Traction Engineering
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Lecture 5
Tutorial

Hi everyone, this is Professor H. Raheman from Agricultural and Food Engineering Department, IIT Kharagpur. I welcome you all to this NPTEL online course on Traction Engineering. This is lecture 35 where I will take a tutorial how to find out the optimum ballast level. And what will happen when you cross this optimum ballast that means in over ballast or under ballast, then how it is going to affect the performance for a 35 hp tractor working at a forward speed of 1.25 meter per second.

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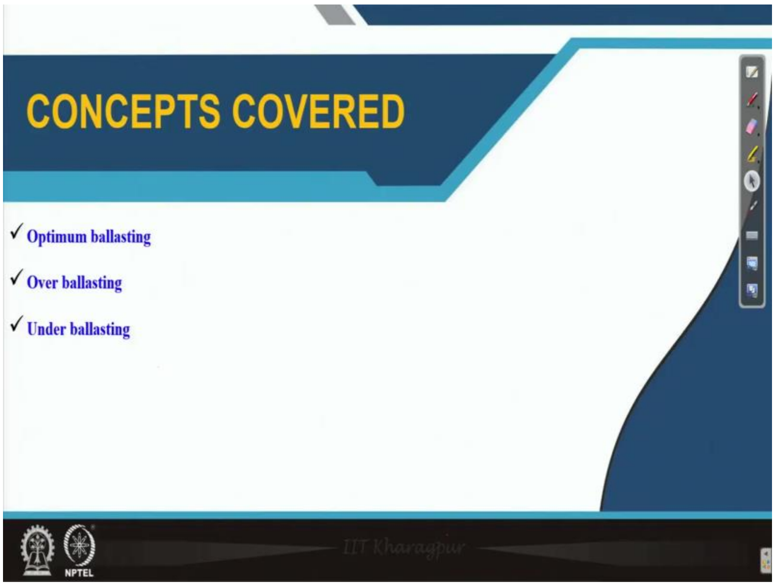

So, mainly I will try to highlight the optimum ballasting conditions based on the recommendations given by Dwyer then I will try to find out what will happen if you over ballast it and if you under ballast it.

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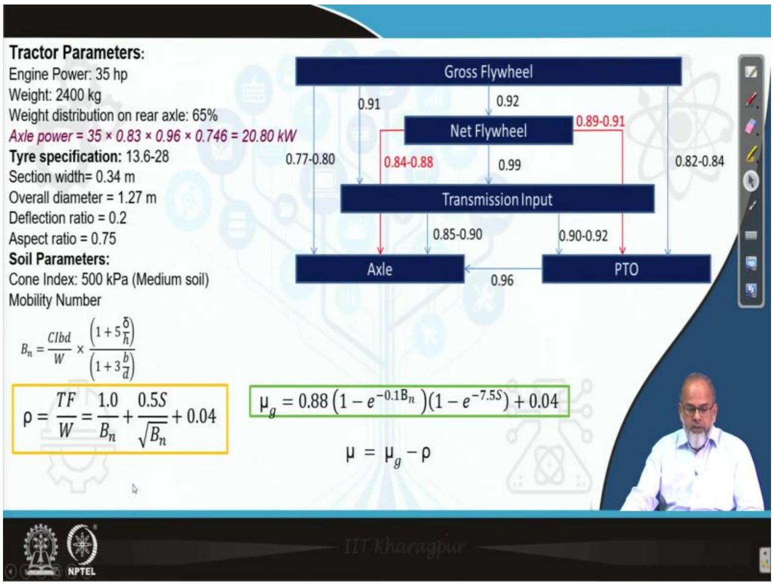

So, when engine power is 35 hp, weight of that tractor is 2400 kg with a static weight distribution of 65 percent on the rear axle and 35 percent on the front axle. So, this is the two-wheel drive tractor. So, I have given you the transmission efficiencies. If you are moving from flywheel to PTO or flywheel to axle, we need to find out how much will be the axle power if the engine power is 35 hp. So, what I have done is, I have taken 35 hp converted to kilo Watts, so multiply with 0.746. And then I multiplied with the transmission efficiency, that means, I have converted the flywheel power to PTO power and then from PTO power to axle power, I multiplied with 0.96. So, that way I am getting 20.80 kW.

So, for an engine power of 35 hp, I am getting 20.8 kW for the axle and the tyre specification is which is fitted to the rear axle is 13.6-28. This is a bias ply tyre. So, section width is 0.34 meter and overall diameter is 1.27 meter and the deflection ratio we have taken as 0.2 and considering an aspect ratio of 0.75, we will verify the ballasting conditions on a medium soil where the cone index is 500 kPa.

So, as I said the main thing is the mobility number. So, we follow the mobility number developed by Brixius. So,

$$B_n = \frac{CIbd}{W} \times \left(\frac{1 + 5\frac{\delta}{h}}{1 + 3\frac{b}{d}} \right)$$

So, all the equation developed by Brixius I have noted down here, a ρ is the motion resistance ratio and μ_g is the gross torque ratio or the coefficient of gross traction and the difference is difference of gross coefficient of traction and motion resistance is nothing but your coefficient of traction COT which is denoted as μ.

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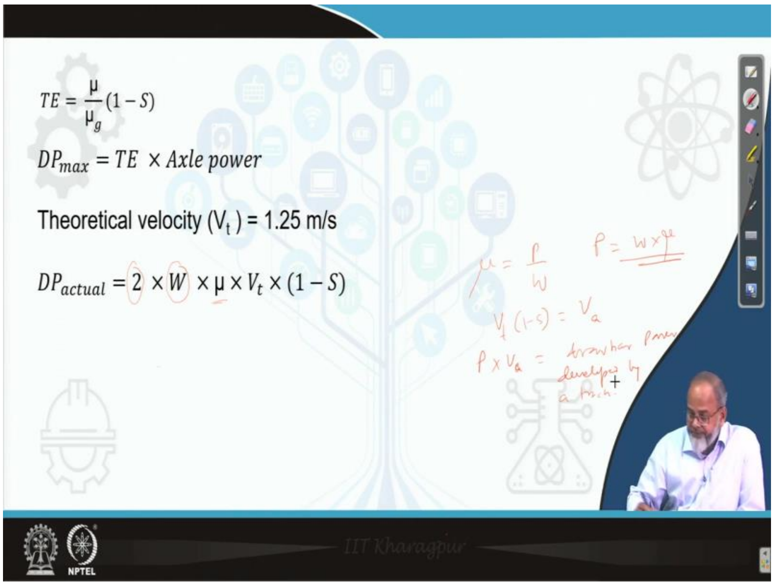

And tractive efficiency is nothing but the axle power by, sorry drawbar power by axle power or in other words,

$$Tractive\ efficiency = \frac{COT}{CGT} \times (1-s)$$

s is the slip. And drawbar power maximum if you want to calculate then axle power has to be multiplied with tractive efficiency and theoretical speed of operation we have taken as 1.25 m/s. Now, what is the DP_{actual}, that means drawbar power actual? So, that you have taken from the coefficient of traction side.

Since there are 2 wheels so, I multiplied with 2, W is the dynamic weight on the rear axle on one of the wheels and mu is the coefficient of traction of one of the wheels. So, coefficient of traction is nothing but μ is the coefficient of traction, that is nothing but P/W. So, W×μ will give you P. So, Drawbar power will be equal to $W \times \mu \times V_t \times (1-s)$, $V_t \times (1-s)$ will give you the value of V_{actual}. So, P × V will give you drawbar power. I have multiplied with the 2 that means for 2 wheels I multiplied by 2 so, P × V will give you drawbar power developed by your tractor. These are the governing equations based on which I am going to discuss.

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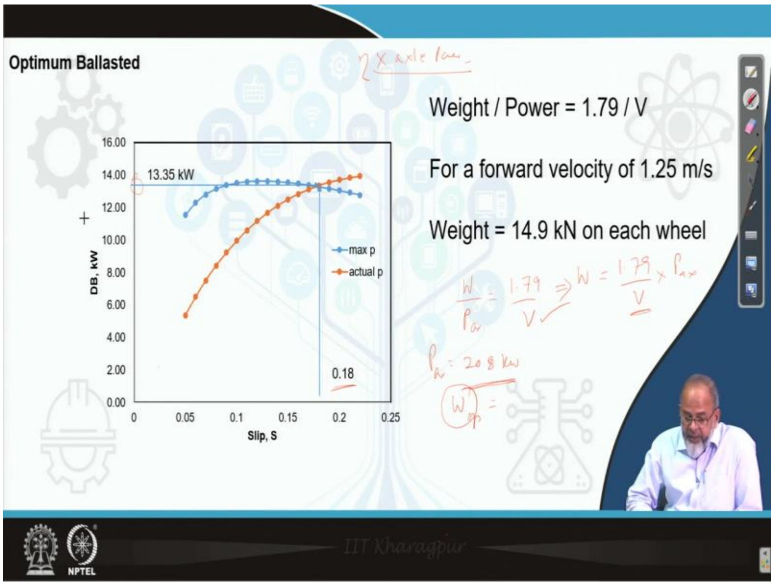

Now, for optimum ballasted condition that means, I followed the Dwyer's recommendation which is nothing but W/P, W is the dynamic weight, P is the axle power this is equal to 1.79/V. So, for 35 hp tractor we calculated that axle power is around 20.8 kW. So, 20.8 kW is the actual power, P_{axle}. Now, these the actual speed we have taken as 1.25 meter per second under this condition. What should be the weight optimum weight so, that will extract the maximum power from the tractor. So, W from this expression W will be equal to $(1.79/V)\times P_{axle}$.

So, P_{axle} is known, V is known, so, I will find out what is the value of W and based on that we try to plot the blue line gives you the maximum power and this orange color line gives you the actual power which is delivered by the tractor. So, to get this blue color line, what we have to do is, the tractive efficiency has to be multiplied with axle power that is it and tractive efficiency has to be multiplied with axle power. So, this has been plotted for different slip values starting from 0.05 that means 5 percent slip to up to 22 to 23 percent slip.

So, what we observe is, at one point, the actual power which is transmitted but the tractor is crossing the maximum power which a tractor is able to deliver. So, that point I have indicated is occurring at a slip of 18 percent and the power which we are getting is 13.35 kW.

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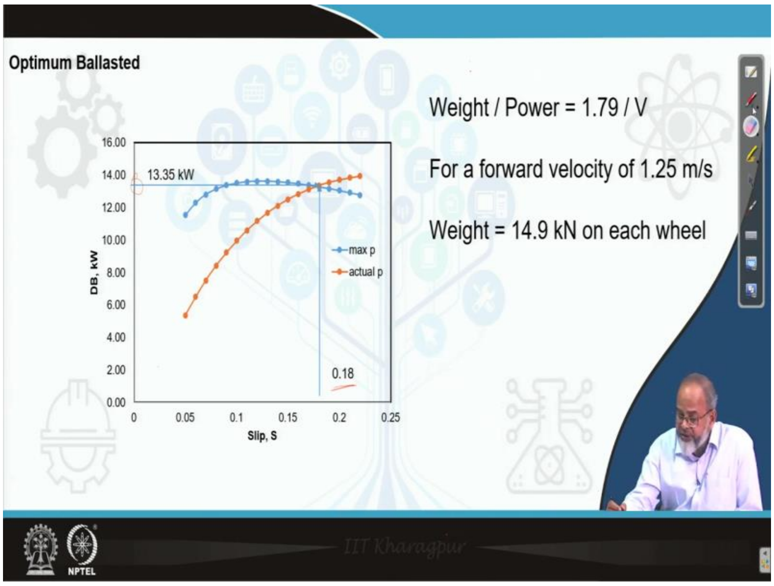

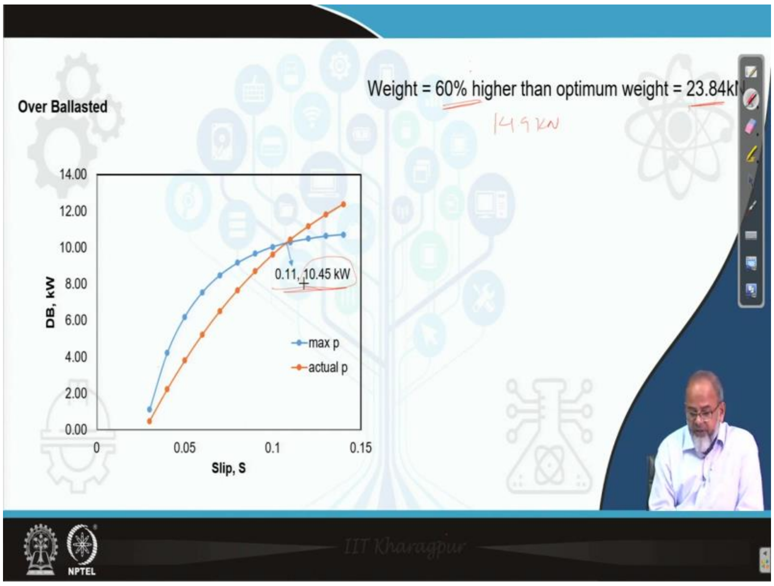

Now, I will show you if I reduce this weight, if I increase the weight or reduce the weight, both the conditions I am going to check now. So, weight required is 14.9 kN. Now I will increase the weight by 60 percent that means, initially it was the optimum loading condition was 14.9 kN now, I have increased by 60 percent so, that becomes 23.84 kN and I carry out the same exercise. That means I tried to plot the maximum power able to be transmitted by the tractor which is denoted by the blue line and the actual power which is delivered that is represented by this orange line.

So, what I observed now is, it is touching at a point both the curves are meeting at a point, this point which refers to a slip of 11 percent and the power maximum power is only 10.45 kW.

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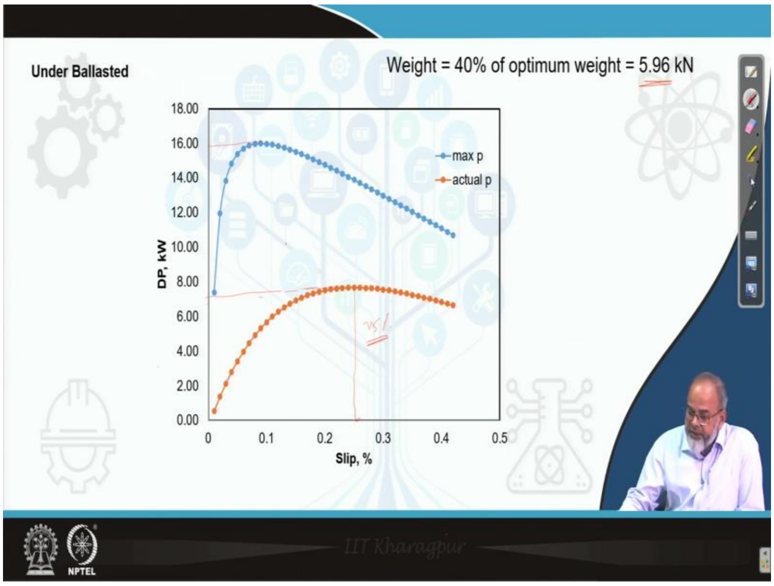

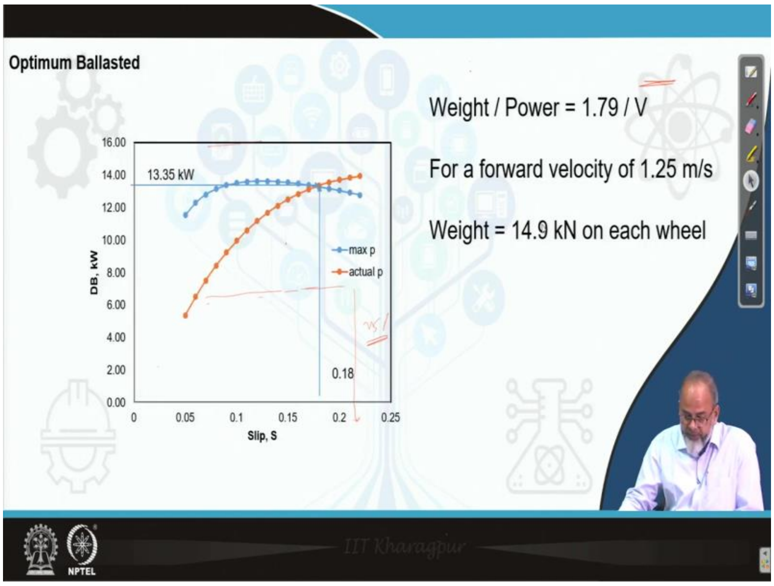

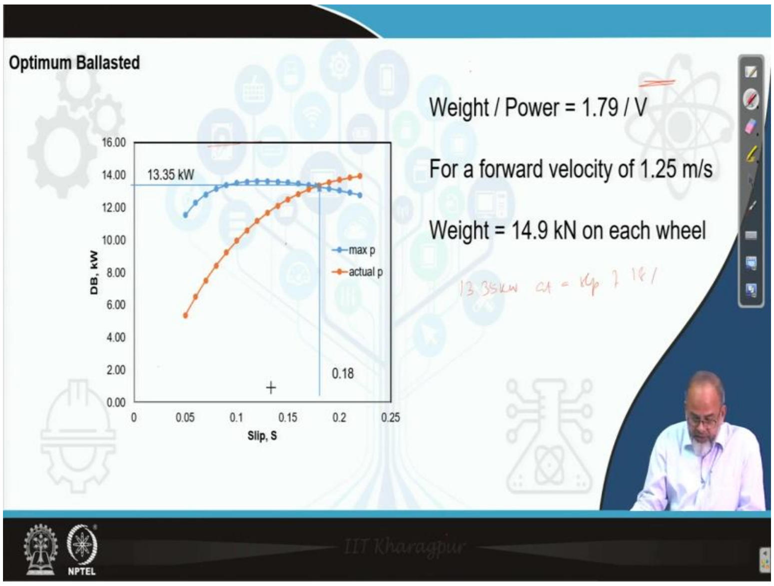

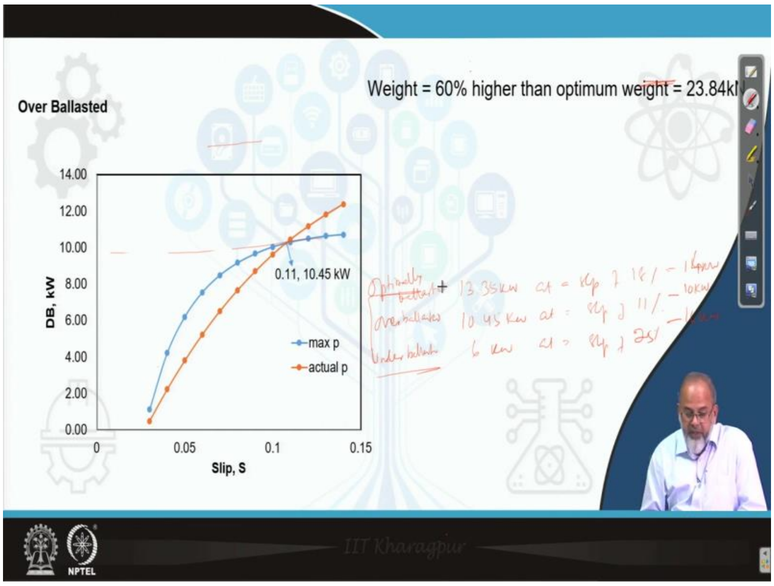

Now, what happened, I tried to decrease the weight instead of 14.9 kN, I have decreased the weight to by 40 percent. Now, the weight has become 5.96 kN. So, again I carried out the same exercise, that means, blue line is for maximum power which a tractor is able to transmit and the orange line is the power which is actually transmitted. So, what we observe is, there is a huge difference that the tractor is able to develop, transmit 16 kW, but we are only utilizing 6 kW, 10 kW is lost and the maximum power which are utilizing is at a slip of 25 percent which is not permissible, 7 kW or 25 percent which is not permissible.

So, if you compare these three, initially we are getting an optimum ballasting condition. We are getting somewhat 13.35 kW at 18 percent slip, sorry 18 percent slip. So, optimum condition 13.35 kW at a slip of 18 percent and in the over ballasting condition, we got 10.4 kW at slip of 11 percent. This is over ballasted and correspondingly this over ballasting condition, if you draw the line, it is only 10 kW, maximum power is only 10 kW.

Now, under ballasted condition, maximum power is 16 kW, but it is only utilizing 6 kW at slip of 25 percent and if we look at the optimum condition, the maximum power developed is around 14 kW. This is 14 kW. So, this is the difference is you are getting if you are, this is optimally ballasted.

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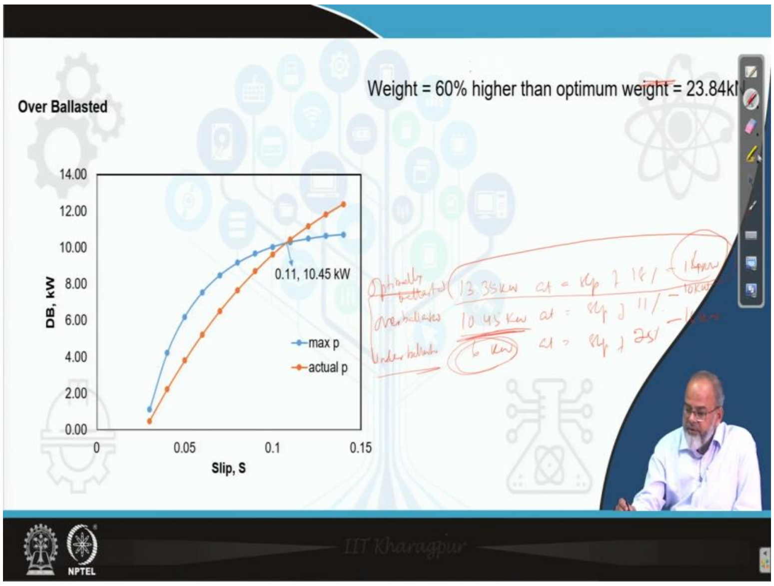

So, look at these figures now, so, that itself indicates what is exactly happening. So, you are closer to 14 kW, the maximum power where, which a tractor is able to transmit. Whereas in case of over ballasting condition, we are developing, only we are utilizing only 10.4 kW. We are supposed to get 14 kW, but we are not developing 14 kW. There is a loss. At under ballasting conditions, we are only utilizing 6 kW. we are supposed to utilize 14 kW.

So, whether it is over ballasted, whether it is under ballasted, in both cases there is a reduction in power which a tractor is able to transmit. So, both are not suitable. So, always we try to maintain a weight which is closer to the optimum ballasting condition, so that we can extract maximum power from the tractor, otherwise there is a loss.

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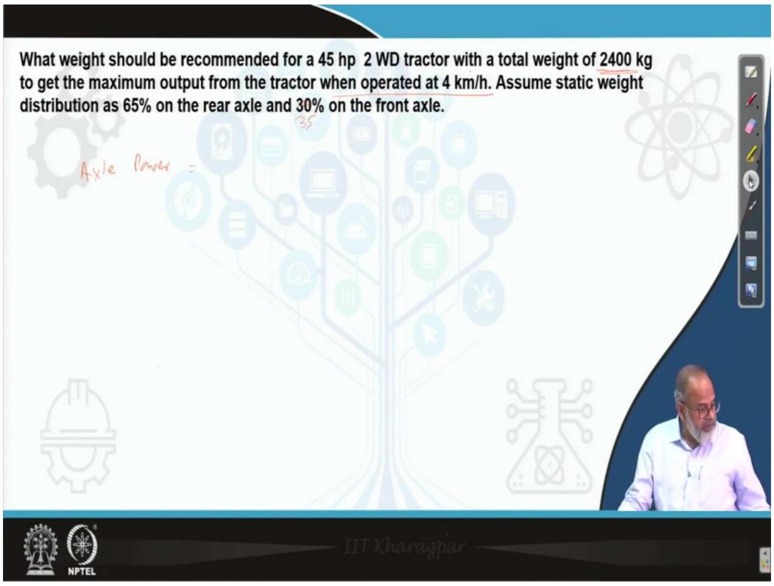

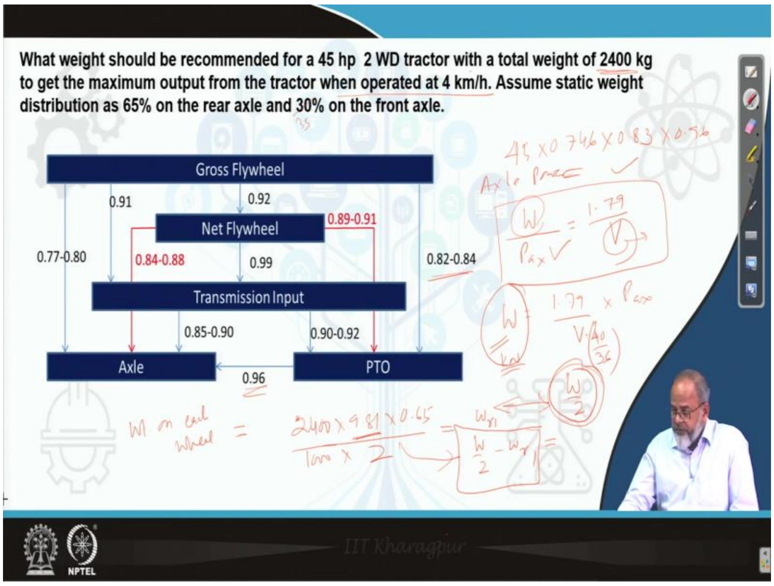

Now, let us see one more problem. What weights would be recommended for a 45 hp 2 wheel drive tractor with a total weight of 2400 kg to get the maximum output from a tractor when it is operated at 4 kilometer per hour? Assume static weight distribution as 65 percent on the rear axle and sorry this is 35 percent on the front axle. So, how do we recommend this? Total weight is given as 2400 kg and weight distribution given as 65, this is 35 percent in different on the front axle and 65 percent on the rear axle then it is to be operated at a 4 kilometer per hour. So, there is actual speed, we need to operate the tractor at 4 kilometer per hour.

So, the recommendation is, if it is a 45 hp tractor, what is the power which is available at the axle you have to find out. What is the axle power? How do you find out? You need to know the transmission losses. So, if I put this, this is the transmission losses. That means 45 hp into

0.746, that becomes a kW, then I multiply with 0.82 to 0.84. Suppose, I take 0.83 so, that will give you power at the PTO and then I again multiply with 0.96 so, that will give you axle power. Since we have to follow the Dwyer's recommendation for optimum ballasting.

So, dynamic weight by axle power will be equal to 1.79/V, V is the actual speed. So, that means, P axle is known from here, then W has to be found out. So, 1.79/V, V is nothing but your 1.4 kilometer per hour so, 40 by 36, 1.11 meter per second. So, this into P axle so, that will be the dynamic weight which is to be given in kilo Newton.

Now, understand the condition, you have got 65 percent of the weight so, that means 2400 into 9.81 into 0.65 so, divided by 2 that will give you weight on each wheel. So, suppose this is the W rear 1. Now, we are getting a value of W from here. So, I multiply 9.81 that will give you a N then I should divide by 1000 so, that will give you a kN.

Now, this is the weight on the axle, dynamic weight on the axle. So, I will divide by 2 to find out what is the dynamic weight required for getting the optimum ballasting. So, W/2 so, now we will find out what is the difference between these two, $(W/2)-W_{r1}$. So, that is the amount of weight which has to be added to either of the wheels. That means, you have to add to each of the wheels not either of the wheels. You have to add this amount of weight to the rear wheels then only you can get the optimum ballasting condition and we can able to develop maximum power. The tractor can able to transmit maximum power.

So, the main thing is, first we have to convert the engine power to axle power because the Dwyer's recommendation is based on axle power. So, that is why we have to convert the engine power to axle power, if drawbar power is given then from drawbar, we can also convert to axle power taking the tractive efficiency into account. But since in this, problem is, engine power is given so, directly we multiply with this transmission ratios to find out what is the axle power, then once you know the axle power following the Dwyer's recommendation W/P_{axle} is equal to 1.79/V. So, we know, at what speed we are going to move in the field. So, that will decide how much should be the dynamic weight on the rear axle.

Now, dynamic weight on the rear axle, if you find out from this equation because P_{axle}, axle power is known, velocity, a forward velocity is known. So, now, you find out what is the total axle weight dynamic then divided by 2 to find out what is the total weight coming on each of the wheels, that is a requirement. Then what is coming in the actual condition which is nothing but from the starting weight distribution we can find out. Since this is given in kg, so, I have multiplied with 9.81 into 0.65 by 1000, so, make it kN then divided by 2 to find out how much the weight which is coming on the one of the rear wheels.

So, now, the difference of W/2 and then weight which is coming from here which is denoted as W_{r1} so, that will give you how much is the extra weight which is required and that has to be added to the wheels of the rear axle. So, I have given you how to recommend the optimum ballasting weight, so that it can extract maximum power. Then also have a discus if you are overloading it or you are under loading it then how it is going to affect the performance of the tractor.

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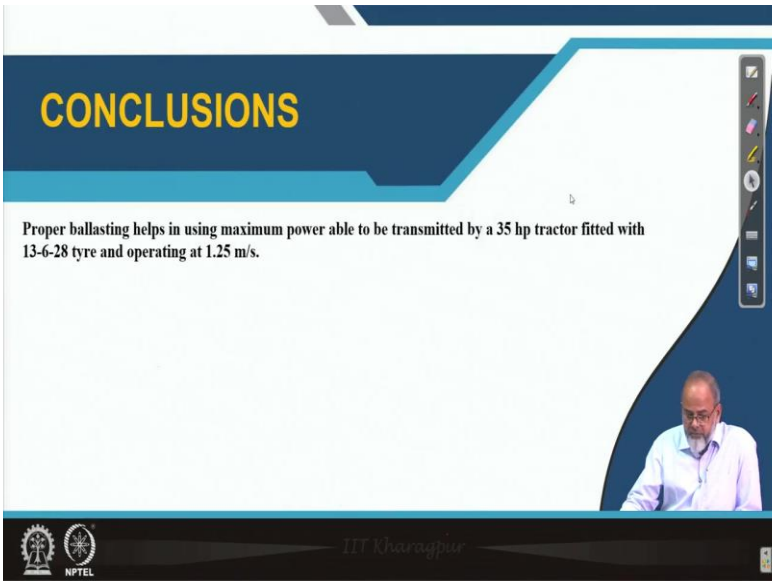

So, this will give you a more or less an idea how to go for ballasting two wheel drive tractor to get the maximum output from the tractor. That is all. Thank you.