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Prototype development of smart brake controller (SBC) for light-duty vehicles (LDVs) with manual transmission

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Abstract. This paper presents the development of a smart brake controller (SBC) that applied to passenger cars to reduce accidents while stopped on a hill road. Crash accidents often occur due to the lack of driver skill or negligence in holding the brake pedal. The smart brake controller works by electro-mechanically to lock the brake system even though the brake pedal is released. The results showed that SBC could work well on a variety of vehicle loads and variations in road slope.

1. Introduction

Recently, traffic accidents have increased very surprisingly both at regional and international levels. In 2016, traffic accidents that occurred in Greece on the highway have reached 59,316 cases [1]. Whereas in 2011, traffic accidents that caused deaths in the European Union reached 30,000 cases. Seeing the fact of traffic accidents that occur today cause technology safety and vehicle safety systems into a worldwide research topic. The technology was developed to improve driving safety and reduce the number of traffic accidents. Traffic accidents that occur on vehicles have several factors. The dominating factors include human error or driver failure and vehicle security system failure. While other factors include, environmental factors that are not good roads and weather/climate that does not support.

Efforts to develop vehicle safety technology in reducing traffic accidents have been widely practiced, including the development of brake system technology. Some brake system innovations have been carried out, one of them with Electronic Vacuum Booster (EVB) [2]. In high-speed vehicles, Support Vector Machine (SVM) has been applied to detect braking system failures that may occur[3]. The Anti Blocking System (ABS) has also been widely developed to prevent the wheels from locking during sudden braking[4–6]. Recently, brake technology with an autonomous system has also been developed [7]–[10].

The development of brake system technology is not limited to control systems but also to its mechanical systems, including research on hybrid vehicle disc brakes with an orientation to reduce braking loads [11]and brake systems with special materials to increase efficiency [12–15]. Another sophisticated brake system is electric parking technology to improve safety [16]and brake systems with regenerative control in electric cars[17]. Recently, fuel consumption control can also be done by the brake system so that the brake system has dual functions[18], [19].

To improve vehicle control on uphill roads in times of congestion or when stuck in red light, some modern cars have been equipped with Hill Start Assist - HSA technology [20]. This feature serves to prevent the vehicle from moving backward when the brake pedal is released. However, HSA is only used on cars with automatic transmission. Modeling studies Research on HSA technology has also been

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carried out, including modeling[21]. Currently, vehicles with pneumatic brake systems have also used HSA technology[22].

HSA is rarely applied to passenger cars with manual transmissions. Most HSA technologies experience multiple detection problems. Another problem is when the vehicle is in a flat position, HSA still functions so that fuel consumption is more wasteful. Another disadvantage is that when the car stops and the engine does not operate, the wheel will be locked so the car must be pulled. For this reason, the aim of this research is to develop a prototype of SBC technology that is applied to passenger cars with manual transmission. This research is important considering the number of passenger cars with manual transmissions dominating the population of commercially available vehicles today.

2. Method

2.1. Design of Smart Brake Controller (SBC)

In this study, an SBC was developed following the systematics presented in Figure 1. This system was developed based on the input signal from the controller. Brake sensors, clutch sensors, TPS sensors, and speed gear sensors are used as controller inputs. The brake sensor sends a digital signal to the controller to provide information about the position of the brake system. TPS sensor as a source of information to determine vehicle acceleration. Clutch sensors have a role in conveying information about the powertrain work system. The controller will process data coming from sensors. Then, data from sensors will be processed to solve problems in the form of braking system operation. Finally, the hydraulic system will be activated by an actuator consisting of DC motors and complementary mechanics.

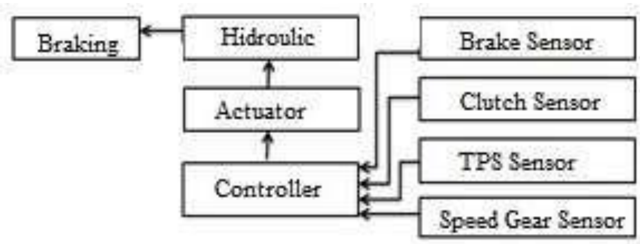

Figure 1. Block diagram of SBC.

The working principle of the SBC developed in this study is divided into three conditions. The first condition, when the driver slows down the car by stepping on the brake pedal. The brake system will work as usual, and the controller seems to not active. The second condition, when the car stops on the uphill road. The driver will release the accelerator pedal, step on the brake and clutch pedal with the speed gear still connected. TPS, speed sensor, brake sensor, and clutch sensor will send a signal to the controller. In this condition, the SBC starts actively. Next, the driver steps on the brake pedal, neutralize the speed gear and releases the clutch pedal. The brakes will remain locked until the car will run again. The third condition, the driver steps on the accelerator pedal, activates the speed gear and releases the brake and clutch pedals. This step is the most important; the SBC is still active for 3 seconds to prevent the car from moving backward. The logic of the controller is shown in Table 1**.**

Table 1. Logic control system.

No.	Selection switch	Ignition switch	Brake sensor	TPS sensor	Clutch sensor	Speed gear sensor	Controller
1.	On	Off	Off	Off	Off	Off	Off
2.	On	On	On	Off	Off	Off	On
3.	On	On	On	On	Off	Off	On
4.	On	On	Off	On	Off	Off	On
5.	On	On	Off	On	On	On	On
6.	On	On	Off	On	Off	On	On (3 seconds)

No.	Selection switch	Ignition switch	Brake sensor	TPS sensor	Clutch sensor	Speed gear sensor	Controller
7.	On	On	On	Off	Off	On	Off
8.	Off	Off	Off	Off	Off	Off	Off
9.	Off	On	On	Off	Off	Off	Off
10.	Off	On	On	On	Off	Off	Off
11.	Off	On	Off	On	Off	Off	Off
12.	Off	On	Off	On	On	On	Off
13.	Off	On	Off	On	Off	On	Off
14.	Off	On	On	Off	Off	On	Off

The brake controller developed in this study has a hydraulic motor as an actuator which is presented in Figure 2, while the wiring connecting the sensor, controller, and the actuator is presented in Figure 3.

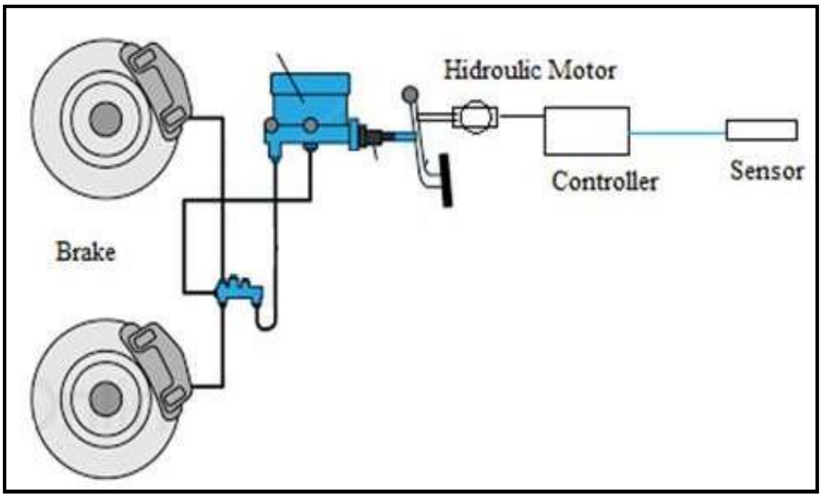

Figure 2. Installation of the hydraulic motor in the brake system.

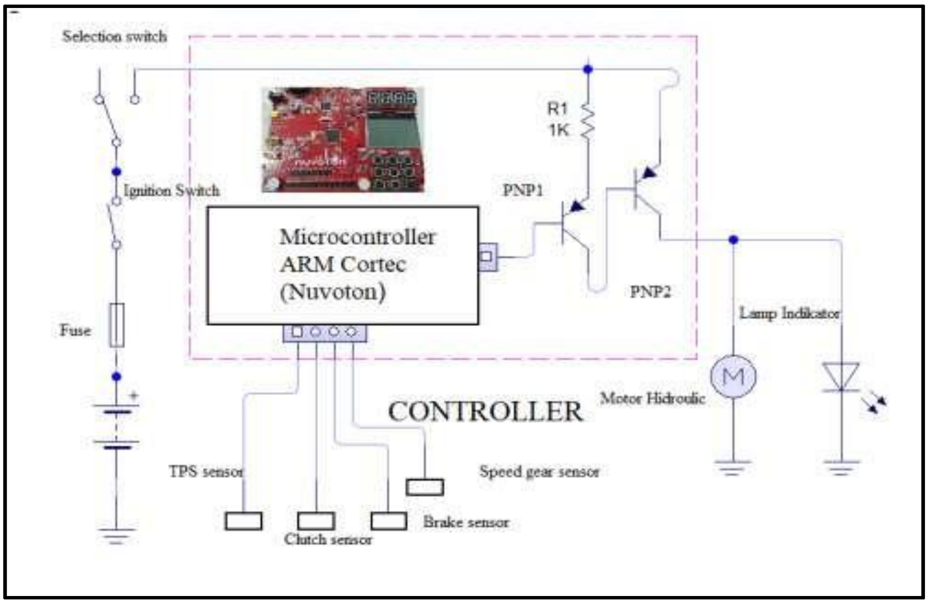

Figure 3. Wiring diagram of SBC.

2.2. Measurement of brake reliability and road slope
The developed SBC prototype was tested on the actual environment with a number of loading including the number of passengers, road angles, and the load of the vehicle itself. A brake pressure gauge is attached to the master cylinder to measure brake system reliability. Then, an inclinometer is used to measure road slope as shown in Figure 4.

Figure 4. Inclinometer.

3. Result and Discussion

3.1. Initial validation
Vehicle testing was carried out at 7°, 9°, and 14° of road slopes. For measuring the slope of the road, a digital inclinometer was used on the vehicle body. Vehicle loads were varied on one, two, three and four passengers as shown in Figure 5a. Measurement of braking capability was carried out by observing the pressure hydraulic pressure mounted on the master cylinder. After braking, the brake pedal is released. Without SBC, the hydraulic pressure on the brake fluid drops rapidly while with SBC, the hydraulic pressure of the brake fluid is held for a few seconds. This is because this is when the brake pedal is released from the driver's leg; the brake pedal is still pressed automatically by the SBC. This condition is characterized by high brake pressure up to 10 seconds. Then the SBC will withstand the hydraulic pressure of the brake oil for 3 seconds when the driver steps on the accelerator pedal, releases the brake pedal, activates the speed gear, and releases the clutch pedal. Furthermore, the brake pressure test was carried out on various slope variations shown in the graph. Figure 5b. Brake fluid pressure has shown that the higher the vehicle load, the higher the hydraulic pressure of the brake fluid.

Figure 5a. Photographic view of initial validation by four passengers.

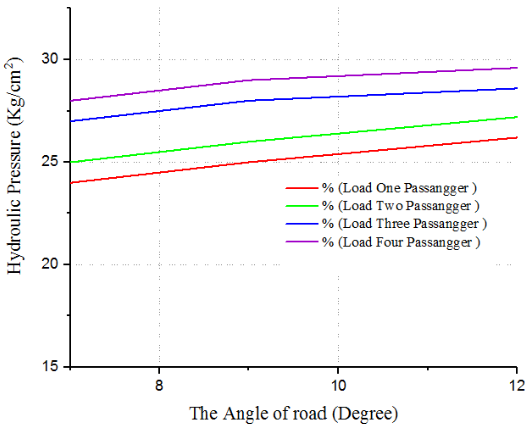

Figure 5b. Fluid pressure, vehicle load, and road slope.

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3.2. Braking performance

The SBC test with a single passenger load (68 kg) shows that the hydraulic pressure remains stable when the brake pedal is released after 2 seconds, while without SBC, the hydraulic pressure drops rapidly when the brake pedal is released after 2 seconds. The same conditions are shown in variations in loads 2 passengers (137 kg), 3 passengers (199), and 4 passengers (265) as shown in Figure 6.

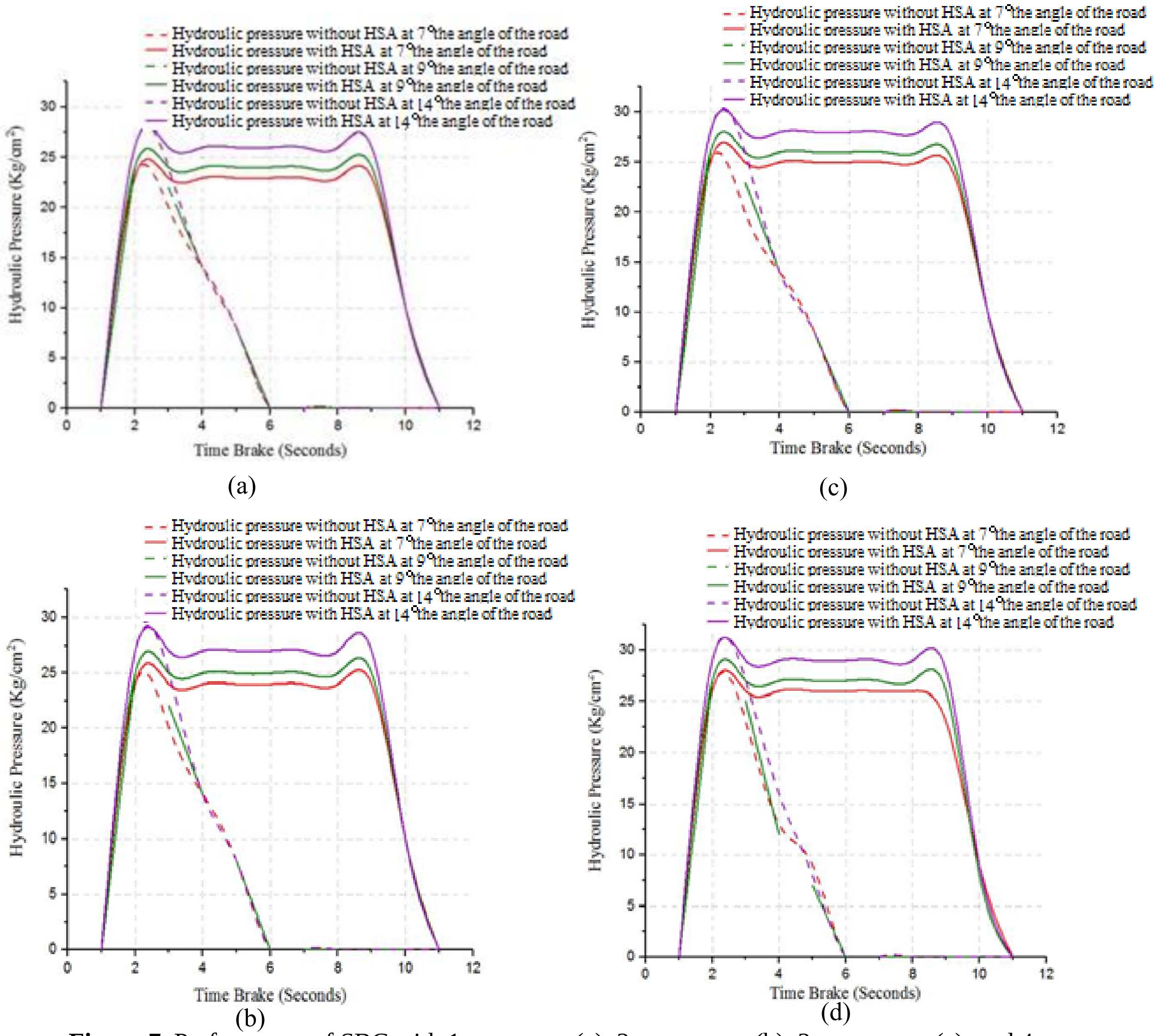

Figure 7. Performance of SBC with 1 passenger (a), 2 passengers (b), 3 passengers (c), and 4 passengers (d).

From Figure 6 and Figure 7, the change in hydraulic pressure is affected by the passenger load and the tilt angle of the road. Hydraulic pressure with a passenger load of 265 kg and a road slope of 14 ° reaches 25 kg / cm2, while hydraulic pressure with a passenger load of 69 kg at a slope of 14 ° is 21 kg / cm2. This difference is because the force (F) given to hold 265 kg is higher than the weight of 69 kg. Thus, SBC has the opportunity to be applied to LDVs with manual transmission. Implementation can be done semi-automatically to give the driver an option in sporty and eco mode.

4. Conclusion

Based on a series of tests that have been carried out, it is concluded that the Smart Brake Controller (SBC) can be applied to LDVs with the manual transmission. The increase in hydraulic pressure which is proportional to the increase in vehicle load indicates that the SBC is responsive to changes in vehicle load. With a load of more than 250 kg at 14^{o} road slope, the hydraulic pressure can be maintained more than 10 kg/cm^2, and the vehicle is still able to stop without rolling backward when accelerating on the uphill road.

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