Fundamentals of Automotive Systems
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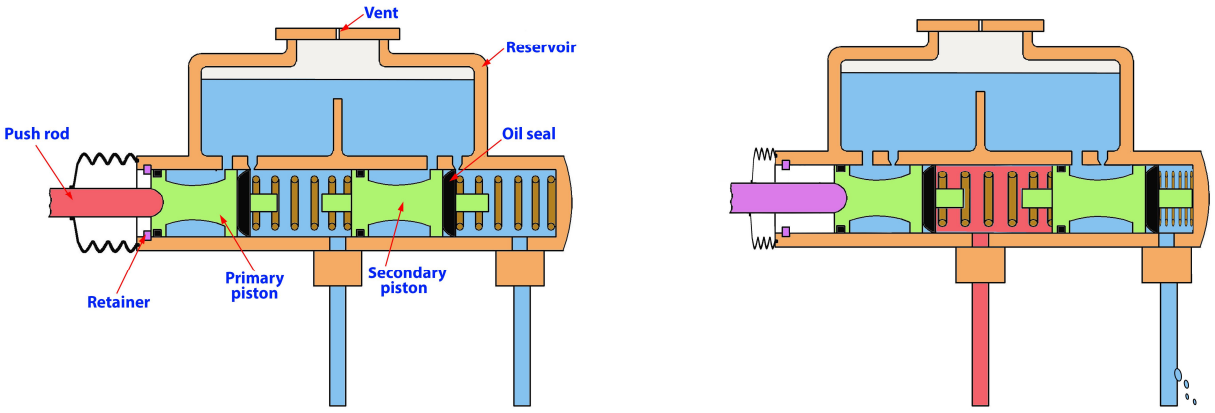
Lecture – 47
Hydraulic Brake System – Part 01

Okay, so greetings, let us get started with today's class, so just a quick recap, where we stop yesterday, we are looking at hydraulic brakes, so in hydraulic brakes, an almost incompressible fluid, right so is used as the energy transmitting medium and this is a broad lay out when the driver presses the brake pedal, the brake force is amplified or augmented by the vacuum booster, then transmitted to the master cylinder, where the force is converted to a pressure.And then like transmitted to the foundation brakes on the wheels, so in yesterday's class, we looked at the vacuum booster, we saw how it works.

So, today let us move on and see how the other components work, so let us get started with the master cylinder, so what happens in the master cylinder so, the force that comes from the vacuum booster, okay essentially is transmitted through this rod and in the master cylinder we can see that there are two circuits; there is a primary circuit and the secondary circuit as we discussed in the previous class.



MASTER CYLINDER

So, we can observe that there is a primary piston and a secondary piston, the rod pushes the primary piston so, the primary piston moves and then closes of this connection to the reservoir, so you can see that there is a connection to the reservoir, right that connection is closed. So, once that connection is closed, what we are having is essentially a stretch of fluid, right so, the mechanical force essentially starts pressurising the fluid.

And we can see that the pressurised fluid starts to essentially, we given to the brakes on wheels, right so that is what happens. Then, what happens; once the pressure in the primary circuit increases that is also going to act on the secondary piston and it is going to push the secondary piston, right, this is like a relay race, okay. So, essentially once the fluid in the primary circuit gets pressurised, the secondary piston is displaced.

And the secondary piston is then closing the connection to the secondary circuit from the reservoir and pressurises the brake fluid and the brake fluid starts flowing to the corresponding foundation brakes, okay so, this is how the master cylinder works and of course, the master cylinder; proper operation of the master cylinder is very critical because this is the place where we have these mechanical force being converted to a fluid pressure, right.

So, now what happens if one of the two circuits fail, right so, here we are; I am just illustrating a case where the secondary circuit, you know like fails, that means there is a leak in the secondary circuit. So, what happens is that the primary circuit continues to work, whereas you can see that the fluid is leaking from the secondary circuit, so at least we have partial braking capacity. Similarly, if there is a leak in the primary circuit, fluid will start leaking from the primary circuit.

But the secondary circuit will still work to generate enough fluid pressure to brake the vehicle obviously, you know like we should not operate the vehicle under such conditions, you know, we should get the what to say, system repaired, right and other mechanisms for us to what to say, enable the detection of these failure, we do have right, so in hydraulic brakes one of the important advantage is that we get is that like there is a good amount of driver feel, right.

When you apply the brake, you know like, you will have; you will get feedback from the master cylinder back to the brake pedal, once the fluid is pressurised, right so, there will be a good amount of pedal feel, right feedback that the driver gets. Now, if there is a leak in the circuit, what is going to happen is that we will feel that the pedal has become soft right, so people call it as pedal going soft or like brake pedal sinkage and so on, right.

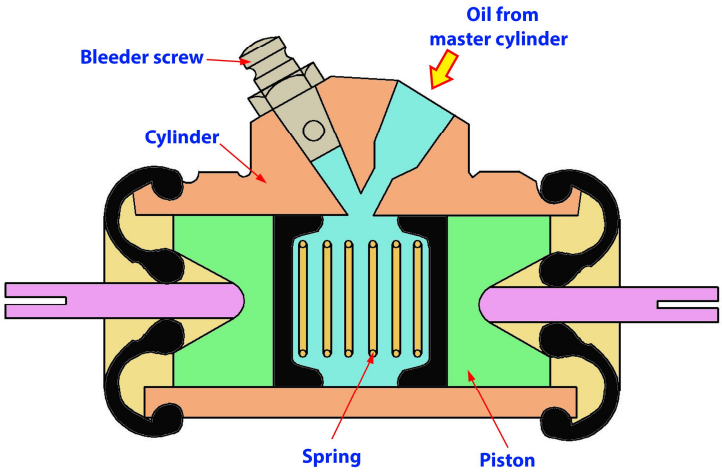
So that is like you try to apply the brake pedal of the same intensity but then you will see that it gets displaced more, right so, you will feel that you know like the feedback has reduced and the pedal is sinking more right, so that is a perception based feedback that we are getting and since the amount of brake fluid is also finite in a hydraulic brake system, once the leakage is severe, what is going to happen?

This reservoir is going to drain, right and once the brake fluid starts getting drain from the reservoir at a rapid rate and in this reservoir, there are levels you know like, a maximum level and a minimum level, you know like and the nominal level of the brake fluid should be between them, right. Once it falls below a certain level you know, we get a warning right, so that there is some problem in the brake system, okay.

So that is another, what to say mechanism by which we have a feedback to inform the driver that there is an issue with the brake system, okay. So, of course we will shortly see what happened in an air brake system, right but in hydraulic brakes you know like these two mechanism, there is a perception based feedback and also the fluid level based feedback you know like are warning, you know like or very critical in handy, okay.

So, this is how the master cylinder works, of course I have just explained from a big picture view point like any other component even the master cylinder has what to say very fine components you know like which have to essentially work together, even if see you know in the master cylinder, you know does not work properly you know, we are going to have insufficient pressure generation, right.

So, we have to produce a manufactured and assembled this master cylinder very carefully, okay because the pressures can be very high right, so typical operating pressures and hydraulic brakes are in the range of 10 power 1 to 10 power 2 bar right, so that is pretty okay.



WHEEL CYLINDER

So, we can immediately observe you know like what is what to say, at least how reliable these components should be right, so to enable proper operation, okay so that is the master cylinder. Now, from the master cylinder you know like going back to this big picture diagram, so we can observe that the brake fluid is being transmitted through these so called combination valve, we will come to combination shortly.

But to the foundation brakes on the wheels, so we have already seen how the brake fluid acts on the piston in the disc brake and then generates a force; actuation force on the brake pad in the disc brake right. Now, what about the drum brake, okay so, in the drum brake, the brake fluid essentially goes into what is called as a wheel cylinder and in the wheel cylinder, the fluid pressure is converted to a mechanical force.

So, what is this wheel cylinder? So, this is the schematic of a wheel cylinder, so what happens here is that the oil from the master cylinder or brake fluid from the master cylinder comes in, right, it goes inside and then we can see that there are two pistons, right so on either side. If you

recall a leading trailing shoe brake right, there are two brake shoes and then like we need actuation forces on both ends, on two ends, right.

So, what happen is that in the wheel cylinder, we have two pistons right, on either side so, the fluid pressure goes and acts on the piston and that generates an actuation force which is going to push this piston and rod and the brake shoes are connected, I am just drawing a piston; indicative shoe, just to not to scale, right so, to just get the idea, right. So, this is going to essentially generate the actuation force, right.

So, essentially we will have the what to say the wheel cylinder having two pistons and that generates the actuation force on the brake shoes of a drum brake in a hydraulic brake system, we will also see when we look at; discuss the air brake system as to how the actuation force is generated on the or transmitted to the brake shoes of a drum brake in an air brake system later on, okay, so this is the wheel cylinder.

And we can see that you know like there is a bleeding screw, bleeding mechanism because if you want to replace the brake fluid from time to time you know like, we can do that through this bleeding mechanism, okay, so that is the function of a wheels cylinder, right, okay. So, wheel cylinder you know like is pretty compact, it fits within the drum brake you know like in a hydraulic brake system and then like it converts the fluid pressure to a mechanical force once again.

So, in fact if you look at master cylinder and wheel cylinder, you know like essentially, the master cylinder; it converts the force output from the vacuum booster to you know a fluid pressure, right so that is the primary purpose. For a wheel cylinder, it converts the fluid pressure to an actuation force on the brake shoes of a drum brake, okay so that is, what is the role of a wheel cylinder, okay, yeah.

So, now we will look at the combination valve, so what is this combination valve, right so, where was the combination valve located? So, in a hydraulic brake, you know if we go back once again to this large schematic, so we can see that the combination valve is located in the hydraulic

circuit right, so from the between the master cylinder and the foundation brakes, okay. So, what is this combination value, what is it constituted off and what is its role?

So, this combination valve is a combination of various valves as the name indicates typically, found in most cars and SUVs and so on with a hydraulic brake system and that are typically equipped with a front disc brakes and rear drum brakes, we also discuss why this configuration is very popular, right in the previous lecture. So, this is a combination valve, so what is the; what are the valves that are essentially present in this combination valve?

So, let us look at that so, the first valve you know in this combination valve is what is called as the proportioning valve. So, what is the role of a proportioning valve? So, a proportioning valve ensures that the fluid pressure is appropriately distributed to the front disc brakes and the rear drum brakes. So, what does this mean? So, if you recall let us say, we take a typical passenger car, right and we are looking at the static load distribution on the front and the rear.

So, let us assume that there is a sixty percentage and forty percentage distribution of mass on the front and the rear respectively and when we do braking analysis, we will observe that there is going to be dynamic load transfer from the rear to front during braking. So, let us what to say assume that for the time being that we want to have seventy percentage of the braking effort coming from the front and thirty from the rear, so we want higher brake force output from the front disc brakes, right, point number one, correct.

So, if I want higher brake force assuming that we have the same brake on all the 4 wheels with the same brake factor, we would require higher actuation forces, is it not? Higher actuation force is actuation force at steady state is going to be the product of the pressure in the; fluid pressure in the piston or the cylinder, right fluid pressure acting on the piston either in the wheel cylinder or in disc brake caliper times the area of that piston, right.

So, if you want higher actuation force assuming the same brake, I would want more pressure on the front that is point number one that is the first reason, right. Second reason is that we have already what to say, looked at the fact that a disc brake has lower brake factor than a drum brake

of course, we are going to design the disc brake appropriately however, not only do we want higher brake force output from the disc brakes, the brake factor of the disc brake is lower than that of the drum brake, right.

That would entire the disc brakes actuation force be even higher, right than the case where the same brake is used on all the four wheels and once again, how do we increase the actuation force; by increasing the pressure of course, that we can adjust the area in the disc brake also but you get the point right, so relatively there is going to be an increase in the fluid pressure due to these two phenomena.

So, a proportioning valve does that, it ensures that the fluid pressure provided to the front and rear brakes are proportioned or distributed appropriately, okay so that is the role of a proportioning valve. Once again, what are the two reasons? The first reason is more brake force output from the front brake, okay irrespective of whether we are using disc or drum, right because more load is there on the front, right.

Second; due to the fact that we are using disc on the front right, so we know that disc brake requires more actuation force, right to generate a desired brake force, okay that is the role of a proportioning valve. So, another mechanism which is typically part of this combination valve is what is called as a pressure differential switch. So, what is this pressure differential switch? So, typically we want the pressure in the primary circuit and the secondary circuit to be almost the same.

Now, let us assume that you know like there is a failure in one of the two circuits, see as a driver we want to be alerted, right that there is a failure, so what this pressure differential switch does is to do that function, right perform that function. So, what we have in a pressure differential switch you know like that actual design can be slightly different but the concept is the following. Let us assume that you have a structure in which there is a piston at the middle.

And at either end you have the fluid coming in from the primary and the secondary circuit, during normal operation yes, during the transience there may be a small fluctuation but at steady

state, the fluid pressure is going to be pretty much the same on; same in both the primary and secondary circuits. So, if that were the case what will happen to the piston; it will stay almost in the middle, right of the cylinder.

Now, assume that one of the two circuits has failed, what is going to happen? The pressure on that side is going to fall down, so when the brake is applied, there is going to be the pressure difference on either side of this piston, so the piston will move and then it will essentially keep the cylinder on one side and that will close an electric circuit which will give a warning to the driver that is a typical concept behind the realisation of this pressure differential switch.

So, it is monitoring the difference in pressure right, between the two circuits that is the role of the pressure differential switch. So, the pressure differential switch is used to alert the driver, if there is a loss of pressure in either circuit, right either the primary or the secondary circuit that is the role of a pressure differential switch. So, in the combination valve typically, there is another valve called as metering valve. So, what is this metering valve? So, once again you know like we are discussing the essentially, a configuration where we have disc brakes on the front and drum brakes on the rear, right.

So, typically these drum brakes take a little bit longer to apply than the disc brakes, okay so, once fluid is provided to it, right so, the construction of the drum brake is such that it takes a little bit longer to apply than the disc brake. So, ideally we would want all the four brakes to be applied at the about the same time, right, so do not want to differential that, right, so the metering valve does that job.

So, it just delays providing the fluid to the disc brake by a calibrated time interval; very small time, okay so that all the four brakes are applied at the same time, okay, so that is the definition; role of; that is the role of a metering valve. So, the drum brakes take slightly longer to be applied than disc brakes. So, this valve; the metering valve delays providing brake pressure to the front disc brakes there by providing sufficient time to apply the rear drum brakes.So that is the role of a metering valve, so these are the constituents of a typical combination valve.