PRODUCT DESIGN OF ELECTRONIC PARKING BRAKE

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Abstract

The Electric Parking Brake (EPB) system is used to engage and disengage the parking brake automatically. It becomes popular in recent years. It usually uses an actuator to drive the mechanism to pull or release the brake cable. This study presents a mechanism that can be used in EPB system. The mechanism can maintain the brake cable position after the actuator of EPB is turn off, and the brake cable can be released by simple tool when the EPB is failure after engaging. The mechanism is designed as an independent system that it can be installed on an existing vehicle easily. To ensure the strength of the mechanism, the stress analysis is done with finite element analysis. Finally, a prototype is developed to ensure the mechanism operation.

Keywords: Electronic parking brake, mechanical design.

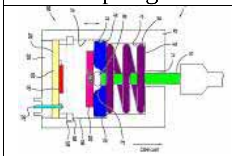
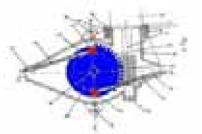
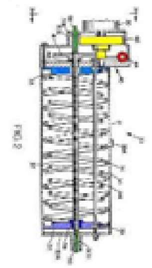
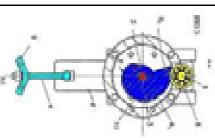
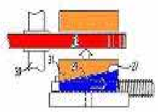
1. Introduction

The Electronic Parking Brake (EPB) is popular in recent years. An electronic actuator substitutes the human operation and simplifies the parking action. The small volume system makes the vehicle interior more commodious. Moreover, a computer-controlled unit actuates the parking brake is used. The parking becomes more intelligent in different situations, such as stopping brake, climbing start, and impermanent stop [1].

There are more and more vehicles installing the EPB system, such as the Jaguar XJ and S-type, the Audi A6 and A8, the Renault New Vel Satis and Scenic, the BMW 7-Series and the Volkswagen Passat. Market needs will strongly support the product development. Although, the EPB system is more convenient and smarter than traditional ones, it still has some problems, such as complexity and higher cost. These disadvantages are required to be improved. Therefore, the main objective of this study is to develop a prototype affordable for common users, and ensure the new design will not infringe current intellectual property rights [2-15].

The mechanism of EPB needs an operator to engage and disengage the parking brake. The operators used in patents are shown in Table 1.

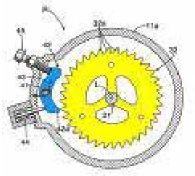
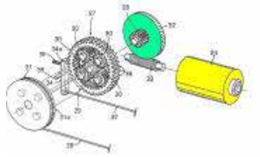
Table 1. Operators

Spring	Worm-gear	Freewheel
 U.S. Patent No. 6609595 [2]	 U.S. Patent No. 6863162 [3]	 U.S. Patent No. 5092432 [6]
Cam	Wedge	
 U.S. Patent No. 6851525 [4]	 U.S. Patent No.20050034939 [5]	

The spring is a simple method to achieve this motion. The utility rate of the spring is much higher than other components. Worm-gears are commonly used because of its self-lock and small volume advantages. The worm gear has been developed for years, and it is also available in the market. Therefore, the cost can be reduced by using the standard components. The cam is usually used in the EPB system because different cam profiles can change the torque when pulling the brake cable. The advantage can reduce the cost from selecting a high performance actuator. The wedge uses the geometric shape to achieve the acting or connecting motions. The advantage is the simple structure and easy manufacturing. The freewheel is not so popular in the EPB system. But, freewheels have a special property that can store the energy from actuators. This advantage can reduce the waste of energy during operating.

In order to avoid the unexpected releasing which will cause dangers, the function of self-lock is required to support the security considerations. The most popular ways to provide self-lock function are shown in Table 2.

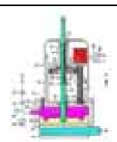
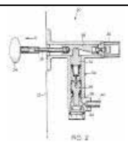
Table 2. Self-lockers

Ratchet wheel	Worm-gear
 U.S. Patent No. 20050077782 [8]	 U.S. Patent No. 6905181 [9]

The ratchet wheel should work with a ratchet lever. These components also have standard products for selection. It is an original ideal to support a locking function. However, the ratchet could disengage the wheel if it suffers a force in opposite direction. As a result, it is easy to get failure when striking with accidental force. The worm-gear has not only the operator function, but also the self-locking function. The reliability of the self-lock function of worm gears is better than ratchet wheels. Thus the worm-gear will be used in the present design.

If the system fails or locks the brake disk unexpectedly, a function to release the brake cable should be provided. It may be a manual or automatic device. For example, a manual handle or a releasing lever can be found in patents as shown in Table 3.

Table 3. Releasers

Manual Handle	
 U.S. Patent No. 5148894 [10]	 U.S. Patent No. 5704693 [11]

After the new design is developed, finite element analysis (FEA) is used to help materials selection and ensure the required strength after the CAD model is developed. Finally, a prototype is fabricated to ensure the mechanism operation.

2. Design

The design of this study is shown in Figure 1. The coupling will be connected to an actuator, which is usually a motor. The cable is fixed in the groove between the cam and the cable fixer. As shown in Figure 2, the cable, not shown, will lay on the groove of the cam, and the cable fixer is fixed on the outer periphery of the cam by inserting pins or bolts in the holes. Two ends of the cable will be laid on different side of the cable fixer. One end of the cable will be assembled with a head, and the other end of the cable is connected to the brake. In this way, the cable is clipped in the groove by the cam and the cable fixer, and the contact portion between them will not be a little point or a short edge. That will reduce the stress concentration.

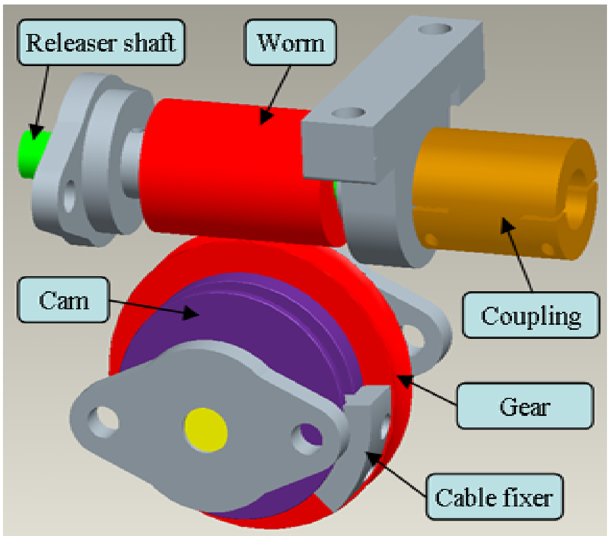


Figure 1. Components of the presented design.

In engaging process, the actuator drives the releaser shaft to turn the worm and the gear, shown in Figure 1. The gear and the cam are fixed on the same shaft. Thus the cam is turned, and the cable fixed between the cam and the cable fixer is pulled to engage the parking brake. After engaging, the power of actuator can be turn off, and the cable will be maintain on the engaging position because of the self-lock function of the worm-gear coupling. In the disengaging process, the actuator will turn with the opposite direction, and the cable can be released.

If the actuator is failure after engaging, i.e. the parking brake cannot be released by the actuator, a hexagon driver can be connect to the hexagon hole, shown in Figure 3, of the releaser shaft, and turn it. The parking brake will be disengaged without destroying the mechanism of EPB system.

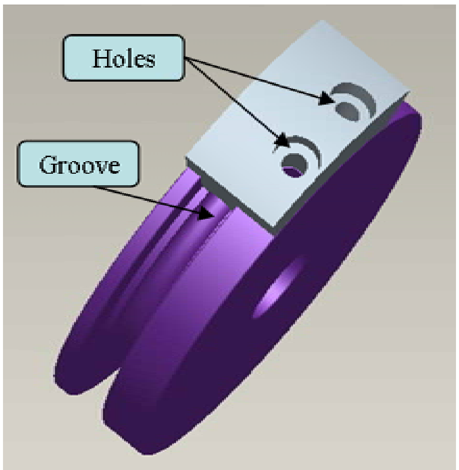


Figure 2. The cam and the cable fixer.

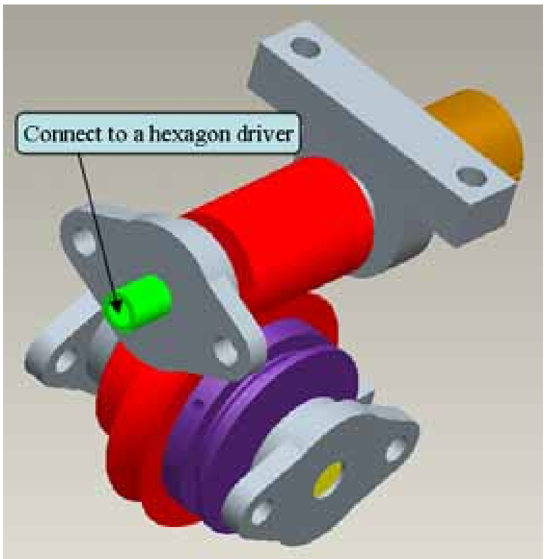


Figure 3. The release mechanism.

Otherwise, this design has some other advantages:

1. The mechanism of this design is very simple and it is not necessary to use a high precision manufacture method. Thus, the cost can be decreased.
2. The EPB system is design as an independent system. Thus it can be added in different existing vehicles.

3. Finite Element Analysis

After the CAD model of this design is developed, the finite element analysis is used to analyze the stress of the EPB components. The most component are commercial products and the assembly methods are proved. Therefore, the stress field of the cam and the cable fixer are analyzed.

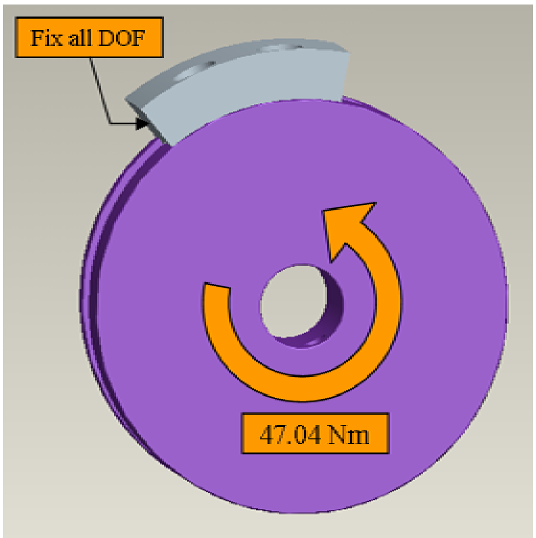


Figure 4. Boundary and loading conditions of analysis 1.

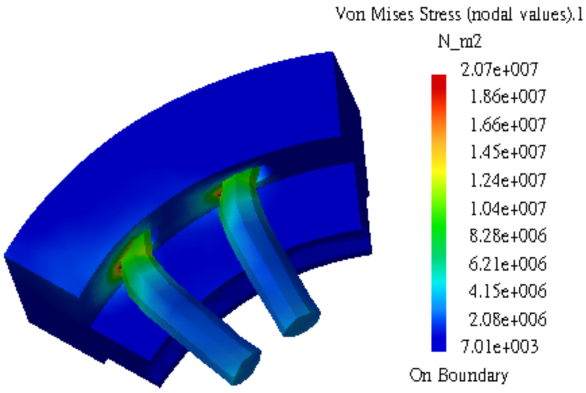


Figure 5. The result of analysis 1.

Analysis 1:

The cable is fixed by the cam and the cable fixer, and the cam and the cable fixer are fixed by inserting pins or bolts in two holes. Thus the interface between bolts, the cam, and the cable fixer will have high stress when engaging the brake. To analyze the stress and simplify the model, only the cam, the cable fixer, and two pins are used in the analysis model.

A torque 47.04 Nm (480 Kg-cm) is apply on the cam as shown in Figure 4. The contact surfaces between the components in this model are set as “contact.” All degrees of freedom (DOF) of the cam are fixed unless rotating in the axis direction. One end of the cable fixer is restrained form all moving and rotating. The materials of all components are set as S45C, and the material properties as shown in Table 4. The stress fields of the bolts and the cable fixer are shown in Figure 5, and the maximum stress is happened on the contact portion between the bolt and the cable fixer. The maximum stress in this analysis is 20.7MPa, it is much less than the yield stress of S45C (343MPa).

Table 4. Material properties of S45C

Young modulus	205 GPa
Poisson ratio	0.29
Yield strength	343 MPa

Analysis 2:

The other analysis in this study is to check the strength requirement of the groove of the cam, but it is difficult to simulate the behavior, i.e. apply force to the cam, of the cable. Thus this study uses an equivalent force on the cam, and fixed the portion that contact with the cable.

The loading is set as a torque 47.04 Nm applying on the cam in the axis direction and a force 2352 N (240 Kgf) applying on the cam in the direction opposite to the contact groove surface as shown in Figure 6. All DOF are fixed on the portion of the groove that contact with the cable. Although this is not equivalent to the contact behavior between the cable and the cam, it can be used as a worse case discussion. The result is shown in Figure 7. The maximum stress is 75.6 MPa, and it is much less than the yield stress of S45C.

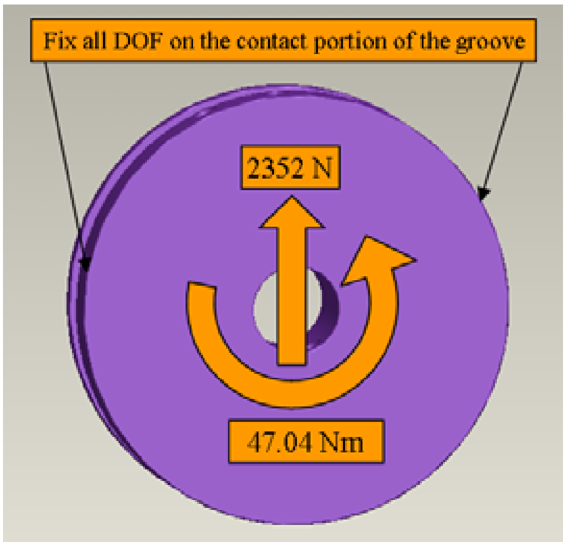


Figure 6. Boundary and loading conditions of analysis 2.

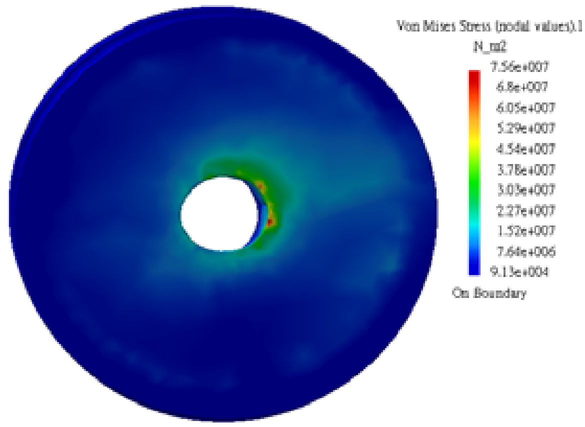


Figure 7. The result of analysis 2.

4. Prototype

The prototype is manufactured as shown in Figure 8. The main mechanism is wrapped in a house, and the house will fixed on the vehicle.

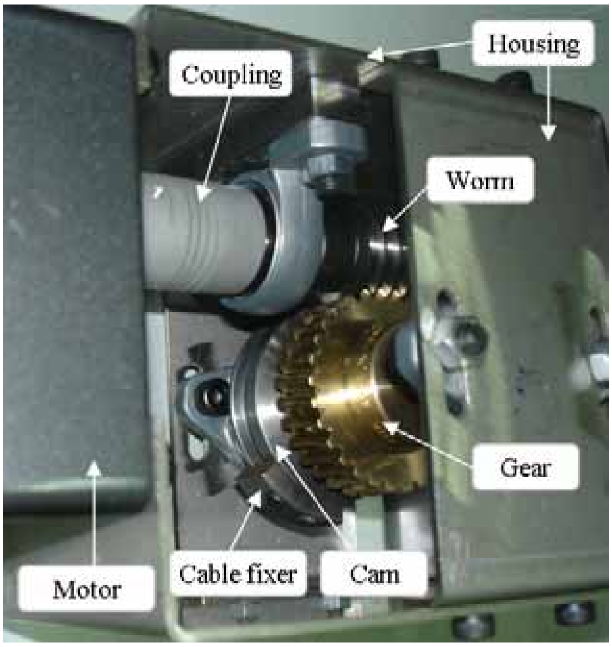


Figure 8. The prototype.

5. Conclusions

The EPB system becomes popular in recent year, and it is usually expansive. This study presents a new design, and it has advantages as follows.

1. The mechanism of this design is very simple and it is not necessary to use a high precision manufacture method. Thus, the cost can be decreased.
2. The cable is fixed in the groove of the cam and the cable fixer by clipping. Thus the cable and the mechanism will not contact on only a little point or

short edge. That will be helpful for avoiding the stress concentration.

3. The worm-gear coupling can provide the self-lock function. Thus the cable can be maintained on the engaging position after the actuator is turned off.
4. The EPB can be released by only using a hexagon driver to turn the releaser shaft when the actuator is failure. Thus, it is not necessary to broken the EPB system.
5. The EPB system is design as an independent system. Thus it can be installed in different existing vehicles.

Otherwise, the main operational components, which materials are set as S45C first, are simulated by the finite element analysis, and the maximum stress is much less than the yield stress. Thus the material of these components can be choused as lower strength materials. That may reduce the total weight or reduce the cost.

6. Acknowledgement

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