Kinematics of Mechanisms and Machines
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Lecture - 08
Grashof Criterion – II

In this lecture I will continue discussing about Grashof Criterion which tells us the presence of crank in a kinematic chain, a link that can rotate completely.

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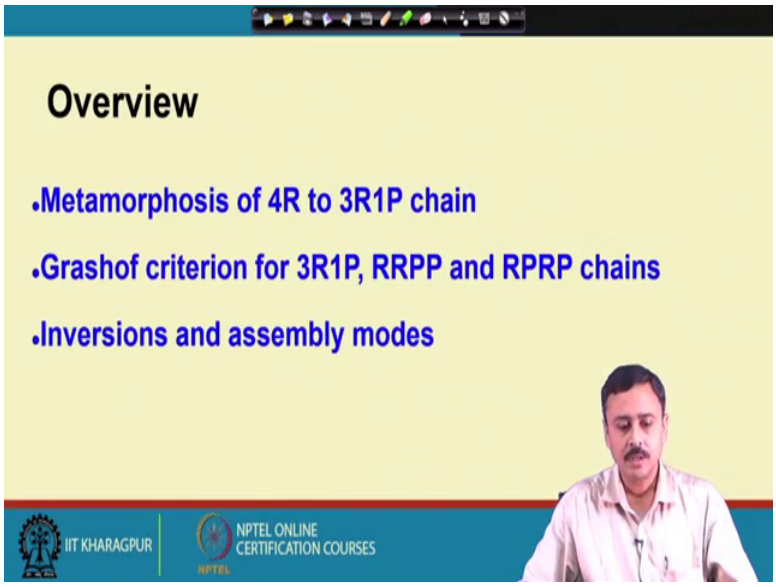

In today's lecture I will take you from the Grashof criterion of a 4R chain to the Grashof criterion of a 3R1P chain. I will show you how the Grashof criterion for 3R1P chain can be derived from the Grashof criterion for the 4R chain. Then I will discuss 3R1P chain, RRPP chain, and RPRP chains. I will also discuss about inversions and assembly modes.

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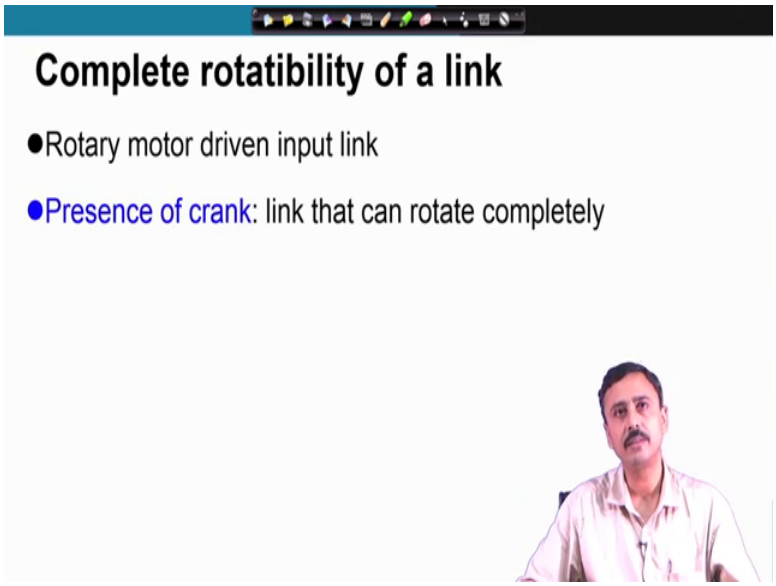

Just to recapitulate link that can rotate completely is known as a crank and in a large number of applications there is a rotary motor which drives the mechanism continuously. So therefore, we require a crank in such kinematic chains or in such mechanisms.

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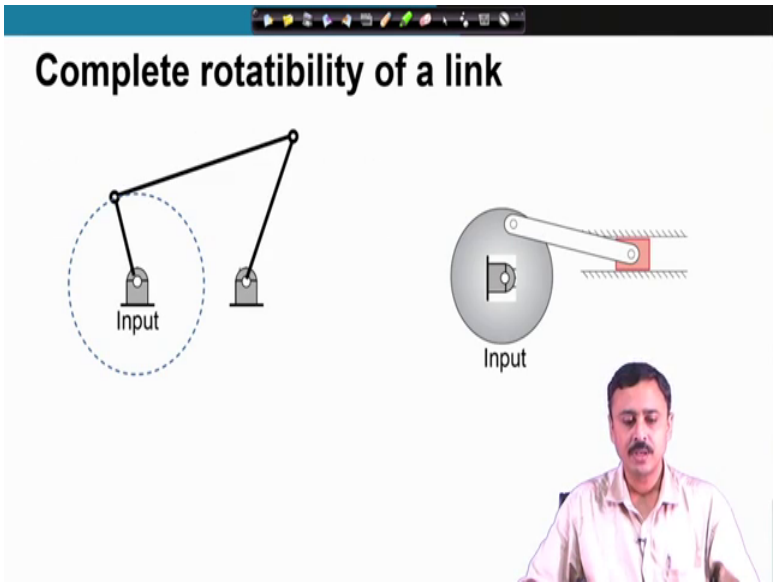

So, complete rotatibility of a link is what we are discussing.

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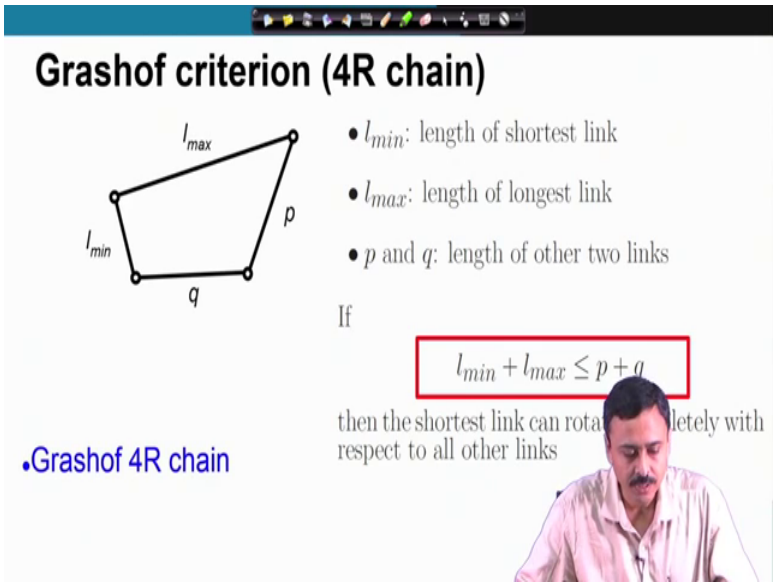

And we have looked at the Grashof criterion for the 4R chain which tells us that; if the length of the shortest link plus the length of the largest link or the longest link is less than the sum of the lengths of the other two links then the shortest link can rotate completely with respect to all other links. So, we have a crank if this Grashof criterion is satisfied.

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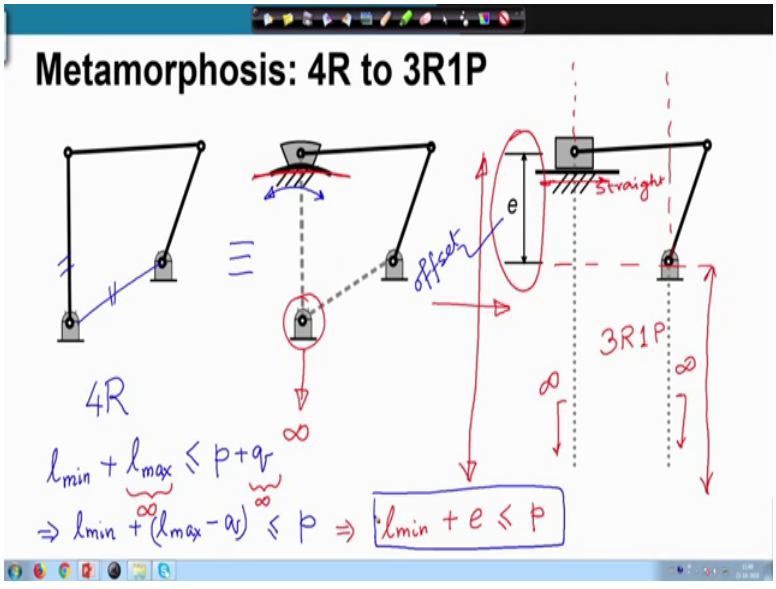

Now, let me discuss about this conversion of a 4R chain to a 3R1P chain. This is a metamorphosis. So, there are there is a there is a sequence of 3 figures I will take you through these figures. Here I have a 4R chain. This 4R chain can be equivalently thought

of as a chain with a slider, where the slider is moving on a curved path as shown here. Therefore, I have removed this link and the ground link or the line of frame and I have introduced this slider which is moving on a curved surface. The relative motions of the remaining links are the same as the original 4 bar.

Let me take this ground hinge farther and farther away in this direction. So, you can imagine that this will get straighter, this path will get straighter and finally, when this goes to infinity we arrive at this configuration where the path is now straight we have a straight path on which the slider is sliding. Why because, I have taken this ground hinge to infinity. Therefore, the radius of curvature of the slider is infinity, so this becomes straight. What we have here is a 3R1P, we have a 3R1P chain.

Now, notice in this 3R1P chain the link lengths, two link lengths are infinite. So, this link length is infinite and this link length is infinite. So, the longest link will obviously, be from one of these in either direction. You can also imagine that these are being taken on the other side the hinges may taken in other side once they become parallel, once I have taken it to the infinity. So, two link lengths are infinite. So, the longest link length is definitely infinity.

Now, let us go back to the Grashof criterion for the 4R chain; l min just l max is less than equal to p plus q. Now, what has happened in this metamorphosis is that l max has become infinity. There is another link that also has become infinity let us say q has become infinity but then notice here that the difference of these two lengths. So, this is one length, and this is the other length, the difference of these two lengths is a finite quantity which is known as the offset we will call this the offset. The difference of these two links which are now infinitely long, the difference of the lengths of these two links is e which is the offset.

Therefore, I can write l min plus l max minus q should be less than equal to p. Now, l max minus q is e therefore, I have finally, l min plus e should be less than equal to p for the chain to be Grashof. So, this is our Grashof criterion for a 3R1P chain. So, the sum of the minimum link length plus the offset should be less than the link length of the remaining link.

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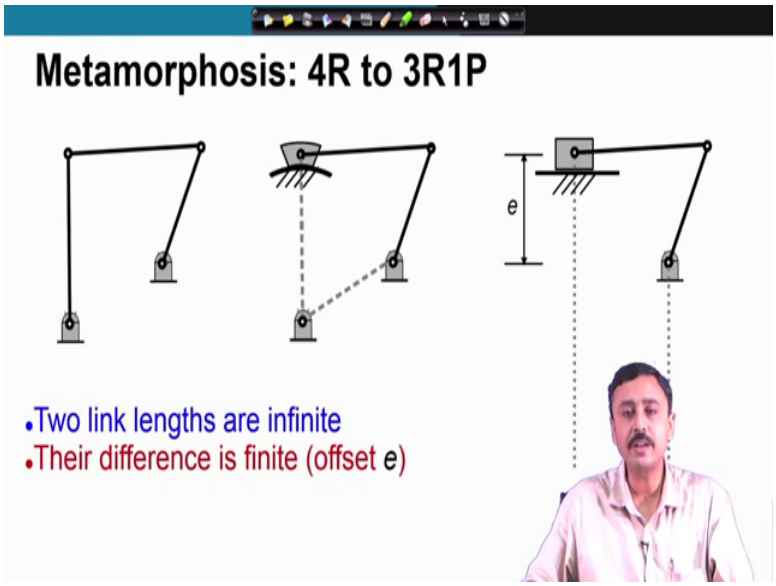

So, as I mentioned two link lengths are infinite, their difference is finite which we call the offset. And therefore, the Grashof criterion now is given by l min plus e should be less than the other link, the remaining link length.

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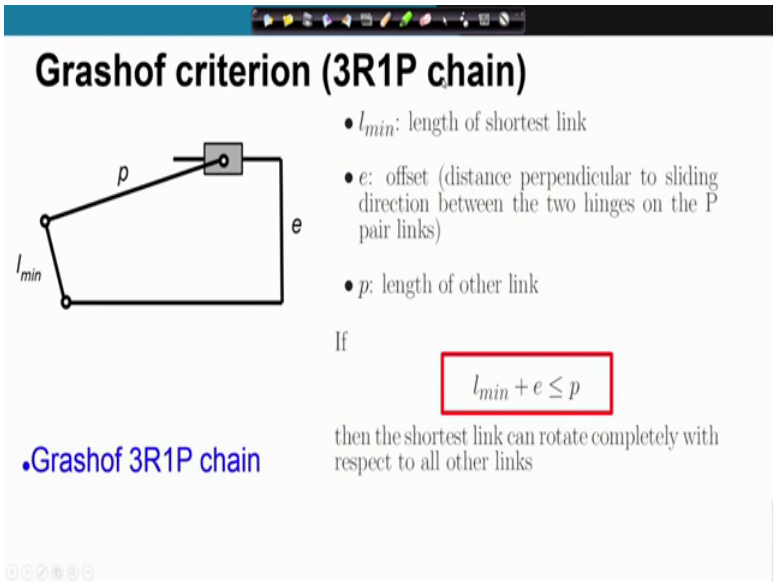

Then the shortest link can rotate completely with respect to all other links. So, this is the Grashof criterion for a 3R1P chain.

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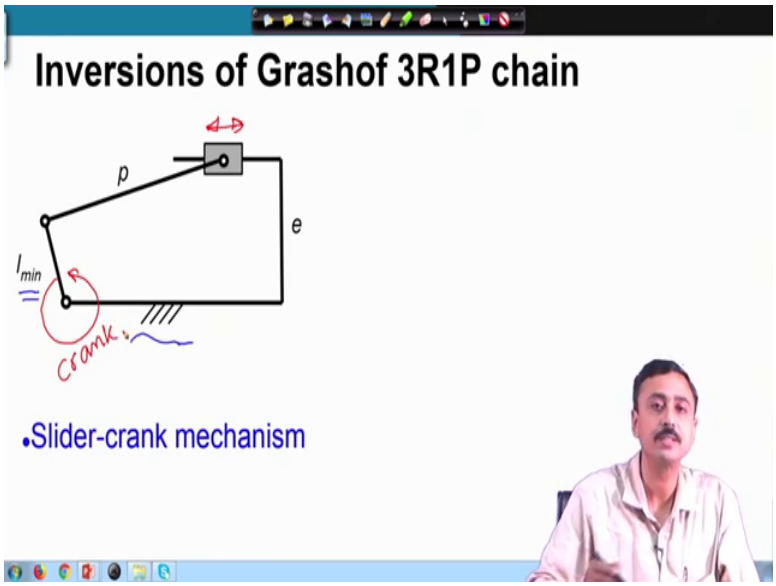

Let us look at inversions. So, inversions are the mechanisms obtained by fixing, the different links of the kinematic chain. Here I have fixed this link and this is our l min which can rotate completely. This is known as a slider crank mechanism, this slider can rock or move between two limits. This is called a slider crank mechanism. So, this is our crank, l min is the crank.

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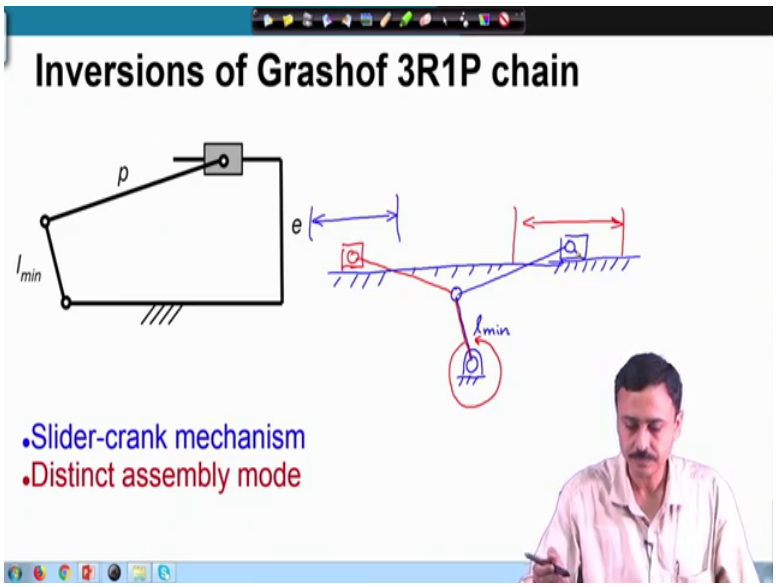

Once again we have distinct assembly modes. To understand assembly modes in this case let me draw out the mechanism. So, this is the slider crank mechanism with this as l min.

I can also assemble the mechanism in this configuration. So, this is the ground. So, I can put the mechanism in this configuration, so the blue configuration and the red configuration.

Here as this crank rotates this slider is going to slide between two limits and the other assembly mode in the other assembly mode is going to slide between another two limits and these two limits do not cross they are distinct. Therefore, if I start from the blue configuration I can never go to the red configuration this is a Grashof chain. In a Grashof chain as we have mentioned, again before that assembly modes are distinct starting from one assembly mode you cannot go to the other assembly mode.

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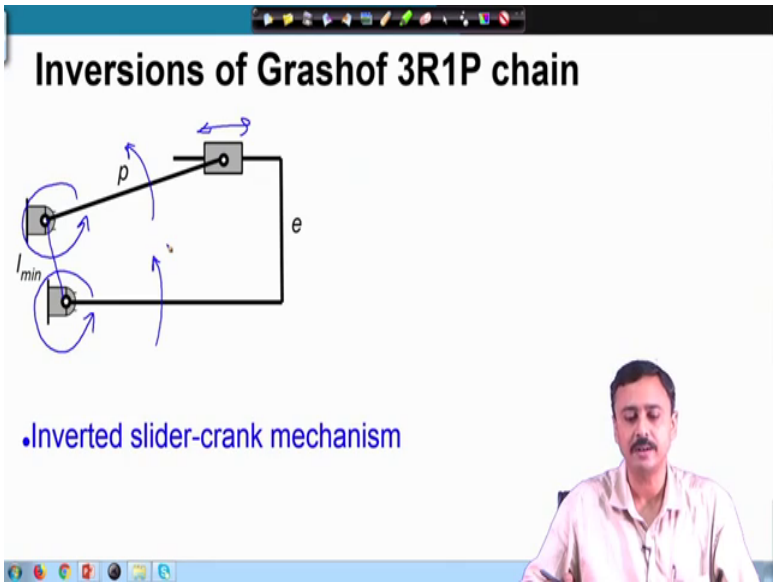

If I fix the l min the link which is the shortest, then what happens? As we have seen that l min can rotate completely with respect to all other links. Therefore, now if I fix l min the other links should be able to rotate completely with respect to l min. This is called an inverted slider crank mechanism. So, here we have a slider which will slide but these two links can rotate completely. So, this is an inverted slider crank mechanism, this is a Grashof n chain.

If I fix this link whose length is p, once again I have l min which can rotate completely with respect to the fix link. Therefore, I have again an inverted slider crank mechanism.

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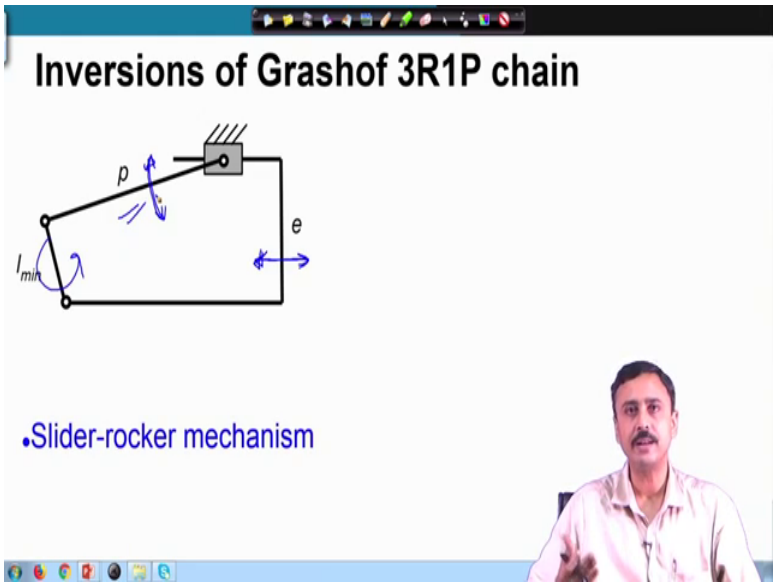

If I fix the slider itself now, because these links can only rock, these links this will rock, this will slide, and l min can rotate completely. This is a slider rocker mechanism. So, the link that is connected to the ground which has the length p which is indicated by this can only rock this is a slider rocker mechanism.

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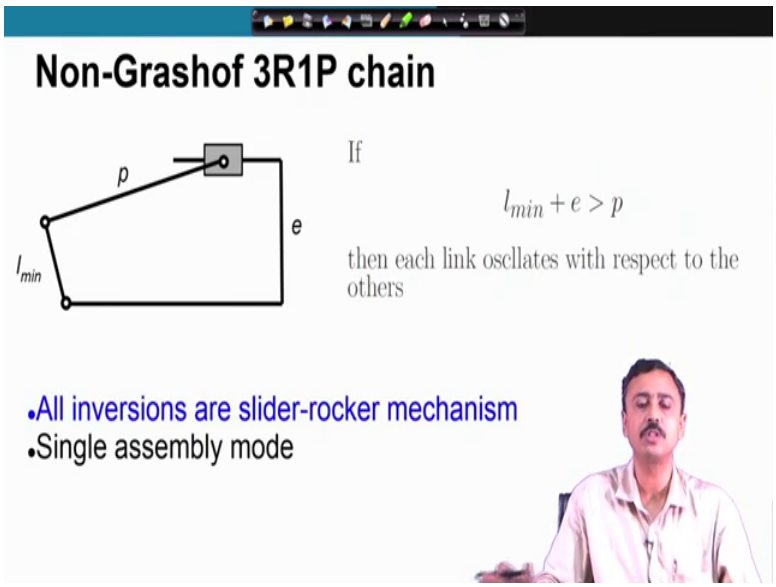

Now, we have non-Grashof chain 3R1P chain, where l min plus e is greater than p the other link in that case all links can only rock or slide between limits. So, these are non-Grashof chains.

All the inversions are slider rocker mechanisms. There is a single assembly mode, so now because you do not have distinct assembly modes if you assemble the mechanism in a particular assembly mode you can go to any other mode. There is only one assembly mode, there is there is no two assembly mode which are distinct. So, here we have single assembly mode.

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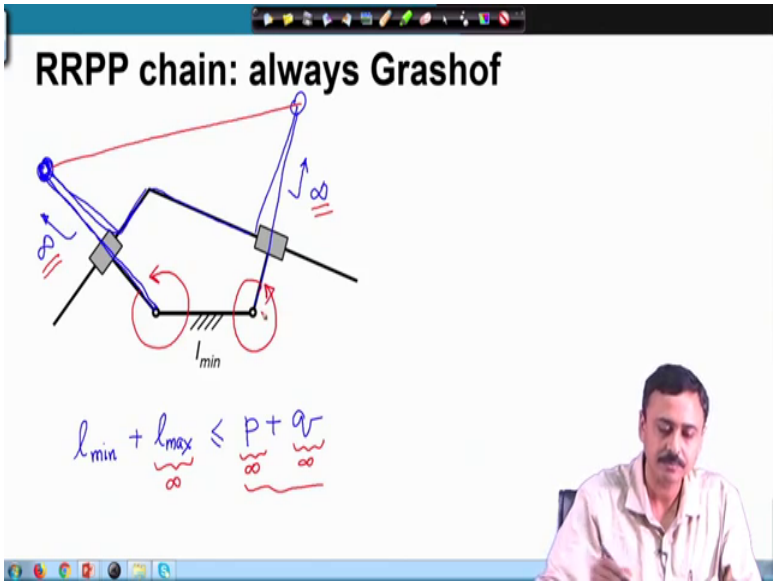

Now, let us look at RRPP chain this chain is always Grashof. Let us see why. You can replace these p pairs by infinitely long links as we have done as you have discussed previously. Therefore, this p I can imagine like there is this link which is of now infinite length. Therefore, this also goes to infinity and here this also goes to infinity.

In this case therefore, there are link lengths this is infinitely long, this is infinitely long, the other link which is equivalently this is also infinitely long. As these two hinges go to infinity the coupling link also goes to infinity if the shape that is slightly different in this case that is the only thing. Therefore, there are 3 link lengths that are infinite. In that case, let me first rewrite the Grashof criterion for a 4R chain l max is definitely infinity and the other lengths are also infinity. Then it always satisfies the Grashof criterion. Why because, there are two infinite infinity sitting on the right; and here there is an l min plus infinity. Therefore, the left hand side will always be smaller than the right hand side.

Therefore this chain RRPP chain is always a Grashof chain. And since, l min can rotate completely therefore, the links that are connected to l min now can rotate completely.

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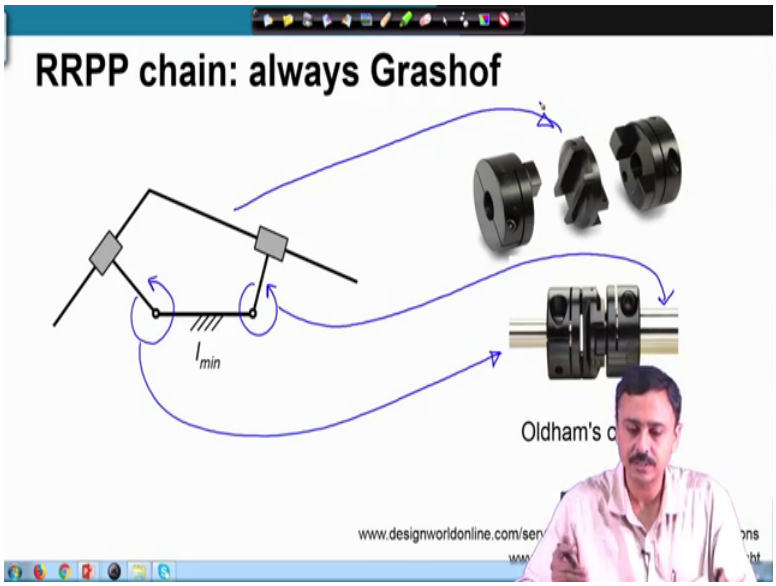

An application we have seen this before the old ham coupling. This is one shaft, let us say this shaft, this is the other shaft, they have to rotate completely and which they can and the coupling is this link. So, that is the coupling link. Since this is always a Grashof chain. So, we are assured of complete rotation of the two shafts.

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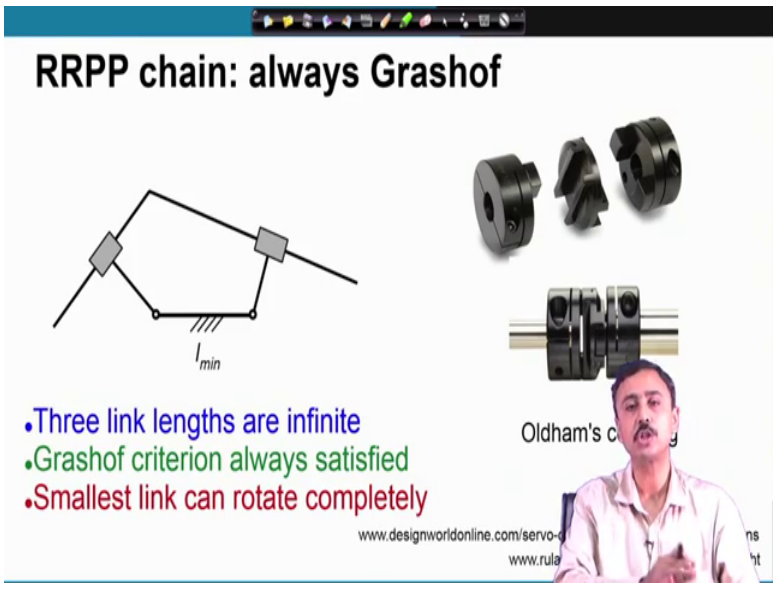

Grashof criterion is always satisfied and the smallest link can rotate completely but now because smallest link has been fixed in this inversion. So, in this mechanism other the links which are hinged to the shortest link they can now relatively rotate completely.

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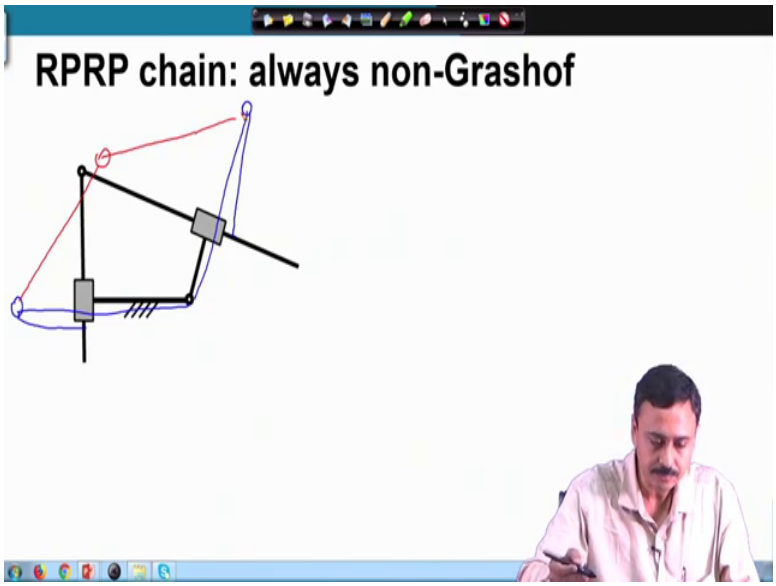

Now, RPRP kinematic chain, this is always non-Grashof. Here all the link lengths are infinite. We can replace this similarly you can replace this and this length. Therefore, goes to infinity. So, all the link lengths here go to infinity.

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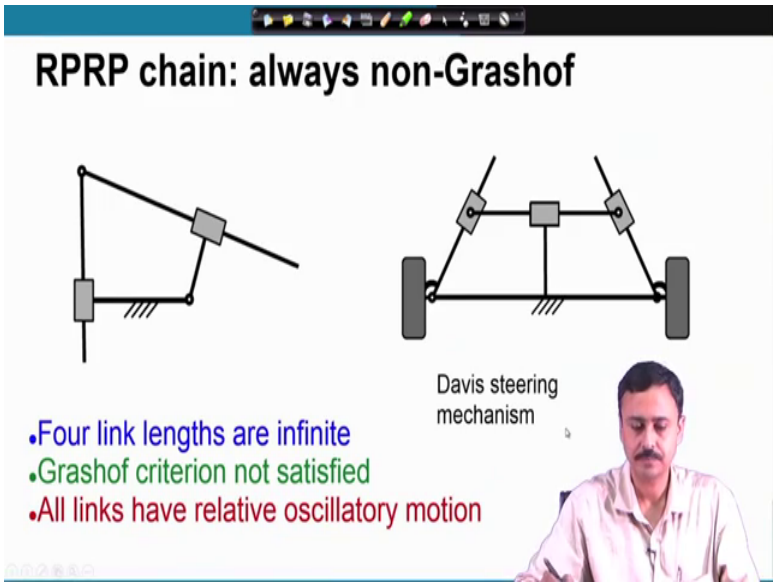

An example of the RPRP chain is the Davis steering mechanism. So, there are 4 link lengths that are infinite Grashof criterion is not satisfied. There are 4 infinities it breaks down. So, here we do not have Grashof criterion. So, this is never satisfied. So, therefore, all links have relative oscillatory motion only. This is a non-Grashof chain.

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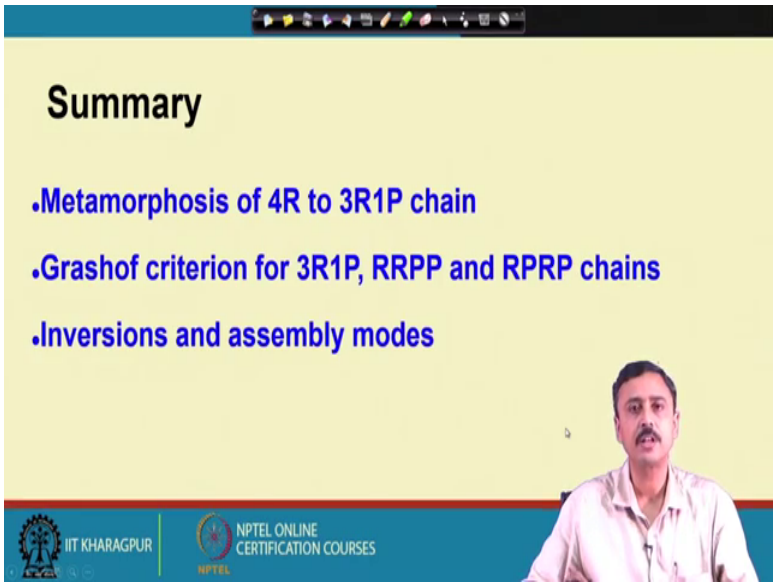

Let me summarize. We have looked at the metamorphosis of a 4R chain to a 3R1P chain and derived the Grashof criterion for the 3R1P chain. Then we have looked at the RRPP and RPRP chain. The RRPP chain is always Grashof, whereas the RPRP chain is always done non-Grashof. We have looked at the inversions and assembly modes of these chains the both Grashof and non-Grashof. And we have seen that a Grashof chain has distinct assembly modes whereas, a non-Grashof chain has a single assembly mode.

So with that, I will conclude this lecture.