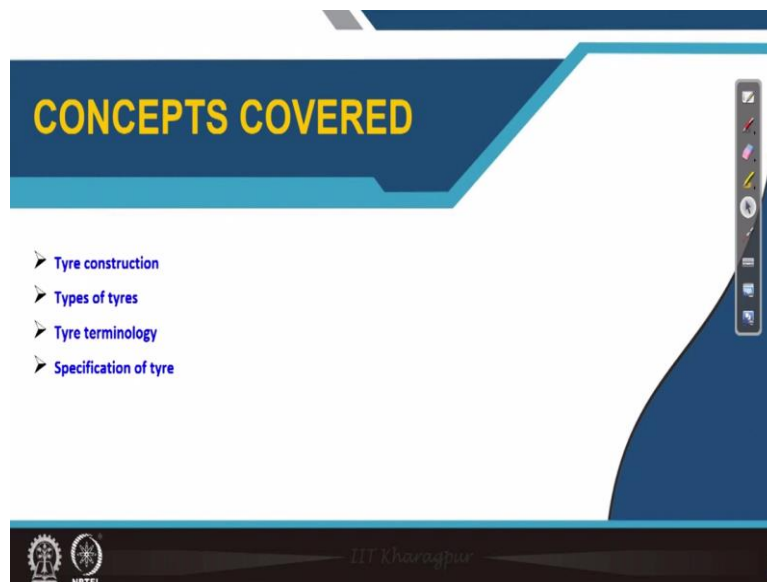


Traction Engineering
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Lecture – 03

Tyre Constructions and its Specification

Hi everyone. This is Professor H. Raheman from Agricultural and Food Engineering Department, IIT Kharagpur. I welcome you all to this NPTEL online course. Today is Lecture 3 and where I will try to cover tyre construction and its specification. The first thing which will come to our mind is why required to use a tyre?

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So, I will cover in details about the tyre construction, types of tyres, tyre terminology, specifications of tyre.

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KEY POINTS

- Carcass
- Beads
- Crown angle
- Aspect ratio
- Tyre specifications
- Overall tyre diameter

The slide features a dark blue header with the title 'KEY POINTS' in yellow. Below the title is a list of six key points, each preceded by a blue arrowhead. In the bottom right corner, there is a small inset video of a man with a beard and glasses, wearing a white shirt. The footer contains the NPTEL logo and the text 'IIT Kharagpur'.

Now, the key points are the carcass, beads, crown angle, aspect ratio, tyre specification and finally the overall tyre diameter.

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Tractor Tyres

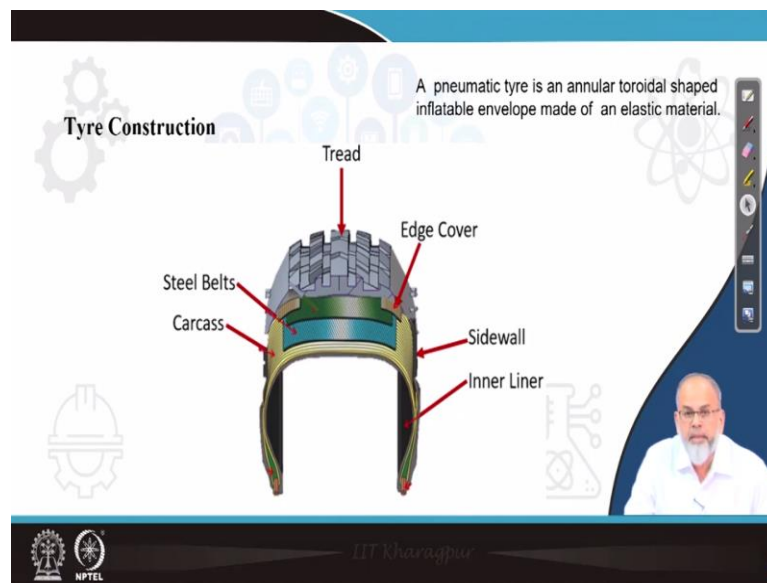
The wheel of a ground vehicle is generally required to fulfill the following functions:

- To support the weight of the vehicle
- To cushion the vehicle when riding over surface irregularities
- To provide sufficient traction for driving and braking
- To provide adequate steering control and directional stability

The slide has a light blue background with a faint gear and circuit pattern. On the right side, there is a photograph of a blue tractor with a large rear wheel and a smaller front wheel. In the bottom right corner, there is a small inset video of the same man as in the previous slide. The footer contains the NPTEL logo and the text 'IIT Kharagpur'.

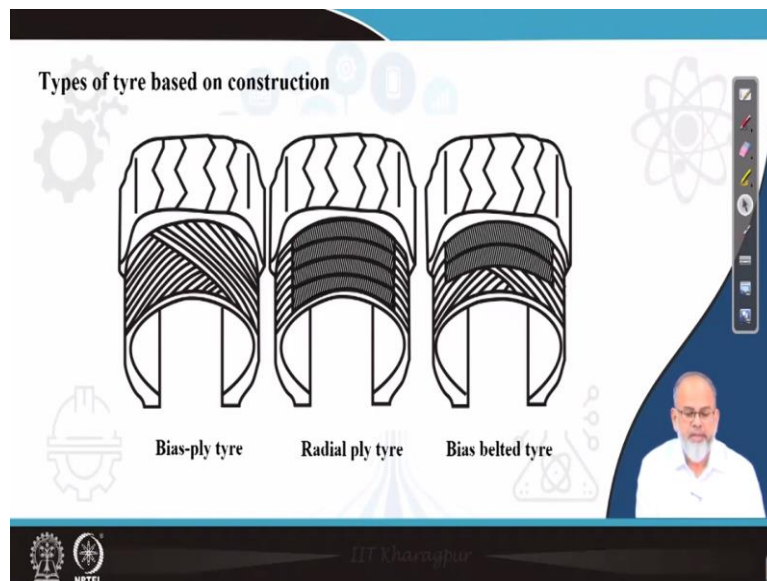
We use wheel in a ground vehicle to fulfill certain objectives. Objectives are to support the weight of the vehicle, to cushion the vehicle when riding over surface irregularities, then third one is to provide sufficient traction for driving as well as braking, then the last one is to provide adequate steering control and directional stability. So, these functions are efficiently done and affectively done by pneumatic tyre. So, if you look at the right hand corner, the tractors are therefore generally provided with wheels, pneumatic tyres.

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So, what is a pneumatic tyre? It is an annular toroidal shaped inflatable envelope made up of an elastic material. So, there are different types of tyres like bias ply tyre, radial tyre, bias belted tyre. But all these tyres, they have some common components like tread which is tyre tread, then carcass, then beads, sidewall and the last one is optional; optional in the sense the belt is provided or it may not be provided.

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So, I will discuss in detail about first the bias ply tyre, then I will switch on to the radial ply tyre and then in the last, I will discuss about bias belted tyre. So, in this figure, as I said whether it is a bias ply tyre, radial ply tyre or bias belted tyre all are carrying certain common

components like tread, then carcass, then beads and sidewall. So, what is a tread, how it is going to help us? The tread is the toughest portion of the tyre which transmits your tractive force and steering forces etcetera while in contact with the soil.

Then comes your carcass, this is the most important structural element of a tyre, it comprises of layers of cords of high modulus of elasticity materials and they are anchored around beads which are made up of very high strength material steel wires. These cords are encased with matrix of low modulus rubber compounds, natural synthetic or metallic composition and they run in different directions; different direction in the sense in case of a bias ply tyre.

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Bias-ply tyre

- Its carcass comprises layers of flexible cords of high modulus of elasticity encased in a matrix of low modulus rubber compounds
- Cords are made up of natural, synthetic or metallic composition and are anchored around the beads.
- Plies run from one bead to other bead at an angle. The angle between the cord and circumferential centre line of the tyre is called crown angle.
- Cords of adjacent layers run in opposite direction, thus the cords overlap in a diamond pattern (criss-cross).
- Sidewalls of a bias tyre are relatively stiff due to this criss-crossing of body plies which offers advantages during operation in severe environment.
- Because of this criss-crossing, bias-ply tyre has more internal friction.

The slide includes a diagram of a bias-ply tyre cross-section showing the internal cord structure. A small inset diagram shows two intersecting lines forming a diamond shape, representing the criss-crossing of cords. A video player interface is visible on the right side of the slide, and a small inset photo of a man is in the bottom right corner.

I will show in detail. They run from one bead to other bead in diagonally; diagonal in the sense, it is making an angle with the circumference, central lines of the tyre circumference. So, central line of the tyre circumference means, if I, this is the one central line and these lines are cords. So, they are making an angle. So that angle is called crown angle. So, this angle is called crown angle. The crown angle decides two things. What will be the type of cornering behavior, what will be the type of riding quality. If crown angle is low then cornering properties are better, but the riding quality is very rough. If the crown angle is more then riding... Cords are made up of natural, synthetic, and metallic composition and they are anchored around the beads. So, the two adjacent layers of cords, they run in opposite direction that means they overlap in a diamond shape.

One cord is in this direction, other cord in this direction like that. So, basically there is a diamond shape. Here, in other words, we call it as crisscrossing because of that what happens

during operation, when there is a load there will be deflection of tyre and its diamond shaped portion is getting deflected, elongated. So, that creates a kind of action where there will be wiping between tread and the road, so resulting in good amount of rolling resistance.

So, the beads, carcass, tread and the carcass, bead at the side of that, there will be a sidewall. So, this is the constructional features of a bias ply tyre. Now, coming to the constructional features of radial tyre how it is different from bias ply tyre?

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Radial-ply tyre

- Body chords run parallel to each other from bead to bead at right angle to tread centreline.
- A belt of several layers of cords of high modulus of elasticity (usually steel or higher strength material) fitted under the tread.
- The cords in the belt are laid at a lower crown angle approximately 20° .
- Most flexing occurs in side-line area, while tread area remain relatively stiff due to belts.
- Sidewalls are prone to cut and puncture while working in severe environment.
- Advantages by 6-14% in traction, fuel efficiency and reduced wheel slippage over bias-ply tyres.

So now, you look at the radial ply tyre. Here the cords are, carcass is there, cords are there then in addition to this there will be a belt and on the top of the belt there will be tyre tread. So, the cords here, which run from one bead to other bead they are at crown angle of 90 degree. So, that is the advantage; advantage means it gives a better ride, riding ability then this several layers of cords are of high modulus of elasticity, usually steel or higher strength material fitted under the tread. So, this is, I am talking about the belt.

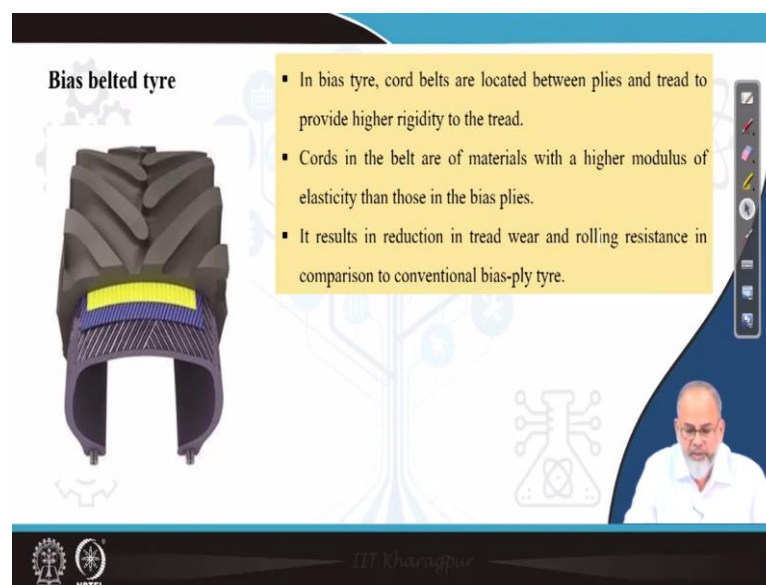
Now the cords which are run from one bead to another bead they are of little lesser high modulus of elasticity as compared to the cords which are present in the belt. The cords in the belt lay at a crown angle which is lesser than the crown angle of the cords which are provided in the carcass. So, crown angle of the carcass is around 90 degrees, whereas crown angle of the cords which are present in the belt, this is around 20 degrees.

So, because of that, because of this belt, the tread is stiffened. So, when there is flexing of tyre during operation, the tread remains relatively stiff so the sidewall becomes deflected and

there is a probability or a chance that there could be damage to the tyre when it is operated in a severe conditions like stones are there or stumps are there, so those are the severe conditions that may affect the tyre; affect in the sense it may damage the tyre.

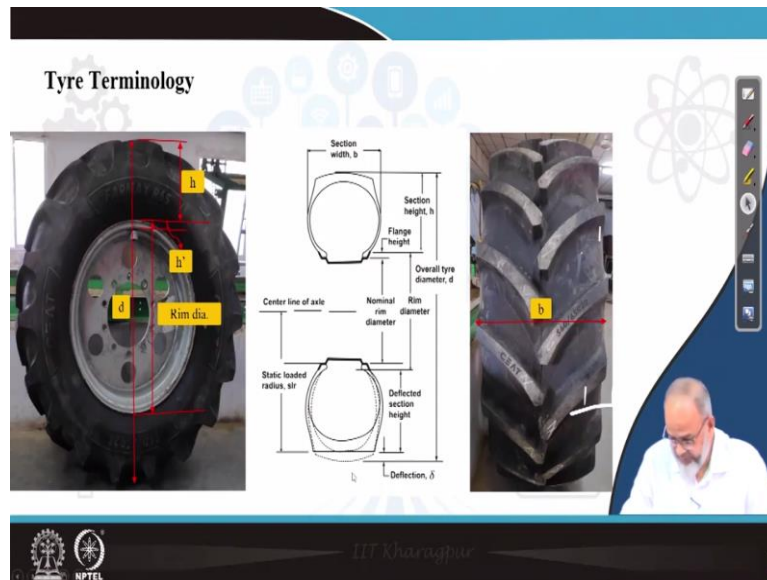
Then the advantage over bias ply tyre is, there is a gain in fuel efficiency, there is a gain in wheel slippage; gain in wheel slippage means reduction in wheel slippage to the tune of 6 to 14 per cent. Then comes our bias belted tyre.

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In case of a bias belted tyre, in addition to the cords which are provided in the carcass of a bias tyre, there will be a belt made up of higher modulus of elasticity and this is provided in between the tread and the carcass. So, that means it is partly bias ply tyre and partly radial tyre. So, it gives stiffness to the tread. So, the wiping action is reduced, so the rolling resistance is reduced as compared bias ply tyre and the wear of the tread is also reduced because of the stiffness and the rest of the things that means, the carcass where the beads are provided and the carcass the layers of course, they run at a crown angle which is around 40 degrees. So, all those other components remain same as that of bias ply tyre, but only an addition of belt has been provided so that it gives extra rigidity to the tyre tread. So, thereby what happens now, there will be a reduction in tread wear and there will be reduction in rolling resistance as compared to conventional bias ply tyres.

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Now, after knowing in details about the constructional features, the next thing is, what are the different terminology associated with a tyre whether it is a bias ply tyre whether it is a belted tyre whether it is a bias belted tyre. These terminologies remain same; same in the sense it has section width, it has section height, it has overall diameter. So, all those things we are going to discuss in detail.

And in figure, you can see, where I have indicated the different sections like section width, section height, flange height then rim diameter then overall tyre diameter. So, in the bottom of the figure if you look at there is some deflection; a deflection is shown here. So, during operation, what happens, because of the weight, the tyre gets deflected and the deflected height is lesser than the section height, a deflection depends on many factors like what is the material of the tyre. What is the type of tyre like whether it is a bias ply tyre or whether it is a radial ply tyre or whether it is a bias belted tyre. And it also depends on what is the inflation pressure, it also depends on what is the soil condition. So, deflection of the tyre will reduce the rolling radius that means it will reduce the tyre radius and thereby the rolling radius is reduced.

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- ❑ Section width (b)
It is the width of a new tyre, including 24 h inflation growth and normal side walls, but not protective side ribs, bars or decorations.
- ❑ Section height (h)
It is the distance between top of the flange to the top of the tyre tread.
- ❑ Aspect ratio
It is the ratio of section height to section width. It is measured in percentage.
- ❑ Static loaded radius (SLR)
It is the dimension measured from section centreline to the ground when tyre is under load.
- ❑ Overall diameter (d)
It is defined as rim diameter plus twice the section height of a new tyre, including 24 h inflation growth.
- ❑ Rolling circumference
It is the distance travelled in one revolution of the tyre under maximum load and inflation for that particular tyre on a level paved surface

Now, what is the section width? It is the width of the new tyre including 24 hour inflation growth and normal sidewalls, but not protective side ribs, bars or decorations. And section height, it is the distance between top of the flange to the top of the tyre tread. So, one of the important aspect of a tyre is aspect ratio. What is that? It is the ratio of section height to the section width and it is measured in percentage.

Then, as I told, static loaded radius, it is the dimension measured from section center line to the ground when the tyre is under load. That means, if I draw a tyre here, this is when it is not loaded. Now, when I load it there will be a deflection. So, this is your reduction in radius of the tyre. So, static loaded radius means from this point to this point. So, this is static loaded radius. Now, overall diameter, it is defined as the rim diameter plus twice the section height of a new tyre including 24 hour inflation growth.

Now, rolling circumference is the distance travelled in one revolution of the tyre under maximum load and inflation pressure for that particular tyre on a level paved surface, that is it is on a hard surface. So, this is little bit of different dimensions or different sections which are discussed. Next, I will try to find out how the tyre is specified.

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▪ Rim diameter can be obtained by
- adding 50 mm to nominal rim diameter
- adding 6% to nominal rim diameter

▪ Overall diameter = rim diameter + 2×(aspect ratio × section width)

▪ Overall diameter = 1.06×nominal rim diameter + 2 × (aspect ratio × section width)

The diagram shows a tire with a vertical red line through its center. A horizontal yellow box labeled 'd' indicates the rim diameter. Two vertical yellow boxes labeled 'h' indicate the section height on both sides of the rim. A yellow box labeled 'Rim dia.' points to the center of the rim. The slide also features the NPTEL logo and the text 'IIT Kharagpur' at the bottom.

There are two terminologies I have used: one is nominal rim diameter the other one is rim diameter. The difference is, if you multiply 6 per cent of the; if you add 6 per cent of the nominal rim diameter to the original rim diameter that becomes your rim diameter that means 1.06 times nominal rim diameter will become the rim diameter. Now, if you know the rim diameter, if you look at this figure.

If you know the rim diameter which is indicated from this point to this point then I add the section height here h on both the sides then it becomes the overall diameter. If you do not want to do like this, then you add rim diameter plus twice the aspect ratio, a product of aspect ratio and section width because the tyre is usually specified by certain numericals like...

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Tyre specification

Radial ply

	Standard	Metric
	18.4R46	480/80 R 46 <u>155A8</u>
18.4 - Tyre section width (inch)		480 - Tyre section width (mm) 80 - Aspect ratio*
R - Radial		R - Radial
46 - Nominal rim diameter (inch)		46 - Nominal rim diameter (mm) 155 - Load index number- maximum load the tyre can carry at rated inflation pressure A8 - Speed symbol- maximum speed for which this load rating is applicable -Refers to speed of 40 km/h

Bias ply

- 13.6-28 (12)
- 13.6 - Tyre section width (inch)
- 28 - Nominal rim diameter (inch)
- 12 - Ply rating

1.06 x 28 + 2 x 13.6 x 0.75

If you look at this slide, you can see this tyre. If it is a bias ply tyre, it is specified by a number like 13.6 28 or 16.9 28. So, what does it mean exactly? 13.6 refers to tyre section width and 28 refers to nominal rim diameter and in the bracket 12 means ply rating. So, now 13.6, the unit is in inches and 28, the unit is also in inches. So, if you want to find out the diameter then you need to know the section height.

So, section height is not given that means the aspect ratio is to be used here. So, usually the aspect ratio is taken as 0.75, if it is not specified. So, if it is specified, if you look at the right side figure of the tyre 13.6 28, very clearly written 13.6-28. So, there was no mention about the aspect ratio. So, here we assume the aspect ratio as 0.75. So, now 13.6, so first I have to find out the rim diameter, so

$$1.06 \times 28 + 2 \times \text{section width (13.6)} \times \text{aspect ratio}$$

I take 0.75.

So, this you will get in inches, the diameter will be obtained in inches. Now, you can convert into centimeter or millimeter or meter whatever. Now, if you look at the tyre specification, radial tyre, it is mentioned like 18.4 46. So, 18.4 R46. So, the difference between bias ply tyre and radial tyre is, in bias ply tyre there is no alphabets whereas in radial tyre standard system you can see 18.4 there is an alphabet R46.

So, 18.4 is again the tyre section width which is in inches and R represents that the tyre is radial and 46 represents nominal rim diameter where you can follow the same rule whatever I mentioned here

$$1.06 \times \text{nominal rim diameter} + 2 \times \text{section width} \times \text{aspect ratio}$$

So, that will give you diameter of the radial ply tyre. But in a matrix system, the radial ply tyre is specified as you can see the numbers 480/80, R 46, 155, A8. So, there are good amount of numbers.

So, the first number 480 represents the tyre section width in millimeter, 80 is the aspect ratio which is no this is not millimeter this is in percentage, then R is the radial tyre, then 46 is the nominal rim diameter which is in inches and the number 155 that represents load index that means it is a load index number which represents, which represents maximum load the tyre can carry at the rated inflation pressure.

And A8, this is a symbol for speed which indicates the maximum speed for which the load rating is applicable. A8 usually refers to 40 kilometer per hour. So, this is how we can specify a tyre. So, the only difference from the outside you can know is whether it is a radial tyre, whether it is a bias ply tyre. If R is there then immediately you can say that this is a radial tyre. If R is absent in that specification, then immediately you can say that this is a bias ply tyre.

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□ Ply rating
It is used to identify a given tyre with its maximum recommended load when used in a specific type of service. It is an index of tyre strength and doesn't represent necessarily the number of layers of cords.

□ Load ratings
Previously tyres were rated by actual number of plies used in the tyre to carry the vertical load. Now a days, an 8-ply rated tyre may have only six actual plies, but carries an 8-ply load rating. Originally, ply rating of radial tyre and bias tyre for loads and inflation pressure was equivalent. But in 1987, Tyre and Rim association increased radial load by 7% over equivalent size bias tyre and then brought star rating to variation in inflation pressure.

□ Star rating
Tyre and rim association created a star rating system for radial tyres to denote the rated inflation pressure for maximum rated load.
Single star (*) - Maximum inflation of 18 psi.
Each additional star - increase the inflation pressure by 6 psi.

Ply rating, this is very important parameter which indicates the index of tyre strength. It does not represent the number of layers of cords which are present in the carcass. Before World War 2, when the cords are made up of cotton bodies, during that time, number of ply rating means if it is a 12 ply rating that means there will be 12 cords passing in the carcass, but nowadays it is not the number of ply it is the strength that indicates, a 8 ply can carry the strength of 12 ply rating. So, that is the difference.

Then, the second one is load rating. Previously what happens, the tyres were rated by actual number of plies used in the tyre to carry the vertical load, but nowadays, an 8 ply rated tyre may have only 6 actual plies, but it can carry 8 ply load rating. So, originally the ply rating of radial tyre and bias ply tyres for loads and inflation pressure they are equivalent.

Whether it is a radial tyre or bias ply tyre, their load carrying ability and the inflation pressure they are equivalent. But, now the tyre and rim association, they have increased the radial load by 7 per cent over the equivalent size bias tyre and they have also indicated another component that is a star rating to take care of the variation in inflation pressure. So, what is star rating? The tyre and rim association they created a star rating system for radial tyres to denote the rated inflation pressure for maximum rated load.

If a single star is there that means the maximum inflation pressure it can carry is 18 psi. If two stars are there then it will be 24 psi, if three stars are there then it will be 30 psi that each addition of star increase the maximum inflation pressure by an amount of 6 psi.

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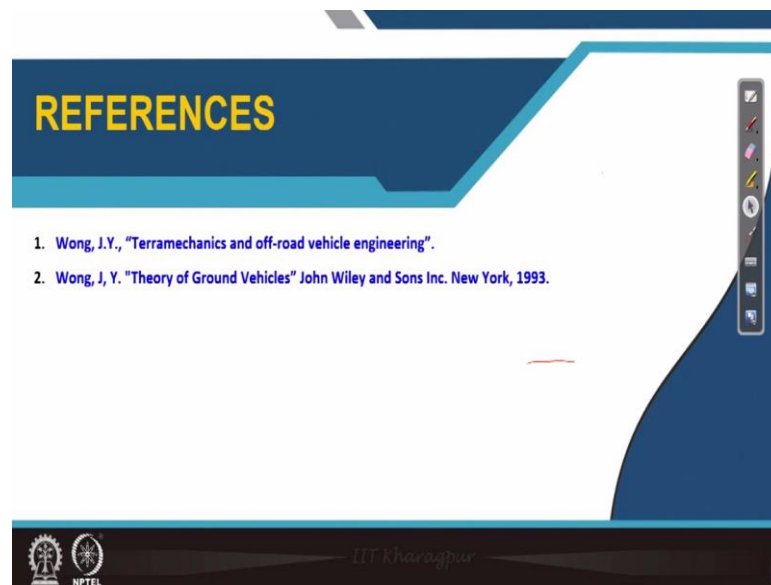
CONCLUSION

In this lecture I tried to cover the details of construction of different types of tyre, specifications of tyre and how to calculate the diameter of the tyre.

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So, in brief what I can say, in this lecture, I tried to cover the details of constructional features of the tyre, how they are specified and how to calculate the overall diameter of the tyre.

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So, these are the books which can be referred to give more input to your understanding.

Thank you.