Farm Machinery

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Lecture - 08
Mechanics of tractor implement hitch system and traction prediction models

Well, in my previous lecture we discussed about the hitching of the implements of different kinds, the pull type implements in the vertical and horizontal hitching as well as 3-point linkage hitching. Now when we have this hitching with the tractor, what is the mechanics behind the implement and tractor combination?

And what are the different prediction models which people have developed over the years, researchers have done over the years in order to find out the total draft requirement? And hence the total power requirement, because this will help us in designing particular equipment for matching to the power source.

Let us have a look at the different slides through these slides we will go through. And I have named this lecture as mechanics of tractor implement hitch system and traction prediction models.

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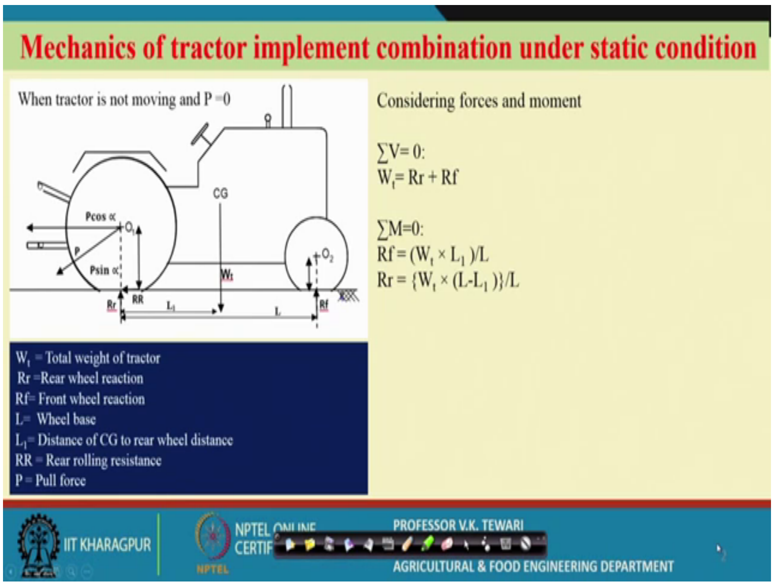

Yes, mechanics have tried to implement combination under static condition; where you must have seen that when the tractor is simply standing condition, and when the this P is

0 the very simple. What I have done through the slide difference slide you will find, that I have made things very simple and not complicated by keeping all the forces acting in on the soil, and the wheel at one point of time. So, that you can understand step by step how are these things happening.

So, in the in this one we have given a very simple diagram, which will talk of the current reaction this is the rear reaction, and there is a P load P here, which I have assumed to be 0. Then in this condition only the CG the chess is center of gravity of the tractor is over here, and this total weight is W t. So, if you take forces in the vertical direction, we get this only. And if you take moment here that you get R f is equal to this, and R is equal to this.

Now, move the moment there is a force on to this. There will be change in these reaction forces. So, those think we call as weight transfer, that the moment there is a value of P, when P is positive not 0 more than that, then there will be a weight transfer taking place between these and to these and these size. We will talk of this slightly later.

Now, let us go to the next slide.

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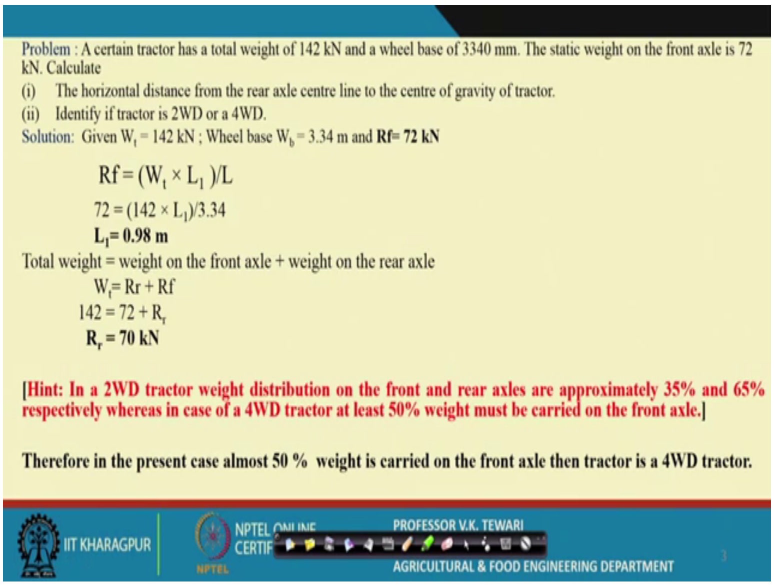

Here well, but before I go to actual so, you then differences, I have tried to make you understand how that aspect of the same here, now, yes. So, now you can see that these are the forces the R r and R f here. So, if you consider this with respect to this particular figure particular problem, we find that in very easily we can find out what is the horizontal distance from rear axle centre line to the centre gravity of the tractor.

The center of gravity is if it is here, we are interested to know what is this distance. This is wheelbase, we know this is wheelbase ah. It has been already said earlier. So, taking a simple moment as we described earlier, you can find out what is the value of L 1 here. And once you know the value of L 1, there is another aspect which is asked identify if the tractor is 2-wheel drive or 4 wheel drive the total weight is given over here.

So, it is such that the moment we know that on a 2-wheel drive tractor, the weight distribution is slightly different. About 60 to 65 percent I have said earlier also and the rest weight on the rear wheels. But when the weight is approximately 50 percent on both sides, then we call that tractor to be 4-wheel drive tractor.

So, that is the hint I have given here. That when it a 2-wheel drives tractor weight distribution front and rear axle approximately 35 and 65 and for a 4 wheel drive it is 50 percent. And on that basis you can answer this question here. Because, the R r which is 70, 80 kilo Newton and this value the front axle is 72 kilo Newton, which is already given to you.

So, from here you can know that R r is this and R f is 72 kilo Newton; that means, this tractor is a 4-wheel drive tractor. And hence the answer is there is a 4-wheel drive tractor.

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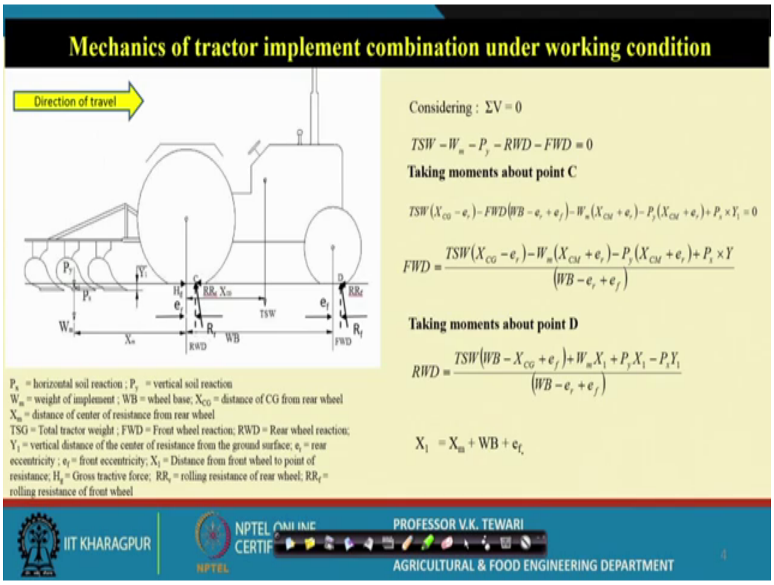

Well we go to a working condition. Now the moment we go to a working condition you please consider the previous figure and this figure here. There we had not talked of the force and we have said that P is equal to 0.

Now, here we have put an implement put a yeah.

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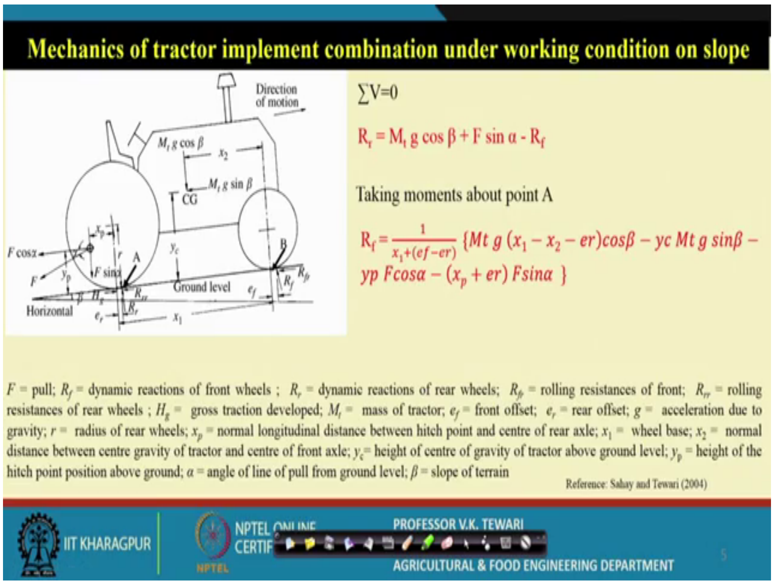

So, here we have said that there is a force here. And this will have 2 components very simple as you have seen earlier that when there will be a line of pull, through the line of pull there will be a pull force acting. So, the horizontal component will be the pull, and this P y will be acting downwards. Now this is the location where it acts where the weight of the implement is also acting at this particular point

The location of this particular point is about distance Y 1 which is Y 1, vertical distance of center of resistance from the ground wheel this. Here the moment the tractor is in soil you will find that the contact point is not exactly under the center line as we had seen in the earlier case

Ah In the earlier case, it is slightly at a distance e f, in case of the e f and in case of the front wheels and e r in case of the rear wheels. And therefore, you will find that this distance e r and e f have been very clearly indicated when the same when the implement is in the working condition, and the implement is working condition in the soil. And the other related forces will be R r rolling resistance in the front; similarly, R r rolling resistance at the rear and h this is the cross tractive force.

So now from the static condition of simple in the tractor, you have come to a condition where this combination is working in the field this will have. So, if we take the vertical this is v is equal to 0, and then the forces if we take the summation of the forces this is what we get here. Then taking moment about c, this is the point c here. So, if we take moment about the point c here, we get the equation tsw with respect to this here, where W m P y P X r are indicated here, P X P a, W m is the weight, P X is in this direction, P y is here so, we get this.

Then the in a forward the front wheel dynamic reaction is given by this here. Now taking moment about point D, when you take moment about point D over here, we get the rear wheel dynamic reaction by this. And X 1 total distance which comprises X m; that means, distance from the center line of the wheel to the center of the resistance. And the wheelbase plus e f, because this will talk if you are taking moment about D then X 1 is given by this where X 1 has been used, in the equation wherever X 1 has been used in equation this is the value which happens.

So, if you take the moment, then from the previous 1 now here condition different. Now we will see another condition in which when it is at certain angle, yes. So, these this you can see that same combination, but now it is a certain angle slow. It is on a slope here.

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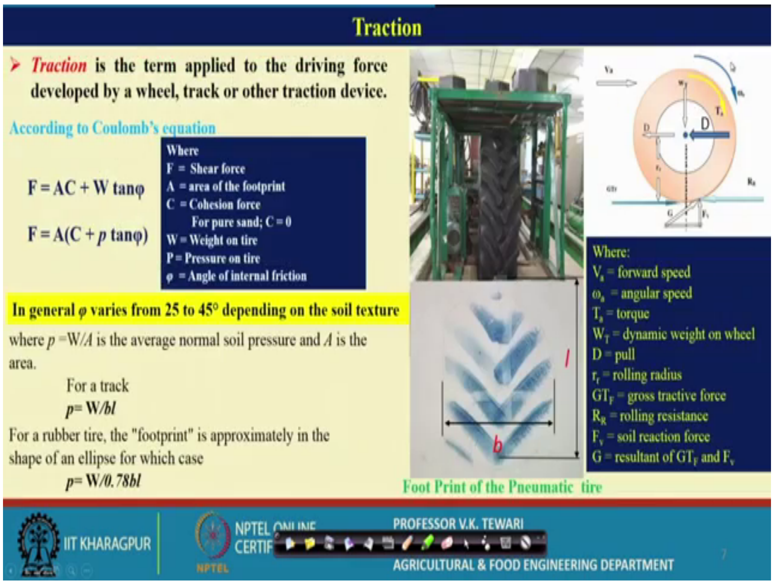

So, the moment it is on a slope beta comes into play here. And then we have the forces which we discussed earlier the CG will act here, and these components the because beta will be in this direction, sine beta will be acting in this direction here, and then this is the force f which acts the line pull. Then it will it will have a component f cos l by here, then a component which is f sine alpha here.

And this is the R f over here, this is the point of resistance g this portion in the rolling resistance. In fact, this should be rolling resistance here r of front field and this r r here current resistance in this. All the forces which we have shown there are same here. Except that the nomenclature certain distance is say xp is the distance from this centre of this point h, ok. And y y p is is from this location here.

So, y p and x p has been explained to you as what is their position with respect to this line? This is the line which is drawn which is at an angle of beta from the horizontal line. So, considering similar aspects of mechanics here we find if the pull f is equal to F s and is given by this here.

And at R f is equal to 0 now, this is a condition which needs to be considered, what will happen is the moment I have said earlier. The moment there is a pull onto the tractor, the there will be change in the reaction. And hence there will be may not be a physical, but there will be a weight transfer taking place this weight transfer. And that means, this value of R f the reaction force on the front wheel it is start decreasing. It will start decreasing.

So, a point a limiting point where we can say that the maximum pull force that we can get F s the maximum pull force which will be equal to F s e when R f is equal to 0. So, R f is equal to 0 this is the value. We know the angle alpha, we know angle beta, we know M t, we know yc, we know yp all this X 1 X 2 all the details are there. Then we will be in a position to find out this F s.

Now, look at the traction. How do we get actually the pulling ability of the tractor wheel of the implement? How what do we get from there? See, here we have given the certain tractor wheel here. And it is imprint it is footprint is shown over here. And you can see that this is virtually an elliptical in shape here it is virtually elliptical in shape with the length here and breadth here.

Now, what happens? Whenever we have s supposing that these grips these grips, when here soil is fixed now where the moment it goes into the soil, soil will come inside. This it is just like as if we have some sort of a here, and there will be soil into this.

Now, if there is a load on this here, say in certain load W, then the force required to put here and F. So, when we are trying to push this what will happen is this will have a resistance being offered. Now that resistance will be offered on the basis of what is the area. And what is the cohesion force you can say cohesion between the particles here?

Now, this same thing has been very nicely said by coulombs equation which is given as over here. F is equal to AC plus W tan phi. So, the force this force is the force which is the shear force. This shear force is given as W is the normal weight coming on to this. And A is is the area on which it is acting area of the footprint. So, we get that F is equal to AC into this. Where phi is the angle of a internal friction which has been explained over here.

Now, this is very important so far as the capability of the tractors lug is there. Because then this lug is the there is the change in the design of the lug will have a greater bearing on the pulling ability of the tractor. And higher tractors have higher sizes of the tractor fields you might have seen that we are starting from 12.4 into 28 to 13.6 and maybe even higher than that. So, those values will have a greater bearing; so, the larger tractors have larger fields and because they can pull these the implement larger implements.

Of course the torque is on to the tractor axle here, and we know that when the torque is acting at this position here, at this location is the pull here. So, we have to have a this is the one which we are talking of the torque here, now this torque and this center distance we will make up the total torque the force here, and this order will make the torque.

Now, while we are getting the torque out of this, the important parameter is the lugs which are here. So, these lugs if these lugs are not properly designed or these are worn out, then the pulling ability will decrease of this. So, it is important to understand that the lugs of the tractor are important, and if the lugs are not there then this the pulling ability will be simply virtually 0 and is given by the famous equation this. This footprint is not necessarily a rectangular one. This footprint is in fact, a we find that this is generally an elliptical in shape. This is elliptical in shape, you can say that this is elliptical in shape here with l and b.

And therefore, as it is said here therefore, the pressure which we get on to these P is W by 0.78 bl this has been worked out. That the value is 0.78 times not bl, which is for a rectangular case. For a track of course, this is W by bl. And the value of this angle of internal friction varies from 25 to 45 depending on the soil structure yes. And C is the cohesion force, and cohesion force for a pure sand C is equal to 0.

So, when we talk of the traction which is nothing but the driving force developed by a wheel track or other traction device. This is traction. It is important to understand that without the proper tractive traction field, you cannot get enough traction or enough cooling ability of the tractor or from the power of the tractor.

So, a traction is the driving force developed by the wheel or a track or any other device which we get, and it is bearing is on the lugs which are there which has a gripping capability onto the soil, when they grip the soil and is being pulled depending upon the type of the soil, the C and phi values the C and phi values the amount of force, this force shear force will depend. And we will be in a position with what is the total pulling ability of the tractor.

Now, if you see the same thing here it is very nicely you may told about this particular driving wheel. That D is the pull here, and W t is weight coming onto this. And the force is here this is soil force over here rolling resistance over here, and this is the vertical force of the soil reaction. And GT as gross track gross tractive force over here, and tau is the torque. So, this is the mechanics or the one or the point of consideration for you when you want to design a particular implement or try to find out the total power for a particular implement width of an implement while connected to a soil.

So, it is very important to understand this aspect of traction. And when we are talking of attaching of the implements, we are simply talking how to attach. Once it attached, we must see what are the forces which are acting there. And once the forces are coming, we should see what is the traction device which is developing this particular amount of traction; which will actually help us in getting the design of the implement which we want.

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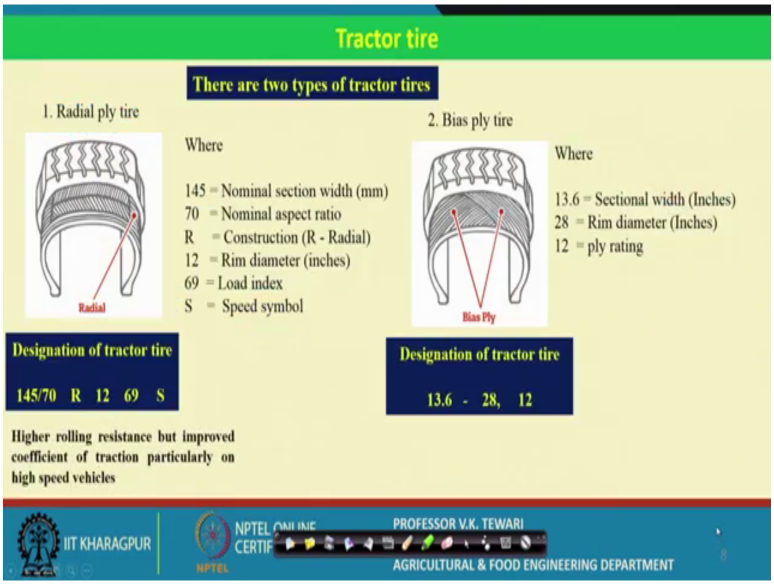

Well I talked of the tires it is also very important to know what are these tires. And how these tires are employed, and what is their design, under what conditions which type of tires are used, why certain type of tires are used under field conditions, why different types of tires are used under road conditions. We see that most of the tire track tires which we have are the bias ply tires which are used like this here.

Now, this is the rim diameter say 12 ply rating, 13.6 if this is the designation of this particular tire. Then we know it has also been told to you earlier even in the field condition I told; that what is the meaning of these which is written on the tire itself. You can see the crossing bias ply these plies these fibers and these fibers are making an angle of 45 degrees.

In case of this is not a situation they are parallel here virtually and the condition under which these radial tires. In fact, these radial tires rolling higher rolling resistance, but improved coefficient of traction is obtained in case of radial tires. And these radial tires you must have seen that mostly these are our passenger vehicles which are mostly going onto the roads and high speed vehicles. They have their own advantages, but when we talk of the tracking ability or the pulling ability there is not so much in these as compared to the bias ply ratings or bias ply type of tires.

So, it is important to understand why this type of tires are used mostly in tractors, and not this type; although, in European condition these are also used because most of the time those are being used on road conditions and for haulage operations are other earthmoving operations. So, those are being used, but these are the ones which are used under Indian conditions or not European non-European conditions.

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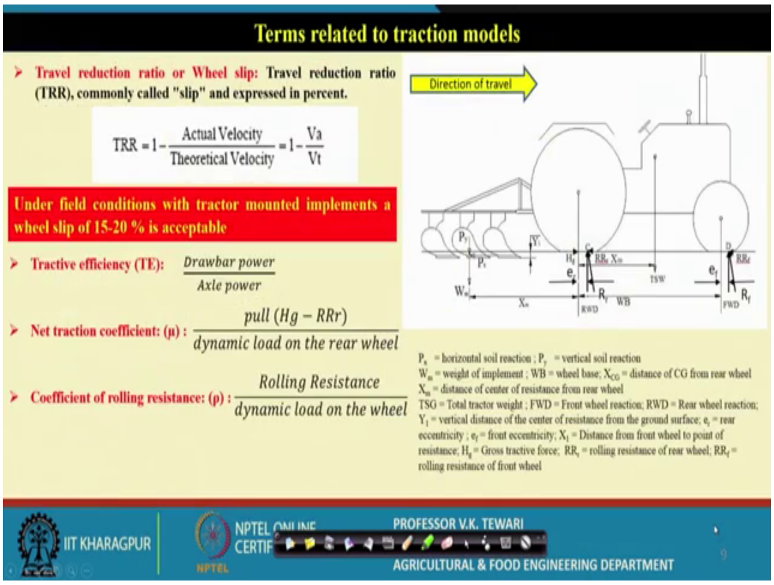

Terms related to traction models. Now, we talked I had said that we will we also talking of some of the prediction models.

Now, I have been telling in the beginning itself that the moment there will be the forces are there on the wheels. And the moment there is a pull behind the tractor because of the implement there will be change in these reactions. And when there is a change in reactions there will be weight transfer taking place which is physically we do not see, but yes there is a change. Because as we discussed earlier, that the moment R f comes to 0 virtually the implement will get lifted. And that is why at a limiting value of R f, we find what is the maximum pull that we can get. And once we must limit the maximum pull within pull within that value.

Now, the moment we have a wheel, we have a wheel, and if this wheel is rolled let us say that for one rotation. So, this distance if this is the diameter of the wheel is D, this D here; this will be pi D for one revolution. Now a condition on a condition, if you see that this is on a road on a road or level road, where there is no load, where no load on the wheel.

So, when there is no load on the wheel, we will call this the radius of the wheel, this diameter d is equal to 2 r. So, this radius is then known as rolling radius. So, this r r is known as rolling radius. So, the rolling radius is the radius obtained when under 0 conditions, that is under 0 conditions. So, if we want to define this, what is rolling resistance rolling a radius rolling radius is the radius obtained by rotation of the wheel under a 0 load condition and divided by 2 pi.

So, these distances suppose this is the distance s. So, s pi 2 pi will be r here. This is what is the rolling radius which we design here. Now since there is there will be a change in the reaction these reactions, and if this distance is changed because of some load. Now this was the condition when there was no load. When there is a load now, supposing there is a load on the wheel. So, there will be load on the wheel.

The moment there is a load on the wheel what will happen? The earlier distance OD will not remain OD. Now it will become now OD say, 1 where, where the this D 1 will be less than D where this D 1 will be less than D. Now since D 1 is less than D we will say that there is a reduction in the distance travelled. Because this pi D will become now pi D 1 and pi D 1. So, the distance pi d is greater than pi D 1.

Now, that means, there is a reduction. So, this reduction is known as travel reduction. And now this travel reduction happens because of the load behind the wheel because of which there is a slippage of the wheel which occurs. So, sometimes interchangeably this travel reduction is also known as wheel slip then I which has to happen, ideally it should be 0. Ideally what we want is D 1 should be equal to D only, but it does not happen. There because the definitely when the load is required there will be some resistance required for overcoming that. And that is why we will have a wheel slippage. So, we talk of that as wheel slippage the v 2 it could be wheel slip or it could be called travel reduction or travel reduction ratio.

Now, this table direction ratio is now given as 1 minus b v by v where actual velocity theoretical velocity here. Then other aspects of the attractive model stock of drawbar power. Now we know the drawbar power, we have if we know the drawbar force. We can multiply by the velocity we can get the drawbar power. And the axle power the axle power is the power which we are getting at the axle of the tractor. Which is in fact, not possible to find out, there are other ways by which we can find out, but yes there is it that power which is coming at the axle. And from here we go through the wheels now.

Net traction; so, why we call net traction here? Because the pull which we have got earlier and the rolling resistance which you have got there will be difference in this and then the dynamic rear. So, the net traction coefficient is given through this equation. And coefficient of rolling resistance is rolling resistance by dynamic load onto the wheel. So, it is it is easier to understand once you know about what is a rolling radius and what are the travel reductions.

What slippage takes place, what slippage happens in the wheel, because of which there will be a traction which will be a gross traction, and then there will be a traction which is net traction, because the growth traction will take care of everything and the moment we talk of net traction we have to I mean subtract the rolling resistance. And then we will be in a position to get.

Now, if we talk of coefficients, we have to talk with respect to the total dynamic load which is coming out to the wheel. And that is why we are talking of coefficient here. Otherwise this is what is the net load which is net traction which we are getting. And the moment we divide by this we are talking of the net coefficient.

Similarly, rolling resistance we get here. This is the value, but the moment we talk of with respect to the dynamic load which is coming on to the wheel it becomes a coefficient.

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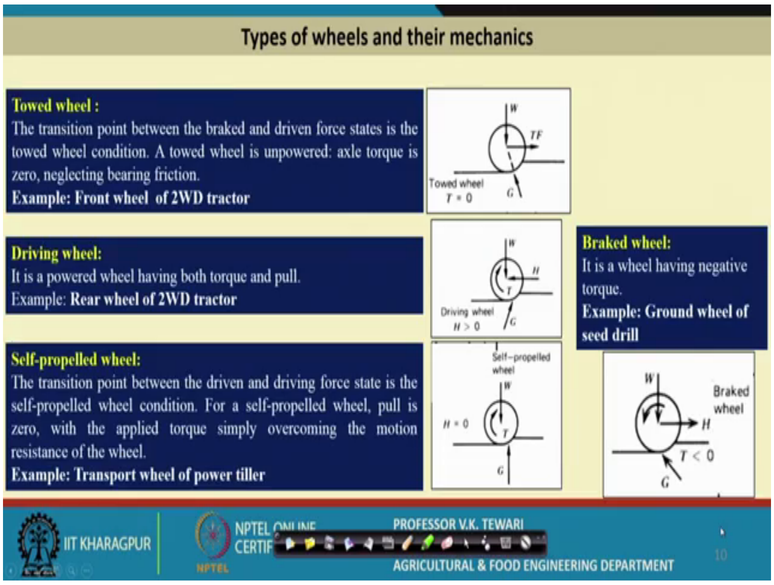

There are certain other aspects which need to be explained about the wheels. See wheel a simple wheel which has only to be pulled here, we call this wheel where there is no no torque this torque is not there. So, this is towed wheel.

This is we call as towed wheel. The famous example is the front wheel of the tire tractor. Driving wheel, now the moment we have a torque coming onto this wheel weight remaining same, and the horizontal this pull is there h pull is over here. So, when the driving pull h is 0 greater than 0 we have and this is the reaction here, we call this as a driving wheel.

The moment we have everything that is the weight coming here the reaction of the soil, but there is no pull here, when the pull is not there, h is the pull. So, when the pull is 0 we call this as a self-propelled. And the example of this is the transport wheel of the power tiller. So, rear wheel will drive is the driving wheel. And towed wheel is the front wheel, and a self-propelled wheel is the wheel example is a power field.

And braked wheel is where we are calling where braked wheel where this torque is there, and there is a soil reaction here. And the pull is also over here, we call this to be a braked wheel.

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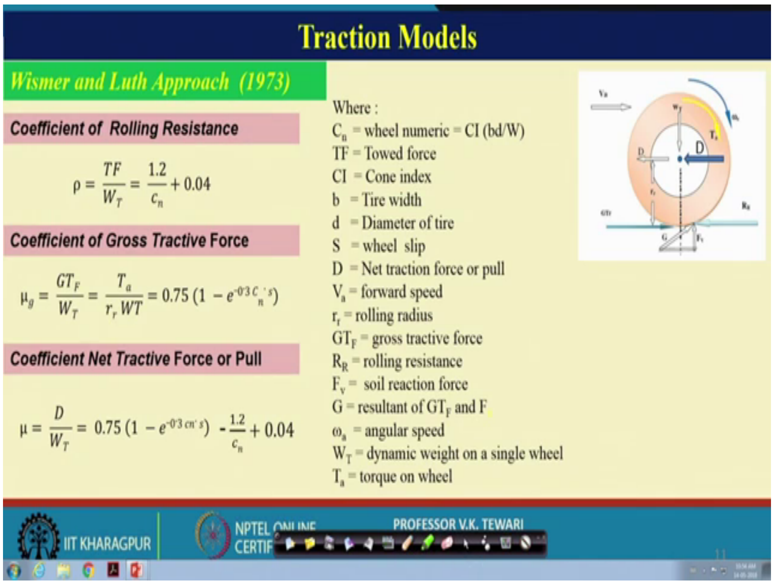

Traction models where there are the several scientists have done several studies. And they have found out on the different types of models.

Particularly in order to find out what are the different coefficients of rolling resistance gross traction, and the net traction I have talked of gross traction net traction. But the equations which have been given are just have a look at this, that this is the equation which is given by Wismer and Luth in 1973 for the rolling resistance for gross traction. This is the equation, here he has talked of the wheel slip in this case and C n a wheel numeric which talks of CI bd by W where CI is the cone index. We will talk of cone index slightly later; it is talk of the strength of the soil.

And the tractive force here; the moment we talked net tractive force it has to be gross tractive force minus g the rolling resistance. So, you can just see that the net tractive force comes like this. And these are the details are explained over here. So, this is the traction model given by Wismer and Luth.

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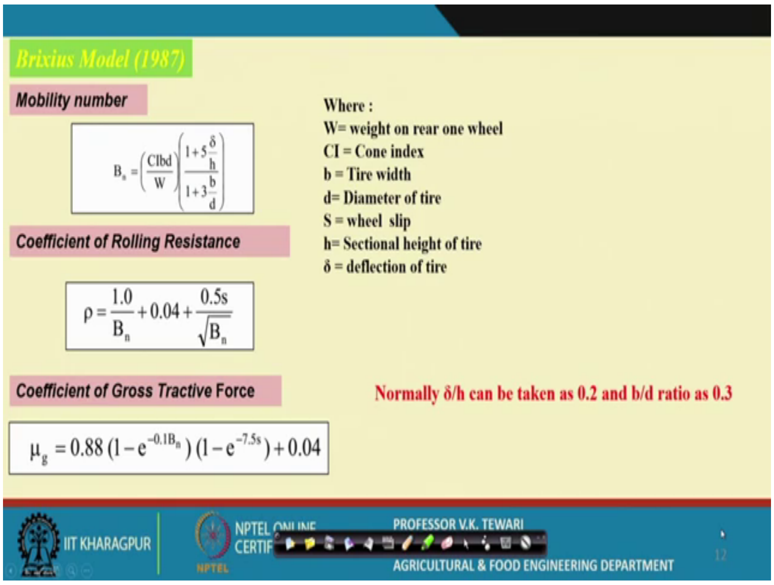

Now, another scientist in 1987 Brixius model. What the Wismer and Luth did not consider was this aspect of the delta by h. Delta by h which delta caused the deflection of the tire and h is the sectional height. We know that when the tire is over here and then because of this there will be a deflection coming up because of the soil pressure there will be deflections.

Now, this deflection we generally take this deflection d delta h in the ratio of del by point 20 percent of this, on a normal pressure that we maintain in these wires ah, in this tires. So, he has considered this aspect and accordingly then he got a number instead of the wheel numeric which was there in case of this. Here you got a mobility number between given with this. And he has also found out the rolling resistance as well gross traction. And so, if you want to get the net traction definitely there is a difference of these 2.

So, these 2 models have been used all over the world being used all over the world, depending on the soil, depending on the condition which the person wants to study, and they have been very popularly used, and lot of research is going on. People at other locations also have done some work.

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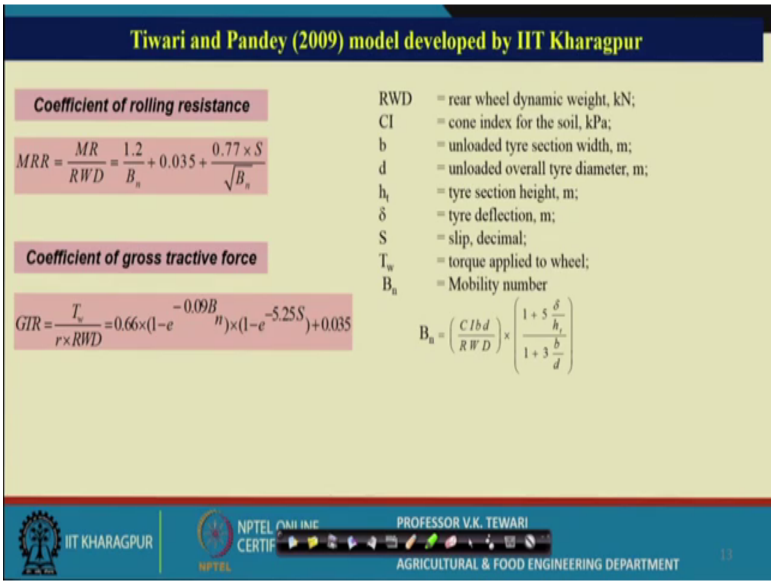

Ah Say at IIT Kharagpur also we have done similar work and found out for reactions, particularly with respect to the soils which are in sandy lateritic sandy clay loam soils which are there in Indian conditions.

So, well these are the different traction models, as I said from Brixius and Wismer and Luth and the conditions in under in Indian conditions we have developed these models. We will like in our next class, I would also like to show you how we take we test these, and what is a soil strength, how do you maintain soil strength, how do you measure soil strength, how do you measure the traction into the lab conditions. We will show you these in the next course of classes.

Thank you.