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Design and Development of Disc in Four wheeler to Maintain Gyroscopic effect

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Abstract— At the time of driving four wheeler vehicles like sedan, station wagon types, of which wheel base to track width ratio is high, if any sudden or sharp turn is taken at higher speed on the curved path, then there a possible risk of rollover accident of vehicle. To avoid such kind of accidents, gyroscope (as a rotating disc) can be used within vehicle to produce gyroscopic reaction. Gyroscope here used balances the forces induced at the time of turning of vehicle over a curved path that causes vehicle rollover. Determination of external forces acting on vehicle during a turn on the road helps to design the gyroscope disc. By design procedure we can balance the external force by providing factor of safety.

Keywords— Gyroscope, Four wheeler, Balancing, Disc, Design

I. INTRODUCTION

For safety of human life while driving a vehicle at any time, it is necessary to examine the alternative methods. For example driving condition of passenger will change with location and roads. So the efforts are made in the direction of improving vehicle's safety. If the internal guiding force is provided within vehicle at the time of misguiding condition of vehicle then great causality can be avoided.

Stephen C. Spry et al. [1] in his presentation of Gyroscopic Stabilization of Unstable Vehicles derived the lagrangian equations of motion for different cases and derived the linear equation of motion for the same. They have also considered the feedback controller and later verified in simulation. The stability conditions of vehicle depend on the rate of change of orientation.

Alexander Berg et al. [2] in his work, the importance of occupant's safety equipments like seatbelt is described. In rollover safety systems it has to be study whether the sensors trigger the rollover protection system at the right time. Even though different protection system provided the seat belt wearing is necessary.

Ralf Eger et al. [3] in his investigation, two methods are explained to estimate the vehicles motion using only accelerometer. First was linear quadratic estimation that requires high efforts. And second was based on linear quadratic estimation but with time variant feedback. Position estimation is based on recursive evaluation.

Stephen A. Ridella et al. [4] States the methodology to develop restraint system for rollover crash conditions. Using computer as a tool, model of rollover restraint system was developed. Different rollover conditions depend on the number of occupants, occupants with seatbelt or not etc. he studied rollover mode data and injury to use it in determining restraint interventions.

Essentially, a gyroscope is a top combined with a pair of gimbals. Tops were invented in many different civilizations, including classical Greece, Rome, and China. Most of these were not utilized as instruments. The first known apparatus similar to a gyroscope (the "Whirling Speculum" or "Serson's Speculum") was invented by John Serson in 1743. It was used as a level, to locate the horizon in foggy or misty conditions.

The first instrument used more like an actual gyroscope was made by Johann Bohnenberger of Germany, who first wrote about it in 1817. At first he called it the "Machine". In 1852, Foucault used it in an experiment involving the rotation of the Earth. It was Foucault who gave the device its modern name, in an experiment to see (Greek *skopeein*, to see) the Earth's rotation (Greek *gyros*, circle or rotation), which was visible in the 8 to 10 minutes before friction slowed the spinning rotor.

II. General condition of stability

For the stability of vehicle against rollover under the motion with the help of external gyroscope following condition must be satisfied.

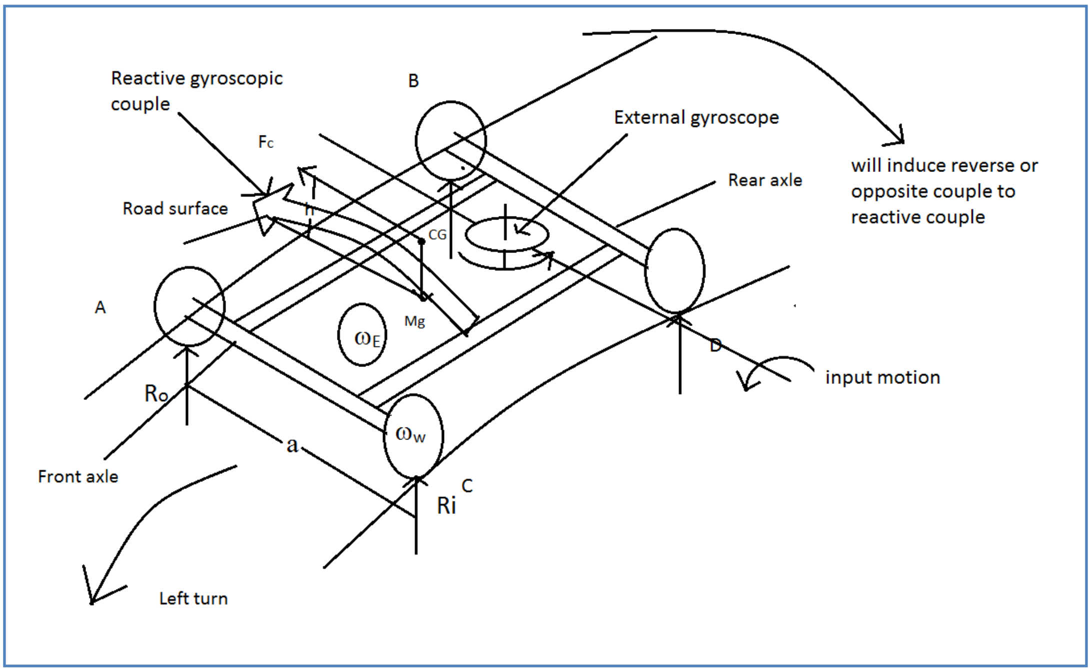

Fig 2.1 gyroscopic couple required to prevent rollover of vehicle taking a turn on curved path

Here centrifugal force and reactive gyroscopic couple will try to flip vehicle towards right side of the road as shown.

So we are introducing external gyroscope within vehicle, so that the reactive gyroscopic couple of external gyroscope become active gyroscopic couple against reactive gyroscopic couple of rotating and engine parts as well as centrifugal force.

Case 1:
Assume that gyroscope is mounted on the line passing by the C.G.

Let's assume
I_{ex} = mass moment of inertia of external gyroscope disc, kg-m^2
ω_{ex} = angular velocity of the external gyroscope disc, rad/s
ω_{pex} = precessional angular velocity of the disc of external gyroscope = $d\theta/dt$, rad/s
Where θ = angle by which ext. gyroscopic disc is tilted
t = time taken to precess axis by θ angle of ext gyroscope disc

In order to keep inner wheels of vehicle on the road (against reaction at inner wheels due to centrifugal force and gyroscopic couple) following condition must be satisfied,

$$\boxed{\therefore\ R_i \leq \frac{Mg}{4} + I_{ex} \cdot \omega_{ex} \cdot \frac{d\theta}{dt}}$$

Fig 2.2 Condition of Stability

Case 2:
If it is mounted offset to the line of C.G.:
Then $C_{ext} = F_{ex} \cdot d_{ex}$
Where, F_{ex} = Force produced by external gyroscope, N
d_{ex} = distance between line of C.G. passing through center of vehicle and line of action of F_{ex}, m

III. DETERMINATION OF CENTRE OF GRAVITY

To find Centre of Gravity of normal solid bodies, we can use different geometrical formulas, but to determine the centre of gravity of vehicle (four wheeler), we cannot use simple mathematical formulas.

To find centre of gravity of vehicle, there is test procedure mentioned in Indian standard "IS: 11849-1986"[5]

Car: 7 seater, Diesel

1). Weight of car with Front axle only: 705 kg
2). Total weight of the car: 1320 kg
3). Weight of the car with rear axle only: 615 kg
4). Weight of right side of the car: 660 kg
5). Weight of front axle with rear axle lifted: 720 kg

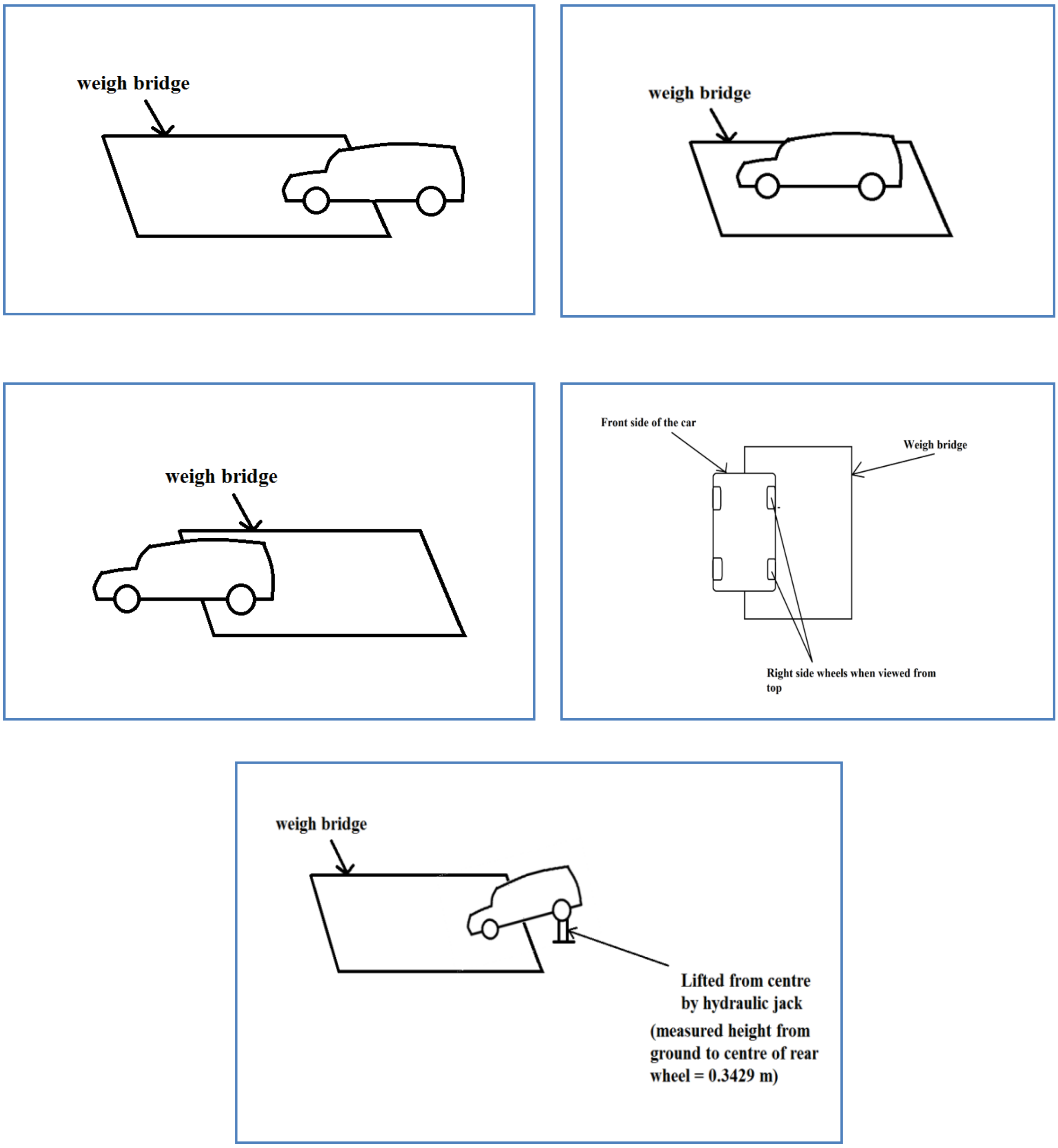

Fig 3.1 Determination of centre of gravity

Height of C.G. = 0.534 m (above the ground)
Distance of C.G. from front axle = 1.267 m
Distance of C.G. on transverse axis = 0 m (this means it is on centre point of transverse axis)

IV. EXPERIMENTAL DESIGN

Selection of material

Since, the basic operating principle of gyroscope and flywheel is almost same, we are selecting the material for gyroscope that is used in flywheel.

Traditionally, flywheel are made of cast iron.

Table I Cast iron properties

Density	7500 kg/m^3
Elongation at Break	0.52%
Tensile Strength	370 MPa

Couple induced by the gyroscope disc can be given by,

$C = I \cdot \omega \cdot \omega_p$

Experimental Design data

Table II Experimental design data

Mass of disc, m (kg)	**30**
Radius of disc, r (m)	**0.2**
Thickness of disc, t (m)	**0.03**
Density of disc material, ρ (kg/m^3)	**7500**
RPM, N	**5000**
Precessional angular velocity, ω_p (rad/s)	**381**
Couple produced, C (N-m)	**60000**
Rotational kinetic energy, K (Joule)	**41,123.5**

V. OVERALL DESIGN

Since, it is difficult to fabricate prototype from experimental design data, first car chassis is 1/5th modelled by geometry (geometric similarity). Then gyroscope should be tested on the same. Simultaneously analysis is done with rigid dynamic simulation.

Fig 5.1 Overall design

Table III Rotational velocity

Steps	Time [s]	Rotational Velocity [rpm]
1	0.	0.
	1.	5000.
2	2.	= 5000.
3	3.	
4	4.	
5	5.	

Table IV Joint Rotation

Steps	Time [s]	Rotation [°]
1	0.	0.
	1.	18.
2	2.	36.
3	3.	54.
4	4.	72.
5	5.	90.

VI. CONCLUSIONS

1. Compare to other gyroscopes, the mechanical or rotary type of gyroscope can generate more torque in short time.
2. Thickness of gyroscope disc can be reduced by increasing radius.
3. Gyroscopic couple depends only upon angular velocities and moment of inertia of disc
4. Increase in RPM of disc reduces precessional angular velocity
5. consumption at initial stage increases with time and becomes constant.
6. Directional deformation and directional velocity exhibits elliptical characteristics.

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