Fundamentals of Automotive Systems
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Lecture - 42
Brake System -Part 02

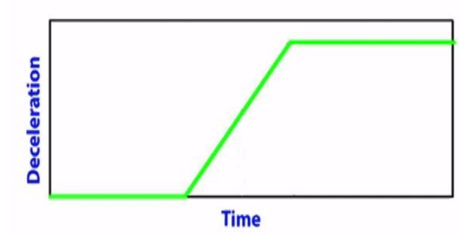
Now based on the function that the brakes perform we have various groups okay so let us title them as a functional grouping of brakes. Okay so how do we functional group brakes based on the function that they serve. Okay so these are all some terms that we must be aware of so the first one is what is called as a service brake.

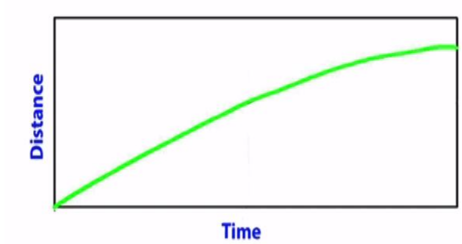
So what is a service brake a service brake is used for normal braking okay the normal brake which we use is what is called as a service brake. Okay when everything is working fine then we have what are called as secondary or emergency brakes that are used during partial brake failure. Okay so let us say you know part of the brake system fails you know the question is that like do we have any other mechanism to ensure that we still are able to generate some amount of brake force to decelerate the vehicle.

Okay so that is a secondary or emergency brake then we have what is called as a parking brake. Okay so depending on the functions that the brake system serves you know these are typical classifications. Of course we will shortly see when we look at you know different types of brakes that there is a there will be a good amount of overlap between these 3 functional groupings of brakes that is one component can perform more than one task okay in the brake components.

So if you take a look at the set of brake components in a brake system these are the set is not mutually exclusive for each of these groups. So what do I mean by that some components of the safe service brake will also act as secondary or emergency brake all right parking brake may also act as an emergency brake and so on right. So you will see that there's going to be some overlap but this, so we visualize it functionally all right.

Now some points to note when we are dealing with brake systems what is one important attribute which we want to essentially look at you know whenever we talk about vehicle braking. We are





always going to be interested in the stopping distance of the vehicle. Suppose let us say I am going on a highway at 80 kilometers per hour and I have some emergency in front of me I essentially slammed the brake pedal right.

The question is that like how soon or in what distance will I stop my vehicle that is very important right is it not? So stopping distance is an important attribute to characterize a brake system. So in this regard the stopping distance of a vehicle during the process of braking has different components. Okay so what are these components so let us look at what components make up the stopping distance.

So typically the stopping distance is the sum of the distances covered in the one driver reaction time okay second one is the brake response time. Okay the third one is the braking time so what do I mean by that of course I am going to explain these things by looking at the schematic and there will be some small variations depending on you know like certain other representations of this stopping distance.

Okay depending on how some people will view certain parameters in this diagram differently okay but I am just going to have a very physically intuitive way of characterizing these phases. So let us say you know like we are driving a vehicle and there is a scenario which necessitates a requirement of braking. See for example we are traveling on the highway let us say some human being or some animal runs in front of us right or we see some obstacle in front of us alright.

So what do we do from the time we perceive the requirement of braking and we take a decision and we move our foot let us say we are driving a car you know like to the brake pedal you know like we have some finite amount of time right. During which the driver reacts to a scenario that requires braking and essentially attempts to apply the brake. So that is what comes under what is called as driver reaction time.

So let us say we call it as tdr. This tdr essentially is required for the driver to respond to an situation that necessitates braking and start the braking process right actuate the brake, right? So of course the vehicle is going to travel some distance during that phase right. So of course please note that all these are to say the scales are all what I am doing are quantitative okay so sorry qualitative not quantitative right.

So please interpret them in that manner so let us just extend it so if I extend it these are to not the scale. So this is the distance traveled in the driver reaction phase then let us say we apply the brake pedal the driver apply presses the brake pedal in the car what happens that force needs to be transmitted to the wheels. We will see how that is transmitted so there is going to be some time delay in transmitting that force there is also going to be some time required for the brake to respond even if you have a disc brake or a drum brake.

We have already seen that the brake shoes have to move right and then contact the rotating drum only then the brake torque can be generated, and the brake force can be generated. Only if we generate a reasonable amount of brake force are, we going to have a reasonable amount of deceleration. Okay so here we are going to look at only deceleration due to the brake force so we will see that there is going to be a phase due to the response of the brake and the corresponding time required before which the deceleration becomes significant okay.

And that phase corresponds to what is called as the brake response time. Okay so let us call this as tdr this as tbr right that is the brake response. Then once the brake torque is generated acceleration or deceleration ramps up and then leg reaches the final value and then the vehicle speed decreases and whatever time that is required for the brake you know to essentially stop the vehicle you know like let us call it as tb okay so that is the braking time right.

So the next stopping time is going to be the sum of the three and consequently the stopping distance is going to be a sum of these distances. So this part as I told you this is not to scale right. So if we start from here to here this one can call as the reaction distance that is the distance travelled by the vehicle when the driver is reacting and also the brake is responding all right and this one can say it is the braking distance.

Okay so when the brake system is generating the brake torque and the vehicle gets decelerated to zero speed. So the stopping distance is going to be the sum of the distances in all these phases. As I told there may be some small variations in the way people look at what to say these I what to say this attribute of stopping distance. But the concept is the same I hope it is clear right, so it involves the driver response driver reaction phase the brake response phase on the actual braking phase right.

So those are the three main attributes obviously you know you would want the stopping distance to be as small as possible. So we want to ideally reduce all the three components the driver reaction time is not in our control right because it is highly subjective and even for the same person depending on the state of the driver state of that person the driver reaction time is going to be different.

Brake response time is something the designer can try to minimize through better design to essentially ensure that the time delay and the response time in the brake system are reduced. The braking time also in addition to other things also depends on the tyre road interface. So what do I mean by this let us say we are in a panic situation where we slammed the brake pedal you know like I want the maximum possible brake force generated.

So the brake torque which are generated on the wheels or other design limits and as we will shortly see when we do braking analysis. We design the brake system to generate those peak torques corresponding to what is the force that can be sustained at the so called tyre and road interface. When we did this powertrain analysis? We saw that the maximum traction you know like that we could get was mu p times w right?

And I told that we will come to a detailed discussion of that when we come to anti-lock brake systems and the braking phenomena which we will come in a few lectures. The peak friction levels or the peak friction coefficient that mu p depends on the road condition. So what happens is that let us say you know like we are braking a vehicle on a dry asphalt road and our vehicle and brake are designed for the best performance on that particular road.

And let us say it has rained and the road has become wet the vehicle is the same, the brake is the same, the driver is the same. But then the tyre road interface condition has now changed, and we encounter the same emergency. We slam the brake we hit the brake the brake system may generate the maximum possible brake torque. However, the interface between the tyre and road may not be able to sustain the torque.

Okay so then we will have issues which we are going to discuss when we look at anti-lock brake systems. Okay so the tyre road interface plays a very important role when we consider the process of braking and also like when we are looking at stopping distance in response to a braking maneuver.

Okay the next attribute that we consider during braking is broadly what is called as braking stability. So or to be very accurate this is the stability of the vehicle during braking okay so that is what we are referring to. So what does this mean see we would have seen that in some cases you know when the vehicle is braked you know the vehicle would have spun out of control right, we are going to discuss under what cases such things happen.

So we will see that you know when the vehicle is slammed you know like the vehicle will sorry the brake is just slammed right there may be some scenarios where the vehicle made a skid okay along straight-line you know sometimes it spins out of control and so on right. Those are scenarios which are undesirable that means that you know like we do not want such scenarios to happen so what is braking stability?

Let us try to articulate it a good brake must ensure a short stopping distance while maintaining the vehicle in a stable condition. So here once again I am putting stable under quotes so what we mean stable is that like the vehicles should not spin out of control you know like vehicles should not skid. You know the driver should be able to retain control over the vehicle steering you know sometimes you know like when we have what is called as front wheel lock you know like.

And we have a front wheel steered vehicle you know like the driver loses the ability to steer the vehicle you know we can turn the steering wheel as much as we want but the vehicles over heading will not change you know those are all like undesirable scenarios right outcomes. So this is what we mean by stable here we will realize that this requires proper distribution of brake forces at the front and rear wheels.

Okay so that is important we need to distribute the brake force properly between the front and the rear alright. So that is braking stability okay so we will come to brake force distribution when we do the analysis. So when we looked at powertrain by and large by and large right most road vehicles which are operating or either front-wheel driven, or rear wheel driven. We have 4 wheel drive vehicles also but by and large we drive either the front wheels or the rear wheels.

So you see that when during the so-called process of traction using the powertrain. We drive only one set of wheels but by and large during braking we want to enable that all wheels are used to generate the deceleration force braking forces. So that the sum of the braking forces is increased to the maximum possible extent what will that help us even if we consider F=MA very rudimentary argument right.

So let us say F is the total decelerating force if you are braking all the 4 wheels as opposed to only braking either the front or the rear wheels you will be able to generate more braking force. So more is the F for the same mass higher will be the deceleration and higher is the deceleration smaller will be the stopping distance given the same initial speed at braking right at the start of braking.

So consequently we want the brake system in a typical car or other road vehicles we essentially go and brake all the 4 wheels in a typical what is called a single unit vehicle like a car or a single unit bus or a single unit truck. Okay so that is what we do right so that requires proper distribution of the brake force you know like we will come to that later on that analysis later on.

Okay so another aspect which is very important as far as brake systems are concerned is the reliability. What do we mean by reliability? You know like how essentially secure or robust is a brake system you know like to essentially even small perturbations you know like in terms of let us say some small failure of some of the components. The question is it like can I get a brake force even when the system is not optimal right. So that the process of braking does not get disrupted completely.

See braking is a very serious safety issue because the brake is the most important actuator which is available for regulating the vehicle speed right and enable the enable drivers control over the vehicle all right. So we want to ensure that the brake system performs at least even partially even when there is a failure so that at least it can the vehicle can be brought to rest. So that is what we are asked requiring when we are talking about the reliability of the brake system right.

Of course how about parametric variations how about variations in the brake systems itself you know like can you provide a consistent brake force always you know that is something we will discuss later on. But as far as the idea of reliability is concerned the transmission, we are going to look at components of a brake system shortly. The transmission part of a brake you know like typically in the form of let us say mechanical links you know like a hydraulic system in passenger cars.

See we use like mechanical links like cables, rods, levers and all in bicycles motorbikes liked two wheelers and so on right hydraulic brakes are common now in cars and even like certain class of two wheelers and then like we have a compressed air system in heavy vehicles. We will look at all these types is typically the weakest link in the brake system. So how do we address this weakest link what we do is that like we try to ensure that there is a redundancy.

So even if you take a simple example as that of a bicycle you would see that there is a brake on the front brake on the rear and the way things are you know like it is designed such that our control over the front and the rear are separate. Let us say even when I press the hand lever of a bicycle brake right. Let us say the brake wire gets cut know it fails right at least I have the other brake to enable me to decelerate the vehicle and stop it in a passenger car.

This so-called split between the brakes on the different wheels happens inside see when you are driving a passenger car you know like we are only applying the brake through the foot pedal. There are no two control points right or actuation points by the driver but within the system you know like the effort gets split you know we learn it later okay when we deal with the hydraulic brake system.

So what happens is that hence a redundancy is introduced in the transmission that has led to the use of what are called as dual circuit brake systems. Okay so we have what are called as dual circuit brake systems okay which essentially ensure that brakes do not fail right. So if the even if there is partial braking failure, we still have some deceleration capacity. So I will stop here for this lecture so we will continue with the typical components of a brake system in the next class. Thank you.