Fundamentals of Automotive Systems
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Module No # 12
Lecture No # 57
Steering System – Part 01

So greeting so welcome to today's class so we will get started with steering systems from today so as many of us are exposed to while travel in a car right. So the driver essentially rotates the steering wheel and it is expected that the orientation of the heading of the vehicle changes in response to the drivers input so in this module what we are going to learn is how is this task achieved in a typical automobile right so that is what we are going to learn.

So from the driver steering wheel what how is the command for steering transmitted to the steered wheels and from there how does the orientation of the vehicle changes. So those are the points that we are going to address in this particular module. So we will follow a similar structure you know like not necessarily in the same order that is like we look at the functions the requirements, the components, the operation and the analysis right so that is what we are going to do in this particular module.

So to begin with let us first articulate what are, all the function of an automotive steering system? And then we will be able to correlate them as and when we look at specific components subsystems right. So if you look at a board level a steering system should enable the driver to regulate the vehicle along a desired path okay. So that is one important requirement and should enable the control of the vehicle trajectory under normal and emergency conditions.

So this is true with both manual steering and today given the growing interest in autonomous vehicles even one wants the vehicle steer vehicle to steer autonomously the steering system should respond to a controllers command and then enable them right. So that is very important and it is a critical system steering system is well studied and even the vehicle steering responds or what is called as cornering responses of great importance to vehicle designers because it is something you know like which the driver is also sensitive to you know like how the vehicle responds when the vehicle steered the same thing is important for acceleration braking and so on other systems that we have studied.

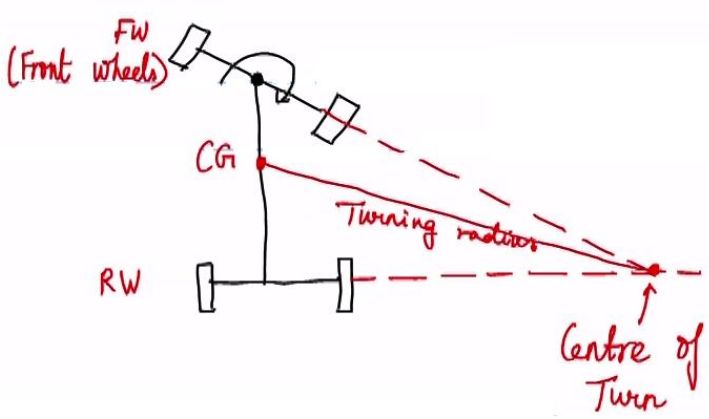
So similarly the steering is also important because it is a critical system to ensure proper what is called as handling of the vehicle. So when we take a course on vehicle dynamics right so one would spend quite a bit of time in learning what is called as cornering dynamics or handling dynamics now where which essentially deals with how the vehicle responds when it is being steered.

Because when we are steering a vehicle we are also displacing the vehicle along the lateral direction right and then the question becomes what are the corresponding dynamic phenomena that we need to be considering and how does the driver respond to then right and whether it is within reasonable limits as far as the driver is concerned okay. So that is why it is called handling you know like how well the vehicle performs you know like when steered okay that essentially goes under what is called as handling dynamics or cornering dynamics that you will study in a course on vehicle dynamics.

But we now in this course we are going to look at how the steering system is constituted and it works currently right so that is going to be the scope of our

discussion. So before we go and look at of course once again we are going to restrict ourselves to a typical 4 wheeled road vehicle steering you know in particular we are going to look at passenger car steering you know like and maybe like single unit vehicle steering you know to be general right.

So in by and large if you look at most passenger cars most SUV's and buses and trucks you know like which are single unit vehicles. So we would observe that the front wheels are the ones which are steered right so we are going to look at how this is achieved and how that translates into a change in the orientation of the vehicle that is something which we are going to study.



FIFTH WHEEL STEERING

So before the current steering mechanisms came into fifth wheel we had what is called as fifth wheel steering you know like what is this fifth wheel steering. So let us let me draw a very simple schematic so just not to scale you know like this to convey the point. So let us say you know like I consider a vehicle and let us say these are my rear wheels and let us suppose you know like I am rotating my entire front axle about this pivot point ok the front axle is pivoted at about this point and let us say we rotate the entire front axle about this point what is going to happen is then if I project the rear axle center an also the center line of this front axle.

They are going to intersect at some point which is the center of turn okay and let us assume that this is my vehicle center of gravity the distance between the center of the turn and the vehicle center of gravity is what is called as the turning radius. So in this fifth wheel steering so these are the front wheels these are the rear wheels okay. So in a fifth wheel steering what happens is that the entire front axle is steered or turned about a pivot okay.

So this happened in the older generation vehicles but not today so if you look at critical important aspects of the fifth wheel steering the entire steered axle in general front okay it is not necessary that we always need to steer only the front wheels but by and large we stay at the front wheels right the entire steered axle or the front axle is turned or rotated about its pivot right this changes the orientation of the front wheels because when we want to take turn from a straight path you know we need to turn the wheels right some wheels.

So that like it the vehicle now goes follows the goes along at curved path right so that is important so this changes the relative orientation of the front wheels from it is straight ahead position okay. So this is what is called as fifth wheel steering so this was initially used utilized but however you know one can immediately note that if I want to rotate the entire steered axle one needs to put in a lot of effort and as the vehicle speed increased you know this effort also increased okay.

So that is a limitation of fifth wheel steering okay high force required to rotate the entire axle so which rendered at unsuitable as speed increased you know like so as vehicle speed increased in you know like i think like this was difficult right so this is what is called fifth wheel steering. So then how did steering system in a evolved you know people came up with different steering mechanisms which enable which ensure that we are only rotating the wheels not the entire axle right think about it

no why should I rotate the entire axle to change the orientation of the vehicle so what did people think of they thought that okay.

Let us rotate only the wheels which are steered so those are what are called steered wheels right so the steered wheels orientation alone was changed and that gave rise to different steering designs right. And we are going to look at 1 mechanisms or 1 sets thought process which is commonly used in current automobiles alright and how it is released in a few clauses of vehicles you know like for example let us say even if we take battle tanks alright.

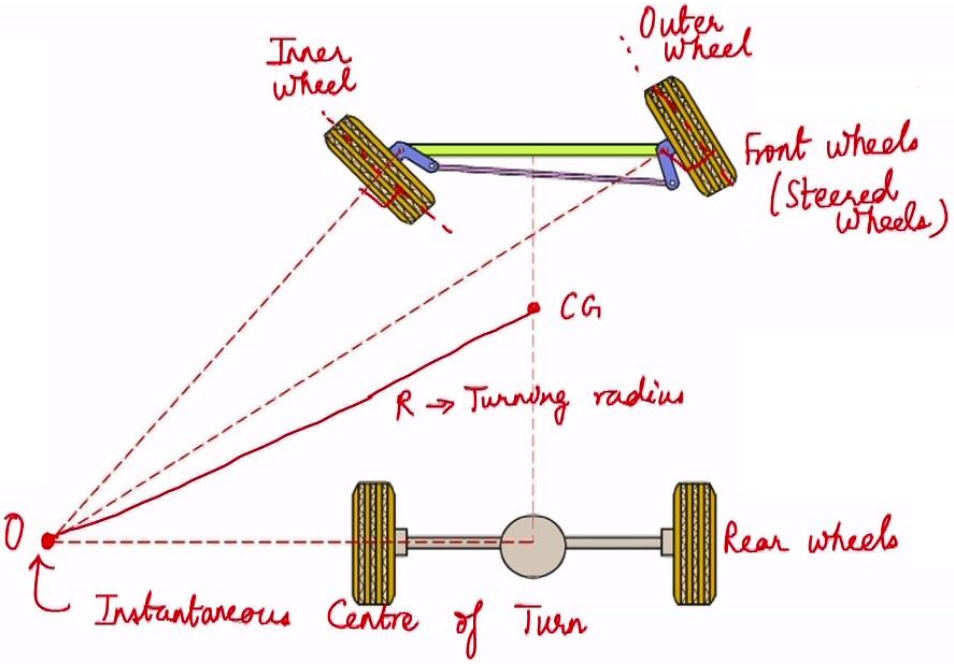
So which have a tracked vehicle configuration right in a battle tank you will see the there are tracks on the left and the right hand side. So we have what is called skid steering so what happens is that the tracks on both sides when one wants to rotate they are rotated at different speeds so the speed difference essentially creates a yaw motion that is what is called as skid steering okay then essentially the tracks skid okay and the wheel rotates we are not going to look at that right. So our focus is going to be only on linkage based steering's you know which are used in current automobiles.

But the main idea you know still you like irrespective of this final steering mechanism which is used are the main requirement is that while taking a turn the axis of rotation this is the ideal requirement so axis of rotation of the front wheels. See of course okay throughout this discussion let us consider you know as I told single unit vehicles single unit 4 wheeled vehicles let me be even more specific right with the front wheel being steered okay.

So unless otherwise I explicitly say so this is going to be the scope of a discussion so this is what we will consider so if we consider this clause of vehicles where the

front wheels are being steered. So what happens is that the axis of rotation of the front wheel I will essentially illustrate at using a simple schematic should intersect the axis of the rear wheels which are un-steered at a common point okay.

So this common point of intersection is the instantaneous center of turn okay so that is the main idea here right okay. So what do I mean by this you know like let me I will give a simple schematic then we will come to this.



COMMON POINT OF INTERSECTION

So let us look at this diagram right so if we look at this schematic we will see that these are the rear wheels okay these are the front wheels. Suppose let us now only rotate the steered wheels okay so these are what are called as the steered wheels okay. So the left and the right front wheels suppose we rotate the 2 steered wheels and we draw 2 lines which are perpendicular to the plain of the steered wheels right so let us say that is my axis of the wheels right.

So this is a very simple schematic we will as when we go to later part of steering we are looking at what are called as wheel alignment parameters we will also see how a wheel is aligned okay with respect the vehicle and also other entities right. So if we draw a simple to have a simple visualization let us say you we draw 2 lines which are perpendicular to the plane of the 2 steered wheels then we draw a line which is coming from the rear axle center and all of them meet at a some point a common point right then we essentially this is what is called as a instantaneous center of turn okay.

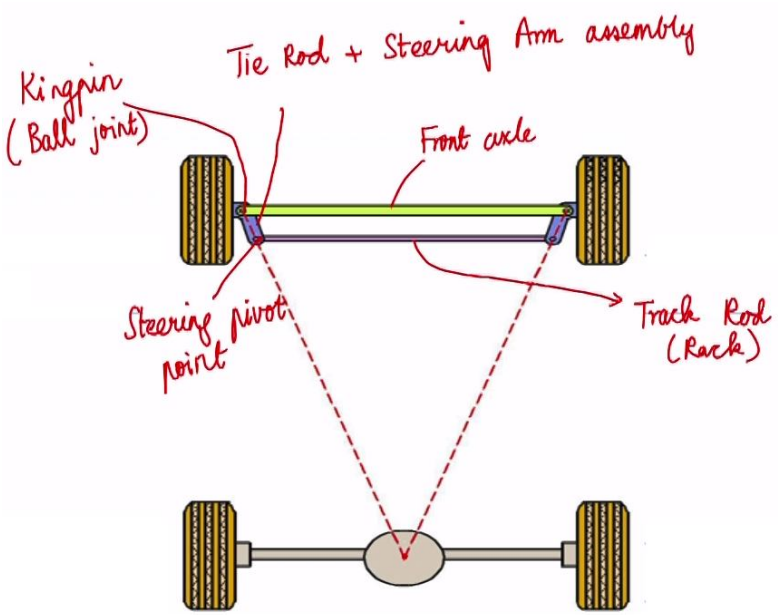
So then what happens is that let us say we call this point O right and let us say this is our CG you draw a line segment from O to the center of gravity this is the turning radius okay. So this is the idea you know like so of course why this way because you will see that when we are having such an arrangement right we will see that the so called inner wheel will turn on a circle of smaller radius that the outer wheel.

So these 2 wheels one which is inside is what is called as a inner wheel it can be the left or the right wheel okay depending on the direction of turn so that is going to be on a circle of smaller radius when compared to the outer wheel right which is going to be on a circle of larger radius okay. So that is the a requirement okay so essentially we note that we have a few requirements while taking a turn the inner wheel has to be has to travel right on a circle of smaller radius than the outer wheel.

So this requires that hence the steering system should ensure or enable that enable the rotation of the inner wheel by a larger angle than the outer wheel okay. So that is how we can achieve the requirement that the inner wheels travels on a smaller

radius than the outer wheel okay. So this is achieved by what is called as the steering geometry so what is this steering geometry it is nothing but a combination of linkages that provide for the inner and outer wheels to trace out circles of different radii okay that is the steering geometry okay.

So this is the steering geometry so that will enable this functionality to be achieved so an engineer named Ackerman right or is credited to come up with a geometry which essentially satisfies these requirements okay.



ACKERMAN STEERING GEOMETRY

So let us look at that so we are going to look at what is called as the Ackerman steering geometry okay. So we know what a steering geometry is right so it is just a arrangement of linkages. So what is this Ackerman steering geometry you know like let us look at that so the core idea will see how this helps right we will also look at the components of a typical steering system and the steered wheel so for the time being although this is to even for other types of vehicles right.

So let us consider what is called as a solid axle steering okay so that is like there is a solid front axle you know which is being steered. So let me mark all the important components in this figure so this is the front axle so you can immediately see that there is a rod here which is placed this is what is called as a track rod in passenger cars you know they due to the steering gear arrangements we will see that this takes a name of a rack okay depending on the what type of steering we have.

Then you can see that there are 2 elements okay here this is what is called as a tie rod plus a steering arm assembly we will you look closer at this entire assembly when we come to the components right. So this is what is called as a tie rod and a steering arm assembly there are 2 of them on either side so you can see that these 4 elements the front axle the tie rod steering arm assembly 2 on either side and the track rod form a set of 4 linkages and the idea proposed by Ackerman is to have them as a trapezoid okay.

And this front axle is essentially mounted on a spindle which is also connected to this tie rod and steering arm assembly using these joints or what are called as kingpins in heavy vehicles okay. We will see that this is the kingpin and essentially and if you look at rack and pinion steering which are used in passenger cars you know people call it as a ball joint okay we look at both short as we go look at the components right.

So these are the joints at which everything is held together right so that is the axle and the tie rod steering arm assembly are held together what to say through a pivot where you have a kingpin all right they are held together by either a kingpin or a ball joint okay. So that is what this is the term kingpin is used for heavy vehicle

steering traditionally if you look at passenger cars which have a rack and pinion steering it is what is called as a ball joint right okay.

So what is the core idea of this Ackerman steering geometry is that we draw a line segment from this kingpin to the center of the rear axle okay on both the left and the right hand side. So this point is what is called as the steering pivot point okay so that is where the track rod is connected to the tie rod okay. So the idea is to place this steering pivot point on the line segment joining the kingpin and the center point of the rear axle okay. So that is the core idea behind this Ackerman steering geometry so that all the 4 element take the form of a trapezoid right.

So let me write down the key points of the steering geometry so the 2 ends of the steered axle have a spindle pivoted around a kingpin okay. So then the tie rods or the steering arm assembly right so are attached to the kingpin okay so that is the second point then and each steering pivot point is placed on the line segment joining the corresponding kingpin to the center of the rear axle okay. So this is the these are the key points of this Ackerman steering mechanism.