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FABRICATION OF COMBINED IN-PHASE AND COUNTER-PHASE STEERING MECHANISM OF A FOUR WHEEL DRIVE

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Abstract

In standard 2 wheel steering system, the rear set of wheels are always directed forward and do not play an active role in controlling the steering. While in 4 wheel steering system, the rear wheels do play an active role of steering, which can be guided at high as well as low speeds. Production cars are designed to under steer and rarely do them over steer. If a car could automatically compensate for an under steer/over steer problem, the driver would enjoy nearly neutral steering under varying operation conditions. Also in situations like low speed cornering, vehicle parking and driving in city conditions with heavy traffic in tight spaces, driving would be very difficult due to a sedan's large wheelbase and track width. Hence there is a requirement of a mechanism which result in less turning radius. We have developed an innovative 4 wheel steering design to implement a mechanism that can serve the purpose of changing in-phase and counter-phase steering of rear wheels depending upon the conditions of turning and lane changing with respect to front wheels, thus enhancing the manoeuvrability of a sedan in accordance with its speed.

Our 4 wheel steering system gives 64.4% reduction in turning circle radius of a sedan which is reduced from 5.394m to 1.92m, considering Honda civic as a standard car for our calculations, and steering ratio therby obtained is 8.177:1 which gives much better manoeuvrability and control on the car even while driving at high speeds.

Keywords:

Manoeuvrability;
Steering;
In-phase steering;
Counter-phase steering.

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1. INTRODUCTION:

1.1 Steering mechanism: Ingeneral steering mechanism only the front wheel steer, rear wheels don't involve in the steering mechanism. Ackerman steering is the general steering mechanism used in present vehicles. This steering mechanism is not efficient in taking a turn in high. The rear wheels do not turn in the direction of curve which decreases the efficiency of steer.So a steering mechanism which involves all the four wheels is used which is called as four wheel steering mechanism or all wheel steering.

1.2 Four wheel steering mechanism**:** Four wheel steering (or all wheel steering) is a system employed by some vehicles to improve steering response, increase vehicle stability while maneuvering at high speed, or to decrease turning radius at low speed [1].

4WheelSteeringSystem isemployed invehicles to achievebettermaneuverability athighspeeds,reducingthe turning circleradiusofthecarandtoreduce thedriver'ssteering effort [2].Inmostactive4wheelsteeringsystem,the guiding computer orelectronic equipmentplayamajorrole, inourprojectwehavetriedtokeepthemechanismasmuch mechanical aspossiblewhichcanbeeasytomanufacturing andmaintenance.

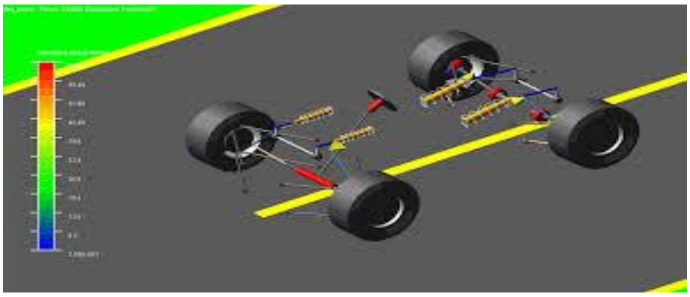

Fig 1. Four wheel steering mechanism

1.2.1 Why Four Steering Mechanism?

To understand the advantages of four-wheel steering, it is wise to review the dynamics of typical steering maneuvers with a conventional front -steered vehicle [3]. The tires are subject to the forces of grip, momentum, and steering input when making a movement other than straight-ahead driving. These forces compete with each other during steering maneuvers. With a front-steered vehicle, the rear end is always trying to catch up to the directional changes of the front wheels. This causes the vehicle to sway. As a normal part of operating a vehicle, the driver learns to adjust to these forces without thinking about them.

When turning, the driver is putting into motion a complex series of forces. Each of these must be balanced against the others. The tires are subjected to road grip and slip angle. Grip holds the car's wheels to the road, and momentum moves the car straight ahead [11]. Steering input causes the front wheels to turn. The car momentarily resists the turning motion, causing a tire slip angle to form.

Once the vehicle begins to respond to the steering input, cornering forces are generated. The vehicle sways as the rear wheels attempt to keep up with the cornering forces already generated by the front tires. This is referred to as rear-end lag, because there is a time delay between steering input and vehicle reaction. When the front wheels are turned back to a straight ahead position, the vehicle must again try to adjust by reversing the same forces developed by the turn. As the steering is turned, the vehicle body sways as the rear wheels again try to keep up with the cornering forces generated by the front wheels.

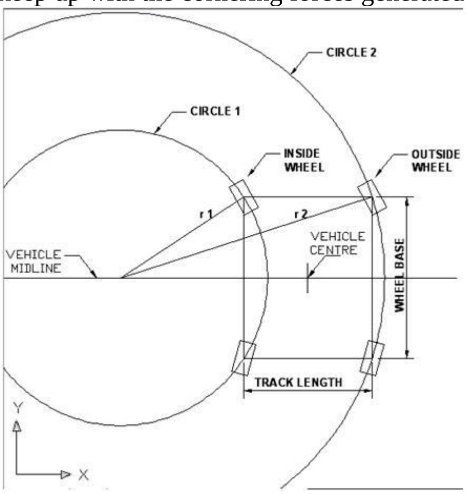

Fig 2. Diagrammatic representation of turning radius

The idea behind four-wheel steering is that a vehicle requires less driver input for any steering maneuver if all four wheels are steering the vehicle. As with two-wheel steer vehicles, tire grip holds the four wheels on the road [10]. However, when the driver turns the wheel slightly, all four wheels react to the steering input, causing slip angles to form at all four wheels. The entire vehicle moves in one direction rather than the rear half attempting to catch up to the front. There is also less sway when the wheels are turned back to a straight-ahead position. The vehicle responds more quickly to steering input because rear wheel lag is eliminated.

In this steering mechanism along with the front wheels, rear wheels also get steer. By using this we can achieve movement of the vehicle in all directions and also turning radius can be reduced [4]. This mechanism is used in some special vehicles used in agricultural farms, tankers etc.
So if this mechanism is implemented in general vehicles the efficiency of steering can be increased rapidly and ease in driving can be achieved.

1.3 Moments in four wheel steering mechanism:

Thereare mainly two phases in four wheel steering mechanism. They are:

1. In-phase steering mechanism
2. Counter-phase steering mechanism

Beyond these two mechanisms there is one more mechanism in which the front wheels move inwards and the rear wheels move outwards.

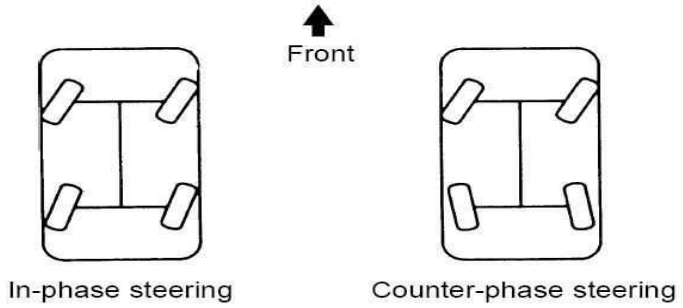

Fig 3.in phase and counter phase mechanisms

1.3.1 In-phase steering mechanism:

In this steering mechanism the wheels connected to steering mechanism rotate in same direction with an equal angle [5]. This kind of steering is also called as anti-Ackerman steering mechanism. This is used in race cars.

In four wheel steering mechanism all the four wheels turn in the same direction with an equal angle when connected in in-phase steering.

Fig 4. In-phase steering mechanism in car

1.3.2 Counter-phase steering mechanism:

Inthis steering mechanism the front wheels and the rear wheels rotate in the opposite direction. The angle of turn of the rear wheels depends on the design of the steering mechanism [6]. Generally, the rear wheels turn an angle less than that of the front wheels to avoid disadvantages in moderate speed. This steering is used mainly in slow speeds. By using this mechanism, we can reduce the turning radius up to 50% [7].

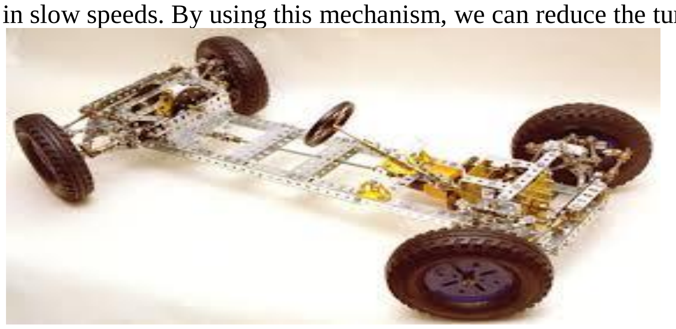

Fig 5. Counter-phase steering mechanism

1.4 Comparison of two wheel, in-phase and counter phase steering:

Two wheel steering	In phase steering	Counter phase steering
1. More turning radius. 2. Wheels cannot rotate 90 degrees. 3. Efficient in all speeds. 4.Overall efficiency is moderate comparatively	1.No turning radius 2. Wheels can rotate 90 degrees. 3. Efficient in high speeds. 4.Overall efficiency is less	1. Less turning radius. 2. Wheels cannot rotate 90 degrees. 3. Efficient in slow speeds. 4. Overall efficiency is less .

Table-1: Comparison of steering mechanisms.

1.5 Combination of in-phase and counter phase steering mechanism with four wheel drive:
The abovecomparison shows that the in-phase and counter-phase steering mechanisms have their advantages and disadvantages when used separately[8].But it is clear that the problems in one mode are the strengths in other mode, so when both the mechanisms are combined in a single vehicle all the problems are solved and an efficient steering mechanism is formed.
So we are attempting to combine both the in-phase and the counter-phase steering mechanisms.
But to obtain all the possible moments of four wheel steering mechanism we need to use four wheel drive i.e., all the wheels are connected to the engine or each wheel is powered with a separate motor[9].So a four wheel drive with four wheel steering mechanism is to de designed.

Fig 6. Combination of both mechanisms.

2. METHODS USED AND MATERIALS FABRICATED:

2.1 FABRICATION METHODS USED:
In fabrication of parts we use Welding, Grinding, and drilling process are used. By using this process, we have to design the parts of the Combination of In-phase and Counter phase four wheel drive model.

2.2 FABRICATED PARTS:Many parts used in the combination of in-phase and counter-phase mechanism model. The parts list has to be shown below. And the fabrication also explained on wards.
1. Steering column
2. Gears
3. Chains
4. Bases
5. Electric motors
6. Phase shifting mechanism
7. Steer rod
8. Ackerman's steering mechanism
9. Wheels

2.2.1 Steering column:

Steering column is one the main parts in this steering mechanism. It is not only the main part of this mechanism, but it is the main shaft or column on which the entire vehicle rests, when it is practically used. This is the column on which the wheel rests and it is responsible for the wheel to steer. All the driven wheels are rested on this column.

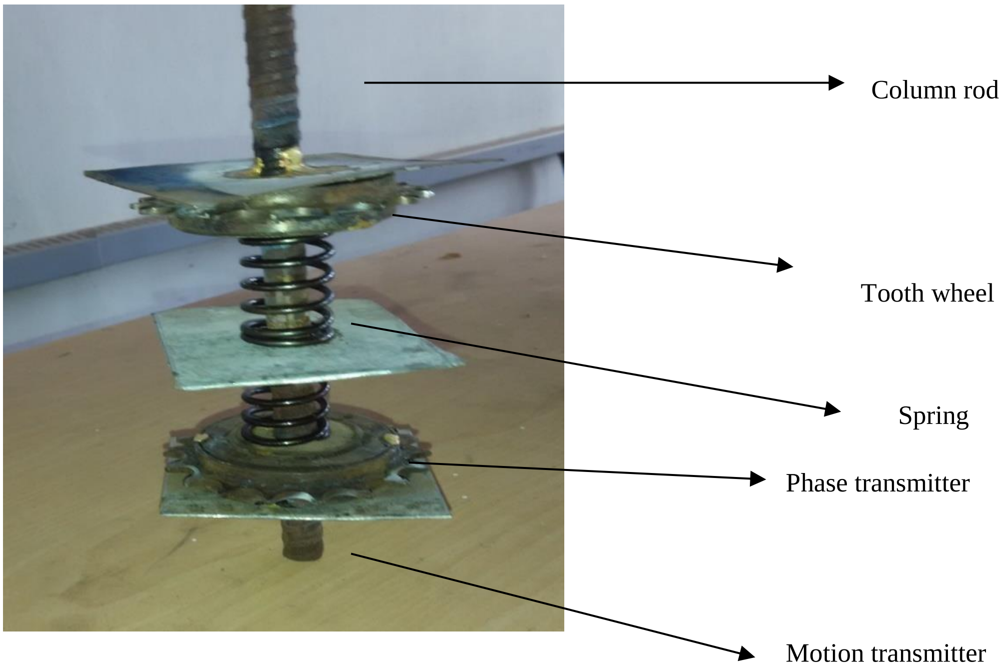

Fig 11. Steering column

2.2.2 Column rod:

This is the main shaft on which all the other components of the steering column rest. This is made of TMT steel. For putting the springs and tooth wheels with wood we have to grind the surface of the column rod. Total 4 column rods are made. For every column rod we put 2 springs, 2tooth wheels, and 3 GI sheets are used. This column rod must be straight and very hard. At the bottom of column rod we welded the nut. In the nut we have to put the motors. To this motors we have to put the wheels.

Length of the rod = 35cm

Diameter of the rod = 14.5mm

2.2.3 Motion transmitters:

These are plates attached to the column rod. These transmit the motion of the tooth wheels on the steering column to the column rods. These plates are in the material of GI sheet. These plates have the dimensions 6x6cms. We have to take the long GI sheet and cut into the pieces by using bench sharing vice. After cutting pieces now put the holes by using drilling. This hole is to put the column rod into the holes So the hole must be in the size of exact diameter of the column rod. There are two plates attached to the column rod above and below the two gear wheels. They transmit the motion of required tooth wheel to achieve required steering mechanism i.e., either counter-phase or in-phase mechanism. After putting the plates above and below the tooth wheels welded the plates to the column rod by gas welding. We use gas welding instead of arc welding because the GI sheet is thin and less hardened. For every steering column 2 motion transmitters used. So for the four column rods we have to use the 8 motion transmitters.

Material : GI sheet

Dimensions of the plate : 8x8cm

2.2.4 Phase shifters:

This is used to decide required mechanism to be in use currently i.e., either counter-phase or in-phase mechanism. This is a plate which is present in between the two springs. This plate has also in the dimension of the 6x6cms. We have to take the long GI sheet and cut into the pieces by using bench sharing vice. After cutting pieces now put the holes by using drilling. This hole is to put the column rod into the holes so the hole must be in the size of exact diameter of the column rod.

Based on its position required mechanism comes into play. If it is downwards counter-phase mechanism comes into play and vice versa. We use gas welding instead of arc welding because the GI sheet is thin and less hardened. For every column rod there is on phase transmitter. Totally we using four column rods so four phase transmitters are used in the combination of in-phase and counter-phase steering four wheel drive model.

Material : GI sheet

Dimensions of the plate :8x8cm

2.2.5 Springs:

Spring is an elastic object used to store mechanical energy. Springs are usually made of spring steel. We are using in this is coil spring. A helical spring is compressed for stretched slightly from rest, the force it exerts is approximately proportional to its change in length.

These are present above and below the phase shifters. Their work is to increase friction between the tooth wheels and the motion transmitters by holding them together.

Length of the spring : 6cm
Inside diameter of the spring : 25mm

Fig 12. springs

2.2.6 Tooth wheels:

The tooth wheel upon which radial projections engage a chain passing over it. It is completely different from the gear. These are used in the cycles, motor bicycles etc. These tooth wheels are used to transfer the rotary motion from one shaft to another shaft.These are main parts of the mechanism. They are used to transmit the motion of the steering wheel to the wheels. These wheels will rest on the springs and they will contact the motion transmitters when the springs exerts force on them.

Fig 13. Tooth wheel

Diameter of the tooth wheel : 70mm
No. of teeth : 18
Inner diameter of the wheel : 35mm

The inner diameter of the tooth wheel is much greater than the column rod. So to avoid the horizontal movement of the tooth wheel across column rod, the inner diameter of the tooth wheel is to be reduced. So a wooden piece of outer diameter equal to inner diameter of the tooth wheel and inner diameter equal to the outer diameter of column rod is inserted in the tooth wheel. After putting the wooden piece into the tooth wheel we have to weld the tooth and the bearing because there is no motion between them. For every column rod at the top and bottom tooth wheels are weld by using gas welding technique. In this model we are using four column rods so for every column rod 2 tooth wheels so totally 8 tooth wheels are using. In the main shaft steering column rod 3 tooth wheels are used. Once we rotated the tooth wheel does not rotates, the steering column should rotates.

2.2.7 Gears:

In the present model, we use counter-phase mechanism along with in-phase steering. In counter-phase steering the front wheels and rear wheels must turn in opposite direction. So there is a need to reverse the motion of the steering for the rear wheels, to achieve this pair of spur gears are used.

Fig 14 . Gears

In the current model, two gears are used, the first wheel has a smaller and bigger wheel attached to each other and second wheel which is bigger. The two gear wheels are attached to two tooth wheels by using a steel pipe to transmit motion to the tooth wheels in the steering column and to take input from the steer rod.

Specifications of gear:

No. of teeth in bigger wheel : 72

No. of teeth in smaller wheel : 16

2.2.8 Chains:

A chain is a roller chain that transfers power and motion from the one tooth wheel to another wheel. These chains are made up of cast iron and different alloys.

As we are using tooth wheels e require a chain to complete the mechanism.

Three chains are used in this model

Chain 1 : To connect all the tooth wheels of in-phase steering mechanism.

Chain 2 : To connect the gear wheels and the steer rod

Chain 3 : To connect gears with tooth wheels of rear steering columns for counter-phase Steering mechanism.

Fig 15. Chains

2.2.9 Bases:

This is the main part due to which the entire mechanism stays rigid. All the steering columns, steering rod and gears rest on this base. It consists of two flat plywood plates at a distance. The two plywood's are kept stable by using bolt and nut arrangement. All the steering mechanism lies between these two plywood's.

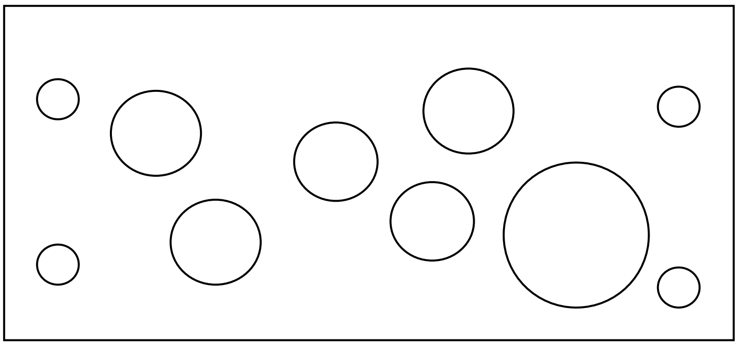

Fig 16. Representation of base

Dimensions of the plywood : 55x35cm

In this plywood we have to put the holes for putting the column rods. By using 30mm drill bit we put a hole for putting main steering column rod. At the centre of the plywood by using 12mm drill bit put a hole for Ackerman's steering column rod. At the corners by using 8mm drill bit put holes for full threaded screws. Total four holes for steering column rods, one Ackermann column rod, and four screw threaded holes are put on plywood. The same procedure repeats on another plywood also. We using two plywoods' because for the model should be in the straight direction and protection of the parts.

2.2.10 Electric Motors: Electric motors are produce linear or rotary motion and should be distinguished from devices such as magnetic solenoids and loud speakers that convert electricity into motion.

Fig 17. electric motors

Specifications:
Torque: 1N/m.
Rpm: 500rpm.
This motors having one nut. This nut is welded to the bottom of the steering column rod by arc welding. In the nut the motor should be fixed. To this motors the wheels are fixed. For four steering column rod we used four electric motors.

2.2.11 phase shifting mechanism:

The phase shifting mechanism is used to move the phase shifter up and down to achieve the required mechanism. Two identical phase shifting mechanisms are used. They are supported the nut and bolt arrangement used to support the base.
It consists of four rods. Two rods are placed one above the other and they are welded to a mild steel piece. Four pieces of this kind of equipment is made.
A phase shifting mechanism to one side is made by welding two things mentioned above by placing phase shifters in the gap between the rods.
A nut is welded to the phase shifters at each end and they are passed through the bolts fitted to the base.

Rods used:

Length of the rod	:	52cm
Diameter of the rod	:	5mm
Material	:	cast iron
Dimensions of the plate	:	5x5cm
Inner diameter of the nut	:	8mm
Outer diameter of the bolt	:	12mm

2.2.12 Steer rod:
It is the main shaft steering column rod. It acts as the steer rod. It consists of three tooth wheels. One tooth wheel is put on the top of the steer rod. And second tooth wheel is welded at the bottom of the first tooth wheel. These tooth wheels are linked to the steering column rods by using chain linkage mechanism. Third tooth wheel also welded to the steer rod. These welding process are gas welding processes.

Fig 18. Steer rod

When we rotate the steer road the four steering column rods also rotates. The steer rod having diameter 30mm. The steer rod put into the bottom plywood and the upper plywood.

2.2.13 Wheels:

A wheel is a circular component that it is intended to rotate on an axial bearing. The wheel is one of the main components of the wheel and axle. Wheel enables the efficient movement of an object across a surface where there is a force pressing the object to the surface

Fig 19. Wheel

The wheels are attached to the motors. For every steering column rod one motor and o that one wheel is arranged. So that in this model we are using four column rods so four motors and to that four wheels arranged.

3. DESIGN AND MECHANISM OF STEERING:

3.1 Design of Ackermann steering mechanism:
Ackerman steering is a geometric arrangement of linkages in the steering of a car or other vehicle designed to solve the problems of wheels on the inside and outside of a turn needing to trace out circles of different radius. The intention of Ackerman's steering is to avoid the need for tires to slip sideways when following the path around a curve. This solution is for all wheels to have their axles arranged as radii of a circle with common centre point. As the rear wheels are fixed, this centre point must be on a line extended from the rear axle.

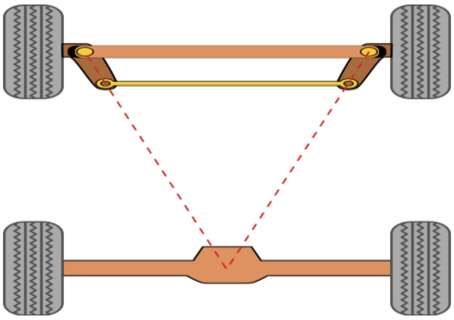

Fig 20. Ackerman's steering mechanism

To the design the Ackermann steering a line is drawn joining the front steering columns and the midpoint of the line joining the rear steering columns. Tie rods are connected to the stub axles at the end of stub axles located on this line.

3.2 Model Preparation: After the completion of fabrication of parts assembly has to be done. Assembly of the fabrication parts is in different stages. Assembly should be done carefully. While doing assembly the fabrication of parts should not be damage.

3.3 Arrangement of steering column: First we take the plywood and the put the holes in the required dimension manner. While putting the holes we have to concern about the holes dimensions. In the first we drill the holes of 12.5mm and after we enlarge the holes to the steering column rod by filing. After put hole of main steers rod. This rod have large diameter than column rods. So take the 30mm drill bit and put the hole. We have concern about the holes because the rods freely rotate and move in the holes. After putting the holes we have to put the steering column rods and once check that the steering column rods are freely moving. The steering column rods are before fabricated and explained above.

Fig 21.arrangement of steering columns

The steering column rods are not damage while putting into the holes. because all steering column rods are accurate dimension. These column rods are fabricated by gas welding and put the tooth wheels into these rods. After put column rods into the bottom plywood holes, we put the phase changing arrangement. This phase changing arrangement contains total threaded screws, metal strips welded with two rods and having nut.

Fig 22 : Arrangement of phase shifting

Now there are four metal strips with containing nuts and these arrangements are fixed in between the two column rods. These column rods are in the linear position and with one side of the plywood. This phase changing arrangement is done on the phase transmitter. These two rods are put aside of rod and now the strips are welded by arc welding technique. This same procedure is repeated on the other side of steering column rods also. In these nuts we have to put the total threaded screws and also it moves to the bottom plywood also. At the down of bottom plywood we welded the washers for the steering column rods to put stable and the nuts for treaded screws for restricting the motion. When these nuts are moving threaded screw will be move in up and down ward direction.

3.5 Arrangements of Ackerman's mechanism:

After arranging the phase transmission put the meshing gears in the middle line of the base and at the side of the base. From the steer rod a chain linkage is passed to these meshing gears and for rotating in-phase direction of moment. Fabrication of these gears is very difficult and these gears are welded with tooth wheel by using gas welding technique. A rod is passed in between these gear and tooth wheel. This is put on the base and it also freely rotate on the base so we have to put a hole on the plywood also. Another gear with same dimension also fabricated and this have a small gear. This gear is meshed up with the small gear. When the small gear rotates the bigger also rotates and it has tooth wheel with chain linkage mechanism.

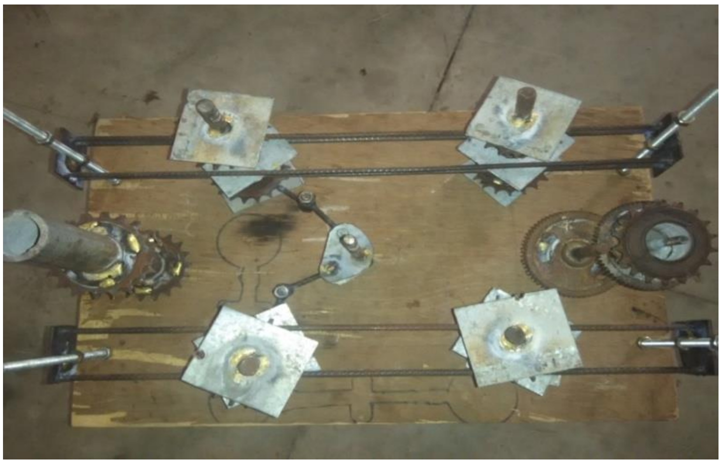

Fig 23: arrangement of Ackerman's steering mechanism

After arranging the meshing of gear mechanism we have to put the Ackerman's steering mechanism. Because Ackerman's steering mechanism is the best and advantageous also. It doesn't slide in turnings. Fabrication of Ackerman's steering mechanism is very difficult. While doing this we have noted the dimensions very carefully. The Ackerman's angle should be in between 45-60 degrees. We put two GI sheets at a distance apart. In these sheets put a hole by using gas welding because to put the Ackerman's column rods into the base plywood. In this we have to weld two nuts with a small iron rod to the front wheel column rods. The same process to the GI sheets also. With help of screw threaded and nuts these Ackerman's steering mechanism is fitted. Before put hole on the dimension of Ackerman's column rod on the base plywood.

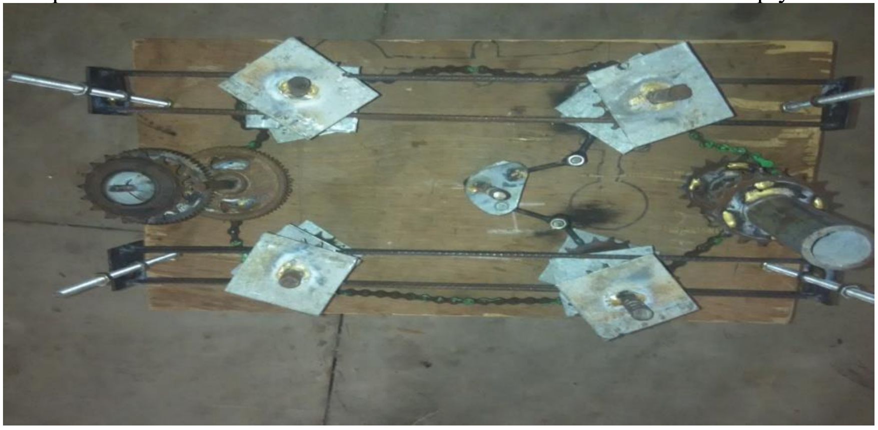

Fig 24 : combined in-phase and counter phase mechanism.

After putting the Ackerman's, meshing gear mechanism and phase changing mechanism we put the chain perfectly. The bottom tooth wheels are fixed with chain linkage for in-phase mechanism. When the steer rod rotates the tooth wheels are rotated in the phase direction. After that bottom of column rods are welded with motor nut.

Now screw the motors in the nuts. After that the wheels are attached to the motors. Now put the upper base plywood. It has also holes in the same dimension of the bottom base plywood. Now carefully put the upper base and fix the plywood holes to the steering column rods, steer rod, and the threaded screws. Now fix the nuts on the threaded screws tightly on upper base. This plywood helps the all parts are in standard direction and the model moves freely without vibrations. The disadvantage is friction producing is more because the material is wood. In the assembly we have to concern on while rotating steer rod only the column rods with tooth wheel also rotates. So on doing gas and arc welding we have to pay concern on them.

4. MECHANISM:

In combination of In-phase and Counter-phase steering model consists of three mechanisms.

1) In phase-steering mechanism
2) Counter-phase steering
3) Phase changing mechanism

4.1 In phase-steering mechanism:

In-phase steering mechanism , where by the rear wheels rotate in the same direction as the front wheels.
In this mechanism all the four wheels must rotate in same direction with same angle of rotation. So, a chain is connected to all the tooth wheels located at the top of the steering corner and to the tooth wheel at the top of the steering rod.

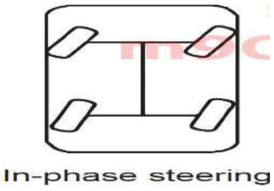

Fig 25. in –phase steering mechanism

When the steering rod is rotated, all the four tooth wheels are connected to the chain are rotated in same direction. Thus, the In phase-steering mechanism is obtained.
In – phase steering mechanism obtains high sppeds. At high speeds, turning the rear wheels through an angle opposite to the front wheels might lead to vehicles in stability and is thus unsuitable. Hence the rear wheels are turned in the same direction of front wheels in the four wheel steering mechanism.

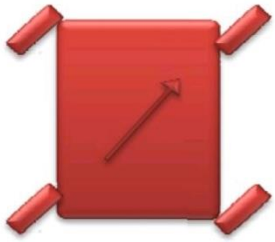

Fig 26. In-phase mechanism with high speeds

4.2 Counter-phase steering:
Counter phase steering is used by single track vehicle operators, such as cyclists and motor cyclists to initiate a turn toward a given direction by momentously steering counter to the desired direction.In counter-phase steering mechanism the rear must rotate in the opposite direction to that of to the front wheels. So,gear wheels are used to reverse the direction.
In this mechanism, Ackermann steering is used for the front wheels. So a chain is connected to the steering rod and to the Ackermann steering column.

Fig 27. Counter- phase steering mechanism.

Another chain is connected to the steering rod and to the smaller gear wheel. The bottom tooth wheels of the rear steering column are connected to the bigger gear wheel using a chain.
Working: When the steering rod is rotated the front wheels are rotated according to the Ackermann mechanism. Also, a change of direction occurs due to the gear wheels and the tooth wheels connected to the bigger gear wheels are rotated in the opposite direction. Thus, counter-phase steering is obtained. Counter steering is also used by vehicles to steer on the opposite direction of the turn to maintain control in response to significant rear wheel.

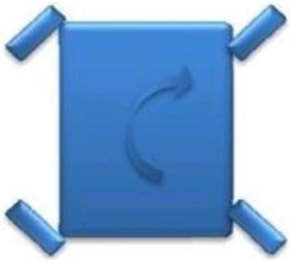

Fig 28.counter-phase mechanism with low speeds

Counter-phase steering occurs at slow speeds. At slow speeds rear wheels turn in opposite direction to that of front wheels. This mode is navigating through hilly areas and in congested city where better cornering is required for U turn and tight streets with low turning circle which can be reduced.

4.3 Phase changing mechanism:

This mechanism is used to switch between the In phase and Counter-phase mechanisms. It works on the principle of screw jack. When the bolt is rotated the phaseshifting rods moves towards and forwards over the bolt.When the phase shifting rods move upwards the upper tooth wheels of the steering column come into contact with the motion transmitter's results in In-phase steering.

When the phase shifting rods move downwards the lower tooth wheels of the steering column come into contact with the motion transmitter's results in Counter-phase steering.

4.4 Advantages :

Superior controlling stability:

The vehicle cornering behavior becomes more stable and controllable at high speeds as well as on wet skippering road surfaces.

Improved steering response and precision: The vehicle response to steering input becomes quicker and more precise throughout the vehicle enter speed range.

High speed straight line stability:The vehicles straight line stability at high speeds is improved. Negative effects of road irregularities and cross winds on the vehicles stability are minimized.

Improved rapid lane changing maneuvers:This is stability in lane changing at high speed is improved. In high speed type operation become easier. The vehicle less likely to go into a spin even in situations in which the driver must take a sudden and relatively large change of direction.

Smaller turning radius: By steering the rear wheels in the opposite direction the front wheels at low speed, the vehicle turning circle is greatly reduced. Therefore vehicle maneuvering on narrow roads and during parking become easier.

Controlling:Controlled quad steer can be switched on and off and has an effective trailer towing mode.

4.5 Disadvantages:

This model due to constructive of many components the system becomes more expensive and complex. The system includes many components there is a always a chance to get any of the part in active, thus the system becomes inoperative.

4.6 Applications:

Parking:

During a parking a vehicles driver typically turns the steering wheels through a large angle to achieve a small turning radius. By counter phase mechanism of the rare wheels of four-wheel system realizes a smaller turning radius then is possible within the two wheel steering system. As a result, small turning radius in parking.

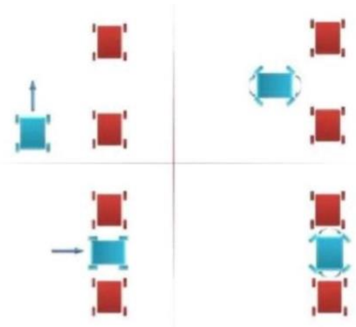

Fig 29 : In-Phase Lane changing

Junctions:

On a cross roads or other junction where roads intersect at 90degrees or tighter angles, counter phase steering mechanism of the rear wheels causes the front and rear wheels to follow more path or less path. As a result the vehicle can be turned easily at a junction.

Slippery road surfaces:

During steering operation on low friction surfaces, steering of the rear vehicles suppress sideways drift of the vehicles rear end as a result the vehicles direction is easier to control.

Narrow roads:

On narrow roads with tight bends counter phase steering of the rear wheels minimizes the vehicles turning radius there by reducing side to side rotation of steering wheels.

High speed lane changing:

Another driving maneuver that frequently becomes cumbersome and even dangerous is changing lanes at fairly high speeds. Although this is less steering intensive, this is does not require a lot concentration from the driver since he has to judge the space and vehicles behind him. Here is how the mode can simply the action

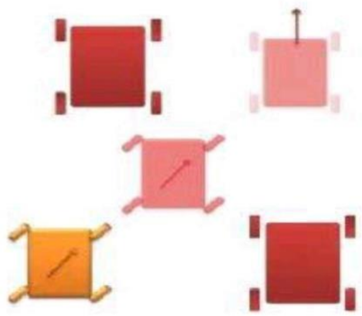

Fig 30: high speed lane changing

5. RESULTS:

Turning angle in general in-phase steering mechanism :55-60^0

Turning angle in the present in-phase steering mechanism : 75-80^0

Turning angle of front wheels in general counter-phase mechanism: 12-26^0

Turning angle of rear wheels in general counter-phase mechanism: 15-20°

Turning angle of front wheels in present counter-phase mechanism: 15-30^0

Turning angle of front wheels in present counter-phase mechanism: 45^0

Type of steering	Turning angle	General two wheel steering mechanism	General four wheel steering mechanism	Combined in-phase and counter-phase mechanism
In-phase steering	Front wheels	60^0	60^0	$75\text{-}80^0$
Counter-phase steering	Front wheels	No counter phase mechanism	$12\text{-}26^0$	$15\text{-}30^0$
In-phase steering	Rear wheels	No movement to rear wheels	Based upon speed i.e., $5\text{-}10^0$	90^0
Counter-phase steering	Rear wheels	No movement to rear wheels	$5\text{-}10^0$	Up to 15^0

Table-2 : observations of inphase and counterphase mechanisms

Extra movements added to the vehicle due to the usage of this mechanism:

- Lateral movement of the car.
- Rotation of car at a fixed point.
- Near neutral steering
- Superiorcorneringstability.
- Improvedsteeringresponsivenessandprecision.
- Highspeedstraight linestability.
- Notableimprovementinrapidlane changing maneuvers.
- Smaller turningradius and tightspace maneuverability atlowspeed.
- Relativewheelanglesandtheircontrol.

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