Biomechanics
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Lecture - 44
D.O.F Mobility, Open or Closed Chain

Welcome to this video on biomechanics. We have been looking at kinematic chains. We take the example of reaching and grasping to explain the broader concept of kinematic change. Remember kinematic chains are present in other parts of the body for example, the upper leg, lower leg can be considered to be a 2 link kinematic chain broadly, we can consider that also. Here we restrict our attention to the upper limb which is the upper arm, fore arm as a 2 link kinematic chain.

This analysis can be used to study other kinematic change within the human body. So, this is an example to the study of kinematic chains.

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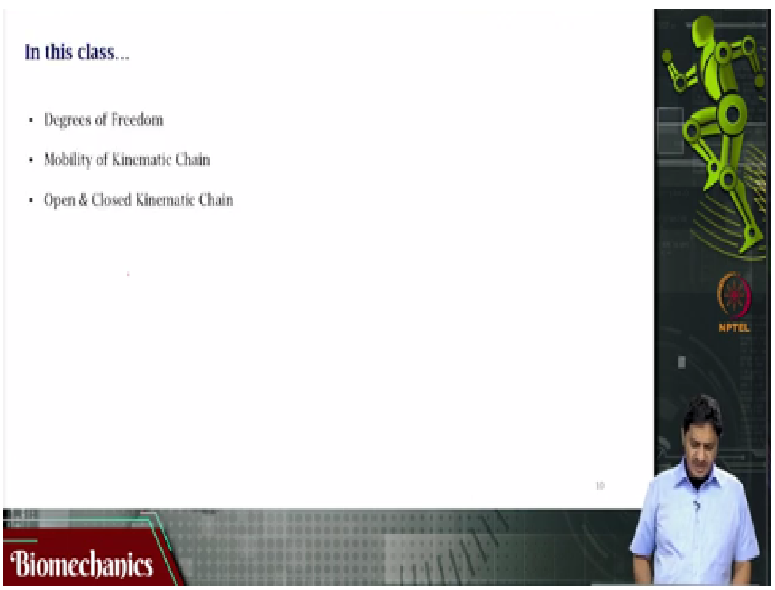

So, in this video we will be discussing kinematic change. What are degrees of freedom of a rigid body? Then of a kinematic chain mobility of a kinematic chain. And open and closed kinematic chains degrees of freedom.

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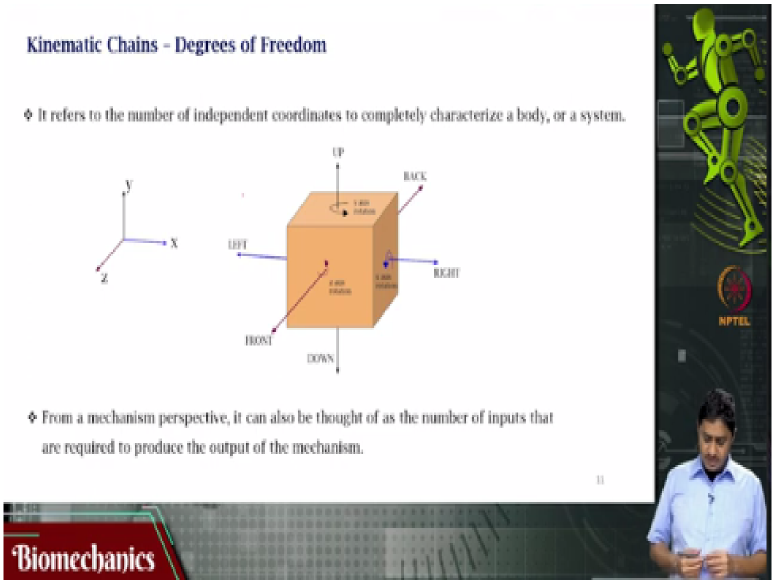

We have discussed this in some of the previous videos, what is degrees of freedom? The number of independent coordinates that are required to completely describe a given body. So, I have this body, I have this object. This object, can translate upward or downward accelerate upward or downward one degree of freedom, can accelerate to the left or the right or can translate towards you or towards me.

This is something that you may not be able to see but I can show you I can do that, for example. So, these three translational degrees of freedoms it can do that translation degree of freedom. And then about each of these axes it can rotate. For example, about the access Antero posterior axis or the axis between you and me between the screen and you like this. About this axis it can rotate like this, it can do that rotation.

About the superior inferior axis or the axis that goes from the top to the bottom it can rotate like this. Then about the axis that goes from left to the right about this axis it can rotate like this. So, there are three rotational degrees of freedom and then there are three translational degrees of freedom. So, the number of independent coordinates that are required to completely describe this body that we just now saw are six.

You need six independent coordinates to describe this body in space because this has no other constraint. I mean if you do not count the constraints that my hand holding by my hand is posing on it there is no other constraint, it can rotate in any of the three direct directions it can translate in any of the three directions. This is for that body that is completely free. But now if you have joints or rigid bodies that are connected to each other that means that there are constraints about which movements can happen.

That means that the number of degrees of freedom will reduce and specific degrees of freedom will be curtailed. Some degrees of freedom will be present others will not be present something to keep in mind. So, from a mechanism perspective if you are looking at degrees of freedom it is the number of inputs that are required to produce the output of the mechanism. So, if you have a mechanism how many inputs do you need to produce a particular output depending on the values of the input the output will vary of course.

But some particular specific inputs are needed for you to produce any output at all, if you have one link of an n link kinematic chain grounded or attached that is called as a mechanism. Kinematic mechanism that is called as a mechanism. So, when we discuss mechanisms, this is the mechanism that we are looking at. So, we just discussed the number of degrees of freedom that are required for an object in 3D space how many rotation degrees of freedom it will have?

And how many translational degree of freedom it will have? This is what we discussed. But suppose I am having the same object and I am saying it will move only in the plane of the screen it will only move in this plane it can only move within this plane say for example. That means it can translate left to right like this it can accelerate, decelerate it can translate in this direction. It can translate up and down and it can rotate.

These three motions are possible within this plane any other motion for example this motion is out of plane motion. So, if you are looking at planar moments, the number of degrees of freedom that this body will have is only three it has two translational degrees of freedom and one rotational degree of freedom.

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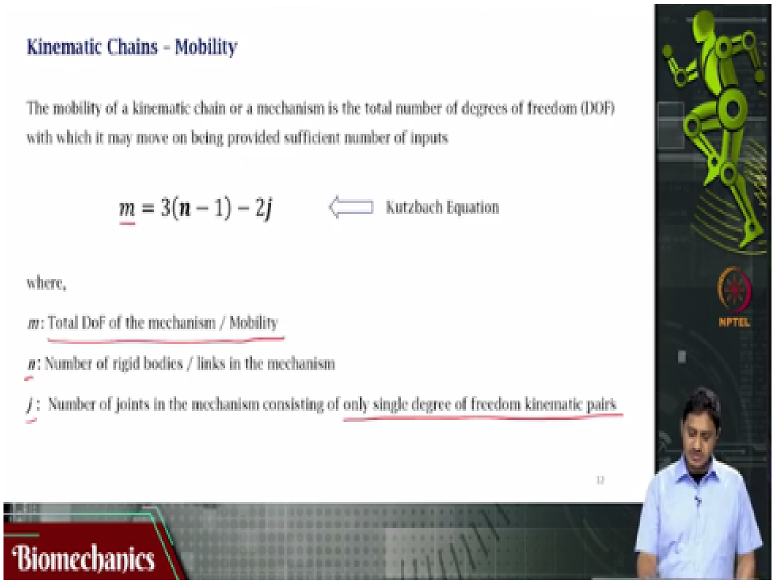

So, when we discuss kinematic change, we are interested in one more concept which is mobility is the total number of degrees of freedom with which it may move. When the sufficient number of inputs are being given. There is a formula for this, this is called where m is the total number of degrees of freedom of the system of the mechanism are also called as mobility which is why it is called m.

And n is the number of rigid bodies are the links that are present in the mechanism. And j is the number of joints that are present in the mechanism with only one single degree of freedom kinematic press. How many joints have only? One single degree of freedom that. This equation describes the relationship between mobility and the number of links and the number of joints with one degree of freedom kinematic pairs. This equation is called Kutzbach equation.

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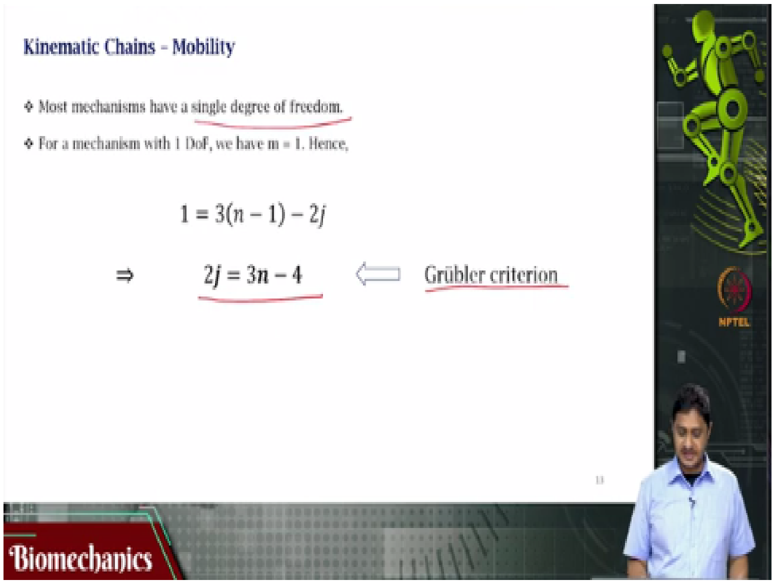

Now for a mechanism with one degree of freedom that means it has mobility m = 1 I substitute m = 1. Many mechanisms that are under discussion will have only a single degree of freedom and our analysis will also have a single degree of freedom whether it is. Once you substitute m = 1 immediately the number of joints and the number of links are related to each other and 2j = 3n - 4.

So, the number of joints and the number of links are related like this this criterion is also called as Grubler criterion. The number of joints and the number of links. In this case remember j still refers to the number of joints with single degree of freedom kinematic pairs.

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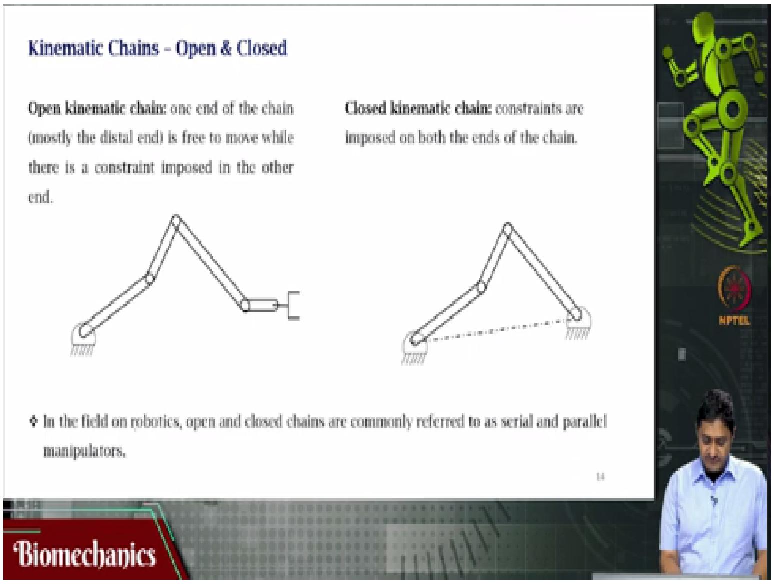

Then you have open kinematic change and closed kinematic change. For example, I can consider the arm system as an open kinematic chain. The end effector is open it is not attached to any particular point or a body or another body. So, one end of the chain mostly the distal end. So, this is in this case this is approximal and that is the distal end. Or mostly the distal end is free to move it can move anywhere, not anywhere it can move it is free to move.

While constraint is applied at the other end. Whereas my shoulder joint cannot move outside the shoulder it is constrained which is why this is a mechanism because this can be considered to be the ground for the purpose of this discussion. This is the fixed attachment or this is the ground to which this link is attached. Or the humerus is attached to the shoulder joint for the purpose of this discussion that means this makes it a mechanism.

Whereas the end point is open which is where this is an open kinematic chain, for example like this. Then you have a closed kinematic chain in which constraints are applied both on the distal end also on the proximation. Suppose my hand is attached to the other hand and it can move anywhere it wants but it should not remove itself from the other hand like this for example. Now there is a constraint on this distal end also.

So, constraints are imposed on both hands or both ends of the chain, this is a closed kinematic chain. So, for the purpose of discussion in the field of robotics, this is a system discipline for us open and close chains are frequently referred to as serial and parallel manipulators. So, these open manipulators or the open chain is called as a serial link. It is a serial manipulator whereas in this case this is these two are these two serve as a parallel manipulator.

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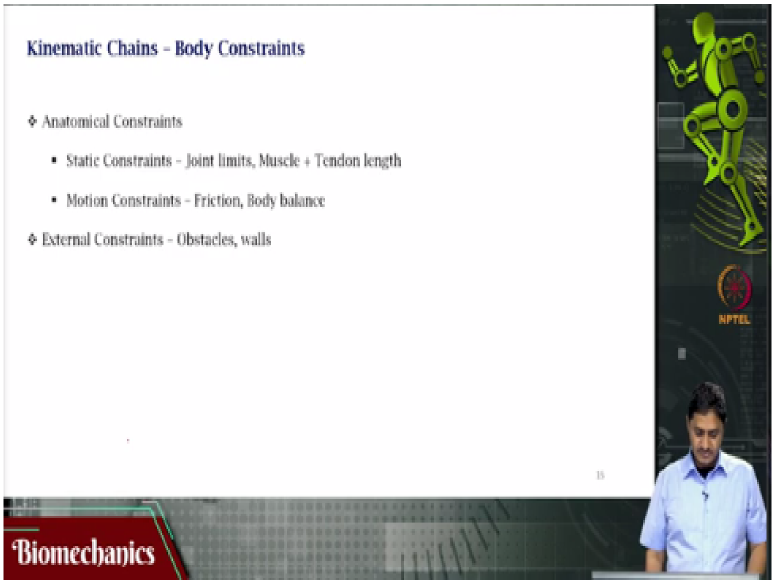

There are also constraints imposed by the body for example, limits within which the joint can move. For example, the elbow joint can extend like this but not really hyper extent can do that. So, the range of movement is between that angle but not beyond this for example, joint limits. This is specific to the giant to the person changes as a function of age. But in almost all the cases there is no hyper extension in the elbow.

So, there are some rigid constraints then muscle plus tendon length. And then there are also other motion constraints like for example, when you are walking there is a restriction that is posed by the open kinematic chain which is my foot can be considered as the distal end of an open kinematic chain. But it is constrained by the floor I am keeping my foot on the floor there is a constraint. Because the floor is rigid my foot is not going down it.

Otherwise, my foot if for example, you place your feet or one of your foot in muddy water for example, your foot will go down or will get slightly pushed inside. So, that is that lack of that constraint for example, for comparison. Also, while you are walking there are other constraints that come into the picture while you are walking there is the friction that is the force between the as in the shear force there is force that is parallel to the ground and the foot the frictional force all these things.

Then there are the external constraints that is the wall there are obstacles or objects with which you are interacting and so on and so forth. So, there are constraints with which this kinematic change operate.

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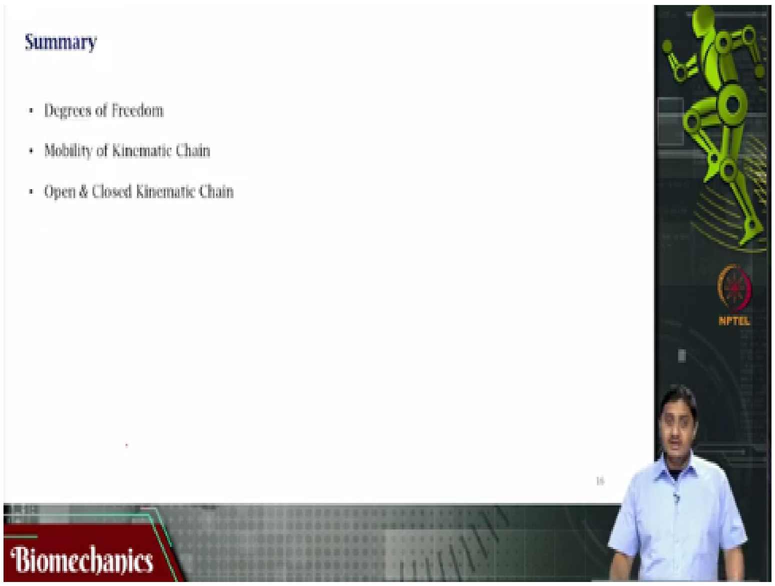

So, with this we come to the end of this video. In this video we saw what is degrees of freedom and how many degrees of freedom are there in a free body or in planar or a body restricted to moving within a plane, mobility of a kinematic chain what are open and closed kinematic chains. Thank you very much for your attention.