International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 02 | Feb 2021 www.irjet.net p-ISSN: 2395-0072

Study and Design of Front Bumper for Light Motor and Heavy Motor Vehicles

Tushar Kale[1], Gaurang Gulwade[2]

[1,2]Research Scholar Bachelors of Mechanical Engineer, AMRAVATI UNIVERSITY (INDIA)

Abstract - Now day's ratio of automobiles accident increasing day by day and millions of people are losing their lives. For this, present bumper is one of the main responsible components as it is not capable enough to restrict striking of vehicle away from driver cabin. These accidents can be avoided if we design strong bumper system for vehicle car which will able to sustain impact maximum load and would not allow striking vehicle to reach driver cabin.

In this research paper we have discussed about structural changes and component by putting which we can make bumpers stronger and more effective, design analysis of that component.

Key Words: Bumper, Mechanical Damper, CATIA V5 Software.

1. INTRODUCTION

Today human comfort and safety is the most important parameter that manufacturers have to consider while designing new vehicle. In case of accident first part of the vehicle that comes in the contact with striking vehicle is front bumper therefore it should design in such way that it should be capable enough to resist the impact. Is still working on bumper design to improve its impact resisting capacity but they didn't get succeed till now. Strong, durable bumpers are an important piece of protective equipment that many off-road vehicles should have. In these accidents maximum accident occurred between heavy trucks and light motive vehicles. Bumper systems are designed to prevent or reduce physical damage to the front or rear ends of vehicles in collision condition. Deaths in road accident in India evident in figure (1) and heavy vehicle contribution is evident in figure (2).

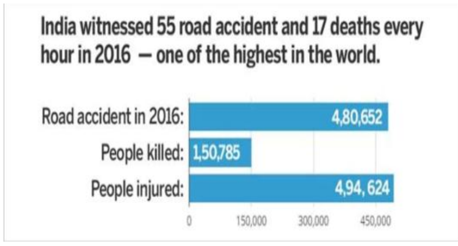


Fig: 1 Number Road accident in India. [1]

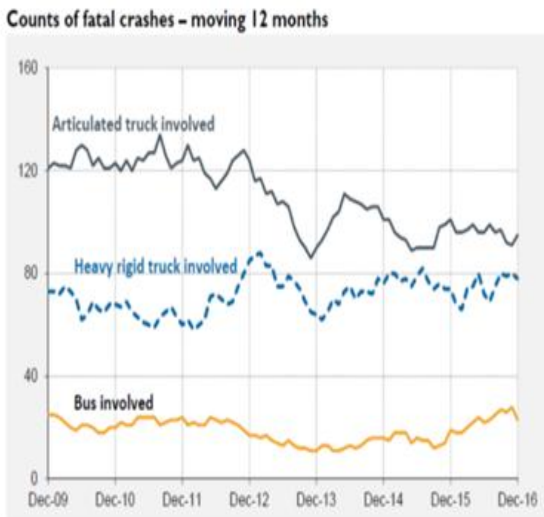


Figure: 2 Heavy Vehicle Contributions in Accidents. [2]

2. LITRATURE REVIEW

1. Hosseinzadehetal studied the structure, shape, and impact condition of glass mat thermoplastic (GMT) bumper by using LS-DYNA pre solver and the results are compared with conventional metals like steel and aluminum. GMT showed very good impact behavior compared with steel and aluminum, which all failed and showed manufacturing difficulties due to strengthening ribs or weight increase due to use more dense materials.[3]
2. Bautistaeta studied the different impact standards and for the specific material they optimized the shape of bumper beam by performing the software simulation. They also studied the effect of metallic energy absorber in bumper system. Maximum stress and deformation were used as design criteria. They have complied many international standards for bumper beam design.[4]

3. Mohapatra S discusses that automotive development cycles are getting shorter by the day. With increasing competition in the marketplace, the OEM's and suppliers main challenge is to come up with time efficient design solutions. Researchers are trying to improve many of existing designs using novel approaches. Many times there is conflicting performance and cost requirements, this puts additional challenge with R&D units to come up with a number of alternative design solutions in less time and cost compared to existing designs. These best solutions are best achieved in a CAE environment using some of the modern CAD and FEM tools. Such tools are capable of effecting quick changes in the design within virtual environment.[5]
4. This bumper absorbs impact energy with its deformation or transfers it perpendicular to the impact direction with the aid of a spring mechanism that is able to convert about 80% of the kinetic energy to the spring potential energy in low-speed impacts according to American standard. The main design concepts of this bumper are based on aerodynamic forms and frontal configuration of passenger cars. The CATIA data of the bumper structure have imported to LS- Dyne and analyses have done with nonlinear explicit impact modeling elements. Modeling, solving and analysis were carried out with respect to the American standard and a bumper assembly was designed with 9.8 kg weight which has reduced compared with a similar stamping steel bumper.[6]

3. DESIGIN OF FRONT BUMPER OF VEHICLEL[LMV&HMV]

A bumper is a shield made of steel, aluminum, rubber, or plastic that is mounted on the front and rear of a passenger car. When a low-speed collision occurs, the bumper system absorbs the shock to prevent or reduce damage to the car. Some bumpers use energy absorbers or brackets and others are made with a foam cushioning material.

The car bumper is designed to prevent or reduce physical damage to the front and rear ends of passenger motor vehicles in low-speed collisions. Automobile bumpers are not typically designed to be structural components that would significantly contribute to vehicle crashworthiness or occupant protection during front or rear collisions. **It is not a safety feature intended to prevent or mitigate injury severity to occupants in the passenger cars.** Bumpers are designed to protect the hood, trunk, grille, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights in low speed collisions. [7]

4. Design of System

During collision at the beginning total force will act on front bumper which has capacity to sustain this load up to predetermine limit, then rest of the force will act on mechanical damper. Diagram of front bumper system is shown below.

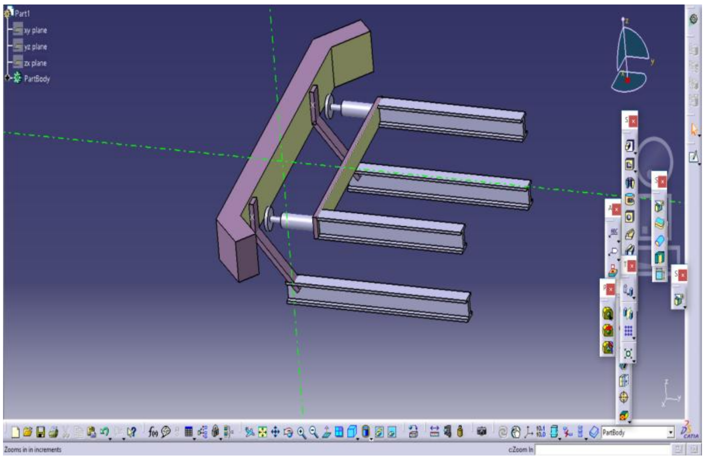


Fig: 3 CATIA based design of front Bumper of vehicle

A) Material selection

Bumper is the first part of vehicle which will face maximum striking forces. For minimizing effect of collision, we have to choose effective material which will have good anti-collision properties. EPDM is the material which fulfills this requirement. EPDM material has following chemical composition and mechanical properties as mentioned below.

Properties	A	B	C	D	E
Tensile Strength[mpa]	7.8	13.6	16.5	22.7	20.2
Elongation [%]	393	555	581	636	584
Modulus@100[mpa]	1.2	1.3	1.4	1.9	1.8
Hardness [shore A]	49	60	53	61	59
Tear strength [KN/m]	20.9	27.1	30.3	39.6	39.5

Table: 1 Mechanical Properties of EPDM Material [8]

Following are the chemical properties of EPDM material which is essential while designing bumper.

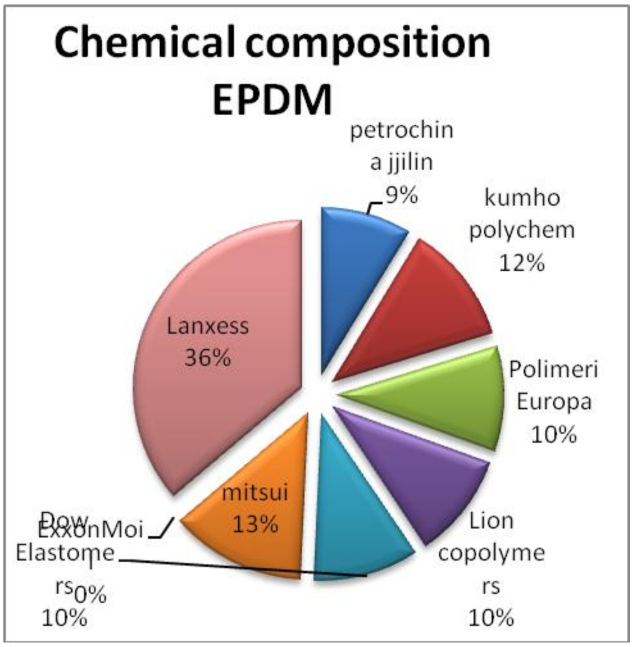


Chart: 1Chemical Composition [9]

B) During collision maximum absorb forces by bumper, initial force Acting on Bumper 19.30 KN (without displacement)

To determining collision force we have consider two vehicle having same velocity and mass.
Mass of vehicle **=** 1554 kg
Average mass of persons = 3440kg
Total mass = 1894kg
Speed of car = 36 km/hr = 10 m/s
Length of Bumper = 1132.25 mm
Width = 64 mm

1. Deceleration of car $\alpha = \frac{v-u}{t}$ [10]

$\alpha = \frac{10}{0.1}$

$\alpha = 100\ m/s^2$

2. Force acting during collision $F = M\alpha$ [10]

$F = 1894 * 100$

$F = 189.4\ KN$

3. Pressure acting on bumper $P = \frac{F}{A}$ [10]

$P = \frac{189400}{1132.25 * 64}$

$P = 2.61 * 10^6\ N/m^2$

This is the amount of pressure intensity beyond which bumper will start to displace from original position.

C) After collision, as the limit of sustainability of bumper cross, bumper displaces from its original position. Displacement Calculations for 300KN (6g) force Acting on Bumper (with displacement)

By Considering Maximum Force 300 KN

4. Force acting during collision $F = M\alpha$ [10]

$\alpha = \frac{189.4}{300}$

$= 1.58\ m/s^2$

5. Deceleration of car $\alpha = \frac{v-u}{t}$ [10]

$1.58 = \frac{10-u}{0.1}$

$u = 9.84\ m/s$

6. Horizontal Component of force 300KN

$= \text{F}\cos\theta$

$= 300\cos 45$

$212\ KN$

7. $Displacement[\delta] = \frac{PL}{AE}$ [11]

$\frac{212 * 10^3 * 0.064}{0.07264 * 0.007 * 10^9}$

$= \mathbf{26.69\ mm}$

26.69 mm is the required displacement for actuating the damper**.**

D) Analysis of front bumper

Differrnt models of bumpers and its analysis for LMV and HMV made by using CATIA software is as evident in figures below acoording to design loads we analysed the front bumper displacement .

Fig: 4(a) static Case Solution.1 – Von mises stress

Loading conditions are assumed to be static. By analyzing loading condition we found the location of maximum deflection and maximum stresses agree well with the theoretical maximum location of simple beam under uniform load distribution. The calculations of the stress produce in bumper are calculated by moment distribution method. [12]

The analysis done on bumper which gives the maximum generated von-misses stress (7.680e+005N) within a permissible value.

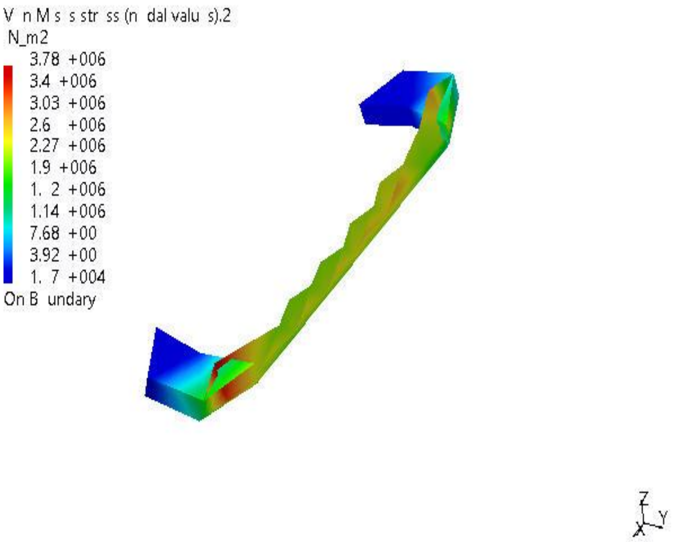


Fig: 4(b) static Case Solution.1 – Von miscellaneous stress

E)Design of mechnical damper :

As we know that if the stricking force is greater than limite force then bumper get dissplace and total load is act on damper.Following design parameter are used to design mechanical damper.

Sr.No	**Dimensions**	
1	**Force on piston**	300 KN
2	Cylinder diameter	40 mm
3	Piston diameter	20 mm
4	Total length of shock absorber	380 mm

Table no. 2 Design parameter

F) Design of spring

There are two mechanical dampers which are fixed with frame. It consists of spring and hydraulic oil. By choosing proper damping oil we will considered the damping effect of fluid. Spring is made of carbon still material. Carbon steel has following properties and chemical composition.

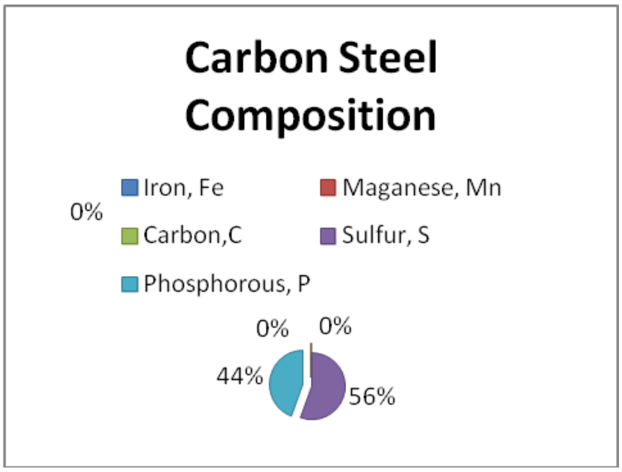


Chart: 2 Carbon steel Composition.[13]

- **Mechanical Properties**

Tensile Strenght Ultimate	635 mpa, 92100 psi
Tensile strenght yeild	490 mpa, 71100 psi
Modulus of elasticity	0.27-0.30 mpa
Bulk modulus	140 gpa, 20300 ksi
Poissions ratio	0.27-0.30
Hardness, Brinell	187 mpa, 187 psi

Table:3 Mechanical prooperties of carbon steel

- **Calculation**

Factor of Safety = 2 .....(Range = 1 to 12)

i. Design Load (W_{design})
   W_{design} = 300KN
   Load acting on spring = 212KN
   Load on single spring =106KN

Modulus of Rigidity (G) = 84 Gpa = $84*10^9$ N/M^2

Mean Diameter of Spring (D) = 30

Wire Diameter (d) = 10 mm

1. Inside Diameter (D_i) = D – d
   = 30 – 10
   = 20 mm
2. Outer Diameter (D_o) = D + d
   = 30 +10
   = 40
3. $Spring\ index = \frac{D}{d}$ [14]

$$Spring\ index = \frac{30}{10}$$

$$Spring\ index = 3$$

4. Whals curvature factor or stress factor

$$K = \frac{4c-1}{4c-4} + \frac{0.165}{c}\ [14]$$

$$K = \frac{4*7-1}{4*7-4} + \frac{0.165}{7}$$

$$K = 1.53$$

5. Shear stress (τ)

$$\tau = \frac{8W_{design}D_oK}{\pi d^3}\ [14]$$

$$\tau = \frac{8*106*10^3 0.04*1.53*6}{\pi 0.01^3}$$

$$\tau = 66.44*10^6\ N/m^2$$

6. Deflection (δ)

$$\delta = \frac{8WGD_o{}^3n}{GD^4}\ [14] \quad = \frac{8*106*10^3*0.04^3*6}{84*10^3*0.01^4}$$

$$= 0.01516\ m$$

$$= 15.16\ mm$$

7. Total number of active turn

$$n' = n + 2\ [14]$$

$$n' = 6 + 2$$

$$n' = 8$$

8. Solid length (L_s)

$$L_s = n' * d\ [14]$$

$$L_s = 8*10$$

$$L_s = 80\ mm$$

9. Free length (L_f)

$$L_f = L_s + \delta + 0.15*\delta\ [14]$$

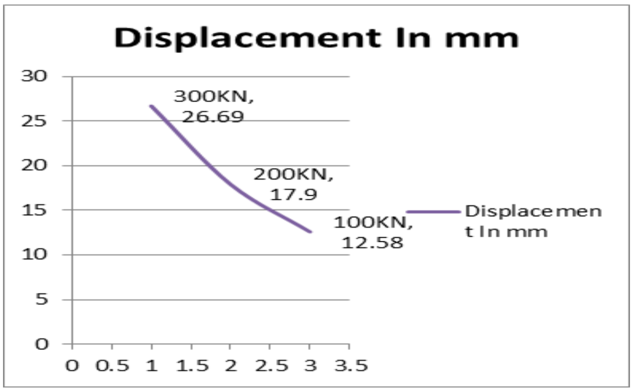
$$L_f = 80 + 15.16 + 0.15*15.16$$

$$L_f = 98mm$$

10. Pitch
11. $P = \frac{98}{6}$
12. $P = 16.33mm$

Force [KN]	Displacement[mm]
300	26.69
200	17.90
100	12.58

Table: 5 Force Displacement calculations



Graph: 1 Force vs. Displacement

Design of spring with anlysis to decide wheather spring is capable to resist the ipact load or not is evendent in figures below.

Fig: 5(a) application of load on spring

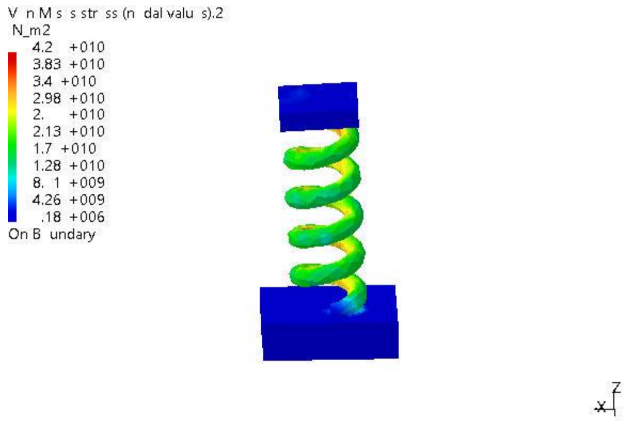


Fig: 5(b) spring analysis

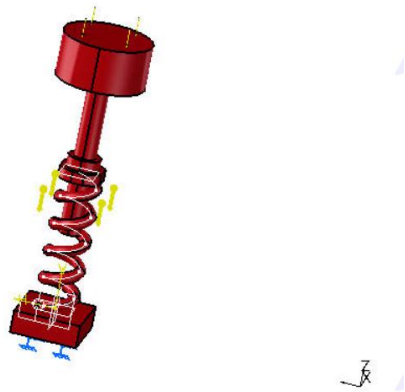


Fig: 6(a) Static Case Solution.1 - Von Miscellaneous stress (nodal values).2

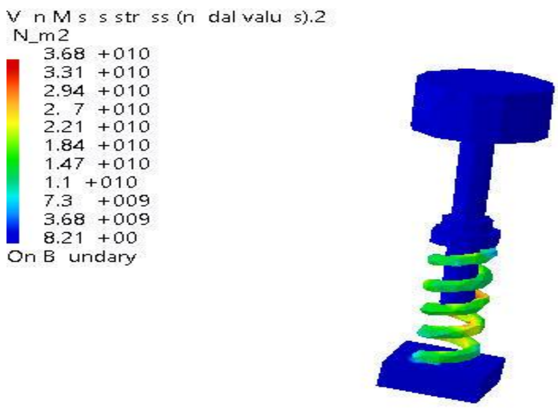


Fig: 6(b) Static Case Solution.1 - Von Miscellaneous stress (nodal values).2

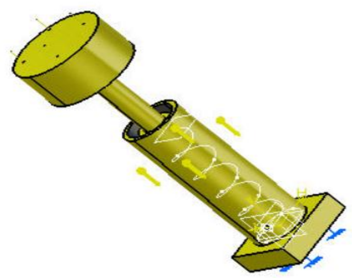


Fig: 6(c) Static Case Solution.1 - Von Miscellaneous stress (nodal values).2

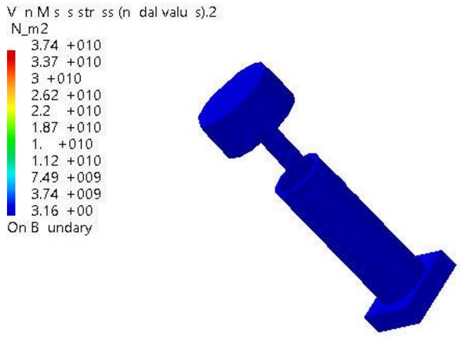


Fig: 6(d) Static Case Solution.1 - Von Miscellaneous stress (nodal values).2

In final analysis of mechanical damper we can observed that von-misses stresses (7.490e+005N) are within permissible limit.

e) Frequency Calculations For 300KN Force Acting on Bumper

A. Spring stiffness$[s] = \frac{W}{\delta}$

$$= \frac{212 * 10^3}{0.0266}$$

$$= 7.96 * 10^6 \frac{N}{M}$$

B. *Critical Damping coeficint*$[c]$

$$= 2m * \sqrt{\frac{s}{m}}$$

$$= 2 * 212 * 10^3 \sqrt{\frac{7.96 * 10^6}{212 * 10^3}}$$

$$2.59 * 10^6 \, N - \frac{s}{m}$$

Circular Damped Frequency$[w_d] =$

$$= \sqrt{\frac{s}{m} - \left(\frac{c}{2*m}\right)^2}\ [15]$$

$$= \sqrt{\frac{7.96*10^6}{212*10^3} - \left(\frac{2.599*10^6}{2*212*10^3}\right)^2}$$

$$= 0.479\,\frac{rad}{s}$$

C. $Periodic\ time[t_p] = \frac{2\pi}{w_d}$ [15]

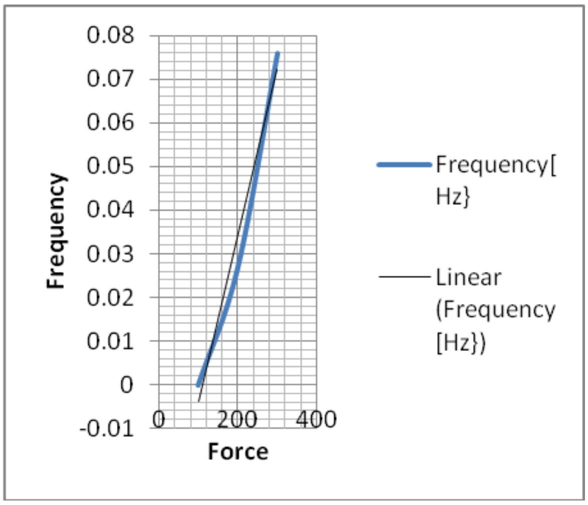
$$= \frac{2\pi}{0.479}$$

$$= 13.11\ sec$$

D. $Damped\ Frequency = \frac{1}{t_p}$ [16]

$$= \frac{1}{13.11} = \mathbf{0.076\ H_z}$$

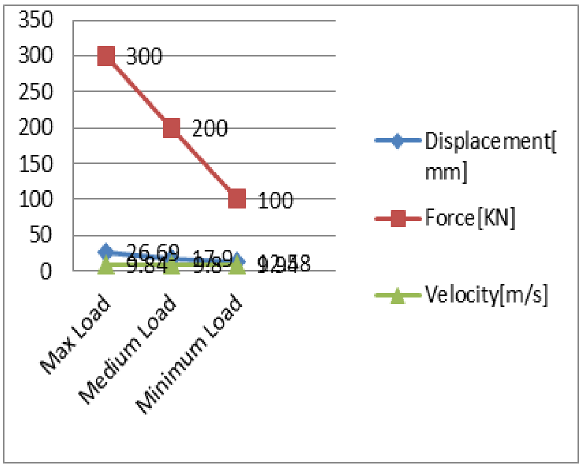
- Observations for different loading conditions are given below with graphs for better understanding of result



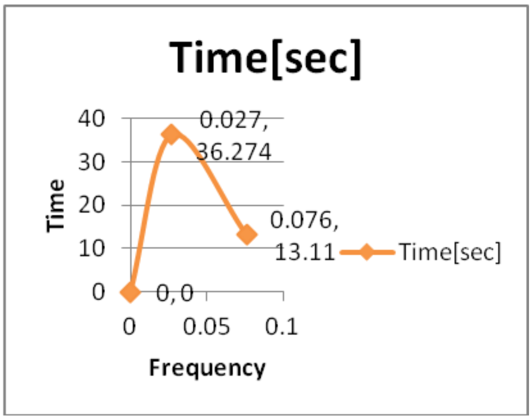
Graph: 3 Frequencies vs. Force

Displacement[mm]	Force[KN]	Velocity[m/s]
26.69	300	9.84
17.90	200	9.8
12.58	100	9.94

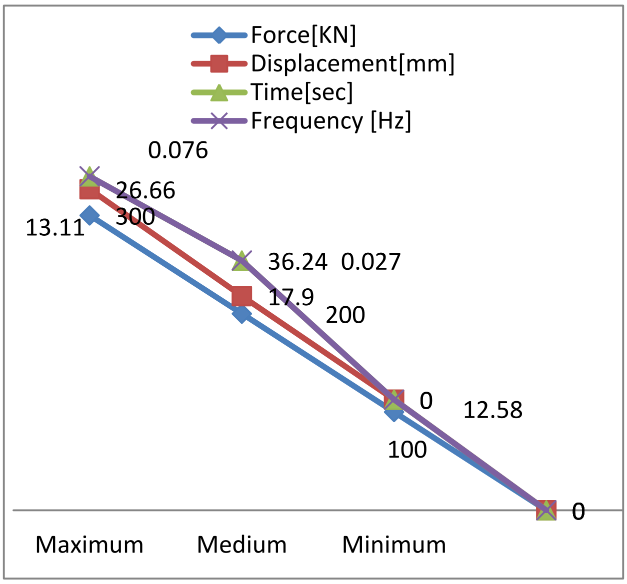
Table:4 Displacement, force, velocity calculations



- Graph:2 Displacement vs. Force vs. velocity



Graph:4 Frequency vs. Time



Graph: 5 comparison of all

5. ADVANTAGES

1. It has good reliability
2. High impact resistance
3. It has less cost
4. Simple in construction

5. Good wear and corrosion resistance property.
6. EPDM has long life spa

6. CONCLUSION

As we know bumper is one of the important part of vehicle as per the safety concerned therefor it should design in manner it will resist the impact force of striking to vehicle. If we use this kind of bumper in vehicles there will be less damage to vehicles and more protection to driver and for passengers as well. It simple and cheap so we don't need to invest much more amount in it case of damage.

7. REFERENCES

1] www.hindustantimes.com/india-news/road-accidents-claimed-nearly-400-lives-every-day-in-india-in-2016/story-7DlmtdnvMYLLZVGxXKOaJN.html. Retrieved on 21 march 2018.

2] www,bitre.gov.au/publications/ongoing/road-trauma-involving-heavy-vehicles.aspx. Retrieved on 21 march 2018.

3] Hosseinzadeh RM, Shokrieh M, and Lessard LB, "Parametric study of automotive composite bumper beams subjected to lowvelocity impacts", Composite Structures 68 (2005) 419–427, Elsevier Ltd.

4] BautistaGarret, HardinChad, TaylorBen, "Best-In-Class Global Bumper Reinforcement Beam", AISI 123-129.California Polytechnic State UniversitySan Luis Obispo2009

5] Mohapatra S, "Rapid Design Solutions for Automotive Bumper Energy Absorbers using Morphing Technique", Altair CAE users Conference 2005, Bangalore, India. 5.http://www.google.com/patents/about/6817638_Bumper _system.html?id=c1gQAAAAE AJ

6]Manideep Kumar Vandanapu1, Ratnakar Pandu2 "Design Optimization of Passenger Car Front Bumper"IJSR Volume 4 Issue 11, November 2015

7]www.one.nhtsa.gov/cars/problems/studies/bumper/index.html. Retrieved on 25 march 2018

8] Vijayalekshimi.V and Abdul Majeed.S.S.M Mechanical, thermal and electrical properties of EDPM/ Silicone blend Nanocomposites,IJERA, Vol.3, Issue2, March-April2013,pp.177-1180

9]Klaus warner stockelhubr, amit das, rane jurk Contribution of physic chemical properties of interface on dispensability, adhesion and fluctuation of filler practical in rubber,polymer 51 (2010) 1954-1963, Elsevier.

10] R K **B**ansal, strenght of material

11] R S Khurmi,Theory of Machine, page no.913

12] strojniski bstnik, generals of mechanical engg,stress based metrology for the design of front bumper,june 2-2011

13] Daramola O. Oluyemi, Oladele Isiaka Oluwole, Study of the properties of heat treated rolled medium Carbon steel, material research 2011; 14(2) 135-141

14] R S Khurmi, Theory of Machine,page number 820-843

15] R S Khurmi, Theory of Machine,page number 937-950

16]] R S Khurmi, Theory of Machine,page number 927-930

8. AUTHOR PROFILE

Tushar NandkishoR Kale Inventor, Researcher, Author. Received Diploma In Mechanical Engineering in 2016 From VYWS Polytechnic Badnera. Published 3 Research paper He now Pursuing Bachelors of Mechanical Engineering Third year at Prof. Ram meghe Institute Of Technology And Research Badnera.

Gaurang Madhukar Gulwade Researcher Received Diploma In Mechanical Engineering in 2016 From VYWS Polytechnic Badnera. Published 2 Research papers. In 2019 Completed Bachelors of Mechanical Engineering from G.H Raisoni College of Engineering and Management, Amravati.