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Smart Hybrid Braking System: A Novel Approach to Enhanced Vehicle Safety

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Abstract
The growing need for sophisticated braking systems has given rise to smart hybrid braking systems. This pa-per introduces a Smart Hybrid Braking System that combines electromagnetic and drum brakes with an Arduino Nano microcontroller. The system automati-cally changes between the two braking modes depend-ing on speed and obstacle detection to provide maximum braking efficiency and safety. During cruising speeds, the system utilizes electromagnetic braking to provide smooth braking, while obstacle detection automatically activates an immediate switch to drum brakes for emer-gency braking. The proposed system provides greater vehicle stability and less wear on conventional braking parts.

Keyword:**–Smart braking, hybrid braking system, elec-tromagnetic braking, Arduino Uno, vehicle safety, ob-stacle detection.**

I INTRODUCTION

Braking systems are also important in terms of ensuring safety in vehicles. They slow or stop a vehicle, and proper functioning is critical to avoid accidents. The conventional braking systems, however, have a number of limitations[1]. They are subject to wear and tear, and as a result, their braking performance can decrease while maintenance becomes expensive. Conventional brakes can also have slow response times, and this can be crucial during emergencies.

Conventional braking systems also suffer from over-heating, especially under frequent braking or downhill driving[2]. This causes the brakes to fade, resulting in a loss of braking performance. Additionally, conventional brakes use friction to slow or stop a vehicle, and that may cause wear on the brake components. This not only results in higher maintenance costs but also decreases braking performance[3]. With the drawbacks of conven-tional braking systems, contemporary braking systems are combining electronic and hybrid braking methods. Electromagnetic brakes, for instance, offer frictionless braking, minimizing maintenance costs and increasing efficiency[4]. Magnetic brakes employ electromagnetic forces to decelerate or stop a vehicle without friction. In contrast, drum brakes ensure effective emergency brak-ing, offering a fail-safe method in situations where it really matters[5].

This study deals with the integration of a Smart Hy-brid Braking System (SHBS) that adaptively toggles be-tween electromagnetic and drum brakes as per driving situations[6]. The SHBS integrates advanced sensors and control algorithms to constantly monitor the vehicle speed, acceleration, and braking needs. With this in-formation, the system best toggles between the electro-magnetic and drum brakes for effective and safe braking performance. The SHBS can potentially improve ve-hicle safety tremendously, lower maintenance cost, and increase overall brake efficiency.

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II EXISTING METHOD

In the present-day automobile world, most automobiles use conventional brakes like hydraulic drum brakes or disc brakes. Such brakes are dependent on the mechanical transfer of power from the foot of the driver to brake shoes or pads using brake fluid and ultimately to the braking of the car. While these braking systems are established and efficient in normal driving conditions, they still rely heavily on the judgment and reaction time of the driver. This can be a significant limitation in emergency situations where prompt action is needed to prevent accidents.

In order to enhance safety, certain cars have Anti-lock Braking Systems (ABS), which avoid locking of wheels at the time of sudden braking. ABS enhances steering control and reduces skidding, especially on a slippery surface. Even ABS operates reactively and does not avoid accidents due to slow reaction by the driver. It does not offer any kind of automation or intelligent decision-making based on external situations such as roadblocks or traffic patterns.

In recent times, more advanced technologies like electromagnetic brakes and electronic braking systems (EBS) have been coming into use, particularly in premium and commercial vehicles. These mechanisms employ electrical impulses and magnetic attraction to provide braking, with benefits of quicker responses and less mechanical wear. Nonetheless, such devices tend to be costly and do not find many applications in mass-market passenger vehicles because of the complexity and higher expense involved. In addition, they typically operate separately and are not coupled with sensor-based automation to toggle between types of braking based on real-time conditions.

A few high-end cars have begun to employ adaptive braking systems based on radar, LiDAR, or ultrasonic sensors. These assist in sensing the obstacles ahead of the vehicle and automatically brake when the driver does not respond in time. This provides an extra layer of safety, but features like these are typically reserved for luxury segments and are not economical or available for the masses. In addition, even such systems normally function on a single type of braking and do not have the flexibility or the intelligence to alternate between various types of braking based on speed or proximity to obstacles. This reflects a glaring lacuna in current approaches where intelligent, affordable hybrid braking systems remain underdeveloped and underutilized in the broader automotive sector.

III PROPOSED SYSTEM

The system brings forth a hybrid smart braking mechanism that integrates both electromagnetic braking and conventional drum braking, regulated wisely by a microcontroller. The main aim is to improve safety, responsiveness, and efficiency through automatic switching between braking modes in accordance with the speed of the vehicle and proximity to objects. In contrast to the traditional systems dependent only on the input from drivers, this system is based on real-time sensor data for decision-making, thus eliminating human mistakes and response time in emergency situations.

During cruising speeds, the system uses electromagnetic braking to provide smoother deceleration with reduced mechanical wear. Electromagnetic brakes provide fast response and are more effective for control in nor-mal driving conditions. Yet, when an obstacle is sensed within a specified distance, the system immediately over-rides the electromagnetic brake and engages the drum brake to supply stronger and faster stopping power. This intelligent switching between the two braking modes as-sists in helping to ensure safety without any loss of ride comfort or brake life.

The system also includes an ultrasonic sensor for detecting obstacles and a potentiometer for emulating vari-able speed input. The sensor data is processed and the braking mode controlled by a microcontroller like an Arduino Nano. A 16-bit display is also utilized to dis-play appropriate information like brake status and the distance to the closest obstacle. The circuit is powered by a 12V battery, and a buck converter is employed to reduce the voltage to 5V for devices that need lower power.

Through the integration of intelligent control with dual-mode braking, this hybrid system overcomes the shortcomings of current braking solutions. It is an economical and effective solution for improving vehicle safety, particularly for mid-range and affordable vehicles. The suggested system illustrates how sensor-based automation can be integrated with conventional hardware to create smarter, more efficient, and safer braking systems for future transport.

IV BLOCK DIAGRAM

Fig.1 illustrates an intelligent hybrid braking system. The system includes an ultrasonic sensor on the bumper to sense obstacles, a speedometer on the transmission to capture speed, and a microcontroller that receives input from both sensors. The system is powered by the battery. Depending on the speed and presence of obstacles, the microcontroller regulates the brake mechanism through activation of either the Electronic Brake Control Module (EBCM) in case of drum braking or an electromagnetic coil in the case of electromagnetic braking. During cruising speeds, the system resorts to electromagnetic braking but switches to drum braking as soon as an obstacle is detected for safety purposes.

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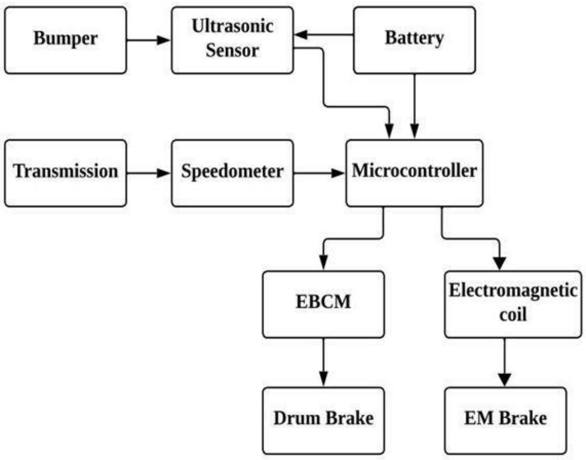

Figure 1: Block Diagram

V CIRCUIT DIAGRAM

The Smart Hybrid Braking System circuit,shown in Fig.2, is designed to enhance vehicle safety by integrating both electromagnetic and drum braking mechanisms, controlled by an Arduino Nano. The system is powered by a 12V battery, which provides energy to various components. Since some components re-quire a lower voltage, a buck converter (LM2596) steps down 12V to 5V for safe operation of the Arduino, sen-sors, servo motor, and LCD display. The Arduino Nano acts as the central controller, processing sensor data and managing braking actions based on real-time conditions. The vehicle's motion is simulated using a DC motor (M1), which is controlled by an IBT-4 H-Bridge motor driver (M3). The Arduino regulates the motor's speed using PWM signals, allowing speed adjustments similar to an actual vehicle.

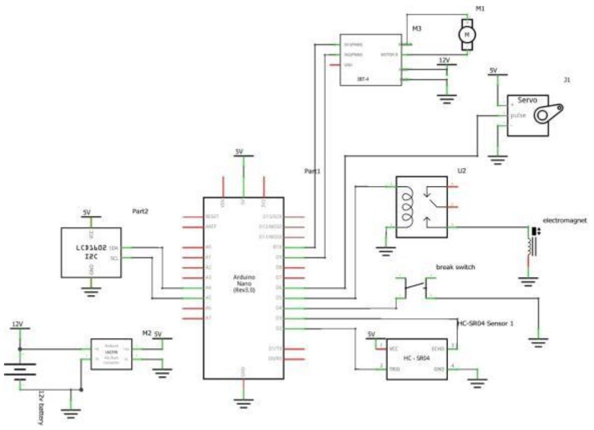

Figure 2: circuit diagram

For obstacle detection, an HC-SR04 ultrasonic sensor continuously monitors the distance between the vehicle and objects in its path. The sensor emits ultrasonic waves, which reflect off obstacles and return to the sensor. The Arduino calculates the distance based on the time taken for the waves to return, making it capable of identifying nearby obstacles. If the distance falls within a critical range, the system immediately disengages the electromagnetic brake and activates the drum brake, ensuring an immediate stop to prevent a collision. The system functions in three modes: during normal driving at cruising speeds between 35-70 kmph, the system engages the electromagnetic brake, which generates a magnetic field that slows the vehicle gradually, reducing mechanical wear on the drum brake. If an obstacle is detected, the electromagnetic brake is turned off, and the drum brake is engaged using a servo motor that moves a brake lever. Additionally, a manual brake switch allows the driver to override the system and apply the drum brake in emergency situations.

A relay module (U2) is used to control the electromagnet, allowing the system to switch between braking modes as needed. The system also includes an LCD1602 display with an I2C interface, which provides real-time feedback on the braking mode, distance to obstacles, and brake status. This ensures that the driver or system operator is always aware of the vehicle's braking con-dition. The circuit effectively enhances vehicle safety and braking efficiency by integrating automated obsta-cle detection with a dual-braking mechanism. By en-suring smooth transitions between braking modes based on real-time conditions, this system is a cost-effective and practical innovation for modern vehicles, including autonomous cars, electric vehicles, and advanced driver assistance systems.

VI SIMULATION AND RESULT

The performance of the SHBS simulated is illustrated in Fig.3, illustrating how the system acts under varying conditions.

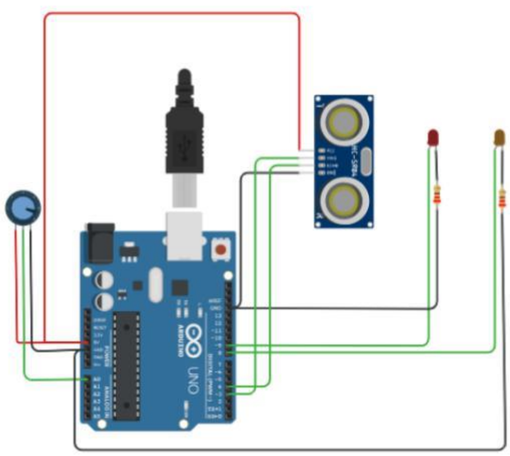

Figure 3: Simulation Diagram

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The drum brake LED lights up, indicating that the drum brake is engaged and the electromagnetic brake LED remains off as shown in Fig.4.The electromagnetic brake LED lights up, showing that the system has engaged the electromagnetic brake. The drum brake LED remains off as shown in Fig.5. Upon detecting an obstacle, the system immediately switches from the electromagnetic brake to the drum brake for a quick stop. The drum brake LED lights up, while the electromagnetic brake LED turns off as shown in Fig.6.

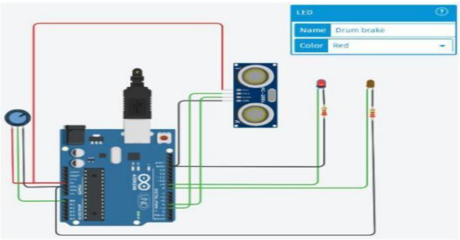

Figure 4: Drum Brake Engagement at Low Speeds

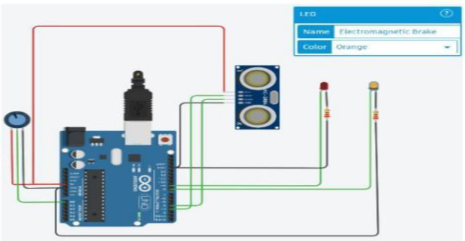

Figure 5: Electromagnetic Brake Engagement at Cruis-ing Speed

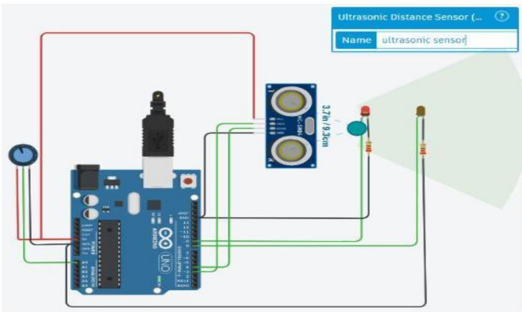

Figure 6: Automatic Brake Switching to Drum Brake Upon Obstacle Detection

Figure 7: Smart Hybrid Braking System

The experimental findings validate that the Smart Hybrid Braking System dramatically improves efficiency and safety in braking systems. Application of electromagnetic brakes at moderate speeds minimized the application of drum brakes, thus reducing mechanical wear and tear. The decrease in mechanical wear not only increases the lifespan of the braking system but also saves fuel and reduces maintenance costs in vehicles. By maximizing braking efficiency, the Smart Hybrid Braking System presents a potential solution to enhance vehicle safety and efficiency. The Smart Hybrid Braking System's readiness to switch instantly to drum brakes if an obstacle is sensed provides optimum braking power, essential for preventing accidents. Real-world application would need extremely precise sensors to prevent false triggering and accurate sensing of obsta-cles. False triggering or loss of detection could lead to catastrophic consequences in the form of undesired brak-ing or accidents. Thus, the creation of highly precise and dependable sensors is crucial for the effective deploy-ment of the Smart Hybrid Braking System. Although the simulation results are promising, the Smart Hybrid Braking System has some limitations. The simulation was validated in a controlled Tinkercad environment, and actual testing would entail hardware calibration and adjustments. Improvements in the future can target the incorporation of artificial intelligence (AI) in predictive braking, improving sensor precision, and power con-sumption optimization in electromagnetic braking[20]. By identifying these limitations and investigating poten-tial areas for improvement, the Smart Hybrid Braking System can be further developed to offer even more safety and efficiency advantages in actual use.

VII HARDWARE IMPLEMENTATION

Smart Hybrid Braking System proved to switch between electromagnetic and drum braking effectively under con-ditions of speed. Below a certain speed, the drum brakes were continuously engaged, offering assured stopping capability. With a rise in speed, the system automat-ically engaged the electromagnetic brakes, decreasing mechanical wear and tear. This was done at a preselected speed level, providing a smooth and secure braking ex-perience. In addition, at increased speeds, the system re-activated the drum brakes for increased safety, showing that it could respond to varying driving conditions. The Smart Hybrid Braking System also performed outstand-ingly in obstacle detection and emergency braking tests. When an obstacle was detected, the system promptly changed to drum braking, taking priority over electro-magnetic braking. Such prompt action guaranteed short reaction times on the road, with a measured response time for obstacle detection to drum brake engagement being within milliseconds. This great performance high-lights the system's ability to deliver dependable and ef-fective emergency braking, greatly improving vehicle

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safety. The Smart Hybrid Braking System also registered significant gains in power efficiency and performance. The electromagnetic braking system exhibited reduced energy consumption during cruising speeds in comparison to continuous drum brake use. Additionally, switching between braking modes was smooth and effi-cient, without any apparent lag. This smooth transition guarantees a comfortable and secure driving experience, while minimizing energy consumption and wear on the braking system. Generally, the findings establish the efficacy and effectiveness of the Smart Hybrid Braking System. The hardware is shown in Fig.7.

VIII CONCLUSIONS

The Smart Hybrid Braking System is a revolutionary development in the field of automobile safety, bringing a new level of braking technology. Through a smooth combination of electromagnetic and drum braking, the system offers a complete solution to improved braking efficiency. The intelligent design allows the Smart Hy-brid Braking System to overcome the constraints of con-ventional braking systems, which are usually limited to mechanical functionality. The Smart Hybrid Braking System has several major advantages, such as enhanced braking efficiency, minimized wear and tear, and better response during emergency braking. The system can adjust to varying driving conditions so that the car is always armed with the most efficient braking technique. By reducing wear on mechanical parts, the Smart Hybrid Braking System also leads to lower maintenance costs and a longer vehicle life As the Smart Hybrid Brak-ing System develops further, future innovations might involve incorporating machine learning algorithms to allow adaptive braking techniques. This cutting-edge technique would enable the system to learn from ac-tual driving conditions and adapt its braking patterns accordingly. With the help of machine learning, the Smart Hybrid Braking System could enhance its per-formance even more, offering drivers even more safety and efficiency advantages. To further confirm the effi-cacy of the Smart Hybrid Braking System, real-world testing is needed. This would be done by integrating the system in a vehicle and testing it stringently under a range of driving conditions. Real-world testing would yield rich data on the system's performance, allowing researchers to fine-tune and optimize its design. With simulation-based testing supported by real-world valida-tion, the Smart Hybrid Braking System has the potential to be engineered as a safe and effective braking solution for the car industry.

REFERENCES

1. Uday Pratap Singh, A.K.Jain, "Design and analysis of drum brake by fea: A Review", 2018 IJRTI — Volume 3, Issue 6 — ISSN: 2456-3315.
2. Shrinidhi D, Swasthik DK, Uday Kiran P, Ujwal N and Saleem Khan, "Design and fabrication of air brake system using IC engine exhaust gas", Inter-national Journal of Science and Research Archive, 2022, 07(02), 161–167.
3. Ramachandru, Guduru Rama Krishna Reddy, Vinod Kumar S, " Dynamic Analysis Of Mechan-ical Braking System".Open Journal of Technology and Engineering Disciplines (OJTED) Vol. 2, No. 4, December 2016, pp. 178 185 ISSN: 2455-6971.
4. Sandeep Ramarao, Anant Dhobale, "Electromagnetic Braking System",ICONIC RESEARCH AND ENGINEERING JOURNALS ,IRE Journals — Volume 5 Issue 1 — ISSN: 2456-8880.
5. Dr. S. R. Pawar, Shubham D. Satam, Saif Ali Shaikh, Amit R. Shah, "Analysis of Electromag-netic Braking System",International Journal of Re-search in Engineering and Science (IJRES) ISSN (Online): 2320-9364, ISSN (Print): 2320-9356 ,ijres Volume 10 Issue 4, 2022, PP. 19-26
6. Yuxuan Shi, Jihong Pang,Yuzuanhong Chen, "An Intelligent Control Model Based on Digital Twin Technology and Optimized LeastSquares Support Vector Regression for Predicting Electromagnetic Brake Assembly Quality", IEEE Access, vol. 11, pp. 137303-137316, 2023, doi: 10.1109/AC-CESS.2023.3331734.
7. Sabri, M.; Fauza, A., "Analysis of vehicle braking behaviour and distance stopping.", IOP Conf. Ser. Mater. Sci. Eng. 2018, 309, 012020.
8. Kchaou, M.; Sellami, A. Riadh Elleuch, R.; Singh, H, "Friction characteristics of a brake friction ma-terial under different braking conditions", Mater. Des. 2013, 52, 533–540.
9. Bao, J.; Liu, J.; Yin, Y.; Liu, "Characterization and experiments on the friction catastrophe behaviors of brake material during emergency braking", iEng. Fail. Anal. 2015, 55, 55–62
10. Rashid, "A. Overview of Disc Brakes and Related Phenomena—A review", Int. J. Veh. Noise Vib. 2014, 10, 257–301.
11. popa, M.-F.; Burnete, N.V, "Study of Brake Sys-tem Parameters for Commercial Vehicles",. In Pro-ceedings of the 4th International Congress of Auto-motive and Transport Engineering (AMMA 2018); Springer: Cham, Switzerland, 2019.
12. Borawski, A, "Impact of Operating Time on Se-lected Tribological Properties of the Friction Mate-rial in the Brake Pads of Passenger Cars", Materials 2021, 14, 884.
13. AH. Xu and F. Wu, "The Analysis of Crane Drum Brake's Frictional Behavior Based on ADAMS", 2017, doi: 10.2991/ifmca-16.2017.57
14. Mohammed Abdul Aleem , Asrar Ahmed Saad , Abdul Sohail , Shaik Mohammed Siraj , M. Raghunath Reddy, "Design And Analysis of Drum Brakes" ISSN 2348–2370 Vol.10,Issue.04, April-2018,

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 04, April-2025

15. JaeWoong Lee. Seoul"Magnetic Brake System For a Vehicle", Rep. of Korea United States Patent Patent Number: 5,746,294
16. Ren He,Xuejun Liu "Brake Performance Analysis of ABS for Eddy Current and Electrohydraulic Hybrid Brake System" School of Automotive & Traffic Engineering, Jiangsu University, Zhenjiang 212013, China Received 24 September 2013; Revised 29 October 2013; Accepted 30 October 2013
17. G. G. Desta, "Eddy Current Brake System," 2004, US 6,698,554 B2.
18. Limpert Rudolf "Brake design and Safety", Society of Automotive Engineers, Warrandable, Inc, PA, USA, 1992
19. A.J., Harding,P.R.J. and Newcomb, T.P,"combined thermal and mechanical analysis of drum brakes"Proc.Inst.Mech. Engr., vol 198D,No.15,1984,pp 287-294
20. Donld E. Schenk, Richard L. Wells and Jon E. Miller, "Intelligent Braking for Current and Future Vehicles", SAE paper.