Traction Engineering
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Lecture 02
Classification of wheels, Forces and moments acting on wheel

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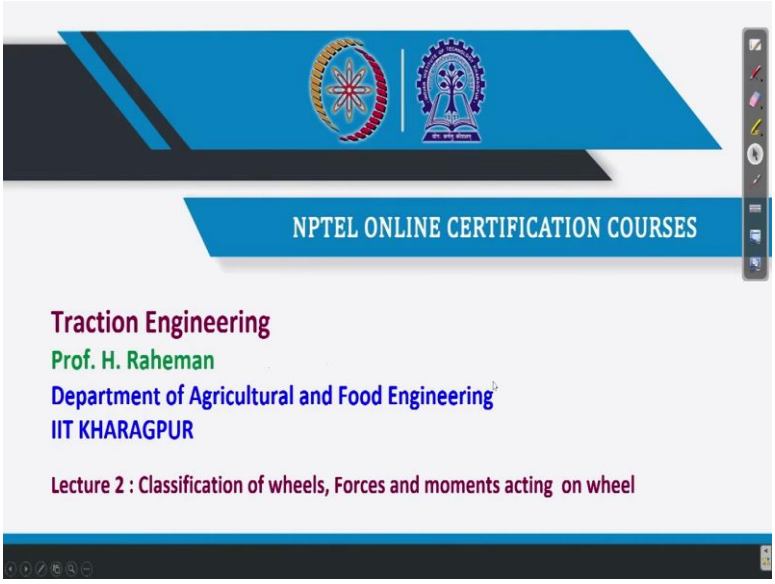

Hi, everyone. This is Professor H Raheman, I welcome you to the Lecture 2 of Traction Engineering course, where I will try to cover the classification of wheels, forces and moments acting on the wheel.

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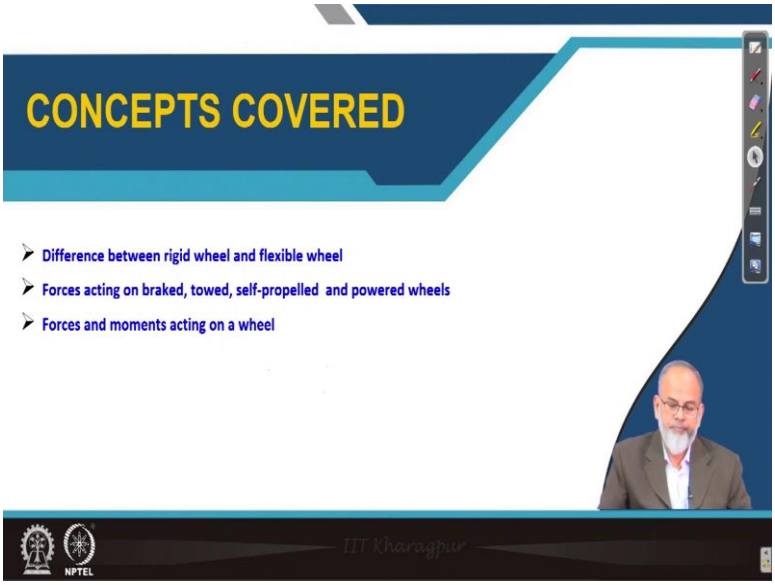

The concepts which will be covered will be difference between the rigid wheel and flexible wheel. Forces which are acting on braked, towed, self-propelled and powered wheels. Then forces and moments acting on a wheel.

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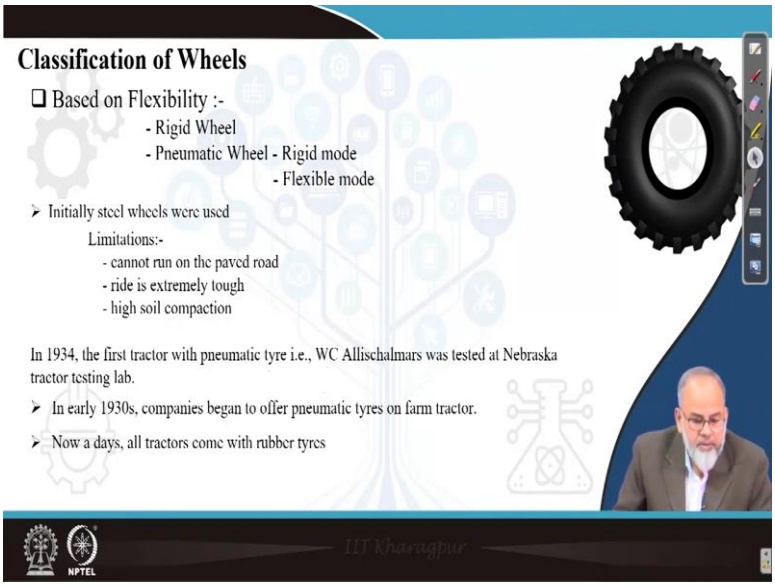

When you talk about wheels, wheels could be a rigid wheel, wheels could be pneumatic wheel, again pneumatic wheel can be divided into two types: rigid mode of operation and flexible mode of operation. When I said rigid mode of operation that means the ground pressure is not sufficient, the ground is not sufficiently strong, ground does not have sufficient strength to support the wheel. So as a result, wheel will sink and it will behave like a rigid wheel.

When the ground has sufficient strength, it will try to deflect the wheel, so it will be in a flexible mode of operation. So, sometimes the pneumatic wheels behave like a rigid wheel just like your cage wheel. Initially, so what happened now, the steel wheels are fitted with tractors, but the limitations are, it cannot run on the paved road, the ride is an extremely tough in the sense there will be a good amount of vibrations and there will be high soil compaction.

So, in 1934 the first tractor which came with a pneumatic tyre that is WC Allischalmars who tested this tractor fitted with the rubber tires at Nebraska tractor testing laboratory in the UK. In early 1930s, companies began to offer pneumatic tyres on farm tractor. Nowadays, almost all tractors are provided with pneumatic wheels or the rubber tires. Then the other traction element which is used is your tracks. Tracks could be again rubber track; it could be metallic tracks. So, now coming to the wheel.

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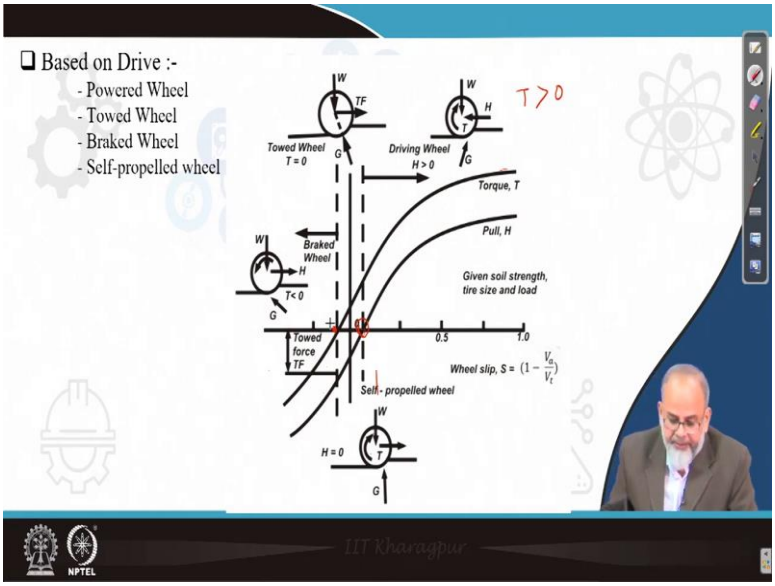

The wheel can be classified as powered wheel, it can be classified as towed wheel, it can be classified as braked wheel or it can be classified as self-propelled wheel. So, these classifications are based on power and torque characteristics of the tyre versus slip. Now, what is a powered wheel? When a wheel is provided with a torque that means initiate with a torque then it is powered.

But now, if you look at the torque and pull characteristic of a rubber wheel. I have indicated here, this is the torque, this is the pull and torque is touching the x axis at this point where pull is touching the x axis at this point, origin is this point. Now, first we look at this point where the pull is 0 but still some torque is acting. And that condition is called self-propelled condition. What do you mean by the self-propelled condition?

Self-propelled condition means the thrust which is developed because of the interaction, because of the supply of input power or input torque that is sufficient to develop a tractive force which will overcome the rolling resistance. There is no pull, so pull is 0 which is indicated ‘H’ as 0. Now, this point refers to self-propelled condition. The best example of self-propelled condition or self-propelled wheel is your cars, the bus, tyres of the buses, trucks, etcetera.

So, these are the best example of self-propelled condition. Now, in self-propelled condition, T is greater than 0 that means Torque has certain value, it has a weight W then this is the tractive force which is developed and G is the soil reaction. Look at the orientation of soil reaction. So, it is towards the contact patch and it is vertical.

Now, the other condition which I have indicated is this point where torque is equal to 0. When torque is equal to 0 means, that condition refers to towed wheel. Towed wheel means, there is no torque, only weight is acting and the soil reaction. Look at the orientation of soil reaction. This is no more vertical like this; this is inclined and it is passing through the centerline of the wheel. And this towing force is the force required to roll the wheel.

So, here, there is no torque. T is equal to 0. So, this condition is represented by the point here. And the difference between this point to this point, so this is the towing force that means, this much force is required to roll the wheel forward. I am talking about these forces on a horizontal plane. If the plane is inclined, then a weight component will come into picture. Now, the third wheel about which we will be talking about is your braked wheel.

If you look at this figure, braked wheel, the torque applied is just opposite to the direction of motion. Just like in case of self-propelled wheel, the torque is applied in a clockwise direction and the wheel is moving forward. But here, the torque is applied in the opposite direction. And where it is applied? And look at the soil reaction, it is still inclined, inclined more than the soil reaction which is obtained in case of towed wheel.

And there is a thrust, there is a pull H. Pull is there. So, torque is less than 0. So, this is called braked wheel. The best example of braked wheel is your ground wheel of a seed-drill. The best example of towed wheel is the wheels which are provided in a bullock cart. Now, the fourth wheel is your powered wheel. In case of powered wheel, torque is applied so torque is greater than 0.

There will be weight, and pull is applied and the soil reaction will be inclined in the opposite direction to that which you can see in case of a braked wheel or in case of a towed wheel. So, because of the torque application, there will be interaction of this wheel with soil and the force which is developed that is tractive force that will take care of this pull H and the rolling resistance.

So, if you look at these four wheels, what are the forces which are acting on these wheels and how the ground reaction is behaving, how it is orienting towards the left side or towards the right side that is very clear from this figure. So, that is why, I have indicated that any wheels coming towards this side will be called as driving wheel. Any wheels coming towards the left side from this line will be braked wheel. And the border lines will be your self-propelled wheel. And in this side, this will be towed wheel.

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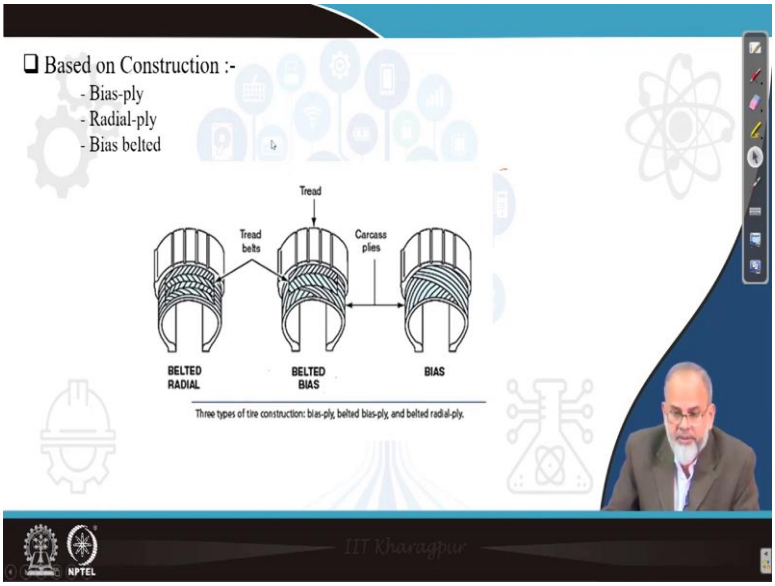

Now, based on construction, the pneumatic wheels can be called as a bias tyre or bias belted tyre or radial tire. Commonly, the bias belted are being used by the tractor manufacturers either bias tyre or bias belted tyre and nowadays radial tires are coming into picture, the only advantage in case of radial tyre is, it will have more sidewall deflection, so contact area is more. That is the main advantage over belted or bias belted tyre.

Then, the difference between bias tyre and the bias belted tyre is: in case of bias tyre, there is no belt provided below the carcass whereas in case of a bias belted tyre there is a belt provided which will provide more stiffness or which will give more stiffness to the tyre, so deflection of tyre is reduced. Whereas in case of a radial tyre, there will be a belt. So, these are the basic differences and we will cover in detail ‘the tyre construction’ in my subsequent classes, where I am going to take the little bit about tyre construction.

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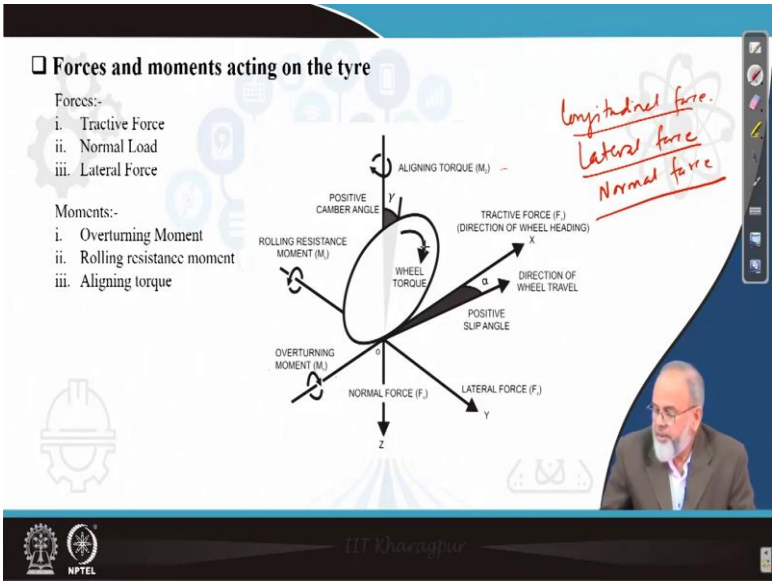

Now, the next important thing is what are the forces of moments acting and how do we represent it, that is important. So, to describe the forces and moments acting on a wheel, we have to take the help of a axis system which has been recommended by Society of Automotive Engineers. Where, there will be three forces, three moments and this will be indicated in this figure which you can see on the right side.

Then, first we have to define the x axis. The x axis is nothing but the intersection of the wheel plane with the ground plane. Then, y axis is perpendicular to the ground plane, perpendicular to the x axis. And the z axis is, the y axis is your ground plane itself and the z axis is perpendicular to the ground plane. The positive directions are, for the x axis the positive direction is indicated here that means moving forward. And z axis, the positive direction is downward and y axis, the positive direction is towards the right side, so that the entire axis systems become orthogonal and right-hand type.

The next thing is what are the moments acting. There are moments about x axis, there are moments about y axis, there are moments about z axis. So, the moment about the x axis is called the overturning moment. The moment about y axis is called the rolling resistance moment. And the moment about z axis is called aligning torque. So, when the wheel is moving in any soil, so there will be soil reaction coming from the ground to the wheel.

So, when you resolve the soil reaction into longitudinal direction, that becomes your x axis. When we resolve that reaction force which is coming from the ground to the wheel in the x direction, that becomes your longitudinal force, we call it longitudinal force. And when it is

resolved in the y axis, that is called lateral force, when it is resolved in z axis, about z axis that is called normal force.

So, these are the three forces which are coming from the ground reaction which is acting on the wheel. Now, in addition to these three forces and three moments, there are two angles indicated here. One is slip angle alpha, the other one is camber angle, positive camber angle gamma. This slip angle is nothing but the angle between the direction of travel of the wheel and the intersection of wheel plane with ground plane.

So, this angle is called slip angle. And camber angle is the angle which the wheel plane is making with the x-z plane. So, these two angles are important because they will be responsible for developing the cornering forces and the steering as well as the cornering forces. When we will try to cover, there, we will discuss what is its effect and how it is to be controlled.

So, in summary, you can say there will be three forces acting, three moments acting and this is the axis system which has been prescribed by Society of Automotive Engineers to mention or to define different performance parameters.

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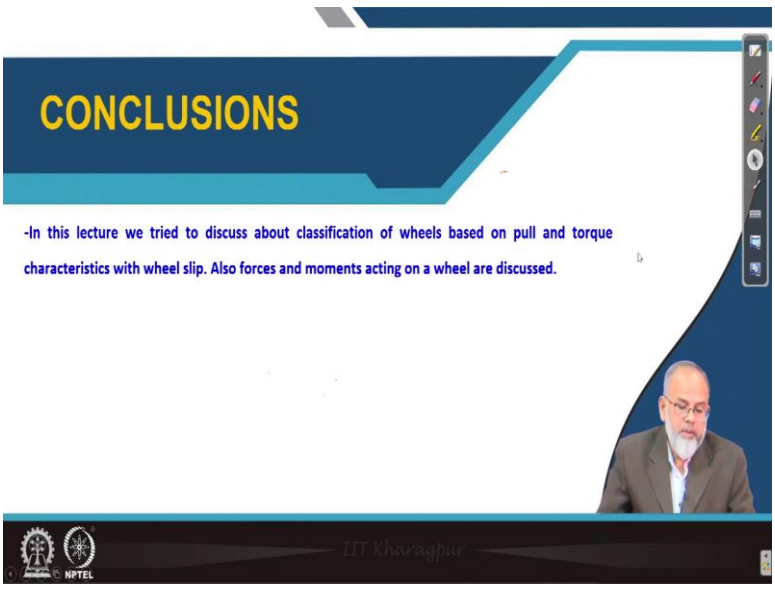

So, we can conclude that in this lecture, we tried to discuss about the classification of wheels based on pull, based on torque. And then we tried to define the moments and the forces which are acting and the two important angles which are associated with the wheel. Thank you.