Traction Engineering
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Lecture 01
Concept of Traction and Traction Devices

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Hi everyone, this is Professor H Raheman from Department of Agricultural and Food Engineering, IIT Kharagpur. I welcome you all to this NPTEL online certification course on Traction Engineering. This is the first class where I will try to cover the concept of traction and the traction devices.

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So, these are the concepts which will be covered like definition of traction, role of traction, how it is produced, how to improve traction and what are the different traction devices used for developing traction.

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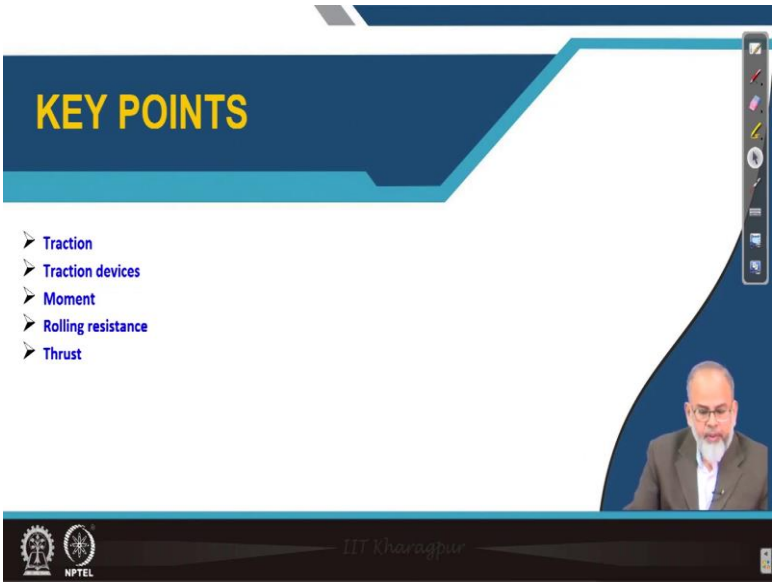

These are the key points like traction, traction devices, moment, rolling resistance and thrust. These are the key points.

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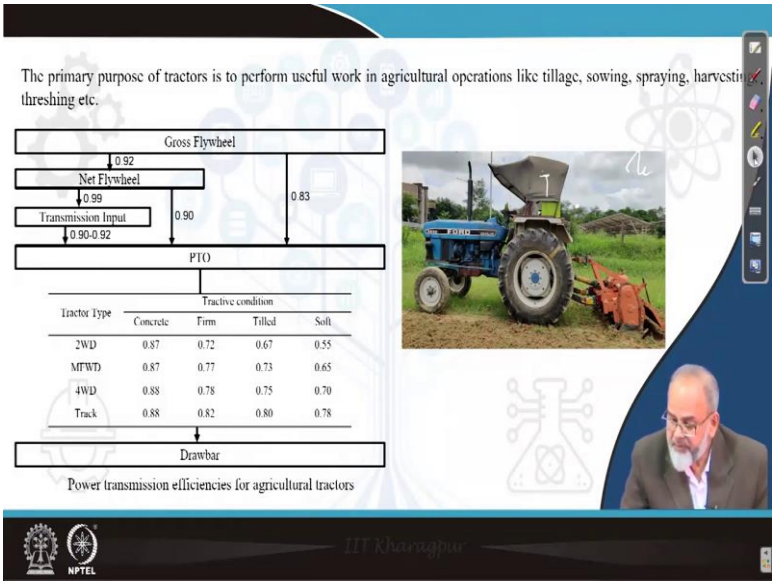

Tractor Type	Tractive condition			
	Concrete	Firm	Tilled	Soft
2WD	0.87	0.72	0.67	0.55
MFWD	0.87	0.77	0.73	0.65
4WD	0.88	0.78	0.75	0.70
Track	0.88	0.82	0.80	0.78

Now, if you look at the power sources which are commonly used in farms are your tractor and power tillers. So, what I have shown here is, how the power is transmitted and how much

power is available at the drawbar and at the PTO. So, if you look at this, in a tractor, about 83 per cent of the power which is developed in the gross flywheel is available at the PTO.

Now, if you want to find out the power which is available at the drawbar, then again there will be reduction of say in a two wheeled tractor there will be 0.87 times the power which is available at the PTO in concrete surface and in firm soil still less 0.72 times and in tilled soil it is 0.67 times and in soft soil it is 0.55 times.

And for mechanical front wheel assist tractor, this is little better you can see, this is 0.77 and in tilled soil, this is 0.73, so there is an increase in power availability. In soft soil, it is 0.65. In a four-wheel drive tractor still it is better than the mechanical front wheel assist tractor. So, there is an increase from 0.73 to 0.75 in tilled soil and in soft soil there is an increase of 0.05.

So, if it is a track, track is giving the best performance, if you look at this. So, now it is the soil condition, it is the traction element which will decide or which will control the drawbar power availability. So, traction elements, soil conditions, these are the important parameters which are to be taken into consideration. Now, what is traction?

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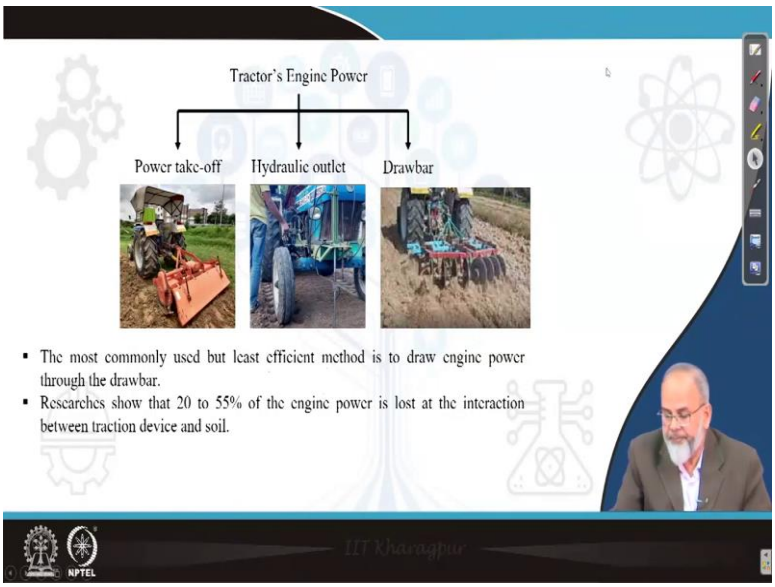

So, before going to traction, we can see here, what are the different power outlets which are available in a tractor? One is PTO or the power take off, the other one is hydraulic outlet, the third one is drawbar. Out of these three, the drawbar is most commonly used, but it is the least efficient among these three. And researchers have indicated that 20 to 55 per cent of the

engine power is lost at the interaction between traction device and soil. But our implements which we have developed mostly are of drawbar driven type.

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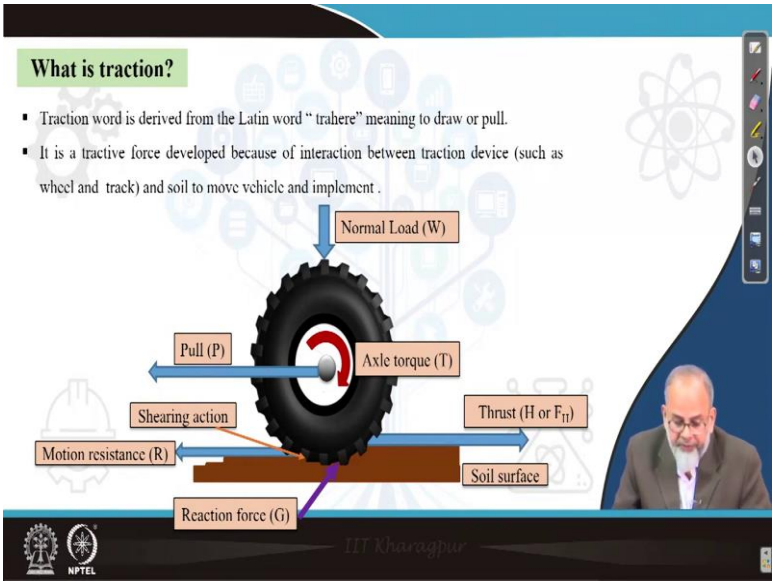

So, let us discuss about what is traction. Traction word is derived from the Latin word "trahere" meaning to draw or pull, is basically a tractive force which is developed because of the interaction between traction device which could be wheel, which could be track and soil to develop a course which will help in moving the vehicle as well as the implement. So, this figure shows a wheel which is subjected to normal load W in addition to its own weight, then it has to be powered, so axle torque is denoted as T, then when it is powered, it will try to rotate.

So, when the wheel will try to rotate, it will come in contact with the soil thereby it will develop some shearing forces. The shearing forces will help in developing the thrust force. So, the thrust force that will be utilized to move the wheel forward. So, because of this weight, because of the shearing force, there will be a soil reaction which is denoted as G, and the initial movement of the wheel will be opposed by the frictional forces, so that is indicated as motion resistance. So, the thrust force which is developed, that will take care of this motion resistance. So, thrust minus motion resistance will be equal to the pull developed.

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So, now, we will see in this slide, what is happening. A wheel is provided with a torque. It is trying to spin about its own axis, but it is not moving forward. The reason is, the wheel is not in contact with the soil. Unless, it is opposed, it will not move forward. So, it is only moving about its, it is rotating about its own axis. Now, the moment I make it to happen that it is in contact with the soil surface, then it starts developing it starts moving forward.

Why it is so? Because when it is in contact with the soil, there will be interaction, interaction between wheel and soil and thereby the shearing action takes place and the force which is developed that will try to push the wheel forward. So, I have indicated, what are the forces acting. But there is no pull here, only the wheel is powered and it is moving forward.

So, W is the weight, this is the torque which is applied and soil reaction is G and rolling resistance is R. And the thrust developed, it will be sufficient to overcome the rolling resistance, thereby it starts moving.

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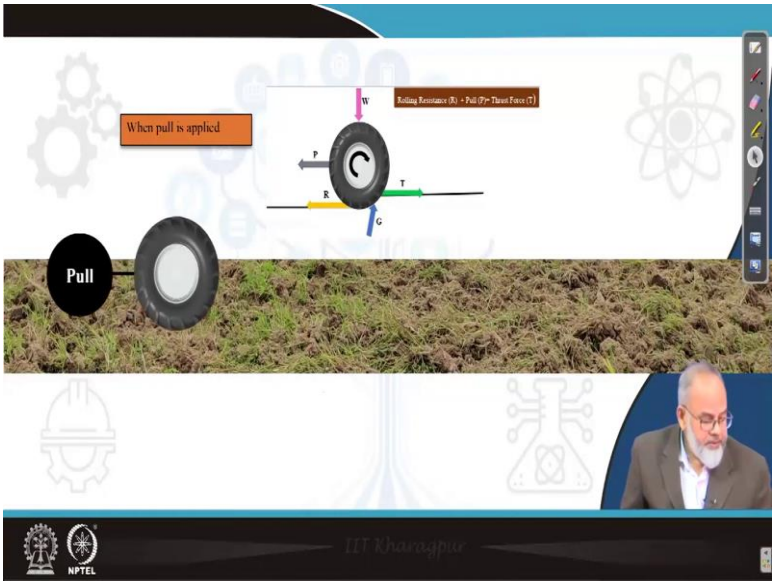

Now, I will show you a second slide when pull is applied to this wheel, everything is same only thing is, pull is applied. But, if you look at this figure, wheel is moving, but it is moving at a lesser speed. The speed at which it was moving when pull was 0 and the speed at which it is moving when pull is applied, they are not same. There is a difference. The speed at which it is moving with a pull is lesser than the speed at which it is moving, the wheel is moving without a pull.

So, why it is happening, because when you apply pull that will oppose the movement of the wheel forward. So, thereby wheel will try to move forward but the pull and the rolling resistance will try to pull it from backward. So, that is why there is a difference. So, slip will

be developed. So, if you look at the forces which are acting on the wheel W, torque T, sorry, torque, input torque, then pull is P and R is the rolling resistance and G is the soil reaction.

If we look at the figure here and the look at the previous slide, where pull is not applied, you can see the direction of soil reaction. G is vertical when pull is not applied and when pull is applied the G is not remaining vertical it is at an angle.

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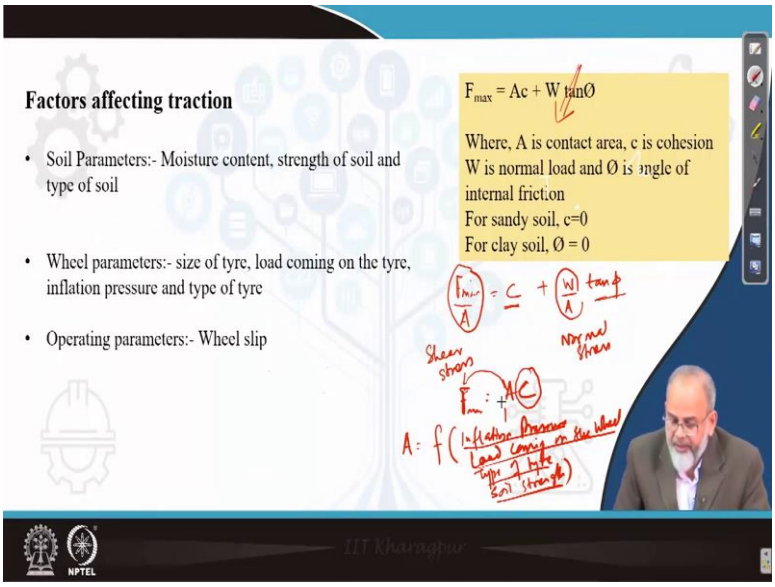

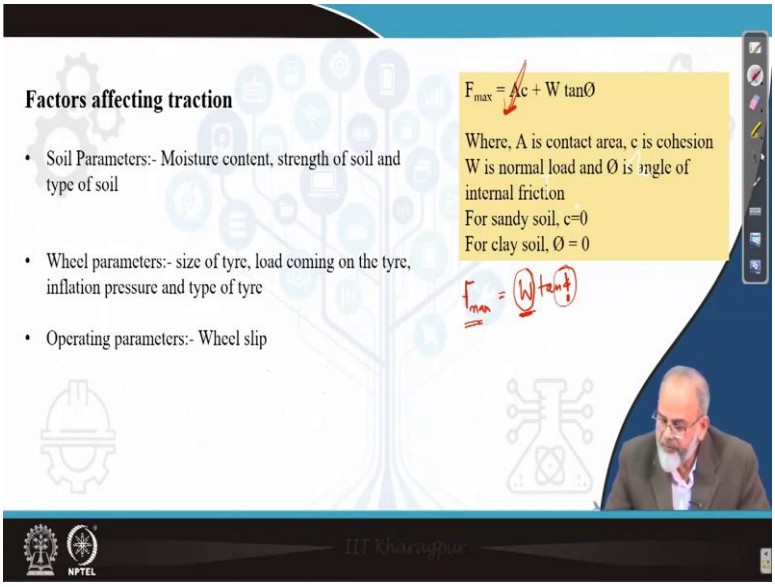

So, from these two slides, one will identify what are the different parameters which are going to affect the tractive force. The first thing is your soil parameters, Second is your wheel parameters, Third is your operating parameters, Under soil parameters, it will be moisture content, strength of soil and type of soil.

Under wheel parameters, it will be the size of tire and the load coming in the tire and the inflation pressure and finally, the type of tire. It could be bias ply, it could be radial ply, it could be a bias belted. So, type of tire has influence on wheel parameters, influence on tractive performance. Then operating parameters, as I just now, we have shown those two slides where wheel slip is important.

So, wheel slip is going to affect the tractive performance or the tractive force. Now, the basic equations which is being used for estimating the maximum tractive force is given as $F_{max} = Ac + W\ tan\emptyset$

So, let me explain the different components of this one. F_{max} is your maximum thrust which is developed, A is the contact area, c is the cohesion of soil, W is the weight that means normal load which is acting on the wheel and ∅ is the angle of internal friction. c and ∅ that contributes to the soil parameters, A depends on the load and depends on the type of tire, it depends on the inflation pressure, it depends on the soil condition, and W is the normal load.

Now, if you try to find out, if you try to express in terms of stress, so

$$F_{max}/_A = c + W/_A\ tan\emptyset$$

So, $F_{max}/_A$ is nothing but your shear stress. And $W/_A$ is nothing but your normal stress. So, in other words, I can say, shear stress is a function of cohesion of the soil, normal stress acting on the soil and the angle of internal friction ∅.

Now, in case of a clayey soil where c has some value but ∅ is 0, angle of internal resistance is 0. So, in that case, 'W' has no role for developing the maximum tractive force. The second component in a clayey soil will be contributing very less almost negligible you can say it is 0. So,

$$F_{max} = A \times c$$

So, for a given soil condition c is fixed.

So, now it is dependent on 'A', the maximum tractive force which is developed is dependent on the contact area. And as you know, contact area is a function of inflation pressure, it is a function of load coming on the wheel, it is a function of type of tyre, is a function of soil

strength. So, now, these are the parameters which will contribute to the contact area. So, more the contact area, more will be the thrust force or the tractive force developed.

Now, if you look at the other condition where the soil is sandy, that means, it has a ∅ value but c value is 0, the cohesion is 0. That means, the first component has negligible effect on tractive force developed, that is maximum tractive force developed. So, F_{max} will be again dependent on $W\ tan\emptyset$. So, now F_{max} is dependent on $W\ tan\emptyset$.

So, for a given soil, ∅ is fixed. We cannot change ∅, only by addition of certain moisture, we can increase a little bit but, it is a function of W only. For a given soil, sandy soil, maximum thrust force is a function of weight coming on the wheel. Higher the weight, more will be the maximum thrust. So, unlike the previous case in a clay soil, where it is dependent on so many factors, inflation pressure, it depends on the type of soil that means the strength of soil, it depends on the type of tyre. So, in this case, it is only dependent on what is the load it can carry, more the load more will be the thrust force.

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Now, let us see what are the different traction devices which are used for developing tractive force or for movement of the vehicle in farms. It could be pneumatic wheel; it could be solid wheel. Solid wheel could be your cage wheels which is shown in this figure. Then it could be simply a towed wheel, which is a bullock cart wheel or it could be a track. Out of these three, the most commonly used one is your pneumatic wheel.

The reason is being, it is flexible, it gives a suspension system while riding over the surface irregularities and it develops more traction as compared to the solid wheels like the cage wheels. Now, if you use cage wheels, the problem will be the transportation, it will try to damage the roads on which it has to move from the workshop for the workshop or shade to the field. And obviously, a towed wheels which are fitted to the bullock cart, these are not powered wheels. Simply, it is a supporting wheel, it is again a solid wheel.

So, this is basically used for transportation of different materials. So, but these are not the wheels which are used for developing tractive force. These are only a towed wheels which are used for carrying different materials from one place to another. Then the track, there is a belt which is wound around two wheels, so the contact area is more. There are arrangements, where rollers are provided to keep the stiffness of the belt tight, so that the contact area, so that the pressure distribution below the contact area is more or less uniform.

As we know that higher the contact area, higher will be the tractive force, but this is associated with certain other difficulties like steering. And researchers are trying to develop a steering mechanism when the power sources like tractors and power tillers are fitted with

tracks. They want to raise it or they want to reduce the contact area so that it can take a easy turn.

Now, if you look at the equation, which I just now discussed,

$$F_{max} = Ac + W \tan\emptyset$$

So, whether it is a sandy soil, whether it is a clay soil or is a loamy soil, A has a role, W has a role. So, the tracks which are provided with bigger size tractor, they will develop definitely higher tractive force. Because A is more, W is more, so, the tractive force which is developed with the track will be definitely higher than the tractive force which is developed in case of wheels.

So, these are some of the traction elements and out of which only the pneumatic wheels which are very common and these are provided with the low hp tractors the commonly used tractors like 45 hp, 55 hp, these are very common.

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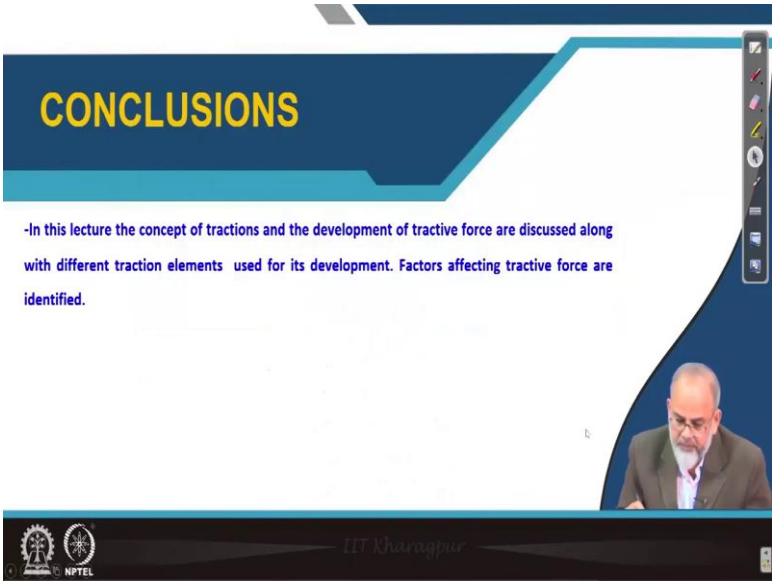

Now, let us conclude, what we have done so far is, we try to develop the concept of traction and how the tractive force is developed and what are the different parameters which affect the tractive force and what are the different traction elements which can be used to convert the engine power to the drawbar power.

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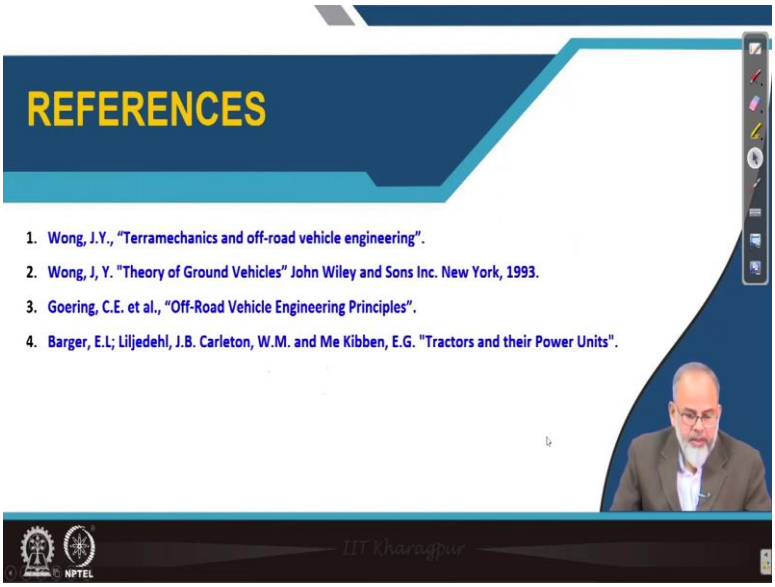

So, the reference you can take Wong, J.Y, Terramechanics and off-road vehicle engineering, theory of ground vehicles again by Wong, J.Y, then off-road vehicle engineering principles Goering, C.E. and tractors and their power units by four authors Barger, Liljedehl, Carleton and Me Kibben. Thank you.