Vehicle Dynamics
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Lecture – 10
Contact Patch and Contact Pressure Distribution

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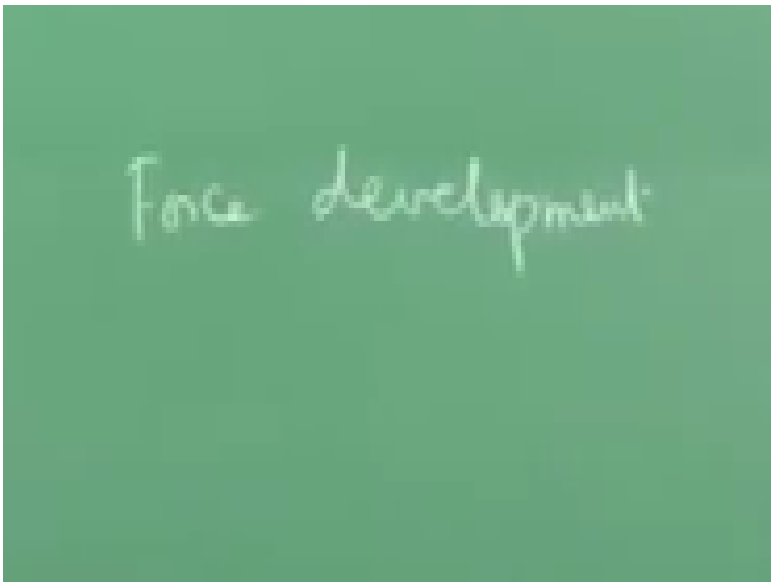

Okay, so the last class and the class; before that we were looking at; or we beginning to look at the force development, right, so that is what we are looking at. It is very clear from a very simple analysis of our free rolling that forced development depends upon the deformations in that tread blocks. When he said tread, it includes belt, it is a very loose term that we are using, okay. So, in other words all that stiffness in the longitudinal direction put together.

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We call that as a tread or tread block here, right. A stiffness of the tread is very very important, you saw what is the tread, that is a tread, even if it continues, it does not matter, it does not matter because we can assume that as if it consists of a number of what we call as bristles, okay we represented these treads by means of bristles, it does not matter that even if it is a continuous piece.

Instead of that, there were some questions in the last class; at the end of the last class; please note that this is the cut section of a tire, right it is a cut section of the tire and that section when you expanded, you know it becomes the tire, right. It is big; one of the questions was big, it looks very different from what we see in the cars, yes; this is not a passenger car tire; it is a truck tire, right.

What we are talking about is a truck tire, passenger car tire are much smaller maybe in the next class we will get passenger car radial tyres. One of the key things that you would have noticed is what is called the aspect ratio and we will look at the aspect ratio effect on rolling resistance shortly. So, the aspect ratio you know what we mean by aspect ratio; the height to width the ratio; right.

So, this is typically of the order of a 50% in the passenger car tires, it can be 45 when you go below you can also go to 35, 30 then you call these tires as low aspect ratio tires. These are

almost 1; almost 1, so these tires aspect ratios are much bigger than these tires in the truck tire aspect ratios are much bigger okay. So, that is one of the things that I want to say. The other thing, other question that was asked as between this what we called as rib tyre and the lug tyre.

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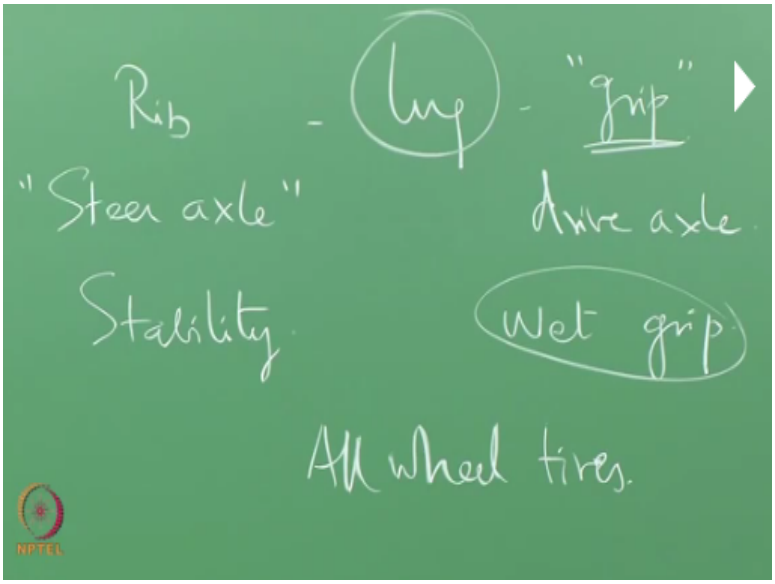

What is this front axle, rear axle and so on? I skirt it a bit because I wanted to finish this topic and you may understand it more as we go along especially when we talk about stability and so on. Since, there was a question yesterday, so I would answer that question with in such a fashion that with your knowledge right now will be able to understand the answers. Lug tires or I would say grip tires; grip, they have what is called grip.

And hence they are supposed to be used in the rear, okay. Now, what is grip? Why is that lug a tire has grip? Does it really have a grip okay? And what is that gives this grip and so on okay. Now, this is a question which would answer very carefully, if you go to most of the websites of the tire manufacturers they would call this rib tire to be this steer axle tires, they would recommend that they would; that you can use this in steer axle.

And many of them would recommend that this lug tires are used in the drive axle, I mean this is what they would recommend, okay. Is there a difference between the 2 is the first question. They would also add something like this; rib tires have steering stability, they would use the word

stability; steering stability is what they would use okay and correspondingly they would suggest that the lug tires or high grip; wet grip tires, okay.

Many of them would say, it has a good wet grip, all of them; okay these statements; all the statements and then there would be tires which I called as hybrid which they would call us all wheel tires and so on, all of them should be taken with the (()) (5:46) with the rider. Basically, the most important thing here is this wet grip with the lug tire because of the fact that there are channels.

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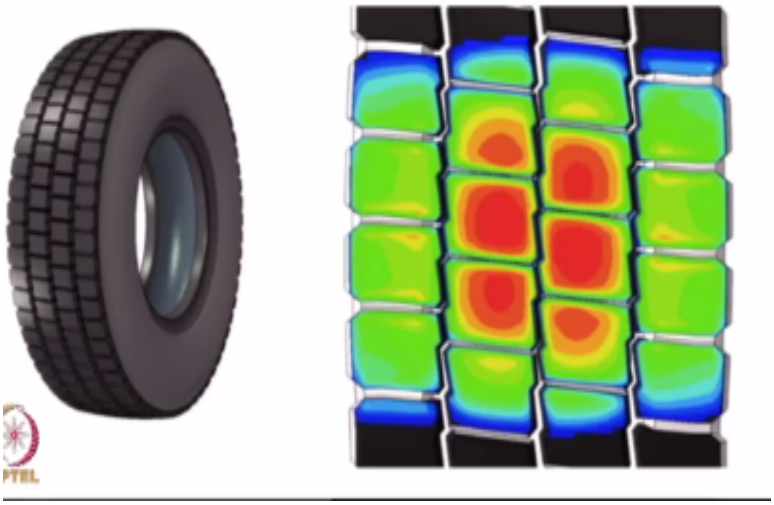

If you look at a lug tire you, would see a number of; you know lateral channels for taking or removing water, okay as it goes along. What is called as hydroplaning? Is avoided in this kind of lug tire, hydroplaning here I am using in the sense that there would be a water film that is formed and the friction coefficient reduces and so on, which will see again in the next couple of classes okay, so there are channels for the water to be carried.

And hence the grip is enhanced by that process and hence you would say wet grip is high. Strictly speaking, dry grip is not necessarily higher than a rib tire, in fact many experiments show that rib tires have good dry grip; dry grip in the sense that when there is no water okay, no fine sand and so on okay, then we say that we have a dry grip and the dry grip is actually better in a rib tire.

Because you have lot more rubber that is sitting on the road, okay. Strictly speaking that is the case, so now the lot of search going on and there are tires where you have a rib like tire with the lateral groove in order to take carry this water and so on. The grooves are very strategically put, I mean lot of analysis is done, this a fluid structure interaction analysis done okay in order to understand how the water flows; these grooves are put, so that the water is carried, clear.

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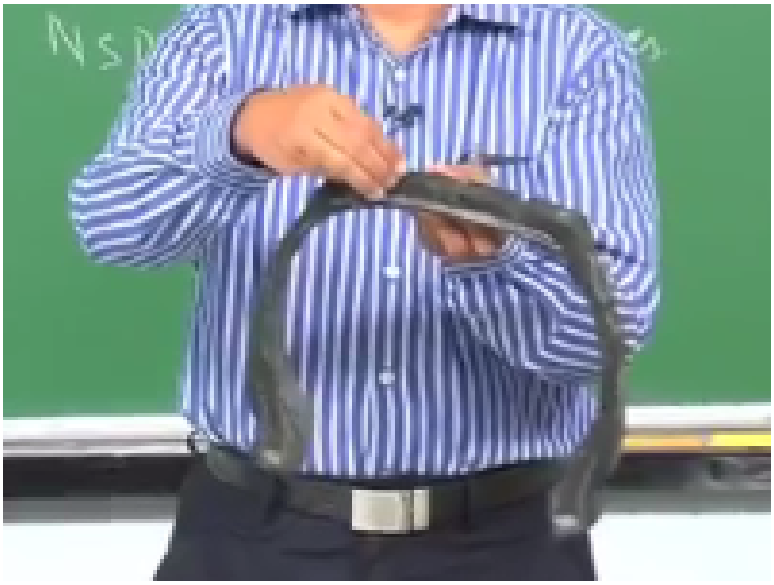

Usually, rib tires; this is nothing, there is no rule okay I am talking about the usual practice, okay. Usually, the rib tires have lesser what is called as the Non skid depth, this is called as NSD; non skid depth. Non skid depth is this depth; look at this depth which is in the group this is the non skid depth, right, to understand that is the non skid depth. So, the non skid depth care, okay or NSD as it is called, is usually for a rib tire lower than that of the lug tire, okay, it is usual practice, that is lower.

In other words, again under most instances, the rib tires have much less rubber mass when compared to the lug tire, okay. Basically, because of the fact that is being used in drive axle, because of the fact that the; where rates are higher, they use it in the; and they wanted for higher mileage and they use lot more rubber there. Because the fact that these tires have less rubber, okay and because of this kind of its construction, usually the rib tires have much or less rolling assistance.

And their noise characteristics are much better; much much better, rolling resistance is slightly you know here and there it cannot make a statement out of it, why I am being very careful in the making the statements is because all the statements okay or maybe in variance when you have different non skid depths. In other words, you have to compare apples and apples. If your one tire is worn out more, the other tire is not worn out.

Then these sentences are not valid and also on. So, you have to be very careful in these sentences, okay and hence all these things you have to understand it with that theoretical background, clear. That is where the noise is concerned again, the rib tires have much better noise characteristics when compared to the lug tire, I would not have; that is an other course, I cannot, I would not be able to go into the noise aspects, okay.

But nevertheless just understand that the noise levels of a lug tire is much higher than the rib tire, the decibel scale can be as high as 4 to 5 dp. **"Professor - student conversation starts"** Yes, okay what is noise? What do I mean by noise? Obviously, all of us have a stood near a truck, do you hear the noise as it goes okay pass you. Now, there are number of sources of noise in a vehicle and one of the major source of noise specially what is called as pass by noise, as it passes by you will hear that noise is from the tire, right.

We will sort of indicate this towards the end of the course, so it is noise generated from the tire is what we are talking about will indicate maybe in half a class what we mean by noise, towards the end of the course but it is a separate topic by itself, okay. Your question; that is exactly what I am saying that what of the tires used in; there are 2 things here, okay, what we are talking about in those kind of trucks, we have drive axles, we have dummy axle okay.

Dummy axle and we have what is called as steer axle, right. These are the 3 different types of you know; axles you have, right. **"Professor - student conversation ends"**. So, the first rule is that especially in Indian conditions unfortunately, many people mix tires like for example, they would put a nylon; nylon is a loose colloquial term for bias tires, okay, so will they put a bias tires and they would mix it with what is called as the radial tires, okay.

It is the usual practice to put bias tires in the front and the radial tires at the rear okay. In other words, rib tires are still not very popular in specially in Indian market and usually put a bias tire in the front basically, because rib tires are extremely sensitive to the camber of the vehicle and as well as the toe; toe and camber has a large effect on the tire performance and in fact, the vehicle parameters as we would call suspension parameters are such as, toe and camber as well as what is called is the axis of thrust which will defined later, okay.

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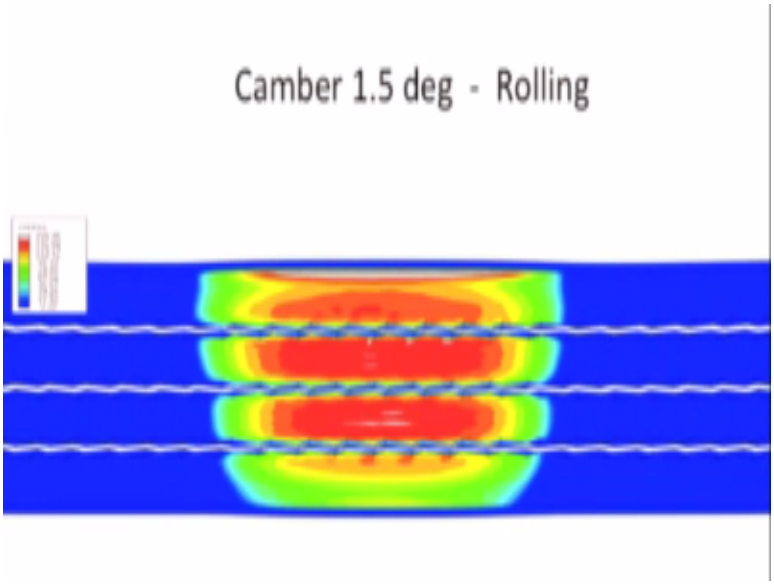

These things have an important effect on the wear of this rib tires and these factors usually make the tire not to wear uniformly, okay there would be an uneven wear in that tire, why is it so? Quickly look at; so you can see the difference between that is the contact pressure distribution when you have a camber. The camber is a very tricky business, the whole; it changes the world contact pressure distribution and hence it changes the wear.

The way wear takes place in these what are called as ribs. It is very tricky business because you have 2 things; one is the camber of the road okay, road has its own camber okay may be of 1 degree, most roads in this country has 1 degree, okay but it depends upon varies from country to country and this governed by certain standards and you also have what is called as the vehicle camber.

All of you know camber, you studied this in your earlier classes on automotive systems, so these 2 combined okay the road camber, the vehicle camber combined, sometimes it neutralizes, sometimes it makes it or in sense, one sided it makes, it neutralizes the other side makes it more and so on. So, this camber actually affects the; that is the pressure distribution remember last time it was such a; you know nice symmetrical pressure distribution if you had.

And the distribution is completely affected when you have a camber and you have a toe then the again the differences and the wear is not uniform in these ribs, so when the wear is not uniform in this ribs, so uniformly does not wear, what I mean is that this end is these, do not go down in an uniform first, right usually, what happens is one side say, one side; this side okay, the wear maybe and this side the wear may be less.

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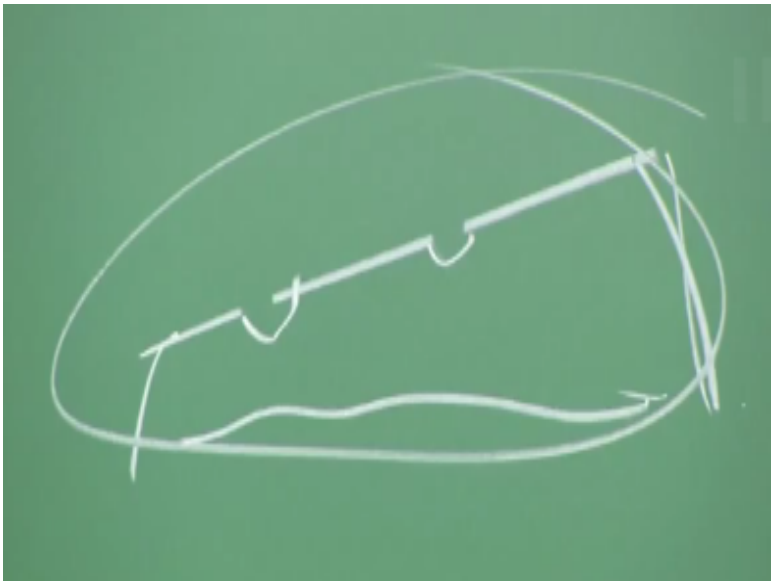

So, the tire ultimately assumes a shape something like this, okay that is the group, so let us say that it would be I am just exaggerating it, so it would be something like this. So, there is a one sided wear, okay one sided uneven that takes place and so, the tires are usually rotated from one wheel to the other, that is what is called as a rotation plan which the vehicle manufacturers or the tire manufactures more importantly give you, so that it is rotated, right.

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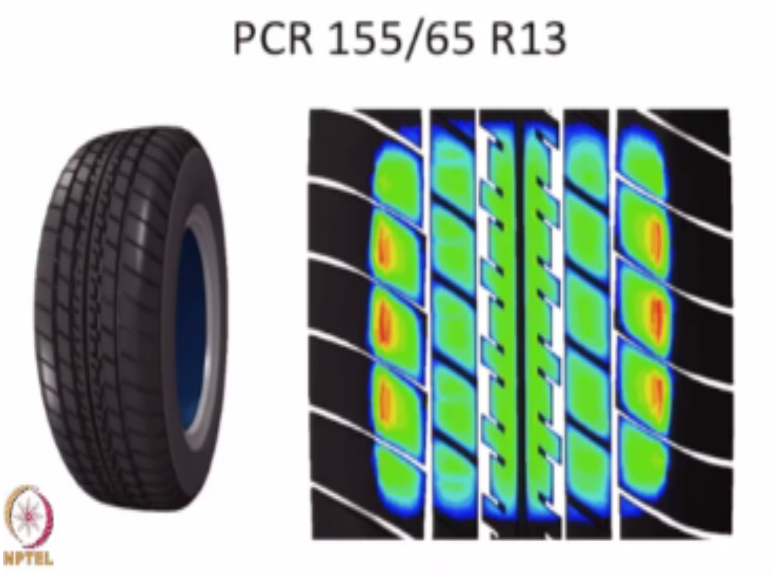

"Professor - student conversation starts", Yes, the lug tires since it is at the rear, you do not have this problem okay, so you have a semi; what we call a semi lug tire or hybrid tire between a lug and the rib, okay. It is something like a semi lug tire, a typical example I would not call this but typical example here is something like this, you have lugs as well as ribs here okay. A semi lug tire is used as all wheel vehicles even there many times you see this kind of uneven wear, okay.

Due to certain reasons which you would not be able to discuss now. **"Professor - student conversation ends"**. The bias tires because of the contact pressure distribution and so on, the bias contact pressure distribution is very different, I said that we are not go into the details of the pressure; contact pressure distribution in bias tire but because of that, these tires are not very prone to the vehicle geometry and hence people prefer to put the bias tires in the front.

And when they put the bias tires in the front, their rolling assistance definitely is higher okay then the radial tires and hence there is a fuel consumption which they have to pay; the penalty which they have to pay because of this factor. It is very tricky business to actually design a rib tire with the uniform wear, okay. The course is not on tire designs, so I would not able to; again sorry that I have to digress go here and there.

But nevertheless, it is a very interesting and a tricky business to design a rib tire, peoples were interested the best places to look at the patterns; the number of patterns that have been; there are file in rib tire design, huge numbers which does also such things in order to mitigate this problem of camber and but anyway camber and toe reality and they have an effect both of them have an effect.

It is very important that the truck owners and the guys would drive the truck they actually look at the; what I would say changes in the camber and the toe, right. Let us come back to do this, okay with so lot more to that question and anyway quick answer to that question is this and the contact pressure distribution is said is local bending that is instead of understanding, every all these; you know, nice these inside local bending is better to look at contact pressure distribution from a finite element analysis, which you would understand quite here okay.

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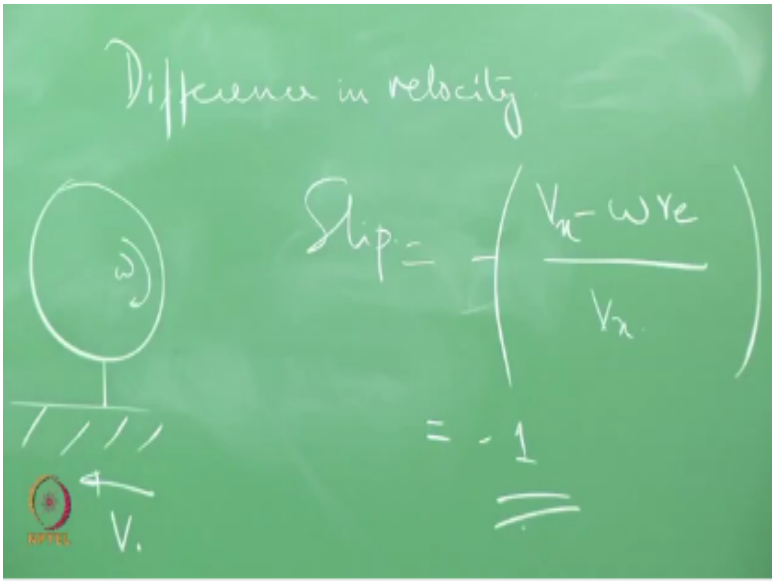

Now, we have lots more to cover, so let us go a bit faster, let us understand 3 things; the traction, braking and cornering before we derive simple formula in order to appreciate the physics that we are going to bring in here okay. One thing is very clear from what we did in the last class, on the classes before that there is a difference in velocity okay, difference in velocity, what is the difference; Velocity between the tangential velocity and the ground velocity; right.

There is a difference in velocity, this is what causes deformation right, if the ground velocity Vx happens to be the same as that of the tangential velocity, say let us say that omega Re= V, that is how we defined and that both of them are the same, remember that we had it at the point then what would happen to this tread elements, so let us say, just look at this one; tread element, okay.

Let us say that it is rotating such a fashion that there is no difference in the tangential velocity due to rotation omega versus I mean difference, in compared to the V of the road, there is no difference okay, these tread elements are not going to be subjected to any force, right that it is not going to subject to any force, so it is this difference which is responsible for braking, traction as well as okay a similar thing would extended for what is called as the lateral force okay.

So, it is the deformation, which is responsible for all these things and we are going to define a quantity called slip after some time okay, so we understand first the physics and then we put this in the difference between the tangential velocity, the velocity of the ground okay, so that would give rise to here quantity which we would call us slip okay. So, we can define the slip to be; let me define it, so that the first quantity that is of interest, what would call as Vx, okay.

We will why we are put minus there, Vx – omega re, that is the difference and that is what causes the; what you call us the deformation and hence the force okay, that can be divided either by or normalized; either by Vx on by omega re, okay either by Vx or omega re, right okay. So, let us look at what this quantity meets? What happens when omega =0, what happens when omega =0, omega is actually an angular velocity, okay.

So, what is the condition of braking? Worst case of braking where I have the jam the brakes and the wheel is no more rotating, okay, in which case what happens to that slip; maximum slip value or a minimum value rather because this is -1, so -1 is the; I mean what is the minimum value that happens to be -1, right. So, the breaking condition which is worse is as the slip ratio, it is the slip of -1.

“Professor - student conversation starts”. Please note that when we brake, okay we are not talking when the vehicle completely comes to halt, when we brake okay, we are applying the

break, jamming the brake that has to be a force generated okay that is why we have; F=ma, okay that force generated has to stop it and the force is generated by these pulling, remember that we are going to explain that again here okay pulling off those bristles okay.

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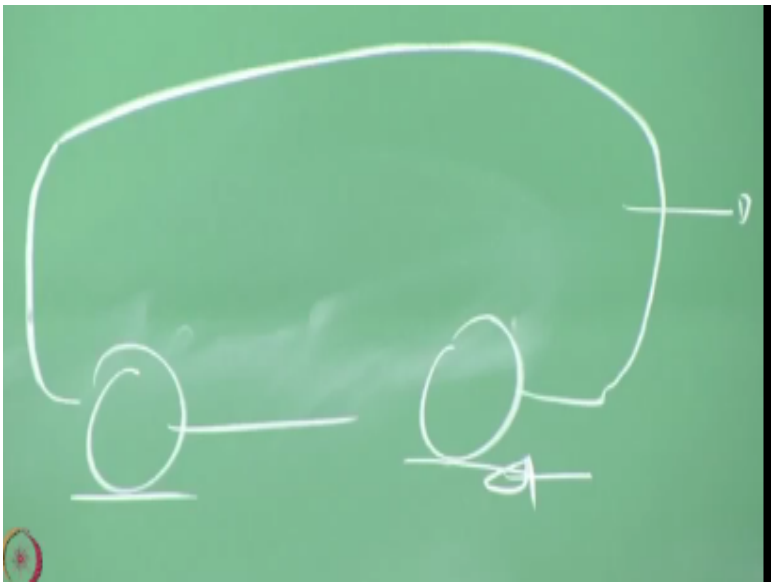

When they are stuck to the ground, right that is what causes the force because I have a wheel okay of a vehicle, right let us say that it is going in this direction, I am going to stop it, so I have to have braking force, how do I create the braking force okay, so I have to; that braking force creation is what we are talking about. So, we are not talking when the vehicle comes to hard nothing happens after that.

So, when I jam the brake, worse condition, my wheels stop rotating, does not mean, you would have seen severe braking conditions, does not mean that the vehicle immediately comes to halt; right, so the worst condition is omega = 0, okay in which case this becomes -1. **"Professor - student conversation ends"**. What is the other condition, the other side; the other side is the vehicle stationary okay and then the wheel just keeps rotating, so in other words, V = 0; Vx =0.

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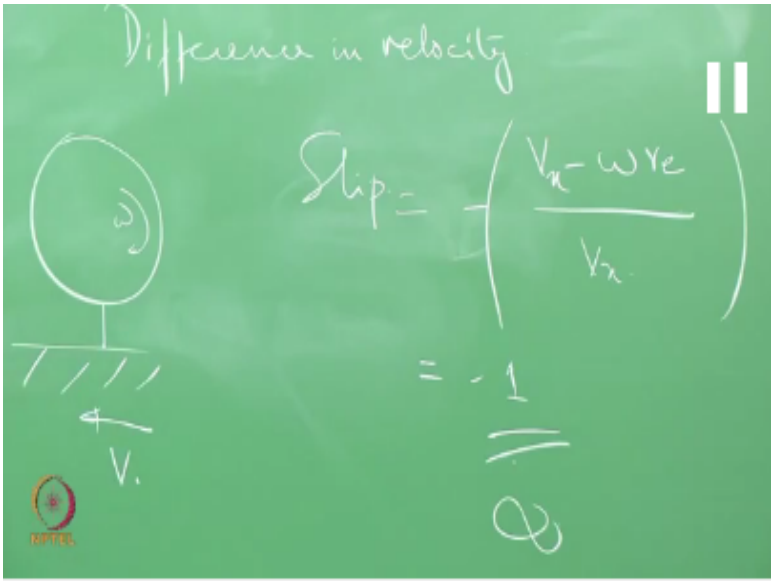

So, in other words that condition is infinity and that is the; they tend to try the vehicle but not able to drive it because it is not able to have what we call as grip, right. So, these are the 2 extreme conditions but before we go there, let us understand the mechanics first and we will put on; we will spend a class to understand these things from a mathematical perspective okay right **"Professor - student conversation starts"**. Because this is = 0.

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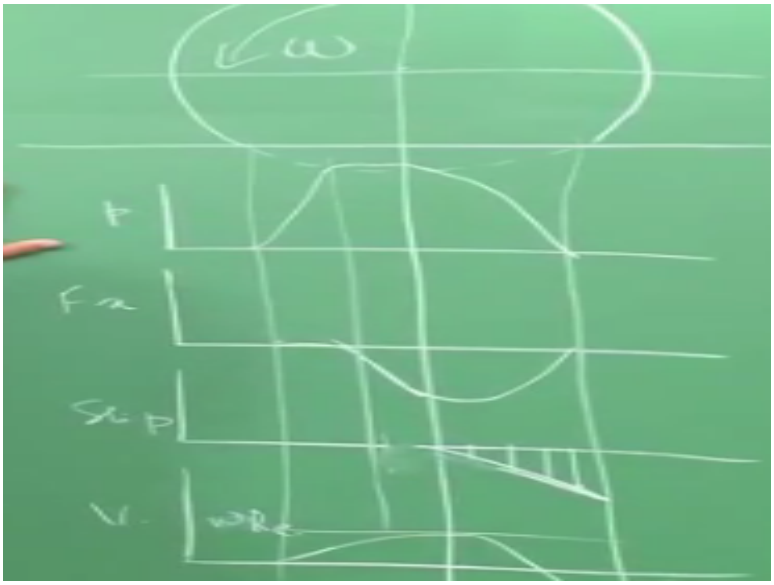

Sir, what is the actual thing if the wheel is moving? Here, the wheel is rotating, okay so, omega is present but there is no grip, so the vehicle is not moving, you would have seen this many times, you know if in water, the wheel rotates, the vehicle is not moving or in sand, it does not

develop enough force for the vehicle to move, right. So, that is the condition, right okay. Now let us now understand this. **"Professor - student conversation ends"**.

And appreciate that this is very beautiful micro mechanisms that are happening in the time okay. In fact, there is a lot of; we would say, race between various quantities which decides how the tire is going to be here, clear okay. Now, the first thing is pressure, we know this, I am not going to repeat anything out of this, there is the contact pressure okay, the vehicle is moving in that direction, right and that is the contact pressure. No problem.

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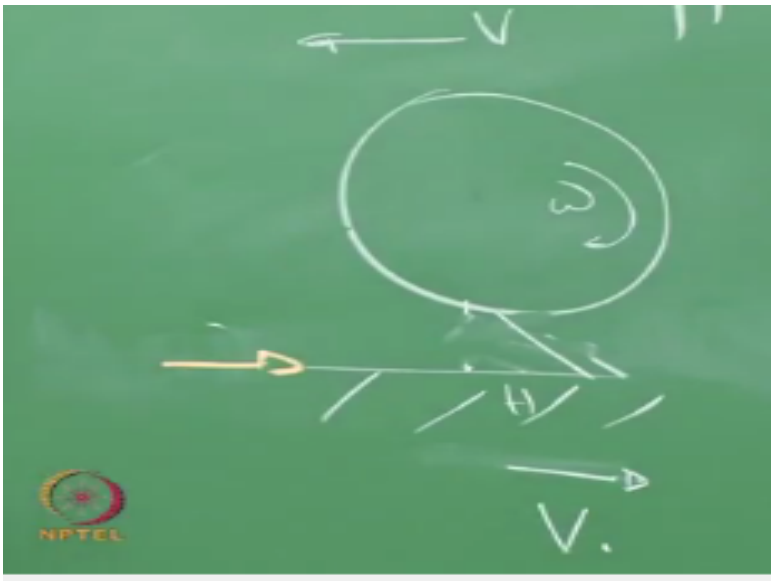

Now, let us analyse the braking condition that is analysed the braking condition. Let us look at that; that bristle, okay which is called as brush; people call this as brush model and so on; looks as the comb, comb; brush of the comb, it is called as brush model, right okay. There are number of actually; number of these guys who are going to come and sit and that is the ground. Let just understand one of them and then we will extended or we will put a much larger thing, right okay.

Now, my velocity is in this direction, so I would; my ground velocity is in this direction, okay. Now, ground velocity is in this direction, velocities in this direction but my acceleration is in this direction, right because I want decelerate, so in other words, I have to produce a force which is going to act like that, yes, **"Professor - student conversation starts"**. That is exactly what we said in the last class that we can have 2 views; one is the vehicle is moving, ground is stationary.

The ground is moving in the opposite direction, vehicle is stationary and that is what okay, so please remember that I am going to repeat that again and again, right okay. **"Professor - student conversation ends"**. Now, just let us concentrate on 1%, I am braking and now what is a condition under this? Let us call this is the head and that is the tail of the bristle, head has hit the ground okay and there is a contact patch pressure that is built on the head, okay.

This fellow is actually under pressure. According to what we have seen now, what is the condition the ground okay, the ground velocity which is opposite of the vehicle velocity, will it be more or less than the wheel tangential velocity? It will be more okay. So, in other words what would happen to this how would this bristle look like, okay. If I now look at the relative thing, it will be in that direction okay, so let me remove that, so it will be in this direction okay.

The guy is going to; the ground is going to run away as if it is going to run away with a head, right. It is going to go, run away with the head. The leg of the tail is sitting on the tire, on the wheel tire, right okay. So, what happens now this guy is going to develop tension and is actually going to pull the wheel and that is what we saw one of the earlier classes and that is going to give rise to the braking force?

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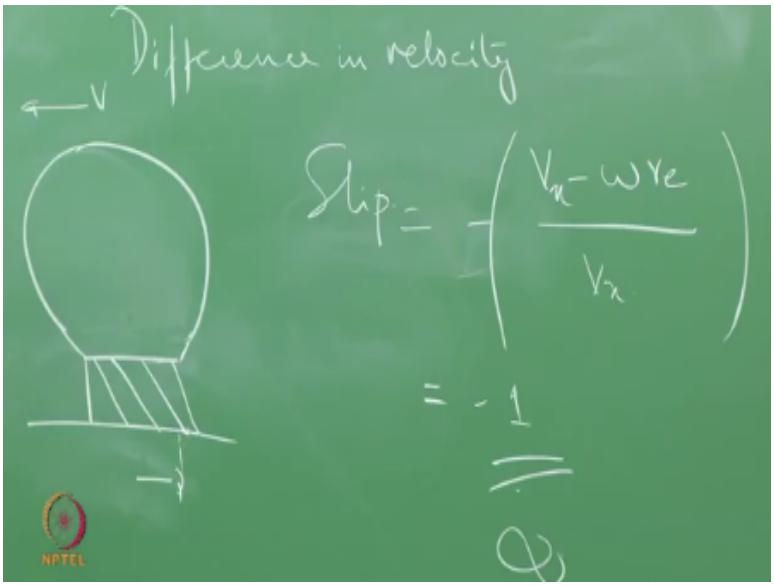

It is not actually; one bristle, just to illustrated it this as one but there are number of guys who are going to participate okay. Now let us extended; let us extend from 1 to several. This is a; just make it flat, okay so the ground is moving like that, it hits; let us say it hits; just hits, just realise the ground, so slowly it will; the number of this presence okay, it is just for an illustration we are saying this.

They are now going to develop, these are the ones which are going to give you the braking force, fine but then that force, there is also a force, you know, this guy is not going to leave, this is going to be an equal and opposite reaction, right okay. So, in other words, there is a tangential force which is generated at the interface between this bristle or we called as bristle head and the ground, right.

So, there is a tangential force that is generated that is the opposite reaction. If this force overcomes the friction force, what would happen? The guy would slip, this is what we called as micro slip, I am just repeating it, so that the things are clear, so he would now slip, keep on holding, as long as the ground is able to hold him, he is going to be stuck to the ground. Once the friction coefficient multiplied by the normal force that is exceeded by the tangential force, the guys going to slip now, okay.

So, at one point of time in this race between the tangential force and the normal force, the tangential force wins okay, the guy is going to now slip; he is going to slip, okay. So, an oxymoron that unless there is a deformation, unless there is a slip note this; force is not generated, okay, you think that when it slips and there is no force but actually in a tire, when there is no slip, there is no force generated; number one okay.

When the tangential velocity and this are the same, they are the; they are not going to generate; the bristles are not going to generate the force, it is point number 1. Point number 2; I want to distinguish between; when I say this slips, I have just defined a slip quantity here, so, what is this slip and what is this slip? So, I would call this is as a micro slip right, there is a micro slip okay. This motion is a small motion just this bristle just moves okay.

Moves in such a fashion, that comes under again to equilibrium, okay. Now, this is what we studied before on how used it, okay. Now, **"Professor - student conversation starts"**. Now No, no we are talking about here braking force development; rolling resistance is anyway present okay even we said, even in the free rolling; rolling resistance is present and it opposes this motion, okay, yes okay; so that is a good question, how would I characterize this friction.

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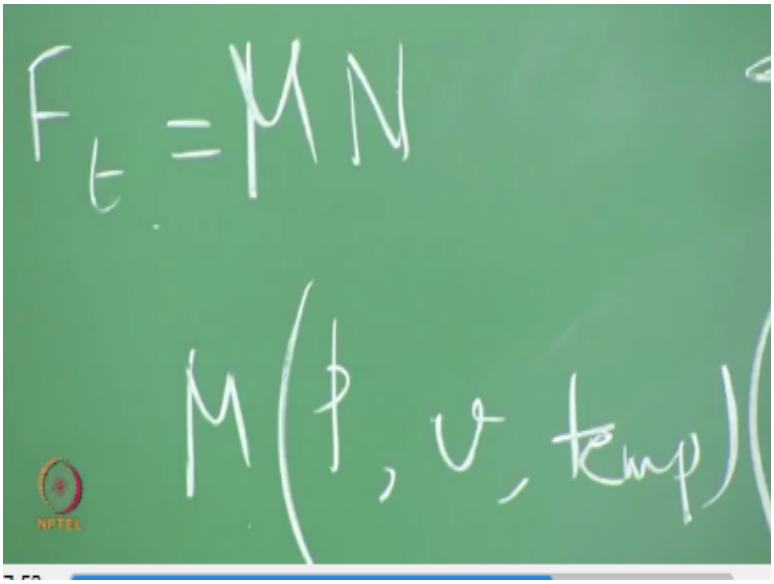

In other words, how do I characterize this friction, I know that quantity called mu, which is Coulomb friction, can I just write mu * N okay is the limiting tangential force case, is mu a constant, that is the question, right; good question, it is a difficult question. **"Professor - student conversation ends"**. Because strictly speaking, this is not a correct model because any researcher who works on an elastomer friction who said this is nonsense, okay.

Because the friction coefficient depends upon interestingly the contact pressure P, it is a function of contact pressure P, it is a function of that slip velocity v, okay because v is proportionate to omega, omega affects to velocity on building, and so on, temperature; very important okay and so on but is a very difficult factor to take into account this; these things. So, what people do? As to follow Coulomb friction and say that the Coulomb friction for example, for a truck tire is 0.75 Coulomb frictions for a motorcycle tire is 1.02 and so on, right.

So, we sort of have an approximation which is not necessarily correct but some where we have to start working and hence we have to follow Coulomb friction. If you go and look at the literature there are number of papers on how friction is developed and so on. **"Professor - student conversation starts"**. I said there itself that we will dump everything, we call at that time and I gave one of the previous lectures as I said, we will call this as friction, right.

So, the friction as I said then itself that viscoelasticity plays a great role, right, so pressure, velocity of slip all those things it gives rise to a number of other phenomena let us just move on okay we will look at this thing quickly. **"Professor - student conversation ends"**. So, the first thing is that, there is summarizes the race between the 2, this is normal pressure okay then there is this Fx, which is this guy is pulling, okay. So, remember that these are actually different.

You can view it as a different condition also of the same bristle, with time the same bristle goes through that kind of variation in the tangential force, clear. So, if I now plot the tangential force variation okay to be something like that; something like that I keep varying; I keep increasing; I come to position where the normal force is no more able to sustain this tangential force. So, at that point, things are going to micro slip and it undergoes a micro slip okay.

So, again the force is start now dropping because micro slip brings it back; the bristles brings it back and so this elongation now reduces, so as it happens, there is a drop in the tangential force and so on, okay. So, that is what happens, of course under all these conditions and all these conditions, the omega re or in other words, the what we plotted as as velocity changes okay, to similar to what we had done before or what we had seen before, is a compression okay.

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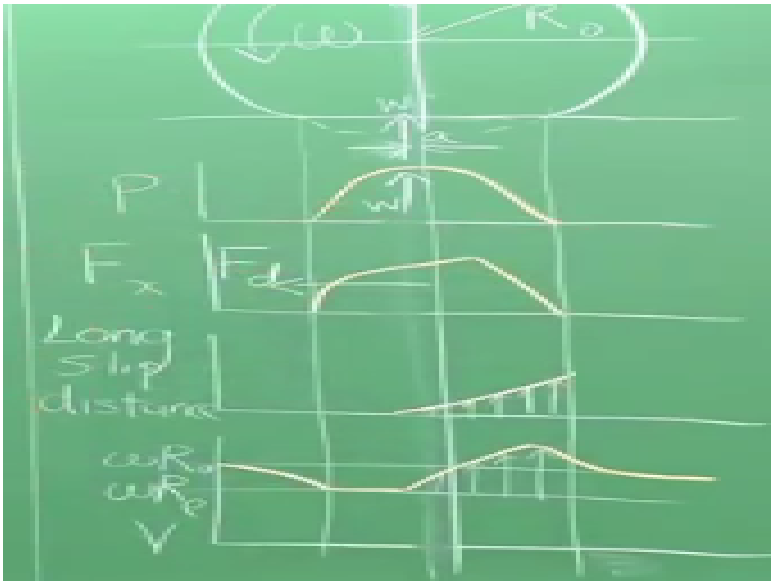

The compression reduces the radius, so all those things happen like what we have seen before, so you can interpret that from our previous free rolling condition okay. Now, what happens is exactly similar in the case of acceleration or traction conditions. People call this is as traction whenever there is acceleration, okay. Now, the scene is just the other way okay, we are accelerating that means that you have given the acceleration, a torque is generated okay.

The torque most of the walls are rotates the tire faster than what the ground is moving and hence this whole thing is the other way okay, the bristles are now in this direction okay and hence the force that is generated, remember that is the velocity and I want the traction forced to be in this direction, now the force that is generated is like that pulls okay and so there will be a traction force.

Both braking and traction force is hence generated by that difference okay being telling that again and again because it is a very important concept. This graph and this are exactly similar, only thing that force directions are different, again there is a slip, there is a micro slip and again there is a variation of velocity and so on, right. So, that slip gives rise to a very important and interesting phenomenon.

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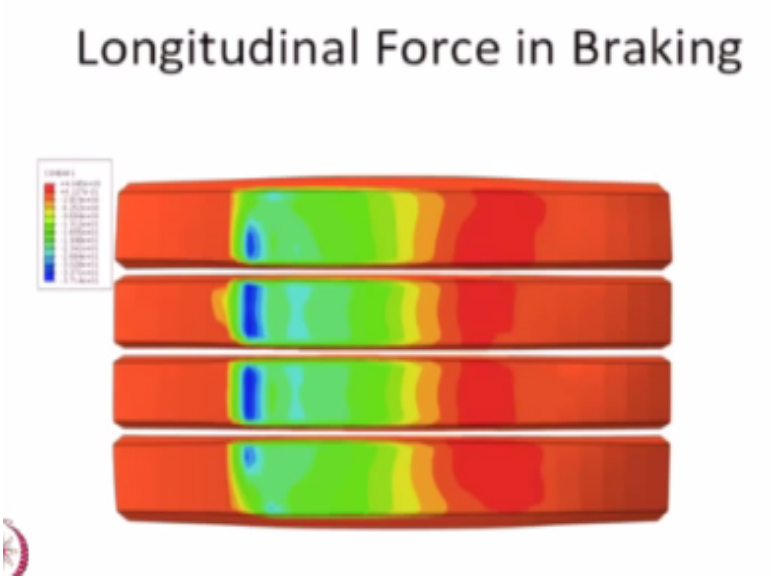

Let us now look at the think I have some slides which gives you; yes so that is the longitudinal force development you know in braking there is a longitudinal force development in braking reaches a maximum and then you see that towards the end it comes back okay. **"Professor - student conversation starts"**. And because there will be a; when there is a change, the velocity is not negative in the sense it drops below omega R0 you know R, so it is not that R becomes negative.

Obviously not, from omega R what it starts okay goes to omega re and then again goes to omega R and there is a variation in the; the whole thing is very simple. It is what is the basis for this graph; what is the basis for this graph? The basis for this graph is nothing but, no, what is that basis for that graph. The basis for the graph; if you remember in one of our earlier classes we said is the compression expansion along the circumferential direction.

I said I asked you to go and lie down here okay and compression expansion right, so that is exactly what is depicted here, it is not that it becomes negative okay; omega r0 becomes omega re, then goes below omega ro, and then goes again r, okay. **"Professor - student conversation ends"**. Now, why is this very important? This is very important from one perspective; this is what gives wear to a tire. People keep; lot of sanctity to this; what we call us contact pressure in the tire community okay, looking at contact pressure.

They usually say this is a good contact pressure, this is a bad contact pressure, and this is which gives you wear, this and that so on and unfortunately they do not really understand or I would not say understand, they do not want to go into the details of how actually there is a race and there is a micro slip and the micro slip is responsible for wear, right. So, there is a slip and force multiplied by that displacement that gives the work done by this friction; fiction energy which is responsible for wear.

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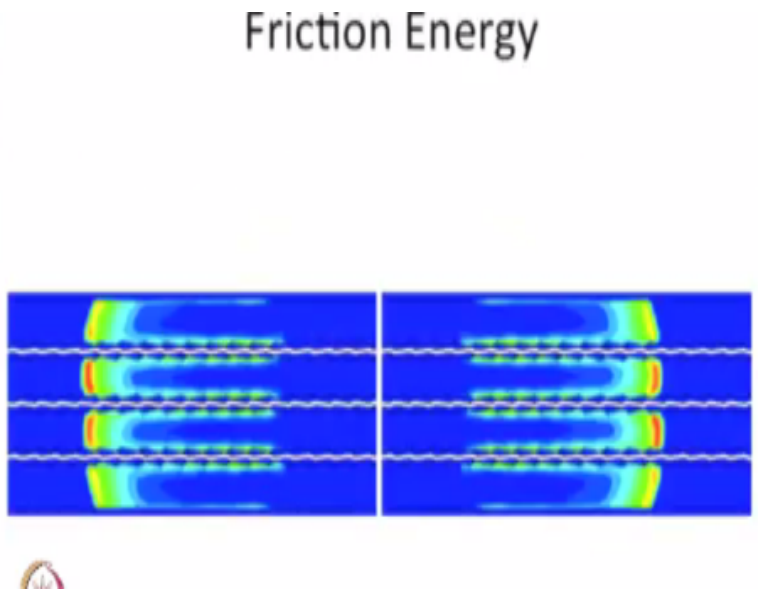

In other words, the interesting point I wanted to note is that all that energy; fiction energy that is what causes friction okay is concentrated at the rear of the contact patch on either side okay is concentrated at the rear of the contact patch because whatever be it, this is the reverse direction, so do not look at the right hand side, look at left, so you would see that whatever be the condition it is that micro slip that causes or that gives the energy for wear, that is responsible for wear.

That is why we were important to understand this race and understand how wear is created in a tyre, clear okay, whenever this wear rates are different in different what we call as ribs or different positions then we have uneven wear, okay. These block tires; these tires are prone to what is called as wheel and toe wear, sorry heel and toe wear. These wheels are these tyres are prone to what we called as heel and toe wear.

Because of this distribution of pressure or we do not have a graph here, you would see that each block; one side of the block has of one wear rate at the other side, another and so on, so there is an uneven wear even in that blocks which will give rise to what is called as the heel and toe wear, okay. We will get into the maths behind it but before that we will explain what happens or how is the force generated in cornering okay.

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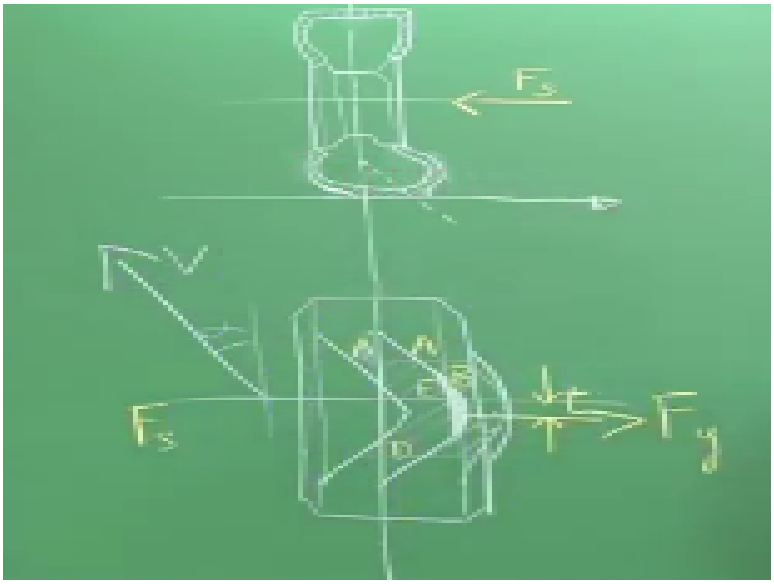

How is the lateral force generated in cornering, right, so let us say that is the lateral force that is generated and that is actually quite interesting and slightly more complex than what we have seen till now, after all, I need a centripetal force, if I take; if I corner a vehicle, I need to centripetal force okay. Let us say that is the centripetal force that needs to be generated okay and of course this is the D'Alembert force which you would call us a centrifugal force okay.

So, the centrifugal force what does it do? It tends to push the wheel and the centripetal force would now pull or oppose that okay a moving is quiet are; was the F, right or = F, okay. Let us see how this force is generated? This is you have to be very careful understanding; imagine that there is also rotation okay, this wheel is actually rotate; rotating, so part of the wheel get stuck here okay.

So, the guy again my good old road is going to hold it, here it is hold it, right and the wheel is now pushed out, the wheel is now pushed out and it now rotates. So, now what happens, if you

are a material element, if you are an element sitting here, if you go and sit in the material element, now ass you go now down, you are going to go towards to the; I mean toward the right, so as you touch the ground okay.

Because these tread guys are going to sit there and they were going to held by the ground okay; you are going to drive a very complex path okay; you are going to drive a complex path, in other words, your head which is in the ground and your leg which is say in the carcass okay, will be like this, right because this guy has been pushed out, so it will be like this. In other words, this inclination which is going to increase; which is going increase as you travel the contact patch.

Travel inside the contact patch gives rise to that pull; our good old pull which we saw there and that pull will results in what is called as the centripetal force and in that whole process, the tyre is completely twisted, it is not just that, it is going to be in one plane that whole process the tyre gets twisted right. We will stop here and continue in the next class.