Design of Mechanical Transmission Systems

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Week – 06

Lecture – 16

Lecture 16_ Brake: Introduction, Working Principle and Types.

Welcome to all, today we are going to study about different unit which is talks about brake system design. Before going to design an analysis of brake's aspect I would like to show some videos how brake functions and also, I would like to show brake samples where I can describe about what are the components are present in the brake system. Not only that and also, I will show the different types of brake systems that are available in automobile application. I can show the first how car brake works this is taken from YouTube video. You can see this is the entire brake things one is on your left side you can see the disc brake system and the right side you will see the drum brake system the two types are available this is a brake pedal where you are going to give a mechanical force with that it will amplify right using the booster then this is called master cylinder you can see that yeah then this is boost even smaller movement it will boost the pressure aspect then it goes to the this the brake fluid activate and the pistons moves and the brake fluid flow through the brake fluid structure. So, the pressure fluid will reach to the both disc brake as well as drum brake system and this is the disc okay this is the caliper this is the arrangement you can see that.

So as the fluid enter we try to push the piston to make the contact once make the contact they have self-adjusting so another pad also will make a contact and apply a force to stop the disc this is how the disc brake works and if you look at the drum brake system this is called wheel cylinder okay the brake fluid goes and apply through piston both ways and such a way that okay the force will apply on to the braking shoe this is called the brake shoe which will make a contact along the rotating drum okay and stop the vehicle. So, this is how the disc as well as drum brakes works and in fact you can see the difference between regular brake system and ABS brake system, okay. ABS you know it is a mostly preferred one.

So, this is the way the ABS brake system works and apart from a drum and disc brake you have other two types maybe I can show the first is duo servo drum brake system. That's you can see that this is a self-duo servo thing there's one more when you have a heavy vehicles where we talk about the trucks, buses where you need to have an air brake system there you need to have a smooth transition so instead of wheel cylinder, you have a S-cam type when the brake fluid approaches here the cam will rotate equally on the both sides you can say that okay this is normal one okay and the moment you apply a brake you can see that what is happening here yeah so they have equal forces right you can have equal forces so that it will be more stable and not only that the wear rate between the two brake shoes will be linear okay so those are the videos taken.

Now, we will show samples now which are there nothing but your drum brake system right this is a drum brake system this is the backing plate you can see and this is if this is called

wheel cylinder okay maybe I can show this is both are wheel cylinder in fact this arrangement is called leading-leading brake shoe we'll discuss what you mean by leading and generally you will have a leading and trailing, but since you have a two cylinders that means given force right both will activate whereas earlier if you have one cylinder alone one shoe will be used for the same direction of rotation other will be opposite direction if you have another cylinder right both will have a same direction of the disc so it will be much easier to stop the vehicle that's a reason to have leading-leading shoe brake system. You can see that, this is we'll have a piston again inside the fluid will go through you can see that how the fluid goes inside right and this is for a bleeding, bleeding means suppose the brake fluid traps with the air you have to release the air otherwise you will have a problem so that can be eliminated using this bleeding thing and interestingly you can look at here this is your friction material or brake length material this is the one which create friction converting all kinetic energy right into friction energy this is what this is very important interface between your brake with respect to rotating wheel you can see the both way both ways yeah. Similarly, I'll want to show the other one okay this is a casting plate if you remove it will come off easily, it is heavy though this just to place it on the thing right you could see here again could you please tell me what is it it's a drum brake system is a leading-trailing or leading-leading it's a leading-leading because you could see the two wheel cylinders are there right and again back is a backing plate will be there and you can see this is the spring for retaining aspect maybe I could see here yeah these are the springs for retract once you release the brake right you should come back to the original position whereas that one can be arranged another one self-adjusting that's that is the one is called the duo brake system okay again you can you could see this this is a friction lining very hard material to create the friction between the two rubbing surfaces so far we discuss about the drum brakes aspect now you could see the another one which is a much preferred one, your disc brake system right this is the rotor we rotate very freely right this is the rotor and this is called caliper the caliper will have a similar to the wheel cylinder arrangement right the only difference is will have one piston where in wheel cylinder you'll have two piston the brake fluid will go and try to move the piston both ways whereas this is the only way since the caliper has a self-adjusting mechanism other side are the pad also will come automatically and make a contact at the same time to stop the rotor so this is the typical preferred disc brake system maybe I could see that yeah you can see that, I think and these are the different types of friction material you can see that these are the different type of friction material used for the again you can see that very hard composite material for a friction aspect.

Now, I think we'll go back to lecture now right, topics to be covered introduction brake types brake working method design and analysis of different types of brakes aspects and we'll understand more importantly dynamics which is very important for any automobile or any vehicle brake system aspect this is the one we'll indicate about the size of the vehicle right that's a that's information and also we will discuss a terminal aspects of vehicle braking and design of brakes for application passenger that's the one we are going to focus more in this unit. Already, we have seen the videos and also seen the samples okay in today's lecture the learning outcome will understand the basics of brake system which already seen that so let me ask few questions so what is the friction, whether friction is good or bad, where friction is useful, right friction is nothing but to resist the motion right that's a basic information about friction okay whether it is good or bad again depends on the what application right. In general, friction will tend to reduce the performance in turn reduce the overall efficiency in general any starting for the bearings or your engine parts gears right cam and valve tappets right can shop where you

have relative motion right then they would reduce the performance due to the friction. However, it is also useful where you want to use the clutch right, clutch mean you want to hold it okay when you want to hold it if a high friction is easy to hold it similarly brakes so there the friction is very essential so very useful though, okay so that's how I'm saying is very useful and this is a typical automotive brake system you can see this taken from Ferrari sports car Ferrari sports car run maybe around 200 to 250, or 300 km/h, what would be the braking time typical what will be the braking time, is in seconds or seconds right will be a second and half, one and a half, 1.5 seconds that's the time you need to stop the vehicle such a very high precision and you can see this nice glowing right yeah this is glowing happening when you press brake in fact this is a disc brake system and you can see the caliper also when you apply the so much heat energy is dissipated through friction yeah that's what you could see here, yeah.

So, it provides a means of using friction to either to slow stop or hold the wheels of vehicle that's the important thing. When car is moving it has energy stored in the form of finish a kinetic energy. To stop the vehicle the brakes, convert kinetic energy into heat energy, that is what is happening. So very importantly, it must be high reliability because if the brake is not working it's going to be have a fatality right so that makes the brakes has to go legal aspect also it has to go to follow the regulations each country will have a brake regulation that must be harder whoever designed the brake so which is very critical for a reliability aspect.

The braking system you can see the various type of braking system given so you could see the service brake a continuous service brake parking brake okay so within the continuous service brake you can have an engine brake system or retarded type system within the engine brake you will have exhaust valve systems and turbo systems and retarder hydrodynamic electromagnetic primary secondary inline outline all those things are there okay. So, our concern is we would focus the under continuous brake system the engine thing we are going to focus this is what we are going to learn from engine brake aspects, yeah.

Let me give you information, what does it mean continuous service brake. A continuous service brake is a supplementary braking system capable of producing and maintaining the braking force over a long period without any noticeable wear. The continuous service a brake must be therefore function reliably regardless of the condition and effectiveness of other braking system. So now we'll understand what is the mean the continuous service the one which is going to be there permanently forever when now you want to stop or slow down the vehicle okay. Whereas, the service brakes brake acts on all wheels, the continuous brake only on the wheels which are connected to the drive aspect. So, what are you seen right the continuous service brakes must be connected with the wheel drive okay so then that is called a continuous service brake. Let me ask question you might have seen the long cargo type trailer when you say trailer is another name called a Lowry right. They might be having how many wheels at least more than four wheels right they may have 12 wheels or 18 wheels depends on the application. So, question is would you expect a brake in all the wheels do you think that's viable yeah just think about that okay. So, wherever your power system is there you have a brake system which is continuous brake system wherever you want important thing only for certain aspect without connecting to the power there you need to have service brake system okay.

So, typical a brake system will consist of energy source from where you want to generate the power, apply system, energy transmission system, and wheel or foundation brakes. You could see this is the nice braking system okay and this is the drum brake usually fixed in the rear

wheel and disc brake are at the front axles you could see that the front axle will have a disc brake system which is traditional way of doing, whereas rare will have a drum brake system. Now, that is the system used to be followed now not necessary even the rear wheel also can have a disc brake system okay. Let me ask question, which is a preferred one why the drum brake generally preferred to have a rare brake system, whereas disc brake system at the front axle what is the reason behind that? Just think about that, okay. Another question, when a brake is applied how the energy is distributed, would you think the more braking energy go for a it's a rear axle system or front axle front brake system, so question is the energy whether it's higher or will be equally divided okay, that's you thought about it. Let me give one more example you are moving a car applying the brake, the moment you apply a brake what is the motion you observe will you tend to move forward or will you tend to move backward, forward right. So, when you tend to forward because of the that is the direction where the vehicle is moving right so what happened when you move forward why it is moving forward during them when you move forward what happened to the weight of the vehicle do you think that the entire vehicle will be stay there or will be transferred to the front. So, there we have to look because of that you have to take care of your brake energy also you have to distribute accordingly that we are going to discuss while designing aspects. And, this is you can see that and again the typical brake system with the ABS. The only difference is the between the regular brake system and ABS is that ABS is a microprocessor controller, whereas regular brake system is a manual where the driver the maneuvering of the driver is comes into picture, okay. Have you observed how when you apply the brake what happened to the wheel, what is the motion of the wheel what is the motion of the wheel, is a rolling or sliding or roll slide what is the exactly happening, right. Please understand which has the more friction, is it rolling friction or sliding friction. Sliding has a more friction whereas rolling is a less friction, that is there yeah that is there, okay.

So, maybe I can show you the $\mu_{rolling}$, we can say. μ is nothing but coefficient of friction rolling. And, it is just $\mu_{sliding}$. I will put sliding things, okay. So, as you aware of this my rolling friction always lesser than the sliding friction that is there okay. So, the moment you apply a brake what do you expect the normal vehicle the wheel rotation of the wheel will stop and start to slide that we need to have high friction because rolling friction is low. So obviously if you see the response, this is the time just make it as a time in seconds of course we are talking in seconds not in the minutes, and this is your friction okay this is your coefficient of friction so what happened it goes like this and stop this is a regular brake system okay it's a regular brake system, right. How about ABS remember in the video it's clearly mentioned the pulse is given in the regular time period interval right pulse is given. What does it mean the wheel is rotating the moment apply a brake it sliding right at that time right again release the brake if the release the brake what you expect start rolling right, start rolling. Again, apply a brake then will go to sliding so when you give the pulses it goes rolling and sliding and rolling and sliding. By doing that what is that you are going to achieve, by doing that you have a control of your vehicle that is a more safe, more reliable rather than the allowing the entire vehicle to slide. In fact, so if you look at this the same response right, look at this it's must follow same thing after that it moves like this. So, the high friction is what it's a sliding friction right high friction is sliding friction μ_s right, this is the μ_s and this is your rolling friction μ_r. So, you are creating a it's called stick-slip phenomena. Have you heard about stick slip phenomena? Stick means stick together, slip means slide, stick and slide, stick and slide, this way this is phenomena cause stick-slide, stick-slip phenomena. This is the concept is applied in ABS brake system okay.

Now you know the difference between a regular brake system and ABS brake system okay. So, the friction has to be lowered down right so that you will have better control.

Yeah, type of energy source. So, energy source how does the energy comes to the brake system right when you talk about energy to stop the vehicle not about the vehicle energy. So, either you can give through muscular drive pedal effort or else you can have a brake boost system which I already explained, braking aspect, or else you can do the power brake systems okay or else you can have a surge brake or drop weight brake and spring. These are the four ways where you have to give your input for applying a brake. You could see that right, so it's like a fulcrum method if you give a small effort, if you give a small effort that has to be magnified or amplified you could see this is called typical vacuum booster. So, what happened so you could see there is an opening valve is given like a kind of a diaphragm, right. So, when you give a small moment, the air goes inside and give what happened the big force by giving that you can activate your master cylinder okay with a small effort that's why it's a booster like a enhancing the performance, right. This is the vacuum booster, okay and you could see again the same thing with this is we talking about the power brake aspect. So, we have pedal, pedal to vacuum booster from there you will move your this is called a master cylinder from master cylinder this is the piston arrangement, the piston will try to move such a way that the brake field will pass it through the breakthrough brake linings, okay.

Now, we talk about energy transmission medium. So, either you could have a mechanical brake through rods, levers, cables and cams you can see the race your handbrake system for blocking a braking aspect, parking braking aspect, hydraulic brakes, air brakes, and electric brakes and the mixed brakes. These are the various type of energy transmission mediums aspect and right. And, this is the brake pedal design advantage. Normally, it's like a leverage method, if you give a small effort due to your lever method right like a momentum right. So, it will enhance the effort that's one aspect. And, this is another one is a hydraulic, inside that you apply by mechanical force pedal through here then, fluid will generate the pressure right the fluid will generate the pressure and try to activate through a caliper as well as drum brake system, this is happening through hydraulic brake system, okay. And, this is the information about the brake fluid generally the brake fluid will have a following characteristics: should have a correct viscosity at all temperature if the temperature changes, then flow will affect, okay; it should have high boiling point so that it should not catch with the fire; and should have non-corrosive and water tolerant lubricates components; and the low freezing point. These are the typical characteristics you would expect for a brake fluid and this concentration is given DOT 3, DOT 4, DOT 5, this is a typical a brake fluids aspect it's given when the department transport by US they are the one who designed them and define them the brake fluids okay. DOT 3 is the low lowest boiling point, whereas DOT 4 is the middle boiling point, and DOT 5 is the highest boiling point, okay. Generally, you can mix to enhance the performance between 3 and 4 but you can't mix that DOT 3 because it's already highest boiling point, there is no reason for that, okay. And, this is for air brake system, air brake system earlier uses the mechanical movement then hydraulic through pressure sometime instead of hydraulic you can have air brake system also I am sure you would have understood whenever you travel for long distance, they will say our bus is fitted with the air brake system. Because the execution of the power very smooth. So, you don't feel much vibrations or shakes right due to braking aspect.

Now, we will talk about the types of brake system okay, talking about a brake system. How do you want to you connect the brake fluid, whether you want to diagonally split or else

longitudinal split, which is a preferred one? Diagonally split one is the best one, okay. Why I am saying that that is the good one this is the best one even some due to some improper thing you have assuming that you have a leakage here in this pipe right in this if you have leakage at least with the support of one front wheel, one rear wheel I can able to balance the vehicle, okay. Assuming instead of that, if the leak happens either rear or front doesn't matter what happened to my vehicle stability? it's not good, right. So, it's a preferred to have a diagonally split arrangement for the braking aspect, right. So, rear wheel drive one piston from front brakes and one for here this is for rear wheel drive. Usually, even if a leak occurs you could lose a front brake right the front wheel drives vehicles one piston drive front wheel and one rear wheel. Diagonally layout allows to maintain the directional control even if leak occurs that's advantage having a diagonally split brake system. And yeah, that's what I asked the question right. The braking ratio when you give the braking effort the entire energy won't go to front axle or rear axle it has to split right. So, you can see that a front brakes may handle from 60 to 70 % of the braking the rear is 30 to 40 %, why is less in the rear? When you apply a brake some amount of weight of the vehicle is transferred to front axle, but you don't know how much we'll discuss as we move on, we'll show exactly how much is load is going to be transferred from rear axle to front axle while braking aspects okay particularly we'll discuss in the dynamic analysis.

So, obviously so whenever you apply a break you have to have more energy towards your front brake system than the rear brake. So, front wheel drives usually will have a more weight is considered on the front wheels, a braking is even higher at the front wheels okay. And, this is the types of friction brake drum, brake use brake shoe that are pushed out in radial direction against the brake drum okay. Either you can have an internal drum expanding brakes or else external expanding. So, what we have seen is externally right is externally expanding a brake system. Disk car brake use pads that are pressed axially against the rotor disk. And these are the images you can see that so this is your disc brake and this is a drum brake you can see this is the caliper arrangement. And, you could see here so tell me this you can see this the wheel cylinder this is the shoe, brake shoe. And, this is the return spring and what you see here at the bottom is a duo system. You can see the self-adjusting screw is given okay that's the one. And, the non-friction brakes again will have engine braking, exhaust brake, magnetic which is types which are not going to focus now right. This already, we have seen the video where the caliper squeezes a patch to create a force on the surfaces of the rotor. Used in automotive application. Its advantage is simple design, self-adjusting caliper, rotor venting allows for a faster cooling aspect okay. Look at the disc brake is very open, whereas a drum brake it has to be enclosed. So, the heat dissipation will be difficult. And, these are the single piston caliper assembly aspect. You could see that what is happened this is you can piston arrangement you could see here. And, this is the disc brake system you can be slotted for a better heat dissipation. Sometime, you may have it's called a vent. Can you see that in railway bogie disc brakes. This type of slotted vent is called okay slotted so that heat dissipation will be much better. Of course, the Indian dialogue so slowly they are moving towards a disc brake system aspect, yeah.

And, now we will go for important thing before going about the design consideration you have to think about the loading aspect when the vehicle is empty or fully loaded, both condition we need to think about for designing the brake system. And also, what is happening static weight distribution for a lightly and fully laden, laden means loaded aspect. And, the more information you should know about the wheelbase this dimension of your vehicle system okay and you

should know center of gravity height for a lightly and fully laden aspect. Intended function, when you talk about intended vehicle function, it means what purpose is a passenger or cargo or offroad vehicle. Based on that your type of brake system also will change and relevant also will change, and tire and rim size okay. Why I am saying the tire and rim size, will brake system can be higher than the tire and rim, no. So, you have to make sure that the disc brake or drum brake whatever you do should be a lesser than the rim. That's a way the brake design will come into picture, okay. And, more important point the what is the maximum speed you are going to operate. So, based on this I think there may be one more point will be there the standard depends on the country, so based on these eight points we are going to discuss the entire braking system design aspect over the coming lectures. I think, I will stop now thank you.