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On Industrial Automation and Control

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Topic Lecture – 47
Introduction to CNC Machines (Contd.)

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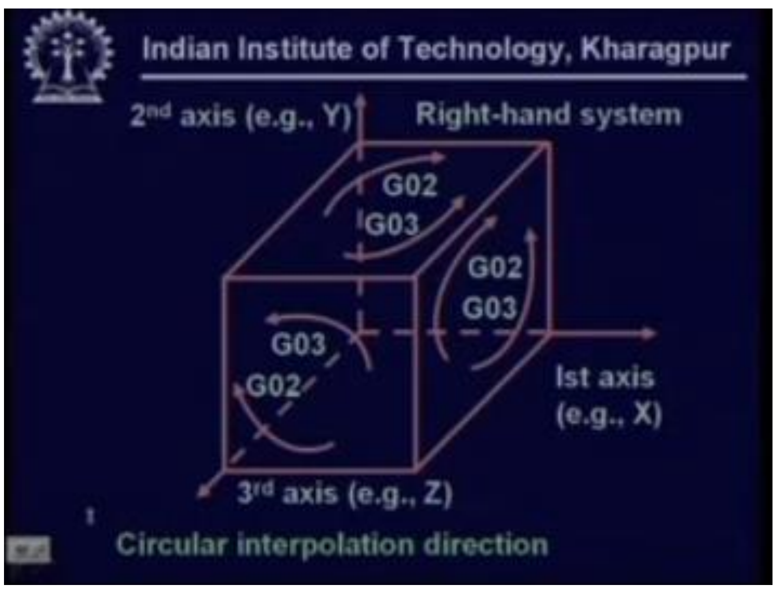

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Now we see that in a particular part program actually you know a part programs are nothing but they are actually particular form in which the with which the manufacturing people have been familiar and convenient, but otherwise it just like you just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

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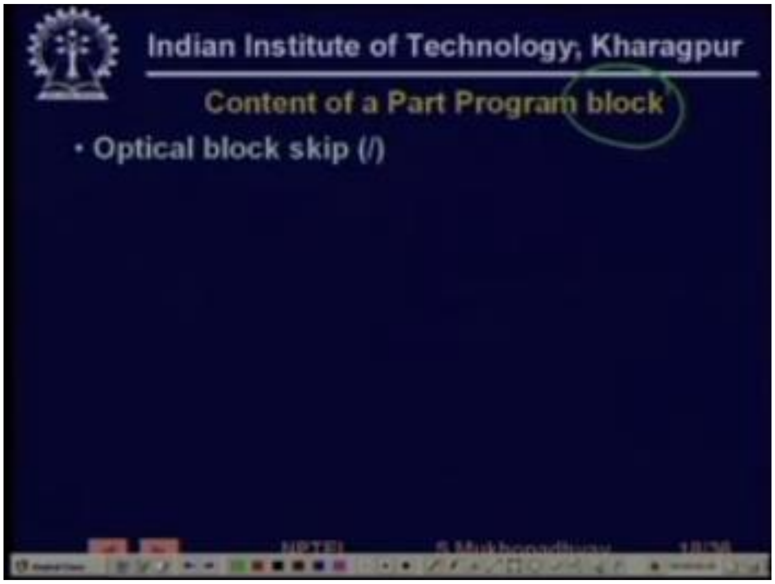

So part program block, so that was the part program basically consists of a number of blocks which get executed. So in a sense it is like you know it is like this PLC runs, so if a so just like a real ladder logic diagram is also adjust just a teachers graphical arrangement so that people who develop programs that is the people from the domain they can understand it, so similarly here we write part program so then finally these part programs are going to be, from the part program the actual execute real-time executive which controls the two drives this it reads the part program and then actually drives the various activities in the machine.

So the first so you can have such parameters in a typical program block like you can have as block skip.

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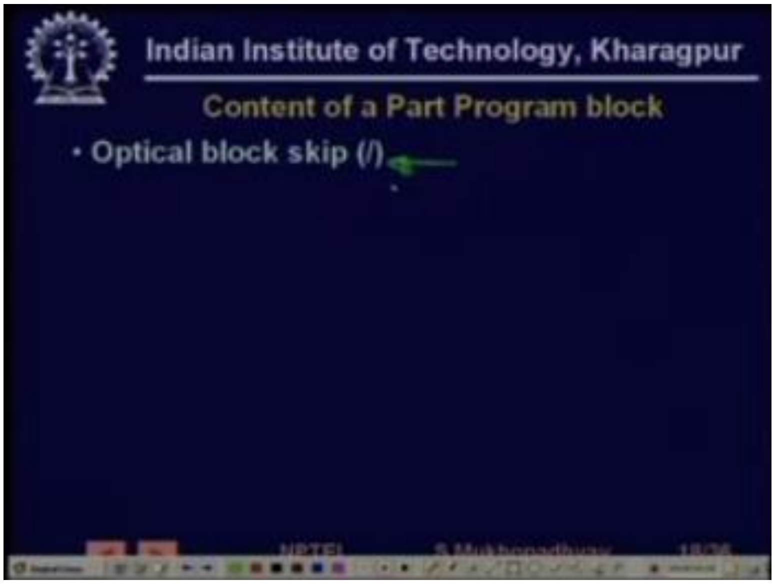

You can have a block skip, so if you have that block skip then that that particular block is ignored.

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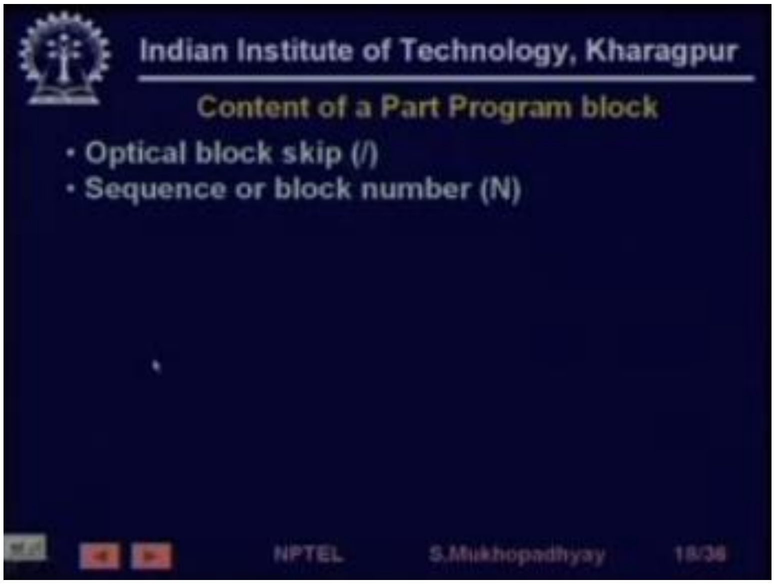

Similarly you have executive a sequence of blocks so you should have a block number.

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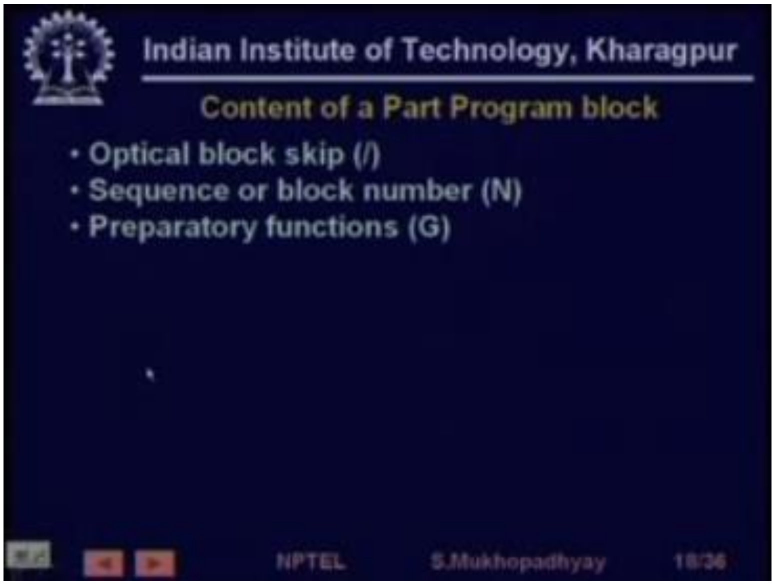

Then there are some functions which are called preparatory functions for example, you know deciding on whether the positioning system is going to be absolute or incremental the values which are given are in metric or at inch why is the origin of the coordinate system extra, extra, so there are some preparatory functions that are to be executed before executing a block.

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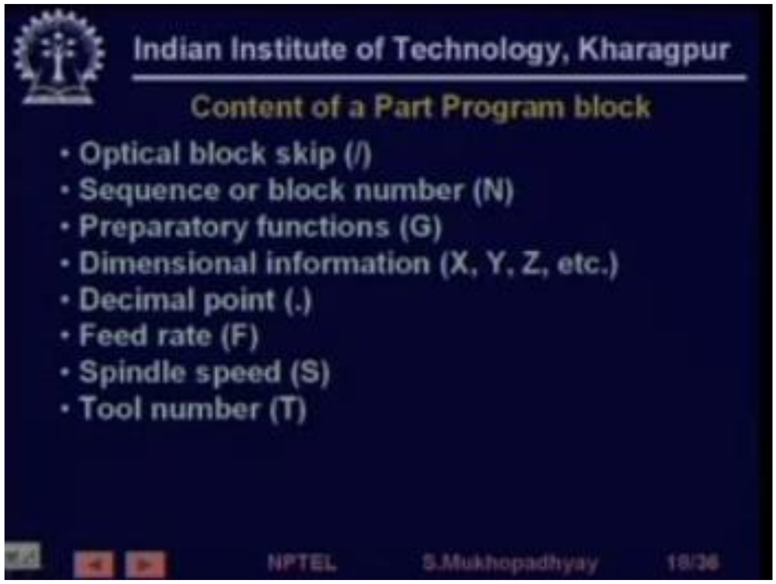

Similarly dimensional information is provided as in X,Y,Z okay, decimal point is fine then you have to provide you know things like feed rate, spindle speed, tool number because tools are uniquely identified by their number in a magazine, so if the machine has to select a particular tool that tool number has to be given.

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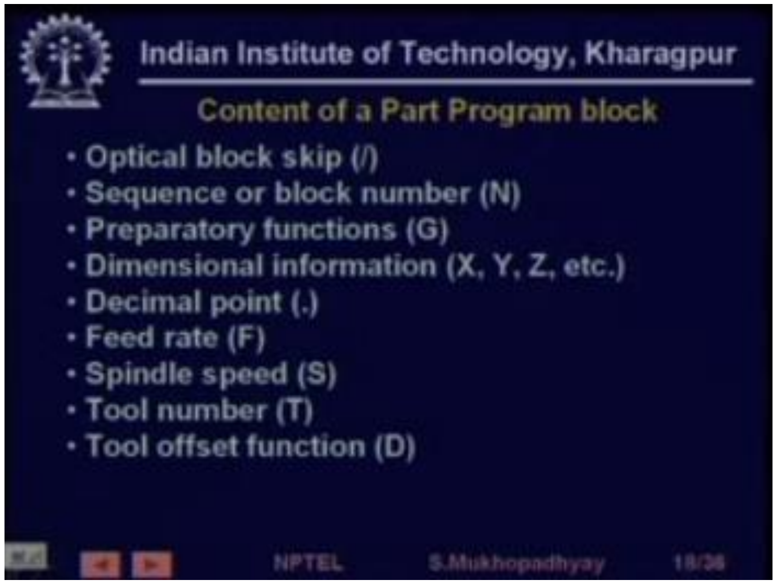

Similarly the tool offset functions so you know there are actually what happens is that for exact dimensional accuracy there are because the tool has a finite you know radius the tool actually has a finite radius.

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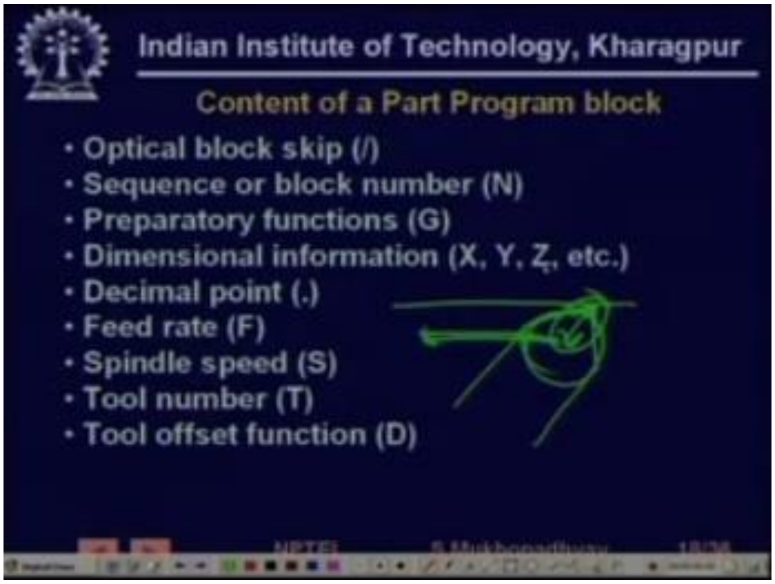

So when the tool moves because of this there is some distance between the center of the between some you know some logical center of the tool tip and the actual point where it is making a contact and it is not only making a contact it is actually gradually getting worn away.

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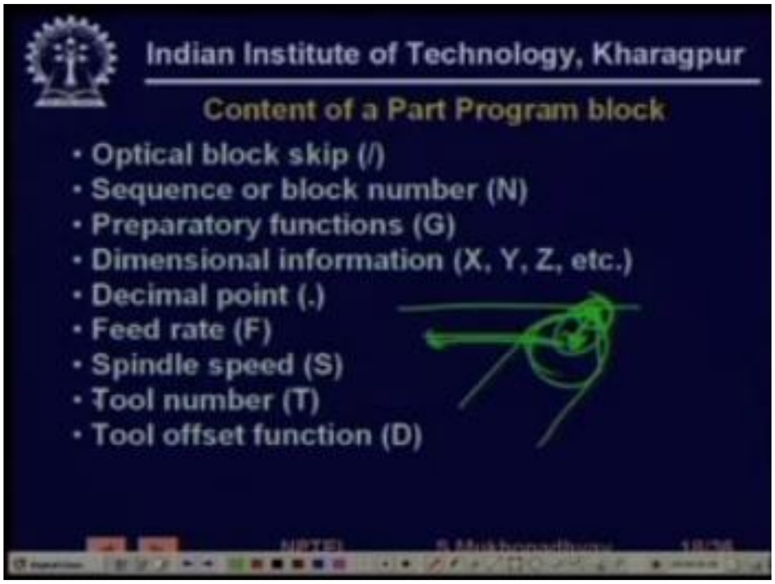

So this length is actually changing is actually shrinking so there are various kinds of offsets are produced and these and that is when you are actually giving the motion so you have to give the motion to the tool in such a manner that after taking care of this finite tool head situation then the right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

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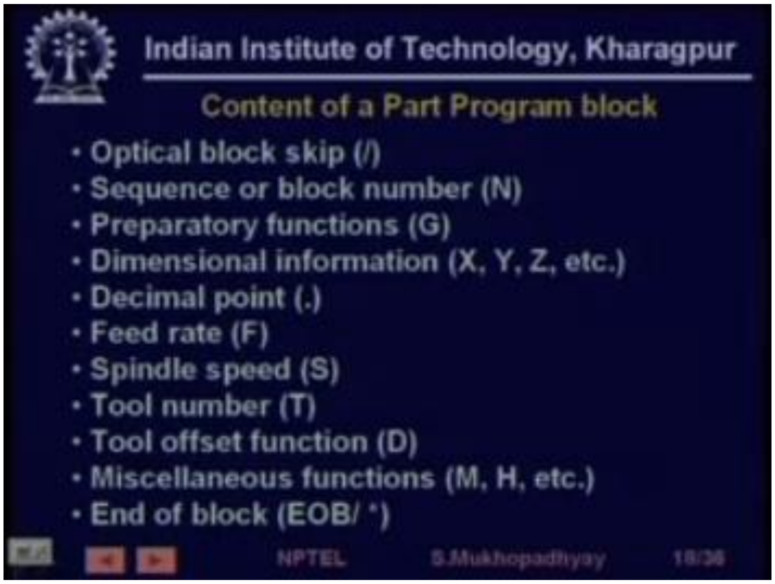

During preparatory phase and there were there can be various other miscellaneous functions there can be other various kinds of auxiliary functions also like switch off coolant switch on coolant and things like that, and finally it has to have an end of block signal.

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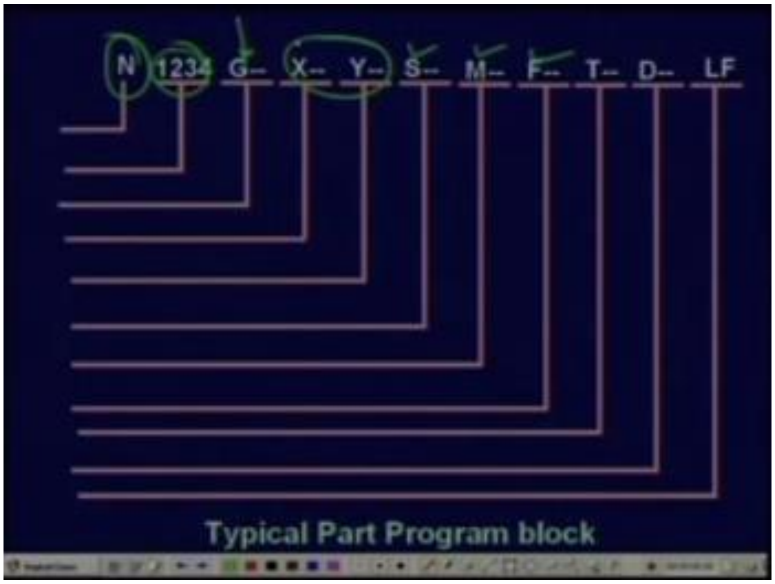

So typically you see a block is defined like this, this is the number then there is a G command then there are some XY commands which are which are you know position coordinates even apart from that there are various other kinds of commands which are, so we are not going to look at all of them, see so in short a particular program block will actually contain such a set of instructions, sometimes these instructions are mostly optional.

So therefore you may or may not have some instructions there can be only one so 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 get CNC machines the typically characterized or classified by and by a number of you know features so some of them are being mentioned here, so you have you know number of controlled axis so 2 or4 and so the same machine may have a may have a number of controlled axis.

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What kind of interpolation you are doing with this linear or with circular or whether it can be parabolic extra, then what kind of feedback you are using whether you are using digital feedback or using analog feedback what is the basic length unit. Similarly the feed rates maximum feed rates that can be achieved and there are certain per minute or per revolution and there are certain other modes related which are called you know rapid traverse rates so when you are moving from one hole to another so you have drilled this hole when you are moving to another then during this time you are not actually cutting and you need to move at the fastest possible rate. So there so that is called a rapid traverse rate.

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Then the kinds of the part program that can be there are used to program if this is a maximum size I/O devices it says the various program parameters. Also for, also some programming parameter that if the operator or some engineer wants to develop a new program there then how easy it is and I mean how it is to be loaded, so they can various methods.

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For example, only manual or can be seen you know background, foreground so it when you have background then you are 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 all that can be made no difference these are very standard things today. So one has to examine what kind of programming facilities exist in the machine before buying it.

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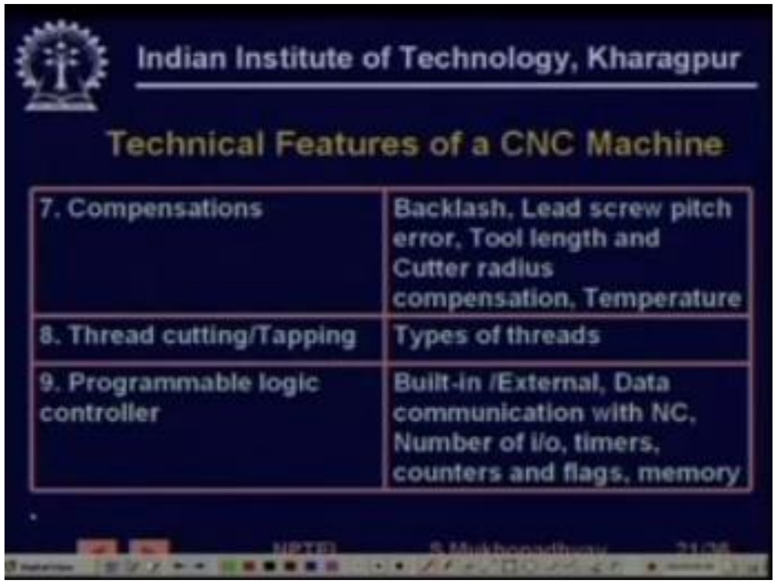

Similarly since accuracy is generally a very major issue so therefore, one has to really look at the various kinds of compensations facilities that are available in the machine because they will they are typically used for achieving a very high accuracy.

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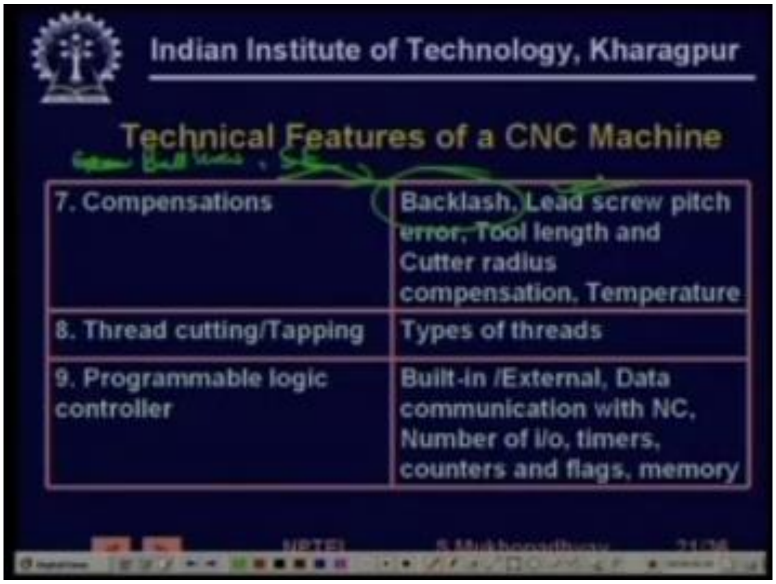

So for example, there can be backlash in the gear or even there can be backlash in the shaft angle encoder. So it can be either on the gear or in the ball screw it can also be on the shaft angle encoder, so there can be lead screw pitch error that is the if one rotation of the lead screw may not need to lead to an advancement of exactly the same amount all along the screw, then there are compensations required for tool length and the cutter radius the thing that I was 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 certain with certain offsets, so these offsets are to be always because the tool will get one so therefore these two these offsets are to be regularly measured and then the proper compensation should be given.

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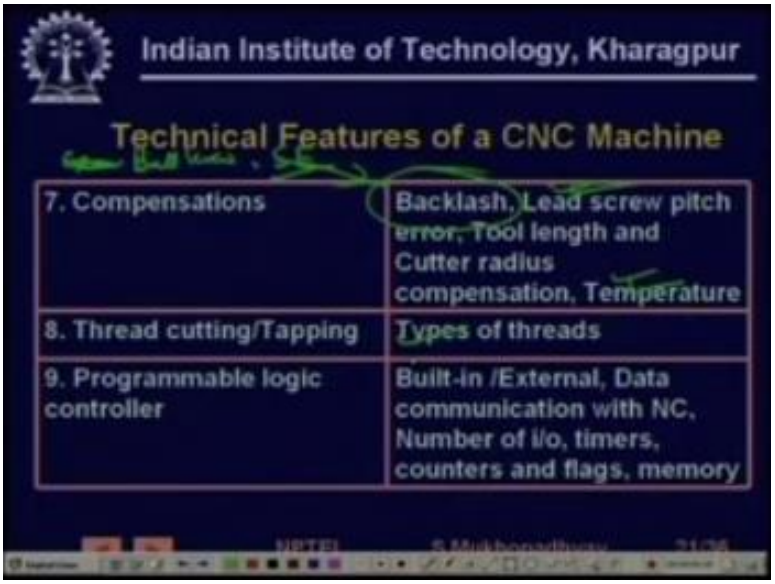

Similarly temperature for very high temperature firstly product quality can be affected and secondly sometimes dimensions can also be affected. Various kinds of you know thread cutting the possible and then what kind of PLCs are used how the PLC is going to want to interact with the drives controller and the number of I/Os that it can handle easy that typically as we will see that the PLC is not to be used for the drive, so close sampled and control is required and sometimes the computation is also involved so under these situations it will not be really useful to so, right.

So it will not be really useful to actually use a PLC to provide a control of these drives, so therefore some special dedicated processors are used and the PLCs are often used for auxiliary functions or as supervisory controllers.

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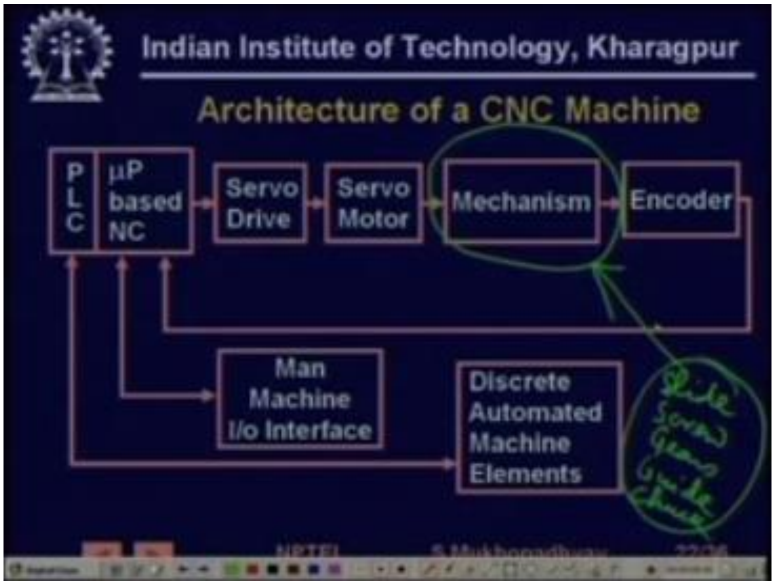

So we look at architectures of CNC machines, so that is what I was saying that typically a CNC machine will be made of this kind of unit. So you have the basic mechanism you know, that is the consisting of the slide, the screw, the gears, the guide, the charka extra. So these are the mechanisms which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

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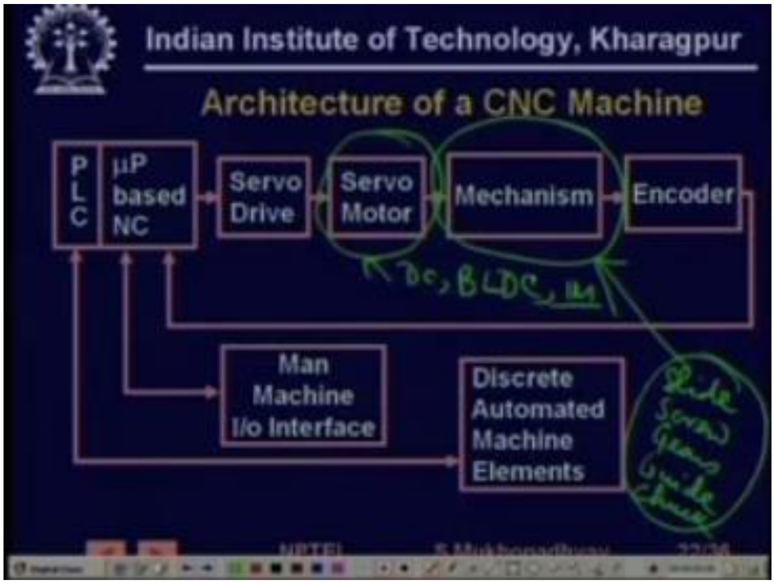

So they are driven by motors typically servo motors this can be DC, BLDC or even induction motors sometime. So these motors are as we will see in our future lessons that these motors are driven by very sophisticated drive.

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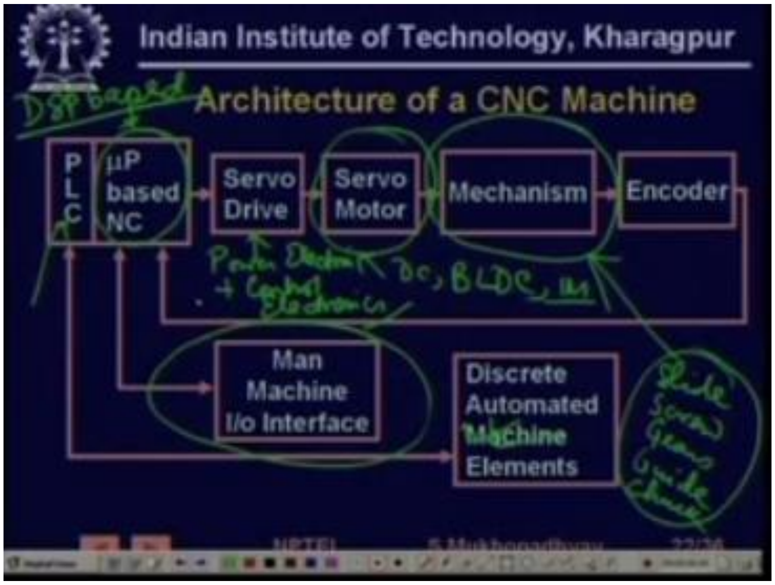

So these are, you know power electronic devices, power electronic devices plus they are controllers control electronics. And now these are again controlled by this source so these are this control electrons and a power electronics is often controlled by microprocessor-based sometimes in this case they are modern machines are becoming DSP based or digital signal processor based drives which can provide very, very sophisticated control for these machines.

Along with that we also have another kind of computer called PLCs that is what we are saying which is mainly used for discrete automation and there is also a man-machine interface which lets the operator program it and also monitor the status of the machine and also there are mechanisms for generating various kinds of alarms, okay. 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 you know switched let us say low power drives like stepper motor drives which are cheap because there they are actually their drive electronics is much simpler, so we have this sometimes we have used this kind of drives which are open loop and use very simple drive electronics.

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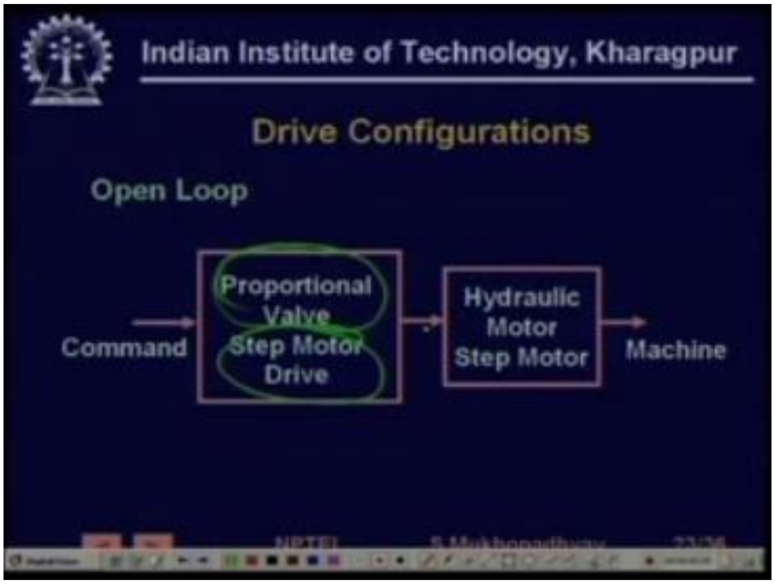

So we can have in the case of motors we can have step motor drives, we can have step motor drives or in the case of hydraulic drives we have proportional valves where we will just give a command and a proportional force or displacement is so you can have a hydraulic motor or a step motor and so the machine is driven an open loop.

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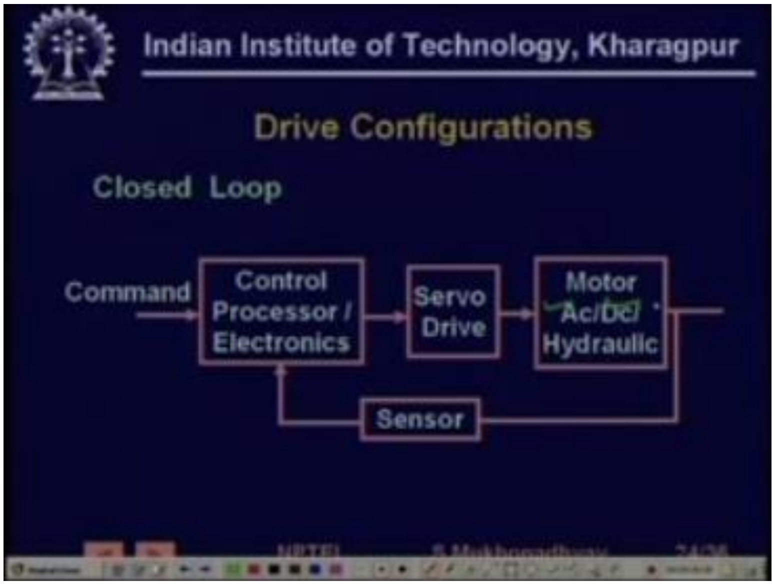

But the best and the most accurate drives are all naturally that there they are closed loop drives, so you have the usual you know motor so which can be Ac or Dc or sometimes we have what we known as a brushless DC which is actually an AC motor but which behaves like a DC motor, so it has the advantages of the both the valves.

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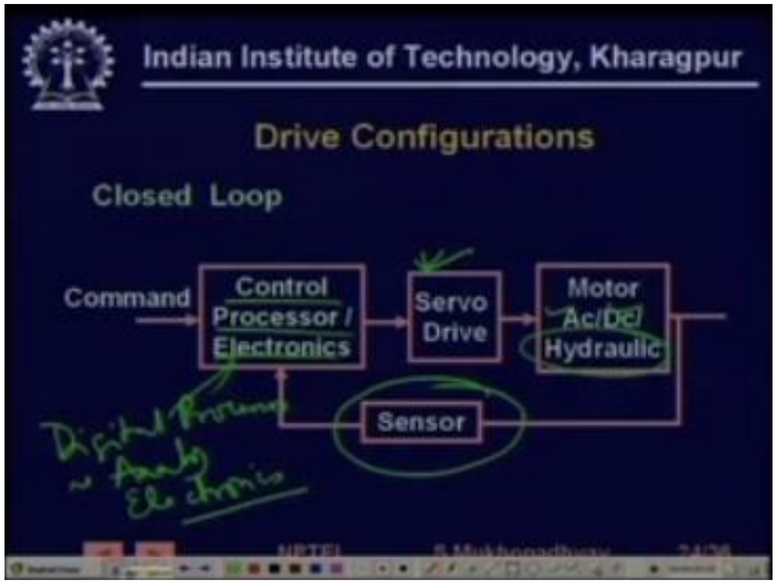

Or it can be hydraulic motor also and then we have the servo drive for the hydraulics which is again controlled by the digital various kinds of digital and analog electronics, digital processors and analog electronics and finally we have the sensors which give the feedback. So these are the closed loop drive configurations which are typically implemented for these machines.

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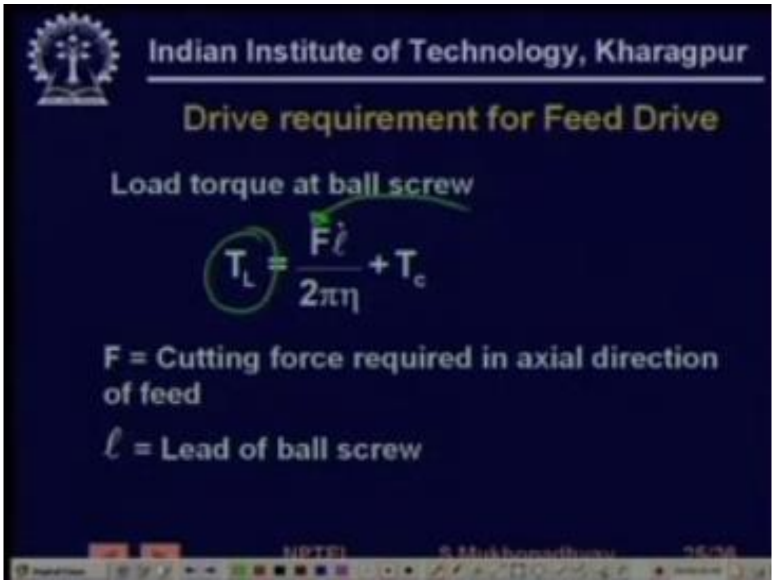

So now we will take a look at the drive requirements for this machine so we have two kinds of drives, one drive is a feed drive, so if you see basically if you see the load on the drive then the load is given by an expression like this, where the load torque this is T_L load torque is the torque so this is the force then the cutting force which is occurring at the which is in this case let us say in the case of turning which is occurring at the tip in the case of turning the feed drive is moving the tool, right.

So the job is rotating the like this and that tool is moving job is rotating at one position the tool is moving from one side to another, right so the force is being created on the tip of the tool and the tool is being driven from a screw, so 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 is can be calculated by this force multiplied by this length arm.

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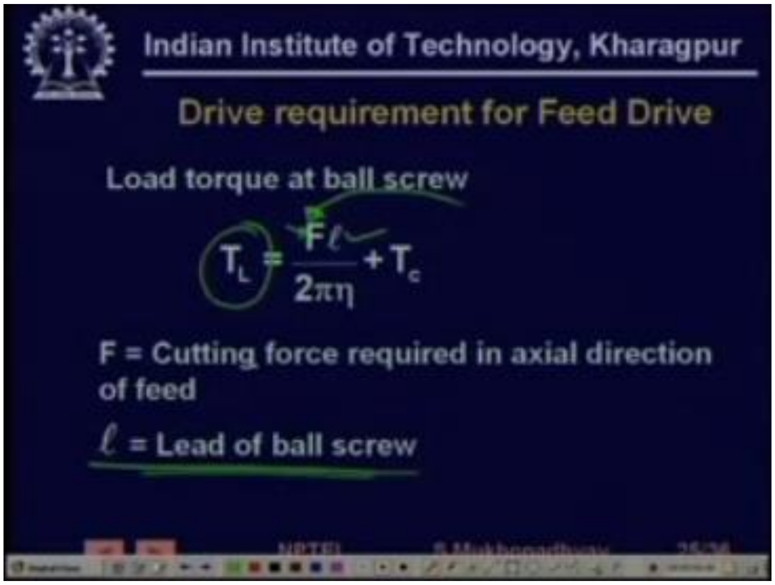

This length arm lead of the ball screw also cutting force required in axial direction of feed so then that is the lead of the ball screw and then so how is this achieved, because if you have it is achieved by something like a you know energy conservation, so the torque into one rotation of the screw is going to be the force into the pitch, because if by rotation of the screw the linear motion created is one pitch unit, so therefore if we have energy conservation then.

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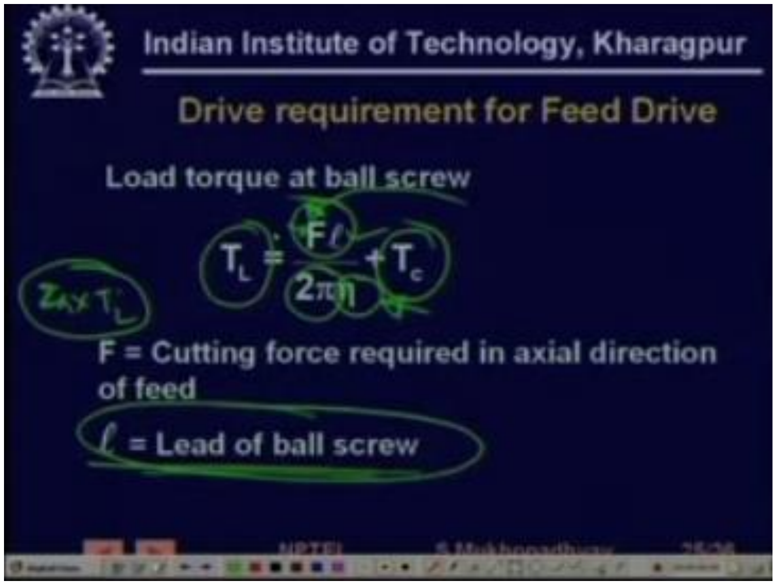

F into the pitch of the lead the pitch of the ball screw must be equal to the torque, because you know one rotation, so one proration is twice π radians, so 2πx T_L this is the input energy, what is the output energy, the output energy is this force into pitch and multiplied by some efficiency factor so you know input and output factors 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, right.

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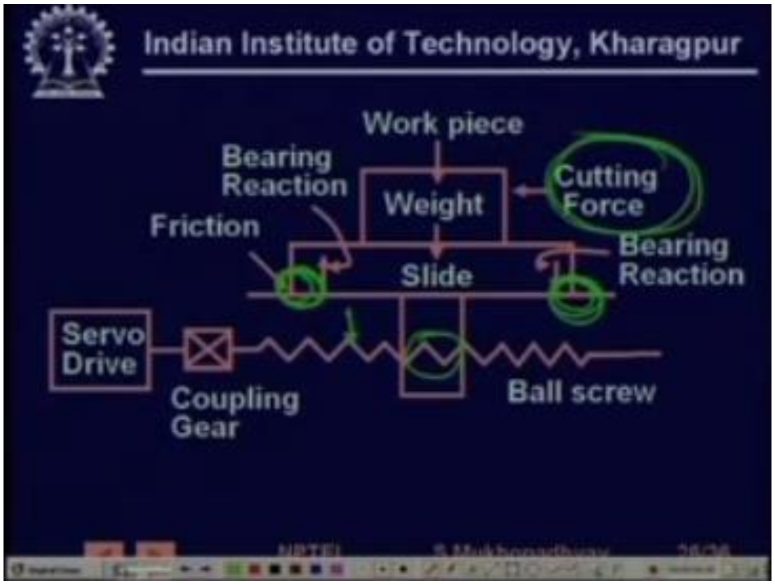

So it remains more or less constant irrespective of the speed, so irrespective of the speed it remains constant. Similarly so you see just to explain that so this is the ball screw so you have weight on the slide and you have various friction forces number 1, number 2 you have cutting force so all these 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 so 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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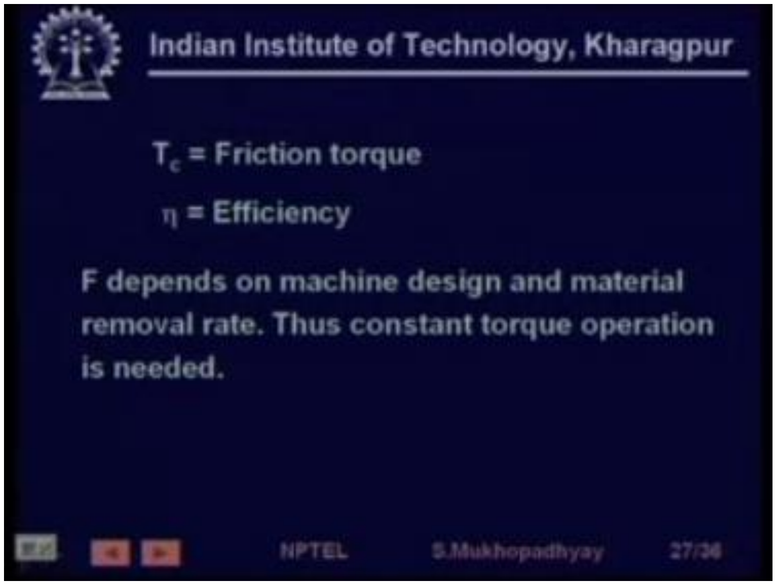

So T_c is friction torque and η is efficiency, so F depends on the machine design and the material removal rate so the depth of cut. So you see that the torque actually depends on the innovate depends on the material removal rate so it depends on the depth of cut as well as the feed. So if they are generally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

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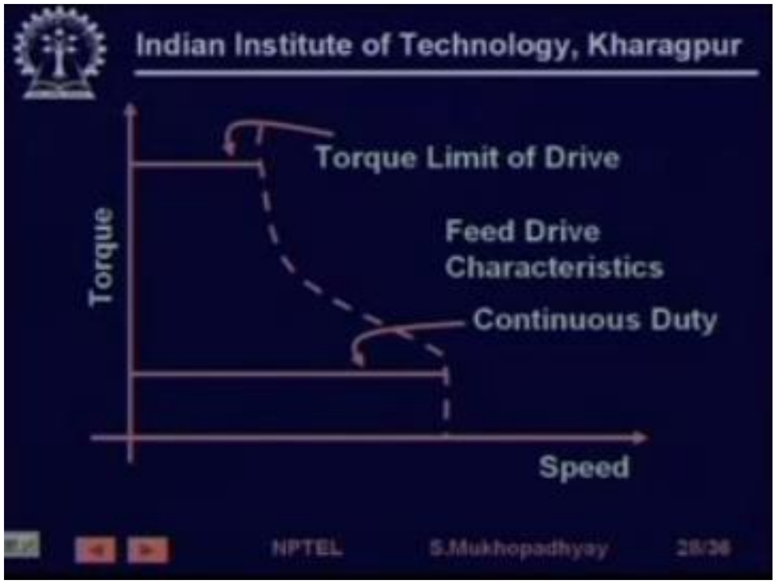

Sometimes it may happen that you know for there is for short times, because of material in homogeneity that is encountered, sometimes these torques can suddenly rise to a very high values but that should not affect the cutting.

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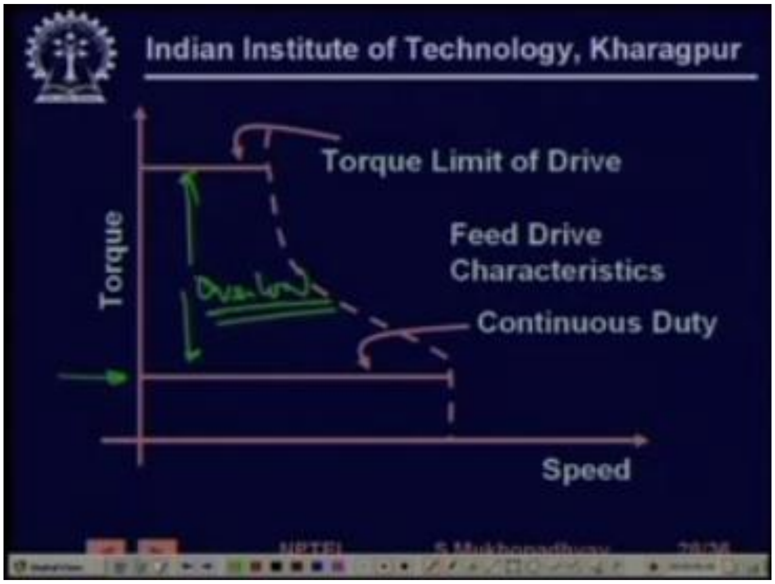

So therefore, the short periods the machine actually should be able to handle the machine actually should be able to handle good amount of you know over load torque. So high overload torques for short durations such drives should be able to provide. While for continuous duty at much lower level of torque may be achieved.

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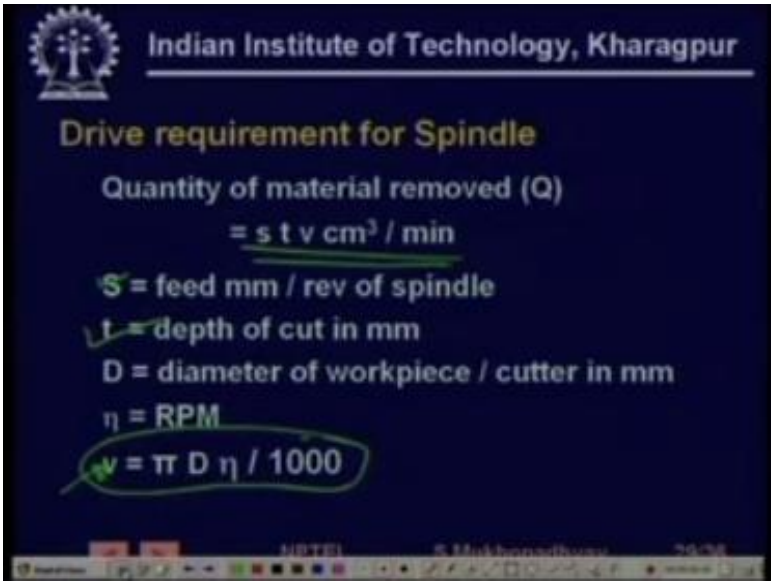

For the spindle it turns out that the again the drive requirement is related to the quantity of material removed, so the quantity of material removed is feed per revolution of spindle, okay feed per revolution of spindle t is the depth of cut and D is the diameter of the work piece of the cutter and η is the RPM then linear velocity is naturally $\pi d\eta/1000$ so this is the linear velocity, so this linear velocity into S into t this gives the quantity of material removed, okay.

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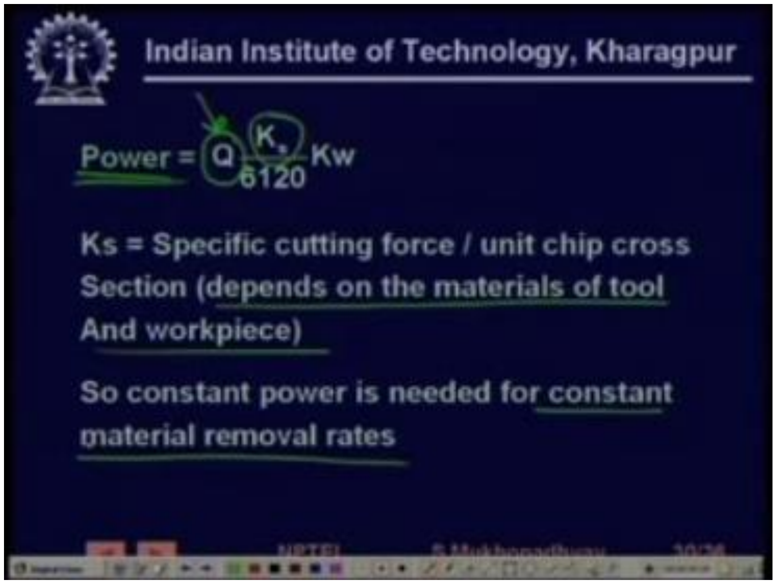

Now the power it turns out that for the spindles the power is actually proportional to QxK_s where K_s is actually the what is known as the specific cutting force per unit chip cross-section so it depends on the material and the it depends on both the material and the work piece and Q is the material removal rate. So in this case it turns out that the power depends on the material removal rate so therefore for constant material removal rate 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 we want to have so in for the spindle drives we have constant power requirement generally.

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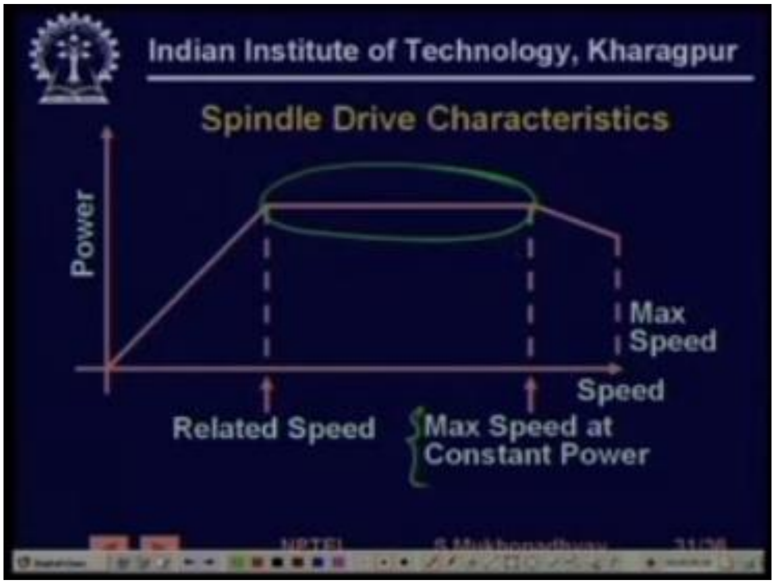

So the spindle drive characteristic is generally of this shape where you have a large constant power region and so this gives the maximum speed so the, so irrespective of the speed a constant power is to be kept. So we will see later when we see the various drive characteristics that how in the motors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

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So in the desirable features of machine drives our spindle drive should there should be accurate from the 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 speed on the other hand she drives could be operated in very, very wide speed ranges, so for some materials they could move real fast for some materials they can move real slow.

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Especially that also depends on the other things like surface finish. Similarly over load 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 drives generally do not require that they have unidirectional motion they can be two quadrant motion is enough and very high, very high speed braking extra are not needed at all.

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But there can be large overloads in encountered especially due to material homogeneity.

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So while then the speed range should be large but it need not be excessively large. Similarly So speed drives require a very good transient response so they are, 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 we should not take too much should not to be.

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So we have come to the end of the lesson summary, so we have come to the lesson summary and so what have we seen, so we have seen the basic structural features of a CNC machine what is made, you have seen is basic operational features how it works and we have seen that basic structure 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.

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We have also seen the basic advantages of this machine that they are much more accurate and much more flexible.

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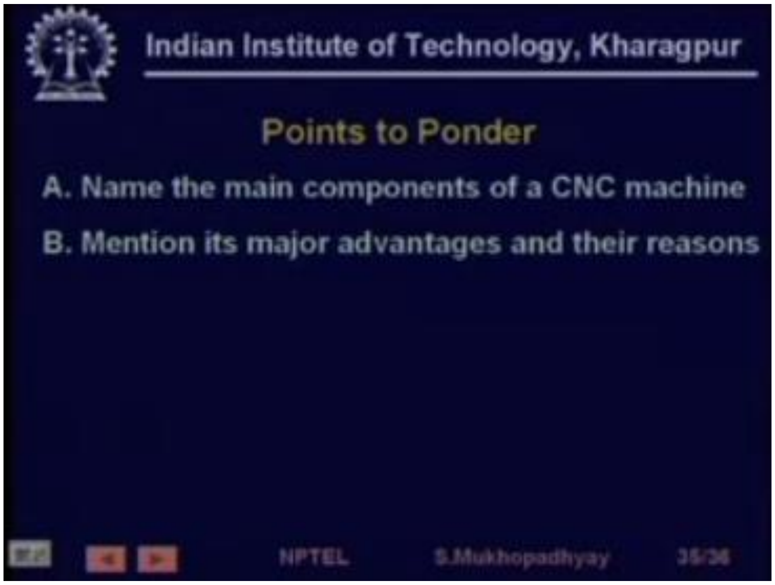

So among some points to ponder you can name the main components of a CNC machine so try to name them. Mention its major advantages and the main reasons has been technological reasons from which these advantages arise.

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Name three features of a part program block, so various features. Mention three differences in the requirements of a spindle drive from that of a feed drive how they are different.

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So that is all for today thank you very much.