Mechanism and Robot Kinematics
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Lecture - 01
Introduction

Welcome to this course on Mechanism and Robot Kinematics. To begin with we should ask the question why we should study this course? But even before that we must look into what is the subject matter? What do we study in this course?

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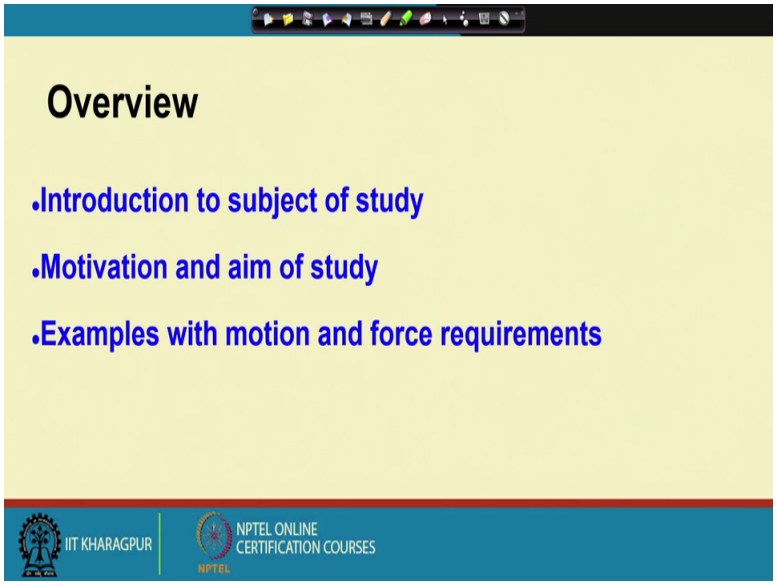

So, here I have listed out the overview of today's talk. So, first I will introduce the subject of study, then I will go over to the motivation and aim of this study. And then I will show you examples with various motion and force requirements in mechanisms and robots.

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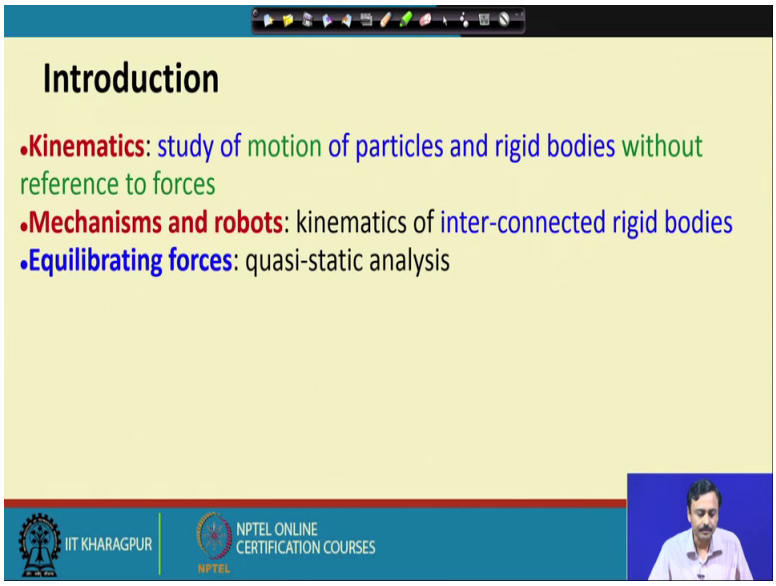

So, to introduce let us look into the definition of kinematics; what is kinematics? Kinematics is the study of motion without reference to forces, now the forces here would mean the forces that produce the motion, so these are called dynamic forces. So, we study under kinematics motion without reference to such forces which produce that motion.

When we come to mechanisms and robots, then the kinematics is of interconnected rigid bodies. Normally in kinetics, we study particles and rigid bodies, but here in mechanisms and robots we have interconnected rigid bodies and we study the motion of such interconnected bodies.

Now that brings in little bit of complication, compared to a single particle or a single rigid body moving. In this course, we are also going to look into forces but these are not the dynamic forces that we usually understand. These are the equilibrating forces, forces that are required to produce equilibrium. For example, if I have to produce a force then my muscles are producing that force at my hand.

So, if I need to produce a certain force what should be forces in my muscles? Is what we are going to look into; now these are not dynamic forces. These are forces which produce equilibrium or which produce a certain force at the end of it; some specified or required force at the end effector; so, these are equilibrium forces.

And for that we are going to study quasi-static analysis to find out these forces.

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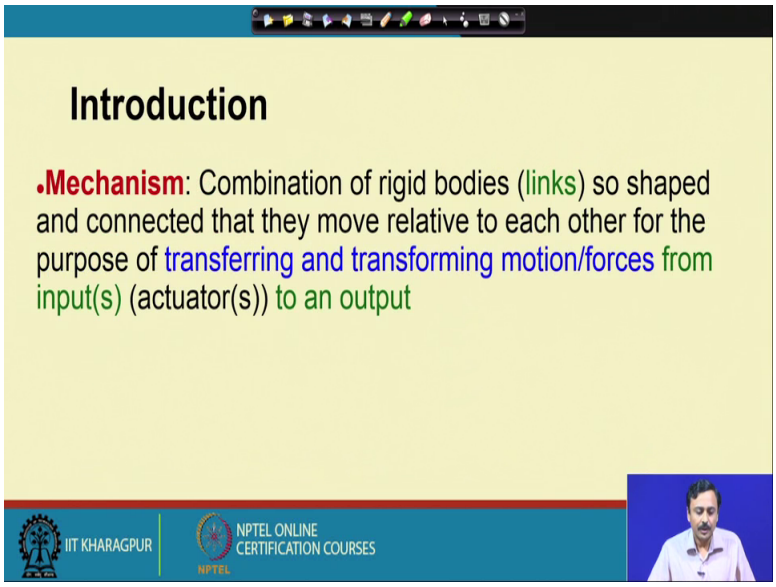

So, what is the mechanism? We should look into this definition of mechanism. So, it is a combination of rigid bodies which we will call links, so shaped and connected that they move relative to each other for the purpose of transferring and transforming motion or forces from inputs, which are the actuators to an output.

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So, this is the definition of mechanisms; so, here there are some keywords which we are going to look at. First is mechanism sensor, so they are use for transmission and

transformation of motion and force. For example, you can transform rotary motion to translatory motion or rotary motion to rotary motion with different velocities; maybe or accelerations or maybe translatory motion to rotary motion, so this transformation of motion.

We also have transformation of forces for example, we can have a motor producing a torque, but at the output; it is a force. So, it transforms forces from the actuator inputs to the outputs. Motion; how do we quantify motion? So, motion is quantified in terms of displacement, velocity, acceleration and path. Force transmission, so as I have mentioned that the mechanism transmits force or transforms force; from the actuators to the output. So, these are the key things that we are going to look at.

Now, we come to the motivation; why should we study this subject? You have seen mechanization, you have seen automation and we all take advantages; we read the benefits of mechanization and automation. And behind this usually, there is a mechanical device or a mechanism or a machine which works. For example, in construction sites; you have excavators, you have robots in assembly lines etcetera. So, these are all mechanical devices which use a certain mechanism.

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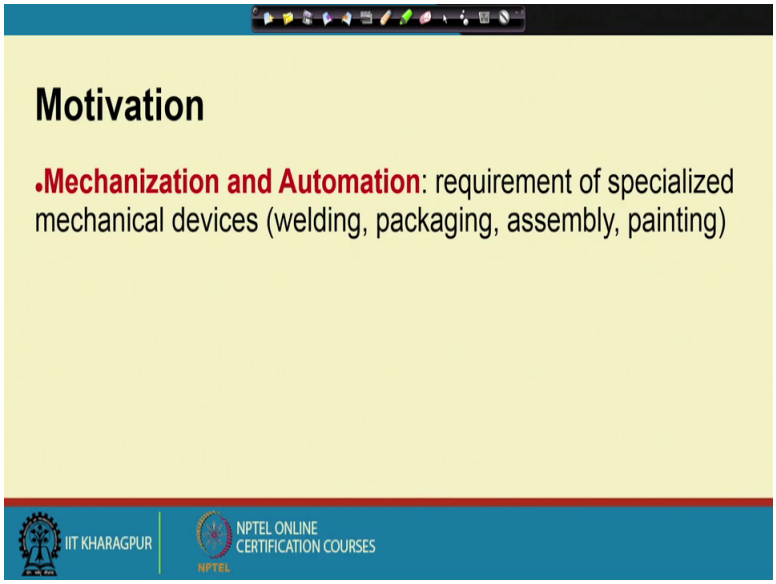

So, the first point of our motivation is this mechanization and automation; we have specialized mechanical devices for various tasks, for example, welding, packaging, assembly, painting, manufacturing etcetera. So, there are various tasks for which we have

different mechanisms; specialized mechanisms or programmable devices which helps us in mechanization and automation.

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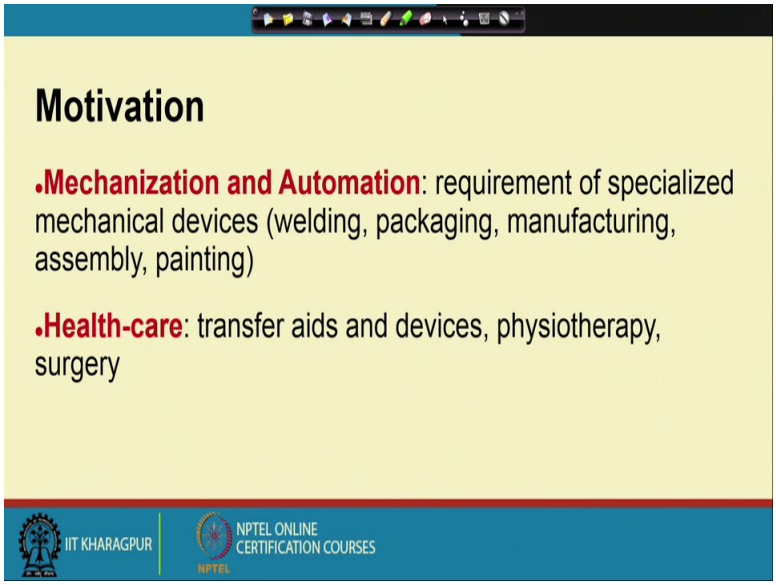

Health-care; nowadays there are various healthcare devices for example, devices which help patients or people with disabilities; to go on with their life. For example, it can help a person to move from a sitting position to a standing position; people who have maybe undergone a surgery or are possibly little disable, so for that there are various devices. Then there are devices for physiotherapy, for surgery; for example, in laparoscopic surgery; we have surgical tools which have to enter the body through small incisions.

So, all these things will require some mechanism and this is what I am going to show you in the course of this lecture.

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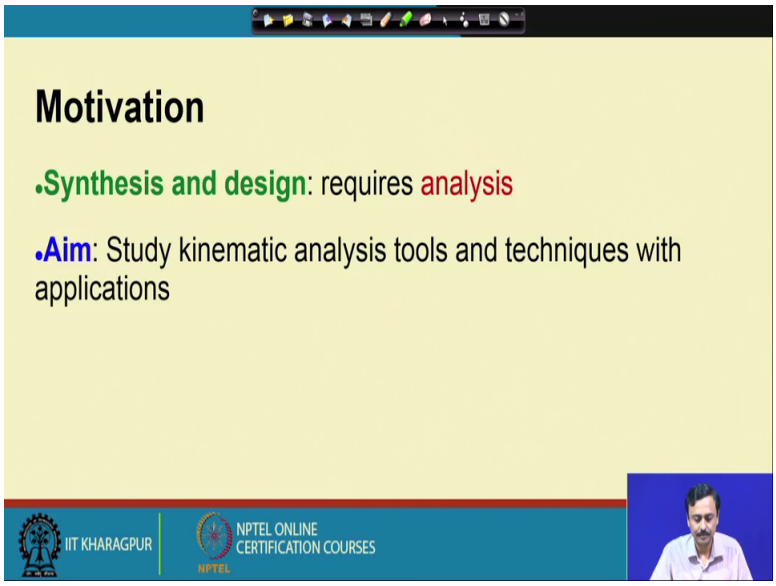

So, now I come to the motivation; so, what motivates us to study again? So, all these devices, they require design and synthesis. So, synthesis means setting up the basic structure; what mechanism you should use? And design would be to set the dimensions of such a mechanism and all these things will require analysis, which we are going to do in this course.

So, let us set our aim; so in this course we are going to study kinematic analysis tools and techniques with applications. Now we come to examples, so through certain examples; I will show you various mechanisms and also tell you about what are the things that we are going to study which are relevant to these mechanisms.

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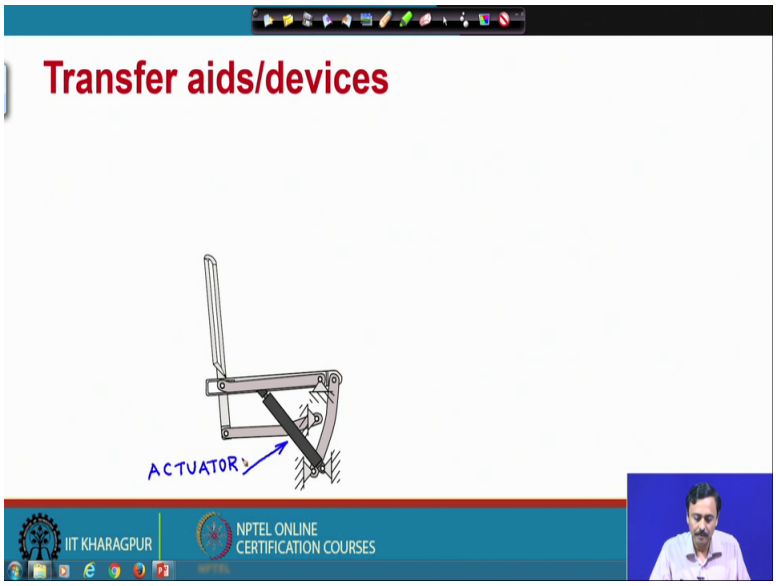

The first mechanism that I am going to show you is; the transfer aid or transfer device. As I was mentioning that patients or people with disabilities, they require devices to carry out certain tasks in everyday life, for example a person who is infirm might require an aide to help him or her to stand from a sitting position. So, here I have a device which is a mechanical chair, which is actuated; so, this is an actuator.

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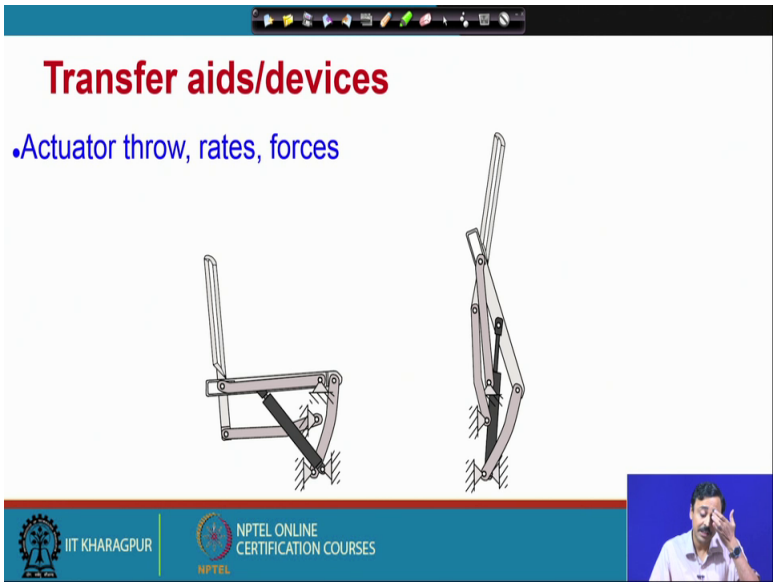

This actuator; drives this linkage mechanism to go from this sitting position to this standing position. So, the actuator takes a person from a sitting position to standing

position; what are the requirements for this kind of a mechanism? Or what is relevant for our study?

For example you can ask the question how much the actuator should expand in order to go from the sitting position to standing position; so, the actuator throw? Second is the rate at which this actuator should expand? Now it should be at a comfortable level, you should not push a person too hard and especially when the person has come to a standing position almost to a standing position, it should not have very high velocity so it pushes the person in front.

Then, we have the requirement of force how much this actuator should apply force at each configuration? Now this force is not the force that will produce lot of acceleration, but it will take the load of the person and the chair; from a certain configuration through certain configurations. Next, I will show you a surgical instrument which is used for laparoscopic surgery. So, in a laparoscopic surgery as you know a small incision is made and tools and maybe a camera is sent in through that incision and surgery is performed.

Now, you can imagine that such a surgery will not be using standard knives or scissors; it will require tools like this.

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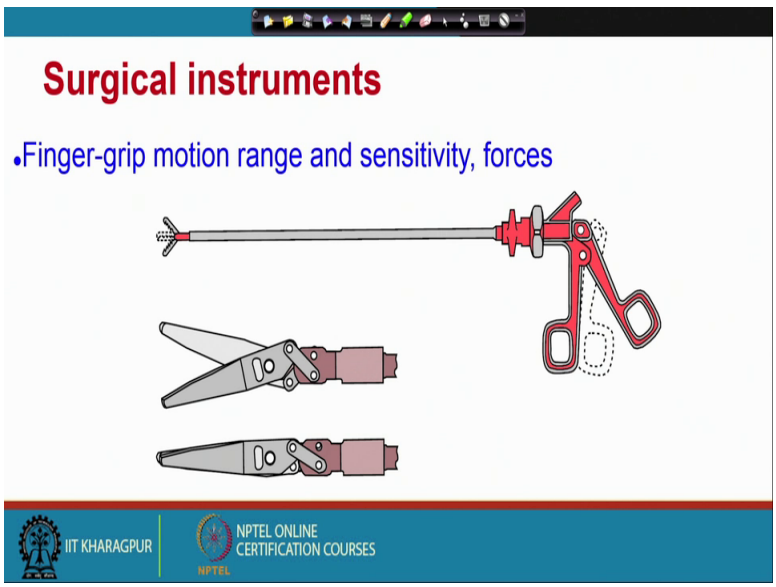

So, you see there is a long cylindrical barrel which can enter into the incision. And the surgeon will operate at this handle and that will operate the end effector, which can be a clamp or which might be a scissor like this, so which can perform the operation.

Now, you can imagine that within this cylindrical tube there must be some mechanism that is transferring the motion of the surgeons fingers to the end effector, which might be a clamp or a scissor. So, what are the things that are relevant to our study here? You know the surgeon can possibly position his or her fingers to level of millimeter maybe or a couple of millimeters, but maybe that surgery requires submillimetre precision, so which means that mechanism must help the surgeon in order to achieve this precision.

So, what is the motion transformation from the surgeons fingers to the end effector? So that this mechanism should be able to perform, so motion range and sensitivity. The other is the forces that the surgeon needs to apply; now surgeon should not be required to apply a lot of force then the precision of surgery will be lost. So, with small force he or she should be able to perform the surgery, so this is another aspect.

Now, this again is not a dynamic force; this is a force that will require equilibrium. Next is the landing gear of an aircraft, now when an aircraft is on the ground; it is on the wheels, it is supported by the wheels. But when the aircraft takes flight, the wheels are folded into the body, so there must be a mechanism which is working there. Nowadays, nobody will allow you to go to an aircraft and watch it; see the wheel mechanism, but you can see it here now.

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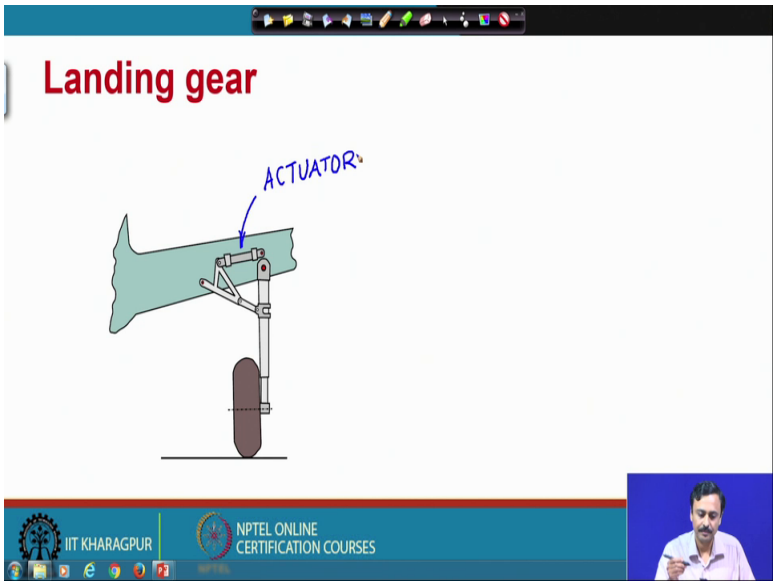

So, this is a schematic of an aircraft landing here; here again there is an actuator, is a hydraulic actuator which will expand.

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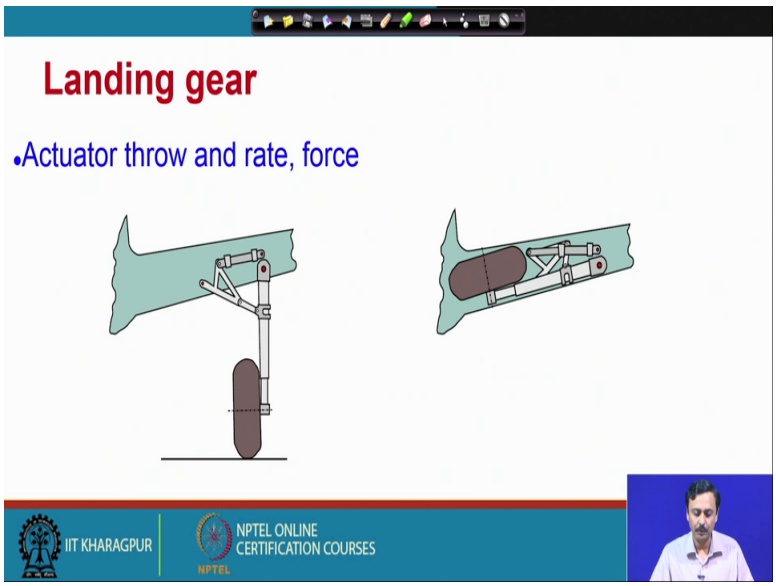

To take the wheel to this folded configuration, so you can see the actuator has expanded and the wheel has correspondingly folded into the wing. So, what are the things which are relevant here? The actuator throw and the rate. So, how much should the actuator expand to take this wheel from its open position to its folded position? How much force

the actuator must apply to keep the wheel in a stable open configuration or keep the wheel in a folded configuration?

Next, we will look at this example of an excavator; you must have seen excavators in construction sites.

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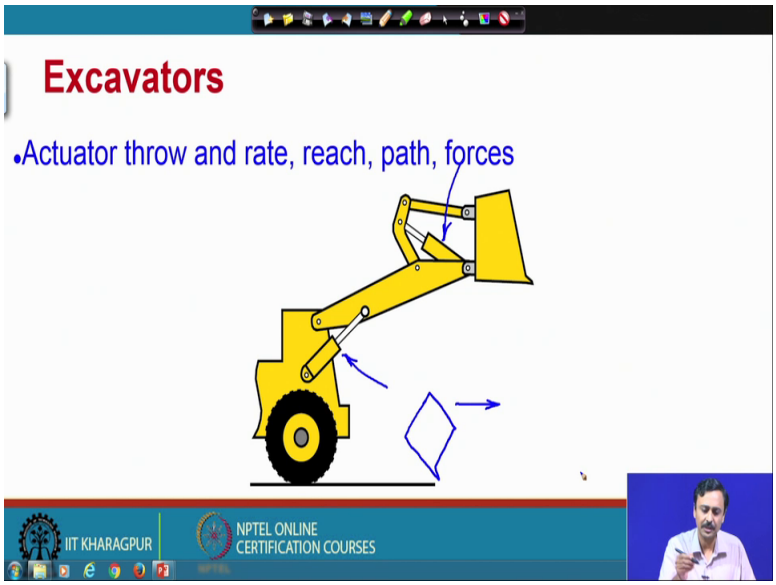

So, these are devices which are used to lift rubble or to remove rubble. So, here is a schematic of an excavator; once again these are the actuators. So, there are two actuators and you have a bin, which is used to move or carry the rubble or dump it somewhere.

So, what are the things that are relevant? The actuator throw and rate of course, how much should the actuator expand or move so that for example, I can take the bin maybe to this configuration? What should be the rate of actuator expansion show so that I can move this bin with a certain velocity or speed? How I should control the actuators so that this bin can move in a line along the ground? So, these are the questions which are very relevant and as you can see since there are two actuators, the control is not very simple or straightforward.

Next is the force; if I have to carry a certain amount of rubble; what forces these actuators must exert in order to carry that? These are certain questions which are relevant for our study. Robots, all of you have some idea of robots; they are used in assembly

lines, in automotive and aerospace industries for various purposes like welding, painting, assembly, various types of manufacturing.

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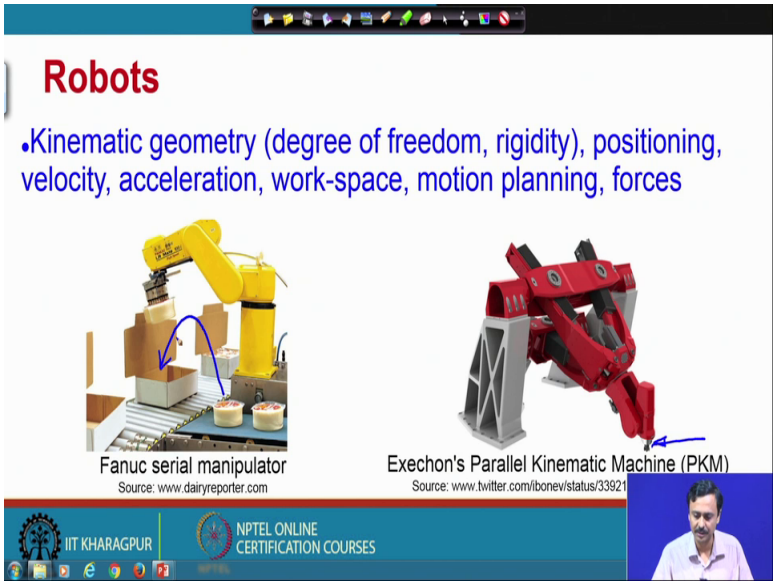

So, here we are going to look at some examples of robots. So, here is a robot; this is called the Fanuc serial manipulator, here you can see this robot being used for packaging of some dairy products. So, certain dairy products in packages is being brought in by a conveyor and this robot is putting it, stacking it into some containers; boxes.

This is a serial manipulator as you can see that these are the links which are actuated. So, here there is an actuator, here there is an actuator, here there is an actuator and here there is another actuator. So, these actuators occur in a series one after the other, so that is why the name serial manipulator. Here is a picture of what is known as a parallel kinematic machine, looks very robust; is not it?

Compared to the serial manipulator which I have shown on the left, this is used for machining operations and this is indeed very robust, it can apply a lot of force whereas this serial manipulator can only perform tasks which do not require too much of force. For example, this packaging or welding or painting or maybe small assembly; a serial manipulator for example, cannot be use for machining. I mean it is very difficult to use them for machining purposes because machining will require lot of force and robustness of the structure. So, for that you use parallel manipulators or parallel kinematic machine as it is called.

So, what are the things that are important here? So, kinematic geometry which I was just telling you that rigidity, what kind of degree of freedom is required? For example, to machine a very complicated shape, you might require 5 or maybe 6 degrees of freedom at this tool. So, here is a tool which will does the machining operation, but for a simple operation like picking a box and putting in a box. So, if you taking this package and putting in a box may not require so many degrees of freedom or may not require too much of rigidity, it would be an overkill.

Then positioning of this tool or this packet; so, how do you control the actuators so that this box can be taken from the conveyor to the or this package will be taken from the conveyor to the box, where it is being packaged? Acceleration; how fast this is going to move and how quickly it is going to accelerate to that speed?

Then the work-space; what is the reach of this actuator? So, for example in this packaging manipulator; Fanuc serial manipulator it requires a reach from this conveyor to the box. Similarly, in this parallel kinematic machine; it will require reach to the different portions that is being machined. Now, that will be decided by how much each actuator can move? So that is workspace, what is the space that this manipulator can cover?

Then the motion planning, suppose you have to move this tool on a path like this or this package like this; how should you plan the motion of various actuators that control this robot? So, that is the topic of motion planning; how you should control individual actuators to generate a certain path of the end effector or end point or the tool. And finally, of course, the forces how much force is required at each individual actuator to produce a force at the end effector; at the end point?

Flight simulators, now you know that pilots; require training and training under different conditions. For example, when an aircraft is moving and falls into an air pocket; the kind of jerky motion that comes onto the aircraft and to the pilot. So, the pilot should be able to maneuver the aircraft or should have that training of facing such situations. And the standard things are of course, they are taking off, landing, turning. So various kinds of operations that a pilot does, it may also help them to fine tune or optimize the takeoff strategy or landing strategy in various airfields.

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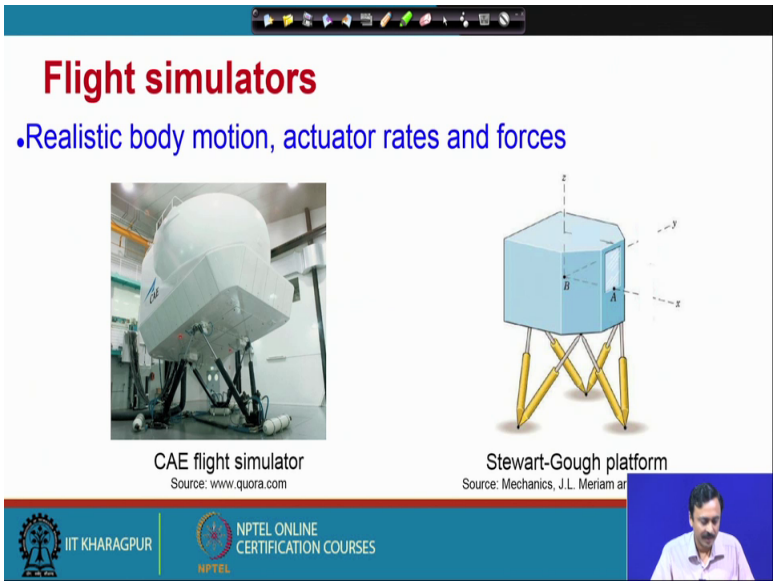

So, you need to give training for such situations, so here I am showing you a figure or a picture of a flight simulator; made by a company called CAE. Now this looks quite complicated, so I have a simpler picture on the right. This is called the Stewart-Gough platform; based on which this flight simulator has been made and you can see the similarity.

So here is the cockpit, where the various instruments and the control panels are present, so the pilot sits inside this cockpit. And you have this actuators, which expand or contract this might be hydraulic or pneumatic actuators, which are controlled in order to generate different kinds of motion of the cockpit.

Now, what is required of such a device? You need to produce realistic body motion or that means, the aircraft motion or you should be able to simulate the aircraft motion. For example, you should be able to simulate; what happens during takeoff? What happens during landing? Or; when an aircraft falls into an air pocket or a low pressure zone, so, such things should you should be able to simulate.

So, how you should control the actuators in order to produce such motion of the cockpit? The actuator rates of course, will decide what kind of roll, pitch, yaw; the aircraft is undergoing. So, that will give the pilot a feel of the aircraft motion because in a rotating frame like that; it is not very intuitive to understand how different forces act, because it

becomes a non inertial frame as you know and the forces that these actuators must provide, in order to keep this in equilibrium in quasi-static equilibrium.

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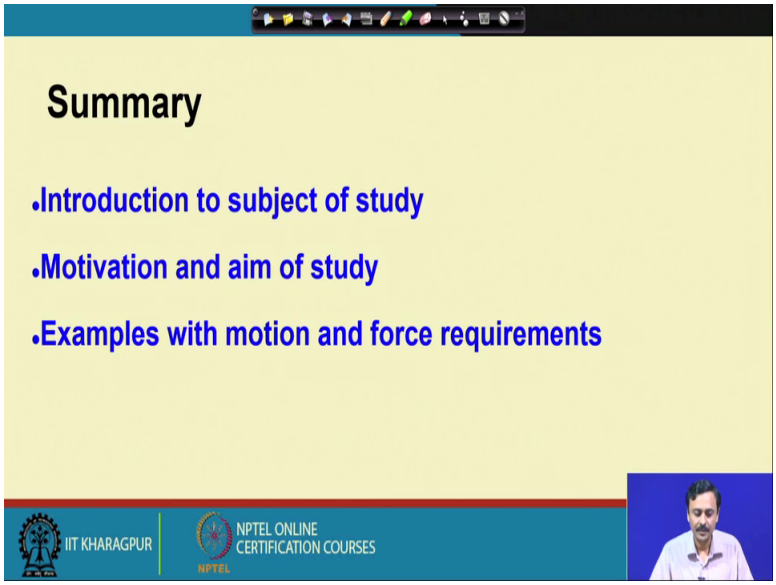

So, finally let me summarize what we have looked at. We have introduced the subject of the study; I have discussed the motivation; why we should study? And I have also said the aim of our study with examples, showing you; what are the different motion and force requirements for these applications? So, with that I will close this lecture.