Traction Engineering
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Lecture 28
Measurement of Theoretical Velocity, Actual Velocity and Slip for a Pneumatic Wheel

Hello everyone, this is professor H Raheman from Agricultural and Food Engineering Department, IIT, Kharagpur. I welcome you all to this NPTEL course, Traction engineering. This is lecture 28 where I will try to cover how to measure theoretical velocity, actual velocity and a parameter called slip for any pneumatic wheel.

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The concept which I will be going to cover is, the theoretical velocity, actual velocity and wheel slip. These parameters are important because the output from a tractor in terms of drawbar depends on the wheel slip. More the wheel slip, more will be the power which is lost. So, that, that way we are getting lesser power, the power which can be utilized will be reduced and if you cause the wheel to slip to a lesser value say 2 percent, 3 percent again, we are losing the power because of the rolling resistance.

So, there is an optimum slip value. Maybe it is varying from 10 to 15 percent or 15 to 20 percent where we are getting maximum output from the wheel. So, that is why wheel slip is important. When you try to mention or when you try to carry out certain tractive performance test, slip is one of the important parameter, features to be mentioned. This much power is developed by a tractor or this much power is developed by a single wheel at this slip, without slip, it does not have any meaning. So, this is the importance of slip. So, how to measure slip? We have to have theoretical velocity, we have to have actual velocity, if you know these 2 velocities, then you can find out what will be the value of slip.

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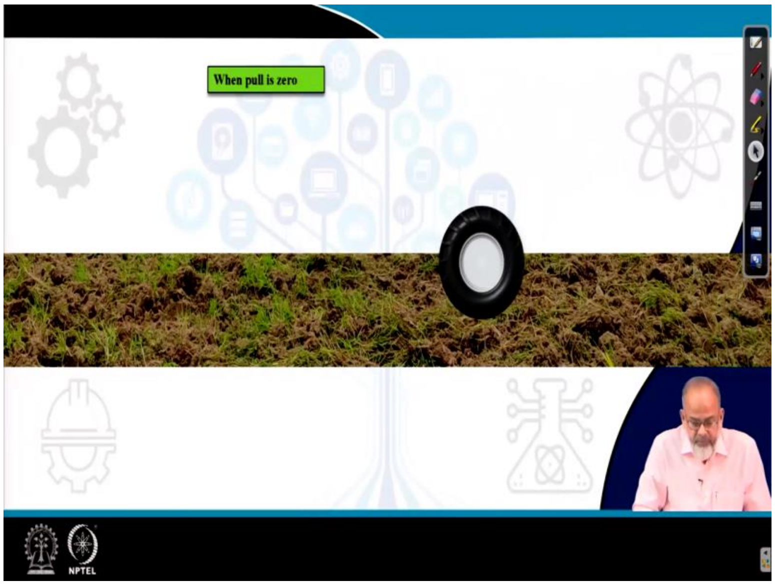

Now, I will show you a slide where a wheel is rotating without any pull that means pull is 0, it is just simply rolling over the soil surface. And now, it is not developing any pull or power because pull is 0.

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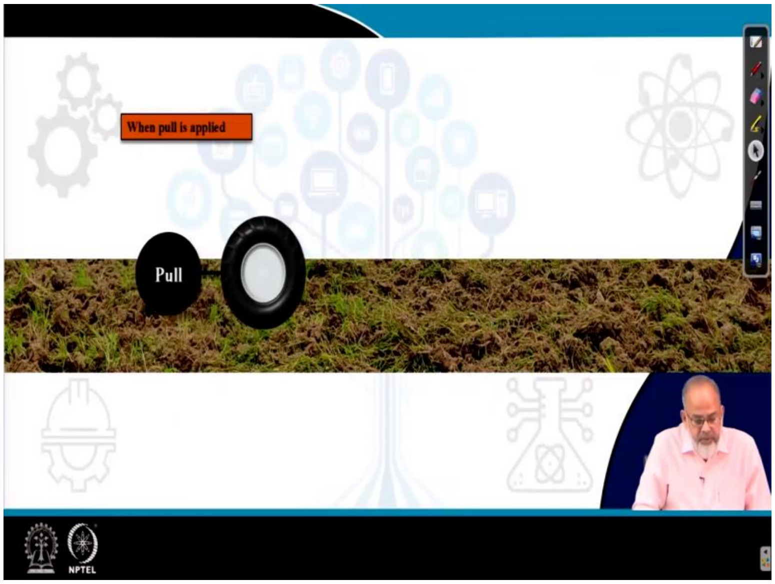

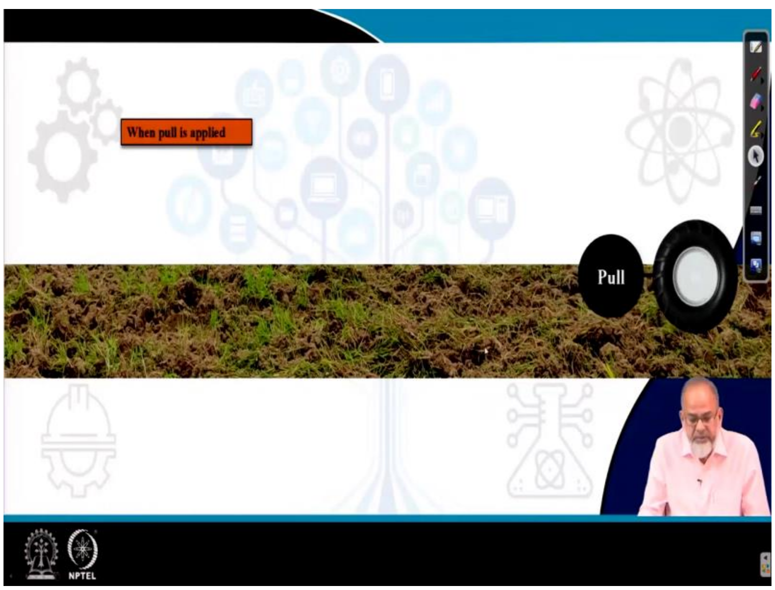

Now, I will show you another slide where a wheel is rotating and we are applying certain pull. When you apply certain pull and then the wheel will interact with soil and it will develop some force which is a tractive force, okay. So, pull when it is developed, it is developed because of the interaction between wheel and soil. If there is no interaction, there will be no pull develop.

So, when there will be interaction, there will be possibility of slip of a wheel. That means we will try to move forward but we are pulling it from pulling the wheel from backward. So, thereby there will be interaction between pull and wheel, wheel and soil, and then finally the wheel is going to slip. So now, I will demonstrate how to find out these parameters like theoretical speed, actual speed and knowing these two parameters, you can derive the value of slip.

So, the setup how I have utilized to measure theoretical velocity and actual velocity that I am going to demonstrate now.

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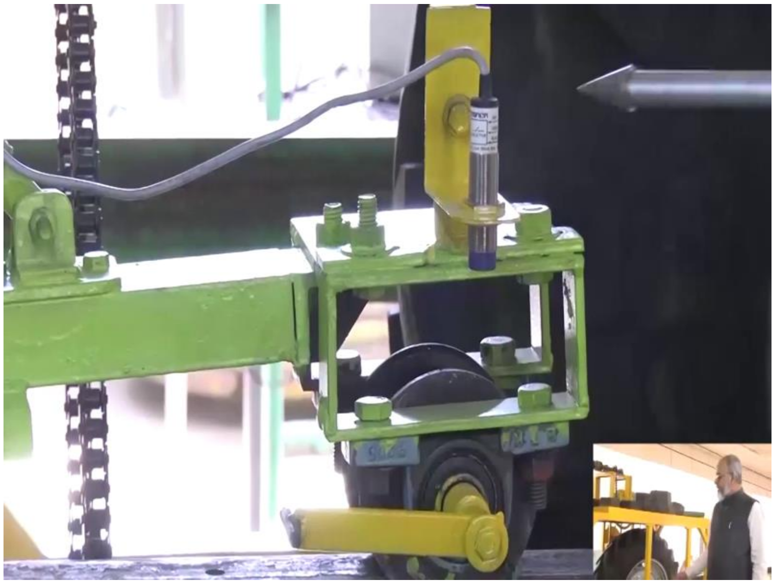

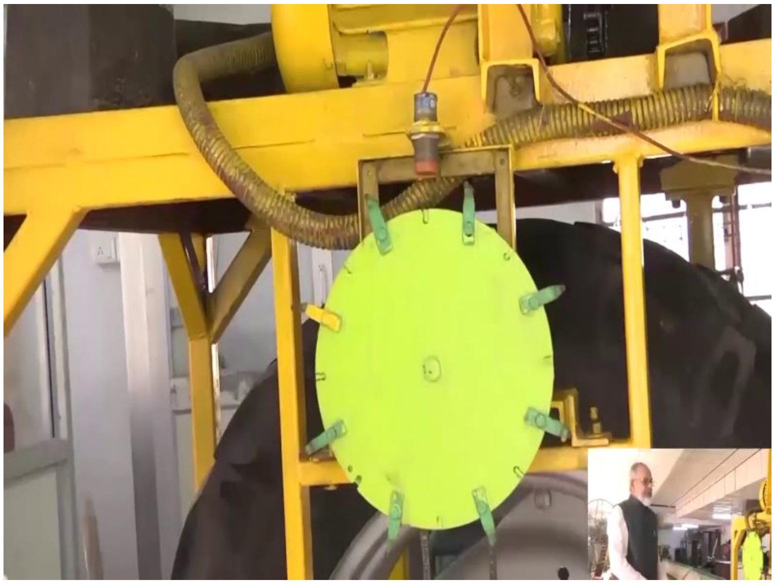

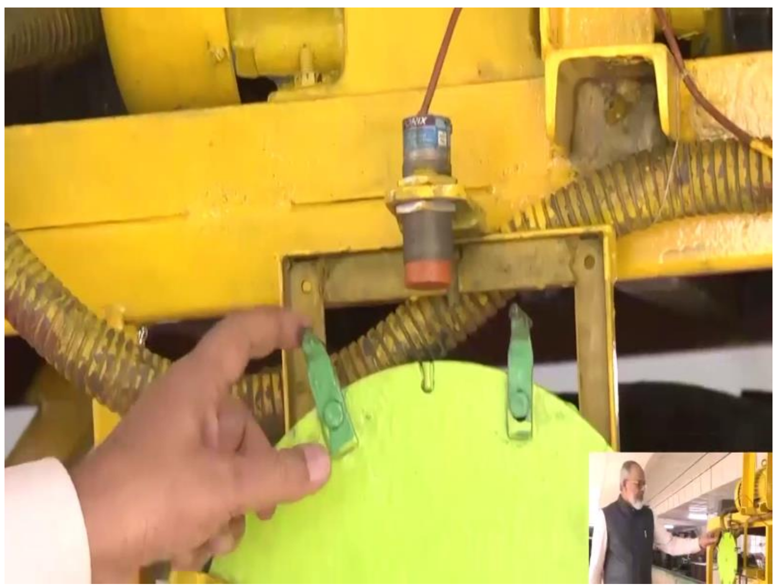

It is important because at a particular slip, we are getting maximum productive efficiency that means the output power is maximum for a given input power. And same is the case with a coefficient of traction, the pull is also maximum at a particular slip. So, that is why we are interested in finding out what is the slip at which we carried out the tractive performance test. So, for measuring slip, we need to know the value of theoretical speed, we need to know the value of actual speed.

So, we measure the actual speed using a proximity setup which is present here. This is the proximity switch and this is the object when the object comes closer to this proximity switch, then the switch will sense its presence and will give a signal and that signal we are going to record in a computer with the help of a data acquisition system and these signals are to be recorded along with the time.

So, if you know how many signals are coming for a given duration of time, then you can find out what is the speed. So, this metal object which is mounted to this arm, this is mounted on a roller and that roller is going to roll over this rail. So, that means, this will give you the actual speed. This is the setup which will be utilized for measuring theoretical speed we have taken power from the axle using a chain and sprocket transmission and this plate is attached to a shaft.

So, the RPM of the axle is equal to the RPM of this plate and then this plate, there are eight spikes provided and on the top of this there is a proximity switch. So, when the spikes or these spikes comes in contact closer to the proximity switch, a pulse will be generated that means, in each revolution, there will be eight spikes or eight times the spokes will come in closer to the proximity switch.

So, if you know the number of pulses and the time which are recorded in the computer through a data equation system, then you can find out how much is the speed of that axial speed. So, which is nothing but your theoretical speed. So, if you know the RPM and then we know the rolling radius, so ωr will give you the theoretical speed. $2\pi N$ will be the ωr and r is the rolling radius, then you can find out what will be the theoretical speed. So, per revolution there will be eight pulses and knowing the time and the pulses, we can find out the RPM.

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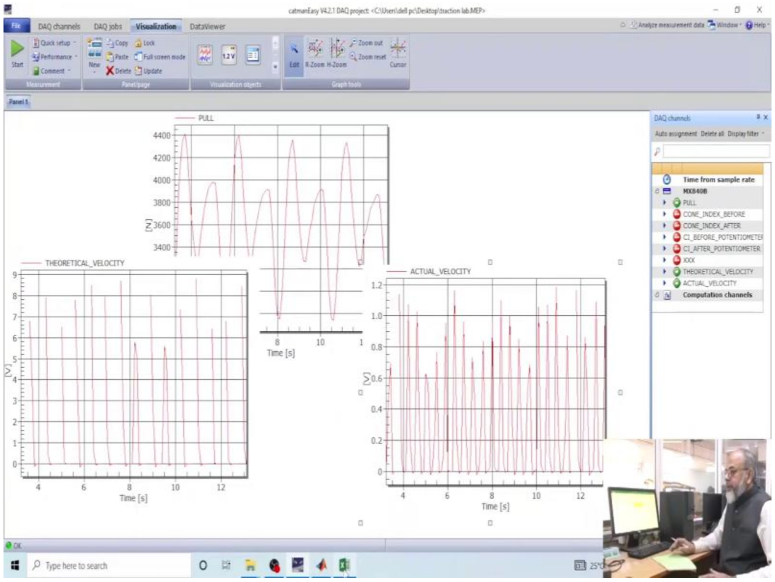

For measurement of pull, we need to know the pulses which are coming related to actual velocity the pulses, which are coming related to the theoretical velocity. So, I can show you the plot how the pulses are varying with time for theoretical velocity. This figure shows you and this is, this figure shows you are the pulses are varying for actual velocity. With the time we are getting more pulses in actual velocity as compared to theoretical velocity. And this has been done for a pull of 44 kg. So, I will show you how to calculate the actual velocity. So, in case of actual velocity, we are getting 27 pulses and for a duration of 11 seconds. So, that means 27 minus 1, we are neglecting 1.

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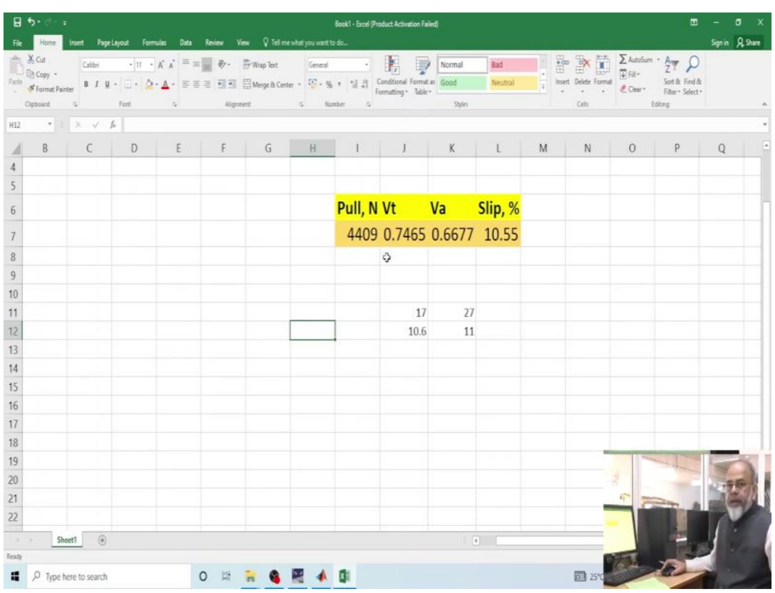

Assuming that we have started at that 0. So, 27 minus 1 divided by 11. So, that will give you the number of pulses per unit time. So, if you know the radius of that wheel and which the spike is mounted, then you can calculate the actual velocity and the radius of that wheel on which the spike is mounted is 0.2825, 4.4 centimeter. So, $2 \times \pi \times r \times (27\text{-}1)/11$. So, that will give you the actual velocity which comes around 0.6677 m/s.

Similarly, for theoretical velocity, we measured number of pulses to be 17 in a duration of 10.6 seconds. So, 17 minus 1, 1 we have neglected assuming that you have started at the beginning we are getting a pulse. So, 17 minus 1 divided by 8, we are dividing 8 because there will be a 1 revolution, in 1 revolution that will be 8 pulses. So, 17 minus 1 divided by 8 and the time duration is 10.6 second, so that will give your number of revolutions per second.

So, $2\pi r$ will give you the distance travelled in 1 revolution. So, distance travelled in 1 revolution multiply by number of revolutions per second. So, that will give you the theoretical velocity which comes around 2.7465. So, now, theoretical speed is known, actual speed is known. So, to find out slip, it is nothing but, $(V_t - V_a)/ V_t$, theoretical velocity if you denote as V_t, actual velocity if you denote as V_a, so $(V_t - V_a)\times 100/ V_t$.

So, that will give you slip percent, so $(0.7465 - 0.6677)\times 100/0.7465$. So, that way it gives a slip of around 10.55 percent. So, for a pull of 44 kg and for a loading condition that means, total weight coming on the wheel as 1400 kg and a soil condition where the cone index is 630 kilo Pascal, we are getting a slip of 10.55 percent.

So, for measuring slip, the arrangement which are made is quite accurate and we have calibrated it manually also by putting a check mark how many revolutions it is making and then finding out the time. So, number of revolution by time we measure so that way we have already calibrated these proximity switch output to the actual output. So, this will give you a mechanism by which you can acquire data related to slip which is a very important parameter while evaluating the tractive performance of a wheel, or a tyre, thank you.

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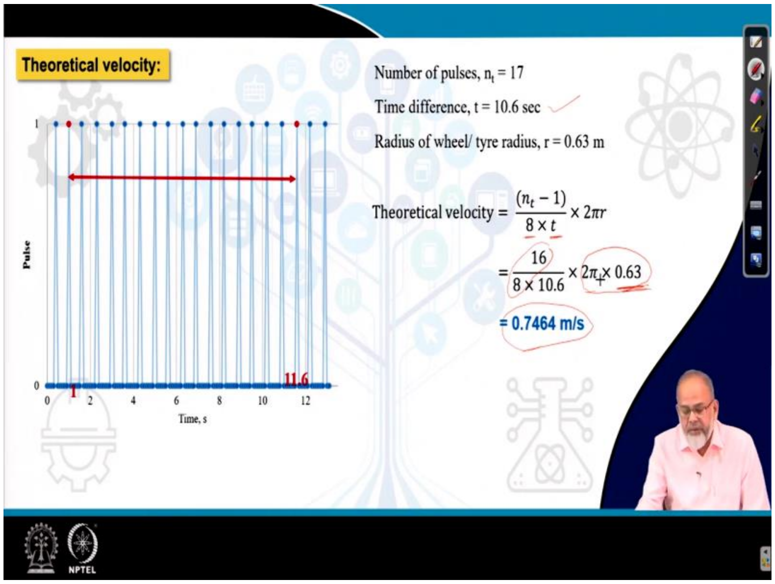

For measuring theoretical velocity, we have utilized a proximity switch and there are 8 spikes which are fixed to a plate which is attached to a shaft, so when there is complete revolution of that shaft you will have 8 spikes because the proximity switch is going to sense those spikes and thereby it will give a signal and that signal is in the form of spikes.

So, the output will be like this. There will be spikes at regular intervals and what we are measuring is the number of spikes and the time duration. So, once you know the number of spikes and the time duration, from there you can find out what will be the theoretical velocity. For example, here we have got so many spikes now, I have indicated a spike with red one and another spike with red one here.

So, the difference between these 2 is nothing but your, the time duration which is 11, 10.6 second. Now, what are the number of spikes we count if you count it 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16. So, 16 spikes, one spike I have not counted in the beginning so 16 spikes plus 1, 17 so 17 minus 1 that will give you 16 spikes, and in 1 revolution of the shaft, there will be 8 spikes.

So, I have divided by 8, I have divided it by 8. Now, the time for getting that 16 spikes will be 11.6 minus 1, so 10.6 seconds. So, time we know, number of spikes we have counted, then we try to find out the theoretical speed by knowing the radius of that shaft, that wheel, this shaft is attached to the wheel. So, whatever is the rotation of the wheel or RPM of the wheel, same RPM will be there for the shaft. So, in 1 revolution, it is covering 2πr distance.

So, for these many revolutions 16 by 8 that means it is giving you 2 revolutions. So, 2 revolutions into 2πr divided by the time that will give you, what is the theoretical speed. So, the important thing here is, how many spikes and what is the time if you know and what is the radius of the wheel rolling radius, then we can find out very easily what will be the value of theoretical velocity. So, next thing is how to measure the actual velocity.

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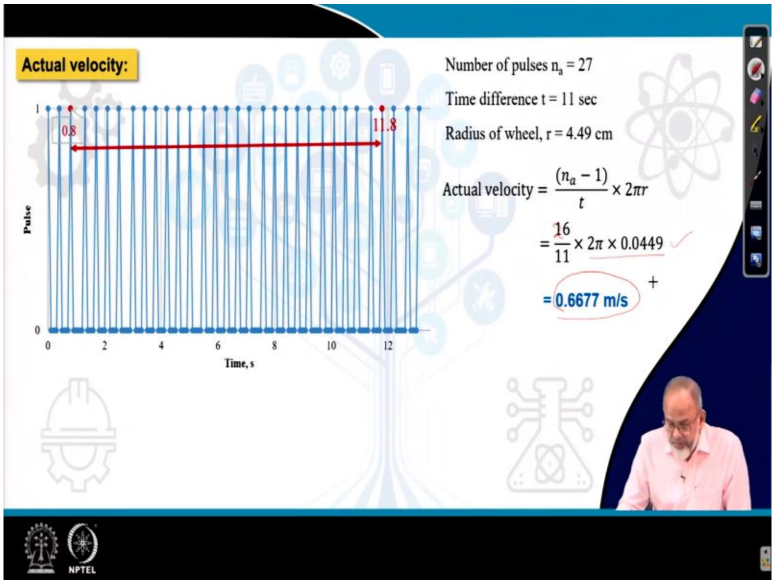

In the setup, there is a proximity switch and there is only 1 spike. So, in each revolution, that will be only 1 spike for measuring the actual velocity and that spike is mounted over a roller which is, which will be rolling over a rail in the soil bin, which I have demonstrated in the video. Now, I will follow the same procedure, how many spikes what is the duration to get those spikes that means the time difference.

If I know then I can find out what will be the value of number of revolutions, then when I know the radius of that wheel on which the spike is mounted, so 2πr will give you what is the distance it is covering in 1 revolution. So, number of revolutions into 2πr, divided by the time that will give you what is the velocity and that velocity is taken as the actual velocity.

So, I have measured at 2 places, one place is for theoretical velocity and the other places is for actual velocity, okay. So, now, actual velocity, if you count, I have started from 0.8 and have gone up to 11.8 seconds, and in between I am getting 27 spikes. So, 27 minus 1 by 11. So, that will give you know 27 minus 1, sorry 26 by 11 into 2πr.

So, this is why, this is 26, so 26 by 11, this is number of revolutions per second, then I have multiplied the distance in 1 revolution, this many this much distance it has covered, so that way I am getting actual velocity as 0.6677 m/s. So, after getting these 2 parameters, 2 values, that is theoretical velocity and actual velocity, the next thing is how to compute slip.

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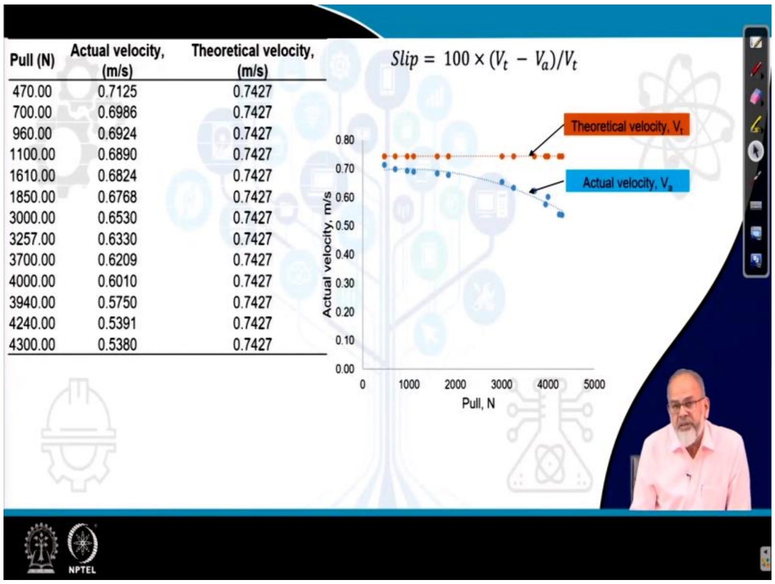

So, I have measured pull, I have measured actual velocity and what is the theoretical velocity. So, these from this data when I try to plot actual velocity versus pull, that mean pull is on the x axis and actual velocities in y axis, then what you can observe is in case of theoretical velocity, it is a constant value almost constant whereas, in case of actual velocity it is going down.

So, when we increase the pull there will be more interaction between wheel and soil thereby there will be more slip. So, as a result, when there is more slip, the actual velocity is reduced from the theoretical velocity by a more amount.

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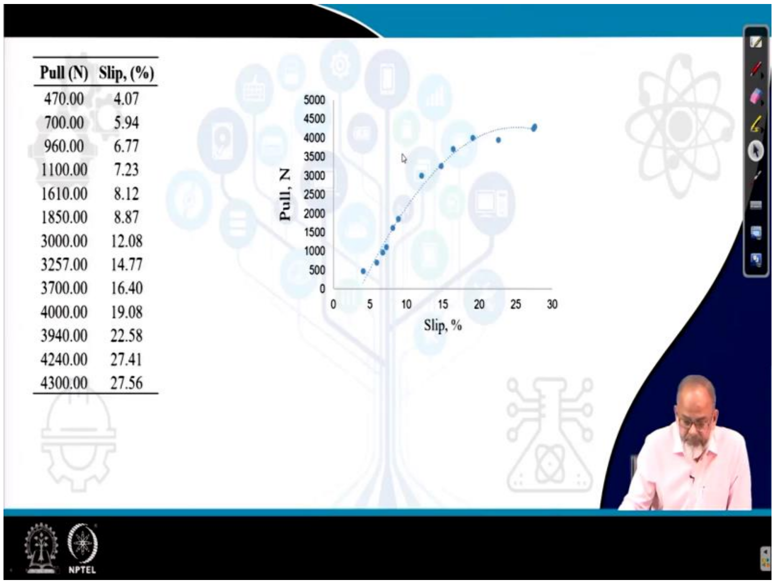

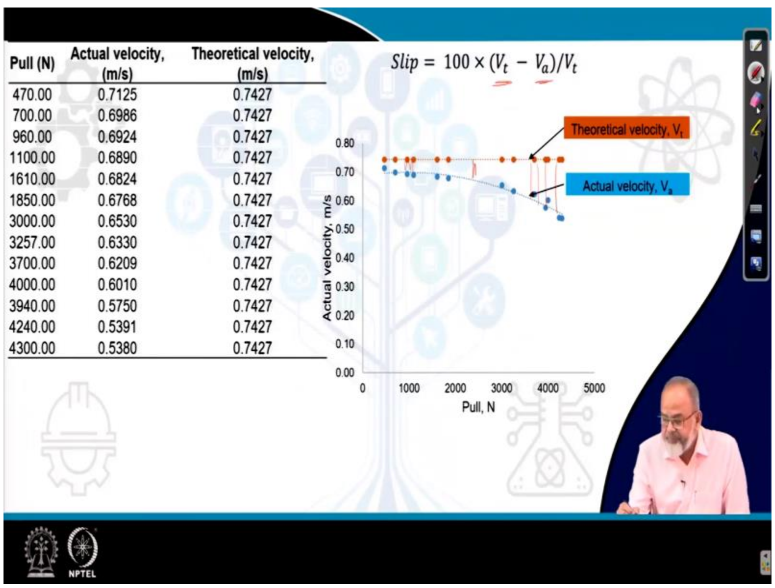

You can see here this difference here and this difference here, they are not same as you increase pull towards higher side there will be more and more of slip. So, now, how to find out that slip, if I know the value of theoretical velocity, if I know the value of actual velocity, then theoretical velocity minus actual velocity by theoretical velocity into 100, that will give you what is the slip in percent. So, that way I have calculated slip.

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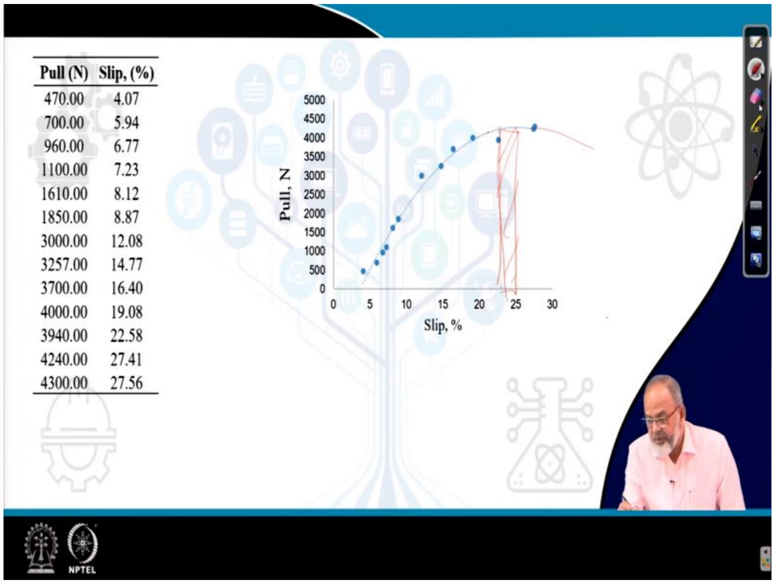

Now, the next slide, pull versus slip. Pull is on the y axis and on the x axis I have taken slip. So, what we are observing here is pull is increasing up to a certain extent, after that, it is almost reaching to a peak and remaining constant there. So, beyond that if you increase slip, if you increase slip, it will come down that means, initially pull will increase as the slip is increasing and then it is reaching to a peak.

And then after that, it is going down if you further increase slip that means, if you further increase pull, so we are getting a peak around 25 like that. In this patch you are getting a maximum slip. So, this is the procedure which has to be followed for finding out slip. And if you want to know how pull is varying with slip or how actual velocities vary with pull, then we have to have data related to pull and actual velocity then we can plot it to know how the velocity actual velocity is varying and how the pull is varying with slip. Thank you.