Fundamentals of Automotive Systems
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Module No # 11
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Introduction to Suspension System – Part 01

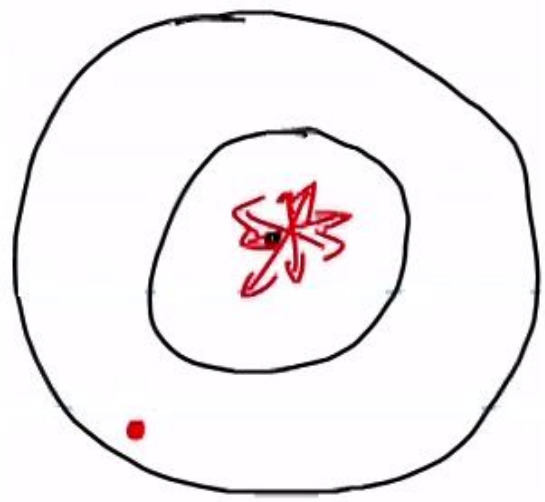
Okay greetings welcome to this lecture brief recap of what we were doing in the previous class we started off with an introduction to wheel alignment we saw that wheel alignment essentially refers to a broad set of parameters that need to be kept in specified design range for proper cornering characteristics that is like what happens when the vehicle turns and also it affects the parameters affect straight line motion of the vehicle and also they play a very important role as far as tyre wear is concerned right.

And we looked at 3 primary parameters camber, caster and toe we discussed what their definitions were and what were the effects and we looked at certain other parameters like steering axis inclination included angles scrub radius setback and thrust angle right so those were some other parameters which are also part of wheel alignment parameters right that need to be regularly monitored.

So typically these parameters should be checked periodically you know like if you go to a mechanic you know like there is wheel alignment machine alright they essentially check the alignment of wheels and they take corrective action needs to be taken any of these parameters go out of the range okay. And typical symptoms of wheel misalignment include uneven and rapid tyre were alright and uncentered steering that is the car pulls from side to side now when we are travelling straight ahead.

You know like or in order to drive straight ahead we may need to give some essentially small steering input from the center steering wheel vibrations that may be excessive steering wheel vibrations may also be a symptom of wheel misalignment and any even like changes you know like significant changes to the driver you know like when they take a turn or drive straight ahead and what can be felt at the steering wheel is a tactile indicator to the driver about wheel misalignment okay.

So we will look at a few more concepts today before we go on to the next topic okay. So the first one is what is called as wheel balancing so what happens when we operate these pneumatic tyres is that like suppose let us say I will draw a simple schematic you know of a pneumatic tyre so with use you know like due to some tyre's defects or uneven wear and so on. So what may happen is it like let us say that some part of the tyre you know like becomes more heavier than the other you know like what is going to happen as it rotates there is going to be a force imbalance right due to a local concentration of unbalanced mass.



OUT OF BALANCE

So what that will create is essentially it will create vibrations on the wheel you know that is going to be detrimental to the vehicle performance. So wheel balancing essentially has to do with addressing this problem okay so a tyre is set to be out of balance when one section of it becomes heavier than the other okay. So then the consequences in this will lead to a force imbalance when the tyre is rotating and this is going to lead to increased vibrations right on the wheel assembly.

So the this problem is solved by process called wheel balancing where a lead weight is attached exactly opposite to where this local concentration of mass takes place you know first one has to identify where this mass as concentrated and then a corrective action is taken by placing a lead weight exactly readily opposite to them right. So that the forces balanced so usually it is compensated by attaching a lead weight okay radially opposite to the heavier part okay.

So this is what wheel balancing is so if I want to balance this wheel you know like we have to attach a lead weight which is readily opposite to this concentration of mass okay so that is called as wheel balancing okay.

So there is another operation which we typically do when we want to maintain vehicles you know like is what is called as tyre rotation. So what is this tyre rotation so typically you now like if we have a 4 wheeled vehicle let us say a car right due to changes in the loading conditions of the car and due to the fact that you know like the front wheels are typically steered and depending on the vehicles you know front wheels may be typically driven right and more braking may be done on the front in a typical passenger car right.

So the front tyres may be subjected to more usage along both longitudinal and lateral direction and they may wear out non-uniformly with respect to the rear tyres right if the same tyres are used in all the 4 wheels. So then what is typically done is that the tyres are swapped you know like from front to rear and side to side and in different combinations okay. So that all the tyres wear out uniformly right so that is the concept behind tyre rotation.

So tyre rotation is typically done because non-uniform or asymmetric tyre where can happen due to different loads varying loads right on the front and rear wheels okay. Turning patterns and of course also wheel misalignment right so this can also play a role okay. So if this happens the process of tyre rotation is one wherein the tyres are switched between the various wheels to ensure uniform wear okay so that is the concept of tyre rotation. So we should not we should be very clear in differentiating between wheel alignment, wheel balancing and tyre rotation so these are different concepts.

INTERPETING TYRE WEARS

And one important you know like topic you know like that we are going to now discuss is how do we interpret tyre wear you know like because if we look at even all these parameters are associated with wheel alignment by and large you know like either the components are not directly visible to our eyes right or even if we are able to see the wheels you know like it may not be perceptible in because these camber, caster and toe and all may be very very small.

You know for perceiving them very accurately alright and even if there is a imbalance it is difficult to just observe with our eyes and figure things out. But on the other hand you know like we can always look at the tyres right and if the tyres are wearing out in a certain manner we could perhaps use that to diagnose what is the problem with the vehicle so let us take a few representative cases and see how one could interpret tyre wear you know like that is something which we are going to do right.

Okay so let us interpret tyre wear by looking at this figure right so let us what to say look at what all this cases and then like we will reason out what could one diagnose right but looking at this wear patterns. So if we look at rapid wear at the shoulders so we can see that these are the shoulders of the tyre right. So one could see that there is the rapid wear at the shoulders of these tyres this could this would potentially mean under inflation right the either the tyres are not inflated to the correct pressure so the shoulder are getting worn out.

Or this could also mean lack of rotation okay that is the tyres are not being swapped okay between the various wheel positions. On the other hand if we look at rapid wear at the center okay so this would mean either the tyre is over inflated right because if we pump in more pressure the central part of the tyre is going to

wear out more or it could also imply lack of wheel rotation right or tyre rotation okay.

And as we discuss in the previous class if we have excessive camber right one side of the tyre is going to wear out so in this what to say figure we can see that this side of the tyre has worn out the threads have worn out more than the other side right. So wear on one side of the tyre is going to point towards excessive camber okay. And if we have a feathered edge if you look at this these edges of the tyres you know like they are feathered like this right.

So that is going to be indicative of incorrect toe so what is going to happen if we have incorrect toe? You know like it is going to essentially let us say there is too much toe in right so the tyres are also going to scrub on the side right at an angle to their central wheel plane while the vehicle is moving straight. So that is going to result in this, corrugated or feathered edges alright. So if we have bald spots on the tyre like this so what are this bald spots?

You can see the threads have worn out at different locations right so we have these bald spots so typically these bald spots point towards an unbalanced wheel we may need to do balancing okay. So there are local wear you know like at various points in the tyre okay. And then we have what is called as scalloped wear on one side so we can see that you know if it gaps the thread on one side worn out okay.

Typically this points towards this may point towards you know like either lack of tyre rotation or worn or out of alignment suspension okay. And then we have crack trends right so we can see all these treads on the tyre which are cracked right so this cracked treads you know like pointing towards either under inflation or

excessive speed. So that is the that is what the we can diagnose from a cracked tyre right.

So this completes our discussion on wheel alignment you will see that typically wheel alignment is very critically linked to both steering and suspension of the vehicle. So we have looked at the steering system so now let us go and look at the suspension system okay that is the next topic we are going to start in this lecture okay. So as all of us can understand you know like and what we have seen from vehicles that we typically use.

If we mention the term suspension the first thing that strikes out mind you know like is essentially a pair of spring and a shock absorber right. So that is installed in vehicles and most of us understand that they are used to essentially protect the occupant from any disturbance that comes from the road the shocks or the vibration that comes due to uneven road surfaces and so on right. So that is the first idea that we get about suspension. But a suspension system also has other important functions to play okay.

So let us start with identifying what are critical the functions of a an automotive suspension. So of course an important function is to ensure that we get good right comfort okay so what is right comfort? You know like when there are perturbations on the road surface you know like we have pothole speed breakers and even like road surface of different profiles you know like with different what to say surface characteristics you know like the occupant of the or occupants of the vehicle should feel comfortable right they should not be subjected to too much of acceleration in the vertical direction due to the road profile changes.

So the suspension should provide good road comfort by minimizing the effect of road inputs or road excitation or we can also call them as road disturbances right. So this property is what is called as road isolation you know like ride comfort recruitment you know there are multiple requirements from an automotive suspension one could classify this under what is called as road isolation or right comfort okay.

The second important requirement is that if we are going on a road surface and let us say if the tyre and the wheel assembly vibrate a lot right due to the changes in the profiles right. So because the varying road profile is going to result in a vertical displacement right at the tyre road interface so now if the resulting vibrations of the wheel assembly in the vertical direction is of very high magnitude right then what is going to happen?

The contact between the tyre and the road is going to be affected. Then if the contact between the tyre and the road is going to be affected due to wheel vibrations then the longitudinal traction and the lateral traction that are generated due to the drive brake system and the steering system are going to be affected.

So we can to minimize such variation because kindly understand that all the forces that act on the vehicle or acting through the tyre road interface so let it be dry let it be breaking let it be steering okay. So we want to ensure that the contact or interface between the tyre and the road it is good right and does not vary too much right in the presence of these excitation or disturbances. So that is a very important function of an automotive suspension.

So an automotive suspension should also minimize the variation in the normal force acting on each wheel okay thereby improving the road holding characteristics

this is called as road holding okay. Because the wheel should or tyre should hold on to the road right so that is why it is called as road holding right road holding characteristics. So this requirement naturally is called as road holding okay.

Then there is another requirement so let us say we are going straight in a car right and the driver applies the brake very hard what is going to happen as we have already seen know there is a longitudinal load transfer from a rear to front okay. Now with the suspension you know like and with this longitudinal load transfer the vehicle will pitch forward that is the front of the vehicle will nose down right when the braking is done very hard.

Now the question is arrases you know like how much should it pitch if it pitches too much and to fast is it going to result in some undesirable effects. Similarly when we take a turn right the vehicle body is going to roll so the question is that like how much should it roll and how effective would be the suspension in minimizing the roll motion. So pitching can happen during acceleration and braking roll happens while corning and under all this maneuver the suspension should ensure that the vehicle remains stable within quotes right.

So that is it should not essentially result in excessive pitch and roll motion that the operation of acceleration braking and cornering. So the suspension should also ensure that roll and pitch motions of the vehicle are kept at minimum possible levels thereby improving the stability of the vehicle so that is an important requirement of the suspension okay. So this requirement essentially people will say that okay look the suspension should ensure stability under cornering acceleration and braking.

So if we look at a suspension you know like primarily most would think oh! it needs to provide a good ride comfort come right. But as we have just discussed you know it also has other important purposes that is also should ensure proper handling of the vehicle while taking a turn and even during acceleration and braking it should ensure that you know like the pitch motions are not excessive. And we will as we discussed suspensions you know like and analyze them we would see that these requirements are going to be essentially result in a tradeoff with one another.

So there is going to be a tradeoff between satisfying these various requirements so what do I mean we will realize that if you want good right comfort we have to compromise on something else and vice-verse so that is where the challenge comes for a suspension designer.

So if you look at the challenges that present themselves you know like when we look at suspension design and analysis there are conflicting requirements. So what does one may mean by conflicting requirement not only are the above requirements conflicting we will see that there are we are going to have a laden and unladen vehicle right. So for example let us say even if we take a heavy single unit bus or a truck right. So we load it completely and let us say the mass of the truck is 16 tons we unload it completely by delivering it’s goods.

You know the mass of the empty truck or completely unladen truck may come down to let us say four and four and half tons there is a huge change in the mass. So that is going to affect the what to say the response of suspension also. So we have varying road surface characteristics right so that is another big challenge

when we are looking at suspensions. And then we have to look at what happens in straight line motion acceleration braking etc., versus cornering right.

So, one could say acceleration or what to say braking in this case alright under straight line motion. So as we have just discussed you know it should ensure it should respond properly all these maneuvers okay. So the suspension system is one which needs to react you know like under when the powertrain is active during acceleration when the brake system is active during braking when this steering system is active during cornering under all these other subsystems they maybe, active at some point or the other right. But the suspension always as to be reacting to changes alright in the vehicle's operating state. So those are all important challenges okay.

Another challenge is that the choice of the suspension is also influenced by drive and steering requirement. So we would when we discuss different types of suspensions we would observe that you know in typical passenger cars where the front wheels are driven right. So we are going to have space constraints right because the front wheels are driven the front wheels are steered. So then the choice of suspension also is constrained by the space which is available right.

So that is going to result in space constraint and also cost constraints okay and we will shortly see that based on how they are what to say they are realized they are different configurations of suspensions okay we will look at the different classes of suspension that we go along.