

Design, Analysis and Development of Automatic Hand Brake in Car

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Abstract: *The automobile industry is rapidly adopting advanced technologies to improve vehicle safety, reliability, and driver comfort, among which the parking brake system plays a vital role in preventing unintended vehicle movement during parking and emergency situations. In conventional vehicles, the hand brake is manually operated, and due to driver negligence, improper application, or failure to release the brake, accidents, brake overheating, and vehicle damage may occur. To overcome these limitations, the present project titled “Design, Analysis and Development of Automatic Hand Brake in Car” focuses on developing an electro-mechanical parking brake system that automatically engages when the ignition switch is turned OFF and automatically disengages when the ignition switch is turned ON. The proposed system consists of a DC motor, worm and worm wheel gearbox, shaft, bearings, brake cable arrangement, and limit switches for automatic control operation. A worm gear mechanism is selected due to its high speed reduction ratio and self-locking capability, which ensures reliable brake holding without reverse motion. The design calculations include motor selection, speed reduction ratio determination, and worm gear design for effective torque transmission. Finite Element Analysis (FEA) using ANSYS software is carried out to analyze the stress and deformation developed in the worm and worm wheel under loading conditions, and the obtained results confirm that the stresses are within allowable limits, proving the safety and strength of the system. The developed automatic hand brake system reduces driver effort, minimizes human error, improves parking safety on inclined roads, enhances driving comfort, and provides an economical and compact solution that can be implemented in both conventional and electric vehicles with minor modifications, making it highly suitable for future automobile applications.*

Keywords: Automatic Hand Brake, Worm Gear Mechanism, Electro-Mechanical System, Parking Brake Automation, Finite Element Analysis

I. INTRODUCTION

The automobile industry has experienced remarkable technological growth in recent years with a major focus on enhancing vehicle safety, reliability, and driving comfort. Among the various safety systems used in automobiles, the parking brake or hand brake is one of the most important components that prevents accidental vehicle movement during parking conditions, especially on inclined surfaces and uneven roads. Conventionally, hand brakes are manually operated through a lever or pedal mechanism connected to the rear wheel braking system using cables. Although the traditional hand brake system is simple and economical, it completely depends upon the driver’s attention and proper operation. Many times, due to negligence or emergency situations, drivers forget to apply or release the hand brake, which may result in vehicle rolling, brake overheating, accidents, and damage to braking components. According to Mulik Vishal Shamrao et al. [1], automated braking systems significantly improve vehicle safety and reduce accidents caused by human error. Therefore, the development of an automatic hand brake system becomes highly important in modern automotive engineering applications.



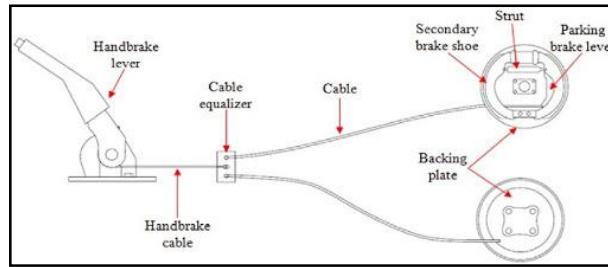


Fig 1: Show Basic Layout of Parking Brake

With the rapid advancement of mechatronics and automotive electronics, conventional mechanical systems are gradually being replaced by intelligent electro-mechanical systems. Modern vehicles are increasingly equipped with Electronic Parking Brake (EPB) systems that use electronic control units, actuators, sensors, and motors for automatic brake operation. Electronic parking brake systems provide better reliability, compactness, ease of operation, and additional safety features such as hill-hold assistance and automatic brake release compared to conventional hand brake mechanisms. Sachin S. Dharia and Sachin S. Bhopale [2] explained that automatic parking brake systems reduce driver effort and improve operational safety during parking and traffic conditions. However, most commercially available EPB systems are expensive and generally implemented only in high-end vehicles. This creates the need for a cost-effective and reliable automatic hand brake system that can be easily incorporated into conventional passenger cars and electric vehicles without significant modifications.

The present project titled “Design, Analysis and Development of Automatic Hand Brake in Car” focuses on developing an electro-mechanical parking brake system that automatically engages when the ignition switch is turned OFF and automatically disengages when the ignition switch is turned ON. The proposed system mainly consists of a DC motor, worm and worm wheel gearbox, shaft, bearings, brake cable arrangement, and limit switches for controlling the braking operation. The worm and worm wheel mechanism is selected because of its high speed reduction capability and self-locking property, which ensures reliable brake holding without reverse motion. Rohan E. Dalvi et al. [4] stated that worm gear-based automatic parking brake systems provide effective locking mechanisms with improved safety and convenience for drivers. The self-locking feature improves vehicle safety by preventing brake release even after power supply interruption. In addition, the proposed system occupies less space near the driver’s seat and improves ergonomic comfort compared to conventional lever-operated hand brakes.

II. PROBLEM STATEMENT

In conventional automobiles, the hand brake system is manually operated and completely dependent on the driver for proper engagement and disengagement. Due to negligence, lack of attention, or emergency situations, drivers often forget to apply or release the parking brake, which may lead to vehicle rolling, brake overheating, brake drum damage, increased wear of braking components, and accidents, especially on inclined roads and parking areas. The conventional hand brake mechanism also occupies additional space near the driver’s seat and requires considerable manual effort for operation, making it less ergonomic and less comfortable for the driver. In electric vehicles and modern automobiles, improper brake engagement can additionally result in overheating of electrical components and excessive load on the motor system. Existing electronic parking brake systems used in high-end vehicles are expensive and difficult to implement in low-cost vehicles. Therefore, there is a need to develop a compact, cost-effective, safe, and reliable automatic hand brake system that can automatically engage and disengage based on the ignition condition of the vehicle while minimizing driver effort and human error.



III. OBJECTIVES

1. To reduce the effort of the driver that leads in conventional one.
2. To increase the comfort and safety for the driver by using modified parking brake system named as automatic handbrake for engagement and release system.
3. In this to developed a warm and warm wheel gear for self locking of system.
4. As when the ignition switch turned ON, handbrake must disengage and vice versa when ignition switch is OFF, handbrake must engage.
5. System may work electro mechanically using motor, sensor and gear box.

IV. LITERATURE SURVEY

Mulik Vishal Shamrao, Chavan Akshay Shivaji, Chavan Akshaykumar Nanaso, and Bagade Ravindra Jalindar [1] presented a review paper on an ignition switch operated parking brake system in which they developed an automatic hand brake system that can be easily implemented in all four-wheelers without making significant changes to the existing manually operated braking system. The authors explained that the operation of the system is simple and efficient and can be successfully incorporated into existing vehicle braking arrangements to improve safety and convenience for drivers.

Sachin S. Dharia and Sachin S. Bhopale [2] discussed advancements in automatic hand brake systems and developed an automatic hand brake release mechanism that improves driver safety by reducing accident possibilities and improper brake disengagement. The researchers stated that the system can be effectively used in commercial cars due to its ease of operation and low cost. Their work also highlighted that the concept can reduce driver effort and eliminate the risks associated with forgetting to apply the hand brake. The proposed system automatically locks the hand brake when the ignition switch is turned OFF, thereby enhancing safety during parking conditions.

Prof. S.C. Shinde, Yadnyesh Patil, Nitish Mane, and Prajakta Nikam [3] developed an automatic hand brake system integrated with an active seat belt mechanism. Their study focused on improving driver safety through an additional locking arrangement near the seat belt buckle. The system prevents the driver from operating the vehicle without wearing the seat belt, thereby reducing the risk of fatal accidents. The researchers explained that modern vehicles equipped with microcontrollers and DSP processors can effectively utilize such intelligent safety systems. Their experimental results demonstrated improved safety performance under braking conditions and highlighted the future scope for implementation in real vehicles.

Rohan E. Dalvi [4] worked on the design and development of an automatic hand brake release system based on engine ignition conditions. The proposed mechanical device brake system automatically applies the brake when the ignition is switched OFF and releases the brake when the ignition is turned ON. The author explained that the system reduces human effort and minimizes operational errors during vehicle parking and starting conditions. The system also provides additional features such as hill-hold assistance and improved vehicle safety on inclined roads and traffic conditions. The study concluded that the system is economical, effective, and suitable for future automobile applications.

Jayesh Chouksey, Pratik Jawade, Sohail Shaikh, and Pradium Jadhav [5] developed an automatic hand brake system for four-wheelers aimed at eliminating the limitations of conventional hand brake systems. Their research emphasized that the use of pneumatic systems allows fast engagement and disengagement of the hand brake while improving vehicle safety. The authors stated that the system reduces manual effort and eliminates operational errors caused by the driver. The proposed mechanism is economical and can be implemented even in low-cost vehicles, making it a practical alternative to expensive electronic parking brake systems used in high-end automobiles.

Nihar Toraskar, Smitesh Mhatre, and Gunjan Rahi [6] reviewed the design and development of automatic emergency parking brake systems. Their work explained the evolution of electronic parking brake systems in modern vehicles since the early 2000s. The researchers described how electronic park brake systems eliminate the need for conventional hand brake levers and cable mechanisms by using electric motors and electronic control units. The system provides automatic brake application and release through a switch-operated mechanism. The study highlighted that parking



brakes are essential not only for vehicle holding but also for assisting drivers during slope starts and improving safety for novice drivers and physically challenged individuals.

V. WORKING OF SYSTEM

1. Ignition Switch OFF Condition

When the ignition switch of the vehicle is turned OFF, the electrical circuit activates the DC motor automatically. The motor starts rotating and transfers power to the worm gear mechanism. Due to the rotation of the worm and worm wheel arrangement, the output shaft rotates with high torque and low speed. This motion pulls the brake cable connected to the parking brake mechanism and applies the hand brake automatically. The self-locking property of the worm gear prevents reverse motion and keeps the brake in locked condition even after the motor stops or the power supply is disconnected.

2. Ignition Switch ON Condition

When the ignition switch is turned ON, the control circuit sends a reverse signal to the DC motor. The motor rotates in the opposite direction, causing the worm and worm wheel mechanism to rotate reversely. This releases the tension in the brake cable and disengages the hand brake automatically. As a result, the vehicle becomes ready for driving without requiring manual release of the parking brake by the driver.

3. Working of Worm and Worm Wheel Mechanism

The worm and worm wheel mechanism is the main power transmission component of the system. It provides a high speed reduction ratio and converts the high-speed rotation of the motor into low-speed high-torque motion required for brake application. The worm gear arrangement also acts as a self-locking mechanism, which prevents the brake from releasing automatically under load conditions. This improves the safety and reliability of the parking brake system.

4. Role of Limit Switches and Sensors

Limit switches are used to control the movement of the motor during brake engagement and disengagement. When the brake reaches its fully applied or released position, the limit switch cuts off the power supply to the motor and stops further rotation. This prevents over-travel of the mechanism and protects the system components from damage. Sensors and switches ensure smooth, automatic, and controlled operation of the hand brake system.

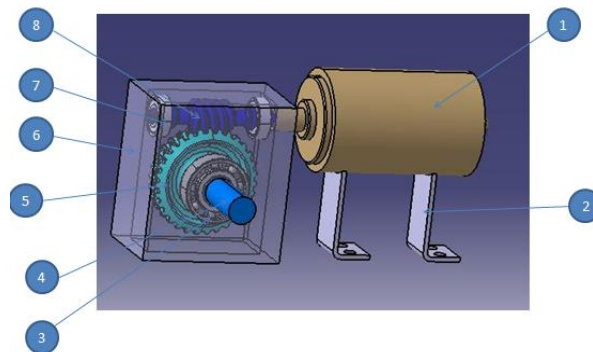


Fig 2: Proposed 3D model of Automatic break

5. Overall System Operation

The complete system works electro-mechanically using a DC motor, gearbox, worm gear arrangement, limit switches, and brake cable mechanism. The automatic hand brake system reduces driver effort, minimizes human error, improves parking safety on inclined roads, and enhances driving comfort. The system is compact, economical, and suitable for implementation in conventional as well as electric vehicles.



VI. SYSTEM DESIGN

1. Design Consideration

The automatic hand brake system is designed to provide safe, reliable, and automatic parking brake operation in automobiles. The design mainly focuses on reducing driver effort, minimizing human error, and improving vehicle safety during parking conditions. The system is designed in such a way that the hand brake automatically engages when the ignition switch is turned OFF and automatically disengages when the ignition switch is turned ON. The important factors considered during the design include compact size, ease of operation, self-locking capability, sufficient braking force, low power consumption, and economical manufacturing.

2. Motor Selection

A DC starter motor is selected for the system because of its high torque generation capability and easy availability. The motor specifications are as follows:

- Rated Voltage = 12 V
- Rated Power = 0.35 kW
- Motor Speed = 7000 RPM
- Maximum Current = 80 A
- Application = Starter Motor

The motor provides the required rotational motion for operating the worm gear mechanism and applying the hand brake automatically.

3. Speed Reduction Gearbox Design

The motor rotates at a very high speed; therefore, a reduction gearbox is required to reduce the speed and increase the output torque. The required output speed for brake application is 240 RPM.

$$\text{Gear Ratio} = \frac{\text{Input Speed}}{\text{Output Speed}}$$

$$i = \frac{7000}{240} = 29.16 \approx 30$$

Hence, a gear reduction ratio of approximately 1:30 is selected. A worm and worm wheel gearbox is used because it provides large speed reduction along with self-locking characteristics.

4. Worm and Worm Wheel Design

The worm and worm wheel are designed to transmit power effectively and provide self-locking action. The specifications used in the design are:

- Module (m) = 3 mm
- Pressure Angle = 20°
- Number of Teeth on Worm Wheel = 60
- Worm Threads = 2
- Worm Diameter = 16 mm
- Worm Wheel Diameter = 115 mm

The worm gear mechanism converts the high-speed rotation of the motor into low-speed high-torque motion required for brake application.

5. Shaft Design

The output shaft is designed to transmit torque from the worm wheel to the brake cable mechanism. The shaft diameter is selected based on torque transmission requirements and strength considerations. Bearings are provided on both sides of the shaft for smooth rotation and proper alignment.

6. Brake Cable Mechanism

The brake cable mechanism connects the output shaft to the vehicle parking brake arrangement. When the shaft rotates, the cable is pulled and the brake is applied automatically. Reverse rotation of the shaft releases the brake cable and disengages the parking brake.



7. Limit Switch Arrangement

Limit switches are provided to stop the motor after complete engagement or disengagement of the brake. These switches prevent over-travel of the mechanism and protect the motor and gearbox from damage.

8. CAD Modeling and Assembly

The complete system is modeled using CAD software to develop the three-dimensional assembly of the automatic hand brake mechanism. The CAD model includes the motor, gearbox, worm gear arrangement, shaft, bearings, support frame, and brake cable system. The CAD model helps in understanding the assembly, alignment, and working of the system before fabrication.

9. Finite Element Analysis (FEA)

Finite Element Analysis is carried out using ANSYS software to determine the stress and deformation developed in the worm and worm wheel under applied loading conditions. The analysis confirms that the stresses are within permissible limits and the designed components are safe for operation.

VII. RESULTS

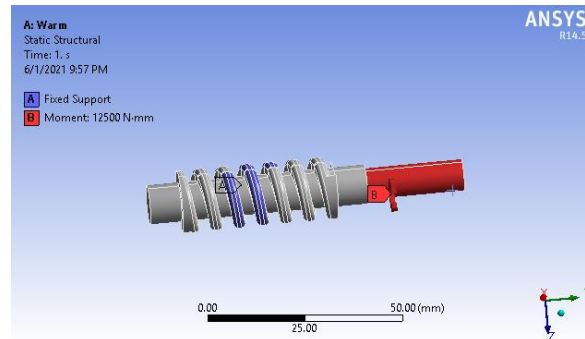


Fig 3: Output 1

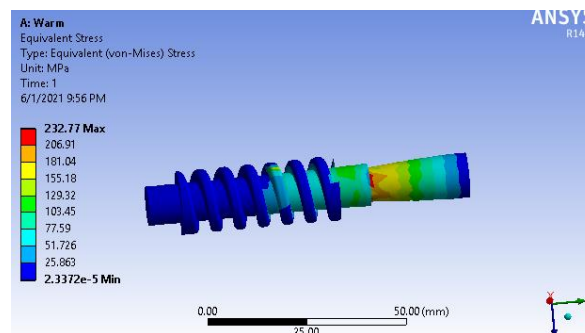


Fig 4: Output 2



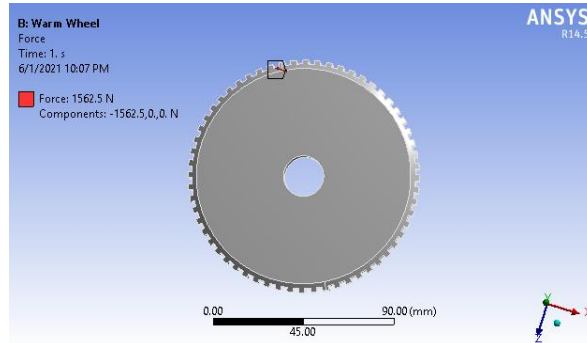


Fig 5: Output 3

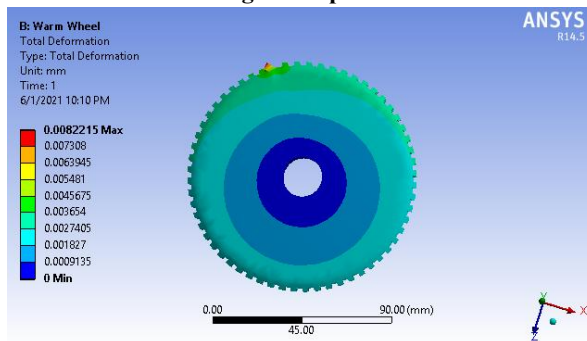


Fig 6: Output 4

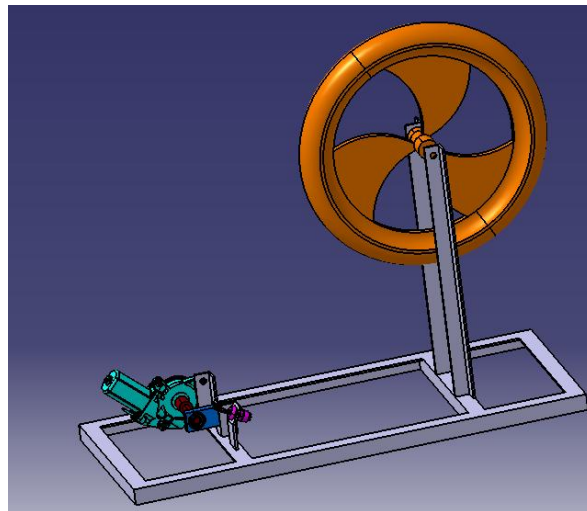


Fig 7: Proposed working model of automatic hand brake system

The automatic hand brake system was successfully designed, fabricated, and analyzed for safe and reliable parking brake operation in automobiles. The system operated according to the expected conditions in which the hand brake automatically engaged when the ignition switch was turned OFF and automatically disengaged when the ignition switch was turned ON. The worm and worm wheel gearbox provided effective speed reduction and sufficient torque for brake application. Due to the self-locking property of the worm gear mechanism, the brake remained in locked condition even after power supply interruption, thereby improving the safety of the system.



Finite Element Analysis (FEA) was carried out using ANSYS software to determine the stress and deformation developed in the worm and worm wheel components under loading conditions. The obtained results confirmed that the stresses developed in both components were within allowable limits and the design was structurally safe. The deformation and stress results obtained during analysis are shown below:

Sr. No.	Boundary Condition	Worm Deformation (mm)	Worm Stress (MPa)	Worm Wheel Deformation (mm)	Worm Wheel Stress (MPa)
1	1562.5 N Force	NA	NA	0.00822	104.28
2	12500 N-mm Moment	0.036	232.77	NA	NA

The worm wheel showed very low deformation under applied force, while the stress values of both worm and worm wheel remained below permissible stress limits. The automatic hand brake system also reduced manual effort, minimized operational errors, and improved parking safety on inclined roads. The developed system was compact, economical, and suitable for implementation in both conventional and electric vehicles.

VIII. CONCLUSION

The present project titled “Design, Analysis and Development of Automatic Hand Brake in Car” was successfully completed with the objective of developing a safe, reliable, and automatic parking brake system for automobiles. The developed system effectively eliminates the limitations associated with conventional manually operated hand brakes by automatically engaging and disengaging the brake based on the ignition switch condition. The automatic operation reduces driver effort, minimizes human error, and improves vehicle safety during parking, especially on inclined roads and traffic conditions.

The proposed system uses an electro-mechanical arrangement consisting of a DC motor, worm and worm wheel gearbox, shaft, bearings, limit switches, and brake cable mechanism. The worm gear arrangement provides high speed reduction and self-locking capability, which ensures effective brake holding even when electrical power is disconnected. The system operates smoothly and provides reliable brake application and release without requiring manual intervention from the driver. Due to its compact and economical design, the mechanism can be easily implemented in conventional as well as electric vehicles with minor modifications.

The design calculations carried out for motor selection, speed reduction ratio, and worm gear mechanism confirmed that the selected components are suitable for the required braking operation. Finite Element Analysis (FEA) performed using ANSYS software showed that the stress and deformation developed in the worm and worm wheel are within allowable limits. The analysis results confirmed that the designed components are structurally safe and capable of withstanding the applied loading conditions during operation.

The developed automatic hand brake system also improves ergonomic comfort by eliminating the need for a conventional hand brake lever near the driver’s seat. The use of limit switches and automatic control mechanisms ensures smooth engagement and disengagement of the brake while preventing over-travel and component damage. The system provides improved operational reliability, reduces accidents caused by improper parking brake operation, and enhances overall driving comfort and safety.

From the overall study and experimental analysis, it can be concluded that the automatic hand brake system is an effective and practical solution for modern automotive applications. The system offers several advantages such as low cost, compactness, automatic operation, improved safety, reduced driver effort, and reliable performance. Therefore, the proposed design has strong potential for future implementation in automobiles and can contribute significantly toward the development of advanced intelligent vehicle safety systems.



IX. FUTURE SCOPE

The developed automatic hand brake system has significant future scope in modern automobile applications due to the increasing demand for vehicle safety, automation, and driver comfort. In future, the system can be integrated with advanced electronic control units, smart sensors, and intelligent vehicle systems for fully automatic brake operation. Additional features such as hill-hold assist, anti-lock braking system (ABS) integration, and advanced driver assistance systems (ADAS) can further improve the safety and reliability of the mechanism. The system can also be connected with IoT-based monitoring and wireless control technologies for remote diagnostics and smart vehicle applications.

Further improvements can be made by reducing the size and weight of the gearbox and motor arrangement using lightweight materials such as aluminum alloys and composite materials. The system can also be implemented effectively in electric vehicles and autonomous vehicles where automatic safety mechanisms are highly essential. Future research may focus on improving response time, reducing power consumption, and enhancing braking efficiency through hydraulic or pneumatic actuation systems. With advancements in automation and artificial intelligence, the proposed automatic hand brake system can become an economical and reliable alternative to expensive electronic parking brake systems used in modern high-end

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