Design and testing of a new electric parking brake actuator
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ABSTRACT

Electric parking brake (EPB) system provides the roomy space for vehicles compared with traditional handbrake system. Combining a control unit realizes the intelligent functions, which make vehicles more convenient and secure, and avoid the vehicle damage and danger caused by the negligence of drivers.

This paper provides a new concept design of the EPB system that has simple and low-cost characteristics. The testing results have proved the feasibility of this design. First we describe the working principle of this new design, and then introduce the arrangement of the testing system, followed by the discussion of experimental data. The last is conclusion paragraph.

INTRODUCTION

The intelligent function of EPB systems makes the parking brake be operated and released automatically. That is more convenient to use than traditional systems, and has the following merits:

1. Use an operation button to replace a hand lever.
2. Because of no hand lever, the vehicle has more spacious space.
3. Combining a control unit, EPB system can be automatically operated and released at the right time, which makes the operation simpler and the driver feel more comfortable and safe.

There are two types of existing EPB. One is the cable puller, and the other is the caliper. This new concept design belongs to the cable puller type. Many design concepts of the cable puller type use the ways of two cables [1,2]. Some perhaps use one cable to connect by way of the balancer one divides into two brakes [3]. Minorities also use the design concept of one cable method [4,5], which has small curvature radius of cable that will reduce the cable life and mechanical efficiency. The new concept design of this paper will also use one cable to connect two sides of the parking brake, but still maintain the cable life and mechanical efficiency.

Benchmarking - In table 1, there are four products of cable type EPB comparing with the new design concept. The important differences are shown as follows.

Table 1. Four products of cable type EPB comparison.

<table>
<thead>
<tr>
<th>Supplier</th>
<th>ADVICS</th>
<th>Continental</th>
<th>Continental</th>
<th>DURAG</th>
<th>New Design concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force sensor</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Balancer</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Inner cable combine interface</td>
<td>Yes (integrate balancer)</td>
<td>Yes (integrate balancer)</td>
<td>Yes</td>
<td>Yes</td>
<td>No (One cable only)</td>
</tr>
<tr>
<td>Self-balance</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

At present only some specific high price vehicles use the EPB system. But according to EPB system market’s tendency report [11], the global EPB system’s market demand will exceed 9 million sets in 2012; the revenue will reach 3500 million dollars.

SYSTEM DESIGN CONCEPT DESCRIPTION

It is not difficult to control an EPB. The mechanism is the key point of EPB system. The important factors that need be considered include:

• Cable-pulling force.
• Parking brake force can be maintained when the power source of electric motor is off.
• Working time of the actuator.
• The force for two sides of parking brake is near.

Actuator parts - The schematic drawing of actuator prototype is shown in Figure 1a. It comprises a brush motor, a pair of screw pole and six reduction gears, and uses one cable and two cable tubes to connect to two sides of brake. The prototype picture is shown in Figure 1b. The length, width and height of
this box are 15cm, 10.5cm and 7cm. The volume is approximately 40% smaller than market products [12].

**Working principle** - This actuator uses one cable only, and two sides of cable connect brakes separately. When the electric motor rotates clockwise, it actuates the reduction gears (process 3 section reduction), and then propels the inner screw pole to rotate. When the inner screw pole rotates, it will actuate the outer screw pole and the guide tube, and then the right cable tube will move to right side, (the outer screw pole, guide tube and right cable tube are fixed as a combination.) Therefore, It will cause the cable tube to provide force to cable to pull the two sides of brakes. Cable-pulling force achieves balance in pulling process, and then keeps the vehicle motionless when it is parked. When the parking brake need be released, the motor reverses and the cable-pulling force will disappear. The principle that can make the cable have large curvature radius will maintain the cable life and mechanical efficiency. Besides, without a cable balancer, it has fewer inner interfaces for the cable, which provides characteristics of simple structure, low cost and easy assembly.

**Force control method** – To control cable-pulling force to keep the vehicle motionless when it is parked is our target. The control method of actuator belongs to close loop control. The controller uses feedback from the current sensor to control the motor. When the feedback motor electric current reach set value, the controller cuts off the power source. As the motor power source is off, the screw pole set has self-locking effect, and then the cable-pulling force will be retained. Using a current sensor instead of force sensor brings benefits of low cost and saving volume.

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**TESTING EQUIPMENT**

**Testing equipment** - The testing equipment of this new concept design prototype includes the following:

- A rigid fixed platform.
- A power supply (maximum : DC 60V/30A).
- A Notebook.
- A control unit of motor.
- Two load cells (5 KN).
- Two amplifiers of load cell.
- A data recorder.

**System testing construction** - This system testing construction is shown in Figure 2. The mechanism of EPB and two cable tubes were fixed on rigid platform, and one end of the cable was connected to the load cell first, and then the load cell was connected to the brake.
The control unit was connected to the power source. When pressed down the start button, the motor started transmitting torque to the mechanism of the EPB, and the cable also started generating pulling force. The cable-pulling force was measured by the load cell, and the signal of load cell passed through amplifier and transmitted into the data recorder shown on the notebook finally. Figure 3 is the picture of the testing construction.

![Figure 3. Testing construction schematic picture.](image)

**TESTING RESULTS**

Several important characteristics of the actuator may be indicated in the ways listed below:

- The linearity of the cable pulling force and electric current.
- The working time of the actuator.
- The feedback motor electric current signal of the actuator.
- The accuracy of the cable-pulling force.
- The repeatability of the cable-pulling force.

**The linearity –** Cable-pulling force to the motor current chart is shown in Figure 4. The control unit was connected to a DC12V power supply. The electric current started from 8A, and the cable pulling force was recorded corresponding to electric current with an increment of 1A until 20A. Because the actuator needs certain start torque, the testing below 7A was not carried out.

![Figure 4. Cable-pulling force to the motor current chart.](image)

In Figure 4, the linear equation of left side cable curve is \( y = 6.8242(x - 8) + 61.5 \), where \( y \) indicates the cable-pulling force, \( x \) indicates motor current value. The linear line \( R^2 \) of this curve is \( R^2 = 0.9954 \). The linear equation of right side cable curve is \( y = 7.0824(x - 8) + 57.4 \), and the linear line \( R^2 \) of curve is \( R^2 = 0.9964 \). From the results, the cable-pulling force to motor current has a good linear relationship, and it is feasible to control the cable-pulling force by means of setting the electric current.

**The feedback of motor electric current signal -** As shown in Figure 5, the electric current was set at 20A. The motor started to rotate and electric current signal rose from 0A to 20A. The data recorder through the low-pass filter circuit recorded the feedbacks of motor electric current signals. The first peak of the current caused by start torque was not considered, but the second peak current represented the loading torque. The range inside the circle shows the current is smooth, which indicates low noise of current signal, and it is helpful to control cable-pulling force.

**The working time –** In Figure 5. The working time of actuator needs 1.7 seconds approximately. Comparing with market vehicle’s EPB [7], the working time within 2 seconds is acceptable.
When supplied a set voltage DC12V and electric current 20A to the motor, the actuator starts to produce the cable pulling force until the motor was stall. The cable pulling force can reach 150Kgf approximately, and could be maintained when motor power source was off.

To Control cable-pulling force - Cable pulling force and electric current to time chart is shown in Figure 7. The cable pulling force was controlled by way of cut-off motor electric current method. The corresponding cable pulling force was 130Kgf when cut-off motor electric current after reaching 20A. There was a drop of cable pulling force by way of cut-off motor electric current method; the drop is 13.3% approximately.
In table 2, when cut-off motor current was at 19.5A, the average values of left side cable-pulling force and right side were 120.5Kgf and 119.9Kgf, and the inaccuracies of cable-pulling force were 1.2% and 1.58%. The average difference of two side cable-pulling force is 0.6Kgf.

When cut-off motor current at 15A, the average values of left side cable-pulling force and right side were 98.4Kgf and 97Kgf, and the inaccuracies of cable-pulling force were 1.62% and 2.06%. The average difference of two side cable-pulling force is 1.4Kgf.

When cut-off motor current at 12A, the average values of left side cable-pulling force and right side were 68.9Kgf and 68.1Kgf, and the inaccuracies of cable-pulling force were 4.2% and 4.55%. The average difference of two side cable-pulling force is 0.7Kgf.

The results show the performance of the actuator is good. Using a current sensor instead of force sensor is feasible and provides low cost and saving actuator volume characteristics.

**CONCLUSION**

This paper describes a new concept design of EPB and the testing for the EPB prototype. The results reveal as follows:

1. This paper provides a new concept design of the EPB system that has simple and low-cost characteristics.
2. The testing results prove the feasibility and excellence of this new concept.
3. This new concept is not only theoretical interest, but also can be applied into a practical parking brake system.

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**REFERENCES**


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