جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

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Senior Design Project Report

Steering System

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

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Abstract:

Lots of people drive the car and rotate the steering wheel thinking that this is the only mechanism to change the direction of the car, without knowing how the car actually have changed the direction. Nevertheless, the steering wheel is not the only part that change the direction of the car many parts are eventually involved in changing the direction of the car are called the steering system transmits which intent to convert it the rotational motion of the steering wheel into the linear motion that turns the wheels and guides your path. Steering is essential in cars, airplanes, and motorcycles, because it is an important way for the vehicle to be directed in the correct direction and without difficulty for the driver. It is made up of components, linkages, to allow any vehicle to follow the required path. There is a power steering through which it helps and strengthens the driver to steer the car, and there are two types of power steering, which is hydraulic system and electric system. It's energy controlled by the steering mechanism so that there is little effort on the driver to direct the vehicle in any direction he wants and without any difficulties or excessive force.

Acknowledgments:

Our project has reached the goal that all of our group members have worked days over days to achieve this work on time, despite the disease that is spread all over the world we haven't stopped our work. Moreover, many thanks to our advisor Dr. Mohammed Asad to his patience in explaining the subject to us he has the favor of our knowledge of the subject, his continuous advice and effort in every part that we worked on was extremely helpful, His assistance is kindly appreciated, and we are extremely thankful for everything he has done. In addition, we would like to appreciate the efforts of Dr. Mohamed ElMehdi Saleh for his constant availability to answer our questions and inquiries; his efforts are very much appreciated. Moreover, we would like to express our appreciations and respects to the entire Mechanical Engineering senior project groups at Prince Mohammed Bin Fahd University for their hard work and their ambitions to get the expected result from them as they done. Finally, big thanks to our group members, the leader Hamad alnaimi for his constant and interest in reviewing all work done to make sure everything is intact, Abdurrahman alshammari for his continuous ambition in achieving the best outcomes and results by keeping track of time and quality of reports and solid work, rashid aldossary for his ability in searching also finding the engineering standards for our work, mohammed alyami for all the

efforts he has done to reach the suitable calculations for the car , and Abdullah alsoqour for his great work in the cad design also to his effort managing the start of manufacturing the work.

List of Tables:

Table of Contents

List of Acronyms (Symbols) used in the report:

Symbol	Definition
D	**Diameter**
ρ	**Density**
m	**Mass**
A	**Area**
F	**Force**
σ	**Stress**
T	**Torque**
L	**Length**

Chapter # 1: Introduction

1.1 Project Definition

Lots of people drive the car and rotate the steering wheel thinking that this is the only mechanism to change the direction of the car, without knowing how the car actually have changed the direction. Nevertheless, the steering wheel is not the only part that change the direction of the car many parts are eventually involved in changing the direction of the car are called the steering system transmits which intent to convert it the rotational motion of the steering wheel into the linear motion that turns the wheels and guides your path.

1.2 Project Objectives

The steering is founded in any automotive vehicle, the following are the main objectives of the project:

- Design and development of a reliable steering mechanism.
- Following the international standards and codes.

- Use these international standards and codes to custom designed solar car.

1.3 Project Specifications

- The axial length is 1330 millimeter, in meters 1.33
- A multiple force, applied through the hydraulic power steering systems, will affect the steering wheels.
- The rotation of the steering wheel is also can be considered under the newton's second law of rotation (the moment of inertia about the rotation axis times the angular acceleration. We can generalize this equation to a rigid body rotating about a fixed axis).
- Applying self-force on the steering wheel that will be a transmitted force to the rod that will directly affect the axial steering, which will affect the angle of the direction and the angle of the rotation.

1.4 Project Applications

The steering system is used in various maneuvering machines, and has an important role in many applications:

- Steering system is founded in all the automotive cars.
- Steering system is founded in goods maneuvering machines.
- Steering system is founded in watercrafts.
- Steering system is founded in Aircrafts and hovercrafts.

Chapter # 2: Literature Review

2.1 Project Background

Steering is essential in cars, airplanes, and motorcycles, because it is an important way for the vehicle to be directed in the correct direction and without difficulty for the driver. It is made up of components, linkages, to allow any vehicle to follow the required path. There is a power steering through which it helps and strengthens the driver to steer the car, and there are two types of power steering, which is hydraulic system and electric system. It's energy controlled by the steering mechanism so that there is little effort on the driver to direct the vehicle in any direction he wants and without any difficulties or excessive force.

2.2 Previous Work

Capstone Project 1: Dynamic analysis of a rotating stepped shaft with and without defects

Overview:

This is a project by Jweeg, Alnomani, and Mohammad (2020), where a model of the rotor of a given centrifugal pump shaft is used to carry out an analysis of the impact of cracking on the natural frequency of the rotor. The students hold that this study is important because any change in natural frequency for any rotor may be an indication of a considerable progress of cracks deep enough to bring about fracture.

Experiment:

For the experiment part, the students used a carbon steel shaft to simulate a stepped shaft. The carbon steel shaft was manufactured with a Young's modulus of 210 x 10^9 N/m^2 and a density of 2.19 kg. Figure 2 shows the dimensions of the carbon steel shaft. Figure 2 also shows the selected locations of cracks.

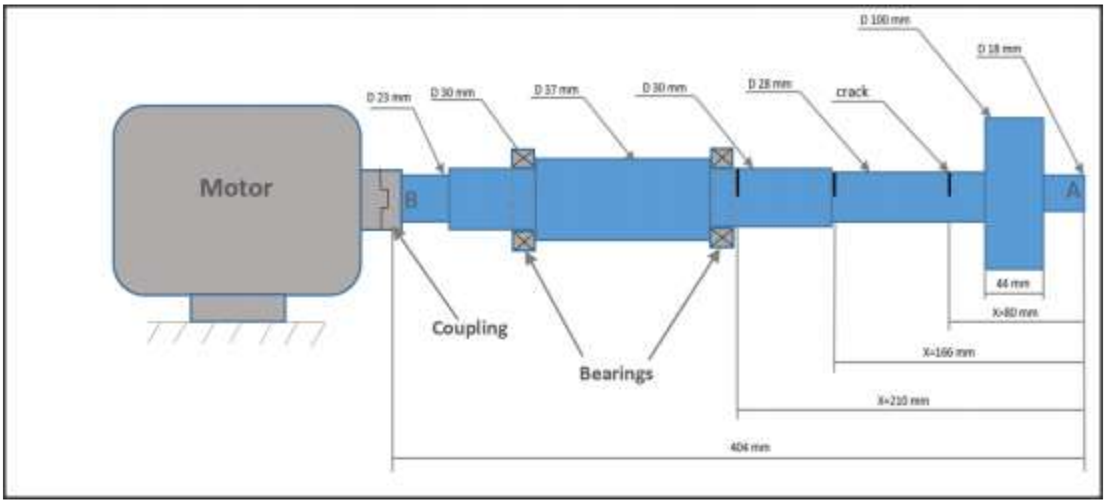


Figure 2: Crack position on the shaft model

The test rig used by the students was manufactured to simulate the operation of real rotors in such devices as steam turbines and centrifugal pumps. The students then used the test rig to calculate and examine critical speeds, as well as natural frequencies and forced excitation response to unbalance forces or external shaking load. In the test rig, the impact hammer is used for generating vibration of excitation external force in the model. Figure 3 shows the test rig.

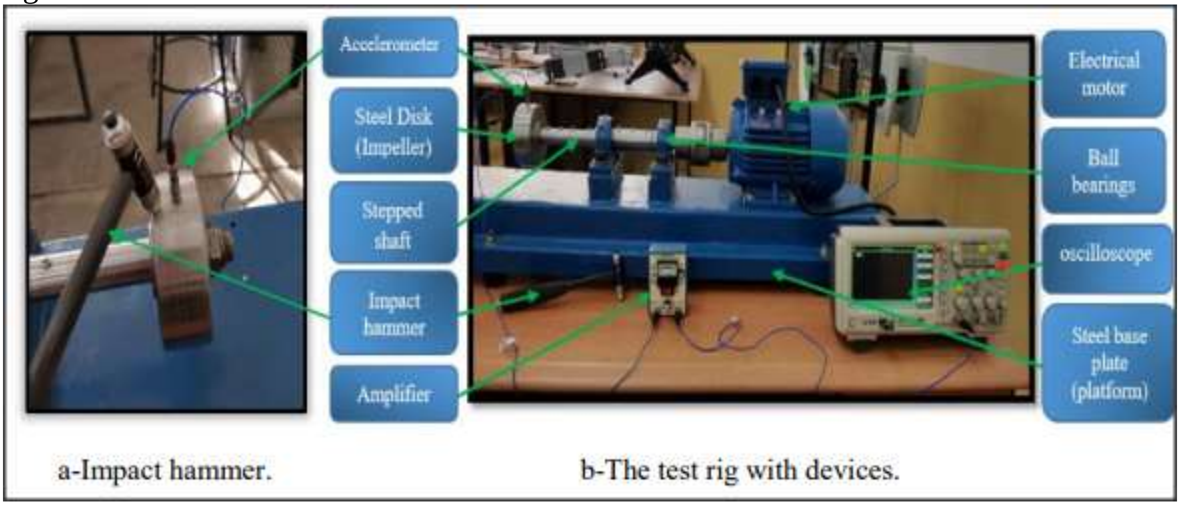


Figure 3: Experimental test rig for the tested stepped shafts

The students used an accelerometer ADS 1202cl model and a maximum frequency of 200MHz together with an appropriate oscilloscope and amplifier. The accelerometer was then installed at six distinct points on the test rig, one on the bearing, another on the disk, and the rest in separate points on the shaft. Figure 4 shows a complete accelerometer installation.

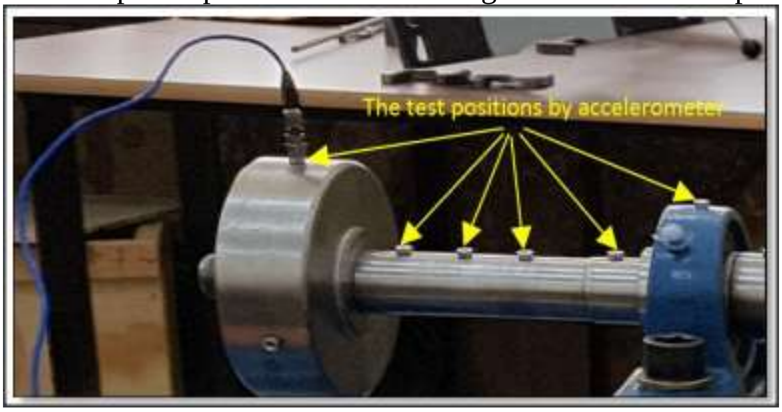


Figure 4: The test positions on the stepped shafts

Capstone Project 2: Experimental Analysis of Cracked Turbine Rotor Shaft using Vibration Measurements

Overview:

This is a project by Mansoor, Al-Shammari, and Al-Hamood (2020), where the students attempt to analyze a cracked turbine rotor shaft using various vibration measurements.

Experiment:

The students used the test rig to simulate the dynamics and vibration of the gas turbine rotor, which produces a capacity of 123.5 MW. The test rig was manufactured by the United States company GE and was designed in to imitate the conditions present in the real rotor gas power station. The disk and the shaft were designed and set with a reduction ratio of 1 to 10 to the initial dimensions of the rotor. Figure 4 shows the test rig.

Figure 3: Layout of the test rig

The students also added an air system to the lubrication system so that the air is compressed to the oil. The oil then reaches the bearings at a constant pressure, thereby eliminating the oscillation pressure when the pump is in use. As a result, there is an improvement in accuracy. Figure 4 shows the combination of the air system and the lubrication system, whereas figure 5 shows the schematics of the lubrication system.

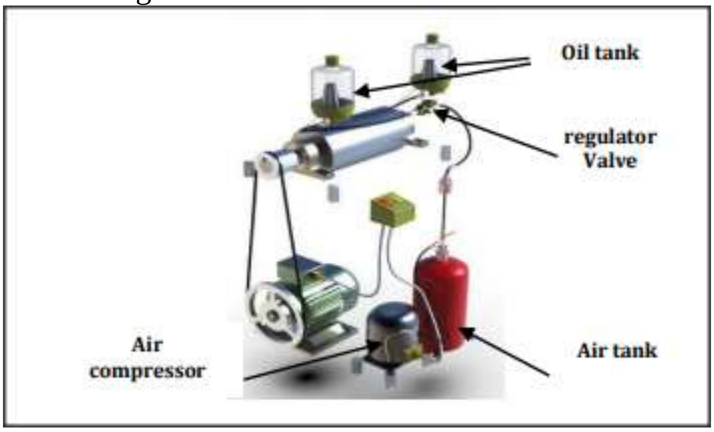


Figure 4: The air and lubrication systems of rotor

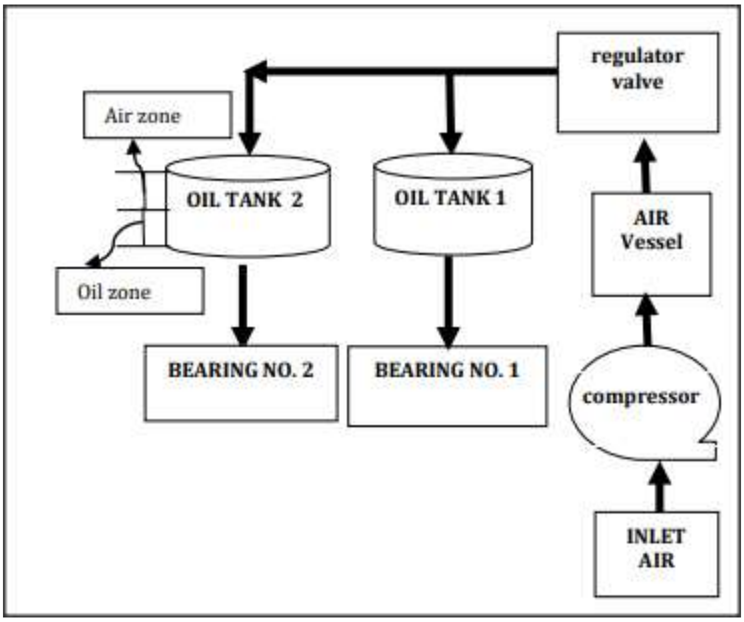


Figure 5: Layout of the lubricant system

Project 3: Dynamics similarity design and verification of rotor system

Overview

This is a project by Chen, Luo, Han, Kuang, Zheng, and Liao (2019), and is aimed at studying the dynamics similarity of the original model to a normal model.

Experiment

The original model comprises a disk and a rotating shaft, as well as two bearings with elasticity. The rotor system's finite element model is determined based on the rotor system's geometric model. The disk is simulated by MASS21, the rotating shaft is simulated by BEAM188, and the bearing is simulated by COMB1214. Figure 6 shows the original model, whereas figure 7 shows the finite element model.


Figure 6: Assembly of rotor system

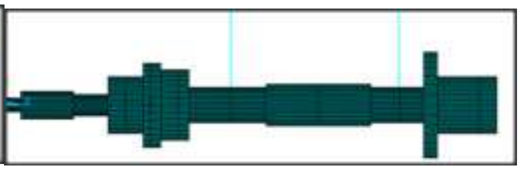


Figure 7: Finite element model

Chapter # 3: System Design

3.1 Design Constraints and Design Methodology

Geometrical Constraints:

Geometrically, designing a good steering wheel requires proper formulation for good turn reactions. The effectiveness of the steering is tested during corner negotiations hence the need for accurate geometrical designs. The functions of the steering cannot be achieved from the geometric designs. The load of the vehicle, the handling, and stability of the car and control of the front tires are parameters, which may not be determined at the geometrical design stage. The scrub radius and the castor angle should be balanced by the weight of the vehicle to be controlled by the steering wheel. However, the mathematical computation at the geometrical design assumes uniformity in speeds and the possibility of self-returning action. The speeds for corner negotiation determine the geometrical approach.

There is a limitation on the use of either Ackermann or parallel steer geometry in the design process; the standard steer angle Θ= R/L where R defines the wheelbase, and L defines the radius of turn. The geometrical design of the steering wheel is limited by the existing parameters for control. For special cars with unique weights, the designing of steering wheels to meet the desired standards require additional computations hence chances of error at the geometrical design stage.

Sustainability:

The sustainability of the steering wheel is defined by two parameters; first, it is durability, and the other is affordability. The steering wheel would be durable, depending on the speed of turning and the weight of the vehicle. The sustainability of steering based on the period of service is achieved by balancing the weight of the vehicle, accuracy of steer angle and tuning speed. The material used to cover the wheel is microfiber leather. The selection of microfiber leather over normal leather was based on its several advantages required for sustainability. The microfiber leather is special; it does not slip and easily absorbs sweat as compared to leather. microfiber leather offers a positive touch experience, which enables the handler to have a firm grip. The surrounding temperatures do not have adverse effects on microfiber leather, making it highly durable and sustainable for low economic production.

Environmental:

Microfiber leather, made from cotton, is highly biodegradable. The steering wheel made of microfiber leather will have lesser impacts on the environment. The fact that microfiber leather can be recycled after their useful lives on the steering wheel is a conservation factor on the environment. The process of disposal can be organized by recycling into other products. The chances of wastes are reduced to nil; hence the environment is protected from pollution. The prevailing surrounding temperatures should not influence the handling of the steering wheel because of overheating. The microfiber leather steering will not overheat whether the temperatures are high. The handling of the wheel will not be dependent on the time of the day hence environmentally friendly. The microfiber leather cannot become very hot or cold, and the material offers a firm grip on the steering, including when the hands are sweating. The biodegradation of cotton does not result in environmental pollution; hence can be safely used.

However, the decomposition of microfiber leather made from cotton takes longer. Consequently, the effects on the environment before decomposition may not be assumed. To reduce this effect, recycling the product into other useful cotton products like household insulation is necessary. The environmental impact of biodegradation would be minimized with increased reuse of the materials.

Social:

The selected design of the steering wheel, both on geometrical design and material selected for sustainability, a positive interaction with drivers is created. The design attempts to shift the attention of the customer base from environmentally unfriendly to environmentally friendly covers. Additionally, the design and material used are intended to show the interactive care for consumers. The microfiber leather is cheap and easy to repair on steering wheels. The users will not be forced to purchase new covers for their wheels in case of damage. Various designs can be developed microfiber leather, unlike other materials like leather. Because of versatility, various forms of designs can be developed based on considering demands hence better social experience with the consumers. The quality of the product is complemented by its aesthetic value that increases the need for social interactions.

Economics:

The central goal for the production of the steering wheels is affordability and durability. The wheels are designed to handle maximum weights and negotiate corners at high speed. The primary advantage of the steering’s to provide a term solution to the current problems faced by drivers. The rates of changing steering wheels are high, and it is not economical. Additionally, the use of microfiber leather promotes the repairing of damaged parts without having to purchase a new covering material. As a result, the cost of maintaining the steering wheel is reduced. The focus of the design is on the increase in the amount of weight that the steering wheel can handle smoothly.

Safety:

Some steering wheels require more force than others during operations. The design principles dictate concentrate load on the steering wheels that make it hard to negotiate a corner. Usually, the stiffness or smoothness of the steering determines the level of safety of the steering.

The steering wheel does not operate based on the heaviness of the vehicles, but the efficiency is calculated based on the smoothness after turning. The self-returning action is a salient principle to minimize the need to control after negotiating a bend. The material used on the steering wheel is skid-proof. The implication is that the hands may not easily slip from the steering hence limiting chances of causing an accident. In hot temperatures, hands get sweaty, increasing the chances of skid. The microfiber leather is essential as it absorbs the sweat, thus, increasing safety during operation. Because of the durability of the microfiber leather, it does not wear easily. Safety is guaranteed when the fabric is durable. The comfort that comes with firmly holding microfiber leather is ergonomic to the hands, therefore, improving the operational experience of the driver.

Ethics:

The process of designing the steering wheel is not interpreted as a new invention. The idea has been patented in the past as several other steering wheels have been developed. The project is directed towards putting the mechanical engineering principles into practice without claiming possibilities of new inventions. However, the design takes into account a few oversights such as ergonomics, comfort, safety, and challenges in designing stages to achieve the intended goal. Developing a steering wheel that provides both comfort and safety to the driver is essential. The mathematical calculations are borrowed from the previous designs hence no original ideas.

The project points out gaps that exist in the design of the steering wheel to improve the experience of the drivers and reduce possibilities of harm. Improvement of safety can only be achieved if the minute details such as possibilities of skidding during driving are eliminated. Since most risks occur during turning, illustrating the benefits of smooth turning and self-returning action are crucial. These principles have been developed in the previous inventions, and this design brings them together for the best experience.

3.2 Engineering Design standards

* Magnesium AM60B cast alloy has excellent ductility, superior energy absorbing properties, and good strength and cast ability.
* This standard of carbon steel (AISI 1020) has high ductility, and high strength
* AISI 304 is the most common stainless steel.

3.3 Theory and Theoretical Calculations

We might have a ground-breaking motor and a super-responsive, exceptionally efficient transmission that moves this crude vitality to your wheels, however in the event that you don't have an approach to control the haggles them toward the path you need to go, at that point you'd in any case end up with nothing not exactly a profoundly glorified road luge. However, even a road luge has an approach to permit itself to be moved. That makes a vehicle without a controlling framework look increasingly like a colossal stone moving along, reliant on gravity to take it where it needs to go.

A vehicle's directing framework is as significant as the vehicle's motor and. While the last

Component	Standards	Details
Steering wheel	AM60B	Diameter: 180 mm
Steering column transmits	AISI 1020	Length: 1000 mm
Rack-and-pinion	AISI 1020	Length: 1320 mm
The tie rod	AISI 304	Diameter: 4.76 mm

two are what adequately put vitality to the wheels, you have to comprehend that the controlling framework is the thing that controls the course of the wheels. Go right. Go left. Go straight advance or back. That is the capacity of the controlling wheel moving the vehicle's wheels as vitality is applied onto the wheels. It's a perplexing framework, truly. In any case, that is what we're here for. We will demystify this piece of the vehicle that, to put it obtusely, you're clutching each time you take your vehicle for a drive.

Guiding: Essential to Driving:

As we have just begun gabbing about in the start of this article, the directing wheel is a significant part of your vehicle. It resembles what might be compared to the reins on your pony which you use to guide the steed to a specific heading or even to control it on the off chance that you see a deterrent in front of you. The controlling wheel is likewise what might be compared to the handlebar on your basic food item handcar, which you use to move and explore through the different areas of your preferred basic food item or general store.

Car steering

To lay it out plainly, altering your vehicle's going or course will essentially be inconceivable without the guiding wheel. Without it, you won't have the option to make split-second course rectifications to abstain from getting into a traffic impact or vehicular mishap. Without it, you will likewise not have the option to drive it into and out of your carport or in your stopping opening.

It is for this very explanation that a vehicle's directing framework is an extremely fundamental part since it essentially guarantees more secure driving by bearing you greatest control of your vehicle's wheels. Beside the change stick or gear move switch that you control now and again, your hands will consistently be on the controlling wheel. The vibrations, slight pulling development towards one side, and so forth are encounters that you can possibly acquire when your hands are firmly planted on the guiding wheel. These 'encounters' give you criticism on what your vehicle is doing, how it is acting out and about, and whether these 'encounters' are indications of a looming mechanical or even electrical issue.

To put it plainly, the guiding wheel gives you control of the vehicle's course as it moves along the street.

Car Steering Systems Work

Directing wheel:

This is the piece of the directing framework that everybody knows about. It is the thing that we hold and control while driving. The directing wheels of the past were surprisingly enormous in distance across, making you think they were the steerage of a boat intentionally incorporated with the vehicle. They were generally slenderer, as well, and made for the most part of hard plastic. The present guiding wheels are commonly cushioned, bearing you comfort while clutching it for broadened periods. Some accompany ergonomic notches that embrace the shapes of your palms and fingers. Inside splines forestall the controlling wheel from sneaking off the guiding shaft.

The size of the guiding wheel is significant in driving since size is conversely relative to the exertion expected to turn the wheel. This implies the bigger the controlling wheel distance across the lesser is the exertion you should apply to turn it. Then again, the littler the width of the directing wheel the more that you will feel as though you're fighting with the wheel.

The guiding wheel additionally houses an assortment of connections, for example, the horn switch and the driver's air pack framework. In fresher vehicles, the sound of music controls, paddle shifters, just as the journey control are additionally mounted here. The air sack is officially called as the supplemental inflatable limitation or SIR framework. On the off chance that the vehicle figures in a frontal crash, the effect triggers the electronic effect sensors to actuate the air sack squib which, thusly, touches off a flammable substance extending the gas and sending the pack. These happen in one-tenths of a second after impact.

Guiding shaft and section:

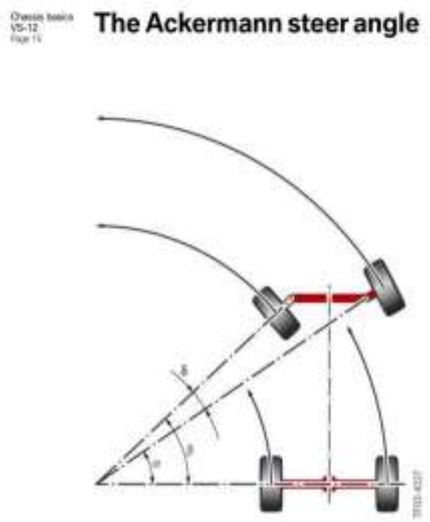
Aggregately called the controlling framework, the guiding section and shaft associate the directing wheel to the remainder of the directing framework found close or in the wheels. Most present-day vehicles accompany an extending controlling shaft made out of two steel tubes, one of which is strong and the other empty. The strong cylinder slides inside the empty cylinder permitting it to fall in case of a crash. The controlling shaft likewise has a directing coupler situated at the base which serves to retain vibrations while additionally considering slight variety happening in the arrangement between the cow gear and the pole. Numerous cutting-edge vehicles need more leeway to encourage a straight association between the guiding shaft and the controlling rigging. In such vehicles, are incorporated to permit the pole to pivot at an edge.

The directing segment covers the controlling shaft. You can take a gander at the guiding shaft and section as a syringe with the directing shaft being the unclogged of the syringe and the controlling segment the barrel of the syringe. Permitting the segment to openly move are ball or roller shaft direction situated at the top and base of the section. Some controlling segments are completely movable to make driving significantly progressively agreeable. These can be tilting or extending guiding sections, taking into account the upward and descending modification or the forward and in reverse change of the controlling segment, individually.

The Ackermann Angle:

Since we're basically discussing how a vehicle turns at whatever point we think about the controlling framework, it is imperative to comprehend one significant geometric guideline in play – the Ackermann Angle or the. The geometric standard was really evolved by Georg Lankensperger in 1817 in Munich. Notwithstanding, the structure was never licensed until about a year later Lankensperger's specialist, Rudolph Ackerman in England. From that point forward, the rule was known as the Ackermann Angle in spite of the fact that it ought to be legitimately called the Lankensperger Angle. As a matter of fact, there is some case that the

Lankensperger disclosure may have come later since there were reports that Erasmus Darwin put a comparable rule in 1758.



Well, enough of that. How is the Ackermann Angle relevant to steering systems? In case you have noticed, every time you turn your wheels, the 2 front wheels will be angled differently in relation to one another with the inside wheel (the wheel to the side where you're turning to) having a slightly more acute angle than the outer wheel (the wheel towards the side opposite the direction you're turning in). This is because when you turn, the wheels follow an arc which is technically a part of a circle. And whenever circles are concerned, you have the radius to think about which is the distance to the pivot.

Since the inner wheel is nearer the pivot, it has a smaller radius relative to the outer wheel. This means that the inner wheel will travel a shorter distance while the outer wheel will have to cover a longer distance. Because of this difference in turning radius and the relative distance traveled by the front wheels, the inner and outer wheels have to be pointed at slightly different angles relative to the car's center line. This is achieved by making simple arrangements in the various components of the steering column.

Theory and theoretical calculations:

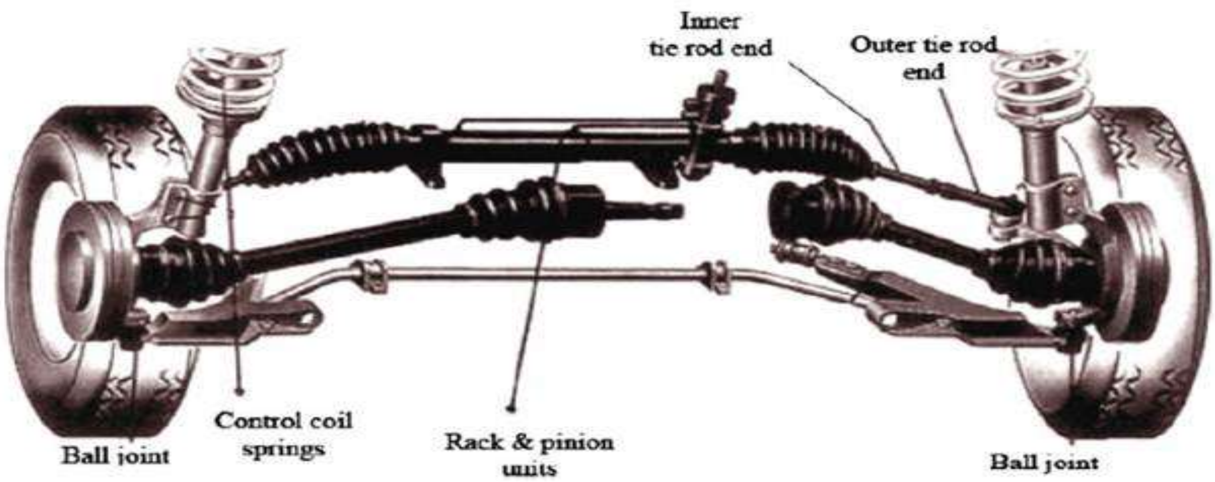
Table 1 shows the calculated steering arm angle for 100% Ackerman steering with the steering rack behind the axle (rear steer) and a wide variety of wheelbase and track width combinations. If you use this approach always check the actual Ackerman after as tie rod angles alter the results. On a front steer suspension this can be used as a guide. Getting as much as possible out of the steer arms and positioning the rack properly can make some gains toward true Ackerman.

	Wheelbase length (in)						
Front KP Span or track (in)	94	95	96	97	98	99	100
	Inward angle (deg.) of the steer arms (KP-Heim attachment bolt) with steer arms behind the axle centerline						
70	20.4	20.2	20.0	19.8	19.7	19.5	19.3
68	19.9	19.7	19.5	19.3	19.1	19.0	18.8
66	19.3	19.2	19.0	18.8	18.6	18.4	18.3
64	18.8	18.6	18.4	18.3	18.1	17.9	17.7
62	18.3	18.1	17.9	17.7	17.6	17.4	17.2
60	17.7	17.5	17.4	17.2	17.0	16.9	16.7
58	17.1	17.0	16.8	16.6	16.5	16.3	16.2

Table 1: Steering arm angle producing Ackerman with a rear steer front axle

Vehicle Specs Mass of vehicle:
Total mass = 140 kg
Mass of the vehicle with driver = 200 kg

Mass on the front = 0.45 x 200= 90 kg
Mass on the rear =110kg
Corner mass front = 45kg
Corner mass rear = 55 kg



The steer angle (SA) required to make a turn with no consideration for tire slip angle is shown in. If you use the equation the different steer angle inside and outside are calculated by simply increasing the radius (R) by the track width (t) for the outside wheel.

	Wheelbase length (in)						
Turn Radius (ft)	94	95	96	97	98	99	100
	Front track width				70	in	
	Estimated tire slip angle (deg)				4	deg	
	Degrees of steer of the inside (LF) tire with slip angle considered						
50	13.45	13.55	13.64	13.74	13.84	13.94	14.04
75	10.20	10.27	10.33	10.40	10.46	10.53	10.60
100	8.61	8.66	8.71	8.76	8.81	8.86	8.91
125	7.67	7.71	7.75	7.79	7.83	7.87	7.91
100	8.61	8.66	8.71	8.76	8.81	8.86	8.91
125	7.67	7.71	7.75	7.79	7.83	7.87	7.91
150	7.05	7.08	7.11	7.15	7.18	7.21	7.24
175	6.61	6.63	6.66	6.69	6.72	6.74	6.77
200	6.28	6.30	6.32	6.35	6.37	6.40	6.42

Table 2: Steer angle for various wheelbase lengths and turn radii with 4 degrees of tire slip angle

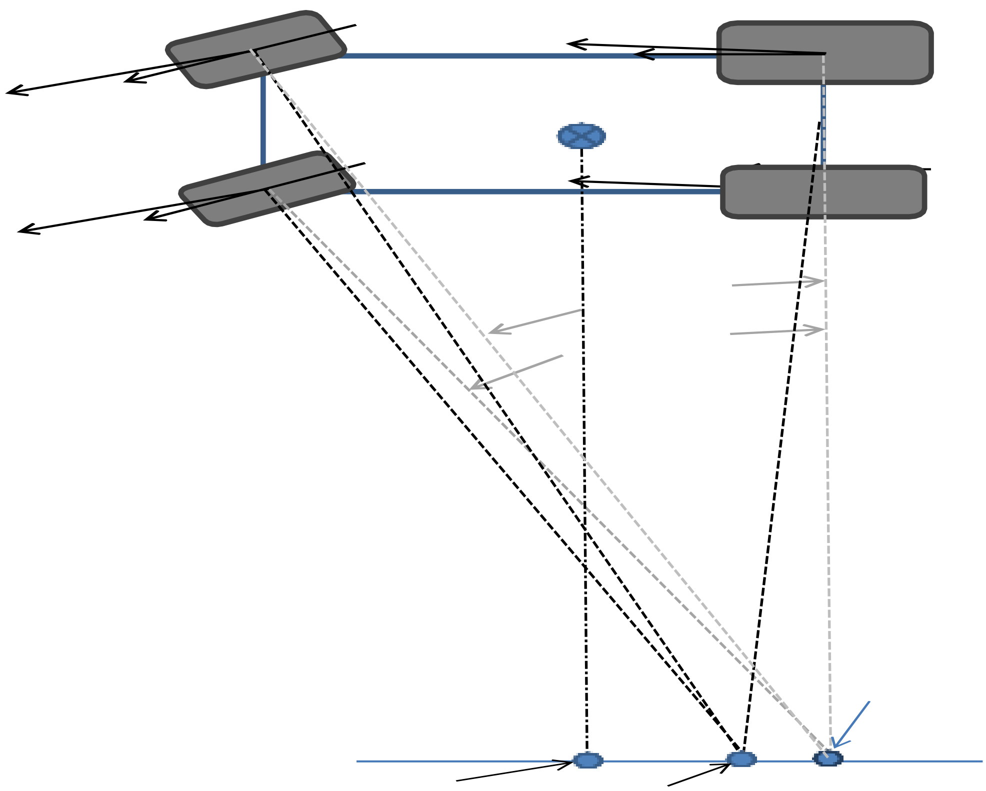
In Table 2, I added a 4-degree slip angle to the calculation as front slip angle increases the required steer input and decreases the radius of the turn. Note from the values of Table 2 that as the wheelbase length of the race car is increased, the amount of Ackerman needed increases.

Table 3 present the actual toe-out and steer angle for 100% Ackerman. I did the calculation for a fairly standard wheelbase of 96 inches and front track of 70 inches. I find measuring at either 8 degrees or 10 degrees of left front steer angle is about the best to help reduce the error in the measurement. As always measuring toe-out in steps as you move toward 8 or 10 is best because tie rod angles can affect the actual toe-out obtained. It is also suggested that you measure it both for left turn and right turn to make sure nothing is out-of-normal either way.

Input Data in GREEN CELLS ONLY!				
Wheel Base Length	96	Inches		
FRONT Wheel Track	70	Inches		
REAR Wheel Track	70	inches		
	Left	Right		
Front Tire Circumference	78	80	in.	
Rear Tire Circumference	82	87	in.	
Front Rolling Diameter	24.8	25.5	in.	
Front Rolling Radius	12.4	12.7	in.	

LF steer angle (deg.)	Turn Radius (ft)	**RF steer angle (deg.)**	**Toe Out for 100% Ackerman (inch)**	
1	461.3	**1.0**	**0.006**	0
2	232.0	**2.0**	**0.022**	0
3	155.6	**2.9**	**0.048**	1/16
4	117.3	**3.8**	**0.085**	1/16
5	94.4	**4.7**	**0.131**	2/16
6	79.0	**5.6**	**0.186**	3/16
7	68.1	**6.4**	**0.250**	4/16
8	59.8	**7.3**	**0.323**	5/16
9	53.4	**8.1**	**0.403**	6/16
10	48.3	**8.9**	**0.491**	8/16
11	44.1	**9.7**	**0.587**	9/16
12	40.6	**10.4**	**0.690**	11/16
13	37.6	**11.2**	**0.800**	13/16
14	35.0	**11.9**	**0.916**	15/16
15	32.8	**12.6**	**1.038**	1 1/16

Table 3: Toe-out and Steer angles for 100% Ackerman



3.4 Product Subsystems and selection of Components

The main components of Steering system are:

- **Steering Wheel:**

The steering wheel is the driver-manipulated component of the steering system; the rest of the steering system responds to these driver inputs. This can be achieved by direct mechanical contact such as in recirculating ball or rack and pinion steering gears, without or with the aid of hydraulic power steering; HPS, or with the help of computer-controlled engines, known as Electric Power Steering, as in certain early production vehicles.

- **Rack-and-pinion:**

Steering quickly becomes the most common form of steering on cars, small trucks and SUVs. It really is a really easy process. A rack-and-pinion gear set is wrapped in a metal frame, with the wire protruding from either end of the rack. A pin, called a tie loop, connects with each end of the rack.

- **Steering column:**

Can contain universal joints in order to allow it to deviate somewhat from a straight line in order to reach the best position on the steering gear brace.

- **Tie rods:**

Attach either end of the steering rack to the steering knuckles that the front wheels rotate on when turning the steering wheel.

3.5 Manufacturing and assembly (Implementation)

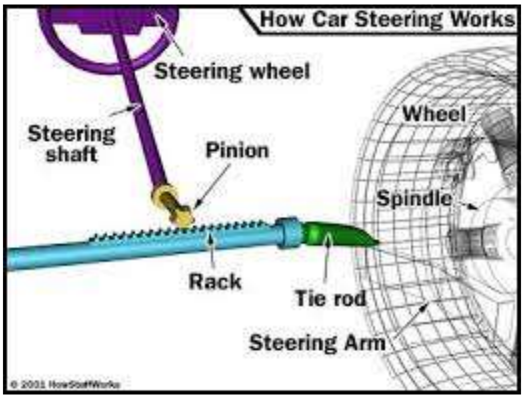
In terms of selection of materials, all steering parts in cars are very similar, but there are two different systems, but with the same principles, the first is a **hydraulic** steering wheel, and the second is an electric steering wheel. The first part, steering wheel is usually made of thermoplastic metal material as **AISI1020**, which has the characteristics that help the driver in ease of its inputs, in addition to its light weight and comfortable grip (see figure 3.5.1). The second part, steering column transmits the torque force from this steering wheel to the steering shaft and pinion and is made of high-quality steel(see figure 3.5.2) . Third part, Rack-and-pinion steering convert the rotational motion of the steering wheel into the linear motion needed to turn the wheels and made of high-quality steel. There are two fluid ports, one on either side of the piston using for power steering. On either end of the steering rack are rubberized plastic bellows **AISI1020**, which secure to the rack body and the moving part of the rack to keep dust from entering the rack and pinion unit(see figure 3.5.3). Forth part, the tie rod transmits force from the steering center link or rack gear to the steering knuckle and made a low-alloy steel **AISI304** (see figure 3.5.4).

Figure 3.5.1

Figure 3.5.2

Figure 3.5.3

Figure 3.5.4



Chapter 4: Conclusions and Future Recommendations

4.1 Conclusions:

In conclusion, the main result is that we accomplished the full report about the steering system and there content. Also, we followed and applied the international standards of the steering system in our work in term of the solid works and manufacture. We did the solid works in term of 2D sketch, assembly and drawing for the steering wheel, rack-and-pinion, steering column and the tie rods. The main point is that we now have the knowledge and general idea about steering system and we got a stage that we can build it or in another word manufacture it. Because of the conditions in the world and the workshops closed we could not complete the entire project. In the challenges and the experience, its the first time that we work in a part of a real car and study about it and know how its work, what are the materials standard that must be chose so that it will not filed. We also, faced difficulty of choosing the dimensional of the steering because the car was built on our dimensional. Also in the manufacture we faced a lot of challenges in term of the choosing the best workshop and the cheapest and the one who will finish our work early, but unfortunately the situation was not in our side so that we couldn’t complete the project.

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Appendix A: Progress Reports

	SDP – WEEKLY MEETING REPORT
	Department of Electrical Engineering Prince Mohammad bin Fahd University

SEMESTER:	Spring	ACADEMIC YEAR:	2019-2020
PROJECT TITLE	Steering part		
SUPERVISORS	Dr. Muhammed Asad		

Month 2: March

ID Number	Member Name
201501234	Hamad Alnaimi
201600067	Abdulrhman Alshammari
201402547	Rashid Aldossary
201501917	Mohammed Alyami
201402977	Abdullah Alsaqour

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Preparing the midterm presentation	All members	70%	
2	Working on chapter 4	All members	80%	
3	We finished the cad design	All members	70%	

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	Design Constraints and Design Methodology	bdulrhman Alshammari
2	Engineering Design standards	Rashid Aldossary
3	Theory and Theoretical Calculations	Mohammed Alyami
4	Product Subsystems and selection of Components	Hamad Alnaimi
5	Manufacturing and assembly (Implementation)	Abdullah Alsaqour

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome MEEN4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN4A. Demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental and societal context	Fails to demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Shows limited and less than adequate understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Demonstrates satisfactory understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Understands appropriately and accurately the engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts

Outcome MEEN5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN5A: Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Properly and efficently makes team work plans and allocate resources and tasks
MEEN5B: Ability to participate and function effectively in team work projects to meet objectives	Fails to participate and function effectively in team work projects to meet objectives	Shows limited and less than adequate ability to participate and function effectively in team work projects to meet objectives	Demonstrates satisfactory ability to participate and function effectively in team work projects to meet objectives	Function effectively in team work projects to meet objectives

MEEN5C: Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	Communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (MEEN4A)	Criteria (MEEN5A)	Criteria (MEEN5B)	Criteria (MEEN5C)
1	**Hamad Alnaimi**	4	4	4	4
2	**Abdulrhman Alshammari**	4	4	4	4
3	**Rashid Aldossary**	4	4	4	4
4	**Mohammed Alyami**	4	4	4	4
5	**Abdullah Alsaqour**	4	4	4	4

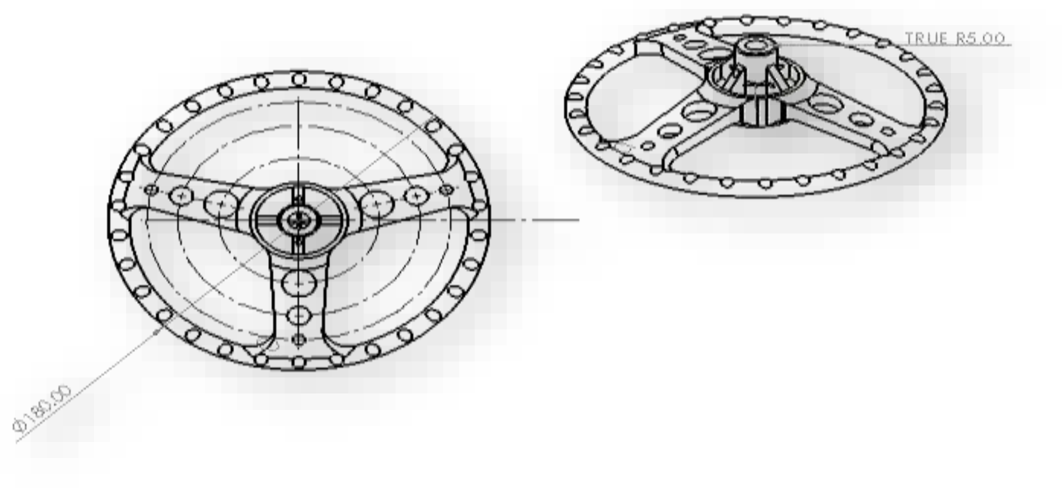
Comments on individual members

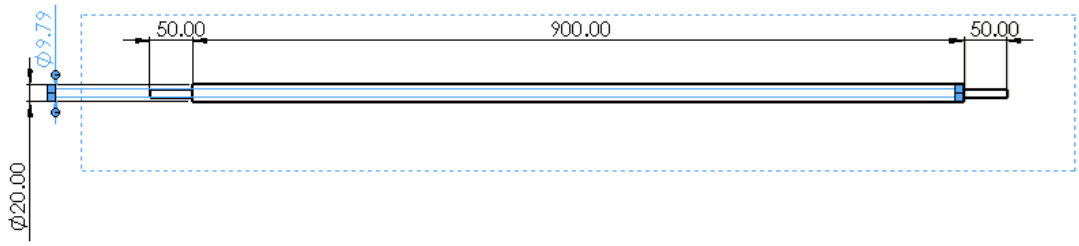
Name	Comments
Hamad Alnaimi	
Abdulrhman Alshammari	
Rashid Aldossary	
Mohammed Alyami	
Abdullah Alsaqour	

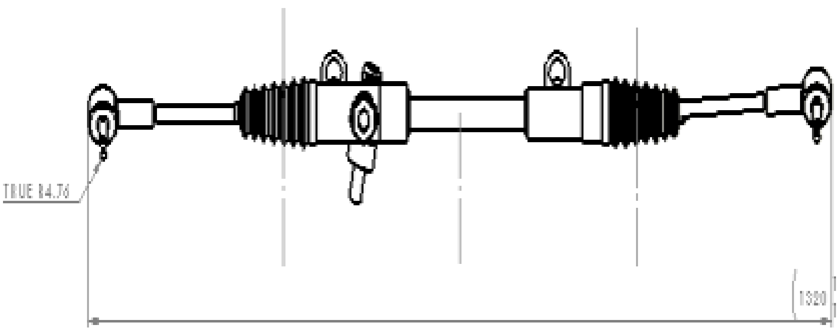
Appendix B: Engineering standards (Local and International)

Component	Standards	Details
Steering wheel	AM60B	Diameter: 180 mm
Steering column transmits	AISI 1020	Length: 1000 mm
Rack-and-pinion	AISI 1020	Length: 1320 mm
The tie rod	AISI 304	Diameter: 4.76 mm

Appendix C: CAD drawings and Bill of Materials







Appendix D: Datasheets

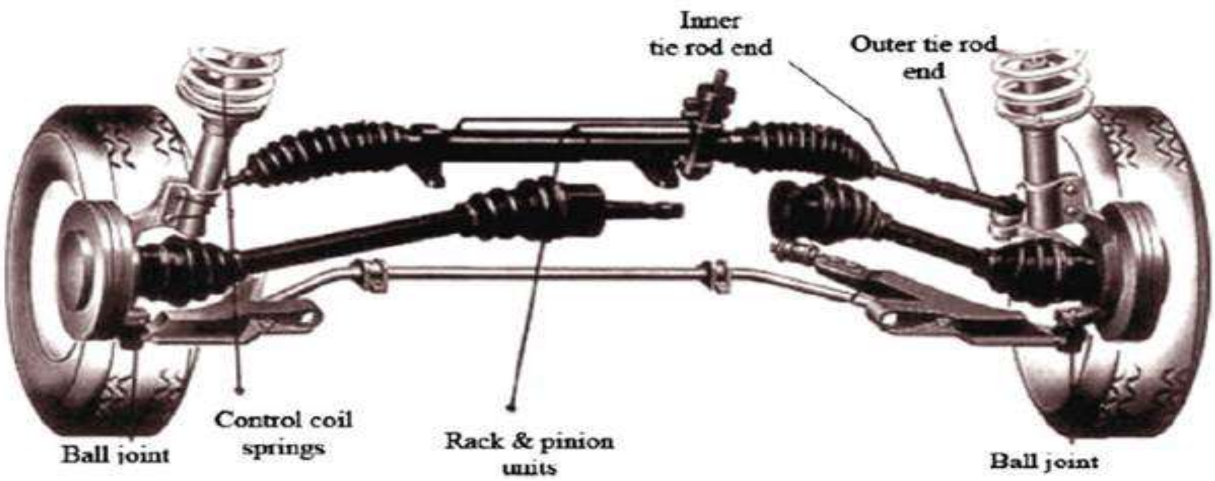
Table 1 shows the calculated steering arm angle for 100% Ackerman steering with the steering rack behind the axle (rear steer) and a wide variety of wheelbase and track width combinations. If you use this approach always check the actual Ackerman after as tie rod angles alter the results. On a front steer suspension this can be used as a guide. Getting as much as possible out of the steer arms and positioning the rack properly can make some gains toward true Ackerman.

	Wheelbase length (in)						
Front KP Span or track (in)	94	95	96	97	98	99	100
	Inward angle (deg.) of the steer arms (KP-Heim attachment bolt) with steer arms behind the axle centerline						
70	20.4	20.2	20.0	19.8	19.7	19.5	19.3
68	19.9	19.7	19.5	19.3	19.1	19.0	18.8
66	19.3	19.2	19.0	18.8	18.6	18.4	18.3
64	18.8	18.6	18.4	18.3	18.1	17.9	17.7
62	18.3	18.1	17.9	17.7	17.6	17.4	17.2
60	17.7	17.5	17.4	17.2	17.0	16.9	16.7
58	17.1	17.0	16.8	16.6	16.5	16.3	16.2

Table 1: Steering arm angle producing Ackerman with a rear steer front axle

Vehicle Specs Mass of vehicle:
Total mass = 140 kg
Mass of the vehicle with driver = 200 kg

Mass on the front = 0.45 x 200= 90 kg
Mass on the rear =110kg
Corner mass front = 45kg
Corner mass rear = 55 kg



The steer angle (SA) required to make a turn with no consideration for tire slip angle is shown in. If you use the equation the different steer angle inside and outside are calculated by simply increasing the radius (R) by the track width (t) for the outside wheel.

	Wheelbase length (in)						
Turn Radius (ft)	94	95	96	97	98	99	100
	Front track width				70	in	
	Estimated tire slip angle (deg)				4	deg	
	Degrees of steer of the inside (LF) tire with slip angle considered						
50	13.45	13.55	13.64	13.74	13.84	13.94	14.04
75	10.20	10.27	10.33	10.40	10.46	10.53	10.60
100	8.61	8.66	8.71	8.76	8.81	8.86	8.91
125	7.67	7.71	7.75	7.79	7.83	7.87	7.91
100	8.61	8.66	8.71	8.76	8.81	8.86	8.91
125	7.67	7.71	7.75	7.79	7.83	7.87	7.91
150	7.05	7.08	7.11	7.15	7.18	7.21	7.24
175	6.61	6.63	6.66	6.69	6.72	6.74	6.77
200	6.28	6.30	6.32	6.35	6.37	6.40	6.42

Table 2: Steer angle for various wheelbase lengths and turn radii with 4 degrees of tire slip angle

In Table 2, I added a 4-degree slip angle to the calculation as front slip angle increases the required steer input and decreases the radius of the turn. Note from the values of Table 2 that as the wheelbase length of the race car is increased, the amount of Ackerman needed increases.

Table 3 present the actual toe-out and steer angle for 100% Ackerman. I did the calculation for a fairly standard wheelbase of 96 inches and front track of 70 inches. I find measuring at either 8 degrees or 10 degrees of left front steer angle is about the best to help reduce the error in the measurement. As always measuring toe-out in steps as you move toward 8 or 10 is best because tie rod angles can affect the actual toe-out obtained. It is also suggested that you measure it both for left turn and right turn to make sure nothing is out-of-normal either way.

Input Data in GREEN CELLS ONLY!			
Wheel Base Length	96	Inches	
FRONT Wheel Track	70	Inches	
REAR Wheel Track	70	inches	
	Left	Right	
Front Tire Circumference	78	80	in.
Rear Tire Circumference	82	87	in.
Front Rolling Diameter	24.8	25.5	in.
Front Rolling Radius	12.4	12.7	in.

LF steer angle (deg.)	Turn Radius (ft)	**RF steer angle (deg.)**	**Toe Out for 100% Ackerman (inch)**	
1	461.3	**1.0**	**0.006**	0
2	232.0	**2.0**	**0.022**	0
3	155.6	**2.9**	**0.048**	1/16
4	117.3	**3.8**	**0.085**	1/16
5	94.4	**4.7**	**0.131**	2/16
6	79.0	**5.6**	**0.186**	3/16
7	68.1	**6.4**	**0.250**	4/16
8	59.8	**7.3**	**0.323**	5/16
9	53.4	**8.1**	**0.403**	6/16
10	48.3	**8.9**	**0.491**	8/16
11	44.1	**9.7**	**0.587**	9/16
12	40.6	**10.4**	**0.690**	11/16
13	37.6	**11.2**	**0.800**	13/16
14	35.0	**11.9**	**0.916**	15/16
15	32.8	**12.6**	**1.038**	1 1/16

Table 3: Toe-out and Steer angles for 100% Ackerman