

Design of a Tilting Mechanism for a Narrow Tilting Car to Increase the Maximum Speed in Curves

¹G.Kathirvel, ²D.Senthil Raja, ³V.Mohanraj, ⁴N.Prabakaran

¹PG Scholar, Engineering Design, Jayam College of Engineering and Technology, Tamilnadu, India

²HOD/Associate Professor, Dept. of Mechanical Engineering, Jayam College of Engineering and Technology, Tamilnadu, India

^{3,4}Assistant Professor, Dept. of Mechanical Engineering, Jayam College of Engineering and Technology, Tamilnadu, India

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.

Keywords: Tilting Mechanism, Narrow Tilting Car, Maximum Speed, Curves.

I. INTRODUCTION

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 coefficient, plus reduced running losses make for a very energy efficient vehicle.

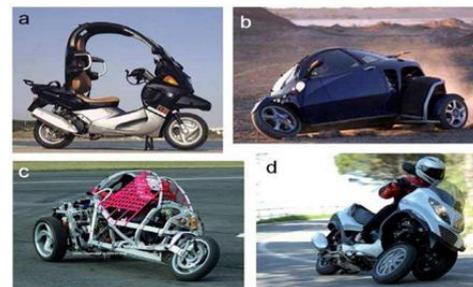


Figure 1: Three Wheeler Tilting Mechanism

All these advantages make the narrow track vehicle as 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 give it the flexibility of a motor cycle. This gave use to the idea of an auto-tilting car.



Figure 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.



Figure 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 in two-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 gripe 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 topl 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.

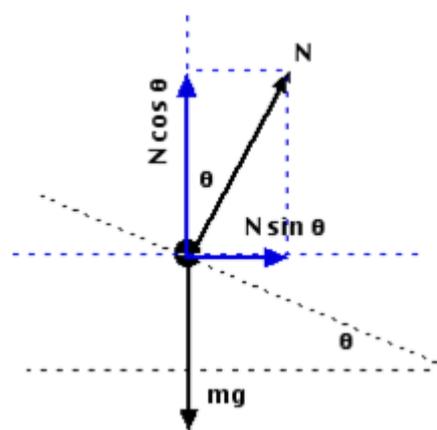


Figure 4: Force Angle Calculation

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.

II. 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.

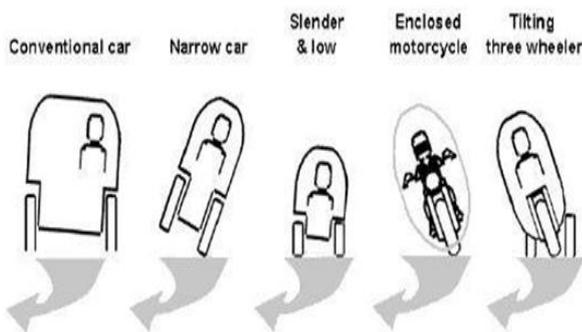


Figure 5: Tilting Mechanism for different Configuration

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.

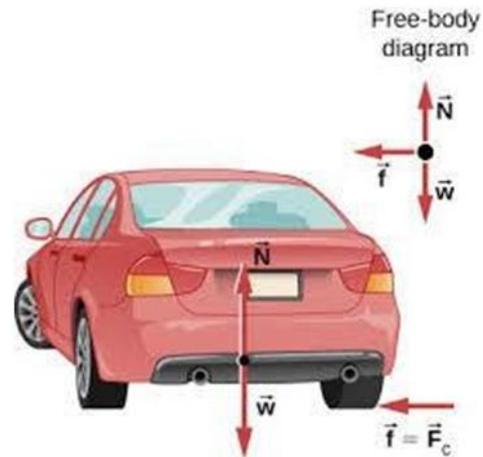


Figure 6: Forces acting on car Body

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.

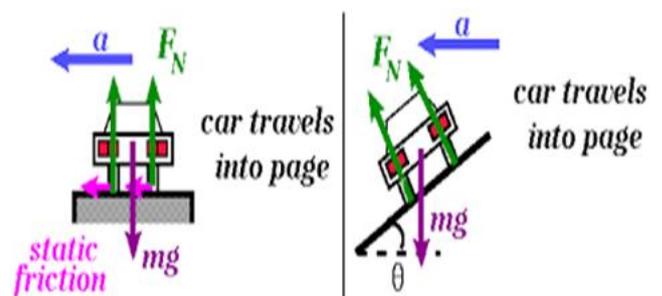


Figure 7: Static Friction

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 coefficient, 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.

III. 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.

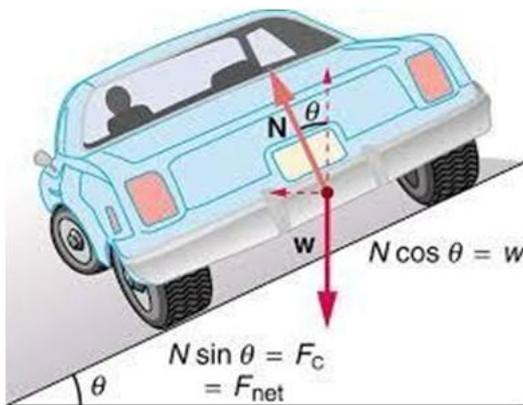


Figure 8: Four Wheeler Dynamics

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.

IV. DESIGN A NARROW TILTING CAR

4.1 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.

4.2 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.

4.3 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.

4.4 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 lookout 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 and 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.

4.5 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.

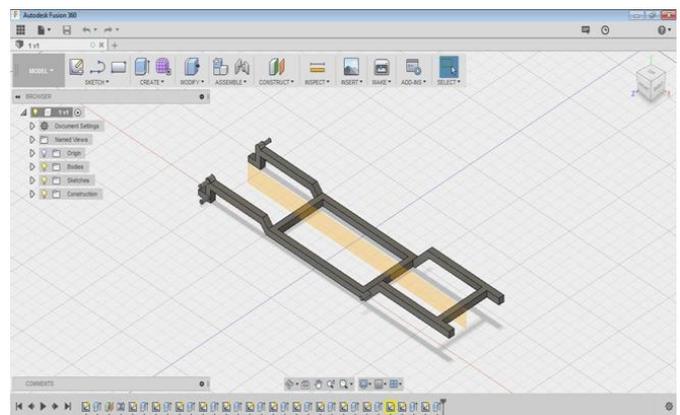


Figure 9: Frame Design

4.6 Shock Absorber

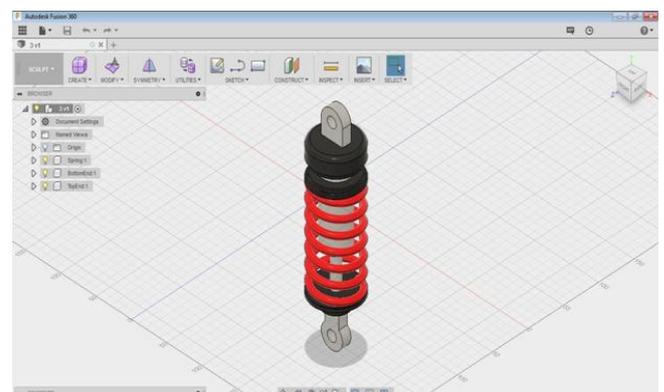


Figure 10: Shock Absorber

4.7 3D Assembled Tilting Car

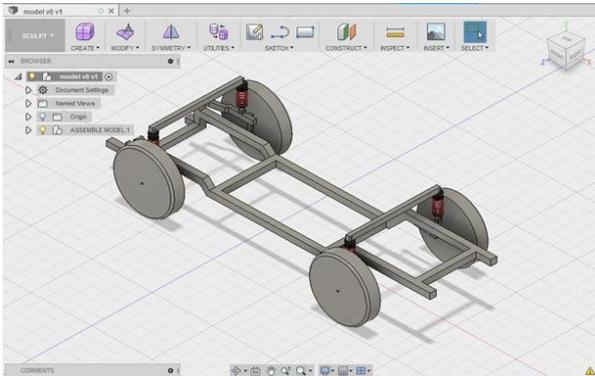


Figure 11: 3D Assembled Tilting Car

4.8 Top View

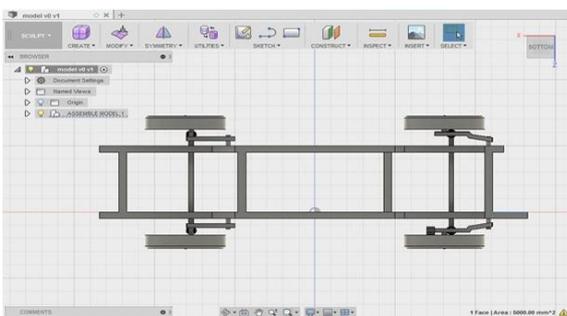


Figure 12: Top View

V. RESULT AND DISCUSSION

5.1 Comparison of Threshold Velocity on Curves for Tilting Cars

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

Maximum sliding velocity, $V_{s2} = gC(\sin\theta + \mu\cos\theta)/(\cos\theta + \mu\sin\theta)$

Maximum overturning velocity, $V_{o2} = gC(a\cos\theta + 2h\sin\theta)/(2h\cos\theta - a\sin\theta)$

For a non-tilting car under the following parameters

$$\mu=0.6$$

$$\theta=200$$

$$C=50m$$

$$g=9.8m/s^2$$

$$a=0.71m$$

$$h=0.68m$$

- 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%

5.2 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.

5.3 Applications

- Off Road Driving.
- Can be suited for Handicapped People.
- Can be used in rainy season.

VI. CONCLUSION AND FUTURE SCOPE

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. 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 leveler in transverse direction using the level sensor, and this feature enables added grad ability in sideward direction.

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