

New Brake By Wire Concept with Mechanical Backup

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 MOBIS

ABSTRACT

Brake-By-Wire (BBW) is a term used to describe next generation brake systems that rely on motor driven electro-mechanical calipers in place of conventional hydraulic components such as the booster, master cylinder, hydraulic unit, and parking brake. Instead the system configuration is simplified to a pedal simulator, electro-mechanical calipers that require no boosting, and electric control units. The active, highly-responsive, and independent control of the brake actuators at each wheel allows for great control flexibility and improved brake performance. It is also very well-suited for easy integration with cooperative regenerative braking and driver assistance functions.

Although such potential and innovations have driven the interest and research into BBW systems through the years, it has yet to be successfully introduced in series production mainly due to the underlying perception of the lack of reliability of electronic components and overall cost concerns.

In the current investigation, a new concept of BBW system is proposed as a step towards overcoming such hurdles. The proposed concept provides a mechanical backup function that does not deter the system from the original performance benefits of a BBW system. It is hoped that such an addition, which provides emergency braking capability with no electrical power, will give the BBW system the ultimate reliability that can help persuade its penetration into the brake market. This system also has the potential to reduce the overall cost of the system since reliance on complex system architectures, redundancies, and highly reliable electrical components can be reduced.

This study will investigate the feasibility and basic performance of the proposed BBW concept. First, prototype actuators for the proposed system were designed and manufactured. After checking the samples in bench tests, the actuators were built into a car to access the braking capability of the system.

CITATION: Cheon, J., Kim, J. and Jeon, J., "New Brake By Wire Concept with Mechanical Backup," *SAE Int. J. Passeng. Cars - Mech. Syst.* 5(4):2012, doi:10.4271/2012-01-1800.

INTRODUCTION

The most common Brake-by-Wire (BBW) configuration uses four electro-mechanical brakes (EMB) [1-2] at each wheel. However, as high braking forces on the front axle leads to high power consumption, an alternative has been to use electric wedge brakes (EWB) [3-4] or other types of self-energizing brakes [5], which make use of the vehicle kinetic energy for braking. A simple comparison of conventional and self-energizing type actuator mechanism is described in figure 1. As can be seen the EWB has the benefit of using the frictional force between the disc and friction pad which allows for less use of electrical power input while the EMB relies solely on the power input to create the needed clamping force. While an EWB actuator has the benefit of lower power consumption, it usually requires a more complex design for functions such as wear adjustment or electric parking and as such using a conventional EMB on the rear has benefits. The components that make up this type of configuration [6] are

shown in figure 2. During normal operation, the brake demand is processed by the pedal and the main controller will command the amount of braking required by the actuators of each wheel. The pedal simulator has stroke and force sensors to recognize the driver's desired brake demand and the front EWB and rear EMB are composed of the caliper, torque member, actuator housing (gear box, screw, wedge mechanism, etc.) and the motor.

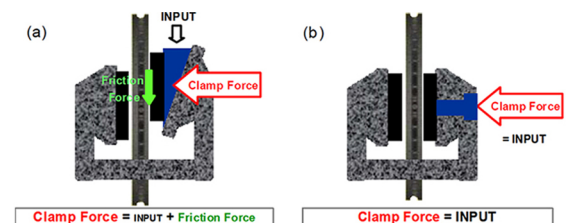


Figure 1. Basic mechanisms of (a) EWB and (b) EMB actuators.

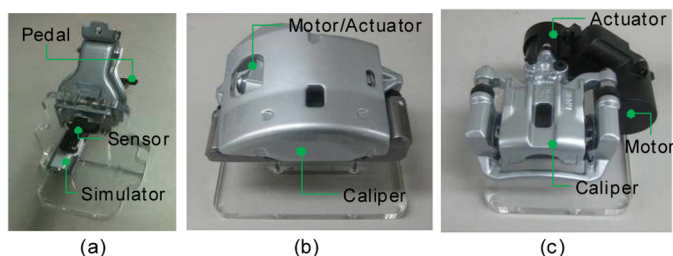


Figure 2. BBW components : (a) pedal simulator, (b) EWB, and (c) EMB.

In general, BBW systems with highly-responsive and active independent control of the brake actuators at each wheel can lead to great dynamic control flexibility and improved brake performance. Furthermore, integration with other chassis control systems, cooperative regenerative braking, and various driver assistance functions is simple due to such inherent properties. However, BBW systems have yet to be successfully introduced in series production mainly due to the underlying perception of the lack of reliability of electronic components and overall cost concerns. Thus, studies targeted at the functional safety design of BBW systems are ongoing [7].

Another approach is to combine conventional hydraulic brake components and BBW components. Such use of hydraulics has the main advantage of providing a reliable backup emergency braking function if any electronics or power problems occur in the vehicle. At the same time this approach can provide invaluable field performance information to BBW engineers. A common system configuration being investigated is to use hydraulic components in the front and using EMB calipers in the rear [8].

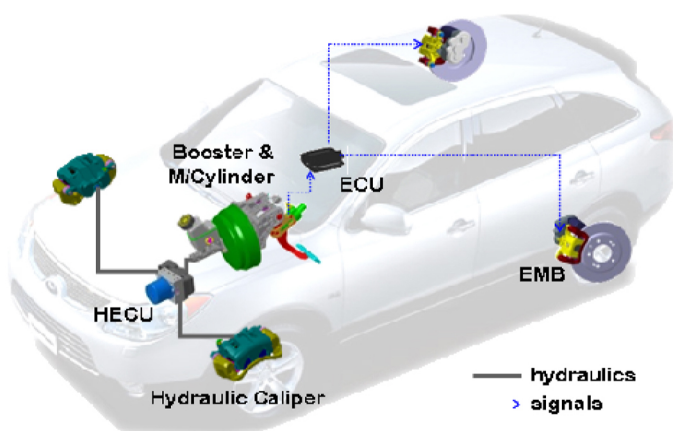


Figure 3. Combined hydraulic / BBW configuration : hydraulic front axle, EMB rear axle.

As shown in figure 3, components such as booster, master cylinder, HECU, and hydraulic calipers make up the brake system for the front axle. Since these components are used only for the front brakes, the size of actuation parts and

HECU can be reduced compared to the conventional case. In the rear axle, EMB calipers are used to provide the rear braking and parking functions through command from the central ECU. Although this configuration has the advantage of increased reliability, the fact that all the traditional hydraulic components are still used takes away from the cost effectiveness of the system. Also, special care will be needed to effectively blend the hydraulic control with BBW control for higher level functions. Furthermore, the benefit of highly responsive and active braking at each wheel cannot be realized in such a system such that more advanced hydraulic brakes will be needed in the front in order to have regenerative brake cooperation (for front driven hybrid or electric vehicles) or braking capability for driver assistance systems.

In the current investigation, a new concept of BBW system configuration is proposed that can maintain the benefits of BBW and at the same time possess a reliable mechanical backup solution. This system also has the potential to reduce the overall cost of the system since reliance on complex system architectures, redundancies, and electrical components for BBW can be reduced. The feasibility and basic performance of the proposed system will be investigated in this study. Prototype actuator samples for the proposed system were made and checked through bench and vehicle tests.

HEWB BASED BRAKE BY WIRE CONFIGURATION

System Configuration

The proposed system is based on the previously described configuration of EWB and EMB calipers on the front and rear axles, respectively. The addition is that hydraulic parts are integrated to the front EWB calipers. These brakes, hEWB (hybrid Electric Wedge Brake) actuators, are connected to the pedal unit by hydraulic lines as shown in figure 4.

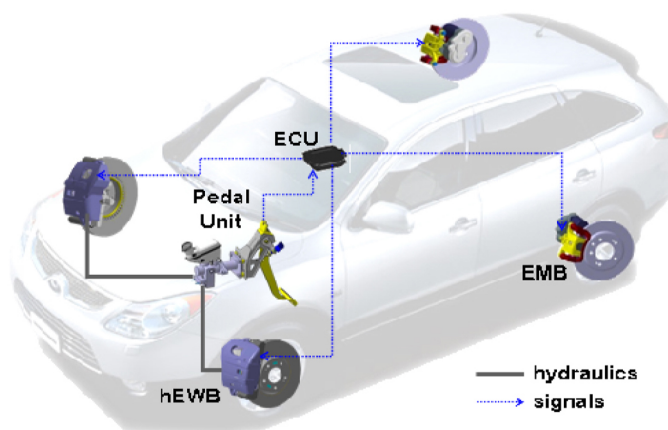


Figure 4. New BBW configuration based on hEWB.

In general, the hydraulic function is not used during normal operation which means the system will run like a fully