IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

DESIGN OF A TILTING MECHANISM FOR A NARROW TILTING CAR TO INCREASE THE MAXIMUM SPEED IN CURVES

1Shankar indran, 2S.murugan, 3C.Aravind, 4Monik jeffrin
1asst professor, 2student, 3student, 4student
1anna university

ABSTRACT

A tilting car is a special type of automobile that has the ability to change the angle between the road and the bottom of the passenger cabin in such way that there are reduced horizontal forces while driving through a curve.it may be 3 or 4 wheeler. These narrow track cars have an increased rolling tendency. The use of tilting mechanism in automobile would decrease the rate of accidents due to slippage. It will give better dynamic stability as well as directional stability to the vehicle, better road grip, and better comfort to the passengers, and the most important load carrying capacity of vehicle increases. In our project work we have tried to develop a tilting mechanism for the vehicle. This feature enables the vehicle to tilt in to the curve while negotiating it. The method we have used is a simple mechanical tilting system by using the shock absorbers. This tilting mechanism if successful would dramatically increase the maximum speed in curves. This would also provide the advantages of increased passenger comfort and handling. In order to develop a tilting mechanism for a narrow track car to give it the flexibility of a motor cycle. This can be operated on reduced lanes thereby increasing the effective capacity of highways.

CHAPTER 1 INTRODUCTION

GENERAL:

Narrow track cars are without doubt the future of urban mobility. These cars have a very short wheel track in comparison to normal cars. Most of the international car companies have production models and prototype of narrow track cars. Some examples are Nissan Land Glider, Nissan Pivo, Honda 3R-C, etc. Such cars are mostly single seated or double seater with back to back seating configuration. These cars have several advantages:

1) Half the width means half the weight, more rigidity, more access to narrow roads, easier parking and much quicker transit times.
2) In an electric vehicle, the lighter weight of this much smaller vehicle will help to enhance torque power characteristics of an electric motor to achieve “linear acceleration”.
3) At highway cruising speeds, such cars will be using half the frontal area and half the drag co efficient, plus reduced running losses make for a very energy efficient vehicle.

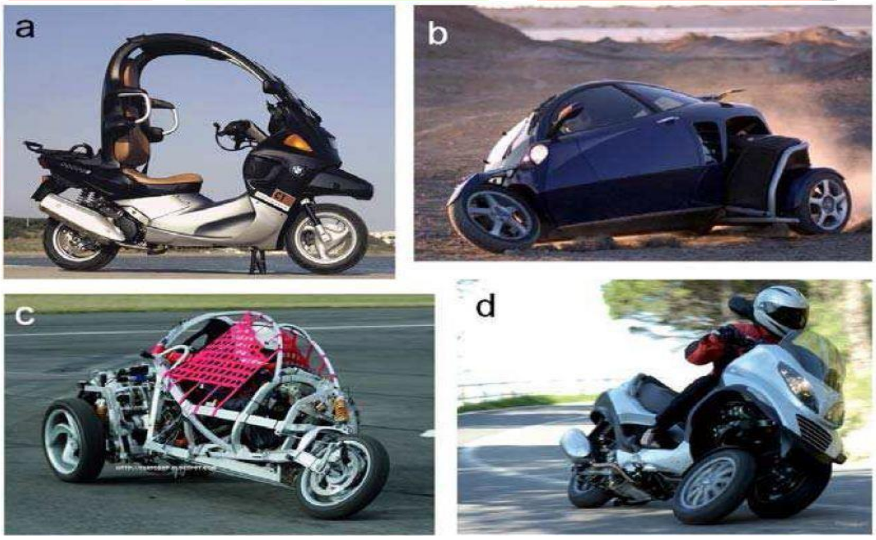


Fig.1.1 Three Wheeler Tilting Mechanism

All these advantages make the narrow track vehicle so appealing as an alternative to the car. Such cars combine the comfort of a car with the functionality of a motor bike. But these cars have a very important and dangerous drawback. With a very comparatively narrow track and heights almost equal to normal cars, these cars are very susceptible to rolling. As of now all such narrow track cars are electrically driven and have a limited top speed and hence this drawback is comparatively negligible. But sooner or later these cars will have to get highway cruising speeds. Then this drawback will be of grave importance. Our project took shape as an attempt to face this drawback. We thought so if the cars have the functionality of a motor cycle why not gives it the flexibility of a motor cycle. This gave use to the idea of an auto-tilting car.

Fig.1.2 Three Wheeler Tilting Mechanism on Unbanked Curve

There have been many tilting body designs in rail but what we have done is not just a body tilting, in it the car tilts as a whole. Recently there had been some development in making three- wheeled tilting cars like the carver, but only prototypes or concepts exist in the field of four-wheeled tilters. In India, the population is rising rapidly. Due to increase in population, the traffic conditions are bad and will be worst in the upcoming years. . The big nasty part of our daily life is the commute and since the countries (like INDIA) are massively overcrowded. For the individual who like to drive the vehicles without affecting the traffic one can choose the bike with Tilting Wheel Mechanism which inhibits the advantages of a 4 wheelers and eliminates the drawbacks of the 2 wheelers.

These type vehicles have several advantages like, better directional stability, increased comfort, reduces wheel slippage, better stopping power.

Fig.1.3 Front Suspension

Due to all these advantages such vehicles combine the comfort of a car with the functionality of a motor bike. But these cars have a very important and dangerous drawback. Due to implementation of tilting mechanism intwo- wheeler, the weight of the vehicle increases which comparatively reduces its efficiency. But when the similar concept would be implemented in the three - wheeler, this mechanism will be of great importance. Our project took shape as an attempt to face this drawback. We thought so if the motor cycle has the flexibility, why not give it the comfort of the car. This gave use to the idea of an auto-tilting car. There have been many tilting body designs in rail but what we have done is not just a body tilting, in it the vehicle tilts as a whole. Recently there had been some development in making three- wheeled tilting cars like the carver, but only prototypes or concepts exist in the field of four-wheeled tilters.

The absurdly named Narrow Tilting Vehicle with Non-Tilting Wheels (or NTVNTW) is a narrow track reverse trike that promises an amazing cornering experience with 52 degrees of lean and three flat car tires giving a huge grippe contact patch and excellent stability.

For the last century and a bit, cars and motorcycles have proven themselves to be affordable, simple transport options across the globe. But there's always been folks wondering – could the two platforms somehow be merged to join their strengths and minimize their weaknesses Cars, while relatively safe, comfortable and totally weatherproof, are much bigger than they need to be, at least 95 percent of the time. They get stuck in traffic. Motorcycles, while efficient, nimble, fun and able to dart through between lanes of traffic, leave the rider exposed to the weather, as well as much higher risks of injury in an accident. This may be calculated from velocity measurements and road curvature information. In real- time however, the driver's actions dictate the required lean angle for a given maneuver. Determination of the required lean angle involves interpreting the driver's intentions. (2) The second issue is reducing the torque that needs to be exerted by the actuator. We found that even though the vehicle is at an equilibrium in a perfectly coordinated turn (and hence only requires small torque for small deviations), tilting the vehicle into a turn at high speeds may require large applied torque values. The tilting and steering need to be synchronized because any lag in the tilting dynamics necessitates large peaks in the required actuator torque.

The main challenge in the control design is thus to provide a systematic approach that synchronizes the tilt and cornering maneuvers in order to reduce actuator requirements and improve ride qualities. Two different approaches are explored in the paper. First, a receding horizon controller (RHC) that makes use of preview information on the road curvature ahead of the vehicle is developed. This controller resides “on top” of two simple stabilizing controllers and initiates tilting before the actual turning begins to reduce the amount of tilting torque required when the vehicle enters the turn.

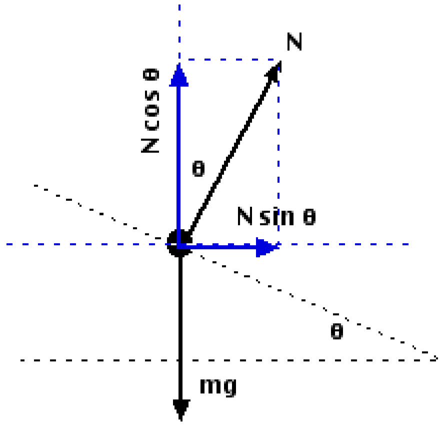


Fig.1.4 Force Angle Calculation

For many years it has looked like somebody is going to make a big splash in the global transport market by coming up with a narrow-track vehicle not much wider than a motorcycle, that's fully enclosed and capable of leaning over in corners to keep its width to a minimum while still being stable in a corner. The NTVNTW is a platform that allows two, three or four wheel configurations, with Kinsley's preferred first run being a three wheeler in a reverse trike style with two wheels at the front. Notably, it uses flat car tires rather than curved motorcycle tires, as the wheels themselves don't tilt relative to the pavement. Instead, the whole vehicle cabin sits in a kind of cradle mechanism that can tilt to shift the cabin weight up to a whopping 52 degrees on either side in a corner or on slanted ground. That's an impressive tilt angle - for reference, top level MotoGP riders on their incredibly sticky qualifying rubber rarely exceed a lean angle of 60 degrees in the turns, while dragging their knees and elbows across the track.

TECHNOLOGICAL CHALLENGE

Designing a tilting slender vehicle requires a nonconventional approach. When the width of a car is reduced to half, cornering becomes a problem, as slim vehicles are more prone to fall over. Of all the possible approaches, tilting when cornering is the best option.

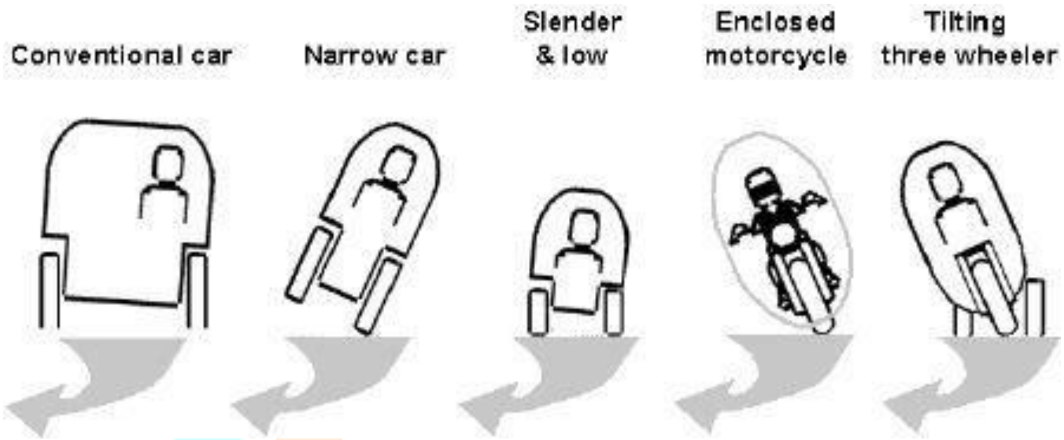


Fig.1.5 Tilting Mechanism for different Configuration

This is actually what a two-wheeler does, and is nothing new. However, if one wishes to have the comfort and safety of a car, the vehicle needs to have an enclosed and solid passenger cabin. With such a cabin the balance control becomes more difficult for the driver, as the vehicle becomes too heavy. Also in that case the driver will be unable to put his/her feet out at low speeds to avoid falling over. Therefore an automatic system is required to take over this balance control. As a result designing a tilting vehicle is not so much a package design problem, but first of all a technological problem requiring the development of a sophisticated automatic balance control system. In order to create a comfortable and safe vehicle, such a control system needs to generate the ideal tilting angle under all the imaginable driving circumstances, such as at all speeds and accelerations, during rapid emergency maneuvers, but also at slippery, irregular or slanting road surfaces. Furthermore it should also be predictable, intuitive and easy to use and last but not least it should be safe, reliable and fail-safe.

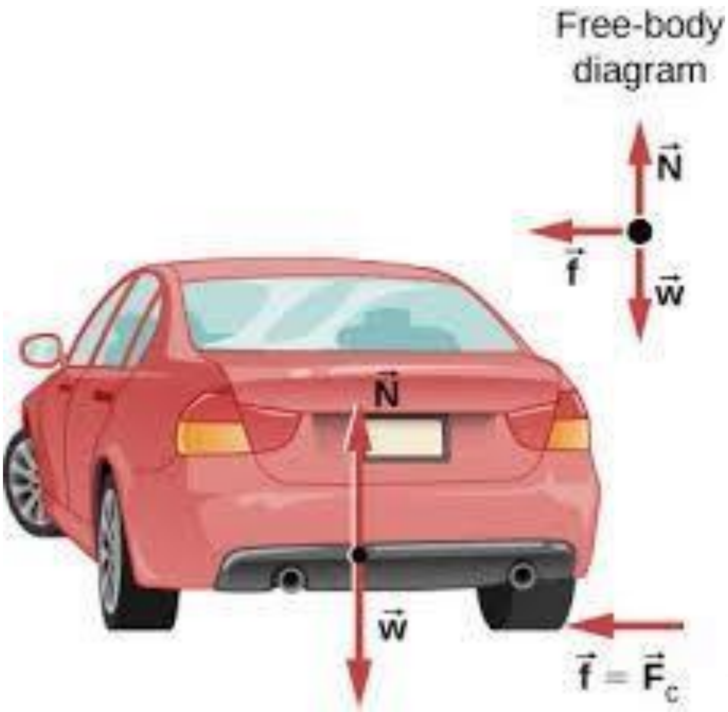


Fig.1.6 Forces Acting on car Body

But those GP riders don't have the advantage of three fat, flat tires with their maximum contact patch in constant contact with the deck – and that's a significant stability boost. This thing has the potential to corner hard. The NTVNTW is a platform that allows two, three or four wheel configurations, with Kinsley's preferred first run being a three wheeler in a reverse trike style with two wheels at the front. Wheels to the main frame so that when the main frame is leaned all wheels lean, producing simultaneous wheel and body lean. Tie rod also connects each control arm to the adjustable steering lever rotating the control arm and axle as a unit. By rotating steering lever from vehicle to 45 degrees forward, the effect achieved is adjustable in relation to the amount of body lean allowing operator to make wide or tight turn and adjust the amount of lean to compensate for cornering forces.. Notably, it uses flat car tires rather than curved motorcycle tires, as the wheels themselves don't tilt relative to the pavement. Instead, the whole vehicle cabin sits in a kind of cradle mechanism that can tilt to shift the cabin weight up to a whopping degrees on either side in a corner or on slanted ground.

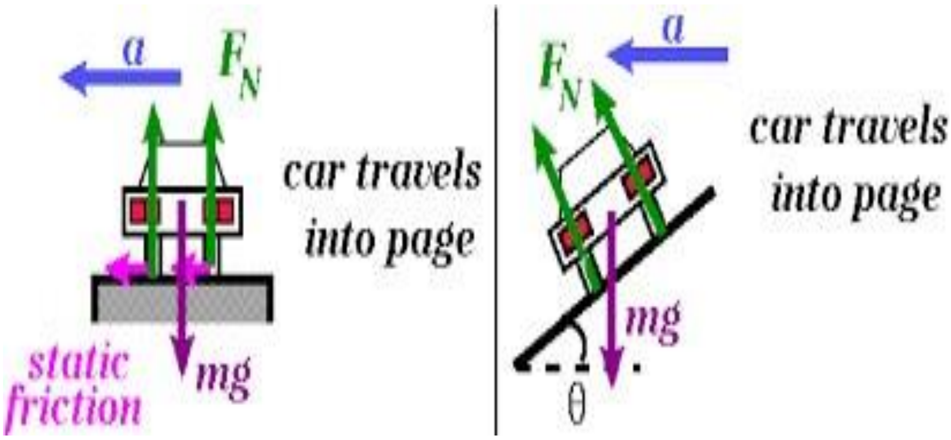


Fig.1.7 Static Friction

That's an impressive tilt angle - for reference, top level MotoGP riders on their incredibly sticky qualifying rubber rarely exceed a lean angle of 60 degrees in the turns, while dragging their knees and elbows across the track. But those GP riders don't have the advantage of three fat, flat tires with their maximum contact patch in constant contact with the deck – and that's a significant stability boost. This thing has the potential to corner hard. Narrow track cars are without doubt the future of urban mobility. These cars have a very short wheel track in comparison to normal cars. Most of the international car companies have production models and prototype of narrow track cars. Some examples are Nissan Land Glider, Nissan Pivo, Honda 3R-C, etc. Such cars are mostly single seated or double seater with back to back seating configuration. These cars have several advantages: Half the width means half the weight, more rigidity, more access to narrow roads, easier parking and much quicker transit times. In an electric vehicle, the lighter weight of this much smaller vehicle will help to enhance torque power characteristics of an electric motor to achieve "linear acceleration". At highway cruising speeds, such cars will be using half the frontal area and half the drag co efficient, plus reduced running losses make for a very energy efficient vehicle. All these advantages make the narrow track vehicle so appealing as an alternative to the car. Such cars combine the comfort of a car with the functionality of a motor bike. But these cars have a very important and dangerous drawback. With a very comparatively narrow track and heights almost equal to normal cars, these cars are very susceptible to rolling.

FOUR WHEELER DYNAMICS

The subject of this research study is a tilting vehicle. Hence, the differences in the dynamics between a bicycle and a tricycle are presented here. It is developed and investigated a tilting three-wheeled vehicle with a four-bar- mechanism as the tilt joint. The former paper focused on the importance of the location and inclination of the tilt axis and the instantaneous center of rotation and the effect on the load transfer between the rear wheels and the handling characteristics. Simulations and experimental measurements were employed to evaluate the steering torque, the handling characteristics, and the load transfer between the rear wheels. The authors concluded that each individual configuration of tilt axis location and inclination had its advantages and disadvantages. With the axis below the ground plane, the vehicle was more stable, but the handling was less good in comparison to the vehicle configured with the axis above the ground. A positive inclination of the tilt axis was found to improve the steering torque effort; however, the propagation of reaction forces with this configuration was sometimes experienced as unpleasant.

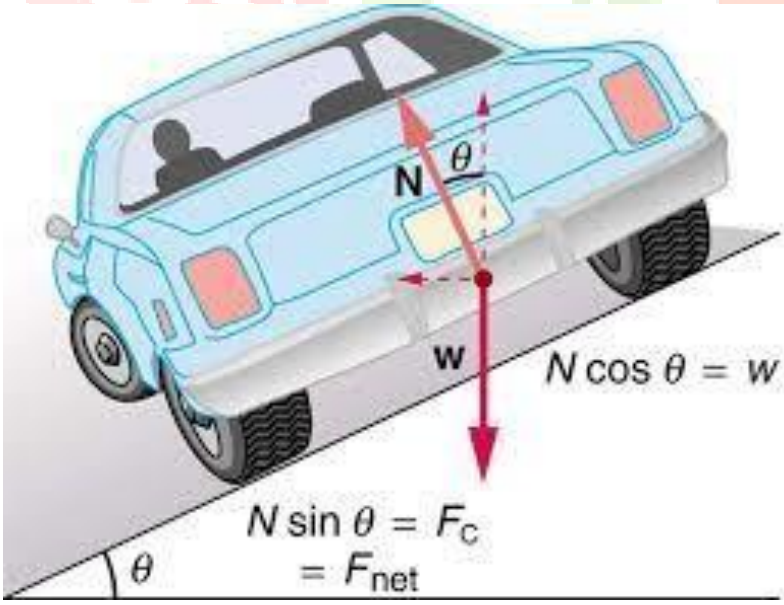


Fig.1.8 Tilting Angle Calculation

As of now all such narrow track cars are electrically driven and have a limited top speed and hence this drawback is comparatively negligible. But sooner or later these cars will have to get highway cruising speeds. Then this drawback will be of grave importance. Our project took shape as an attempt to face this drawback. We thought so if the cars has the functionality of a motor cycle why not give it the flexibility of a motor cycle. This gave use to the idea of an auto-tilting car. There has been many tilting body designs in rail but what we have done is not just a body tilting, in it the car tilts as a whole. Recently there had been some development in making three- wheeled tilting cars like the carver, but only prototypes or concepts exist in the field of four-wheeled tilters. The narrow track cars have an increased rolling tendency. So, there is a need to develop such a mechanism which can increase the vehicle stability and passenger comfort.

The main objective is to provide banking to the car on unbanked curves to run at high speed. The central front suspension has been used to provide vehicle stability. The design has been made and fabricated to minimize rolling tendency of the narrow track cars by introducing the auto-tilting mechanism. It improves the handling of the vehicle and hence provides more comfort to the passengers by minimizing rolling tendency and providing banking to the car. The development of narrow vehicles is a promising alternative that is being proposed to address increasing traffic congestion and limited highway capacity in metropolitan areas. In order to provide an acceptable replacement for today's average passenger car, these vehicles should retain the perceived safety and the ease and comfort of driving a regular four-wheeled vehicle. Narrow vehicles currently used in urban transportation (e.g. motorcycles) require the driver to balance the vehicle while it is turning, meaning that the vehicle must be tilted into the curve to compensate for the tilting moment of the centripetal force generated by the tires. These vehicles also lack the level of safety that the majority of commuters would prefer. This could be addressed by increasing the dimensions of such a vehicle, preferably in terms of height, not to compromise the benefits gained from the narrower lane track. Building narrow vehicles taller tends to increase their tilt and the chances of a rollover during tight cornering. The gyroscope disc is manufactured using CNC lathe and drilling operations.

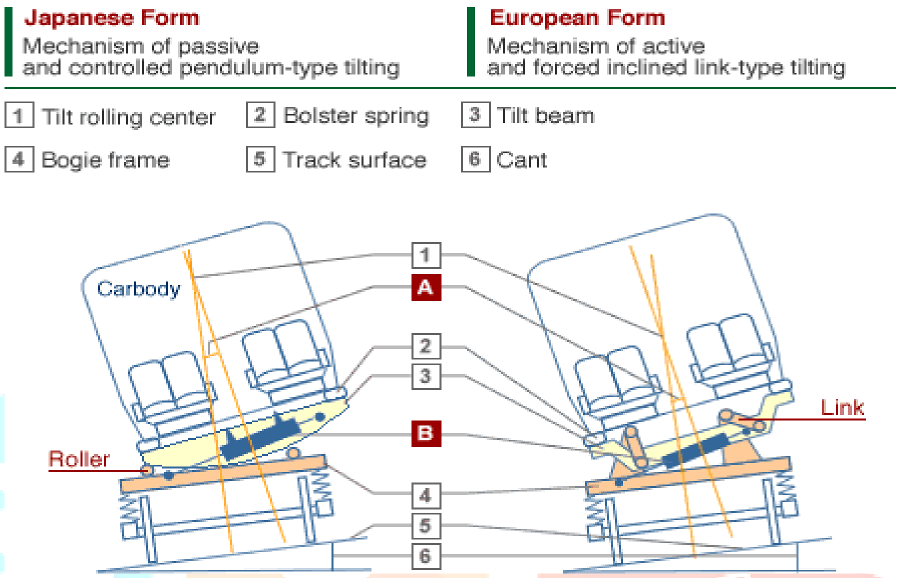


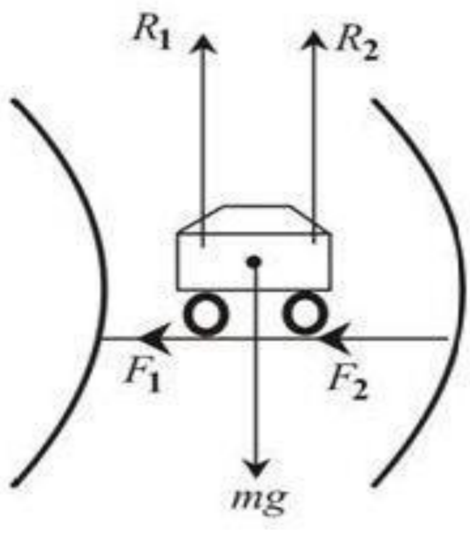
Fig.1.9 Tilting Mechanism in Japanese

The steel frame used is bolted on the bottom steel base. Round edge wheels are fitted to the steel base at the bottom, the holes in the frame are drilled in order to fit the gimble of the gyroscope assembly, the DC motor supported on a U bracket is placed on the gimble. The only pre-requisite for this setup to work is that the mass distribution, the mass should be dominant on the upper side (setup should be top heavy) of the gimble. The center of gravity is thus just above the gimble axis, stainless steel disc used as gyroscope are fitted to the shaft of the motor. The DC motor is bolted to the U-bracket due to which it remains intact with it and the shaft of the DC motor is fixed to a steel hub which has got holes drilled on its top flat surface to be used to finally fix the gyroscope disc by bolting it with the hub. The material used in making the gyroscope disc, hub, steel frame, and U-bracket is Mild Steel. To finally assemble the entire model, various sizes of nuts and bolts were used. One important design consideration that we made in this model is that the gyroscope disc should be freely suspended in the U-bracket connected to the steel frame. So for that, we used ball bearings and studs to make the angular movements and adjustments free and swift. The circlips are placed on the inner ends of the studs to avoid the studs to move out of the ball bearings, thus avoiding breakdown of the model during the running condition. The model has been made in such a way that the front wheel can move to take turns in order to change the direction of movement.

BANKING OF ROADS

The phenomenon of raising outer edge of the curved road above the inner edge is to provide necessary centripetal force to the vehicles to take a safer turn and the curved road is called Banking of Roads. When a vehicle goes round a curved road, it requires some centripetal force. While rounding the curve, the wheels of the vehicle have a tendency to leave the curved path and regain the straight line path. Force of friction between wheels and the roads opposes this tendency of the wheels.

Fig.1.10 Vehicle moving on level road



A banked turn (or banking turn) is a turn or change of direction in which the vehicle banks or inclines, usually towards the inside of the turn. For a road or railroad this is usually due to the roadbed having a transverse down-slope towards the inside of the curve. The bank angle is the angle at which the vehicle is inclined about its longitudinal axis with respect to the horizontal. Suppose we consider a particular car going around a particular banked turn. The centripetal force needed to turn the car (mv2/r) depends on the speed of the car (since the mass of the car and the radius of the turn are fixed) - more speed requires more centripetal force, less speed requires less centripetal force.

Fig.1.11 Bank Road

The centripetal force available to turn the car (the horizontal component of the normal force = mg tan theta if you follow the mathematics) is fixed (since the mass of the car and the bank angle are fixed). So, it makes sense that we found one particular speed at which the centripetal force needed to turn the car equals the centripetal force supplied by the road. This is the "ideal" speed, videal, at which the car the car will negotiate the turn - even if it is covered with perfectly- smooth ice. Any other speed, v, will require a friction force between the car's tires and the pavement to keep the car from sliding up or down the embankment:

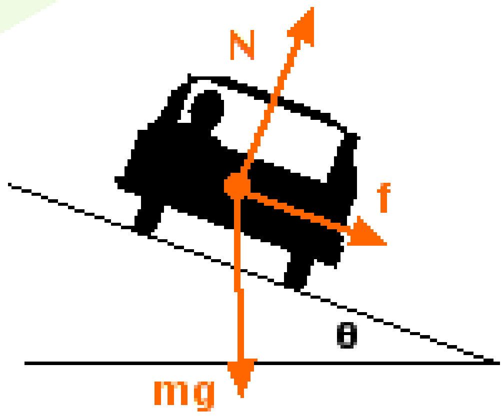


Fig.1.12 Centrifugal force acting on car

v > videal (right diagram): If the speed of the car, v, is greater than the ideal speed for the turn, videal, the horizontal component of the normal force will be less than the required centripetal force, and the car will "want to" slide up the incline, away from the center of the turn. The friction force will oppose this motion and will act to pull the car down the incline, in the general direction of the center of the turn. v < videal (left diagram): If the speed of the car, v, is less than the ideal (no friction) speed for the turn, videal. In this case, the horizontal component of the normal force will be greater than the required centripetal force and the car will "want to" slide down the incline toward the center of the turn. If there is a friction force present between the car's tires and the road it will oppose this relative motion and pull the car up the incline.

NECESSITY OF BANKING:

As the speed of vehicle increases, the centripetal force needed for the circular motion of vehicle also increases. Vehicle moving on level road In the case of unbanked road necessary centripetal force is provided by the friction between the tyres and the surface of the road. But there is a maximum limit for frictional force, which depends on the coefficient of friction between the wheels and road. When the centripetal force needed exceeds the maximum limit of frictional force, the vehicle skids and tries to go off the curved path resulting into an accident. Without proper friction, a vehicle will not be able to move on the curved road with large speed. Vehicle moving on level roadTo avoid this we may increase the force of friction making the road rough. However, this results in the wear and tear of the tyres of the vehicle. Also, the force of friction is not always reliable because it changes when roads are oily or wet due to rains etc. The design has been made and fabricated to minimize rolling tendency of the narrow track cars by introducing the auto-tilting mechanism. It improves the handling of the vehicle and hence provides more comfort to the passengers by minimizing rolling tendency and providing banking to the car. The development of narrow vehicles is a promising alternative that is being proposed to address increasing traffic congestion and limited highway capacity in metropolitan areas. To eliminate this difficulty, the curved roads are generally banked. Due to banking of the road, the necessary centripetal force is provided by the component of the normal reaction.

A Car on a Level Surface

All forces on the car are vertical, so no horizontal force can be generated.

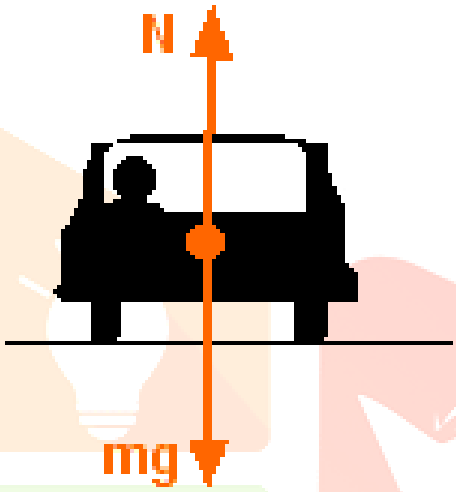


Fig.1.13 Gravity Force

A Car on a Banked Turn

The normal force on the car due to the road is no longer vertical, so a component of the normal force acts in the horizontal direction.

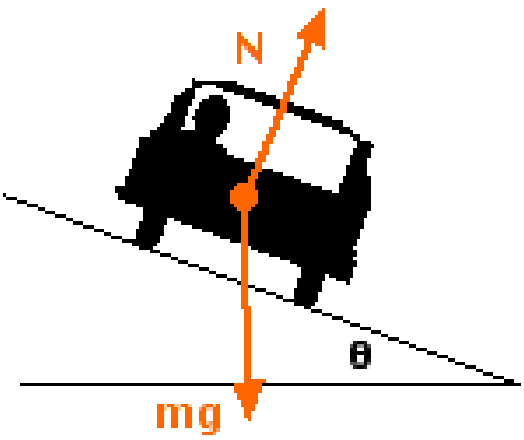


Fig.1.14 Gravity Force at inclined road

The Centripetal Force

The horizontal component of the normal force is shown in blue in the diagram above. This force can supply a centripetal force to turn the car.

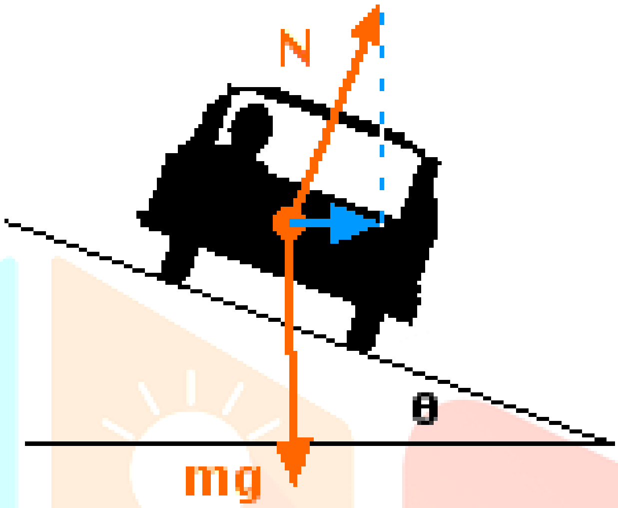


Fig.1.15 Normal Reaction at inclined road

If a car is on a level (unbanked) surface, the forces acting on the car are its weight, mg, pulling the car downward, and the normal force, N, due to the road, which pushes the car upward. Both of these forces act in the vertical direction and have no horizontal component. If there is no friction, there is no force that can supply the centripetal force required to make the car move in a circular path - there is no way that the car can turn.

On the other hand, if the car is on a banked turn, the normal force (which is always perpendicular to the road's surface) is no longer vertical. The normal force now has a horizontal component, and this component can act as the centripetal force on the car! The car will have to move with just the right speed so that it needs a centripetal force equal to this available force, but it could be done. Given just the right speed, a car could safely negotiate a banked curve even if the road is covered with perfectly smooth ice! Turning in a circle requires a vehicle to have a centripetal acceleration inwards on the turn, and so there must be some centripetal force that produces this acceleration. For a vehicle driving on flat ground, this force must be produced by a sideways friction force on the tires. This introduces two problems: If the coefficient of friction is not high enough (say the road is wet or icy), then the friction force will be insufficient and the vehicle will slide off the road. Even if the friction force is high enough, because it acts at the bottom of the tires, it produces a net moment about the center of mass, which can cause the vehicle to roll over.

UNBANK CURVE

Fig.1.16 Unbank Curve

To avoid both of these problems, the road can be banked inwards, so that the outer edge of the road is higher than the inner edge. This is called super elevation and means that some of the centripetal force can be provided by the normal force with the road, reducing the friction force and minimizing the risk of slip or roll. The figure below shows a bus driving around a sharp corner at high speed on a heavily banked road. To understand the dynamics of this vehicle and the design tradeoffs for cornering on banked turns, we need a model. We will start below with a simple point mass model, which will be enough to understand friction and sliding, and then move on to a 2D rigid-body body to understand roll behavior. It includes steering/coupling linkage disposed adjacent to the lower end of a steering column having a handle bar attached to its upper end. A three wheeled vehicle, with two steerable front wheels and a driven rear wheel which may be either rider- or motor-powdered, includes steering/coupling linkage disposed adjacent to the lower end of a steering column having a handlebar attached to its upper end. The steering/coupling linkage pivotally couples a forward frame to a rear frame which supports the rider and includes the rear wheel and its means for propulsion. The steering/coupling linkage includes a pivot shaft, a bearing housing and a mechanical connection for leaning the rear frame in the direction of a turn so as to compensate for centrifugal force encountered in turning the vehicle. The mechanical connection causes the rear frame to lean in a controlled relationship to the amount of rotation of the steering shaft, within rotational limits, to emulate the leaning action of a conventional bike when making a turn.

LEANING VEHICLE WITH CENTRIFUGAL FORCE COMPENSATION

A three wheeled vehicle, with two steerable front wheels and a driven rear wheels which may be either rider or motor powered includes steering linkage disposed adjacent to the lower end of the steering column having a handlebar attached to its upper end. The steering linkage pivotally couples a forward frame to a rear frame which supports the rider and includes the rear wheels and its mean for propulsion. The steering linkage includes a pivot shaft, a bearing housing and a mechanical connection for leaning the rear frame in a direction of a turn so as to compensate for centrifugal force encountered in turning the vehicle. The mechanical connection causes the rear frame to lean in a controlled relationship to the amount of rotation of the steering shaft, within rotational limits, to emulate the leaning action of a conventional bicycle when making a turn

LEAN TO STEER RECUMBENT VEHICLE

Two versions of recumbent human powered three wheeled vehicles are disclosed. Both are of the tadpole type with two front wheels and one rear drive wheel. Both versions lean into turns causing weight transfer towards the inside of turns to prevent roll over during turn at speed.

RECUMBENT BICYCLE WITH CONTROLLED WHEEL & BODY & LEAN

Three-wheeled vehicle with an adjustable leaning and steering mechanism, permitting operator controlled wheel and body lean as a vehicle is taking a turn. The vehicle has a leaning main frame that carries a pedal and crank assembly, recumbent seat and rear wheel. Towards the front of the vehicle, a perpendicular axle housing mounted with pivotal collar allows the main frame to lean right or left. Axle housing carries the cantilevered steering arm and adjustable steering lever. An axle runs through the axle housing and a spindle and control arm is pivotally connected to each end of the axle. Wheels to the main frame so that when the main frame is leaned all wheels lean, producing simultaneous wheel and body lean. Tie rod also connects each control arm to the adjustable steering lever rotating the control arm and axle as a unit. Operator supplies power to lean frame by use of arms pushing body right or left; the body, being cradled in seat causes frame to lean right or left. By rotating steering lever from vehicle to 45 degrees forward, the effect achieved is adjustable in relation to the amount of body lean allowing operator to make wide or tight turn and adjust the amount of lean to compensate for cornering forces to optimize the center of gravity or go straight and adjust body lean to compensate for road pitch.

A straight road generally has the center somewhat higher than the edges to allow water to run off. This is called cross slope or camber. When it is desired to have a banked turn, then the outer edge of the road is raised to produce superelevation, with the outer edge rising above both the center and the inner edge. The bank angle is chosen based on the radius of curvature of the turn and the expected speed of cars going around the turn, while still allowing for the fact that cars might be moving slowly or even stopped. The angle should thus not be chosen to eliminate all friction forces when cars are traveling at maximum speed, as this would be dangerous if traffic had to stop on the road. Velodromes are arenas with tracks designed for high-speed bicycle races, as shown below, with speeds up to 85 km/h. The bank angle on velodrome tracks is chosen to minimize sideways forces on the bicycles when they are traveling at near maximum speeds, so the angle chosen depends on the radius of curvature of the track corners. For example, the Blaine velodrome track pictured below is 250 m long and has a 43° bank angle on the corners and 15° banking on the straightaways. Narrow commuter vehicles can address many congestion, parking and pollution issues associated with urban transportation.

In making narrow vehicles safe, comfortable and acceptable to the public, active tilt control systems are likely to play a crucial role. This paper focuses on the development of an active direct tilt control system for a narrow vehicle that utilizes an actuator in the vehicle suspension. A simple PD controller can stabilize the tilt dynamics of the vehicle to any desired tilt angle. However, the challenges in the tilt control system design arise in determining the desired lean angle in real- time and in minimizing tilt actuator torque requirements. Minimizing torque requirements requires the tilting and turning of the vehicle to be synchronized as closely as possible. This paper explores two different control design approaches to meet these challenges.

A Receding Horizon Controller (RHC) is first developed so as to systematically incorporate preview on road curvature and synchronize tilting with driver initiated turning. Second, a nonlinear control system that utilizes feedback linearization is developed and found to be effective in reducing torque. A close analysis of the complex feedback linearization controller provides insight into which terms are important for reducing actuator effort.

DESIGN A NARROW TILTING CAR

OBJECTIVES:

The objective of this project work is to successfully develop a design of a tilting mechanism for a narrow tilting car. The mechanism is to be reliable, simple, cost-effective and practically feasible. The aim of this tilting mechanism is to provide banking to the car on unbanked curves, so as to enable added threshold speed on curves in comparison to a narrow non-tilting car. This system is also supposed to enhance passenger comfort as the side force felt by passengers in a car taking a turn is comparatively less in a tilting car. Also in our purpose is the fabrication of a mini-prototype –a remote controlled toy car-to demonstrate the tilting in real world.

METHODOLOGY:

The methodology adopted to use standard and presently used components in design rather than to design all components from ground up. The advantage of this method is that, you do not have to spend ridiculous amount and time in testing the integrity of each part as they have already proved their worth in real world applications. Initially the frame design was adopted from an already existing narrow car and minor changes were made to suite our purpose, the tilting mechanism first devised was based on using power screw driven by stepper motor lifting and lowering each wheel of the car.

TILTING TRAIN

Tilting trains are today common in Europe and Japan. These trains are rail-running, they have very high curve velocities. In order to enable trains, to negotiate curves at high speeds, tracks are slightly banked (up to 20 degrees). But these trains are too fast, and it is not possible to tilt track beyond a limit because trains also pass along these curves really slowly at times. Tilting trains are an optimum solution for this problem. These types of train, tilts the body on the curve, this in a sort enables faster curve threshold speed and increased passenger comfort. The figure below shows two tilting mechanisms used in trains.

DESIGN OF THE TILTING MECHANISM

The tilting mechanism design was a complex question. Initially it was decided to use power screw driven screw driven screw holders for each individual wheel controlled by a stepper motor. The design almost completed. It had several advantages:

1) Each wheel could be moved independent of the other.

2) More precise control was possible with power screw lifters.

3) It could be modified to incorporate other systems like body level control, ground clearance adjustment system etc.

But analysis showed some critical disadvantages of screw lifters. They were

1) Their response was slow at very high speed and repeated steering and control steering.

2) The wear and tear in screw parts was more than desirable. This would only aggravate in a real life situation where dust and sand particles can accelerate the wear of the screw and lifters.

Hence the design was discarded and we were on the look out for a new and simple tilting mechanism. It was at this point, it was decided to use the present design of a tilting mechanical tyre, controlled by a stepper motor. The ends of the tyre were linked to each rear wheel through struts as used in bikes rear shocks but with universal joints on both sides. Wheels to the main frame so that when the main frame is leaned all wheels lean, producing simultaneous wheel and body lean. Tie rod also connects each control arm to the adjustable steering lever rotating the control arm and axle as a unit. Operator supplies power to lean frame by use of arms pushing body right or left; the body, being cradled in seat causes frame to lean right or left. By rotating steering lever from vehicle to 45 degrees forward, the effect achieved is adjustable in relation to the amount of body lean allowing operator to make wide or tight turn and adjust the amount of lean to compensate for cornering forces to optimize the center of gravity or go straight and adjust body lean to compensate for road pitch. The tyre is moved about a central pivot mount on the frame, this motion in result lifts the wheel on one side, while lowering the other, this in result tilts the vehicle to one side. After much thought and consultation, it was decided to power only the rear rotating tyre, the front was free and was supposed to follow the rear. This was adopted not to reduce the cost but it had the following advantages:

1) It provided more freedom of movement to the front wheels, which ensured better comfort.
2) The freedom of movement of front wheels also give the vehicle added steer ability and maneuverability.
3) It also reduced the overall weight of the vehicle.

FRAME DESIGN

The frame has been designed with parameters taken from an already existing and successful narrow track car. The entire suspension system has been redesigned and an additional tilting tyre holder was welded on the frame both at front and rear. The adoption of an already existing frame for our design ruled out the requirement of stress analysis. The frame is sure to hold on, even in case of most hostile conditions, as it is a tried and tested design.

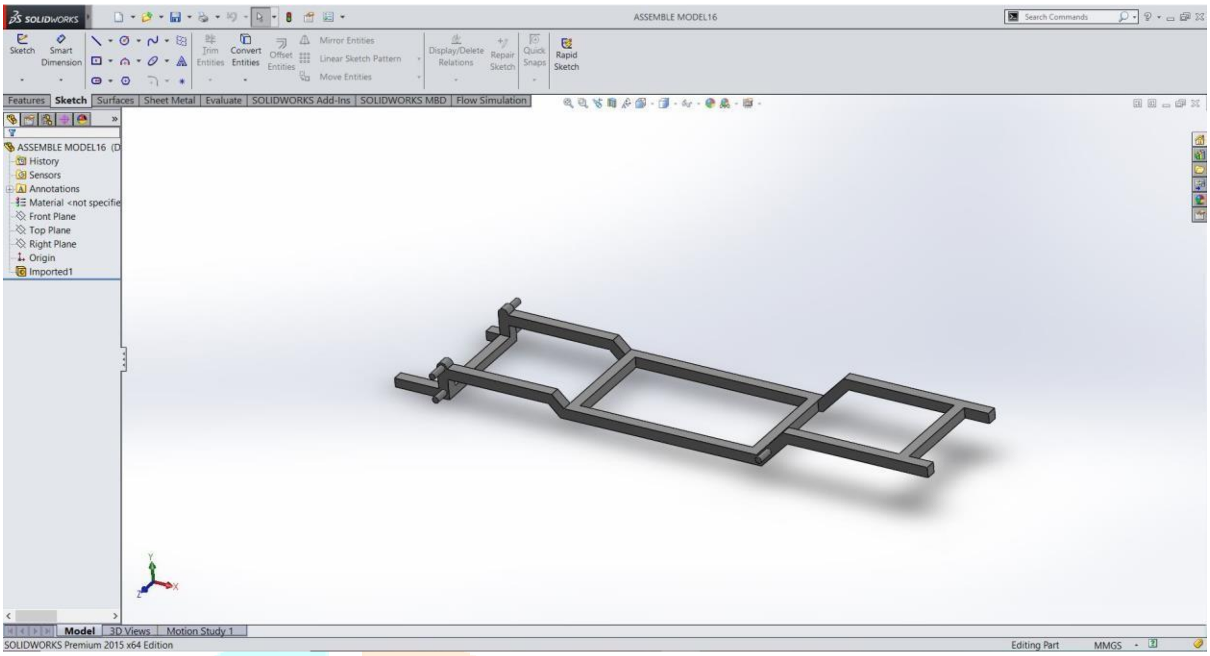


Fig.3.1 Frame Design

SHOCK ABSORBER

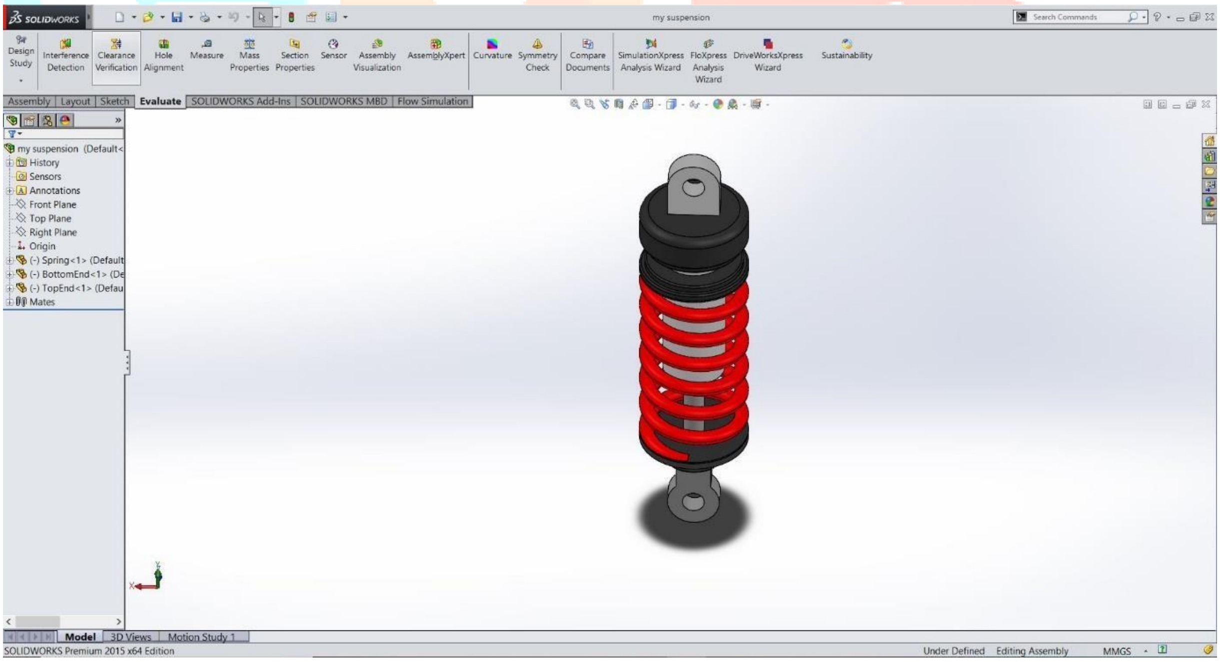


Fig.3.2 Shock Absorber

3D ASSEMBLED TILTING CAR

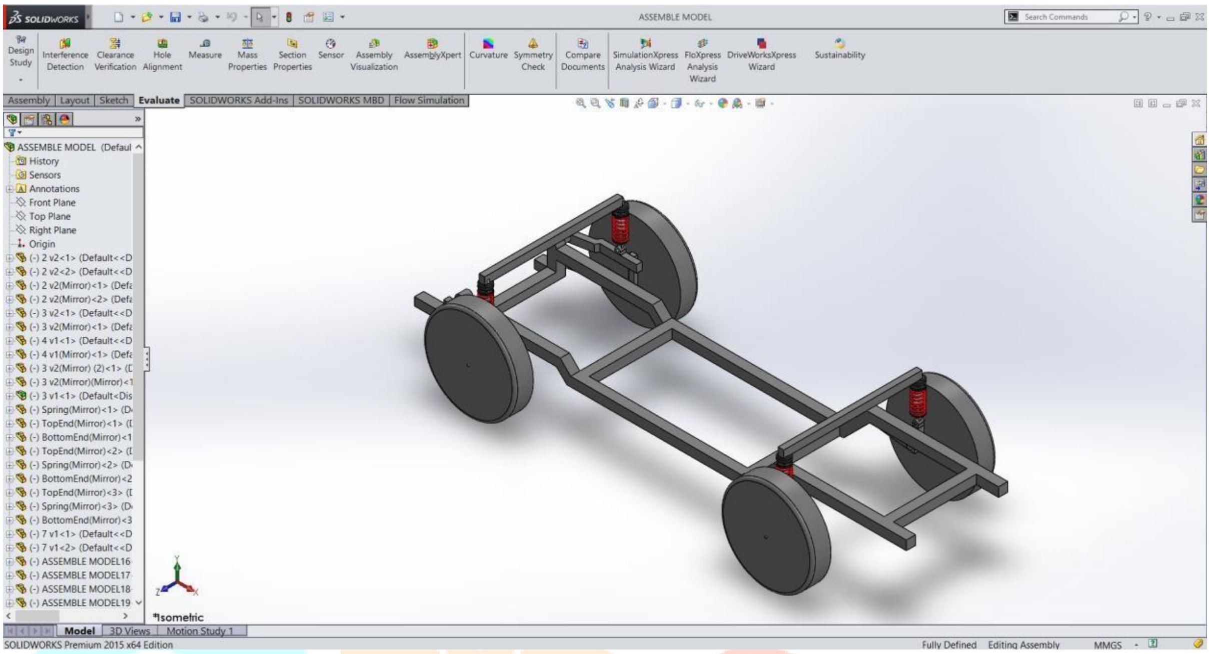


Fig.3.3 3D Assembled Tilting Car

TOP VIEW

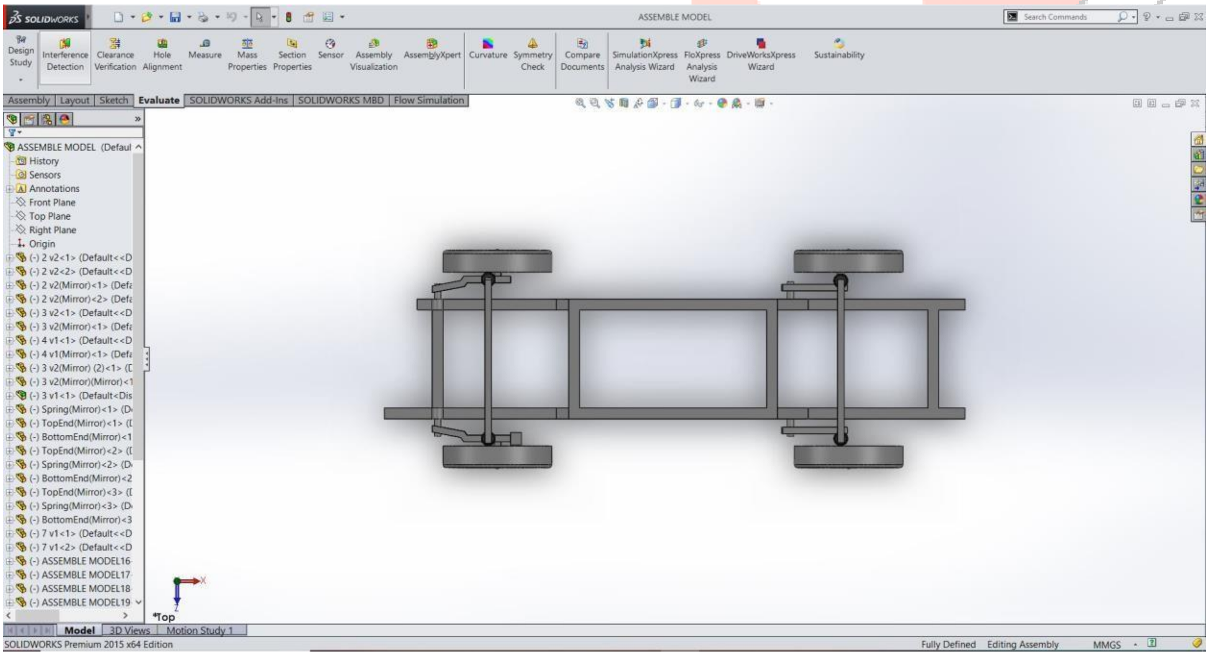


Fig.3.4 Top View

FRONT VIEW

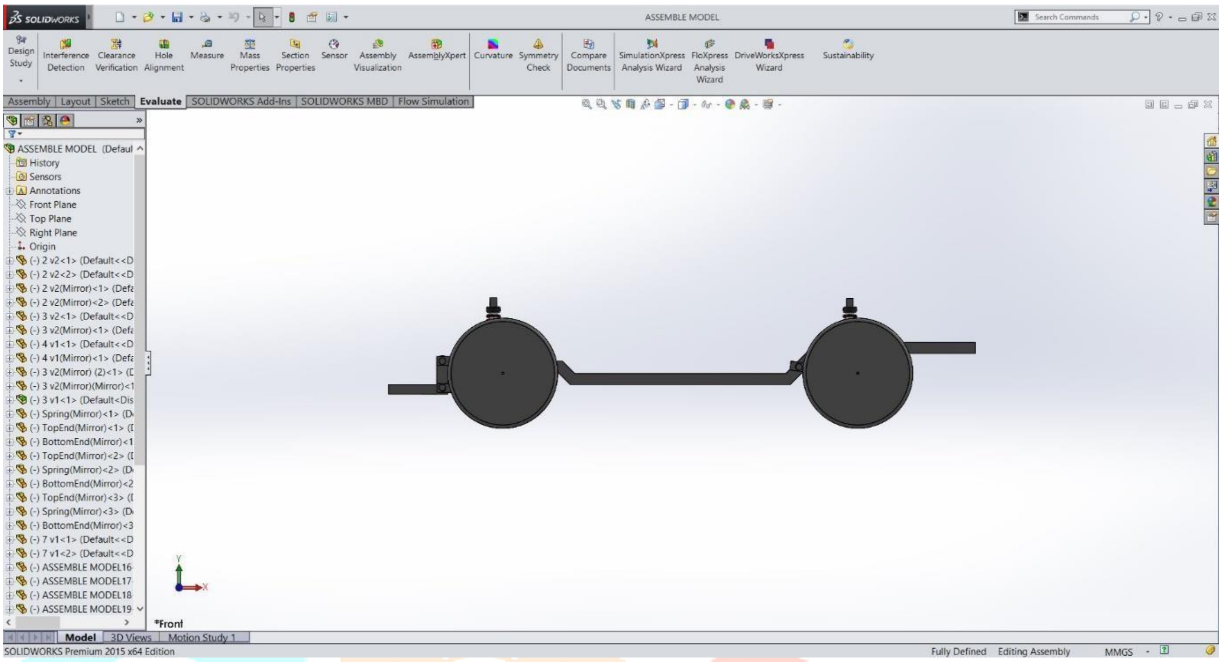


Fig.3.5 Front View

RIGHT SIDE VIEW

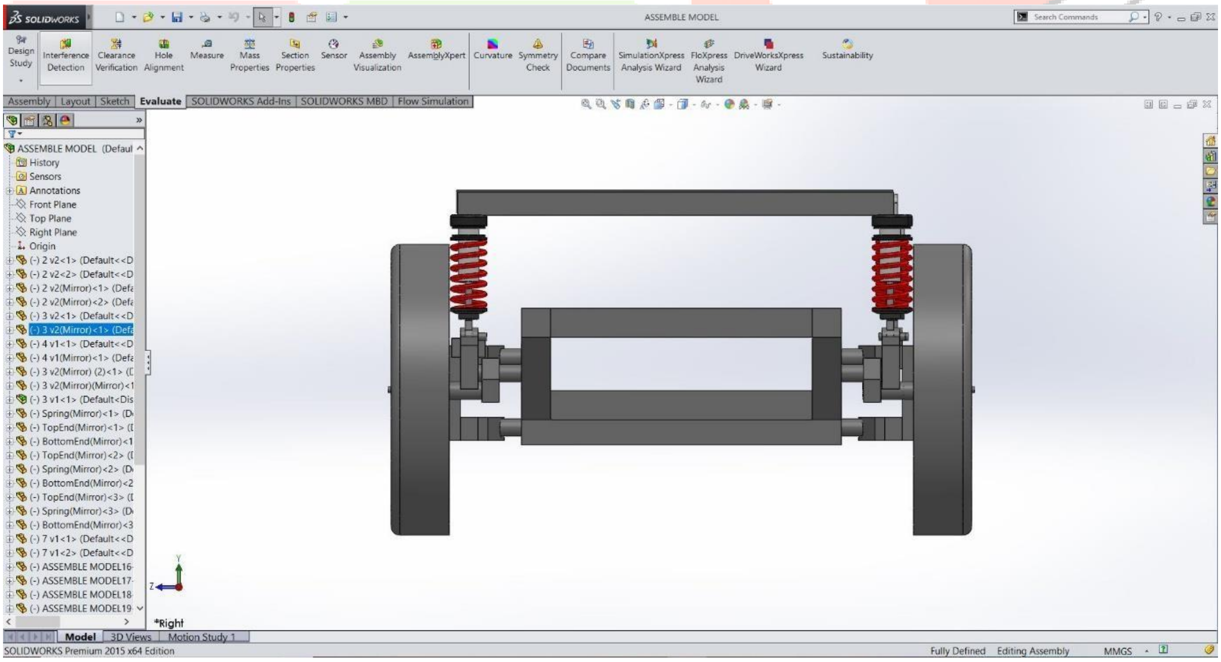


Fig.3.6 Right Side View

COMPARISON OF THRESHOLD VELOCITY ON CURVES FOR TILTING CARS

From equations of vehicle dynamics, for a vehicle in a curve

Maximum sliding velocity, Vs_2 = $gC(\sin\theta + \mu\cos\theta)/(\cos\theta + \mu\sin\theta)$ Maximum overturning velocity, Vo_2 = $gC(a\cos\theta + 2h\sin\theta)/(2h\cos\theta - a\sin\theta)$ For a non-tilting car under the following parameters

$\mu=0.6$

$\theta=20^0$

C=50m

g=9.8m/s2

a=0.71m

h=0.68m

1) Sliding velocity for non-tilting car =17.14m/s = 61.7kmph
2) Overturning velocity for the same =15.99m/s = 57.56kmph

Whereas for a tilting car that can tilt 20 degrees into the curve,

1) Sliding velocity = 24.58m/s = 88.48kmph
2) Overturning velocity = 82.86kmph
3) Increase in sliding velocity = 43.4%
4) Increase in overturning velocity =43.9%

ADVANTAGES OF NARROW TILTING CAR

Several of the advantages of our design over conventional car was discussed previously. They are summarized below:

1) This car is much more efficient than a conventional gasoline car due to reduced aerodynamic drag at cruising speed due to reduced frontal area.
2) This design combines the utility of a car with the flexibility of motor bike.
3) Narrow track cars are definitely future of urban mobility, but our tilting car can also handle highway cruising as well.
4) Like any other electric car, it is cheap to run and environment friendly.
5) It is also likely to be a solution to real day traffic congestion.

APPLICATION:

1. Off Road Driving.
2. Can be suited for Handicapped People.
3. Can be used in rainy season.

CONCLUSION

It can be seen from the above result that, our objective to increase the threshold velocity of a narrow car in a curve has been successful. The design of the car and tilting mechanism has been done successfully. All these facts point to the completion of our objective in high esteem.

FUTURE DEVELOPMENTS

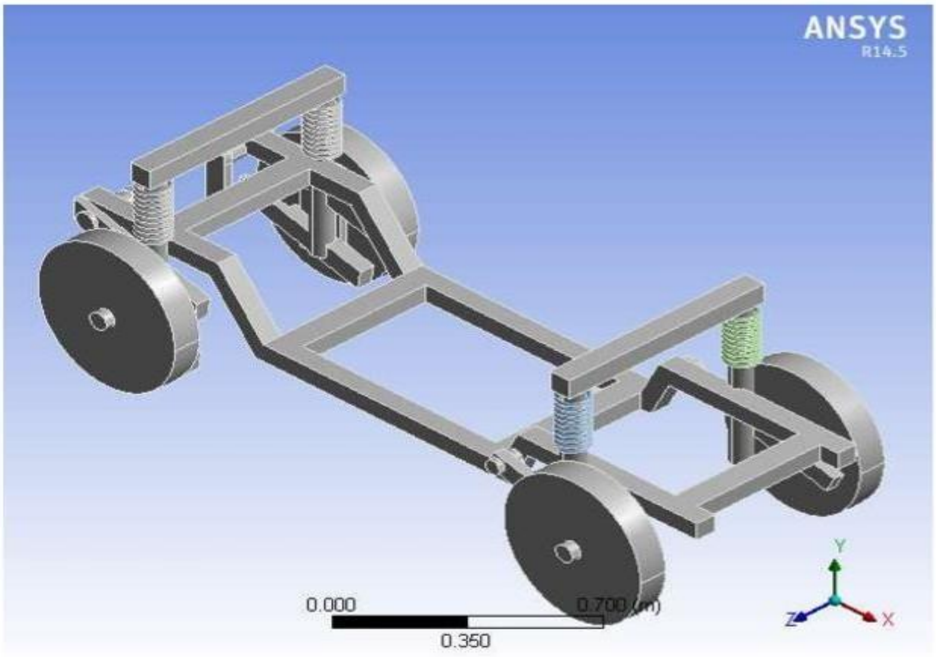
The car design in itself is futuristic and can be soon find in some production versions of four-wheeled tilting cars. A feature can be added to the existing suspension using a minor programming change, the system can also act as body leveller in transverse direction using the level sensor, and this feature enables added grad ability in sideward direction.

ANALYSIS

ANSYS

Project

First Saved	Tuesday, February 26, 2019
Last Saved	Tuesday, February 26, 2019
Product Version	14.5 Release
Save Project Before Solution	No
Save Project After Solution	No



REFERENCE

1. normal Fuel Run Tilting Car Using Robotic Formalism.
2. Benjamin Drew, Kevin Edge, Matt Barker, Jos Darling & Geraint
3. Owen.,"System Development For Hydraulic Tilt Actuation Of A Tilting
4. Narrow Vehicle".,The Ninth Scandinavian International Conference on
5. Fluid Power, SICFP '05, June 1-3, 2005, Linköping, Sweden
6. Gohl J- Rajamani R., Development of a Novel Tilting Controlled
7. Normal Fuel Run Commuter Vehicle., Vehicle Dynamics And Control.,2003.
8. N.K. GIRI. , Automobile Mechanics.
9. Chris Longhurst., "Suspension Bible.

10. Reza N Jazar .,"Vehicledynamics.,PHI.,2008. 11.Ulrich W Seiffert, Hans Herman Braess., SAE Intl. 12.Handbook of Automation. Springer

13. Fuzzy vehicle dynamic control
14. A low cost control mechanism for the improvement of vehicle roll over stability in turning maneuvers. ICMET2010
15. Marcelo Gaudezi Di Faria, Enric Fossas colet.," A Siding mode controlled three wheeled Narrow Vehicle"Int.J. Vehicle design., Vol 62., Nos.2/3/4.,pp 123-146.