Fundamentals of Automotive Systems
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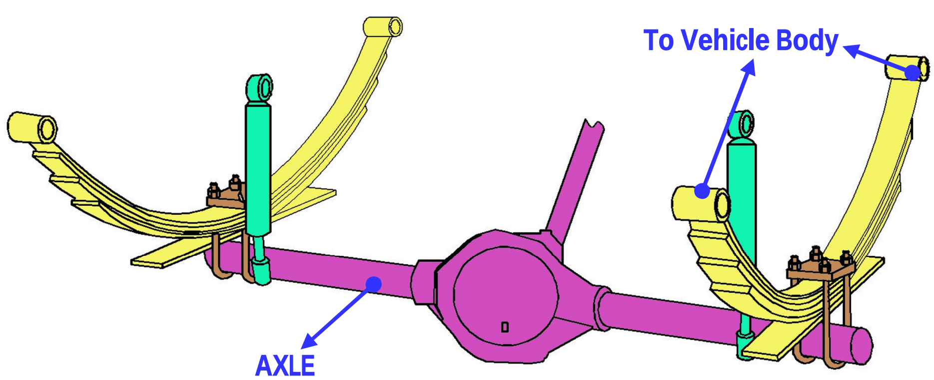
Module No # 12
Lecture No # 69
Dependent Suspension and Suspension Analysis – Part 01

Fine greetings so welcome to today's class so we will continue from where we left off in the previous lecture you know like in the previous lecture we were discussing about different types of suspensions. So and we stop with a discussion on independent suspensions. So today we will look at various common realization and configurations of dependent suspensions okay. So the first dependent suspension that we would be looking at is what is called as a solid axle leaf spring suspension okay that is the first configuration that we will look at.

So this is very popular particularly on vehicles you know like where the rear wheels are driven okay so you can see this propeller shaft you know like just splitting the drive torque between the left and the right wheels through the



DEPENDENT SUSPENSION

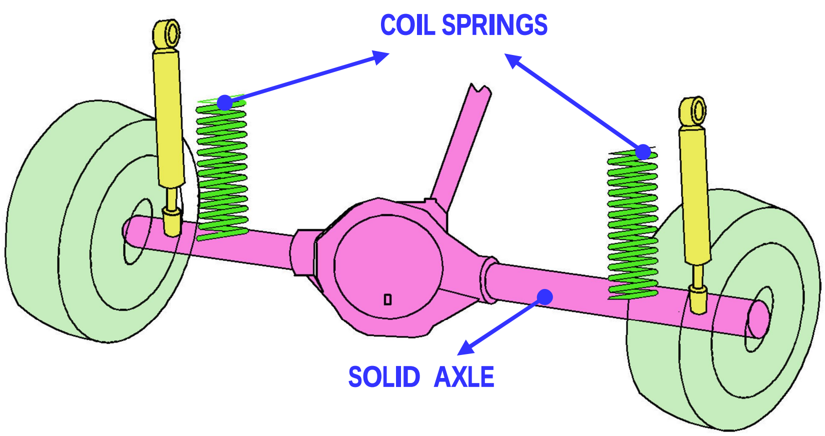
differential unit and here you know like we have a solid axle right. So this is our drive axle and what happens here is that like the leaf springs you know are clamp to the axle and we can see these eyes which are then attached to the vehicle body okay.

And there is also a shock absorber that is provides damping to the vibration arised okay so this is very common pretty popular dependent suspension. So we can immediately observe that the leaf springs are clamped to the axle okay and their other ends are attached and their ends right. So are attached to the vehicle body so that is a solid axle suspension so now we can observe that the leaf spring also provides some sense of support you know like to the suspension with respect to the vehicle body along the other directions right.

So because since the ends of the leaf springs the eyes are clamped to the vehicle body now it provides some support along the longitudinal direction right. So that is a feature of this particular configuration so the leaf spring also provides a reasonable support to the suspension okay along the longitudinal and lateral direction right. So in a certain sense if the axle tries to move with respect to the vehicle body along the lateral direction there is some stiffness right to essentially prevent that okay.

So longitudinal or lateral directions okay so that is one advantage so of course these leaf spring suspension are simple and economical but however due to the presence of a solid axle and the spring itself being significantly heavy right these suspensions are heavy right. They result in higher unsprung mass okay and this results in issues with rite quality and handling characteristics okay. So these are some issues with solid axle leaf spring suspension okay.

The next type of dependent suspension that is commonly used is what is called as a solid axle coil spring suspension. So in the case of the solid axle leaf spring suspension that we just discussed the suspension stiffness is provided by means of a leaf spring in this solid axle coil spring suspension the leaf spring is replaced with a coil spring. So that is the main difference in this version so this is also a popular dependent suspension.



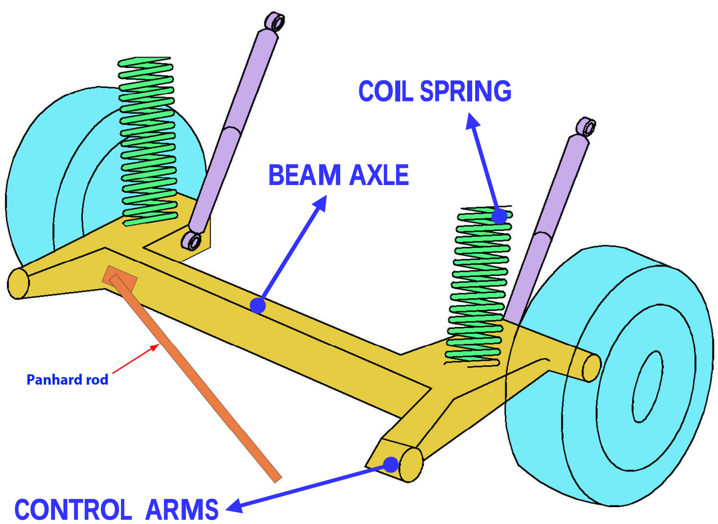
SOLID AXLE COIL SPRING SUSPENSION

So as we can observe so this is a rigid axle and we can observe that there is a coil spring that provides the compliance in the suspension and there is a shock absorber which also serves to attenuate the effect of road disturbances right and help in energy dissipation. So in a coil spring suspension since the coil spring can typically give support only along the axis of the spring we require additional elements such as control arms to provide support along the longitudinal and lateral directions.

So a control arm is typically used in a solid axle coil spring suspension to provide structural support. So let us summarize a few importance points of a solid axle coil spring suspension. So here as we discussed coil springs replace the leaf springs.

However since the coil spring provide support only along it is axis typically control arms are used to provide structural support along the longitudinal and lateral directions and these control arms connect the solid axle to the vehicle body okay. So that is how they provide the structural support.

So this is the coil solid axle coil spring suspension another popular category of a dependent suspension is a beam axle suspension. So this beam axle suspension this schematic of which is as for given here so one could observe that there is a beam on which the spring and the shock observer are mounted you know and such a beam axle suspension is commonly used on the rear of front wheel driven cars okay.



BEAM AXLE SUSPENSION

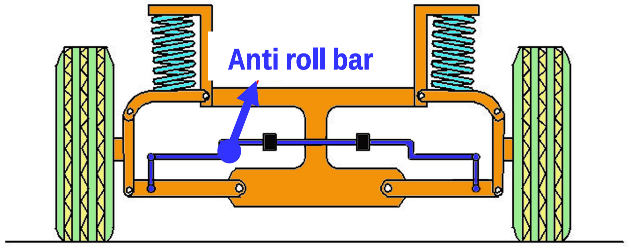
So this is the beam which connects which lies in between the two wheels and we can see that there is a coil spring and a shock absorber and typically what are called as trailing arms are provided on the beam axle suspension that connect the beam to the vehicle body so that like structural support is provided in the longitudinal and lateral directions. And we can also observe another, components which is termed as panhard rod which we will shortly encounter.

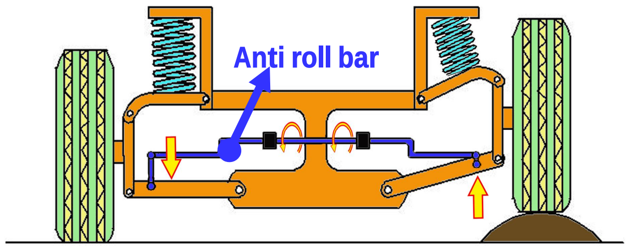
But the panhard rod serves to improve the roll stiffness of the vehicle so for example when a vehicle takes a turn there is what is called as lateral load transfer from the inner wheels to the outer wheels then in order to ensure that the body vehicle body does not roll significantly we need to use elements like the panhard rod to improve the roll stiffness of the vehicle you know. So that is one important function of a panhard rod.

In the case of independent suspension we will shortly see that the same functionality is achieved by means of what is called as a anti roll bar. An anti-roll bar is typically used in an independent suspension to improve the roll stiffness such that when the vehicle takes a turn and there is a load transfer from the inner to the outer wheels along the lateral direction of the vehicle the body does not roll significantly okay.

So that is a very important action and the anti-roll bar which is used in independent suspension also ensures that when there are disturbances from the road the two sides can move with certain degree of independent with respect to each other and that a independence does not affect the contact between the tyre and road the anti-roll bar will take care of that aspect also which we will see shortly okay.

The beam axle suspension is commonly used in the rear of front wheel driven cars and the vehicle body is connected to the beam through springs and shock absorbers. And trailing arms are used to connect the beam to the vehicle body to provide support along the longitudinal slash lateral directions okay. So that is a beam axle suspension which is also a commonly use dependent suspension system. Now a few other elements in the suspension okay are as follows so we have what is called as an anti-roll bar or a stabilizer bar, sway bar so what is this anti-roll bar?





ANTI ROLL BAR

So this anti-roll bar as the name indicates it provides some resistance to roll motion okay. So and where are they used typically as we discussed when we have a independent suspension there is some what to say flexibility available you know like to ensure that a disturbance which is felt by a wheel on one side is not transmitted to the other side okay.

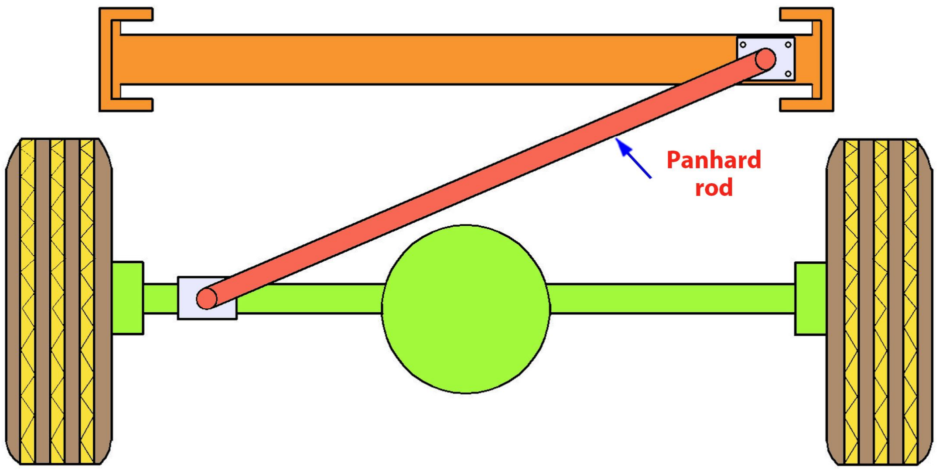
So this is an independent suspension and we can immediately observe that the disturbance which is let us say felt on either side you know like is basically attenuated right before it reaches the other side. The anti-roll bar essentially ensures that with while this disturbance from side to side is attenuated the roll resistance or the roll stiffness is not affected okay. So that is the function of an anti-roll bar okay.

So what this anti-roll bar does which is indicated here is that suppose let us say the right wheel hits a bump it is going to go up right and due to the location of the anti-roll bar and it is orientation this vertical motion of these links is going to result in a twist of this anti-roll bar and what is that going to do the anti-roll bar has some torsional stiffness okay. So it provides a resistance to this twist so that this wheel is ensure that this wheel stays in contact with the road surface and does is not lift off okay.

So there is a reaction due to the torsional stiffness of the anti-roll bar to ensure that this right wheel in this figure maintains sufficient contact with the tyre road interface. So that is the function of an anti-roll bar so let me are write the main points so typically used with independent suspension since the independent motion of the left and right wheels can result in roll while cornering and travelling over irregular surfaces okay so that is one purpose.

And what happens is that like this anti-roll bar as the name indicates it minimizes the roll motion okay under these circumstances okay. So it is connected to the suspension units on both sides okay and twist when one suspension is displaced with respect to the other right relative to the other in the vertical direction obviously okay. So that is the function of an anti-roll so it effectively it increases the so called roll stiffness or the resistance to roll okay so as far as the vehicle body is concerned. So this is one mechanism another mechanism which is used in vehicles you know with a dependent suspension is what is called as this panhard rod right?

So the panhard rod also ensures that you know the suspension right with respect to



PANHARD ROD

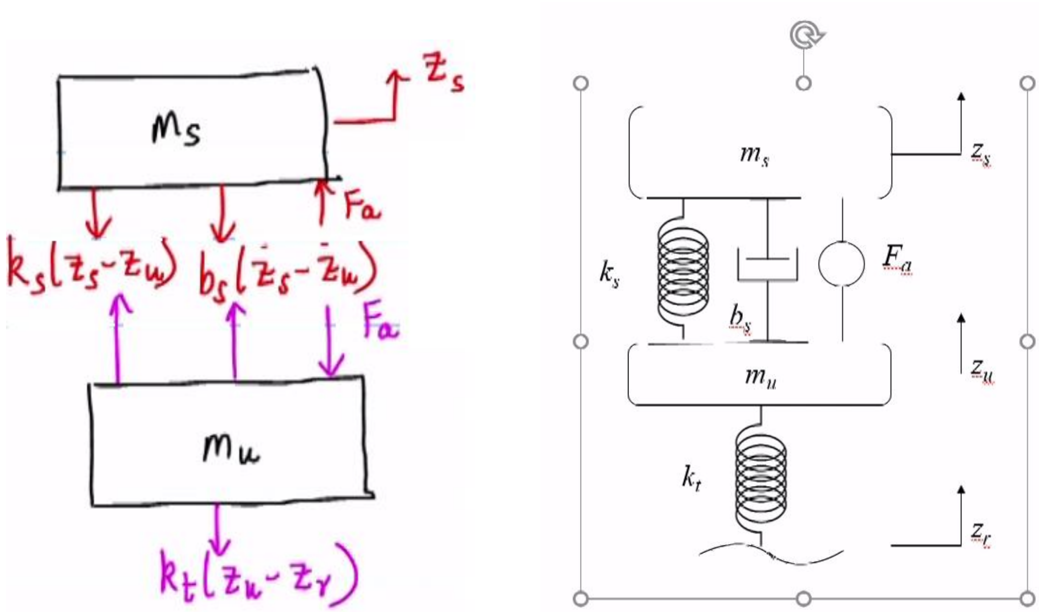
the vehicle body does not travel too much from side to side in a dependent suspension while cornering and going on irregular roads. So it is a very simple mechanism let us say we have a solid axle or a beam axle dependent suspension. So what happens is that this panhard rod one end of it is connected to somewhere near the suspension unit on the one wheel right and other end of the panhard rod is connected to the vehicle body at the other end right.

So if you view it from this you know like it is just in the opposite end in the along the lateral axis along the lateral direction right. So that is a panhard rod so the main objective of the panhard rod is that it prevents or reduces side to side movement or lateral movement of the dependent rear axle while cornering and on irregular roads okay. So one end of the panhard rod is attached to the axle and the other end is attached at the laterally opposite side okay.

Of course attached to the vehicle body and the laterally opposite side okay so that is the feature so the advantage is that like it is a simple it provides that what to say so called stiffness right to this side to side motion right but one limitation is that like the relative motion of this axle and the vehicle body can only now take place constraint by this rigid rod right.

So for example the axle must travel in an arc if the vehicle body is displaced you know like it has to travel and in an arc as constraint by the length of this panhard rod and vice versa right. So that is the constraint imposed by the panhard rod okay so these are different components as far as the typical automotive suspension is concerned.

So the next topic you know like which we are going to look at is do a simple analysis of the suspension system right. So having looked at what are all the functional requirements of a suspension system how they are realized and how they are classified and what are the features of each types of suspension. So let us use base dynamics you know like to analyze the response at least from one perspective.



SUSPENSION ANALYSIS – QUARTER CAR MODEL

So what we are going to do is essentially look at how one can do ride analysis of suspensions right using a what is called as a quarter car model. So as a name indicates a quarter car model you know it considers you know like one suspension unit in a four wheel vehicle right. So if we have four wheels a single unit four wheel vehicle right so it considers one suspension unit in a four wheeled vehicle.

So let us look at a simple schematic and this is something which you know like the derivation of this equations is pretty straight forward and that follows from dynamics you know that is about it okay. So if we look at this schematic you know like of this quarter car model so it is a two degree of freedom model. So let me explain what this model is so the entire mass of the suspension which is supported on sorry entire mass of the vehicle body which is supported on the suspension is what is called as sprung mass right.

So that is something which we have already defined so let us say the sprung mass is M_s and the un-sprung mass is Mu and okay and let the displacement of the sprung mass from it is equilibrium state be Z_s the vertical displacement right and let the vertical displacement of the un-sprung mass from it is equilibrium state be Z_u and Z_r is the road input right the road there is an input that comes due to the road profile at the tyre road interface.

So that is Z_r and a k_t is indicative of the tyre stiffness in the vertical direction and k_s is the suspension stiffness right the stiffness of the suspension spring b_s is the suspension damping. So this F_a without loss of generality what we will do is that like let us consider an active suspension which has an actuator to deliver a force right. So if we have an active suspension we have an actuation force or an actuator force that is placed between the sprung and the unsprung mass okay.

So let us consider the F_a is force that comes out of this actuator okay of course b_s is a suspension damping coefficient. So if we were to draw the free body diagram of this sprung mass and the un-sprung mass we would get the following. So if we draw the free body diagram of this sprung mass ms so what are the forces acting on it we would have k_s times Z_s minus Z_u which is the restoring force from the suspension spring okay of course Z_s, Z_u and Z_r of functions of time in this free body diagram I am suppressing that function of time symbol you know just to because of space constraints right.

And the force from the damper is going to be bs times Z_s dot equals Z_u dot okay so we are considering a linear spring and a linear damping element and without loss of generality let us assume that the actuation force F_a acts upwards on the sprung mass okay. So similarly if we were to draw the free body diagram of unsprung mass what would we have? We would have the same restoring force from the suspension spring now will be acting will be trying to pull up the unsprung mass okay.

And the damping force will also be acting now upwards on the unsprung mass right and this actuation force will now act downwards on the unsprung mass. And there is a restoring force due to the tyre stiffness which will be acting in this manner so that is going to be having k_t times Z_u minus Z_r okay. So that is going to be the restoring force from this tyre stiffness term alright.

So now what are the two degrees of freedom of this what to say quarter car model they are nothing but the vertical displacements of the sprung mass and the un-sprung mass. So those are the two degrees of the freedom there is Z_s and which is indicated by Z_s and Z_u .