Automated Pneumatic Bumper For Vehicle Safety

Sathiskumar S, Dhanush Guru R, Dhavaneeswaran N

Abstract: In automobiles, safety considered as a key thing while designing. The vehicle frontal structure has a bumper, structural parts, which resist and reduces damages due to vehicle frontal crashes and ensures safety by absorbing the impact. The Pneumatics plays a major role in the field of automation and actuation control techniques. The aim is to design and fabricate an automated pneumatic based vehicle bumper system that uses a sensor with a pneumatic operated bumper in order to avoid car dents and scratches. This system incorporated with an IR transmitter and Receiver circuit, Control Unit, Pneumatic bumper system. The IR sensor senses the obstacle, which approaches the vehicle. When there is any obstacle closer to the vehicle (within 2-3 feet), 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. This system only actuated when the vehicle speed is above 30-40 km/hr. This vehicle speed sensed by the proximity sensor and monitored continuously, this signal given to the control unit, and it actuates the pneumatic bumper system accordingly.

Index Terms: Bumper Design, Electronic Circuit, IR Sensor, Pneumatic Cylinder, Solenoid valve, Vehicle Bumper, Vehicle Safety.

1. INTRODUCTION

The target is a safety system based on the pneumatic actuation of the vehicle bumper. This system guarantees passenger safety within the vehicle. The ultimate objective of this model is to absorb impact force while a collision takes place without passing force to the car body. It minimizes the severity of the damage caused by the vehicle crash and improves the safety of vehicle insiders. Several scientists performed different experiments with stroke models and stroke content. The bumpers absorb the force of impact that is the cinematic energy generated by the collision during deformation. Therefore, the material for the bumper is important in restricting the impact force.

2 REVIEW OF BUMPER ANALYSIS

2.1 Procedure for Static Analysis

Code reaches the values of various features, such as mass density, Young's modulus, Poisson ratio, and thermal conductivity. A further major step is the meshing by selecting the part mesh using the C3D10 M element, which allows seeds and the global size of as 50 to be finer. The next step in the process is to integrate the code. This analysis based on the general analysis of the static form. After that, the boundary conditions and the load must be applied. The choice of the area where the motions were arrested also relevant while applying the boundary condition.

2.2 Procedure for Impact Analysis

Dynamic-explicit type of analysis used for completion of impact analysis in ABAQUS. Then the creation of a datum point at the center of the plate is necessary. For meshing, the seeding is important, in the seeding the entire geometry divided into small elements having size 35. The type of element used is C3D10M (10-node modified quadratic tetrahedron). The meshing of the entire geometry results in 5873 nodes and 2762 elements. Meshing only needed to the bumper.

2.3 Procedure for Modal Analysis

In the modal analysis, the number of mode shapes, which we have to extract should be specified. This analysis was done by using ANSYS Workbench 11.0. The limit of the frequency range can be given as an input if required. In this case, only the first 10 modes are found out and the frequency limit is given as 0 to 1000 Hz during the analysis. Then the entire model is meshed into small elements by using fine mesh. During meshing the entire model is divided into 10752 elements having 4120 nodes by using a solid185 element.

2.4 Procedure of Dynamic Analysis in ANSYS

After completing this step the harmonic response analysis should be carried out to find out the total deformation, von mises stress and strain components at various frequencies. In this analysis, all loads, as well as the structure's response, vary sinusoidally at the same frequency. A typical harmonic analysis will calculate the response of the structure to cyclic loads over a frequency range and obtain a graph of some response quantity versus frequency. "Peak" responses are then identified from graphs of response vs. frequency and stresses are then reviewed at those peak frequencies. Separate meshing and material selections are not necessary since this harmonic analysis is doing as a continuation of the modal analysis which is completed in ANSYS Workbench 11.0. In the analysis setting option of the software, we have to select the range minimum and maximum of frequency, mode frequency range, a number of modes, mode range minimum and maximum, constant damping ratio as 0.01etc. After completing this boundary condition and the load has been applied in the respective area of the imported model.

3 EFFECT OF THE BUMPER ON CRASHES

3.1 Bumper Test Configurations

On each model vehicle, four different crash tests are carried out on the contoured, bumper-like barrier. Total simultaneous checks for front and rear were performed at 10 km / h and tests for the front and rear corner at 5 km / h. The four tests were conducted to facilitate reliable and stable interfaces between cars in the fleet and to ensure energy absorption. In

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order to simulate a broader spectrum of impacts on actual road collisions, the barrier heights for the overlap and corner analysis differ. The four checks were conducted by two cars.

3.2 Impact Barrier Specifications.
The impact barrier with a radius of 3.404 mm and a flat vertical area of 102 mm has been applied to all bumper tests. The barrier is made of a steel plate of 12,5 mm and is mounted to a block of 145,150 kg of enhanced concrete. The upper surface of the buffer wall has a metal backstop. The rear end also has a 12.5 mm steel platform with a width of 1.524 mm with a radius of 3.404 mm and a flat vertical surface of 200 mm. The back-end positioned 25 mm from the rear of the barrier with its middle offset. The impact zone of the barrier face with nylon push-pin rivets is attached to a plastic energy absorber. Likewise, the upper and lower flanks with an overlying plastic cover are placed on the barrier by slots. Net Shape Company manufactures the energy absorber and cover and has a diameter of 152 mm from top to bottom. It has a length of 1.524 mm, a thickness of 102 mm and a width of 51 mm. The impact barrier mounted so that the majority of the bottom of the barrier is 457 mm off the floor for both the front and rear full overlap tests. The centerline of the vehicle aligned with the centerline of the barrier. The impact barrier installed on the front and rear corner tests so that the bulk of the lower edge of the barrier to the front is 406 mm from the ground. On effect, the vehicle overlaps the barrier lateral edge by 15% of the width of the car, measured at the wheel wells in the corresponding axle— front axle for testing the front corner and rear axle for testing the rear corner.

3.3 Photography
Tests are recorded using at least one overhead and one digital image imager mount (500 fps) or film camera (125 fps) and the Sony Betacam video camera mounted on the floor (30 fps). After the test is done, a digital still camera is used to document any resulting damage. The vehicle is photographed More closing photographs are taken with ready visible damage; photographs are also taken in order to record concealed damage during the wear down / assessment process.

3.4 Damage Estimates
The method of damage assessment is performed in a repair shop. In general, each bumper is removed and inspected for hidden damages. Due to industry standard assessment technologies, Damage repair estimates are performed and documented by Audatex, a Solera company, as part of a computerized system. Audatex offers an average labor rate for the repair of bodywork and finishing used in its client's actual country figures for the most recent calendar year trimesters for the hourly work rate as calculated in the reports. This average rate is rounded to the closest dollar and used for labor costs calculations. The prices of paint and related materials are also based on the average price used by Audatex consumers over the last quarter and are directly commensurate with the overall time to finish that calculation.

3.5 Impact of Speed Measurement
Impact speed measured by means of an optical speed sensor on the side of the vehicle to detect reflective strips of the floor in the hall crash. 456 mm apart on the front edges of the plates. The impact rate recorded, therefore, is the average speed over 456 mm vehicle journey length that ends with the barrier about 150 mm before the vehicle strikes. The velocity sensor has its timing module, powered by batteries, inside the truck, which shows the speed of the truck in kilometers per hour. An optical measurement device that assists the speed sensor on the vehicle also mounted on the propulsion system. The tool tests the hardware speed at which the vehicle is connected to the propulsion system just before the vehicle's launch. Before launch, the speed measured over 1,000 mm of travel length and ends at 500 mm.

4 METHODOLOGY AND DESIGN DEVELOPMENT

4.1 Methods of Concept Development
The design is based on the design and development method of the products. Next, it is recognized the need for the automatic pneumatic bumper system. The different theoretical concepts were defined for the development of the process. A thorough analysis of the principles is carried out using a scoring matrix and the best product between various types of materials is chosen by the grading process. Finally, for the appropriate dimensions, the selected material and design shall be reviewed. The system will be constructed in two dimensions and the system is then modeled in three dimensions. For safe layout under deformation stresses the template is then analyzed.

4.2 Method of Design and Analysis
The system will be designed in two dimensions with AUTOCAD and modeled with the version software SOLIDWORKS–2016. In different conditions of impact force, stress rates and the deformation, ANSYS technology will then be used to evaluate the individual components for protection.

4.3 Method of Controlling Pneumatic Bumper
Our system is a sensor-based system that is used to detect if an object is just 2-3 feet away. If any object comes close to the system, it is sensed by the IR sensor. Then the signal is sent to the microprocessor which in turn operates the relay. Then the relay actuates the solenoid-operated Directional Control Valve, the air from the reservoir tank enters into the pneumatic cylinder through a flow control valve. Then the pneumatic cylinder pushes out the bumper to absorb the collision impact and to stop coming too close to the vehicle body. It retracts when the risk it from subsides. All the electronic circuits and pneumatic components are mounted on a frame with supporting bed having four wheels that resemble the vehicle. If we force any object to this vehicle system, the bumper extends to resist and retracts after the risk subsides.

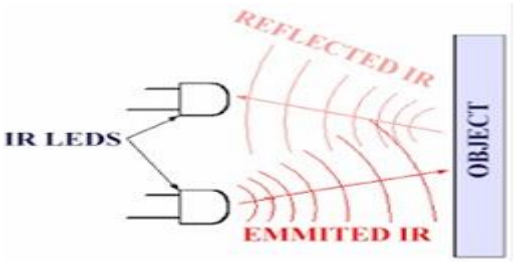

Fig 1. *IR sensor detecting object*

4.3 Concept Generation

The automated pneumatic bumper system is designed and developed using the "Concept Development process" method as shown in Fig 2. Concept generation is the process of introducing new ideas based on the inputs and complaints provided by the customers. The four steps involved in concept generation are listed below.

- Compressor – compressor used to create air and it is stored in the reservoir tank
- IR sensor – IR sensor used for detects the object
- Solenoid – solenoid actuates the DCV
- Pneumatic cylinder – it is used to extend and retract the bumper

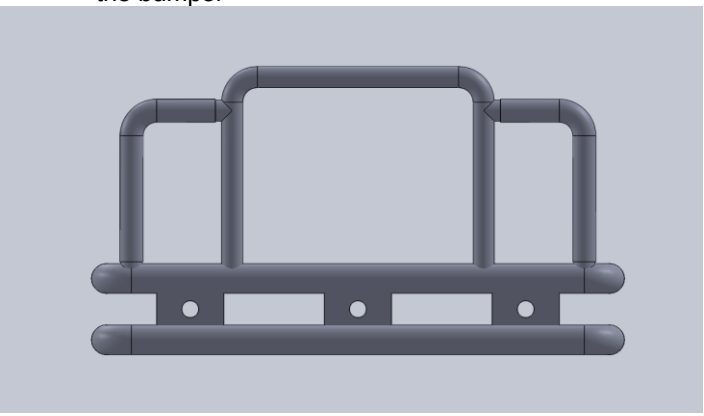

Fig 2*. Steps involved in Concept development Process*

5 BUMPER DESIGN

The design was slightly varied from the conventional bumper design. The circular channels were used in the design, which is uncommon among the commercially available in the vehicle bumper. The diameter of the channel used was 25 mm. The thickness used was around 3 mm. The front length of the bumper is 156 cm. The bumper is modeled using SOLIDWORKS software and the end product was reviewed.

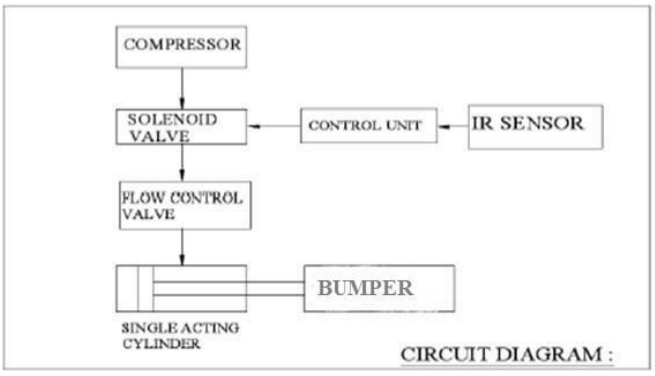

Fig 3*. 3-D modeling of bumper*

5.1 Concept 1:

The pumper first material is mild steel. It'scontaining approximately 0.05 – 0.25% carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and easy to form. Surface hardness can be increased through carburizing. Mild steel also has easy machinability. So the main reason behind using mild steel is manufacturing material is its excellent machinability. The most important properties of steel are great formability and durability. The density of the material is 7850 kg/m3and young's modulus is 206GPa and yield stress is 318 MPa. The mild steel bumper is undergoing impact force and stress concentration analysis using ANSYS software.

5.2 Concept 2:

Aluminum alloy is in which aluminum is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, and zinc. The most cast aluminum alloy is Al-Si where the high levels of silicon (4-13%). aluminum alloy is widely used in engineering structures and components where lightweight or corrosion resistance. Aluminum alloy much less-flammable contains a very high percentage of magnesium. Aluminum alloy has a tensile strength, ductile, formability, workability and corrosion résistance. Aluminum alloy has a tensile strength of 220 MPa and an elastic modulus of 80GPa and it has a low weight. The Aluminium alloy bumper is undergoing impact force and stress concentration analysis using ANSYS software.

5.3 Concept 3:

A thermoplastic or thermosoftening plastic is a plastic material, a polymer, which becomes pliable above a specific temperature. Most thermoplastics have a high molecular weight. The polymers chains associate through intermolecular forces, which weaken rapidly with increased temperature, yield a viscous liquid.it is manufactured by injection molding, compression molding, and extrusion. Engineering plastics include polycarbonate and polyamides, acrylonitrile butadiene styrene used for car bumpers and dashboards. Engineering plastics are gradually replaced by traditional materials in many applications.

5.4 Description of Selected Bumper Material

From the above studies, it is clear that the use of automated pneumatic actuating extendable and retractable bumper of glass mat reinforced thermoplastic is a very good solution for the enhancement of safety in a vehicle and to reduce damages due to collision in vehicle accidents. The designed bumper has a diameter of 25mm and a thickness of 3mm. Glass mate thermoplastic replaced material usage in the automotive vehicles. using glass mate thermoplastic comparatively it has equal strength like aluminum and steel. GMT is a weightless material.GMT in thin sheets of 3mm thickness with various fibers mates like continuous, chopped, randomly laid that all yield specific characteristics. GMT material has 12 GPa young's modulus and the Poisson ratio of 0.41, a density of 1280 kg/m3. The bumper beam supporting structure composed of a kelvin Voigt spring dashpot system. GMT damping parameter of c=0.015.the above Table III shows that GMT is about 85% and 77% respectively lightweight and exceeding yield strength.

6 DESIGN ANALYSIS OF BUMPER SYSTEM

6.1 Load Analysis

During vehicle collision, the impact force is calculated and then the calculated impact force is applied on the bumper materials. Impact force calculation mass of the vehicle and vehicle initial and final velocity are considered.

6.2 Impact force

For calculating the impact force of the vehicle mass of the vehicle consider as 20kg and accidents are happen more than 30 km/hr. so vehicle speed is considered as 35 km/hr.

Mass of the vehicle = 20 kg (approx)
Acceleration = final velocity – initial velocity/time
Vehicle speed = 35 km/hr
When it hit an object, coming to a complete stop in 0.05 seconds = 0 - 9.72 /0.05
= - 194.44m/s^2
Force = Mass*Acceleration
= 194.44*20
Impact Force = 3888.8N

6.2 Mild Steel Bumper Analysis

The impact force of 3888.8 N applied in the steel bumper to deformation and stress concentrations are noted. During vehicle collision, mild steel bumper get more deformation and very high-stress concentration

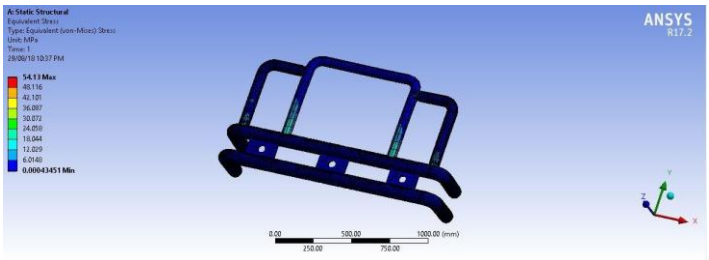

Fig 4. *Mild steel deformation*

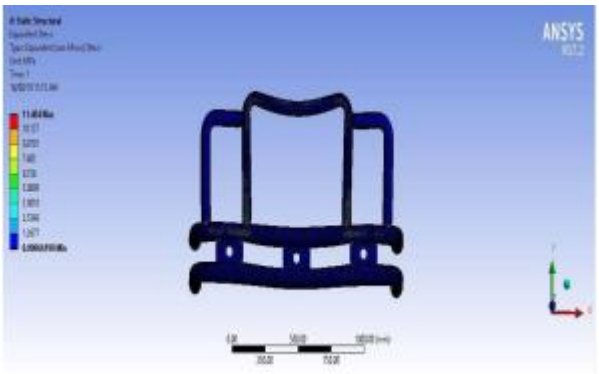

Fig 5*. Mild steel stress concentration*

6.3 Aluminium Alloy Bumper Analysis

The impact force of 3888.8 N applied in the steel bumper to deformation and stress concentrations are noted. During vehicle collision, aluminum alloy bumper get less deformation and stress concentration also less

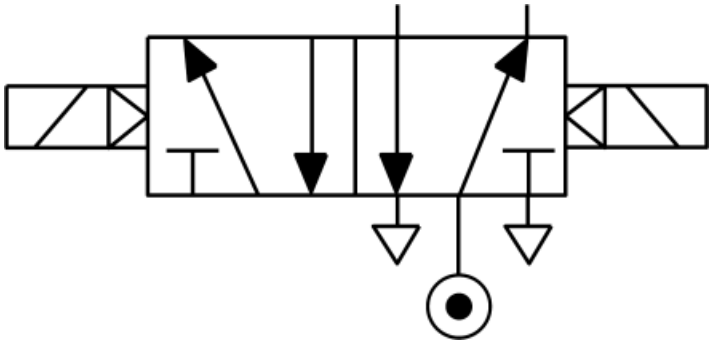

Fig 6*. Aluminum Alloy Deformation*

7 BUMPER DRIVING COMPONENTS

7.1 Pneumatic Cylinder

The cylinder is a Double-acting cylinder one, which means that the air pressure operates forward and backward strokes. The air from the compressor is passed through the 5/2 solenoid valve which controls the pressure to the required amount by adjusting its knob. A pressure gauge is attached to the air storage tank for showing the pressure.

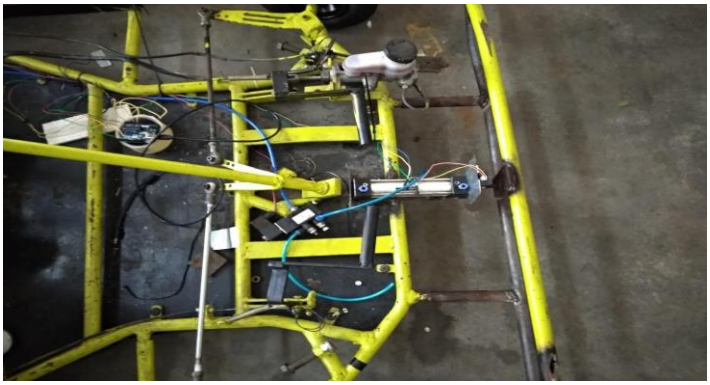

Fig 7*. Aluminum Alloy Stress concentration*

Pneumatic cylinder pulling capacity:
Force = Pressure x Area
Air compressor of 3 bars pressure.
Pneumatic cylinder piston diameter = 25mm
Area of the piston = πR^2
= 490.87 mm^2
Total thrust force = 490.87 x 10^{-6} m^2 x 3 x 10^5 Nm^2
= 140.36 N
Load = 140.36/9.81
= 15 kg capacity of pull force.
The 25mm diameter of pneumatic cylinder pulling up to 15kg

7.2 Direction Control Valve

The directional valve is one of the important parts of a pneumatic system. A solenoid valve is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid. In the case of a two-port valve, the flow is switched on or off, in the case of a three-port valve, the outflow is switched between the two outlet ports.

TABLE- 1
COMPONENT SPECIFICATION

Type	5/2
Voltage	12 DC
Power	6VA
Working pressure	1.5 -10 Bar

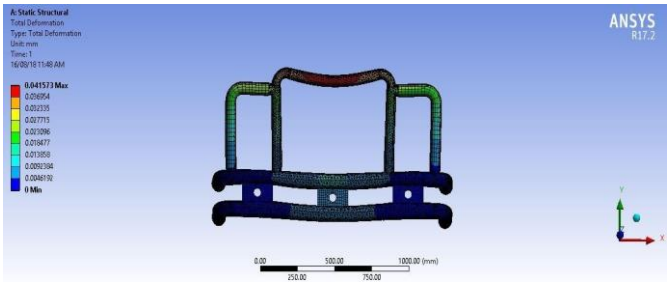

Fig 8*. 5/2 DCV*

8 FABRICATION WORK

8.1 Mechanical components

Automated pneumatic bumper mechanical components are bumper fabrication and cylinder bed. The bumper is fabricated by using the bending machine and welding process. The bumper is made by using a glass mate thermoplastic material .cylinder bed is used for mounting the pneumatic cylinder.

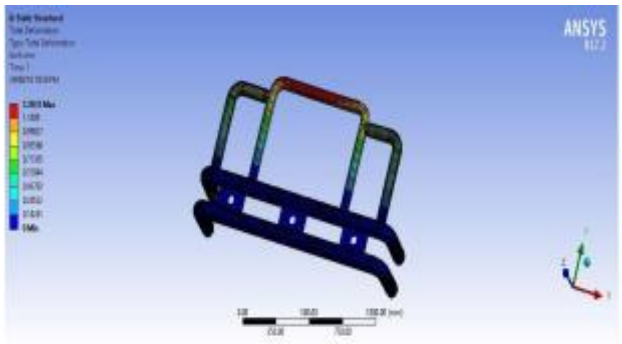

Fig 9. *Pneumatic Cylinder Bed*

8.2 Electric work

- Arduino Uno
- IR sensor
- Hall sensor

8.3 Program

The below program is used to control the bumper actuation.

```
int a = A1;
int y;
int relay = 13;
 inthallsensor = 2;
volatile byte counter;
unsigned int rpm;
unsigned long passedtime;
void isr()
{
counter++;
}
void setup() {
 Serial.begin(9600);
 pinMode(A1, INPUT);
pinMode(relay , OUTPUT);
 attachInterrupt(0, isr, RISING);
pinMode(hallsensor, INPUT); counter = 0;
rpm = 0;
passedtime = 0;}
void loop() {
delay(100);//Update RPM every second
  detachInterrupt(0); //Interrupts are disabled
rpm = 60*1000/(millis() -passedtime)*counter;
  passedtime = millis();
    counter = 0;
     Serial.print("RPM=");
Serial.println(rpm); //Print out result to monitor
  attachInterrupt(0, isr, RISING);
y = analogRead(A1); Serial.print(y); Serial.print("\n");
    if (y>200)
    if(rpm==0){ digitalWrite(relay, HIGH );} else{
    digitalWrite(relay, LOW );}
```

9 CONCLUSION

Thus, the proposed project pneumatic bumper system is fabricated and developed as per the design and calculations are done for this system. The pneumatic bumper is to reduce vehicle damage during a vehicle collision.

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