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Automatic Pneumatic Bumper and Braking System for Four-Wheelers

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ABSTRACT

Road accidents are a major concern worldwide especially those caused due to sudden obstacles or brake failure. To reduce the impact of such collisions and enhance vehicle safety, this paper proposes an Automatic Pneumatic Bumper and Braking System for four-wheelers. The system uses proximity sensors to detect obstacles in the vehicle's path and activates a pneumatic bumper along with the braking system automatically. A microcontroller unit (such as Arduino) processes the data from the ultrasonic sensors and triggers a solenoid valve to actuate a pneumatic cylinder. The pneumatic bumper absorbs part of the impact, while the automatic braking system stops the vehicle in time, reducing potential damage. This intelligent safety mechanism works as a dual protection unit for both low- and high-speed scenarios. The system has been prototyped and tested on a scaled model, showing significant reduction in damage during simulated collision tests. The use of pneumatics offers quick response, low cost, and high reliability. This project showcases how automation and mechanical systems can be integrated to build proactive safety features in vehicles

Keyword: - Automatic braking, pneumatic system, vehicle safety, ultrasonic sensor, Arduino, accident prevention

1. INTRODUCTION

With the increasing number of vehicles on roads, accidents due to driver negligence, brake failure, or delayed reaction time are common. Modern vehicles need smart safety mechanisms that act before the driver can respond. One such innovation is the automatic braking system integrated with a pneumatic bumper. This system uses real-time obstacle detection and compressed air to actuate bumpers, reducing the damage caused by collisions. Unlike traditional bumpers that passively absorb shock, this system deploys a pneumatic mechanism to actively engage upon threat detection. The goal of this project is to integrate proximity sensing, Arduino-based control, and pneumatic actuation to enhance vehicular safety..

1.1 Problem Statement

Manual braking is prone to delays, especially during distractions or mechanical failure. Traditional bumpers are only passive, absorbing shock but not preventing impact. There is a need for a system that combines proactive braking and physical protection mechanisms.

1.2 Objectives of the System

- Automatically activate brakes when obstacles are detected.
- Deploy a pneumatic bumper system to reduce collision impact.
- Enhance driver and passenger safety in critical conditions.
- Use cost-effective and easily available materials for implementation.

2. SYSTEM DESIGN AND ARCHITECTURE

The proposed system combines mechanical, electronic, and pneumatic components. The major units include an ultrasonic sensor for obstacle detection, Arduino UNO microcontroller for logic control, a solenoid valve to actuate the air flow, and a pneumatic cylinder to extend the bumper. Braking is also controlled using an additional servo motor or mechanical braking linkage.

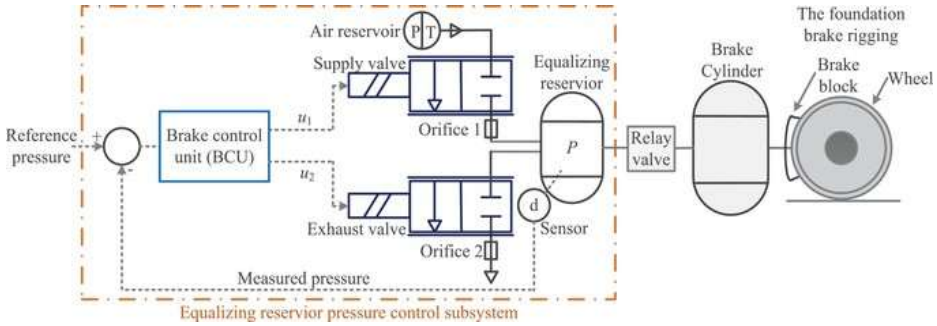

Fig -1: Block Diagram of Automatic Pneumatic Bumper and Braking System

2.1 Block Diagram of the System

• Ultrasonic Sensor (HC-SR04):

The HC-SR04 is a widely used proximity sensor that utilizes ultrasonic sound waves to detect the distance of objects in its path. It emits a high-frequency sound pulse and measures the time it takes for the echo to return after hitting an obstacle. This time delay is then converted into distance using the speed of sound formula. The HC-SR04 has a detection range of approximately 2 cm to 400 cm with an accuracy of about 3 mm. In the proposed system, it continuously scans the front of the vehicle. When an object is detected within a predefined threshold (e.g., 30 cm), it sends a signal to the Arduino to trigger the braking and bumper actuation system.

• Arduino UNO:

Arduino UNO is an open-source microcontroller board based on the ATmega328P chip. It features 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, and a power jack. In this project, the Arduino UNO acts as the central control unit. It receives distance data from the ultrasonic sensor, processes it according to the programmed threshold, and sends output signals to actuate the solenoid valve and servo motor. The Arduino ensures real-time decision-making and synchronization between different subsystems of the project.

• Pneumatic Cylinder and Compressor:

The pneumatic cylinder is a mechanical device that uses compressed air to create linear motion. In this system, a single-acting pneumatic cylinder is used to push out the bumper upon activation. The compressor provides the required pressurized air supply, typically between 5 to 8 bar, and stores it in an air tank or directly feeds it to the solenoid valve. When the system detects an obstacle, the solenoid valve opens, and the compressed air pushes the cylinder piston forward, thereby deploying the bumper in milliseconds to absorb or deflect the impact.

• Solenoid Valve:

A solenoid valve is an electromechanically operated valve used to control the flow of air or fluids. In this setup, a 12V DC solenoid valve is connected between the compressor and the pneumatic cylinder. It stays closed by default and opens only when energized by a signal from the Arduino. When the valve opens, compressed air flows into the pneumatic cylinder, causing the bumper to extend. After the system resets or the object is cleared, the valve closes, allowing the cylinder to retract. It plays a critical role in controlling the timing and precision of bumper deployment.

• Battery:

A rechargeable 12V battery is used to power all the electrical components of the system, including the Arduino, solenoid valve, ultrasonic sensor, and servo motor. A stable power supply is essential to ensure real-time performance and avoid latency in safety-critical operations. The battery also ensures portability and uninterrupted operation in the event of main power failure or during mobile demonstrations.

• Servo Motor for Braking Mechanism:

The servo motor is a rotary actuator that allows for precise control of angular position. In this project, it is used to mimic a braking mechanism. Upon receiving a signal from the Arduino, the servo motor rotates to pull a lever or push a braking plate attached to the prototype's wheel mechanism. The braking system immediately halts the vehicle to prevent collision. Servo motors are chosen for their quick response, precision, and ease of control via PWM (Pulse Width Modulation) signals from the Arduino.

2.2 Working Principle

- The ultrasonic sensor continuously monitors the front region of the vehicle.
- If any object comes within a pre-defined critical distance (e.g., 30 cm), it sends a signal to the Arduino.
- The Arduino processes the signal and activates the solenoid valve, allowing compressed air to push the pneumatic cylinder forward.

- Simultaneously, the Arduino also activates the brake via a motorized system or linear actuator.
- The bumper retracts after the obstacle is removed.

3. COMPONENTS USED AND SPECIFICATIONS

Component	Specification	Function
Arduino UNO	ATmega328P	Controls sensor input and output signals
Ultrasonic Sensor	HC-SR04, 2 cm to 400 cm range	Detects obstacles in front of the vehicle
Pneumatic Cylinder	Single acting, 16 mm bore, 100 mm stroke	Extends bumper using compressed air
Solenoid Valve	12V DC, 2-way valve	Regulates air flow to pneumatic cylinder
Air Compressor	12V mini compressor	Provides compressed air for the system
Relay Module	5V Relay Module	Switches solenoid valve on/off
Servo Motor	180° rotation	Applies braking force

Chart -1

4. SYSTEM FEATURES AND ADVANTAGES

• Real-time obstacle detection:
Ultrasonic sensors allow constant monitoring of the vehicle's path, ensuring immediate detection of any obstruction. This real-time data processing ensures minimal response time.
• Automatic braking mechanism:
The system includes an automated brake actuation, either via servo motor or electromechanical linkage, that stops the vehicle as soon as an obstacle is detected.
• Pneumatic bumper actuation:
The pneumatic system is activated instantly using compressed air, pushing out a buffer zone that physically prevents direct impact and absorbs collision forces.
• Fail-safe and low maintenance:
The system uses simple mechanical and electronic parts with minimal power consumption. It has fewer wear parts and can be maintained easily.
• Compact and cost-effective:
Designed using standard, affordable components, the system is scalable and can be installed in commercial vehicles with minimal modification.

5. RESULTS AND OBSERVATIONS

A prototype was built and tested under controlled conditions using a scaled four-wheeler model. The following observations were made:
Obstacle detection accuracy: >95% for objects within 30 cm
Response time (sensor to bumper activation): ~0.2 seconds
Braking efficiency: Full stop achieved within 1 meter at 5 km/h prototype speed
bumper durability: Absorbed multiple test collisions without damage

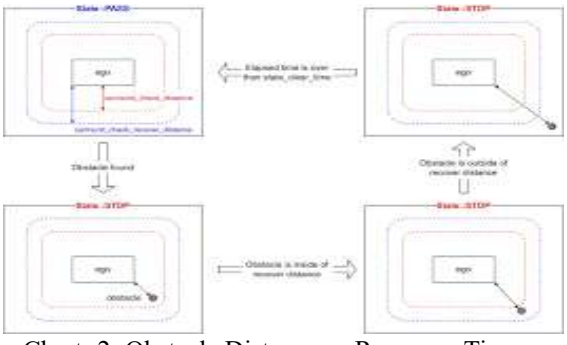

Chart -2: Obstacle Distance vs Response Time

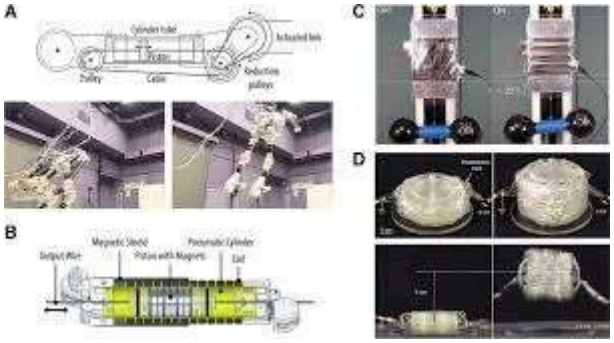

Fig -2: Pneumatic Bumper Actuated on Test Collision

The tests proved that the system reliably detects threats and responds quickly enough to reduce or prevent damage.

6. CONCLUSION

The Automatic Pneumatic Bumper and Braking System is an effective solution to enhance safety in modern vehicles. By integrating proximity sensors, microcontroller logic, and pneumatic technology, the system offers dual protection — stopping the vehicle and deploying a protective barrier. The system is cost-effective, easy to implement, and significantly reduces collision damage. With further optimization and real-world testing, this can be scaled for commercial vehicles to prevent accident-related injuries and property loss.

7. ACKNOWLEDGEMENT

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8. REFERENCES

1. R. Kumar, “Pneumatic Bumper and Braking System,” IJERT, Vol. 6, Issue 2, 2019
2. Arduino.cc – Arduino UNO Documentation
3. HC-SR04 Ultrasonic Sensor Datasheet
4. Solenoid Valve Control Using Arduino – CircuitDigest
5. M. Mehta, “Smart Vehicle Systems Using IoT,” IRJET, Vol. 5, 2020