SIX-BAR STEERING MECHANISM

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ABSTRACT

In this paper a steering system is designed for a Low weight SUPRA or BAJA car, which adopts a rack-and-pinion steering mechanism. The theoretical modelling of the system as well as the derivations of optimal parameter values are presented here. First, the steering angles of the front wheels are derived based on the geometry of the steering system. Second, linear equations representing the axial lines of the front wheels are derived based on the steering angles of the front wheels. Then the Ackermann steering

Errors are computed on the axial line of the rear wheels using the axial lines of the front wheels. Finally, the optimum values of the parameters of the steering system are obtained via computer programming such that the obtained values of the parameters minimize the Ackermann steering error on the axial line of the rear wheels.

Keyword: - *Steering mechanism, Rack and pinion, Ackermann steering*

1. INTRODUCTION

In this paper, the steering mechanism of a vehicle is considered as a planar linkage. The optimum distance from the front wheel axle to the steering rack axis is obtained such that the steering system satisfies the Ackermann principle with minimum steering error on the axial line of the rear wheel. First, the steering angles of the front wheels are derived based on the geometry of the steering system. Then linear equations representing the axial lines of both front wheels are obtained based on the steering angles, the distance between the left and right wheels, and the distance between the front and rear axles. Finally, the steering error, based on the Ackermann principle, is computed as a function of the displacement of the steering rack and the distance from the front axle to the steering rack axis.

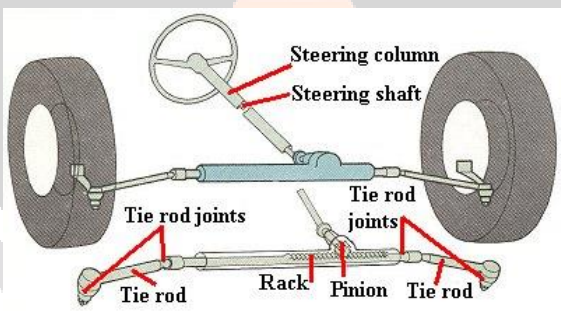


Fig. 1: Rack and pinion steering mechanism

2. STEERING SYSTEM

2.1 Ackerman principal of steering design

Figure 2 shows the Ackermann principle, in which θl and θr denote the left and right steering angles, respectively; *lw* and *la* denote the distance between the left and right wheels and the distance from the front axle to the rear axle respectively. The Ackermann principle requires that the axial lines of all the wheels should meet at the same point which represents the centre of turning. A steering linkage must be designed based on the Ackermann principle to ensure pure rolling and to minimize the skidding and thus wear of the tires. Rather than the preceding "turntable" steering, where both front wheels turned around a common pivot, each wheel gained its own pivot, close to its own hub. While more complex, this arrangement enhances controllability by avoiding large inputs from road surface variations being applied to the end of a long lever arm, as well as greatly reducing the fore-and-aft travel of the steered wheels.

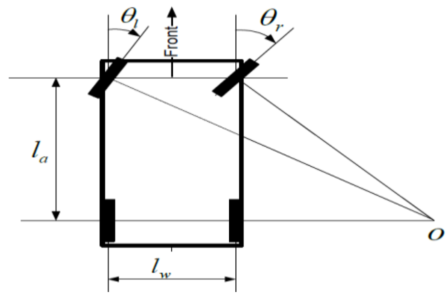


Figure 2

A linkage between these hubs pivots the two wheels together, and by careful arrangement of the linkage dimensions the Ackermann geometry could be approximated. This was achieved by making the linkage not a simple parallelogram, but by making the length of the tie rod (the moving link between the hubs) shorter than that of the axle, so that the steering arms of the hubs appeared to "toe out". As the steering moved, the wheels turned according to Ackermann, with the inner wheel turning further. If the track rod is placed ahead of the axle, it should instead be longer in comparison, thus preserving this same "toe out".

2.2 Ackermann steering design

The Ackermann principle states that the extended lines from the steering arms meet in the middle of the rear axle as shown in Fig. 3

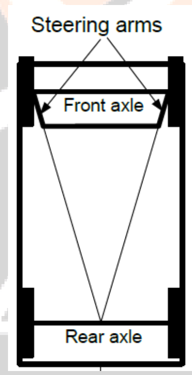


Figure 3

A rack-and-pinion steering mechanism, shown in Fig. 4, is used in this steering design, in which the distance from the front axle to the rack axis is considered a design parameter.

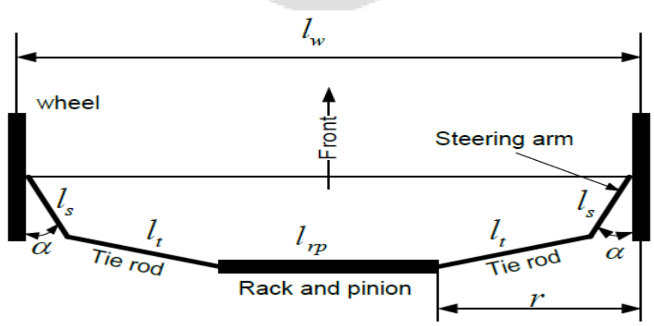


Figure 4: Rack and Pinion

A simple approximation to perfect Ackermann steering geometry may be generated by moving the steering pivot points inward so as to lie on a line drawn between the steering kingpins and the center of the rear axle. The steering pivot points are joined by a rigid bar called the tie rod which can also be part of the steering mechanism, in the form of a rack and pinion for instance. With perfect Ackermann, at any angle of steering, the center point of all of the circles traced by all wheels will lie at a common point. Note that this may be difficult to arrange in practice with simple linkages, and designers are advised to draw or analyses their steering systems over the full range of steering angles. Modern cars do not use pure Ackermann steering, partly because it ignores important dynamic and compliant effects, but the principle is sound for low-speed maneuvers.

Some racing cars use reverse Ackermann geometry to compensate for the large difference in slip angle between the inner and outer front tyres while cornering at high speed. The use of such geometry helps reduce tyre temperatures during high-speed cornering but compromises performance in low-speed maneuvers.

2.3 Design Objective

The design objective in this work is to find an optimum value of the distance between the front axle and the rack axis so that the optimum value results in minimum steering error on the line of rear axle.

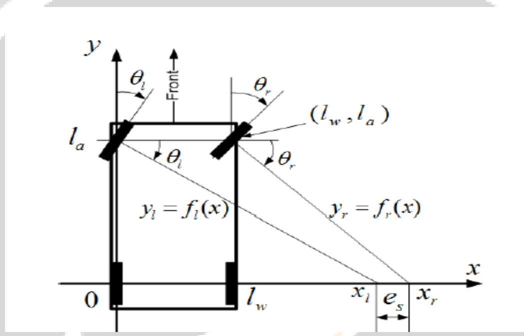


Figure 5

The steering error is to be made as small as possible. .The error found out by the difference of the actual six bar mechanism and the basic four bar steering mechanism is to be minimal.

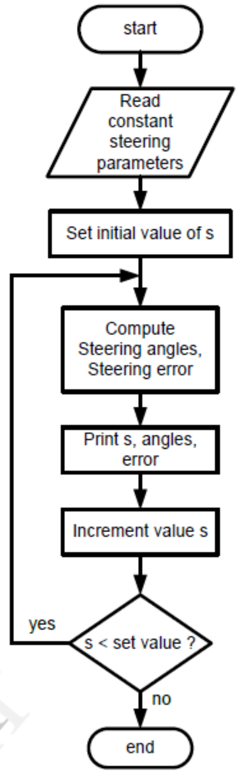
3. EFFECTS OF STEERING ERRORS

The above Figure shows the coordinate system that defines the steering error on the axial line of the rear wheels, based on the Ackermann principle. In other words the error can be defined as the distance between the axis of rotation of the wheels when measured along the axis of rotation of the rear wheels. As we have been using a non-standard Ackerman system because or constrains of other parameters such as the depth of hub, off the shelf Ackerman arms, or any other link. If this errors are not rectified or eliminated, this may cause many adverse effects on the ergonomics of the vehicle. As the vehicle might be able to carry less speed into the corners. This happens majorly due to incorrect instantaneous centres of rotations of the wheels, which further results in the skidding of the tires, which increases the slip angle of the vehicle and reduces the life of the tire drastically.

Figure 6

4. PROCEDURE FOR COMPUTATION OF STEERING ERROR

1. As we start the design procedure for the steering mechanism we set the initial constant parameters of the vehicle such as wheelbase, track width, rack length.
2. Then we also take in consideration the parameters which have to be fixed due to the constraints of the other systems or stock parts.
3. Then we take an initial guess of the distance between the rack axis and the kingpin to kingpin axis of the wheels
4. According to it we find out the lengths of the tie rods of the mechanisms
5. Further we analyses the steering error that has occurred due to the constrains and the set parameters
6. We then further try out different iterations so as to reduce the steering error and increase the steering performance of the system
7. If the iterated values gives us a steering error greater than acceptable we then assume another length between the rack and the wheel axis
8. Repeat the process until we get an acceptable value of the steering error
9. After getting a rough value of the geometry of the mechanism we need to optimize the steering mechanism by further iterating the values taking in consideration the forces and the efforts required by the operator.



5. RESULTS AND ITERATIONS

	A	B	C	D	E	F	G	H	I	J
1	WHEELBASE	KINGPIN TO KINGPIN	ACKERMAN ARM RADIUS	RACK TRAVEL()	TIEROD LENGTH	THETA	PHI	PHI IDEAL	RACK TO AXEL	RACK LENGTH
2	60	45	3.93	1.57	14.55109592	1	0.9890097	0.9870804	3.6811	11.944
3	60	45	3.93	1.57	14.54618376	2	1.9564905	1.9489956	3.6811	11.944
4	60	45	3.93	1.57	14.54202516	3	2.9030631	2.8867377	3.6811	11.944
5	60	45	3.93	1.57	14.5386451	4	3.829278	3.8012729	3.6811	11.944
6	60	45	3.93	1.57	14.53606839	5	4.7356237	4.6935398	3.6811	11.944
7	60	45	3.93	1.57	14.53431967	6	5.6225328	5.5644488	3.6811	11.944
8	60	45	3.93	1.57	14.53342338	7	6.4903881	6.414881	3.6811	11.944
9	60	45	3.93	1.57	14.53340375	8	7.3395268	7.2456887	3.6811	11.944
10	60	45	3.93	1.57	14.53428475	9	8.1702456	8.0576948	3.6811	11.944
11	60	45	3.93	1.57	14.5360901	10	8.9828039	8.8516932	3.6811	11.944
12	60	45	3.93	1.57	14.53884322	11	9.7774272	9.6284492	3.6811	11.944

Table 1: Result and Iterations

5.1 After Multiple Iteration The Finalised Dimensions Were:

- RACK LENGTH= 11.944 INCHES
- ACKERMAN ANGLE=30.1450DEGREES
- ACKERMAN ARM RADIUS=3.93 INCHES
- TIEROD LENGTH=14.55 INCHES
- WHEELBASE=60 INCHES
- TRACK WIDTH=45 INCHES

6. ADVANTAGES AND DISADVANTAGES

1. **Disadvantages of four bar mechanism**
    - Moving member inside the cabin.
    - Improper meshing of rack and pinion.
    - Unable to adjust bump steer.

2. **Advantages of six bar mechanism**
    - Absorbs road shocks.
    - Minimum efforts.
    - Helps in proper meshing of rack and pinion.
    - Less moving parts inside the cabin.
    - Adjustment of bump steer can be done.

3. **Disadvantages of six bar mechanism**
    - More number of links
    - More calculations
    - Not an exact steering mechanism
    - Small change in variables impacts largely on the mechanism

7. CONCLUSION AND FUTURE WORK

The rack and pinion steering system, designed for an SELU Mini Baja car, was constrained to use off the shelf commercial assemblies of a rack-and-pinion assembly and a steering knuckle assembly designed for go-carts. Due to this constraint the design cannot be Ackerman compliant, therefore the design must be optimized using the rest of the system geometry parameters.

The optimum value of the distance between the front axle and the steering rack axis has been systematically obtained so that the optimum value minimizes the Ackermann steering error on the axial line of the rear wheels.

This work serves as a guideline for the steering design of other Mini Baja cars or custom-built cars when production constraints do not make it possible to meet Ackerman compliance and thus optimization of other design parameters is necessary. The contribution is the methodology used to obtain the optimal design parameters using numerical methods.

8. REFRENCES

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