Fundamentals of Automotive Systems

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Lecture – 46

Disc Brake and Introduction to Hydraulic Brake – Part 02

So, now these are the advantages of a disc brake, so let us look at for the other side, we have already looked at the limitation right, what is the limitation; now, we need to get the same brake force, we need to provide higher actuation force right, so that is a limitation that is something is a trade-off we need to be ready to take. Next question arises is what we discussed at the beginning, right.

In most passenger cars right, we have disc brakes are used in a front and drum brakes are used in the rear, the question is why, correct so, this is the most common configuration we see, disc brakes in the front and drum brakes in the rear right, in most passenger cars. So, the question becomes why. So, the answer is also like something which we have already seen right, so we are going to do a more quantitative evaluation when we do braking analysis, okay that is going to come up.

But just as a thought experiment right, so we will essentially answer this question by reasoning out on the based on the analysis that we have done till now, so if you look at a typical passenger car, you would see that the front wheels will have more load; static load than the rear wheels because in typical passenger cars, SUVs and all, you will have the engine, the powertrain everything mounted closer to the front than the rear.

So, you would see that even in a car stationary, the static load on the front wheels are going to be more than the static load on the; loads on the rear wheels, point number 1. Second point is when we break that is going to be what is called as dynamic longitudinal load transfer from the rear to a front, we would have observed it for example, when we are travelling in a car and let us say the driver slams a brake what happens to all of us?

All of us tend to go forward, we will find out the physics behind it okay, we are going to come that, right but as a result, there is going to be a what is called as a longitudinal dynamic load transfer is dynamic because it depends on the deceleration levels which can change with time right, from the rear to the front. So, consequently what is going to happen is that the net effect is that during braking in a typical passenger car, we are going to have more normal load on the front wheels compared to the rear wheels.

So, more normal load on the front wheels means, we will see that there is more capability of extracting more braking output from the front than the rear, so now this sounds counterintuitive right, so if we want more braking force from the front, would I not use a drum because we have seen that essentially, the drum brake will give more brake force output for the same input right, why would I give a; why would I use a disc brake on the front?

The reason is exactly what we discuss right, mu sensitivity; the primary reason, so let us once again consider a vehicle where we want hundred Newton's of total brake force and once again taking the round number of hundred, right. So, let us say you know like there is a seventy, thirty split between the front and the rear, we will see how to come up with these numbers, okay when we do what is called as brake force distribution analysis, right.

So, let us say we want a seventy, thirty front rear split, what it means is that; out of that hundred, I want seventy Newtons from the front and thirty Newtons from the rear, right. Why do we then use a disc brake in a front? I want a higher brake force but however, I do not want that higher number to vary too much, right because ultimately, if you look at; if we neglect all the other forces, right even if you use F equals MA for a given mass, the deceleration is going to be dependent on the brake force that we are going to develop, right.

The decelerating force that we are going to develop through the brake system, so that is going to be a sum of the brake force developed on the front wheel and that on the rear wheel, so we have more brake force capability on the front and with time; with usage of the vehicle all right, with temperature increase, I do not want that seventy Newton to fall steeply is not it, although a drum brake would have given that seventy Newton for a smaller actuation force, the price I would have paid would have been maybe perhaps not acceptable, right.

Because the brake output will decrease steeply with decrease in mu so, we go for the more reliable solution which is a disc brake on the front where we are having higher braking capacity and then on the rear, as a trade-off between performance, cause, complexity everything right, we use a drum brake, okay because let us say we want to generate only thirty Newtons on the rear drum brake.

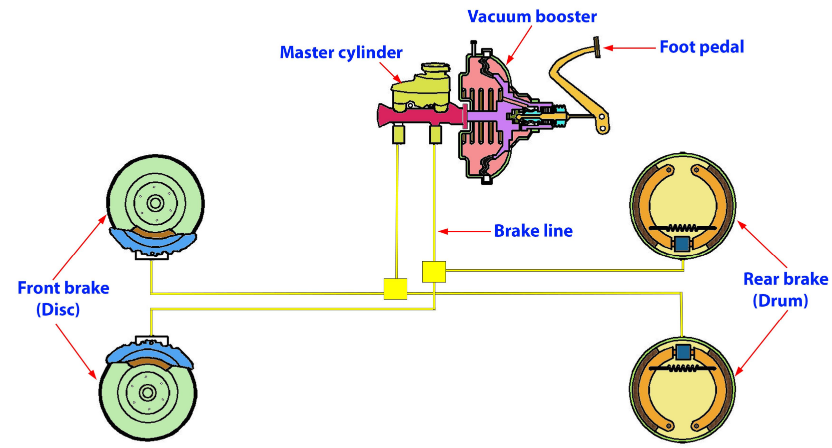
Let us say even thirty Newton's drop by twenty percentage, let us say to twenty four Newton's numerically, I can leave six Newtons right, of decrease in brake force but if the seventy Newtons drops away twenty percentage right, numerically that is going to correspond to a decrease of fourteen Newtons, right so, that may be a steep decrease right, so it is a trade-off once again, right. So, this is one primary reason why we are going for a very common configuration of disc brakes on the front and drum brakes on the rear in a typical passenger car.

There is one more reason which is and; this is the main reason, there is one more secondary reason which will figure out when we look at parking brakes and so on, right as we go along right. So, I hope it is clear from this discussion why we are using this particular configuration as I mentioned; we will do a quantitative analysis as we go forward, right, okay. So, essentially this completes our discussion of disc and drum brakes, okay.

So, now the next topic what I am going to start in this lecture is a discussion on hydraulic brakes, okay let us look at the hydraulic brake system. So, just to write on a brief answer to this question, we will see that typically, a more normal load is available on the front wheels and we will discuss when we do analysis and also a discussion on anti-lock brake systems that this would imply more potential for; more potential braking force, right from the front, right.

This implies that need a reliable brake on the front, okay so, this leads to choosing disc brake on front alright okay, so that is the broad answer to that question. Now, let us look at the hydraulic brake system, let me start the explanation with a simple schematic, so let us consider a simple schematic which shows layout of a hydraulic brake system in a typical passenger car, SUV and so on, right.

So, hydraulic brake system as the name indicates it uses what is; what we call as a brake fluid and almost incompressible fluid, right for as a energy transmission medium okay so, the hydraulic brake uses an almost incompressible brake fluid as the energy transmitting medium, okay.



HYDRAULIC BRAKE SYSTEM

So, if we recall the broad set of components of a typical brake right, what were they; source of energy, a mechanism for applying the brake, a means of transmitting the energy and foundation brakes, right.

So, from a big picture view point, so let us look at what happens in a typical passenger car, so we can observe that you know like that the source of energy is the drivers pedal input right, so drivers pedal effort okay or input is the source of energy. So, then the foot pedal is the mechanism for applying the brake, so that is the second one. So, now what happens in a hydraulic break, so let us say you know like the driver presses the brake pedal, right?

So, what is going to happen is that, that brake pedal is going to be magnified due to a lever ratio and that is going to be transmitted to this rod which goes to what is called as a vacuum booster, okay. So, what is this vacuum booster; we will look at each of these components in detail. The vacuum booster essentially augments the driver input; brake input force, right, so we will see how it works, right shortly.

So, when the brake pedal is pressed, the force is transmitted to the vacuum booster and the vacuum booster augments or adds on to the force which is transmitted to, now the augmented force goes to what is called as a master cylinder, so master cylinder is the component where the mechanical force is converted to a fluid pressure. So, the brake fluid which is there in the master cylinder is pressurized, okay due to the force that comes that acts on the pistons in the master cylinder.

Now, we discussed previously that for ensuring reliability you know like, we have a dual circuit brake system, so this is where the dual, two circuits come in okay, so the master cylinder has a primary circuit and a secondary circuit, okay, so P stands for primary circuit okay, S stands for secondary circuit. So, there are two circuits in the master cylinder, so that is why this is a dual circuit, okay mechanism.

So, we have primary and secondary okay, so this is where the split happens, right because in a typical passenger car hydraulic brake, the source of application is only 1 but the split happens in the master cylinder, in a typical two wheeler for example, the split is evident to us, right because when you apply the right hand lever, we brake the front and when we apply the left hand lever in vehicles without a clutch, right or explicit clutch mechanism you know like we are braking the rear, right.

When we have a manual transmission, a geared motor cycle what happens is that we use a foot pedal right, to brake the rear, so we can see that the split is explicit and decoupled, right whereas, in a hydraulic brake system, the split is inbuilt okay, so this is where the split happens, right. So, we can see that there is a primary circuit and the secondary circuit so, the primary circuit, we are going; we look at each of these components in detail.

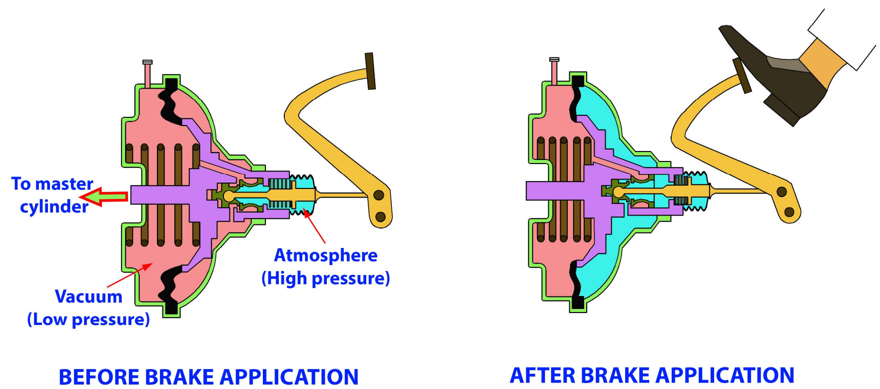
The primary circuit essentially provides brake fluid, these are what are called combination valves, we will discuss them in more detail as we go along, so there is something called as a combination valve, the fluid from the primary circuit output comes to the respective combination valve and if we trace it, we can see that the primary circuit is going to essentially actuate this front disc brake and this rear drum brake, right.

So, that is how it is arranged so, primary circuit fluid is going to go to these two brakes and the secondary circuit comes through its own combination valve and actuates this disc brake and this drum brake, okay. So, this is what is called as a; this configuration which is quite popular in passenger cars is what is called as a diagonal split or an X split. So, you see that the split is like an X, okay and it is diagonal, right, so diagonal or X split.

So, we can also have a front rear split which is quite popular in heavy vehicles okay, when we look at air brake systems, we will see that we are going to have a front rear splits that is one circuit will provide flow it to the front and another to the rear, right and we can see that the fluid goes to the disc and the drum brakes and in the disc brakes we have already seen earlier in this lecture as to how that fluid pressure is converted to an actuation force.

In the drum brake used in a typical passenger car, there is something called as a wheel cylinder you know like, so which essentially, converts the fluid pressure into an actuation force, right and then like transmits it to the brake shoes as we discussed in the previous lecture, okay. So, this is a broad overview of this hydraulic brake system, okay. So, let us start discussing each one of these components in greater detail.

So, let us start with the vacuum booster okay, so if we look at the vacuum booster per se and if you look at a simple schematic of that, this is how it works. So, if we look at a typical vacuum booster we can understand its operation from this simple schematic, so as the name indicates right, so it is going to use vacuum right, for augmenting the input force by the driver.



VACUUM BOOSTER

So, what happens is the following; so when the brake is not applied you know there is a diaphragm, okay in the vacuum booster which essentially, is subjected to air at partial vacuum on both sides, so you can see that both sides of this what to say, diaphragm is subjected, the cavity is essentially, filled with air at partial vacuum. Now, the question is that like how do we get this vacuum in a vehicle?

So, typically in a naturally aspirated petrol engine right, we discussed this when we looked at engines right, so during the suction stroke, the pressure in the inlet manifold is going to be lower than atmospheric, so we will tap into that you know into the intake manifold in a naturally aspirated SI engine to get this vacuum but if you need additional vacuum, we can always have a separate vacuum pump you know to generate; it depends on the design, right.

So, essentially one can always use a vacuum pump, in turbocharged diesel engines; powered vehicles, there is no vacuum source in the engine per se right because at the inlet manifold itself like air is pumped in at higher pressures, so we need a separate vacuum pump you know to enable this source of vacuum, right so those are the choices that are available to us. So, now before the brake is applied, both sides are subjected to vacuum.

Now, when the brake is applied what happens is it; this rod moves and then let us say you know like we look at this side as side 1 and this is; this side as; this half as half two okay, now when the brake pedal is applied what happens is that previously, both halves one and two were at the same pressure, the movement of this rod will close the opening that attach; that connects this first half to the source of vacuum.

Then it will open a cavity through which atmospheric air will flow in, right that is air from the atmosphere will start flowing it so, obviously this is air at atmospheric pressure and that is going to be higher than the vacuum pressure, is it not. So, once ait at atmospheric pressure flows in with brake application, what is going to happen; there is going to be a pressure difference, right.

So, the pressure difference is going to be essentially, P_1 minus P_2 at steady state times the effective area, right of the diaphragm, right that is going to be the net force from the vacuum booster, is it not. So, this force augments whatever force is coming into the vacuum booster, right and that augmented force is now transmitted to the master cylinder, okay, so this is the way in which the vacuum booster operates, right okay.

So, once again to summarize you know like before brake application, the two sides in the; two halves in the vacuum booster are exposed or maintained at partial vacuum right, when the brake pedal is pressed, one side; the first half what we have label as half one is filled with air at atmospheric pressure and the resulting pressure difference will provide a net force which will augment the input force from the driver, right.

And this is going to be transmitted to the master cylinder so, we will look at master cylinder and other components tomorrow and then like we will continue with our discussion on hydraulic brake systems okay, thank you.