Automation in Manufacturing
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Week – 08
Mechanisms
Lecture – 25
Application of indexing mechanisms in automation

In this lecture, we will be studying various indexing mechanisms and then we will have a discussion on application of these indexing mechanisms.

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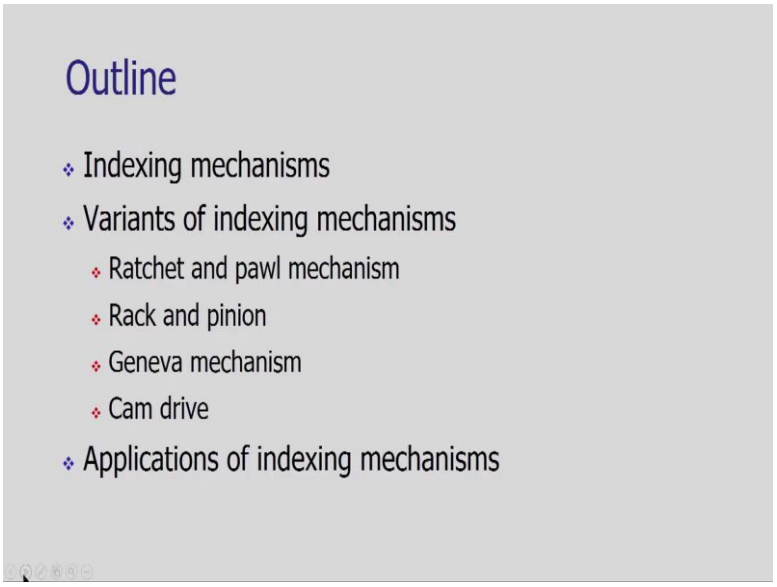

At start we will see the meaning of indexing mechanism, there are various types of indexing mechanisms are used in the industry; these are ratchet and pawl mechanism, rack and pinion mechanism, Geneva mechanism, cam drive mechanism. We will see the construction details of all these mechanisms and where we can apply these mechanisms to get the required automation done.

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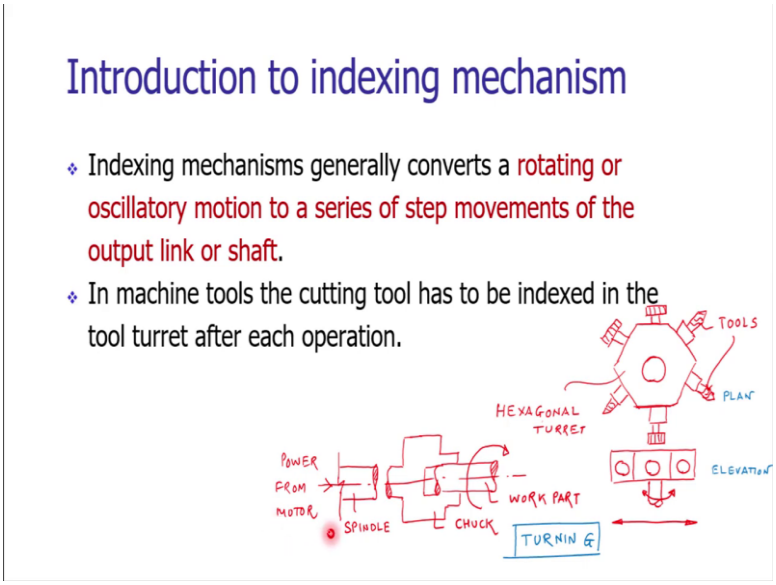

In industry and in shop floor, we need to have series of step movements for variety of purposes. Say, it may be for processing of the work part at various locations, at various stations or it is indexing or selection of a specified or a desired cutting tool from a bunch of cutting tools. To carry out such operations, to carry out the stepwise operations; indexing mechanisms are helping a lot in the automation process.

Indexing mechanism in general are converting the rotary motion or oscillatory motion into a series of steps. And that stepwise motion is utilized for our intended purpose; it may be for the processing or it may be for the tool change. Very important simple application of indexing mechanism is in the tool turret; basically tool turret is nothing, but a mechanism in which we are storing the cutting tools on a production lathe machine.

In our previous classes, we have seen the concept of the lathe machine or the CNC turning machine. In lathe machine or the CNC turning machine, we need to utilize a number of tools to carry out the operations. But to select a proper tool and to get the proper tool, we need to have certain mechanism; that mechanism must be productive, it must fast, it must be very accurate.

For that purpose, we need the indexing mechanism; to understand the concept of tool turret, let us look at the diagram which is there on your screen. The tool turrets are basically used in turning operations. In turning operation, we are reducing the size of

axisymmetric work parts; we are working on axisymmetric work parts consider a cylindrical bar is held in a chuck.

Chuck is a work holding device; the chuck is driven by an electric motor. As the spindle rotates, the chuck is also rotating; as the chuck is rotating, the work part will also rotate about its own axis. We are using a cutting tool which is harder than the work part; and by having the relative motion of the cutting tool with the work part, we are reducing the size of the work part. But during the turning operations, we may need to have multiple number of cutting tools.

Instead of changing them manually; can we have an automatic option, can we change the tool automatically? This will save a lot of time and we can enhance the productivity. For this purpose, we are using a hexagonal turret; the shape of the equipment is hexagonal that is why it is called as hexagonal turret. Turret on the faces of the turret, we are mounting various cutting tools.

On the screen we can see, this is the hexagonal turret; this is a plan view, the elevation in this. We are rotating the hexagonal turret about its x axis, its vertical axis; but this rotation is not continuous, it is in incremental. And to have that incremental rotary motion of the turret, we need to have certain indexing mechanism.

As per the need, we are rotating the turret; the tool will come in contact with a work part by having the longitudinal movement of the cutting tool with respect to the work part and then we are getting the required operation done that is reduction in the diameter.

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Introduction to indexing mechanism

- In production machines the product has to be indexed from station to station and need to be stopped if any operation is being performed in the station. Such motions can be accomplished by indexing mechanisms.
- Indexing mechanisms are also useful for machine tool feeds.
- There are several methods used to index but important types are ratchet and pawl, rack and pinion, Geneva mechanism and cam drive.

Thus we can say that, in production machines, we need to have an indexing mechanism for processing of the product at various stations. At the stations, the product need to be stopped for the required operation. In addition to this stepwise motion, we also need to have the indexing mechanism for feeding of the machine tools.

In general, five basic types of indexing mechanisms are used in the industry, and these are ratchet and pawl mechanism, rack and pinion mechanism, Geneva mechanism and cam drive.

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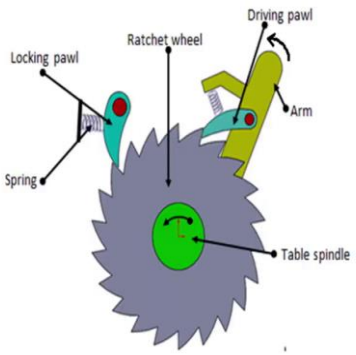
Ratchet and pawl mechanism

- A ratchet is a device that allows linear or rotary motion in only one direction.
- Used in rotary machines to index air operated indexing tables.
- Ratchets consist of a gearwheel and a pivoting spring loaded pawl that engages the teeth.



The first mechanism is ratchet and pawl mechanism; this device allows the linear or rotary motion in only one direction. This mechanism has a wheel that we call ratchet wheel. On the periphery of the wheel, there are teeth; these teeth are engaged with a driving pawl, which is pivoted in an arm. The arm is connected to the center point of the spindle; we can swivel the arm and by swiveling the arm, the driving pawl is driving the ratchet wheel.

Let us consider the driving pawl is moving in the anticlockwise direction. As we are moving from right to left in anticlockwise direction, the pawl is driving the ratchet wheel. It will move the ratchet wheel in anticlockwise direction for certain angular distance. Afterwards the pawl will return due to the spring force which is applied on it. Again we have to drive the arm; we have to rotate the arm into in anticlockwise direction.

As we rotate it once again; we can have another incremental angular motion in the ratchet wheel. To restrict the opposite motion, opposite direction motion that is the clockwise direction motion; we are using a locking pawl, locking pawl arrangement can be seen on your screen. It is spring loaded locking pawl; but the springs are used to have the continuous engagement of the pawl with the teeth of the ratchet wheel.

As the driving pawl is driving, the wheel is rotating in anticlockwise direction to avoid the rotation of the wheel in clockwise direction, the locking pawl is used. Generally, the rotary machines which are operated by air by pneumatics, such arrangements are used.

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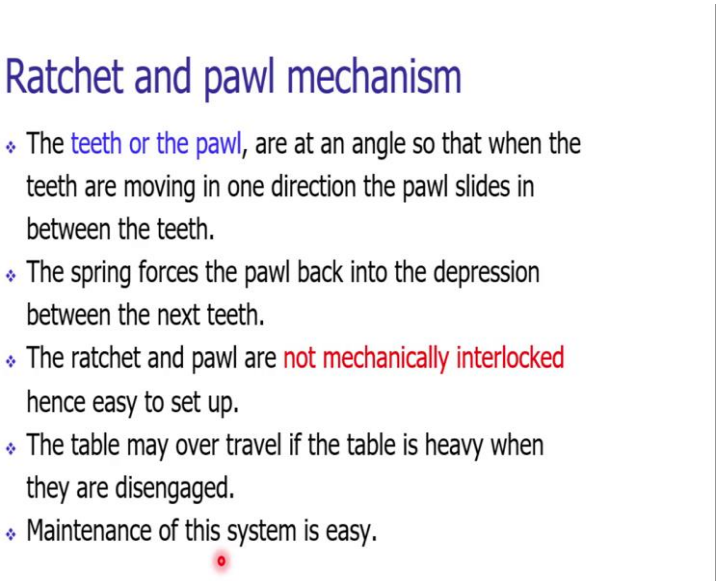

The teeth or the pawl, are at an angle, so that when the teeth are moving in one direction, the pawl slides in between the teeth. As I mentioned, there is a spring and that spring is forcing the pawl back into the depression between the next teeth. In this way, the springs are ensuring the continuous contact of the pawl with the ratchet wheel.

The advantage of ratchet and pawl is that, they are not mechanically interlocked; we can easily remove them. Therefore, the ratchet and pawl mechanism is easy to setup. But if the table is heavy, if the inertia of the table is very high; during that incremental motion of the table, the table may override, it may over run due to its own inertia.

As we are giving angular motion, the locking pawl will not have the sufficient strength to avoid its reverse motion; that may be due to the heavy table. As there are no mechanical interlocking of its elements, the maintenance of the system is quite easy.

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The important applications of the ratchet and pawl mechanism are in jacks and the winding mechanisms, winding machines. Jacks we are using to lift the systems, to lift the products. And winding machines are used to wind the wire or the cables, either manually or automatically. In machine tools, we are using the ratchet and pawl mechanism, rotary indexing motion to the tool turret.

In this way we can feed the work piece to the required tool; we are changing the tool according to our need and then we are getting the required work done.

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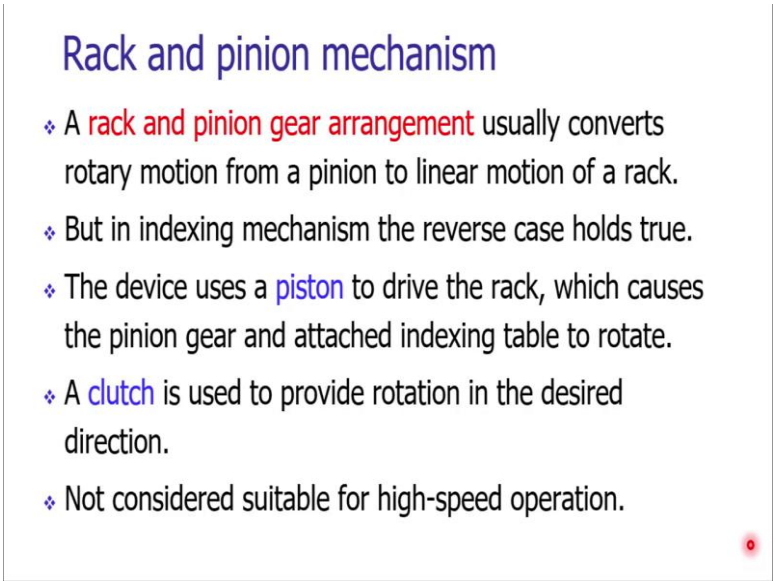

Well the next mechanism is rack and pinion mechanism. In general, the rack and pinion arrangement is used to convert the rotary motion of pinion into the linear motion of the rack. Pinion is an element which is rotating about its axis, so that rotary motion of the pinion, generally the pinions are driven by electric motor. And as we are rotating the pinion, it is converting that rotary motion into the linear motion of the rack.

The rack is again a mechanism; a mechanical element which is having teeth, and we can consider the rack as a small portion of an internal gear with infinite radius. We will see the diagram of the rack in the next slide; but in indexing application, we need the reverse case. What is the reverse case? The reverse case is we need to get the rotary motion of the pinion, due to the linear motion of the rack.

We are providing linear motion, linear reciprocating motion of the rack or we can have the straight one direction linear motion to the rack and that should be converted into the rotary motion of the pinion and we are attaching the work part, we are attaching the work table to the pinion. As the pinion is rotating, incrementally we are getting the indexing of the table which is connected to the pinion. In this way, we are getting the indexing of the table which is attached to the pinion by the linear motion of the rack.

To have the indexing mechanism using a rack and pinion, we are using a piston to drive the rack, which causes the pinion gear engaged with the rack and the rack will drive the pinion gear. To have the contact of the rack and pinion, we are using clutch. These type of arrangements are not suitable for high speed operations. Since, they are mechanically interlocking with each other; when we want to have very high speed indexing, so for that purpose, this kind of arrangements may not be suitable.

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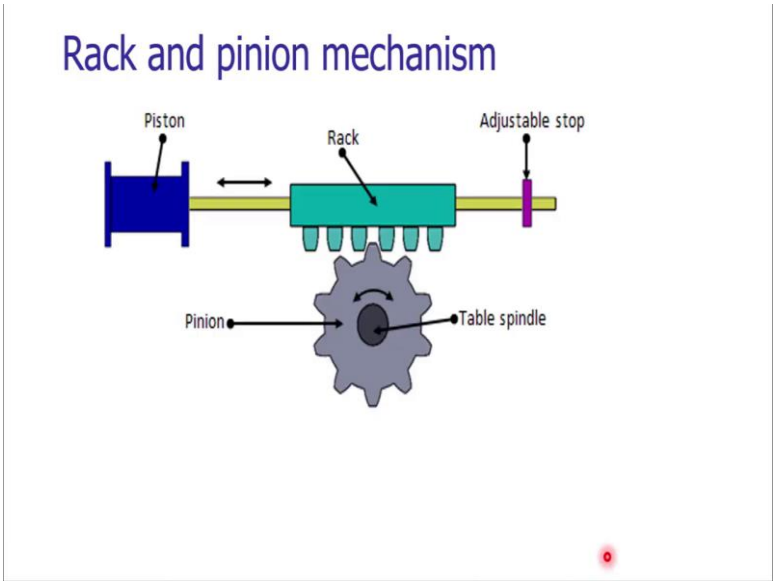

Let us look at the schematic. A rack is a device, which are having teeth and there is a pinion; pinion is nothing but a gear. This gear is having external teeth; the rack you can consider a part of an internal gear of infinite radius and that internal gear as we know well, it is having internal teeth.

The internal teeth of rack are engaged with the external teeth of the pinion. If I push the rack in linear direction, it will drive the pinion and that is our intended motion of the pinion. In this arrangement, we are also using an adjustable stop, which will control the linear motion of the rack. This piston cylinder arrangement is working based upon either hydraulic energy or the pneumatic energy; we will be learning about the hydraulics and pneumatics in coming weeks.

As the piston is extending, as the piston is getting out from the cylinder; the rack will be pushed from left to right direction and that will drive the pinion in clockwise direction. The rack will move along these direction; there would be incremental angular motion of the pinion.

Then the rack will be disengaged by using the clutch; it will be get back to its original position and again it will be driven by the piston. To have the disengagement of the rack from the pinion and further engagement of the rack with the pinion, we need to have a clutch arrangement.

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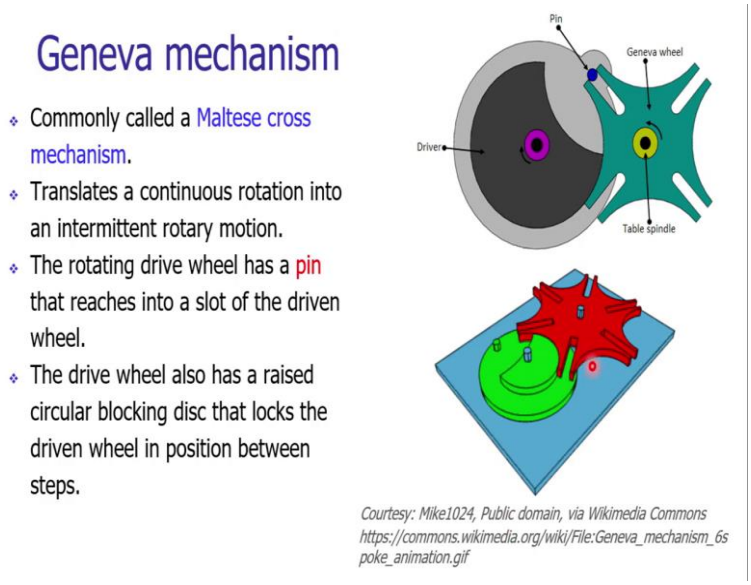

The next important mechanism is Geneva mechanism; this is very widely used in indexing operations in the industry. This mechanism is also called as Maltese cross mechanism. Till now we have seen that, the linear motion of the rack is converted into intermittent rotary motion. In Geneva mechanism, we are converting the continuous rotation into intermittent rotary motion. We are having the electric motors and that electrical motors are giving us continuous rotary mechanical energy, continuous rotation of the shaft.

Now, we need to have a mechanism which will convert this continuous rotation into the intermittent motion. For that purpose, we are using a simple arrangement and that can be seen on the screen. It has a wheel that we call the Geneva wheel; on your screen you can see the Geneva wheel which is designed to provide four intermittent motions, four intermittent rotary motions of the spindle.

The Geneva wheel is mounted on the spindle and on the same spindle, there is table will be mounted. This particular view is the plan of the arrangement, there will be a table which is mounting over here. The Geneva wheel has a peculiar shape; this peculiar shape you can see over here, these curves are designed.

There would be a proper locking of the Geneva wheel with the driver wheel. The Geneva wheel also has slots and these are slots which are getting engaged with the pin of the

driver wheel. In Geneva mechanism, we are having a driver, we are having a driving wheel and that driving wheel is mounted on the shaft of the electric motor.

The driving wheel is continuously rotating; it has a raised circular block and that raised circular block is getting engaged with the peculiar shape of the Geneva wheel. Now, the operation is very interesting as you can see on the screen; when we are rotating the driving wheel, the pin is getting engaged in the slot of the driven wheel that is a Geneva wheel. As we are continuously rotating the driving wheel, the pin will slide along the slot and it will give the intermittent rotary motion to the Geneva wheel.

On your screen, you can understand the mechanism by looking at this animation; this is the driving wheel and it is connected to the electrical motor. And as the pin is getting engaged in the slot, the driving wheel is driving the Geneva wheel that is a driven wheel. As the pin is getting engaged and disengaged, we are getting the required intermittent motion.

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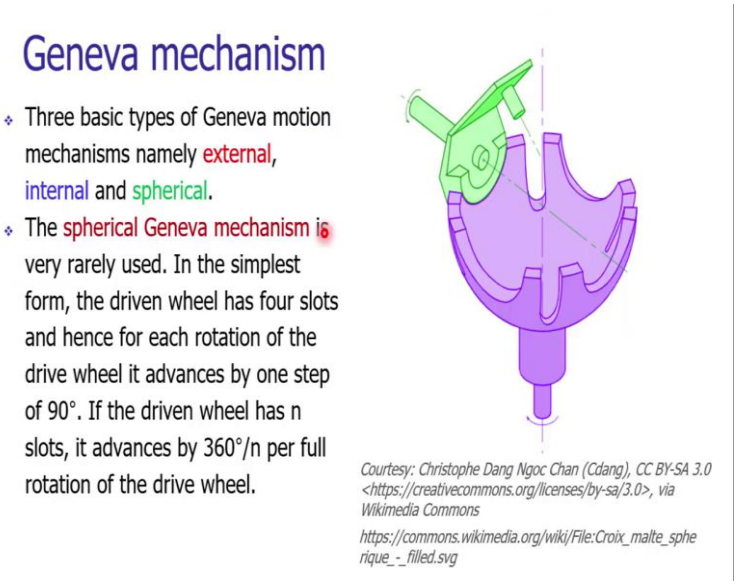

Basically, there are three types of Geneva motion mechanisms are used; these are external Geneva mechanism, internal Geneva mechanism, and the spherical Geneva mechanism. Spherical Geneva mechanism is not that widely used. In the simplest form as we have seen, we can have a disk; the disk is cut into a peculiar shape with certain slots and that will be engaged with another disk with raised surface with a pin arrangement.

The number of steps will decide the angle basically; if suppose you want to have the four steps, naturally the angle of rotation would be around 90 degrees there, the incremental rotation would be of 90 degrees that is for the full rotation of the driving wheel. Well, on your screen you can see the arrangement of spherical Geneva mechanism, it is very interesting. This Geneva mechanism is cut, it designed on a spherical work part; the engagement of the Geneva mechanism with the driving wheel is due to this surfaces.

These are the surfaces which are cut; these are analogous to the surfaces which we have seen in our previous slide, which are in contact with the raised portion of the driving wheel. These are the slots in which the pin of the driving wheel will get inserted and that is driving the Geneva wheel; instead of having a wheel, we are having a spherical arrangement which is working as the wheel itself.

An important advantage of the spherical Geneva mechanism is that, we can have an orthogonal transmission of the power. Here you notice the driving wheel is the driving wheel axis is 90 degrees to the driven wheel axis. In the previous cases, in the previous slide we have seen that, the driving wheel and the driven wheel axis are parallel to each other.

In spherical Geneva mechanism, the driving wheel axis and the driven wheel axis are mutually perpendicular to each other; they are orthogonal to each other. This is the arrangement of the driving wheel. It is having the shape which is cut, which is in contact with the shape of the Geneva mechanism; this is the raised portion analogous to our the previous slide. This pin will get engaged with the lot of the Geneva mechanism and it is driving.

We are giving continuous rotary motion to the driving wheel and that continues rotary motion will be transmitted into the intermittent rotary motion of the Geneva mechanism. We can attach the indexing table or we can have a raised portion on which we can attach the indexing table and we can get the required indexing done.

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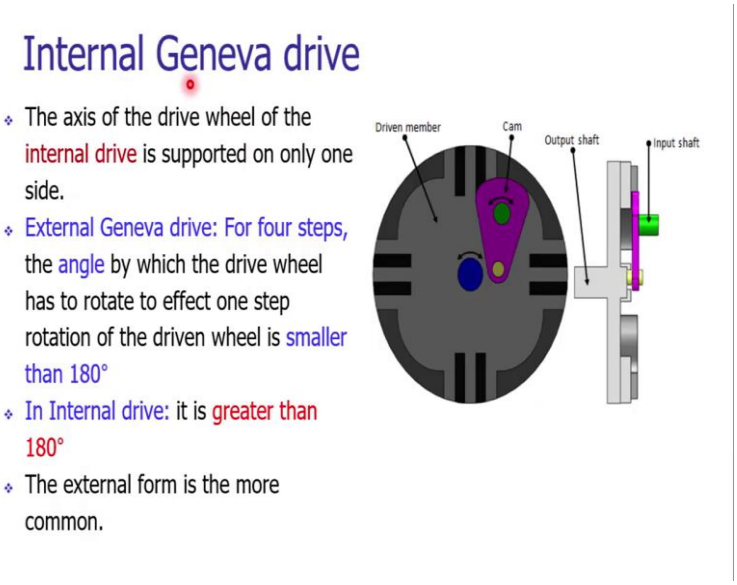

In internal Geneva drive, instead of having the slots or instead of having the peculiar shape which is cut on the outside of the disk, on the external site of the disk; we are having that slots or engagement of the pin in the slots in the internal side of the drive. For that purpose, we are using a disk and in the disk the slots are cut as you can see on your the on the screen.

This disk is mounted on a shaft which is supported at only one side. There is a cam arrangement, which is connected to the continuous rotary motion provider that is a motor. As the cam is rotating, it is driving the driven member that is the Geneva mechanism, Geneva wheel.

The driving would be carried out by the contact of the pin in the slot. As this cam is rotated, the pin will come into contact with the slot and as that cam is rotating, it is driving the driven member. And to have the continuous contact, the outer portion of the cam would be in contact with the internal portion of the driven member, which is cut in a peculiar way.

In external Geneva drive, the angle by which the drive will has to rotate to effect one step rotation of the driven wheel is smaller than 180 degrees. The angle by which the drive wheel has to rotate to effect one step rotation of the driven wheel is smaller than 180 degrees; but in internal drive, it is greater than 180 degrees. To have one step

rotation of the Geneva mechanism; how much the cam is rotating or how much the driving wheel is rotating in a simple Geneva mechanism?

If the arrangement is external than the drive wheel is rotating less than 180 degrees, then and then only we are getting one step. But in internal drive, the drive wheel has to rotate more than 180 degrees; this is the external Geneva mechanism. And you just look at here, it is getting included from this point to this point, the angle of engagement and disengagement of the pin with respect to the Geneva wheel is less than 180 degree. This particular angle is less than 180 degrees.

The same would be we can see here, in this case there are four slots; the angle of engagement from this, the angle of engagement of the pin at this point, and the angle of disengagement of the pin at this point, these particular angle is always less than 180 degrees. This is not true in the internal Geneva mechanism, this particular angle would be more than 180 degrees.

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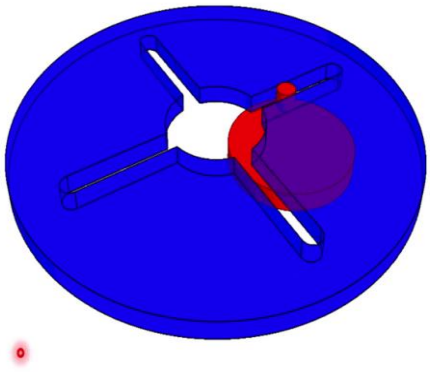

Courtesy: Coolhandscot, Public domain, via Wikimedia Commons
https://commons.wikimedia.org/wiki/File:Internal_Geneva_wheel_ani.gif

Now, here you can see the engagement has been done and the disk has to rotate more than 180 degrees to have the disengagement of the pin from the slot. The two here you notice, the pin is engaged here and it is getting disengaged at this particular point. Thus, engagement up to the disengagement, that particular angle is more than 180 degrees.

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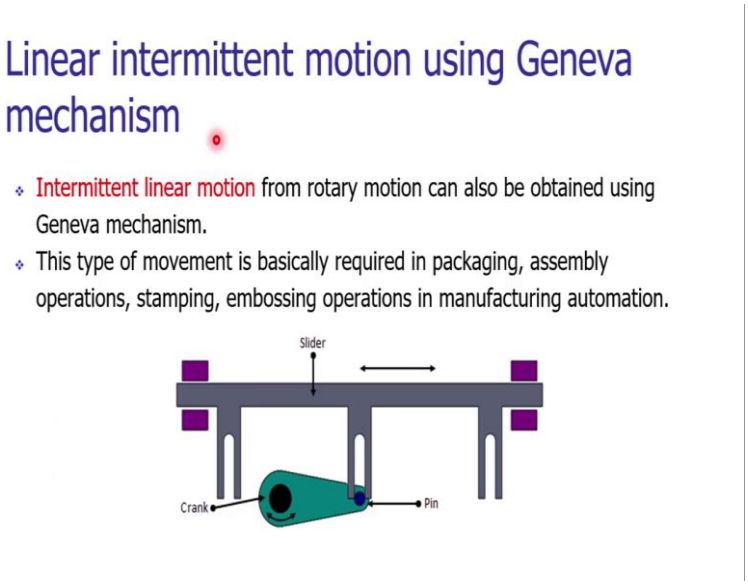

Well to have the linear intermittent motion; in previous slide we have seen that the Geneva mechanism can be utilized to have rotary intermittent motion. We can also have the linear intermittent motion using the Geneva mechanism and that is another important aspect in automation industry.

For example, you are working on a transfer line; you have to carry out multiple processing operations on the product which is moving over a platform which is intermittently moving in a linear direction. To have such moment, we are using the Geneva mechanism as well and that particular arrangement is shown on your screen.

It has a slider, on the slider we are putting the work parts or slider we are having the table; on the downward direction of the on the bottom side of the slider, we are having slotted plates which are attached to the slider. That slotted plates are engaged with a crank, the crank is mounted on crankshaft.

On one side of the crank, we are having a pin which is in connection with the slots. We are giving continuous motion, continuous rotary motion to the crank. And as the crank is rotating, the pin will get engaged to the slot and it will drive the slider. Of course, the slider has to be supported and we should avoid its movement along the vertical direction. Thus, proper support has to be provided.

These type of arrangements are basically used for packaging, for assembly, for stamping, for embossing which are used in the manufacturing automation.

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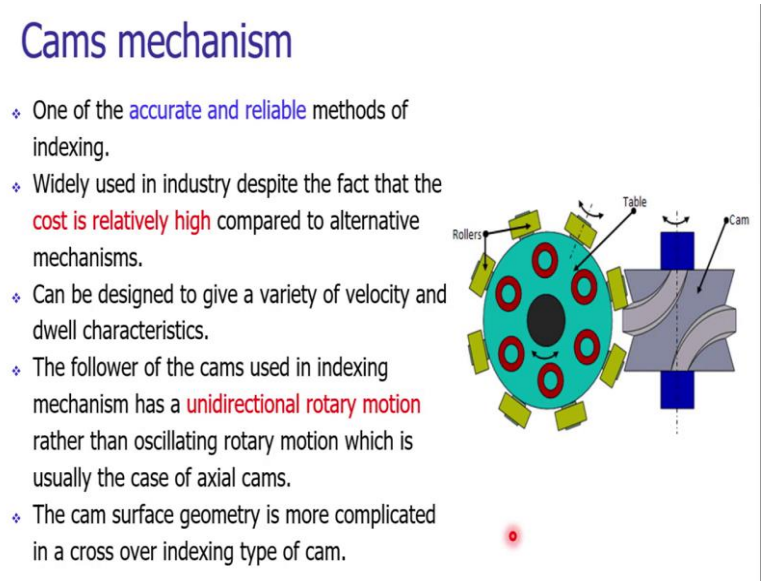

The third mechanism is the camps mechanism itself. This is very interesting, but it is very complicated mechanism to manufacture. On your screen you can see a table and on the table, various stations are there, on which you have to carry out the processing operation. This is the plan of the table; on the periphery of the table, we are attaching rollers and these rollers are engage to a cam.

We have seen the cam mechanism in our previous week; you notice here the axis of the table is perpendicular to the plane of paper. This axis is perpendicular, the axis of the cam is orthogonal to the axis of the table; but they are not intersecting, they are parallel. They are orthogonal, but they are parallel to each other.

This is a cylindrical cam and on the cylindrical cam, a peculiar shape is machined. The shape is machined in such a way that, as we are rotating the camp; there would be displacement, angular displacement of the table.

When I am rotating the cam in clockwise direction, this portion will come in contact with this particular roller. As I am rotating in a clockwise direction, this portion would get; this portion is having the raised height. As this portion is getting in contact with the roller, this roller will be pushed in anticlockwise direction. Rotary motion of the cam

would be converted into intermittent anticlockwise motion of this particular table which is mounted on a shaft.

In this way, we can achieve the rotary indexing of the table by using the camps mechanism. The cam mechanism or the cams base mechanism is widely used in the industry, despite the fact that it is very costly. Why it is costly? Because of the arrangement, because of the complexity in manufacturing of the cam, its assembly with the table because, we need to have the president rollers as well here.

The advantage of cam mechanism is that, we can have a variety of velocities and the dual characteristics; dual means is the time for which we are having the stopping of or the time during which there would not be any a rotary motion of the spindle, there will not be any rotary motion of the table. And we are using the roller followers; these are the roller followers, which are having the unidirectional rotary motion.

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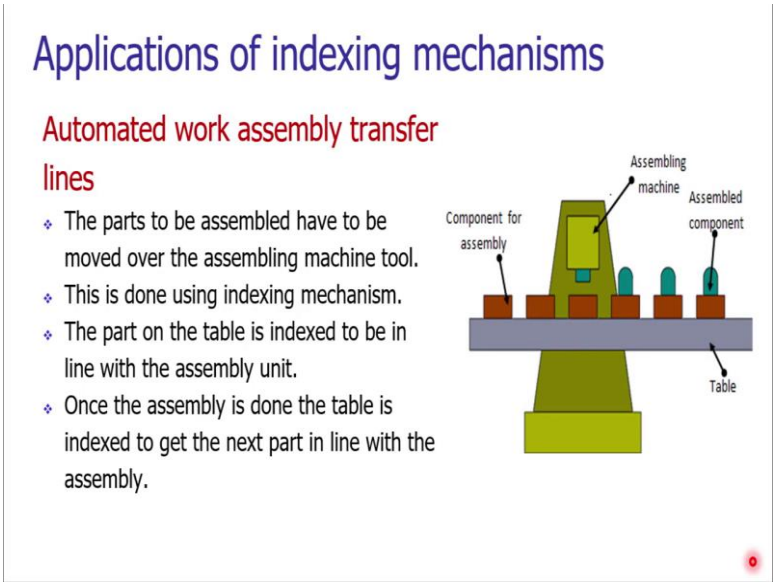

We can use the indexing mechanism for processing of the work parts at various workstations. In addition to this processing at various workstations, we can have the assembly operation; automatic assembly operation by using the indexing mechanism. Consider there are two sub assemblies and we need to assemble them together. For that purpose, we can have a table and that table has to be intermittently moved in a linear direction.

This is the assembling machine and this assembling machine is assembling, the assembly sub assembly, two with the sub assembly one. We have to design by using the cam operated arrangement, which we have seen in our previous slide. The parts to be assembled, how to be moved over the assembling machine tool; this is the tool to over which we are moving the parts. Once the assembly is done, the table is index to get the next part in the line with the assembly.

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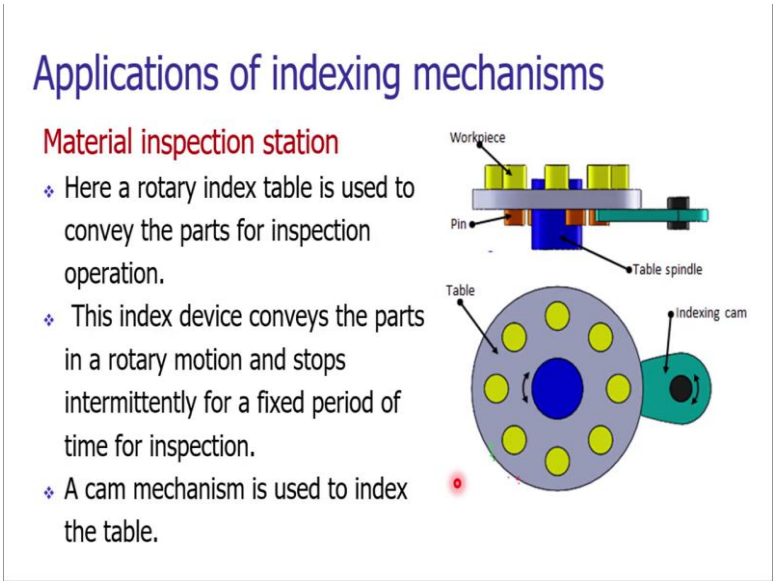

We can use the indexing mechanism for the inspection operation as well. A typical arrangement can be seen on your screen, there is a circular table; the table is mounted on spindle and the spindle is being driven by an indexing cam. Various work parts are held on the table by using various holding mechanisms; either may be mechanical holding mechanism or magnetic holding mechanisms.

The inspection may of the geometry of the work part or the surface quality of the work part or it may be the mechanical testing of the work part as well. By having the intermittent rotary motion, we can carry out the hundred percent inspection of the work parts. The intermittent stoppage of the work part at the particular location, for the inspection is totally dependent upon the velocity of the indexing way.

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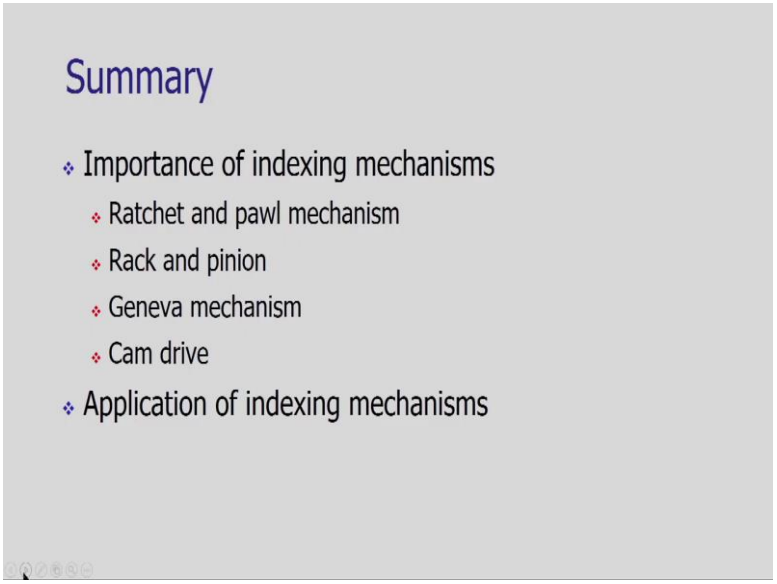

Well my friends, let me summarize the lecture 1 of week 8. In this lecture, we have studied the importance of indexing mechanisms and then we learnt various indexing mechanisms such as ratchet and pawl mechanism, rack and pinion mechanism, Geneva mechanism, and cam drive mechanism. We have seen the principle of operation of these mechanisms; we have studied the applications of these mechanisms.

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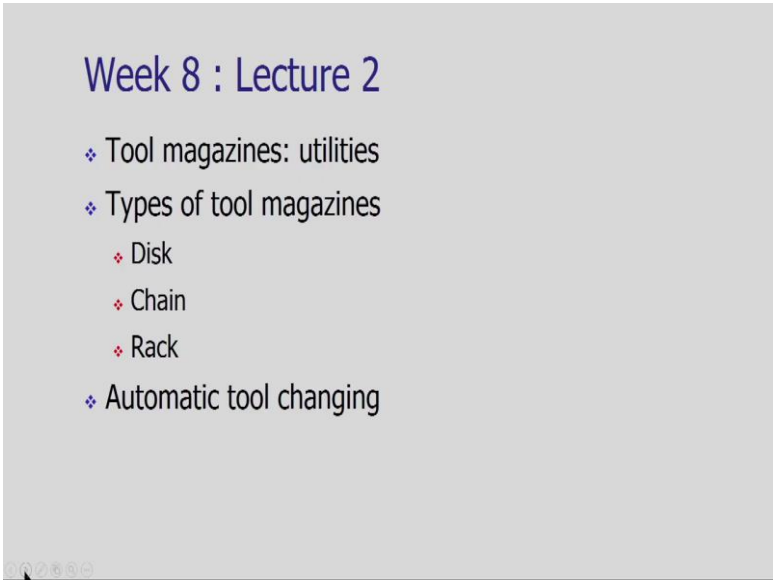

In the next lecture of week 8, we will study a very useful utility that is tool magazines of CNC machining center. CNC machine tools are an integrated part of automated

manufacturing system. And the tool change or tool related factors are very crucial in deciding the productivity of the CNC based automated system. The automatic tool changing is contributing a lot to enhance the productivity of a CNC machine tool; that is why it is essential for us to study the tool magazines.

There are various types of tool magazines are used; these are disk type, chain type, and rack type. We will see the construction of these tool magazines and at the end we will see how to change the tool automatically in CNC machine tools.

Thank you very much.

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Week – 08
Mechanisms
Lecture – 26
Application of tool magazines in automation

Hello and welcome to the week 8 lecture 2 of Automation in Manufacturing. The lecture 2 of week 8 is focused upon Application of tool magazines in automation.

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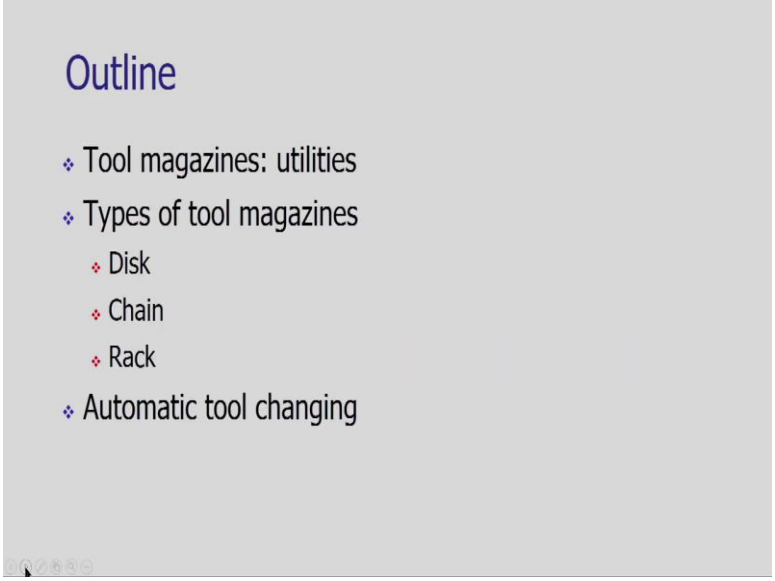

CNC machine tools are an integrated and important element of an automated manufacturing system. The productivity of entire tool room or the productivity of the automated manufacturing system is dependent upon the tool changing. How efficiently we can change the tool? How efficiently we can manage the tool related operations?

It may be change of the tool, handling of the tool, storage of the tool and maintenance of the tool. The crucial element in the entire operation is the tool magazine. In this lecture, the importance of tool magazine will be studied. There are various types of tool magazines used. These are disk type, chain type, rack type tool magazines. At the end of this lecture, the automatic tool changing operation will also be studied.

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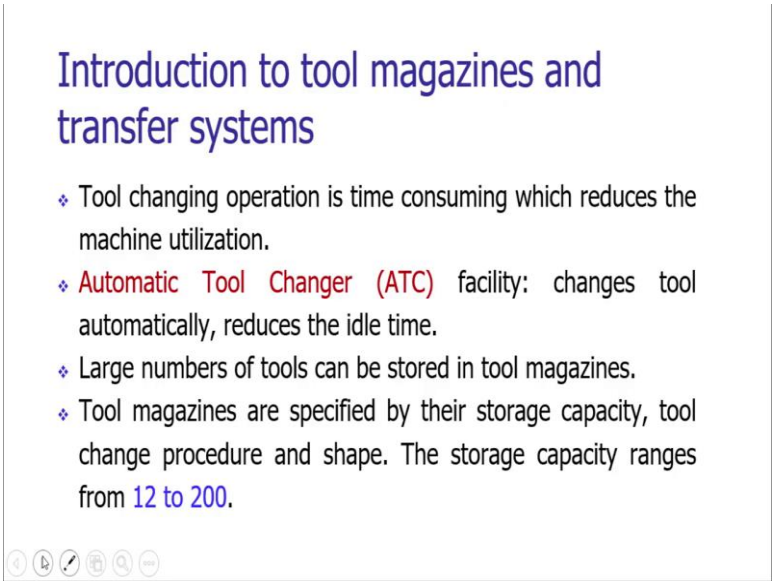

The product life cycle have been studied in our previous lectures. The product life cycle has design related operations and it also has the manufacturing related operations. In manufacturing, basically we are transforming the raw material into finished product by using various machine tool arrangements.

In machine tools, the tool is the critical parameter or factor, which is affecting the productivity. There are various time elements associated with the tool. The fundamental time element is the cutting time when the tool is in contact with the work piece. And, during that contact, it is removing the material from the work part. The next is the tool change time and it consumes lot of energy, lot of time during the operation.

We are storing tool somewhere and when we change the tool, there may be chances of having the error as well. When the tool is worn out, we need to either replace the tool, by another new tool, or we have to regrind the tool, and then reuse the same tool. This entire operation is very time consuming. When we are working with very hard material, high strain material, the tool worn out possibilities are very high, the tool is wearing off very height.

Thus, there will be more frequent tool changing operations need to be carried out. These are affecting the productivity. In automation to have the real 100% automation of the manufacturing system, we should have automatic storage of the tools and automatic

changing of the tool from the spindle operation. That is why it is very essential for us to understand to learn the concepts of the tool magazines and the tool transfer system.

In general, a facility which is providing, the tool changing in automation is called as automatic tool changers. In the magazines we can store or hold, many number of tools they may be ranging from around 12 to 50. Sometimes, we can even have magazines we can which can store more than 100 number of tools may be around 200 number of tools.

Tool magazines are generally specified according to their storage capacity, the procedure to change the tool and the kind of shapes of the tool, the tool magazine is able to accommodate or store.

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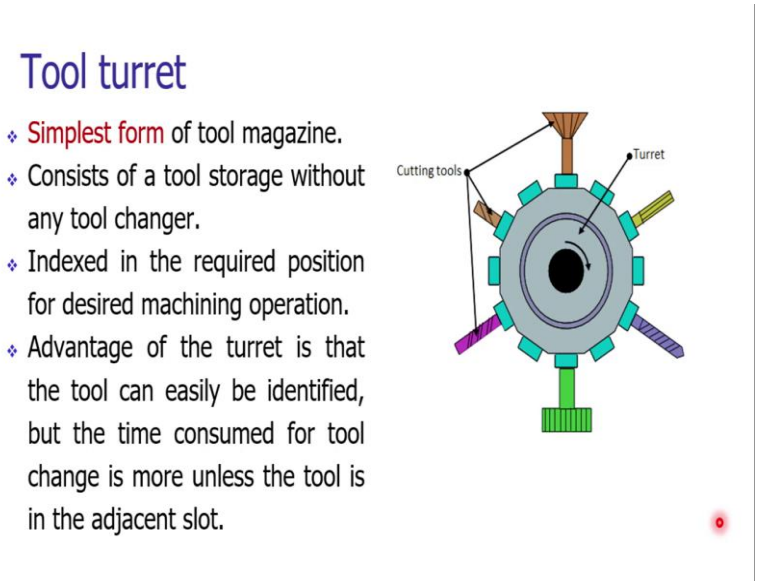

The first and very simple type of tool magazine or tool storage system is tool turret. In the slide, we can see a tool turret, it is a device which can store multiple number of tools, it can be indexed and that indexing mechanisms we have seen in our previous lecture. The tool turrets are generally used on production lathe machines.

We can index tool very easily, but the changing of the tool from the spindle of the machine tool and from the tool changing facility that it is a tool turret is manual. These type of arrangement does not have any automatic tool changing operation. Tool turrets are basically used in semi automatic mode of the automation.

In some of the in automatic mode of the operations, where we are using small capacity tool magazines, or where we need to store limited number of tools. There as well we can utilize this tool turret kind of arrangement, which is compact. Some of the machine tools they do have the arrangement of changing the tool from the tool turret and loading them to the spindle of the machine tool.

These type of arrangements are nowadays available on the CNC machine tools. But, overall if the tool turret is at a certain distance, it will take certain amount of time, for the travel of the tool from the tool turret to the desired spindle of the machine tool.

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The tool magazine is an advanced or modified version of tool turret itself. The capacity of tool magazines is high in comparison with the tool turret. In general, in tool turret we can accommodate around 15 to 20 tools easily, but when we are trying to have a variety of operation that to be carried out on the work part. Say it may be drilling operations it may be, pocket milling operation, slot milling, finishing so on and so forth. For such operations we need to have an arrangement which can store multiple number of or many number of the tools.

As mentioned the problem of tool wearing, the tool regrinding is very time consuming process. To solve this problem, we can have duplicate tools, we can have multiple number of tools of the same type. When one tool which is there in operation gets worn

out, we can ask the machine tool by using the CNC part program to go for the next fresh tool, which is of the same type.

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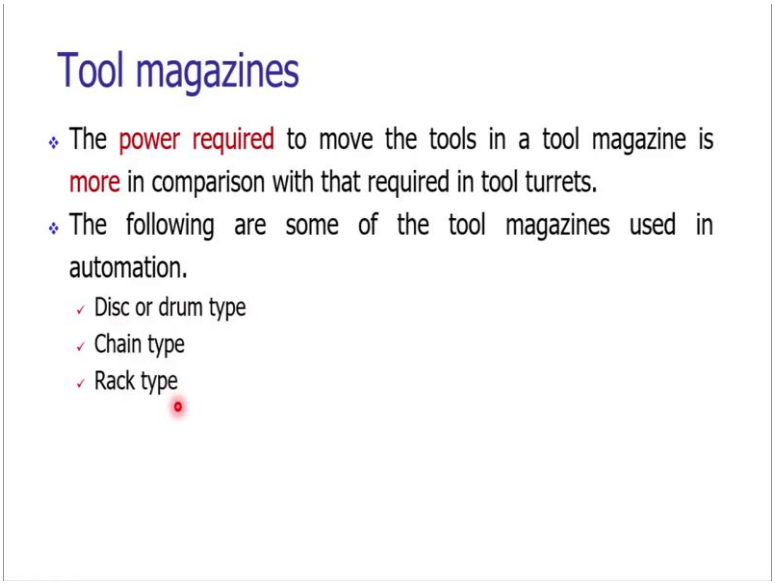

That duplication facility is very much possible with the tool magazines. Of course, the energy required or the power required to move the tools in a tool magazine is more than the tool turret. Since the size of the tool turret is small, naturally the power requirement would be less. There are various types of tool magazines being used in the industry and these are disc and drum type, chain type, rack type.

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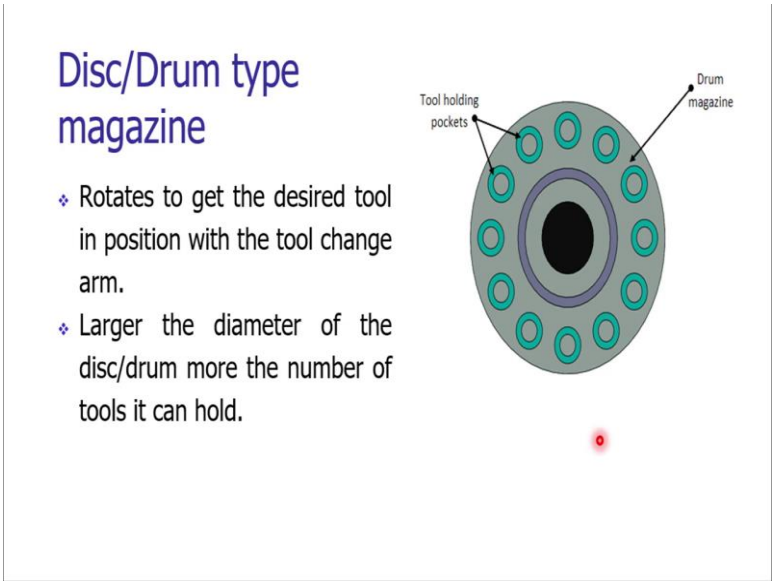

Let us look at the first type of the magazine, that is disc or the drum type magazine. The arrangement is very simple, we are using a disc or a drum and on the surface of the disc or the drum we are generating tool holding pockets. Inside the tool holding pockets the tools are getting mounted. The drum or the disc will be mounted on a spindle on an indexing mechanism, which we have seen in our previous lecture.

As per the indexing is programmed in a CNC machine tool, we are getting the required tool at the tool pickup station, at the tool pickup point. If we increase the diameter of the disc or the drum naturally you can hold the many number of cutting tools or the processing tools.

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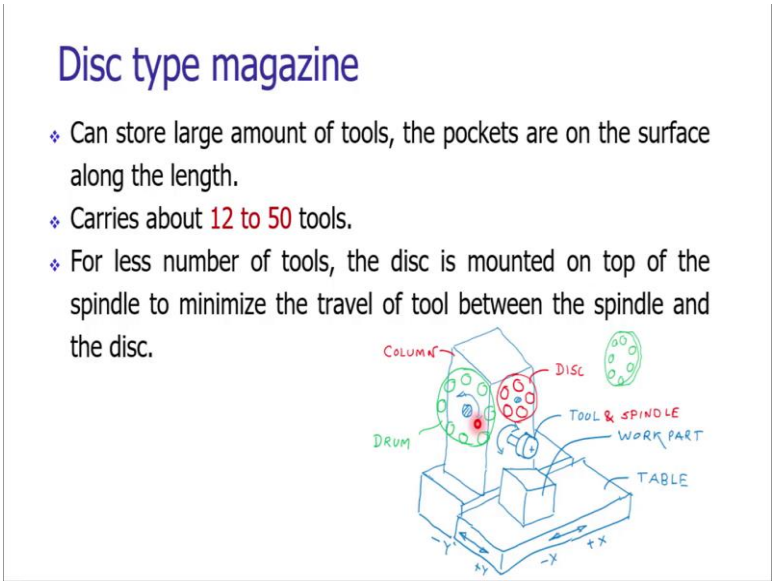

The disc type magazine can store about 12 to 50 number of tools. If we want to increase the number of tools that to be mounted on the disc type mechanism then we have to use various configurations. In general, the disc which is containing these tools is mounted just above the spindle of the cutting tool.

Let us look at the arrangement. In the slide, we can see a typical CNC machining center, here we are having a table on the table the work part is held. There is a column. On the column we are housing the electrical drive. The electrical drive is driving the spindle and on the spindle the tool is attached.

Now, if the disc is of a smaller size and we are accommodating, we are storing, limited number of cutting tools then we can easily have the disc mounted just above the spindle. The reason behind this is that we can reduce the time of tool changing operation. Quickly we can process the work parts. In case the number of tools that are to be used are huge in number, then we cannot accommodate the drum or the disc just above the spindle, then we have to take use of the other side of the column.

Now, on the adjacent side of the column we can mount the drum. The drum will be indexed and there will be a tool changing mechanism we will be seeing that tool changing mechanism in the next slides.

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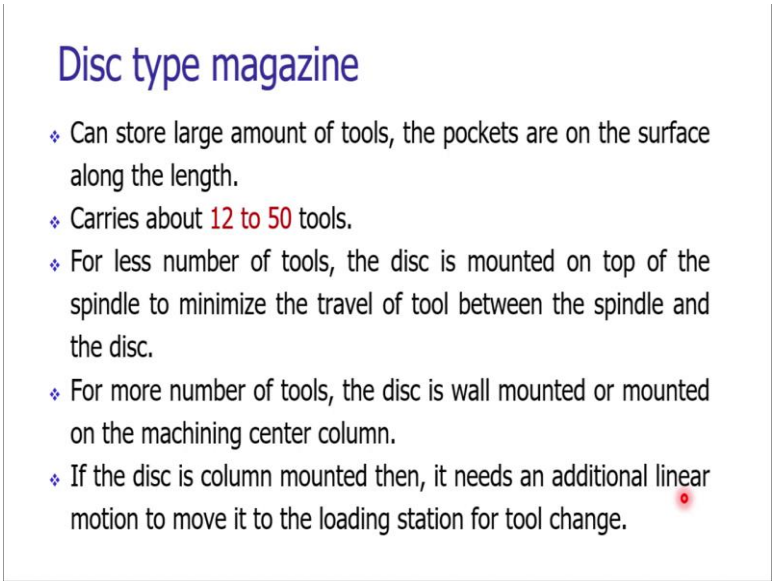

Thus we can say that, if the disc is mounted on top of the spindle, it will minimize a travel between the tool and spindle to the disc. If more number of tools are to be used, then we can have a wall mounted disc arrangement or we can use the adjacent side of the machining center column. Of course, it will take certain time to get the tool from the wall mounted facility or the column mounted facility.

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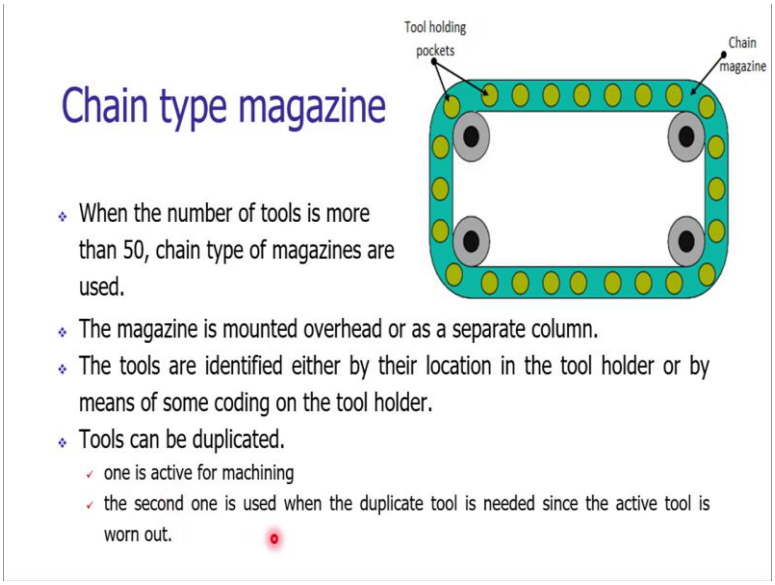

The next type of magazine is chain type magazine. In this arrangement we are using a long chain, which is operated by the sprockets; these sprockets are driven by electric motors. In the chains we are having pool holding pockets, as the chain is moving which is driven by the sprockets we are getting the required indexing of the tools. Based on the required tool a tool changing mechanism will take out the tool from the chain magazine and that will be inserted into the spindle.

In general, the number of tools are more in the chain type magazines. When we are talking about more than 50 number of tools, then these type of arrangement is suitable rather than the drum or the disc. To accommodate more than 50 the drum side size would be very high very large and the inertia would be very high and that may affect the rigidity of the machine tool as well, because we are hanging the drum or the disc overhead.

In general, the chain type magazines are mounted as a separate entity, separate column is designed and developed, and over which we are mounting the chain type of magazine. There is a systematic coding need to be done for each and every tool, which is there in the chain magazine, the numbers are provided, the numbers are encoded in the automatic system that is designed to operate the chains, in synchronization with the machine tool operation.

The machine control unit has to be programmed by taking into consideration of the location and the tool number of the chain magazine. The advantage of tool magazine is that we can duplicate the tools. We can have multiple number of tools of the same kind, which will save our lot of time in case of the tool worn out. Tool wearing of it is very usual in the high speed machining or in heavy duty machining.

We can have an active tool for machining, but the second one may be there in our store in the magazine, which can easily be used once the previous one is worn out.

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In the slide we can see chain type of magazine; you cannot notice here a variety of tools are mounted. These are the drilling tools, milling tools, the end milling operation tools, cutting operation. The end milling may have a variety of capacity tools, there is a duplication of tool as well. This is the tool changing mechanism. This tool changing mechanism is having an arm, the both the ends of the arm are both the ends of the arm are utilized for tool changing operation.

This is the separate column which is designed and developed to host the chain type of tool magazine. We will have a detailed discussion on the tool changing facility in the coming slides.

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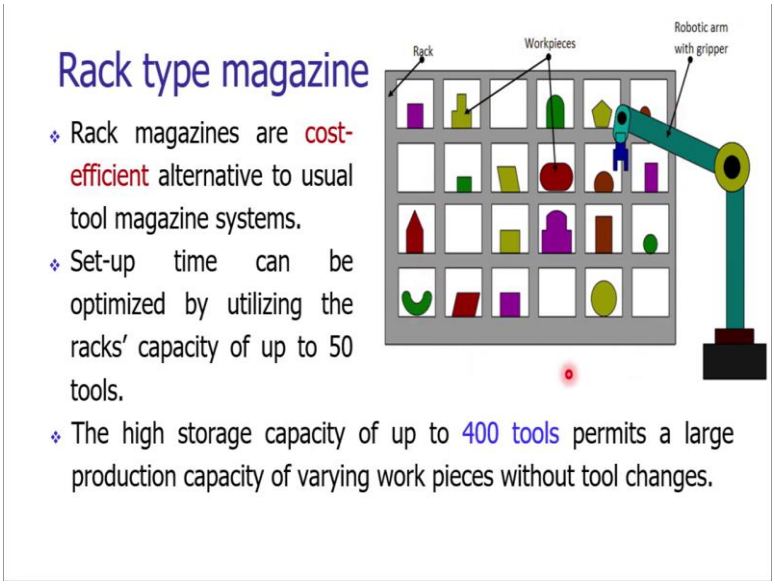

The next type of magazine is rack type of magazine. This is cost efficient, because we can hold more than 300, may be around 400 number of tools in the rack type of magazines. Inside the rack the tools are stored and we need to have a robotic based arrangement to select to get the required tool from the rack and then mount that tool in the spindle of the machine.

Here we can see a robotic arm with gripper arrangement, which is used to get the required tool. Of course, the racks can be utilized to store the workpiece as well. Thus we can have an integrated or a single system, which will hold the workpiece, which will hold the tools as well, and the robotic based system is feeding the workpiece to the machine tool, and it is orienting the cutting tool in the spindle of the machine tool itself. Single rack would be very useful to have the automated production operations.

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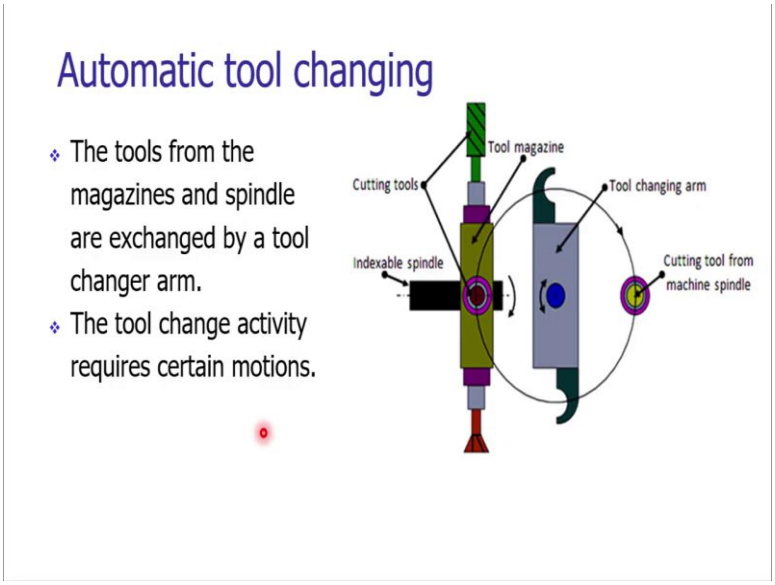

Now, let us see how the tool changing operation is being carried out. In general there are many variants of tool changing operation. Let us look at a simple tool changing operation by using a tool changing arm. In the slide we can see a cutting tool which is mounted on the machine spindle. The spindle axis is perpendicular to the plane of paper i.e. perpendicular to the plane of paper and consider the tool is mounted over here.

This is the tool magazine; the tool magazine is mounted on the indexable spindle. On the periphery of the tool magazines various tools are mounted, various tools are held. Let us look at this situation, this particular tool its axis is also perpendicular to the plane of paper. Now to have the efficient or to have the proper tool change operation, we have to select the arrangement in such a way that, the axis of the tool that to be chosen should be parallel to the axis of the machine spindle itself.

This axis is parallel to the axis of the machine tool spindle and there is the mechanism of tool changing arm, whose axis of swiveling is also parallel to the tool spindle and the axis of the cutting tool that to be chosen. To carry out the tool change operation we need to go through certain motions.

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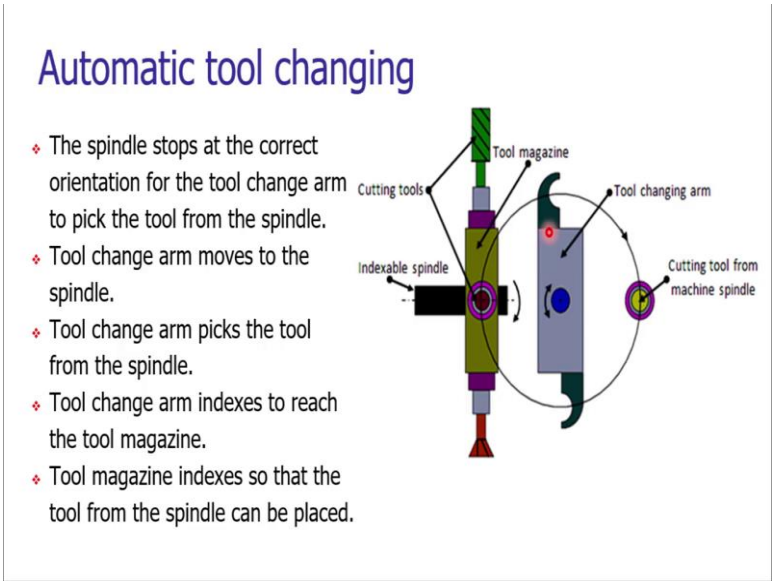

Let us see what are these motions? It is essential that the spindle should stop at correct orientation for the tool change arm to pick up the tool from the spindle. What is the first motion? Proper orientation of the cutting tool in the machine spindle, there is pick up of the tool that to be replaced from the machine spindle.

Swiveling of the arm to collect the tool from the spindle, we have to move in a clockwise direction to get the cutting tool, the tool arm is moving in this direction, it will collect the cutting tool from the machine spindle. Picking up of the tool from the spindle. At the same time the other end of the arm is getting engaged with the tool that to be put in the machine table.

This tool is to be utilized, when we are taking out this particular tool; the tool that to be taking out we will get engaged with the other end of the swiveling arm, tool changing arm. Then the swiveling has to be carried out as the arm is getting swiveled the tool which is taken out from the spindle will be kept at. For initial 90 degrees of the rotation of the tool changing arm; the tool changing arm will be in contact with machine tool spindle, where the cutting tool is mounted.

It will pick up the cutting tool, then for the next 90 degrees it will come in this particular situation, where it is having the taken out cutting tool and it is having the cutting tool that to be mounted in the spindle.

Well now we have to wait here for some time, because the destination of this particular tool is not the same destination from where we have taken the fresh cutting tool. If, this is the case of duplication we can put this cutting tool in the same location, but that is not the case in general. In case of different types of cutting tools the destination of the tool which is taken out may be different.

For that purpose, we have to wait or we have to hold the tool changing arm in this situation. After, that we have to index the tool magazine; the tool magazine will index in a incremental way and it will take the empty or the required empty slot where we need to put this particular used cutting tool.

It is predetermined, it is a pre stored, it is a pre programmed number, and that pre programmed number spot will be indexed by the MCU as the vacant slot will come to get the use tool, then the next 90 degrees would be operated. As we are operating the next 90 degrees then the tool will be put at the desired location and simultaneously there would be mounting of the next tool.

In this way we can have the efficient tool changing operation carried out. Single tool changing arm is taking out the tool from the tool magazine, it is feeding, it is mounting, the tool inside the machine spindle and helping to automate the entire tool changing operation. As mentioned the tool changing operation is the time consuming, that is the bottleneck and it is affecting the lead time of the product manufacturing.

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In general, it can be said that there are various advantages of using this automatic tool changing. The huge tools may be having very high temperature and the tool changing operation may harm the operator or the worker. When we are carrying out this automatic tool changing operation, certainly it is enhancing the safety. The changing of the tool is at a rapid way.

We are changing the tool in seconds and that is boosting the productivity, we are having a great flexibility. We can accommodate the huge variety of the cutting tools in the magazine and that enhances the capability of the CNC machine tool. We can easily handle heavy or the large tools, heavy size tools can easily be handled, certain tools the weight is very high for the human being as well it is difficult to handled. Overall it is reducing the production time, it is enhancing the efficiency of the system and that will lead to more productive environment.

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Let me summarize the lecture 2 of week 8 that is the tool magazines used in the automation. In this lecture we learnt the importance of tool magazine, we understood the principle of operation of a tool magazine, we have seen various variants of tool magazines, such as disk, type, chain type, rack type; at the end we studied the concept of automatic tool changing operation. And, we found that it is an important utility in the automated manufacturing systems.

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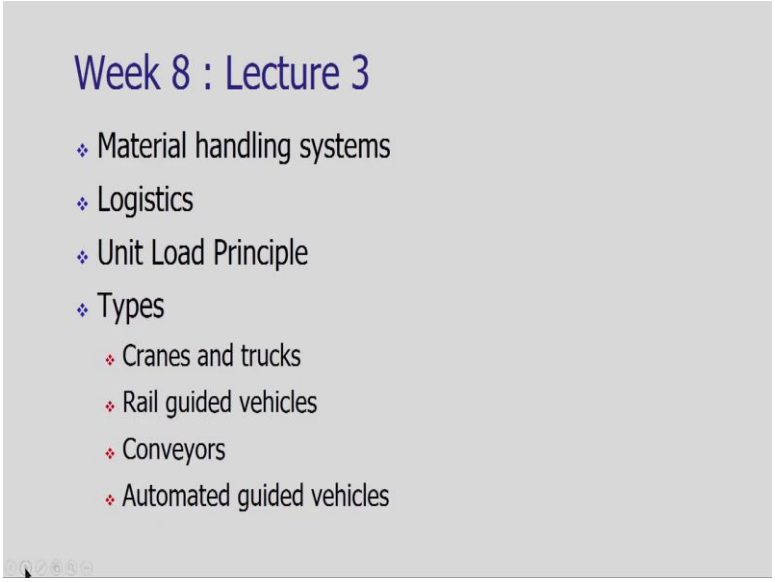

In the next lecture that is lecture 3 of week 8, we will be learning about the material handling systems, we will see the concept of logistics, the definition of unit load principle. And then we will have a elaborate discussion on cranes, trucks, rail guided vehicles, conveyors, and automated guided vehicles, which are used in the automation.

Thank you.

Automation in Manufacturing
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Week – 08
Mechanisms
Lecture – 27
Material handling systems

Well, I welcome you all to the lecture-3 of week-8. In lecture-3, we will be studying various Material handling systems those are used in the Automation in Manufacturing.

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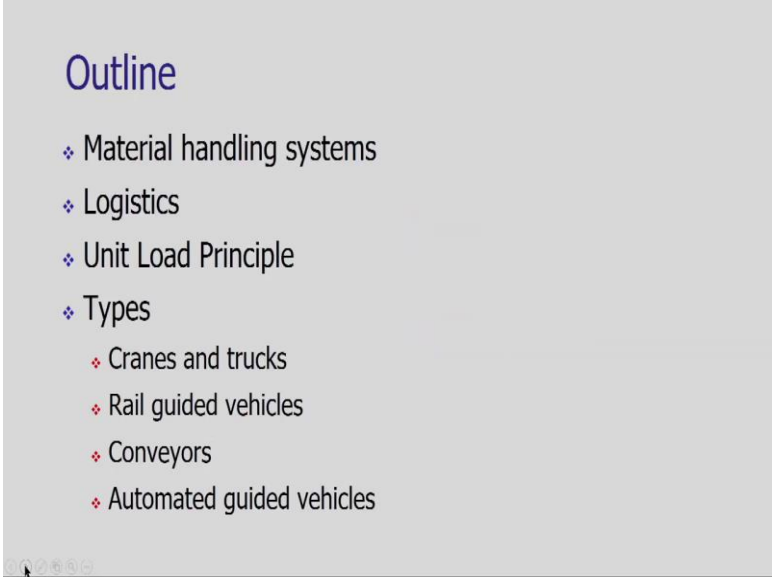

The outline of the lecture is on our screen. At start of lecture, we will study the various material handling systems, their concepts, definitions. Then we will have a discussion on the concept of logistics and unit load principle. After that we will study various material handling systems in detail. These are cranes and trucks, RGVs (Rail Guided Vehicles), conveyors and automated guided vehicles.

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In industry or in any shop floor we are dealing with various materials, parts and products. The materials, parts and products are to be moved, we have to store them, and we have to track them, we have to make a record. And this is so quite usual in any commercial infrastructure. The term logistics or the word logistics we often use which is related to the materials.

Logistics is nothing but acquisition of the material, acquisition of the parts and products, activities related to movement of these commodities, storage of these parts, products and distribution of them in the factory, or in the enterprise. It is not only acquisition movement storage and distribution. The operations related to planning and control of these functions is called as the logistics. Of course, all these things we are doing to satisfy the customer demand.

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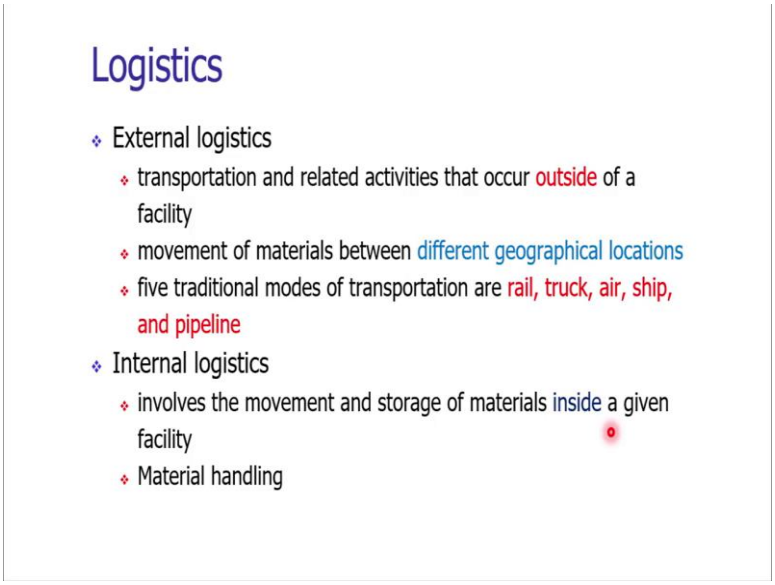

The logistics can be defined as an external logistics or it can be an internal logistics. When we are saying that we are transporting the goods or the product outside of a facility, the operations related to the storage, transportation of the goods and products outside the facility can be said it is a external logistics.

When we say that we are moving the material from one geographical location to the other geographical location, it involves basically the transport of the material, raw material, finish finished goods, semi-finished goods, products from place of manufacture to the destination that maybe market destination or the distribution destination.

We are carrying out the transportation of raw material or the finished or semi-finished goods in external logistics through various transport systems such as rail, truck, by air, or by ship, or by using the pipeline as well. The fluids say water or the petrochemical gases, they are transported through the pipeline.

In case of internal logistics, we are moving or storing the materials inside a given facility. In the enterprise, there are various things are needed. And when we are storing them we are acquiring them and making a record of all the things, then the operations related to this is called as the internal logistics. The basic element and important element in the logistics is the material handling. And in this lecture, we are studying the various material handling equipment those who are important for the automation purpose.

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We need the material handling equipment for variety of operation. The first is the transport operation. For that purpose, we need transport equipment. We need the equipment for positioning. We got the material over the conveyor at the destination, but we have to locate them at proper place.

We have to feed the tool to the spindle. For positioning, we need certain mechanical equipment, these are called as the positioning equipment. Unit load formation equipment – we are assembling, we are taking the commodities together, and we are storing them at a as a unit. To make the commodities as an unit, certain equipment are used these are called as unit load formation equipment.

Storage equipment, variety of equipment are needed to store the commodities at the workplace. Positioning means we are talking about specific application; storing means in a bulk way we are we need certain equipment that is to be used for storage of the bulk material or bulk commodities. In a factory, there are many equipment, there are many tools, raw materials, finished products. We need to have the proper record, efficient record of all this elements.

For that purpose, we should have automated identification equipment. For that purpose, the mechatronics based systems are used. It may be bar coding based technology or the RFID technology. Tthe identification and control equipment are the 5th type of material handling equipment which are required in automation and manufacturing.

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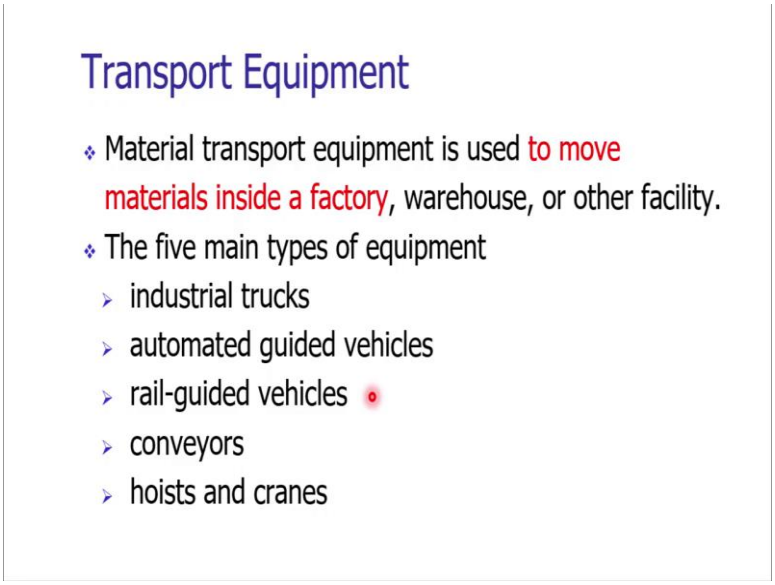

The transport equipment as I mentioned are required to move the materials inside a factory or warehouse or the facility. There are basically five types of equipment are used. And these are industrial trucks, automated guided vehicles, rail-guided vehicles, conveyors, hoists and cranes.

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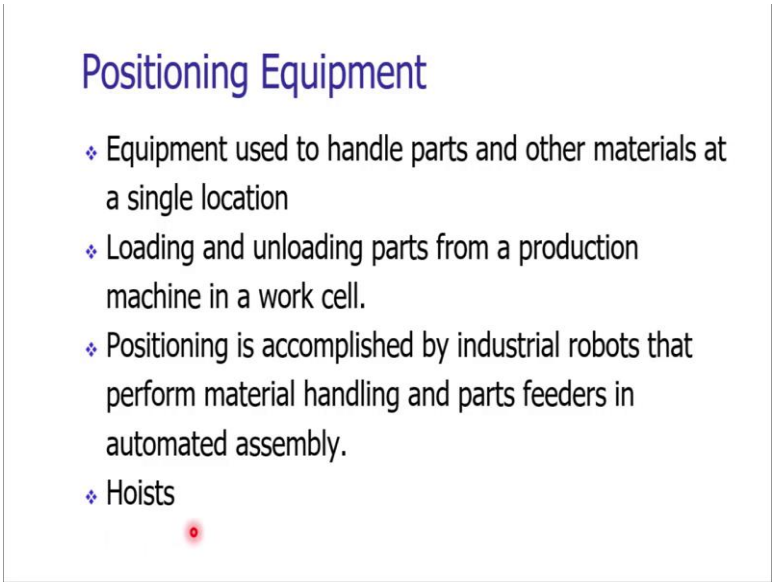

Positioning equipment, as mentioned are used to handle the parts of the materials at single location only. Say at feeding of the tool or orientation of the tool in a machining center or pick and place arrangement at the ASRS. The loading and unloading parts from

a production machine in a work cell can be treated as a best example of the positioning equipment.

In general, these activities are carried out by industrial robots which are performing the material handling, part feeding in the automated assembly. For positioning of bulky components or bulky tools say dies, molds or machine parts, we are using hoists which are lifting the components, and they are positioning wherever it is required.

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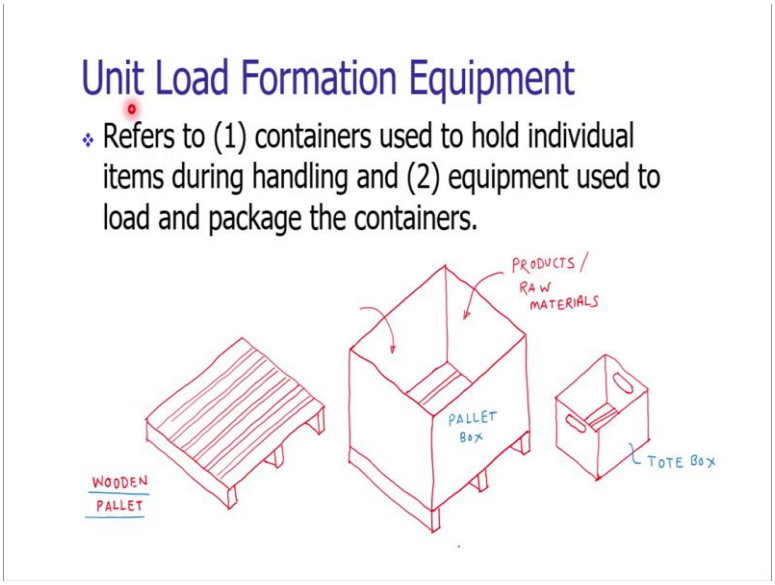

Unit load formation equipment, the unit load formation basically deals with making a container which is holding the individual atoms together, so that we can easily handle them. Let us consider we are having a wooden pallet. The wooden pallet is nothing but a platform of specified size, standard size over which we are putting the finished products say the boxes over each other and with specified number of boxes we are considering that as a unit of a pallet.

After that we are wrapping that specified number of packets or boxes together and that will be considered as 1 unit of 50 boxes, 1 unit of n number of products. We can also have a smaller version of the wooden pallet. This is a box or a basket kind of thing. In the tote box as well we can have the commodities such as the food products say fruits, berries, or apples.

1 tote box of apple that will be considered as a unit load. If the products are heavy if the products are more, we can have a larger version of the unit load and that is called as the pallet box. In the pallet box, we can accommodate or we can have the products which are stored in a semi-finished way.

Let us consider we are using certain raw material for some operation, we are storing that in a pallet box, and that will be utilized for the sub assembly or the processing operations. To transfer the finished products or to make the unit load of finished products, in general wooden pallets are considered. For making a unit load of the commodities which are in process which are yet to be processed we are using the pallet box given for handling the larger volume we are going for the pallet box.

We can put the products or the raw materials inside the pallet box. Of course, we are not wrapping this material by using the plastic. This is also used to handle the raw materials or semi-finished products.

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Palletizing, basically, an operation which is automatically shrink wrapping the plastic film around the unit load which is there on the pallet and that wrapped unit of the products will be sent for the shipping. The operations related to shrink-wrapping the plastic film is called as the palletizing. We need to arrange the products on the pallet, so that they will not fall down and then we have to wrap them by using the plastic film. To

carry out this operation, we need the automatic machines, these machines are called as the palletizers.

In a similar way, we also need depalletizers as well. Consider we are having a distribution center of the same enterprise. From the manufacturing unit, we are getting the palletized products. We need to now depelletized them and we have to unload the cartoons from the pallet. To carry out this operation in automatic way, we need the equipment these are called as depalletizers.

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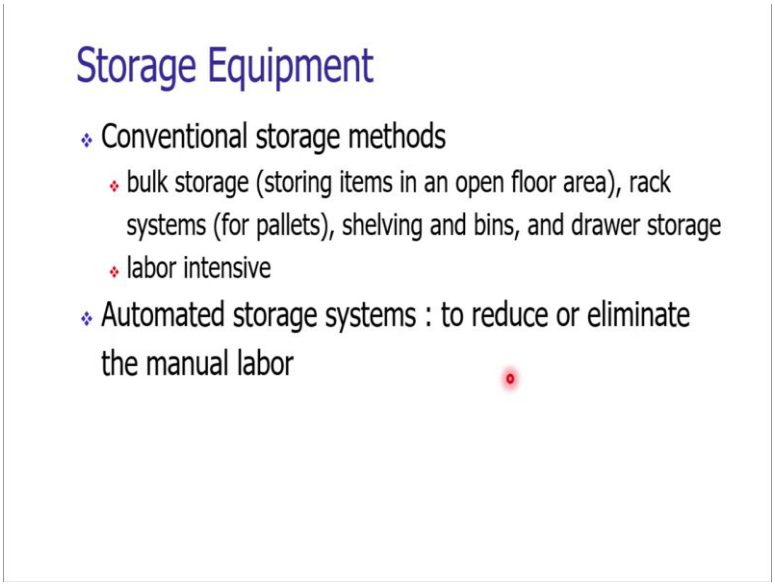

Storage equipments, the conventional method is the bulk storage that is on the open floor area. Consider we are having food grain bags which are store in a food grain godown. We are stacking the food grain bags, and generally these kind of storage is on the open floor area. Even in the industry, we are using the open floor area for stacking of the bigger size boxes or the cartoons. The rack type of system is the more sophisticated way. The racks are designed to accommodate the pallets. We have to prepare the pallets of the commodities or the products and straight forward we can put this pallets inside the rack system.

The rack system may have the specified numbers, they are coded basically. And we can easily automate the process of the rack system. Such systems are called as automated storage and retrieval system which are having the automated racks. We also use shelving and bins, the shelving and bins are utilized to store smaller components, a screws, nuts,

various tools. We are using drawers, but handling of the shelving and bins it is manual, it is a labor intensive. Overall, the handling of the open floor area storing and the rack system storing non-automated way is labor intensive.

For that purpose, we have to go for automated storage system which is suddenly reducing and eliminating the manual labor. When we are automating the process of storage in the racks and handling of the various items inside the rack, that will converted into automated storage and retrieval system.

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As mentioned before we have to identify and control these commodities or equipment in the shop floor. We have to keep track of these materials that to be moved and store. For that purpose, we are using barcode technology which often we use in the retail markets as well. In the retail markets say in the garment markets as well we are using RFID technology that is a Radio-frequency identification technology.

Both these technologies are also used in industry. We are tracking, we are providing first the barcodes to the palletized unit loads and then we can retrieve the specified pallet for either dispatch or for unpalletization or for its further utilization.

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Now, what are the various design consideration that to be studied? The design of a material handling system basically depends upon the materials that to be handled. What type of material we are handling, what is the quantity and distance that to be moved? When we are choosing a certain material handling equipment, first of all we should know what is the type of material whether it is a solid, or it is a liquid material, or it is a the gases product. Based on that, we have to choose appropriate material handling technology.

Quantities, whether it is a low quantity medium quantity or high quantity, then the distance for how long the material handling has to be carried out for how long we have to transport the material inside the warehouse or the automated industry. Based on that as well a suitable choice can be made with available options with us. Then what kind of production facility we be getting served by the material handling?

Whatever the products or the commodities we are transporting for which purpose for which production operation we are utilizing them. Whether it is a machining operation, or it is painting operation, or packaging operation, how much precision is there, whether it is a clean room or non clean room, whether it is a general purpose shop floor, so all these aspects are very essential that to be consider when we choose or when we design a material handling system.

Of course, the next parameter is the budget, the cost. The type of material that to be remove, the type of material that to be moved, the quantity or distance that to be move, what kind of application of that metal is there during the transportation and the cost associated with that.

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During optimal selection of material handling equipment in automation, we have to consider the type of layout of the plant for which we are selecting the material handling equipment. In the industry basically three types of layouts are used. These are process layout, product layout and fixed position layout.

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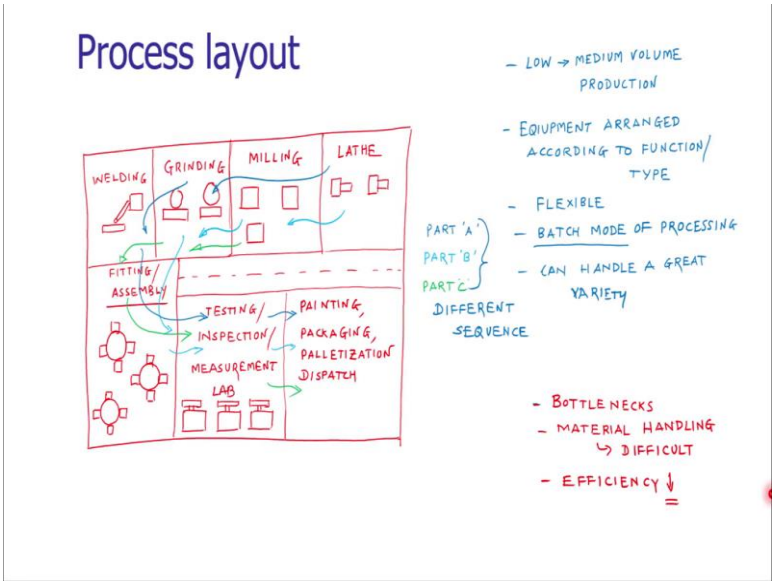

The layout is nothing but arrangement of the equipment or facility inside a factory. In process layout, we are arranging the equipment or the facility based upon the similarity of their utilization. On our screen, you can see a facility related to the tool room. Here we have grouped various equipments based upon their utilization. We can see the sections based upon their utilization, a lathe section, a turning section where we are reducing the diameter of the work pieces.

Milling machining operations, grinding operations which are finishing operations, semi-finishing operations. Welding operation, it is a joining operation or assembly operation. Fitting and assembly related activities. The equipment machines which are similar in utilization are grouped together and we have made a sections of them.

Also we are having a testing and inspection or measurement lab. We are all the finished or semi-finished products will be tested tools will be tested inspected. At the end, we can have the painting, packaging and the pelletization. Consider there is a part A which is to be processed at lathe operation and the grinding, welding, it will go to testing, it will not have any fitting related activity.

Part B is moving from lathe to milling operation, from milling to grinding and from grinding it will come to the fitting operation. After that it will go to inspection and testing and then it will be package. There is one component that is part C which is to be

process only on milling that finished on grinding, it will be welded, then it will be processed in the inspection section directly.

If we look at the operations which are need to need to be carried out on part A, part B, and part C are different, their sequence may also be different. The process layout is basically catering the low volume production or the medium volume production. Around say 1 to 100 number of parts that to be manufactured for that purpose the process layout is ok.

In process layout, the advantages that we can have a great variety of parts that can be processed. The part A, B and C are entirely different in their processing. The flexibility is the biggest advantage of the process layout and it is basically used for the batch mode of the operation. When we are carrying out the work parts in batch mode, we can easily have the process kind of layout.

When we are transporting the material from one shop to the other shop, we have to choose the equipment accordingly. Here we cannot have the conveyor based arrangement. We cannot lay down the conveyor that would be the fixed mode of transportation. Here we can have the AGVs that Automated Guided Vehicles, or we have to carry out that by using the cranes. Otherwise, we have to use the fork lift trucks which are manually operated, but definitely the fixed automation cannot be employed for the process layout.

When we are processing in a batch mode, based upon the limited availability of the equipment in shops, there are chances of having bottlenecks. Consider 50 number of components are having very less time of processing at lathe, but they are having more time of processing at the milling operation. There may be a bottlenecking. For that purpose either we have to increase the number of equipment at the milling operation, or we have to wait or we have to lose our time. That losing of the time is definitely losing the efficiency of the system.

Due to the bottlenecking as well we cannot have efficient material handling. The material handling is difficult in a process kind of layout. Thus the layout of the company, the layout of the factory is an important aspect in selecting the material handling equipment during the automation process.

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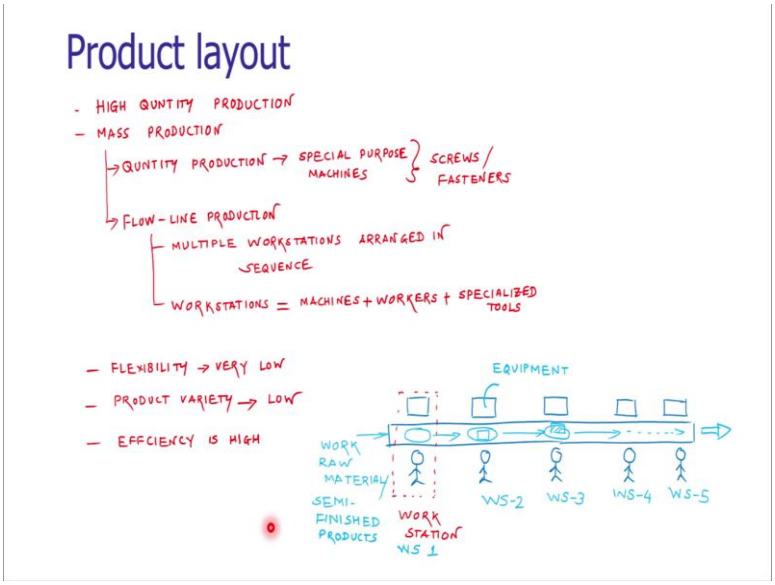

Consider there is a scenario that is of high quantity production. The company is having only one product and we have to produce the product at a high volume at the mass scale. Then mass production as well the production may be a quantity based production. Quantity based production means a manufacturing of screws and fasteners if the companies having the objective to manufacture only one product that is the screw.

We can have a special purpose machine we are just now producing a large quantity of the screws and nuts per day that is the product. And we are just selling them that out that is called; that is called as the quantity production, a single product, single commodity which may not be having any assembly.

The second type of mass production is flow line based production. System is there and that system is having variety of sub systems. These sub systems may be produced in house or some of the subsystems might have procured from the outside, we are outsourcing them.

At a faster rate, at a rapid rate, we have to assemble the sub assemblies, we have to assemble the parts which are either produced in house or outsource. For that purpose, we have to have a dedicated transfer line, such type of production facility is called as flow line production facility. The flow line production facility may have multiple number of workstations, these work stations are arranged in a sequence.

Consider we are having a transfer line. The transfer line is having multiple workstations. A workstation is defined as a unit which is having an equipment and the concern manpower. It may be worker, or it may be an engineer, it may be a skilled or semi skilled person and then there is a required tooling – specialized tooling.

Nowadays, the 100 percent automation factories are replacing the human work workers by the robots. A machine, specialized tooling and the control element that may be human being or the robot is together called as the workstation.

In flow line production systems, we are having many such work stations which are arranged in a sequence. The raw material is entering in that transfer line at one end, the commodities are entering at one end and the workstations are processing this commodities and at the end of the flow line at the end of the transfer line we are getting the semi-finished product or the finished product.

The characteristic of product layout is that its flexibility is very low. In certain cases if the system is very hard and probably we may not have any chance to incorporate any changes in the product design. So we have to redesign or rearrange the entire hardware of the flow line. Therefore, the flexibility of the product layout is very low. The product variety naturally is also very low. W are working only on one product.

In quantity production, consider we are having a special purpose machine which is manufacturing only one type of product for the variation in that product we have to go for another type of special purpose machine. The machine may not have the capability to accommodate the variations in the design. However, the efficiency of the product layout is very high. We are producing enormous quantity of the work parts or the systems per day.

The product layout is basically utilized for mass production systems. When we are trying to have the material handling system for mass production systems, the conveyors, the robots, the indexing mechanisms, these are very useful. Consider we want to just have the sequential motion of the work part instead of using the trucks or AGVs, we are simply using conveyors. And over the conveyors, the parts are moving. And there are equipment that are that equipment are processing the parts which are just moving on the conveyor.

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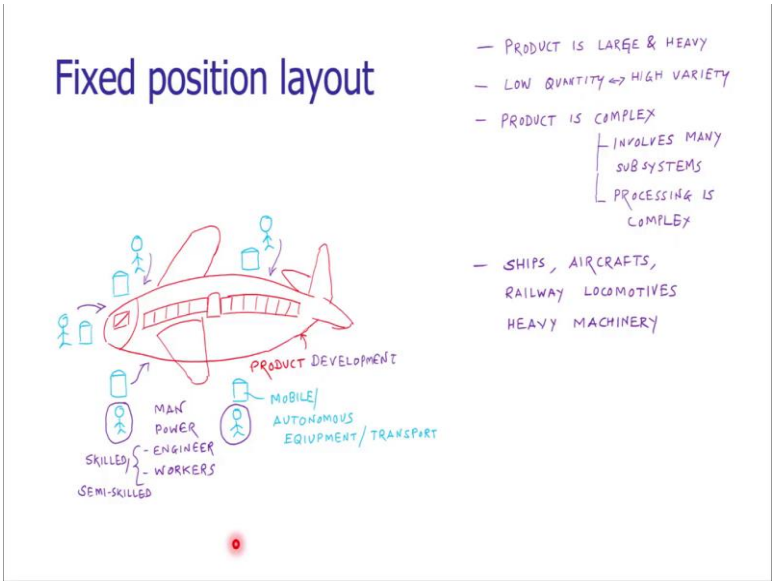

But you consider in certain cases we are having only one product, one system that to be developed. Consider case of aeroplane manufacturing or ship manufacturing, or we can have an example of the railway locomotive manufacturing or heavy machinery. For such applications which are very heavy, very bulky which are difficult to handle very difficult to move from one shop to the other shop.

In this situation, we are arranging the workstation, we are arranging the equipment around this product itself, around the system itself. We are taking the machines, we are taking the equipment at the site itself, and then we are carrying out the processing. Such type of layout is called as the fixed position layout.

Here you consider we are building up an aeroplane. We need the equipment. Now, to get the equipment from the storage, the equipment may be a machine. To get the equipment from the storage from its destination to its work place, we need to have certain material handling equipment. For that purpose, either we can go for forklift type of trucks or we have to go for the hoist or cranes.

We cannot use here the conveyors, because if we lay down the conveyors that will definitely obstruct the material movement of the other operation. Either we take this equipment or you can mount the equipment on mobile devices you can have the wheels into this equipment, so that we can easily take them to the fixed position of manufacturing.

In fixed position layout, the quantity is very less maybe one or two products that to be manufactured. The designs are very complex; they are involving many subsystems. The processing of the products is very complex. Many sub systems are involved and we have to assemble them, the processing is difficult and complex.

Naturally the efficiency of fixed position layout is very minimal, because we are developing only one product per unit time. It may be in days or in may be in months or years.

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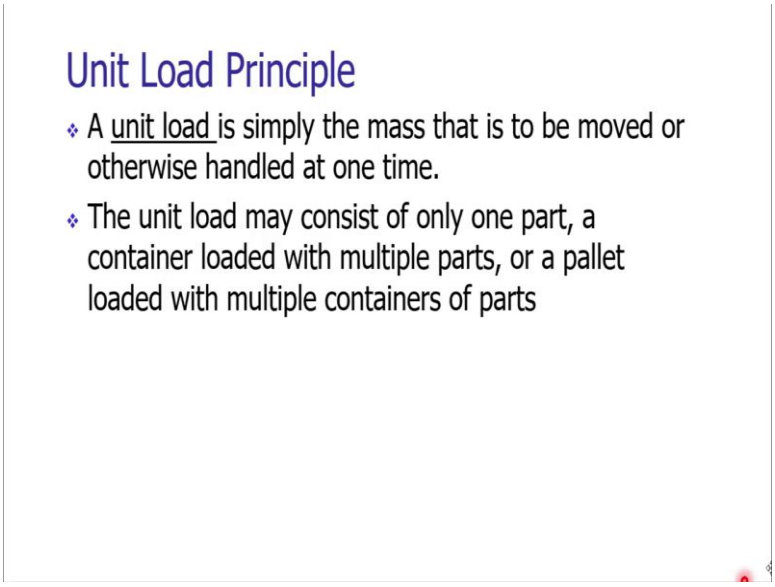

We have seen the term unit load. Actually let us have the formal definition of the unit load. The unit load is simply a mass that is to be moved or otherwise handle at one time. What the unit load may comprise of? It will have either one part say only one product or a system which we are putting on the pallet, or we may have a container with multiple number of parts.

Or these multiple number of parts are loaded on the pallet and then we are palletizing them, then we are wrapping them with the plastic. This is this unit load is very much useful in record making, in handling of the parts.

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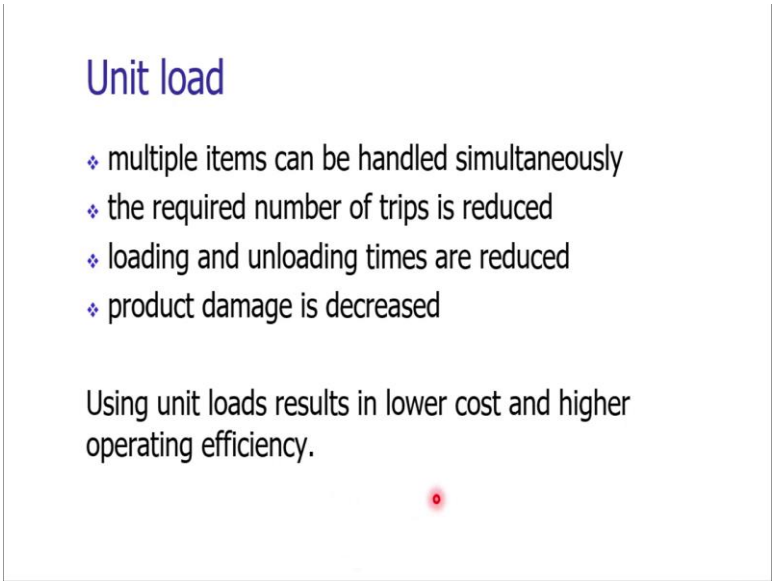

The concept of the unit load or the principle of unit load is helping us to handle the multiple number of atoms simultaneously. Based on this, we can efficiently manage the logistics, we can efficiently count the number of trips and we can even reduce the number of trips.

If we are making the parts palletized we are arranging them in a proper manner, then we can reduce the number of trips of the material handling inside the factory, or it may be the outside of the factory as well.

The loading and unloading times is also reducing, we are not handling a single box or a single product, they are handling multiple atoms which are temporarily bounded together. Since the handling is efficient the product damage would be less. Thus by using the unit loads we can reduce the cost and we can increase the efficiency.

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There are many transport equipment used in the industry. And these are industrial trucks, and that industrial trucks may be the manual or they may be powered. Automated guided vehicles, rail guided vehicles, conveyors, cranes and hoists.

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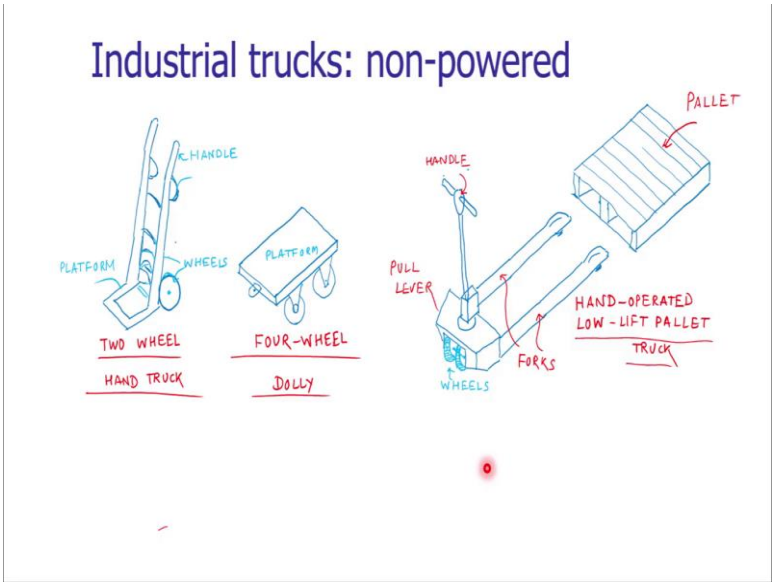

Some simple equipment which are often used on the shop floor and these are the industrial trucks. Some examples are there on your screen. These are non-powered trucks simple two wheel hand truck which is used to transport lighter products. This is the platform over which we are putting the product, and then we can easily convey them. Or

we can have the four wheel dolly, either you can drive the dolly manually or you can drive number of dollies by using an automated guided vehicle. Four wheel dollies are very much useful in the airports for transfer of luggage from areophane to its destination that is the conveyor.

We can also have the hand operated low lift pallet trucks. They do have the forks. The forks will be inserted into the pallet and forks will be lifted hydraulically, but the lifting is very small. As the forks are lifting the pallet the commodities will be lifted and then we are transferring them to the desired location. All these trucks are non-powered.

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As per as the automation are concerned, we are using the power trucks. Though they are manually operated, but these entities are very much useful in semi-automated industry. Where we are talking about material handling in process layout or in fixed position layout to handle the bulkier component say dies and molds or the tools or the raw material, we need to have an equipment that is the power truck of the forklift truck.

This is a typical arrangement you can see. Here we are having the forks and there is a hydraulic system, hydraulically we are lifting the forks. The lifting is comparatively very high. There is a train and it is having a very heavy engine. That engine is operating the hydraulic system as well. By using the hydraulic system, we are operating the forks and that forks are lifting, and then we are maneuvering we are transporting or conveying the commodities at their desired location.

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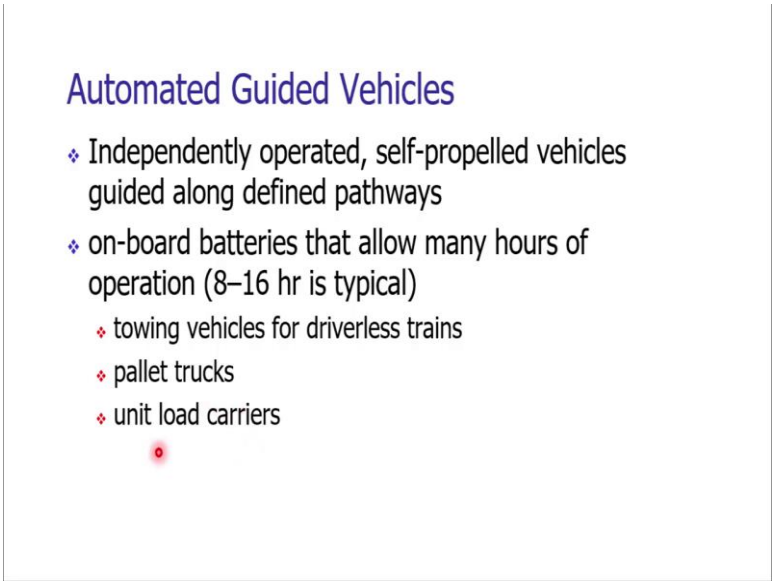

Automated guided vehicles are widely used in automation. These are independently operated, they are independent. They are propelling themselves. They are self-propelled vehicles, they are guiding themselves. The AGVs are having onboard batteries. The battery life may be around 8 to 16 hours. There are basically three types of AGVs are used in the industry. These are towing vehicles, pallet trucks or unit load carriers.

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On our screen, we can see a towing truck, say driverless towing truck, it is remotely controlled by a central computer or it is self-propelled or self-controlled as well. It has

the forks and over the forks a palletized commodity can be seen. This is a wooden pallet over which a unit load is placed. The unit load can easily be handled by the forks of this the AGV; the AGVs having the capability of controlling remotely wirelessly.

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This is another variant. It is the unit load carrier. This unit load carrier is having low height, and we can handle only the typical unit load for which it has been designed. Only one pallet at one time is being handled by such system.

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The next one is the pallet career. Consider we are having a AGV and which is driving which is taking along with it a dolly. And over the dolly, we are having the pallets. We can have a multiple number of dollies which are arranged in sequence. And based upon the capacity of the AGV, it can drive the dollies.

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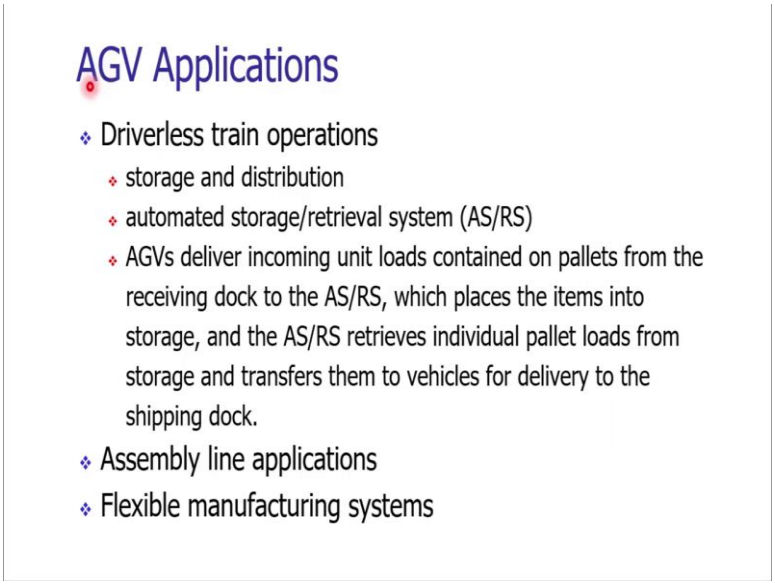

The AGVs are providing the driverless train operations. We can efficiently handle the storage and distribution. The AGVs are basically used for automated storage and distribution of commodities or the raw materials. AGVs are the integrated part of AS RS automated storage and retrieval system which we have seen in our very first week of this course.

We have seen one video where AS RS is taking assistance of the automated guided vehicle. How the AGVs are helping? The AGVs are feeding the automated and storage retrieval system. They are getting the unit loads on pallets from the receiving dock. Consider a truck has arrived in an enterprise of raw material and it is having multiple number of unit loads.

Now, AGVs will go to this dock, they will receive the unit loads, they will receive the pallets, and then they are feeding that pallets to the AS RS in a systematic manner the AS RS system is placing these atoms into the storage. The AS RS also retrieving the individual pallet from the load and then they are transferring that to the vehicles for delivery purpose.

Consider we are storing the atoms now. And after certain time, we have to deliver them. This is the case of a distribution center. We got the unit loads from the factory. Now, we have to distribute them, it is a storage, it is a warehouse. AGVs are taking in the pallets from the dock, they are putting them in the automated storage retrieval system. At the time of delivery, at a time of the shipping, we are requesting the AS RS to get back the stored pallets, and then that stored pallets will be transferred to the trucks at a docking station.

The AGVs are also helpful in assembly line applications. And as mentioned for the process type layout, the process type layout is widely used in flexible manufacturing system. When we are talking about the best type of production, when we are talking about the medium volume medium variety of production the AGVs are very much important. We cannot have a permanent arrangement say conveyors in the process layout.

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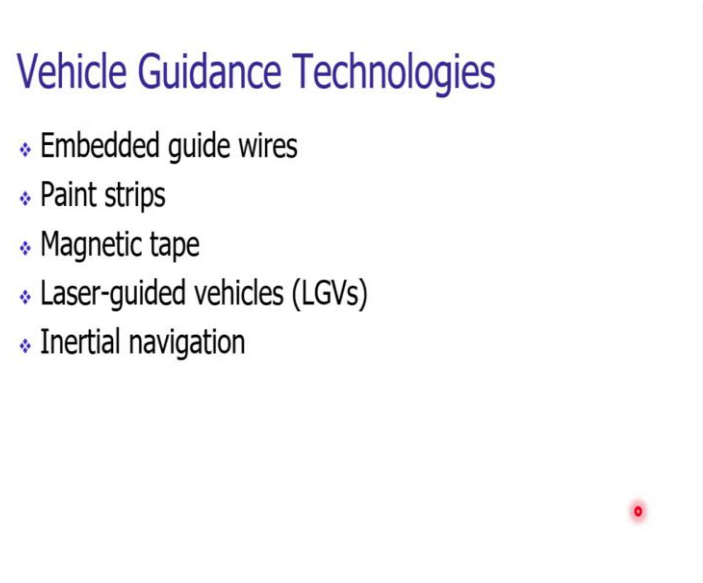

There are basically five types of guidance technologies are used in the navigation of the automated guided vehicles. We can use either the embedded wires which are guiding the AGVs. We can have paint strips or magnetic tapes. Some of the guided vehicles are working based upon utilization of the laser based technology these are called as the LGVs – the laser guided vehicles. We can also use the gyroscopes for the navigation purpose; these are called as the inertial navigation based AGVs.

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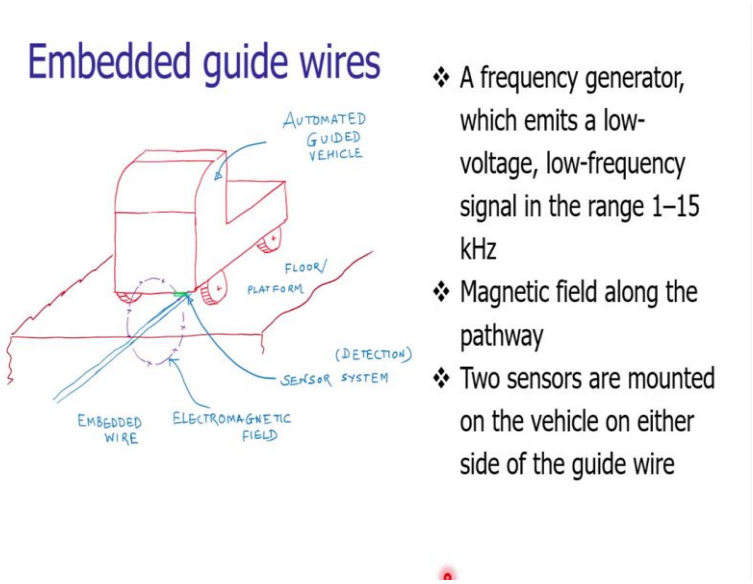

Embedded guide wires based technology; we are cutting a slot over the shop floor. And in that slot, we are embedding the wire which will be guiding the AGVs. This wire is generating low frequency signals based upon the input which is given. The frequency is around 1 to 15 kilo Hertz. Due to this low frequency signals, the magnetic field is getting generated. And that magnetic field will be utilized to navigate the AVG along the defined path. The magnetic field will be sensed by the induction based sensors.

On our screen, you can see the automated guided vehicle which is having the sensor arrangement at its bottom. And the sensor is sensing the magnetic field which is generated by the embedded wire. According to the sensor signals, the navigation or the control unit of AGV will control the speed and direction of movement of the AGV.

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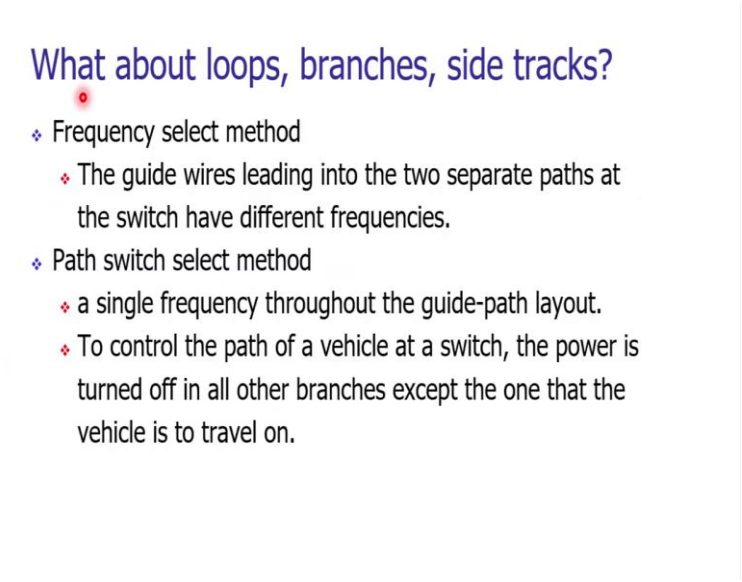

What will happen when we are working in loops or branches or side tracks? To handle these situations in embedded guide kind of technology, we are working with the frequency select method or the path switch select method. In frequency select method, the guide wires into two separate paths are having different frequencies. In the loops or in the branches or in the side tracks when we have to change the track we can have the different frequency of the signals electrical signals which are there in the guide wires.

When the central computer is giving instruction to the AGV or the program of the AGV itself is having the instruction to select a particular frequency or to look for a particular frequency, if that frequency is available along the branch path the AGV will the AGV will follow that. At branching if the programmed frequency is matching with the available frequency of the branch path, the AGV will follow that particular path; or we may have the paths which select method.

When we are having the options, the right option or the option that to be chosen we are giving the electrical signals to that particular option only. The electrical signals or the magnetic fields at all other paths will back switched off. We are switching off the electricity to all other not required paths. Whatever the path is to be utilized that particular path signal will be on. As it is on, the AGV will follow that particular path, and it will convey the product along that path only.

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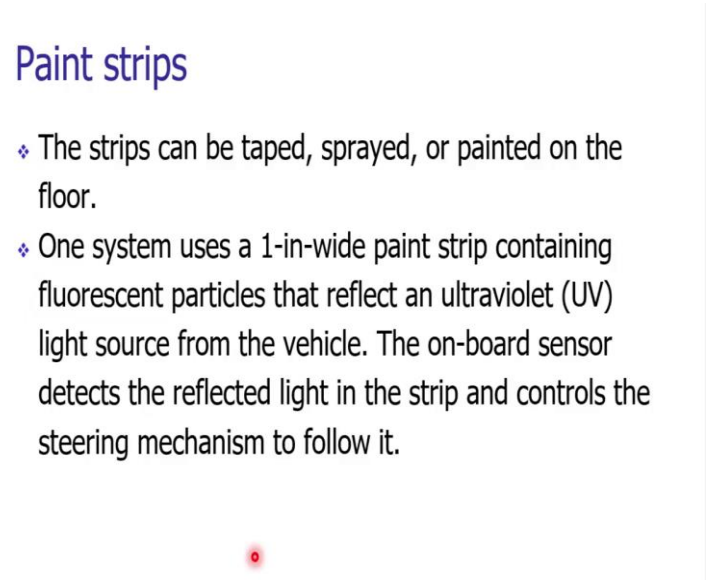

We can have the navigation by using strips which are painted. These strips are having fluorescent particles which are reflecting the ultraviolet light. The onboard sensor of the AGV will detect that light. This phototransistor, it will detect the light, and accordingly it will get maneuvered along that particular path.

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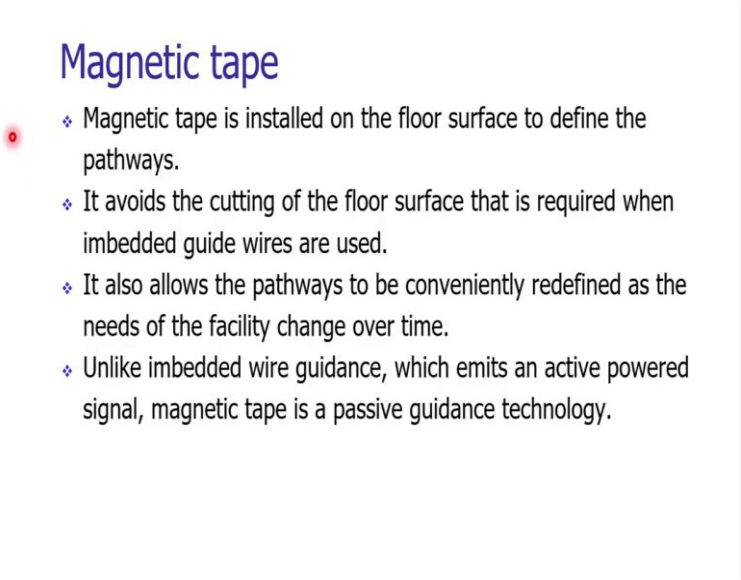

We can also have the magnetic tapes. Instead of having the painting or painted arrangement, we can have the magnetic tapes which are installed on the lower surface along the defined pathways. The magnetic tapes arrangement is avoiding the cutting of

floor surface which is there in the embedded wire technology. We have to cut the floor system. That can be saved by using the magnetic tape arrangement.

We can easily redefine the path. If we remove the magnetic tape from the floor, we can rearrange, we can relocate the magnetic tapes and we can change the path very easily. The magnetic tapes are generating passive signals in the embedded wire technology, the active signals are being generated, but in magnetic tape it is a passive signals of course that need to be converted into the active signals by using the signal processing devices.

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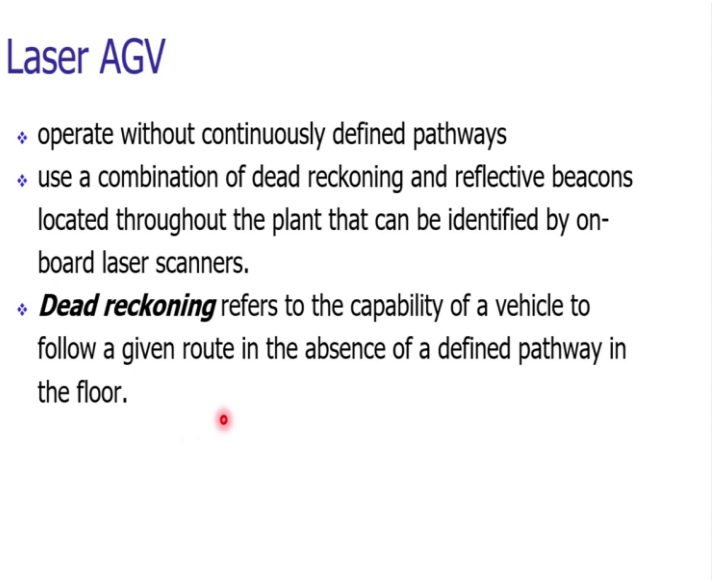

We can use lasers for the navigation purpose. In laser based AGVs, there is no need of any wire which is embedded, there is no need of any magnetic tape or we may not required as a the painted strip on the floor. In laser based AGV, we are using a combination of dead reckoning and reflective beacons. Beacons is a mechanical element which is having the reflections on it.

Various reflective beacons are arranged in the plant and the AGV is having a laser. The laser being is being continuously transmitted from the AGV, that laser will get struck to the beacon. And from that beacon, it will get reflected. The reflected signal from the beacon will be stored inside the processing unit of the AGV and that stored information will be utilized to know the current position of the AGV and it is utilized to compute the destination that to be achieved.

The dead reckoning is a term that is refer to the capability of a vehicle to follow a given route in the absence of defined pathway in the floor. It is basically a system which is making the AGVs capable of finding the path or following a path when a defined pathway is not available on the shop floor. We are not having any embedded wire technology, we are not having any magnetic strips, we do not have any the painted strips over the floor.

The AGV is free to move and based upon the beacons which are available based upon the programming it is having, the AGV is taking its own control then it is moving on its own inside the shop floor. This particular capability of having navigation control with the in the absence of the defined pathway that is called as the dead reckoning.

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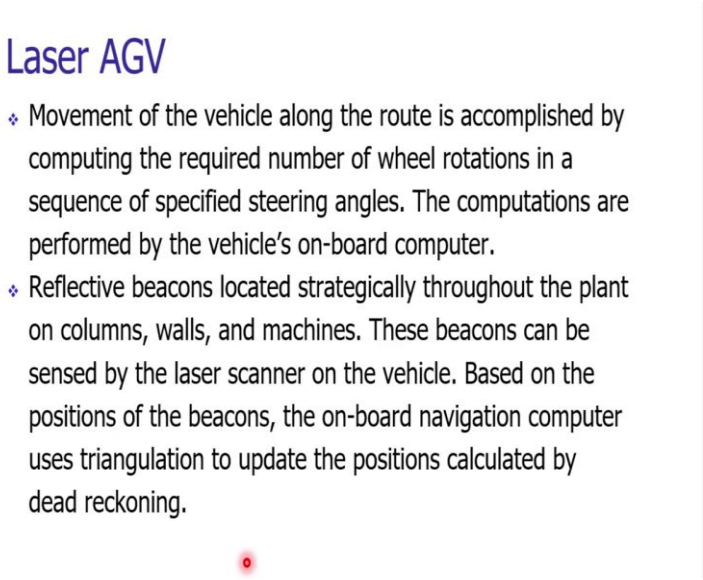

In the laser AGVs, the movement of the vehicle along the route is obtained by computing the required number of wheel rotations. During the movement of the AGVs, the number of rotations of the wheels are computed, servomotor may be there or a stepper motor may be there, and that number of rotations are utilized to get the required location of the AGV. The computer is computing the present location of the AGV based upon the number of rotations. Of course, the steering angles also need to be considered to get the required destination as well.

Inside the factory, the reflective beacons are located strategically. The beacons are located at variety of places strategically. The lasers are sending the laser energy that is

photon based energy and they are getting reflections, the AGVs are getting reflections. The reflections received by three beacons inside the shop floor can be utilized to have the triangulation, can be utilized to get to find out the present location of the AGV.

Of course, the reflections from the beacons and the programming or the methodology of dead reckoning made the AGVs self-propellant, self-sufficient to take its own pathway inside the factory.

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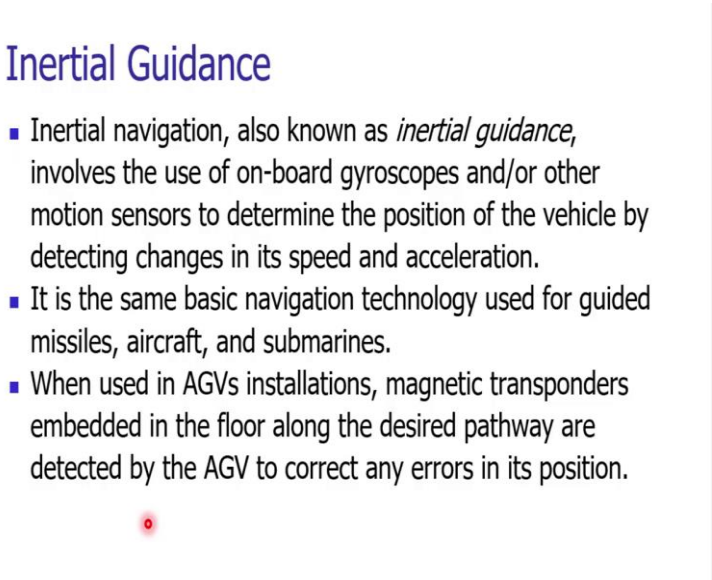

We can also have the inertial guidance. Inertial guidance, basically we are using on-board gyroscopes and motion sensors to determine the position of the vehicle by detecting the changes in the speed and acceleration. Gyroscopes are mounted. And these gyroscopes and motion sensors are continuously computing the speed and acceleration. And based on that, the microprocessor of the AGV is continuously recording the position of the vehicle.

Similar technology is used in the aircraft, submarines and the missiles. In addition to the gyroscopes, these AGVs also have the magnetic transponders which are embedded in the floor. These are the additional systems which are ensuring whether the AGVs following the correct path or not. Basically the AGVs are very much useful in the process layout kind of manufacturing automation.

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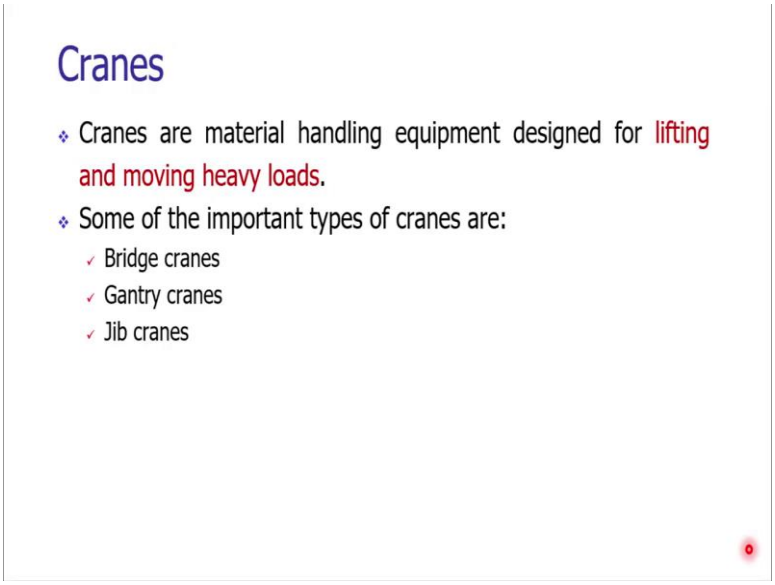

In the manufacturing industry, we are using cranes to handle or to lift the heavy loads, heavy parts. The heavy loads or heavy parts may be the dice, molds, machinery, raw material. There are three types of cranes which are used in the industry these are bridge crane, gantry crane and jib crane.

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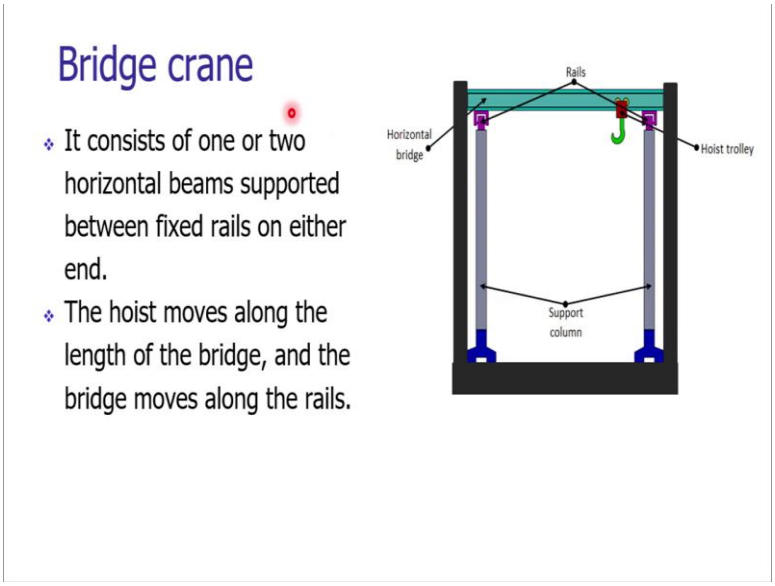

In bridge crane, there are one or two horizontal beams which are supported on the fixed rails on either ends. And these horizontal beams are moving in the direction perpendicular to the plane of paper. These horizontal beams are hosting the hoist. This is

the hoist. And this hoist is moving along the z-direction. We can move the hoist along the length of the horizontal beam. Let us consider this is the x axis moment of the hoist trolley. The horizontal beam is moving perpendicular to the plane of paper that is the y direction. And that perpendicular moment to the paper is possible by using these two rails. These rails are supported by supporting columns.

The end of the hoist can be moved along the vertical direction that is the z-direction. It will come down it will leave the object, and then we can move the object or the product along the x-direction or along the y-direction. The bridge crane is basically used to handle heavier objects. The big manufacturing industry, when we want to handle a very huge size work parts, components or machinery, bridge cranes are utilized.

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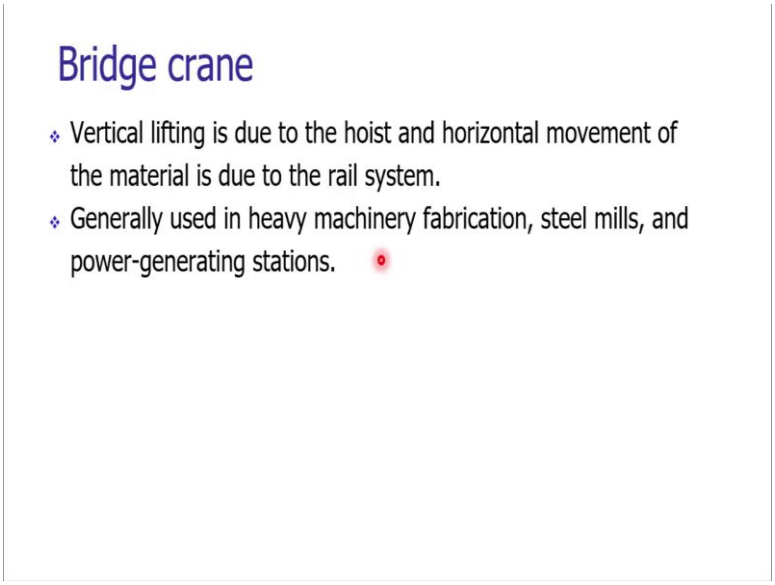

In bridge crane, the vertical lifting is carried out by using the hoist, whereas the horizontal movement is done by using the rail system. As mentioned, the bridge crane is used to handle the heavy machinery, steel mills and it is basically used in power generating stations where we need to handle the impellors turbines of large size.

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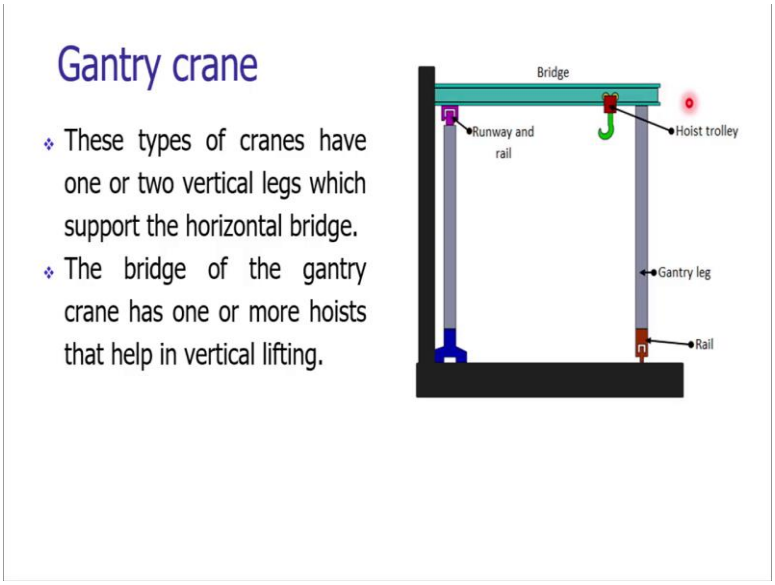

The next version is the gantry crane. It is very similar to the bridge crane itself, but the handling capacity of the gantry crane is lesser than the bridge crane. In gantry crane, we are also using a bridge which is supported at one end on the runway and a rail which is hosted on a support column. The other end of the bridge is supported by a gantry leg. And the gantry leg is moving over a rail.

The arrangement of the gantry crane is smaller, and we can handle small or a medium type of work parts, not very huge work parts are being handled by the gantry crane. The gantry crane we can move inside the warehouse, inside the shop floor or the factory. We can take the crane anywhere we want and we can handle the work parts.

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There are certain variations in the gantry crane as well. We can have a double gantry crane which is having two legs, which are moving over the rollers. The other types are like half gantries or the cantilever gantries. In half gantry crane, there is a single leg on one end of the bridge, and the other end is supported by the rail mounted on the wall.

The same configuration we have seen in our previous slide, that is the half gantry crane. In cantilever type, the bridge extends beyond the length of the support length. This is the half gantry crane. If the bridge is extending beyond the support provided, then that type of crane is called as the cantilever type gantry crane.

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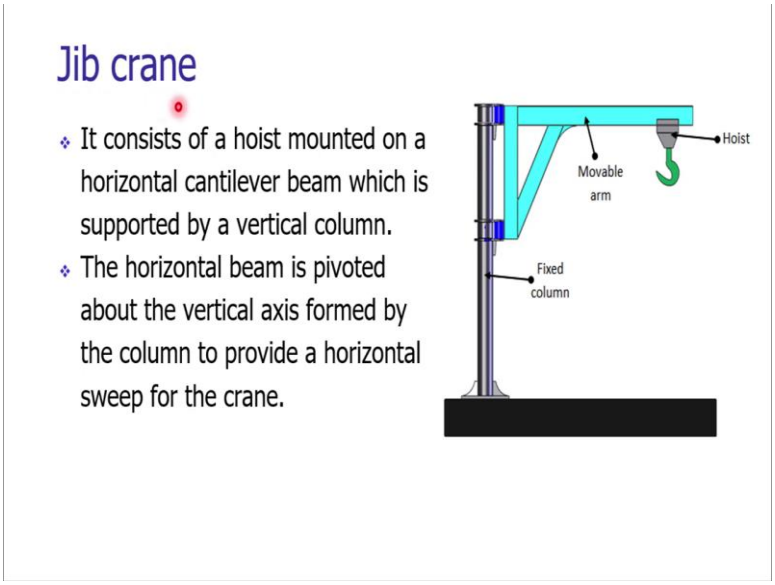

The third variant of crane is jib crane. In jib crane we are using a movable arm which is pivoted to a fixed column. This movable arm is hosting the hoist. Hoist can be moved along the length of the column. Suppose, there is the work part or the commodities which are placed on the floor, the hoist will come down and will lift it. The movable arm can rotate about the axis of the fixed column. It can rotate about this axis, so that we can cover up considerable area inside the shop floor.

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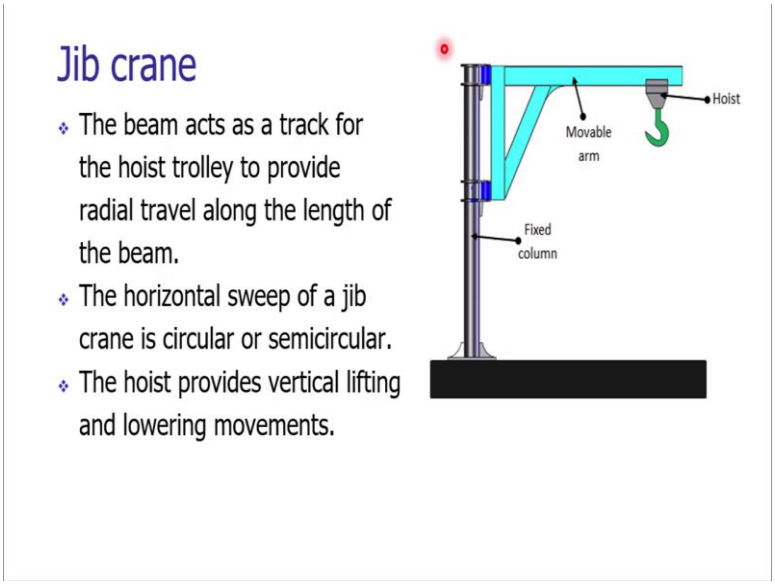

The hoist is moving along the length of the movable arm, and the horizontal sweep of the jip is circular or semicircular. If it is circular, it can cover up the considerable area and we can utilize the jib crane for wide variety of applications. The movable arm is providing the radial travel to the hoist.

We can have the radial travel along this direction away from the center of the column. The movable arm can sweep about the jib axis. It may be circular or semi circular form. And the hoist is moving in a downward direction. Lifting the work part up and then it is moving in upward direction. Then either it can move in a radial direction towards the center of the column, or it can be rotated about the column of the jib crane itself.

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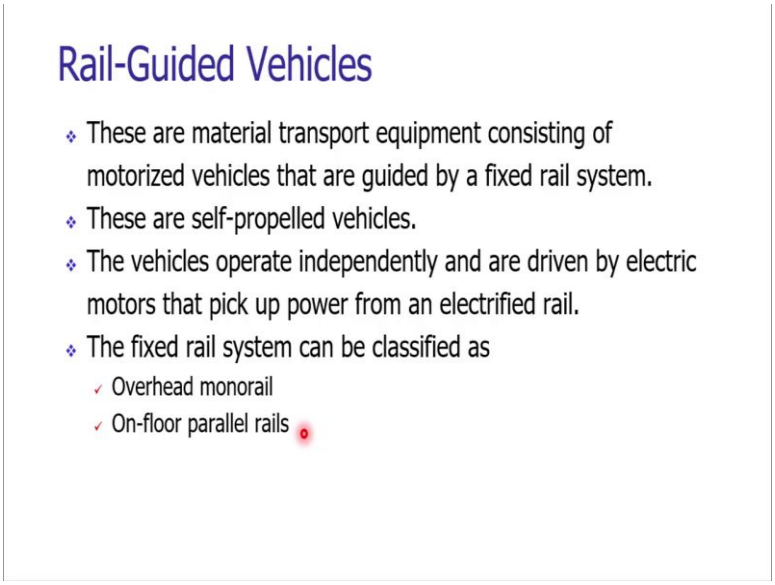

The manufacturing industry also employ rail guided vehicles. These equipment are consisting of motorized vehicles which are guided by fixed rail system. The typical motorized vehicles are there which are fixed to the rail system. These vehicles are self-propelled; they are getting propelled by themselves only. They are operating independently and are driven by electric motors. These are the electrical driven vehicles, and they pick up the power from the electrified rail. We can have basically two classes of the fixed rail system and these are overhead monorail or on floor parallel rails.

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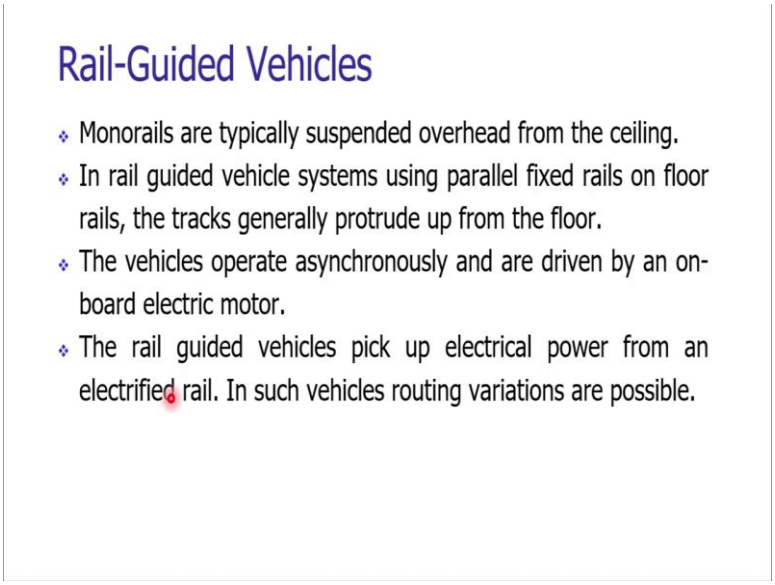

In overhead type monorails, the rails are suspended overhead, they are suspended from the ceiling. As the work parts or the machinery or the raw material is being carried out in over on position, we can save a lot of floor space when we are employing the monorails. The work parts are moving along the rails which are mounted above the floor space.

The ground space can be utilized. It can be saved for other another operation or for some other purpose as well. In rail guided vehicle systems using parallel fixed rails, the tracks are generally protruding up from the floor. We are having a typical rails which are protruding up from the floor, and over which the vehicles are moving.

The vehicles are moved in an asynchronous way and they are being driven by the onboard electrical motors. Basically the rail guided vehicles are picking up the electrical power from the rail itself. And in such vehicles, we can easily have the routing variations. We can change the route or we can change the speed of the electrical vehicles easily.

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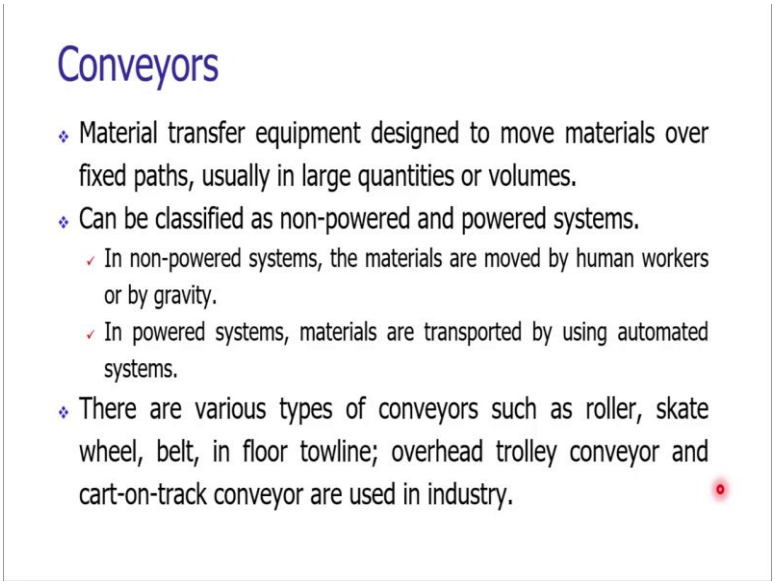

The manufacturing industry also employed or utilized conveyors, particularly in the product layout kind of system where we want to get in the raw material at one end of the floor line and the finished product would be done at the other end of the floor line. The conveyance of the raw material from one end to the other end has to be in a continuous mode or in intermittent mode based upon the requirement of the operation, which is possible by using the conveyors.

When we are supposed to handle the large quantities or the volumes, the conveyors are best suited. We can have non-powered conveyors or the powered conveyors. In non-powered systems, human intervention is required, we have to employ the human workers to handle the systems or we can utilize the gravity. We can have the slope and roller, roller type of conveyors. And by using the rolling friction and the gravity, we can easily convey the materials.

The power systems are more sophisticated systematic ways to convey the commodities. Of course, we have to spend a power to get the required work done. There are various types of conveyors such as the roller, skate wheel, belt, in floor towline; overhead, overhead trolley conveyor and cart-on-track conveyor which are used in the industry.

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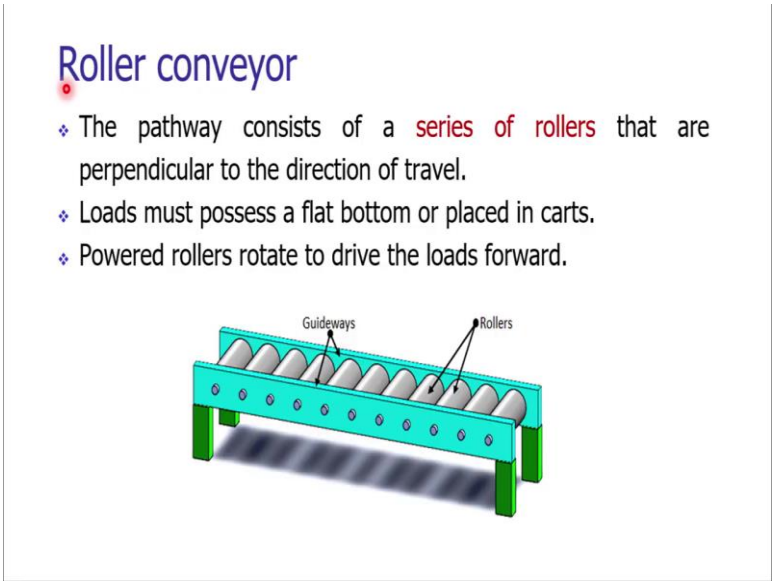

Some of the conveyors will be studied now. The roller conveyor is the basic and simple example of the conveyor system used in the automation. It comprises of a series of rollers which are perpendicular to the direction of travel. The construction is very simple we are having two frames two guideways, and there is a set of rollers which are connected in between these two guideways. We are using the rolling friction here. The cartons which are having the flat bottoms can be easily conveyed over the roller based conveying system.

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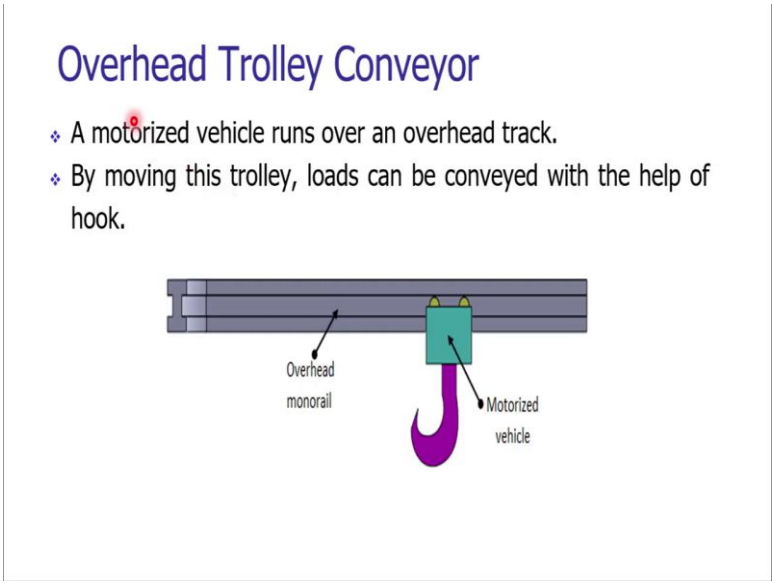

We can have the overhead trolley conveyor. By moving the trolley, we can easily convey the objects with the help of a hook. Over the overhead monorail, we are having a motorized vehicle and it has the hook. We can hand the work part in the hook and then we can easily convey the work part along the length of the overhead monorail.

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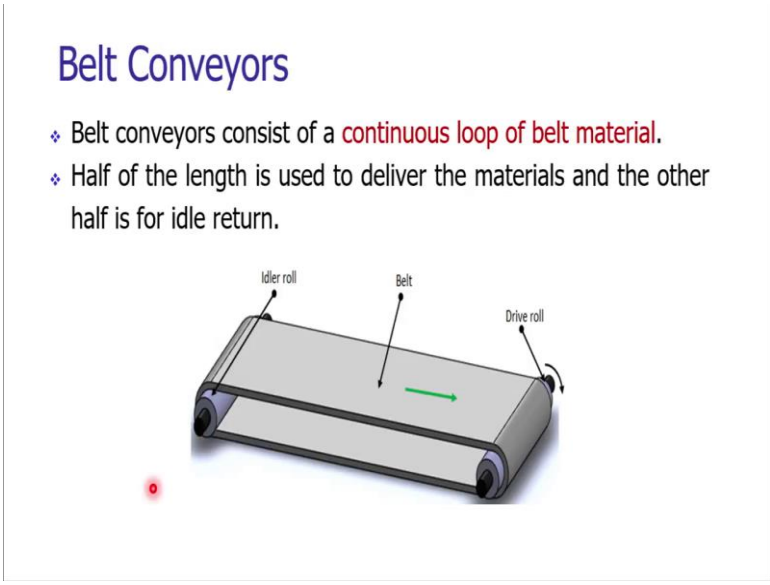

These type of arrangements are basically used to convey dies and molds. The belt conveyors are also very popular and important type. It consist of continuous loop of belt material. So, this is a belt. There is a continuous movement of the belt. The belt is driven by the drive role and there is an idler role. The drive role is being operated by the electric motor. The idler roller is helping to have the sufficient tension in the belt.

At any movement we can notice that the half the length of the belt is being utilized for the convenience. However, the remaining half will not be utilized for the conveyance that we can consider as a limitation of the belt conveying.

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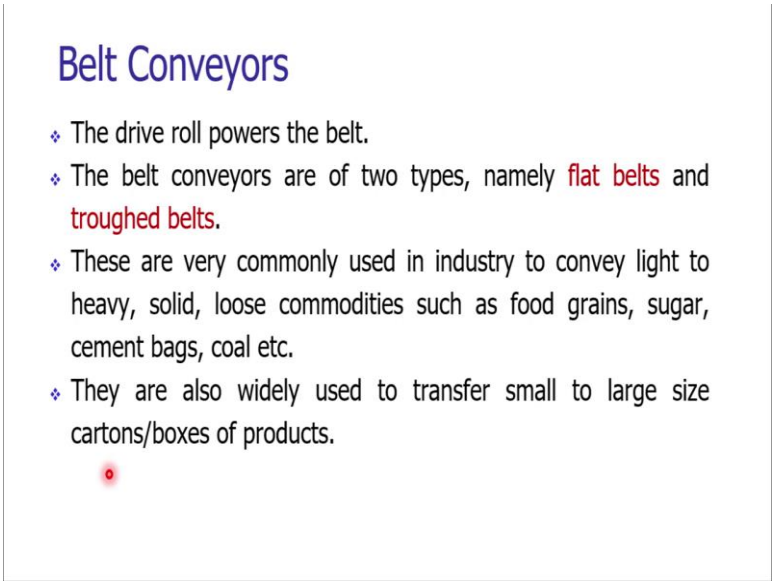

We can have two variants of the belt conveyors; these are flat belts and troughed belts. Belt conveyors are commonly used to convey light to heavy solid or loose commodities such as food grains, sugar, cement bags, coal. Even belts can also be used to convey the flat material or flat bottom material. This flat bottom material may be cartons or the boxes of the products.

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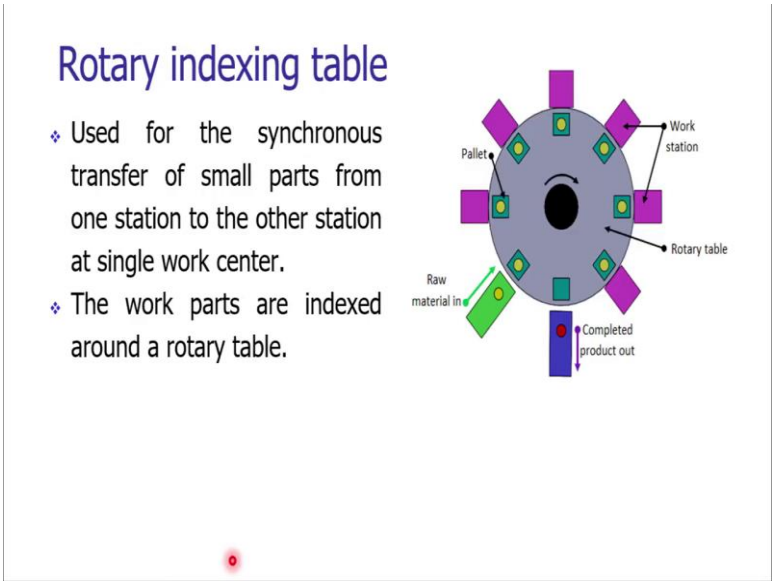

In automation industry, the rotary indexing tables are heavily used. We have already seen the rotary indexing operation in our previous lecture. The rotary indexing table is

required for the assembly operation. Here we can notice a rotary indexing table which is mounted on a spindle, and that spindle is being intermittently rotated by the indexing mechanism. On the rotary indexing table, we are having pallets. And there are workstations which are arranged on its periphery. The raw material will be taken in the loop of the rotary indexing operation.

Here the raw material is taken. And as the rotary table is indexed in clockwise motion, that raw material will be processed at variety of work station. After completion of the processing at the last work station at the unloading station, the work piece the processed work piece or the finished product will be taken out. The indexing table can itself be considered as conveyance system. Basically this type of system is used in product type of layout.

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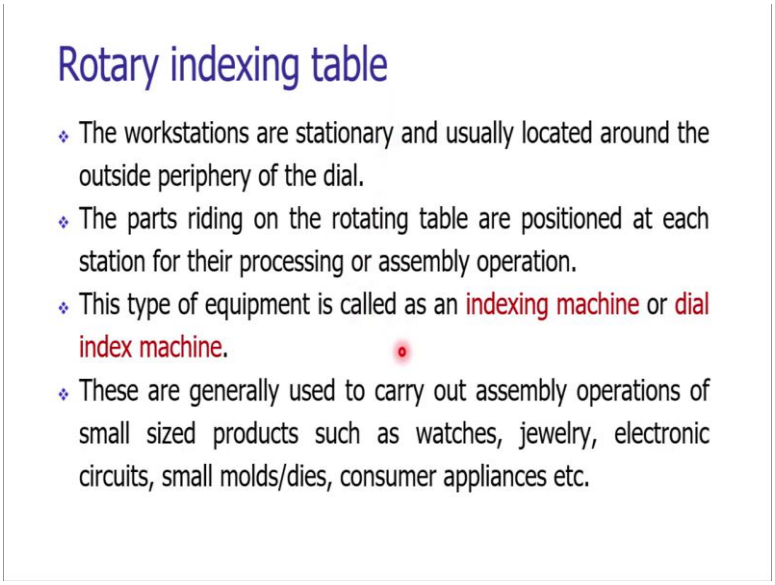

We can summarize this as: the work stations are stationary while the table is rotating, and the work stations are arranged around the periphery of the dial. The rotary indexing table is also called as the dial index machine. The parts are riding on the rotating table are positioned at each station for their processing. The rotary indexing table is generally used to carry out various assembly and processing operations required in watches, jewelry, electronic circuitry, assembly of small molds or dies and to create or to develop the consumer appliances.

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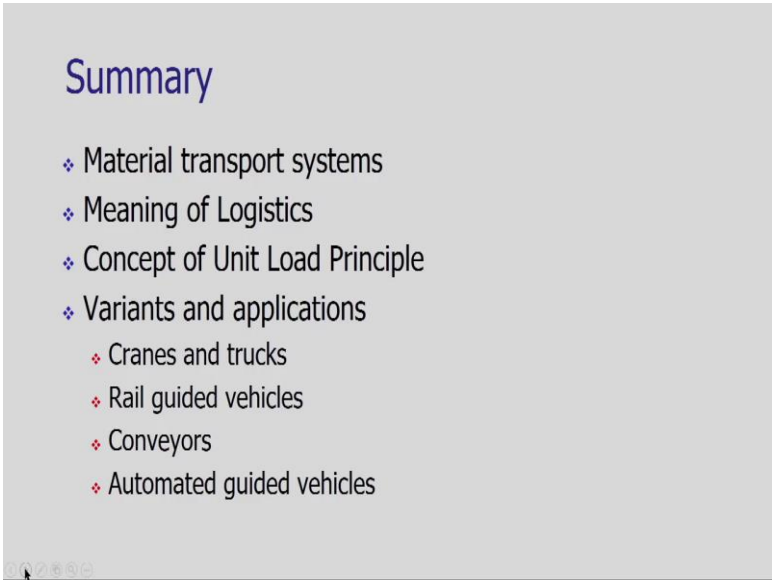

Well, my friends let me summarize this lecture. In this lecture, we studied the various material transport systems; we studied the meaning of logistics and the concept of unit load. After that we had a detailed discussion on variants and applications of the material transport systems. There are many types we have seen the cranes, trucks, rail guided vehicles, conveyors and automated guided vehicles which are used in the automation industry.

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

Week – 28
Hydraulic Systems
Lecture – 01
Fundamental Concepts

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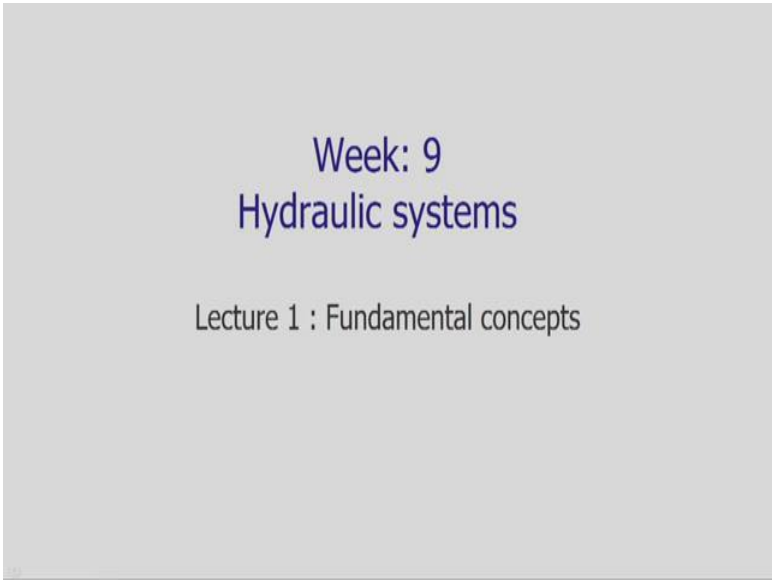

Hello and welcome you all to the week 9 of Automation in Manufacturing. The week 9 is dedicated to the study of Hydraulic Systems, which are used in automation industry. In previous weeks, we have seen electrical drives, hydraulic drives and pneumatic drives are also used to carry out variety of production operations in the automation. We will be learning the fundamental concepts in the 1st lecture of this week.

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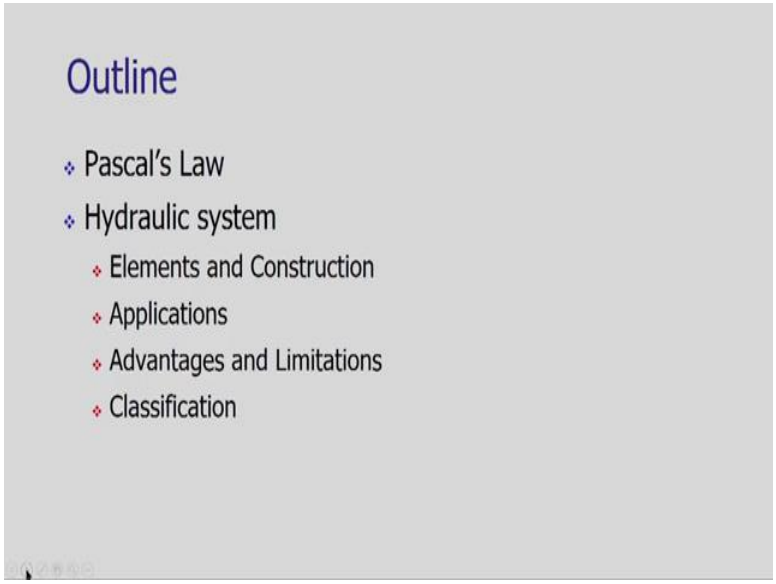

Let us look at the outline of this lecture. At start of the lecture, we will be studying the Pascal's law on which the hydraulic systems are working. Then we will have a study of various elements of a typical hydraulic system, the construction of a hydraulic power pack.

We will study various applications in the automation. After that we will have a discussion on the advantages and limitations of the hydraulic system. At the end of the lecture we will have the classification of hydraulic systems. Let us begin the lecture 1.

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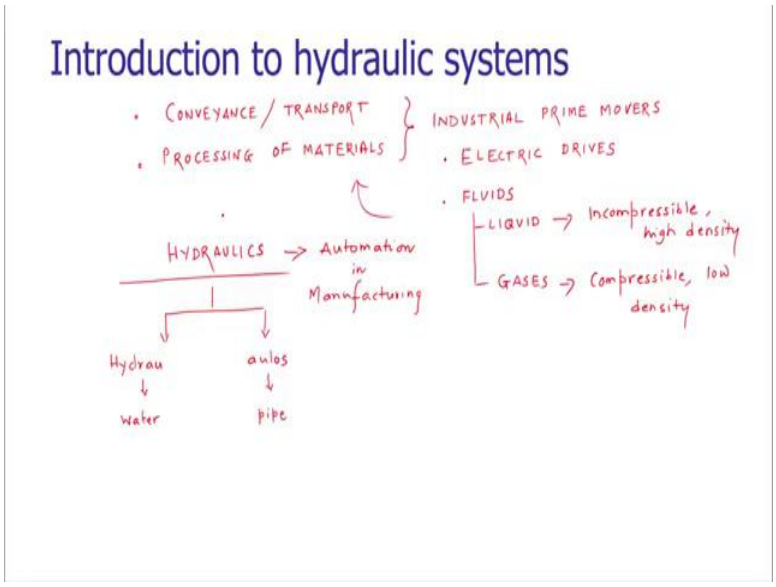

In industry we required the energy to carry out basically two functions, that is conveyance or transport and processing of materials. And to carry out these operations whatever the systems are required in terms of the energy are called as industrial prime movers. We have seen one industrial prime mover that is the electrical drives in our previous weeks.

Electrical drives are very widely used in the industry to convert the rotary motion into the translatory motion or even the rotary motion itself can be utilized to carry outs variety of operation. In addition to the electrical drives we are also using fluids to carry out these operations.

Fluids are required when we want to have a very huge amount of energy, very huge amount of power which may be for the processing or it may be for holding, the load at it is position. When, we are using fluids such as the liquid or the gases to carry out the operation.

In liquid it may be oil or the water is used or in gases we are using the compressed air for variety of applications. Liquid as we know it is incompressible, but it has high density in comparison with gases. The gases are compressible; however, they are having low density in comparison with hydraulics. Both these forms of the fluid can be utilized effectively to carry out these two operation that is a conveyance and the processing of materials.

In this particular week, we are studying the hydraulics and hydraulic systems, which are required in our purpose that is automation in manufacturing. Basically the word hydraulics has come from Greek. It has two terms; first term is hydrau and the second term is aulos. Hydrau means water whereas, aulos means pipe.

The system which is comprising of a pipe and the system, which is flowing or transporting the water through the pipes. All the aspects related to the flow of water through pipes is made, it may be fluid low pressure, it is application so on and so forth. The aspects or the studies of various elements of water flowing through pipes is called as the hydraulics.

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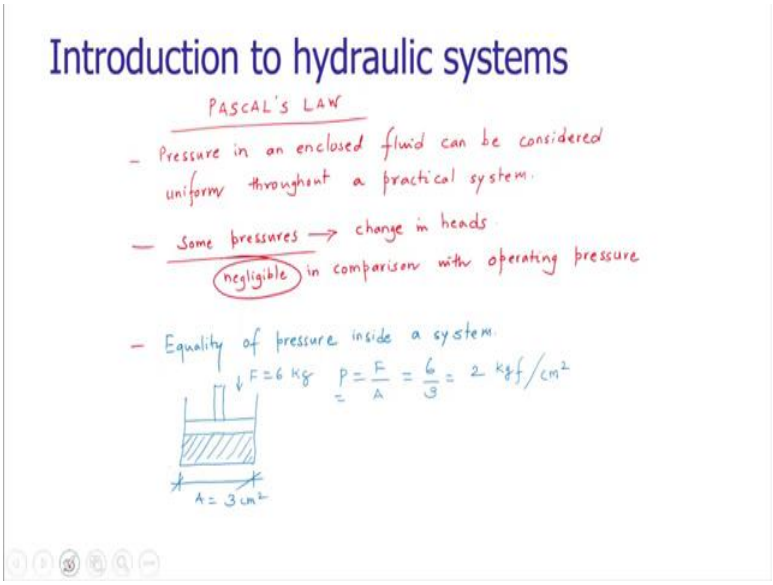

The hydraulic systems are working based upon a law and that law is Pascal's law. The Pascal's law states that, pressure in an enclosed fluid can be considered uniform throughout a practical system. In a practical system, if, we are using an enclosed fluid the pressure can be considered as uniform throughout the entire system.

That has been suggested by the Pascal and which is the basic principle of all the hydraulic systems, but in a typical system we may have some pressures due to the change in the head. We can say there are some pressures that may be generated due to change in heads.

However, this pressures are negligible. They are very small in comparison with the operating pressures. The operating pressures in the hydraulic systems are very huge and very large as we have seen that 150 bar. In comparison with these the heads, which are generating the pressure it is quite small. We can certainly neglect them or in a simplified word we can say that, this equality of pressure inside the system is nothing, but the Pascal's law, equality of pressure inside a system.

To understand it in a better way let us take an example. Consider we are having open system. Now, let us make it close so we are using a container and then the container has a piston and there is liquid, which is filled in the container and over the liquid, we are having a piston.

Consider we are applying a force (F) of 6 kilogram. F is equal to 6 kilogram. And, the area over which we are applying that is considered this area is equal to 3 cmcm^2. What we are getting here? The pressure (P) is equal to:

$$P = \frac{F}{A}$$

and that is coming around 2 kgf/cm^2.

As per the Pascal's law, the pressure of 2 kgf/cm^{2}is uniform inside the system. 2 kgf/cm^2 is the pressure applied by the fluid over valves of the system.

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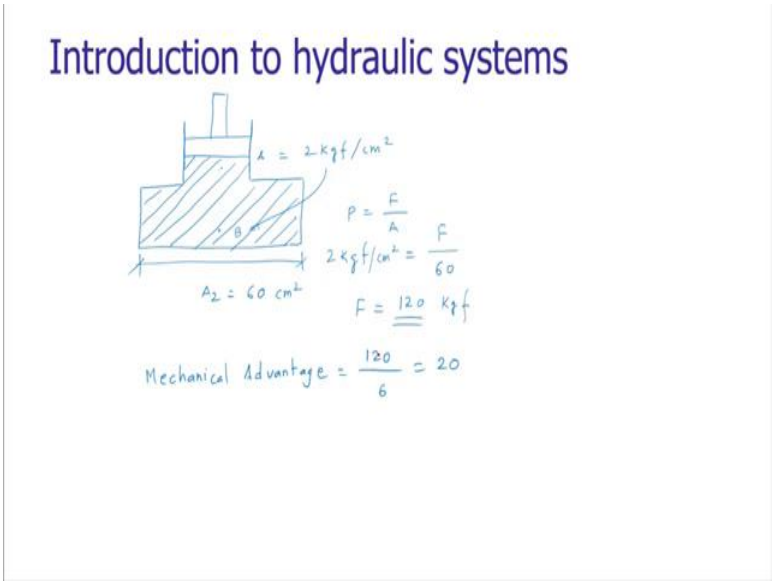

Let us consider we are having the change in the geometry. Consider we are just adding 1 more container to the previous container whose area is larger than the previous container. Let us consider, the same container with the piston arrangement has been enlarged and a fluid is filled inside the system.

Now, as per Pascal's law, the pressure here a point A is 2 kgf/cm^2. The same pressure would be there in a point B, which is in the bottom portion of the system as well. So, here as well the pressure is 2 kgf/cm^2. However, the area has been increased now; the area of application of this pressure is increased.

As the area of application has been enhanced what thing we are getting hereI if I use the same correlation?

$$P = \frac{F}{A}$$

the pressure is 2 kgf/cm^2 , we have need to find out how much is the force, which is being generated.

Area now let us consider it has been increased. The area is increased to around 60 cm^2. If we use the area as 60, the force applied would be around 120 kgf. The meaning is that if we increase the area of application, the force is getting increased. This same principle can be used to carry out our operation.

Here we notice an application of 6 kg at the top surface. The 6 kg at the top surface in container A is generating around 120 kgf at the bottom side of the container. Meaning is that there is enhancement in the application of the load, that we call the mechanical advantage. By application of 6 kg we are generating 120 kg.

The mechanical advantage which is generated here is:

$$\frac{120}{6} = 20$$

. 20 times we have enhanced the input force and this arrangement; this peculiarity can be utilized to carry out variety of operations in the hydraulic system.

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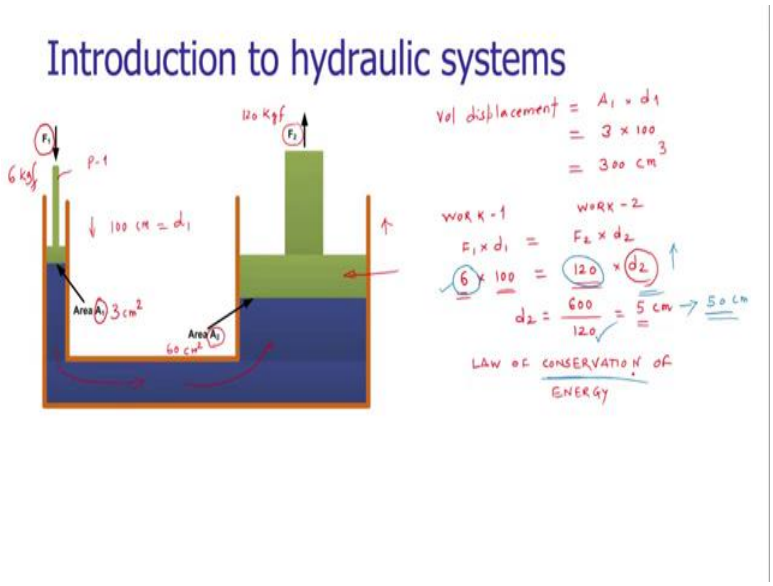

Now, let us see how we can utilize this mechanical advantage in the engineering applications? For this purpose, let us redraw the diagram, which we have seen in the previous slide. We considered F_1 as 6 kgf the area A_1 of 3 cm^2, area A_2 was 60 cm^2 and we computed the force F_2 as 120 kgf.

Now, the system is in equilibrium. If we push the piston P_1, by say around 100 cm in downward direction , there would be a volume displacement, the fluid which is there in this area or the on the left side of the system will get displaced. We would will get displaced and it will go to the right side.

The volume can be computed:

$$Vol\ displacement = A1 \times d1$$

$$= 30 \times 100$$

$$= 300\ cm^3$$

This volume will be applied on the right side of the system due to the displacement of this volume, there would be lifting of the force F_2, there would be displacement of the piston at the part 2. This lifting can be computed by using the law of conservation of energy.

As we know, that whatever the energy that we are spending, whatever the work done that we are doing or whatever the work done we are inputting that would be just converted into the another form. The energy is getting conserved, it is getting just transferred from or it is transformed from 1 form to the another form.

Work 1 = Work 2

$F_1 \times d_1 = F_2 \times d_2$

$6 \times 100 = 120 \times d_2$

$d_2 = 5$ cm

That is interesting to know that, there is magnification of the force from the left to right, 6 is getting enhanced, it is a magnification from 6 to 120 kgf, but there is a reduction in the displacement. The reduction is from 100 cm at the left to the 5 cm of the right side of the system. This follows basically the law of conservation of energy. What is our interest here?

If we notice, we are applying 6 k g and we are generating 120 kgf force in the system in the other part of the system; that means, there is a magnification; however, the displacement is less. To have the increase in the displacement to have the desired high level of the displacement for example, the 5 cm we are expecting to increase that to the 50 cm.

Meaning is that, to generate a displacement of 120 kgf of the force from 5 cm to the 50 cm. In that proportion we have to apply the pressure that in that proportion, we have to apply the input energy. But our cylinder is small, 6 kgf force we are applying. The system input system is able to apply only the 6 kgf. In that case we have to increase the displacement.

Instead of having only 1 time application of 100 cm, we have to apply around 10 times application of the 100 cm. Means the 10 strokes fluid is to be pushed in the right side of the part of the system to get the 50 cm displacement of the F_2.

That same principle is applied in the hydraulics. We are making the system compact, we are making the input compact, but we are applying that small input for number of times. And, that increase in the frequency of application of the input will be generating the desired results. We can have a small system which is giving the input of 6 kg, the displacement is 100 cm, but it is producing a result of 120 kgf, the displacement is small.

We push in for 10 times of this 6 kgf for 100 cm stroke at the left side of the system, it can easily generate a 50 cm displacement of 120 kgf of the load. A small system is driving a big system. The small portion of the system is driving a big system to the application of the energy would be constant.

We are conserving, we need the energy only the thing is that we can have a system, which can be easily operated easily handled. That is nothing but the hydraulic system. Let us look at what are the various components of the hydraulic system in our coming slides.

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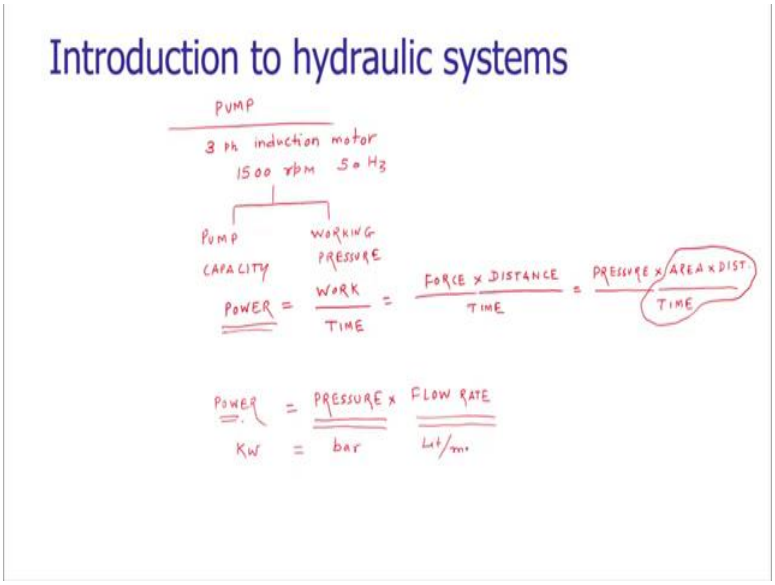

The main element in hydraulic system is the hydraulic pump. In general the hydraulic pump is driven by a 3 phase induction motor, which we generally operate at 1500 rpm and at 50 Hertz. The pumps are characterized or the pumps are specified by using 2 parameters; the first one is pump capacity and the second one is the working pressure.

In general we are computing the power as the work done per unit time. The power which is being generated by mechanical system is nothing, but the work per minute time work divided by time, as we have seen that the work done carried out by a hydraulic system is nothing, but the product of force and displacement.

Force we know that, it is product of the pressure and area of application, or here we can just write:

$$Power = \frac{Work}{Time} = \frac{Force \times Distance}{Time} = \frac{Pressure \times Area \times Distance}{Time}$$

If we consider the product of area and the distance is nothing, but the volume of the fluid that is getting displaced. Thus we can write:

$$Power = \frac{Pressure \times Area \times Distance}{Time} = \frac{Pressure \times Volume}{Time}$$
$$= Pressure \times Flow\ rate$$

Hence, the power capacity or the power requirement or the powers characteristic of a hydraulic system is the pressure being handled by the hydraulic system and the flow rate. The pressure is the working pressure of the system and the flow rate is it is the capacity the pump capacity. Basically, the power is given into the kilowatt, the pressure is defined in bar and the flow rate is defined into the litre per minute.

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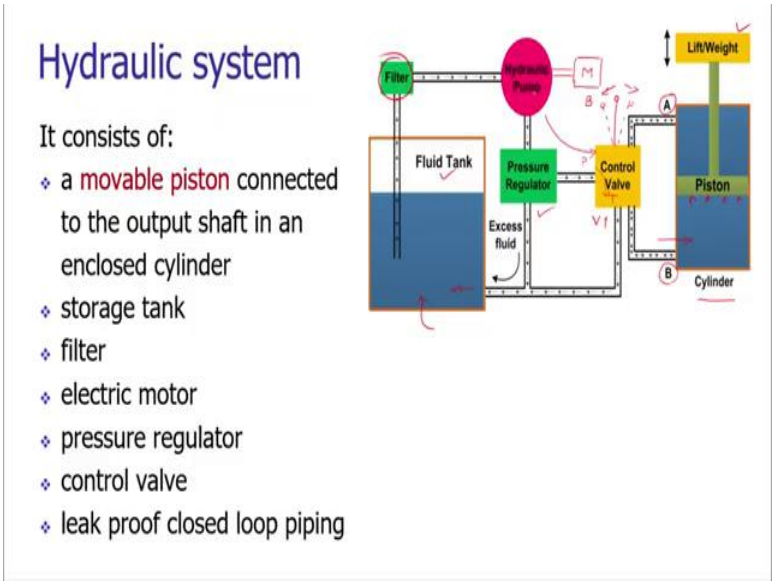

Let us look at what are the various elements of a hydraulic system. We have seen that in general the hydraulic systems are used to apply the load we have or we have to hold. The load on our screen, we can see a schematic, where a task is there and that is the task of lifting a weight, task of lifting a load.

For that purpose, we are using a piston cylinder arrangement, the actuator and the weight is applied over here, weight is applied over a piston cylinder arrangement. We need the pressurized fluid and that pressurized fluid is stored in a tank and the hydraulic pump is drawing the fluid from the fluid tank and that will put in the piston cylinder arrangement to get the required work done. It may be the lifting or the lowering of the load.

The hydraulic pump is managed or it is driven by motor, we need electrical motor. The hydraulic pump is drawing the fluid from the fluid tank, it is increasing it is pressure and that

pressure will be applied at the bottom portion of the piston, to increase the extension of the piston rod.

For that purpose, to have the control of the direction of fluid flow, we need certain arrangement and that is nothing but the control valve. We can control the direction by using a control valve, we can change the direction of the fluid flow by operating the valve.

We can have the three position control of the control valve. Let us considered control valve V 1 is at it is the normal position that is the closed position. Tthere is no fluid which is flowing in port A and there is no fluid which is flowing in port B. If, we want to raise the load, so then you can just operate the valve, so you can operate the valve to open the port B.

As you open the port B the fluid is flowing at this side and we can lift we can lift or we can raise the load in this case. To lower the load, we have to operate the side B of the control valve, so that the pressurized fluid will be applied on the other side of the piston and in this way we can lower the load.

If, we are at the central position at the normal position and the system pressure will increase, because a continuous pressurized fluid is being flow in inside the system due to the continuous operation of the hydraulic pump. That increase in the pressure will definitely harm the system.

For that purpose we have to spill out the excess pressure pressurized fluid from the system. Ffor that purpose we are using a pressure regulator. In this case, if the fluid pressure is more than the critical pressure the excess fluid will be passed through the pressure regulator valve and it will get back to the fluid tank.

When the control valve it is normal position, in that case as well there is a port, that is a tank port, the from the power port we are getting the pressurized fluid. And, that pressurized fluid will directly be passed to the tank port through which the excess pressurized fluid will be taken back to the fluid tank.

In this way there are various elements those are helping to have an efficient operation of the hydraulic system. In hydraulic system we also face the problem of the dirt or we also face the problem of inclusion of some dust particles. That dirt or the dust particles will harm the system.

For that purpose we have to filter the operating fluid that is whatever it may be the water or it may be some special oil. We have to filter it out to protect or to enhance the efficiency of the hydraulic pump.

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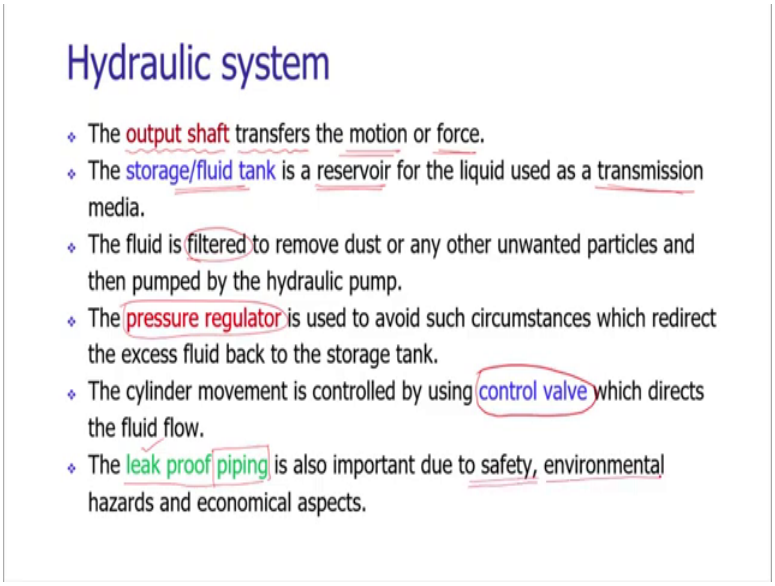

Let us summarize. In hydraulic system we need an output shaft, which is used to transfer the motion or the force. There is a reservoir and that reservoir is storing the fluid, which is used as the transmission media.

We need to filter out the dust or the unwanted particles that are to be pumped inside the system. We need to have a pressure regulator to avoid the circumstances in which there may be the failure of the system due to the excess pressure.

There is a control valve and that control valve is controlling the direction of fluid flow inside the system. In addition to the controlling elements, we also need the transportation elements and these are the piping. The piping's must be leak proof to have the high efficiency of the hydraulic system. The piping's should be leak proof to have the safer operation and less environmental hazards.

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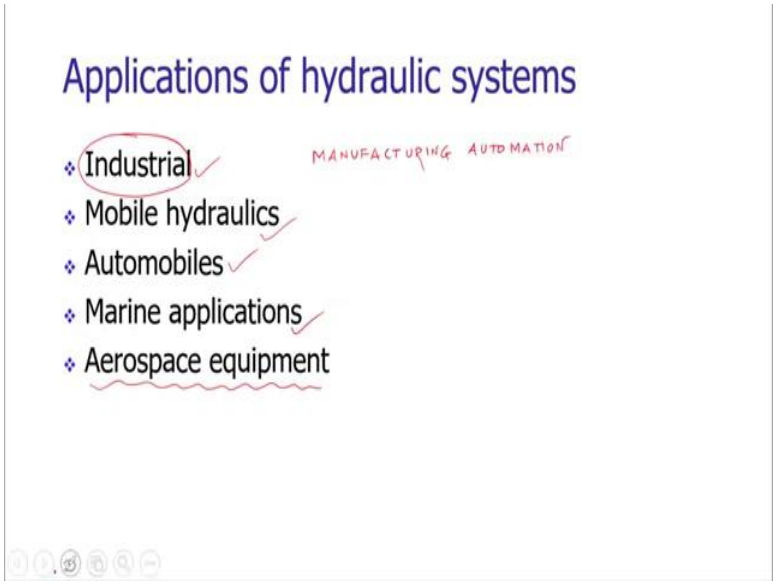

The hydraulic systems have variety of applications in manufacturing industry, in mobile hydraulics. It is meaning an excavators or the earth moving equipment, they are working based on the hydraulics. In automobiles in a shock absorber, we are using the hydraulic systems.

In marine applications also we are using the hydraulics; in aerospace equipment also we are using the hydraulic systems. As per as the course is concerned we are more focused upon the pumps or the elements which are required for the industrial manufacturing. In the context of this present course, we are more focused upon the application of hydraulic systems in manufacturing.

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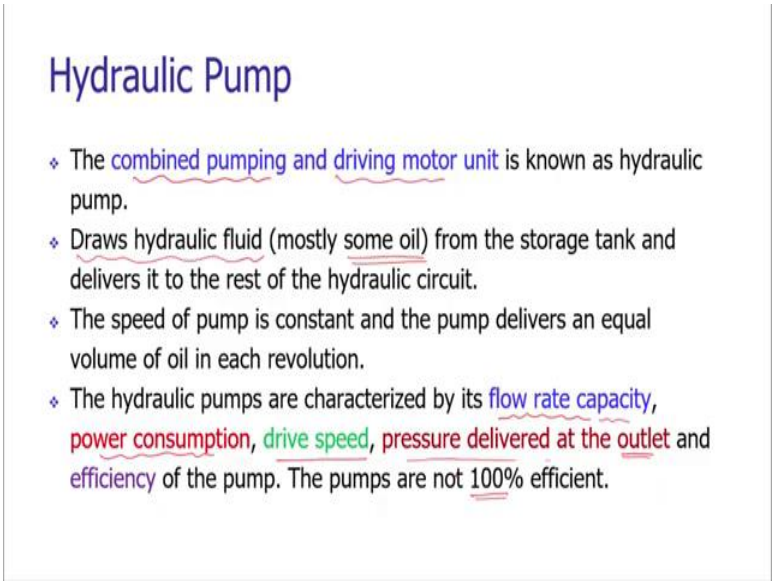

The hydraulic pump is the combined pumping unit; it is having the driving motor as well. As we have seen that it is drawing the hydraulic fluid mostly some oil from the tank and then it is delivering that to the rest of the hydraulic circuit.

In positive displacement pumps the speed of the pump is constant and the pump is delivering an equal volume of oil in each revolution, but in hydrodynamic pump the volume of the delivery is varying it is not constant.

In general, the hydraulic pumps are characterized by the flow rate capacity, power consumption, drive speed, pressure that to be delivered at the outlet, and in general the hydraulic systems are having very good efficiency, but certainly not the 100 %t efficiency.

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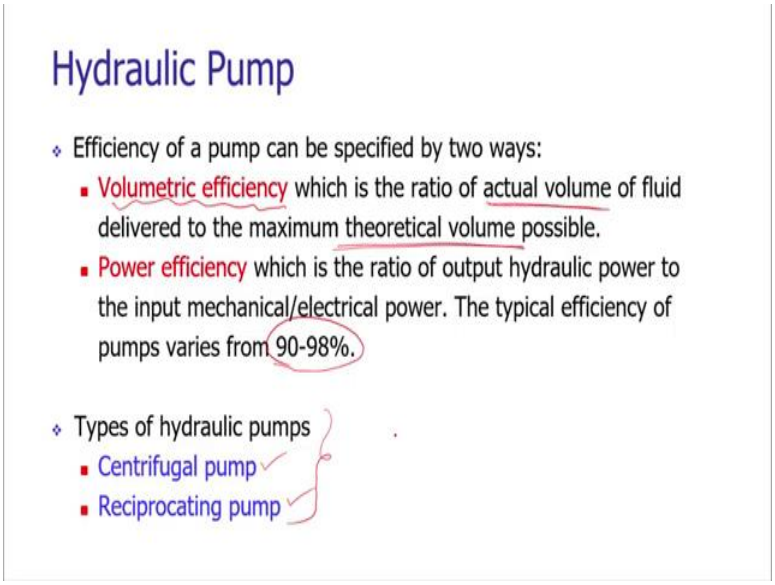

We can define the volumetric efficiency of a hydraulic pump as the ratio of the actual volume of the fluid delivered by the system to the theoretical volume possible. By theoretical we are computing based upon the correlations that we have seen in the previous slide, but in actual sense these things are not possible, due to the inherent problems of the systems due to certain. Errors due to having the incapability or the manufacturing errors of the pumps itself.

Volumetric efficiency will not be 100 %. I it could be less than the 100 %. The power efficiency is also not 100 %, but the hydraulics they are generating around 90 to 98 %t of the power efficiency. The power efficiency is defined as the ratio of the output hydraulic power that we are getting to the input mechanical or the electrical power.

In general, two types of pumps are used these are the centrifugal pumps and the reciprocating pumps, we will be studying about them in the next slides and in detail in the next lecture.

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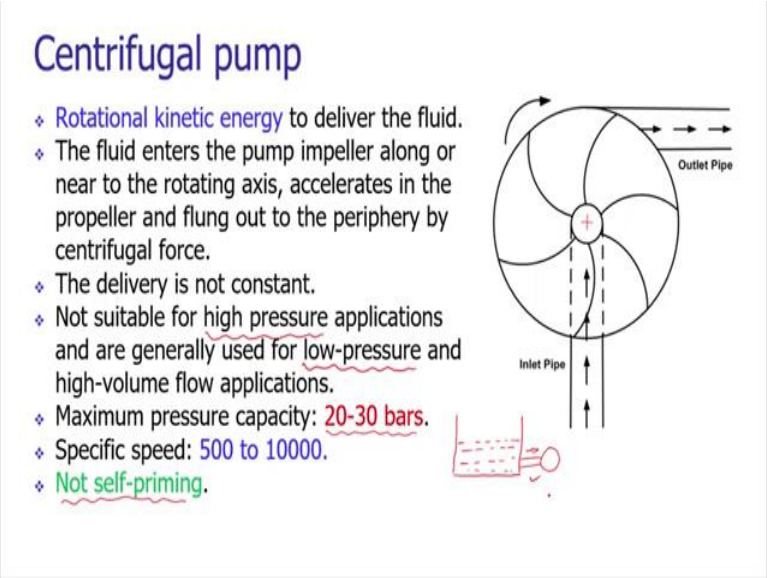

The centrifugal pump is very widely used in the domestic water distribution, domestic water handling. It is using the rotational kinetic energy to deliver the fluid the, typical arrangement of the centrifugal pump can be seen on your screen.

There is an inlet pipe, there is a circular disc or over the circular disc, we are having the impellers and there is a output pipe. The fluid is entering the pump impeller along or near to the rotary axis. This is the axis of the impeller and the fluid is coming at the center or near the center of the rotating disc which is having the impellers.

The impellers are driven by an electric motor, a rotary motion is given to the impeller disc. And, as the impeller disc is rotating due to the centrifugal force the fluid which is coming inside the system will be plunged out. It will be moved in a radial direction outward direction and in this way we are increasing the pressure of the fluid. The delivery or the volume delivery of the centrifugal pump is not constant it is varying.

It is not that suitable for the high pressure applications, these are not consistently developing the pressure as well. So, these are in general used to deliver the high volume fluid at the low pressure. In general, we are using the centrifugal pumps for around 20 to 30 bars. The centrifugal pumps are not self-priming. Ppriming is a process where the pumps are having the capability to get in the fluid inside the system.

Consider there is a tank and the tank has the fluid and there is a pump, which is attached here this is the pump, the pump by the gravity itself. There is no need to push, or there is no need to have any mechanism, to get the fluid inside the pump, that is called as the self-priming.

This is fine way in case of this kind of situation when the level of the fluid, inside the system and the level of the pump inside the system at the same or the pump is at the lower level than the storage tank.

In case the pump is located at certain height. There is some lifting is to be carried out, the initial lifting of the fluid at the start of the operation of the pump is called as the priming. That facility or that capability is not there in the centrifugal pump. We have to have the manual or additional mechanism to prime the pump to add the extra fluid inside the pump.

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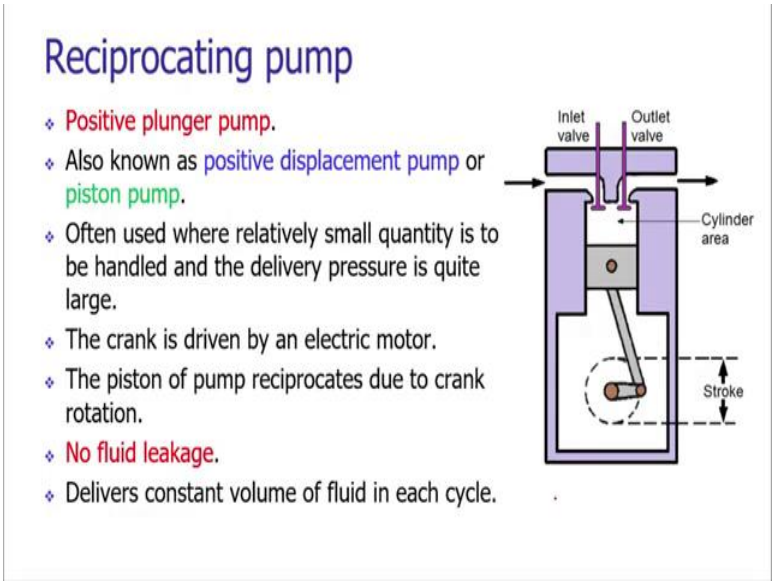

The second broad category is the reciprocating pump or the second important pump is the reciprocating pump, that is called as the positive plunger pump as well. These kind of arrangements are producing small quantity of the pressurized fluid in each stroke the arrangement can be seen on our screen.

It is having a cylinder area there is a piston, the piston is having connecting rod, then there is a crank, crankshaft, at the top of the cylinder there are two openings. And, these two openings are having valves, that is the inlet valve and the outlet valve the inlet valve has the inlet port and the outlet valve is having the outlet port.

The crankshaft is rotated by using an electric motor as the crankshaft is rotating the crank is also rotating about the axis of the crankshaft. And, the rotary motion of the crank will be converted into reciprocating motion of the piston. As a piston comes down. This is called as the top dead center of the piston, cylinder arrangement and this is the bottom dead center.

As the piston is moving from TDC to BDC, the fluid will be drawn inside the cylinder area and during the returns stoke, the half stroke that is from BDC to TDC the pressure on the fluid would be increased. That pressurized fluid will pass through the outlet valve and it will be taken to the application through outlet port.

The piston cylinder arrangement inside the reciprocating pump is having a smaller volume that is why the quantity of the pressurized fluid would be less in a reciprocating pump.

We cannot have very bigger size or larger size of the reciprocating pump, the construction or the manufacturing of such a huge reciprocating pump is difficult. The advantage of the reciprocating pump is that the leakage is less and the systems are delivering constant volume of fluid in each cycle. By having a multiple number of such cycles, we can deliver in a precise amount of the fluid for our application.

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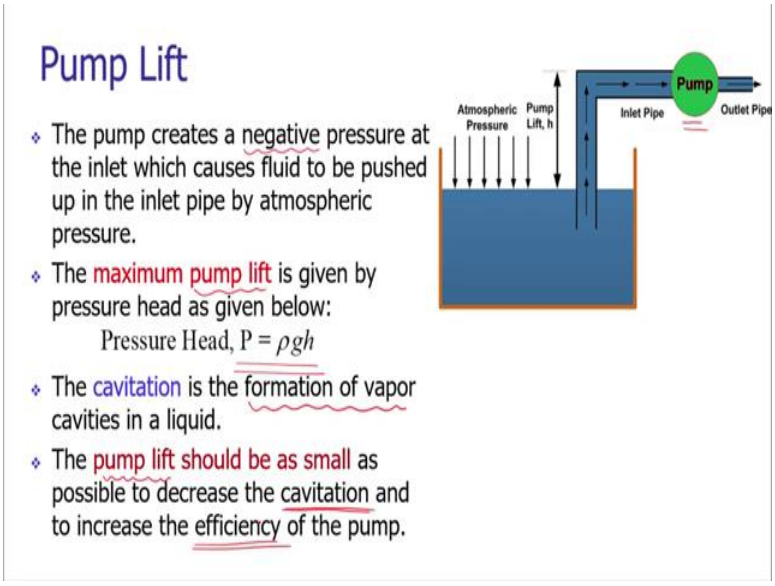

As mentioned, in general the pumps are located or they may be located at a certain height from the fluid level inside the tank. In this situation, the pumps are creating the negative pressure, which is causing a vacuum and that vacuum is drawing the fluid from the fluid tank. That

negative pressure which is lower than the atmospheric pressure will make the system will make the atmospheric pressure to push the fluid inside the inlet pipe and in this way we can have the start of the pump.

The maximum pump lift is generally given by the pressure head. That pressure head we can easily compute by the correlation:

$$P = \rho g h$$

where,, ρ is the density of the fluid, g is the gravitational constant and h is the pump lift. When are we working with the pumps? Lot of heat energy is generated due to the high frequency operations particularly in the reciprocating pumps.

Since the volume is less, we have to run the pump at a very high rpm and when the high rpm pumps are working the friction would be more the thermal energy generated would be more temperatures are very high. These high temperatures are generating the vapors, this high temperatures are converting the liquid into it is vapor form. That process is called as the cavitation process.

And, this cavitation is leading the problem. It is creating the problem, it may also have the failure of the system. To have the lower problems inside the systems, it is recommended to have the lower pump lift, and that will lead to lower cavitation problems and enhancement in the efficiency of the pump.

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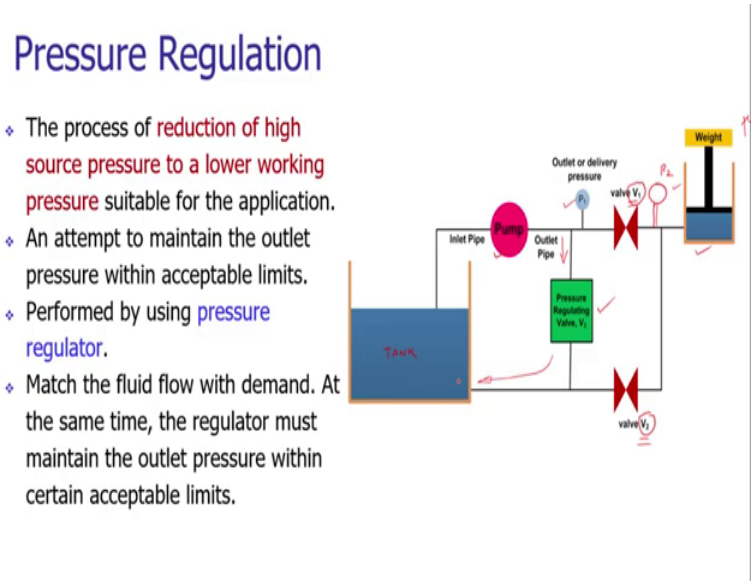

In applications of the hydraulic system, many a times we need to have the holding of the weight for example the hydraulic clamps. The hydraulic clamps the hydraulic clamps the continuous pressurized fluid is to be applied, but that continuous application is leading to the increase in the pressure of the system, the pressure may be more than the operating pressure of the system.

For that purpose, we have to regulate the pressure inside the systems. Let us take an example, which is there on our screen. There is a system to lift the weight and it is having the tank, there is a pump and the piston cylinder arrangement.

There are two pressure gauges P 1 and P 2. The pump is drawing the fluid from the tank and it is pumping inside the piston cylinder arrangement. So, the valve V 1 and valve V 2 are controlling the flow of the pressurized fluid inside the system. The pressure gauge P 1 and P 2 are monitoring the pressure inside the system. Pressure gauge P 1 is monitoring the pressure at the outlet of the pump and the pressure gauge P 2 is monitoring the system at the load.

We are having two control valves V 1 and V 2. If, we operate valve V 1 and if we if we close valve V 2, the pressurized fluid is applied inside the piston cylinder arrangement and we can have the lifting of the weight. If, we close valve V 1 and the valve V 2 is open then we can have the lowering of the weight.

Let us consider valve V 1 and V 2 both are closed. And, the pump is the motor is on the pump is also on there is a continuous flow of pressurized fluid inside the system. This continuous flow is increasing the pressure inside the system. And, to regulate that pressure to reduce that high pressure to the working pressure, we are using the pressure regulating valve.

The pressure the pressure regulating valve is non-return type. It is operating; it is allowing the fluid that to flow in only one direction, but it will open at certain threshold value. And, that threshold value is set by the operator can be set by the operating person, when valve V 1 and V 2 are closed and the pressure inside the system is very high.

In that case the valve V 3 will open and the excess fluid will spill through this valve V 3 and it will be get back to the tank. In this way, we can safeguard the system by using a pressure regulating valve.

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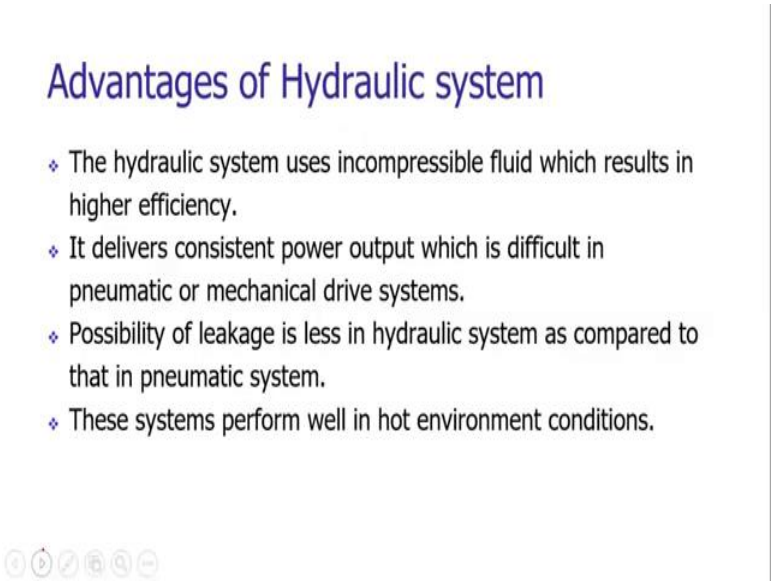

Hydraulic systems offer us a very good advantages the hydraulic systems are having higher efficiencies we are using incompressible fluid, that is resulting in a very good efficiency. The hydraulic systems are delivering consistent power, which is difficulty in the other prime movers such as pneumatics and mechanical drive systems.

The possibility of leakage in hydraulic systems is less in comparison with the pneumatic systems. And, the important advantage is that in hot conditions, when the temperatures are high, in that conditions as well hydraulic systems perform well in comparison with the other system that is pneumatic.

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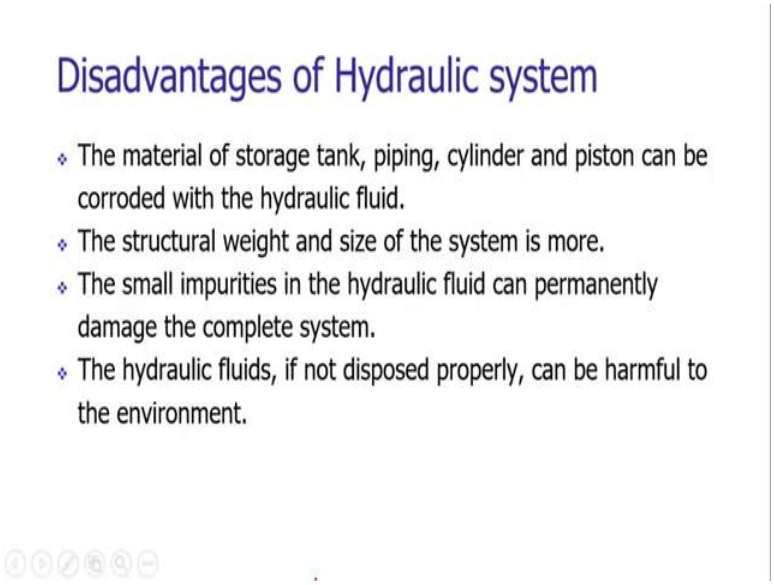

There are certain limitations to the hydraulic system as well the hydraulic systems are quite bulky, they involve, they comprise of many elements such as tanks, piping's, cylinder, piston and these elements are in contact with the hydraulic fluid. There may be chances of having corrosion of the hydraulic fluid, there may be having corrosion of all these elements. We have to protect this elements we have to have the regular maintenance of these mechanical elements.

As number of elements are more, the size of the hydraulic system is also quite high these systems are bulky. In case there are certain impurities although they are in small quantities that made permanently affect the performance of the system. The hydraulic fluids which are the integral part of the hydraulic systems, if we do not dispose them properly that may lead to the environment hazards.

We have to take care about the disposal proper disposal of the hydraulic fluids. This is a limitation because we have to invest the time energy and money for the proper disposal of the hydraulic fluids. Well let me summarize the lecture 1, we started hydraulic systems in this week.

In the first lecture of week 9, we studied the fundamental concepts of the hydraulic system. The hydraulic system worked on Pascal's law, we have seen the definition of the Pascal's law. And, it is application how it is related to the hydraulic systems? After that, we studied various elements and the construction of elements of the hydraulic system.

There are certain applications which are very useful in automation industry that we have seen, later we had a discussion on the advantages and limitations of the hydraulic system. At the end we had a look at the classification of hydraulic systems.

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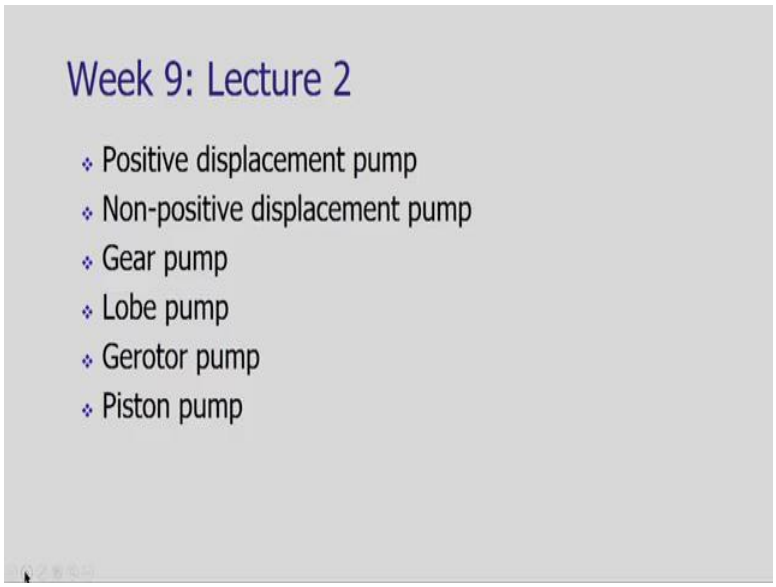

In lecture 2 of week 9, we will study various types of pumps the positive displacement pump and non-positive displacement pump. A variety of pumps are being utilized in manufacturing industry which are the reciprocating pumps, gear pump, lobe pump, gerotor pump and many more. We will look at the important types of pumps which are useful in the industry.

Automation in Manufacturing
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Lecture – 29
Hydraulic pumps

I welcome you to the lecture 2 of week 9 of Automation in Manufacturing. In this lecture we will be studying the Hydraulic Pumps.

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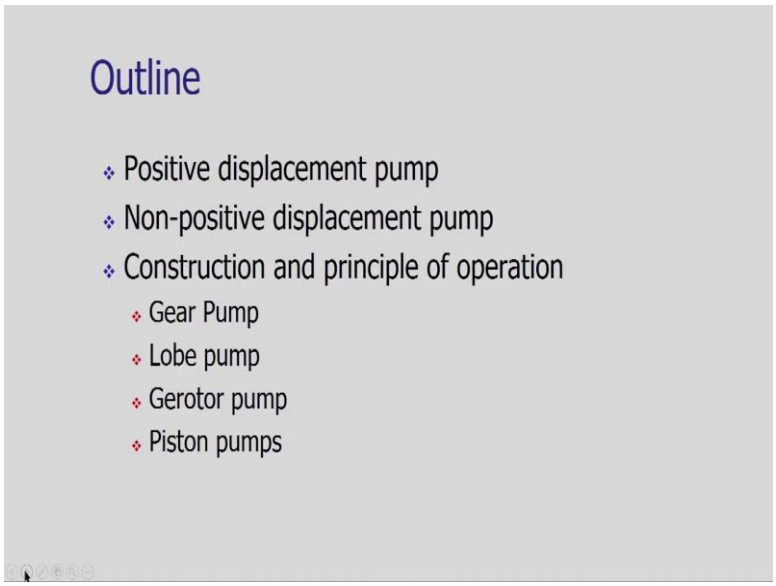

The outline of the lecture is as follows. At start of the lecture, we will have a discussion on the classification of the pump. Basically, the pumps are classified into two classes. These are positive displacement pumps and non-positive displacement pumps.

We will study various pumps in the perspective of their construction, principle of operation, advantages, limitations and applications in the automation. Some of the pump pumps the gear pump, lobe pump, gerotor pump and the piston pumps.

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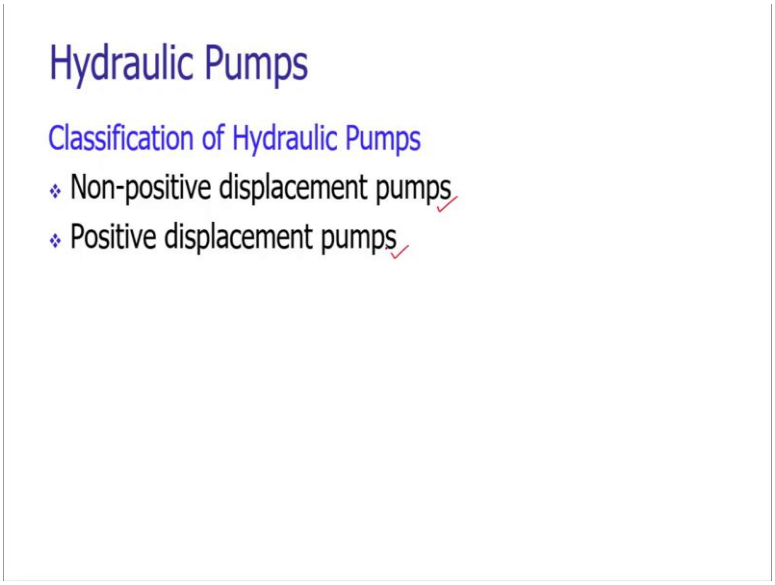

So, let us begin. The hydraulic pumps are basically classified into two groups. The first one is non positive displacement pumps and the second one is positive displacement pumps. Let us look at the meaning of non positive displacement pump and positive displacement pump. Also we will look at what are the various types of these pumps are utilized, their construction and working.

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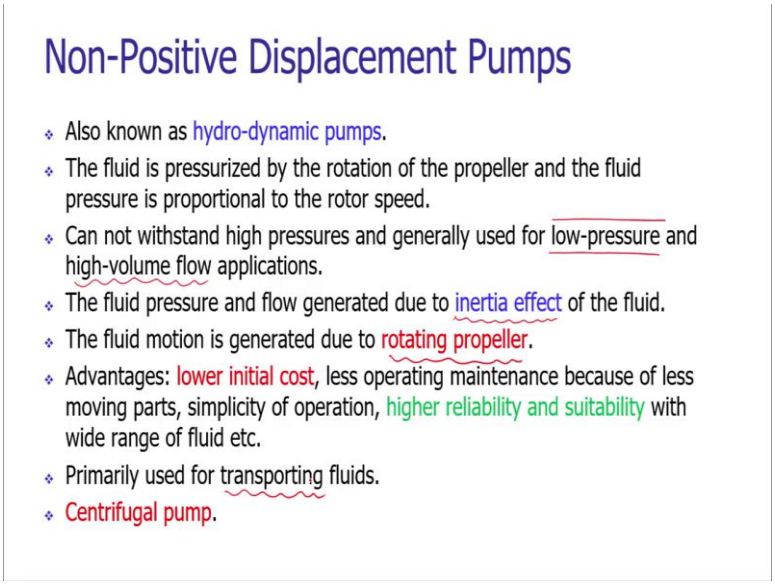

The non-positive displacement pumps are also called as hydrodynamic pumps. In this pumps, the fluid is being pressurized by the rotation of a propeller. The construction is having a

propeller, the rotation of the propeller i.e. the centrifugal force is generated and that centrifugal force will be utilized to increase the pressure of the fluid inside the casing. The fluid pressure is proportional to the speed of the rotor.

The non-positive displacement pumps are basically used for the low pressure applications. This pumps are generating very high volume of flow. Basically, the fluid pressure and the flow is being generated by the inertia effect of the fluid, whereas, the fluid motion is generated due to the rotation of the propeller. Motion is generated by the propeller rotation and the inertia of the fluid itself, the weight of the fluid itself is creating the pressure and a flow inside this kind of pumps.

In general the hydrodynamic pumps are utilizing water and they are widely used for the domestic water distribution purposes. These pumps are having low initial cost. Their maintenance is also quite easy because the number of moving parts are less. The construction is simple.

The reliability of this pumps is quite high and they are suitable for a wide range of fluid. It can be a water it can be any sort of oil or chemical. We can easily have the hydrodynamic nature of fluid flow by using this non positive pumps.

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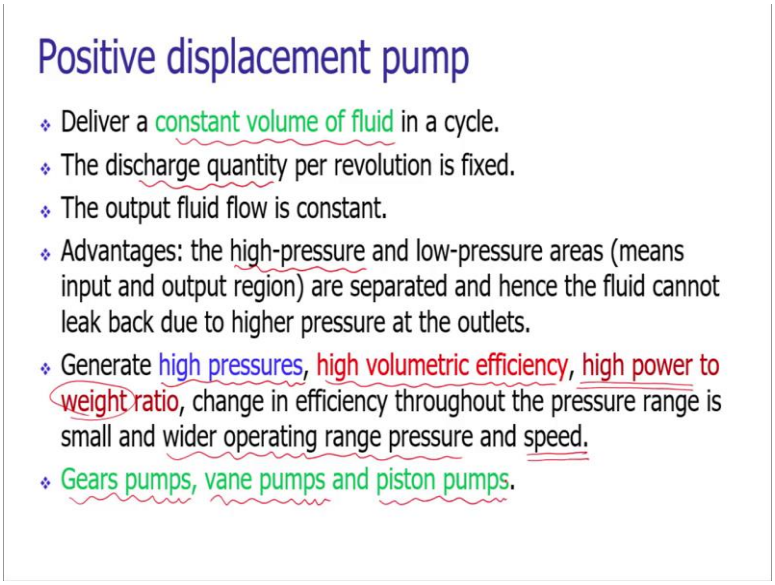

The primary purpose of the non-positive pump is for the transportation is for the conveyance and the best example is the centrifugal pump. The second category of the displacement pump

is the positive displacement pump. These pumps are generating a constant volume of fluid. In many applications we need a constant fixed volume of the fluid in a typical cycle of the pump.

As the constant volume is being delivered we are getting the fixed discharge from this pump. That these are the advantages of the positive displacement pump. The output fluid flow is constant.

In positive displacement pumps there is distinction between the high pressure areas and low pressure areas. Due to these separations the fluid cannot be leaked from the pump area from the casing that is not the case in centrifugal pump. There is no clear cut distinction between the low pressure area and the high pressure area.

Positive displacement pumps are generating high pressures. They do have a very good volumetric efficiency. They are generating high power in comparison with the application of very small weight very small construction. Therefore, we can say that they do have or they do provide high power to weight ratio.

Positive displacement pumps are offering us it is a wide range of pressure and they are offering very good variations in the speed as well. There are various types of pumps being utilized in the manufacturing industry and these are gear pumps, vane pumps and the piston pumps.

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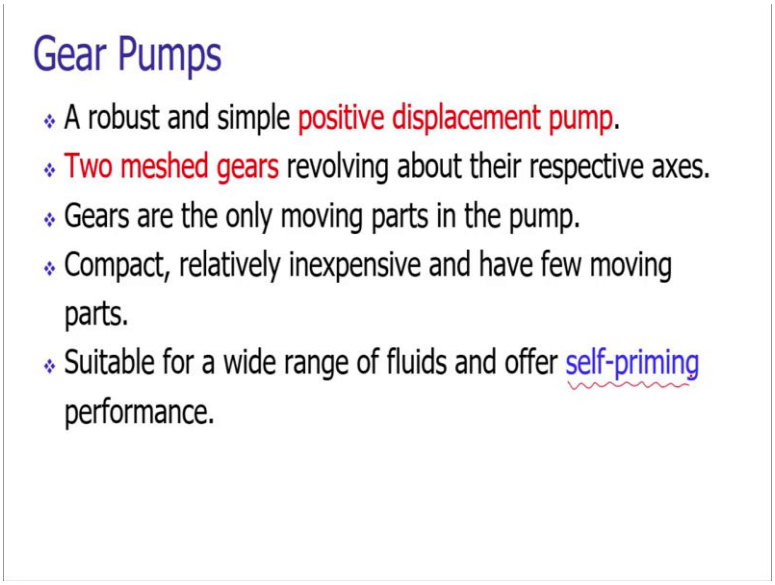

Let us look at the construction working of the gear pump. Gear pump is robust and simple positive displacement pump. As the name indicates, it is having two gears. These two gears are

meshed and they are revolving about their own axis. The both the gears are rotating. These are the moving parts in the pump.

The gear pumps are quite compact and they are inexpensive due to less moving parts. They are suitable for the wide range of fluids and they do have the self-priming performance. They can create a vacuum so that we can get the fluid in.

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Various types of gear pumps are being utilized. These are the external gear pumps, lobe pumps, internal gear pumps, gerotor pumps. And certain applications are there in front of you. The gear pumps are basically used to convey petrochemicals, chemicals, paint and ink resins and adhesives, pulp and paper and the food products as well or the products or the raw material which are needed for the food products.

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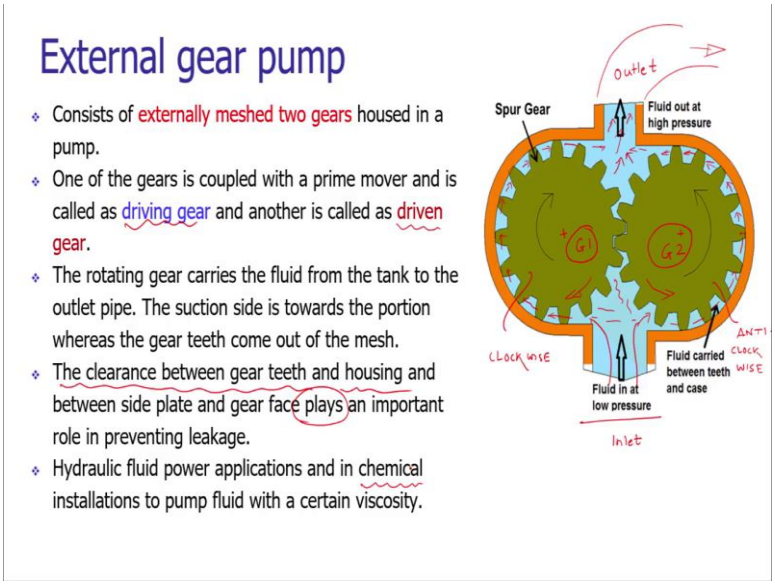

Now, let us look at an interesting configuration of the gear pump that is external gear pump. On our screen you can see there are two spur gears which are meshed together. This is a gear number 1 and we are having the another gear that is a gear number 2. These two gears are meshed and they are assembled in a casing. The casing is having two ports.

The first port is the fluid in port and the second port is the output port. This is the inlet port and this is the outlet port. The gear 1 is rotating in clockwise direction, whereas, gear 2 is rotating in anticlockwise direction. As we can see that during the rotation, some of the gear teeth are getting engaged and they will get disengaged. Here you can notice that the gear teeth are engaged and as the gears are rotating there would be disengagement.

When there is a disengagement a negative pressure is created in this zone. The negative due to the negative pressure the fluid will get driven in. As the fluid is coming inside in the inlet, this gear teeth are driving them. The fluid will become inside in this way and they will occupy the empty spaces in the gear teeth in between the gear teeth and the casing.

The fluid will get occupied in the vacant spaces as the teeth are moving further as the teeth are moving in this direction, the fluid will be pass through the empty spaces. The teeth are driving the fluid along these directions, along the space between the casing and the gear teeth.

As the gear is rotating at a higher speed, the pressure over the fluid would be increased and suddenly at the outlet port the pressurized fluid is getting space to get out of the casing. From

here the pressurized fluid will come out and it will be utilized for the intended load application purposes.

In this way by having the rotation of the gear teeth we can have the generation of pressurized fluid. Out of these two gears, one has been attached to the electric motor and that is called as the driving gear and other one is the driven gear.

The clearance between the gear teeth and housing and between the side plate and their face they are playing the important role in preventing the leakage. Basically in chemical applications such type of gear pumps are widely used.

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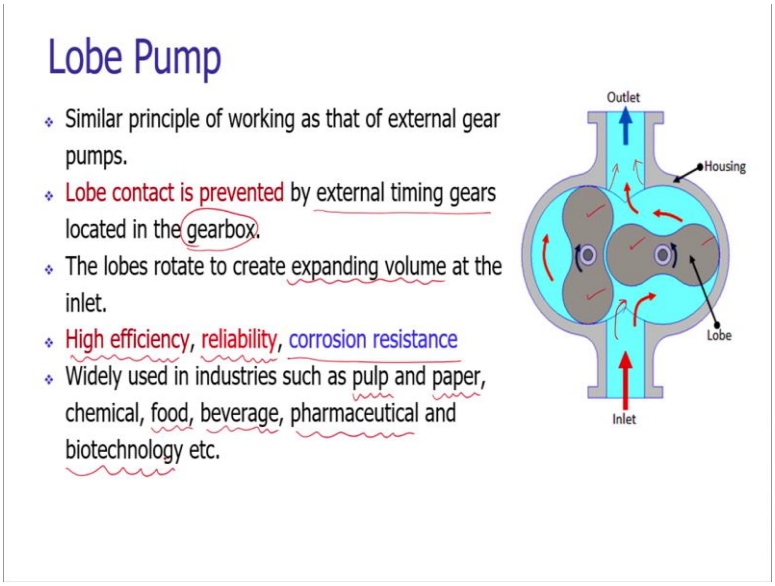

The next variant is the lobe pump. It is you can say the modification of the external gear pump itself. Instead of having many number of gear teeth, the gear teeth profile can be changed into a lobe ship kind of thing. Instead of having many number of teeth we are having only 2 teeth.

We can consider as teeth number 1 and teeth number 2 of gear 1. Teeth number 1 and teeth number 2 of gear 2. The same principle or similar principle as of the external gear has been utilized in the lobe pump itself.

The contact between the corresponding lobes of the two gears is avoided by using the external timing gears. In case the lobe 1 of gear 2 and lobe 1 of gear 1 they will come in contact they may be there may be collision and that will lead to the ceasing of the lobe pump itself, it will be a failure. That contact has been prevented by using an external timing gears, which are

located in the gearbox of the pump. The lobes are rotating and they are generating expanding volume.

As the volume is getting expanded, there would be drop in pressure and the drop in pressure will get the fluid inside the casing. And as the lobes are rotating that low pressure fluid will get driven by the lobes and they are increasing its pressure. The high pressure fluid will be moved through the outlet.

The lobe pumps are having quite good efficiency. The efficiency is quite high. They are reliable in operation. The lobe pumps are basically used to handle pulps and papers they are able to handle the semi solids. Food items, beverages, pharmaceutical and biotechnology products are also being handled by the lobe pumps.

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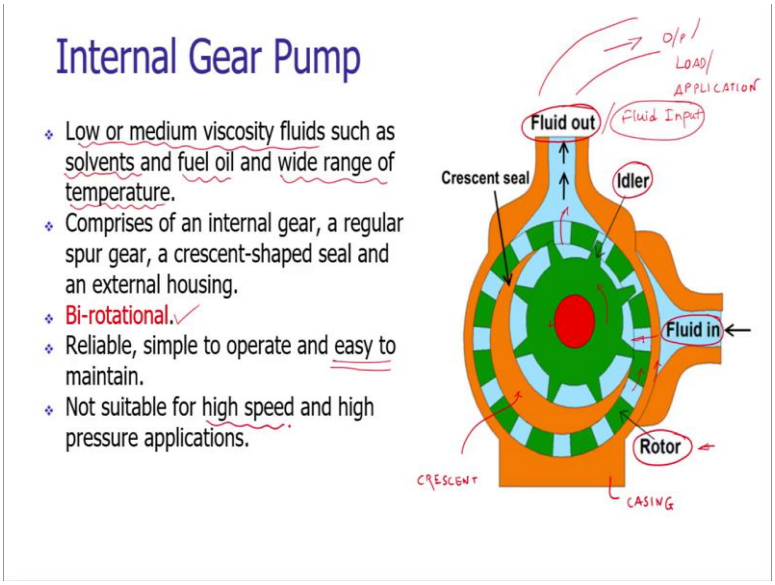

The next variant is internal gear pump. In internal gear pump the construction is little complex. Here we are using a casing. This is the casing of the internal gear pump. There is a rotor. The rotor is having the slots and that slots can get the fluid. There are two ports; fluid in port and the fluid out port.

We can interchange the fluid in and fluid out. The internal gear pumps are bidirectional by rotational. There is a crescent. Crescent is a special or it is a specially shaped mechanical element, which is kept stationary inside the housing.

The crescent will help to get the required generation of the pressure inside the internal gear pump. In addition to the rotor gear or rotor element we are having an idler element, idler gear. The rotor is being driven by the electric prime mover. As the rotor is rotating which is meshed with the idler gear, the crescent is creating an offset between the axis of the idler gear rotation and axis of the rotor gear rotation.

This crescent as you can see that there is offset, the rotations the rotational axis are having an offset. As the rotor is rotating, we can notice here the gears are getting disengaged and due to the disengagement of the gears there is a creation of negative pressure. The fluid will come inside the gap between the idler gear and the rotor gear.

As the rotor is rotating further, it is driving the idler gear as well. As there is a fluid inside during the rotation of the rotor along with the idler gear there would be application of compressive force on the fluid itself. Both the gears are rotating, the fluid will be moved along the radial direction. Gears are rotating in this direction, the rotor is rotating, it is driving the idler gear. During the disengagement the fluid will come inside and during the engagement it will be pressurized.

Fluid will be pressurized and that fluid pressurized fluid would be released wherever it is getting the empty space. When the pressurized fluid will come at the fluid output port, the pressurized fluid will be taken out it, it will take the path of the output port and it would be applied at the lobe.

The construction of the internal gear pump is complex. It is quite difficult to generate a very precision crescent because the shape of the crescent, it itself is the crucial element in the efficient pressurization of the fluid by using the internal gear pump. There are basically two rotating parts, but the number of contacts are more. The wearing and tearing of the internal gear pump is quite high. The friction is very high because the number of contact points are quite large.

The gear pumps are basically used for low to medium viscosity fluids such as the chemical solvents, fuel oils and we can handle these solvents at a wide range of temperature. At high temperature as well the internal gear pump can work. So, as I mentioned it is a bi-rotational arrangement. Either we can have this as a fluid output port or we can have this as fluid inlet port as well.

We can interchange this. The internal gear pump is so, reliable, simple to operate and easy to maintain. The internal gear pump is reliable and it is simple to operate and it and it is easy to maintained.

Although the construction is quite complex and there is a wear and tear, but the maintenance of the internal gear pump is quite easy because there are only two elements, if we just remove the idler gear or the rotor gear and we can easily clean it out. However, the internal gear pumps are not suitable for high speed application and the high pressure application.

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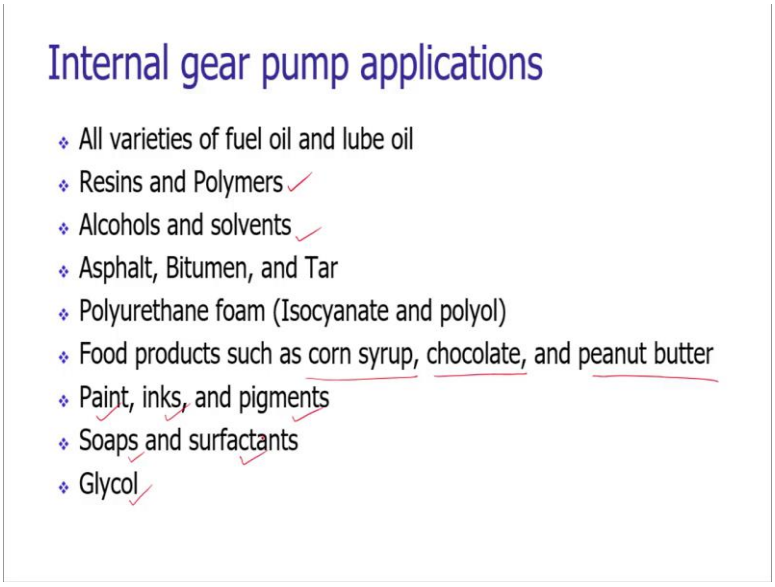

The internal gear pumps are widely used for all varieties of fuel and the lubricating oils. They are used for resins and polymers, alcohols and solvents, bitumen tar, various types of foams; food products such as corn syrup, chocolate and peanut butter. This pumps are also utilized for transportation of paints, inks and pigments. They are also used for soaps and surfactants of the detergents which are used for the cleaning purposes. They are also used for the glycol.

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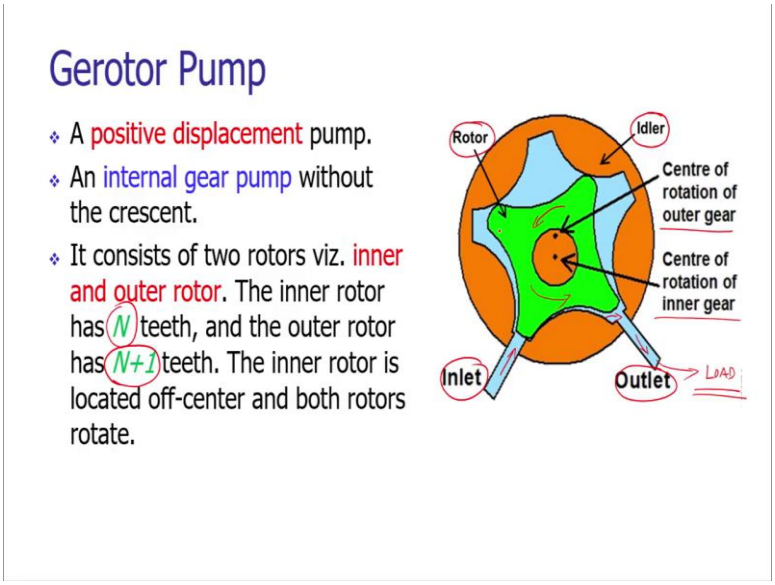

The next positive displacement pump is gerotor pump. As we have seen, the crescent is generating the pressure difference. It is helping to get the fluid in the pump, it is helping to increase the pressure of the fluid, but manufacturing of crescent, assembly of the crescent is little difficult, little complex.

Instead of having a crescent, can we have another configuration which will do the same work of the internal gear pump? That is possible by using the gerotor pump. If we look at the diagram of the gerotor pump, we will find that there is a idler gear and there is a rotor gear. If we look at the number of teeth on the rotor gear and the idler gear, we will notice that the rotor has 4 number of teeth whereas, the idler is having 5 number of teeth.

The difference in number of teeth is working as the crescent. The difference is working or it is carrying out the function of the crescent which was there in the internal gear pump. If it is said that the number of teeth that to be there on the inner rotor are N then the number of teeth that to be put on the idler gear as N+1.

Now, how it is helping to get the required work done? If we look at the construction you will find that there is offset between the center of rotation of the outer gear and center of rotation of the inner gear.

These two points are not concentric and this eccentricity is also helping to carry out the function of the crescent. There are two ports that is the inlet port and the outlet port. They are doing the

regular duty of taking the fluid inside the pump and to deliver the pressure as fluid to the load or the application.

The fluid is coming inside; the rotor is rotating. As the rotor is rotating it is driving the idler gear as well. If we notice here, if we consider the rotor is rotating in anticlockwise direction. It is coming in contact with the idler gear, it is driving the idler gear and as it is driving the idler gear there may be disengagement of the rotor gear with the idler gear.

There may be disengagement of the rotor teeth with the idler teeth and that disengagement is creating a gap its creating negative pressure at the inlet. Due to that negative pressure the fluid will be coming inside, but the rotor is continuously rotating as the fluid is getting inside the rotor driving that fluid inside the gap of the rotor and the idler.

The gap is small. That is why there is increase in a pressure of the inside fluid. The rotor is driving the idler and it is also driving the fluid with increasing the pressure. As the pressurized fluid will come at the opening of the outlet port through the opening, the pressurized fluid will come out of the pump and that will be applied to the load. As the rotor is continuously rotating there is a disengagement.

Due to the disengagement of the teeth the fluid will come inside. As the teeth are gradually getting engaged, the fluid will be pressurized and it will be conveyed further to the outlet port. In this way the difference in number of teeth is driving the fluid, it is pressurizing the fluid and we are getting the required output at the outlet port.

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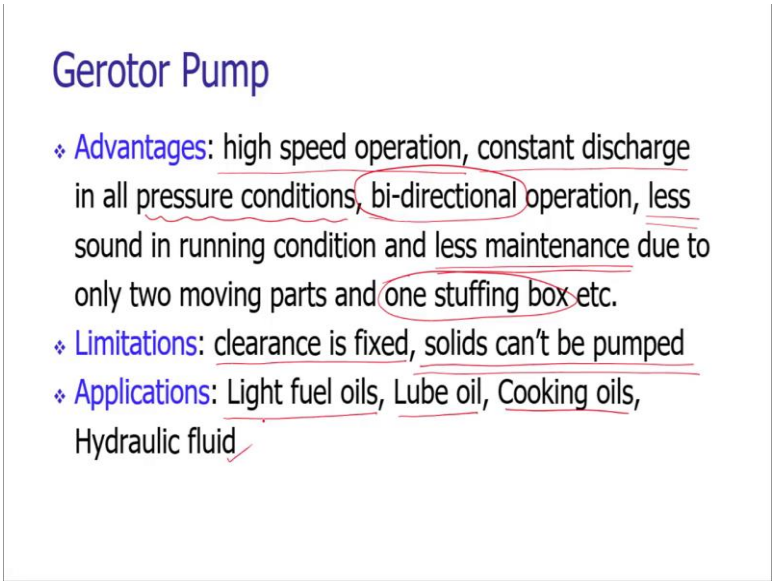

Gerotor pump offers various advantages and these are on our screen. They are providing us high speed operation; they generate constant discharge in all pressure conditions.

We can have the bidirectional operation, the in a clockwise or anticlockwise direction we can easily carry out the operation. The sound is less and the maintenance is also less. The construction is compact. They are accommodated in a stuffing box. However, gerotor pump has certain limitations.

The clearance is fixed. We cannot modulate. We cannot vary the eccentricity. We cannot vary the offset between the rotation. These forms are not suitable to pump the solid or the semi solid fluids. If the solid is like cherries or the tomatoes or the slurry of cherry or tomato in the food processing industry, it is very difficult to convey them.

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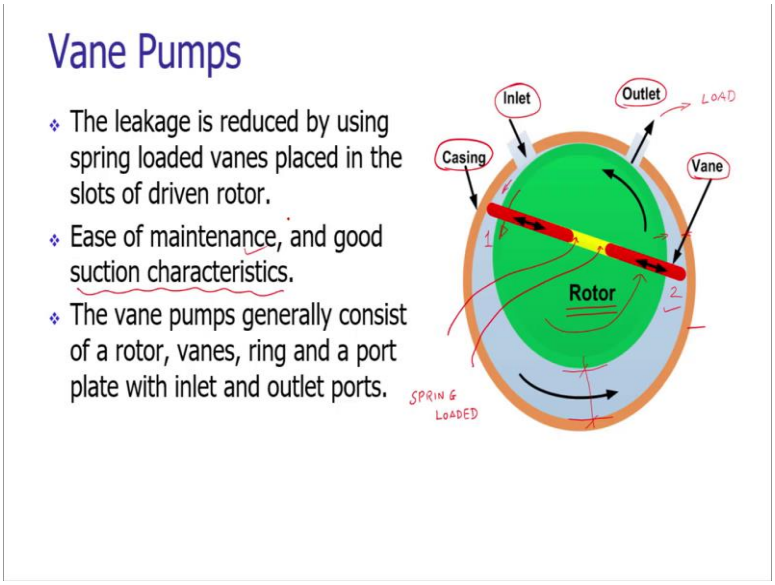

The gerotor pumps are very good for the light fuel oils or lubricating oils, cooking oils and the hydraulic fluid itself. The vane pumps are designed with spring loaded vanes which are placed in the slots of the driven rotor and this arrangement is reducing the leakage. On our screen we can see the schematic of a vane pump. It is having a circular casing.

This circular casing is hosting a rotor, but we can note here the rotor axis is offset to the axis of the circular casing. The rotor has radial slots and inside the radial slots we are hosting the vanes. The vanes are spring loaded. These springs are ensuring the contact of the end of the vane with the casing. The casing is having an inlet port and it also has an outlet port.

The rotor is rotating by the prime mover electric motor. As the rotor is rotating, there is translatory motion of the vanes inside the slot and the translatory motion is due to the offset of the rotor axis with the casing axis. If we consider if the axis of the rotor and casing is concentric there will not be any displacement. Wherever the outer surface of the rotor is in contact with the casing internal surface or it is in close proximity with the casing internal surface. We do not get any gap.

When the rotor is rotating, due to the spring action wherever there is a gap is high the vane will come out it will move radially outward due to the spring pressure. As it is moving radially outward, it is creating the pressure difference, it is creating the negative pressure at the inlet and it is creating positive pressure at the outlet.

Let us consider the rotor is rotating in anticlockwise direction as it has been shown. As the vane is moving in anticlockwise direction there is a generation of the negative pressure. The fluid will be taken inside.

As a rotor further rotates then the vane number 2 will come in contact. It will come a disposition and whatever the fluid which has come inside the gap which is created by the vane number 1, that fluid will be pressurized further by the vane number 2.

The vane number 2 will drive the fluid and it will take the fluid inside the inlet and it will take the fluid, it will convey the fluid inside the casing. As there is a gap is getting reduced between the outer surface of the rotor with the inner surface of the vane the fluid will get pressurized. Here we notice the gap is getting reduced. As the gap is getting reduced wherever there is opening the pressurized fluid will get through that opening the fluid will just move with the high pressure and that will be applied to the lobe.

In this way the offset between the rotor with the casing is creating the pressure. It is working as a crescent in this vane pumps. As there is a continuous contact of the vane winds with the casing these vane pumps are having very good suction characteristic. They are easy in maintenance as well. What are the applications of the vane pumps?

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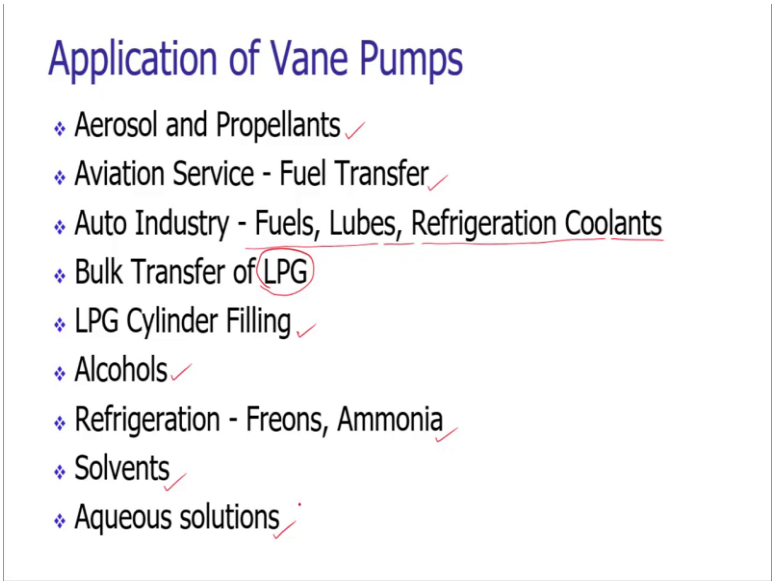

Vane pumps are used for aerosol and the propellant transportation. They are used in the fuel transfer in aviation services. They are widely used for transportation of the fuels, lubrications

and refrigerant coolants. These pumps are also used for transfer of liquid petroleum gas, filling of the LPG inside the cylinders. They are widely used for conveyance of alcohols, various refrigerants such as Freon's and Ammonia, various chemical solvents and aqueous solution.

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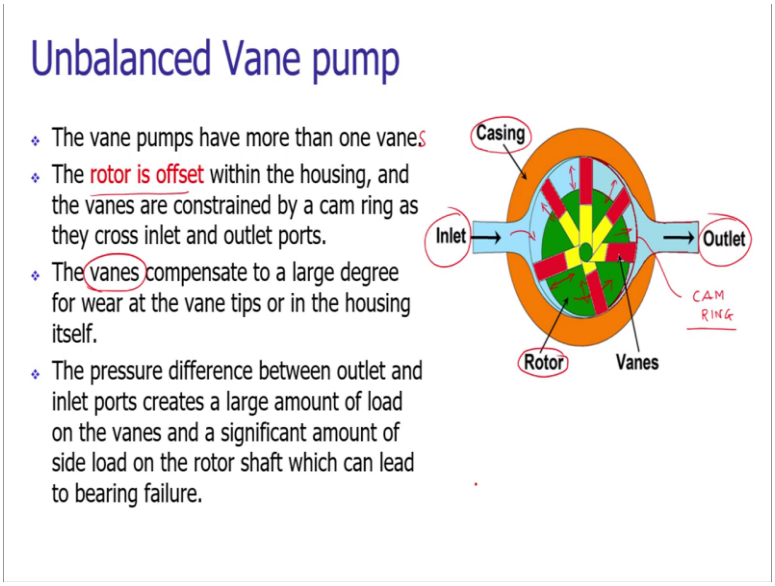

On our screen we can see a configuration of vane pump and it is called as unbalanced vane pump. We can notice the construction. As the cylindrical casing which is having a rotating element that we called rotor. The rotor has radial slots and these radial slots are housing the vanes.

The vanes are spring loaded. The rotor axis is offset to the casing and there is one element that is added called as the cam ring. A ring which is having a cam shapeor abron shape, it is not circular. It is to be noted that the cam ring is not circular.

The abron shape of the cam is helping to get the required pressure done. The rotor is rotating and as the rotor is rotating the contact length or the protrusion or the projection of the end point of the vanes out of the rotor is getting changed. We notice here that this vane which is in contact with the cam ring, the outer surface of the rotor is in contact with the cam ring.

The entire vane is inside the slot itself, but as the rotor is rotating and when there is an increase in gap between the outer surface of the rotor with the inner surface of the cam ring due to the spring action, the vanes are coming out and that vanes which are coming out are driving in the

fluid. Here we notice they are driving in the fluid and then they are pressurizing, they are applying the pressure on the fluid as well.

Getting the fluid inside and driving them will be carried out by this translatory motion of the vanes inside the respective slots. Thus the unbalanced vane pumps do have more than one vanes. The rotor is offset as we have notice. The vanes are compensating. It is very useful characteristics of the vane pumps. Although there is wear and tear of the endpoint of the vanes due to the sliding friction between the casing and the end point, due to the spring action that wear and tear will get compensated.

There is the compensation of the wear, is by itself that is a very good characteristic of the vane pump. However, the difference at the inlet; however, the difference at the pressure at inlet and outlet is creating problems in the unbalanced vane pump.

That inlet the pressure is very low and outlet the pressure is very high due to this imbalance in the pressure that is affecting on the performance of the bearing. There are regular problems of bearing failure on which the shaft of the rotor is mounted. To tackle these problem, we are using a balanced vane pump.

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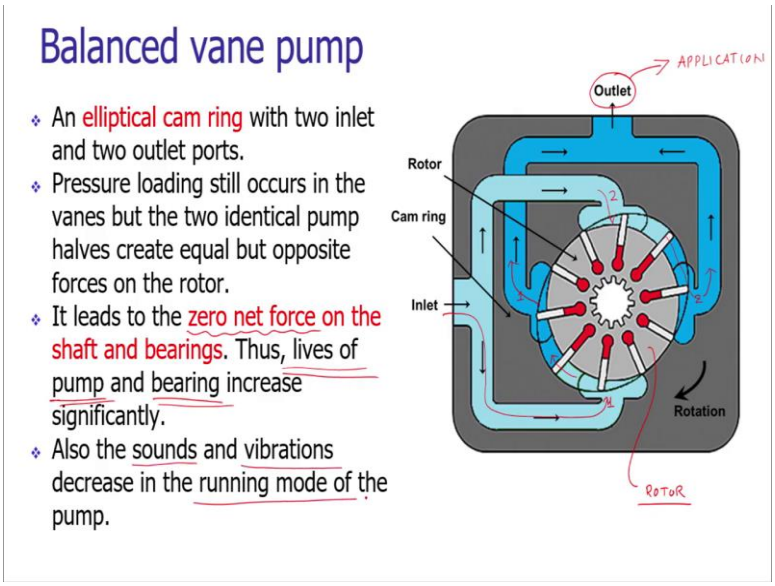

Instead of having one pair of inlet outlet we can have two pairs of inlet outlet. This peculiar arrangement can be seen on our screen. It has the rotor and as usual the rotor is having radial slots with the vanes. The vanes are spring loaded.

There is a cam ring which is very similar to unbalanced vane pump. Instead of having only one pair of the inlet outlet we are having two pairs. We notice here the inlet. This is inlet number 1 and inlet number 2. Now, we are having the outlet number 1 here and the outlet number 2.

As the rotor is rotating, the similar kind of fluid taken operation and pressurization operation would be carried out. But, due to the balancing of the pressure, we will not be getting the imbalance pressure application on the bearing. The bearing pressure will be balanced by having the equal pressure on the both the side of the shaft by having two different outlet ports on both the side of the shaft.

Here we notice 1 and 2 are exactly in opposite direction. The pressure which is being applied by the outlet port 1 and port 2 will cancel each other's effect. Through inlet the fluid is coming inside the balance vane pump and it will be pressurized here.

The pressurized fluid will be taken out by the outlet port 1 that is a respective outlet port 1. In a similar fashion the fluid will come here in the inlet port 2 and that will be pressurized that will be driven by the vanes and the pressurized fluid would be taken out by port 2.

Cumulatively we are taking the pressurized fluid from 1 and 2 and that would be utilized for our application. Due to the balancing of the forces, the net force which is zero on the shaft and bearings are certainly increasing the lives of the pump and the bearing and this also helping to reduce the sounds and the vibrations in the running mode of the pump.

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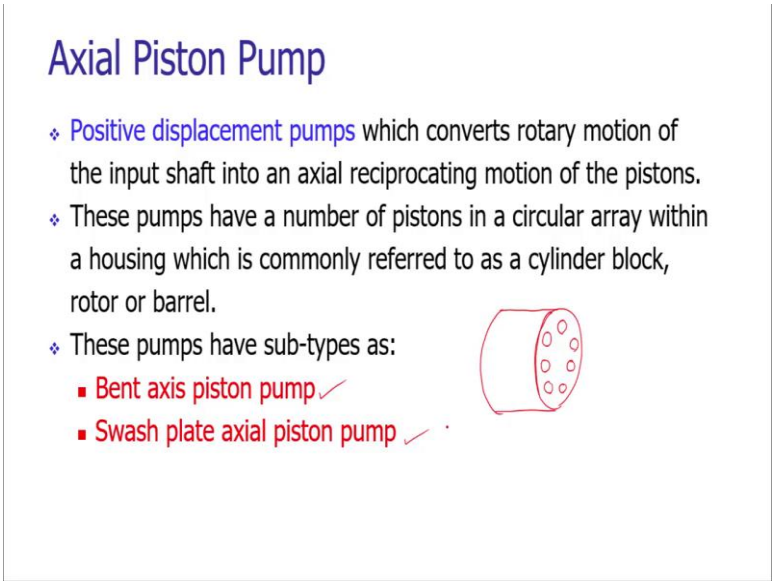

The next group of pumps is axial piston pump. Axial piston pumps are positive displacement pumps and they are converting the rotary motion of the input shaft into the axial reciprocation of the pistons.

Rotary motion of the input shaft is being converted into the reciprocating motion of the pistons. These pumps have a number of pistons which are assembled in a circular array within housing which is commonly referred as a cylinder block or a rotor or a barrel.

Typical arrangement can be shown. This is circular block and on the surface of the circular block there are bores. There is an array of bores and these bores are housing the pistons. In addition to a circular cylinder block, we are having one more block which is the fixed block through which we are getting the fluid in and through the same block we are sending the pressurized fluid to the application.

As we rotate the cylinder block pistons are reciprocating. Rotary motion of the cylinder block will be converted into the reciprocation motion of the pistons. There are two types of piston pumps used in the industry. These are bent axis piston pump and swash plate axial piston pump.

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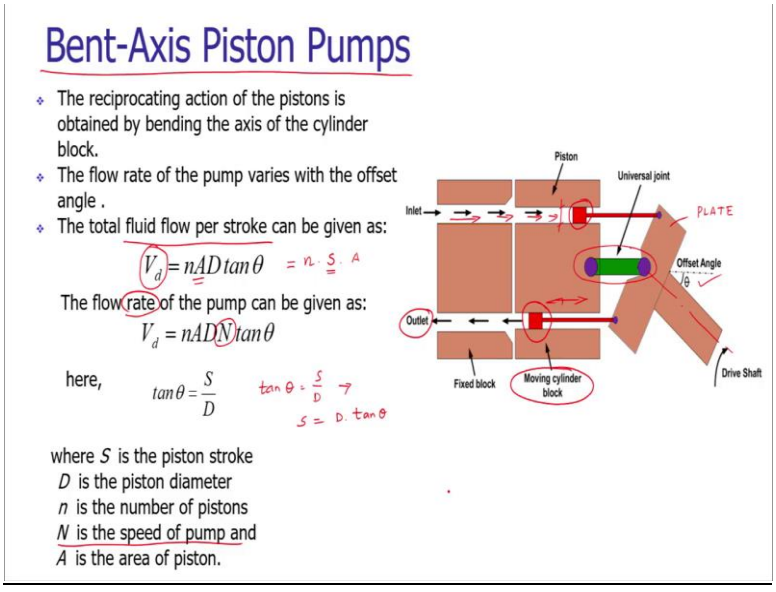

Let us look at the construction and working of the bent axis pump and swash plate type of the piston pump. In the first type that is bent axis piston pumps we are using a moving cylinder block. This moving cylinder block has a number of bores. These bores are thorough bores.

Inside this bores we are housing the pistons. These are the pistons. The pistons are having piston rods and these rods are connected to a plate.

This is a plate. This plate is also connected to the rotating block with the universal joint and the plate is having a shaft, but the shaft is offset. This offset angle is ɵ. We are driving the shaft by using an electric motor. As the shaft is rotating the plate is also rotating. As the plate is rotating there would be reciprocation of the piston rods and pistons inside the respective bores.

It is to be noted that as the shaft is rotating, it is driving the plate it is driving the cylinder as well, but due to the angle ɵ we are getting the reciprocation motion. If this angle is 0, so, what will happen? There will not be any movement of the piston inside the bore. This moment would be 0.

As we increase the angle ɵ from 0 to some positive value we can get the reciprocation motion. And these reciprocatory motion is utilized to take the fluid inside the empty bores and when the gap between the end of the plate with the cylinder which is rotating is reducing, during that moment the piston would be pushed inside.

During the movement of the piston inside the cylinder block, it is applying the pressure over the fluid and that pressurized fluid will be taken out at the outlet port. The drive shaft is driving the plate and that plate is converting the rotary motion into the reciprocation motion and that reciprocation motion is utilized for sucking in the fluid and generation of the fluid pressure.

The total fluid flow per stroke can be computed by a correlation.

$$V_d = nADtan\theta$$

V_d is the volume, A is nothing but the area the cross sectional area of the bore or we can consider the area of the piston into the distance travelled by the piston that is the stroke. Distance travelled by the piston or the stroke can be computed as:

$$tan\theta = \frac{S}{D}$$

$$S = Dtan\theta$$

Here we can see that:

$$V_d = nADtan\theta = nSA$$

Flow we can easily be computed by using this correlation. Then the rate of the flow that is to compute that we need to just multiply the flow volume into the speed of rotation N.

In this way we can easily compute flow and the flow rate of the bent axis pump. During the operation during the operation it is very difficult to have the exact bent angle. It is also having the universal joint and many reciprocating distance and rotating parts. The construction is quite complex. A simplified version is by using this swash plate axial piston pump.

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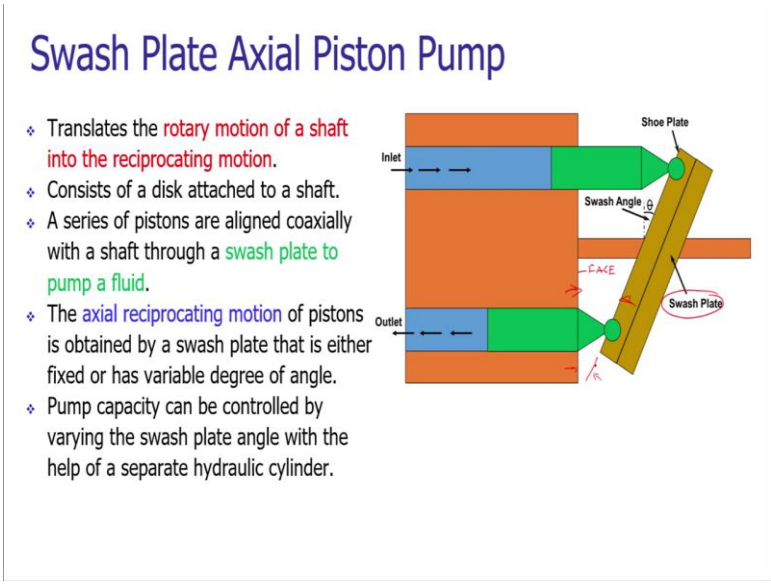

Here a swash plate is used instead of having the bent axis, we are using a plate. The plate is inclined. The plate is not parallel to the surface of the cylinder block. It is inclined to the face of the block. This is the face the block and this swash plate is making angle ɵ. This swash plate is connected to a shoe plate. The assembly of the shoe plate and the swash plate is mounted on the rod.

This rod is connected to the rotating block, this block is rotating. This movable block or the rotating block is getting the fluid from the fixed block as we have seen in our previous slide.

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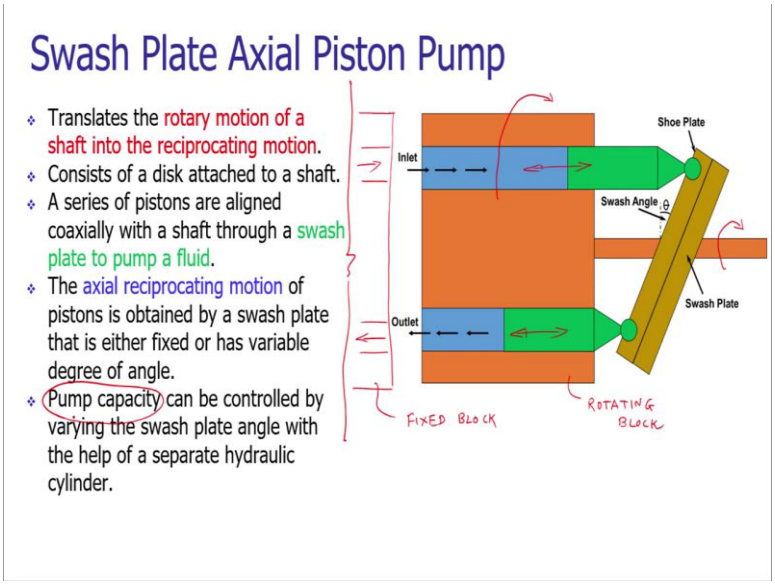

We are having a fixed block here and there is inlet. So, this is the fixed block. Fixed block has the inlet port as well as the outlet port. This is a rotating block. We are giving the rotary motion to the rotating block by using a prime mover.

As the rotating block is rotating, due to the inclination given to the swash plate we are getting the reciprocatory motion of the pistons along the axial direction. The operation is very similar to the bent axis piston pump which we discussed in the previous slide.

Now, here we are having a opportunity to control the pump capacity. By changing the angle of the swash plate we can easily modulate, we can easily change the pump capacity.

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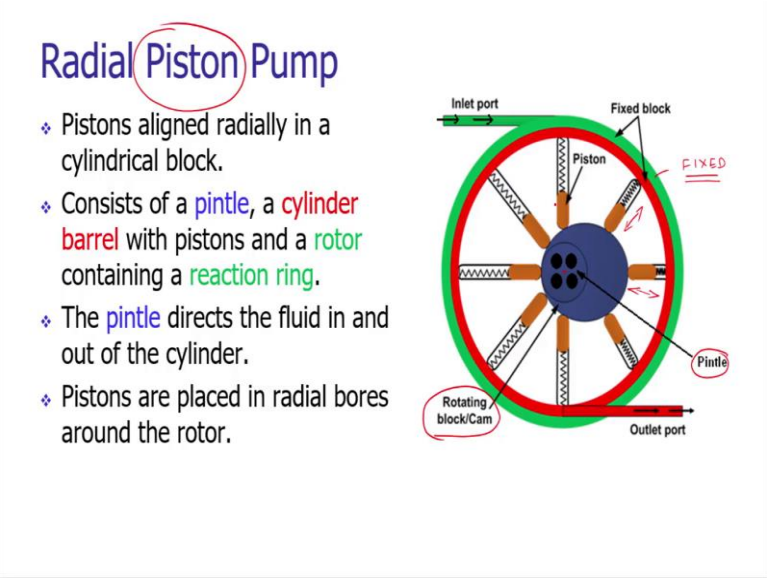

Now, instead of having the axial reciprocatory motion we can also have the radial reciprocatory motion of the pistons. These kind of configuration is called as radial piston pump. The diagram or the schematic can be seen on our screen, which is having a pintle. Pintle is mechanical element which is holding the casing.

There is a cam; this rotating block or the cam. The pintle and the cam block are housed inside a fixed block. Radial piston pumps has the radial slots and inside the radial slots, the pistons are housed. The pistons are spring loaded. The reciprocatory movement of the piston would be coordinated by the shape of the cam.

As we can see if the shape of the cam is very similar to the pintle here, we may not get any reciprocatory motion. As the shape of the cam is abron, we can get the reciprocatory motion. Here we notice from the center of the pintle this point is near to the center; however, this point is at the farthest distance from the center.

This increase in the radial distance from the center we can get the reciprocatory motion of the pistons. We have seen that principle in the lecture of the mechanisms, we have seen various types of camps. As the rotating block is rotating they are driving the piston and that pistons are doing the regular duty and that is taking the fluid inside and the pressurizing the fluid to the outlet port.

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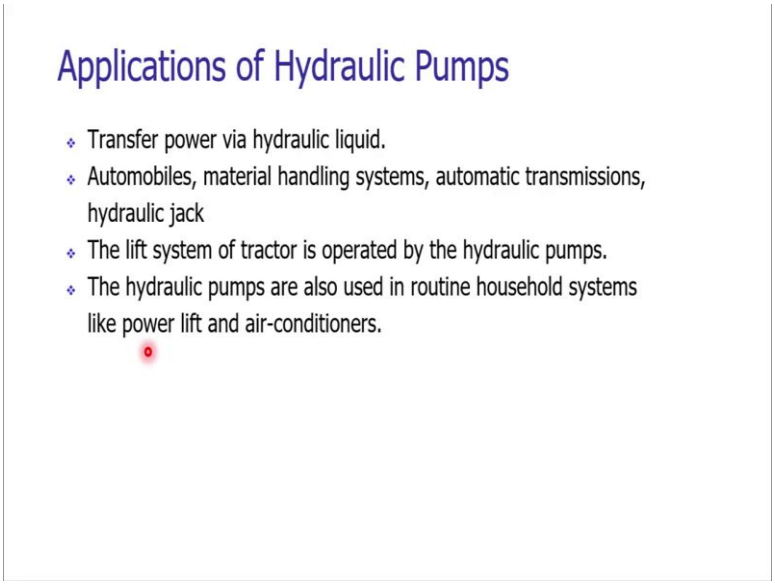

The hydraulic pumps are having a variety of applications in the industry as well as at domestic level. In industry we need the power that to carry out variety of processing. Say hydraulic based shipping operation, for material removal as well we can utilize the hydraulic fluid.

For power transfer, for power application we need hydraulic fluid. In automobiles, in material handling system, in automatic transmissions and to have the lifting based on the hydraulic jack, we are using the hydraulic pumps. In tractors also we are using the hydraulic pumps to arrange the lift system. In household atoms, we are using the hydraulic pumps, in air conditioners as well as the lifting operations.

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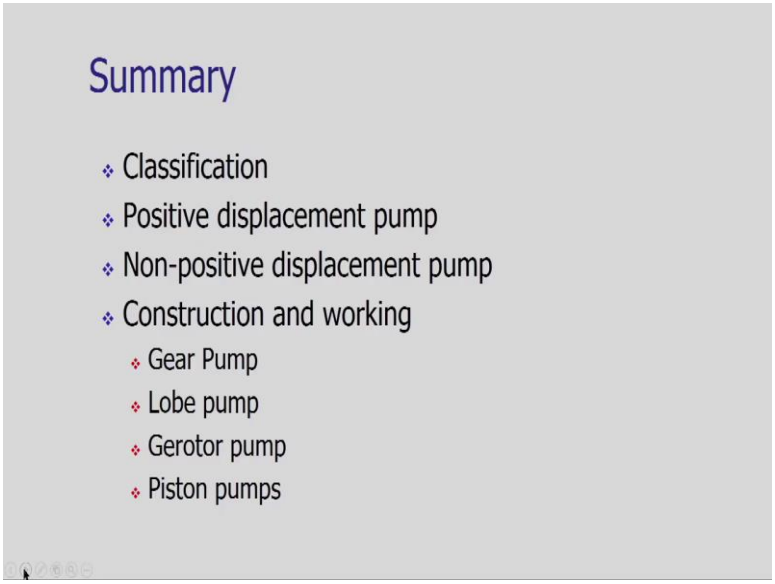

Let us summarize the lecture 2 of week 9. In this lecture we studied the classification of hydraulic pumps. We have seen various important pump such as gear pump, lobe pump, gerotor pump and piston pumps. We have seen their construction, their working, their advantages, limitations and applications in automation in manufacturing.

Automation in Manufacturing
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Week – 10
Control valves and graphical representation Lecture – 30
Direction control valves

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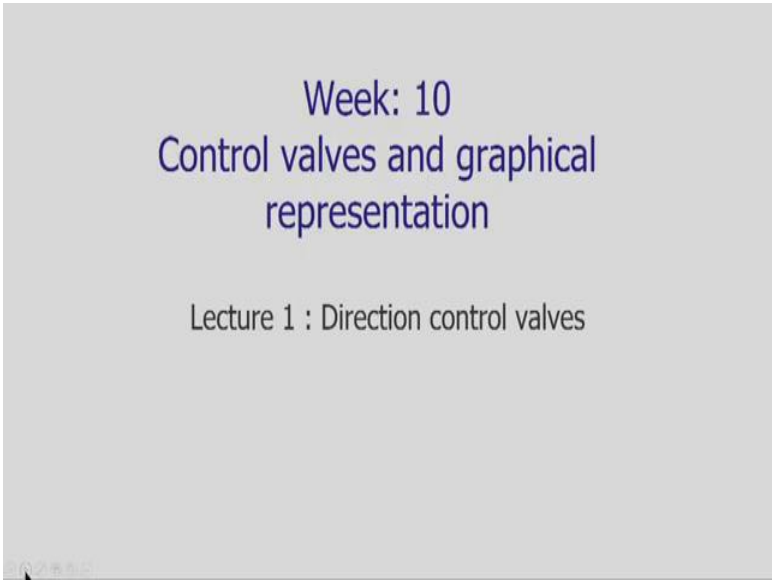

Hello and welcome you all to the week 10 of Automation in Manufacturing. In our previous week we have seen, the hydraulic systems the fundamentals of hydraulic systems and the hydraulic pumps. The next important element of a typical hydraulic system is control valves.

In this week, we will be studying various control valves and we will study how to graphically represent the control valves and hydraulic circuits? In lecture 1, we will be focusing upon the Directional control valves.

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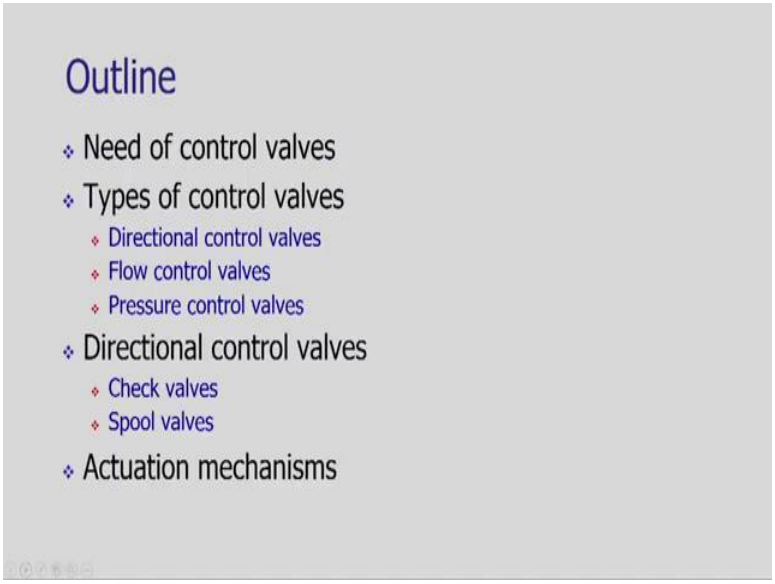

At the start of the lecture, we will have a discussion on the need of control valves, what is the importance of a control valve that to be employed or to be used in a hydraulic circuit.

There are various types of control valves being used these are directional control valve, flow control valves, pressure control valves. We will see the construction, principle of operation and application of all these control valves 1 by 1.

In this lecture we are focusing on directional control valves and these are check valves and the spool valves. At the end of the lecture, we will have a discussion on the various actuation mechanisms of this directional control valves.

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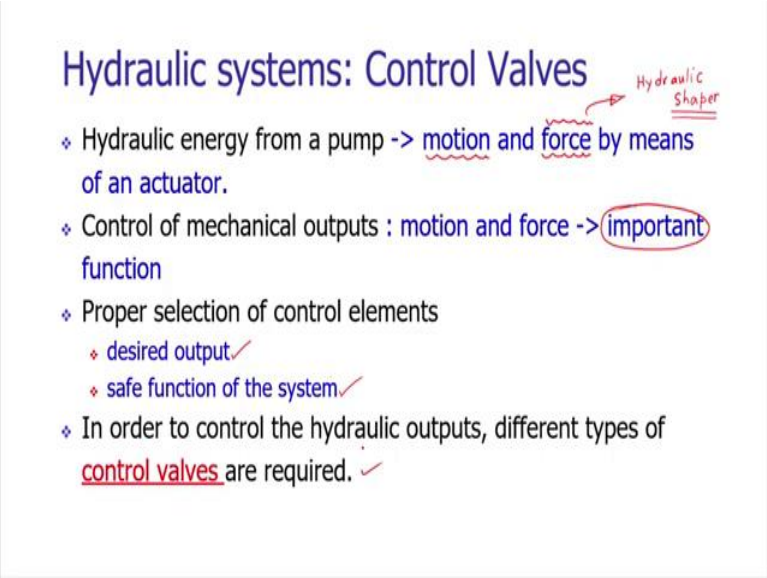

Let us begin the lecture 1. A typical hydraulic system are a machine or a mechanism, based upon the hydraulic system is basically using the hydraulic energy to actuate various elements or the mechanisms. The hydraulic energy is being generated by conversion of the electrical energy. The fundamental element, the pump is being driven by the electrical motors.

Well, what we will do with the hydraulic energy? We have to generate motions and we have to generate the force. The motion may be utilized to carry out number of operation. That motion or the movement of the linkages of the mechanism would be carried out by the converted hydraulic energy, or the force which is generated inside the mechanism, that will that will be utilized for the material processing.

A simple example is the hydraulic based shaper operation. A hydraulic shaper, shaping machine we have seen, it is a material removal machine. In this machine we are having a relative motion between the tool and the work piece.

The work piece is stationary and the tool is reciprocating, it is translating over the work piece material. That translatory cutting motion is developed by the hydraulic system hydraulic energy. The required force will be generated by the hydraulic system in the shaping machines.

When we are getting this motions and force, it is very essential for us to control this motion and force. Uncontrolled forces are not useful for us. Whatever the desired force required,

whatever the desired force is there the system should generate that required force only. For that purpose, we need certain elements and that elements are nothing, but the control elements.

These control elements are essential to be properly selected to generate the desired output and they should provide the safer or protected working environment for the user or the operator.

The safety and the desired output: these two are the essential requirement, that to be considered during the proper selection of this control elements. The fundamental control element in the hydraulic system is hydraulic valve itself.

The hydraulic valves are needed for control the flow of hydraulic fluid, inside the system to have the required pressure of the hydraulic fluid inside the system, because that fluid pressure itself is generating the required force during the application and the direction of application.

There are different types of functions being carried out by the control valves. And, there are various types of control valves are used in the industry. We will see some of the control valves in this lecture.

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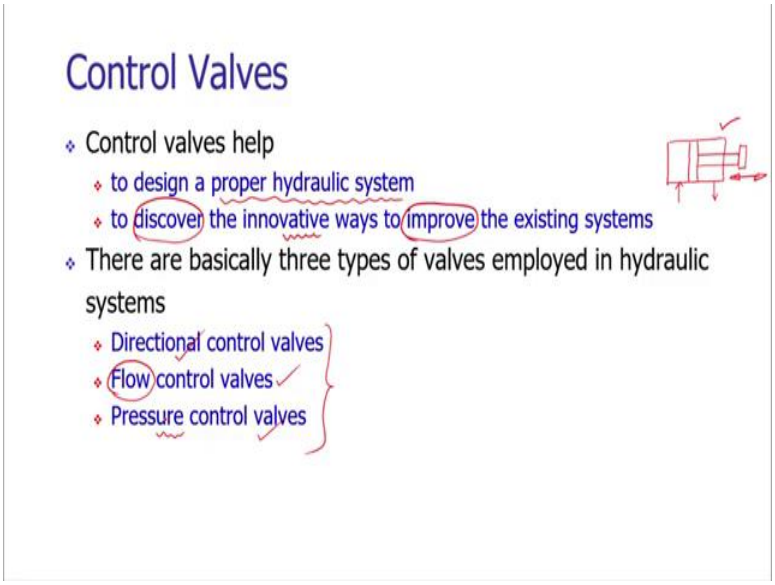

Thus, we can say that the control valves are helping us to design a proper hydraulic system. Meaning of the proper hydraulic system is that all the elements are providing or they are working to generate the output in desired manner only.

The control valves are not only helping to design a proper hydraulic system; they are helping to discover the innovative ways to improve the existing system. A typical actuator in hydraulic system is a single acting piston cylinder arrangement, to actuate a single acting piston cylinder arrangement there are various ways to get the required motion of the piston cylinder arrangement. The required motion in the piston cylinder arrangement is just the extension of the piston rod.

Let us consider typical arrangement here, a single acting cylinder. What may be the various ways to control the activity of this actuator? We can use a simple two way valve, or we can utilize a three way valve, or we can use the regenerative valves, or we can use the proportionate valves to control the activities. These different ways, these innovative ways are helpful to improve the existing system.

The same single acting cylinder can be utilized for variety of applications. It may be just to generate the on off or you can say the discrete motion, whether complete retraction of the single acting cylinder or the complete extension of the single acting cylinder, or it may be a gradual apply of the force at this end by using a proportional control valve.

Now, instead of having a simple two way valve if we can have the proportional control valve to apply the force gradually, this same system can be utilized as a the gradual force application system. That control valves are helping to carry out such operations in the hydraulic systems. In hydraulic systems basically three types of valves are used these are the directional control valves, flow control valves and the pressure control valves.

The directional control valves are controlling the direction of the fluid inside the hydraulic system. As the name suggest the flow control valves are controlling the flow of hydraulic fluid inside the hydraulic system. And, the third one that is the pressure control valve, it is utilized to control the application of pressure of hydraulic liquid at the application or the load.

Let us look at these type of valves 1 by 1, let us start with the directional control valve.

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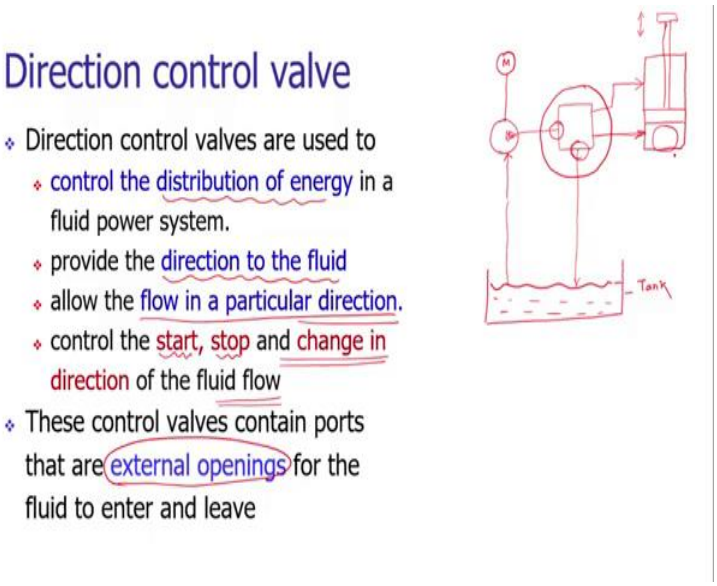

The directional control valves are basically used to control the distribution of energy inside a fluid power system. To understand the requirement of a typical hydraulic system, let us take an example. We are having a tank, the hydraulic fluid is there in the tank and, we are having an actuator.

Let us consider a single acting piston cylinder arrangement is there. And, at the end of the rod of the piston, we are applying the load. That load may be raised or that load maybe lower and for that purpose we need to carry out the hydraulic based operation.

As we have seen in our previous class, we need a motor and that motor is driving a pump. An electric motor is there and that electric motor is driving a pump, let us consider we are having a pump. This pump is getting the fluid from the tank and from the pump, now we have to distribute the energy.

We are getting the pumped fluid, but that fluid has to be distributed inside the system. Distribution of the energy will be carried out by using a unit we need mechanism; we need a mechanical unit or it may be a it may be an electromechanical unit as well.

That unit should distribute the energy. We required energy at the bottom portion of the cylinder to extend the cylinder, we also need the fluid that to be applied on the top side at the top side. That we can retract the cylinder, we can retract the piston rod inside it to reduce its length.

The fluid will be taken to the top side or to the bottom side by a mechanical unit. We also need a mechanism, so that the used fluid is to be given back to the sump or the tank itself. After usage of the hydraulic fluid it has to be taken back to the tank, further heat will be processed, it will be filtered and further processed for the desired application.

For this purpose, we need a control valve, which is distributing the energy inside the system, which is giving the direction of the fluid inside the system and it is allowing the flow in a particular direction only. In the case of the extension of the piston rod arrangement, we have to apply the fluid energy in this area.

In particular direction we need to apply the energy. That function is also to be carried out. The control valves are starting stopping and changing the direction of the fluid flow inside the system.

These control valves are having the external openings, it is having an external opening to get the fluid inside, it is having another external opening to send or to return the used hydraulic fluid inside the system. External openings are there for the fluid to enter and leave inside the direction control valve.

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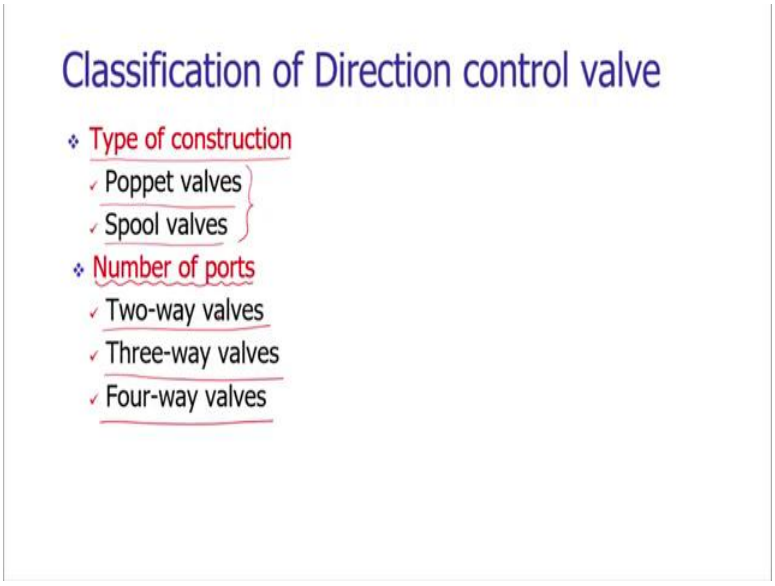

The direction control valves can be classified based on many factors, many parameters. The first factor is the type of construction. We are having two types of valves which are used in the industry, these are poppet valves and spool valves.

In poppet valve we are using small poppets, small cylindrical or spherical poppets which are used to control the flow of the fluid inside the system. The spool valves they are having a cylindrical spool, it is a cylindrical mechanical element which is controlling the flow of fluid, it is controlling the direction of the fluid inside the system.

We are also having the classification based on the number of ports. As we have seen in our previous slide, a typical control valve is having openings, external openings. Based upon the number of openings, the control valve has we can have a variety of types of valves, these are the two-way valves, three-way valves and the four-way valves. We also called these as the two port valves, three port valves or the 4 port valves.

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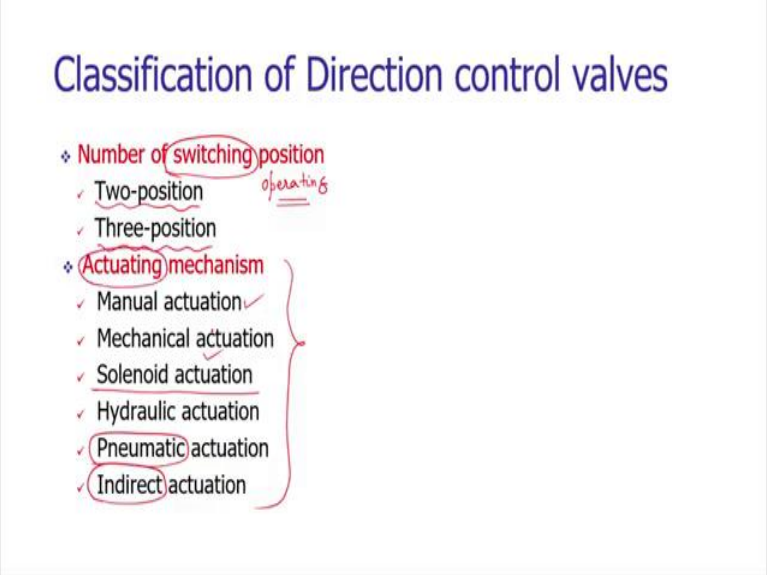

The control valves are also classified based upon the switching position or the operating position. As we have seen in the previous slide for actuation of a single acting cylinder, we need to have the two-position. In first position the fluid is passing at the top side of the piston and the second position the fluid should pass at the bottom side of the piston.

There are two switching position, that is on in the extension of the piston cylinder arrangement off means retraction of the piston cylinder arrangement. We can have the two-position. We also have a third position in which the application is you know the application will have the constant load kind of situation.

We need to hold the work piece we need to hold the force on the work piece. For that purpose a three-position valve is also incorporated. Based upon number of position we are having two-position valves and three-position valve.

Actuation mechanism: how do you actuate the directional control valve. We can have the manual actuation, mechanical actuation, or electrical actuation, that we call the solenoid actuation; we can use the hydraulic energy itself to actuate the control valves, or to operate the control valves.

We can use pneumatics, the compressed air to operate the direction control valve, these are called as the pneumatically actuated control valves, or we can have the indirect actuation, we can have use of a pilot to actuate the control valves. We will have a discussion on the various actuating mechanisms in detail in the coming slides.

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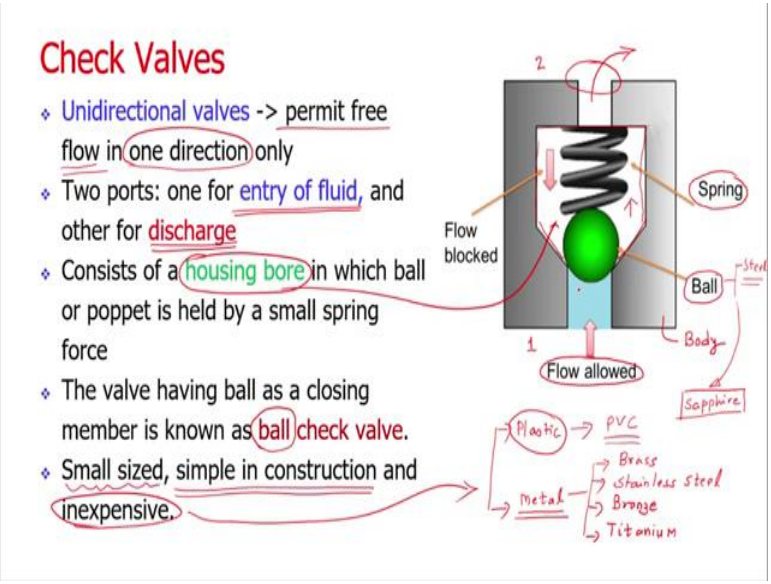

Now, let us study the first valve that is the check valve. The check valves are the unidirectional valves, the unidirectional means they are permitting the flow in only one in one direction. These type of valves are in general we use at the domestic applications as well, we need to just have only one direction flow.

A typical valve construction can be seen on our screen, this is the valve body; body of the valve. And, it is having a passage. The fluid is allowed to enter at this opening and it has another opening from where, we are getting the fluid out. Inside the valve there is a space has been

created, it has been machined, or it has been casted, to have the construction elements of the valve.

The basic construction element of a check valve is a spring. It is a spring loaded ball valve. We are using a ball to control the direction of the fluid inside the valve. The spring is having sufficient stiffness to apply a force on the ball and the ball is seated at the inlet of the valve.

In normal condition the valve is closed, the normal condition the valve is in off position. It is not allowing the fluid that to enter, if the fluid pressure is low it is at the atmospheric pressure.

If the fluid pressure is less than the pressure applied by the spring itself, but when the fluid pressure increases, when the inlet pressure increases above the pressure applied by the spring, there would be displacement of the ball against the spring due to the fluid, which is coming out. And, in that way we can have the flow of fluid from only one direction.

In other direction it is not possible. In this situation we can have the fluid that to be passed from only one direction from the end 1 to the end 2. As mentioned there are two ports, that is entry of the fluid and the other one is for the discharge.

This is the housing bore basically, housing bore is seen on our screen, see in which a ball or a poppet is held. If, we are using the ball to check the fluid flow, that that is called as the ball check valve or we can have the poppet based valves as well.

These kind of valves are small in size and they are simple in construction and they are inexpensive. For domestic purpose we are employing such kind of valves to control the flow of water for our domestic applications. These valves are generally made up of the plastic or they are made up of the metal.

The plastic in general the PVC or in metals, brass, stainless steel, bronze, or in the biomedical application, or in certain industry applications where, we need to have a non-corrosive nature of the valve titanium.

Based upon the metal that we are using, the cost of the valve is increasing. In general, the plastic valves are very inexpensive; we can also have the valves which are plated valves. The balls are made up of steel and in certain cases the balls are also made up of sapphire. Sapphire is very durable, it provides very high strength and it is chemically inert.

When we want to utilize these kind of check valves for precision application for the operations in biomedical industry, wherever it is required to protect the fluid, . so that it will not corrode the valve elements, it will not have any chemical reaction built the valve elements, it will not create any the poisonous gases, it will not get contaminated. In this situation we are using the sapphire which is the durable chemically inert and it is the high strength materials.

When we apply the high pressure here, there would be lot of wear and tear of the balls because the balls are hitting at the inlet position quite often. That is why the balls should have the sufficient strength.

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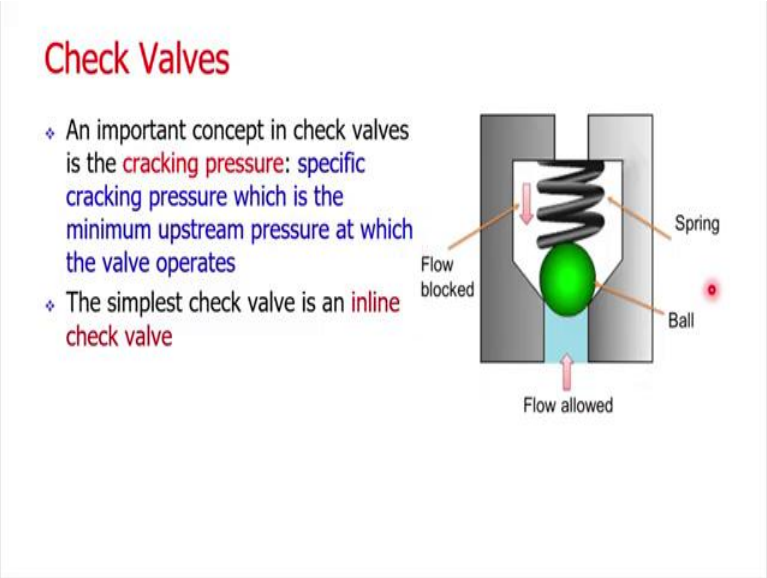

The important concept in check valves is the cracking pressure. As we have seen that the flow is allowed only in one direction and in the other direction it is blocked.

But, the flow is allowed against a spring, against a certain pressure, and when the fluid inlet pressure is more than that certain pressure, than and then only the fluid is allowed to pass through the valve. And, that particular pressure is called as the cracking pressure.

Formally we can define the cracking pressure as a specific pressure or the minimum upstream pressure at which the valve is operating. The upstream pressure the pressure in the upstream direction at which the valve is operating is nothing, but the cracking pressure and that cracking pressure is dependent upon the stiffness of the spring.

In general, a simple check valve is having only one cracking pressure, but if we want to have variable cracking pressure, then we have to use the screw based arrangement in which you can change the stiffness of the spring, you can control the stiffness of the spring. The valve which is shown on your screen it is a very basic arrangement and it is called as the inline check valve.

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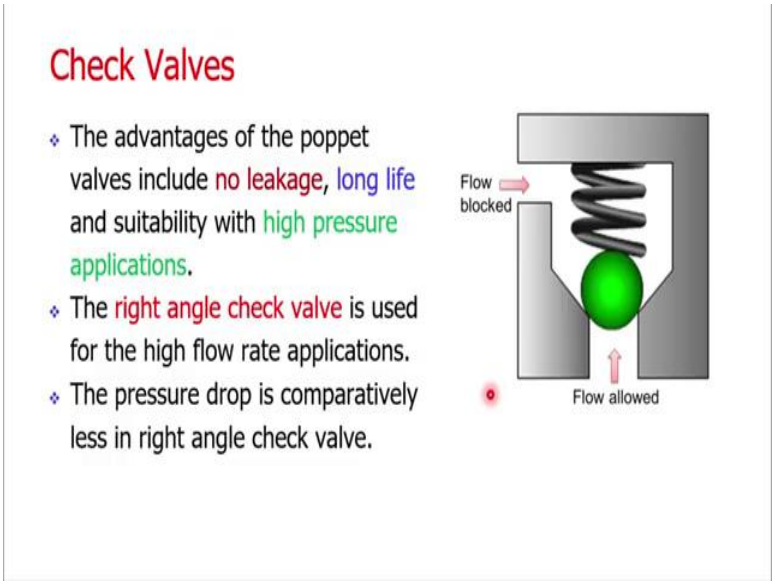

We can also have a right angle arrangement, in this arrangement the fluid flow inlet and the fluid flow outlet directions are at right angle to each other. This is the inlet along which the flow is allowed, this is ball spring and this is the outlet, from outlet to inlet the flow is blocked.

In general, the check valves offer advantages such as the leakage, the leakages less, the life of the check valve is quite long they are durable. They are very much suitable for high pressure application, but for high flowed flow rate application these valves are not that suitable, they can work for the medium to low flow application.

The inline check valves are not suitable for high flow rate applications whereas, the right angle check valves are used for high flow rate application, because the pressure drop along the right angle travel of the fluid is comparatively less than the inline flow of the fluid.

In inline flow of the fluid as we have seen that, there may be a good amount of the pressure reduction that that is been solved by using arrangement which is having the right angle flow.

This certainly reduces the pressure drop. Therefore, the right angle check valves are used for the high flow rate applications whereas; inline check valves are not that suitable for the high flow rate applications.

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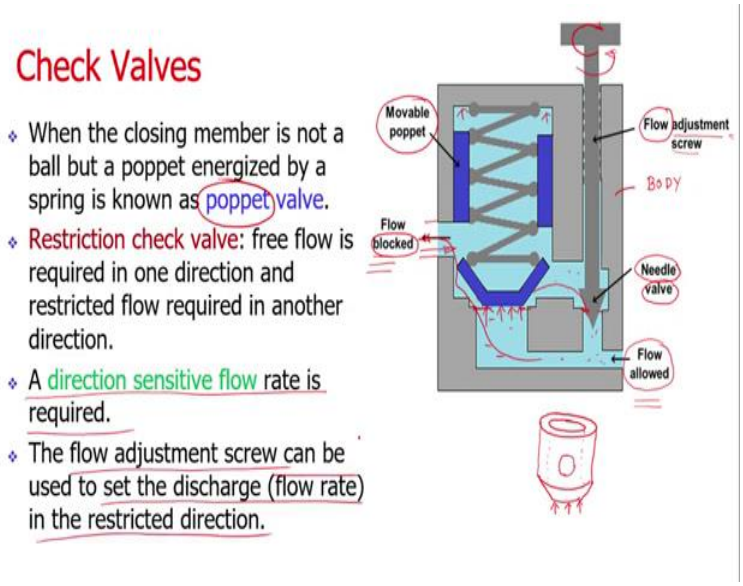

When instead of using a ball a metal ball to restrict or to control the flow of fluid inside a hydraulic valve. If, we are using a poppet a metal poppet that is called as the poppet valve. The poppet is nothing, but a cylindrical mechanical device or element, which can be seen on our screen, it is basically a hollow cylindrical device and it is having a hole as well. Inside the poppet we can accommodate the spring.

A typical construction of a poppet based check valve can be seen on our screen. It is having the body of the valve. It is having the internal spaces or the grooves. These are the internal spaces, the blue color spaces are seen here. Inside the major space provided in the check valve we are having the poppet, the poppet is movable.

Inside the poppet we are having the spring of sufficient stiffness and that stiffness of the spring itself is deciding, the pressure that to be applied during the flow. The check valve as we know that they are allowing the fluid that to be flow in check valves, we know that, the fluid is allowed to flow in only one direction. In this case the fluid is allowed to flow in this particular direction and this is the exit of the fluid flow.

The fluid is allowed only in this direction, the opposite direction fluid is blocked the flow is blocked. To control the flow a flow adjustment screw is also provided. The normal position of this valve is closed. Due to the spring pressure the poppet will sit at this space.

And, due to the spring stiffness or the pressure, it will be rested here. If the flow pressure is not sufficient to surpass the spring stiffness or the pressure given by the spring, there is no occurrence of flow across the check valve.

But, in case the pressure of the inlet is increased we are applying the high pressure fluid, which is coming out of the pump inside the valve. Then, that fluid will apply pressure against this surface of the poppet.

The poppet will try to push in upward direction, but there is a restriction from the spring, but if the fluid pressure is more than the stiffness is more than the cracking pressure of the check valve, then the poppet will be moved in upward direction. As the poppet is moving in the upward direction the fluid will just move inside the gaps and it will pass through the valve and it will be sent to the desired application.

But, during the application, we can even control the flow rate. That is not only controlling the direction of the fluid flow, we can even control the flow rate by using a flow adjustment screw.

Let us consider that this needle valve which is seen on our screen has been tighten by using a screw and this passage has been closed. If we rotate this in a in a clockwise direction, then this screw will go in downward direction this passage will be closed. The fluid pressure at the inlet minus the pressure required to surpass the spring pressure will be the outlet pressure from this particular check valve.

Consider we do not want to have the increase in pressure, if we want to just reduce the flow rate. In that case you can just move this into anti clockwise direction, this needle valve will be open and whatever the fluid which is passing through in the gap between the poppet and the valve that will be moved back to the inlet port.

In this way the pressure inside the space of the valve can be reduced by using this flow adjustment screw. The flow can flow rate can be reduced the pressure can be reduced.

Direction sensitive flow rate if it is required then we can use the flow adjustment screw and that can be set the discharge flow rate in the restricted direction, we can set the flow rate by using the flow adjustment screw.

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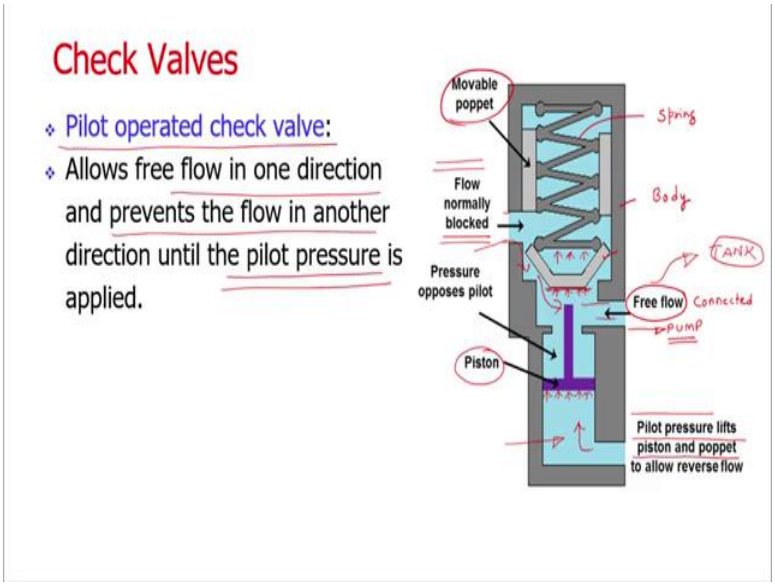

Now, instead of using the inline pressure of the fluid to operate the valve. In case we need to utilize the external pressure, the outside pressure to operate the valve. When we are using such arrangement, when we are using the pilot pressure to operate the check valve that type of valves are called as the pilot operated check valve.

The construction of pilot operated check valve can be seen on our screen, it has the body of the valve and inside the body we are having a poppet. This poppet is having the spring, the poppet is movable, we are having the inlet, the inlet is connected to the pump. This is the outlet of the valve and the reverse flow is normally blocked. The outside from the outside we are getting the pressurized fluid for the desired application.

These valves can be operated by the inline pressure itself, but we can have an external lifting arrangement by using a pilot pressure. Pilot pressure means we are making an arrangement, we are making certain arrangement here, this arrangement is having a small piston and this piston is operated by the external fluid pressure.

The fluid is applied at the side of the piston during the operation. As pressurized fluid is applied here, this piston will be moved in upward direction and that piston is applying the force on the poppet.

Due to the application of the force on this side of the poppet, the poppet would be post in upward direction, the valve will be open and the fluid from the pump will be applied to the particular load.

The advantage here is that, if the inlet pressure is not sufficient to operate we can externally apply the pressure to operate the particular valve. The pilot operated check valves allows free flow in one direction and they prevent the flow in the another direction until the pilot pressure is applied.

Tthe pilot operated check valves can also be considered as the unloading valve as well. We can just consider the case over here, the pressurized fluid is applied from the pump and when this pressurized fluid is pushing the poppet against the spring, it is allowing the pressurized fluid that to pass through the check valve.

Now, let us consider the same valve is to utilized for the unloading purpose. For unloading purpose the simple check valve is not suitable. We cannot use the simple check valve, because it is fundamentally not allowing the flow in the reverse direction. To make it allow in the reverse direction, in that case as well we can use the pilot pressure.

Pilot pressure can be applied here the, the poppet will be pushed in upward direction, as the poppet is pushed in upward direction the reverse flow can be allowed. Let us consider, we want to just unload, unload the fluid flow the fluid will come and it if this is connected to the tank. In this way we can allow the flow of fluid in a reverse direction if the pilot pressure is applied.

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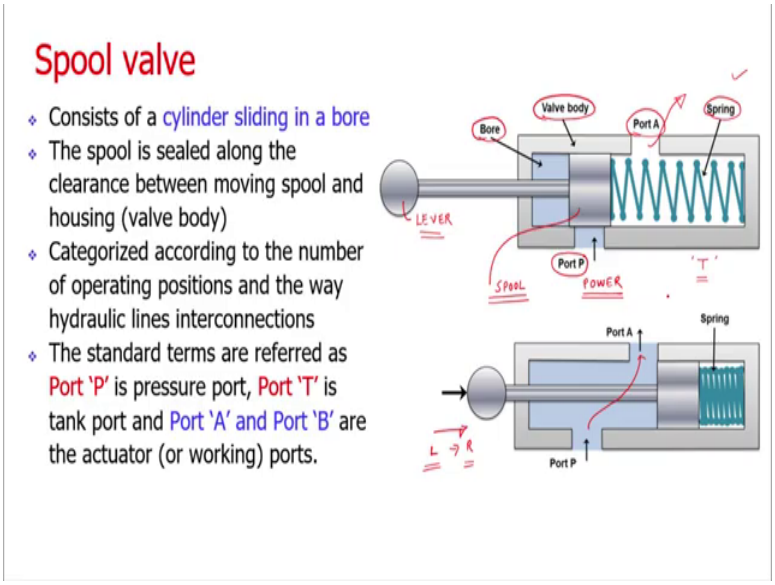

The next type of valve is spool valve. The spool is nothing, but a cylinder a cylindrical element and that cylinder is sliding inside a bore, a typical construction of the spool valve can be seen on our screen.

This is a valve body. The valve body is having a bore and inside the bore a spool is mounted the spool is having the lever and that lever is being operated by a variety of actuation methods.

The valve body is having the ports the port P is the power port, port is nothing, but the external opening. Through this port we are applying the pressurized fluid inside the valve. Port A is the application port through this port we are getting the flow of fluid for particular application. This spool is spring loaded a spring with sufficient stiffness is arranged along with the spool inside the valve.

Based upon the number of ports and based upon the number of positions, we can have a variety of spool valve configurations. There is another port that is called as the tank port. 'T' is designated for the tank that is the sump in hydraulic systems.

In pneumatic systems we are using the letter R, that is an event to the environment. On our screen, we can you can notice that, the power port is blocked. We are not getting any pressurized fluid inside the valve, because of the action of the spring force. If, we want to get the pressurized fluid for a certain application, if we want to get that pressurized fluid from the

port A, then we have to actuate we have to push the lever in this direction from left to the right, left to right.

When it is happening, then the port P will be opened to the application. The pressurized fluid is allowed to flow through the valve and it will be allowed to apply at the desired location. In this way the spool valve is working.

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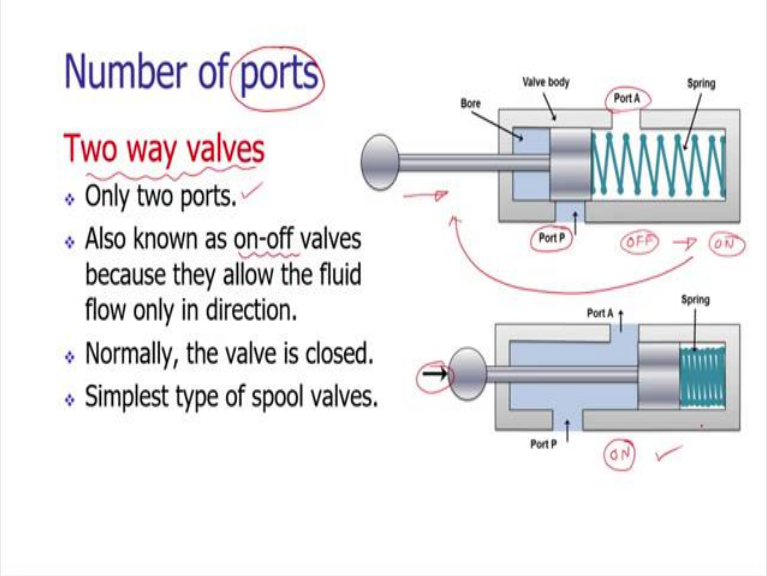

The next type of classification is based upon number of ports. As mentioned, number of ports are nothing, but number of openings to a particular valve. We can have the two way valves, when two ports are there. That that kind of valve is called as the two way valve. Here we can see two openings are provided.

This is the two way valve. This is a typical on off valve we can we can carry out a simple on off application. In normal it is the off position, as the valve is actuated that will change the off condition to the on condition, off condition will be converted into the on condition, when we apply a force at the lever.

When we apply the force at the lever as we can see here the condition is on the valve is allowing the pressurized fluid to flow through it. And, the simplest example of the two way valves is the spool valve which we have seen in the previous slide itself.

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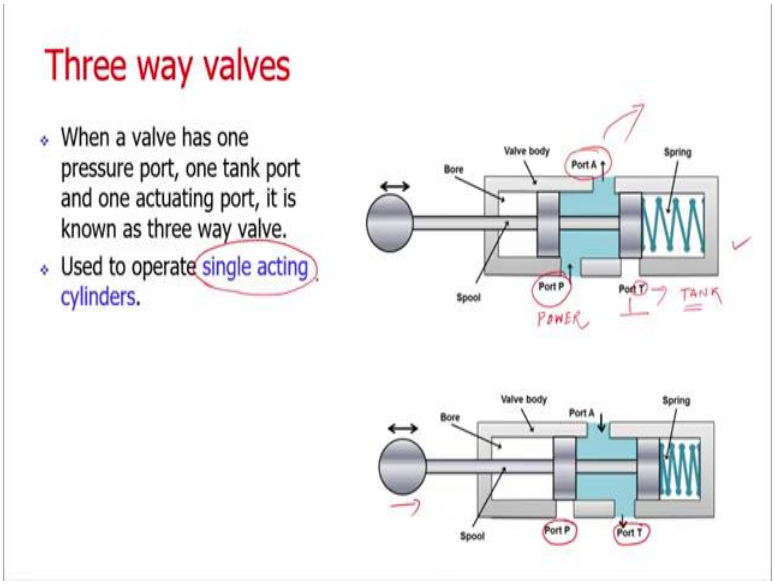

The three way valve, when we are having three openings, port A is for the application, port P is the power port, through which we are applying the pressurized fluid which is connected to the pump. Pump is operated by the motor. port T is the tank port some port during the unloading application we need to get the used fluid, that to be passed to the tank which can further be utilized for the pressure pressurization application.

Generally the three way valves are used to actuate or to operate the single acting cylinders. In this case, the power port is connected to the application port and the tank port is blocked, no fluid is coming to the tank. If, we operate the spool then the power port is blocked, no fluid is coming in from the power port, and we are getting the fluid from the port A to the tank port. This is the unloading operation in the single acting cylinders.

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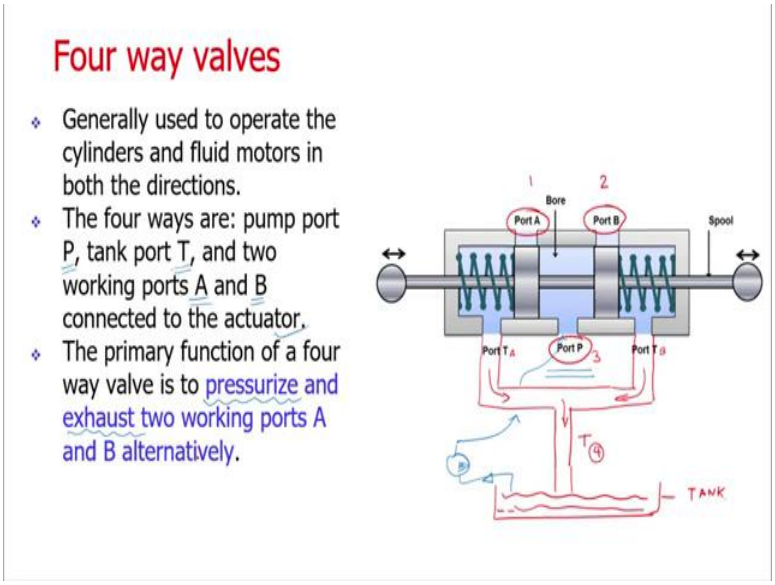

We can also have the four way valves. In the four way valves, we are using two application ports, port A and port B and we are having a power port and tank port. Here it is mentioned that, there are two tank ports can be seen. We can consider this is the tank port T A for unloading from port A and port T B, from unloading the port B.

But, internally these ports are connected to each other. We are having a common passage which is bifurcated, the inside construction is something like this. Now, the port T A and port T B are connected each other and we are having common passage to the tank.

Number of ways to be noted here are 1, 2, 3 and 4. Even though T A and T B are bifurcated it is considered as only 1 port. It is to be noted over here. The power port is connected to the pump, it is having it is separate passage we are having a pump, and then pump is connected over here. The pump is getting the fluid from the tank and it is just passing to the power port here.

There are four ways as mentioned the pump port P, tank port T and two working ports A and B, these are connected to the actuator. The primary function of the four way valve is the pressurization, it is used to pressurize, it is used to apply the pressurized fluid and it is also used to exhaust the two working ports. When the operation has been done, we can even exhaust the working port we can unload the fluid through working port.

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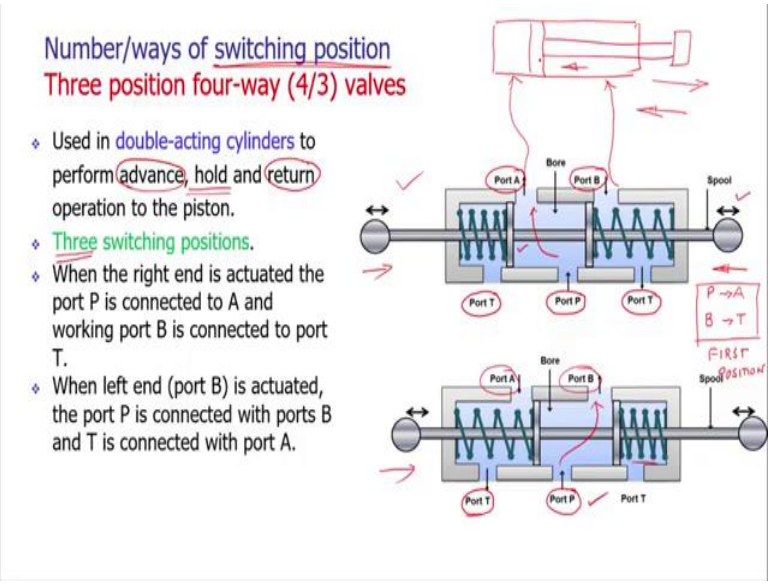

Well in the in the next type of the classification of the valves. We can categorize the valves based upon the number of switching positions. In our previous classification we have seen that number of ports or a number of openings now the number of switching position.

To operate a double acting cylinder, the fundamentally we need to you know carry out the three different applications. The advancement of the actuating cylinder, the return of the actuating cylinder, extension of the actuating cylinder, and the retraction of the actuating cylinder, that is advance and return and holding the cylinder at it is own position.

We need the three different positions of the control valve. The first in first position the control valve will actuate the cylinder to advanced it the typical arrangement is seen on our screen.

Here we can see there are four ports; port A, port B are the application ports; port P is the pump port or the power port and the port T is the tank port or the sump port. This configuration provides us the three position when we apply the force at the right end.

Here we can see the spring related to the spool the spring related to spool near to port A is compressed when the pressure is applied on the spring related to port A. The fluid port P is connected to the application port A. Here the fluid port P is connected to the application port A and the port B is connected to the tank port the P to A and B to T is the first position.

Iif we apply the pressure if you actuate the port B that is the left hand, if we apply the pressure over here. What will happen? When we are applying pressure at the left end the spring related to the spool near to port B is compressed.

Now, the port A is connected to the port T and the power port or the pump port is connected to the B. So, the pressurized fluid is moving at port B; the port B may be connected anywhere or at any side of the cylinder. Let us consider if we are having the cylinder here, the actuating cylinder which is having a piston and we can have the connections.

If this portion is connected over here and this portion is connected over. Now for now, first position when the pressurized fluid is pumped through port A, there would be extension and for the next position B, there would be retraction the B is connected over here to the power port. The pressurized fluid is applied and it is moving in the direction from right to left that is retraction or the contraction of the cylinder.

In between also we can achieve the position, that position is the holding position. That third position is applied when we are not connecting the power port with port A or port B. Iit may be situation that port B is connected to the tank port itself and port A and port B are blocked.

They are not connected to port P or they are not connected to port T, whatever the fluid inside the actuator actuating cylinder that will be there itself, or we can have a situation where the port A and port B are connected to the tank port itself.

Whatever the fluid which is there it is a relieving basically so, we are getting the pressurized fluid from both the sides of the piston and that that is going to the tank port. Based on the requirement we can have the different configuration for the third positions. Wwe will see some of the configurations in our next slide.

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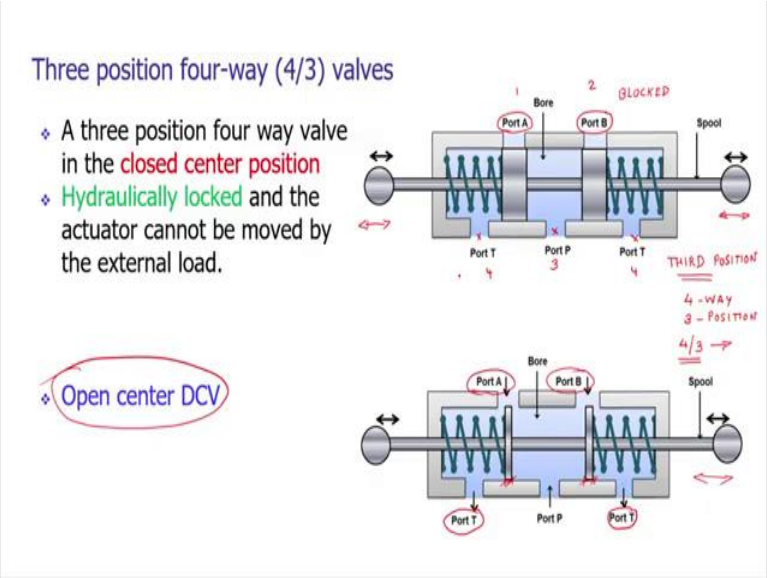

We have seen the two positions in our previous slide; the third position can be the closed center position or the open center position. In closed center position the actuator is locked. It is hydraulically locked the actuator cannot move by the external load.

To make it lock, we can see the arrangement how can we lock the cylinder? We are not moving the spool the spool is met to stand at this particular location, where the port A is blocked, port B is also blocked. They are not connected to the power port and even they are not connected to the tank port.

This situation is called as the third position. The valve is having 4 ports 1, 2, 3 and 4. It is a 4 way, but number of positions are 3, 3 position. This is called as 4 by 3, there are 3 position that to be operated by the 4 ports, that is the 4 by 3 valve, while somebody will say that I want to have a open center DC. Open center DC valve can be made by using this arrangement see here you can see.

Instead of having a very broad spool, we can have a thin spool and that thin spool can be utilized to connect the port A to tank port, and port B to the tank port during the unloading operation or due to during the relieving operation. By moving this spool we can operate the port A and port B, but at it is middle position at it is third position, we can directly connect port A and port B to the tank to relieve the pressure of the system.

These kind of valves are called as the open center direction control valves. There is a fundamental drawback or fundamental problem in the closed center position valve. The closed center position valve is not allowing the pressurized fluid that to pass through port A and port B, but the pump is continuously flowing in the pressurized fluid inside the system.

And due to the application of the continuous flow inside the system, the temperature of the system is getting increased. There is no utilization of the pressurized fluid, due to the putting up the energy inside system that will be converted into the thermal energy. The temperature may increase and that may lead to the failure of the system.

To avoid this we need to have a certain arrangement. In that arrangement the port P can be connected to the port T, so that we can produce the pressure, we can produce the thermal energy which is generated inside the system.

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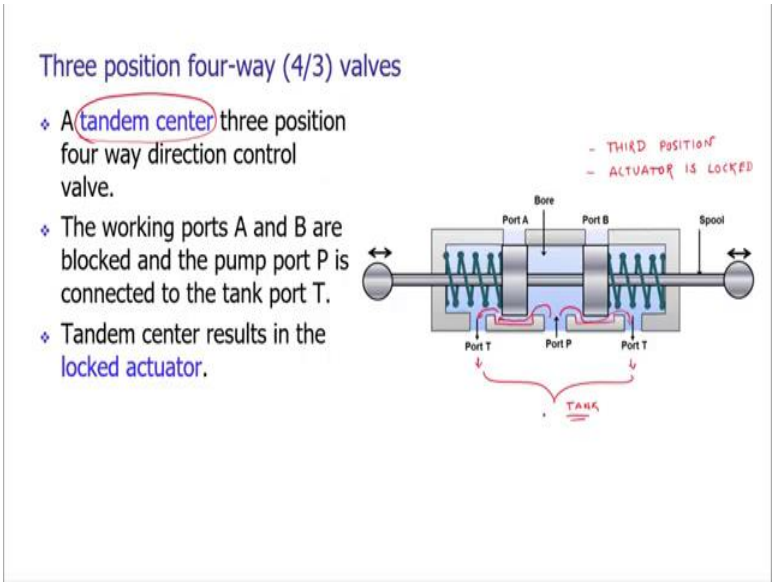

That particular arrangement is called as the third position with tandem center. Here we can see third position in tandem center. How we can achieve this? The valve is the third position, it is at third position, the actuator is locked is hydraulically locked and we need to protect the valve or the system against the building of the heat energy, the heating up the system.

Here we can see we are providing the grooves or the ports; we are providing grooves inside the system. When the third position is there, the fluid from the port P will be pass through this spaces and they will get back to the tank. During this third position, we can easily protect the

entire system from the unnecessarily heating up of the system due to the continuous pumping of energy from the pump.

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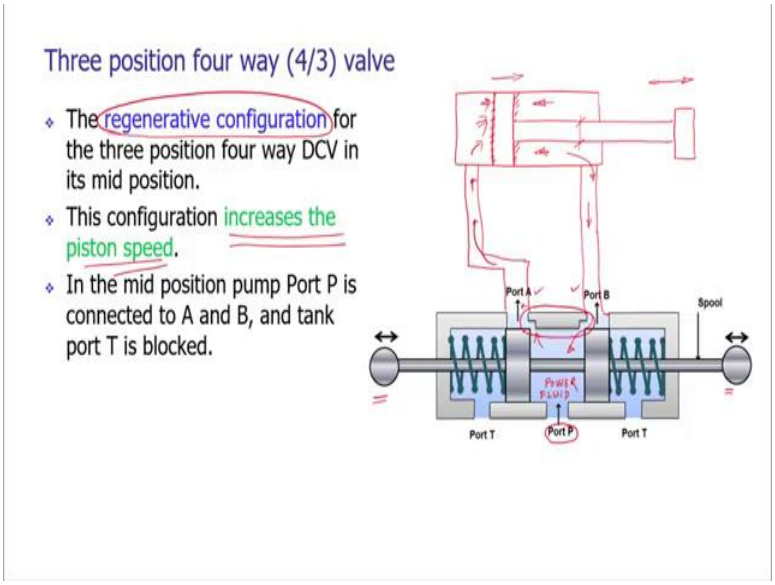

In certain cases, we are using a regenerative configuration as well. Consider we are having a piston cylinder arrangement this is piston cylinder arrangement that we do have and here it is connected to certain rod.

Now, the top center of the piston is connected to the port A and the bottom center is connected to port B. During the application of the hydraulic energy in activation of the cylinders, we have seen that we are applying the pressure as should on one side of the piston and then there is the movement of the piston inside the actuator cylinder.

We are all also applying the pressurized fluid on the other side of the cylinder and then there is the retraction of the cylinder are as well. Now, let us consider the port P is connected to the port A and port B simultaneously.

What will happen in this case, that the high pressure fluid is applied on both the side was on this side and on this side as well. As the area is more as the application area is more, the high pressure fluid will move on the on this side and it will apply the pressurized fluid on the top side of the piston.

The pressurized fluid is also there on the other side, but the area of application is less, due to some area has been consumed by the rod cross sectional area. The application area is less, due

to the less application area we are getting the pressurized fluid back from this portion to the port P itself.

The fluid which is there on the other side is coming back, it is returning back through port B and it is getting mixed at the power port itself. And, that is adding the pressure to the pressurized fluid coming from the pump.

These additional pressurized fluid is again pumping in this direction, that is increasing the pressure and due to in the increasing the pressure, we can further utilize it to increase the velocity. Thus the pressure which is generated on the rod side can be utilized to apply more pressure on the piston side. The energy which otherwise will get wasted, that energy will be getting down to the tank itself, can be utilized to apply more energy.

We can regenerate the energy; we can save the energy and that extra energy that we apply, that will certainly increase the speed. These kind of configuration is called as the regenerative configuration.

In the regenerative configuration we can have a typical arrangement which you can see here; this typical arrangement is providing us the facility, when the spool is in this position. It is helping to increase the speed of actuation, by getting the pressurized fluid from the piston rod side of the actuating cylinder and that is adding to the already pressurized fluid and that is increasing the speed of the piston.

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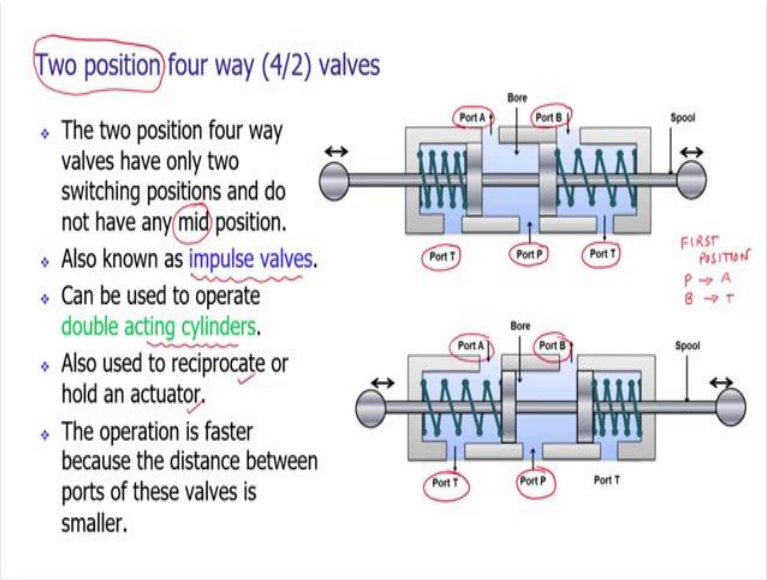

Well in the next type of configuration we are using two positions. Instead of having three position, in certain applications we need to have the two positions as well, the two position four way valve that is four by two valve can be seen on our screen.

It is having port A application port A, application port B, power port or pump port, then the tank port. Four ports are there and it is having two positions, see it will not have the mid position. Generally these kind of valves are called as the impulse valves, impulse application is here they can be used to operate the double acting cylinders.

Basically, they are used to have the reciprocation motion or the holding position of an actuator. The operation by using the two position four way valve is faster, because the distance between the ports of this valve is smaller.

At one position as you can see, in the first position the pump port P is connected to the application port A and the B is connected to the tank port. When we actuate the actuator by using the valve, when we actuate the cylinder then port P will be connected to port B, and the pressurized fluid from port A will taken back to the tank port T.

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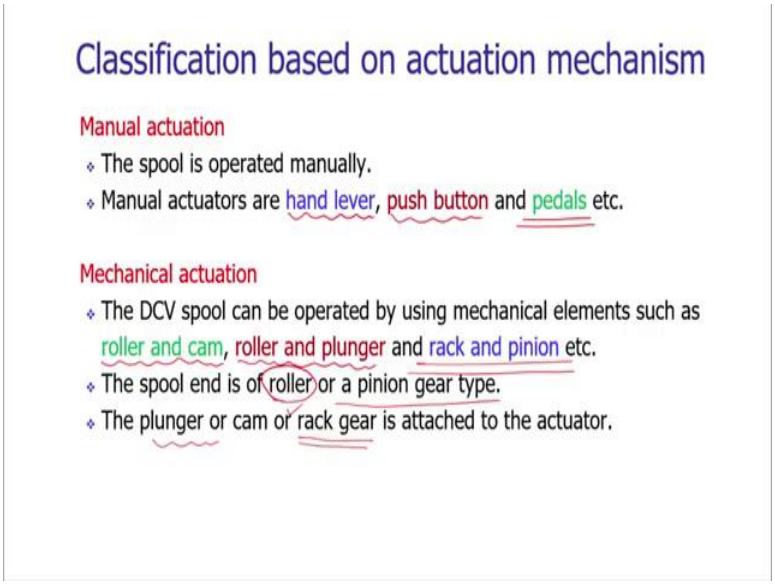

The next classification or the next groups of valves are based on their actuation mechanism. We can manually actuate the valves by using the hand lever, or by using push button, or by operating the valves using the pedals.

Mechanical actuation can also be done. To actuate the valves we are using the roller and cam mechanism, in our previous weeks we have already seen that, the roller and cam can be utilized for the actuation purpose, then roller and plunger arrangement.

Now, instead of having a cam arrangement we can have the plunger arrangement also, rack and pinion mechanisms can be incorporated to operate these valves. In the typical mechanical actuations, we can have the spool end is of roller or the pinion gear type. To this pinion gear type we are attaching the rack gear and the rack gear is actuating the pinion gear and in this way we are actuating the various valves.

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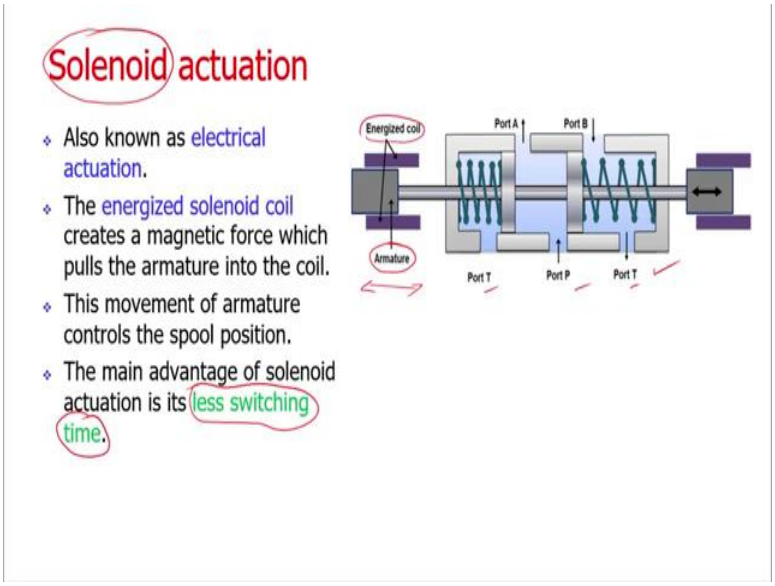

The next important group of the actuation mechanism based valve is the solenoid actuation mechanism based valve. This is an important element in the hydraulics basically the control valves are being operated by using the electrical energy. Typical arrangement of this solenoid based actuation can be seen on your screen.

We are having a valve, the valve is having it is routine ports port A B pump port P and the T. The spool of the valve is connected to solenoid actuation system. And, the solenoid actuation system is having an armature and this armature is placed inside an energized coil.

We are applying the electrical energy to the coil the coil is generating electromagnetic force and that electromagnetic force is operating the armature. The movement of the armature is

based upon the formation of electromagnetic force, the main advantage of the solenoid actuation is the switching time is less.

In mechanical actuation or in the manual actuation the switching time is little long. In the electrical actuation we have to just give the electrical pulse, electrical energy pulse to the or to the actuation system, it is immediately actuating the valves.

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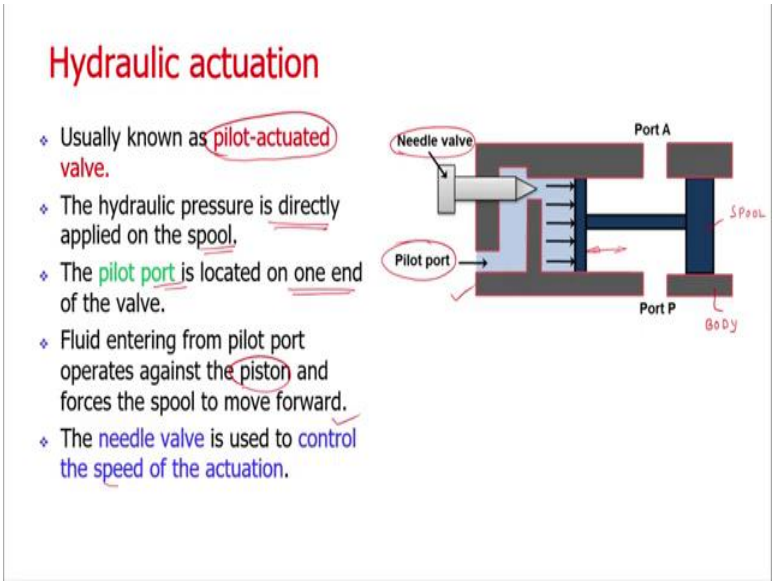

We can also have the hydraulic actuation; it is called as the pilot actuated valve. In hydraulic actuation we are applying the hydraulic energy to operate the valve. The typical arrangement can be seen on our screen. We are having a body of the valve here and inside the body of the valve, here is the internal spaces in this internal spaces we are having the spool, the spool is having an area over which we are applying external pressurized hydraulic fluid.

The external pressurized hydraulic fluid is applying the pressure on the spool and that is displacing the spool from it is the original position, it is operating the spool. The flow control of the pressurized fluid through the pilot port is controlled by a needle valve.

Already, we have seen that the screw based needle valve can be utilized to control the flow of the fluid inside the system. These kind of actuations are called as the hydraulic actuation based valves or the pilot port based valves.

The hydraulic pressure is directly applied on the spool and the pilot port is located on you know one side of the valve. It is on one side the pilot port is applied. The fluid is entering from the

pilot port and that is operating against the piston and that is forcing this spool to move in the forward direction. As mentioned the needle valve is used to control the speed of the actuation.

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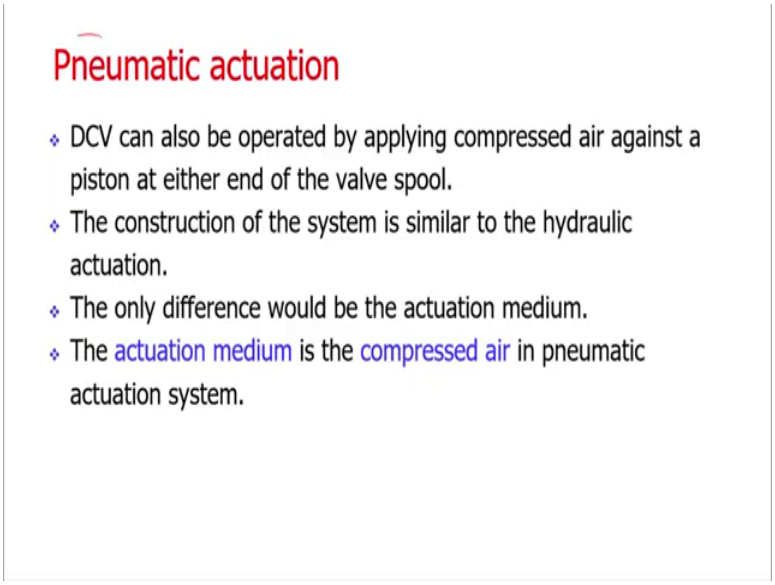

We can use pneumatic energy as well, we can use the compressed air to actuate the directional control valves by using the compressed air against the piston. Instead of having the pressurized fluid we can have the compressed air, at the piston to move the piston in particular direction. The construction of the system is similar to the hydraulic actuation system itself. We are having the similar type of construction. Instead of having a hydraulic fluid here we are using the compressed air.

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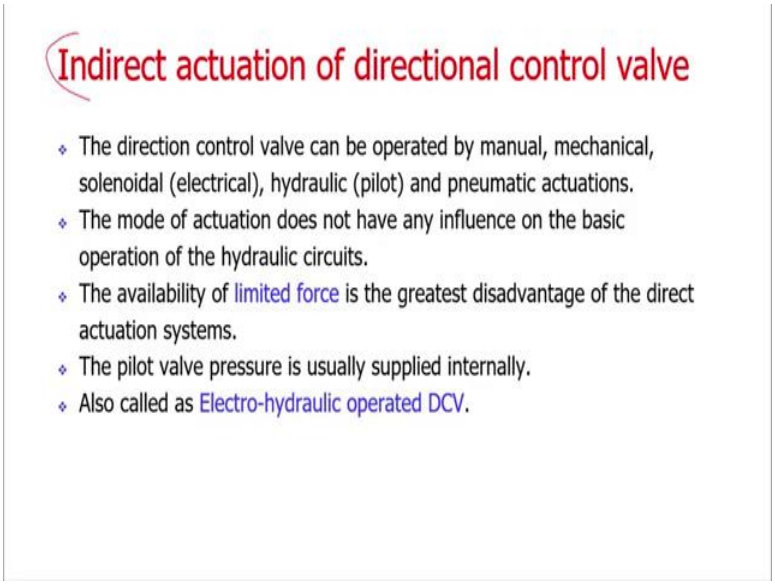

Well the next is the indirect actuation of the DCV. We have seen that manual operation mechanical operation or hydraulic or pneumatic actuation, but all they are having a limited force capability. If we consider a directional control valve for the distribution of water, the distribution of water in the very large size of the pipes. Let us consider we are using the directional control valves in a hydro power project.

There very huge valves are employed and to operate the valves we need a lot of energy. In this particular case we cannot have the direct application of the energy or we cannot have the direct actuation: may be manual or the mechanical.

To operate such a huge valves we are using another valve, we are using a supplementary valve to operate this directional control valve. And, this the extra valve which is operating the directional control valve is working based upon the electrical energy itself. These are called as the electro hydraulic operated DCVs.

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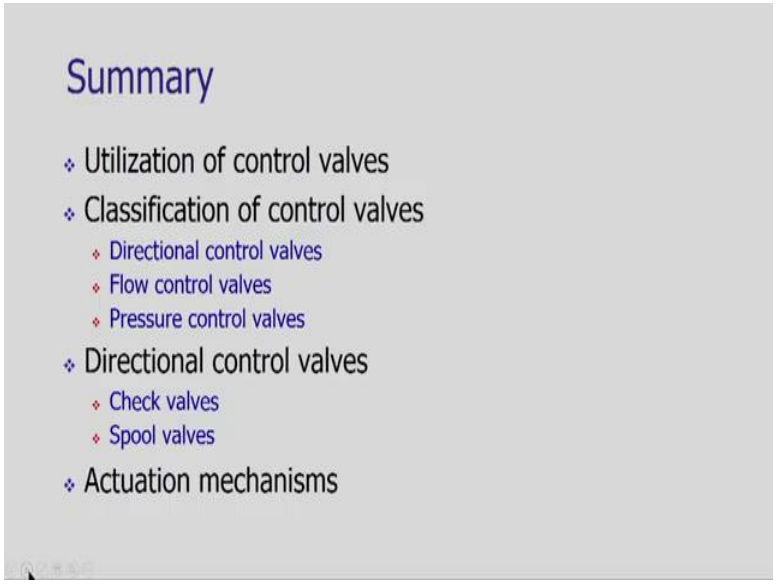

Well my friend, well my friends let me summarize the lecture 1. In this lecture we have seen the utilization of control valves what are the applications of the control valves, construction and the working details of various control valves such as the check valves and spool valves.

In addition to the directional control valves flow control valves and pressure control valves are also to be are discussed, that we are seeing in the next lecture that is lecture 2. In this lecture we also seen the actuation mechanisms, for a typical directional control valve.

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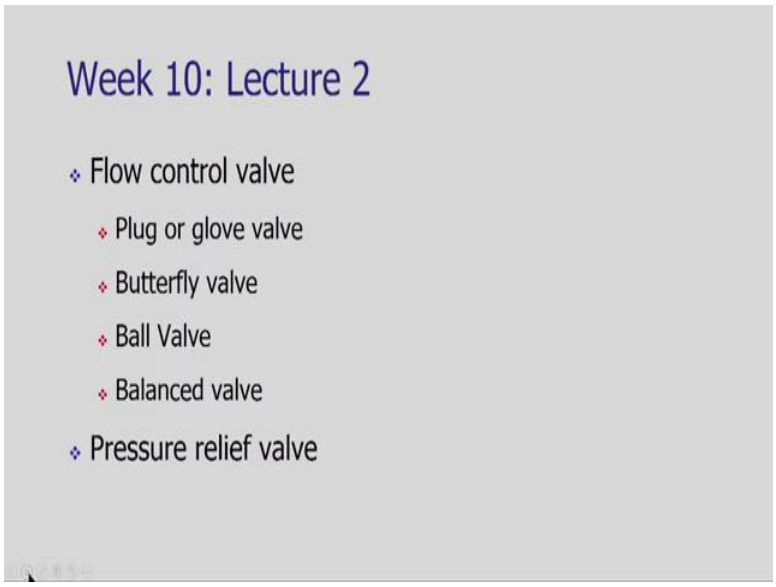

In the next lecture, that is lecture 2 we will study the flow control valve and pressure relief valve. There are various types of flow control valves are used in the industry and these are plug or a glow valves, butterfly valve, ball valve, and balanced valve.

Then, thank you and let us meet in the lecture 2.