Traction Engineering

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Lecture 13: Motion resistance of a track

Hi everyone, this is Professor H. Raheman from Agricultural and Food Engineering Department from IIT Kharagpur. I welcome you all to this NPTEL certification course on Traction engineering. This is lecture 13, where I will try to cover how to find out motion resistance of a track. Track and wheel, these are the two important traction systems which are used for developing traction in case of a tractor or crawler tractor or in case of high HP tractors.

So, the concept will be, how to find out motion resistance of a track? That means, how much force is required to tow this track. So, the track is basically assumed to be similar to rigid footing and the track, if you look at the right-side figure, there I have indicated a track. So, it will have certain amount of lugs, but the lugs are not that prominent as in case of a wheel. So, it has certain width which is not visible in this diagram.

So in the cross section, I have given width as B and length as L and it will be carrying certain amount of weight W and there will be rollers to give tension to this track so that during engagement with the soil that means during shearing action which the track is going to create during operation, so, the belt has to be in tension or the track has to be in tension. That is why, we have provided these rollers. So here, what we have assumed is, the normal reaction during the interaction process with the soil the reaction will be exerted on the track by the terrain, and here we have assumed that the pressure is uniform throughout the contact. That is an important assumption you can say. And the normal reaction exerted on the track by the terrain can be equated to that beneath a sinkage plate at the same depth in a plate sinkage test. So, this is very important.

So, the normal reaction will be equal to your pressure beneath a sinkage plate which is at the same depth as that of then depth at which the track is moving. So, the assumptions are, the track layer does not tilt in operation. That is number one assumption, and the load on the track is uniformly distributed. If it is not uniformly distributed then the reaction which you are getting at the soil track interaction surfaces, it may not be uniform. So, that is why we say load on the track is uniformly distributed and the track layer does not tilt during operation. The contact area very simple, I have done, this is the length and this is the width.

Length and width multiplication will give you how much will be the contact area and the force which I have indicated F here, is the thrust force. But we are not interested in developing thrust force. Now we will be discussing about that little later. So, only what we can discuss is, how much is the force required to tow this forward. So, we know that in a plate at sinkage test

$$p = k\, {Z_0}^n$$

$$p = \frac{W}{bl}$$

If plate has to be sunk into a depth of z_0 then pressure at that depth will be equal to

$$Z_0 = \left({}^{p}/_{k}\right)^{1/n} = \left(\frac{W}{bl.k}\right)^{1/n}$$

Now P, as you have assumed that the pressure is uniformly distributed that means load is uniformly distributed. So, weight divided by area, that can be denoted as pressure. Now I substitute here, W is the normal load which is acting on the track, then b is the width of the track and l is the length of the track in contact with the soil.

Now, the work which is done in compacting the soil along the track length l and it will make a rut of width b, because wheel width is B. So, this is your width B which is denoted as B. So, it will make a rut in the bottom surface when it is in contact with the soil so that area is equal to B into L. Now, what will be the work done in making a rut of depth Z_0?

$$W.D. = bl \int_0^{Z_0} p dz = bl \int_0^{Z_0} k\, z^n dz = bl\, k\, \frac{{Z_0}^{n+1}}{n+1}$$

$$= \frac{bl}{(n+1)k^{1/n}} \left(\frac{W}{bl}\right)^{\frac{n+1}{n}}$$

This is the work done expression. Now, if I want to tow this track to a distance ‘say L’ in a horizontal direction. And then the work done in towing this track by a force which is called towing force that will be equal in magnitude to the motion resistance due to torque and compaction. So, let me repeat again. If I want to tow this track to a distance L by applying a force which is called towing force then that towing force will be equal in magnitude to the motion resistance. Why? Due to compaction of soil.

And, if that is so, then I can write, work done in compacting the soil will be equal to your towing force. Towing force, if you denote it as R, it has to be towed for a distance l. So,

$$W.D. = R.l$$

$$R \times l = \frac{b \times l}{(n+1)\left(\frac{k_c}{b} + k_\emptyset\right)^{1/(n)}} \times \left[\frac{W}{bl}\right]^{(n+1)/n}$$

$$\mathrm{R} = \frac{b}{(n+1)\left(\frac{k_c}{b} + k_\emptyset\right)^{1/(n)}} \times \left[\frac{W}{bl}\right]^{(n+1)/n}$$

$$\mathrm{R} = \frac{1}{(n+1)b^{1/n}\left(\frac{k_c}{b} + k_\emptyset\right)^{1/(n)}} \times \left[\frac{W}{l}\right]^{(n+1)/n}$$

So, contact area we have taken as length of the flat person L1 × section width. So, W by L2 × B, so, that means more or less they are similar. Then the question arises, which one will give you lesser rolling resistance when they are carrying the same parameters nearly same expressions because $P_{gr}^{(n+1)/n}$, $(W/BL)^{(n+1)/n}$. Then the question arises, which one will give you lesser rolling resistance and why? So, if you think little bit, this BL for track and BL1 for wheel, they are not same. Usually, the tracks are longer and width of tracks are longer whereas, the section width of wheel or contact length of a flattened portion of the wheel, they are much smaller than the contact length and section width of track. So, that means, this area of the wheel is, if you denote it as area of wheel and if you denote it as area of track.

So, area of wheel is much-much less than area of track. For the same load, your contact pressure is more in case of wheel and in case of track, it is less. That means, there will be more compaction in case of wheel and hence, there will be more rolling resistance. So, that is the reason a track gives lesser rolling resistance as compared to your pneumatic wheel. Now, if you compare with a rigid wheel, rolling resistance of track and rolling resistance of a towed rigid wheel. So, what is the difference? Here, you are not getting anything related to pressure. You are only getting in terms of W, in case of in terms of diameter, and the section width B and the modulus of sinkage is K, so, it is difficult to compare in fact.

In the previous case, these are similar. So, that is why, I made it very clear, which one should give you lesser rolling resistance. But if you look at now this equation, it is $W^{(2n+2)/(2n+1)}$. This is very-very high, whereas, it is only $W^{(n+1)/n}$. So, that itself gives you that, yes track is better than rolling resistance of a rigid wheel. If the weight is same then track is going to give you lesser rolling resistance.

Now, coming to the diameter, as we increase the diameter, the rolling resistance of towed rigid wheel reduces because is the negative, the power $(2r)^{-(n+1)/(2n+1)}$. Here also, the area$^{(n+1)/n}$. But the area which is obtained in case of a track and the area which is obtained in case of a towed wheel they are also different. The area of a track is much-much higher than area of a towed rigid wheel. Because, towed rigid wheels, its width cannot be more than say 5 centimeter, 2 inches, whereas, track width is much more than that. And length of the track is even, if it is kept same as the diameter of the towed wheel then definitely, A_t will be higher than A_{trw}.

So, that means track, rolling resistance of a track is lesser than the rolling resistance of a rigid wheel. Now, comparing the modulus of sinkage, because this is same for you, cannot change the soil conditions. So, it is $K^{1/L}$ whereas, it is $K^{-1/(2n+1)}$. So, there is an advantage here. Advantage means, -1/(2n+1).

So, this will give a little higher resistance. Denominator is 2n+1, whereas, it is in the numerator, it is only 1/n. So, that way if you compare again, the rolling resistance of a track can be seen to be lesser than the rolling resistance of a rigid wheel. So, in total, we can say, rolling resistance of a track will be always lesser than the rolling resistance of a pneumatic wheel when they are operated in the same soil condition, in the same under same weight, and same is the case with rolling resistance of a rigid wheel.

So, in this lecture, what I have done is, I have tried to derive expression for rolling resistance of track. Then, we tried to compare the rolling resistance of pneumatic wheel and rigid wheel expression which we derived earlier, and then we had a comparison individually, and then what we conclude from here is that rolling resistance of a track is lesser than the rolling resistance of a pneumatic wheel or rigid wheel. So, briefly, if I conclude about this lecture, I have made an attempt where I derived the equation for predicting motion resistance of a track, then I tried to verify how it is different from pneumatic wheel or towed rigid wheel and you can refer the book theory of ground breaking by Wong J Y. Thank you.