Fundamentals of Automotive Systems
Prof. C.S. Shankar Ram
Department of Engineering Design
Indian Institute of Technology - Madras

Module No # 11
Lecture No # 54
Antilock Brake System 2 Part – 02

So now if you look at operating methodologies in an ABS what are the different choices you know like we will shortly see what are the see there are of course lot of variants you know and another choices I am just presenting a few samples which are commonly discussed so that we are aware of those terminologies you know that is my objective here. So if we are looking at ABS operation methodologies broadly we look at what is called a single wheel control.

So what is single wheel control? In single wheel control each wheel obviously is controlled independently right. So essentially we want to look at every wheel independently and then control it. Obviously what is the advantage, results in the maximum braking possible on each wheel right because every wheel can be on a different friction surface right in general. So if you use single wheel control we are going to try and maximize the traction at the tyre road interface of each wheel.

So we are going to get try to maximize the traction available at each wheel right but what is the flip side? The flip side is that if you have something called as a split Mu surface so what is the split Mu surface? Let us say you know I am going on a road surface where let us say the one side is on a dry road another side is on icy surface. So what is going to happen is that if I am trying to maximize the traction on the dry road.

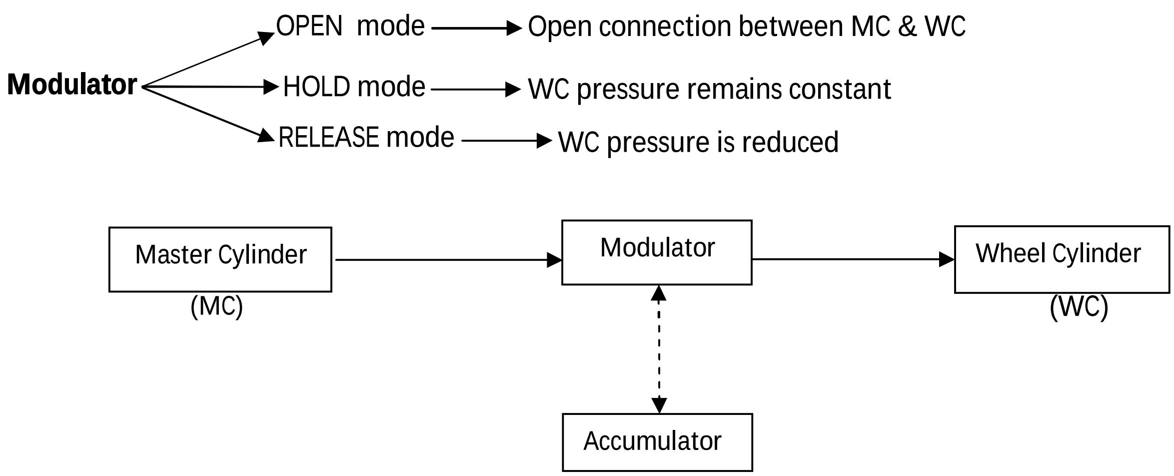
These braking forces are going to be much higher than what I can generate at the icy surface so immediately we can see that there is going to be an imbalance right in the moment alright. So that is essentially going to may result in a significant yaw moment okay which can have a yaw which can result in yaw motion of a vehicles. So we need to be careful okay it is not that cannot be used we have to see when it can be used right and cannot so can introduce a yaw moment on a split Mu road service.

So that is what is called single wheel control the second thing is to go very conservative so we go for what is called select low control so we are saying look I do not want yaw at any cost but I will do is that on a particular axle the wheel on the lower friction surface will dictate what should be the braking on both sides. So in other words let us say this surface is on ice right in this case if you consider left and right the right wheels are on ice.

So on let us say we consider the wheels then the left front wheels traction is also are braking is lowered to the level of the traction available on the right wheel which is on an icy surface. Similarly since the right rear wheel is on an icy surface we lower the braking done on the left rear wheel to match that of a right rear wheel so said there is no yaw moment in a split Mu surface but what is the tradeoff we are not utilizing the traction on the high Mu surface completely is it not?

So that will result in higher stopping distance because the net braking force is now lowered right at the expense of not having yaw motion. So in select low control the wheel with the lowered traction controls the level of braking on both wheels of particular axle okay so the advantage is that no yaw movement significant yaw movement in a split Mu surface but the trade off as we just discussed is that the net braking force will be lower so stopping distance will increase.

But the traction force on the higher Mu surface is not completely utilized this implies larger stopping distance. So it depends you know like on what surface we are you know what is the relative level of traction you know like what is the yaw moment value which is generated you know all those needs to be facted in. So these are only concepts you know like what I am discussing all are only broad concepts.



COMPONENTS OF ABS- FLOW CHART OF OPERATION

But the decision by the controller the logic should be programmed in such a way that it has to take into account all these various practice right. So the compliment of this is called select high control right so obviously the meaning is clear so now if the levels of tractions on both sides let us say we have a dry surface and a slightly wet surface as opposed to an icy surface you know are not very high that is the difference in the levels of traction is not very high between let us say the left and the right then what happen is that like we go for select high were in the high friction road surface controls the level of braking on both wheels.

So consequently the net braking force is higher however there is a possibility that on the lower friction surface since we are applying more braking force then what is possible at the tyre road interface there may be partial wheel lock or some level of momentary full wheel lock okay. So that is the risk that we need to live it then when it go to lock ABS to intervene and then try to bring it to you know like essentially lower slip values and so on okay so that is the tradeoff.

You know but the advantage is that the net braking force is increased right so that is the concept of select high control okay so the wheel with the higher traction force at the tyre corresponding tyre road interface decides the level of braking on both wheel of an axle okay that is select high. So this implies that higher net braking force of course we can use it we have to be careful right we can use it if the level of traction on either surface differs by a large amount right then what happens is that what essentially we can have an unbalanced moment right.

So which can result in yaw motion right so presence of an presence of unbalanced forces may result okay depends on the level may results in a yaw moment on a split Mu surface okay. So this is what happens in select high control okay. So these are different methodologies now if we look at the modulator itself so let us consider the hydraulic modulator okay. So or we can just say modulator does not matter so we are looking at passenger cars you know where we have a hydraulic brake system right as we already studied.

So the modulator essentially acts like a hydraulic link between the master cylinder and the either the wheel cylinder or the actuator in the disc brake so if you recall we have wheel cylinder in the drum brake right and a piston cylinder arrangement in a disc brake okay. So the modulator is placed in between okay in the hydraulic circuit okay so typically this modulator can act in 3 modes so the first mode is what is called as an open mode. So without loss of generality let me consider the modulator to be placed between the master cylinder and the wheel cylinder.

You know like let us consider the drum brake without loss of generality I can we can argue the same thing with the disc brake also right okay. So let us say you know the modulator is placed in between then what happens is that the link is like this in the hydraulic circuit. So in the open mode the modulator does not do anything as the name indicates it is open that means whatever fluid is coming from the master cylinder goes to the wheel cylinder.

Once again I am just considering wheel cylinder as an example to discuss the concept the wheel cylinder can be replaced with the disc brake’s actuator also concept remains the same right. So in the open mode so the what to say essentially there is a connection open connection between let us say master cylinder and wheel cylinder. So MC I am using the abbreviation MC for masters cylinder WC for wheel cylinder right. The second mode is what is called as the hold mode.

In the hold mode what happens is that the modulator closes the connection between the master cylinder and the wheel cylinder. So the wheel cylinder pressure remains constant right so now what happens in the master cylinder let us say the master cylinder pressure may increase keep on increasing but the additional fluid from the master cylinder will be redirected to an accumulator.

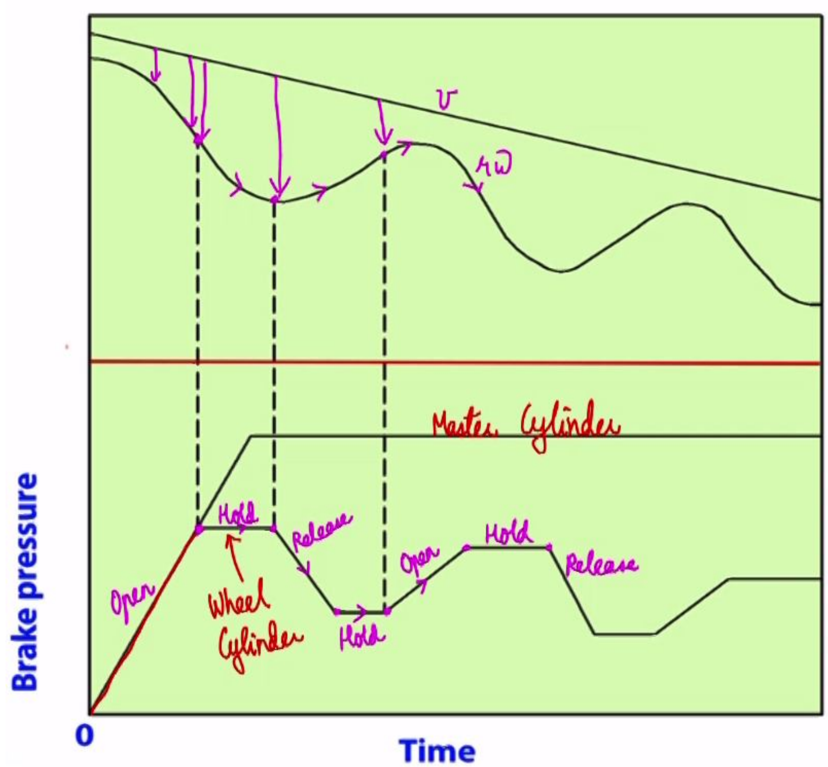
So let me put an accumulator in dashed line from the modulator just to show that there is another circuit another component here in this circuit okay. I am putting a 2 directional arrow the meaning will be clear shortly right so essentially it can either the modulator can take fluid or pump fluid into the accumulator okay. So what happens in that the whole mode the wheels in the pressure remains constant why any fluid which comes from the master cylinder is essentially redirected to the accumulator right.

Now the third mode is what is called as a release mode so what happens in the release mode? In the release mode the wheel cylinder pressure is reduced okay that means that the modulator still essentially closes the link between the master cylinder and the wheel cylinder. But however the modulator also starts taking fluid from the wheel cylinder so that the wheel cylinder pressure is reduced and then stores the fluid in the accumulator okay.

So that is how it releases the wheel cylinder pressure so from a broad concept essentially how does this system work we shall see shortly using a simple schematic. So thus the modulator works or functions as a hydraulic link between the master cylinder and the wheel cylinder okay and wheel cylinder slash brake actuator in a disc brake okay. It cycles between the above 3 modes I will not say cycles at transitions right between the above 3 modes there is open, hold and released okay when ABS action is triggered by the ECU.

So this is what is called like pulsation right so in this domain they will say ABS is pulsing or something like that right. So essentially they that refers to the pulsation you will see what is pulsing okay. So let me explain that function by a simple schematic.

So let us consider this figure so what is this figure? So essentially this is a very qualitative schematic to illustrate what is going on? So this in this figure if you look at the lower half you know brake pressure and time have been plotted okay so from the moment the brake is applied. So this line is the master cylinder pressure so it ramps up and then remains constant. So that is like a typical brake application



BRAKE PRESSURE Vs TIME

right so the driver presses the pedal the master cylinder pressure increases and then goes to a steady state value right.

So initially there is a small time lag between the master cylinder and the wheel cylinder pressure but let us say for the time being we are not worried about that. This curve illustrates the wheel cylinder pressure okay initially we can see that both the master cylinder and the wheel cylinder pressure were almost lying on top of one another right they were the wheel cylinder pressure was almost very close to the master cylinder pressure.

So what have a plotted on the above graph this is V okay this is r omega okay so V is the vehicle longitudinal speed r omega is the wheels circumferential speed alright. Now what air slip ratio? Please recall lambda was defined as V minus r omega by V so obviously if the gap between V and r omega increases I should be careful so that is the motivation right. So during braking there is V is going to be greater that r omega now we can see that starting from this point the gap between V and r omega is increasing.

So at this point the logic triggers the control mechanism or the control scheme has somehow realized you will see of course that depends on the design on the control scheme okay which we are not going to discuss here right because we have to figure what is V and how we an accurately determine this gap and so on right. So let us say we have all those mechanism estimation schemes set up everything right. So you see that controller detects that at this point the gap has crossed a certain threshold right.

Then what happens is that till here the modulator was on open mode then what happens is that the moderator is triggered to the hold mode okay. So in the hold mode we can see that the drop in r omega has reduced right but still the gap between V and r omega although it is increasing it is increasing at a lowered rate. So it goes to the hold mode and then realizes look and now I need to go to release because still the gap between V and r omega is large because the wheel cylinder pressure is much higher than that corresponding to the traction force at the tyre road interface.

So if we do not take any action the wheel will tend to lock so what happens it goes to release so it went to hold it went to release. So when I release the pressure what happens now the wheel speed will start increasing why because we are reducing the braking torque on the wheel right so we can observe that the wheel speed has started to increase right and although the vehicle speed is still decreasing okay the vehicle is still being decelerated the wheel speed is beginning to increase and we can observe that it is going closer and closer to V okay r omega is going closer to V.

So let us say this is my threshold because I want to get to the lambda where I get the peak Mu right. So then what do we do? We essentially go to hold first and then if the threshold is reached alright for the gap between V and r omega this is in this case is the lower threshold right. So once this threshold is reached what happens we go to open mode right. So open mode means how fluid is pumped into the wheel cylinder so the wheel cylinder pressure is increased.

So we can see that the wheel speed starts to low what to say reduce and then the same cycle starts right. If the road traction levels are still low then the wheel circumferential speed r omega starts to move away from V. So that has to be detected it goes to hold then it goes to release and then hold open so on okay. So we can immediately see that the modulator is programmed such that it goes in the sequence open hold release then it goes to hold okay then open and the same cycle keep on repeating okay.

So this people call as ABS pulsing or pulsations in ABS and so on right so essentially what do I mean by pulse is this cycle right. So these this depends on lot of factors okay and most importantly of course having a good estimate of lambda but one important thing that affects how fast or how slow we can pulse is the band width of the brake actuator see we can command whatever we want from the ECU right but then the actuation system should be able to meet that right.

So that is becomes very critical in a typical hydraulic ABS people have found out that you know like one can pulse around 5 to 6 times a second okay in an air brake it is even slower right. So typical hydraulic ABS you know like the frequency of these pulsations is around 5 to 6 hertz by and large that is what people have found okay. So this is how a typical antilock brake system will work in concept of course now the challenges are how do I figure out when to trigger and how do I actually realize it in practice right those are all important practical challenges okay.

So with this I conclude my discussion on antilock brake system so in the next class what we will so is that we will look at analysis of brakes okay. So we did analysis of drive we are going to do analysis of brakes and then we will derive some simple expressions okay thank you.