Design and Fabrication of Ackerman Steering Mechanism Combining with ABS

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Abstract—The Ackerman steering mechanism is to avoid the slip of tyres on sideways when following the path around a curve. This mechanism is for all wheels to have their axles arrangement as radii of circles with a common centre point. As the rear wheels are fixed this centre point must be on the line extended from the rear axle. Intersecting the axes of front wheels on this line as well requires that the inside front wheel is turned through a greater angle than the outside wheel. Wheel locking is a predominant phenomenon during panic braking and this will cause vehicle skidding resulting in injuries and road accidents. As the road safety regulations are becoming more stringent, the anti-lock brake system will replace the conventional brake systems in all road vehicles to avoid accidents and to improve vehicle safety.

Key words: Ackerman Steering Mechanism, ABS

I. INTRODUCTION

A. Ackerman Steering

The most conventional steering arrangement is to turn the front wheels using a hand operated steering wheel which is positioned in front of the driver, via the steering column which may contain universal joints, to allow it to deviate somewhat from a straight line. The basic aim of the Ackerman steering is to arrange in linkages in the steering of vehicles of wheels on the inside and outside of a turn needing to trace out circles of different radii and to ensure that the wheels are pointing in the desired directions by series of linkages, rods, pivot and gears. The steering linkages connecting the steering box and the wheels usually conforms to a variation of Ackerman steering geometry to account for the fact that in a turn, the inner wheel is actually travelling a path of smaller radius than the outer wheel. So that the degree of toe suitable for driving in a straight path is not suitable for turns. The angle the wheels make with the vertical plane also influences steering dynamics as do the tires.

B. Anti-Lock Braking System

A brake is a mechanical device which inhibits motion. Most commonly brakes use Friction to convert kinetic energy into heat, though other methods of energy conversion may be employed. For example regenerative braking converts much of the energy to electrical energy, which may be stored for later use. Other methods convert kinetic energy into potential energy in such stored forms as pressurized air or pressurized oil. Eddy current brakes use magnetic fields to convert kinetic energy into electric current in the brake disc, fin, or rail, which is converted into heat.

Still other braking methods even transform kinetic energy into different forms, for example by transferring the energy to a rotating flywheel. Brakes are generally applied to rotating axles or wheels, but may also take other forms such as the surface of a moving fluid. Some vehicles use a combination of braking mechanisms, such as drag racing cars with both wheel brakes and a parachute, or airplanes with both wheel brakes and drag flaps raised into the air during landing.

An anti-lock braking system is an automobile safety system that allows the wheels on a vehicle to maintain tractive contact with the road surface according to driver inputs while braking. This helps to preventing the wheels from locking up and avoiding uncontrolled skidding.

ABS provides good vehicle control and decreases stopping distance on dry and slippery surfaces.

C. History

1) Ackerman Steering

Ackerman was born in Stolberg in Saxony, in 1764. At an early age he began his apprenticeship in coach building and design at his father’s shop. After becoming o journey man he left and traveled to other German towns, Paris and finally London where for 10 years he was engaged as a designer for many of the principal coach builders in that area. He died in 1834, long before the earliest automobiles, crude as they were, appeared. He spend most of his later year in the publishing business.

Perhaps, at this point, it might be proper into enter the principle of steering. In the old horse and buddy days, pulling on one of the reins would swing the horse to that side. The shaft or pole attached to the horse is also attached to the front axle, which is pivoted on a king pin.

Going straight ahead, the front and rear wheels of any vehicles move in a straight line. In making a turn to one side or the other, the front wheels are turned so that they are at an angle to the rear wheels. In a horse-drawn vehicle, the wheels are square with the axle as the wheels and axle swing or turn together, in an automobile, the front axle does not swing; instead, each wheel pivots at the end of the axle. It would not be practical to steer an automobile like a horse-drawn vehicle as the axle would have to be quite heavy to support the weight, making it quite hard to turn. Also the height of the automobile would be excessive to allow for wheel clearance when making a short turn. On the fixed axle of the model T and other early cars, the pivot on which the front wheels swing is as close to the hubs as possible, among other reasons.

2) Anti-Lock Braking System

ABS was first developed for aircraft use in 1929 by the French automobile and aircraft pioneer Gabriel Voisin, as threshold braking on airplanes. This system uses a flywheel and valve attached to a hydraulic line that feeds the brake cylinders. The flywheel is attached to a drum that runs at the same speed as the wheel. In normal braking, the drum and flywheel should spin at the same speed. However, when a wheel slows down, then the drum would do the same ,
leaving the flywheel spinning at a faster rate. This causes the valve to open, allowing a small amount of brake fluid to bypass the master cylinder into a local reservoir, lowering the pressure on the cylinder and releasing the brakes. The use of drum and flywheel meant the valve only opened when the wheel was turning. In testing, 30% improvement in braking performance was noted, because the pilots immediately applied full brakes instead of slowly increasing pressure in order to find the skid point. An additional benefit was the elimination of burned or burst tires.

In 1958, a Royal Enfield’s super meteor motorcycle was used by the Road Research Laboratory to test the Maxaret anti-lock brakes can be of great value to motorcycles, for which skidding is involved in high proportion of accidents. Stopping distances were reduced in most of the tests compared with locked wheel braking particularly on slippery surfaces, in which the improvement could be as much as 30 percent.

Electronically controlled anti-skid brakes on Toyota crown in 1972, four wheel drive triumph 2500 estates were fitted with Mullard electronic systems as standards.

In 1988, BMW introduced the first motorcycle with an electronic-hydraulic ABS: the BMW k100.In 2007 Suzuki launched its GSF1200SA with an ABS.

II. ACKERMAN STEERING MECHANISM

A. The Ackerman Principle

To achieve true rolling for a four wheeled vehicle moving on a curve track, the lines drawn through each of the four wheel axes intersect at the instantaneous center. The actual position the instantaneous center constantly changes due to the alternation of the front wheel angular position to correct the steered vehicle path.Since both rear vehicles are fixed on the same axis but the front wheel axles are independent of each other, the instantaneous centers lies somewhere along an imaginary extended line drawn through the axis of the rear axle. The Ackerman principle is based on the two front steered wheels being pivoted at the ends of an axle beam. The original Ackerman linkage as parallel set track rod arms, so that both steered vehicles swivel at equal angles. Consequently, the intersecting projection lines do not meet at one point. If both front wheels are free to follow their own natural paths, they would converge eventually cross each other. Since the vehicle moves along a single mean path, both wheel tracks continuously with each other causing tire slip and tread scrub. Subsequently modified linkage uses inclined track rod arms so that the inner wheels swivels about its king pin slightly more than the outer wheel. Hence the lines drawn through the stub axles converge at a single point somewhere along the rear axle projection.

B. Ackerman Linkage

The self-propelled motor vehicle almost from the beginning, use the double pivot wheel steering system. This was invented for horse drawn vehicles. With this layout of the linkage the track rod arms are set parallel to each other and track rod joints them together. In the straight ahead position of the steering, the linkage and the axle beam forms a rectangle, but as the stub axles are rotated about their kingpins the steering arrangement forms the parallelogram. This linkage configuration turns both wheels the same amount. Charles Jeant and introduced an improvement to Ackermann linkage layout in which inclined track rod arms from trapezium .This trapezium linkage configuration allows the inner wheel to rotate about its kingpin pivot by a greater amount than the outer wheel, which is needed for providing semi true rolling. True rolling is obtained in straight ahead position and on the left and right hand turns. The degree of departure from true rolling and hence amount of tyre scrubs occurrence depends mainly on the ratio of the track rod to track rod arm lengths, and on the track rod arm angular inclination or set. In case the steering linkage dimensions and settings are carefully selected, a very misalignment takes place for angle of turn up to about 15 degree beyond which the error increases rapidly. Also the deviation of linkage from the theoretical of true rolling angle can readily be corrected by the tyres side wall flexibility and thread distortion, provided the angular error between the steered wheels is small .Since the rear wheels turn on a smaller radius than the front wheels, it is easier to manoeuvre a vehicle in reverse than in the forward direction when parking.
C. True Ackerman Angle – Zero Toe on Turn in
True Ackerman steering geometry is defined by angling the steering arms so that a line drawn between both the king pin and steering arm pivot points intersect with the center line of rear axle.

As this gives true Ackerman steering geometry, there is no toe angle change on the inside wheel (the wheel is aligned with the circumference of the circle).

D. More Ackerman Angle-Toe Out on Turn in
More Ackerman angle can be added to a steering setup, which involves adjusting the angle of the pivot points on the steering arms. So that the point of intersection is forward of the center line of the rear axle.

This steering geometry achieves greater angular inequality of the turned wheels, which results in the inside wheel trying to follow a smaller diameter circle than it actually does.

E. Less Ackerman Angle-Toe In on Turn in
Less Ackerman angle can be set on a steering setup, which involves adjusting the angle of the pivot points on the steering arms so that the point of intersection is behind the centre line of the rear axle. Please refer to the image on the right. This steering geometry achieves a reduced amount of angular inequality of the turned wheels, which results in the inside wheel trying to follow a larger diameter circle than it actually does. This effect can be seen in the image above left and generates Toe In on the front inside wheel.

F. Steering System
Steering is the collection of components, linkages, etc. which allow a vehicle to follow the desired course. It is essential to improve the efficiency and reduce the complexity while steering. The steering system is classified according to its performance and efficiency.

Essentially, there are two major types of steering system:
- Manual steering system
- Power assisted steering system

1) Manual Steering System
Manual steering is considered to be entirely adequate for smaller vehicles. It is tight, fast, and accurate in maintaining steering control. However large and heavier engines, greater front overhang on the larger vehicles, and a trend toward wide tread tires have increased the steering effort required. Steering mechanism with higher gear ratios were tried but dependable power steering systems were found to be the answer. There are different types of manual steering systems which are as follows:
- Worm and sector
- Worm and rotter
- Cam and lever
- Worm and nut
- Rack and pinion

G. Anti-Ackerman
Anti-Ackerman takes into consideration the optimum slip angle for the tyre at reduced vertical load (inner wheel). If inner wheel stays on the ground at cornering speeds and we have pro Ackerman the inner wheel have more steering angle= more slip angle but as much less vertical load. So we are not using inner wheel properly. As we have learned tyres do not like to be punished at vertical loads. With pro Ackerman the inner wheel has less steering angle than the outer wheel but as more grip.

The maximum lock of the outward tyre in the corner can be increased, as the inner wheel does not steer more than the outer wheel. Clearance wise it is much better and aero wise for sure as the inner wheel does not block the air flow as much when there is not much lock available on the outside wheel.

H. Steering Material
- Mild Steel
- Aluminium
- Advanced Composite Material
- Glass Fiber Composite
I. Advantages

In using Ackerman steering we hope to be able to influence the slip angle on the inside tyre to our advantage. There will be a range of slip angles where the inside tyre will be producing near maximum grip (Figure 3). So we have a degree of flexibility in how much Ackerman we use. To rotate the car on corner entry we are talking about creating increasing drag at the inside tire. As the cornering force builds the inside tyre must at some point reach it's optimum lateral grip. We then use Ackerman to toe the tyre out further - say increase the slip angle a couple of degrees. The tyre grip doesn't change that much but the longitudinal component of tyre grip, the tyre drag, does increase in line with the increased slip angle. For this to work we would need to know that we have sufficient steering angle to generate the Ackerman needed.

- If in the process above, we started to lose outside tyre grip, and the driver wound on some more lock, we would have increased drag at the outside tyre. We would then lose the effect. The over steer torque we were looking for would be overcome by the larger understeer torque.
- We will probably use initial toe out to help turn in. The idea is to get the inside tyre working as discussed earlier. Other settings you would use to help initial turn in are stiffer front shocks, and higher front roll center height. By delaying the roll we help to keep the weight on the inside, to again keep the inside tyre working.

III. Braking System

A. Braking System

A vehicle braking system, including the tires, is most effective, i.e., produces the optimum retarding force, when the wheel speeds are approximately 85 to 90% of the vehicle speed. The difference is called the percent slip of a particular wheel. The 10 to 15% slip retarding force is greater than the locked wheel retarding force, so optimum braking is achieved when the slip is 10 to 15% and no more. Over-applying foundation brakes can cause wheels to lock (100% slip), so a system that prevents this can improve braking effectiveness.

B. Types of Brakes

Brakes are one of the most important safety features on your vehicle. There are different types of brakes, both between vehicles and within a vehicle. The brakes used to stop a vehicle while driving are known as the service brakes, which are either a disc and drum brake. Vehicles also come equipped with other braking systems, including anti-lock and emergency brakes:

- Disc brakes
- Drum brakes
- Emergency brakes
- Anti-lock brakes
- Electromagnetic brakes

1) Disc Brake

Disc brakes consist of a disc brake rotor - which is attached to the wheel - and a caliper, which holds the disc brake pads. Hydraulic pressure from the master cylinder causes the caliper piston to clamp the disc brake rotor between the disc brake pads. This creates friction between the pads and rotor, causing your car to slow down or stop.

2) Drum Brake

Drum brakes consist of a brake drum attached to the wheel, a wheel cylinder, brake shoes, and brake return springs. Hydraulic pressure from the master cylinder causes the wheel cylinder to press the brake shoes against the brake drum. This creates friction between the shoes and drum to slow or stop your car.
3) Emergency Brakes

Vehicles also come equipped with a secondary braking system, known as emergency or parking brakes. Emergency brakes are independent of the service brakes, and are not powered by hydraulics. Parking brakes use cables to mechanically apply the brakes (usually the rear brake). There are a few different types of emergency brakes, which include: a stick lever located between the driver and passenger seats; a pedal located to the left of the floor pedals; or a push button or handle located somewhere near the steering column. Emergency brakes are most often used as a parking brake to help keep a vehicle stationary while parked. And, yes, they are also used in emergency situations, in case the other brake system fails!

4) Anti-Lock Brakes

Computer-controlled anti-lock braking systems (ABS) are an important safety feature which is equipped on most new vehicles. When brakes are applied suddenly, ABS prevents the wheels from locking up and the tires from skidding. The system monitors the speed of each wheel and automatically pulses the brake pressure on and off rapidly on any wheels where skidding is detected. This is beneficial for driving on wet and slippery roads. ABS works with the service brakes to decrease stopping distance and increase control and stability of the vehicle during hard braking.

Control of vehicle track is the most important reason for the use of ABS. It has been shown that for poor road conditions (sand, ice, snow, water, etc.), a system that prevented wheel lockup and gave significantly increased directional control, in exchange for a small loss of absolute stopping distance, provided a major benefit to overall vehicle performance. This is accomplished by using an ECU to sense individual wheel speeds, and then isolate and reduce brake fluid pressure to the wheel or wheels that are locking up. A schematic of such a feedback system where the controller is an ECU, the controlled parameter is wheel cylinder pressure (via electrical solenoid valves), and the feedback elements are individual electronic wheel speed sensors (WSS).

The WSS signals are typically generated via a pickup coil mounted adjacent to a toothed ring at each controlled wheel, where the pickup coil generates a varying voltage output proportional to the amplitude and frequency of the magnetic flux change as the ring teeth pass by it.

By monitoring the frequency output of each WSS, the ECU can decide if an individual wheel slip exceeds a desired threshold. When such a threshold is exceeded at a particular wheel, the ECU directs the hydraulic control unit to isolate that wheel and reduce hydraulic pressure at that wheel, so that the wheel can resume rotation.

Once the wheel is again rotating at about optimum slip (assuming the brakes are still applied) pressure is reapplied to that particular wheel. Typically, each wheel control circuit is called a channel and the hydraulic control unit is typically called a hydraulic modulator. Hydraulic modulators typically include three functions for each controlled wheel circuit: isolation, pressure-dump, and pressure-reapply. This control sequence causes pulsed apply/release/apply as ABS is controlling a wheel in an emergency stop, often up to ten times per second.

5) Electro-Magnetic Brakes

An Electromagnetic Braking system uses Magnetic force to engage the brake, but the power required for braking is transmitted manually. The disc is connected to a shaft and the electromagnet is mounted on the frame. When electricity is applied to the coil a magnetic field is developed across the armature because of the current flowing across the coil and causes armature to get attracted towards the coil. As a result it develops a torque and eventually the vehicle comes to rest. In this project the advantage of using the electromagnetic braking system in automobile is studied. These brakes can be incorporated in heavy vehicles as an auxiliary brake. The electromagnetic brakes can be used in commercial vehicles by controlling the current supplied to produce the magnetic flux. Making some improvements in the brakes it can be used in automobiles in future.

C. Components of ABS

- Speed Sensor
- Valve
- Pump
- Controller
- Coil

1) Speed Sensor

A speed sensor is used to determine the acceleration or deceleration of the wheel. These sensors use a magnet and a Hall Effect sensor, or a toothed wheel and an electromagnetic coil to generate a signal. The rotation of the wheel or differential induces a magnetic field around the sensor. The fluctuation of this magnetic field generates a voltage in the sensor. Since the voltage induced in the sensor is a result of the rotating wheel, this sensor can become inaccurate at slow speeds. The slower rotation of the wheel can cause inaccurate fluctuation in the magnetic field and thus cause inaccurate readings to the controller.
2) **Valves**  
There is a valve in the brake line of each brake controlled by the ABS. On some systems, the valve as 3 positions:
- In position 1, the valve is open, pressure from the master cylinder is passed right through to the brake.
- In position 2, the valve blocks the line, isolating that brake from the master cylinder. This prevents the pressure from rising further should the driver push the brake pedal harder.
- In position 3, the valve releases some of the pressure from the brake.

3) **Pump**  
The pump in the ABS is used to restore the pressure to the hydraulic brakes after the valves have released it. A signal from the controller will release the valve at detection of wheel slip. After a valve release the pressure supplied from the user, the pump is used to restore a desired amount of pressure to the braking system. The controller will modulate the pumps status in order provides the desired amount of pressure and slipping.

4) **Controller**  
The controller is an ECU type unit in the car which receives information from each individual wheel speed sensor, in turn if a wheel loses traction the signal is send to the controller, the controller will then limit the brake force and activate the ABS modulator which actuates the braking valves on and off.

5) **Coil**  
An electromagnetic coil is formed when a conductor is wound around a core or form to create an inductor or electromagnet. When electricity is passed through a coil, it generates a magnetic field. One loop of wire is usually referred to as a turn or a winding, and a coil consists of one or more turns. For use in an electronic circuit, electrical connection terminals called taps are often connected to a coil. Coils are often coated with varnish or wrapped with insulating tape to provide additional insulation and secure them in place. A completed coil assembly with one or more set of coils and taps is often called the windings.

The conducting material used for the windings depends upon the application, but in all cases the individual turns must be electrically insulated from each other to ensure that the current travels throughout every turn. For small power and signal applications, in which currents are low and the potential difference between adjacent turns is small, the coils are often wound from enameled magnet wire, such as Formvar wire. Larger power transformers operating at high voltages may be wound with copper rectangular strip conductors insulated by oil-impregnated paper and blocks of pressboard.

![Fig. 6: A Valves](image)

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The pump in the ABS is used to restore the pressure to the hydraulic brakes after the valves have released it. A signal from the controller will release the valve at detection of wheel slip. After a valve release the pressure supplied from the user, the pump is used to restore a desired amount of pressure to the braking system. The controller will modulate the pumps status in order provides the desired amount of pressure and slipping.

![Fig. 7: A Pump](image)

D. **Advantages of ABS**
- Stopping on ice: an ABS prevents lock-ups and skidding, even in slippery conditions. Anti-lock brakes have been proven to save lives in some situations by helping drivers keep control of a vehicle.
- Lower insurance costs: because it’s a thoroughly tested safety device with a track record of effectiveness, insurers often give customers specific discounts for having an ABS on their vehicle.
- Higher resale value: as a feature on a car or truck, on ABS raises the market value of the vehicle. Now a days where ABS technology has become standard on many vehicles, not having it could result in a lower price for resale.
- Traction control: an ABS shares some of the infra structures of a traction control system, where new technology helps ensure that each wheel has traction on the road. That makes it easy for manufacturers to install both of these features at the factory.

E. **Disadvantages of ABS**
- Inconsistent stop times: Anti-lock brakes are made to provide for surer braking in slippery conditions. However, some drivers report that they find stopping distances for regular conditions are lengthened by their ABS, either because there may be errors in the system, or because the clunking or noise of the ABS may contribute to the driver not braking at the same rate.
- Expense: an ABS can be expensive to maintain. Expense sensor on each wheel can cost hundreds of dollars to fix if they get out of calibration or develop other problems. For some, this is a big reason to decline on ABS in a vehicle.
- Delicate system: it’s easy to cause a problem in an ABS by messing around with the brakes. Problems include disorientation of the ABS, where a compensating brake sensor causes the vehicle to shudder, make loud noise or generally brake worse.

IV. **DESIGN OF ACKERMAN STEERING**

A. **Design of Ackerman Steering Setup**
The Ackerman steering system contains the following parts:
1) **Outer Frame**
The outer frame is made of mild steel of thickness 1 inch X 1 inch. The main purpose of the frame is to hold the rack and pinion, arms, wheels etc. The length of the frame is around 330mm and the breadth of 300mm. The rack and pinion set up is on upper portion of it. This is designed in such a way that it can be handled easily.

![Fig. 4: A Frame](image)

2) **Rack and Pinion**
Rack and pinion combinations are often used as a part of a simple linear actuator where the rotation of the shaft powered by hand or by a motor is converted to linear motion. We used the plastic rack and pinion in this setup. Rack is of 140mm length and pinion is 10mm diameter. It is capable to give angular motion to arms of 124.7mm length.

![Fig. 5: A Rack and Pinion](image)

3) **Inclined Arms**
Arms are made up of mild steel in the dimension of 124.7mm length. Here arms are fixed inclined at an angle of 45 to the rack. Due to inclined arms angular motion of wheels takes place while turning.

![Fig. 6: A ARMS](image)

4) **Wheels**
For this setup robotic wheels are fixed with 3 inch diameter. It is enough to carry the load up to 5kg. These robotic wheels cannot not wear easily. Hence it is suitable for mini steering system.

![Fig. 7: A Wheel](image)

**B. Calculation of Ackerman Angle**
If the slight inclination of the track rod (Fig. 4.5) is neglected, the movements of M and N in the direction parallel to the axle beam PQ can be considered as the same, say z. Let M’, N’ represent the correct steering position and, r, denote the cross-arm radius.

\[
\sin(\alpha + \theta) = \frac{y + z}{r} \quad \text{and} \quad \sin(\alpha - \phi) = \frac{y - z}{r}
\]

With the help of the above equation the variables \( \theta \) and \( \phi \) can be calculated for the correct steering.

**C. Photographs**

![Fig. 8: Calculation of Ackerman Angle](image)

![Fig. 9: Ackerman Steering](image)

![Fig. 10: Switch Mode Power Supply](image)
D. Cost Estimation

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Table 4: Cost Estimation

E. Bill of Materials

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Table 4: Bill of Materials

V. CONCLUSION

Ackerman steering mechanism and ABS helps us to easy control of vehicle. These principles shows that the importance of steering and braking systems. Thus these principles are studied in this report, angle for perfect steering is calculated by this basics. Ackerman mechanism is for all wheels to have their axels arrangement as radii of circles with a common centre point. As the rear wheels are fixed this centre point must be on the line extended from the rear axle. Intersecting the axes of front wheels on this line as well requires that the inside front wheel is turned through a greater angle than the outside wheel and Wheel locking is a predominant phenomenon during panic braking and this will cause vehicle skidding resulting in injuries and road accidents. As the road safety regulations are becoming more stringent, the anti-lock brake system will replace the conventional brake systems in all road vehicles to avoid accidents and to improve vehicle safety.

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