Fundamentals of Automotive Systems
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Lecture - 41
Brake system - Part 01

Okay greetings so welcome to today's lecture. So we are going to start with braking from todays class. Till now if you have a quick recap of what we have done. We have looked at the power train. So we looked at the internal combustion engine and then we looked at the transmission. So if you look at the power train. The power train essentially converts chemical energy into heat energy in the IC engine.

And then heat energy is then converted to kinetic energy in the engine and that kinetic energy is transformed to the wheels and then like used to propel the vehicle. So in a broad sense if you look at the energy conversion mechanism from chemical to thermal to kinetic that is what is happening in the conventional powertrain that we have learned. Braking in a certain sense is just a compliment of what happens in a power train.

And what we are going to learn we will encounter other types of braking. We are going to learn what is called as friction braking. That is going to be the scope of our study you will see what a friction braking is so what happens in friction braking is that like kinetic energy of the vehicle is converted to thermal energy and dissipated to the atmosphere.

So that is what happens in friction braking. So in a certain sense in an power train you know like you have chemical to thermal to kinetic here you have kinetic energy converted to thermal energy and dissipated to the atmosphere so we can see that it performs the complementary operation right? As far as our friction brake is concerned. So in this discussion on Braking we are going to look at once again how a brake is constituted.

In other words you know we are going to look at the various components that make up the brake system. We are also going to look at how a typical vehicle brake system operates and we are also going to look at analysing the braking process and brake system itself. So that is going to be the broad outline of this module. But before we go to the discussion on braking just to give a perspective of what we are talking about right?

So before even we do this calculation let us say you know like if someone asks you know like which is more powerful right? The IC engine or the brakes for most of us you know like we see the IC engine you know like and we can feel the IC engine right in a vehicle. So it you hear the sound right? You go closer to the place where the engine is mounted it radiates heat energy and it appears to be bulky.

So many components and it we feel that its powerful right? On the other hand brakes are some things which we hardly see right? So they are hidden from our view in the wheel hub typically and they quietly go about doing the operation. So at first glance we see we seem to have a very clear answer on which is more powerful. But let us see what is the actual scenario? Okay so let us say we consider a vehicle of mass ten thousand kilograms.

Let us see I am just taking round numbers. So that like our calculations become easy right? So first let us look at the power train. So we are going to do a very simple preliminary analysis of the numbers involved. So let us say we have the vehicle going from 0 kilometres per hour to 72 kilometres per hour let us say in 20 seconds right? So 72 kilometres per hour is 20 meters per second. That is why I am just taking round numbers to help us with our calculations.

So this implies that the average acceleration is going to be what? 20 meters per second minus 0 meters per second divided by 20 seconds. So that is going to be around 1 meters per second squared right? That is the average acceleration that the vehicle is going to have. All right? As I told very simple calculation. Now if I want to calculate let us say what is the acceleration power? Once again we are not going to go into too many details here.

But what I am going to do is it like from a macroscopic viewpoint we take the initial kinetic energy of the vehicle the final kinetic energy or the vehicle subtract the two. That is a change in energy and the rate of change of energy right? But it gave me this quantity right? Is it not right?

So that is what we are going to do. So essentially we are going to do half m v_f square minus v_1 square divided by delta t.

$$\text{“Acceleration Power”} = \frac{\frac{1}{2}m\left(v_f^2 - v_i^2\right)}{\Delta t}$$

So this is going to give us half times 10000 kilograms times 20 square minus 0 square divided by 20 seconds. Of course this unit becomes meter square per second square. So if we process this right what we are going to get is 100 kilowatts right? I hope my calculation is correct. So that is why I took very round numbers so that like we just are looking at ballpark figures right? So we get around a 100 kilowatts. So in other words you know like we need a power train that can essentially deliver a power of around100 kilowatts to enable me to meet this specification.

$$\text{“Braking Power”} = \frac{\frac{1}{2}m\left(v_f^2 - v_i^2\right)}{\Delta t}$$

Let us look at the compliment right? So now let us look at the brake so now Braking is the reverse. 72 to 0. So typically you know like most vehicles depending on where we live. You know like one important specification is 0 to x kilometres per hour in so many seconds. But very few people talk about the x kilometres per hour to 0 in so many seconds. So let us talk about that. So let us say we want to go from 72 to 0 let us say in 4 seconds.

Obviously we want to this is the what to say worst case scenario right? What we call a panic Braking right? One hopes that we do not encounter such scenarios but that is how that is how the design is done right? So we can immediately see that the average deceleration of course I do not need to do so many calculations because using the timescale itself you can figure things out. But then let us say we do it you know like the average deceleration is now going to be okay average acceleration is going to be this.

So you get a negative number 0 minus 5 which implies that the vehicle is decelerating. So completive to a braking power if we calculate the same way right? Half m v_f square minus v_i squared divided by delta t of course let us say I am interested only in the magnitude right? Now the sign persay now if you do the calculations you will see that the numerator is the same denominator this one fifth. So the power should be 5 times.

So in a certain sense you know like the brakes the energy or the rate at which the brake should extract the energy from the vehicle is more. But the only thing is that like which can be told to provide a balance to you the powertrain continuously when the vehicle is operated you know the engine to continuously or be operated and provide the necessary traction right? But how are the brakes going to be operated? Only intermittently one hopes right? And so that just puts things in perspective right?

So a 5 meter second squared deceleration where a stopping maneuver has to be executed and 4 second is not something which we will encounter a day in and day out hopefully. Right? Okay so just these numbers just put things in perspective right? So as per as the brake and the power train is concerned. So essentially the brake system is pretty important.

Because by and large for most road vehicles the peak accelerations and the peak decelerations if you compare the design values or the design specifications by and large the peak deceleration values are going to be higher than the peak acceleration value okay? So one needs to essentially be aware of the fact and ensure that we come up with a brake which achieves that in practice.

So now let us articulate what are the functions of a brake system. So very intuitively we understand what a brake system should do right? Because particularly road vehicles are somethings you know like entities that you and I encounter every day. So we have an intuitive understanding but let us formally write things down. So if brake should be able to decelerate the vehicle and stop it when necessary.

Okay this is one requirement of a brake system. Is it not this essentially implies that this should provide sufficient okay brake force that is an important requirement? Is it not? Okay. Because in order to achieve a certain deceleration and stop the vehicle the brake system should have enough capacity to provide the necessary braking force. Right? Then a brake should also help us in maintaining the speed of the vehicle while traveling downhill.

Okay so it should essentially help us in maintaining see because when we are coming down the hill w sin theta will essentially try to accelerate the vehicle right? So the brake should be applied more often than not to ensure that the vehicle is what to say kept at a controllable speed so that we can take turns and navigate the narrow roads when we come down hill right from a hill for example right?

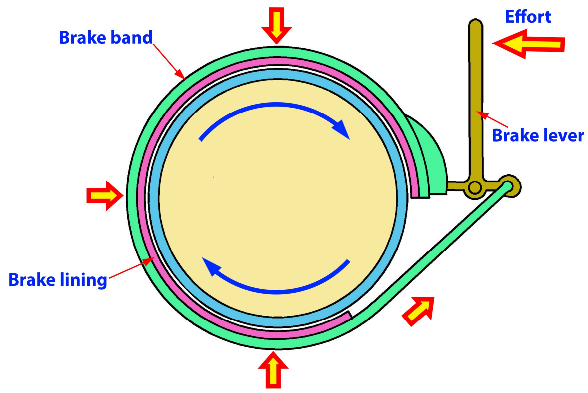
So this should imply that yes the brakes should have enough capacity but if you look at friction braking what is going to happen? The kinetic energy is converted to heat energy and dissipated. So what is going to happen to the brake components? That temperatures are going to get hot and we are dealing with friction material when the temperature of the friction material reaches high levels.

Their friction properties go down or decrease then we will not be able to achieve the design brake force or brake torque or the under vehicle deceleration that is expected. So consequently if one wants to meet this expectation the brake should be able to dissipate the heat energy effectively. Okay so that the temperature is maintained in reasonable levels right? So that is important.

Then a brake system should also be able to hold the vehicle stationary on a grade. This is very important right? So when we are on a grade and due what our reason we park or we are waiting in traffic we should ensure that you know that the vehicle does not roll down. So the brake system should also be in a position to hold the vehicle stationary. Okay as and when desired on a gradient.

So these are some functions and we are going to see how these functions have been realized in vehicles you know like shortly before that let us go and look at how did brakes evolve in vehicles friction brakes. See of course throughout this module unless otherwise I explicitly specify when I use brake or Braking we are dealing with friction brake and friction Braking respectively. Okay. So how did brakes evolve?

EXTERNAL CONTRACTING BRAKES



So initially what happened was that wheels were braked the initial mechanism were all mechanical were braked by wedging a shoe against the rim. So what this means is that let us say you know like we have a wheel okay. If you compare a horse driven carriage and so on right? You have a wheel and typically what happens is there is a brake shoe and that is essentially controlled by a lever which go which is under the control of the driver.

It goes upstream and then when the driver actuates this lever this wedges is going to be pushed against the wheel. And that generates friction so this these were the initial mechanisms this was okay as long as we moved to pneumatic tyres. Once we moved to pneumatic tyres such a wedging mechanism on the periphery is not practical right? Because we can just apply pressure on the external surface of the pneumatic tyres if too much force is applied it may burst.

So what happened people then looked at moving the brake mechanism into the wheel assembly. So from here we transition to what is called as an external contracting brake okay just typically realized as what is called as a band brake. So what does this band brake? So just to have a simple schematic so we can immediately observe that in a band brake. This is our what to say rotating wheel the blue entity.

Then what happens is that a band is wrapped around the wheel. All right? So sorry the blue is not the wheel it is the wheel hub. Okay so this blue coloured cylindrical shape that you see there right is the wheel hub? So the brakes is move within the wheel assembly into the hub right? So essentially a band which we can see in green colour is wrapped around it. And on the internal surface of the band we have the friction material the pink colour lining that you can see.

So when the brake is not applied you know like there is a small gap between the friction lining and the external surface of the wheel hub. Now when the brake lever is pulled this band is tightened right? So what happens? So this band contacts and then pushes the friction lining against the wheel hub and the Braking torque is generated. Okay and the wheel is decelerated right. Okay so that is why it is called as external contracting brake.

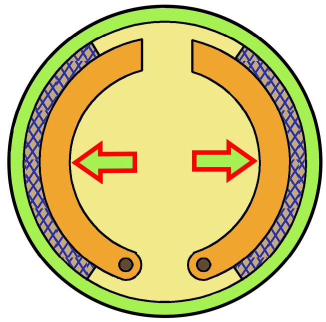
Why it is called external because the mechanism for Braking is external to the rotating element and the band and the friction lining contract that is they are radially inwards when applied. Okay so that is the band brake once again pretty simple right? What is a potential limitation of this band brake? One limitation which essentially affects the performance of this band brake is that we already have discussed that during this process of friction Braking kinetic energy is converted to thermal energy.

Now when these components get heated up what is going to happen? The band and also the wheel hub are going to expand right due to thermal expansion. Now when they expand what is going to happen to the gap between the friction lining and the wheel hub that will reduce. So the friction lining may accidentally rub against the wheel hub even when there is no requirement. Of course the band also needs to be carefully supported.

So that like even when cold the band the friction lining should not rub against the wheel hub. Even if we addressed that problem during operation due to thermal energy what to say a conversion of kinetic to thermal energy we are going to have this issue right? So one limitation is that the band may rub against the drum. So we call this is wheel hub or drum. Okay so okay against the drum due to thermal expansion. So that was one other requirement what to say next step.

Now the idea that people had to essentially solve the issues is that can we go the other way. That is can the friction material expand from inside a drum and then they contact the internal surface

INTERNAL EXPANDING BRAKE



of the drum rather than the external surface. Okay so that led to what is called as an internal expanding brake. Okay what we typically see as a drum brake. So today drum brakes are used along with disc brakes as common friction brakes in road vehicles.

We will analyse both in detail but the idea is to have this sort of arrangement that is wherein we had the drum okay external to the fiction material. Okay so we can see these brake shoe which is pivoted on a backing plate right? And when we apply a force on the free end of this shoe what happens is that this brake lining is then pushed against the drum rotating drum right? The drum is rotating along with the wheel.

So that is why it is called as an internal expanding brake. Okay so internal means internal represents the fact that the brake shoe or the brake lining is inside to the drum and when the brake is applied it expands and then contacts the internal surface of the rotating drum right? So that is the drum brake of course even this has issues right? So we face a what to say issues due to thermal expansion right?

So in this case what happens is like due to thermal expansion the gap between the lining and the drum will now increase right? Because the drum expands right? So then what will happen is that we need to have more travel for the shoe to contact the drum. And there are a few more issues. Okay which we will discuss when we discuss both drum brake and disc brake. But however this internal expanding brake is quite popular even today.

And from here we also have gone to what are called disc brakes where the displacement of this brake lining you know like is along the axis of the rotation of a wheel. We will look at disc brakes in greater detail. And so if you picturize a rotor rotating between my two hands what is going to happen is that when the brake is applied the two if these two hands are the brake shoes or the brake pads they are going to move along the axis of rotation and then oppose the rotor from either side.

Okay? So that is the concept behind a disc brake. Okay so the displacement is along the axis of rotation. So we will analyse we will look at drum brakes and disc brakes in greater detail and then like we will what to say look at the what to say various attributes. Okay so that is in a broad sense you know gives us a picture of how did these friction brakes evolve with time right?