Kinematics of Mechanisms and Machines
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Lecture – 07
Grashof Criterion – I

In the number of applications, a mechanism is driven by rotary motor which rotates continuously. Therefore, the link to which this motor is connected must be able to rotate completely. Therefore, there must be something called a crank; that means a link that can rotate completely. So, in today's lecture we are going to discuss this point.

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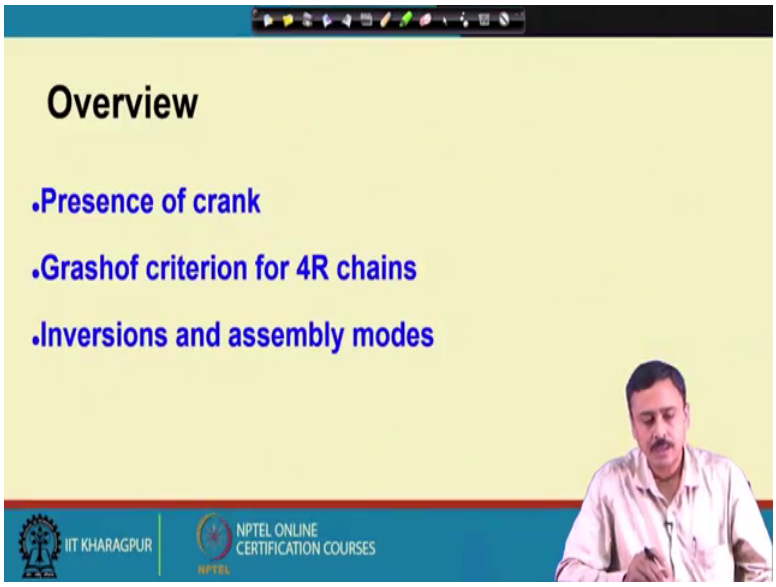

The overview of this lecture starts with presence of crank in a mechanism in a kinematic chain, then we will discuss the Grashof criterion for 4R chains and then I will discuss inversions and assembly modes.

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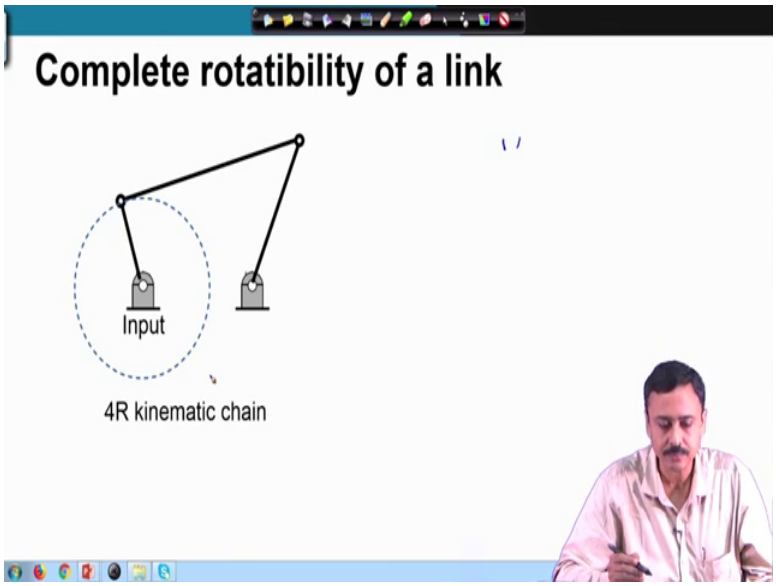

So, as I mentioned we require complete rotate ability of a particular link if it is to be driven by a rotary motor rotating continuously. Here I have shown a 4R kinematic chain where I have indicated the input. So, this link should be able to rotate completely. Suppose this is what I require that this link should be able to rotate completely.

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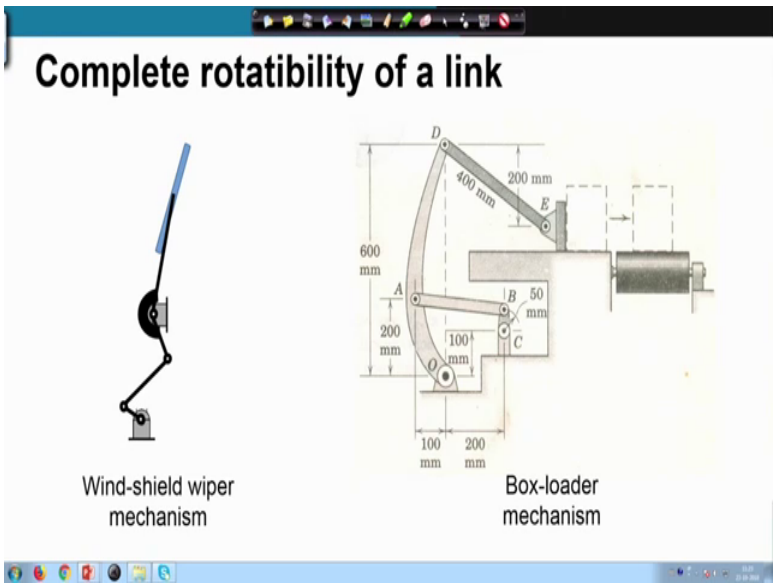

These are some applications where we require complete rotate ability. This is a windshield wiper mechanism. Here we require that this link be able to rotate completely because we have a motor here connected to this link and the wiper will oscillate.

Therefore, in this kinematic chain this is a 4R kinematic chain there is a crank, This is our crank.

This is another example; this is a box loader mechanism. What it does is it pushes boxes onto the conveyor here is the link that is attached or connected to a rotary motor and it must rotate continuously. Therefore in this 4R chain the link BC; link BC should be able to rotate completely.

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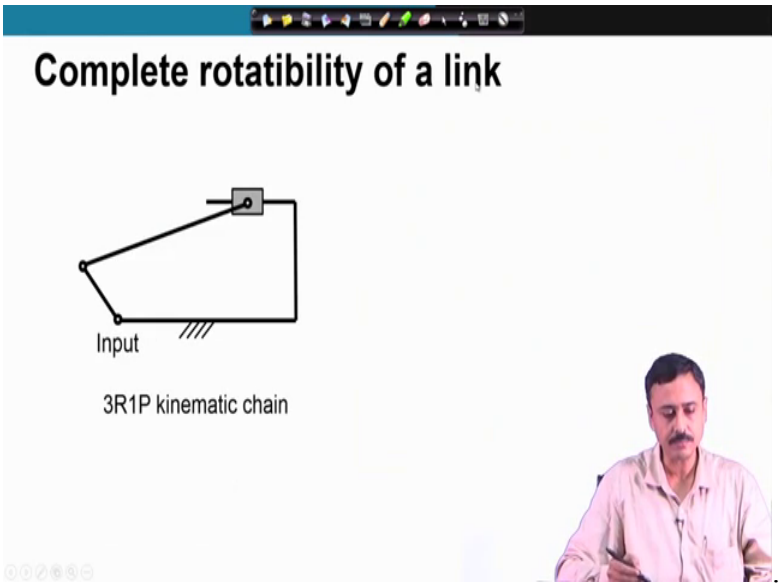

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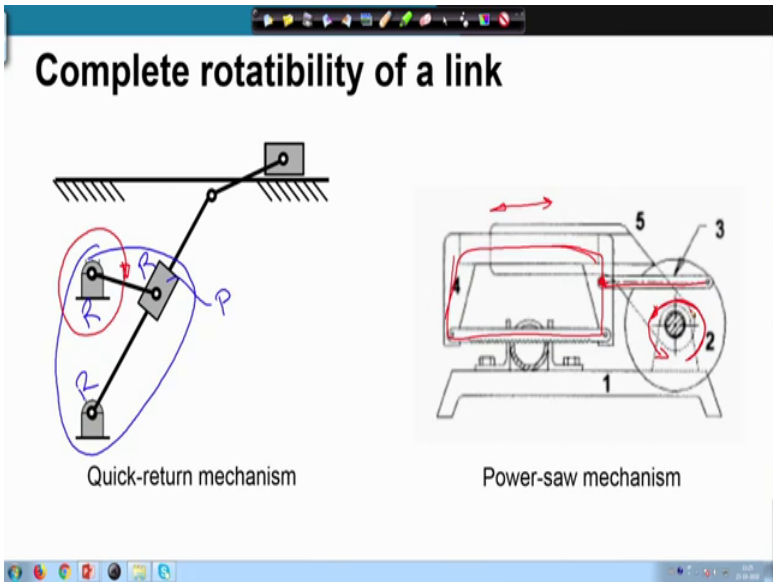

Let us look at 3R1P kinematic chain. This is an example of a quick return mechanism in which uses a 3R1P chain. So, this is R, this is R and here we have another R and here there is a P. So, this is a 3R1P chain and we require that this link be able to rotate completely. So, that will be the crank.

This is a power-saw mechanism once again, this is the motor which rotates continuously and therefore, this coupler which drives the slider, this power slope this saw is the slider that oscillates in response to continuous rotation of the motor. So, the again we have a crank.

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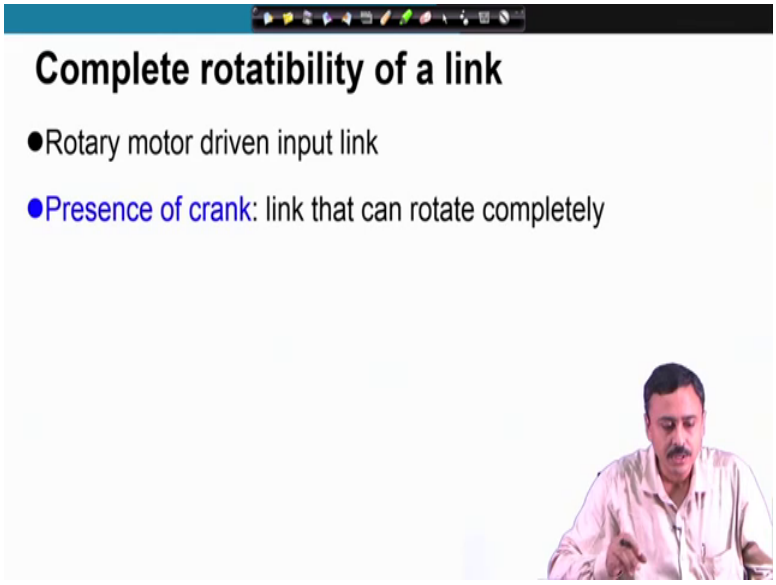

As I have mentioned that the motor the rotary motor which drives a link continuously must be so, the mechanism should be such that this link to which the motor is connected can rotate continuously. We call this link a crank.

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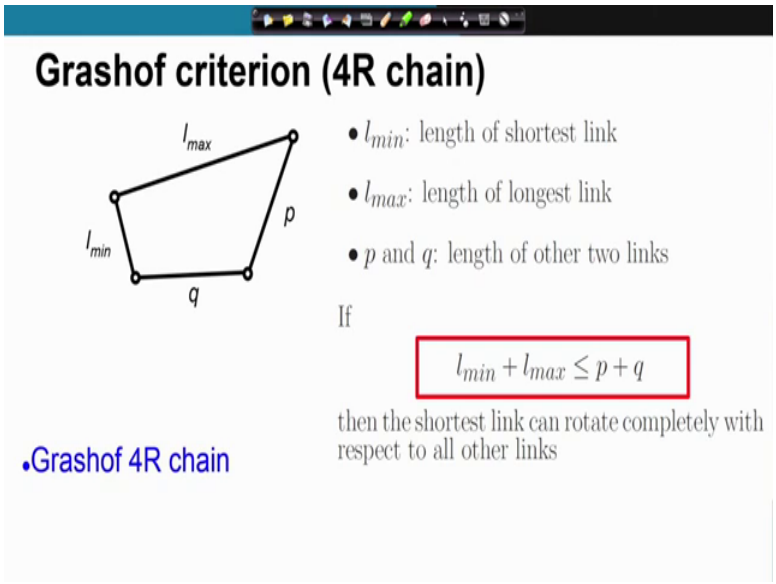

Now, the criterion that tells us whether there is a crank in a kinematic chain or not is known as the Grashof criterion. We will start with the Grashof criterion for the 4R chain. Here I have drawn a 4R chain and I have marked the link lengths. There is one length which I called call l min, the minimum length. There is one link which I call a l max which is the longest link and there are two intermediate links p and q. So, shortest link is l min, the longest link is l max and the intermediate links are p and q.

Given this the Grashof criterion tells us that if l min plus l max is less than equal to p plus q, then the shortest link can rotate completely with respect to all other links. This is the Grashof criterion. Here I am giving you the criterion without any proof. So, what is the criterion? If the shortest link plus the longest link length is less than the sum of the other two link lengths then the shortest link is the crank, the shortest link can rotate continuously. If a chain is such is the dimensions of the chain is such that it satisfies this Grashof criterion, then we say that the chain is a Grashof 4R chain.

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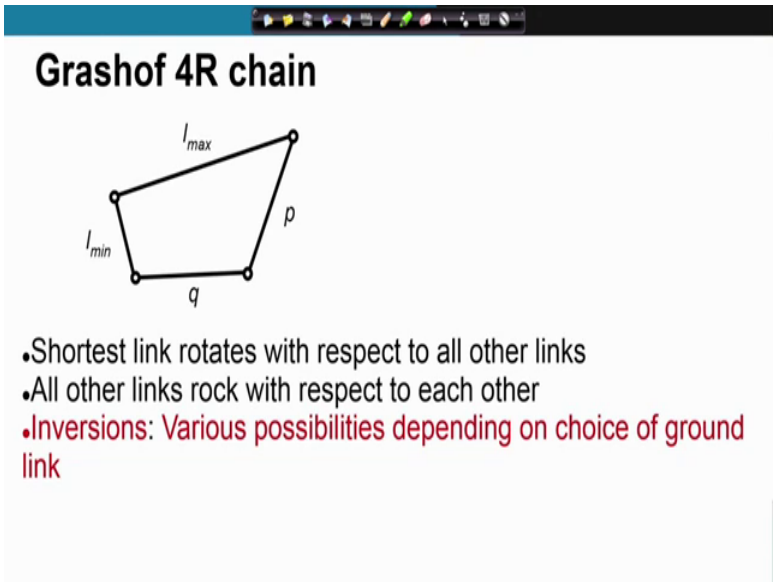

Now, this shortest link since it can rotate continuously, it must be with respect to a link. If it can rotate continuously with respect to a link then it can rotate continuously with respect to all other links and the other links will all rock with respect to each other. The other links will rock with respect to each other. I will also introduce this concept of inversion. So, inversions are the various possibilities that arise depending on the choice of the fixed link.

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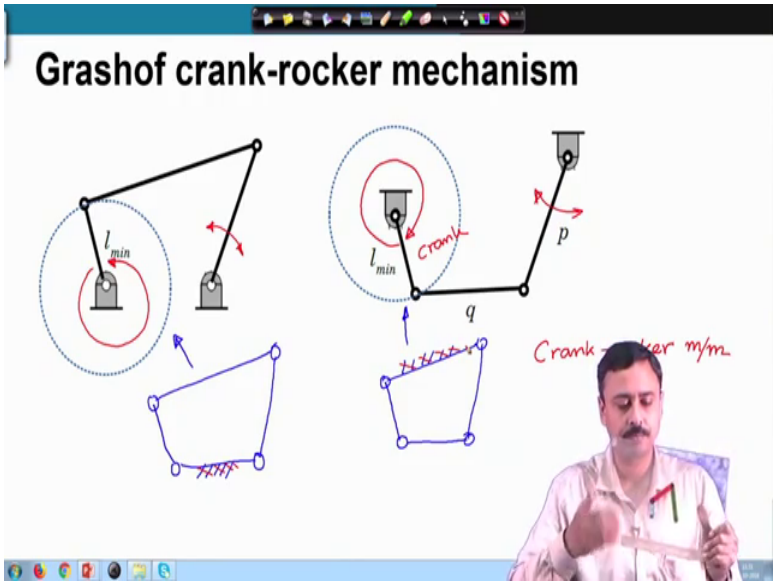

Now, here I have shown the Grashof chain that we have here I have fixed one of the links. So, our Grashof chain was like this. When I fix this link then we have this mechanism and since l min can rotate continuously this link therefore, can is a crank.

Similarly, if instead of this link, now, I fix this link then I have this mechanism once again this is the l min and it can rotate completely, therefore, this is the crank. The other links will only rock here or here. Therefore, this mechanism is known as a crank rocker mechanism. So, here we have a crank rocker mechanism if I fix either this link or this link. Let me show you a crank rocker mechanism.

So, here I have a crank rocker mechanism. The link that I am rotating can rotate completely, this is the crank and you can see that the other links they only rock. This is the crank rocker mechanism.

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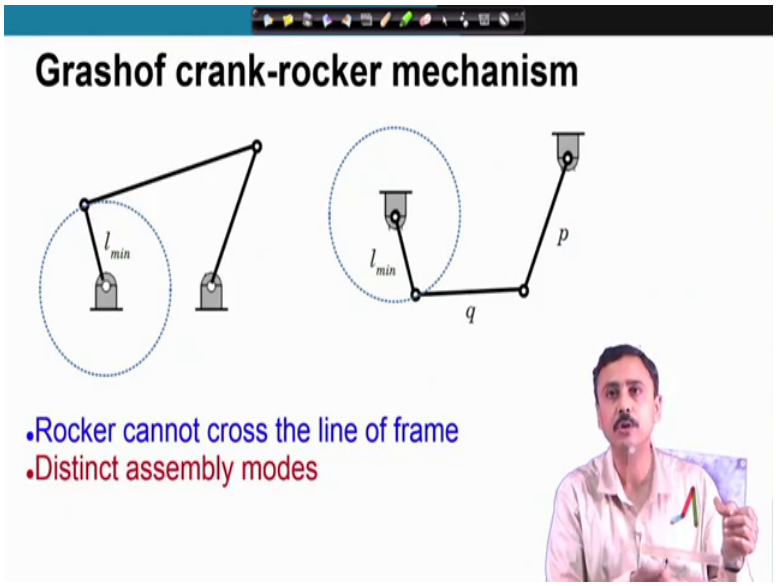

As you can see that in this example once again the rocker cannot cross the line of frame so, this is the rocker. Let me move it again. You can see the rocker, the green link, it is rocking between two angles, but it cannot cross the line of frame this is the line of frame the fixed link is the line of frame. So, it is always above the line of frame.

There is another concept of assembly mode. Given these link lengths I can assemble the mechanism either in this form where the rocker rocks above or I can assemble the mechanism like this where the rocker rocks below. This is the rocker rocking above and

here is a rocker rocking below. So, these are the two modes of assembly and they are distinct which means starting from this assembly mode I cannot go to the other assembly mode where the rocker is below the line of frame because the rocker cannot cross the line of frame. So, we have distinct assembly modes in a Grashof chain.

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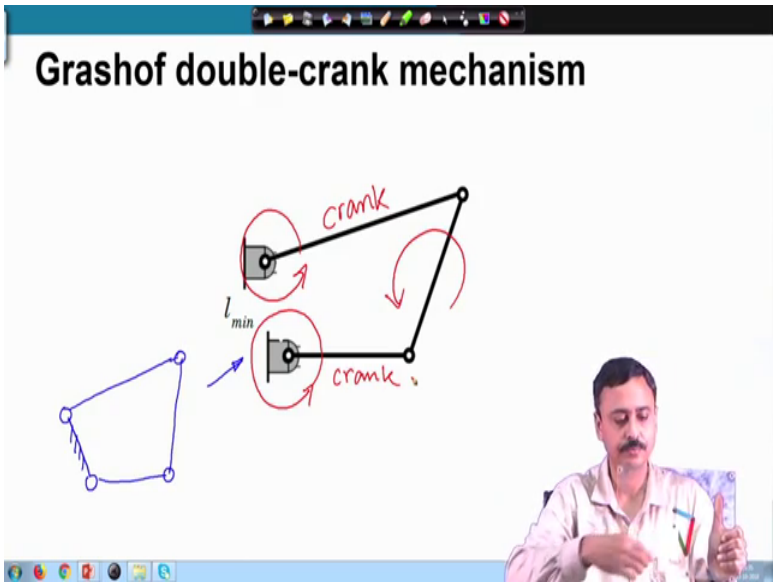

Now, what happens if I fix the shortest link; let me redraw the chain again. This was the our chain. If I fix this link then this is the mechanism that I have. So, l min is now the ground that is the fixed link. Now, because l min can rotate completely with respect to other links so, if I fix l min then other links will rotate completely with respect to l min. So, they will all rotate completely with respect to the ground link.

This is called a double crank mechanism because I have fixed l min this can rotate completely; this can rotate completely, as well as this can also rotate completely. So, this is a crank and this is also a crank so, this is a double crank mechanism. Let me show you an example of a double crank mechanism. So, this is a double crank mechanism let me move the mechanism you can see that all the links are rotating completely. So, this blue link can rotate completely and this green link can also rotate completely. This is a double crank mechanism.

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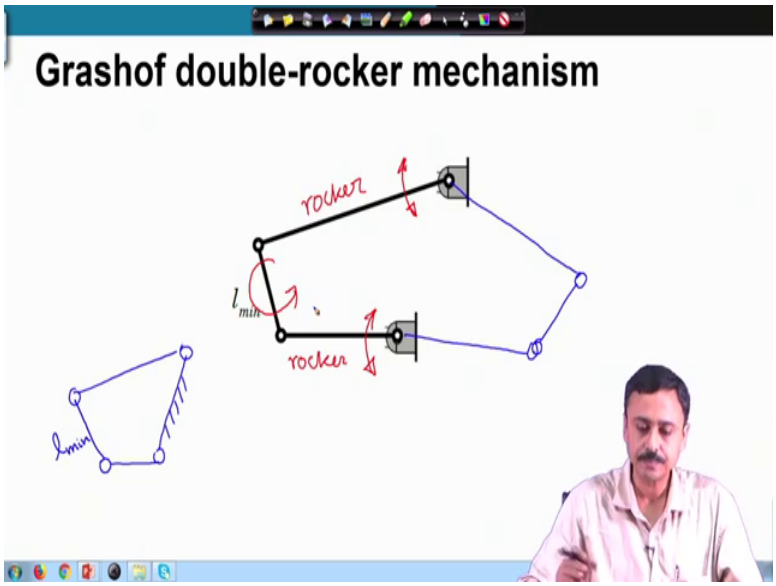

Here I have fixed the remaining link that was free till now, let me redraw the chain. Here I have fixed this link, this is l min. Now, what happens here because the other links always rocked with respect to one another. Therefore, this will rock and this will also rock, they can only rock, they cannot rotate completely, but this l min can rotate completely; l min will rotate completely as these two links rock, this is called a double rocker. This is a rocker, this is a rocker so, there are two rockers connected to the frame. So, that is why it is called a double rocker mechanism. So, this is a Grashof double rocker mechanism.

Once again notice that these rockers will not cross the line of frame. In a Grashof chain rockers never cross the line of frame, therefore, there are two assembly modes. So, one is this, the other assembly mode you can imagine is this. It can never go from one assembly mode to another as the mechanism moves so, assembly modes are distinct.

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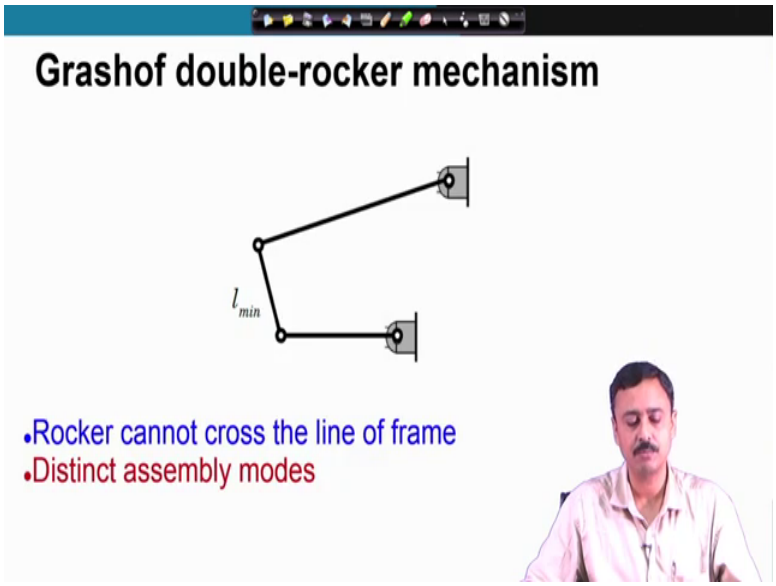

So, rockers cannot cross the line of frame so, there are distinct assembly modes.

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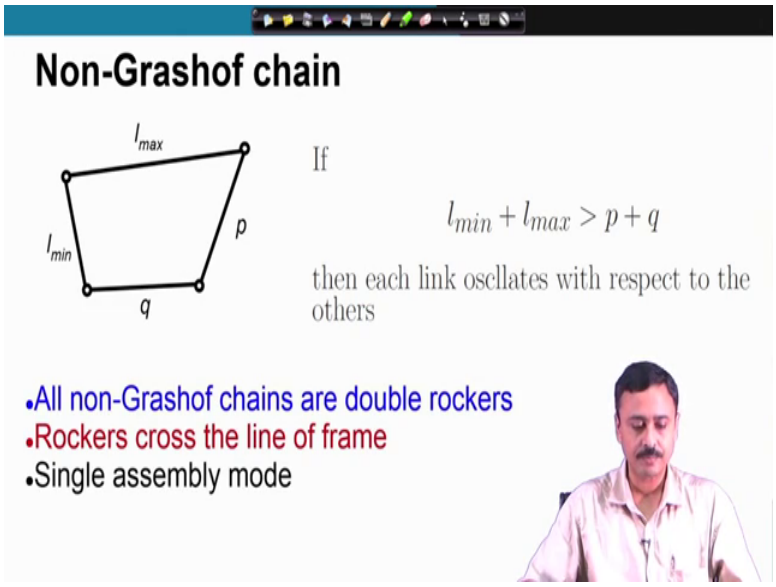

Now, what is the non Grashof chain therefore? It is a chain that does not satisfy the Grashof criterion. Therefore, l min plus l max the sum of lengths of the shortest link and the longest link is greater than the sum of the other two links, then all links will rock with respect to one another. So, this is a non-Grashof chain.

All non-Grashof chains are double rockers because the links can only rock with respect to one another. There is no link that can rotate completely. So, these are all double

rockers and here the rockers can cross the line of frame; the rockers can cross the line of frame so, there is only a single assembly mode.

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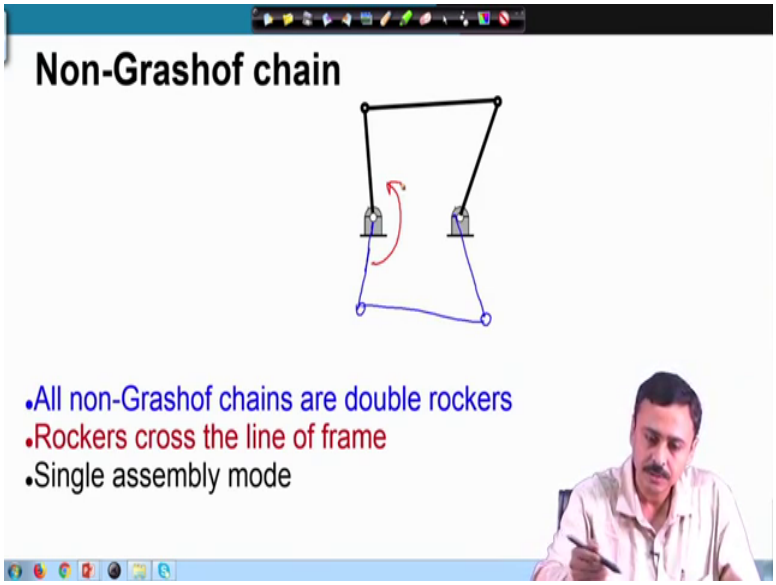

If you consider this as a non-Grashof chain, then as this rocks it will come to another configuration something like this and this can move till it reaches a configuration beyond which it cannot rotate. So, it will stop. You if you assemble the mechanism let us say in this configuration, then it can go from this to this configuration. These are not distinct assembly modes because the rocker can cross the line of frame.

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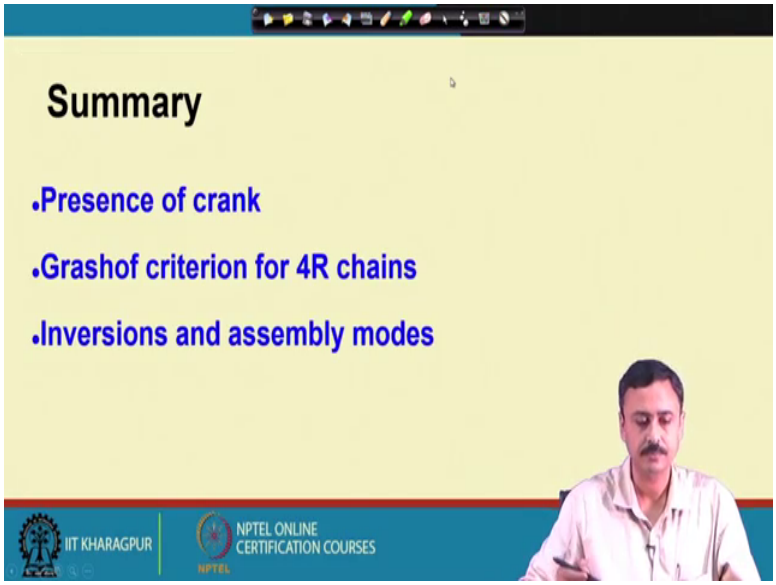

So, let me summarize; in this lecture first I have introduced the concept of a crank, the link that can rotate completely in a kinematic chain. I have discussed about the Grashof criterion which tells us how to determine a chain whether it has a crank or not. So, we have discussed 4R chains, I have also introduced the concept of inversion and assembly modes for 4R chains. So, with that I will conclude this lecture.