Fundamentals of Automotive Systems
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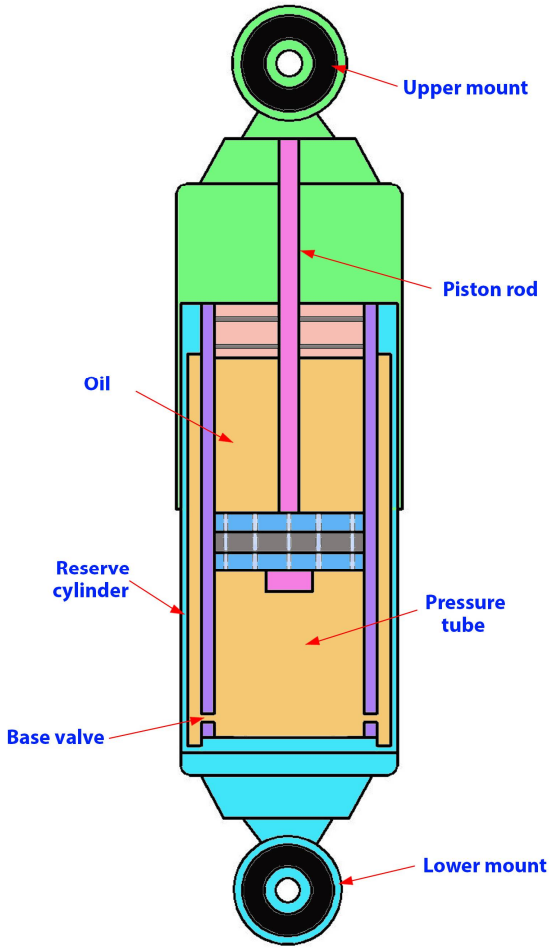
Module No # 12
Lecture No # 67
Shock Absorbers and Independent Suspension - Part 01

Okay so greetings so welcome to today's class so a recap in yesterday's class we looked at we started looking at suspensions right. So we identified that broadly an automotive suspension has two components you know like an energy absorbing components realized in form of a spring and an energy dissipating component realized in the form of shock absorbers and other linkages which we will discuss as we go along okay.

So yesterday we looked at springs we looked at different class of leaf springs and discussed the characteristics we looked at leaf springs, torsion bar, coils springs and air spring okay. So today let us gets started with discussion on shock absorbers. So what is the roll of a shock absorber in automotive suspension ok.
The shock absorber essentially is used to convert the kinetic energy to thermal energy which is then dissipated okay so that is the primary role of a shock absorber and this way it will serve to dampen the vibrations okay like that come about when the vibrates due to road perturbations okay. So primarily you know like what are called as oil filled telescopic shock absorbers are used in automotive applications okay. So what are these oil filled telescopic shock absorbers let us look at a simple schematic.

So here we can see that you know like there are two tubes okay we can see that there is an upper tube okay and a lower tube and we can see that the two tubes can



TELESCOPIC SHOCK ABSORBER

slide into each other right slide in and out of each other right. So that is why it is called as a telescopic arrangement okay and we can observe that the upper tube has an upper mount which is connected to the vehicle body okay. And to this upper mount is a rod a piston rod at the end of which there is a piston okay and that is immersed in a hydraulic oil okay inside this tube arrangement.

Now what is going to happen is that this lower mount obviously is connected to suspension linkages ultimately connected to the wheel assembly okay so as the wheel assembly vibrates or gets displayed with respect to the vehicle body these tubes are going to slide relative to each other in and out of each other right. What

will happen to the fluid then this piston as small grooves in it through which the hydraulic oil is forced from either the top side to bottom or vice versa depending on the travel of the two tubes.

When the oil is forced to the small orifices due to the viscosity of the oil there is going to be energy dissipation okay. So that is how the shock absorber dissipates the energy and converts the kinetic energy to thermal energy and dissipates it okay that is the mechanism of dampening the vibrations that are felt okay. So this is the typical arrangement so let me write down the key points about the shock absorbers.

So the shock absorbers are connected between the vehicle frame or body okay and the wheel assembly so then the upper mount is connected to a rod which has a piston immersed in oil. So this lower tube is called as a pressure tube okay so this lower tube in which the piston moves inside a so called pressure tube during which oil flows through small orifices in the piston leading to energy dissipation okay so that is what happens in the shock absorber.

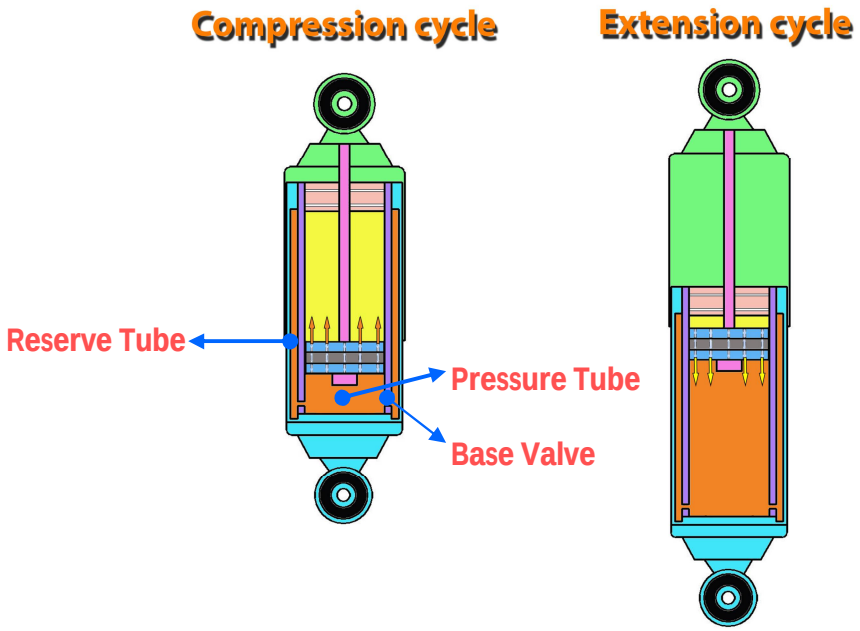
Now a broadly you know like there are two strokes of this shock absorber okay what is called as a the compression or a bumps cycle and an extension or an rebound cycle okay so we will look at both of them as to what happens okay? So two cycles are strokes right so the first one is what is called as a compression or a bump cycle so in this compression or a bumps cycle to what happens is that the piston moves downwards right with respect to the pressure tube and consequently the fluid below the piston is going to be pressurized and that flows through the orifices okay.

And in the extension or rebound cycle the fluid moves sorry the piston moves upwards relative to the pressure tubes so the fluid above the piston is going to be

pressurized and the fluid flows downwards with respect to the piston okay. So for example when are, we going to have a compression or a bumps cycle suppose let us say we are driving a car and we go over a speed breaker right. So then we are going to have a compression or a bump cycle.

So let us say we go into a pot hole one of the wheels go into a pot hole and going to have a and extension or an rebound cycle of course when we have vibrations we are going to have both right periodically.

So now depending on the number of tubes in the lower half okay we have what is called as a twin tube shock absorber and a mono tube shock absorber so what are these? So anyway shock absorber which is used in automotive application has two tubes and upper tube and lower tube right what is called lower tube follows pressure tube which slide into each other okay.



TWIN TUBE SHOCK ABSORBER

So then what is that twin tube? Inside the lower tube there are two annular cylinders or tubes okay that is why it is called as a twin tubes shock absorber.

So let us look at them so let us look at a twin tube shock absorber so happens in this twin tube shock absorber? We can immediately absorb that now there are two tubes so this central one is what is called as a pressure tube okay. And then you can see a small annular region between the central tube and the external surface of this shock absorber which is what is called as a reserve tube or reserve cylinder okay.

So there is a the pressure tube which is the central tube or central cylinder and there is an annular region around it which is called as the reserve tube. And there is an opening which is what is called as a base valve which connects the pressure tube to the reserve tube okay. So now what happens so this stroke corresponds to a compression cycle so when the piston moves downwards relative to the pressure tube right and the pressure tube is going into the upper tube what is going to happens is that?

The pressure is going to increase below the piston right as the result we can see that the fluid flows from bottom to top in the cylinder right from through the piston orifices. Now when the piston moves in so we can see immediately what is the role of the reserve tube so the excess fluid when the piston moves down and pressurizes because oil is incompressible right. So almost incompressible so what is going to happen is that like the excess fluid will go into the reserve tube okay so that is the purpose of a reserve so the reserve tube acts like a reservoir right for the excess tube.

Now during the rebound or extension cycle the opposite sequence of operation happens right the piston is the outer tube is going to move downwards relative to

top tube sorry the lower tube is going to move downwards relative to upper tube and then what happens is that the pressure increases above the piston and so the fluid flow is from the top to the bottom through the orifices once again okay.

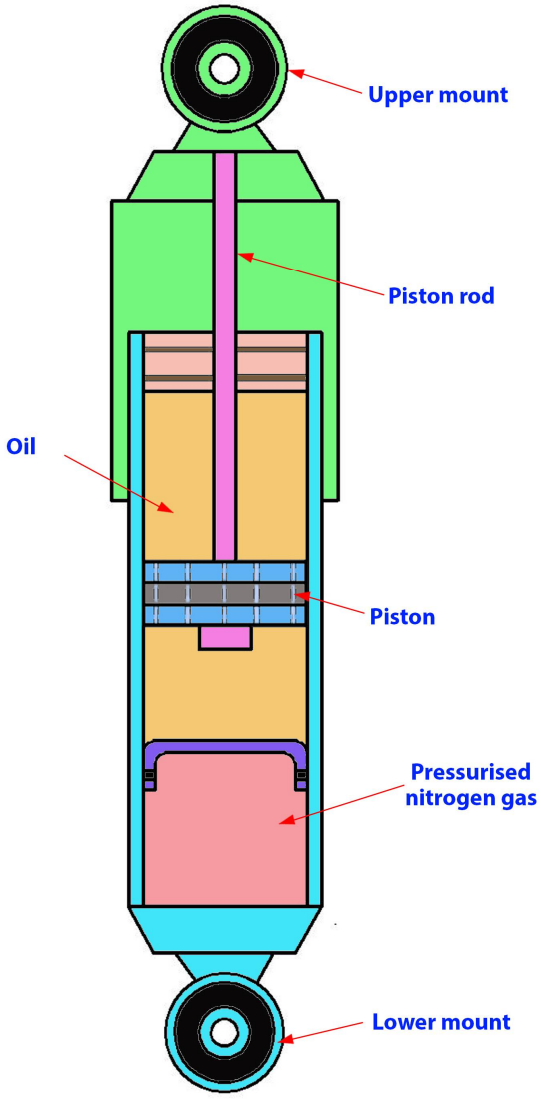
So the reserve tube acts like a reservoir right to store the excess fluid and even during the extension cycle fluid is anyway taken from it right. So that is what happens in the twin tube shock absorber okay. So few quick points we can immediately see that there are two tubes in the lower half okay so those are the pressure tube or cylinder and the reserve tube okay. So the primary function of this reserve tube is that it acts as a reservoir for excess fluid okay.

So now there is a base valve through which the fluid flows between the pressure tube and the reserve tube okay. So these are the mains components and operation of a twin tube shock absorber. So there is something called as a gas charged twin tube so what happens is that in a so called gas charged twin tube shock absorber there is some nitrogen gas you know like which is filled at low pressure in the reserve tube okay the purpose of this having this nitrogen gas is to ensure that this oil is not leaking you know like from the twin tube assembly with operation.

Please note that you know like with operation you know like the tubes are going to be displaced relative to each other and there is also heat energy right, which essentially need to be dissipated. So consequently in order to prevent any leakage of this fluid shock absorber fluid from the reserve tube a small pocket of nitrogen gas is at low pressure is introduced in the reserve tube or reserve cylinder that acts like a cushion alright and also ensures that the fluid does not leak.
So that is essentially what is called as a gas charged twin tube. So in a gas charged twin tube a low pressure nitrogen gas pocket is present in the reserve tube okay that prevents the fluid from dripping or leaking out of the assembly so that is what

is called as the gas charged twin tube alright. So that is the twin tube shock absorber.

Now the second variant is what is called as a mono tube shock absorber so what is this mono tube shock absorber. So let us look at them right so as the name indicates a mono tube shock absorber has only one tube in the bottom part alright.



MONO TUBE SHOCK ABSORBER

So opposed to a twin tube shock, absorber. So let us look at the mono tube shock absorber so we can see that there is only one pressure tube as the lower tube right so there is no what to say annular reserve tube right in the bottom part okay.

And there is a pocket of pressurize nitrogen gas which takes up the change in volume right when the hydraulic fluid is pressurized alright due to the compression and extension cycle okay. So this nitrogen gas is compressed or it expands depending on the stroke and we have what is called as a floating piston which essentially separates the shock absorber fluid from this nitrogen gas okay that is the main difference.

So as with the twin tube we can see that there is an upper mount which as a rod which is connected to a piston which is immersed in this oil right and oil flows through the orifices as the two tubes sliding in and out of each other during the extension and compression strokes. So the main difference is that like instead of two tubes in the bottom half there is now only one tube but at the bottom of the tube there is a high pressure nitrogen gas pocket okay so that is the mono tube shock absorber.

So the mono tube shock absorber does not have a reserve tube okay it has a floating piston that floating piston separates the hydraulic fluid from the nitrogen gas okay. So there are a few more components in the suspension system right we have looked at spring and shock absorber so there are a few more components which we will encounter as we are going to discuss various suspension configurations are the suspension linkages which play a critical role right okay.

So before we look at different types of suspensions you know like a few points to note and also few terms which we will be encountering shortly the first one is what

is called as the sprung mass what is that sprung mass? It is typically if we visualize a suspension you know as a unit that is that has one mass lump of mass above it and one lump of mass below it right connecting two assemblies.

The mass which is supported on top of the suspension which includes the vehicle body is what is called as a sprung mass okay. So the term sprung mass indicates the mass supported on the suspension system okay so for example the vehicle body right.

So that is what is called sprung mass the term un-sprung mass is what is between the suspension and the road right. So it is the mass it is indicative of the mass between the suspension and the road so what can the un-sprung mass include for example the wheel assembly the axle right the brakes etc., so the foundation brakes alright. So the disk brakes and the drum brakes that are mounted in the wheel assembly all those form part of the un-sprung mass okay.

So we use the term loosely sprung vehicles to refer to those vehicle that have a softer spring okay which implies better ride comfort or improved ride comfort right. So if we have a softer spring that is going to absorb you know like variation or perturbations from the road but that is going to be at the expense of but there is a trade off in road holding okay. And also other what to say functions or requirements like cornering braking acceleration characteristics right of the suspension.

So that is the tradeoff that we have in a loosely sprung vehicle the complement of this is what is called as a the tightly sprung vehicle. So these are all terms that we would be in encountering when we deal with suspensions so a tightly sprung

vehicle have a stiffer spring right as the name indicates so obviously they will have better road holding okay and cornering characteristic the role stiffness would be more so but on the other hand there is a tradeoff in ride comfort okay.

So we can immediately see the challenge in suspension design so we want to have a balance right between the various conflicting requirements you know like of an automotive suspension right okay so these are some terms. So now the next topic that we are going to look at is how do we classify suspension systems okay so let us look different categories of suspension systems.

The first classification is going to be from the perspective of I would say broadly performance alright how adoptable it is and so on right. So from the perspective of performance you know like we can classify a suspension into the following groups by and large you know like more suspension which are used in road vehicle are what are called as passive suspension so what is passive suspension?

Passive suspensions means we design the suspension let us say we fix the spring the shock absorber we select them we install them in the vehicle and that is it right. We cannot change the characteristics of the spring and shock absorber as the vehicle operates okay. So there is always a tradeoff between various functional requirements of suspension and even as the suspension keeps on working there may be some variations in the characteristics of the spring and the shock absorber right.

So those are limitations but it is very simple and inexpensive right so has a spring and a shock absorber with fixed stiffness and damping characteristics so that is the absorber that is the main feature. So obviously it represents a tradeoff or

compromise between ride comfort road holding and other functions alright of a suspension right.

So that is a passive suspension then we can have what are called as semi active suspension so what is this semi-active suspension? So as the vehicle keeps operating okay depending on the operating conditions and the response of the suspension to the vehicle's operating conditions the semi-active suspension can regulate the damping characteristics of the shock absorber the spring stiffness characteristic remain the same right however the shock absorber or damper characteristics can be changed alright depending on the operating conditions so that is why it is called as a semi-active suspension.

So in a semi-active suspension it typically use a variable damping element such as a twin tube viscous damper in which such as a adjustable right. Twin tube viscous damper in which the damping characteristics can be changed by varying for example the area of the orifice in the piston okay so that is one way of this one so essentially that is the semi-active suspension right.

So a fully active suspension of course in a semi-active suspension the stiffness characteristics this spring remains the same okay so that is fixed. So there is improvement over a passive suspension of course if we look at it from functional stand point the best option would be what is called as a active or a fully active suspension what is an active suspension? In an active suspension in addition to a spring and a shock absorber we have an actuator which can provide a time varying force on the sprung and the un-sprung mass to regulate the suspension performance okay.

So that we can get very good control on how the vehicle is responding to road input cornering and acceleration braking and so on okay. So that is an active suspension so an active suspension uses an electronically controlled actuator to provide improved performance okay of course it is very good but then like we have higher cost and complexity and another important challenge is the actuator bandwidth you know because we are going to have a road input over a frequencies right.

So the actuator should possess sufficiently high band width to respond to a reasonable wide frequency range so those are challenges you know as far as active suspensions is concerned okay.