Vehicle Dynamics
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Lecture – 09
Tire Construction and Force Development

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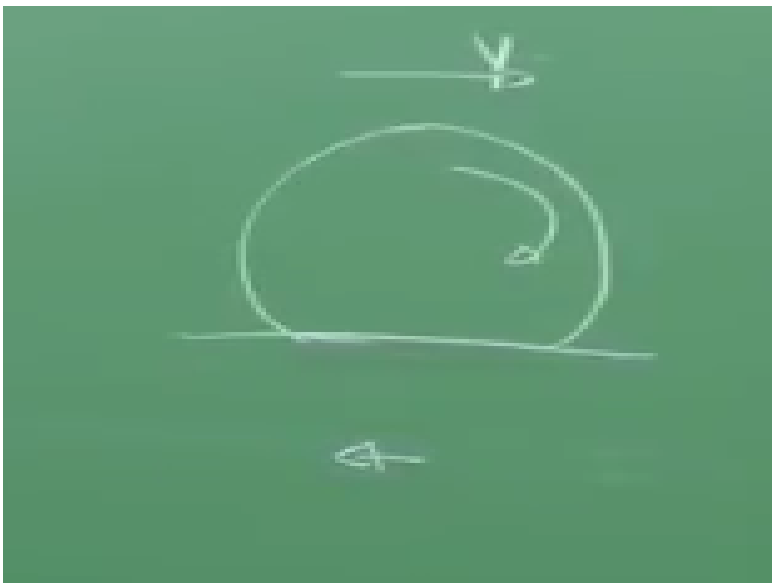

Okay, let us continue what we were doing in the last class. We were looking at rolling tires, we were looking at what we called as free rolling and we were also; that is what we were doing free rolling and we were going in deep into the concept of how contact pressure influences various things that are happening at the contact patch. To the small you know; the slip of tongue in the last class.

Please note that when I drew the tire okay, I think that is how we drew the tire and that is the velocity, so whether it is braking or accelerating the velocities; the direction is the same, so I think that instead of acceleration being in this direction, I put velocity; please note that is acceleration. So, the acceleration is in that direction, so the ground we said will be; you can have that stationary and the ground moving in the opposite direction.

We said that, that is the relative velocity, so please note that it is the acceleration and it is obvious but nevertheless, I just wanted to make it clear as to what we were talking about. Right, there were some questions on tires like; how tires are built and so on? This is a vast topic in

fact, tire mechanics can be a course unfortunately, this is only a part of this course so, we would not be able to go into the details of tire mechanics completely.

We will only talk about tire mechanics from the perspective of vehicle dynamics, how the tires interaction is going to affect the vehicle performance that is what we are going to talk about. We are not going to talk about tire design and so on, I know that is a topic by itself but nevertheless it is important that we talk about how or what is the construction of the tire okay and Courtesy JK tyres.

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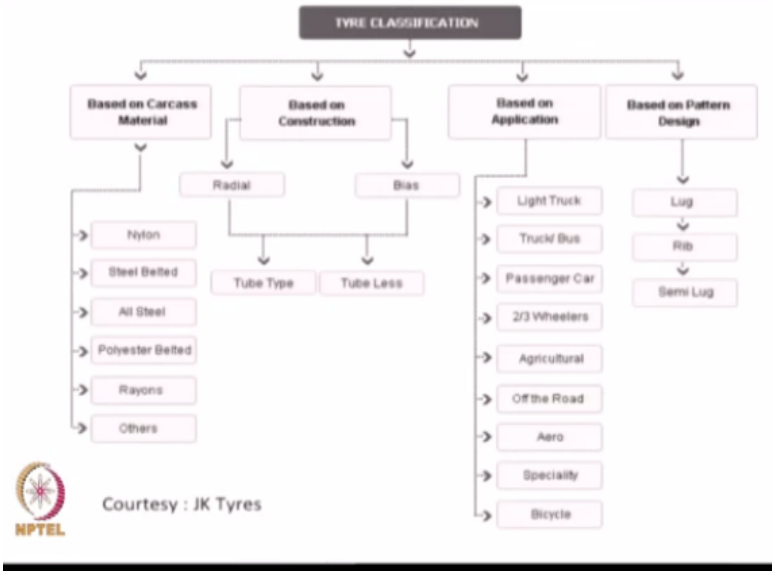

I am giving you the slide you know which talks about how tires can be classified. So, tires are classified based on construction into what we call as a radial tyre or a bias tyre. Today, radial tires would become extremely popular and all passenger car tires are radial tires. In this country in India about 10 to 25% of the tires in the truck are radial but elsewhere in for example North America 90 to 95% of the tires in the truck or the bus segment are radial tires.

Still, there are bias tires running in India but in most of the developed countries, the tires are radial. There was a lot of advantages of radial tires, the foremost amongst them being the fuel efficiency. Practical data shows that the fuel efficiency or the difference in fuel consumption can be as high as 5%, so radial tires are extremely popular in the truck market now and it is becoming popular rather in the truck market. The other tire is what is called as a bias tire.

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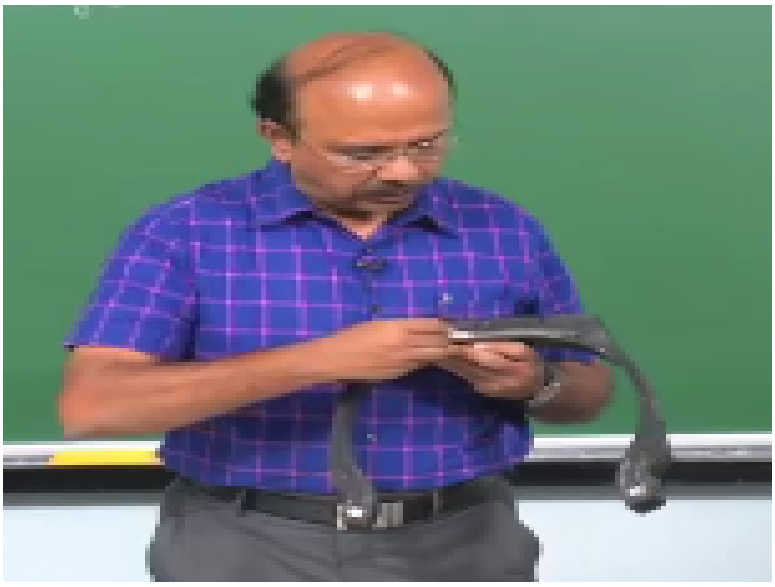

Let us understand what these radial tires mean? Okay, this is a cut section of a radial tire, the cut section of a radial tire, so you can see here that there are; say look at that there are steels, steel what are called a steel belts okay and this is what is called as a ply. Let us get a cut section, so that you understand this much more clearly okay.

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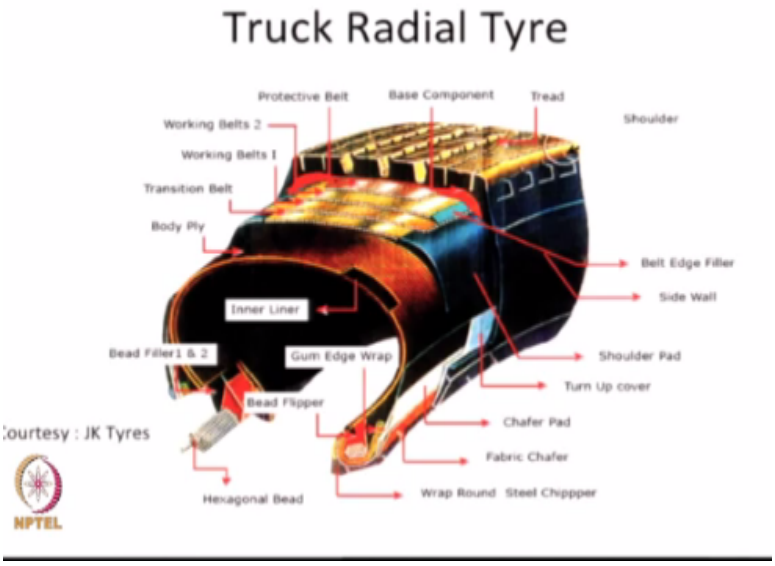

That is a truck radial tyre, look at that it is extremely complex, it is complex from 2 points of view; one is that it has a number of materials and several reinforcements that make it stable, that make it efficient, that make it last longer gives you a good ride and as far as possible reduces the fuel efficiency; reduces the fuel consumption, it increases the fuel efficiency okay. Again Courtesy JK tyres, we will look at what are other sections.

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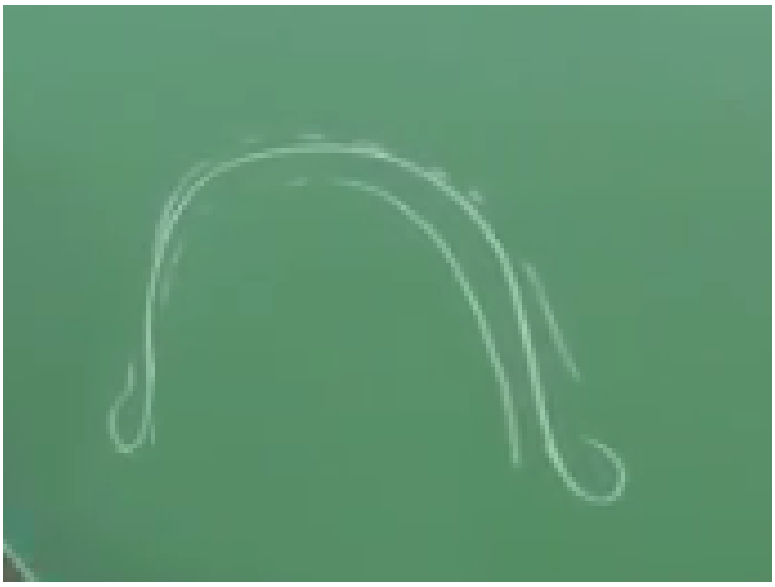

I mean look at the different components in the sections and what the section is made up. You would see that there is what is called as a body ply okay, you can see that the body ply which is; which consists of a number of wires and number of wires, so they run like that okay from one bead to the other, so you would see that it keeps running like this right. So, they are radial in nature that is why it is called radial tyres.

So, the body ply has steel reinforcement in a truck tyre, we are talking about truck tyre here, so that is the body ply here you can see it, may be here more carefully, you can see that, that is the reinforcement okay in the body ply and you see that the body ply. The body ply has rubber on either sides, the most important; there are number of times I am not going to explain each one of them.

The most important which is towards the inner side okay it is called as the inner liner; inner liner okay, so in other words it is inside, if this is the body ply and then what is inside? This is what is called as the inner liner okay and outside this; outside this you can see that predominantly that is what is called as the sidewall. In other words, the questions are what is sidewall?

So, this is the sidewall of the tyre, okay. So, in between the 2 okay, there are some components let us not worry about it, so there is a reinforcement for us as well we are concerned, there is a reinforcement; steel reinforcement which is rather protected on either side okay by rubber and this side this is what is called as the sidewall. This region of the tire is what we call as the buttress okay, buttress of the tire.

Now, you can see that the steel reinforcements go all the way and then wraps around what is called as the bead or the bead core, you can see that here there is a bead and then the reinforcement; the steel reinforcement wraps around and comes out in the other direction, so you can see that here very clearly that it goes like that and then comes around and then okay wraps around the beam, right okay.

Now, around that portion of bead; the solid heavy you know, this is a very important guy, last time itself we saw that he is the guy who is going to interact with the rim in order that the loads are properly transferred and so on, so that portion is a; is made up of a number of reinforcements okay there is, what is called as a steel chipper wrap around okay to protect the bead and then you have the chafer and so on.

The chafer and chipper all of them help the beat to actually interact with the rim alright. So, there are other things there, let us not worry about it, so the first thing is that this body ply important component, either side of it has rubber, sidewall and inner liner wraps around the bead, then when you come to the top, you have what are called as belts, okay. These are what are called as the belts you can see it here; they are in this case this is all steel radial.

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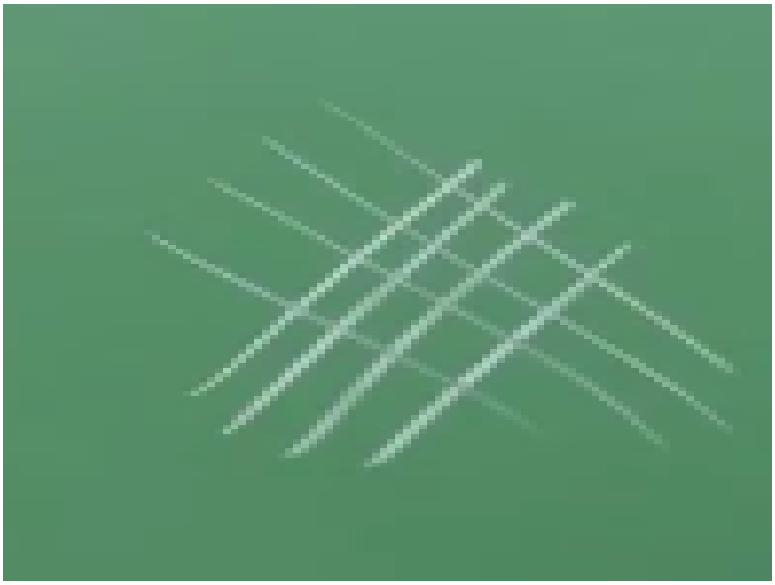

So, this is; this ply is steel as well as these belts are made up of steel right, they are steel belts, they give the stability for the tread and you can see though that there is not only one belt, there are a number of belts that is what is called as a transition belt and there are 2 working belts and

then there is a protective belts. So, these belts have steel wires running say for example; if you look at it from the top, so you have wires running like that okay, one of the belts.

And then running like that in another belts okay and so on, so the 2 belts; working belt one and 2 are very important belts and as I said that gives that stiffness; the lateral stiffness and the longitudinal stiffness to the tread okay. The construction there is very complex we will leave it for a minute because we are only looking at the mechanics of the tire and not into the mechanics of load carrying and stresses and so on into the tyres.

So, we are not going to look at the design, from design point of view how you place that belt, what is the width of the belt? What is the angle? And all these things, how many belts are used? All these things become important. There can be 4 belts; there can be 3 belts, and so on. Then on top of it okay, there are some layers again of rubber and then ultimately you have the tread about which we were talking about.

So, these are the; this is the tread we will see that in a 3 dimensional picture and this is the tread, okay. Tread is the one which is in contact with the ground and the mechanics has lot to do with the tread as well as the belt okay and how that interacts with the road that is becomes very important and that is what we have been talking about and we will continue to talk about that okay in this class.

"Professor - student conversation starts". Tread is made up of elastomers, rubbers, okay we will see, I am not going to the details of what is this composition, how it works and so on okay. It can be a natural rubber, natural NR+ natural rubber is usually called as NR, butadiene rubber BR, styrene butadiene rubber which is SBR and so on okay. So, it is a combination of all these materials, so we will not go into the details of these materials okay. **"Professor - student conversation ends"**.

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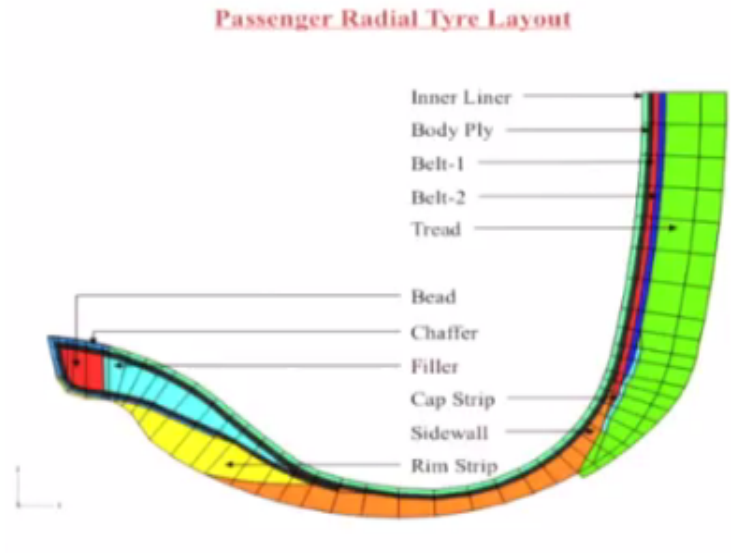

Nevertheless to say that; oh; that is the passenger car we will come to that in a minute yes, so you can see that a passenger car tyre for example, as well as the tractor is made up of a number of different components of elastomers in other words, different regions of the tyres have different compounds of rubber. So it is not one rubber; rubber or elastomer is a very generic term it is not that there is only one compound that covers the complete tyre.

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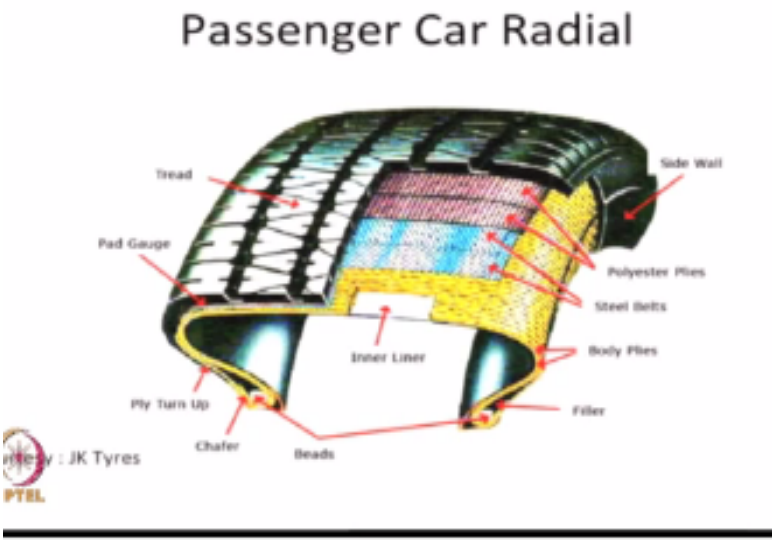

In other words, tyre is just not made up of only one compound, the number of compounds as I said that is not the intention in this course now okay, that is the passenger car tire essentially the construction is similar but not exactly the same. The body plies are not necessarily made up of the same you know steel but it can be of different materials okay.

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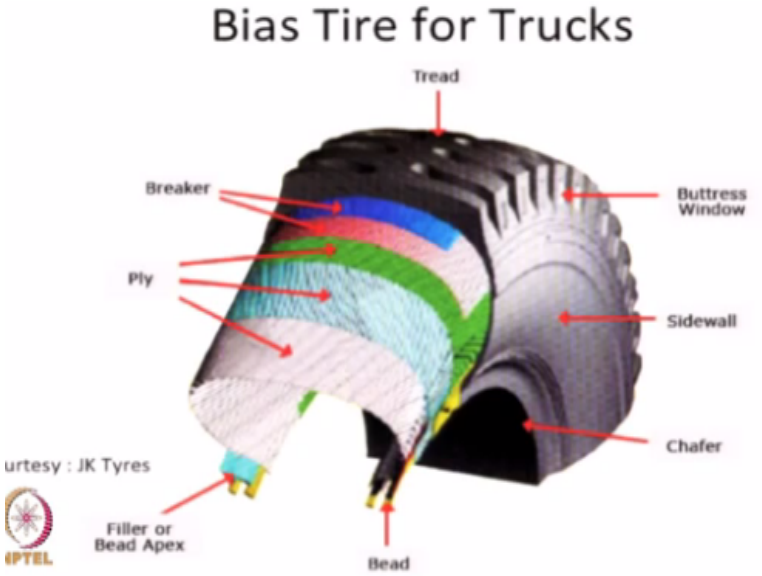

And then as I said we will not; we will look at the bias tire; biased truck tire, unlike that radial tire where you had one body ply and then you had belts okay, here you have what are called as plies which run throughout okay, 1, 2, 3 plies as you can see okay which runs throughout okay and are arranged in a position okay, arranged in such a fashion as you can see that they are crossing each other okay and that gives the strength for the tyre.

Because of the way these are arranged, there is a performance difference between the bias and the radial tire but since the bias tire is almost given way to radial tires we are not going to talk much about, there is no point in now comparing bias tire and radial tires okay. So, we will concentrate on radial tires and how that works. I just wanted to say that there is also what is called as a bias tire; bias tires are still used in trucks okay.

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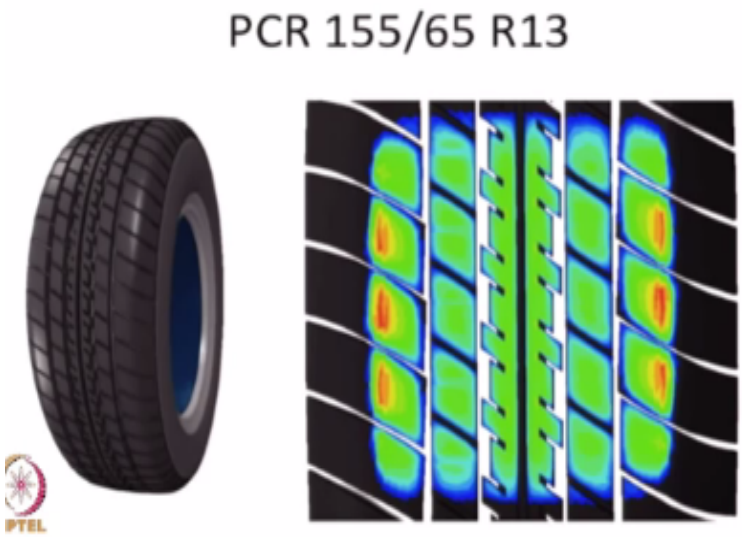

Now, that is a typical passenger car tire, you can see the treads there okay. The treads are very clearly seen, there are various ways in which treads are designed you can see that there are grooves there; there are grooves in the tread okay. These grooves; this is a passenger car tire and these grooves are there in order to carry water or minute sand you know as you go over say a sheet of water.

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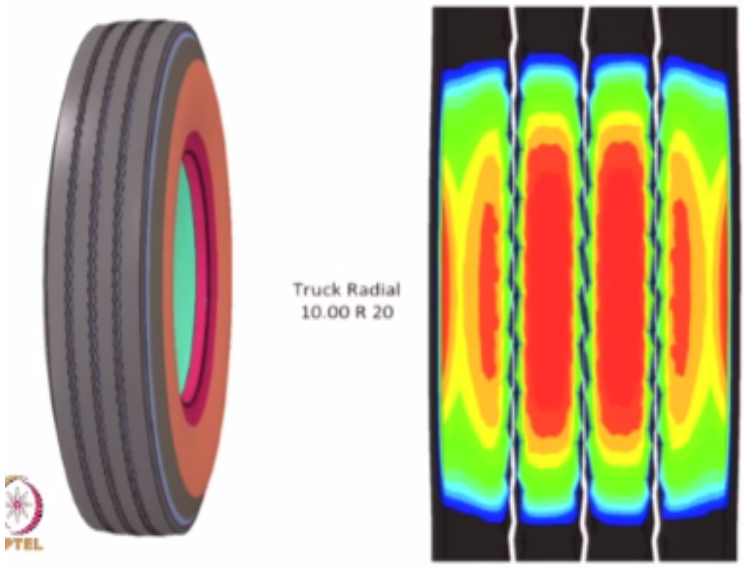

In other words, they are channels for the water to escape as you go in under wet conditions, right. The tires are basically classified into what are called as rib tyre, there is a truck rib tire okay, you can see that there are ribs; there are 4 ribs in this tyre.

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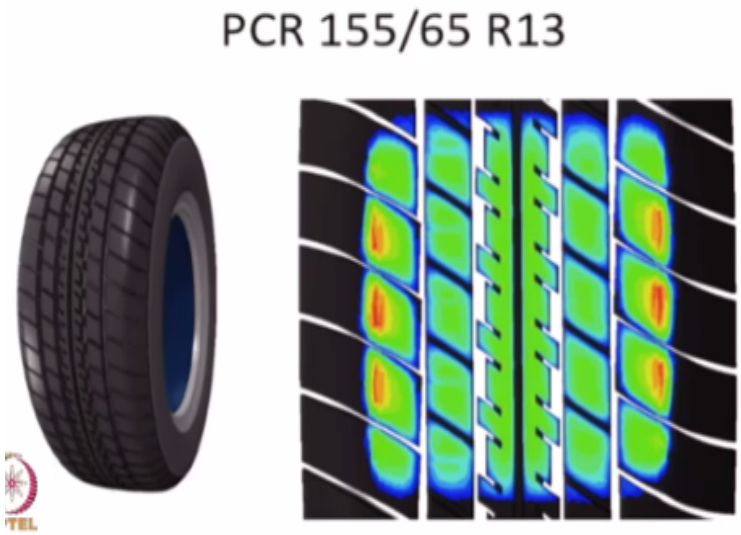

And lug tires; these are what are called lug tires. The rib tires are usually used in the front in the front wheel not necessarily that it should only be used in the front because there are buses

which uses this in the rear also. This basically this is a steer axle tire performs very well when it is in the steer axle, so this is a rib tire okay which is used in the steer axle and that is a lug tire which is usually used in the drive axle that is the rear okay.

So, these are rear tires and the one; the front is a rib tyre but in a passenger car, you cannot have 2 different types of tires, so you have tires which are a combination or hybrid of these 2 which would say all wheel tires. So, all wheel tires are a combination of this kind of lug pattern and a rib pattern okay. So, you would see that a passenger car tyre is sort of a combination of these 2.

Even for truck, you have a combination okay all wheel tires, where you can use, which you can use the front as well as in the rear okay. So, this is a sort of a very brief introduction on how the tires look like, though we are not going to use that knowledge in this course okay, we are going to go more into how the tires interact but nevertheless I think it is good to know how the tires look like and so on.

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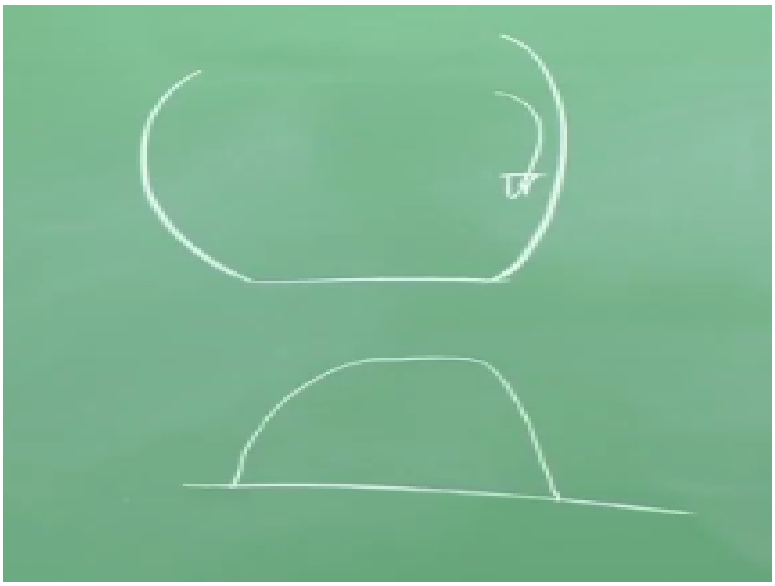

Now, coming back to our contact patch, coming back to our longitudinal forces and all that what we did in the last class, remember that we were looking at a tire which is under free rolling condition. Let us get back to what we were doing in the last class. We will switch and go back and look at some practical aspects of this contact patch, as we go along okay, so that was a tire which was rolling. We talked about the varying radiuses in this tire.

We talked about R0 becoming Re and then becoming Rh and so on and under this we had drawn 3 figures, we talked about the contact patch okay, we just given a 2 dimensional

representation of the contact patch okay and let us now look at 3 dimensional representation of this contact patch, 2 dimensional sense that is just cut at the centre and looked at it.

It is very yes; it is very theoretical but let us, look at it from a very practical point of view, actually, how the contact patch looks like? Okay, so this is a finite element model again courtesy JK tyres, we have a contact patch, you know finite element model of a contact patch. Different colours here indicate the magnitude, red being that the contact, pressures are higher okay and blue being the lowest, right.

So, in other words you see that the contact patch is not uniform and as you go to a; say for example a truck rib tire, the contact patch is absolutely not uniform okay though we assumed that a shape in order to understand the fundamental interactions, the contact patch is not uniform. Let us understand a bit about contact patch because that is an important parameter for the vehicle road interactions, right okay.

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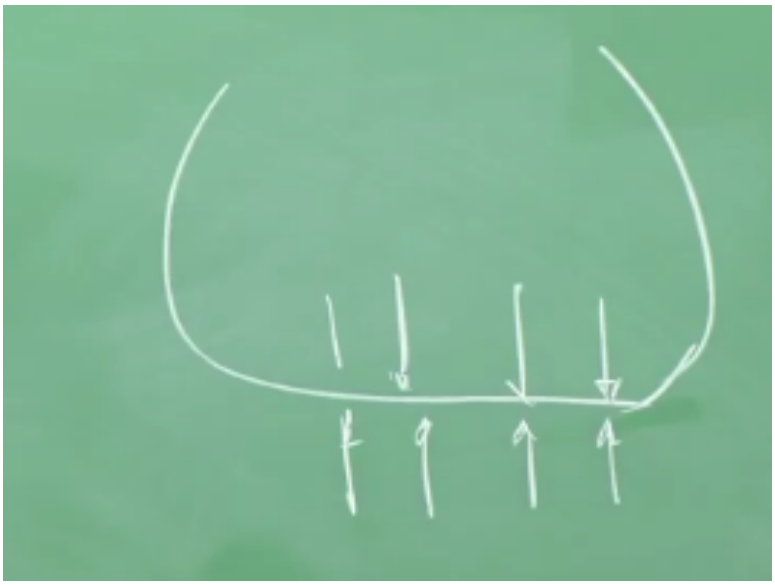

If this tyre is to be made up of membrane whose bending stiffnesses are very low okay, say for example, you take a balloon, blow it okay and then just press it on the ground right, the contact pressure will be uniform, contact pressure has to be just equally break this; the inflation pressure and so the contact pressure okay will be uniform, strict conditions that has to be the case or theoretically that has to be the case when there is no bending stiffnesses.

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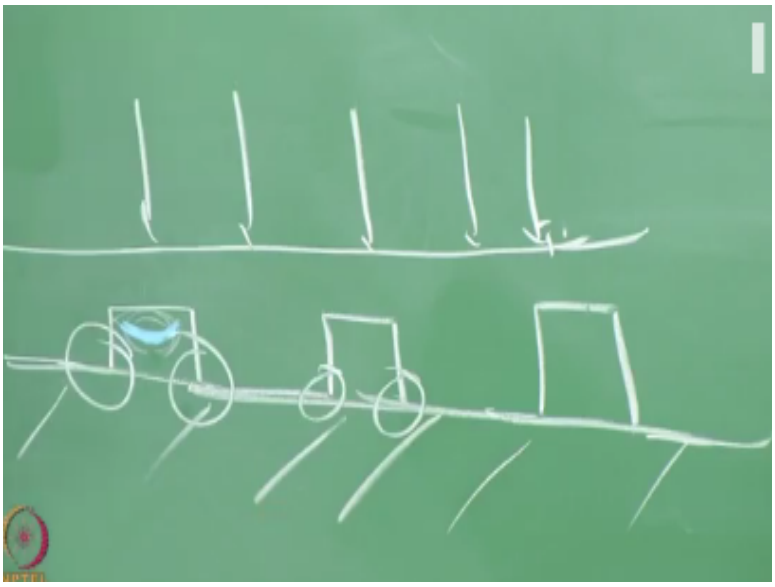

And other things that are; that we are going to talk about are involved. Unfortunately, our tyre has a lot more things than balloon all right. The first thing is that the tire is not straight like that, so it has; you can see that it has say grooves; that is what you see here, that it has this kind of grooves okay. So, contact pressure is actually, let us look at that; let us say that is the inside, I am just extrapolating or I mean exaggerating or gluing or zooming to the area at the centre okay.

Now, here is the inflation pressure that is acting and here is the road surface okay, that is the road surface, so in other words there are grooves; the grooves become quite complex if you really look at that kind of tires, you know the grooves become complex and here again you have grooves. If you now again we will do a thought experiment; if you go and sit here, this part is not supported okay.

That is not supported, so because of which there is going to be a local bending, so there will be; you know this part of it will now start bending, because it does not have a support right. There is an inflation pressure that is acting, that is going to sag okay, that is going to get deflect or in other words there are lot of local deflection number 1; when compared to a nice membrane or a balloon which you keep it at the surface, they are going to be local deflections.

"Professor - student conversation starts". Yes; we are now right now we are not talking about water or anything entering there, we have just as it rolls, you know this is exactly how it looks like in that picture okay as it rolls, right fine, so we are not; in other words, we are not looking at a soil, road I mean sorry a tire in a deformable soil. We are looking at tire which is running

on an asphalt road okay which does not deform right, for all practical purposes that is fine, right okay.

If the soil then the whole analysis is very different okay, how it; how the soil deforms all those things have to be taken into account okay, that is why you have what is called off the road tires which is called a OTR; off the road tires. We are talking about truck tires is running on a; as follow a flat roads, right okay. **"Professor - student conversation ends"**. So, the first thing is that the constant pressure is affected by this kind of local bending, right.

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So, the pressures in this region on either side, in these regions they are going to be affected, that is going to be affected, that is the first thing, right. So, as one factor, the other is the sidewall, so that is the sidewall, so actually what happens is this, so under; look at that you know under pressure the sidewall will be like this and so there is a deformation of side wall and the shape of the sidewall is different from what it is now.

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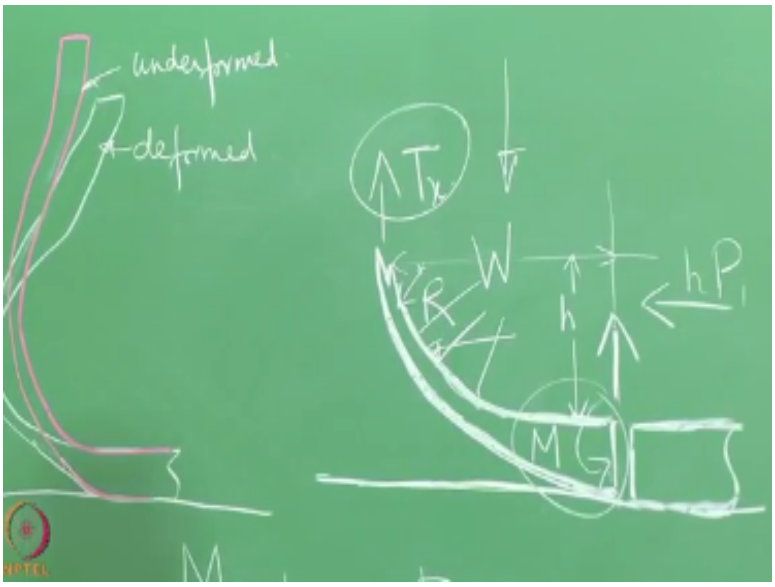

And when it is under pressure then the sidewall shape changes right and that is going to have an effect, which is very important for this contact pressure distribution. In other words, you will see that if this is the undeformed sidewall then under load, this becomes that deformed side, right. So, under these conditions there are a number of forces that act on to this tire. There is going to be tension or in other words a membrane force that acts there.

And there is going to be an inflation pressure force that is going to act at that point okay. So, there is going to be a membrane, there is going to be an inflation pressure okay and there is going to be a; of course the ground reaction and so on. So, because of this effect okay if I call this as Tx okay because of this effect, we have a bending okay, this is actually; you can imagine that; first let us look at it physically then we look at that equation okay.

It has a tendency, so there will be actually this will be the inflation pressures that will be acting and so there will be a force which will be acting okay in that direction, the sum of this inflation pressure forces okay it may be not here okay maybe somewhere you can say here acting and so on. So, because of this, there is a bending because of these forces, these forces and all, that okay there is a bending; that is bending moment that is created okay.

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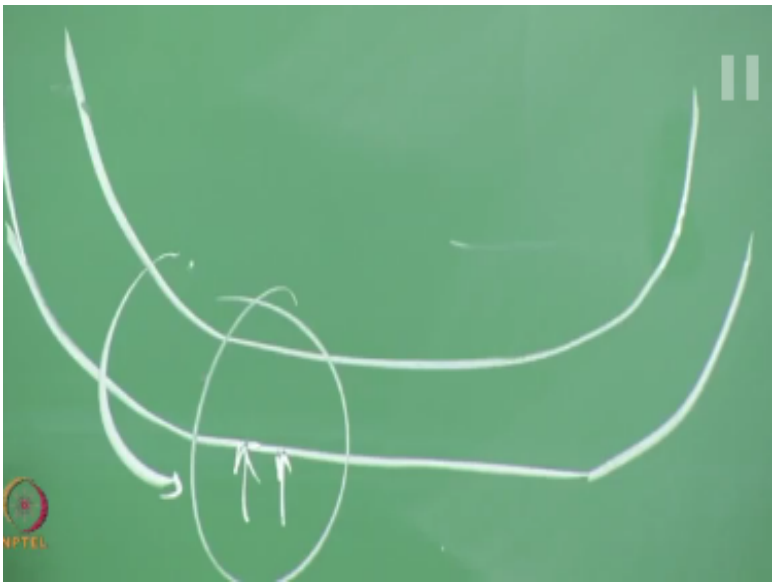

The bending moment is the sum and substance of all the forces that are acting okay. One in the positive direction, the other in the negative direction and so on right, so that bending moment what really; we will look at that bending moment closely now. So, that bending moment let us s get into this and let us just expand that, so that is the side wall, now assume that this whole thing is now bent and so we have a bending moment acting at this place as you had seen there.

Okay, so now what would happen because of that bending moment, there will be more reaction forces here okay, there will be a reaction force, in depending upon who wins; there are a number of forces there, who wins there will be a reaction force at this edge. In other words, this bending is going to alter the contact pressure distribution, this bending is going to alter the contact pressure distribution, clear here okay.

Suppose, the bending wins over or one of the forces here wins over and the bending is like this what would happen to the contact pressure in this region, the contact pressure would increase okay; the contact pressure here would increase. So, in other words the side wall geometry and configuration would result in a bending moment at the ends because of which okay, the pressure here; the bending moment here will be compensated by the; that will be the reaction okay.

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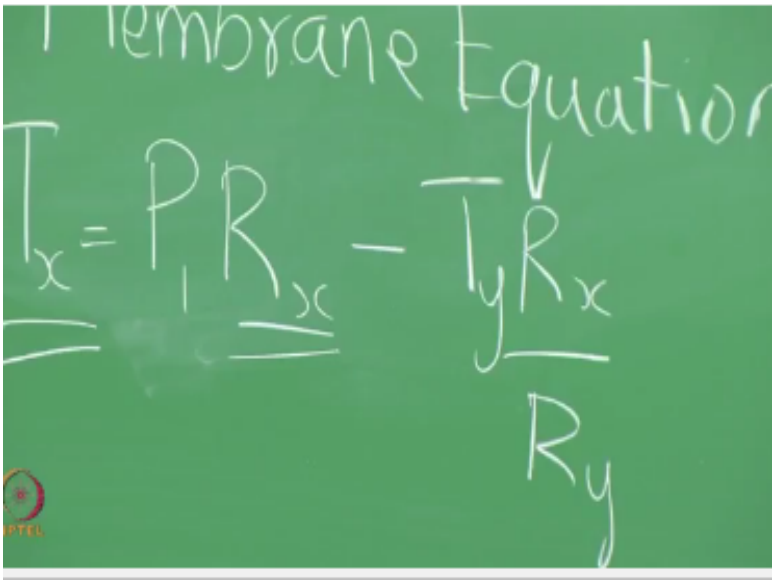

This is the action and the reaction and because of which there will be contact pressure will be here higher or higher contact pressure would result at the edges, so that is what you see here in this in this figure, at the 2 edges, you would see that the contact pressures are higher. It is not necessary that it would be like this it depends upon a number of forces that are acting. Number one is that there is; what is called as the membrane force okay.

This which we had drawn there as T and the membrane force depends upon 2 things; one is that it depends upon the radius of curvature; the radius of curve; please understand that there are 2 radiuses of curvature okay. One for example here is a radius of curvature; the radius of curvature here is going to change and then there is a radius of curvature in the other direction okay, so there are 2 radiuses of curvature in the tire right.

And so the both the radius of curvature have an effect on this Tx, right, both the radius of curvature have an effect on Tx. Of course, the other things that have an effect on Tx or the inflation pressure and the force in the Ty direction, right. We will not go into the details of this equation I just want to say that there is a force in the sidewall which you could loosely call as a membrane force okay which acts as a sidewall which has an effect of course on the bending okay at the contact patch edge, right.

That is the first thing, that the only thing I want to point out is that this force is affected by the shape of the; or the profile of the sidewall as well as the inflation pressure to which you subject the tire okay. These are the 2 things, when I say geometry it is Rx and Ry are included, right.

That is the first thing, the other things that affect the moment are the inflation pressures okay; the inflation pressure.

And the inflation pressures, so that is that there are 2 ways in which it acts you know you can resolve it in 2 directions; vertical and the horizontal direction okay, that is what you see there the inflation pressure is acting in the horizontal and the vertical direction. So, they have a tendency to okay have a bending moment in this direction; one direction and this Tx has a tendency to have a bending moment in the opposite direction.

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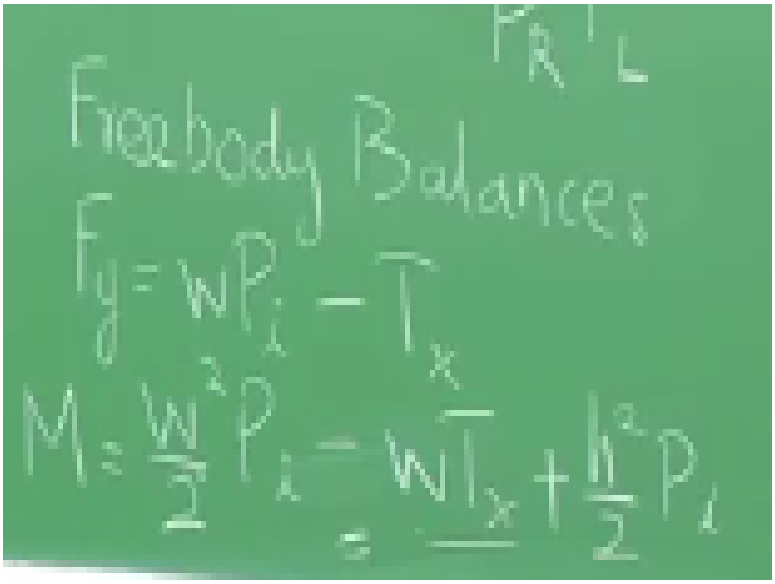

With the result that there is an addition and there is a subtraction, right so if in other words, it is very simple to understand, so if this is the W okay what is that W? Let us get back, so say this is the W this distance is the W okay, so hence you will see that everything here depends upon the geometry, so if that is the W then you can see that there is a minus sign here which acts in one direction and then the other things is in the opposite direction due to inflation pressures in opposite direction and acts okay like this.

So, ultimately what is this moment; bending moment that decides the variation or the difference in pressure? Just to summarize what it simply means is that the inflation pressure that is acting would have been the same as that of the contact pressure but for the presence of local bending which we saw here as well as a global bending I would call it as we had seen here, so because of this bending and of course because of the membrane forces and so on, the contact pressure is not the same as that of the inflation pressure, clear okay.

That is the first important point. Now, there are a number of design parameters which affect the contact pressure, let us agree that it is not the same okay. Actually, we were looking at the rolling tire right and right now our explanations are more to do with the stationary tyre. Rolling tire has other factors which are very interesting, right. Before we go to the rolling tire, it is a free rolling tire then we will go to a tire which is braking.

How the contact pressure changes or accelerating and lastly the most difficult of these cases what happens when the vehicle takes a turn or cornering, right. So, in this class, in todays class we will concentrate only on rolling tire; free rolling tire and we will just get into what we call as braking or traction okay, the next class we will expand it and so on, clear, any questions?

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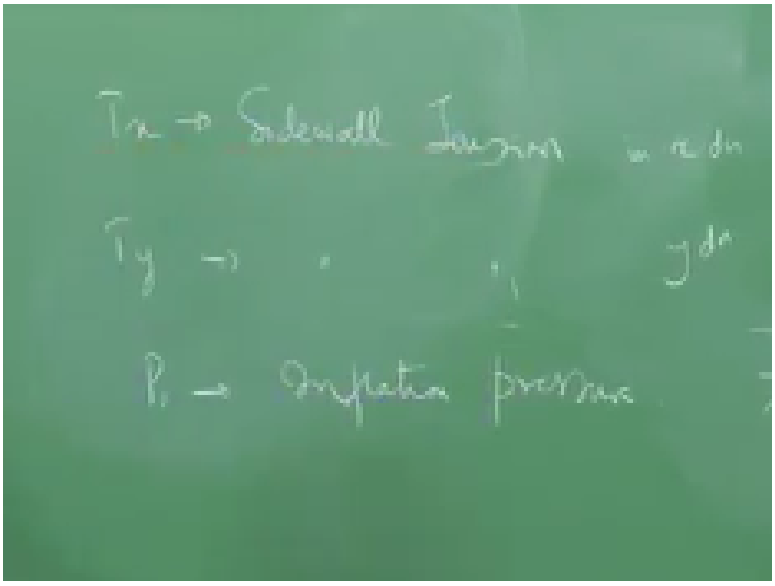

"Professor - student conversation starts". In the y direction, right in the y direction; yes in the y direction; x and y, x I had given here, y is in the other direction okay, fy is in the other direction. Pressure; Pi is the inflation pressure okay, let me write down if you have doubts, let me let me write down Tx and Ty are already explained; Tx is the sidewall tension in x direction and Ty is the side wall tension in the y direction okay, Pi is the inflation pressure; Yeah! one minute; inflation pressure.

This is the free body diagram okay from which we are determining the; say I what I have done is essentially I have cut this and then put the equal and you know forces here, right. Yes, see what we are: good question actually, in most of these analysis we have left out centrifugal force okay sorry it rotates, in some of these conditions if you look at, let us, centrifugal force becomes important okay.

But under many conditions okay we neglect the centrifugal force because of rotation okay. It will be careful usually, in a truck tire, we are looking at the truck tire, this centrifugal forces are not that very important because of the speeds but in a passenger car tires centrifugal forces become becoming poor okay. Right now, we are not considering that but okay then there will be another force or other forces.

And it will; there would be some changes here and so on, right. So, this is only to explain more physically the bending you know what happens okay I am not going to relay on this equation today most of us do not rely on analytical expressions, we go to finite elements okay, so all these things; all the results that you get all the niceties are beautifully brought out in finite element analysis.

But nevertheless this becomes important in order to understand what really happens or why the results are what you see in finite element, that is the reason why we explain what is bending you know, how does it bend you know, what are the forces which cause bending, we cannot do hand waving okay, that is reason why we write down this equations and see look there is a moment and the moment consists of; or the moment is due to various forces and forces act because of inflation pressure.

Because of the force of the membrane or the side wall forces okay, these participate in this moment and so on. All these effects okay, are accurately brought out by the finite element analysis and hence we look at the results ultimately in the finite element, you know contact pressure distribution, clear in which case you can also add the centrifugal force and so on. So, we will look at now rolling tyre.

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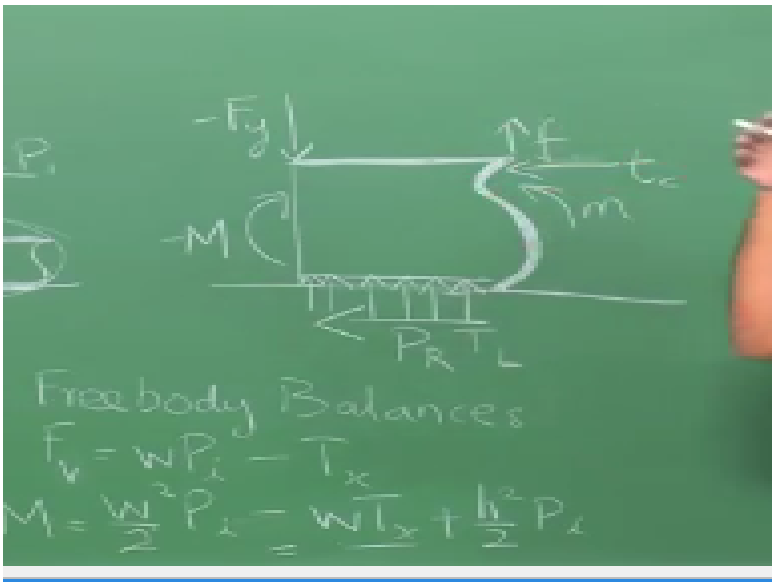

There are other things that become important okay; y coming in the x direction, This is the way actually the; this is the membrane theory, we are not going into the equations okay, so we would right now not going to the derivations of this equation; y Ry Rx, Rx Ry and all that, right we will not; because then the topic becomes very difficult and so, this is not F, this is not F, this is FV, I thought you are asking RyV, this is FV.

And FV is this force that is acting here in this direction okay, the force which is acting at the centre here and that is F okay that is not Fy, that is FV okay but Rx and Ry come into picture and that is the F V actually, it is not the total vertical reaction force that is acting okay, this is not Fy, you are right but Rx and Ry come into picture because of this radiuses on either x and y directions.

The M is the bending moment that acts at the edge okay at the edge, right, so there what we do is simply we take bending moment due to the distributed loads okay in due to inflation which is divided into 2 parts okay, that is what we do this and this, right. So, as if there is a distributed load like that here okay and this is the result of the bending moment due to the distributed load and that acts in the opposite direction okay.

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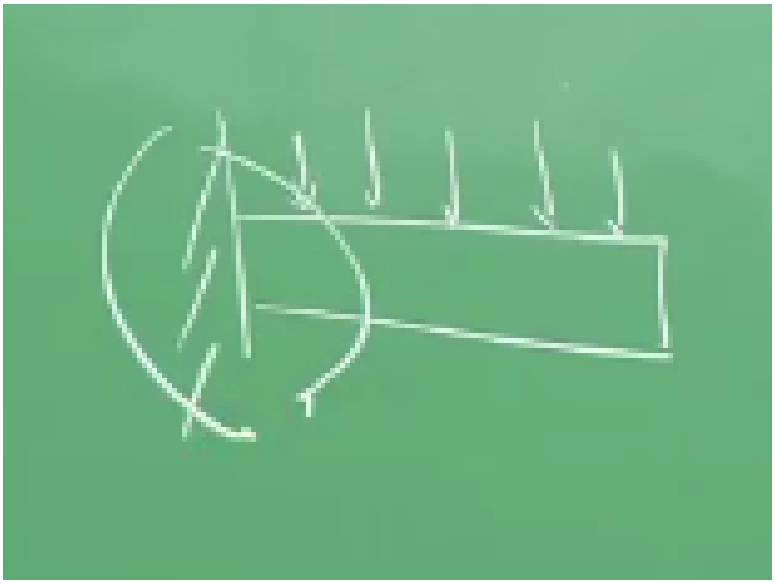

Ultimately, you have a bending at the edge. Yes; yes, see what does this; what do we mean by distribution of these forces if you want to understand this, it is again very simple, if you have a doubt let us say that I have a cantilever beam okay. Now, I have; it is a distributed load that is acting on the cantilever beam okay, so there is an action here okay and there is a reaction at this point, okay right.

So, we are talking about the same action and reaction here, so this is something like a cantilever beam when there is an action and a reaction, so the reaction is in the opposite direction which means it should be in this direction, so you will have a load distribution here such that it will oppose this moment that is acting here. In the same fashion, as you have in the cantilever beam, clear okay.

So, the only thing difference between these 2 is that here we have a cantilever beam within quotes; cantilever beam and sense that it is okay curved beam okay and for associate. Of course, there are effects of local bending you can see that there are; there are green, in some places that are green and there are as you near the grooves and then you have again red and so on okay, so there is a sort of a relief here okay that is happening.

In other words, what happens is that when it really bends okay when it bends then there is a small lift and so on there is a redistribution and that is why you will see that near the grooves they are not red, okay, there is a change, right. So, there is an inflation pressure that is why the 2 components or what we give that. No; there is no; this Pi only one pressure; one pressure that is acting this direction that is the inflation pressure, the force.

The result of the inflation pressure can be divided into 2 parts okay or 2 in the x and y direction, so what we have drawn here is the inflation pressure, right. **"Professor - student conversation ends"**. Let us come back here and so we are talking about rolling, so this is the; what we call as static pressure. Rolling has a very interesting thing that going to happen when you, when it is rolling with respect to contact pressure. Let us see what happens?

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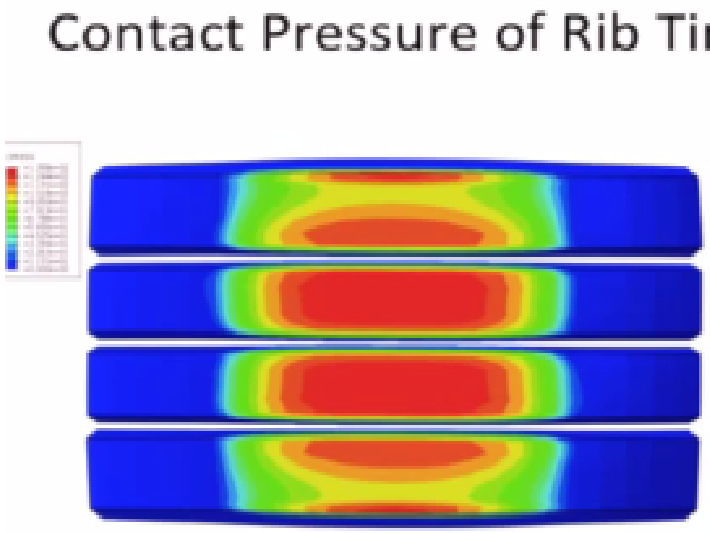

And then we will explain okay, that is a contact pressure of a rib tire, look at that when it this is a sudden change okay.

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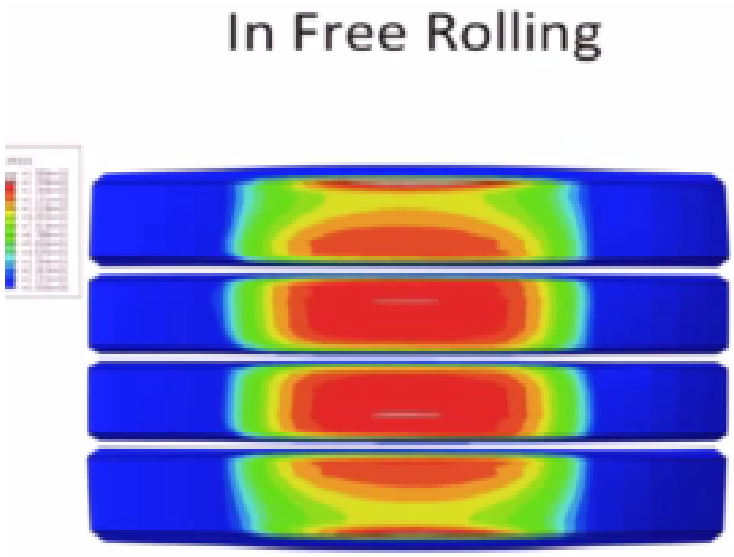

You will see that there is a change between the 2 contact pressure when it is stationary and you can see the whole thing gets twisted, right.

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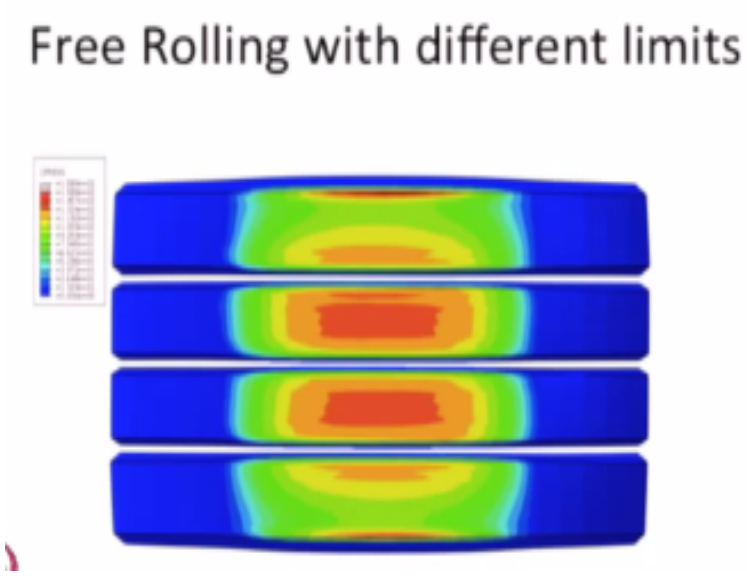

You see further when it is okay, the same thing with the different limits.

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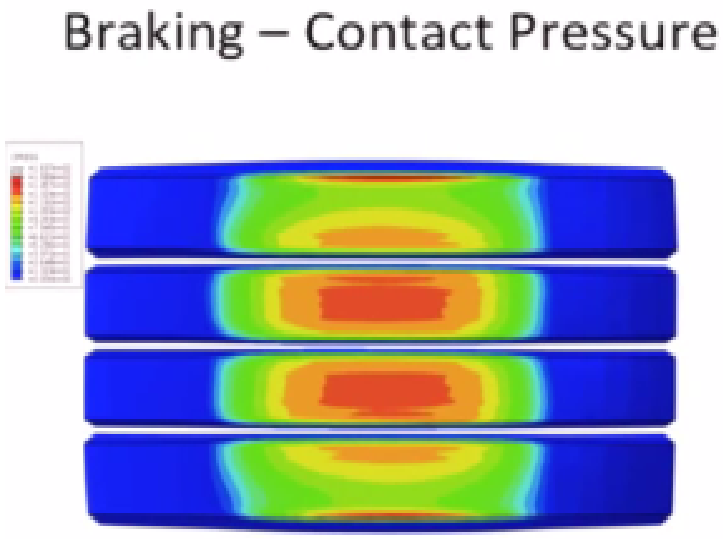

You would see when it is breaking, look at the way the contact pressure now changes.

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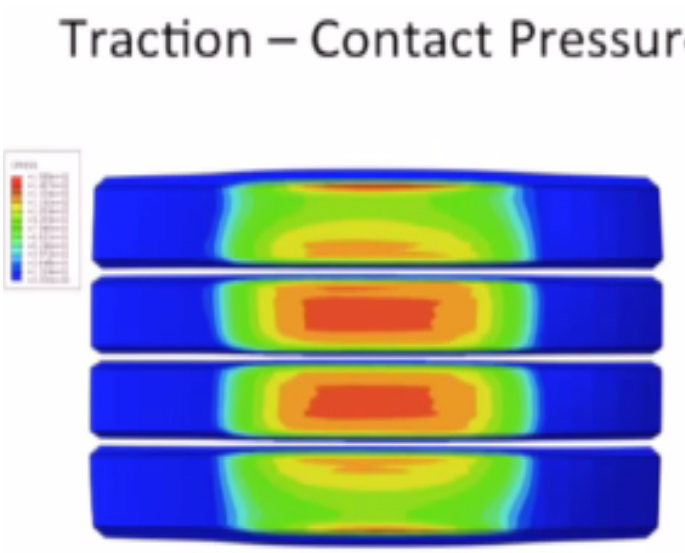

When it is traction look at the way the contact pressure changes. So, in other words you can see that let us get back to this, so you can see that there is a change in contact pressure okay, there is an adjustment of contact pressure. Why does that happen? Right that is our next question. We are looking at contact pressure in; this is the contact pressure. Now as I travel from one end of the contact pressure to the other okay.

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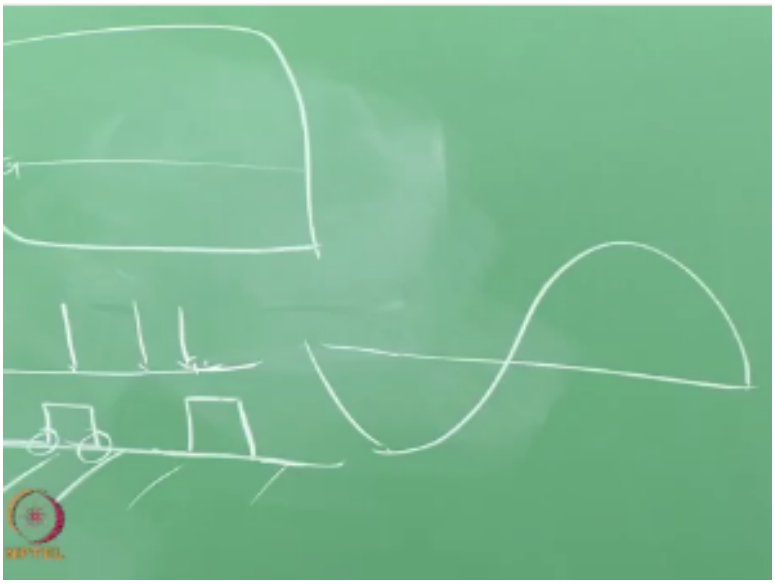

In other words, just look at the contact, so let us sorry; contact patch, if this is the contact patch okay as I travel from one end to the other, there is going to be a longitudinal force, we saw that in the last class, there is going to be a longitudinal force goes up and comes down. Remember last time we saw that okay something like this, we also saw that this longitudinal force okay reaches some maximum Re.

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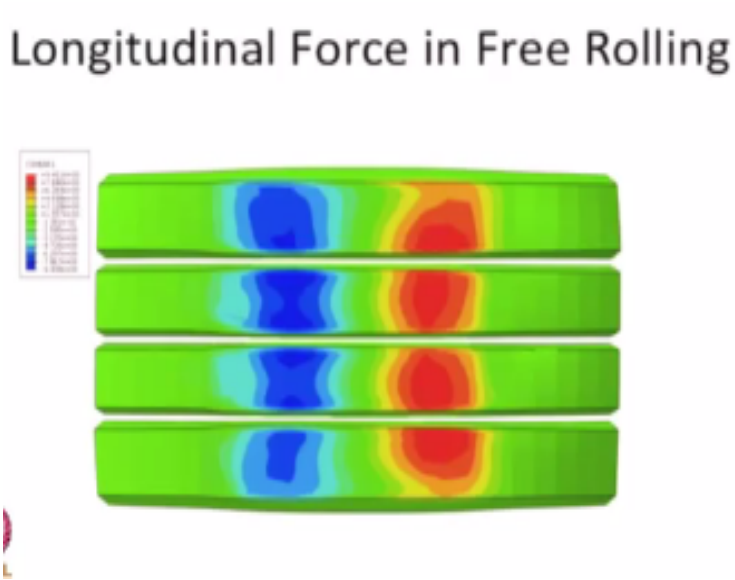

Remember that we talked about R; variation of R, okay in a to b, b to c, c to d, d to e and so on in the last class and this longitudinal force has a very interesting effect okay. Now, just see how that is in finite element, let us; that is the a longitudinal force okay, I hope you are able to see one is in the positive and the other is in the blues is the negative the red is in the positive, so it goes up, goes to zero in the middle comes up and this is exactly what you see here is what you see in this case.

But unfortunately, since there is no unfortunate here but anyway, the rib, all the ribs as you can see here do not have the same longitudinal force due to the construction of the tire okay, let me explain, they do not have the same longitudinal forces, they are different in different ribs, you can see that okay. Now the tire, so that is the; let us, so the first point is that the longitudinal force as we had seen there is not a constant in all the ribs.

They are different at different ribs because of which okay, the tire now rotates a bit about the vertical direction, so that the total strain energy; total strain energy becomes minimum. So, in other words this distribution of our uneven distribution of forces causes that tire to adjust, okay adjust or in other words, the contact pressure now is such that becomes a minimum that the total strain energy is minimum.

As a system, it would like to go to minimum strain energy and so there is a twist. So, that you can very well see that here, look at that, so it sort of twist in such a fashion that it becomes slightly more okay, uniform right. So, in other words the longitudinal forces that are acting has

an effect on the contact pressure distribution itself right and for example, the longitudinal forces which we are going to see in the next class due to braking has further look at that.

Has further effect on the contact patch, right; any questions, okay. Just to summarize what we what we said we will continue this that the contact patch is an important or influences the interaction between the tire and the road. Another contact patch though one would like it to be very uniform is not uniform and that there are some local effects and there are some global effects, which has an effect on the contact patch distribution.

And that the contact patch is also affected by the uneven distribution of longitudinal forces between the various ribs and the ribs tend to or the contact patch tends to adjust itself, so that the strain energy is brought to a minimum or there is a redistribution such that the strain energy levels as a system is brought to a minimum okay. So, there is a small rotation that is as far as the free rolling is concerned. We will look at braking and then go to the contact patch in the next class, right let us stop here.