Fundamentals of Automotive Systems
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Module No # 12
Lecture No # 59
Manual Steering Systems – Part 01

Okay so greeting let us get started so to have a quick recap of what we did yesterday we started off it with a discussion of the steering system right. So we looked at what is called as Ackerman steering geometry we started off by looking at what happens to the wheels which are in contact with the road and how this Ackerman steering condition relates the steering the wheel angle of the inner and the outer wheels are to the vehicles specification right the track and the wheel base of the vehicle okay.

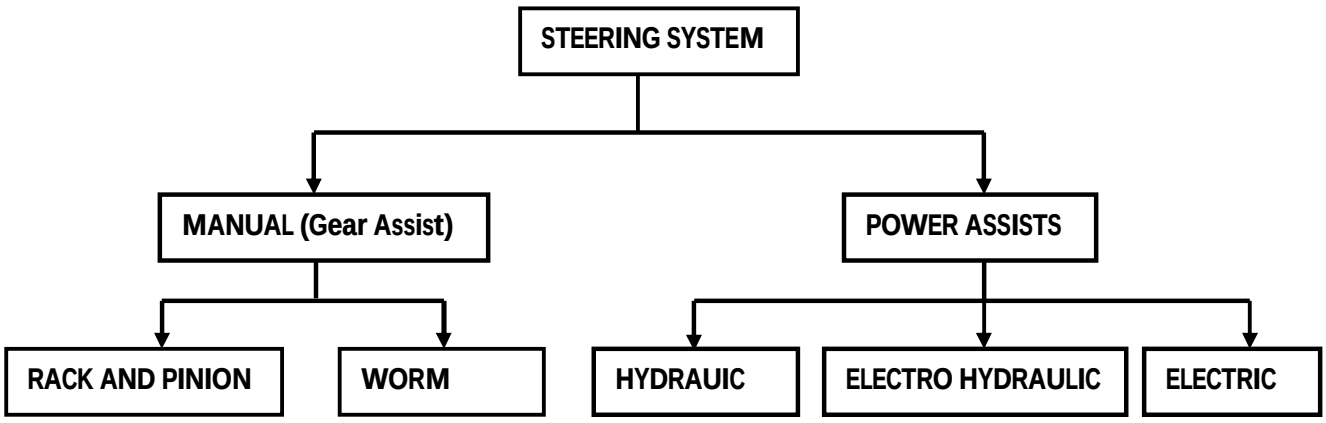
So then we considered the trapezoidal steering mechanism we looked at what are all what is the equation that relates the various parameters. So the question that we stopped with was the following you know like question is how do, we choose this these 2 parameters “d” and beta right.

So the question that naturally arises from yesterday’s discussion is that how to choose “d” and beta such that the Ackerman steering condition is satisfied. So that is the question to ask right so of course to the best possible extent right so let me write in as a comment so if we do an exercise we will be able to see that we are not going to be in a position to satisfy the Ackerman steering condition with a trapezoidal steering mechanism for any arbitrary steering wheel input.

So the question becomes how close can we get to the Ackerman steering condition? So to the best extent okay possible okay so that is the question that one needs to ask so that can be a subject of further analysis okay.

So in today's class we are going to start off by asking this question okay so we looked at what happens to the steered wheels right. So, essentially the wheels which are in contact with the road surface now the question that arises is that like how do I first of all turn those wheels that are steered right by using an appropriate mechanism. So that is a question we are going to discuss today.

So how does one turn the steered wheels okay so what do we mean by steered wheels? Steered wheels are the once that are in contact with the ground okay or the road in our case right. So essentially that is where a steering system are comes into play so a steering system is an assembly of various sub systems and components which help us in achieving this task. So let us see you know like how this steering system is classified right.



CLASSIFICATION OF STEERING SYSTEM

So one class of steering system is what is called as a manual steering system where the assistance to the driver to turn a steered wheel is provided by a geared

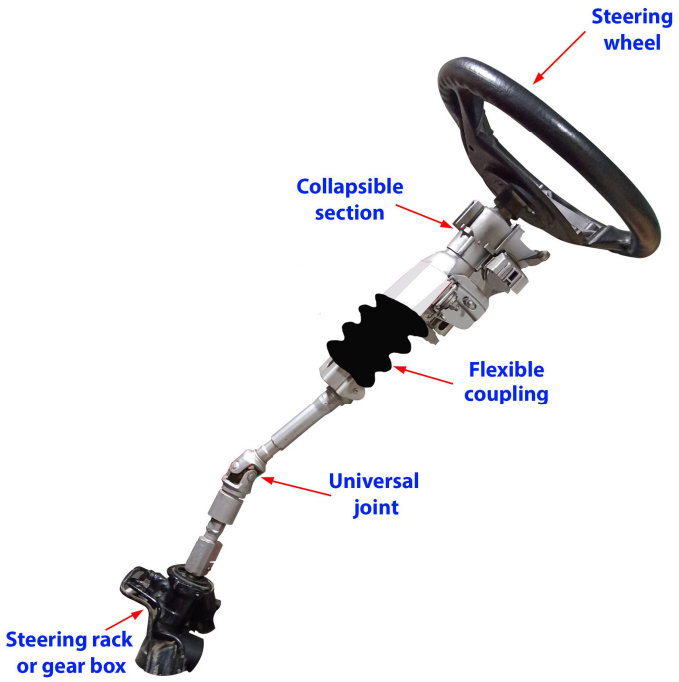
assembly please note that we have to rotate a wheel assembly which is loaded if you consider a typical passenger car once you set the car on the ground there are normal loads acting on at the tyre road interface at a corresponding wheel.

So if you consider the front wheels obviously there are normal roads acting at the front tyre road interface. So we need to be in a position to rotate the front wheels when it is subjected to this normal load consequently that driver need some assist to assistance to do this task. So if that comes purely from mechanical linkages and a gear assembly that is typically classified as a manual steering system and manual steering systems are further classified into two types one is depending on the gear which is used one is what is called as the rack and pinion steering which is commonly used in cars and the one which is used in heavy vehicles is basically a worm gear based system alright.

So these are 2 gear assemblies which are used now on the other hand so let me draw arrows so this is the classification of a manual steering system on the other hand if you look at modern steering systems you know like we use what is called as a power steering right wherein the effort which is expected from the driver which is further reduced by assisting the driver through some other energy source right.

So what are these systems? So the second class of system you know like that we are going to look at or what are called as power assist systems power assisted steering system. So these are further divided into depending on how this power assist comes in it can be pure hydraulic power assist system it can be what is called as an electro hydraulic power assistance system and it can be pure electric power assist system okay.

So this is a further sub classification of these power assist systems so what we are going to do is that like we are first going to look at what are the general components that make up a steering system once we do that we are going to look at you know how each of these you know systems are realized in practice and how they operate and so that like we can compare the features right the pros and cons so that is something which are going to do.



STEERING COLUMN

So to begin with let us first look at the components of a typical vehicle automobile steering system. So the components of a typical steering system include the following so if you look at a simple schematic we can identify these components easily. So if you look at a schematic so we can immediately see that the driver controls the steering wheel so that is what is under the control of the driver and then the command from the steering wheel is transmitted through a steering column.

So this entire assembly is what is called as a steering column okay so this entire steering column transmits the effort or input provided by the driver to the steering gear okay which is mounted at the end of the steering column alight. So, essentially this is not a rack but a pinion in a rack and pinion or a gear box okay so essentially the energy is transmitted to a steering gear through the steering column.

The steering column has a collapsible section the reason being that in the event of a crash the steering wheel should not come and hit the driver right. So in order to enable in order to prevent that so the steering column consist of a collapsible section such that in the event of a crash this essentially does the steering wheel would not injure the driver okay. And there are flexible couplings and universal joints which transmit the motion and this shaft which does it is what is called as the intermediate shaft okay or I shaft.

So in as far as steering system is concerned if we talk about I shaft we are talking about this intermediate shaft which consist of all these components right and it has universal joints to transmits the motion right to the steering gear okay. So we look at what are the different choices of steering gear and then how they are subsequently connected to the steered wheels right. So to enumerate the components of a typical steering system the first component which the driver actuates is what is called as the steering wheel then we have the steering column which consist of the intermediate shaft or the, I shaft and the universal joints.

Then the steering gear is attached at the end of the steering column this provides the mechanical advantage right. Essentially it amplifies the torque provided by the driver right. So that is the primary purpose of the steering gear so steering gear essentially gives us mechanical advantage right within quotes. So what is

mechanical advantage it is essentially amplifies the torque which is provided by the driver then we have the steering mechanism.

So what we looked at in the previous class right from the steering gear you know like effort is transmitted to the track rod or rack depending on the steering system then we have tie rods okay we have what are called as pitman arms we are going to look at those components today right. And then like we have the steering arm so yesterday we consider the tie rod and the steering arm assembly right the steering arms then what is called as the steering knuckle.

Steering knuckle is a component on which you know like the wheel assembly the steered wheel assembly is mounted right it is connected to the steered wheel assembly so that like the steered wheel is rotated right it is part of the steering mechanism. And then like we have the ball joints or kingpins so which once again we looked at them yesterday alright. So these are the typical components that make up a typical steering system okay.

So in fact if we try you know like of we go and try to turn the steering wheel of a car which is suspended let us say we take it to a two post lift and then like rise the car such that the tyres are no longer in contact with the ground and we try to turn the steering wheel you will see that the wheel rotates pretty easily because the wheels are suspended in air. But the same car once placed on the ground is requires more effort to rotate the steering wheels why?

Because now there is the normal load at the tyre road interface of the steered wheels so that is why a parameter called as steering ratio becomes very important. So the steering ratio is an important parameter as far as the steering system is concerned and how it is defined? It is the ratio of the angle through which the

steering wheel is turned. So what is the steering wheel this one right so this component. So the steering wheel is this, component right what we are talking about right.

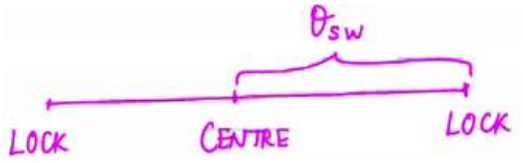
So the angle through which the steering wheel is turned to the corresponding angle let us say we called it as the angular displacement of the steered wheel. So let us say the front wheels which are steered what is the corresponding angular displacement of the steered wheel right. So that is what is called as the steering ratio why is this important because this is how it is defined so as we can see you know like neglecting energy losses you will see that the torque is going to be amplified by the same ratio that is if the steering ratio is let us say 10 for a particular steering system and I am just taking a round number.

You know so if I want one degree of displacement at steered wheel right which is in contact with the ground I need to rotate my steering wheel by 10 degrees that is the meaning. Consequently if I apply 1 Newton meter of steering wheel torque right that is going to result in 10 Newton meter of torque at the steered wheel okay neglecting energy losses right so that is what we are going to achieve right.

So typically for most cars this ratio is between 12 : 1 to 20: 1 okay and the primary purpose why we ensure that the steering ratio is proper is to enable the gear reduction is required to achieve the necessary mechanical advantage as we already observed right. So the necessary mechanical advantage since we need to turn a loaded tyre see that is important right because the tyre is loaded.

So, since we need to turn a loaded tyre wheel assembly so we need this mechanical advantage okay. So this also brings us to what is the total angular displacement from center to lock and lock to lock okay. So what do I mean by that so typically

when the steering wheel so let us say you know if we plot the this is just a illustration so let us say you know like I am going straight you know my steering wheel is at the centre position it is at the centre position right.



$\theta_{sw} = 12 * 40^{\circ} = 480^{\circ} \Rightarrow 1\frac{1}{3}\ turns\ of\ the\ steering\ wheel \rightarrow Centre\ to\ lock.$

$Lock - to - Lock\ Turns = 2\frac{2}{3}$

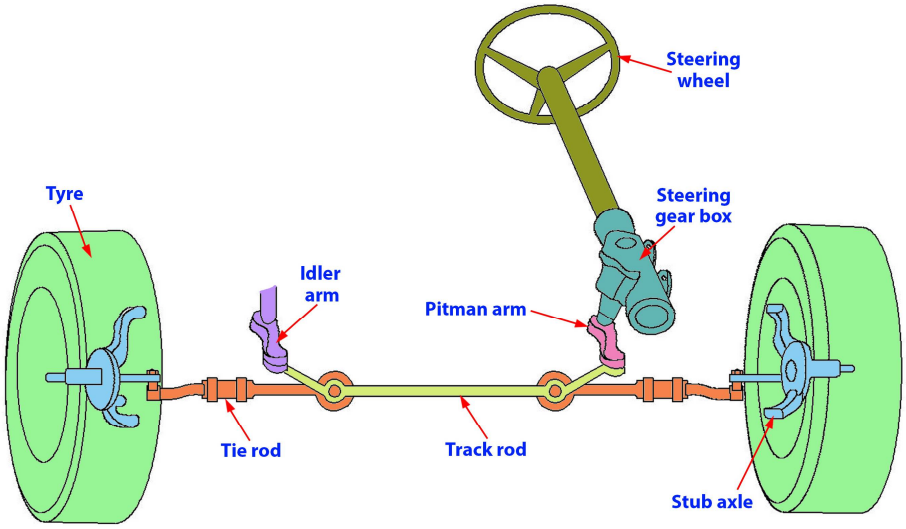
So if I turn it all the way to the right till it locks we find out what is the total angular displacement to go there similarly if I turn it all the way to the left let us say we come to the lock position on the other side right. So the steering ratio also helps us in figuring out what is the lock to lock angular displacement of steering wheel for a required displacement of the steered wheel and vice versa okay.

So what do I mean by this let us say you know like this is what is called as you know like let us say you know like theta steering wheel right let me call as theta SW alright. So just as a simple exercise let us consider this right so example so let us consider a steering ratio of 12 alright 12: 1 alright. So let the steered wheels so or we will say it is required that the steered wheels we rotated by 40 degrees from center to lock on either side that is what do I mean by steered wheel the ones which are in contact to the ground right.

This implies that what we called as theta steering wheel is going to be what 12 times 40 degrees right. So that is going to be the displacement of the steering wheels the corresponding steering wheel and that is essentially a 480 degrees. So 480 degrees corresponds to how many turns one and one third turns so of the

steering wheel right. So this is from center to lock right so this implies the so called lock to lock turns is going to be two and two third turns alight or revolutions of the steering wheel okay.

So we can essentially observe that how this steering ratio helps us in determining how many turns we need to rotate the steering wheel to calculate to achieve a certain angular displacement of the steer wheel okay.



MANUAL ASSIST STEERING SYSTEM –PITMAN ARM

So now let us move ahead and then like look at manual assist steering systems so if we go up you know like manual assist steering systems are gear assisted right. So as we have already seen we have a rack and pinion and a worm gear based system so first let us look at worm gear based steering systems or what is generally called as pitman arm type steering? Okay so this is the one which is based on worm gears.

So what is this pitman arm type steering system so let us consider a simple schematic to understand that so what happens in a pitman arm type steering is the following and the construction of this steering system is as shown here. So what

happens here so we have this the steering system once again start at the steering wheel there is as steering column right so and that ends in a steering gear box so we look at what are the different choices available for a steering gear in a pitman arm type steering.

So in this gear you know like input torque provides by the driver is amplified and that torque is essentially provided to what is called as a pitman arm. So you can see that there is a component called as this pitman arm which is which can be rotated. So that pitman arm you know like then displaces this track rod right and we can immediately observe that the track rods are connected to a tie rod on each end. A tie rod is connected to the steering arm which in turn is continuously so called steering knuckle on which that entire tyre assembly or wheel assembly is mounted.

So the steering wheel is rotated motion is transmitted through the steering column to the steering wheel gear the torque is amplified and then provided to the pitman arm. The pitman arm replaces the track rod and the track rod essentially displaces the tie rod then turn rotates the steered wheels through the steering arm and the steering knuckle okay. So that is what happens in this pitman arm type steering.

So essentially these are worm gear based steering okay so let me not write it here so I will write it down here a few quick points these are worm gear based steering systems okay and these typically equipped with what is called as a steering box within quotes. This steering box is nothing but the steering gear right and typically it has a high steering ratio. So one advantage is that like a result it gives better mechanical advantage not only due to the gear ratio but also to the arrangement of the linkages the pitman arm and others give some lever advantage also right. So essentially it gives better mechanical advantage through it is due to its realization.

So but the one limitation is that it gives less feedback is available to the driver compared to rack and pinion right in the event of changes in road conditions okay so under changes in road condition there is a feedback but with changes in road conditions the change in feedback available to the driver is comparatively lower right in this pitman arm steering systems so that is a limitation okay. So this is the construction of a pitman arm type steering system.