Conceptual Design to Prevent Vehicle Rollover

[I]Yash Sharma, [II]Samveg S Parmar, [III]Tanay D Khanwalkar, [IV]Samarth Nema
[I,II,III,IV]B.E. Mechanical Engineering, (R.G.P.V Bhopal), Madhya Pradesh, India

Abstract

A Rollover is a type of vehicle crash in which a vehicle tips over onto its side or roof. Rollovers have a higher fatality rate than other types of vehicle collisions. When the cornering force is less than the sum of inertial force and gravity force, rollover occurs. Sometimes irresponsible driving also leads to roll over. Rollover basically is of two types; Longitudinal Rollover and Lateral Rollover. This paper focuses on Longitudinal Rollover and we are working on dynamically shifting the Centre of Gravity of the vehicle at the instant of rollover with the help of fluid. The concept is tested and run successfully on Ansys software.

Keywords

Rollover, Fluid, Centre of Gravity, Vehicle Crash, Discharge, Velocity.

I. Introduction

A rollover is a type of vehicle crash in which a vehicle tips over onto its side or roof. Rollovers have a higher fatality rate than other types of vehicle collisions. Vehicle rollovers are divided into two categories: tripped and untripped.

Centre of Gravity: The centre of gravity (CG) of an object is the point at which weight is evenly dispersed and all sides are in balance. It is a fixed point on any body. Greater the centre of gravity height (CGH) of any vehicle, higher are its chances of tipping.

1. Problem

When,

Cornering forces < (Inertia force + Gravity force); Vehicle get rolls over.

All vehicles are susceptible to rollovers to various extents. Generally, rollover tendency increases with the height of the centre of mass, narrowness of the axle track, steering sensitivity, and increased speed.

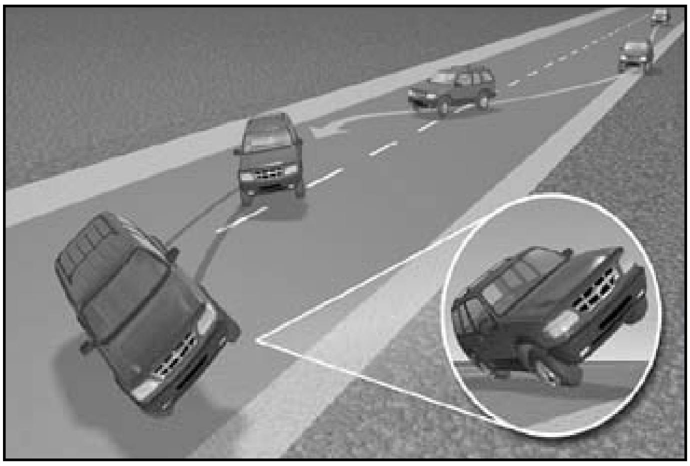

Fig.1 : Showing rollover phenomena.

II. Literature Review

An anti-roll bar (roll bar, anti-sway bar, sway bar, stabilizer bar) is a part of many automobile suspensions that helps reduce the body roll of a vehicle during fast cornering or over road irregularities. It connects opposite (left/right) wheels together through short lever arms linked by a torsion spring. A sway bar increases the suspension's roll stiffness—its resistance to roll in turns, independent of its spring rate in the vertical direction. The first stabilizer bar patent was awarded to Canadian inventor Stephen Coleman of Fredericton, New Brunswick on April 22, 1919.

Because an anti-roll bar connects wheels on opposite sides of the vehicle, the bar transmits the force of a bump on one wheel to the opposite wheel. On rough or broken pavement, anti-roll bars can produce jarring, side-to-side body motions (a "waddling" sensation), which increase in severity with the diameter and stiffness of the sway bars. Other suspension techniques can delay or dampen this effect of the connecting bar.

III. Methodology

The idea deals with developing a system that can effectively and dynamically balancing an automobile by shifting its C.G. with the help of weight generated by the fluid. The mechanism was modeled using SolidWorks and analyzed using Ansys. Proper dimensions were given in designing and required boundary conditions were provided at the time of analysis. The mechanism was solved using four different pipe diameters and the results from the respective analysis were compared.

1. Construction

This system comprises of these parts:

1. Base.
2. Reservoirs:
   - unit of main reservoir.
   - units of secondary reservoir.
3. Pump.
4. Pipes for fluid flow.
5. Fluid approximately (900kg).

IV. Designing a Model

Model of our mechanism was developed in 3D modelling software SOLIDWORKDS. It consists of base, reservoirs (main and secondary), pump and piping system.

Table 1 : Properties of fluid used

Properties	Mercury(Hg)
Density(kg/m^3)	13600
Specific heat capacity(J/gm K)	0.14
Dynamic viscosity(Pa s)	0.0015

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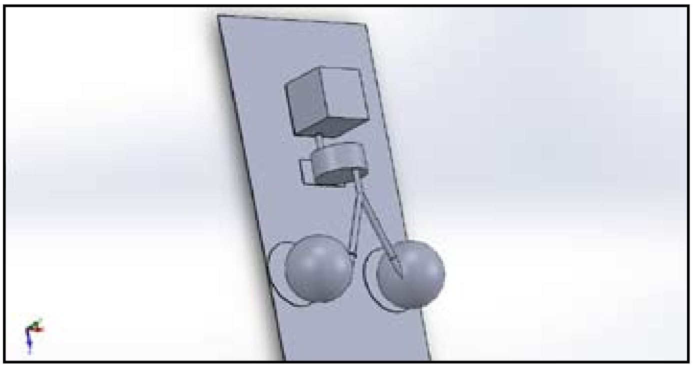

Fig. 2 : Final assembly

V. Calculations

Experimental Data

Vehicle: Wagon R
Curb Weight: 870Kg
Gross Weight: 1370Kg
Length: 3599mm
Width: 1495mm
Experimental Setup :

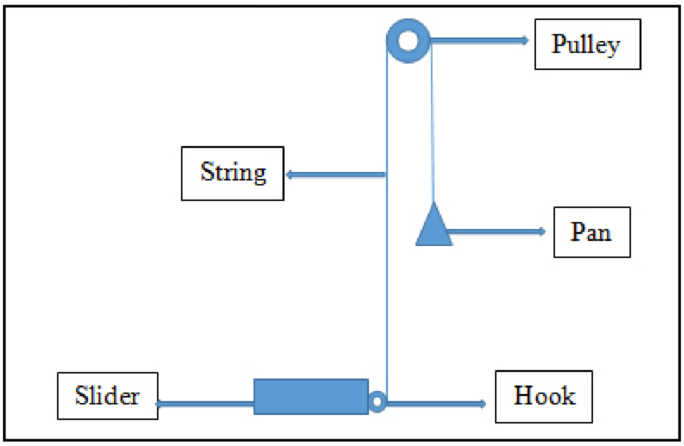

Fig.3 : Experimental setup

We calculated counter weight for a slab of 1Kg in lab at different angles.

Slider Base: 148mm
Pan Weight: 10g

Table 2 : Table between slider bases, inclination, counter weight & height of slider from ground.

Slider Base (mm)	Inclination	Counter Weight (gm)	Height of Slider from Ground (mm)
148	1°	660	2.5
	2°	646.3	5.1
	3°	632.47	7.7
	4°	618.5	10.3

From the results of our conducted experiment in the lab, scaling them to our vehicle dimensions, we get the following results:-

Table 3 : Table between wheel bases, inclination, counter weight & height of slider from ground.

Wheel Base (mm)	Inclination	Counter Weight (Kg)	Height of Vehicle from Ground (mm)
1495	1°	904.21	26.09
	2°	885.21	52.20
	3°	866.48	78.34
	4°	847.34	104.50

Vehicle Specifications

- Centre of gravity = 0.683m.....(i)
- Ground clearance = 0.165m.....(ii)
- Total centre of gravity height (C.G.H.)= (i)+(ii) =0.848m

Now,
Considering general curve radius (r):-
For flat road = 780m
For rolling road = 515m
For mountain road = 350m

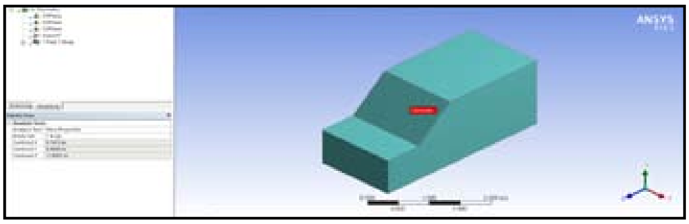

Fig. 4 : Location of centroid

Table 4 : Table for steady to tilt time.

Radius (m)	Θ (°)	Velocity (v)	Angular velocity (ω)	Time (Δt) (sec)
780	1	11.55	0.0148	1.18
780	2	16.34	0.0209	1.67
780	3	20.02	0.0256	2.043
780	4	23.13	0.0296	2.328
515	1	9.39	0.0182	0.958
515	2	13.28	0.0257	1.358
515	3	16.27	0.0315	1.662
515	4	18.79	0.0364	1.928
350	1	7.74	0.0221	0.789
350	2	10.94	0.0312	1.118
350	3	13.41	0.0383	1.367
350	4	15.49	0.0442	1.579

Table 5 : Table for steady to tilt time.

Radius (m)	Θ (°)	Steady to tilt Time (Δt)(sec)	Tilt to steady Time (Δt)(sec)
780	1	1.18	0.59
780	2	1.67	0.835
780	3	2.043	1.0215
780	4	2.358	1.179
515	1	0.958	0.479
515	2	1.358	0.679

515	3	1.662	0.831
515	4	1.928	0.964
350	1	0.789	0.394
350	2	1.118	0.559
350	3	1.367	0.683
350	4	1.579	0.789

Table 6 : Table between pipe diameter, velocity & discharge

Steady To Tilt Time T_{min} (Sec)	**Pipe Diameter (mm)**	**Area Of Pipe Hole, A (m^2)**	**Velocity (m/s)**	**Discharge (Q=A*V)**
0.789	35	0.000962	56.23	0.0541
0.789	40	0.00125	43.05	0.0541
0.789	45	0.00159	34.01	0.0541
0.789	50	0.00196	27.55	0.0541

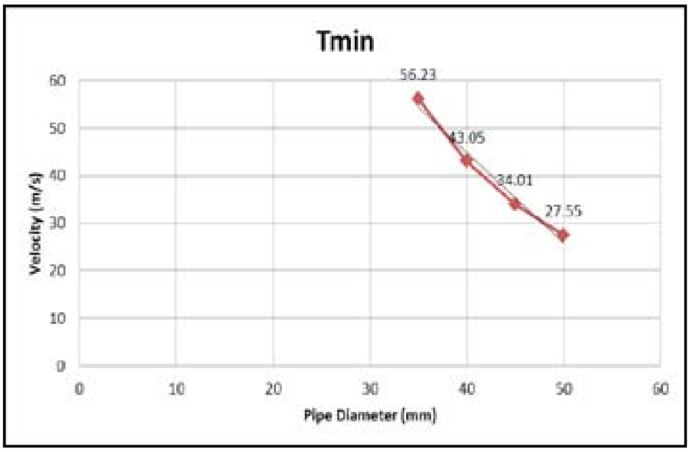

Fig. 5 : D vs V Graph

Table 7 : Table between pipe diameter, velocity & discharge

Steady To Tilt Time, T_{max} (Sec)	**Pipe Diameter (mm)**	**Area Of Pipe Hole, A (m^2)**	**Velocity (m/s)**	**Discharge (Q=A*V)**
2.358	35	0.000962	29.31	0.028
2.358	40	0.00125	22.44	0.028
2.358	45	0.00159	17.73	0.028
2.358	50	0.00196	14.36	0.028

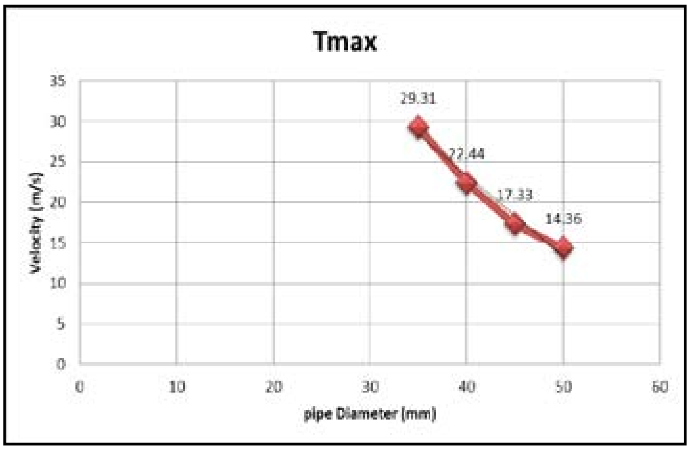

Fig.6 : D vs V Graph

Since, Dynamic Pressure = $\frac{1}{2}\rho v^2$

Table 8: Table between velocity and pressure (Minimum time)

ρ (Kg/m^3)	**v (m/s)**	**P (Pa)**	**t_{min} (sec)**
13600	56.23	1580.906	0.789
	43.05	926.6512	
	34.01	578.34	
	27.55	379.0501	

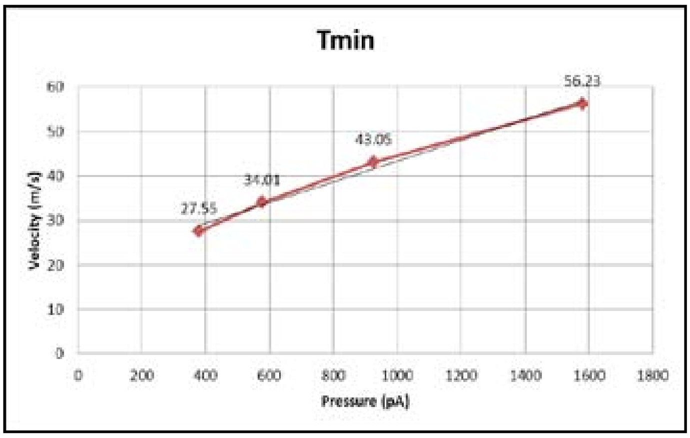

Fig.7 : P vs V Graph

Again, Dynamic Pressure = $\frac{1}{2}\rho v^2$

Table 9: Table between velocity and pressure (Maximum time)

ρ (kg/m^3)	v (m/s)	$P\ (Pa)$	$t_{max}\ (sec)$
13600	29.31	429.538	2.358
	22.44	251.7768	
	17.73	157.176	
	14.36	103.104	

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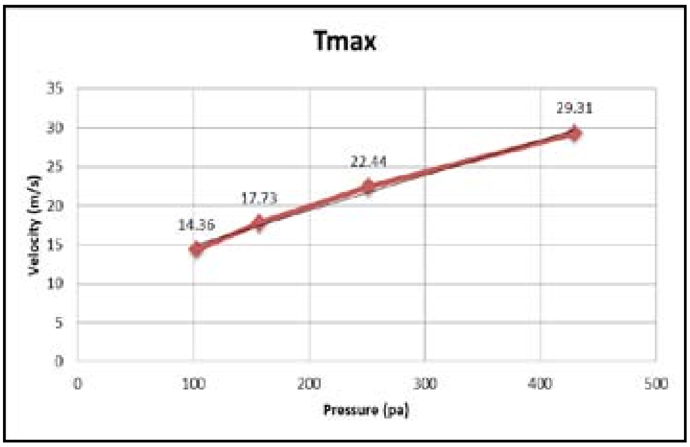

Fig.8 : P vs V Graph

Calculation of back pressure:

Table 10 : Table for pressure at various axis for various faces for diameter 50mm (Maximum time)

FACES	X- axis (Pa)	Y-axis (Pa)	Z-axis (Pa)
Full assembly	4.17766e+006	-2.53108e+009	3.832e+006
Inlet	1.18969e+006	1.18969e+006	1.18969e+006
Interface 1	0	0	903230
Interface 2	0	0	917186

VI. Analysis

1. For pipe diameter 35mm

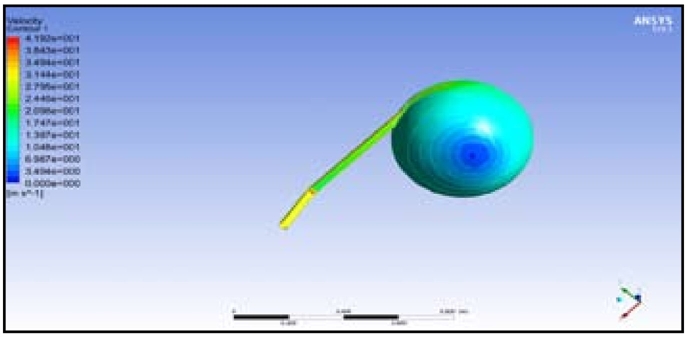

Fig.9 : Contour

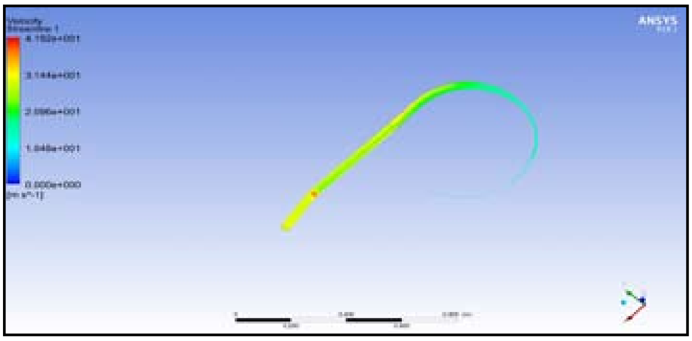

Fig.10 : Streamline Analysis

2. For pipe diameter 40mm

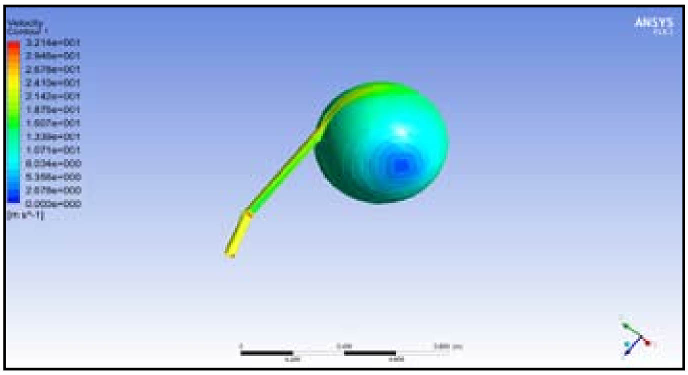

Fig. 11 : Contour

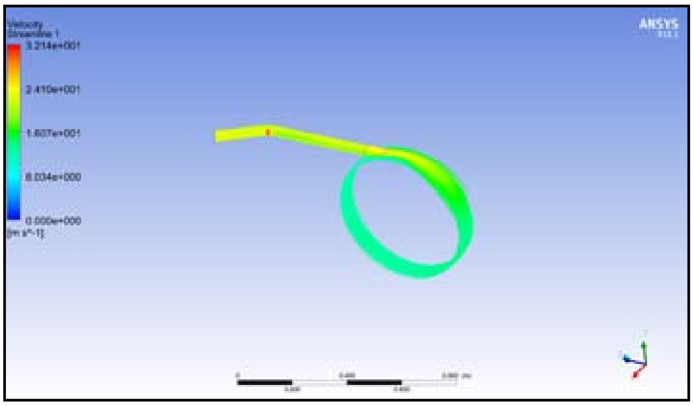

Fig.12 : Streamline Analysis

3. For pipe diameter 45mm

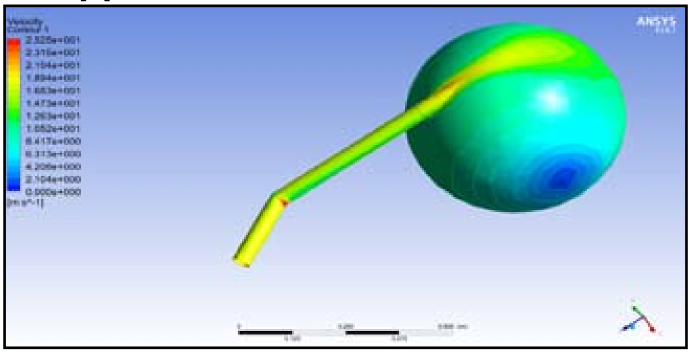

Fig.13 : Contour

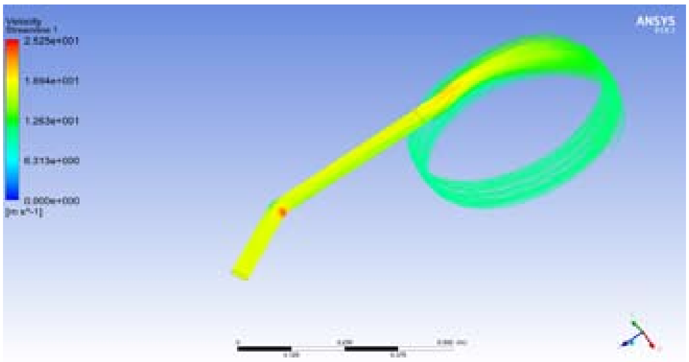

Fig.14: Streamline Analysis

4. For pipe diameter 50mm

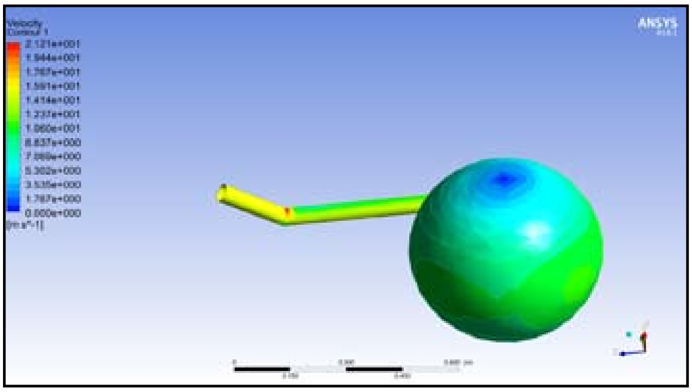

Fig.15 : Contour

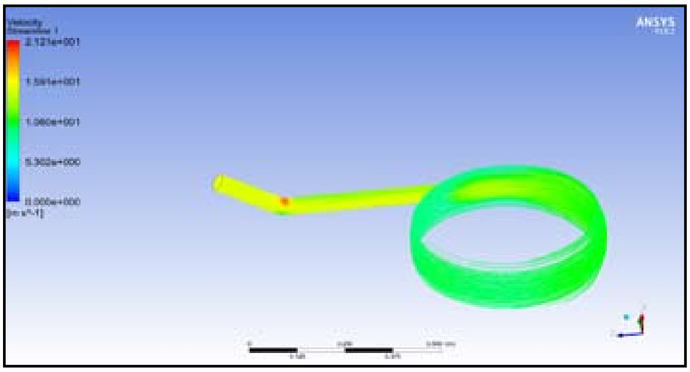

Fig.16 : Streamline Analysis

VII. Conclusion

As shown in table 10 we noticed that the minimum value of back pressure is in pipe diameter of 50mm when calculated with the help of Ansys.

50mm diameter pipe is optimized design as it showed best characteristics on analysis.

Future Scope

1. In future, with the help of high end technical support we are thinking to expand this methodology by taking account of various factors which we have neglected now.
2. Use of Mercury can be eliminated by analyzing and working on different elements having various physical and chemical properties which can suit better to our method.
3. Fabrication work can also be done with the help of major automobile industries like MARUTI SUZUKI, TATA MOTORS, HONDA and many more.

VIII. Links & Bookmarks:

1. **Rollover**
   https://en.wikipedia.org/wiki/Rollover
2. **Rollover analysis of a vehicle**
   https://www.slideshare.net/hebronashraf/vehicle-rollover-analysis
3. **Mobility and Transport Road Safety**
   https://ec.europa.eu/transport/road_safety/specialist/knowledge/road/getting_initial_safety_design_principles_right_en
4. **Air flow analysis on a sports car**
   https://www.youtube.com/watch?v=9NG3Qc5f68U
5. **Flow discharge rate**
   http://www.calctool.org/CALC/eng/fluid/flow_rate
6. **Static pressure in fluid**
   https://www.engineeringtoolbox.com/static-pressure-head-d_610.html
7. **Bernoulli's Equation**
   https://www.khanacademy.org/science/physics/fluids/fluid-dynamics/v/fluids-part-8
8. **Wagon R specifications**
   https://www.cardekho.com/maruti/maruti-wagon-r-specifications.htm

IX. Acknowledgement

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Authors Profile

YASH SHARMA, B.E. Mechanical Engineering, Gyan Ganga Institute of Technology & Sciences Jabalpur (M.P.)

TANAY D KHANWALKAR, B.E. Mechanical Engineering, Gyan Ganga Institute of Technology & Sciences Jabalpur (M.P.)

SAMVEG SINGH PARMAR, B.E. Mechanical Engineering, Gyan Ganga Institute of Technology & Sciences Jabalpur (M.P.)

SAMARTH NEMA, B.E. Mechanical Engineering, Gyan Ganga Institute of Technology & Sciences Jabalpur (M.P.)