Vibration Control
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Module - 6
Principles of Passive Vibration Control
Lecture - 3
Shock Absorber

Hi, this is Dr. S. P. Harsha from Mechanical and Industrial Department, IIT Roorkee. In the course of Vibration Control, we have mainly discussed about the vibration generations, the vibration controls specially when it is being generated at the source or transmission features or at the receiver end. So, in this module you see, we are discussing mainly on the principles of vibration control, the passive vibration control. And in that, we discussed about, what exactly the basic features when we are adding something in terms of the spring or damper or the mass.

And how we can suppress the vibration at the source or how we can deviate the path at the transmission feature through metallic surface or through air duct or through airborne structure or even, how we can suppress the vibration at the receiver end. And in the last lecture, we discussed about the design of the shock absorber, because we know that, when any continuous or impulsive features are there from the ground or any source to the machine, there is certain abrupt changes or the continuous kind of sinusoidal featured vibrations are there.

And when we are designing this, we can say isolator or shock absorber then we need to think that, what exactly the amount of these impulsive or these impact forces are being there, in which the abrupt change is there in the force magnitude and the direction as well. So, we discussed about the added mass, through which we can straightaway absorb the entire vibrations or vibration amplitude and we can keep the vibrating mass at the zero amplitude when the added mass and the vibrating masses are being tuned.

And we discussed about you see that, how we can make the single degree of freedom system to two degree of freedom system so that, we can simply deviate the resonant frequency from 1 to 2. And then by that way, you see at least we can reduce the huge amount of energy or the amplitude at the resonant condition. We also discussed about the vibration absorber or the shock absorber in terms of the spring and the damper feature,

we discussed about the viscoelastic feature of the shock absorber. So, in last lecture, in the passive vibration control, all three features including added mass, spring and damper, how they are being effectively used, that part we discussed. In this lecture also, we are mainly going to discuss about, how the shock absorber is really working and where you see they have applications specially.

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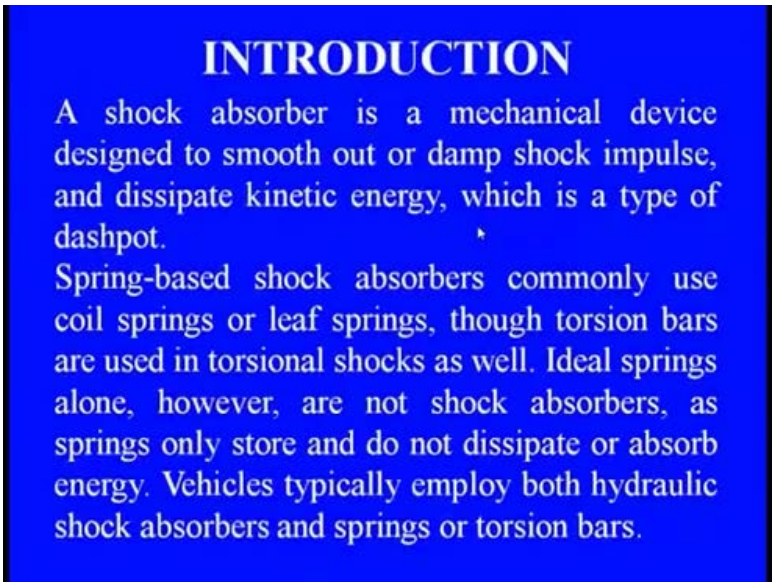

Because, when we are talking about the shock absorber, the first thing is coming that, it is a mechanical device, which is mainly designed to smooth out or we can say, rather just to damp out the shock impulse. And whatever the energy, which is being there at the excitation part, it is being dissipated in terms of the kinetic energy, which is simply converted into the heat part. So, the shock absorber is something like a dashpot, but all along this dashpot is not the featured part, absolute featured part of the shock absorber.

The spring based shock absorber commonly use the coil spring or leaf spring, though the torsion bars are just using the torsional shocks for that, but generally we are using the coil spring along with the damper. So, idle springs alone are not perfectly the shock absorber, because we know that, the spring is only storing the energy, it is not dissipating or it is not even absorbing that, it is just storing the feature.

So, you see when it is being, we can say the compression part, it is stored and when it is releases, again the energy is being released to the system. So, ultimately the energy is being transferred at the source, again back you see here, so that is not the perfect device

for absorbing or dissipating the energy. So, along with the spring, there is a need for damper as well, but damper even you see here, the damper itself is not the perfect device at that point of time, when the shock impulse is there.

So, at that time you see here, there is a need to store first the energy from, when it is coming from transient nature to the steady state nature. And then you see we can say that, that energy can be absorbed or can be dissipated in terms of heat. So, the vehicles which employs like both, we can say the hydraulic shock absorber or the spring or we can say that, torsional bar are the perfect devices for having the smooth control on the shocking part. So, that is why that, we are saying that, these are the shock absorber, in which the absorbing and the storing feature of the energy are coupled together.

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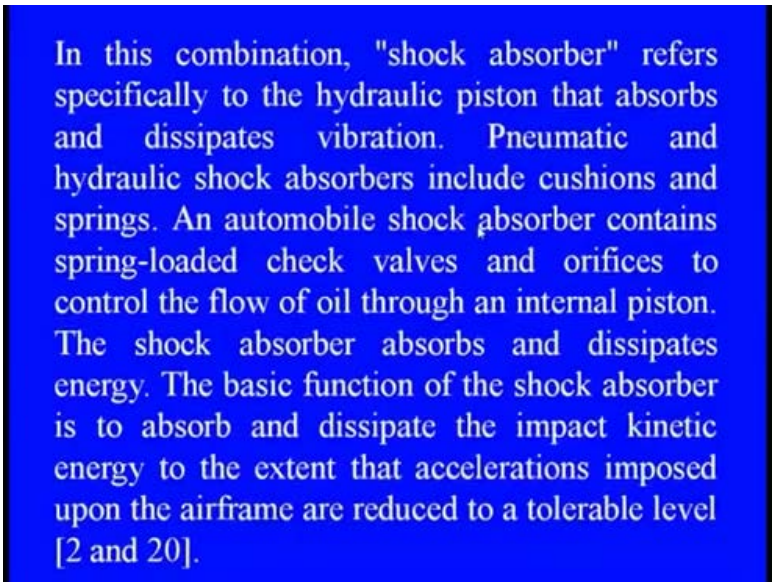

So, in this combination, the shock absorber mainly refers to the hydraulic piston that absorb and dissipate the vibration. We can say, the pneumatic and hydraulic shock absorber, they are always included the cushion and the spring effects together, so these shock absorber are having main application in the automobile. So, an automobile shock absorber contains spring loaded check valves and even the orifices to control the flow of oil through the internal piston.

So, when the shock absorber absorbs and dissipate the energy we know that, the entire part which is being acting at the contact point and whatever due to friction or due to any action under the dynamic feature, we can say that, the energy is being created, straight

way it is being converted into the heat by kinetic or the strain energy feature. So, the basic function of the shock absorber is to absorb first, through the spring and dissipate the impact kinetic energy.

So, that is what you see here, what we are talking general is a continuous kinetic energy and through that you see, the strain energies is forming and then it is being transmitted or dissipated. But, here we have the impact kinetic energy to the extent that, acceleration imposed upon the air frame or anything you see here, on the structure can be straight way reduced to the tolerable level by this absorption and the dissipation feature of the shock absorber, so that is a basic function of the shock absorber is.

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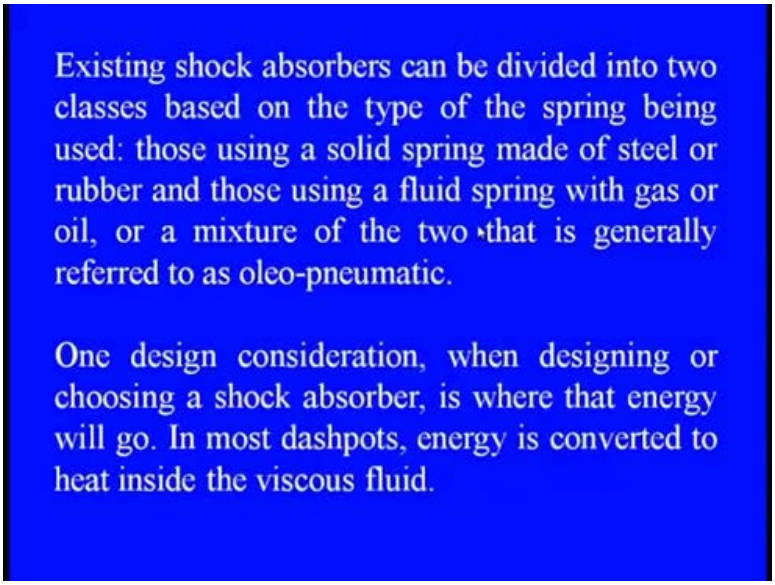

So, you see, we can divide these existing shock absorber into two basic classification just based on the type of spring which is being used along with the damper. First those shock absorber which are using the solid spring made of steel or rubber and those which are using the fluid spring just like the gas, air or oil or even the mixing of any two features, which generally we are saying that, this is the oleo pneumatic shock absorber.

So, you see the one design consideration when we are designing or choosing a shock absorber is, where that energy will go means, when we are just dissipating, what exactly the path through which this transformation occur and this heat is going where. So, you see here, in most of the dashpot, the energy is converted into heat inside the fluid, whatever the viscosity features are there, associated with the fluid.

So, that is why sometimes, when we are saying that, the dashpots are been designed, it is being designed based on the kinematic action of the piston and the viscous effect of the fluid, in which the piston is moving. Because ultimately whatever the heat or the energy is coming to the piston, it has to be absorbed by the viscous part of the fluid.

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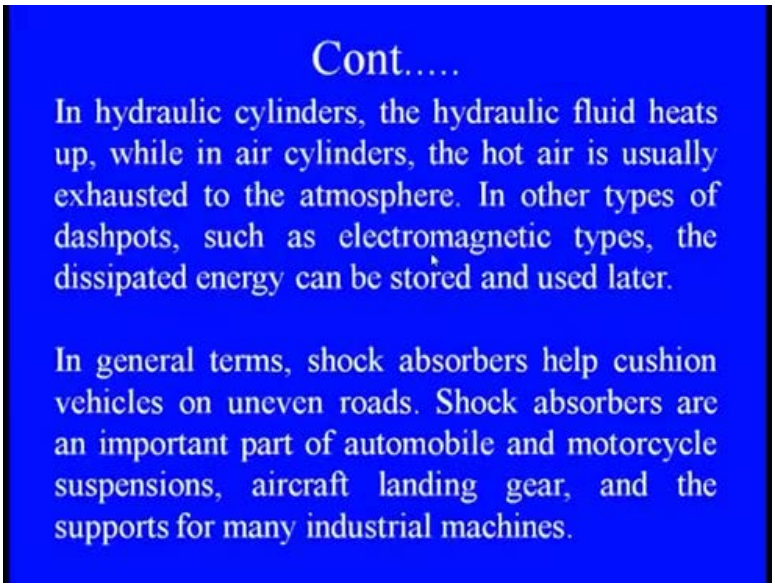

So, when we are talking about the hydraulic cylinders, especially in terms of the energy transfer, the hydraulic fluid heats up means, you see here, whatever the hydraulic fluids are there inside the piston cylinder, immediately it absorb the heat and it is heats are like that. While when we are using the air cylinder, the hot air is usually exhausted to the atmosphere and the fresh air can be build up and we can maintain the pressure inside.

And when we are talking about the other types of dashpot, in which the electromagnetic features are there with the fluid then the dissipated energy can be stored with the electromagnetic particles within that you see and that can be used later for any fruitful part. So, either we are using hydraulic air or we can say the electromagnetic type, they have a specific path for dissipation of the energy. So, in general terms, when we are talking about the shock absorber, it always help the cushion feature in the vehicles on uneven roads.

Because, in uneven roads you see here, the shock or we can say in terms of the impulse forces, they are excited with the system. So, shock absorbers are important part of the automobile, we can say adjust the motorcycle suspension, aircraft landing gear or even

they are giving a good support to many industrial machines. So, you see here, whenever we are just saying that, the type of loading is of impact part then we need to make somewhat more tougher part, because you see the abrupt energy or abrupt forces are being imparted towards the machine itself.

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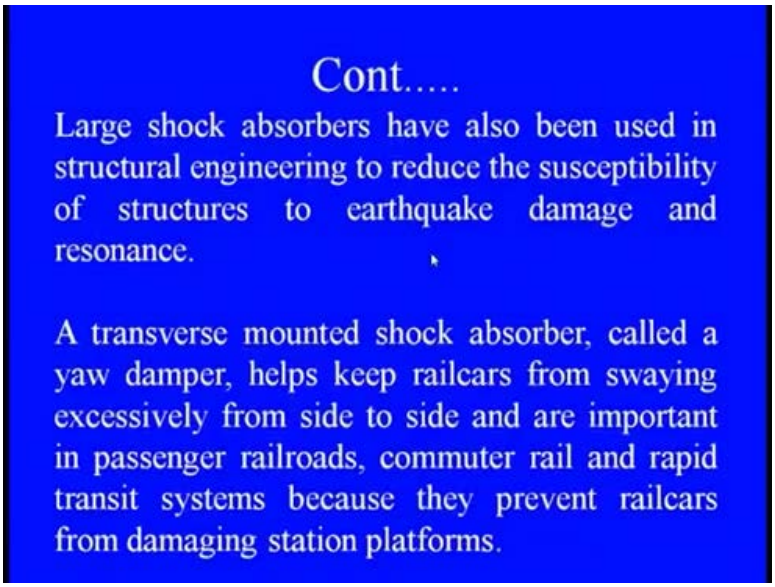

So, large shock absorber have also being used in the structural engineering, just to reduce the susceptibility of the structure to the earthquake damage or even the resonant feature in the entire large structures. So, transverse mounted shock absorber, which sometimes we are saying that the yaw damper, which also helps to keep the railcars from swaying. You see what are the swaying effect is coming excessively from side to side and also you see, it is quite important in the passenger railroads when the passenger vehicles are there in the rails and even the commutative rail or rapid transit system.

Because, they prevent the railcars or entire we can say, the wagon or the car body from damaging the station platform. Because, they are absolutely absorbing those things and they are not transmitting the vibration and the sound or the noise towards the means, that much energy of the noise is being absorbed and it is not transmitting to the platforms. Otherwise, these transmissions of vibration and the noise can damage, because it is a continuous feature.

It is continuous you see, when the rails are moving at 120 kilometer per hour, the huge noise or the vibrations are being generated, when there is an impact part is there or even

when there is a continuous contact is there of the wheel to rail. So, that is why, this is one of the important part, the transverse mounting shock absorber and I am going to show you the yaw dampers are always an important part of the railway vehicles.

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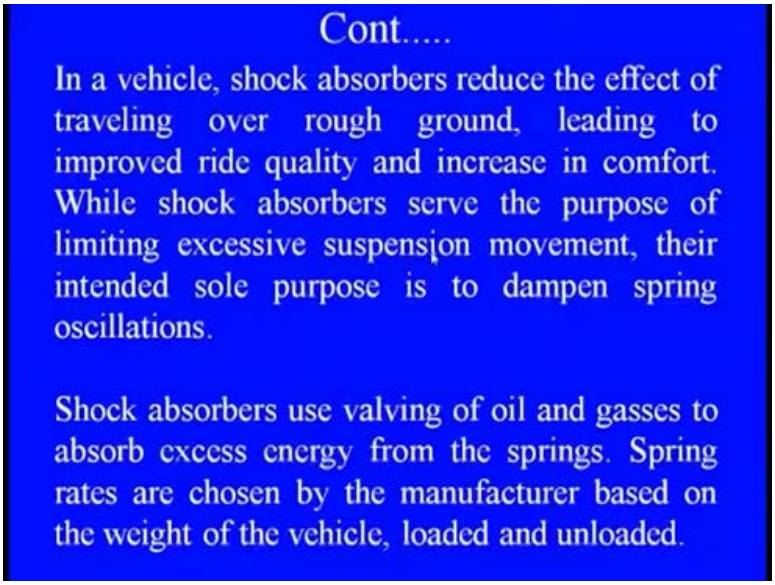

So, when we are talking about the vehicle, the shock absorber is mainly reduce the effect of the traveling over rough ground, which leading to improve the ride quality and also increase the comfortness within the vehicle itself and that is what, the main featured are. While shock absorber serve the purpose of limiting excessive suspension movement and their intent sole purpose is to dampen the spring oscillation also.

Because, sometimes you see here, when we are saying that, we just want to control the oscillation from the amplitude point of view, the spring is ok. But, when such kind of the abrupt or impulse feature of the vibrations are coming then the spring alone is not the suitable one, we need to adopt both the thing together. So, shock absorber is always being uses valving of oil or gasses to absorb the even excessive energy from the spring and spring rates are being chosen by the manufacture, based on what the weight of vehicle, the loading and unloading conditions.

So, you see here, when we are talking about the stiffness of the spring or whatever the material part is there, it is absolutely the application based system is means, how much the load unload features is there and what is the weight of the vehicle or which you see, below that the springs are being installed. So, along with the spring, we need to check it

out that, when the shock absorber are just to be coupled with the spring, the oil or gasses whatever you see inside this piston cylinder arrangement is, they are absolutely absorbing whatever the excessive energy is being there from the spring only. Because, it is stored and then you see here, whatever the stored energy is there, that is being transferred to this oil or the gasses inside this dashpot. So, this is what the internal mechanism, which is working there.

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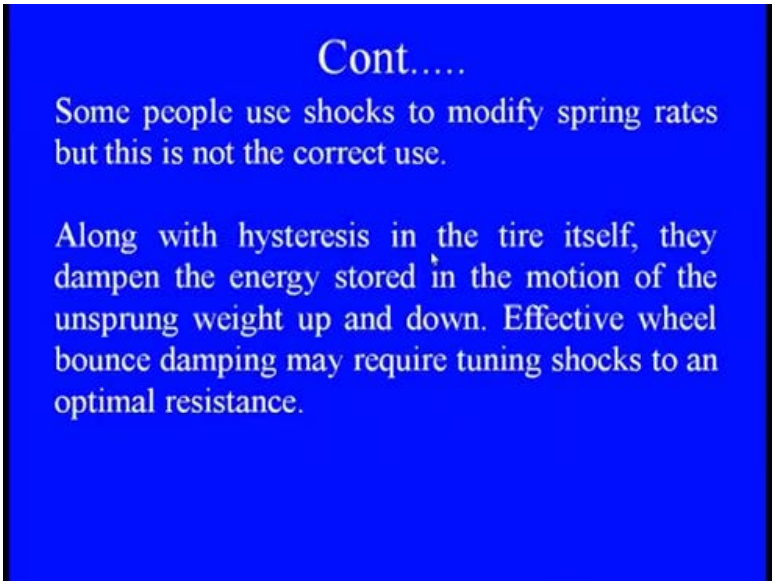

So, we are also saying that, these shock absorber, it is just the modification of the spring or we can say the damper arrangement, according to the amplitude of the shocks are. But also, along with the hysteresis in the tire itself, we need to dampen the energy stored in the motion of the unsprung weight during the up and down motion. And this is effectively can be done when we are just trying to use the shock absorber absolutely at the optimal resistances.

So, as you can see on your screen, we have a rear wheel of the motorcycle and the strut, which is clearly showing that, there is a piston inside the coil spring and this coil spring is always, whenever you see it is just going on the bumping side. The spring of outside is being compressed and store the energy, whatever the excessive impulsive feature energies are being coming or the forces are being coming to the system through the tire.

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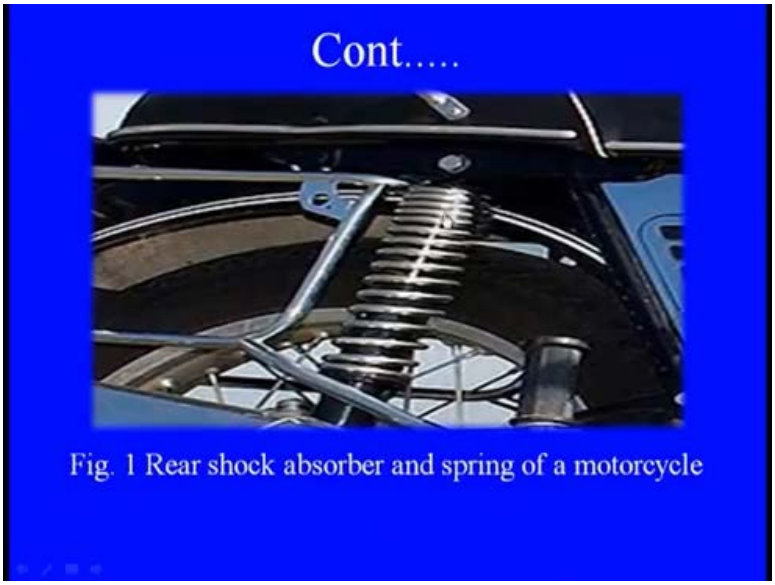

And when you see and it is also connected to the upper seat, so whatever the vibrations in terms of the shock feature is coming, it is being compressed there in that leaf spring, this coiled spring and this energy is being absorbed by the viscosity of the fluid, which is being there inside the piston. So, that is why, there is a clear coupled part of the spring and the dashpot is there and through the walls, whatever the stored energy is there, it is being transferred into the dashpot part and there you see the high viscosity fluids are there, it is being absorbed.

So, on the upper side you see, when we are just talking about on the top part, there is not many vibrations are there, because it is effectively being controlled by this. So, and then you see, after that we have the cushion feature, so even some of the damping is being provided here, but mainly these struts even on the front wheel or in the rear wheel of the motorcycle, the struts are there on both the sides. So, we can effectively control whatever the shock features are coming, from the ground to the vehicle.

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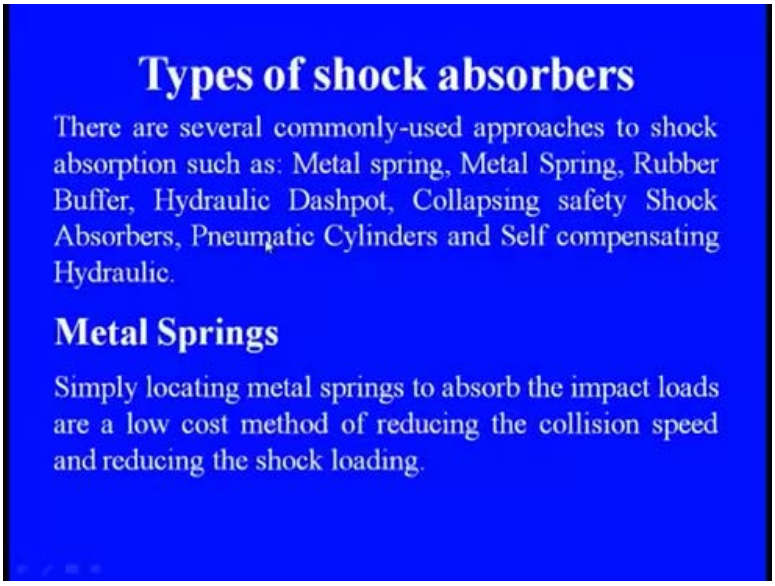

So, this is the basic mechanism of the shock absorber, now when we are talking about the types of shock absorber, there are various types are there, which are being available based on the various concept. So, the commonly used approaches to shock absorber like the metal springs, the rubber, whatever the rubber buffers are there, the hydraulic dashpots are there. Even we can say that, the collapsing safety shock absorber, which is specifically used in the rail vehicles then pneumatics cylinders and the self compensating hydraulics are there.

So, based on the type of application, surroundings and you see the operating conditions of the vehicle or any machine, these are being chosen. So, when we are talking about the first part, that is the metallic spring, it is simply as we can see that, the spring part is there, which is being manufactured using the metal part. So, it is a simple locating, we can say metal springs, just to absorb the impact loads at the point of the contact, where you see the force is being transmitted means, the direction of force is being there for the transmission purpose.

Since it is a only metal spring, so certainly you see here, the absorbing feature of the impact loads are at the low cost for reducing the collision part of the speed and also it is reducing the shock loading. But, it is only a absorbing part, it is not dissipating, there is no we can say the absorption feature is there, it is only when we can say that, just saving that means. When it is being coming to the spring, when the compression feature is there,

it is being stored part. When it is releasing means, when it is just the spring is released, whatever the stored amount of energy is there, again it is being released out.

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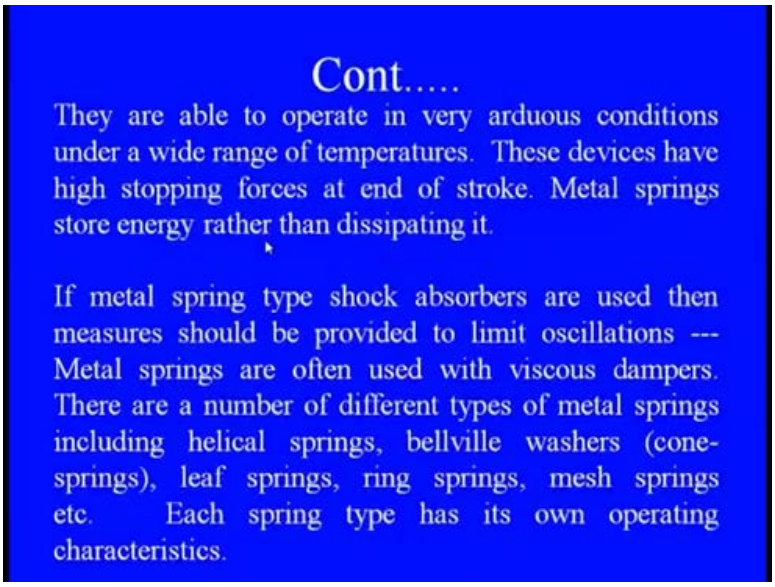

So, they are able to operate in the various arduous means, the tough conditions under wide range of the temperatures, because the metallic springs according to the metal properties, it can be varied from lower temperature to very high temperature. And these devices has, whatever these devices you see, which we are using in the metal springs, they have the high stopping forces at the end of the stroke, because they are just storing the energy, not the dissipating feature.

So, at the end of the stroke, they can simply stop whatever the impact forces are coming at the end of that. So, especially, if we are using the metallic type of springs as a shock absorber then we need to see that, we are only limiting the oscillation feature of the vibration. So, that is why you see here, the metallic springs are always being used along with the viscous dampers.

Because, we know that, there are various types of sprigs, which have been used according to the type of the forces, which are coming means, it is the impact force by the way, but what the directions are there and what the space, at which we need to provide this feature. So, the number of springs are there as we know that, the helical springs are there, the bellville washers are there in which the cone springs are there, the leaf springs are there, the ring springs are there, the mesh springs are there.

Even you see here, whatever the metallic or even the non metallic feature, it can be shaped in either of these types of springs. And each type of spring has it is own operating characteristics and that is why you see here, we need to adopt according to the space, the service condition and the environmental features of the entire vehicle or the machines are.

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So, you can see that, we have a metallic spring shock absorber, in which the coiled spring is there, helical, coiled or anything you see here, and that can be just put on the damper just to effectively control the vibration by storing and absorbing feature. The second is the elastomeric shock absorber, as per the name itself the elastomeric means, based on the elastic feature of the entire device, we are just absorbing the energy through the whatever the material, which is been provided from the shock absorbing part.

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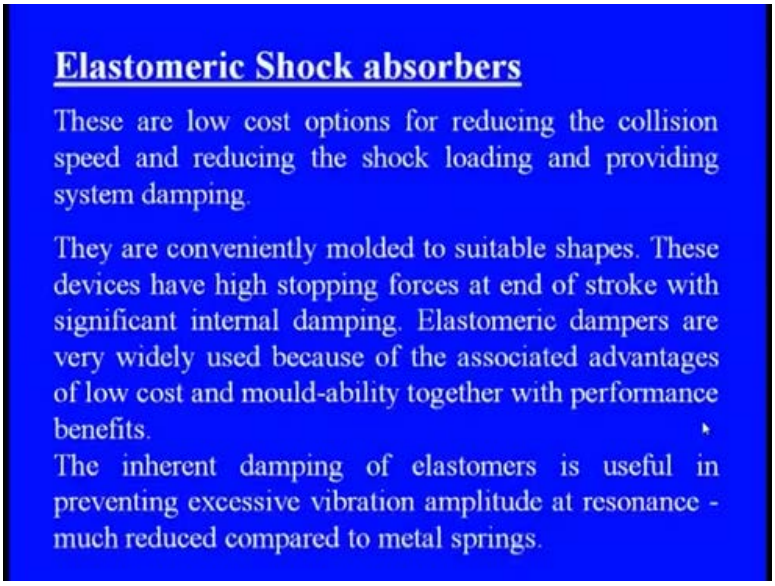

And these are also you see, the low cost option for reducing the oscillation speed and reducing the shock loading and also they are providing the damping to the system, because of the elastomeric feature. So, we can say that, these are conveniently model to the suitable shape and these devices have the high stopping forces at the end of the stroke with the significant internal damping of the elastomeric feature. So, elastomeric dampers are generally being used, because they are also associated with the low cost and mouldability together with the performance benefits.

And we know that, in these elastomeric dampers, they have the inherent damping feature, because of the elastomers which we are using. So, we can straight way prevent the excessive vibration amplitude, even at the resonant part and that is why you see here, we are not solely depend on the spring part on that. Because, the elastomer is effective device, which can be absorb the huge amount of energy at the resonance and that can be even the metallic spring, which are being there just to store the energy.

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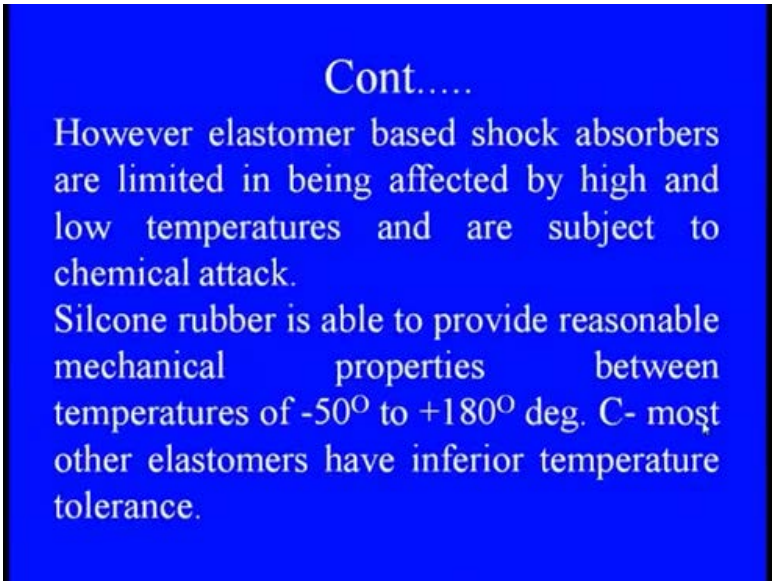

But, the elastomers based the shock absorber is always being affected by the temperature variation and they are very sensitive, because we know that, when the high and low temperature are being there, there is always a clear impact of this temperature variation. And whatever you see the inside inherent feature of the elastomers are there, the material properties, they are being affected by that. And also you see here, sometimes they are also being attacked by the chemical orientation feature.

So, we need to check it out that, what type of elastomer is being used in this elastomeric shock absorber. And accordingly we can say that, this much temperature variation can be only applied or can be worked for the, such kind of things. Like you see here, one of the best elastomeric shock absorber is the silicon rubber, which can even provide all the mechanical properties within the temperature is of say minus 50 to 180 degree Celsius. This is one of the best, but all others are showing a inferior kind of mechanical properties with even the low temperature variations. So, that is why you see, it is very sensitive to the temperature part and we need to use according to the temperature variations for the object itself.

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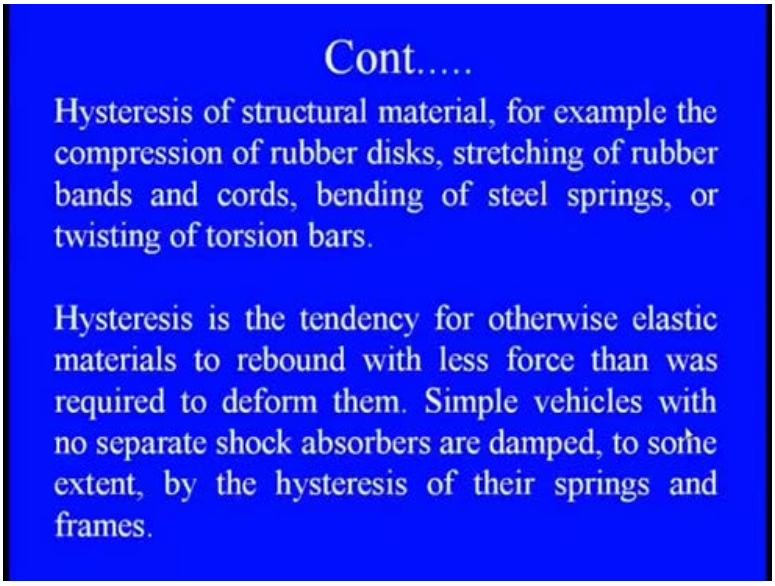

The second part is the hysteresis of the structural material, like you see here, we are using the compression part of the rubber disk, stretching of rubber band, the cords or the bending of the steel spring or twisting of any torsion bars. So, these are the structural, these are the hysteresis part of the structural material and this hysteresis is nothing but the tendency. For otherwise, you see the elastic material is to rebound with the less force than to us being just required to deform at that point.

So, when we are using the vehicles without the shock absorber, we can say that, there are simple damping or we can say, what are the hysteresis features are there, they can be straightaway applied to the spring, even by we can say compression or extension or even the bending or twisting of these things. So, that is why you see here, if we want to remove the hysteresis effect with the structural element, we need to put the damper with the shock absorber. Otherwise, you see here, such kind of the hysteresis losses are being always being associated with the damper.

So, you see that, this is what my elastomeric shock absorber, in which we have this elastomeric material in between and this is straight way affecting the entire resonant feature of the vibration, even at the shock kinetic energy. But, the basic problem as we discussed is the temperature variation, which can immediately you see just put the inferior effect on the absorber part, it immediately it can deviate that part.

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Fig. 3 Elastomeric Shock absorbers

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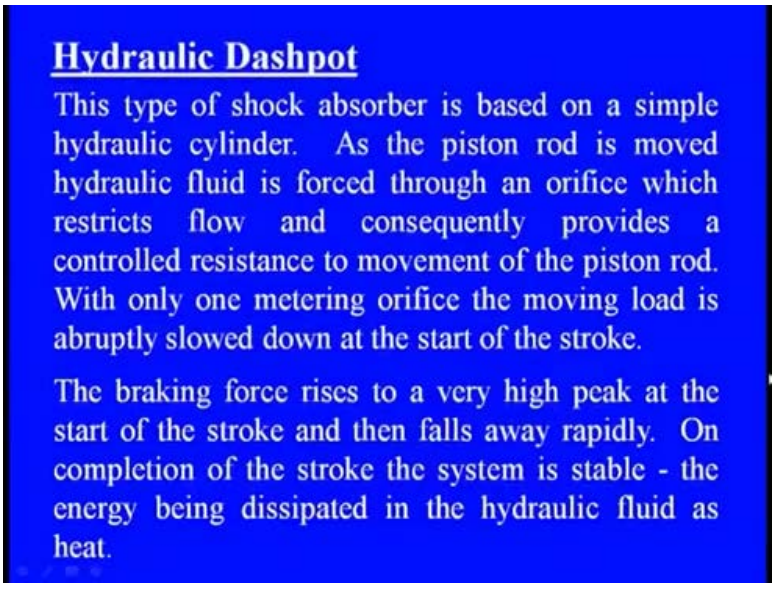

Then, we have the hydraulic dashpot, as we know the hydraulic or the fluidic feature in the dashpot is one of the important criteria for absorbing the energy. So, this type of shock absorber is simply based on that fluid and the cylinder. And when the piston rod is moving in the hydraulic fluid, we know that through this orifice, when it is being having the reciprocating motion, the corresponding energy which is being transferred to the fluid, is being clearly absorbed and provide a controlled resistance to the movement of piston rod.

And then whatever the energy is being coming, slowly it is being absorbed and provide the controlled motion at the outside. So, when we are talking about the breaking force, which is being rises to the highest peak at the start of the stroke and then falls out rapidly, at that time you see here, we certainly need such kind of things. And on the completion of the stroke of the system, we need the stable part, the energy which is being dissipated in the hydraulic fluid can be absorbed in terms of the heat. So, you see here, whenever we are just talking about the impulsive nature, whether the breaking force starting or any kind of the transient feature of the force is coming to the vehicle, the hydraulic dashpot is the perfect device to absorb the entire energy or to dissipate the entire energy at that time.

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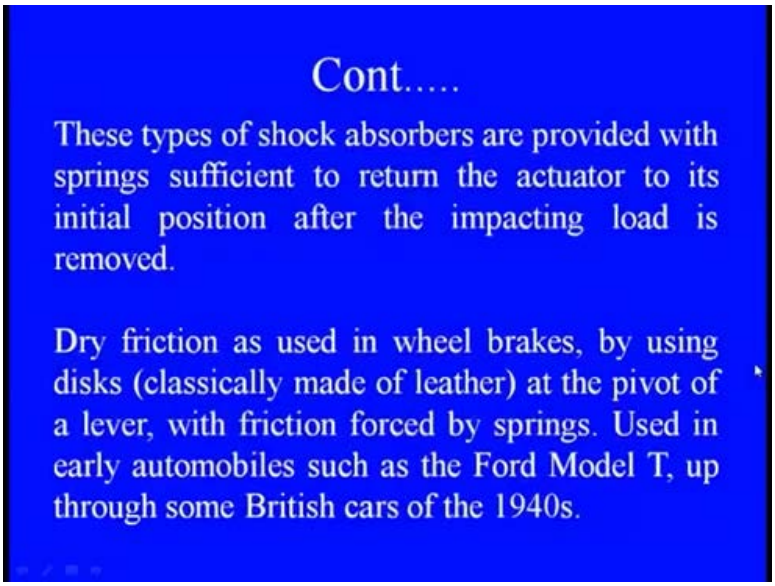

And these types of shock absorber are always provided the spring feature, which is sufficient to return the actuator to the initial position after the impact loading is being removed. Like you see here, the dry fiction which were used earlier in the wheel brakes, which we have the disk, the classical made of a leather was there the disk at the pivot of the lever and what are the frictional forces which are being there at the spring, these dry frictions were very commonly being used in the automobiles. Somewhere you see in 1940, this concept came because of this you see here, the heat generations are there. And you see due to this frictional forces, whatever the resistances are being provided, they can be straightaway controlled by this springs.

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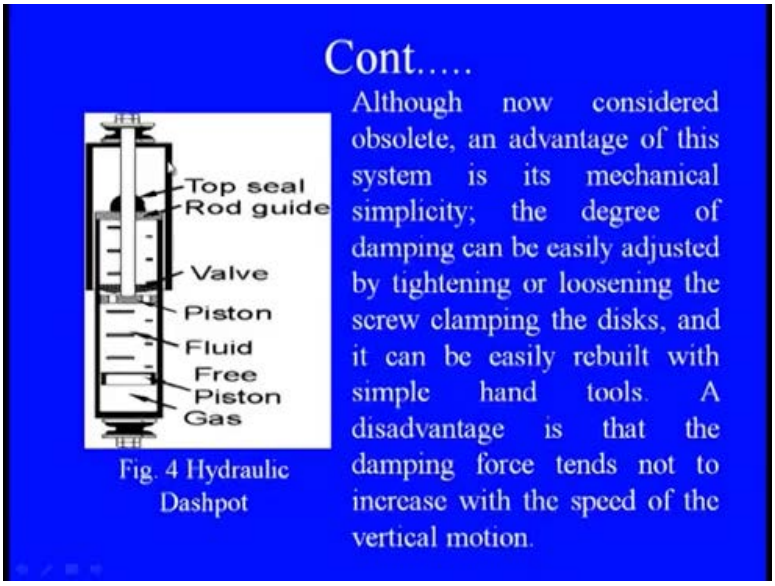

So, we can see this hydraulic dashpot, which is very common device you see here, we have a piston and in that you see, we have through the wall or we can say through this orifice, this entire fluid is being there. And that you see here, the piston is clearly moving whatever the viscosity is there in the fluid, is providing a smooth motion or the slow motion, rather I should say according to the viscosity of this piston movement.

So, this is something you see here, the previous concept was there and if we want to adjust the degree of damping, we need to adjust this screw with the tightening or the looseness so that, a proper damping can be provided at that time to the disk particularly. So, you see here one of the big disadvantage of this is the damping force tend to increase with the speed is not the effective part. When we are speeding the feature, the damping feature is not closely coupled with this speed or with the amount of this, we can say the impulsive force. So, that is one of the drawbacks and that is why you see here, alone that part is not featured out for absorbing the shock vibrations.

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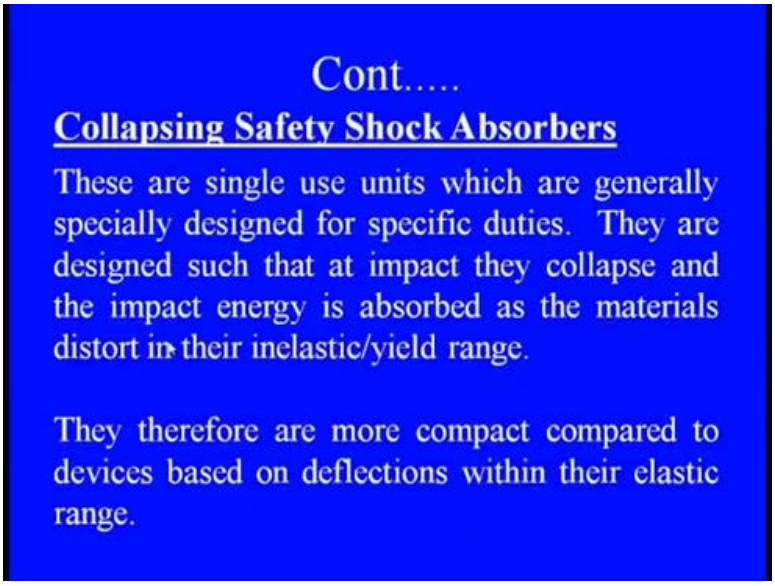

Then, we have a special device called collapsing safety shock absorber, so the name itself is saying, it just collapsing when the requirement of the safety features in the devices. So, these are just the single used unit, as the specifically you see here, they are being designed for very specific unit for safety measures. And these are designed in such a way that, the impact or which you see the things are being coming, they immediately collapse and the impact energy is being immediately absorbed by the material distort in their inelastic or the yield range.

So, means that you see here, though it is going to fail or die, but it is simply absorb that amount of impact energy abruptly at that point of action. So therefore, more compact compared to devices, whatever you see based on the deflections are being designed there. Because, you see within their elastic range or even we can say within their plastic range, they immediately absorb the entire amount of energy.

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As you can see on the screen, this is what you see the rail wheel contact is there and whatever the abrupt forces as you can see on the black arrow, where these things are coming. And they have such a high excessive amplitudes are there, immediately this feature will just go towards the failure and prior to that, they simply absorb the high impact energy, prior to just go to the upper part of the bearing from this transmission. The next is the pneumatic springs or the air springs, because you see here, the air springs are frequently using for many applications, but again they have many limitations as well.

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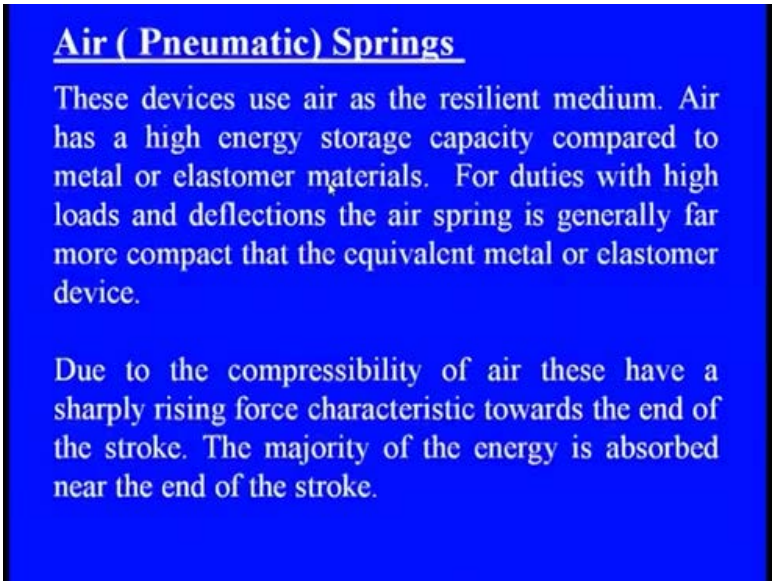

So, these devices are just using the air as the resilience medium and the air, which has the high energy storage capacity compared to any metal or the elastic materials, are the perfect choice, where you see we know that, the high fluctuations are there. And for duties with the high loads and the deflections, the air springs are giving up accurate results as compared to the equivalent metal or the elastomeric devices. So, that is why you see here, this is one of the effective tool, where we know that, the high loads or heavy duty applications are there in that.

And due to the compressibility nature of the air, this can simply put in such a way that, whatever the rising force characteristics are there, it can be straight way absorbed at the end of the stroke. And the majority of the energy, it can be straightaway absorbed at the end of the stroke and that can be exhausted to the atmospheric pressure.

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Fig. 6 Air (Pneumatic) Springs

And in this you see here, whatever the force which is being coming to the air cylinder buffer, can be straight way determined by the polytrophic process, whatever the processes are there, we can simply keep in the polytrophic featured P V to the power n equals to constant. So, this is one of the best suited feature under these applications, but they have one of the big drawback that, they need a proper maintenances just to keep the air pressure at the appropriate level so that, the proper suspension can be provided.

Second, the important thing is that, you see what the temperature ranges are there in that and then you see here, we need to make not only the pressure and temperature within

that. What the devices through which the robust nature of the air is to be there, it cannot be leaked out or we can say, there are many things, when the loadings are being there on that. So, you can see that, we have a simple device on that and in this, you have a clear, this is the main inlet part is there and this is the screwed part and in between you see, this the air cylinders are there means, the air is being compressed there. And then you see here we can use this log P V to the power n equals to constant for separation features there itself.

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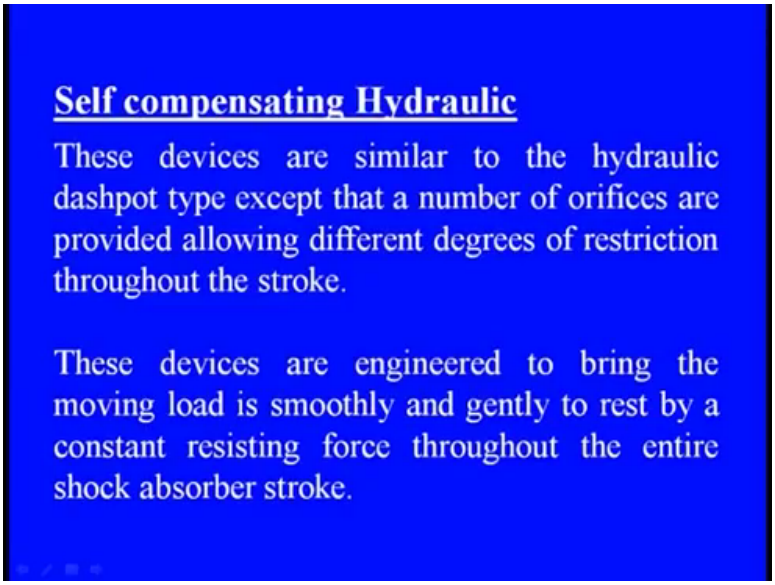

The next is the self compensating hydraulics, the name itself speaks that, there is a self compensating feature in these hydraulic dashpots. So, these devices are absolutely similar to the hydraulic, because hydraulic dashpots are there, but they have number of orifices just to provide a different degree of restrictions throughout the strokes. So, as we have seen, when we have a simple hydraulic device, there is a single orifice and through that, the piston movements are there according to the viscosity of fluid and that will smoothen the motion.

But, here we have the number of orifices, which are being settled in the path and then I have accordingly, we have a different degrees of the restrictions. So, we have such kind of flexibility now, to adopt what type of restrictions, which we want to provide during the stroke. So, these devices are being designed, just to bring the moving load in the smoother way and gently to rest by the constant restoring force, which is being provided

by the spring throughout the entire shock absorber stroke, so this is you see the main feature in that.

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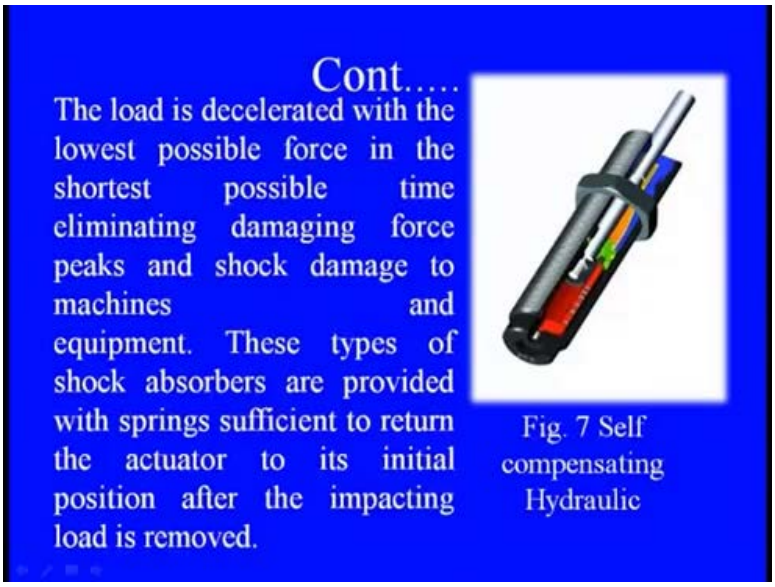

So, you can see that, the load is straightaway decelerated with the lowest possible force in the shortest possible time by simply eliminating the damping force peaks and the shock damage to the machine or the equipment. So, this is what you see here, if you look at these things, we have these all slots, the small small slots, they are simply providing you the orifice nature. And accordingly you see here, we can simply use these orifices for controlling the amount of or for restricting the amount of the stroke part.

So, these types of shock absorber is always provide the, we can say whatever against the shocking action, whatever the spring featured are there. So that means, because you see we have the lube oil and how much lube oil which we want, accordingly we can provide the number of orifices there itself for the smoother motion and also along with these, we have the spring if you look at these things.

So, these springs are just provided to return the entire stroke in the smoother way to the actuator exactly at the initial position after the impacting load is being removed. So, when it is being released out for a smoother motion, these springs are perfect to provide in terms of the releasing energy.

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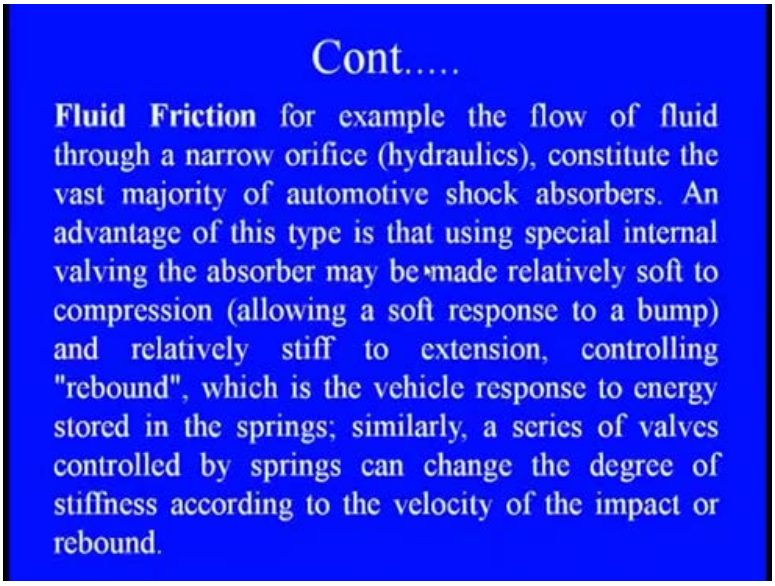

The next one is the fluid friction, as we know that, even we are just using the viscosity part low or high, the flow of fluid through this narrow orifices in the hydraulics part, is always constitute the vast majority of various shock absorber and whatever you see the viscosity features, which are being considered there, simply giving one of the specific kind is the fluid friction.

So, the advantage of these devices, we can say the hydraulic feature in this particular kind of application is always being there with the using of internal valving, which can be act as a absorber with the soft compression or whatever we can say, the soft spring, and also relatively stiff to the extension, when just controlling or we can say the rebounding to just the initial conditions. So, if the vehicle is responding to energy stored feature in the spring and when it is releasing, when unloading features are there, this fluid friction component is also playing a critical role in that.

So, the series of valves are being adopted in controlling the entire feature by the spring and they can change the degree of stiffness according to the velocity of the impact or the rebounding. So, this is one of the good concept, when the rebounding is there, how the fluid friction can be adopted with the number of orifices just to control the velocity during the rebounding or this thing.

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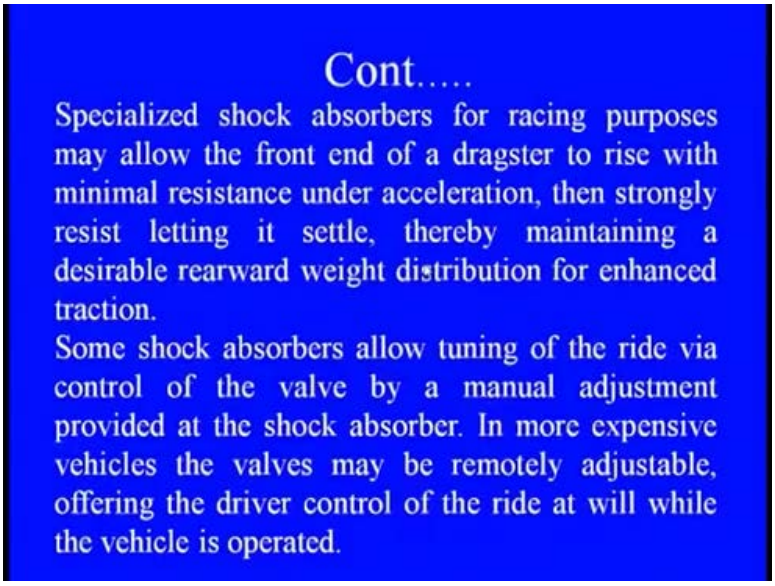

But, when we are talking about the racing cars, in which the speed is one of the significant criteria, there are specialized shock absorber, which may allow the front and dragsters means, the drag forces to rise with the minimal resistance under these accelerating features. And then again they strongly resist letting the settle and thereby you see, maintaining the desirable rearward weight distribution for enhancing the traction forces.

So, when we are just talking about the rearward weight distribution, we need to say that, when it is being just going down towards, because you see, there is a huge acceleration and when you see the things have been coming back to when unloading is there, we need to check it out, that what exactly the traction features are. So, some of the shock absorber, they are also allow just tuning of the ride via control of the valve by simple manual adjustment, provided at the shock absorber. And these are you see, since it is a manual part, so we need to check it out that, whether it can be remotely actuated or adjustable or not, according to whatever the operating conditions are.

So, the ultimate control is to be provided by the dynamic valve control via we can say, whatever the sensor or the actuators are being there and accordingly they can adopt these things. So, many shock absorbers are pressurized with the compressed nitrogen, just to reduce the tendency of oil to cavitate under the heavy use. So, sometimes this nitrogen compression is a good isolator, when we are just going for the cavitation feature of this

and this causes foaming with the temporarily reduces damping ability of the unit.

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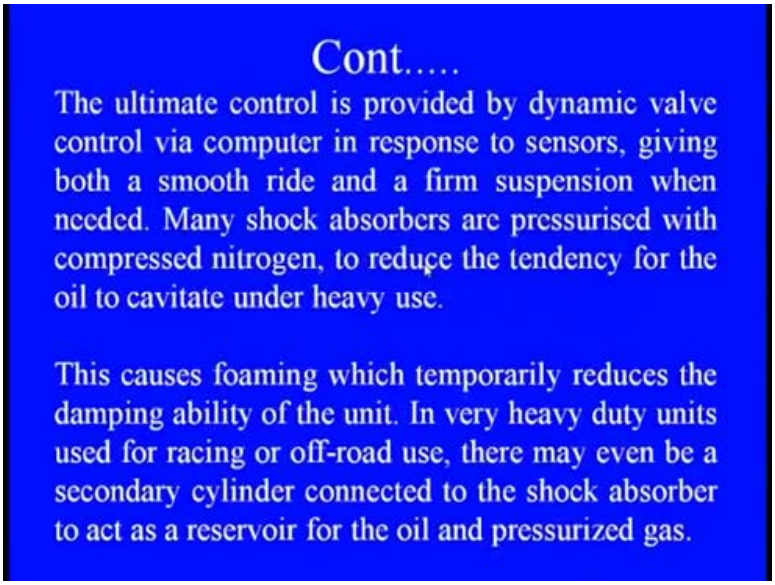

So, when you are using the heavy duty units for racing or off road use, there may be even secondary cylinder connected to the shock absorber, just to act as a reservoir for oil and pressurized gas and they can be act, whenever it is being required during the operations. So, these were the various types of the shock absorbers are there, according to the application, type of loading and you see service conditions, we can be straightaway adopt those things.

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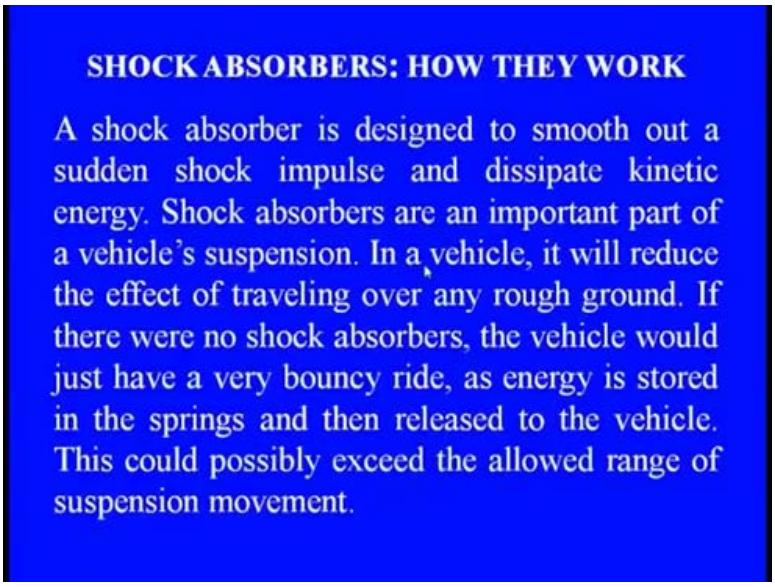

And when we are talking about that how these shock absorbers are using we know that, they are being designed to smooth out the sudden shock impulse and dissipate the kinetic energy in terms of the heat. And what are the way, through which you see the dissipation is there, this is also one of the critical part in designing of that. So, shock absorber is one of the important part in the vehicle for suspension and it will straightaway reduce the traveling feature when they are just going on the rough road. And if we can feel that, if these shock absorbers are not there, certainly there is a huge impulsive force, which can straightaway come to the rider and make the discomfort at that point.

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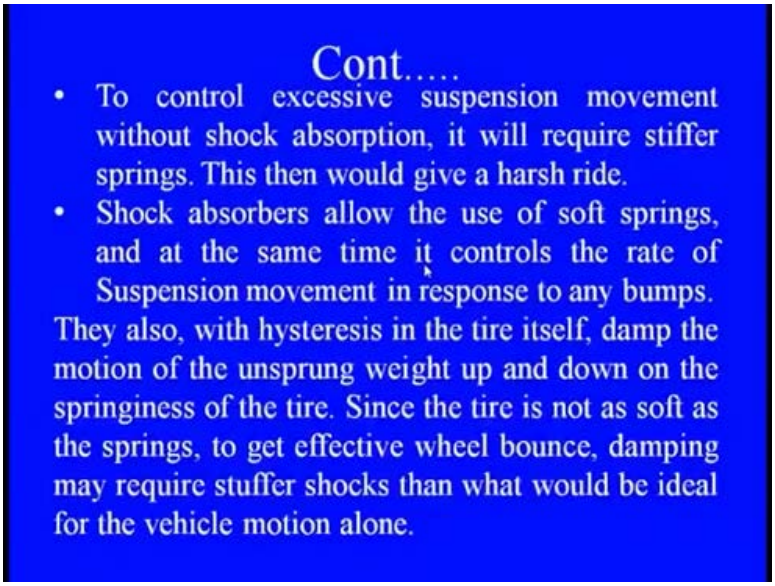

So, to control the excessive suspension movement without shock absorption, it will certainly require the stiffer spring. So, but this will give a very rough ride or the harsh ride towards that and a shock absorber allow the use of soft spring, at the same time it controls a rate of suspension movement in response to any bumps or any impulsive feature of that. And we know that, the hysteresis in the tire itself, the bump motion of unsprung weight up and down on the springness of the tire can be straight way put together.

And since the tire is not as soft as the spring, certainly we know that, there is a clear effect feature of the bounce is coming and the damping is straightaway requiring to absorb this much shock vibration. So, you see when we are looking for that, we know that, what kind of applications are there, either we can go with the pneumatic, we can go

with the hydraulic shock absorber, according to what the kind of you see or what the amount of this impulses are there.

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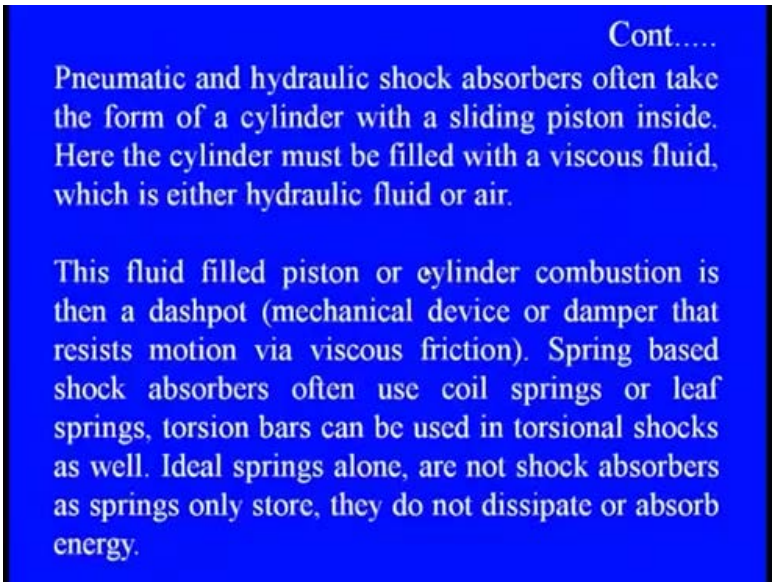

Because, we know that, when we are just talking about the fluid filled piston or the cylinder, we need to check it out that, what is the viscous features are there in that. Because, accordingly, the resistance is being provided by the viscous frictions and the spring based this shock absorber, they are having very least use.

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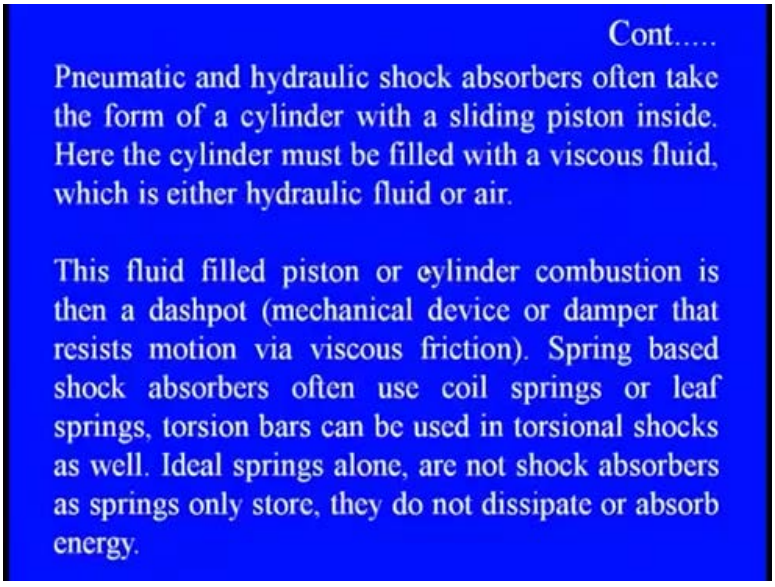

Because, we know that, these either we are using coil or the leaf spring, they cannot

absorb or dissipate the energy. So, most of the time we can say that, there are many different types of shock absorbers are there, and we can straightaway use according to the type of these, either the hydraulic, air, electromagnetic, according to how the energy is being dissipated and how much amplitude of the impulsive forces are being here.

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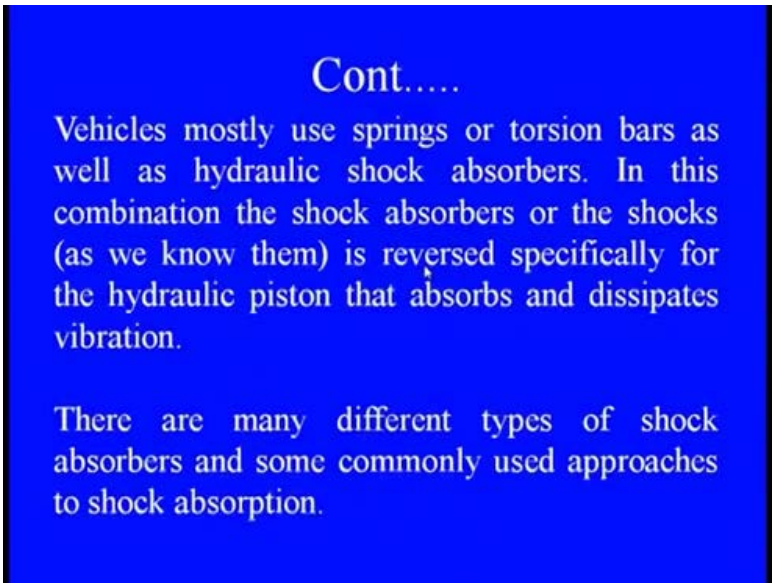

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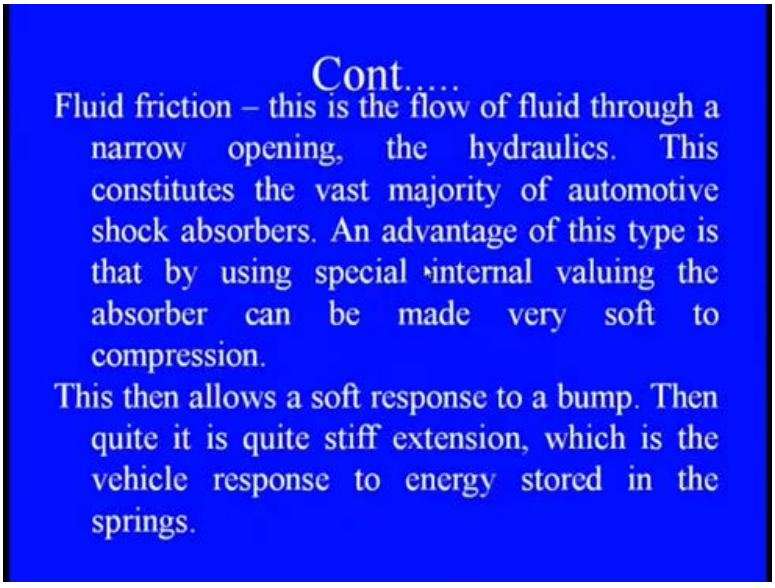

So, when you are talking about this, there are various reasons in which you see, the control should be there when we are designing this first hysteresis part, in which the compression of the rubber disk, bending of these, twisting of the torsion bar or the coiled

spring is being there, we need to take care of this. We need to see the dry friction, when the wheel brakes are there or whenever the abrupt changes are there, when it is just going from the bump and all, we need to check that, whether these are the fruitful one or not.

The fluid friction as we discussed, because it is one of the important feature when it is being rebounded, when unloading is there. So, we know that, when we are just talking about the soft response to a bump, we need to see that, what the viscosity is to be there so that, it can provide a smoother action when loading and unloading conditions are.

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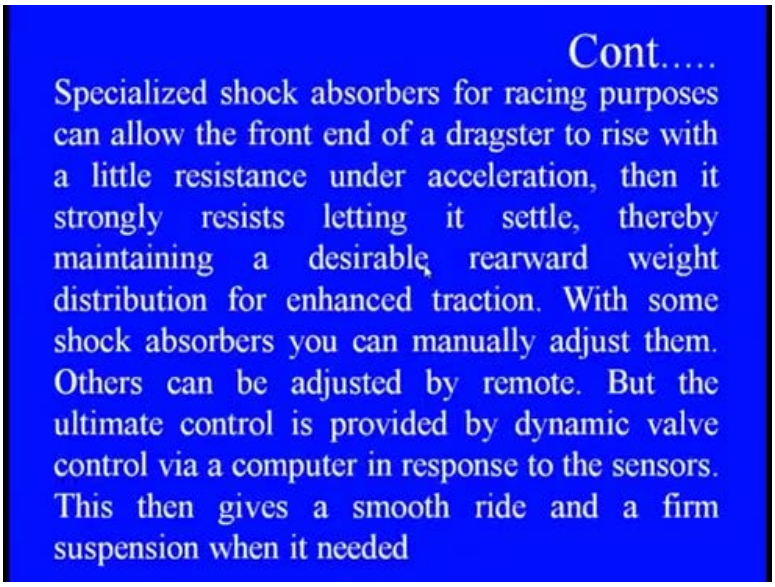

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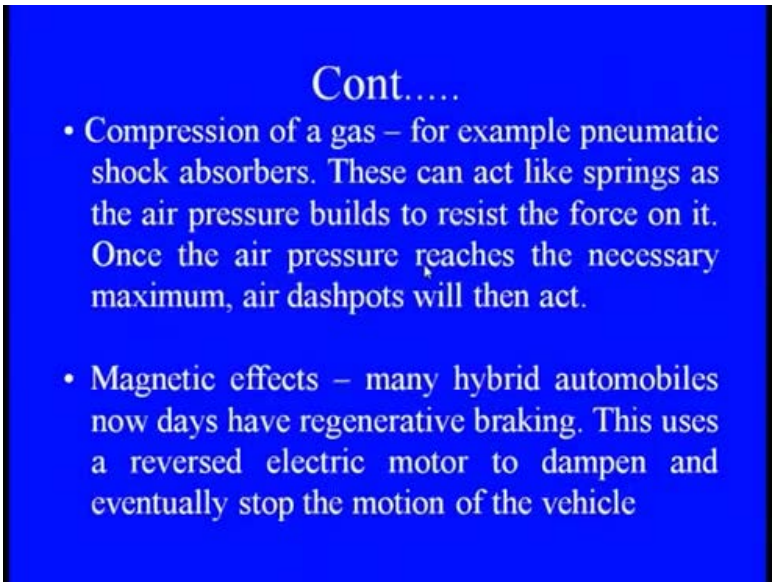

So, various specialized shock absorber also being there for the racing purpose when we know that, the dragster features are there and they are being providing a huge feature in that or else we can say that, the compression of gas or the air, they are also one of the best use. We need to check it out that, whether we are maintaining the pressure of the temperature of that. The magnetic effect, in which the hybrid automobile nowadays which we are using, they can also regenerate the braking systems in that. And this use a reversed electric motor to dampen and eventually stop the motion of the vehicle with the magnetic effect.

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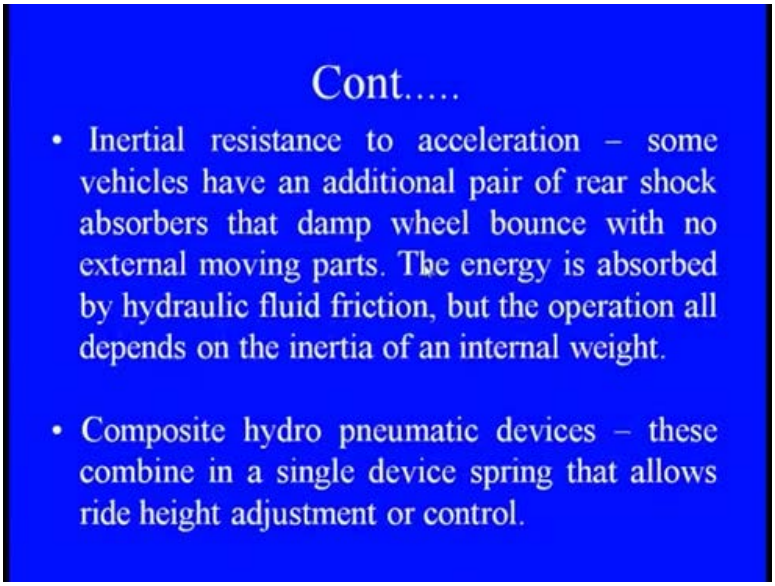

The inertial resistance to the acceleration, when we know that, an additional pair of rear shock absorber, through which you see, we can damp the wheel bounce with no external movement part, that is one of the best use of this. And the energy which is being absorbed by this hydraulic fluid friction, can also be operate along with the inertia of the inertial weight, which is being attached with. We can also go in this the composite hydro pneumatic device, in which a single device of a spring is always being allowed to ride at the high adjustment or the controlling feature.

The last part is the GVA, which is absolutely based on the gyroscopic action and based on that, we can simply use the vibration absorber. So, in this you see here, we can say that, it simply the inertial conservative means of the reacting a sinusoidal force. That means, when a natural frequency of the entire system is decoupled with the gyroscopic

vibration absorber then we can achieve simply the effective control of the vibration, how.

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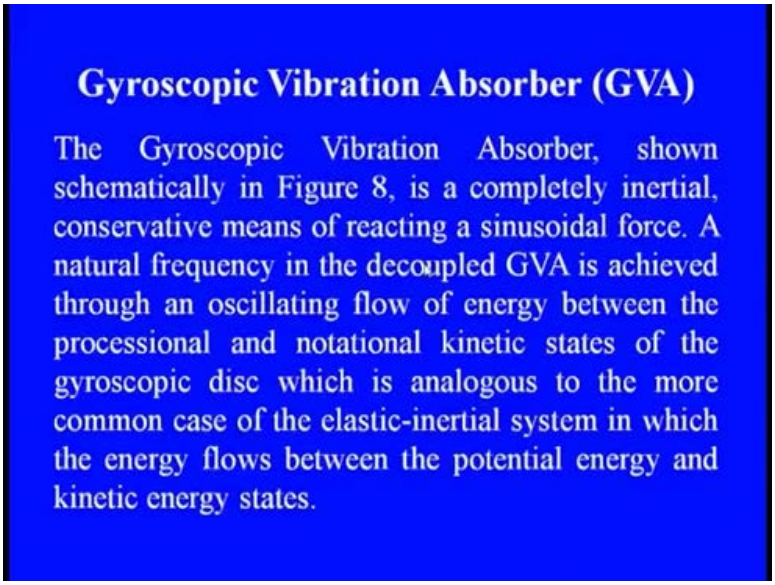

It can be achieved through the oscillating flow of energy between the processional and the notational kinetic states of the gyroscopic disc, which is analogous to more common case of the elastic material system, in which we have the inertial feature of the elastic nature and the energy is flowing between the potential and the kinetic states in these rotational. So, we have the two main state of the kinetic, one is the processional and one is the notational part.

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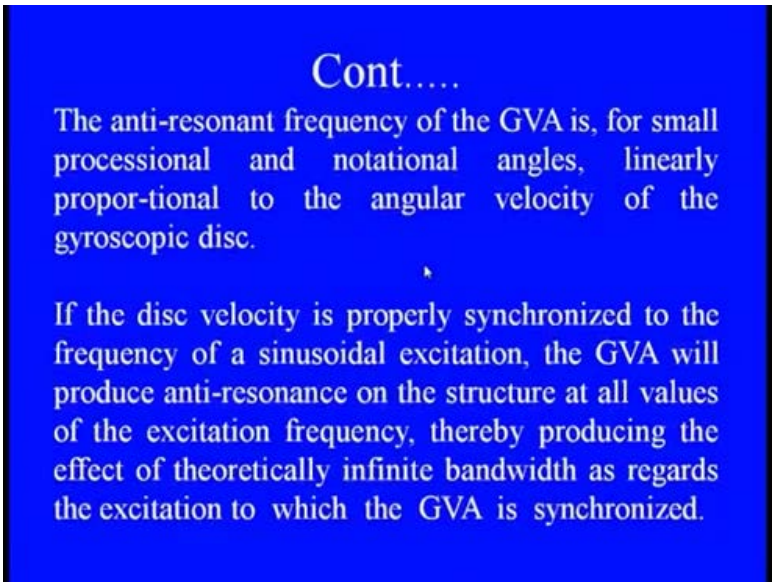

And this anti resonant frequency of the GVA can be used for a small, we can say the processional and notational angles and this is absolutely depending on, what the angular velocity of the gyroscopic disc is. And if the disc velocity is proportional, is properly synchronized to the frequency of the exciting part, the forcing part we can say sinusoidal feature, this gyroscopic vibration absorber will produce the anti resonance frequency to the structure at all the values of the exciting frequencies.

And thereby, producing the effect of the theoretical infinite bandwidth, the entire excitations at which you see the GVA is synchronized can be effectively used to cancel out these excitation.

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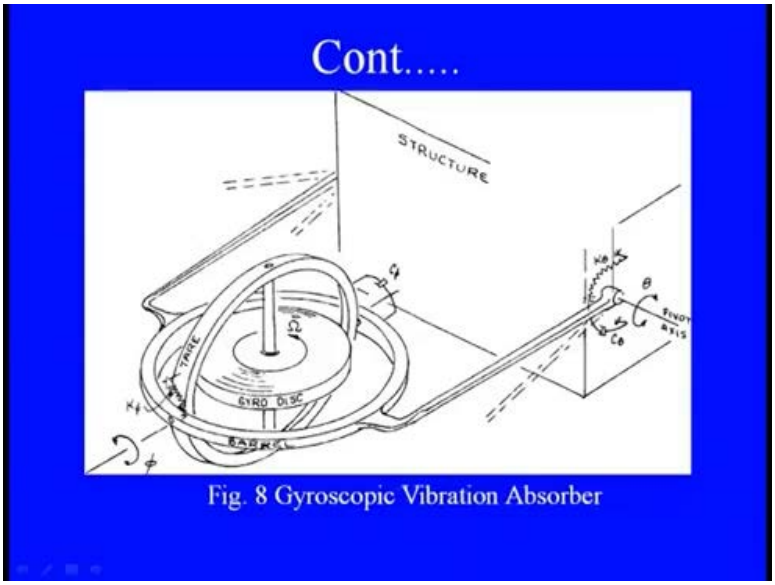

Fig. 8 Gyroscopic Vibration Absorber

So, you can see that, in this diagram it is clearly showing that, we have you see, this is my gyro disc, which is being rotating here and this is what my barrel, at which the entire features are there and this motion is absolutely controlled by this spring at the pivot axis. So, when the things are being, just whatever the motions are coming in the shock absorbing feature, this anti resonant feature, the excitation features are being generated by this rotation of this gyro disc. And it can be simply cancel out whatever the exciting features are there, which have been coming out through this transmission of the structure.

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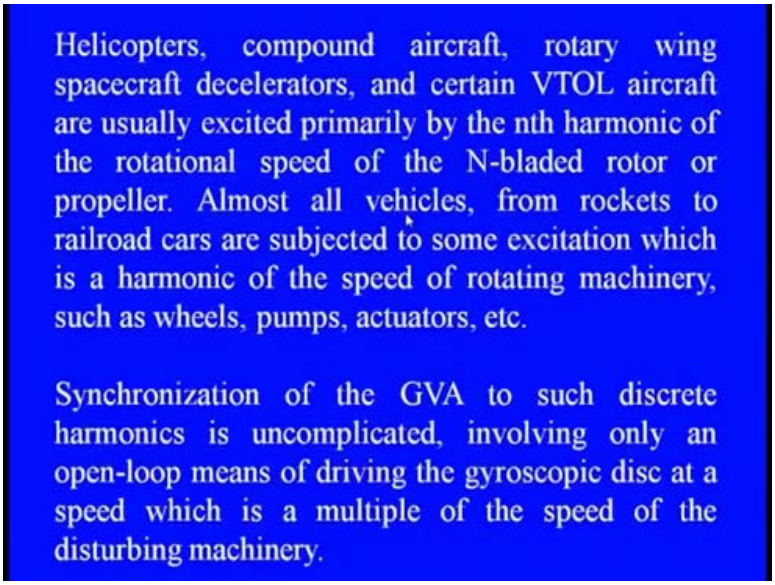

So, this is one of the good concept being used in the helicopters, the compound aircraft. The rotary wing spacecraft, in which the decelerator is one of the key feature and certain aircraft, in which you see the VTOL effect is there and in that you see here, whatever the harmonics of the rotational speeds are there with the N bladed rotor or the propeller, there you see the anti resonant frequencies can be generated using the gyroscopic concept.

And almost all vehicles from the rocket to railroad cars, are being subjected to some excitation, at which harmonic of the speed of the rotating machinery is always been there such as, the wheels, pumps, actuators and there we need the gyroscopic concept to control this. So, synchronization of the gyroscopic vibration absorber to such a discrete harmonic is always uncomplicated and involving only a open loop system, in which the driving of this gyroscopic disc at the speed, at which the multiples of the speed of this disturbing machineries are being there. And we can simply produce such a speed, just to cancel out using these anti resonant frequencies from the gyroscopic concept.

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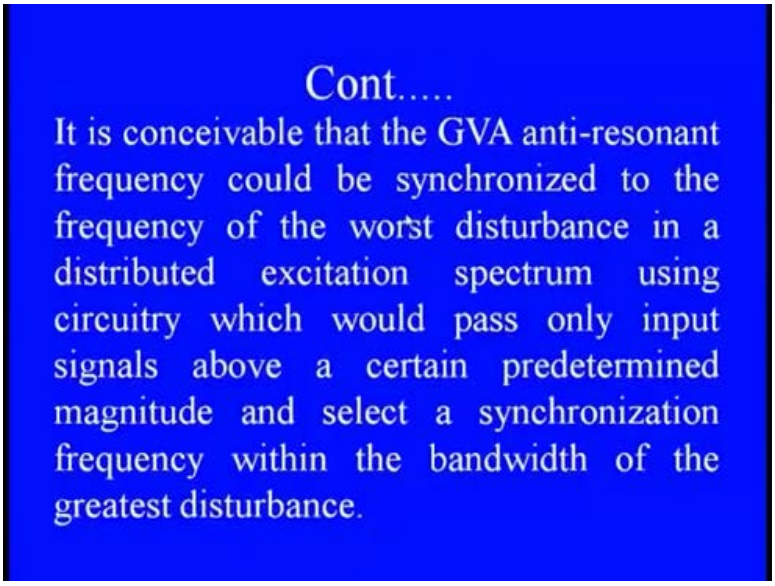

So, it is always convincible that the GVA anti resonant frequency could be synchronized to the frequencies of the worst disturbance in a distributed exciting spectrum using any circuitry feature, through which we can pass only the input signals. And we can simply predetermine, what the magnitude and the phases are there and accordingly, we can synchronize the frequency within the band of this disturbance of the wheel pump or any kind of structure of the entire systems.

So, this is one of the effective tool, where we know that, the multi disturbing features are there and they are absolutely creating the resonant frequencies and disturbing the entire structure. We can create you see the anti resonance feature, using this concept, the gyroscopic vibration absorber. And we can straightaway synchronized this anti resonant frequencies of that to the exciting frequencies of the systems and we can control effectively this.

So, this is one of the key concept, many applications are there, as we discussed and we can use there itself. So, in this lecture, we discussed about the various applications, the various types of the shock absorber and which is one of the effective tool in the recent applications of all the automobiles. Or even we can say, the rail means, we can say rather it is car, railroads or even the industrial machinery, where the shock loadings are there, the impulsive features are there and we just want to absorb, we just want to dissipate and the same time, we just want to store the energy.

So, various types of, either the hydraulic, pneumatic or electromagnetic or various other features are there in the shock absorber. So, in the next lecture now, we are going to discuss mainly about the passive control vibrations, in which the isolator is being designed based on the spring and the dashpot. And there are various other considerations are there, when we are designing the passive vibration controller in that.

Thank you.