Fundamentals of Automotive Systems
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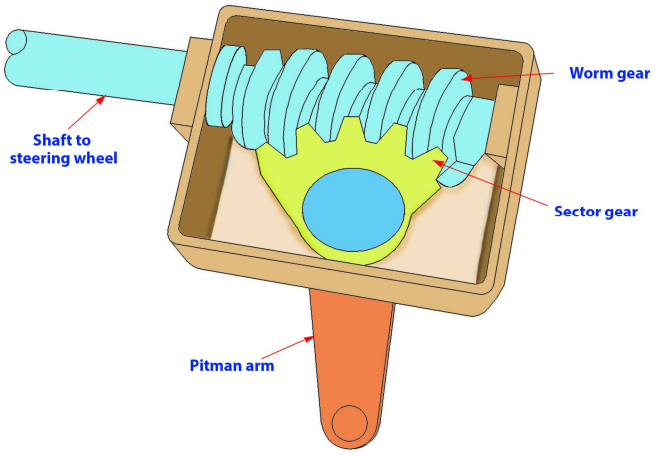
Module No # 12
Lecture No # 60
Manual Steering Systems – Part 02

Now depending on the type of steering gears used we have different classes okay so let us now consider different types of gears used or gears arrangement used in this pitman arm type steering system right. So what are the different gear arrangements used so let us look at some schematics and also try to learn their characteristics.

So one choice is what is called as a worm and a sector gear box so in this worm and sector gear box we can observe that the motion is transmitted from this worm gear the worm gear is connected to the steering column.

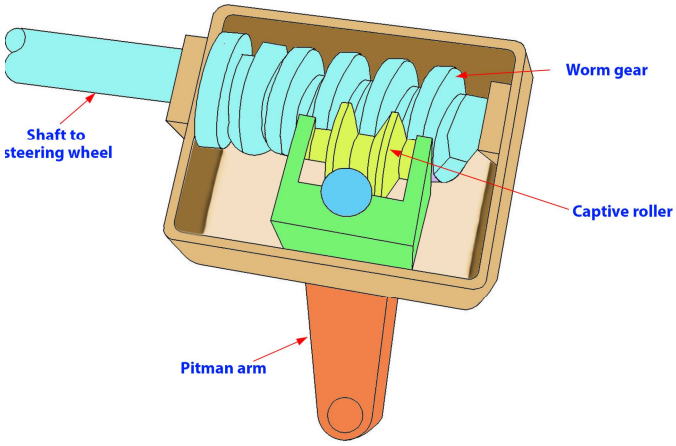


WORM AND SECTOR STEERING BOX

So from the steering wheel to the steering column motion is transmitted to the worm gear right which is mounted in this steering box alright or the gear box. So worm and gear what to sorry sector steering gear or steering box has this arrangement wherein we have this worm gear and then like we have a corresponding sector gear which is meshed with the worm gear right.

So what happens as this worm gear is rotated by the driver the sector gear is also correspondingly rotate right. And consequently the pitman arm is rotated and motion is transmitted to the track rod right. So that is the construction and operation of the worm and sector gearbox of course we can adjust the we can design this worm and sector gear box to achieve that desired gear ratio right. So here the motion is transmitted from the worm gear to a sector gear mounted on the same shaft as that of the pitman arm okay.

So that is what happens in this worm and sector gear box steering box arrangement so what are other alternatives another alternative is what is called as a worm and roller steering box okay so what is this there are different designs.



WORM AND ROLLER STEERING BOX

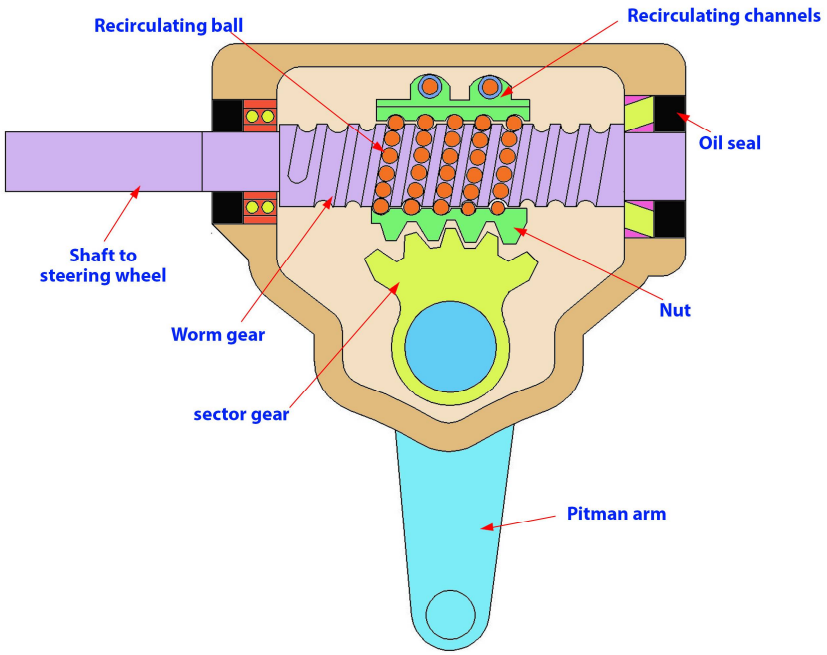
So let us look at a few choices and then we also look at one which is most commonly used okay which is coming up shortly. So what happens in this worm and roller gear box or steering box.

So we can once again see or observe that the motion from the steering wheel is transmitted to the worm gear okay. And this worm gear is meshed to a captive roller okay. So, when this worm gear rotates what this captive roller is essentially going to travel on the profile of the worm and then this is going to twist this cross shaft. So there is a cross shaft alright on which at the end of which this roller is held captive and as a worm gear rotates this roller is going to traverse on the profile of the worm gear and then it is going to twist the cross shaft.

So consequently the pitman arm is going to be rotated okay in this arrangement so this is what is called as the worm and roller steering box okay. So here the main thing to note is that when the worm gear turns okay so the roller twist the cross shaft and thus rotating the pitman. So this is the construction and operation of worm and roller steering box but the most common gear box which is used in this pitman arm type steering is what is called as the recirculating ball type steering box.

So what is this recirculating ball types steering box let us what to say discuss that with a simple schematic.

So in the recirculating ball type steering box what happens is the following. So we can see still observe that the motion from the steering wheel is transmitted to the worm gear right. So this is the third type of steering box in a pitman arm type steering what is called as a recirculating ball steering box so when the motion is transmitted to the worm gear we can see that there is a nut okay what is called as a ball but which is thread what to say meshed with this worm gear.



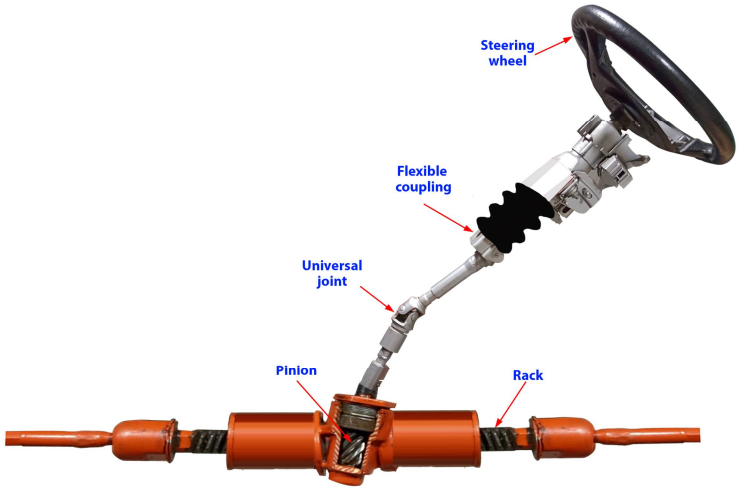
RECIRCULATING BALL STEERING BOX

So when the worm gear is rotated alright this nut traverses on the worm gear and the if you look if you cut open the nut and the worm gear you will see that there are these small recirculating balls okay which essentially provide the contact between the nut and the worm gear threats the consequence of having these recirculating balls is that the friction is reduced okay in the mechanism.

So the frictional losses has become reduced so and it becomes relatively easier to transmit the motion right from the worm gear to the pitman arm and this nut is meshed with the sector and sector is rotated and the pitman arm is rotated. So that is how the motion is transmitted so we can see that a so called ball nut is meshed with the worm gear so what is the path of the energy transfer we can immediately observe that the rotation of the steering wheel results in rotation of motion of the ball nut okay and the sector gear which results in the rotation of the pitman arm.

So that is what happens in this recirculating ball type steering box. So the main advantage of having these balls which are recirculating in these channels is that the balls served to reduce friction and wear right that is those are 2 things you know like which compared to the other choices you know like in this recirculating ball type steering box a friction is reduced and wear of the components also is reduce and this is the most common type of steering box or gear box used in pitman arm type steering system okay.

So that is the recirculating ball system okay. So these are some common choices of the steering box which is available with this pitman arm type steering system okay.



RACK AND PINION STEERING SYSTEM

So now we will look at the second choice of this manual assist or manual gear based steering system and the one which is very popular in passenger cars, SUV's and all is what is called as a rack and pinion steering system so what is this rack and pinion steering system? So typically used in cars we almost in all the class of passenger cars a rack and pinion system is utilized so what happens in this rack and pinion system? So as the name indicates we have the rack and pinion assembly okay. So that is the main gear right so let us look at them.

So in a rack and pinion system once again we have the steering wheel right we can observe that is the motion is transmitted through this steering column right to a pinion. So a pinion is a gear which is attached to the end of the steering column and the pinion gear meshes with a rack so the rotation of the pinion is converted to a translation of a rack okay through the rack and pinion mechanism and this rack is then attached to the tie rods and the steering arm assembly okay which will then essentially steer the steered wheels right so that is the mechanism here.

So if you look at rack and pinion systems they are commonly used in lighter vehicles like cars okay SUV's and so on right so we can see that the rotation of the steering wheel results in rotation of the pinion okay. And that essentially is converted to a translational motion of the rack okay so this is the concept behind the rack and pinion system. So compared to a pitman arm type steering system we can readily observed it is more components as less components and in a certain sense provides a more direct path alright because it has less components you know like direct path to the steered wheels okay.

So that is those are all some advantage of this rack and pinion system. So if we consider a rack and pinion system what happens is that there is some parameters you know like some parameters which are used to characterize a rack and pinion system alright.

One parameter is what is called as a C – Factor so what is this C – Factor in a rack and pinion system? The C- Factor of a rack and pinion system is the distance travelled by the rack in mm. So this is a convention right to take it in millimeters when the steering wheel is turned by one revolution. So that means 360 degrees right so that is the definition of this term C – Factor okay when the steering wheel

is completely turned by one revolution what is the displacement of the rack in millimeters.

So that is the definition of this term C – Factor okay so if we consider this C – Factor right the rack speed neglecting slip at the interface between the pinion and the rack is.

The rack speed (neglecting slip) is

$$v_r = \left(\frac{\omega_s}{2\pi}\right) * \frac{C}{1000} = \frac{\omega_s C}{2000\pi}, \omega_s \rightarrow angular\ speed\ \left(\frac{rad}{s}\right) of the\ pinion.$$

(m/s)

$T_s \rightarrow Torque\ on\ the\ pinion\ required\ to\ obtain\ a\ rack\ force\ of\ F_r$

$$\eta_{rp}(T_s\omega_s) = F_r v_r$$

$$\Rightarrow T_s = \frac{F_r v_r}{\eta_{rp}\omega_s} = \frac{F_r C}{2000\pi\eta_{rp}}$$

Let us say we call it as some V_r. So now let us say omega S is the angular speed in radians per second right of the pinion right so if I do omega S by 2 Pi what am I going to get? I will get the number of revolutions of the pinion per second right.

If omega S is in radians per second if I divide by 2 Pi I get number of revolutions per second and what is the C- Factor? C- Factor is a displacement per revolution. So if I multiply this with the C – Factor what am I going to get? I am going to get the displacement of the rack in millimeter per second right. Now what I do? I want to convert to meters I just divided by 1000 alright. So this is how typically it is written so that is why you know like you will find that the equation for calculating the rack speed is typically return in this manner okay.

So with units so omega S is the angular speed in radians per second of the pinion right so V_r is essentially taken in meters per second so that is why we apply this

factor of 1000 in the denominator right. So if this, are the rack speed then if we want to find what is the total torque which is required to obtain a certain rack force okay. So let us say T_s is the torque required to obtain a rack force of F_r.

So we want a rack force of F_r and T_s is the corresponding torque on the steering wheel right on the pinion alright required to obtain a corresponding rack force of F_r. So how can one obtain an expression for this you know like we can use energy balance right. So T_s times omega S is going to be the what to say rate at which energy is inputted input from the pinion and that should be equal to F_r times V_r right which is the rate at which energy is coming out of the rack.

But of course there is going to be an loss let us say rack and pinion let us say some energy loss due to friction other losses. So we multiply it by an efficiency alright sorry not here right. So essentially this is the output so sorry you know so the input multiplied by the efficiency will give me the output right. So the input term is T_s times omega S that multiplied by the efficiency of the rack and pinion arranged gear will give me the output power right which is force times F_r times V_r.

So then this implies that what is the torque required on the pinion that is going to be F_r times V_r Eta r_p omega S. Now what is V_r times omega S if you look at the above equation that is going to be F_r times C divided by 2000 times Pi times Eta r_p alright. How did I get this? I we just we just use this above equation right for the rack speed okay. So that is the, those are some terms parameters associated with the rack and pinion steering okay.

Now having looked at these 2 classes of manual steering systems if, we go back to the classification of the steering systems right so the manual system as we have already observed they are based on gear assist right. So if we look at the other class

of steering systems where you know like where we use another source of energy to assist the driver and steering the vehicle we come to what are called power assist systems.

So why are power assist systems required? Let us start with the discussion and then like we will go forward right and then we will also look at various types of power assist systems that we have listed. So today if you look at modern auto road vehicles right all the almost all the steering systems are power assisted systems.

So the common term which is used to represent this is what is called power steering alright what is called power steering those are to be more accurate it is power assist steering right. So essentially why do we why have we shifted to this? So with increasing mass vehicle mass and speed and faster steering response right so we want the vehicle so called steering response to be quick right. Then all these factors require more steering torque on the steered wheels okay.

But how can I increase the steering torque on the steered wheels? See we do not want to over burden the driver right. So the steering torque on the steered wheels is the output so in manual assist the steering torque on the steered wheels is the driver input multiplied by the gear ratio right. So if I want to increase the steering torque on the steered wheels for the same driver input what should I do? I have to increase the steering ratio alright which we defined.

So but what is the problem at the increasing steering ratio can I keep on increasing it forward right so why not? Because if I increase steering ratio to increase the torque amplification the price that we pay is it for getting the same angular displacement at the steered wheel now my lock to lock turns would also increase. So that means the driver has to rotate by a larger angular displacement to get the

same steered wheel angular displacement and that is going to be counterproductive right is not it?

We are keeping the torque manageable but then like the angular displacement of the steering wheel may, will increase if we do not do anything about it that is why beyond a limit increasing the steering ratio is not advisable alright. So this can be of course steering torque at the steered wheels alight so as I mentioned that is the output alright so this can be achieved by increasing the steering ratio however this would increase the number of steering wheel turns from lock to lock okay that is the limitation.

So these factor has motivated the development of power steering or power assist systems power assist steering. So what we will do is that in the next class we will look at what are the different types of power assist steering systems what are their features and then like we will compare them alright. So we learn more details about them so we will continue this discussion in the next class thank you.