Design of Bumper for Sudden Impact Reduction in Four Wheeler

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Abstract : India is the largest country in the use of various types of vehicles. As the available resources to run these vehicles like quality of roads and unavailability of new technologies in vehicles are causes for accidents. When the driver sees the obstacle or any vehicle in front of his driving vehicle, he gets irritated or becomes mazy. Due to this the driver fails to give the proper input to braking system. Also, the driver may not able to pay the full attention during night travelling so there are many chances to accidents. After the accident occurs, there is no any provision to minimize the damages of vehicles. This paper proposes a design of a bumper for sudden impact reduction in four-wheelers. The objective of this design is to reduce the damage caused by a sudden impact and to protect the passengers inside the vehicle. The proposed design includes the use of a combination of materials such as rubber, foam, and plastic to absorb the impact and reduce the force of the collision. The bumper is designed to be modular, which makes it easier to replace and repair. The design also takes into consideration the aerodynamics of the vehicle to ensure that it does not affect the performance of the vehicle. Overall, the proposed design provides an effective solution for reducing the impact of sudden collisions and improving the safety of passengers in four-wheelers.

Keywords — Automatic, Bumper system, Electro-pneumatic system, Force, Safety, Sensors.

I. INTRODUCTION

In our daily life we come across the news of road accidents, the statistics shows that ten thousand dead and hundreds/ thousands/ million of wounded each year. Hence, improvement in the safety of automobiles is prerequisite to decrease the numbers of accidents. A bumper is a vital safety component of a four-wheeler that provides protection to the vehicle's front and rear parts in the event of a collision. The primary function of a bumper is to absorb the impact energy of a collision and reduce the damage to the vehicle and its occupants.

In this design project, we will focus on the development of a bumper system that can effectively reduce the sudden impact caused by collisions. The bumper design will take into account factors such as the material properties, shape, size, and weight distribution, to ensure maximum impact absorption and minimize damage to the vehicle. The goal of this project is to design a bumper that can effectively reduce the sudden impact caused by collisions, while also considering the aesthetic and functional requirements of the vehicle. The final design should be cost-effective, durable, and easy to manufacture and install.

This project will require a thorough understanding of material properties, mechanical engineering principles, and an ability to simulate and test the design through various computer-aided techniques. The outcome of this project has the potential to improve the safety of four-wheeler vehicles on the road and prevent severe injuries to passengers during a collision.

A. Problem statement

In currently used vehicles generally bumpers used are of rigid types. These bumpers have specific capacity and when the range of the accidental force is very high then the bumpers are fails and these forces transferred towards the passengers. So, this system never reduces the damage of both vehicle and passengers. To overcome these unwanted effects, other provision is needed in order to achieve safety of car and passenger.

B. Objectives

1) To improve the pre-crash safety.
2) To avoid the percentage of passenger injury by using external vehicle safety.
3) To reduce the requirement of internal safety devices like air bags.

 DOI : 10.35291/2454-9150.2023.0090

ISSN : 2454-9150 Vol-09, Issue-01, Apr 2023

4) To increase the sureness of impact absorption application while vehicle accident.
5) To reduce the response time of safety with bumper system.

C. Flow chart of Methodology

The below Methodology shows the sequential operation/steps that will be performed during the project process.

Figure 1.1 Flowchart of work

II. OVERVIEW

Accidents are the main issue in the Indian road transportation system. In this project, an effort has been made to lessen such accidents. In our project, a proximity sensor is provided, and a pneumatic system moves an automatic bumper in front of the vehicle setup. We have a solenoid valve and a control circuit in this project

The design of the system mainly relates to the diversity in terms of physical limitations and ergonomics, space requirements, arrangement of different frame components at the system, manual/machine interaction, control position, working environment, maintenance, improvement scope, ground level weight of the machine, machine's total weight, and much more.

A. Components

Frame: MS material makes up the frame. Our machine's frame primarily serves to support the pneumatic parts put on it. That is, switches installed on the frame, along with a piston cylinder and a flow control valve.

Double acting cylinders: Pneumatic cylinders are used to convert fluid or air power into mechanical power, and are made of sturdy materials like steel to endure powerful forces. They are used for strong forces and accurate movement.

Pneumatic pipe fittings: Pneumatic tubing is available in a variety of materials, with or without reinforcement. Polyurethane tubing can be used with SMC fittings, which have a positive tube seal while under pressure, to link the pneumatic system to the drill assembly.

5/2Solinoid valve: A 5/2 way directional valve has 5 ports and 2 flow locations, and can be used to seal off and obstruct a fluid passageway. It can be activated in a variety of ways.

Pneumatic connectors, reducer and hose collector:

The hose connector and the reducer are the two sorts of connectors that are employed in our pneumatic system.

IR transmitter and IR receiver sensor:

IR transmitter sends 40 kHz carrier under 555 timer control, receiver receives signal and gives control signal to control unit, activates pneumatic breaking system.

Bearings: A snug at the bottom of the lower brass stops the bush's rotation inside the bearing housing. Bolts and nuts are used to fasten the cap on the pedestal block, and the graphic below shows part drawings for another Plummer block.

Shaft: The shaft is a rotating member used to transmit power, either hollow or solid. It is supported on bearings and rotates a set of gears or pulleys for power transmission. It may be hollow or solid.

12 Volt Battery: An electric battery is a device consisting of electrochemical cells that convert stored chemical energy into electrical energy. Electrolytes allow ions to move between the electrodes and terminals, allowing current to flow.

DC Motors: DC motors are mechanically commutated electric motors powered by direct current (DC). The stator is stationary in space and the current in the rotor is switched to also be stationary, generating maximum torque. DC motors have a rotating armature winding and a static field winding or permanent magnet. Speed can be controlled by changing the voltage applied to the armature or by changing the field current. Modern DC motors are often controlled by power electronics systems called DC drives.

III. DESIGN CALCULATION (PROTOTYPE)

A. Motor selection:

Thus selecting a motor of the following specifications

- **Single phase AC motor**
- **Power = 1/15hp=50 watt**
- **Speed= 60 rpm**

Motor Torque

$$P = \frac{2 \Pi N T}{60}$$

$$T = \frac{60 \times 50}{2 \Pi \times 60}$$

 DOI : 10.35291/2454-9150.2023.0090

T = 7.96N-m

Power is transmitted from the motor shaft to the input shaft by means of an open belt drive,

Motor pulley diameter = 20 mm

IP _ shaft pulley diameter = 60 mm

Reduction ratio = 3

IP shaft speed = 60/3 = 20 rpm

Torque at IP rear shaft = 3 x 7.96= **23.88 Nm**

B. *Design of belt Drive:*

Motor pulley diameter **d** = 20 mm

IP _ shaft pulley diameter **D** = 60 mm

Coefficient of friction = 0.23

Let,

d= diameter of rope = 5 mm

Mass of belt per unit length is given by;

ρ= density of belt material = 950 kg/m^3

m= 0.0285 kg/m

Velocity of rope is given by;

$$V=\frac{\Pi dn}{60 X 1000}$$

$$V=\frac{\Pi x 5 x 60}{60 X 1000}$$

V=0.078 m/s (Linear velocity)

To find out tension in the belt is;

$$P=\frac{(F1-F2)V}{1000}$$

$$50 X 10^{-3} = \frac{(F1-F2) X 0.078}{1000}$$

F1 – F2 = 636.619 N ------------ (1)

Center distance between two pulley of motor & pulley output **C=200mm.**

$$\alpha = \sin^{-1}\frac{D-d}{2C}$$

$$\alpha = \sin^{-1}\frac{(60-20)}{2 X 200}$$

$\alpha = 5.739^0$ **(In Degrees)**

α =5.739 X (Π /180)

$\alpha = 0.10^c$ **(In Radians)**

θ = Angle of lap of belt.

θ = **Π – 2 α**

= Π – [2 X 0.10]

θ = **2.94^c** **(In Radians)**

θ = **168.54^O** **(In Degrees)**

Now $\frac{F1}{F2} = e^{\wedge}\frac{\mu\theta}{\sin\beta}$

$$\frac{F1}{F2} = e^{\wedge}\frac{(0.23x2.94)}{\sin 19^{\circ}}$$

$$\frac{F1}{F2} = 7.97$$

F1= 7.97 F2 ------------------------------(2)

Put Eq. (2) in Eq. (1)

F1- F2 = 636.619

7.97 F2 - F2 = **636.619**

6.972 F2 = **636.619**

F2 = 91.3 N

Put in Eq. (3)

F1 = 727.69 N

Centrifugal force in belt is given by,

$F_c = mV^2$

$=0.0285 X (0.078)^2$

F_c **= 1.73 N**

C. *Shaft design:*

To find diameter of shaft by ASME code

For commercial steel shaft, Actual shear stress $\tau_{act = 55N/mm^2}$

T = Π/16 x τ_{act} xd^3

$$\Rightarrow \tau_{act}=\frac{16xT}{\Pi xd^3}$$

$$7.76^3 = \frac{16 x 55}{\Pi x d^3}$$

d^3=737.089

d=9.033mm select d=20mm

D. *Bearing selection:*

As shaft diameter is 20mm so we have selection a pedestal bearing having shaft outer dia. – 20mm.

E. *Design of Pneumatic Cylinder:*

If we increase the pressure of air as per formula pressure is directly proportional to the force.

Clavarino's equation for closed end cylinder at both ends. For ductile material use to determine the thickness of cylinder.

Let,

Material of the cylinder is Aluminum.

S_{ut} =Ultimate tensile strength = **200N/mm^2**

μ = Poisson's Ratio for the cylinder material =**0.29 (std-)**

di = Inner diameter of cylinder =**25mm**

Consider,

 DOI : 10.35291/2454-9150.2023.0090

ISSN : 2454-9150 Vol-09, Issue-01, Apr 2023

Double acting cylinder **Ø25X 50 (Diameter X Stroke)**

ri =12.5mm

By assuming pressure in working cylinder is, **P = 3 bar =0.3 N/mm^2**

So according to Clavarino's equation,

For closed end cylinder at both ends to determine the thickness of cylinder.

Assume,

$p = 3$ bar $= 0.3$ N/mm^2

$\mu = 0.29$

$r_i = 12.5$mm.

$$t = ri\left[\sqrt{\frac{\sigma t + (1 - 2\mu)P}{\sigma t - (1 + \mu)P}} - 1\right]$$

t = 0.03049 mm.

By considering Factor of safety FOS =1.5

t=1.5 x0.03049 mm. =0.0457mm.

Available thickness, **t = 0.25mm**

Piston dia- = 25mm

Stroke dia- = 50mm

Pistion rod dia- = 10mm.

Let,

A= Force area of cross-section of piston.

$$A = \frac{\pi}{4}(D^2)\ \text{mm}^2$$

$$A = \frac{\pi}{4}(25^2)\ \text{mm}^2$$

A= 490.87 mm2

A_{PR}= Force area of cross-section of piston on rod side.

$$A_{PR} = \frac{\pi}{4}(D^2 - d^2)\ \text{mm}^2$$

$$A_{PR} = \frac{\pi}{4}(25^2 - 10^2)\ \text{mm}^2$$

A_{PR}= 412.334 mm^2

e required to complete stroke is 2 second.

Linear velocity of piston $V = \frac{L}{t}$

$$= \frac{50}{2}$$

= 25 mm/sec.

Piston force acting during forward stroke.

$$F_a = P \times \frac{\pi}{4}(D^2)$$

$= 0.1 \times 490.87$

F_a = 49.087 N.

Piston force acting during return stroke.

$$F_R = P \times \frac{\pi}{4}(D^2 - d^2)$$

$= 0.1 \times 412.33$

F_R = 41.233 N.

F. Impact Force Calculation

CASE 1

Mass of the vehicle = 1703 kg (approx)

Mass of two passengers = 150 kg

Total mass = 1703+ 150

= 1853

Acceleration = Final velocity Initial velocity/ Time

Vehicle Speed = 50 km/hr

When it hit an object, coming to complete stop in 1 second

V = 0 -013.5/ 1

= 13.5*1853

Impact Force = 25015N

CASE 2

Mass of the vehicle = 1703 kg (approx)

Mass of two passengers = 150 kg

Total mass = 1703+ 150

= 1853

Acceleration = Final velocity Initial velocity/ Time

Vehicle Speed = 90 km/hr

When it hit an object, coming to complete stop in 1 second

V = 0 -24.3/ 1

= 24.3 *1853

Impact Force = 45027N

IV. PROTOTYPE DETAILS

Figure 4.1 and 4.2 shows the CAD Model of Bumper and its mounting on the prototype model..

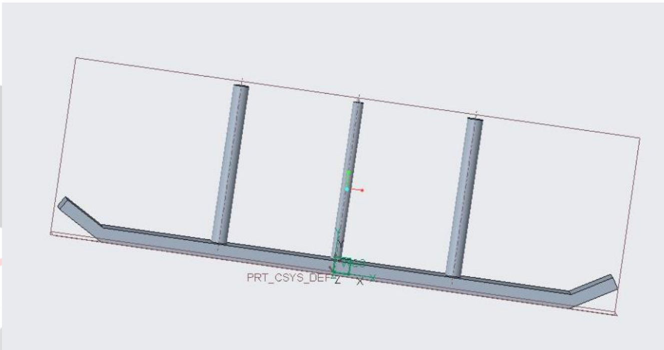

Figure 4.1 : CAD Model of Assembled Bumper

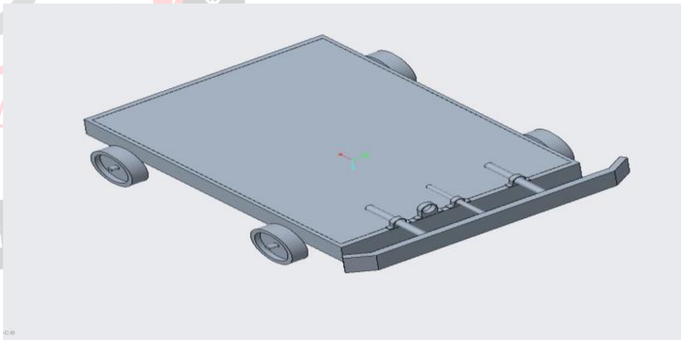

Figure 4.2: CAD Model of Assembled Bumper

Part size : - 600 mm x 450 mm x 5 mm.

Part size (wheel) : - R :- 100mm

Clamp :- 200mm - 150mm - 200mm

Part size (Bumper) : - 450 mm x 50 mm x 5mm

Supporting rod : - 150mm - 100mm - 150mm

Part size (Bumper) : - 450 mm x 50 mm x 5mm

Supporting rod : - 150mm - 100mm - 150mm

DOI : 10.35291/2454-9150.2023.0090

International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-09, Issue-01, Apr 2023

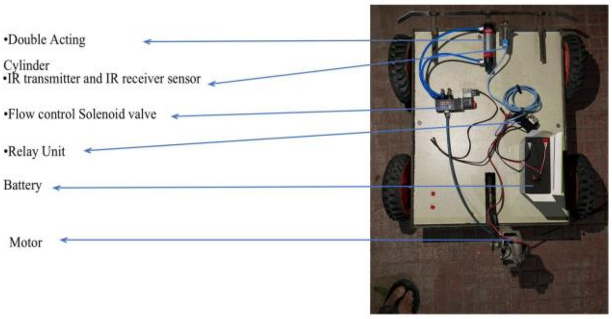

Figure 4.3: Actual working prototype model

V. ANSYS ANALYSIS

Material selection is one of the main uses of ANSYS analysis. Engineers and designers can use ANSYS to simulate how various materials will respond to various circumstances and stresses. This enables them to assess the materials' strength, durability, and other qualities in order to decide which material to utilize for a certain application.

5.1 STEEL : Steel is a commonly used material for bumper construction due to its strength and durability. It provides excellent impact resistance and can absorb and distribute energy effectively. However, it is heavy and can add unnecessary weight to the vehicle

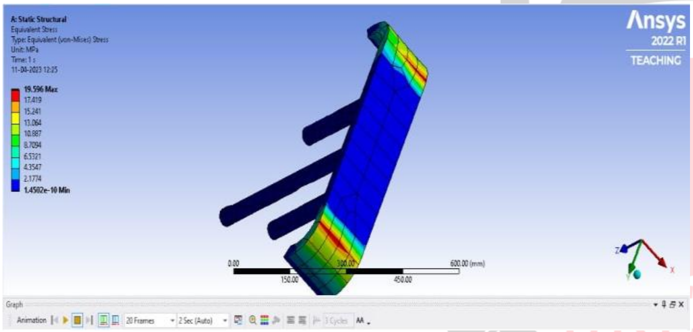

Figure 5.1(a) Equivalent elastic strain

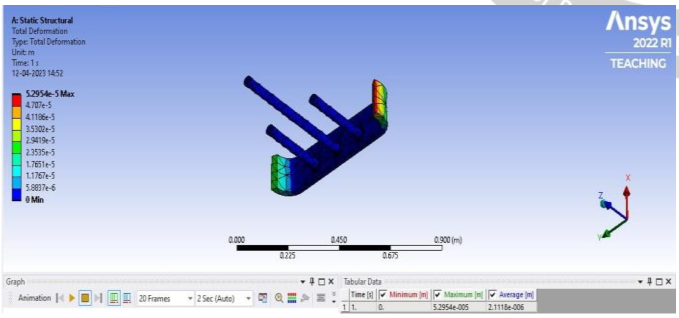

Figure 5.1(b) Total deformation

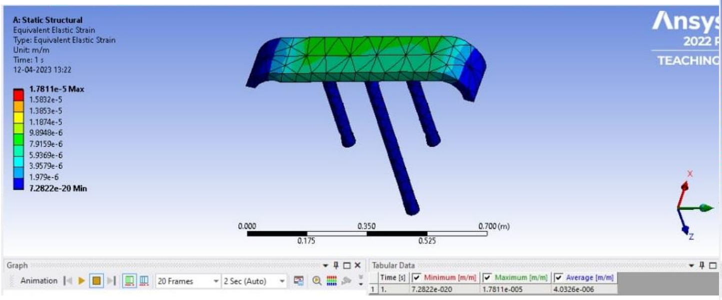

Figure 5.1(c) Equivalent stress

5.2 EPOXY GLASS FIBER : Epoxy glass fiber composites are frequently utilized in a variety of industrial applications, such as the electrical, aerospace, automotive, marine, and construction sectors. They are prized for their excellent corrosion resistance, high strength-to-weight ratio, and toughness in challenging conditions.

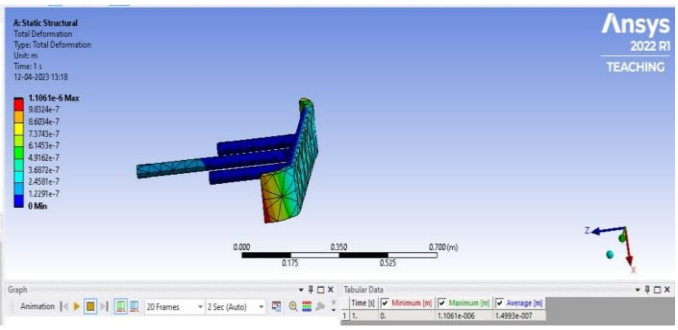

Figure 5.2(a) Total deformation

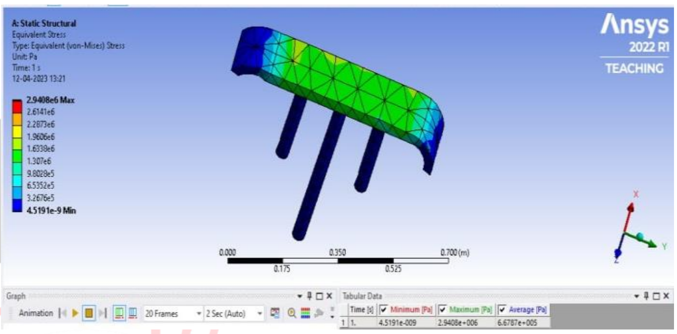

Figure 5.2(b) Equivalent stress

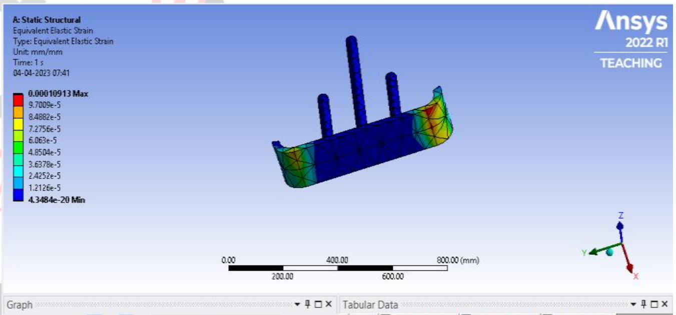

Figure 5.2(c) Equivalent elastic strain

5.3 CARBON FIBER REINFORCED POLYMER (CFRP) : CFRP is a high-strength and lightweight material that is commonly used in high-performance vehicles. It provides excellent impact resistance and can absorb and distribute energy effectively. However, it is relatively expensive and may not be cost-effective for mass production.

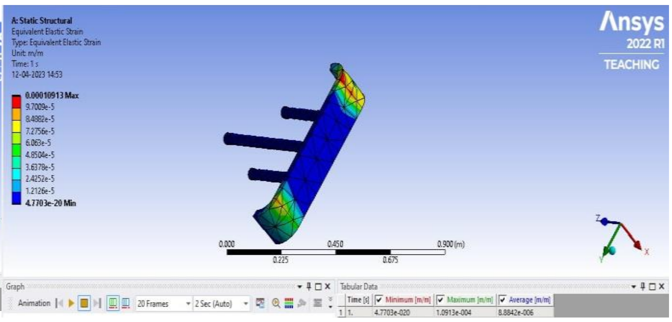

Figure 5.3(a) Equivalent stress

 DOI : 10.35291/2454-9150.2023.0090

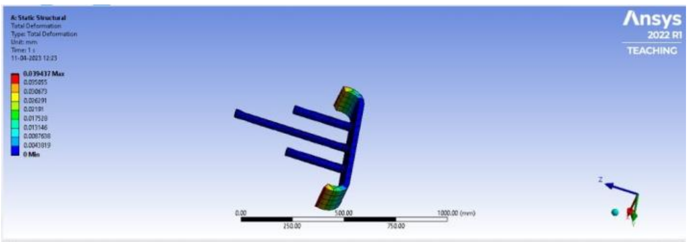

Figure 5.3(b) Total deformation

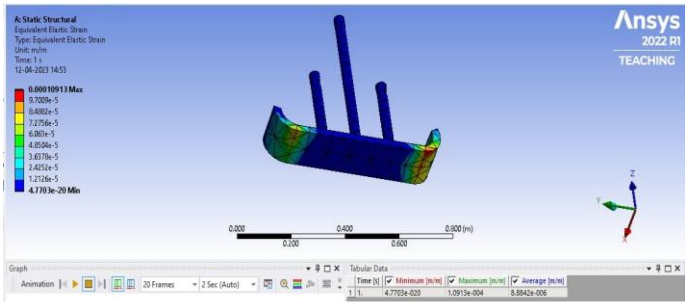

Figure 5.3(c) Equivalent elastic strain

VI. RESULTS AND CONCLUSION

Table 5.1 Results for bumper using stress strain analysis

MATERIAL PROPERTIES	STEEL		GLASS FIBER		CFRP	
	min	max	min	max	min	max
Equivalent stress (Mpa)	1.4502 e-10	19.596	4.5191 e-9	2.9408e 6	2.7941e-9	2.1007e 7
Equivalent elastic strain (m/m)	7.2822 e-20	1.7811 e-5	4.3484 e-20	0.00010 913	4.07703 e-20	0.00010 913
Total deformation (mm)	0	5.2954 e-5	0	1.1061e-6	0	0.03943 7

The most important details in this text are that the bumper is an important member of an automobile from a safety point of view, and that the project has provided practical knowledge regarding planning, purchasing, assembling and machining, as well as understanding the difficulties in maintaining tolerances and quality. The report concludes that the calculation of mechanical aptitude was useful and that the design criterions were overcome due to the availability of good reference books.

In many applications, especially those where weight reduction, high strength, and corrosion resistance are crucial considerations, carbon fiber is superior to steel and glass fiber due to its properties.

FUTURE SCOPE

While designing bumper for vehicles vibration analysis of bumper can be done for minimizing the vibration passed to the vehicle.

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