Traction Engineering
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Lecture 34
Optimum ballasting of a front wheel assisted tractor

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 34 where I will try to cover optimum ballasting for the front wheel assisted tractor. And I said front wheel assisted tractor means it is four wheel drive tractor where the tyre sizes are not same like normal four wheel drive tractor.

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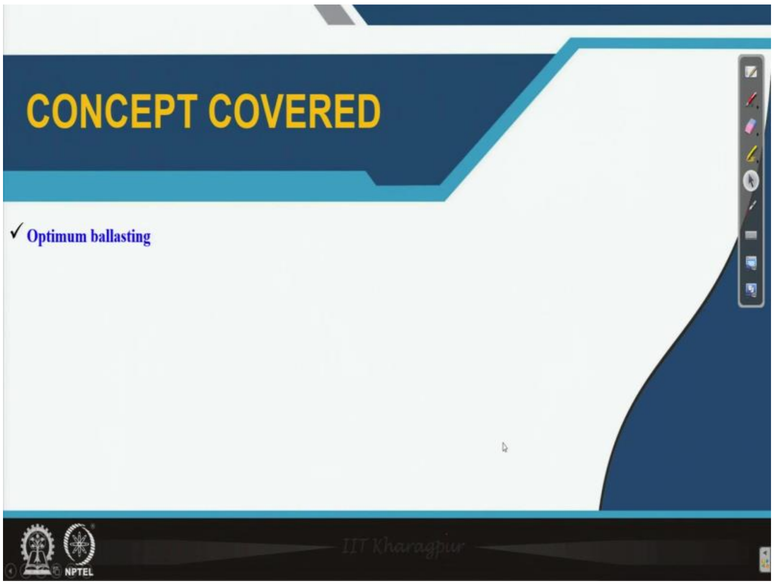

So, I will try to cover the concept is, what is optimum ballasting, how to obtain optimum ballasting in case of front wheel assisted tractor.

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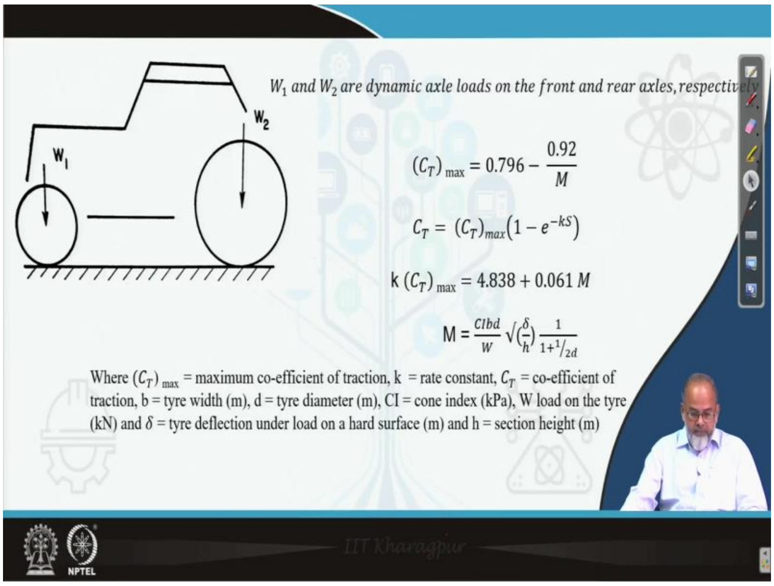

As I said front wheel assisted tractor, from the outside it looks like a two wheeled tractor.That means, the front wheels are smaller and the rear wheels are bigger. But they are powered wheels unlike your two wheeled tractor where the only the rear wheels are powered wheels. So, now, I want to find out what is the optimum ballasting conditions in case of a front wheel assisted tractor? Let W1 be the dynamic weight on the front axle. And W_2 be the dynamic weight on the rear axle.

So, I will take the help of Gee-Clough equations, who has developed a set of equations for predicting the performance of a tractor or performance of a wheel, based on data obtained from 170 field conditions. So, that is a huge number. So, he has developed a, basically four equations you can see. One is related to $(C_T)_{max}$, the other one is related to C_T, the third one is related to $k(C_T)_{max}$ and the fourth one is mobility number. He has also developed application for rolling resistance which I have not included here, because we are not interested for the rolling resistance.

Now, if you look at the equation, whether $(C_T)_{max}$, C_T, $k(C_T)_{max}$, they are all functions of mobility number and the mobility number he defined in a different way

$$M = \frac{CIbd}{W}\sqrt{\frac{\delta}{h}}\left(\frac{1}{1 + {}^{b}/_{2d}}\right)$$

CI is the cone index, bd, b is the section width of the tyre, d is the diameter of the tyre, W is the dynamic weight of the wheel, δ is the tyre deflection under load on a hard surface and h is the section height.

Now, if we look at $(C_T)_{max}$, it is

$$(C_T)\max = 0.796 - \frac{0.92}{M}$$

and C_T can be related to $(C_T)_{max}$ when exponential relationship

$$C_T = (C_T)_{max}(1 - e^{-kS})$$

this k is the rate constant, $k(C_T)_{max}$ is given as

$$K(C_T)\max = 4.838 + 0.061\,M$$

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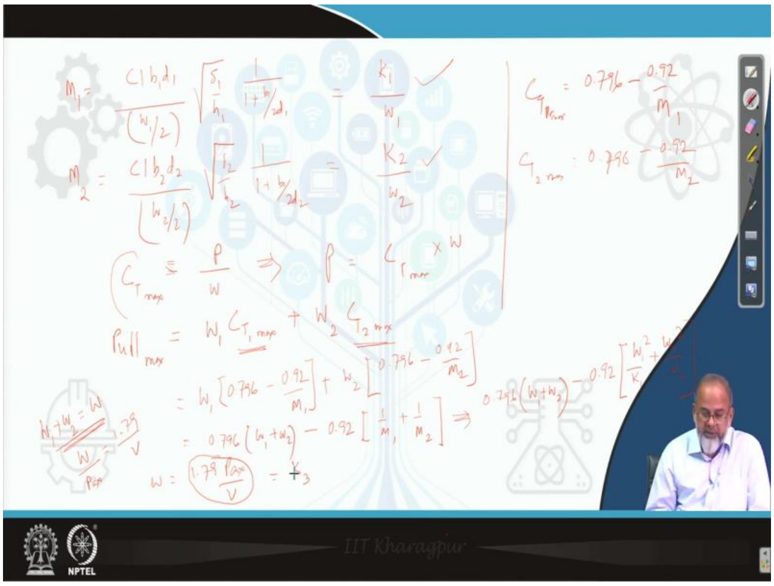

Now, with the help of this, I will try to derive the equations for optimum ballasting for a front wheel assisted tractor. Now, mobility number for the front wheel, assuming that weight is equally distributed among the front axle among the wheels mounted on the front axle and similar is the case in the rear axle. So, mobility number M_1 if I denote it as the mobility number related to front axle tyres then

$$M_1 = \frac{CI\,b_1 d_1}{\left(W_1/2\right)}\sqrt{\frac{\delta_1}{h_1}}\left(\frac{1}{1 + b_1/2d_1}\right)$$

So, for a given size of tyre and for a given soil condition the inflation pressure is varied with loads so that del by h remains constant. So, I can write this as this, all these factors are almost constant except W. So, I can write this as a constant K_1 divided by W_1. Here I have taken W_1 by 2 because W_1 is the weight which is coming in the front axle.

Similarly, for the rear tyres the mobility number I denoted as M_2

$$M_2 = \frac{CIb_2 d_2}{\left({W_2}/{2}\right)} \sqrt{\frac{\delta_2}{h_2}} \left(\frac{1}{1 + {b_2}/{2d_2}} \right)$$

Again, for a given tyre size and given soil conditions, I can take this as a constant K_2 divided by W_2. So, the maximum pull which we can develop will be equal to $(C_T)_{max}$. We know, $(C_T)_{max}$ is nothing but pull upon dynamic weight. So, now, if I multiply $(C_T)_{max}$ with W dynamic load then I can get P. So, from here I can say P will be equal to $(C_T)_{max}$ into W.

Now, the total pull which will be developed by the tractor will be summation of the pull developed by all the rear axle tyres and the front axle tyres. So, what I will do is, pull maximum, this will be

$$Pull_{max} = W_1 C_{T1_{max}} + W_2 C_{T2_{max}}$$

where $(C_{T1})_{max}$ refers to the coefficient of traction, maximum coefficient of traction for the front wheel and $(C_{T2})_{max}$ refers to coefficient of traction of the rear wheel.

We have got the expression for (C_T)max,

$$(C_T)\max = 0.796 - \frac{0.92}{M}$$

For $(C_{T1})_{max}$ –

$$(C_{T1})_{max} = 0.796 - \frac{0.92}{M_1}$$

For $(C_{T2})_{max}$ –

$$(C_{T2})_{max} = 0.796 - \frac{0.92}{M_2}$$

Then

$$Pull_{max} = W_1 \left(0.796 - \frac{0.92}{M_1}\right) + W_2 \left(0.796 - \frac{0.92}{M_2}\right)$$

$$Pull_{max} = 0.796(W_1 + W_2) - 0.92\left(\frac{1}{M_1} + \frac{1}{M_2}\right)$$

Now, we have to substitute for M_1, in previous case we have calculated M_1 is nothing but K_1 by W_1 and M_2 is nothing but K_2 by W_2. So,

$$Pull_{max} = 0.796(W_1 + W_2) - 0.92\left(\frac{{W_1}^2}{K_1} + \frac{{W_2}^2}{K_2}\right)$$

So, for maximum efficiency we are recommending from Dwyer equation ballasting recommendation

$$\frac{W}{P} = \frac{1.79}{V}$$

So, W will be equal to 1.79 P_{axle} by V for a given tractor and for a given forward speed this part is a constant now, for a given tractor this is a constant which I can represent as K_3.

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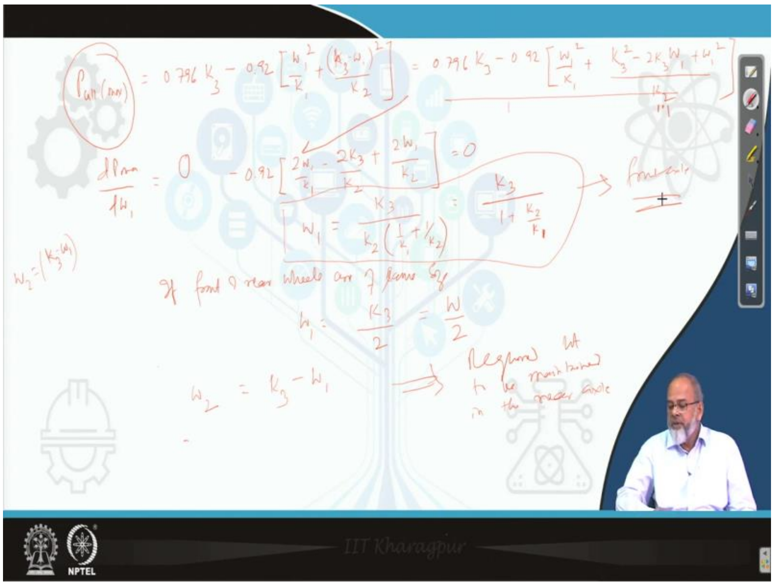

Now, pull maximum, I can write as maximum will be equal to 0.796 K3. So

$$Pull_{max} = 0.796K_3 - 0.92\left(\frac{{W_1}^2}{K_1} + \frac{(K_3 - W_1)^2}{K_2}\right)$$

$$Pull_{max} = 0.796K_3 - 0.92\left(\frac{{W_1}^2}{K_1} + \frac{{K_3}^2 - 2K_3W_1 - {W_1}^2}{K_2}\right)$$

$$\frac{dPull_{max}}{dW_1} = 0 = -0.92\left(\frac{2W_1}{K_1} - \frac{2K_3}{K_2} + \frac{2W_1}{K_2}\right)$$

$$W_1 = \frac{K_3}{K_2\left(\frac{1}{K_1} + \frac{1}{K_2}\right)} = \frac{K_3}{\left(1 + \frac{K_2}{K_1}\right)}$$

If K_1 is equal to K_2, what does it mean? That means, the front wheel and the rear wheels are same and W_1 will be equal to how much, K_3 by 2.

So, once you find out W_1 when the wheels are not same in size, then you find out W_2 which is nothing but K_3 minus W_1. So, that will give you the required weight to be maintained in the rear axle and W1 will give you the required way to maintain the front axle to maximize the output. Output is nothing but your pull. So, this is the way how to find out what is the optimum ballasting condition which will give you the maximum output.

So, what we can do here is we have got the recommendation, recommendation from Dwyer and based on that recommendation, we are calculating for the four-wheel drive tractor or the front wheel assisted tractor.

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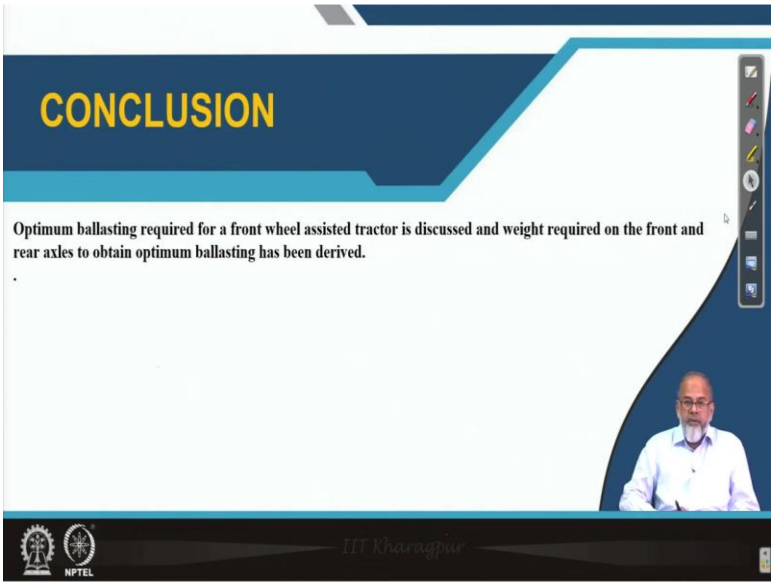

So, in this class I tried to discuss how to find out the optimum ballasting required for a front wheel assisted tractor and how much will be the weight on the front axle as well as the rear axle to get the optimum ballasting that has been derived. Thank you.