Prevention of Toppling of Heavy Vehicles using Gyroscopes

B. Anirudh Pai[1], J. T. Prajwal[2], S. Srijan[3], M. N. Bharath[4]
[1,2,3]*Student, Department of Mechanical Engineering, JSS Science & Technology University, Mysuru, India*
[4]*Assistant Professor, Dept. of Mechanical Engineering, JSS Science & Technology University, Mysuru, India*

***Abstract*: This paper describes how gyroscopes can be used for preventing toppling of heavy vehicles mainly caused due to overloading or slippery roads. The working of gyroscopes and a property of gyroscopes known as precession are discussed. This paper aims to use this property and convert it into a measurable quantity which can help in the prevention of toppling of heavy vehicles, thus preventing injuries to passengers, and loss of goods being carried.**

***Keywords*: Gyroscope, Heavy vehicles, Precession, Toppling, Torque, Angular momentum.**

1. Introduction

Automobiles are an integral part of our lives. They have made our lives easy by considerably reducing time required for travel and transport. The life that we live today would have been unimaginable in olden times, if it had not been for the revolutionary invention, that is the automobile. Even though they have proven to be immensely useful and practical, they have their own drawbacks. Pollution and overcrowding are some, to name a few. The one drawback which is the main concern for today is the accidents occurring due to them, especially in heavy vehicles. Accidents can cause loss of lives, which is indeed a major concern. Heavy vehicles, unlike other vehicles have a larger size and mass which can make the accidents involving them very gruesome. They tend to cause more casualties as the impact generated and momentum transfer occurring when a collision occurs with a heavy vehicle is immense.

Toppling of heavy vehicles is also not uncommon as heavy vehicles tend to have a height which is usually more than their width. Measures to prevent this include proper and evenly distributed loading, proper maintenance of tires, avoiding slippery roads, etc. These measures help in preventing toppling only to a certain extent. Increasing the width of the vehicles is also out of the question as they will occupy more space on the roads, obstructing other vehicles. Thus, other options have to be looked into to prevent more catastrophes from occurring in the future.

2. Literature review

A journal written by Tomáš Náhlík and Dana Smetanová (2018) [1] describes application of finite element method in gyroscope. In conditions where there is centrifugal force of turning, the system can generate a torque which stabilizes the vehicle. Different applications of gyroscope are pendulous integrating gyroscopic accelerometer, transport and logistics, MEMS gyroscopes etc. are described in this journal.

In a journal written by Qingwen Yan, Fuxue Zhang and Wei Zhang (2012) [2], new innovations on gyroscopes are discussed as there were many disadvantages regarding recent developments in gyroscopes. Applications of gyroscopes in auto-piloting of a rotating aircraft are discussed. The roll of gyroscope is used as driver. The frequency of gyroscope signal is linearized in such a way that it is equal to the roll rate of rotating craft, which helps the gyroscope to sense the Coriolis force in space.

A journal written by Stephen C. Spry & Anouck R. Girard (2009) [3] emphasises on gyroscopic stabilisation. Gyroscopic stabilisation is considered to be an efficient method for stabilising unstable bodies which includes two-wheeled cars and monorails. The torque that acts on car from outside can be stabilised by a torque produced by gyroscope from within the vehicle. In such conditions a gyroscope acts as an actuator and not as a sensor. The torque applied on gyroscope because of the tilting of vehicle causes a reaction moment in the gyroscope which will tend to right the vehicle. The two opposite moments balances each other and hence the safety of drivers can be ensured.

A journal written by Wang Hong-wei, Qi Chen-jie, Ni Xiao-ming, Wang Xiao-ni and Xing Zhen-hua (2011) [4] describes a micro-machined gyroscope which gives information of 3-axis angular rate without driven conformation. By following the sequenced processes such as decomposition, data acquisition, and processing gives angle of rotating flying object and 3-axial rotation angular rate. Motion of transport is affected by 3-axial angular rate.

3. Gyroscope

A gyroscope is a circular disc which rotates about an axis passing through its center and perpendicular to the flat surface. Thus, we can say that bicycle wheels, helicopter blades, flywheels and other such objects are gyroscopes. The only thing which sets a gyroscope from being just a disc rotating about an axis of symmetry is a phenomenon known as the gyroscopic effect. Due to this effect, the gyroscope offers a resistance in the axis of rotation about which it is currently rotating.

4. Precession

The gyroscopic effect mentioned in the previous paragraph gives rise to another phenomenon known as precession. This is a phenomenon which tends to tilt the gyroscope in a direction orthogonal to the one in which torque is applied to change the axis of rotation of the gyroscope. This can be better explained by the explanation given below.

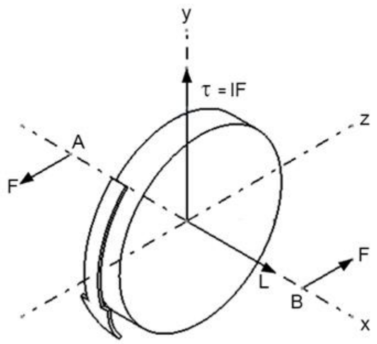

Fig. 1. Gyroscope rotating about its axis in a direction

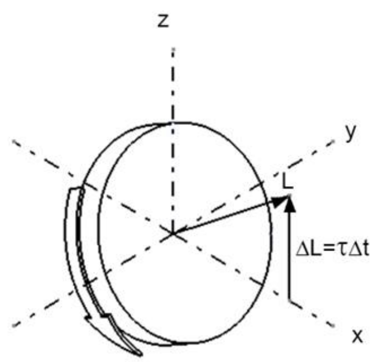

Fig. 2. Angular momentum stays along the axis of rotation

Consider a gyroscope rotating about its axis in a direction as shown in fig.1. The direction of angular momentum produced due to its spinning can be found out using the right-hand thumb rule, and it will be along the axis of rotation, in one of the two directions possible (right or left) depending on the direction of rotation of the gyroscope. When the gyroscope is rotating as mentioned before, suppose equal and opposite forces are applied on its axis with an intention to change its axis of rotation, as shown in fig. 1. The forces applied will produce a torque in a direction as shown in the same fig.

For rotation to take place, the angular momentum must always be along the axis of rotation. The torque that is applied on the gyroscope causes an imbalance and disturbs the rotation of the gyroscope. To overcome this imbalance, the angular momentum moves toward the torque, thus tilting the gyroscope while the angular momentum stays along the axis of rotation as described in fig. 2. This peculiar property of the gyroscope is put to use in many places. In the field of automobiles, they are used for balancing and navigation in ships and airplanes.

5. How to prevent toppling of heavy vehicles by use of precession

A. Construction

A gyroscope which has its axis of rotation parallel to the axle is kept just behind it. It is air-driven, and turns because of slots provided in its periphery. A rod which is exactly parallel to the axis of rotation is fixed just behind the gyroscope. Bearing are provided on either side of the axis of rotation of the gyroscope, and also on the rod at the exact same distance. The bearing on the left end of the gyroscope is connected to the bearing on the left end of the rod by a metallic strip. The bearing on the right end of the gyroscope is connected to the bearing on the right end of the rod similarly. Strain gauges which can detect changes in length are attached to the metallic strips.

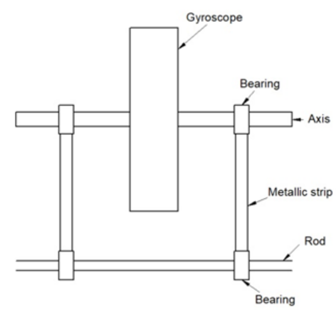

Fig. 3. Construction

B. Working

Consider the vehicle to be moving in a straight line. There will be no torque acting on the axis of the gyroscope, thus precession will not take place and it will continue its motion of rotation. There are two cases where precession can take place due to torque acting on the axis of the gyroscope:

Case 1: When the vehicle executes a turn.

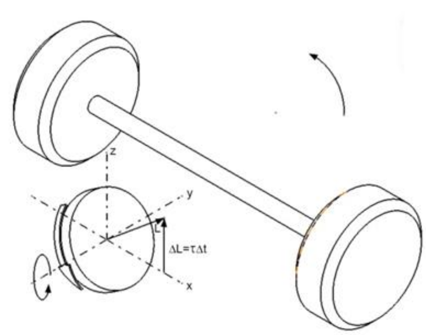

Fig. 4. Case-1: Torque

Assume the vehicle turns in the left direction. Due to action of centrifugal force, a greater force will be acting on the right wheel (because of higher speed). The torque acting due to this force will be as shown in fig. 3. This causes the gyroscope to tilt towards the right. Similarly, when the vehicle executes a right turn, the gyroscope will tilt towards the left. This movement of the gyroscope must be detected at only high speeds, which may cause toppling of the vehicle.

Case 2: When the vehicle gets inclined to the road with one tire higher than the other.

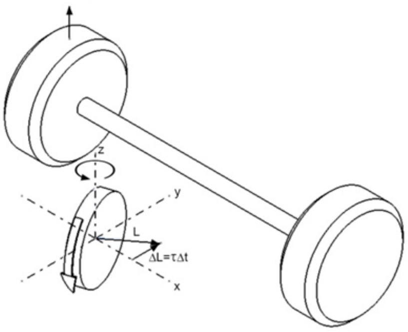

Fig. 5. Case-2

Assume a condition where the left tire gets lifted above the ground. This will cause the vehicle to tilt towards the right. Then, the force acting on the left end of the axis of the gyroscope will be as shown in the fig. The gyroscope will turn through an angle also as shown in fig. 4. This causes a change in length of the metallic strips provided, and the change is detected by the strain gauges. If the difference in the lengths of the metallic strips crosses a certain safe threshold, which will directly send a signal to the ABS (Antilock Braking System), which provides intermittent braking and thus helps the vehicle to stop safely. The signal can also be sent to the dashboard where a warning is shown to the driver for him to take proper precaution to prevent any catastrophe.

6. Conclusion

The heavy vehicles which are run today are mostly old, and have lesser reliability when compared to the later models, which are superior. Safety of passengers commuting in vehicles has always been a major concern. Safety measures which are still theoretical because of the drawbacks they have must be looked into as early as possible for their implementation to take place. With technology advancing at a rapid pace, the scope for improvement in safety is also getting higher.

References

[1] Tomáš Náhlík and Dana Smetanová: Applications of Gyroscopic Effect in Transportation, 28th August 2018.
[2] Qingwen Yan, Fuxue Zhang and Wei Zhang: A Micro-Machined Gyroscope for Rotating Aircraft, 1st June 2012.
[3] Stephen C. Spry & Anouck R. Girard: Gyroscopic stabilisation of unstable vehicles: configurations, dynamics, and control, 28th January 2009.
[4] Wang Hong-wei, Qi Chen-jie, Ni Xiao-ming, Wang Xiao-ni and Xing Zhen-hua, “The Study of Gyroscope for a Rotating Carrier,” 2011.