Automation in Manufacturing
Dr. Shrikrishna N. Joshi
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Week – 07
Mechanisms
Lecture – 01
Types of industrial automation and mechanisms

Hello everyone, I welcome you all to the NPTEL online certification course on Automation in Manufacturing. We are starting Week 7. In week 7, we are going to learn various types of mechanisms, which are used in the development of mechatronics based automated system. Before we start to study the various mechanisms, we will also study what are the various aspects or what are the various circumstances in industrial automation, where we need these type of mechatronics based automated systems.

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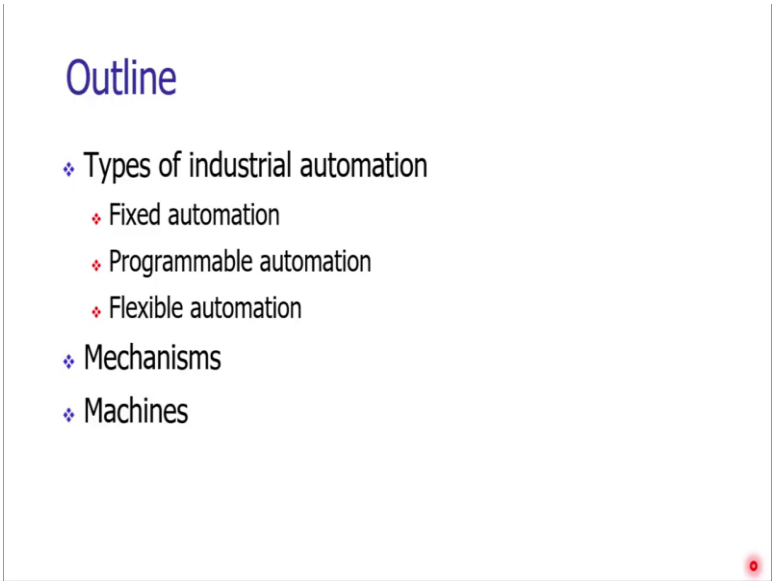

The outline of this lecture is as follows: at the start of the lecture, we will have a discussion on various types of industrial automations which are used. We will study the fixed automation with the case study on turning machine, programmable automation and the flexible automation. We will study where the programmable automation and flexible automation strategies are used. After that, in the context of development of an automated system, various mechanisms or machines used will be studied.

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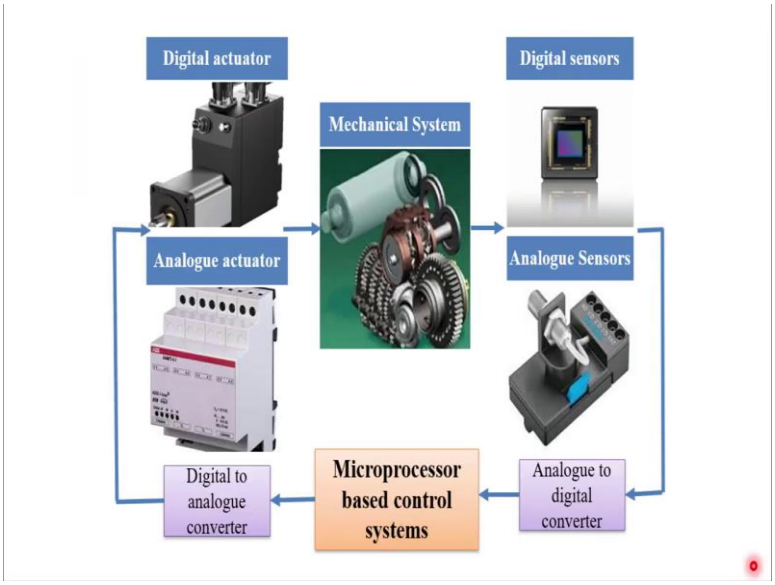

Well my friends, in this course we are exploring various aspects, various blocks of the development of microprocessor based automated system. We have seen the electrical and electronics components as well as the computer related components of an automated system. Now, we will be studying the mechanical systems. During the development of these automated based system, let us look at where the systems are being applied in the industry.

In industry there are various circumstances, there are various types of utilizations of this automated system. The utilizations or the application of these automated systems vary from the situation to situation. Basically, we are having three different types of situations where we can use these industrial automated systems.

These are the types of industrial automations. The first one is the fixed automation, the second is the programmable automation and the third one is the flexible automation. Let us explore these three types of automations and then, we will study the mechanisms and the machines.

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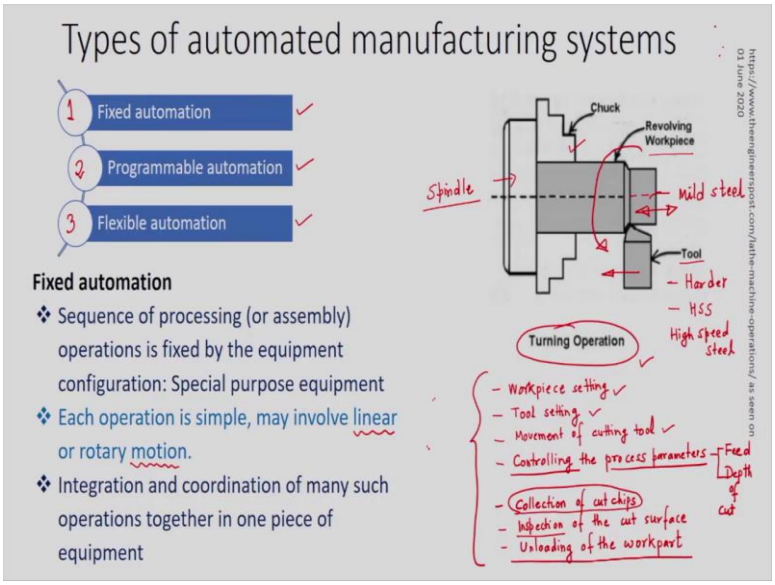

Now, let us see; what are various types of automated manufacturing systems. Basically, there are three types of automated manufacturing systems used in the industry. The first type of automation is fixed automation, the second type of automation is programmable automation and the third type of automation is flexible automation.

Now, it would be very interesting to know; what is the meaning of fixed automation, programmable automation and the flexible automation. In fixed automation, we are carrying out a sequence of operations, it may be processing operations or assembly operations, which are fixed by the equipment configurations. Meaning is that, there is a machine or an equipment which is carrying out a sequence of operation in a very fixed way, in a rigid way, we cannot alter them.

Of course, that sequence of processing is program is designed and that sequence of processing is dependent upon the product design. That is why these equipment are called as the special purpose equipment, they are specially designed to cater the needs to manufacture a specified product or a specified part. That is why it is called as fixed. The automation has been done, the handling is automatic; processing is automatic, but this is fixed, we cannot alter it.

The operations which are there inside this fixed automation are very simple. They may be linear moment of the slides or tools or any other facility or any other thing which is required, say for holding the part, say a fixture or it may be for the wrapping of the part

or it may to fasten the part. All these operations are disintegrated or they are designed in a very simpler mode. They may be a linear motions of the elements, or they may have rotary motion of the element. And, we are combining them, we are integrating all these operations together and we are trying to make them simultaneous to minimize the entire product manufacturing time. We have to integrate them and we have to coordinate many such operations together to make that special purpose equipment efficient and productive.

To understand the concept of fixed automation, let us take a very simple example of a turning operation. The turning operation is very common operation which is used in mechanical industry basically, in the tool rooms. Mechanical engineering or the other the listeners or participants of this course, those who are having mechanical background, they are very well conversant with this turning operation. What is happening in a turning operation? There is a workpiece, workpiece is revolving, and this workpiece is held in a chuck, it is fixed in a chuck, chuck is nothing but, work holding device.

This chuck is mounted on a spindle and that spindle is being run by a motor. Of course, that is a gearbox or there may be a pulley drive through which the spindle is rotating. The spindle is rotating, the chuck will rotate and the it will revolve the workplace. We are using a cutting tool. The cutting tool is, it is harder than the workplace. Generally, at shop floor we are using high speed steel cutting tool, if we are working on a mild steel workpiece.

We are feeding the workpiece against the tool, but in this case, since the workpiece is rotating it cannot move or translate; it is just rotating. The feeding of the workpiece to the tool will be carrying out by moving the tool with respect to the workpiece. The tool will be moved, it will be translated in the direction parallel to the axis of the workpiece.

As the tool is moving related to the workpiece it will carry out the shear deformation it will remove the work part in a gradual manner, in the form of chips. In this way we are reducing the diameter of a bar or a circular component or axisymmetric component in the turning operation. When we carry out this operation just by moving the tool in horizontal direction, we are just carrying out only one operation. And here, if this entire process is manual, then we can consider; what are the various avenues where we can automate the process. Now, if we consider this operation, so first operation, the fitter or the machinist

fixing the work part or it is loading the work part in the chuck. Setting the work part in the chuck, that is the first manual operation.

Workpiece setting and tool setting, both these operations are manual. Then, moment of cutting tool is also manual. This process parameters are feed depth of cut, then we need to collect the cut chips.

Collection of the cut material, the chips which are falling down that we need to cut. Then, inspection of the surface after completion of the operation, then we also carry out the removing of the work apart from the chuck; that means, an unloading. Removal of the work part from the machine, unloading of the work part.

In manual mode all these operations are need to be carried out by a human being, only here the powered things are the spindle is rotating at the given speed. Even the speed also has to be decided and set by the human being. When we try to make such operation automatic, we have to carry out all these operations in an automatic way.

Can we have a system or can we have an equipment which will set the workpiece automatically, which will set the tool. The equipment will move the cutting tool automatically with respect to the workpiece. The equipment should have the facility to set the feed and depth of cut.

Can the machine tool have a facility to collect the cut chips, and can we have automatic inspection, can we have an equipment with this facility, so that, it will read or it will give the idea about the roughness of the surface which is machined, can we unload the component or work part automatically, it will either fall down, it will or given to fitter or the machinist.

When we carry out all these operations in automatic way, we have to design a special equipment. That special equipment will cater machining of only simple product. That is called as the fixed automation. Such systems can easily be designed nowadays and people are using it.

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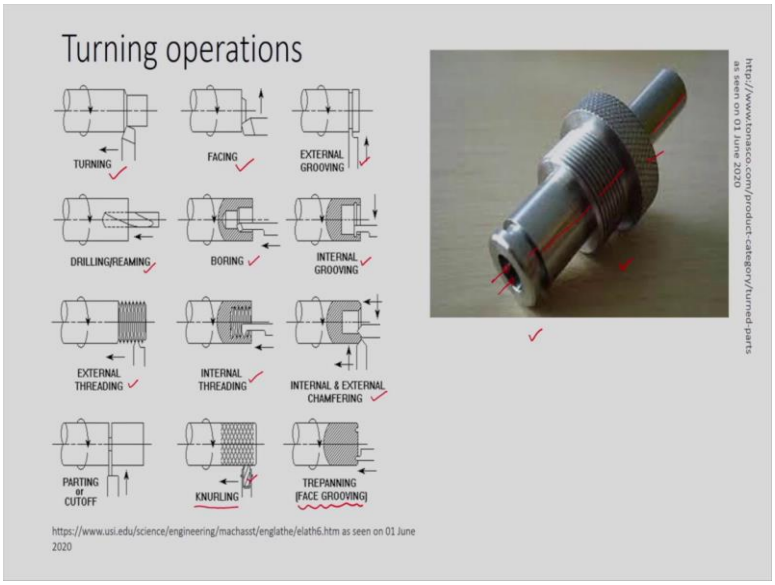

If you look at the complexity of variety of products into reality, in real life condition you will find that there are many operations needed on a component. It is not only a simple one operation that that need to be carried out. If we look at on the screen, as far as turning operations are concerned, there are many operations, many features the turning operations can developed on the workpiece. Simple turning means reduction of the diameter. Facing is the operation where we are making the ends or we are making the ends of the bar stocks in a flat way to make the ends flat plane.

To manufacture the grooves, to drill, to enlarge the already drilled hole or to manufacture the higher diameter internal holes that we call boring operation. To manufacture groovings inside the drilled hole or to manufacturer groves inside the bored holes that we call internal grooving. Threading operation, to manufacture a helical groove that we call threading on the outside surface. To manufacture helical groove inside a bored hole or a drilled hole that is the internal threading. Threadings are useful for fasting.

Chamfering operation is to remove the sharp edges, sharp edges on the work part. We are giving chamfered surface, we are just cutting that surface we are making it a little taper. Then, parting of is the final operation; where, we are just cutting down the processed part or the finished product from the bar stock. Knurling operation is actually this is not material removal operation, is a deformation operation we are using a knurl tool to

manufacture various textures. Particularly, a diamond texture is generated on the work part for the gripping purpose.

Trepanning is the face grooving operation. On the face if you want to manufacture a groove that is called as the trepanning operation. All such operations are need to be carried out on a single part. One such part is there in front of you, on the right side here you can see. Here we notice a simple turn parts is having all such operations, which have been just shown on the left side part.

Here, we can see the groove, the turn portion, the threads which are manufactured, the knurling portion, and again a step turning has been shown over there. This part is also having the drilled hole as well. Such parts or such components are the real components in the industry when our aim is to manufacture such product we have to design an equipment.

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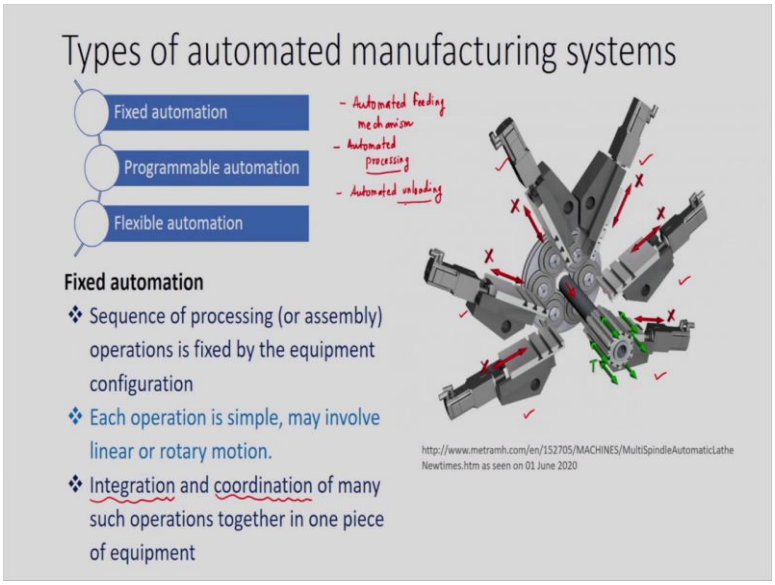

To design such an equipment, we have to integrate all such operations and we have to have an coordination among them. On the right side we can see, you suppose we want to have an specialized equipment, we may need multiple number of tools, and that multiple number of tools are to be mounted on the special slides, that slides are moving with respect to the workpiece.

The equipment should have automatic feeding mechanism; automatic loading mechanism. What things are needed here? We should have automatic feeding mechanism, then automated processing. For automated processing we can see various tools need to be designed for every tool, we are to have a slide. Slide is a mechanism which facilitating the movement of the cutting tool with respect to the workpiece. So, automated processing is needed.

And then, automated unloading. Feeding of the bar should be automated, then processing, and at the end the unloading. When all these operations are clubbed together, we can have a special purpose equipment which will cater to manufacture only one type of component. The simple example is screw manufacturing. The customer may go to the machine tool designer and they say that we want to manufacture or I want to have a screw designing machine.

According to the needs of the customer, according to the machine tool designer will design it and develop the equipment. When such equipment is used by the customer and he is producing enormous number of the screws and selling in the market, and that kind of a system is called as the enterprise based on fixed automation system.

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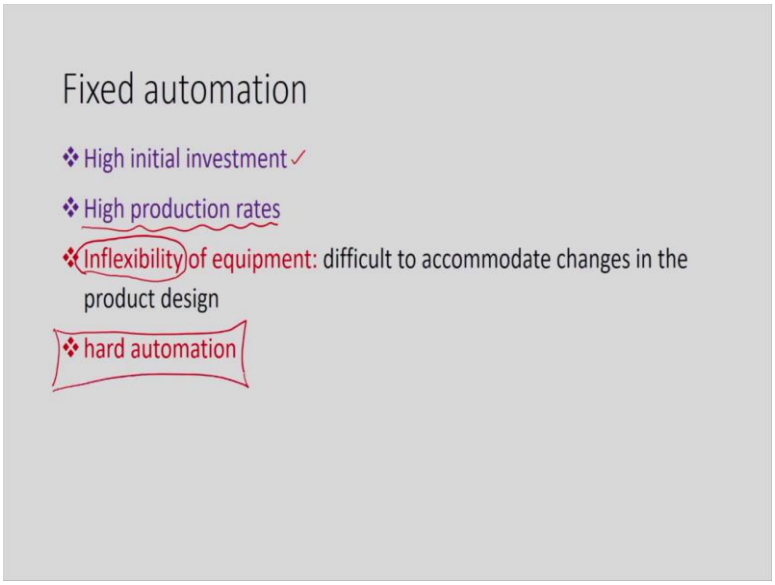

Well, of course, to have such a system that customer has to invest quite heavily. The initial investment in incorporating the fixed automation is quite high. That high initial investment will definitely paid. Now, the customer may have high production rates. But,

the difficulty or the limitation of this system is that fixed automation, there is rigidity in the automation. There is no flexibility. The inflexibility of the equipment is the major limitation of the fixed automation. If the customer or the enterprise wants to change the design, he can change the design. Of course, that special purpose equipment cannot be used to cater or cannot be used to machine the improved design or the modified design. That is why, such type of automations are called as the hard automation. They are hard; difficult to change, difficult to modify.

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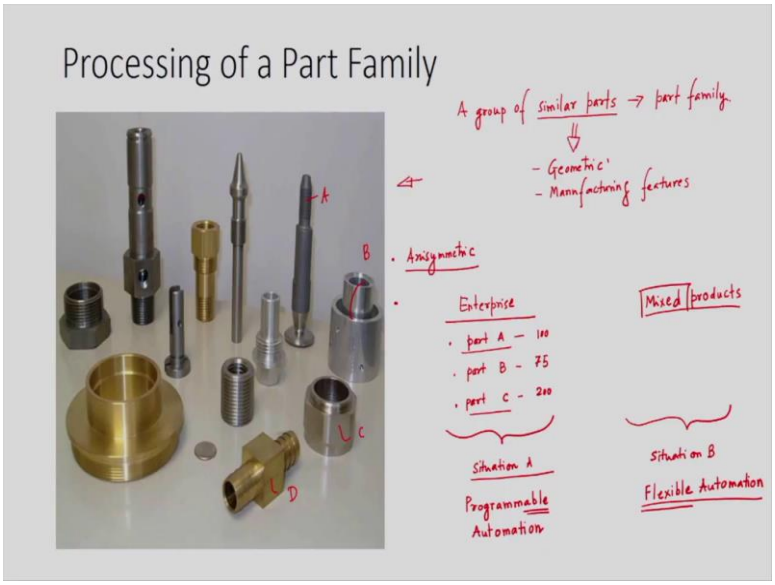

Now, the enterprise or customer may have an option to expand his business, then he can say that I can manufacture variety of components. Of course, all the components are axisymmetric, they are made up of metal. An enterprise has decided to cater or to manufacture the components, which are axisymmetric and which are made up of a metal. When such decision has been taken, then we have to choose what kind of automation we have to go for it. Here, the second type of automation is coming to picture that is the programmable automation.

In front of us, we can see a part family. Part family is nothing but a group of similar parts. That we will simply call a part family. What kind of similarity the parts may have? It may have either a geometric similarity or it may have manufacturing similarity. Now, the part family which is shown over here, so if we closely observe, we will find that the

all the parts are axisymmetric. These parts are axisymmetric, all the parts are axisymmetric and they are having a variety of features which we have already seen.

They are having taper, turning, then internal threads, external threads, drilled holes and bored holes. All these parts are to be manufactured on a single machine. So is it possible? Of course, it is possible. For that purpose, we have to a general purpose automated machine. And, in that general purpose automated machine, will cater the manufacturing of all these parts. Only thing, we have to reprogram the machine tool. We have to change the program, we have to change the settings of the machine tool.

When a machine tool or when a equipment has the capability of reprogramming, that kind of automated systems are called as the program programmable automated systems and the entire process is called as programmable automation. When the decision is taken, that a enterprise will manufacture all these components. Either these components are manufactured in a batches; for example, here you can see product A product B product C product D.

The enterprise may have two objectives; part A, say 100 number of components to be machined, part B around 75, part C around 200. This is a situation A. What situation A is saying that, part A to be manufacture 100, B 75 and C 200. The batch of 100 of part A, 75 of B and 200 of C. In situation B, we do not know, what is the exact requirement of part A, B and C. Somebody will come to the factory owner or the entrepreneur and he and the customer will say that, I want the 2 number of components of type A; around 10 number of components of type B and I need around 5 number of components of part C.

Random way or in a mixed way. We when we are having mixed products. Next situation is the mixed products. How to tackle these two situation? For situation A, when we have the equipment which will cater; part A, part B and part C, but we have to reprogram it according to the design of part A B and C, that we called the programmable automated system or this entire process is called as programmable automation.

Now, since we need to have an equipment, which is capable of catering a part family or the requirement of mixed products, their the automation which is incorporated, which is a special case of the programmable automation it is called as the flexible automation. Flexibility in terms of the type of product. Whatever the product is asked that to be

develop, the automated system should respond to that requirement. That why it is called as flexible automation.

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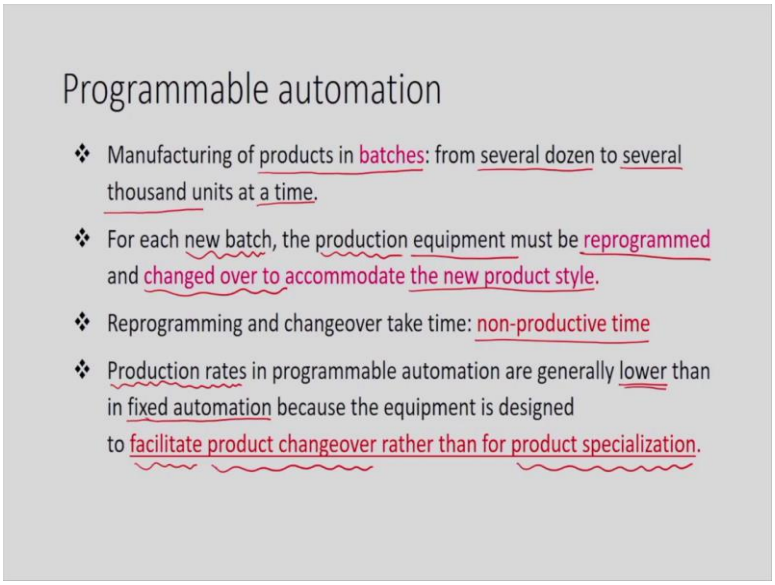

Well, the same concepts are written in the form of text, which are there in front of you. The programmable automation in general is carried out to cater the products, which are to be manufactured in batches. The batches may have the number of products, may be several dozens or to a several thousand units at a time.

If the requirement is to manufacture only one product, then what is the equipment needed? For every new batch, the equipment, the production equipment must be reprogrammed. As I mentioned, if we are changing the product design, we have to reprogram the equipment, and this time it is required to accommodate the new product style.

Of course, this reprogramming would be carried out and some settings will be changed, these are required to accommodate the new product style. The time which is consumed for reprogramming and changeover are non-productive time, they are not productive.

That is why the production rates in programmable automations are generally lower than the fixed automation. Because, this programmable automation is facilitating, it is providing the product changeover rather than product specialization. This programmable automated equipment is taking care of changing of the product design rather than product

specialization. The equipment is general purpose, it is not specialized product. It can use for variety of products, provided we should give some time, we have to spend some time to reprogram the system.

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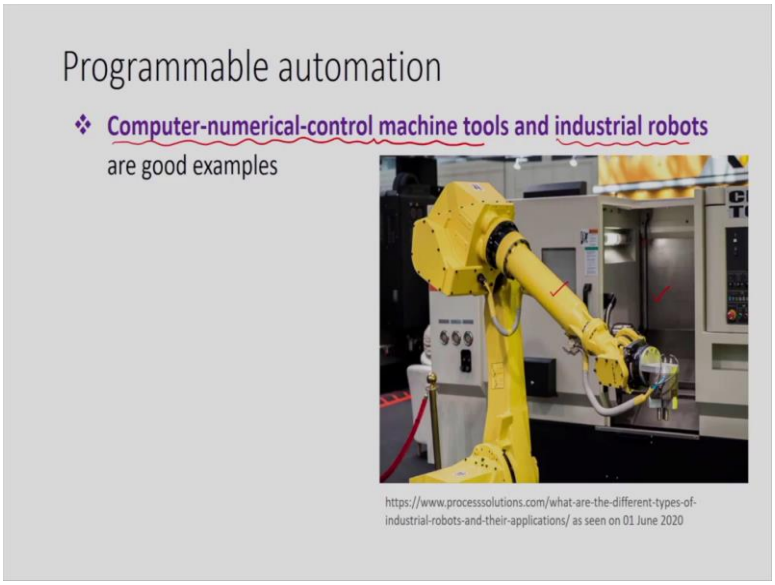

What are the various examples of the programmable automation? Very well-known example is Computer Numerical Control machine tools, CNC machine tools; CNC turning centre or CNC milling centre that we call CNC machining centres. These are the very general and very simple examples of programmable automation. Of course, industrial robots are also good examples of the programmable automation.

In the picture we can see there is an industrial robot and there is a CNC machine tool. With industrial robot which is used to feed the workpiece to the tool, and basically it is for the loading and unloading of the workpiece. And, the CNC machine tool will carry out the various operations, automatic tool changing, processing the work part, controlling the various parameters.

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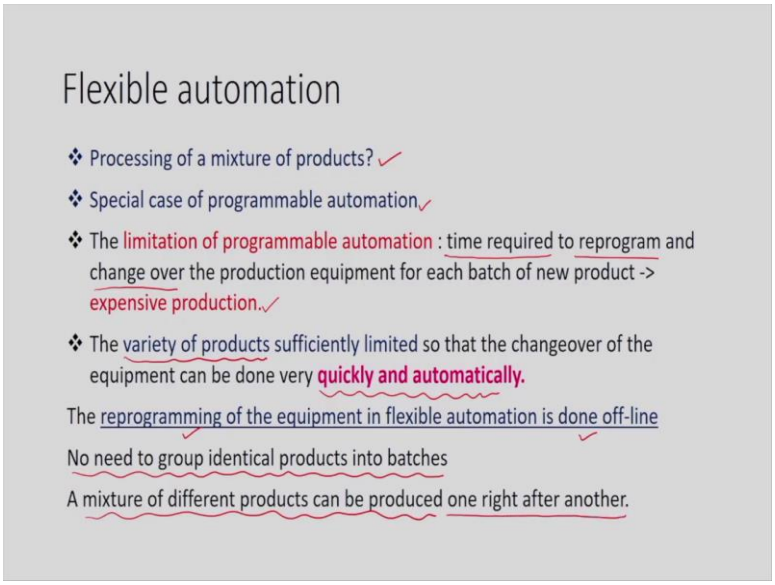

Next type of automation is flexible automation. As we have seen that when we want to process a part family, the part family as many number of products, and if we want to manufacture a single product in batches we are going for programmable automation. But, if the case is, that we want to manufacture a mixture of product, then we have to go for an automated system which will take care of processing of mixture of the products.

we can consider or we can say that flexible automation is an extension of the programmable automation or we can even say that the flexible automation is the special case of the programmable automation. We have seen that in programmable automation there is considerable time is being spent for reprogramming and changeover. This time is unproductive time, this is loss to the enterprise or the factory. That makes the production expensive.

For that purpose we can have a product automated system, which will try to minimize this time as well, but for that purpose we have to restrict the variety of the products being handled by that equipment system. Let us have a limited variety of products in the part family, so that we can quickly and automatically change the setting. That quickness and the automatic changeover will reduce the lead time and will enhance the production efficiency, or we can say the productivity.

How it is possible? How to do that? For that purpose, we will reprogram of the equipment on the offline mode. Instead of carrying out the reprogramming on the

equipment itself, so many of the CNC machine tools the operators are carrying out the reprogramming on console. They are inserting the flash drives, they are transferring the program to the machine, then they are carrying out the simulation on the graphical user interface of the CNC machine tool and afterwards they do the settings.

This reprogramming is being done online. That can be avoided we can do the reprogramming offline. On a computer we can do the offline reprogramming, when one product is getting manufactured. That programming would be done for the next product next new product which is to be manufactured on the equipment. If we do the reprogramming in offline mode that will save lot of time.

There is no need to group the identical products into batches. There is no need to have a the identical products say into batches. It can be a mixed product kind of manufacturing. Mixture of different products can be produced one after the another. One after the another it would be easily possible by using this flexible automation.

We have seen various types of automation systems, all these automation systems are required to have the automated equipment. And, we need to design and develop these automated equipment. The process of designing and development of the automated equipment requires hardware and software.

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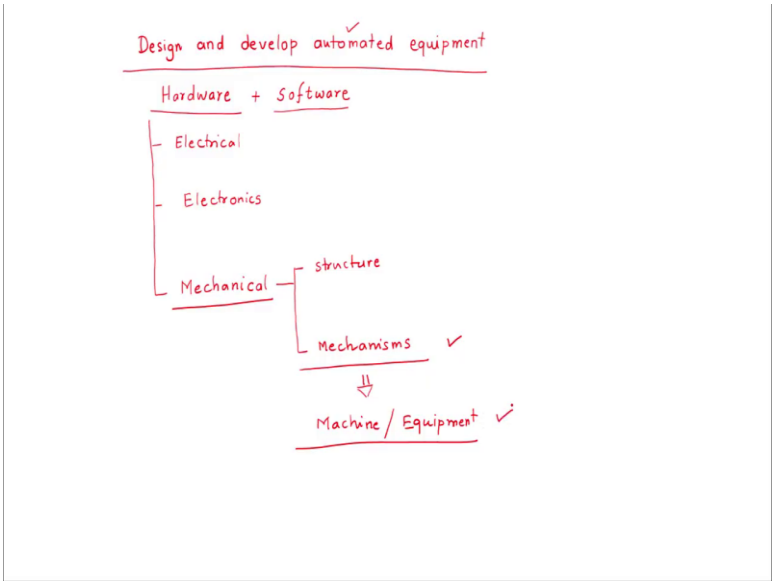

We need to have the design and development of hardware required for the automated equipment and development of software for the automated equipment. Till now, in this course, we have studied the electrical components which are used; the electronics components. Now, we will be at the next stage of the development and here we need to study the mechanical components or mechanical systems, which are required for the automated system.

The mechanical components are related to the structure of the equipment and various mechanisms. When we group together various mechanisms, we are developing the machine or the equipment. Let us study the meaning of the mechanism and the definition of machine or the equipment.

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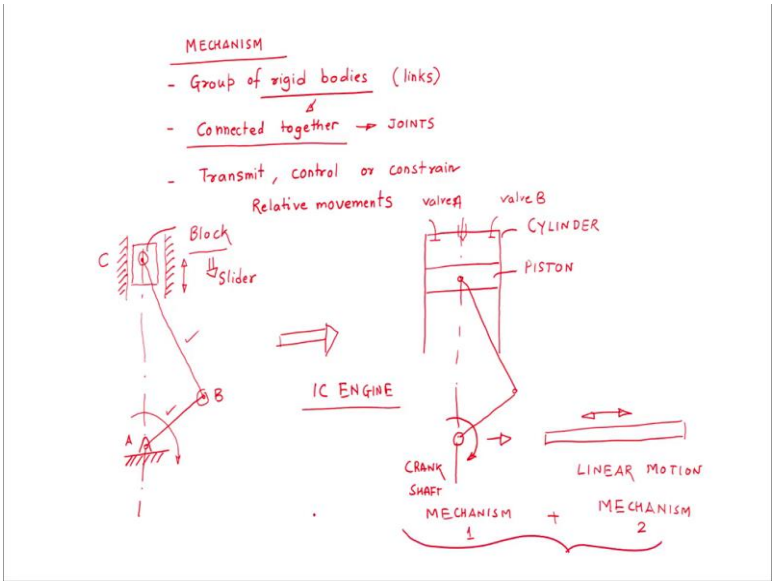

Now, let us see; what is the definition of a mechanism. It is defined as a group of rigid bodies. Mechanism has a group of rigid bodies and these bodies we also call links. When these rigid bodies are connected together, how to connect them? To connect them we are using joints. The group of rigid bodies, which is connected together by joints are performing certain operations. What are the operations they are performing? They are transmitting, controlling or constraining the relative moments among themselves.

That means, if we are having a rigid body, if we are having a group of rigid bodies, which are connected together by joints and this group of rigid bodies are transmitting,

controlling or constraining the relative moments of each other. This is called as the mechanism.

To understand this concept, let us take an example, consider we are having a link A B the end of link A B that is A, it is inched. The link A B is connected to another link that is link B C. And, this B C link, the at the end of the link B C that is point C is connected to a block. The block can slide, it can reciprocate, we are calling that block as slider.

If we apply the definition of mechanism, we are having various links. They are connected to each other and when we are having movement of one link, see here in this case we are rotating the link A B about the joint A, there will be the relative motion between A B and B C and as well as the slider block C. So, the link A B, the rotation of link A B is controlling the movement of block of slider block. They are transmitting motion from one end to the another end. A typical example of the slider crank mechanism, which you know very well is the IC engine.

As we already know that in IC engine we are using a piston. The piston is reciprocating inside a cylinder. The cylinder has openings at its top, there we are having various valves. This piston is connected to the crankshaft; we are having a shaft which is supported in bearings. As we know that when the compressed mixture of fuel and air comes here at the top of the cylinder, we may generate a spark either by using spark plug or we may have the compression of this compressed fluid.

Then, there is explosion and we get the reciprocatory motion of the piston. The piston will be pushed in a downward direction. That downward movement of the piston will be converted into the rotary motion of the shaft. What we will do with this rotary movements that you are getting?

We are converting here, the chemical energy by combustion of a petrochemical into the mechanical energy, that mechanical energy is the linear mechanical motion, which will be converting into the rotary motion. But, this rotary motion we need to further utilize for our intended application.

Consider these rotary motion, this cylinder is connected to the another equipment, but there we need the linear motion. We need to convert the rotary motion of this crankshaft into the translatory motion. To convert the rotary motion into the linear motion, we need

to add one more mechanism here. This is mechanism number 1, and we are having another mechanism; mechanism 2. When we add multiple number of mechanisms together then we are developing a machine.

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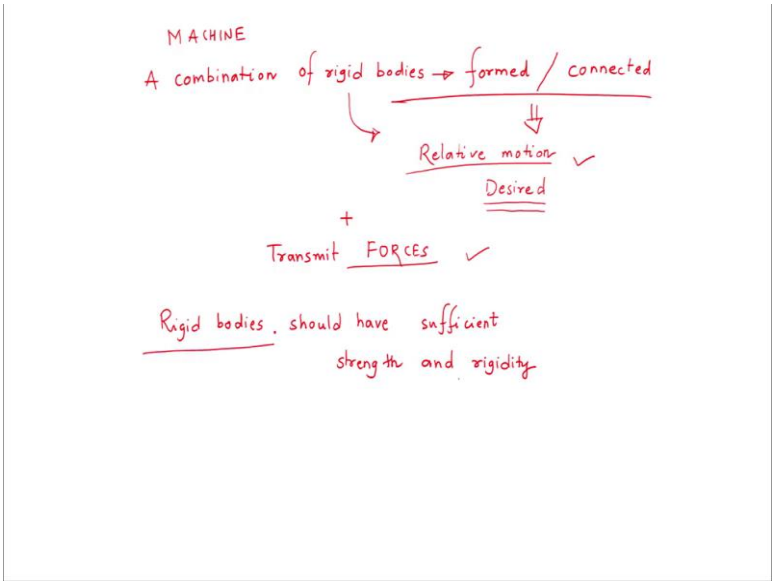

We can define the machine as a combination of rigid bodies. This combination; we are forming or connecting, so that this rigid bodies will move with definite motion. A machine can be defined as a combination of rigid bodies which are formed or connected together to get the relative motion among each other. And, this relative motion is the desired one. Whatever, the expectation is there, we should get that.

In case of the IC engine we are expecting the rotary motion of the crankshaft by converting the reciprocatory motion of the piston. We need to have the relative motion as per our expectation, as per our desire. In addition to the transmission of the motion, or in addition to getting the required motion, the machines are also transmitting the forces. The forces will be transmitted from the source of power to the application.

As we have seen that the source of power is the combustion chamber in IC engine, from that it will be transmitted to the crankshaft. Machine is a combination of rigid bodies which we are forming together, we are and that will generate the relative motion as per the desire and it is transmitting the forces as well.

To satisfy these two requirements, the rigid bodies should have sufficient strength and the rigidity. In the context of automation in manufacturing, let us take a simple example that is CNC machine tools. A variety of CNC machine tools are used in the industry. For our study we are considering the milling center or milling operation.

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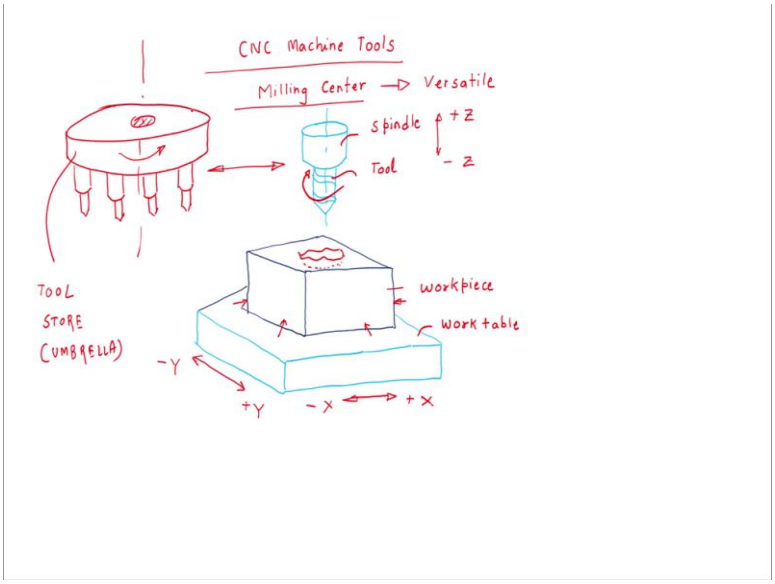

Milling operation is very versatile; very useful in the tool rooms. The CNC milling operation, as we already have seen, is used to develop or used to machine various features, such as slots, pockets, drill holes. The CNC milling operation can also be used to generate complex features. Well, on our screen you can see, a work table on which the workpiece is fixed. It is we are applying the holding force here; we are holding the workpiece on the work table.

There is a spindle; the spindle will rotate about its axis and the spindle is holding the tool cutting tool. When we are having the relative motion with all these mechanisms. What are the mechanisms here? The translatory mechanism, we need to translate the work table along this direction.

Let us consider this as X direction along. We need to translate the workpiece along the longitudinal direction. Let us consider that as the X direction; positive X and negative X along the transverse direction. This is positive Y and negative Y. And, along the depth direction; positive Z and negative Z.

Now, by having the relative motion of the harder tool with a workpiece, we are removing the workpiece as per our desire. Well, to get variety of features we need to utilize a variety of tools. In CNC machine tools, we are using variety of tools, which are mounted on a system that we call the tool umbrella or we may have a magazine, where multiple number of tools are stored. This is tool umbrella or tool storage.

As per the need, to change the tool we needs certain mechanism. That mechanism may be unloading of the tool from the spindle. Taking that unloaded tool to the umbrella and keeping at its predefined position. Then, taking the new tool from the umbrella and then transfer the tool to the spindle location, loading that tool to the spindle.

Translatory motions of the table, rotary motion of the spindle, translatory motion of the spindle, tool change operation, which involves again rotary motion in incremental way; that we call in the indexing, translatory motion of the tool from the umbrella to the spindle location and vice versa. Many relative motions are required, many mechanisms are required.

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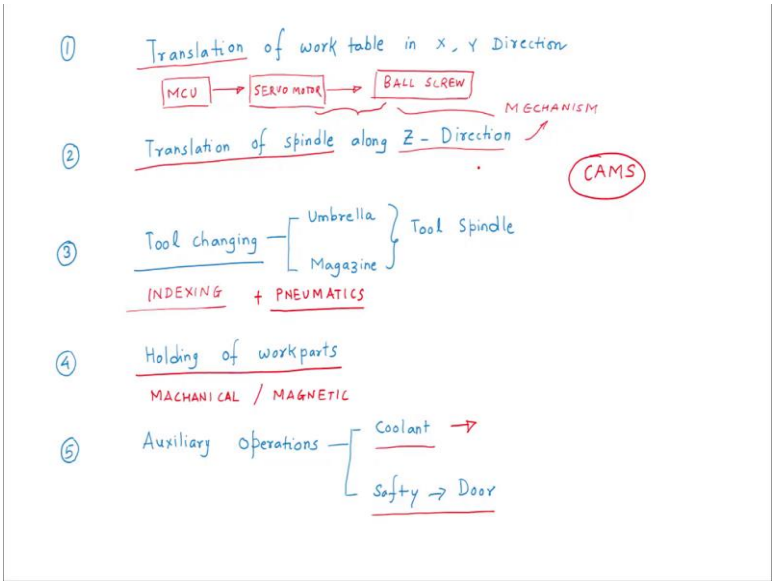

Let us list them down. Firstly, we need the translatory motion; translation of work table in X , Y direction. We also need mechanism for translation of spindle along Z direction. Then, tool changing operation, as we have seen that tool changing would be carried out from the umbrella or magazine to the tool spindle, we need to change the tool.

Then, holding the work parts in fixtures. And, there are certain auxiliary operations and these auxiliary operations are related to the coolant and safety features, as door open or door close. In CNC milling operation, the translatory motion of the work table will be generated by the Machine Control Unit; that we call MCU. It is giving signals to the servo motor. The servo motor is driving the ball screw.

On the ball screw, the table with the ball screws, the work table are engaged, they are attached. As there is rotary motion of the ball screw, we are getting the translatory motion of the work table. We need a mechanism that will convert the rotary motion from the servo motor to the ball screw.

Here, we need a mechanism. In a similar way, for translation of the spindle along Z direction as well we need a mechanism. In tool changing operation as we have seen, we need to have the indexing. We do not require the continuous rotary motion of the umbrella; we need to have the rotary motion of the umbrella in incremental way.

For that purpose, we need to have an indexing mechanism. The change of the tool or holding and unholding of the tool would be carried out by the pneumatics. The change of the tool from the umbrella would be carried out by the pneumatics. We need another mechanism that is the pneumatic mechanism. The holding of work parts; we have to fix the work parts, we have to hold the work parts on the table very firmly.

For that purpose we need mechanism and that maybe a mechanical holding. Say by using vice or by using clamps or we may have magnetic arrangement or we may use the vacuum as well. To operate the coolant, we may need to have hydraulic pump and motor arrangement.

For the safety or the automatic opening and closing, we may again need to have an mechanical arrangement. If we look at the variety of requirements, we can notice here that we need single mechanism or we may or we may need to have a combination of mechanisms, which we are connecting, we are combining together to get the required operations done.

And, the combination of these all mechanisms it is called as the machine. In the next lecture, we will be studying the ball screw based linear motion drives, which is very widely used in automation industry and later we will have a discussion on CAMS.

CAMS are again a very useful mechanism that is used in conversion of the rotary motion into either oscillatory motion or the reciprocatory motion of the mechanical elements.

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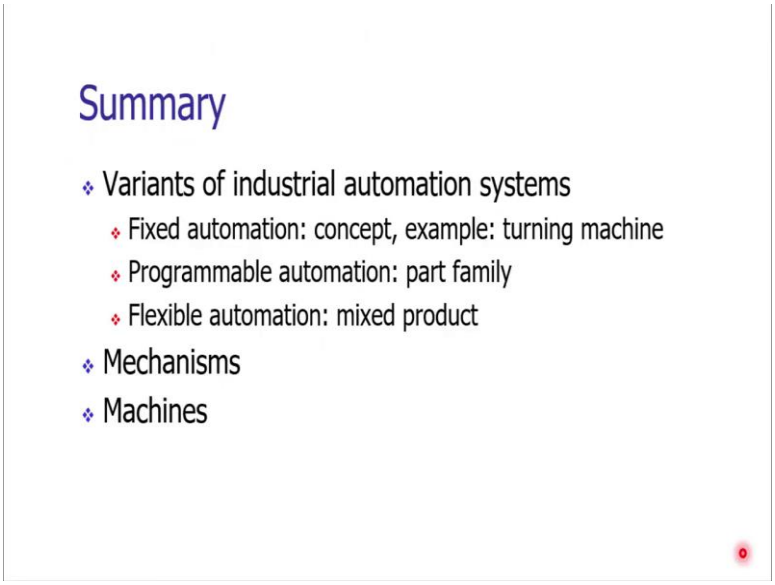

Well my friends, let me summarize the lecture 1 of week 7. In this lecture we studied various industrial automation systems. These are based upon the various requirements of the industry; basically, three types of automation systems are studied. These were the fixed automation; we studied the concept and we have seen an example that is the turning machine. After that, we learnt about the programmable automation, basically it is used to cater the development of a part family to manufacture a part family.

Then, we learnt about the flexible automation, basically it is used to respond to the mixed product kind of the environment. After studying the industrial automation systems, we had a discussion on the definition of mechanism and machines.

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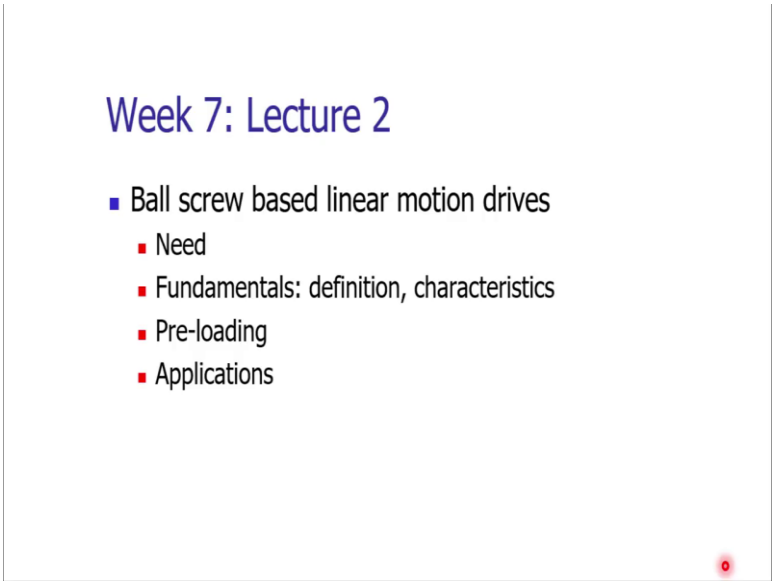

In the next lecture, we will be learning ball screw based linear motion drives. Ball screws are a vital part of an automated system. They are providing us the linear motion. They are converting the rotary motion which they are getting from the electrical drives and converting them to precision linear motion drives.

A discussion on the need or the importance of ball screw base linear motion drives will be carried out. Then, the definition or the fundamentals of ball screw base linear motion drive will be seen. We will see the characteristics of a typical ball screws. There is a necessity to have the preloading condition; the meaning of preloading, why it is essential that we will be studying. At the end of the lecture, we will have a discussion on various applications of the ball screws in automation industry.

Thank you very much, see you in the next lecture.