Mechanism and Robot Kinematics
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Lecture - 03
Kinematic Diagram

Right at the outset, let me give you the overview of today's presentation.

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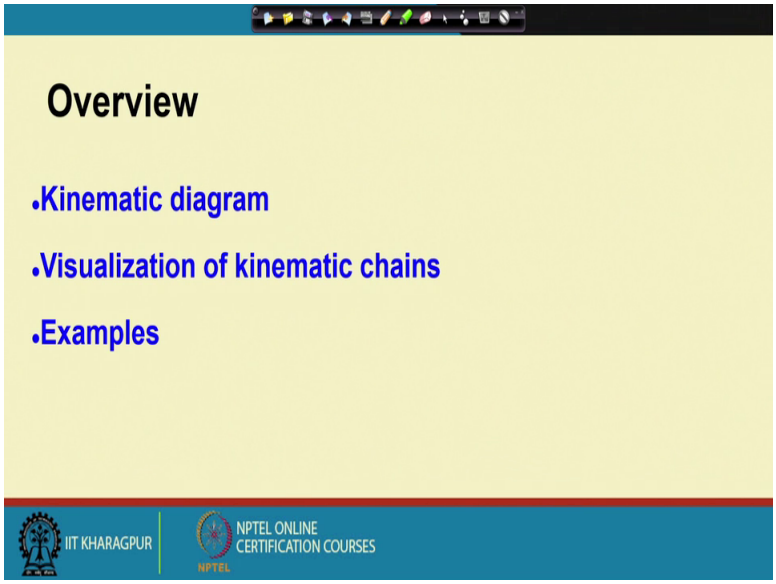

So, first we are going to discuss something known as a kinematic diagram which will help us, allow us to visualize the mechanism. So, it will allow us to identify the kinematic chains as we know them, this I will demonstrate with some examples.

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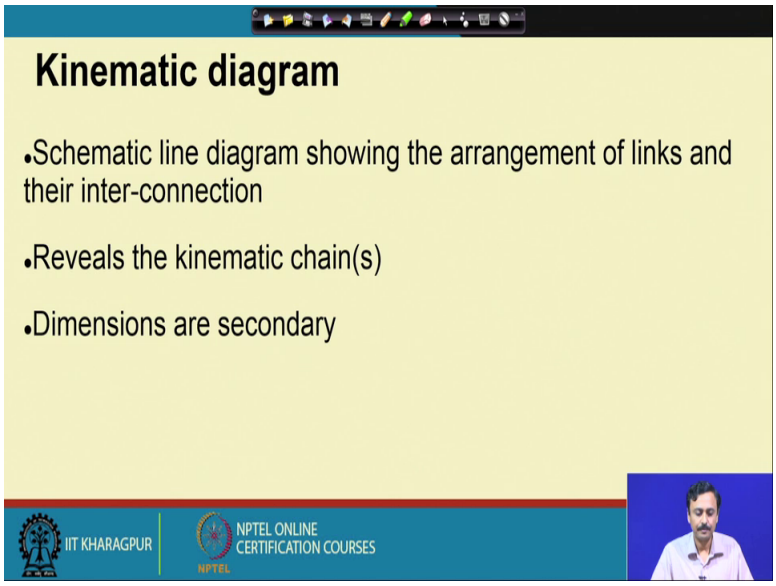

So, what is a kinematic diagram? A kinetic diagram is a schematic line diagram showing the arrangement of links and their interconnections. So, we are not too much interested in how; what is the shape of the link? Or maybe what kind of dimensions the link might have? So, these are not of much importance in kinematic diagram.

But what a kinetic diagram does? It reveals the kinematic chains that go in making a particular mechanism and as I mentioned that dimensions are secondary. Dimension shape of the link etcetera they are secondary. So, what is of primary importance? Is to have a line diagram which clearly brings out the different kinematic chains; that means, the connection between the links and the kinds of links; is there it is a singular link, binary link, ternary link etcetera and the kind of kinematic pair that is present; so that is kinematic diagram.

Let us look into some examples.

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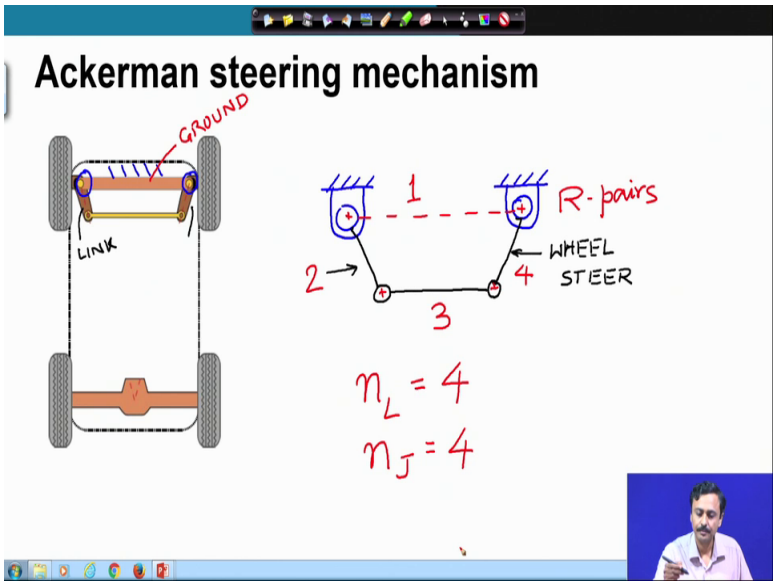

This is the Ackerman's steering mechanism; which is used in cars. So, here we have this link as it is shown; which is fixed to the body of the car. Now this fixed link has two kinematic pairs here and here. So, we will call them as the ground hinges; so this is one ground hinge, this is the other ground hinge.

Now, this kinematic pair connects to this link and this kinetic pair connects to this link. At the end of these two links; there are two more kinematic pairs, which are connected by this coupling link. These links are connected to the wheel; this steer the wheel, this and this they are connected to the wheel. But we are not going to draw the wheel our mechanism is this the Ackerman's steering mechanism is what I have shown you. So, this is the kinematic diagram of the Ackerman's steering mechanism.

Now, here we are going to number the links; remember that ground is a link. So, this is the ground link; we will number the ground link, this is the ground link as 1. Always we will number the ground link as 1; this steering link as 2; this coupling link as 3 and this steering link again as 4; so there are 4 links.

So, we will write number of links as 4 and the kinematic pairs; so, this is one kinematic pair, this is one kinematic pair, this is one kinematic pair, this is one kinematic pair and all of them as you can see are revolute pairs. They are all revolute pairs, we will write number of joints also as 4. So, this is the kinematic diagram of the Ackerman's steering mechanism.

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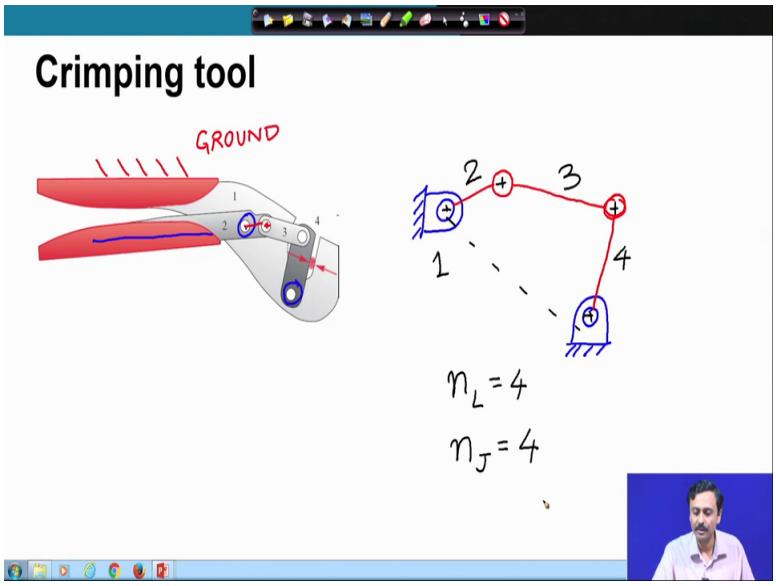

So, let us move on; this is a crimping tool something like a plier, but not like an ordinary plier as you can see; there is a mechanism in it. And as we will see later; how this mechanism is so useful in this tool; again in this we have to identify first; a ground link. So, I identify this as the ground link; then I find that on that ground, there are two kinematic pairs this and this.

So, I draw two kinematic pairs which are grounded, this handle is one of the links which is hinged to the ground at this kinematic pair. So, I am going to draw that; at the end of this handle there is another kinematic pair. Note that I have not drawn the handle; I have just drawn this part of the link. And I have come to this kinematic pair; to that we have another link; at the end of which, there is another kinematic pair; which is again joined to the ground hinge.

So, this is the kinematic diagram of this crimping tool; which brings out the kinematic chain. Now here again, I am going to number; so the ground is numbered as 1 as always. So, this is the ground; this is 2, the coupler is 3 and this is 4; link number four, which actually does the crimping operation; link number 4 as you can see does the crimping operation. So, here number of links is equals to 4; number of kinematic pairs, so this is 1, 2, 3, 4. So, number of joints is also 4; so, that is the kinematic diagram of the crimping tool.

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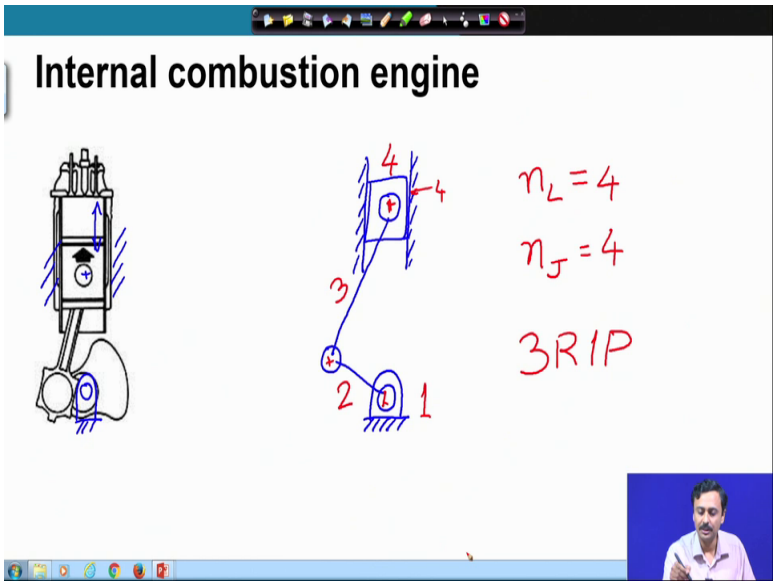

Next we come to this internal combustion engine; which I have shown you a schematic diagram. Let us draw the kinematic diagram; now here you have a ground, this is the crankshaft. So, that is a ground and the other ground is the cylinder; in which this piston is moving. So, we have the slider on which; there is this kinematic pair, a pin which is guided in this slot; fixed to the ground which is there. This is connected by just connecting rod and finally, again to the ground; which goes to the crankshaft.

So, here we have a prismatic pair and three revolute pairs. So, you have three revolute pairs and one prismatic pair; let us number them. So, ground is 1; the crankshaft is 2, the coupler is 3 and the piston; remember is another rigid body, it is a binary link as you have one revolute and one prismatic sliding. So, this is another link, so that is the fourth link. So, again there are 4 links; so in all the example that we have seen, there are 4 links.

So, number of links is equal to 4 and number of joints; as you can see is 1, 2, 3 and 4. So, there are 4 kinematic pairs, there are 3 revolute and 1 prismatic so sometimes; we call this as 3R1P kinematic chain. In the previous examples, they were all revolute; so they were 4 R; now here this is 3R1P. So, this is the kinematic diagram of an internal combustion engine.

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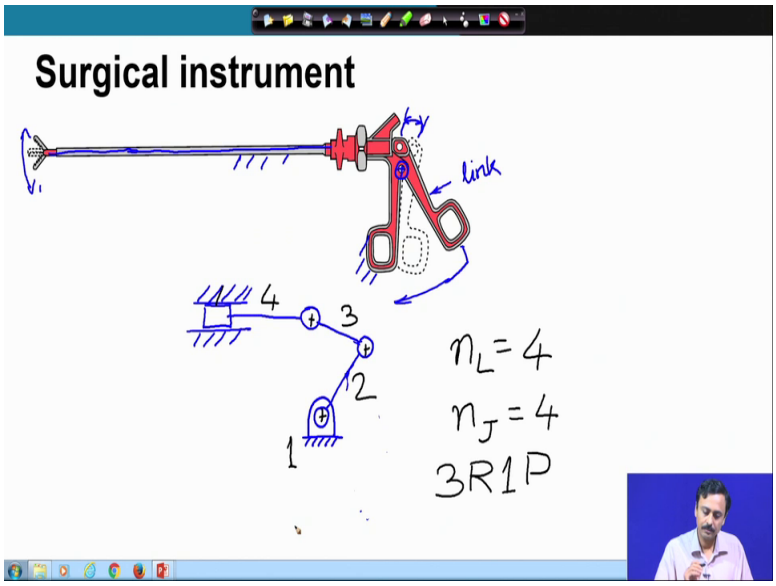

Next, we come to this surgical tool; now we need some details of what is inside this because it is not visible. So, let me draw this; so I have to first select a ground; now this handle which remains static with the body; so this is the body, this is a cylinder; hollow cylinder through which a rod passes, which transmits the motion of the surgeons finger to the; so, this motion to the output motion.

So, we will fix this handle as the ground; this handle is an integral part with this cylindrical barrel. The thing that can move is this grip; so as you can see, there is one ground hinge here. So, this is one ground hinge and there is one hinge as you can see, which can move; this hinge is moving, is rotating about this ground hinge. So, therefore, I must be having a link; so which is this link, which is rotating about the ground hinge; so this is my link.

Now, to connect it to a rod that passes inside this barrel. So, there is a rod that passes; that takes motion from here to the end point, this is connected by another hinge; to this rod which moves inside this cylinder. So, remember this is our handgrip; this link is the handgrip and there is this additional link which connects through another revolute pair to the rod that transmits the motion.

So, I actually need not draw this at all; so this is our kinematic diagram. So, let us again count ground is 1, this handle link is 1, this coupling link is 3 and finally, this rod is 4.

So, again we have 4 bars; number of links is 4 and number of kinematic pairs, number of joints is again you can count 1, 2, 3 and here 4. So, again this is a 3R1P kinematic chain.

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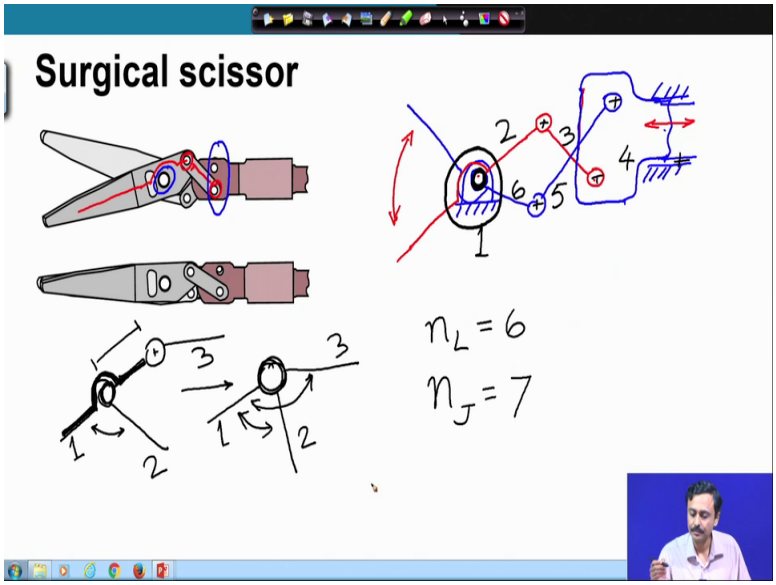

We come to the scissors now; this is a little more complicated, but not as complicated as it looks. So, first of all here you see there is a kinematic pair; between these two blades that; we know in a normal scissors. So, you have a hinge between the two blades; so this is that this hinge and we will ground this hinge, so this hinge we will ground.

Now, let us look at this blade; so this blade is hinged here and continues up to this kinematic pair. So, what I am going to do is; only draw this and that is connected to another link and final to another kinematic pair here. Now, this kinematic pair connects to a slider, which is connected to that rod that comes from the other side of this device; of the surgical instrument which is operated by the surgeon.

So, this is a prismatic pair; this can slide, this is a slider. So, what do we have? For this blade, we have a revolute, revolute, revolute and prismatic. And the same thing goes for the other blade; so we have the other blade like this and which connects again to the same slider as you can see; so this is that connection.

So, as this slider slides; it is going to rotate, these two blades. So, blades let me just show you the extension; so this is one extension of one blade and this is the other blade

extension. So, as you slide these two blades come close or move out; so that is the kinematic diagram of the scissor.

So, let us count ground is 1; this blade is 2, this coupling link is 3; the slider is 4; this coupling link is 5 and the other blade is 6. So, now we have 6 links and how many kinematic pairs? Between link 2 and ground, there is one kinematic pair, between link 6 which is the other blade and ground there is another kinematic pair. Now here we need to understand this; kinematic pair as the name suggests is between two links. It so happens in this case that there seems to be only one hinge; where both the blades are connected to the ground.

But since we are talking of kinematic pairs; we must identify two links which form the pair. For example, 1 and 2; there must be a kinematic pair and 1 and 6; there must be another kinematic pair, we should count them separately. So, here there are two kinetic pairs; at this point there are two kinetic pairs. So, we should count 2, 3, 4, 5, 6 which is the prismatic pair and this is the seven kinematic pair.

So, this is the point to be noted that whenever you have 3 links connecting; these are 3 independent links seems to be a single hinge, they are being connected by a single hinge; these three 1, 2, 3 let us say; they are connected by a single hinge it seems. You have to understand that this is a special case of this situation.

So, this whole link is; link 1, it is being connected to link 2 by this kinematic pair and to link 3; by this kinematic pair. This one is a special case of this, where this distance has gone to 0. So kinematic pairs remember is always between 2 links; so, if 3 links are connected like this, you have to count them as 2 kinematic pairs. So, you have to pair up; so 1 and 2 and maybe 1 and 3, so 2 kinetic pairs. So, that is the kinematic diagram of a surgical scissor.

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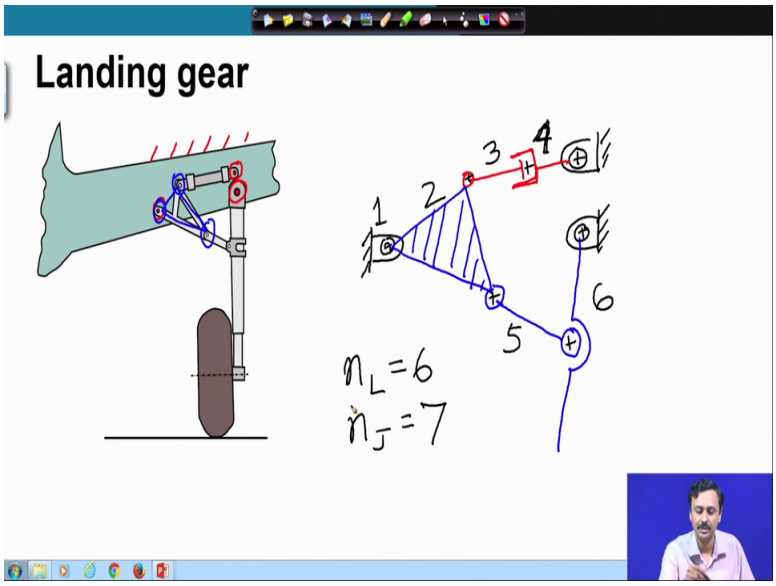

Next, we come to this landing gear mechanism which we have seen. So, here let me point out; there are look at these three hinges, they are marked in red. They are actually attached to the aircraft body; we will fix the aircraft body. We will consider the aircraft body to be the ground; so we have 3 ground hinges.

Now, to this ground hinge; we have an actuator, now actuator is a prismatic pair; a powered prismatic pair which we are going to represent like this. This is a prismatic pair; a powered prismatic pair, so we are going to represent this like; this is would be our convention. To this is attached; this triangular shaped link, you can easily identify now that this is a ternary link, it has got 3 kinematic pair arrangements.

So, one is this, this and this; so this is a ternary link; to this is attached a binary link which is attached to the wheel. So, again let us start counting; ground is 1, ternary 2, now here the actuator is composed of 2 links; 2 rigid bodies, which have a p pair between them; so we count 3, 4. This binary is 5 and this binary is 6; so number of links is 6, number of kinematic pairs. So, 1, 2, 3, 4, 5, 6 and 7; so again we have number of things as 6; number of joints or kinematic pairs as 7. So, this is the kinematic diagram of the landing gear of the aircraft.

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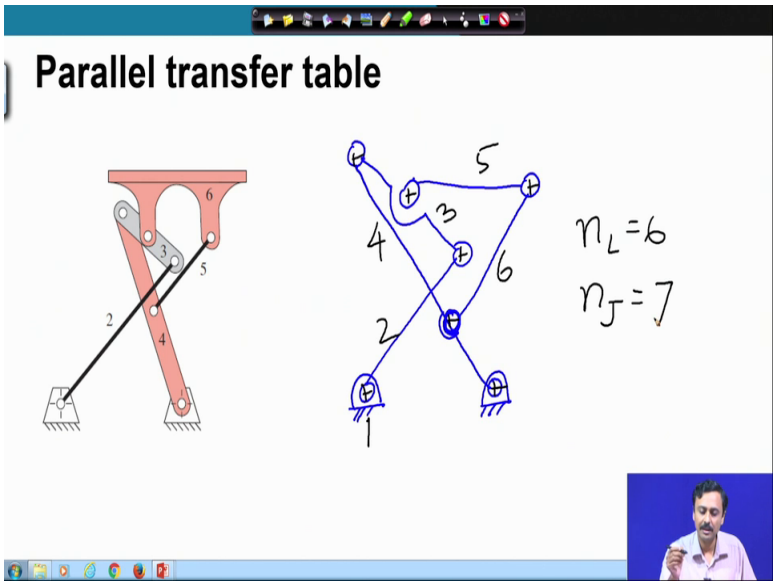

Then we have this parallel transfer table; which is straight forward actually, I will quickly draw this. So, we have two ground hinges; this is connected to a ternary link and this one is connected to the ground. On this, there is this link 6 which is connected to; see this is also a ternary. So, this is the kinematic diagram of this parallel transfer table, so if you count 1, 2, 3 is this ternary; 4 is the other ternary, 5 is a binary, 6 is another binary. So, n L is equals to 6; nj 1, 2, 3 4, 5, 6, 7; again we have 7. So, that is the kinematic diagram of this parallel transfer table.

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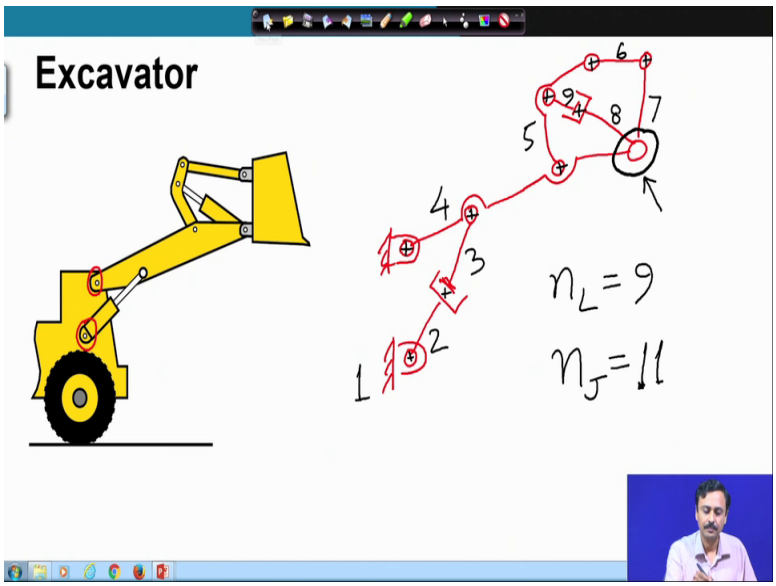

This is the excavator; so once again we have these as our ground hinges. So, in this excavator; we have the ground hinges here and here. Here there is a; as you can see there is a quaternary link, there is a link with 4 kinematic pairs. Here there is an actuator, which is a powered p pair; on this, there is a ternary link. This has a binary link, which is connected to the bin; so this is a bin. And here we have another actuator, which is again a powered p pair; which connects to the bin point.

Now, once again let us start counting; so ground is 1, 2, 3 between 2 and 3; there is a prismatic pair, this quaternary is a 4; link 4, ternary is 5; this binary 6, this is 7, this is 8 and this is 9. So, number of links is 9; number of joints 1, 2, 3, 4, 5, 6, 7, 8; this prismatic is 9 and here again you see there are 3 links connected by 1 hinge. So, I must count this as 2; so 9 plus 2 is 11. So, number of joints in this case; number of kinematic pairs is 11.

So, once again note there are two kinematic pairs at this hinge, so that is the kinematic diagram of the excavator. So, in this lecture now I have given you some overview of what a kinematic diagram is; how to draw kinematic diagrams? How to number the links and how to count the kinematic pairs?

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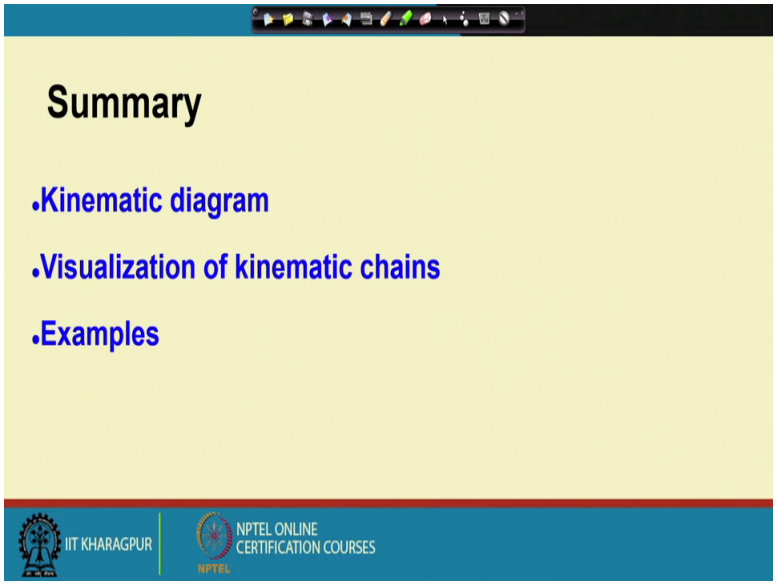

So, I will leave you with the summary of what we have discussed today.