Traction Engineering
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Lecture 24
Performance Evaluation of a Walking Tractor Fitted with Track

Hi everybody, this is Professor H. Raheman and from Agricultural and Food Engineering Department, IIT Kharagpur. I welcome you all to this NPTEL course on traction engineering. This is lecture 24 where I will try to give a description about how to evaluate the performance of a walking tractor when it is fitted with track? Wheels and tracks, these are the two common traction devices which are usually fitted with tractors.

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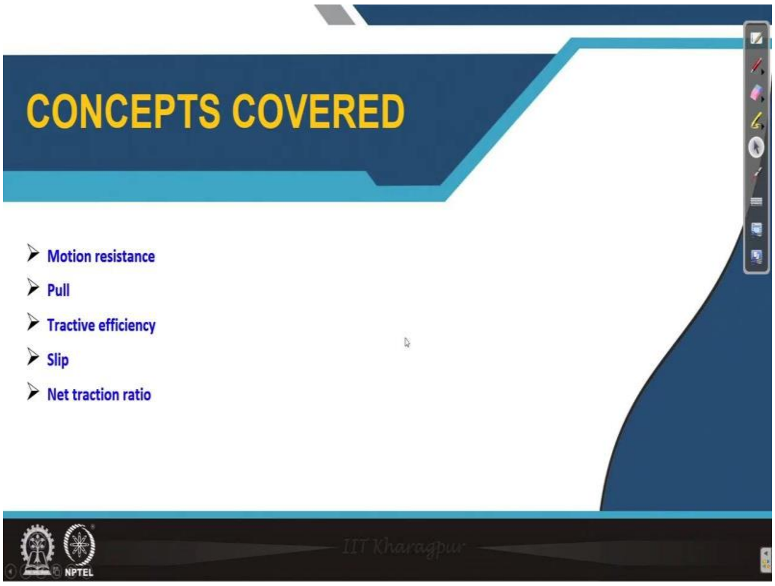

When I say walking tractor, means this study is confined to the power tiller. Since, power tiller is operated by a human being who has to either walk behind or who has to sit on a frame to control or to guide the operation of the power tiller. So, that is why we call it walking tractor. Since the person has to walk behind the power tiller usually, in the power tiller a person has to or the operator has to walk behind so that is why we call it as a walking tractor. So, the concept which I take is the motion resistance, pull, tractive efficiency, slip, net traction ratio. These are the parameters which will be considered for evaluating the performance of a walking tractor when fitted with rubber tracks.

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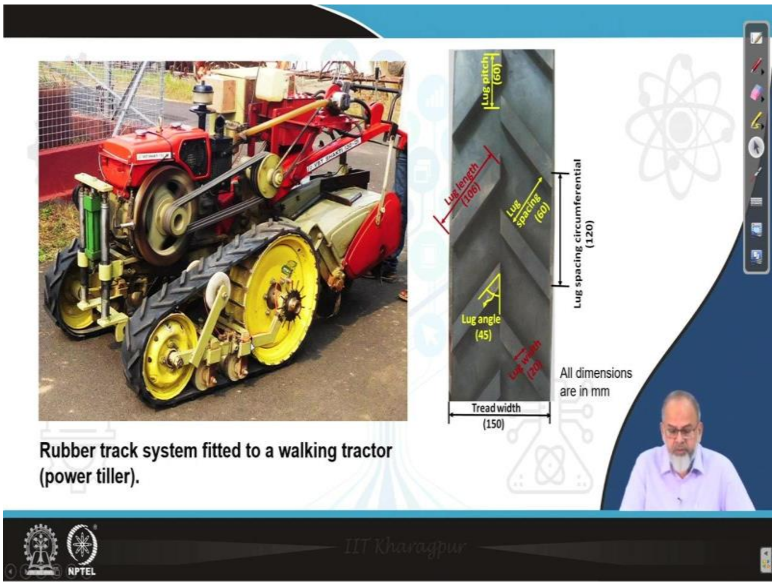

So, this is the power tiller which has been converted to be fitted with tracks. And the tracks details are given in the right figure where the lug height, lug angle etcetera are given and the pitch of the lug all those things are given and the tyre tread pattern and the lug patterns which are provided in the track, they are nearly same. So, now the track, walking tractor has been replaced with a track on both the sides and for mounting the track we require some modifications in the power tiller. That means we have to provide an idler in the front and this is the driver roller that is fitted to the axle of the power tiller. That means this is powered. The front one which is idler is not powered. And to keep tension on the track we provide some intermediate rollers here and here so that during operation, the torque is perfectly horizontal on the surface on which it is going to work.

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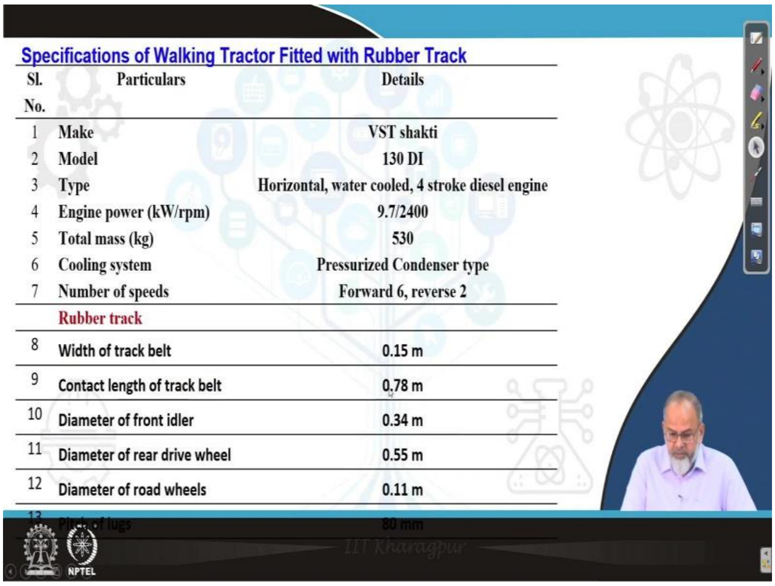

So, the details of walking tractor, what is this engine, what is mass? So, engine is, VST Shakti is the model 130 DI and this is a diesel engine, 4 stroke diesel engine and is the horizontal one and it develops 9.7 kW or 2400 RPM, its total mass after modification, that means after attaching the track comes down to 530 kg initially it was 430 kg with the pneumatic wheel. When you replace the pneumatic wheel, because of these arrangements, its weight has been increased to 530 kg. Then these are the dimensions of the track, width of the track is 0.15 meter, contact length is 0.78 meter and then diameter of the front idler, diameter of the rear drive wheel and diameter the road wheels all are mentioned like 0.34 meter, 0.55 meter and 0.11 meter.

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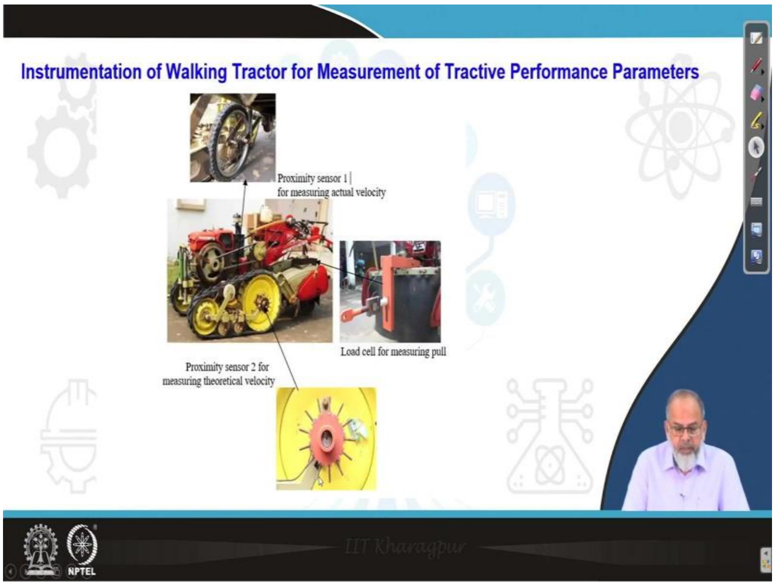

So, to measure different tractive parameters, we need to have some instrumentation, instrumentation for measuring what is the pull which the power tiller the walking tractor is going to develop and how much you pull it is required to tow this power tiller for that also it needs kind of loadcell. So, that is I have indicated here a loadcell which is attached to a frame which is mounted to the power tiller chassis and this is kept horizontal during operation so that whatever pull we are getting that is almost nearly the horizontal component that is equal to your draft. Then the important component, other important component is the wheel actual wheel speed. For measuring actual wheel speed, you need to know what is theoretical speed. And then you need to know what is actual speed? So, for this what we have done is, for measuring theoretical speed, we have put on spikes here. You can see a lot of spikes are present and are fixed to a sprocket which is attached to this rim and then we have a proximity sensor, which will try to sense these spikes so that it can give a signal to the in the output. Basically, a proximity strategy is nothing but it senses the presence of any metallic object like these spikes. So, once it senses then it gives a signal. So, that signal or the spike which you are getting and the output will be counted and the time duration if you know, then you can find out what is the speed of operation. Similar exercise or similar arrangement has to be made for measuring the actual velocity. So, but in power tiller since there are one drive axle and there is no axle in the front, the front one is idler which is provided. So, what we have done is, we have put a separate wheel which is a towed wheel and this is mounted to the walking tractor chassis. So, that speed again has to be measured using his proximity. So, that will give you what is the actual velocity. So, actual velocity, theoretical velocity then that will give you what the corresponding slip. So, we need to know slip, we need to know pull, then only calculate the drawbar power and we utilize this loadcell for measuring the rolling resistance.

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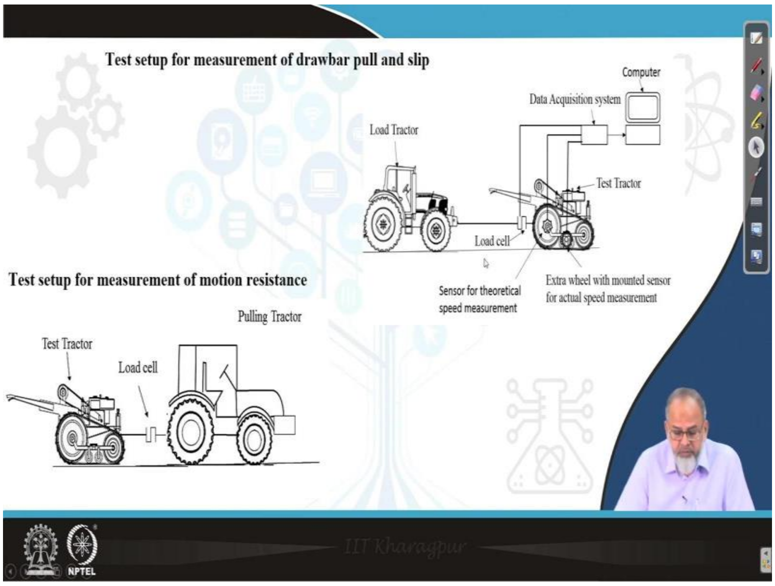

That means, I will show you the setup. How did you measure the rolling resistance? So, we have measured pull by using a loadcell and you have to measure rolling resistance or the motion resistance by using the same loadcell, but the arrangement is a little different. If you look at the top figure, the power tiller is used to pull a tractor that means, this is going to give you the drawbar pull performance for different conditions. Now, the lower one is a set of where the power tiller is kept behind and, in the front, there is a tractor. So, this kind of arrangement is meant for measuring motion resistance that means, how much force is required to tow this walking tractor that has to be measured. So, for which we put a tractor in the front and closer to the tractor we put a loadcell. So, and with the help of wire we tried to connect the power tiller with the loadcell and the tractor in the loadcell. So, the power tiller is kept idle in neutral and then the tractor is going to pull it at a certain speed, speed could be 1 kilometer per hour or speed could be 2 kilometers per hour. Then we try to find out what is the output from the loadcell and that is recorded in a data acquisition system and that is recorded in and computed through a data acquisition system. So, by this we can find out how much is the force required to move this power tiller. So, that becomes your motion resistance.

Now, if we look at the top figure, we are interested in finding out pull developed by the walking tractor for different conditions. Different conditions mean maybe a different slip value. So, how do you control slip here? Here, basically you are not controlling slip, the power tiller is in the front, tractor is in the back side and the loadcell is in between that means it is closer to the power tiller so that the line of pull is almost horizontal and the loadcell one end of loadcell is connected to the tractor and the other end is connected to the power tiller.

So, when you try to find out what is the pull developed? So, you have to run the tractor at a speed which is lesser than the speed at which we want to operate the power tiller so that the tractor can exert some pull. So, by reducing the tractor speed, you can vary the pull and that pull has to be measured along with the wheel slip.

So, that will give you how much drawbar power which is developed by the power tiller. So, this data related to pull and the slip. Slip means the actual velocity and the theoretical velocity, all these information they are collected through a data acquisition system and stored in a computer. These are the basic instrumentation which is required to carry out this kind of study.

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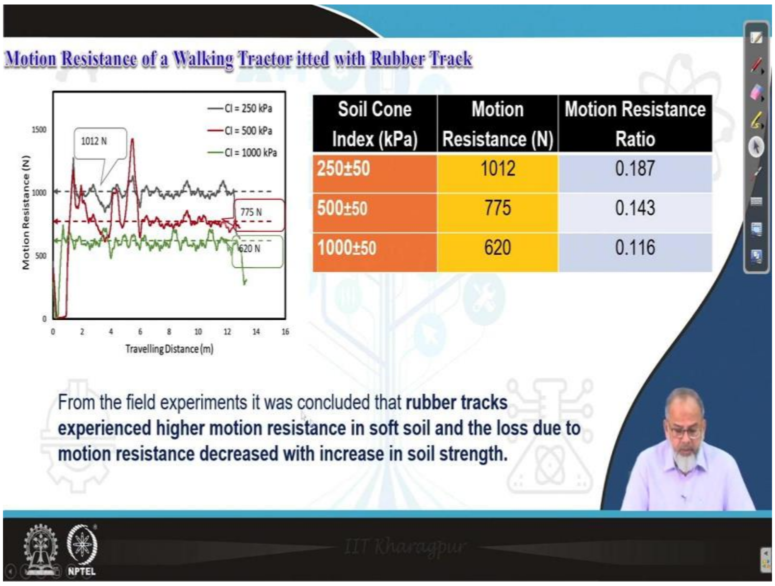

Next, the data which you obtained that we tried to plot. The first is motion resistance. So, motion resistance versus travelling distance, this has been plotted for three different soil conditions. That means, we varied the soil condition starting from 250 kPa to 1000 kPa. The average value I am talking about. So, that means, when this soil cone index is 250 kPa plus or minus 50 that we take as soft soil when the soil cone index is 500 ±50 kPa then we take as medium soil and when the soil condition is 1000 ±50 kPa, we take as hard soil. And for these three different soil conditions what we have measured is, the motion resistance and the values are 1012 in 250 kPa that means, soft soil; 775 Newton in medium soil and 620 Newton in hard soil. Soft soil gives maximum motion resistance as compared to hard soil, same is the case for motion resistance ratio. It is the maximum in case of soft soil and minimum in case of hard soil. Why it is so? It is basically due to sinkage of track in the soil. Since the soil is soft, it may not sustain the weight of the track. So, that might be some kind of compaction and sinkage. So, that creates or that require more force to tow a walking tractor.

So, when the soil is hard, the sinkage is less. So, we require less power to tow it, only less forced to tow it. So, that is motion resistance is less in case of hard soil. This is one of the parameters which you are interested and this was found that rolling resistance variation or the motion resistance variation with slip is not that much, it is very minimal. So, that is why in all calculations, you have taken this as the motion resistance for different pulling conditions.

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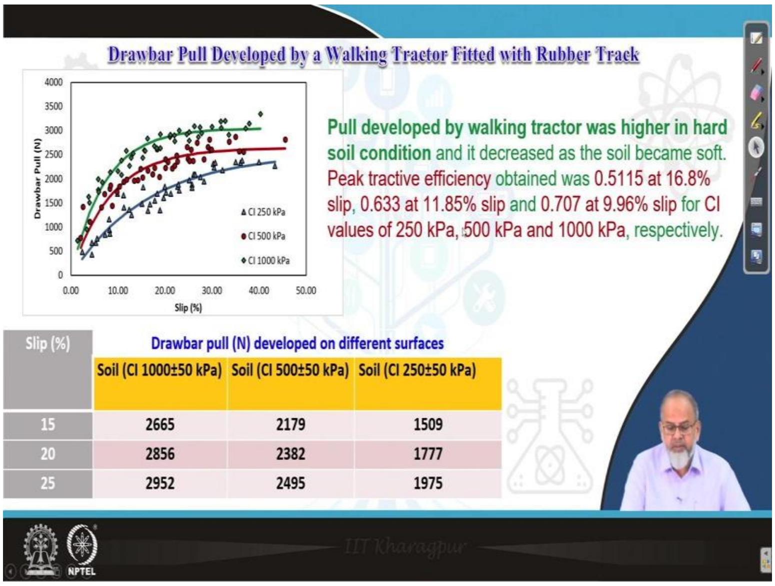

Now, coming to drawbar pull. The pull which is sent by the loadcell that we try to plot versus wheel slip. Again, for three different soil conditions we got three curves: the green one is for hard soil and red one is for medium soil that is 500 plus or minus 50 kilo Pascal and the blue one is for soft soil. So, nature of the curve is similar in all these three soil conditions. That means, it initially increases at a faster rate then slowly it reaches to a peak after that it remains almost constant. So, the pull which is developed in hard soil and the pull which is developed in soft soil, they are not same. There is a variation, variation in the sense there is a difference. So, at different slip values starting from 15, 20 and 25 per cent, I have given the pull values, the drawbar pull which is developed. So, if you look at this, the maximum drawbar pull is developed in 1000 ±50 kPa. That means, in hard soil, pull developed is much higher than the pull which is developed in soft soil whether it is 15 per cent slip, whether it is 20 per cent slip or whether it is 25 per cent slip. So, this is because of the rolling resistance, because rolling resistance is more in case of soft soil.

Even if the tractive effort developed by the power tiller is same, because of the higher rolling resistance, much power is lost due to that, then the net pull is reduced. That could be a reason. Now, if you look at the medium soil it is lying in between these two soil conditions one is the hard soil the other one is the soft soil. Now quantified, how much is the reduction. So, we can see here, pull developed by walking tractor was higher in hard soil condition and a decrease in the soil as the soil became soft. So, peak tractive efficiency which is derived from this pull and coefficient of a rolling resistance, so, together we have to take to find out peak tractive efficiency. So, that values, it has been indicated like 51.15 per cent and what is the corresponding slip. Similarly, in medium soil it is 63.3 per cent and what is the corresponding slip and in hard soil it is 70.7 per cent at around 10 per cent slip. So, for three different soil conditions it has been given.

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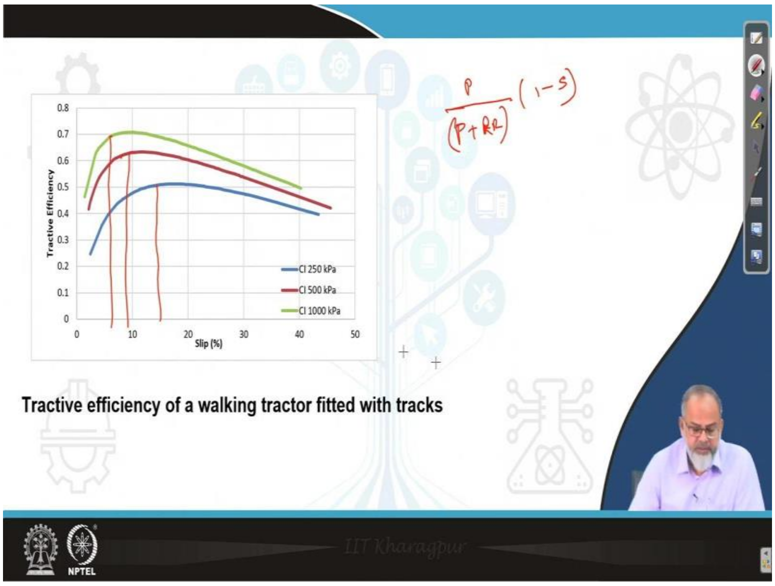

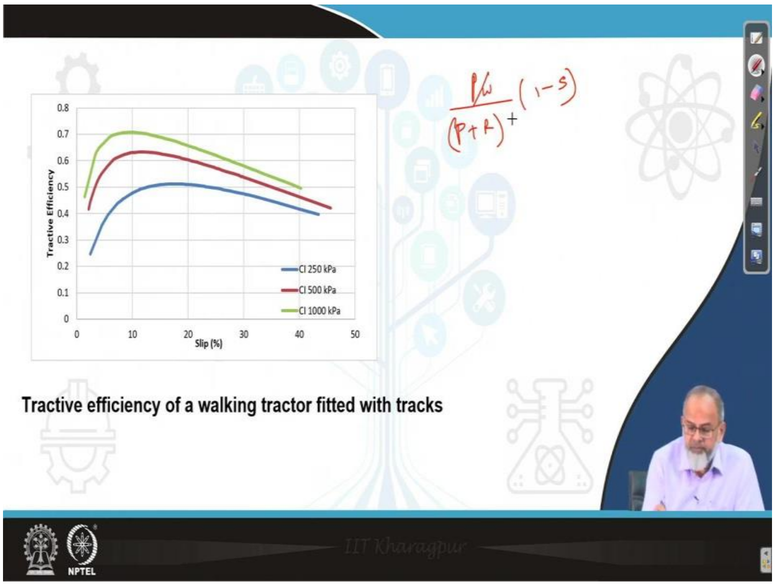

And let us now see the nature of the curve. This is tractive efficiency which is nothing but

pull by tractive effort which is nothing but

$$\frac{Pull(P)}{Pull(P)+R}\times(1-s)$$

So, I have not written W here, because W remains same that is cancelling this one. So, only I have taken P plus, P by P plus RR rolling resistance motion resistance. So, the nature is tractive efficiency is reaching to a peak value after certain slip.

So, if you draw a line here, this is the slip. Here it is getting this in this slip it is getting maximum. Then after that it is slowly going down and the rate of decrease is more in case of hard soil. So, the nature of the curve is same. Initially it rises to a peak at a faster rate then, it goes down. So, the initial reduction in tractive efficiency is because of the power which is lost due to overcome the rolling resistance. And after 20 per cent slip, whatever reduction is there is because of the wheel slip and the track slip. So, the power is lost because of the higher slip. So, that is the reason we are getting a peak at the particular value or in a particular range of slip value.

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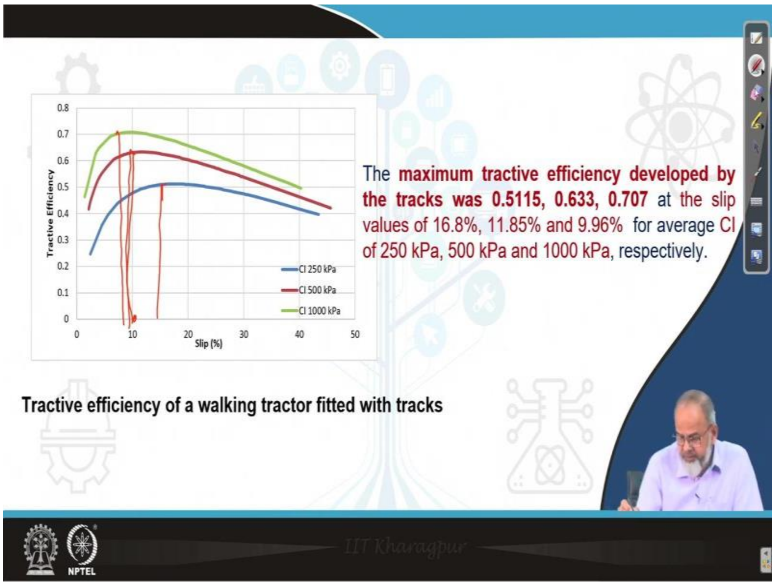

So, the maximum tractive efficiency which is developed by the track was 51.15 or the slip of 16.8 per cent and that is in case of a soft soil, here 16.8 somewhere here and for medium soil it is 0.63 so, at slip of 11.85 somewhere here and for hard soil we are getting a maximum value of 70.7 at the slip of 9.0. So, slip at medium, slip at hard soil they were close. So, that means within 10 to 11 per cent or 12 per cent we are getting the peak values, whereas in case of soft soil we are getting a peak value beyond 15 per cent but nevertheless it is lesser than 20 per cent. Our maximum target is 20 per cent.

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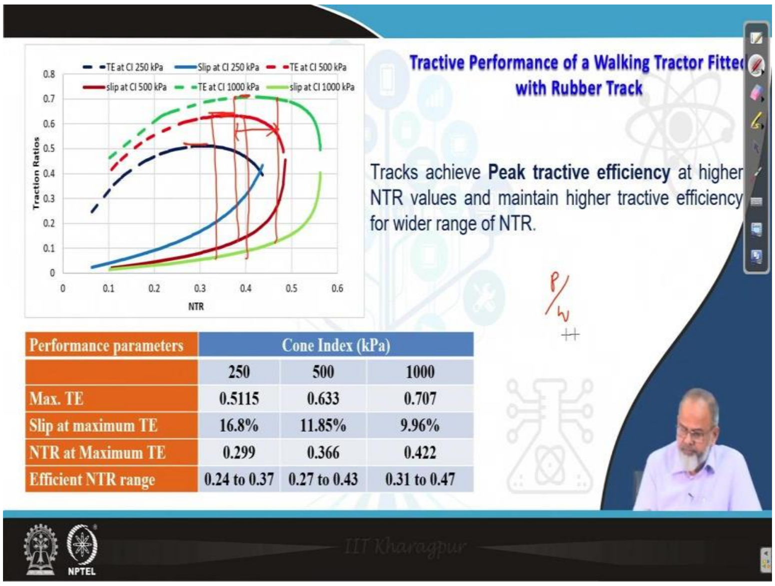

Let us see, now the plot, the different plot where we will see the effect of all the parameters, performance parameters that means in y axis we have traction ratio and slip ratio and on the x axis we have net traction ratio which is nothing but your coefficient of traction. That means the dotted lines are indicating the tractive efficiency for three different soil conditions: the green one is indicating 4000 kilo Pascal, the red one is indicating for 500 kilo Pascal average and the blue one is indicating for soft soil. And the lower three solid lines, the green one is 4000 kilo Pascal (this a slip value) and the red one is for 500 kilo Pascal (this is slip value) and the blue one solid line is indicating the slip value.

So, tracks usually achieve peak tractive efficiency or higher NTR that means higher Net Traction Ratio. If you look at the peak value, it is somewhere here in hard soil and in case of medium soil it is somewhere here and in case of soft soil it is somewhere here. That means, the NTR value maximum we are getting is 0.3 in case of soft soil, in case of medium soil it is 0.3637 like that and in case of hard soil, that is beyond 0.4. So, I have summarized the performance parameters like maximum tractive efficiency, slip at maximum tractive efficiency, what is the NTR at maximum tractive efficiency and the efficient NTR. This is one parameter which I have found out from this curve.

So, if you look at the values, again maximum tractive efficiency values are given. So, it is maximum in case of hard soil and it is minimum in case of soft soil and the peak which you are getting in soft soil is at the higher slip that is 16.8 percent and the peak 0.707 which you are getting is at a track slip of 9.96 percent in case of hard soil. And the corresponding NTR you can see, it is more than 0.42 in hard soil, it is 0.366 in medium soil and 0.29 is roughly equal to 0.3. Now, I have defined the terminology efficient NTR range. That means, if you look at the curve, we can see that you are not getting the peak at a particular point. you are getting a peak at a wider range of NTR. This is the range you can say for medium soil and for hard soil this is the range.

So, that range I have taken as the efficient NTR range. That means, the track is able to develop maximum tractive efficiency for a wider range of pull values. So, when I said NTR, NTR is nothing but P by W. That means for the pull value of 24 per cent to 37 per cent, there we are getting the maximum tractive efficiency in case of a soft soil; in case of medium soil, it is varying from 27 per cent to 43 per cent and in case of hard soil the range is still larger in the sense 31 per cent to 47 per cent. That means the track will perform better for different pulling conditions, which is not the case in case of a pull type tractor.

So, the three parameters if you look at coefficient of traction, then tractive efficiency and the other parameter is slip. And let me discuss a little bit about slip. If you look at slip, nature of the curve, we can see, traction ratio is varying with slip. So, it is reaching to a peak then it is going down, is reaching to a peak then going down. That means, the slip is increasing in case of soft soil to get the maximum peak of a tractive efficiency, the slip is more in case of soft soil as compared to hard soil. So, that is the reason why the tractive efficiency is less. So, higher slip means most of the power is lost in overcoming the rolling resistance. So, that is why you are getting a lesser tractive efficiency.

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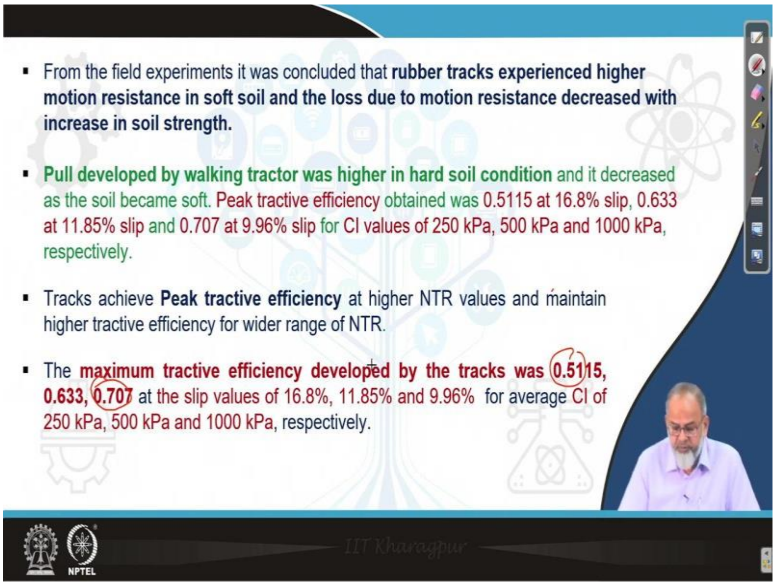

If you summarize this one, what we discussed, these are all field experimental data, so that is why from there we concluded like this rubber track experience the higher motion resistance in soft soil and the loss due to motion resistance decreased with increasing strength, soil strength. The pull which is developed by walking tractor was higher in hard soil condition and a decrease as the soil become soft. Peak tractive efficiency which is obtained as 0.51 at 16.8 per cent, 0.633 at 11.85 per cent and 0.707 at 9.96 per cent track slip for three different soil conditions like 250 kilo Pascal, 500 kilo Pascal and 1000 kilo Pascal.

The peak tractive efficiency, it was higher at higher NTR values and this higher peak tractive efficiency was prevailing for a wider range of NTR, that is the plus point in case of a track. Then the maximum tractive efficiency, which is obtained which I have already discussed, I think, so, that is maximum is 51 per cent in case of soft soil and in case of hard soil it is 70 per cent and the slip is within the limit of 20 per cent, because in case of wheels we usually take wheel slip to be 20 per cent, within 20 percent. But what we are observing here is, in case of a track maximum is obtained at less than 20 per cent.

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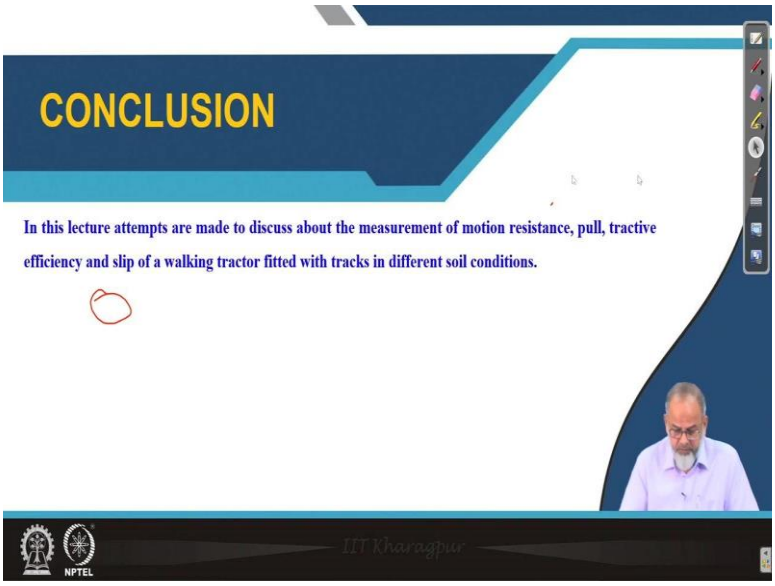

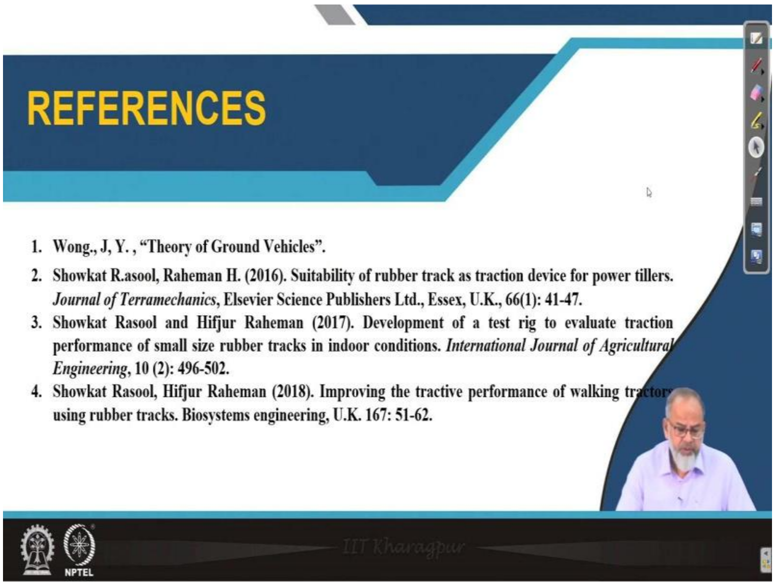

So, in this lecture what I have attempted is, I tried to discuss about the measurement techniques, how to measure the different performance parameters, tractive performance parameters like rolling resistance, pull and slip and then tried to discuss about the data which is obtained, the data which are obtained related to a walking tractor fitted with tracks and then we tried to discuss what is the nature of the curve and how the tractive efficiency is varying and how we observe the important thing which was observed is the range of tractive efficiency maximum tractive efficiency values.

So, that is more important. That is all, thank you.

So, this study has been taken like this field experiment data was related to the experiments which he conducted at IIT Kharagpur and some of the papers we have published and based on this data we have discussed this thing that is all. Thank you.