Industrial Automation & Control
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Lecture - 23
Introduction to CNC Machines

Welcome to lesson 23 of the course in Industrial Automation and Control. Today we will be talking about CNC Machines that is numerically computer numerically controlled machines.

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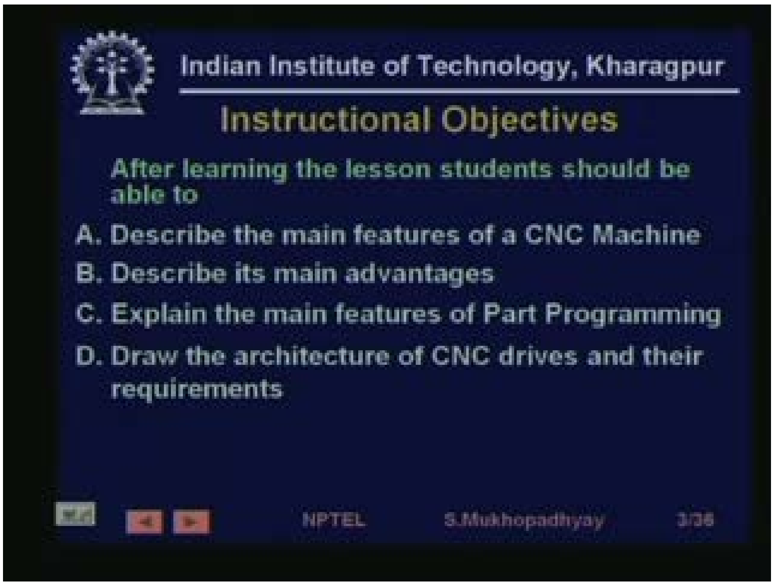

So, as usual let us look at the instructional objectives of this lesson, so after learning the lessons the student should be able to describe the main features of a CNC machine, what makes it. Describe it is main advantages, why we should spend money to buy these machines, they are very expensive. Explain the main features of part programming; because these machines are automated they can be programmed, so the programs are called part programs. So, we will see some basic features of part programming.

And finally, the drives the CNC machines create motions, all machines create motions machines especially which used for manufacturing. So, naturally they involved drives the technology, which generates the power and the control for creating precise motion against heavy loads. We will see these drives and we will see the requirements on the CNC drives. So, that later on when we study the drive technology we can refer to that and we can we will see how these drives are actually realized using electrical machines power electronics and controls.

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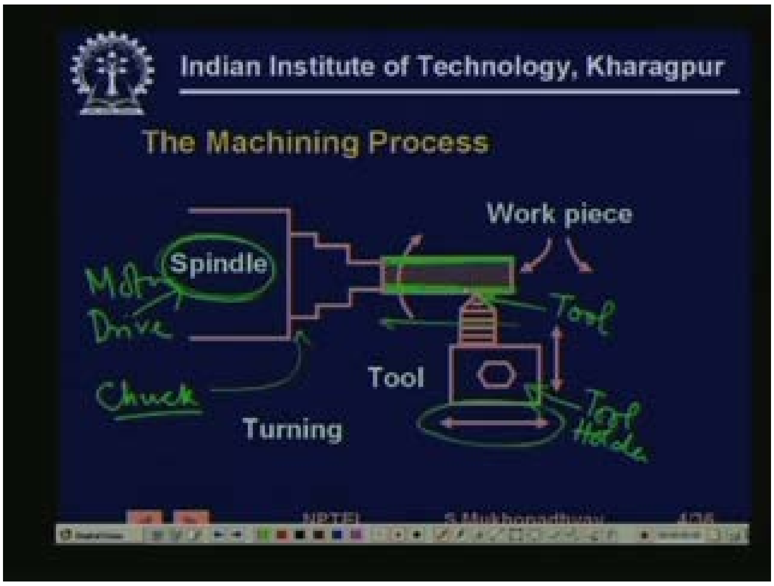

So, let us first look at a machining process right, so basically in a machining process we are talking about manufacturing typically metal I mean metallic materials. So, essentially it is taking a piece of metal and removing metal from that precisely, so that you get a part of a specific of specific geometric dimensions. So, essentially it is metal removal which means that the actually it is removal by a tool which is made of very hard metal things like you know carbide diamond etcetera.

So, essentially we have to produce relative motion against off the job and the tool. So, there are various kinds of machining processes the most common is turning which we say which we seen lathes machine. So, in lathe machine, what happens is that, this is the work piece which is held in a holding mechanism typically known as the chuck and the chuck is rotated by a spindle which is here there is a drive motor.

So, we have a motor drive here and so the work piece is rotating and this is the tool holder which moves. So, the tool holder can move this way can move, so therefore it for example, it can be used to reduce the diameter of the work piece. So, as the thing rotates on the tool moves from this end to that end with a certain degree of penetrations, so this much of metal will be removed.

From both sides, so after the tool moves one cycle the diameter will get reduce to this, so this is the way turning produces. Now then typically, so in this case note that it is the work piece which is rotating rewind by the spindle, while it is the tool which is having linear motion.

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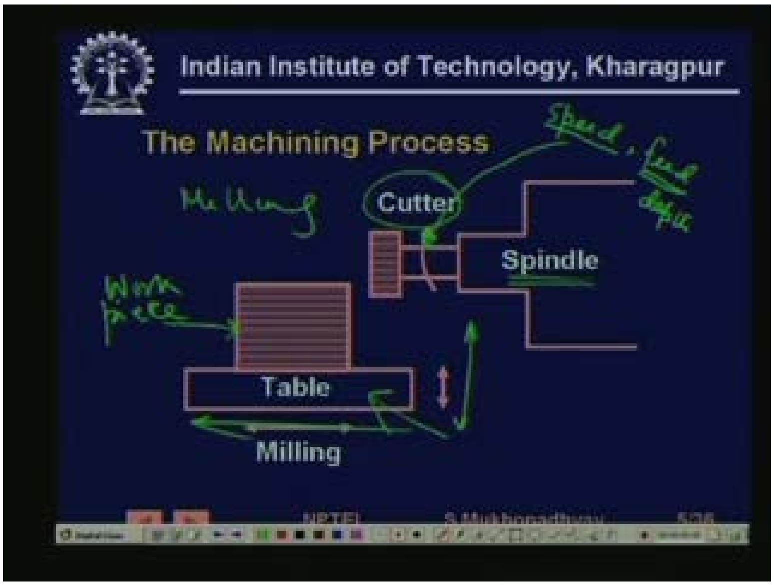

On the other hand if we take another machining processing called milling, there you have a cutter. So, this is the milling cutter which has sharp teeth and which is driven by this spindle and it is the job, this is the table. This is the job work piece which is having rectilinear motion and generally two dimensional rectilinear motions it can move this way that way and the table can move this way that way also.

So, you can create two dimensional motions and the cutter is rotating and steady in one location. So, the compared to turning it is in the turning it was the work piece which was rotating here, it is the tool which is rotating, so it can happen both ways for example, if you take another process called drilling, so in a drilling also it is the work piece which is which has two dimensional motion and because you may like to drill a hole anywhere on the work piece.

On the other hand the work piece is rotating at generally at very high speed it is, so it is rotating at the same time it can come down to actually drill a hole. So, the work piece in this case is capable of it has high speed rotation and it can also move along one axis. Whether the tool can move along one axis and while rotating and the job can move in have rectilinear motion have motion a two dimensional motion, which means this shows that the kind, that any cut metal cutting machine would require motion for the tool; and would require motion for the work piece and these motions naturally have to be very precise.

Number 2 is that for quick cutting the there has to be these are generally parameterize by quantities like speed which shows, which is related to the cutting speed of the rotating body then it could be then there is something called feed. So, feed means that the stroke of the linear motion of the tool, in the case of per rotation by how much does the tool move in the case of turning or by how much does a job move in the case of milling or depth of cut.

So, how much in one complete cycle of motion, how much depth of material is removed. So, such parameters are set typically in such machines and naturally you can understand that even if we want very good surface finish, we generally have to we cannot give very high depth of cut. So, for rough cuts we can for quick production we can give high depth of cuts and high feeds, so naturally that will you are removing metal. So, metal like steel, so naturally it puts a lot of load on the drives. So, the idea is to create very precise motions against very high loads.

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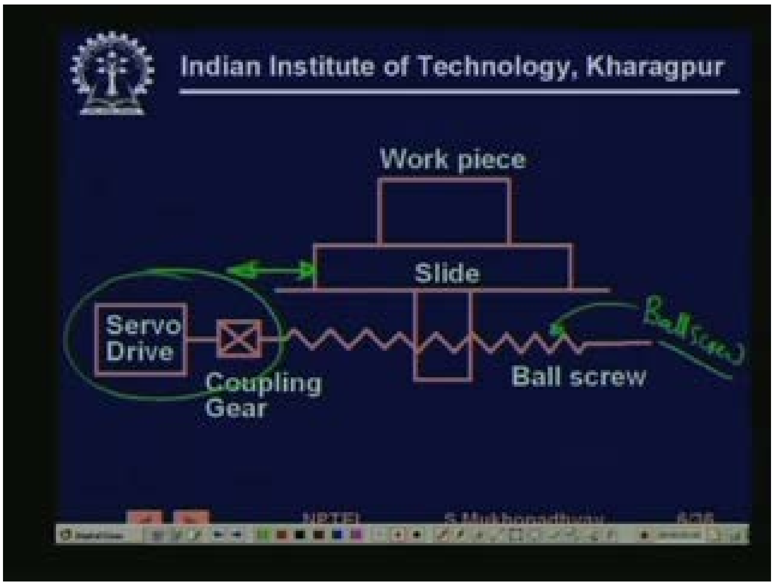

So, the work piece typically show this, how the movement is created? So, the rotating is actually very simple, it is just connected to the shaft of this spindle drive motor. So, as the motor rotates the tool in the case of milling or the work piece or the chuck in the case of turning will rotate that is very simple.

For creating the two dimensional motion of the table, this kind of a mechanism is created where there is a slide, so this slide can we are only showing motion in one direction. So, this direction slide is slide can move along this, because it is connected to what is known as the ball screw, so this is the ball screw.

So, the drive is still a motor, so this is the motor which is coupled to the ball screw may be through a gear. So, as the ball screw rotates this slide can move this way or that way just like a screw motion and this ball screws are very well designed such that there is the precise motion is created and things like back lash which affect the accuracy of manufacturing are minimized. And they can be minimized they are actually minimized by engineering design and whatever remains can be also mostly compensated in these machines.

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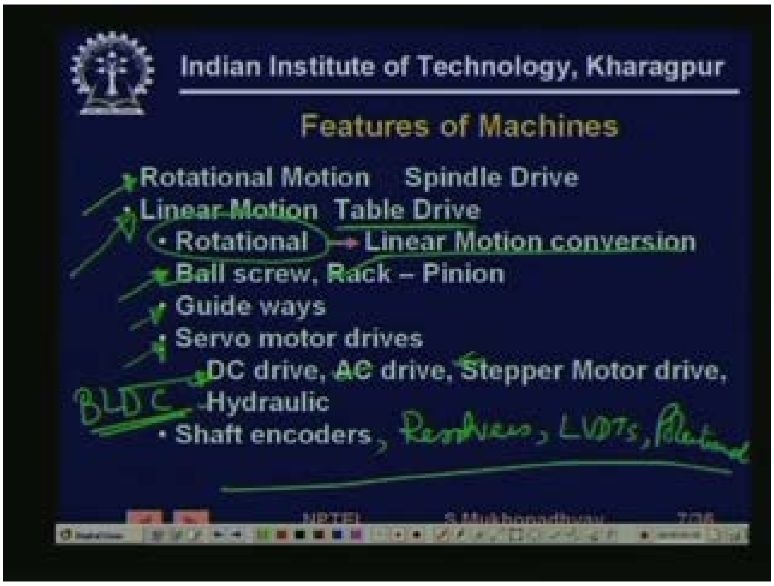

So, to summarize if you look at their feature of the machine, then we have to create rotational motion which is created by the spindle drive. We have to create linear motion which is created by the table drives and in the table drive basically the drive is rotational, there is a linear motion conversion using ball screw or rack-pinion, generally ball screw gives better accuracy and guide ways. So, that the there is no transverse motion, motions are strictly in the direction in which the drive is provided.

This drives that are employed generally servo motor drives, because you need to have precise motion control and you need to have good transient response, because drives have to be very precise position control is required. So, therefore, they have to start and stop at the right movements and sometimes even speed ratios have to be maintained along the two axis for cutting you know things like surfaces says cylindrical surfaces or cutting like cutting corners.

So, we employ servo motor drives DC drives stepper motor or AC drives for very large machines you can have hydraulic drives also. But generally, we employ DC and AC drives for very small things stepper drives are used, but they are generally not of that high rating. So therefore, DC and AC drives are generally used, mostly DC drives the DC and BLDC drives.

Brush less DCs, we will see these drives in detail in some more detail in our lessons on drives then you naturally you need feedback. So, digital feedbacks like shaft encoders or you can have resolvers, sometimes you can have position sensor like LVDTs or potentiometers etcetera.

So, you need basically you have to create rotational linear motion precise motion, so you need precise drives check rated by motors and you need speed and position feedback. So, they are provided by the sensors and similarly you have mechanical arrangements which create precise motion like ball screw etcetera, so these are the major parts in the machine.

Of course, there are various kinds of auxiliary parts like for example; there is very high heat generation at the tool work piece interface. So, there is coolant has to be applied liquid coolant has to be applied directly at the tool job interface, so that the interface does not heat up because that will affect the quality of machining. So, there is a coolant plus there all kinds of other things like for automation there is whole automation set up where somebody can enter programs. So, there is operated display there all kinds of protection mechanisms, so though they are the auxiliary components thus there is power.

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So, actually these machines it was soon developed, it was soon understood that there is a lot of things to be gained if you can control the machines precisely using a digital techniques and finally, by computer like components like especially microprocessors can be interfaced with.

So, this kind of controllers would lead to very precise control of the machine which is generally not possible by a manual operator. So, it was soon realized that these systems can lead to very high quality engineering and also reduce unproductive time.

Or this term, numerical control has been defined by the EIA as a system in which actions are controlled by direct insertion of numerical data at some point. So, at some point numerical data must be used to control the machine and the system must automatically interpret at least some portion of this data. So, even if you do not have a computer, you can have a paper punch card reader they are the ordinary, they were the early versions of the CNC machines.

So, even if you have paper tape which is punched so and there is should be a paper tape reader and that reader is to create the motion. So, even if there is no explicit electronic computer here also in the paper tape you are there is some numeric data which is punched and according to that numeric data the machine was controlled that is why it is called numeric control.

But, in modern machines these things do not exists at all model machines are all computer controlled. So, basically computer numerically controlled means that computer controlled, it can we have it is generally a microprocessor it may be an industrial PC sometimes it there will be a PLC. So, various kinds of industrial computers are used.

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So, it basically is meant to replace manual actions of operators and so the instructions to the machine which are required for this operation are written in the form of a kind of program called part programs which describe the activities which are interpreted and executed by the machine. So, we will see little later, what kind of things can be done using part programs?

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Typically this CNC the CNC machines are very expensive, so it is not that everybody can afford it or that for every kind of a manufacturing operation. One has to procure a CNC, so CNC will be good for parts process frequently in small lots, because if you process parts frequently in small lots. Then, you will if you do not use automation then you are going to end of spending a lot of time by lot of set up time.

So, every time you have a new lot you will spend a good amount of time in setting up then you will manufacture since the lots are small, so you are going to manufacture a little while and then again you have to spend time in set up. So, the actual productive time of a machine which is just the time when it cuts the metal is actually reduced, so therefore, the CNC machine is suitable for this, because it cuts down that set of time significantly using automation.

Whether, part geometry is complex, so you do not have to really rely on the operator skill to just produce a correct part program and if the part program is correct. Then, the machine being automated will absolutely, correctly will produce that geometry irrespective of the operator skill.

Tolerances are close, because the kind of controls that you apply the kind of controls that you apply are sophisticated that it is not possible for manual operators to apply such controls and therefore, very high compliance to the tolerances can be realized. When there are several operations needed on the part again it is related to set of time you may need to have various kinds of tools working on that.

So therefore, again you will lose the lot of time by changing tools why while with the things like technology like automatic tool changers and wide variety of tool magazines these. This tool changing is generally achieved very efficiently in CNC machines. And, parts are expensive, because when parts and expensive you do not like to take a chance that due to faulty manufacturing some part will get wasted. So, that is why you take help of a machine which once it is set up properly it will go on working and producing the parts without any mistake or failure.

When engineering design changes are again likely again this is also related to set of times. So, that there are basically two points, one is situations where a good amount of set up time is required and secondly, where situations are very high skill skills to cater to complex geometry and close tolerances are required. So, it is during these for these two reasons that CNC score over non CNC machine.

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So, manually operated machines from advantage and disadvantages you have flexibility is one advantage which is achieved by programming in. So, you can easily change if just change a program and your hole set up will get change or you can pre stored programs which can be just need to loaded which is a much faster operation.

Disadvantages an of course, accuracy flexibility and accuracy disadvantages come corresponding disadvantages could be one is cost. So, there is a these machines are very expensive and they are very high costs and maintenance, so you need very a expert maintenance for this machines, because if they are not maintain properly. Then, they are going to be damaged and then finally, they will lose their accuracy and things like that.

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So, overall productivity is much improved, due to reduce set up time automated tool changing which is again reduce a set up time I mean unproductive time, sometimes some of these machines will have inherent material handling. So, if you want a tool change a tool, the machine will stop the machine take out the tool put it in the tool magazine bring out another tool. So, all these material handling work will be done by the machine itself.

Scarp rate is reduced, because you must have it is assumed that the part programs are written with carefully using scientific optimization methods. So, from a given piece of material, because you are not going to you have much more precise operations. So, you can have optimal material utilization, therefore scrap rate will be reduced.

Man power is reduced, because much of it much of the work in these machines can done automatically. Sometimes you program a machine for a day and feed it with enough work material, once in a time and then run it hole day without any kind of supervision or any kind of operating personnel these machines can go on manufacturing one of one of after the other the parts.

They have reduced down time; because these are the benefits that you get by paying that high some of money for it is cost. So, down time is reduced, because these machines are very well made they are engineering is very strong. On the other hand, the disadvantages is that be a operation of this machines and maintenance required very highly skilled operator not only just skilled in operation, but in various other kinds of technologies. For example, part program writing etcetera they may require skilled operators.

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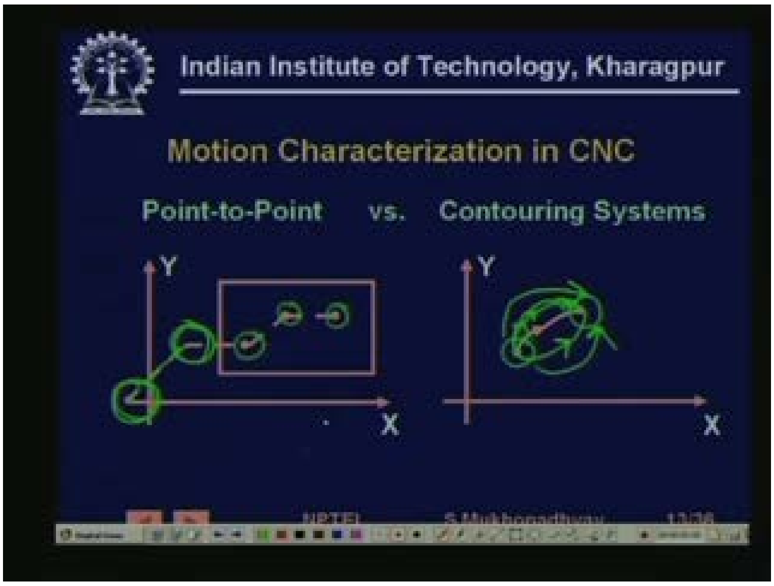

So, we have seen that CNC machines in many situations are amply justified. So now, we will see that what kind of motions theses CNCs can be created such that automatically parts can be manufactured. So, there are generally two kinds of machines; one kind of machines are capable of having making point to point motions.

So, typically used in drilling, so you say that drill a hole here, then a hole here then a hole here, here and here, so you are just specifying certain points. So, the machine is coming to a point doing a certain operation then again going to another point and doing another operation, so the operation that the machines are doing are essentially point operations like drilling.

On the other hand you can have a systems where you can specify the start point in the coordinate space, the end point and then specify some kind of point interpolation let us say a circular interpolation. So, the machine will start from here and depending on your instruction will cut an arc suppose we are talking about circular interpolation will cut an arc from here to here. For it could also cut an arc it could also cut an arc between these two points.

So, that depends on what you are specified if you are specified if you as specified a clock wise arc, then this will be drawn if a specified and anticlockwise arc then this will be this will be cut. So, these are called contouring systems you can note that here the controlled cutting goes on throughout the journey and two be able to achieve certain kinds of profiles like a circle the x and y axis drives for the table have to be very coordinated to be able to get that controlled.

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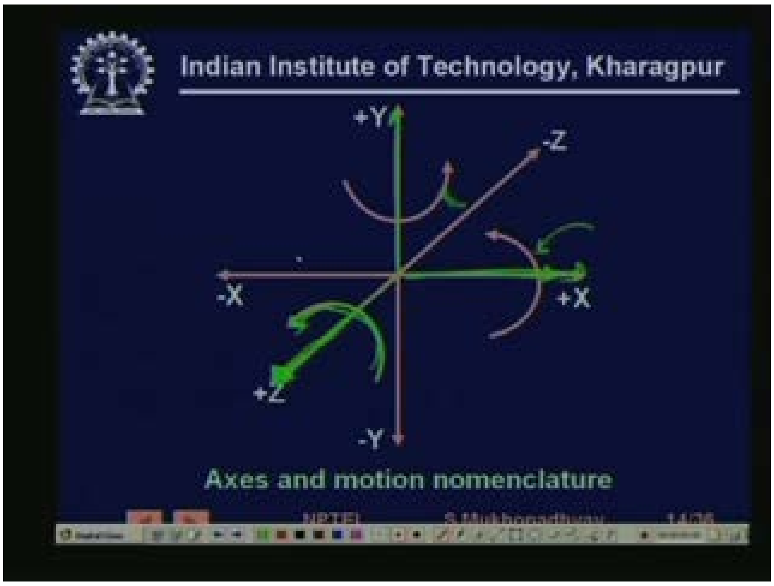

So, it is fundamental to define coordinate systems, because all the part program instructions are given. Most of them are involved especially the main cutting instructions part program instructions all involves various coordinates, so the coordinates phase is actually very simple. So, this is like X in this direction, Y in this direction and right handed coordinate system, so therefore, Z will be the vertical direction.

And therefore, you can also have similarly define rotational direction, so if you take again a right handed system. Then, if you curl your fingers around this, then the positive direction, this direction is positive which were the thumbs will point towards the positive Z axis, so these are given according to that. So, these will be positive rotations and these will be positive translations.

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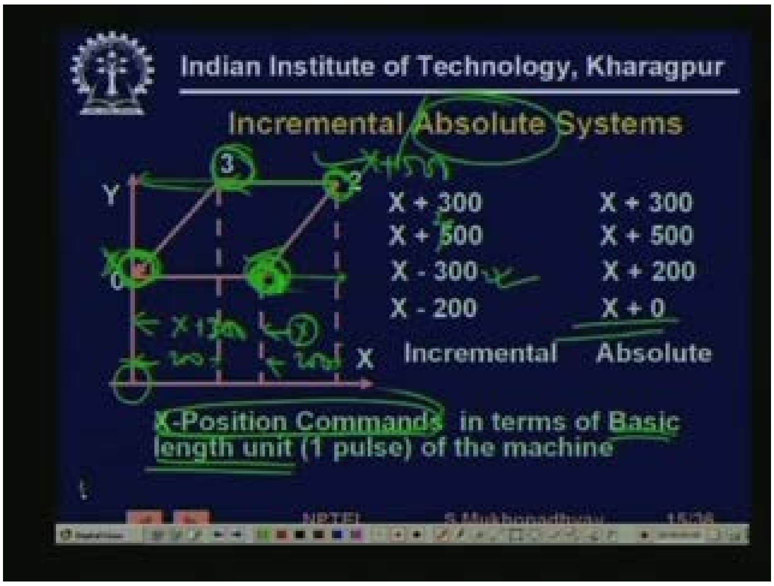

Then, all these point and coordinates which are mentioned are can be mentioned in two ways one is an incremental or an absolute system, generally the absolute system is preferred.

So, that if you want to specify the X axis coordinates of these four points, then in the incremental system you will say suppose this is X here, the X coordinate is going to be X plus 300, similarly you have done X plus 300 now your current position is at 1. So, X is the X coordinate of this point is X plus 300 and the coordinate of this point is X plus 500.

So, in the incremental system you always do it from the current points, so the current point is here, this is going to be 200. So therefore, the next instruction to the machine will be X plus 300 actually this should have been 200, so X plus 300 X plus 200, then X you have come to this point. And then, if you want to go to 3, then you have to do X minus 300, then from 3 to 1 you have to do X minus 200.

On the other hand if you absolute then you adjust always do it from a stationery origin that you have assumed in the coordinate space of the machine. So, the four coordinates are going to be X plus 300 X plus 500, 300 plus 200 is 500 and then this is again X plus 200, because this is 200 and then finally X.

Now, why the absolute system is preferred, because suppose you are trying to hole at drill at these locations. So, even if this location is in error, this location will not be if it is an absolute system, but if it is an incremental system then if at one point the geometric coordinates and not the same then there is a high chance that all are the geometric coordinates will also get affected.

If the system of providing coordinates is incremental and there will also be a units. So, these X positions that are meant at will be typically mentioned are generally mention in terms of, what is known as a basic length unit? So, a basic length unit is suppose you have a shaft encoder. So, the shaft encoder gives a 500 pulses per revolution.

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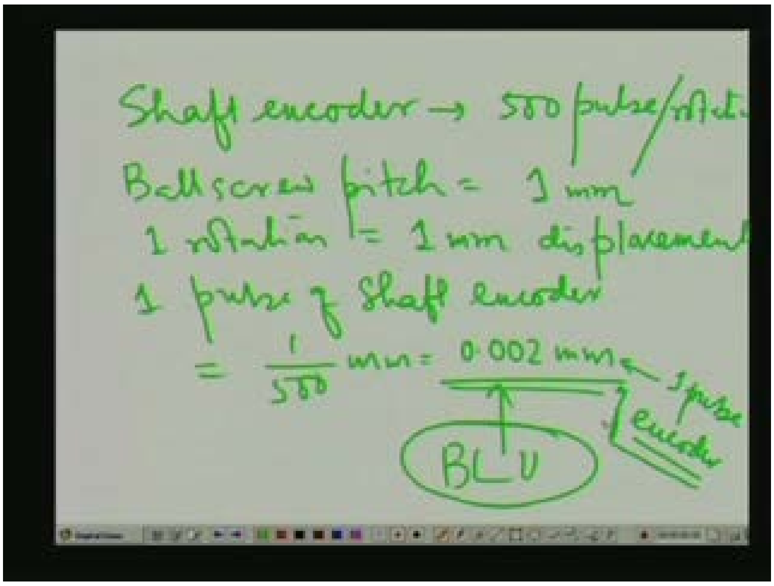

Let us do this to understand what is the basic length unit, so suppose shaft encoder gives 500 pulse per rotation per rotation. On the other hand the ball screw or there will ball screw pitch is say 1 mm.

So, one rotation is equal to 1mm, advancement 1 mm displacement, so 1 pulse of shaft encoder is equal to 1 by 500 mm is equal to 0.002 mm, this is the basic length. This is the smallest unit of displacement that this is a smallest displacement that the machine can be aware off, because this will be 1 pulse of encoder. So, that is the smallest and that is called the basic length units, so all these can be are generally stated in terms of the basic length unit.

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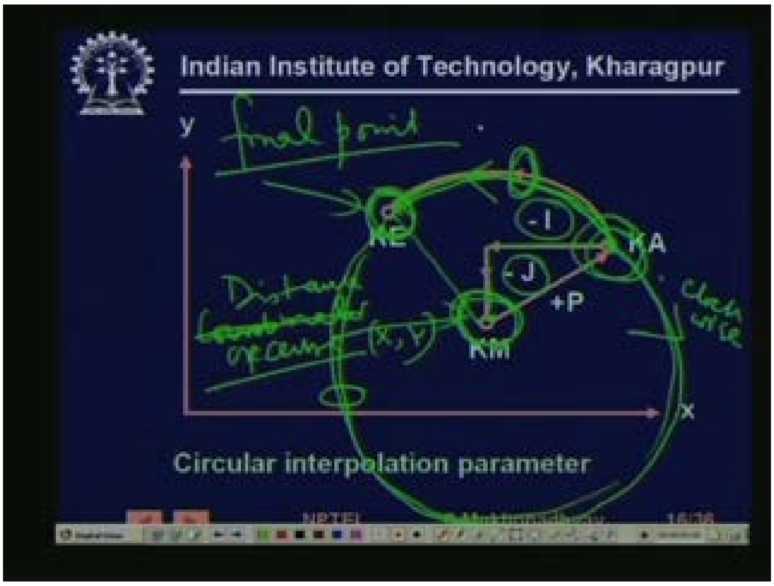

Similarly, if you have circular interpolation, then you have to give the start coordinate, you have to give the end coordinate and you have to give this is going to be a circular arc. So, you have to give the coordinate of the center or other the distance not coordinate distance of center of x and y and sometime if this is given you should be able to draw the circle, sometimes the final point is given.

So, given these you can try to and taking this as center, we have to a draw a circular arc and take the tool along this circular arc, so this is the way typically, the circle parameters are specified. So, this I and J will give the coordinate of the circle, this KA and KE will give the two end points and then you can draw the circle like this also.

So, whether you will this is a start, if you want to draw this circle, then you will go this way which is clockwise. If you wanted to draw this circle, then you will go anticlockwise. So, it needs to be mention, whether the circle has to be drawn in clockwise or in anticlockwise direction.

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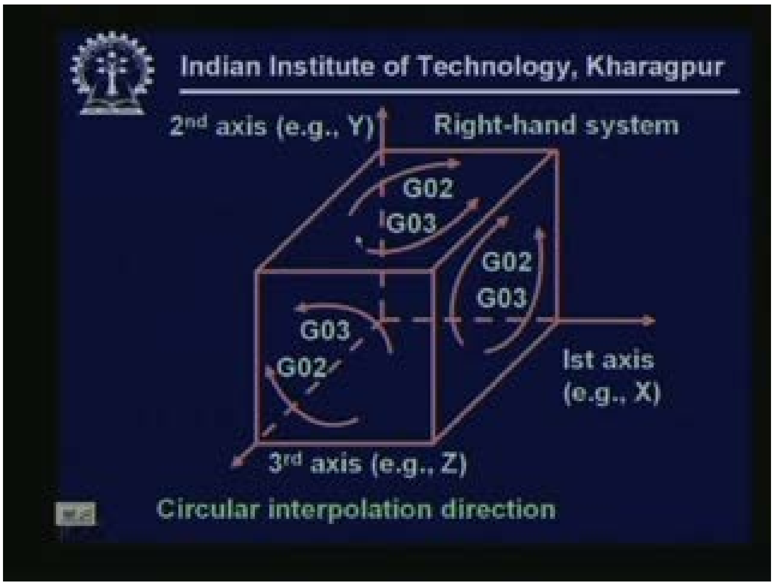

Accordingly either this one or this one will be manufactured; these are the various circular interpolation directions. So along the various axes.

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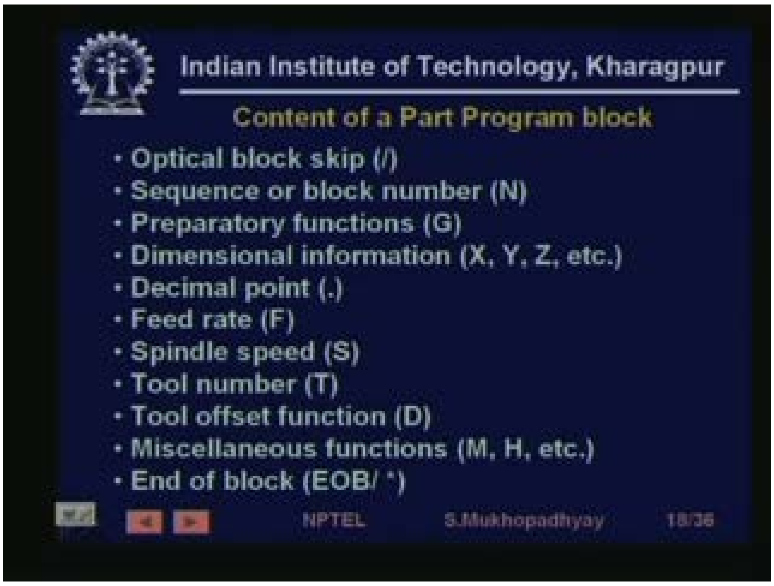

Now, we see that in a particular part program actually part programs are nothing but they are actually particular form in which the manufacturing people have been familiar and convenient. But, otherwise it just like specify some operation, so every unit of operation is called a block.

So, a part program block basically consists of a number of blocks which get executed. So, in a sense it is like this PLC rungs just like a relay ladder logic diagram is also just a suspicious graphical arrangement, so that people who develop programs that is the people from the domain they can understand it.

Similarly here, we write part programs, finally these part programs are going to be the actual real time executive who controls the two drives this it reads the part program and then actually drives the various activities in the machine. So, you can have such parameters in a typical program block like block skip, so if you have that block skip then that particular block is ignored.

Similarly, here executing a sequence of blocks, so you should have a block number, then there are some functions which are called preparatory functions for example, deciding on whether the positioning system is going to be absolute or incremental whether the values which are given are in metric or the inch, where is the origin of the coordinate system etcetera. So, there are some preparatory functions that are to be executed, before executing a block.

Similarly, dimensional information is provided as in XYZ, decimal point is fine. Then you have to provide things like feed rate spindle speed, tool number, because tools are uniquely identified by their number in a in a magazine. So, if the machine has to select a particular tool the tool number has to be given.

Similarly, the tool offset function, there are actually what happens is that, for exact dimensional accuracy because there tool has a finite radius. So, when the tool moves because of this there is some distance between the logical center of the tool tip and the actual point where it is making a contact and it is not only making a contact it is actually gradually getting worn away.

So, this length is actually changing that is actually shrinking, so there are various kinds of offsets are produced and there is when you are actually giving the motion. So, you have to give the motion to the tool in such a manner that after taking care of this finite tool head situation, then the right parameter will be obtained, therefore, the tools must be little bit offset.

So, those functions are to be set during preparatory phase and there are can be various other miscellaneous functions. There can be other various kinds of auxiliary functions also like switch off coolant switch on coolant and things like that and finally, it has to ever end of block signal.

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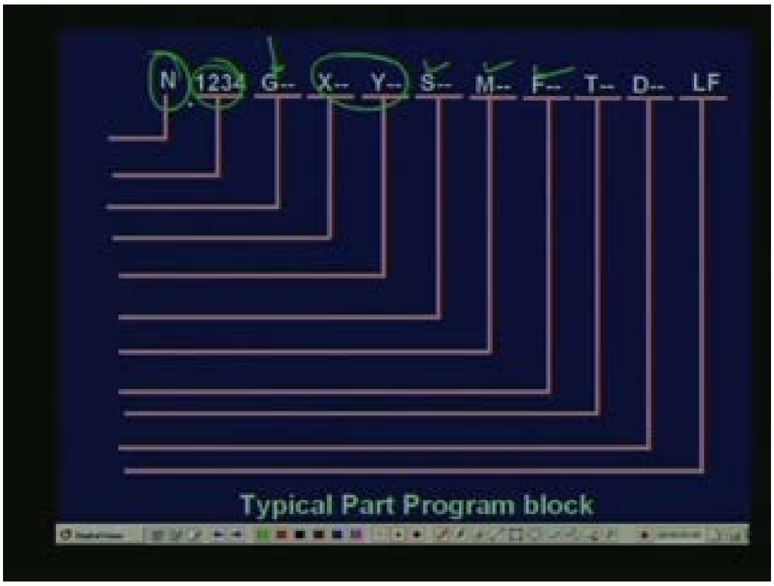

So, typically a block is defined like this is the number, then there is a G command, then there are some XY commands which are position coordinates even apart from that there are various other kinds of commands which are specified. So, we are we are not going to look at all of them. So, in short particular program block will actually contain such a set up instructions sometimes these instruction are mostly optional. So, therefore, you may or may not have some instructions there can be only one called operand and there can be or there can be even 6 7 operands in a particular instruction depending on the requirement.

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So, when you CNC machines are typically characterized or classified by a number of features, some of them are being mentioned here. So, you have no number of controlled axes 2 or 4 and so the same machine may have a number of controlled axes, what kind of interpolation you were doing, whether it is linear or whether circular or whether it can be parabolic etcetera.

Then, what can a feedback you are using, whether you are using digital feedback or you are using analog feedback, what is the basic length unit; similarly, the feed rates maximum feed rates that can achieved and there are certain per minute or per revolution. And, there are certain other modes related which are called rapid traverse rates, so when you are moving from one hole to another.

So, you have drill this hole when you are moving to another then during this time you are not actually cutting and to move at the fastest possible rate that is called a rapid traverse rate. Then, kinds of the part program that can be used to program it this is maximum size IO devices etcetera.

Various program parameters also for also some programming parameter that is if the operator or some engineer wants to develop a new program, then how it is ease and I mean, how it is should be loaded. So, there can be various methods for example, only manual or can be background foreground. So, it when you have background, then you is actually doing things normally.

But, you can always go to, what is known as the background and then start developing some program, while in the foreground something else like a manufacturing operation is actually going on. Similarly, the various environments in which the program developer has to work that can be graphical or that can be menu driven these are with these are very standard things. Today, one has to examine, what kind of programming facilities exist in the machine before buying it.

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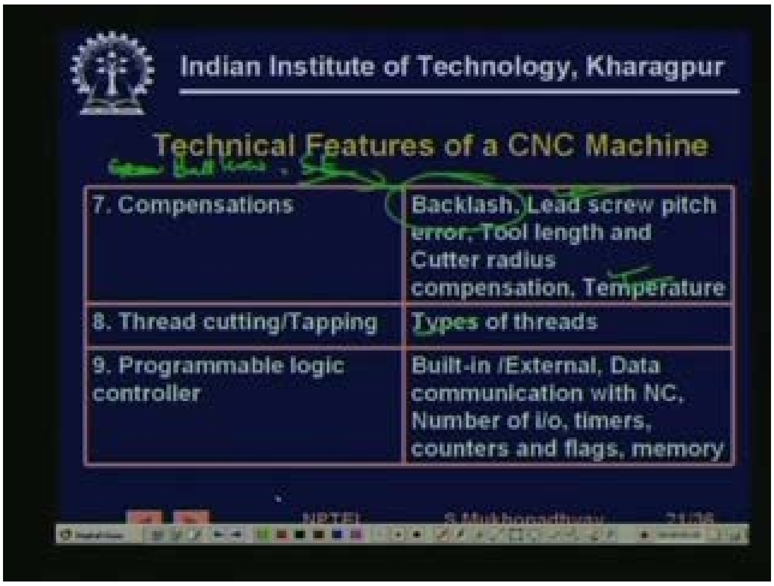

Similarly, since accuracy is generally a very major issue, so therefore one has to really look at the various kinds of compensations facilities that are available in the machine because they are typically used for achieving a very high accuracy.

For example, there can be backlash in the gear or even there can be backlash in the shaft angel encoder. So, it can be either on the gear or in the ball screw it can also be on the shaft angle encoder, so there can be lead screw pitch error that is the one rotation of the lead screw may not lead to an advanced and of the exact to the same amount all along the screw.

Then, there are compensation required for two lengths and the cutter radius the thing there I am just talking now. Because of the finite dimension of the tool, you need to create such a motion, such that the tip actually cuts according to the position where you want to cut it.

But, for that the tool has to be moved in a in a certain with certain offsets, so these offsets are to be always a tool will get worn. So therefore, these tool offsets are to be regularly measured and then the proper compensation should be given.

Similarly, temperature for very high temperature, firstly product quality can be affected and secondly sometimes dimensions can also be effected. Various kinds of thread cutting there will be possible and then, what kind of PLCs are used, how the PLCs going to interact with the drives controller and the number of IOs that it can handle easy that typically as we will see that the PLC is not to be used for the drive for the drive.

So, close sampled and control is required and sometimes the computation is also involved. So, under this situation it will not be really useful to actually use a use a PLC to provide a control of these drives, and therefore some special dedicated processors are used and the PLCs are often used for auxiliary function or as supervisory controllers.

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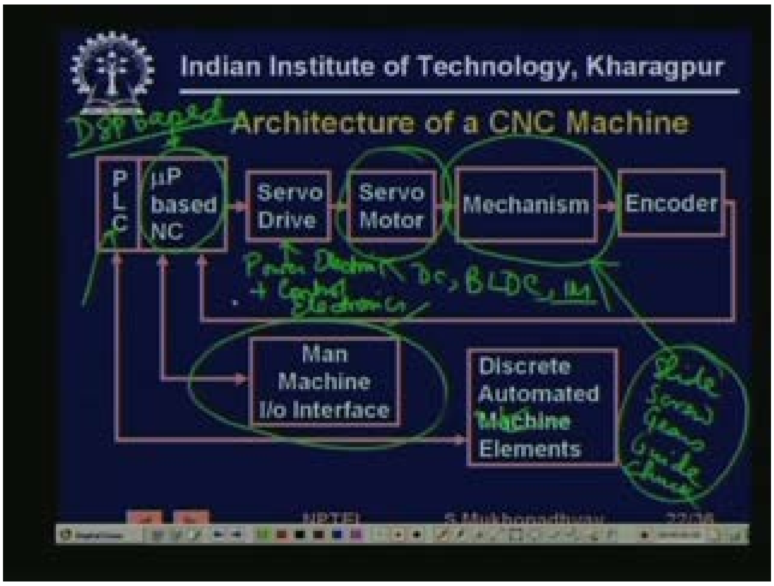

So, we look at architectures of CNC machines, so that is what I was saying that typically a CNC machine will be made of this kind of units. So, you have the basic mechanism that is the consisting of the slide, the screw, the gears, the guide, the chuck etcetera. So, these are the mechanisms which hold and actually mechanical part which hold and move the job and the tool.

So, they are driven by typically servo motors this can be DC BLDC or even induction motor sometime. So, these motors are as we will see in our feature lessons that these motors are to be driven by very sophisticated drive, so these are power electronic devices plus there control electronics and now these are again controlled by these.

So, these are this control electronics and the power electronics is often control by microprocessor based. Sometimes in this case they are modern machines becoming DSP based or digital signal processor based drives, which can provide a very sophisticated control for this machines. Along with that you also have another kind of computer call PLCs that is, what we have saying which is mainly used for discrete automated discrete automation. And, there is also a man machine interface which lets the operator program it and an also monitor the status of the machine and also there are mechanism for generating various kinds of alarms. So, this is the general structure of a CNC machine.

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Typically the drives that are used are sometimes they are open loop especially when they have switched. Let us, say low power drives like stepper motor drives which are cheap because they are actually drive electronics is much simpler. So, we have used this kind of drives which are open loop and use very simple drive electronic. So in the case of motors, we can have step motor drives or in the case of hydraulic drives we have proportional valves where we just give a command and proportional forcer displacement is hydraulic motor or a step motor and the machine is driven in open loop.

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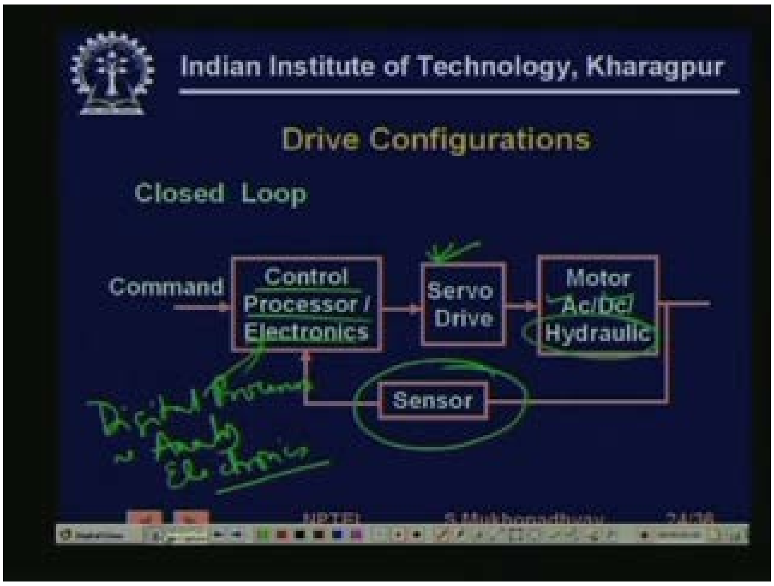

But, the best and the most accurate drives are all naturally that they are closed loop drives, if the usual motor which can be AC or DC or sometimes we have, what we known as the brush less DC, which is actually an AC motor, but which behaves like a DC motor. So, it has the advantages of both the worlds or it can be hydraulic motor also and then we have the servo drive for the hydraulics which is again controlled by the digital a various kinds of digital analog electronics. Digital processors and analog electronics and finally, we have the sensors which give the feedback, so these are the close loop drive configurations which are typically incremented for these machines.

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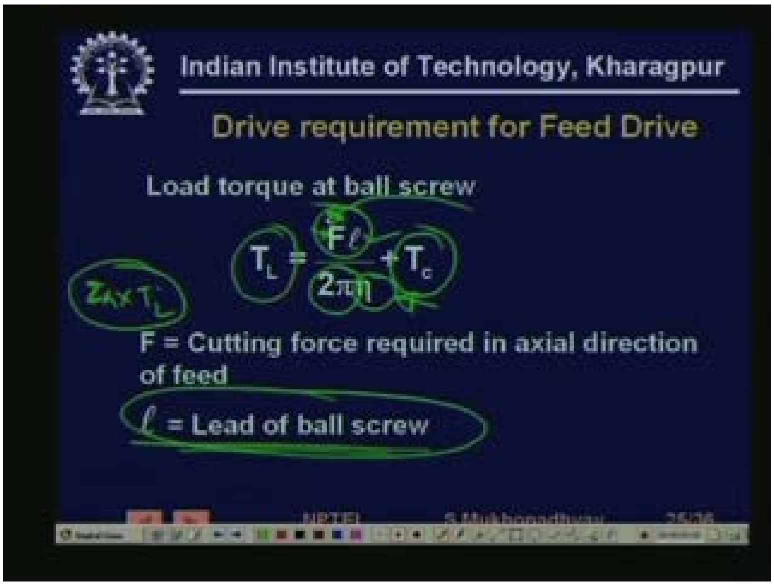

So, we will take a look at the drive requirements for these machines, so we have two kinds of drives, one drive is a feed drive. So, basically if the load on the drive, then the load is given by an expression like this, where the load torque this is T L load torque is the torque, so this is this is the cutting force which is occurring at the tip in the case of turning the feed drive is moving the tool.

So, the job is rotating like this and the job is rotating at one position when the tool is moving from the tool is moving from one side to another. So, the force is being created on the tip of the tool and the tool is being driven from a screw, the screw is rotating here, so the tool is moving.

So, the load on the screw which can be reflected as a load on the motor through the gearing mechanism that is used to be calculated by this force multiplied by this length arm this length arm lead of the ball screw also. Cutting force required in axial direction of feed, then that is the lead of the ball screw and then, how is this achieved, because if it is a achieved by something like energy conservation.

So, the torque into one rotation of the screw is going to be the force into the pitch, because if by one rotation of the screw, the linear motion created is one pitch unit. So, therefore, if we have energy conservation, then F into the pitch of the lead, the pitch of the ball screw must be equal to the torque.

Because, one rotation is twice pi radians, so twice pi into T L, this is the input energy, what is the output energy is force into pitch and multiplied by some efficiency factor. So, input and output factors we will have efficiency plus there are certain other friction torques. So, this is the load torque and we see that it remains more or less constant irrespective of the speed, so irrespective of the speed it remains constant.

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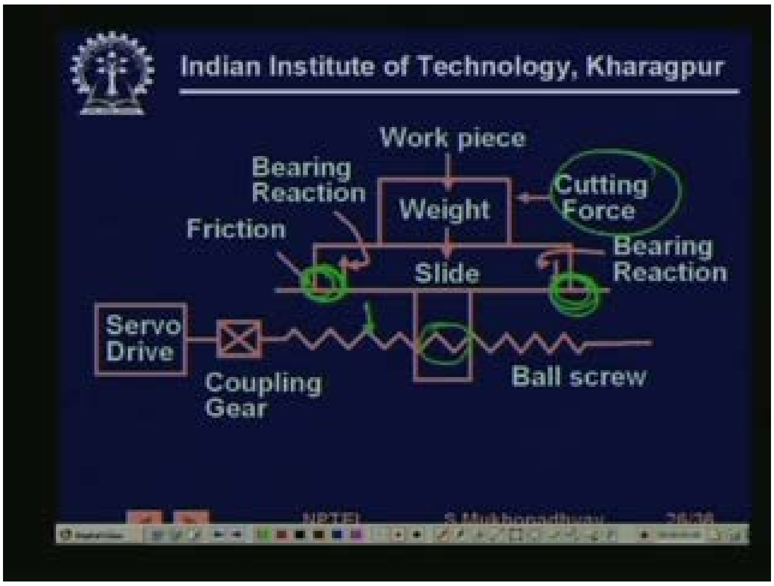

Similarly, just to explain that this is the ball screw, so you have weight on the slide and you have various friction forces number. Number two you have cutting force, so all these forces are going to generate, are going to be reflected as load torque on the screw through this mechanism. So, these are the spurious load torques, because of the weight you have friction you have bearing reaction and this is the main force which is the cutting force.

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So, T C is friction torque and eta is efficiency, so F depends on the machine design and the material removal rate, so the depth of cut. So, that the torque actually depends on the on the material removal rate, so it depends on the depth of cut as well as the feed. So, if they are generally constant then a constant torque operation is needed on the feed drive.

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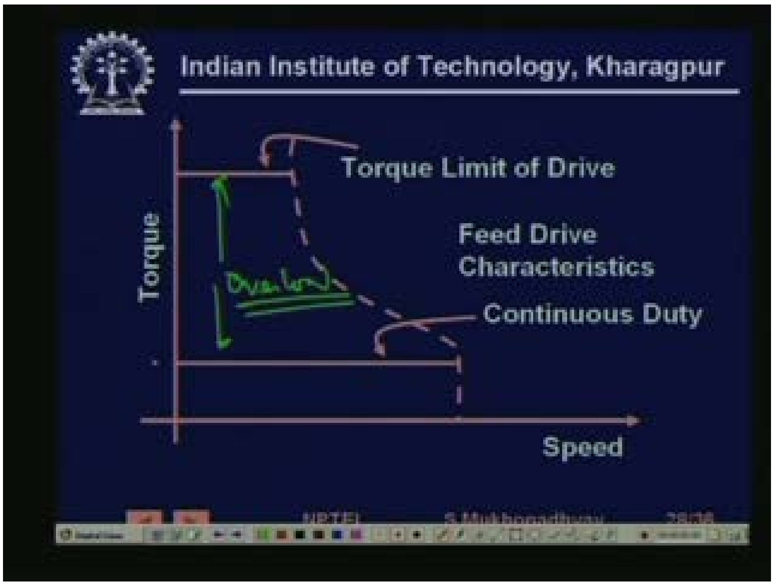

Sometimes it may happen that for there is for short times, because of material in homogeneity that is encountered sometimes these torques can suddenly rise to a very high values, but that should not affect the cutting. Therefore, for short periods the machine actually should be able to handle the good amount of overload torque. So, high overload torque for short durations such drives should be able to provide, while for continuous duty at much lower level of torque may be achieved.

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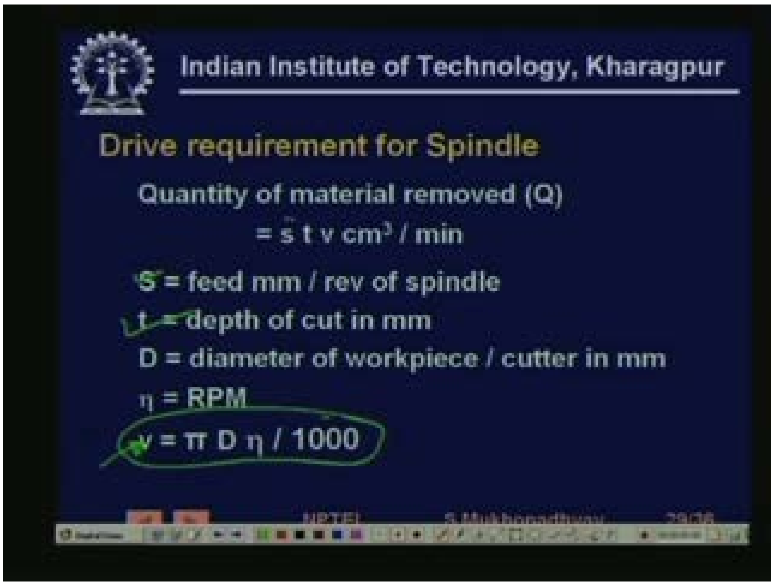

For the spindle it turns out that again the drive requirement is related to the quantity of material removed. So, the quantity of material removed is feed power revolution of spindle, t is the depth of cut and D is the diameter of the work piece of the cutter and eta is the RPM, then linear velocity is naturally pi D eta by 1000. So, this is the linear velocity into S into t, this gives the quantity of material removed.

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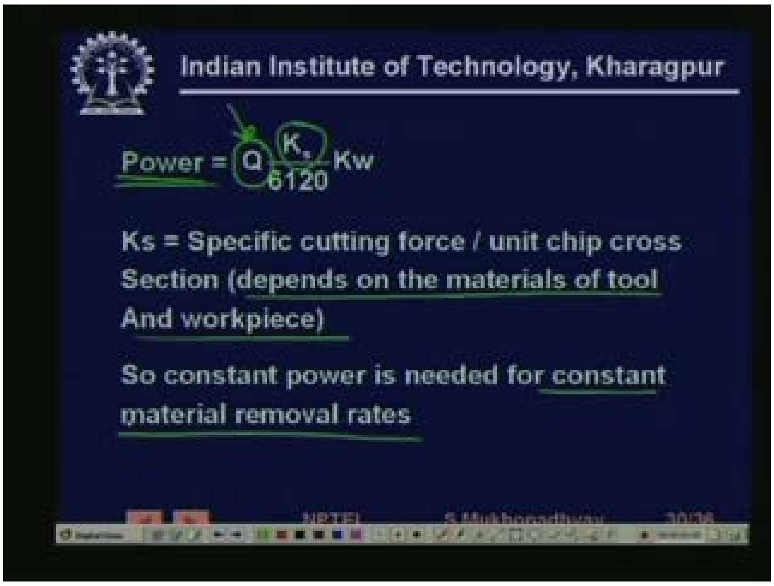

Now, the power it turns out that for the spindles the power is the actually proportional to Q into K s where K s is actually, what is known as the specific cutting force, per unit chip cross section. So, it depends on both material and the work piece and Q is the material removal rate. So in this case, it turns out that the power depends on the material removal rates, so therefore for constant material removal they typically in manufacturing we are going to fix that. We are going to fix the material removal rate depending on the kind of production that you want to have. So, in the for the spindle drives we have constant power requirement generally.

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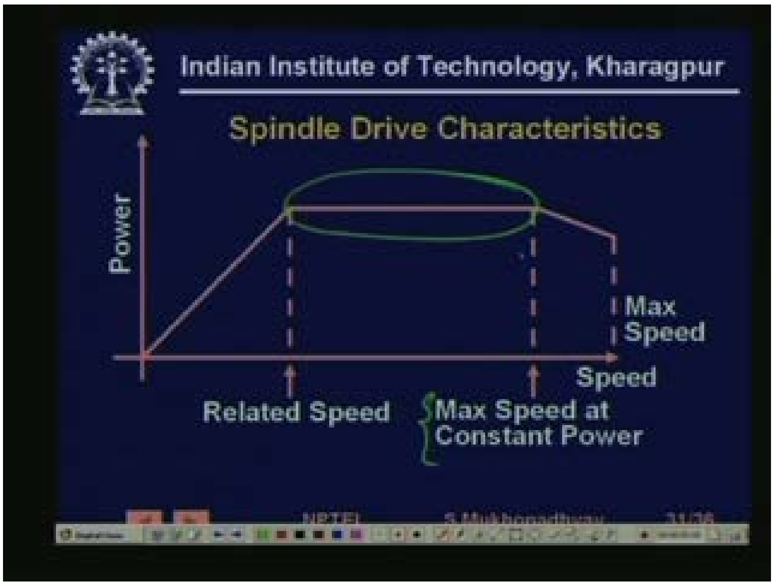

So, the spindle drive characteristic is generally of this shape, where you have a large constant power region and so this gives the maximum speed. So, irrespective of this speed a constant power is to be kept. So, we will see later when we see the various drive characteristics that how in the motors we actually have these regions of constant organ constant power. So, we will operate these drives, according the in the various regions.

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So, the desirable features of machine drives are spindle drive should they are should be accurate from there rotational speed point of view while feed drive should be very accurate in terms of position resolution in terms of microns.

Spindle drive should have fast dynamic response and very wide on the other hand feed drives could be operated in very wide speed ranges. So, for some materials they could move real fast for some material they can move real slow, especially that also depends on the on other things like surface finish.

Similarly, overload capacity four quadrant operation for example, feed drives because they need very good positional accuracy they always have to have four quadrant operation, while spindle drive generally do not require that they have unidirectional motion they can be two quadrant motion is enough and very high very high speed breaking etcetera are not needed at all.

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But, there can be large overloads in encountered especially due to material homogeneity. So, while there the speed range should be large, but it need not be excessively large. Similarly, feed drives require a very good transient response, so they require very fast response. So, low electrical and mechanical time constants are needed and they need constant working torque spindle drives. On the other hand should be of much more compact size, because they are generally to be mounted on a spindle which should not take too much should not be too big.

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So, we have come to the end of the lessons summary. So, we have come to the lessons summary and what we have seen, so we have seen the basic structural features of a CNC machine, what is made, so it you have seen is basic operational features, how it works and you have seen that basic structures of programs. So, we have seen basic look into the blocks and we have looked at the drive requirements typical drive requirements for spindle and feed drives. You have also seen the basic advantages of this machine that they are much more accurate and much more flexible.

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So, among some points to ponder, you can name the main components of a CNC machine. So, try to name them mentions it is major advantages and the main reasons there is main technological reasons from which these advantages arise. Name three features of a part program block, so various features mention three differences in the requirements of a spindle drive from that of feed drive, how they are different, so that is all for today.

Thank you very much.