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Design and Implementation of an Intelligent Autonomous Braking System Using Arduino Microcontroller

Dr. Pothuraju V V Satyanarayana[1], T. Pavan Puthra[2], M.Manikanta Yawanth[3], Y. Dileep Kumar[4], Y.Ganesh[5], B.Sumanth Kumar[6]

[1]*Associate Professor, Department of Mechanical Engineering, Visakha Institute of Engineering & Technology, Narava, Visakhapatnam.*

[2,3,4,5 & 6]*B.Tech Student, Department of Mechanical Engineering, Visakha Institute of Engineering & Technology, Narava, Visakhapatnam.*

Abstract - This paper presents the design and development of an autonomous electromagnetic braking system utilizing Arduino microcontroller technology and ultrasonic sensing. The proposed model detects obstacles in the vehicle path and triggers braking automatically through an electromagnetic braking unit powered via a relay module. This frictionless braking mechanism enhances vehicular safety, especially in robotic and automated systems by eliminating reliance on human response time. The system integrates low-cost components and offers a scalable solution for future intelligent transportation systems.

Key Words: Arduino, Electromagnetic Brake, Ultrasonic Sensor, Autonomous Braking and Safety System.

1. INTRODUCTION

Braking systems are crucial to ensure vehicular safety. Traditional systems rely heavily on human input and are susceptible to delays in reaction time. With the advent of automation, electromagnetic braking (EMB) systems have emerged as efficient, reliable and frictionless alternatives to conventional brakes. This project explores a cost-effective model that employs an Arduino Uno, ultrasonic sensor and an electromagnetic actuator to automatically detect and respond to obstacles.

2. SYSTEM DESIGN AND METHODOLOGY

The system comprises a DC motor for wheel rotation, an Arduino Uno microcontroller, an ultrasonic sensor for object detection and an electromagnetic brake actuated through a relay. Two methods were explored:

1. Braking with EMF Generation
2. Braking without EMF Generation

Due to coil overheating in the first method, the second method was implemented, where a circular steel plate is attracted by the energized electromagnet to generate braking torque without EMF backflow.

Block Diagram:

- Arduino Uno
- HC-SR04 Ultrasonic Sensor
- Channel Relay Module
- Electromagnetic Brake
- External 12V Power Supply

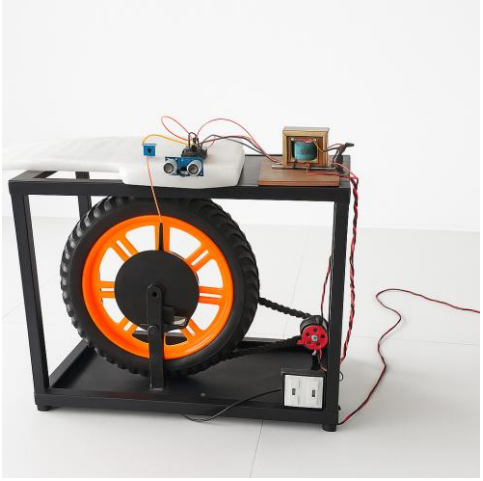

Fig : Autonomous Braking System Using Arduino Microcontroller

Working Principle: The ultrasonic sensor detects obstacles within 20 cm. Arduino processes this data and activates the relay, powering the electromagnetic brake, which halts wheel rotation.

3. COMPONENTS AND CONSTRUCTION

- **Arduino Uno**: Controls the logic for triggering the brake.
- **Ultrasonic Sensor**: Measures distance using echo time.
- **Relay Module**: Electrically isolates and switches the brake circuit.
- **Electromagnetic Brake**: Uses magnetic field interaction with a steel plate to create opposing torque.
- **DC Motor**: Drives wheel via pulley-belt system.

Design Specifications:

- **DC Motor:** 0.25 HP, 180W, 1425 RPM
- **Adapter:** 12V, 10A
- **Pulleys:** Motor - 3.3 cm, Shaft - 10.5 cm
- **Shaft Diameter:** 2 cm
- **Wheel Diameter:** 29 cm

Construction includes mounting the motor on a frame, connecting via pulleys to rotate the shaft and wheel. The braking unit is aligned with the wheel, with a 2 mm gap for frictionless operation.

4. CALCULATIONS

Belt Length: $L = 2C + \{\pi(D + d)/2\} + \{(D-d)^2/4C\} \rightarrow 78.47$ cm

Braking Torque: $T = (HP \times 5252) / RPM$
Braking Time: $t = (M \times R^2 \times N) / (308 \times T) \rightarrow$ varies with RPM
Sample Results:

At 187.5 RPM, braking time = 0.014 sec

5. ARDUINO CODE AND AUTOMATION

```
#define TRIG_PIN 12
#define ECHO_PIN 2
#define BUZZER_PIN 10

void setup() {
  Serial.begin(9600);
  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  pinMode(BUZZER_PIN, OUTPUT);
}

void loop() {
  digitalWrite(TRIG_PIN, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIG_PIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIG_PIN, LOW);

  long duration = pulseIn(ECHO_PIN, HIGH);
  int distance = duration * 0.0344 / 2;

  if (distance < 50) {
    digitalWrite(BUZZER_PIN, LOW);  // Brake engaged
  } else {
    digitalWrite(BUZZER_PIN, HIGH); // Brake disengaged
  }
  delay(200);
}
```

6. CONCLUSIONS

This project successfully implements a low-cost electromagnetic braking system controlled via Arduino. The sensor-based automation effectively halts motion when an obstacle is detected, minimizing risk in autonomous or semi-autonomous environments. It also opens possibilities for integration in smart vehicles, robots and industrial safety systems.

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BIOGRAPHIES

Dr. P. V. V. Satyanarayana
Associate Professor, Mechanical Engineering, VIET. Over 6 years of teaching and research experience. Specialized in Mechatronics and Automation Systems.

T. Pavan Puthra
B.Tech Student, Department of Mechanical Engineering, Visakha Institute of Engineering & Technology, Narava, Visakhapatnam

M. Manikanta Yawanth
B.Tech Student, Department of Mechanical Engineering, Visakha Institute of Engineering & Technology, Narava, Visakhapatnam

Y. Dileep Kumar
B.Tech Student, Department of Mechanical Engineering, Visakha Institute of Engineering & Technology, Narava, Visakhapatnam

Y. Ganesh
B.Tech Student, Department of Mechanical Engineering, Visakha Institute of Engineering & Technology, Narava, Visakhapatnam

B. Sumanth Kumar
B.Tech Student, Department of Mechanical Engineering, Visakha Institute of Engineering & Technology, Narava, Visakhapatnam