Fundamentals of Automotive Systems
Prof. C.S. Shankar Ram
Department of Engineering Design
Indian Institute of Technology - Madras

Module No # 11
Lecture No # 63
Wheel Alignment – Part 01

So greetings welcome to today's class so what we are going to look at today is a discussion on what is called as wheel alignment okay which is very important for vehicle performance and that is something which is related to typically the steering and the suspension system. So let us look what this concept of wheel alignment is and what are the various parameters that are used to quantify wheel alignment.

So the term wheel alignment in a broad sense you know like it is used to indicate or represent an important or a critical set of design and maintenance parameters. So as the wheel as the vehicle is operated so this parameters can change with time and it is important to ensure that the parameters that we are going to learn be kept within the design limits so we would see what happens if we do not do that and these parameters have to be maintained in a specific design range to ensure good vehicle performance particularly cornering performance and maximizing tyre life.

So because it is important that these parameters be maintained in a certain designed range to ensure that the vehicle performance in particular it is cornering performance what do I mean by cornering performance that is the response of a vehicle when it is taking a turn right so that is typically called as cornering and even when the vehicle is going on a straight line you know like straight path and there are going to perturbations.

Then you know the question becomes you know how does the vehicle respond to the perturbations you know like how does a driver get a feedback you know through the steering wheel and what is the comfort level of the driver and it is occupants you know like all those are affected by these parameters okay we are going to look at that okay. So these parameters have a direct impact on cornering the so called straight line performance or straight line response.

See because sometimes you know like when we drive a car you know like we would have observed or we would have felt that even if the driver holds the steering wheel in the centered position the car may you know like drift towards one side or the other right. So we are going to observe when such things can happen right what are the causes of such observed phenomena. So that is what comes under straight line performance okay.

So it is in very important to ensure that you know when the vehicle is driving straight ahead you know and the driver gets good feel and the car does not deviate from its path right it does not drift from the straight line path decide by the driver and more importantly you know like these wheel alignment parameters have a direct impact on tyre wear you know like so tyre is an element in an automobile.

Because all the forces that are transmitted to the vehicle and those which acts at the tyre road what to say that act on the vehicle to brake to drive the vehicle to steer the vehicle right or transmitted through the tyre road interface. So tyre becomes very important and if the wheel alignment is not proper then we are going to have consequences as far as rapid tyre wear is concerned okay.

So what are some practical science you know like of poor wheel alignment let us look at these first and then like we would define various parameters very carefully

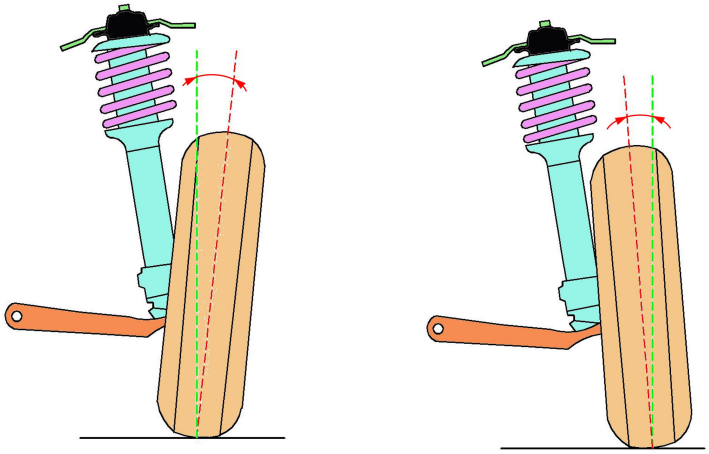
and then like we would correlate these observation that we see in practice. So one sign is vehicle pulling to one side so even if the driver intense to go straight ahead you know one may feel that the vehicle is being pulled or it is drifting to one side that is a sign of poor wheel alignment.

If we look at the tyre if the tread of the tyre right undergoes non-uniform or uneven wear you know that is also a sign of poor wheel alignment later we are going to look at the wear pattern and we are going to observe as to how you know the poor wheel alignment can result in uneven wear on the tread patterns okay. So sometimes we can have what is called as un-centered steering you know like what is called as un-centered steering as we are going straight ahead you know we have to essentially enable the driver to keep the steering wheel in its centered position okay.

But sometimes in order to keep the vehicle going straight you know like small steering input may need to be provided so that is what is called as un-centered steering you know like so that is something which is a sign of a poor wheel alignment okay. So steering wheel is off centre when driving straight okay and sometimes you know like the if the wheel alignment is not proper you know like we will also get steering wheel vibrations okay that are felt by the driver right so which is also for a sign of a poor wheel alignment okay.

So these are the signs of poor wheel alignment so what are the various wheel alignment parameters so by and large you know like there are some you know what are called primary wheel alignment parameters and some what are called as secondary set of wheel alignment parameters.

Generally it is agreed upon that there are 3 important parameters you know which are critical to quantify the wheel alignment okay so the first one it is what is called as the camber so what is camber and how it is defined and what is it impact? So let us look at this simple schematic so what is camber? So camber is nothing but the angle made by the central wheel axis right wheel plane axis right with the vertical direction when you view the wheel from the front of the vehicle so that is what is called as camber.



So let us say this green dashed line is the vertical axis this red dashed line indicates the central wheel plane okay. So essentially it is the angle made by the central wheel plane right with the vertical axis when we viewed from the front of the vehicle so this is what is called as wheel camber okay. So let me write down the definition it is the angle made by the wheel or tyre with the vertical direction when viewed from a front of the vehicle okay so that is what is called as camber.

So it is considered positive when the top portion of the wheel leans away from the vehicle body so we can see here that this schematic is the representation of what is called as positive camber so you can observe that the top part of the wheel you like is leaning away from the vehicle body. When the top part of the wheel is leaning

closer to the vehicle body towards the vehicle body it is considered as negative camber okay so that is the sign convention.

So the positive camber is one when the top of the wheel leans away from the vehicle body okay so that is positive camber. So we get we encounter or we define negative camber as just the opposite okay so if the top of the wheel leans towards the vehicle body okay so that is the negative camber. So why is this camber introduced in the first place you know like so typically if you look at most vehicles you know most cars you know like where the front wheels are steered you would observe that a small negative camber is introduced by design okay why is that? So let me just convey that through a very simple schematic right.

So suppose let us I am drawing a exaggerated diagram to just what to say to convey the point let us say these are my two front wheels right which are steered okay. So we can immediately observe that they have very steep negative camber. Suppose let us say we are taking a turn towards this direction now when we take a turn in this direction what is going to happen to the vehicle? It is going to role in this manner right so always the vehicle will roll out of the turn alright so this will be inner wheel and this will be outer wheel.

Now with this higher negative camber what is going to happen as the vehicle rolls outwards this wheel will be almost made vertical you know or it will shift closer and closer towards the vertical axis so that when the vehicle is taking a turn that will be a good contact you know like between the tyre and the road interface. So this means is that we get a good grip so called grip at the tyre road interface when the vehicle is taking a turn with a small negative camber.

This is also an advantage as far as outer wheel is concerned because this is the outer wheel right in this particular case why? Because this good contact are the tyre road interface is beneficial because during while taking a turn there is always going to be lateral load transfer from the inner wheel to the out wheel okay. So load is going to be transferred always from the inner wheels to the outer wheels.

So it is important that the outer wheels get a good grip at the tyre road interface the outer tyre so that sufficient lateral forces are generated okay. On the other hand let us say we had positive camber okay instead of negative camber I am just drawing the outer wheel alone right so if we have an exaggerated positive camber on the outer wheel what is going to happen? If we take a turn if we do the same exercise the vehicle body is going to roll out and then the outer wheel is going to the positive camber on the outer wheel is going to even more increase so the grip of the corresponding tyre is going to only weaken okay.

So for this reason a small negative camber is typically introduced what is the price or tradeoff we can immediately see that if we introduce a camber a negative camber for example we can immediately see that as the vehicle is going straight you know the inner surfaces of this tyres are going to wear out more than the outer surfaces of course we have excessive camber alright. So that is the tradeoff okay so in order to balance both you know like we essentially introduce a small negative camber okay at the wheels at the steered wheels.

So in essence a small introduction of a negative camber ensures when the vehicle is turning taking a turn and the vehicle body rolls the outer wheel you know like essentially becomes a little bit straight right it becomes straighten so that the contact at the tyre road interfaces pretty good and we get a good grip alright at the corresponding tyre road interface what happens to the inner wheel

You know like with negative camber you know like if I have what to say negative camber on the inner wheel yes the inner wheel is going to roll in this way right but is it going to be so bad as that of the outer wheel there are mechanism when we come to suspension you will see that you know like we have mechanism by which we can adjust this and also we want the outer wheel to have better grip because the of the load transfer you know due to the roll motion okay so that is why a small negative camber is prescribed okay.

So these are various reasons right okay so let me write down the reasons okay so a small negative camber is typically introduced such that when the car body or the vehicle body rolls during cornering the tyre becomes almost upright okay this just a very qualitative figurative usage right that is the negative camber decreases and becomes almost upright with roll resulting in the best possible contact area at the tyre road interface okay so this implies that better grip during cornering okay.

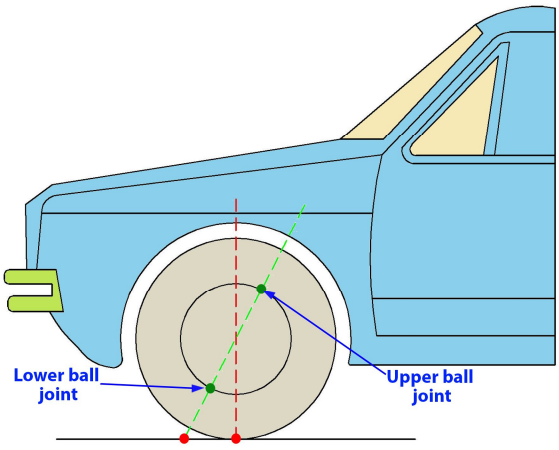
Let me put this grip under quotes okay we get a better grip during cornering the vehicle right and it becomes advantageous as we discussed with the outer wheel because of this dynamic load transfer while taking a turn right from inner to the outer wheels.

Now if camber is out of adjustment okay it will cause wear on one side of the tyre side okay excessive wear right so on one side of the tyres right okay. And if the camber is different from side- to- side it would lead to pulling. So what do I mean by different from side- to- side if you take the same let us say axle you know so to speak right if you look at the right and the left wheels if the camber is different you know like that is going to do what to say create this pulling..

So we will see that when you go to vehicle dynamics you know like if you learn vehicle dynamics you will see that this camber is going to result in what is called as camber thrust you know like which also helps in taking a turn right okay.

So this is wheel camber the second important parameter as far as wheel alignment is concerned is what is called as caster so what is caster so let us look at caster? So for camber we looked at the vehicle from the front so now what we do is that like we go to the side of the vehicle and we look at the vehicle from the side okay. So as we discussed when looking at steering component and steering system if you recall that the tie road essentially went and was fixed at the steering arm right at what is called as the ball joint right.

So let us say this upper ball joint is where typically the tie rod is fixed to the steering arm there is something called as lower ball joint you know which we will come to when we look suspensions you know like depending on the type of suspension you may have a control arm or a wishbone where you will have what is called as a lower ball joint okay.



CASTER

Now if we draw a line passing through these two ball joints that is what is called as the what to say from this perspective you know like it is the axis about which the wheel is going to be steered okay.

So when we draw a line through these are two ball joints so what is caster? So this is the steering axis so caster is nothing but the angle made by this steering axis with the vertical when we look at the vehicle from the side okay so that is the definition of this caster right. So caster is nothing but the angle made by the steering axis with the vertical direction when viewed from side of the vehicle okay so that is caster.

So what is the sign convention so what is being what to say illustrated in the schematic is positive caster. Positive caster means the steering axis leans towards the rear of the vehicle as we go up. So in this schematic we can see that as we go up from the ground right the steering axis is leaning towards the rear of the vehicle okay. So that is positive caster so when will caster be negative it is the other way around alright.

So when the steering axis leans towards the front of the vehicle so what is the impact of caster once again let me draw a simple schematic and explain. So suppose let us say a vehicle is taking a turn right and this front wheel is steered.

So say this is the longitudinal direction axis and let us say this is the orientation of the steered wheel okay. So this is the wheel plane okay so at since the vehicle is being steered in this way okay at the tyre right road contact there is going to be a lateral force Fy which is going to pull the vehicle into the turn. So i am looking the vehicle from the top okay I am considering only one of the two steered wheels so

let us say you know like I have a vehicle and let us say it is taking a turn to the left right.

And so I am looking at the vehicle from the top so this it is turning this way alright as indicated. So there is going to be lateral force at the tyre road interface which is going to pull the vehicle into the turn. Now this steering axis will essentially create a moment you know like so if you project a steering axis now what will happen is that like it will come and intersect the ground somewhere here okay.

Ahead of the tyre road contact patch okay so that is a result of this caster being positive. Now the steering axis hitting the ground at this point so what will happen is that when there is lateral force is generated at the tyre road interface there is going to be a moment of this lateral force about this steering axis is it not okay? And what will this moment try to do it will try to align the tyre back to the longitudinal axis of the vehicle okay so because this is the this is an axis parallel to the longitudinal axis of the vehicle alright.

So this is the wheel plane or the wheel axis alright the self-aligning moment is going to rotate it is going to have a tendency to rotate the tyre and the wheel assembly and make it straight within quotes right. So this is what is called as self-aligning torque or self-aligning moment and we would have observed this when we steer a vehicle right. When we steer a car alright and we take a turn and now we want to come to the straight ahead path right what do we do?

Do we turn the steering wheel back to the center? No right what happens we just release our grip from the steering wheel will start accelerating and then what happen the self-aligning moment will ensure that the steering wheel comes back to its centered position okay. So this distance is essentially what is called as a trial

okay so this trail times the in a very simple manner right so of course we need to analyze it very carefully right but in a very from a very simple perspective this trail times the lateral force you know will give us the magnitude of this self-aligning torque okay.

So that is basically the impact of this positive caster so we can immediately observe that a positive caster results in a trail that creates a self-aligning torque okay. So that is the impact of caster however you know we do not want to make this caster as high as possible right so that is too high alright why not? Because of course we want certain amount of self-aligning movement but if we increase caster to a very large value what is going to happen as then like the effort that needs the driver needs to put into turn the steering we will also increases right because the driver needs to overcome these moment right so to steer the steered wheel right.

So there is a tradeoff high caster means you know like you will have so a high caster results in better straight line performance because any perturbation the steered wheel is not going to essentially turn that much right. So because of this higher trail right so high caster results in or improves straight line performance which is good why does it improves straight line performance because we have more stability due to higher self-aligning torque but leads to higher steering effort alright.

So maneuverability takes ahead right so that is the tradeoff you know like of having a high caster angle so we get lower maneuverability okay with high caster. So there is a tradeoff once again okay so and if caster is different from side to side that is between left and the right sides alright it may result in pulling so that is the impact of caster.