Kinematics of Mechanisms and Machines

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Lecture – 38
Gear Trains – I

In this lecture, I am going to introduce Gear Trains.

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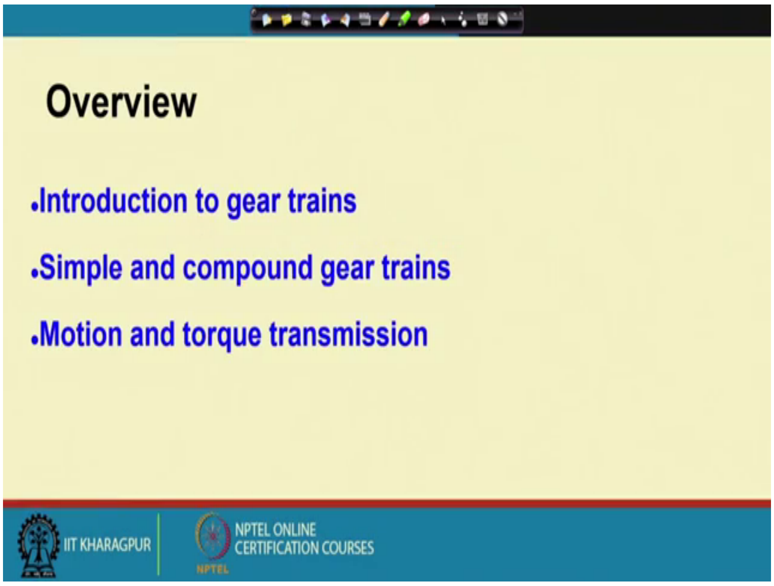

We will discuss about simple and compound gear trains and calculate the motion and torque transmission ratios.

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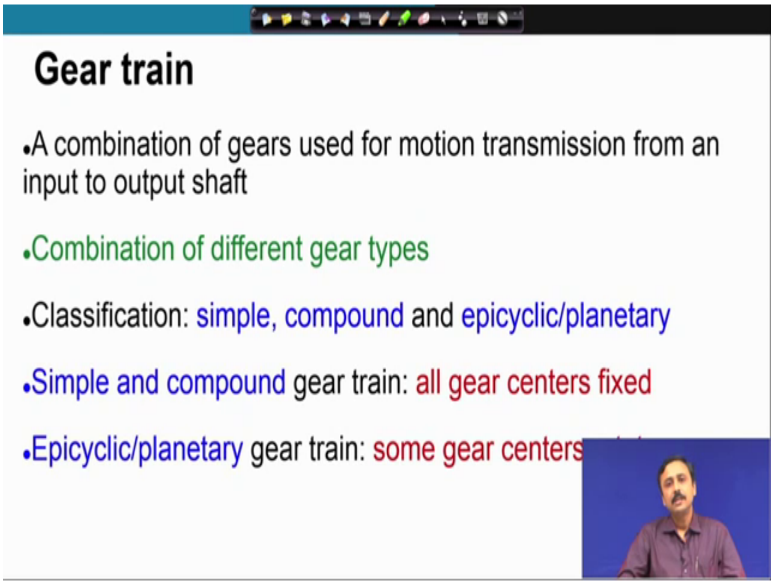

What is a Gear Train? A combination of gears used for motion transmission from an input to an output shaft, this a gear train. There can be combination of different types of gears. For example, you can have spur gears, bevel gears; combination of them. We classify Gear trains as simple, compound and epicyclic or planetary gear trains. In a simple and compound gear train all the centre of rotation of the gears are fixed, we are going to look at examples and understand this. While in an epicyclic gear train, some gears will have their centres which are moving, which are rotating.

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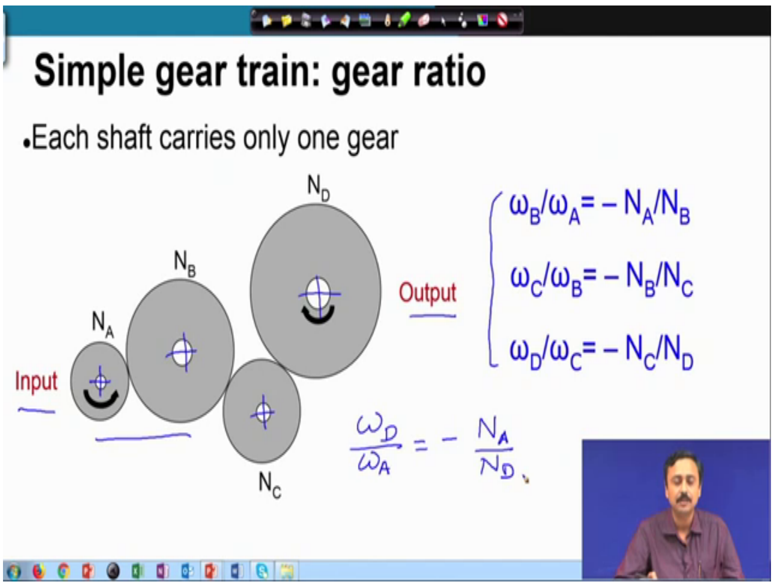

Let us start with the simple gear train and try to calculate the gearing ratio. As I have mentioned in a simple gear train, the centre of rotation of all gears are fixed and in a simple gear train each shaft carries only one gear. So, let us look at an example, here is an example, we have this input; this is the input gear and output gear, all these centres are fixed. If you recall the motion transmission ratio, let us say for this sphere of gears A and B.

So, omega B divided by omega A is minus of N A by N B. There N A and N B are the number of teeth on gears A and B respectively. And the negative sign indicates there direction, they are in opposite directions. Now, if you continue this for the pairs B and C and for C and D, then you have these 3 transmission ratios for these individual pairs. Therefore, if you want to find out the transmission ratio from the input to the output which means you want to find out omega D by omega A that can be obtained by multiplying these 3 ratios and if you do that you will finally, obtain minus of N A by N D, the other terms will cancel off.

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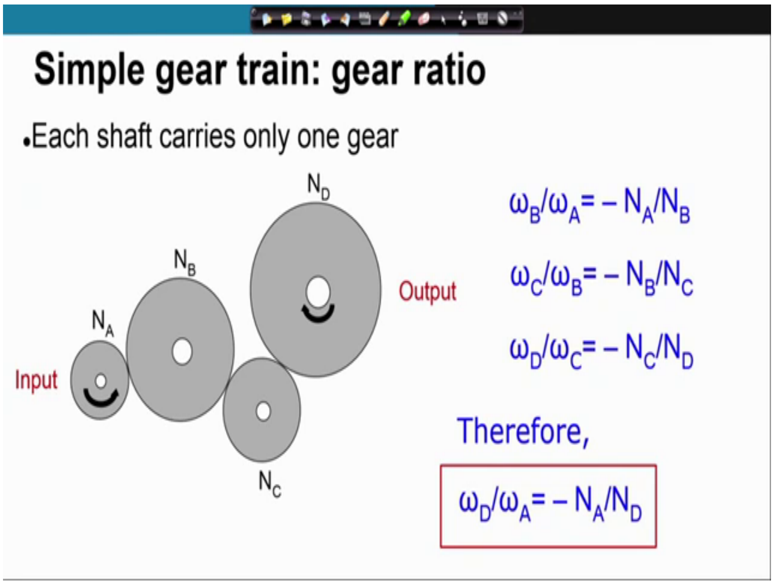

So, this is what I write here finally, omega D by omega is minus of N A by N D. So, this is a simple gear train; each shaft carries only one gear.

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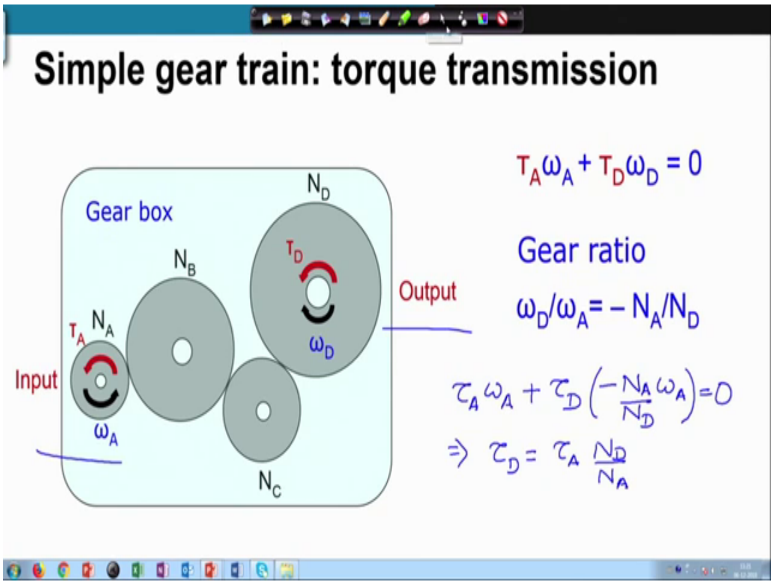

Let us now look at the torque transmission ratio for a simple gear train. Here, I have also introduced the gearbox, the reason for this will become clear very soon. Now, from the power balance, this we have been using and you have used it previously to calculate the force transmission here, I am using the power balance equation.

So, the net rate of work done on the system is 0. There are two sources through which work is being done; one is at the input, the other is at the output and if you do this power balance then you get tau A omega A plus tau D omega D equal to 0. Here, we initially do not know the direction of tau D. If you recall the gearing ratio between A and D which were just now derived which is minus of omega D by omega A is minus of N A by N D. If you substitute this here, then tau A omega A plus tau D omega D is minus of N A N D times omega A so, that is equal to 0.

So, that tells us tau D is equal tau A N D by N A; omega is not equal to 0. So, we have this relation between torque at the output and the torque at the input so, tau D is equal to tau A N D by N A.

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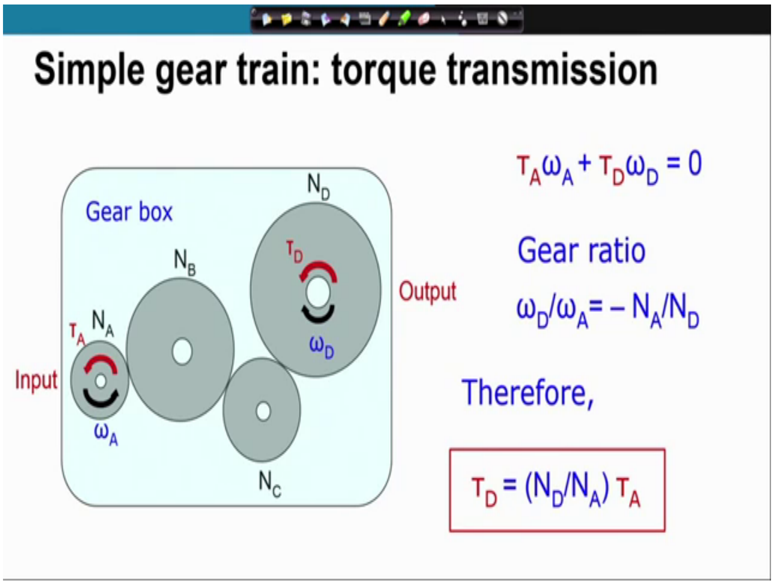

So, this is what I have written out for you ok.

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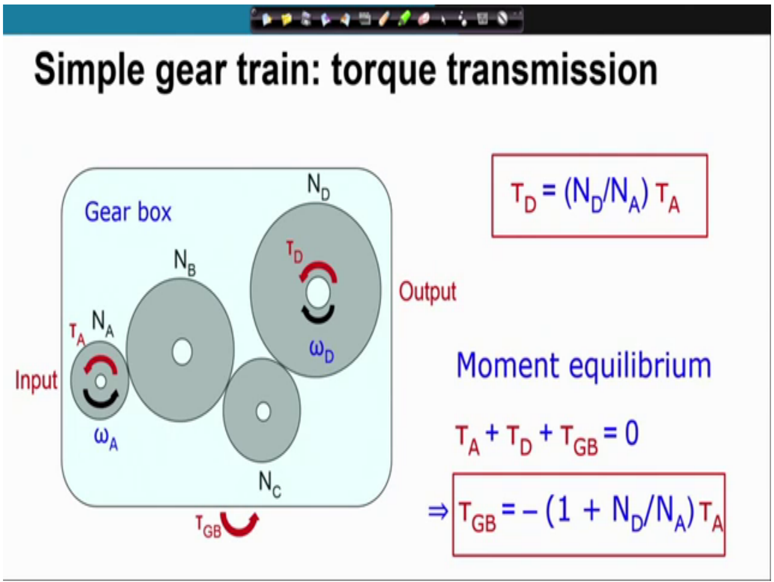

So, this is our torque transmission ratio in general this N D by N A is not equal to 1. Therefore, tau D is not equal to tau A. Now, why are we discussing this? If you look at the equilibrium of the whole system of this gear train, then we have to torques acting on the system tau A and tau D which are not equal. So, therefore, system cannot be in equilibrium, it cannot be in equilibrium.

Unless there is an external torque acting which keeps the whole system in equilibrium and that comes from the gearbox. This gearbox is fixed on to certain base it is it has got its foundation; it is fixed onto the ground and it is not allowed to rotate or move. Now this fixation therefore, introduces another torque which is tau G which I call tau GB.

Now with this the whole system must be in equilibrium. So, moment equilibrium tells me that tau A plus tau D plus tau GB must be equal to 0, of which I know tau D in terms of tau A which I substitute and finally, I can calculate the torque that acts on the gearbox. So, the gearbox foundation has to take this torque.

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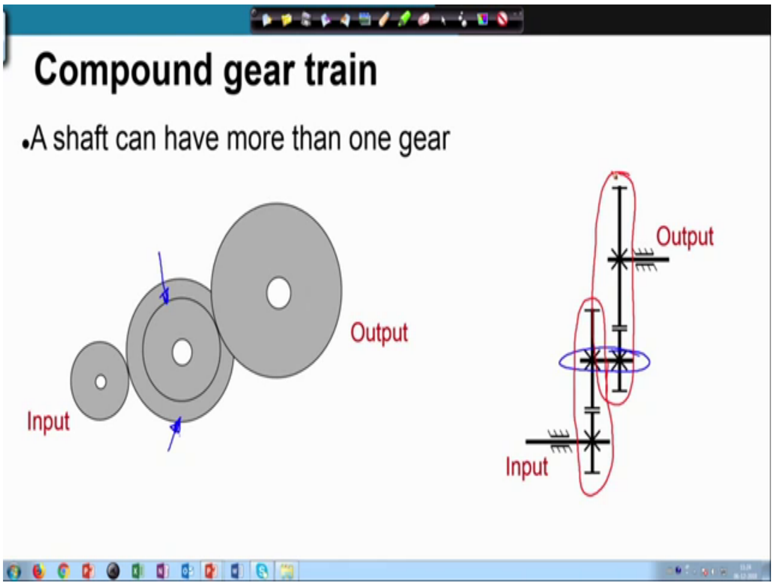

Now, let us go about to a compound gear train. When a shaft contains more than one gear, then the gear train is called a compound gear train and the axes are of course, fixed as we have discussed. This is an example of a compound gear train. Here, we have 2 gears; one is this, the other is this. This will be more clear in this schematic diagram. So, there is this shaft which carries 2 gears fixed to it; both the gears are fixed to this intermediate shaft. There are two meshing gears like this; this is between the input and one of the gears on the intermediate shaft and here is the other meshing to the output.

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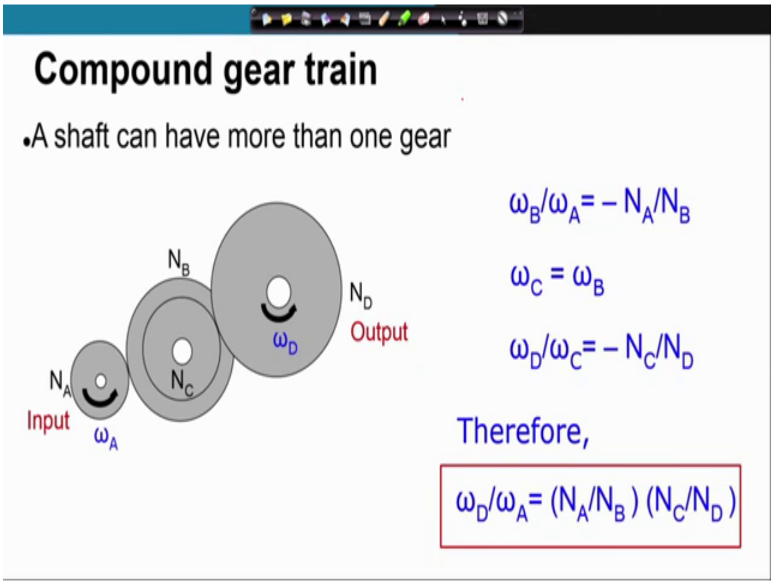

Now, let us try to calculate the transmission ratio we proceed as we have done before. So, omega D by omega A is minus N A by N B. Now omega B and omega C are same because they are on the same shaft. So, omega C is equal to omega B and finally, omega D by omega C is minus of N C by N D. Now, if I want omega D by omega A, then I use these 3 relations and we can easily arrive at this transmission ratio omega D by omega A. Now that is a product of these 2 ratios N A by N B and N C and N D. Here they do not cancel off as in a simple gear train the intermediate gear tooth the number of teeth they cancel off here they do not, this is a compound gear train.

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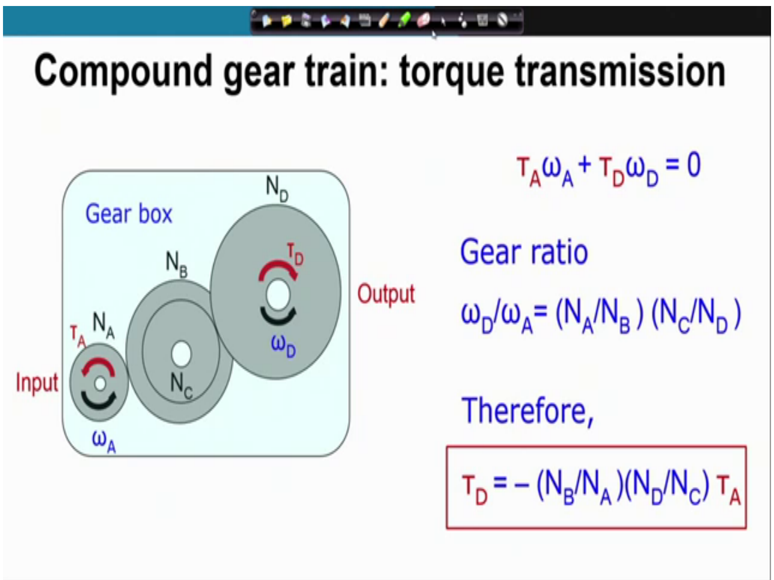

Let us look at the torque transmission ratio for a compound gear train. Once again we start with the power balance, as I have written out here and we have the gear box again for the same reason we are discussed before. Now the motion transmission ratio, we are just now derived and if I substitute in the power transmission; then I have the torque at the output in terms of the torque at the input so, these are very simple calculations.

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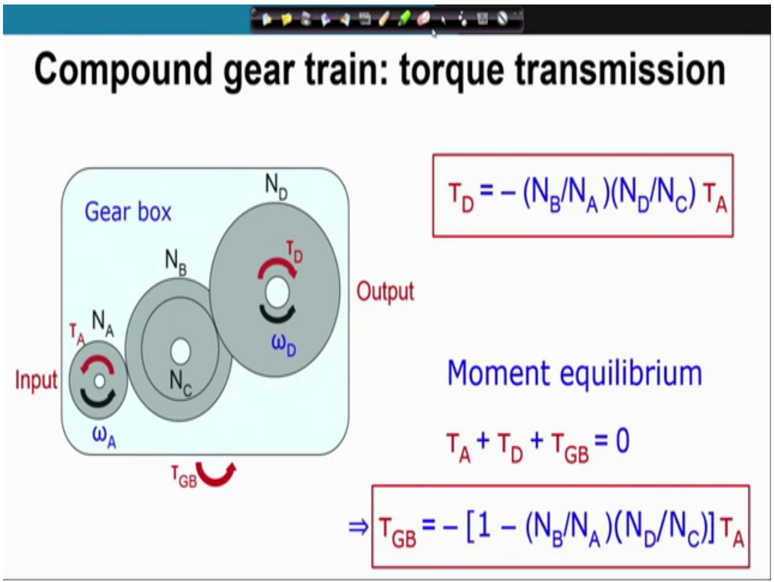

Now, once again the torque tau A and tau D, they are in general not equal. So, therefore, we require an additional torque for equilibrating the whole system which is the torque on the gearbox from the foundation of the gearbox.

If you use the moment equilibrium equation, then that relates tau A tau D and tau GB and that sum must be equal to 0 for equilibrium. We can substitute tau D in terms of tau A and calculate tau GB in terms of tau A so, that relation gives us how much torque has to be resisted by the foundation of the gearbox.

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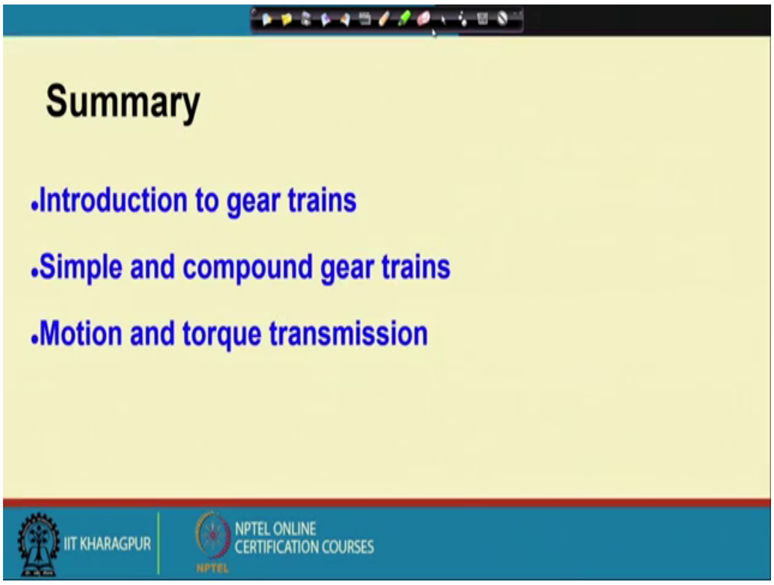

So, that completes our discussion, basically what we have done is we have introduced gear trains; we have looked at two type of gear trains simple and compound. We have calculated the motion transmission ratio and the torque transmission ratio. So, with that I will close this lecture.