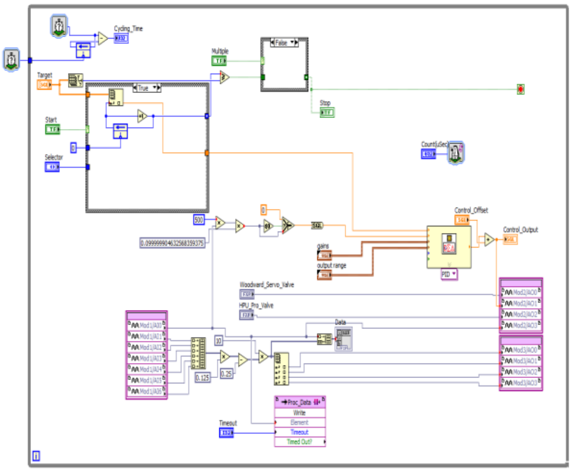

Fig.3 FPGA target configuration

The FPGA (Fig. 3) is a device for controlling a hydraulic servo valve and receiving acceleration data in a short time, and the DAQ model is responsible for all control devices such as pneumatic pressure and hydraulic pressure in addition to the servo valve and acceleration. In the case of a hydraulic servo valve, the FPGA and the DAQ module are separated in order to be sensitive and perform a control command in ms units. The National Instruments LabVIEW FPGA Module uses LabVIEW Embedded technology to extend LabVIEW graphics development to the target FPGA of NI reconfigurable I/O hardware. The LabVIEW FPGA Module enables users to create custom hardware board designs, execute multiple tasks simultaneously, and address many applications, including unique timing and trigger routines, and ultra-fast control (6 μsec). These benefits of the LabVIEW FPGA select the NI-Compactrio 9067 real-time target system with FPGA targets (Fig. 3). Accurate modeling of automobile collision propulsion should be given priority to obtain results most similar to the actual collision test. Fig. 4 is a PID algorithm.

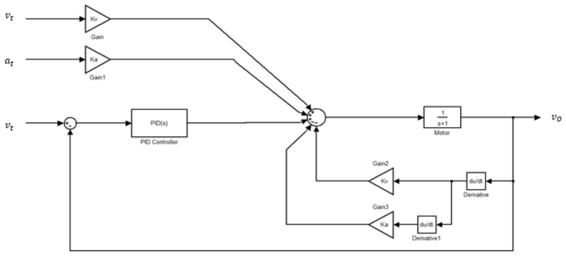

Fig. 4 Velocity control loop

In order to reduce the target tracking error, a target acceleration compensator should be used, and the target acceleration compensator is the same as the “Feedforward Controller” concept and uses a PID controller. In this technology development study, a simulator controller algorithm that inversely generates an acceleration signal generated in a car collision situation was presented. Based on the nonlinear feedback control design and the PID control circuit design, well known as a closed circuit controller, this approach is well applied to a system with bandwidth, and the initial acceleration vibration problem of the simulation result can be solved by controlling the initial brake pressure. As an additional supplement, valve delay compensation and speed error compensation are required. Accurate modeling of automobile collision propulsion should be given priority in order to obtain results most similar to our collision test. In this technology development study, a simulator controller algorithm that inversely generates an acceleration signal generated in a car collision situation was presented.

Labview shows that this approach, based on a nonlinear feedback control design and a PID control circuit design well known as a closed circuit controller, is well applied to a bandwidth system. As a result of the simulation, the initial acceleration vibration problem can be solved by controlling the initial brake pressure. As an additional supplement, valve delay compensation and speed error compensation are required.

III. RESULTS AND ANALYSIS

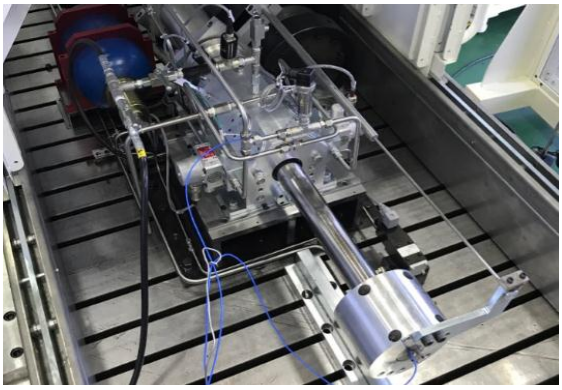

Fig. 5 Photograph of test equipment

Fig. 5 shows a photograph of the servo actuator test equipment. In order to track and control the acceleration and pressure profile using the manufactured collision test equipment, experimental data are obtained by linking it with LabVIEW using the AMESim program. The current system can use an open circuit if used only as a pressure controller and a closed circuit if an acceleration and speed control loop is used. For PID control, the loop was executed at a speed of 2.2 msec, and the control gain value K_P=0.3, K_{NP}=0.05 and τ_{SV}=0.0004 were used. Fig. 6 and 7 show a measurement curve that tracks the pressure profile by pressure and frequency increment, and it can be seen that the error increases as the frequency increases. It shows that the RMS error increases with increasing frequency without using any controlled gain adjustment. In actual cases, it is necessary to try a control gain adjustment method to reduce the tracking curve error as much as possible. In the actual experiment, it can be seen that the control gain must be adjusted as shown in Fig. 8. Control variables were appropriately set to achieve the optimal performance of PID. From Equation 9, first, in the closed circuit loop state, was removed and only a very small value was increased, and then the value was increased until the system response indicated a critical vibration. The remaining variables were set using the system characteristics that appear during critical vibration.

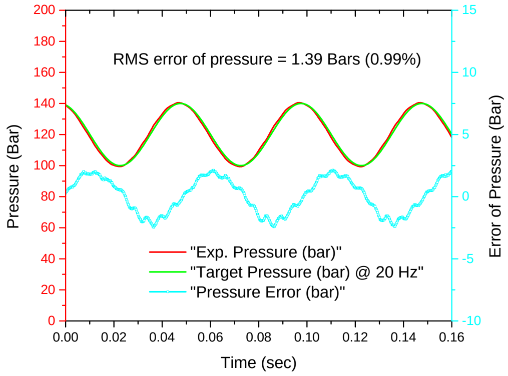

Fig. 6 Tracking pressure graph

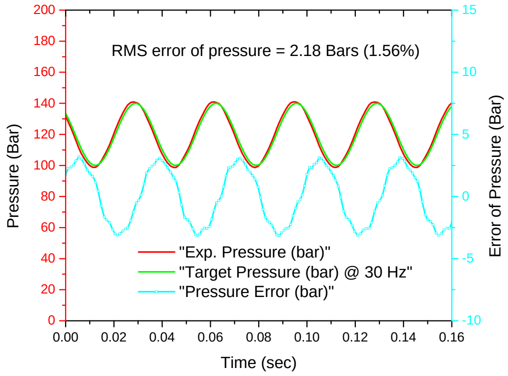

Fig. 7 Tracking pressure graph

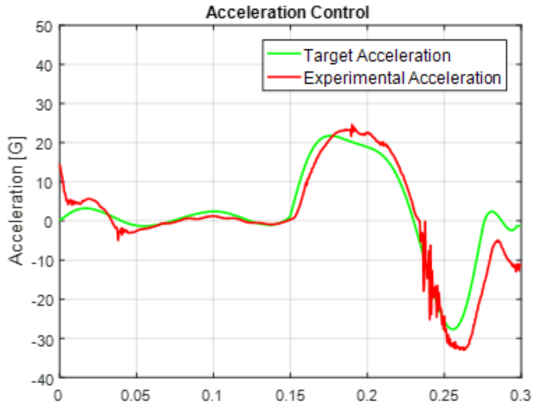

Fig. 8 Tracking pressure graph

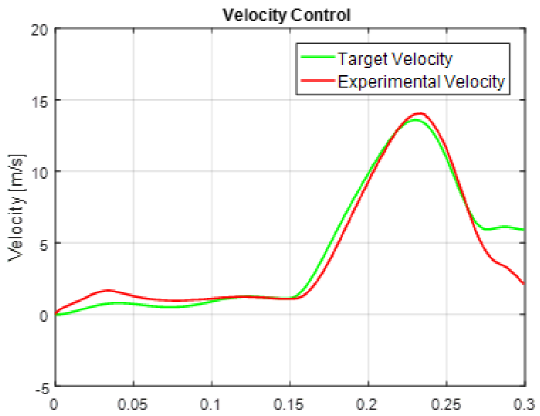

Fig. 9 Tracking pressure graph

III. CONCLUSION

After conducting the test, several conclusions were made for the development of crash test simulators.

1). The PID controller design based on the FPGA was consistent with the system requirement assumption by allowing the test to be performed within approximately 0.3 sec.
2). The PID gain adjustment is related to the target tracking pressure, and the supply pressure of the servo valve also affects when selecting the PID gain.
3). From the experimental results, it can be seen that there is a phase difference between the target pressure profile and the measured pressure.
4). It can be seen that the control error is improved by adjusting the control gain.
5). As the frequency increases, the initial error between the target pressure and the process pressure increases.

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