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Fabrication of Automatic Pneumatic Bumper for Four-Wheeler

L.N.V. NARASIMHA RAO[1], CHANDRA RAO CHANDU[2], R. A. SAI LOHITH[3], R. SAI DEEPU[4]
[1, 2]Assistant Professor, Department of Mechanical Engineering, Sir C. R. Reddy College of Engineering, Vatluru, Eluru District
[3, 4]UG Students, Department of Mechanical Engineering, Sir C. R. Reddy College of Engineering, Vatluru, Eluru District

Abstract- In automobiles, safety is considered as a key thing while designing. The vehicle frontal structure has bumper, structural parts, which resist and reduce damage due to vehicle frontal crashes and ensure safety by absorbing the impact. Pneumatics play a major role in the field of automation and actuation control techniques. The aim is to design and fabricate an AUTOMATIC PNEUMATIC BUMPER FOR FOUR WHEELER vehicles system that uses a sensor with a pneumatic operated bumper to avoid car dents and scratches. This system incorporated with an infrared transmitter and receiver circuit, Control Unit, Pneumatic bumper system. The Infrared sensor senses the obstacle, which approaches the vehicle. When there is any obstacle closer to the vehicle, the control signal is given to the electronic circuit which actuates the bumper automatically to absorb the impact and stopping it from coming too close to the vehicle body. This prevents vehicle damage and ensures the safety of the inmates. The automatic pneumatic bumper system offers a smart and proactive approach to vehicle safety and protection. By automating the deployment and retraction of the bumper, it not only improves the aesthetics of the vehicle but also provides practical benefits such as preventing low-speed collisions, enhancing overall vehicle durability.

Keywords: Automatic Pneumatic Bumper, Pre-Crash Safety, Infrared Sensor, Vehicle Collision Avoidance, Pneumatic Actuation, Active Safety System, Impact Absorption, Intelligent Vehicle Protection.

I. INTRODUCTION

The pneumatic bumper system is designed to protect both the vehicle and its occupants by using compressed air to absorb collision impact. A proximity sensor measures vehicle speed and detects obstacles, sending signals to the control unit, which activates the pneumatic bumper. Unlike traditional rigid bumpers, pneumatic bumpers adjust their cushioning dynamically based on the severity of a collision, offering better protection and reducing damage.

An Automatic Pneumatic Bumper System uses compressed-air cylinders that expand or contract to modify bumper stiffness. An air compressor maintains optimal pressure, while sensors continuously monitor the environment and detect approaching impacts. When a collision is predicted, the control unit instantly adjusts the air pressure:

softening the bumper for low-speed bumps or stiffening it for high-speed crashes. This variable cushioning absorbs and distributes impact energy more efficiently, protecting the vehicle structure and passengers.

Key Benefits

- Adaptive impact protection
- Reduced vehicle damage during low-speed impacts
- Improved passenger safety
- Cost-effective maintenance and repairs

Key Features

- Air-compression–based cushioning
- Collision impact absorption
- Automatic height and firmness adjustment

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- Fully integrated obstacle-detection sensors
- Real-time response to sudden impacts
- Even energy dissipation across the bumper
- Adjustable settings for different road conditions
- Lightweight and durable construction
- Minimal maintenance requirements
- Compatibility with other safety systems

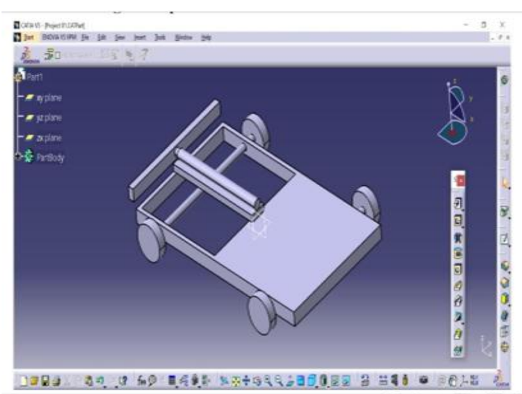
II. BACKGROUND

Early bumpers were rigid metal bars. Over decades, manufacturers introduced energy-absorbing materials and impact-absorbing bumpers. The pneumatic bumper evolved from the need for better crash mitigation and adaptive safety. As ADAS and autonomous systems developed, pneumatic bumpers became integrated with sensors and control units to respond intelligently to varying collision scenarios.

III. DESIGN SPECIFICATIONS & FABRICATION

The above design consists of:

- Base-Frame structure
- Pneumatic cylinder
- Bumper frame
- Wheel mounting
- Supporting wooden block



IV. FABRICATION PROCESS STEPS

1. Cutting and Assembly of Frame: Mild steel bars cut to size and welded to form a rectangular bumper frame.
2. Mounting: Cylinder and motors mounted using brackets and clamps.Wooden base fabricated and components arranged ergonomically.
3. Electrical Integration: Wiring of relay, Arduino, sensors, and solenoid done with power routed through battery. Use of protective terminals and cable sleeves for safety.
4. Testing: System was tested with moving objects. Bumper automatically deployed upon detection.

Components Used in Prototype Fabrication

Component	Dimensions	Remarks
Bumper Frame	508 mm × 305 mm × 4 mm	Bar frame with welding joints
Mounting Board	Custom size	Holds components like Arduino, valves
Pneumatic Cylinder	16 mm bore, 100 mm stroke	Mounted to push the bumper forward
Gear Motors	2 units	Driving system
Compressor	12V, 150 psi	Powers pneumatic system
Battery	Rechargeable	Power source for entire system
Solenoid Valve	5/2-way, 12V	Controls air flow to piston
Ultrasonic Sensor	HC-SR04	Detects objects and triggers system

ARDUINO CODE:

The Arduino UNO code automates the bumper activation by monitoring distance using an ultrasonic sensor and triggering a pneumatic response when an obstacle is detected.

It controls a solenoid valve through a relay module, allowing the pneumatic cylinder to extend the bumper in real time during potential frontal collisions.

The code ensures the system resets after activation, making the bumper mechanism responsive, repeatable, and suitable for real-world scenarios.

Code:

```
int tr=2;
int ec=3;
int m2=8;
int m1=9;
int m4=10;
int m3=11;
int cnt=0;
int dst1;
int dst;
int buz=13;
int valv=7;
int air=6;
int kk=0;
```

```
int maxdst=0;
int dist()
{
maxdst=0;
for (int i= 0; i<=1; i++)
{
digitalWrite(tr,0);
delayMicroseconds(2);
digitalWrite(tr,1);
delayMicroseconds(10);
int dst=pulseIn(ec,1)/58.2;
if(dst>maxdst)
{
maxdst=dst;
}
}
return maxdst;
}
void setup () {
Serial.begin(9600);
pinMode(buz,OUTPUT);
pinMode (m1, OUTPUT);
pinMode (m2, OUTPUT);
pinMode (m3, OUTPUT);
pinMode (m4, OUTPUT);
pinMode(valv,OUTPUT);
pinMode(air,OUTPUT);
pinMode(buz,OUTPUT);
digitalWrite(m1,0);
digitalWrite(m2,0);
digitalWrite(m3,0);
digitalWrite(m4,0);
digitalWrite(valv,1);
digitalWrite(air,1);
pinMode(tr,OUTPUT);
pinMode(ec,INPUT);
pinMode(buz,OUTPUT);
digitalWrite(buz,0);
delay (2000);
digitalWrite(m1,1);
digitalWrite(m2,0);
digitalWrite(m3,1);
digitalWrite(m4,0);
}
void loop () {
dst1=dist();
dst=dst1;
Serial.println(dst);
if((dst<20))
{
if(kk==0)
{
 kk=1;
digitalWrite(m1,0);
digitalWrite(m2,0);
digitalWrite(m3,0);
digitalWrite(m4,0);
digitalWrite(valv,1);
digitalWrite(air,0);
delay (2000);
digitalWrite(air,1);
}
}
else
{
if(kk==1)
{
kk=0;
digitalWrite(air,0);
delay (2000);
digitalWrite(valv,0);
delay (200);
digitalWrite(air,1);
delay (2000);
digitalWrite(valv,1);
digitalWrite(m1,1);
digitalWrite(m2,0);
digitalWrite(m3,1);
digitalWrite(m4,0);
}
}
}
```

V. ANALYSIS OF THE AUTOMATIC PNEUMATIC BUMPER

The analysis phase evaluates the structural strength, impact resistance, and pneumatic performance of the Automatic Pneumatic Bumper using ANSYS simulations. Various analyses—impact, stress, deformation, and force analysis—were conducted to ensure the system can withstand real-world collision loads.

1. Types of Analysis Performed

- Impact Analysis: To check how effectively the bumper absorbs collision forces.
- Stress Analysis: To study stress distribution across the bumper and frame.

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- Deformation Analysis: To measure deformation under load and ensure safe limits.
- Pneumatic Cylinder Analysis: To confirm force output and reliable actuation.

2. Impact Analysis Summary

- Software: ANSYS Workbench
- Materials Used:
- Frame: Mild Steel
- Bumper: ABS Plastic
- Cylinder: Aluminium Alloy
- Conditions:
- Fixed supports at mounting points
- Collision force applied to bumper surface

Key Results

- Maximum stress occurred near the bumper–cylinder connection.
- Bumper deformed safely without breaking, proving effective energy absorption.
- Displacement remained within acceptable limits, reducing force transfer to the vehicle frame.

3. Structural Stress Analysis

- Load cases were applied based on different impact speeds (40–60 km/h).
- All stresses remained below material yield strengths, confirming structural reliability.
- Frame design proved strong and capable of withstanding repeated impacts

4. Deformation Analysis

- ABS bumper deformation stayed within safe limits.
- No permanent deformation on the frame.
- Uniform stress distribution ensured no weak points or failure zones.

5. Force Analysis

Using Newton's Second Law:

- Impact force at 40 km/h ≈ 55 kN
- Impact force at 60 km/h ≈ 83 kN
- Only a portion (~2000 N) reaches the bumper due to energy absorption and system damping.

Material Data Used (Key):

- Aluminium 6061-T6
- Yield Strength: 276 MPa
- Ultimate Strength: 310 MPa
- Impact Area: 0.01 m²
- Applied Impact Force: 2000 N
- Simulation Time: 0.005 s
- All simulated stresses remained below 276 MPa, ensuring safety.

6. Final Observations

- The ANSYS simulations showed that:
- The bumper absorbs impact forces effectively at moderate speeds.
- The frame and pneumatic cylinder remain structurally safe without failure.
- The pneumatic system provides quick, efficient actuation.
- The overall system is robust, reliable, and suitable as a safety enhancement for four- wheelers.

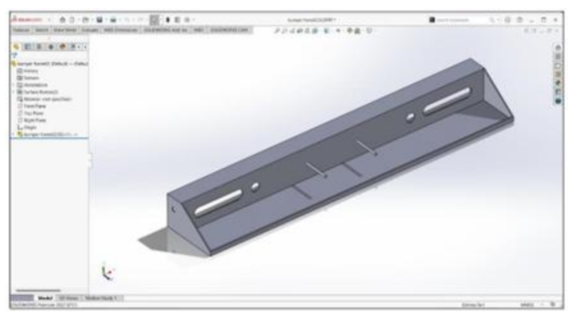
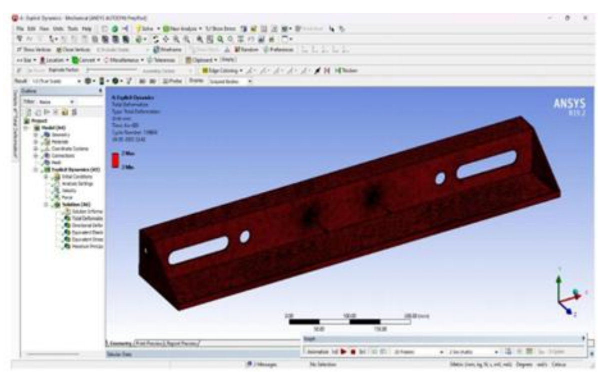


Fig: 5.2 Bumper Frame Design Front view



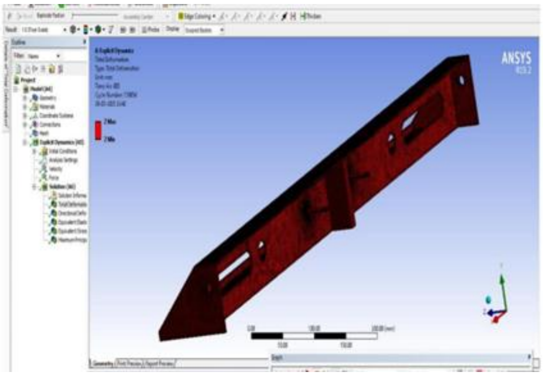


Fig: 5.4 Ansys Results

OUTPUT OF THE PROJECT

The automatic pneumatic bumper system developed in this project successfully demonstrates an intelligent, sensor-based safety mechanism for four- wheelers. The system uses a pneumatic cylinder, air compressor, ultrasonic sensors, solenoid valve, and ECU to automatically extend or retract the bumper based on real-time conditions.

Key Outputs of the System

- Automatic Bumper Extension & Retraction: The bumper extends during potential collisions and retracts during normal driving or parking.
- Enhanced Vehicle Protection:
- The pneumatic bumper absorbs impact energy, reducing structural damage during low-speed collisions.
- Efficient Pneumatic Performance:
- The air compressor, solenoid valve, and cylinder respond quickly to ECU signals, enabling smooth and rapid operation.
- Sensor-Driven Automation:
- Ultrasonic sensors detect nearby obstacles and trigger protective bumper actions automatically.
- Energy-Efficient Operation:
- The system runs on a 12V DC battery, allowing full function even when the engine is off.
- Improved Aesthetic & Convenience:
- The bumper's automated movement enhances appearance and assists in tight parking spaces.
- System Safety & Reliability:
- Relay modules and ECU ensure stable operation, proper switching, and fail-safe functioning.
- Real-Time Monitoring:
- The ECU continuously monitors air pressure, sensor readings, and component status.

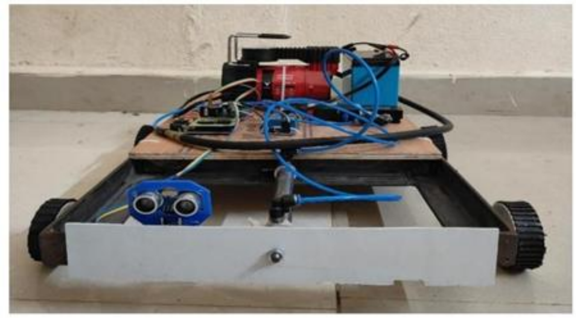


Fig1: Front View of Prototype

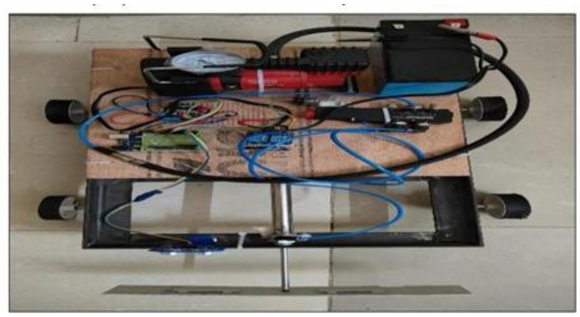


Fig2: Top View of Prototype

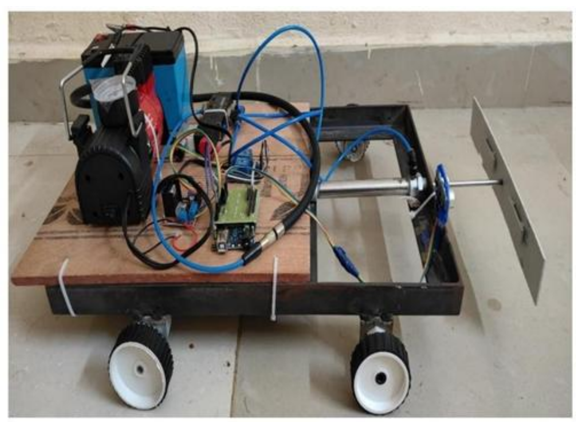


Fig3: Side View of Prototype

VI. CONCLUSION

The project successfully demonstrates that an automatic pneumatic bumper system can significantly enhance vehicle safety and convenience. By integrating pneumatic mechanisms with ultrasonic sensors and electronic control, the system offers:

- Active collision protection
- Independent, energy-efficient operation
- Real-time obstacle detection
- Improved durability and aesthetics

Overall, the system provides a smart, proactive, and reliable approach to reducing low-speed collision damage, improving vehicle safety, and enhancing user convenience. It represents a meaningful step forward in modern automobile safety technology.

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