Computer Numerical Control of Machine Tools and Processes
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Lecture 05
Discussions, MCQ and Numerical Problems

Welcome to this 5th lecture in the open online course Computer numerical control of machine tools and processes. We will be having discussions, multiple-choice questions and numerical problems on the first 4 lecture materials, let us see.

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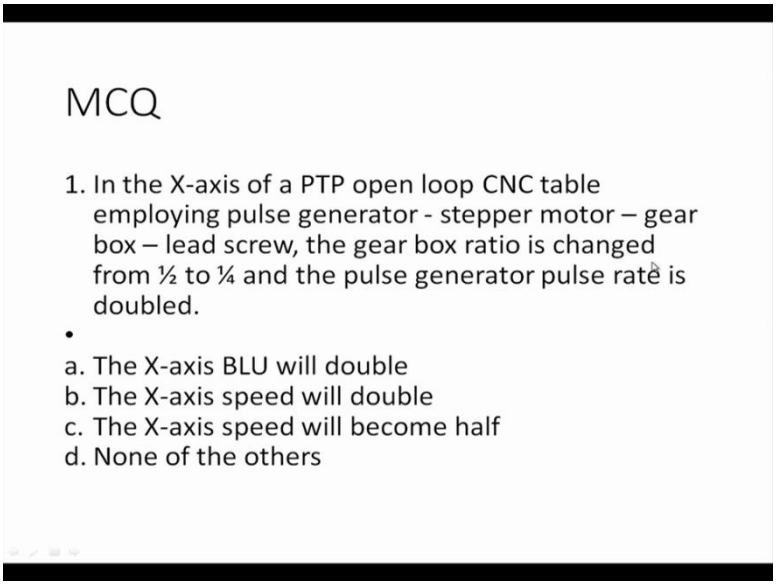

Let us have this one, in the X axis of a point to point open loop CNC table employing pulse generator- stepper motor- gearbox- lead screw; the gearbox which is changed from half to one fourth and the pulse generator pulse rate is doubled. So there are 2 changes, gearbox is changed from half to one fourth and pulse generator rate is doubled and the choice our. As a result, the X-axis basic length unit will double, the X-axis speed will double, the X axis speed will become half and none of the others. So just keep in mind two things gearbox reduces from half to one fourth and pulse generator pulse rate is doubled, let us see.

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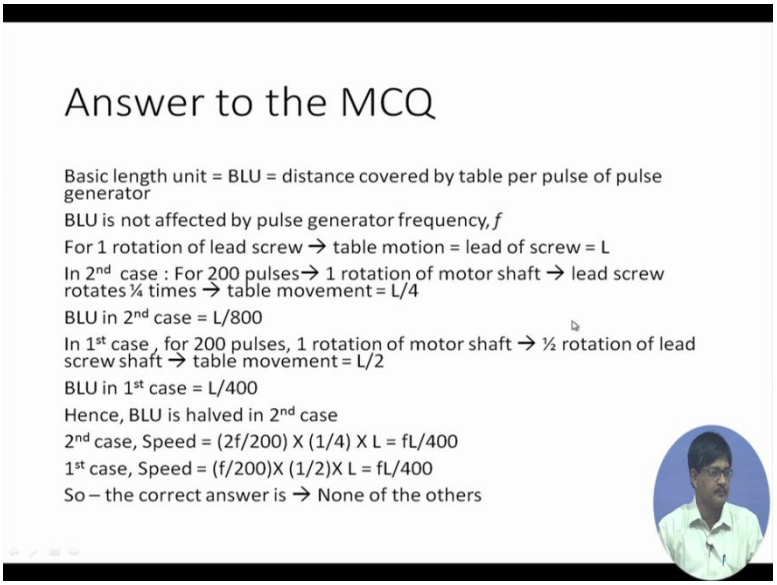

First of all, the basic length unit which is the distance covered by the table per pulse of pulse generator, it is not affected by pulse generator frequency, why because whenever the pulse generator frequency is fast or slow, the distance moved per pulse by the table will always be the same. With this thing in mind, we can say for one rotation of the lead screw okay for one rotation of the lead screw, the table motion will be equal to the lead of the screw equal to say L. So in the 2nd case, for 200 pulses 1 rotation of the motor shaft gives rise to one fourth rotation of the lead screw due to the presence of the gearbox, which gives rise to L by 4 millimetres of movement of the table.

So 2nd case for 200 pulses, the movement is L by 4 and therefore, the basic length unit in the 2nd case will be L by 800 by unitary method, 200 pulses L by 4, so 1 pulse L by 800. In the 1st case, the gearbox is different therefore for 1 rotation of the motor shaft, we have half rotation of the lead screw and hence, the table movement will be L by 2 for 200 pulses. Therefore, the basic length unit in the 1st was L by 400 why, 200 pulses giving L by 2 therefore, one pulse giving L by 400, obviously, the basic length unit is half in the 2nd case with respect to the 1st case because it is becoming L by 800 from L by 400, is it one of the options? Let us have a quick look in the previous slide.

Basic length unit becoming half, no. So, up till now we have not identified the correct answer. Basic length unit is half is doubled is definitely wrong, the 1st one is wrong. Coming back in the 2nd case, let us find out the speed. The frequency is twice F divided by 200 gives us the number of rotations of the stepper motor shaft multiplied by the gearbox ratio one

fourth gives us the lead screw rotation multiplied by L gives us the table movement therefore, collecting all the terms we have FL by 400 that is good.

And in the 1st case therefore it will be F by 200 giving the motor rotation multiplied by half that gives us the lead screw rotation multiplied by L gives us FL by 400, so essentially the speed is remaining the same, so the let us go back and let us find out the correct answer. The X-axis basic length unit will double, no. The X axis speed will double, no. The x-axis speed will become half, definitely not. Therefore, the correct answer is none of the others okay.

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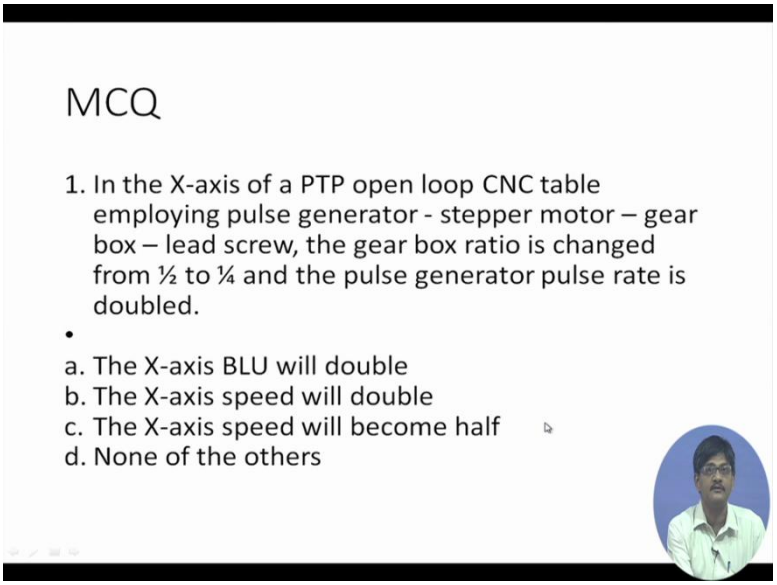

Let us take this problem that seems to be quite formidable. In a point-to-point open loop CNC drilling machine, a stepper motor drives the table in the X direction and the stepper motor shaft is connected to a gearbox with ratio, racially is defined as output RPM by input RPM, ratio is one fourth which is in turn connected to a lead screw of pitch 4 millimetres and number of starts equal to 2. So as we have discussed before, if a lead screw has pitch equal to 4 and number of starts equal to 2, the lead that is the moment which the nut will execute per rotation of the lead screw will be equal to 4 into 2 okay N into P equal to L equal to 8 millimeters.

The stepper motor covers 1 rotation in 200 equal steps and executes one step per pulse, one step per pulse Pulse-generator. Pulse generator frequency is 100 pulses per minute received by motor driver. The pulses output from AND gate go to motor driver and also to a position down counter, these incoming pulses that means incoming into the position counter decrement the content of the position down counter in what way? 1 pulse comes in and

position down counter content goes down by 1. The questions are what are the basic length unit and velocity of the table along X-axis. 2nd, what number in binary will the MCU that means machine control unit put into the position down counter for executing line number 2 of program above?

So there are 3 questions, 1st of all let us see how the system works. If we are putting in some number, so first of all let us accept the machine control unit is capable of putting in some number okay, setting it to a particular number as it pleases so we have to decide what that number should be corresponding to line number 2, but 1st of all let us find out the basic length unit and let us find out the velocity of the table along X-axis. First of all, what is the basic lead unit? We have 200 steps of the motor; let us see I think we have worked out yeah answer.

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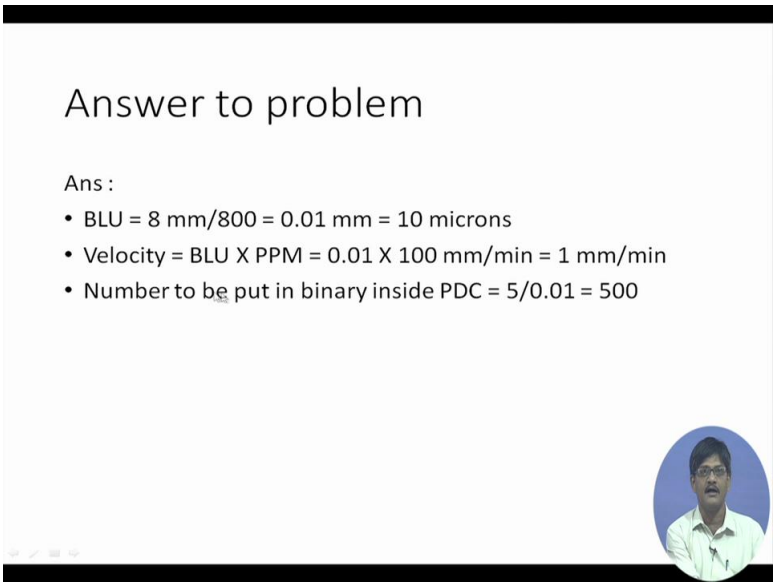

Answer is basic length unit is equal to 8 millimetres that means the lead of the lead screw divided by 800 pulses, one rotation of the lead screw must be requiring 800 pulses of the pulse generator, why so? That is because one rotation of the lead screw is obtained from 4 rotations of the motor because the gearbox ratio is one fourth, so 4 rotations of the stepper motor produces 1 rotation of the lead screw resulting in 8 millimetres of table movement and 4 rotations of stepper motor will require 200 into 4 equal to 800 pulses, so 800 pulses giving 8 millimetres of movement, so that means the basic length unit must be 8 divided by 800 equal to 0.01 millimetres equal to 10 microns, so basic length unit is equal to 10 microns.

What is the velocity? Velocity has is easy to calculate once you have got the basic length unit, it is simply equal to basic length unit into pulses per minute okay, so these many pulses per minute will produce these many basic length units per minute and together this will be 0.01 into 100 millimetres per minute okay 100 pulses per minute that means millimetres per minute, okay. So, this is millimetres per pulse and this is pulses per minute so that becomes millimetres per minute and that means 1 millimetre per minute. But why are we moving in such a slow manner, this must be a micro-system system equipment okay micro-system equipment, so it moves 1 millimetre per minute; this is the velocity with which it moves.

And what should be the number which should be put in binary inside position down counter? For this, let us quickly go back and have a look how it works. This one position down counter once it is loaded with a number, unless and until it is counted down to 0 by these incoming pulses from the AND gate, unless it becomes 0 it will never send out 0 as the output of the OR gate and that will never be able to stop these pulses from coming in and entering the position down counter, and these pulses incidentally are also being sent to the stepper motor.

So when you have sent the required number of pulses to the stepper motor, it should stop so that means those many pulses counted in binary should be put here so that they are discriminated and consequently further pulses will be stopped. So let us find out in order to carry out a 2^{nd} line in command, how much should be the number of pulses or number of basic length units to be moved along X-axis I am sorry. So previously in line number 1 we were at X equal to 20 and now we are at X equal to 25, so naturally we are executing 5 millimetres of movement and how many basic lengths should it be?

It should be equal to 5 divided by 0.01 equal to 500, so if we put 500 in binary in the position down counter, after those many pulses further pulses will be stopped by end of count from reaching the motor okay thank you. Let us see a similar problem in closed loop control, point-to-point still but closed loop control, so let us have a look how it works.

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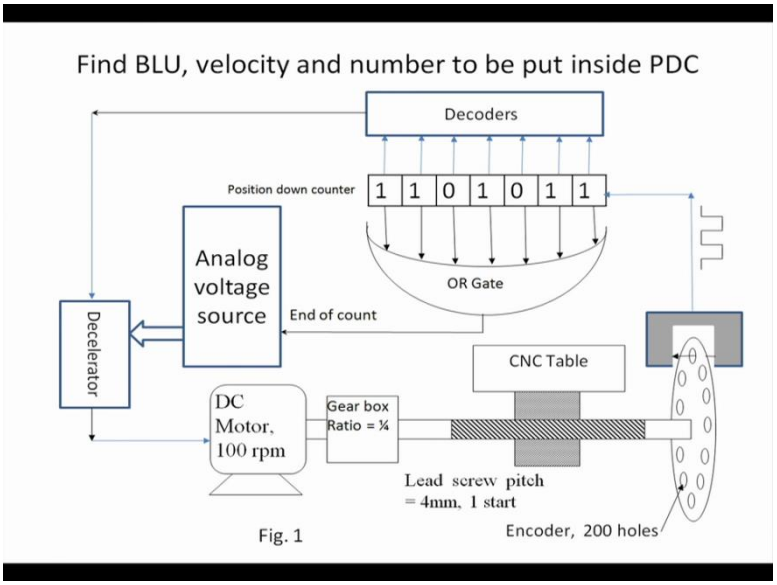

Let us have the same problem here and let us try to solve it. What is the problem? Find out the basic length unit, velocity and number to be put inside PDC to execute that same command okay. 1st of all, let us see how this works and in what way is it different from the previous one? Here the down counting of the position down counter is done by the encoder okay, the encoder pulses are coming, these pulses are entering the position down counter and making it 0. Once it becomes 0, further movement of the DC motor will not be possible.

So let us let us plan it in this way that the number of basic length units corresponding to that the number of pulses are sent corresponding to 5 millimetres of movements, after that this will be counted down to 0, so let us 1st of all find out how much is the basic length unit. Here, the lead screw pitch is 4 millimetres and it is single start okay, slightly different from the previous setup. So 4 millimetres of movement is being carried out due to one rotation of the lead screw and at the same time, 200 holes are passing in between the light emitting device and photoreceptor, so 200 holes corresponding to 4 millimetres of movement therefore, 1 hole corresponds to 4 millimetres divided by 200.

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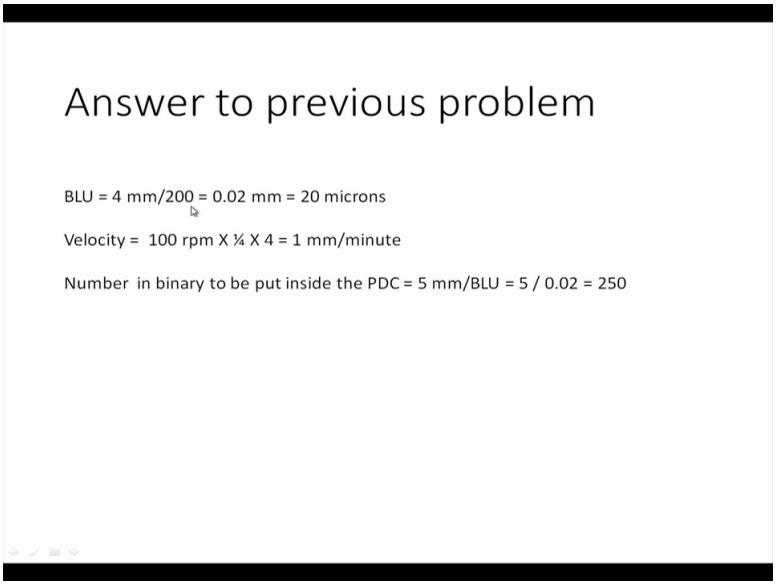

Let us see how much it is that is right, 4 millimetres divided by 200 is equal to 0.02, which is nothing but 20 microns, so the basic length unit is 20 microns this time. What is the velocity? What is the information given about the velocity? Let us have a quick look, DC motor rotates at 100 rpm okay by some means were making this motor rotate at 100 rpm and corresponding to this we are developing a definite velocity, we have to find that out, so how do we do that? So DC motor rotating at 100 rpm will have a transformation through this gearbox, which is one fourth, so this must be rotated at 25 rpm and if it is rotating at 25 rpm multiplied by the pitch that will be 100 okay, let us see the answer.

Yeah, 100 rpm multiplied by one fourth which is the gear ratio multiplied by 4, so how much is that? That is equal to 1 millimetre per minute, why so? Just one moment, 4 millimetres of movement, 100 rpm, so I think there should be it should be 100 millimetres per minute okay, please correct this, it should be 100 millimetres per minute. Now, let us look at the oh sorry I am sorry, this is let me see velocity is 100 rpm, so with every rotation 100 rpm is converted to 25 rpm for the lead screw and 25 rpm multiplied by 4 will be giving us 100 millimetres per minute okay, so we have 100 millimetres per minute, please note it down and I will correct it in the final lecture.

Number in binary to be put inside the position down counter, okay. 5 millimetres of movement have to be realized in 1 basic length unit is 0.02 therefore, 250 should be residing inside the position down counter. Let us see, this is the position down counter, after 250 pulses have moved through, after that this comes to a stop because end of count will be sending out 0 and therefore, the motor will be stopped from further movement okay. So this

is 250 in binary should be put inside the position down counter. I think we have time for you more problems, let us take this one.

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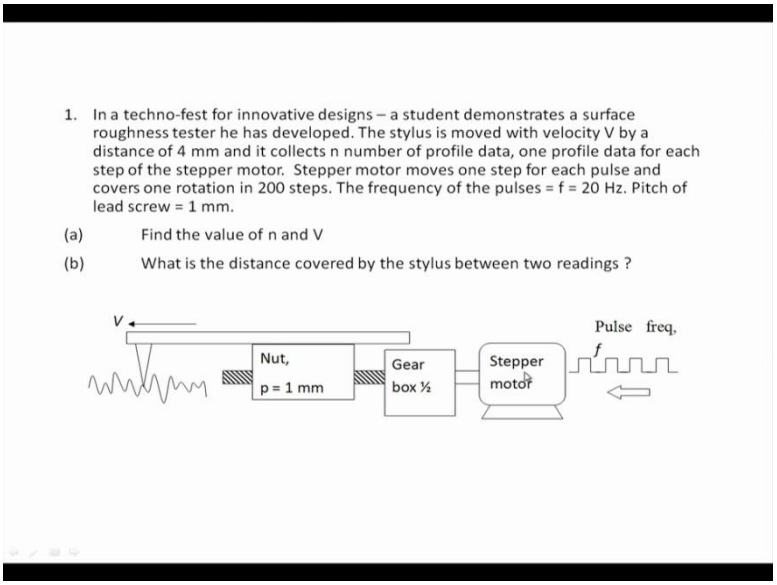

In a techno-fest for innovative design, a student demonstrates a surface roughness tester he has developed, so this is the surface roughness tester the student has developed, how does it work? It has a nut of 1 millimetre pitch and it is connect to the stylus, which records rough values on a rough surface, which is shown on the left side and this nut is made to move by a lead screw, which is being operated by a stepper motor through a gear box of ration half and pulses of frequency f, they are being sent to the stepper motor to make this work.

So surface roughness tester generally work this way, this stylus will move forward and then again come back to its starting position and in between it will record some values of ups and downs (())(17:24) so that this data will be processed to find out roughness of the surface. So the student has developed this through devices that we are conversant with, so let us have a look. The stylus is moved with velocity V by a distance of 4 millimeters, so the movement that the stylus is executing is 4 millimetres and it collects N number of profile data, 1 profile data for each step of the step motor.

Stepper motor moves 1 step for each pulse and covers 1 rotation in 200 steps, the frequency of the pulses F equal to 20 hertz, pitch of the lead screw is 1 millimetre. So the questions are, find out the value of N and V. N is the number of readings it is capable of taking for the 4 millimetres of movement and V is the velocity of the stylus, and what is the distance covered

by the stylus between two readings, this corresponds to our basic length unit, so this should be easy to let us try that. 1st of all, basic length unit how much should it be?

So stepper motor rotations 200 steps will be rotating, as the gearbox ratio is half rotating the lead screw by half rotation, therefore half rotation will amount to 0.5 millimetres of movement, so 200 steps giving 0.5 millimetres of movement therefore, one step should give 0.5 divided by 200. Therefore, distance between successive readings equal to basic length unit equal to 1 millimetre by 400 that means 0.5 by 200 equal to 2.5 microns, so this is the answer to question number 2. Number of readings in 4 millimeters; simply divide it by number of basic length unit, so 4 divided by basic length unit is 1600 readings will be taken in a distance of 4 millimeters.

And the velocity once again equal to basic length unit into pulses per second equal to 0.0025 into 20, which means 0.05 millimetres per second equal to 3 millimetres per minute okay, thank you. This is perhaps the last question that we can manage, let us have a quick look what does it say.

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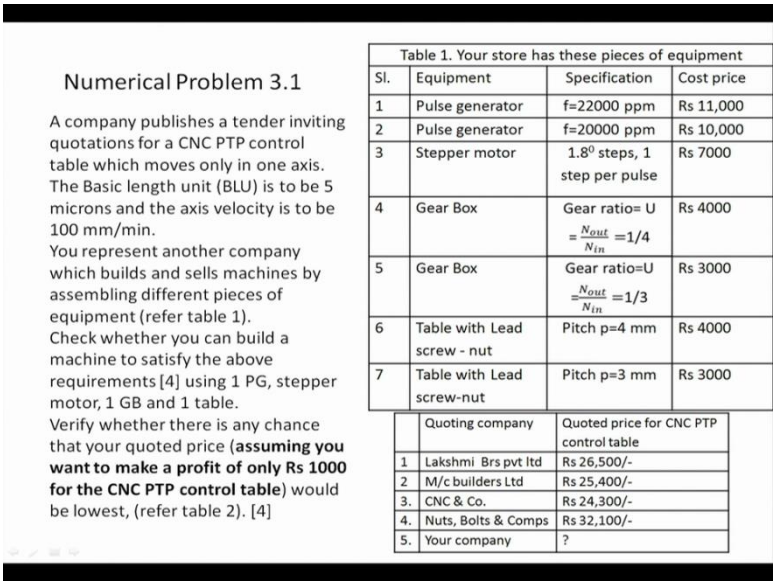

It says that a company publishes tender inviting quotations for a CNC point-to-point control table, which moves only one axis so it is sometimes called a single stage that is fine, the basic length unit is to be 5 microns and the axis velocity is to be 100 millimetres per minute. You represent another company which builds and sells machines by assembling different pieces of equipment and where are these equipments available? It is you can refer to table 1 and it will show you the equipments which is available with you. Check whether you can build a

machine to satisfy above requirements using 1 pulse generator, 1 stepper motor, 1 gearbox and 1 table.

Now, first of all we will find whether there is any chance that your quoted price assuming that you want to make a profit of only 1000 rupees for the CNC point-to-point control table would be the lowest, so what is exactly required here? We have to choose from this inventory of equipment which is available with us, some equipment which is restricted to 1 pulse generator, 1 stepper motor, 1 gearbox and 1 table to make up finally this CNC machine, which is going to be capable of producing a basic length unit of 5 microns and an axis velocity of 100 millimetres per minute. And then by adding up the price and adding a profit of 1000 rupees, we have to find whether we will win the purchase order or not.

So let us 1st have a quick look what is available with us. We have two pulse generators and their frequencies are given to be 22000 and 20,000, can we use any of them? Well, we can use any of them provided that we can attend the specifications which are laid down in the tender that is fine. Stepper motor, there is only one so we have no choice; we have to go for this. Gearbox, there are 2 gearboxes one is having ratio of one fourth and another is having ratio of one third.

Table with lead screw nut pair, which is having a pitch of 4 millimetres and there is a table with a pitch or lead whatever you call it here, it makes no difference of 3 millimeters. So gearbox we have option, pulse generator we have option and table with lead screw we have option and they have different prices, so let us see how we can make up the cheapest machine, which is capable of providing the required basic length unit and axis velocity.

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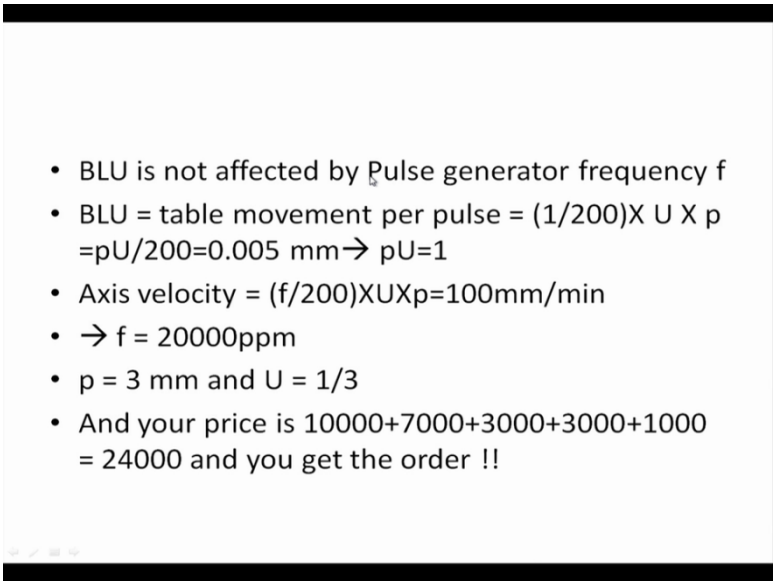

So 1st of all, as we have discussed in 2 previous questions basic length unit is not affected by pulse generator frequency. So basic length unit let us calculate it, basic length unit is the table movement per pulse and therefore, we have 1 pulse of movement creating 1 by 200 of a rotation of a motor shaft creating into U, U being the gear ratio of lead screw rotation and that is leading to multiplied by p, these many millimetres of table movement, so this is the table movement per pulse and it should be equal to 0.005 millimeters.

So if we simplify, collect all the terms properly we have p into U divided by 200, so we have written here p into you divide by 200 should be equal to 5 microns, which gives us pU equal to 1. The axis velocity on the other hand is going to be the frequency of the pulse generator divided by 200 giving us the number of rotations of the stepper motor multiplied by the gear ratio giving rise to the number of rotations of the lead screw and multiplied by p giving us the total amount of movement per minute of the table, so this is the axis velocity in millimetres per minute and it should be equal to 100, we are equating this thing equal to 100.

So we get essentially two equations, one is pU equal to 1 and from here we can put pU equal to one so that f will be equal to 100 into 200, which means 20,000 pulses per minute. Now do we have 20,000 pulses per minute generator here? Yes, this is the one, the item number two, 20,000 per a minute is the one pulse generator that will satisfy our requirements and it it essentially also means that the first pulse generator 22,000 pulses per minute, it will not satisfy our requirements, so we cannot take it. So this is the one pulse generator that we require and that means it will be costing us Rs 10,000, cost price is Rs 10,000, so 10,000 rupees 1st of all is the expenditure for the pulse generator.

Let us see the others, what options we have. Now, if pU is equal to 1, if it is to be equal to 1, let us see whether we have options giving us such a combination, pU equal to 1. Yes if we choose gearbox item number 4 together with item number 6, we have one fourth multiplied by 4 equal to 1, so we could well choose this combination but we could also choose gearbox item number 5 one third and this one pitch equal to 3 item number 7, one third and 3 or one fourth and 4, which one would you choose, both will be sufficient, I mean both will be satisfying your requirements, but they are having different costs, so obviously let us go for the cheaper ones.

So 3000 rupees here gearbox, 3000 rupees for the lead screw nut arrangement gives us 6000 rupees together with that 10,000 that we incurred for a pulse generator, 16,000 and the separate motor you have to take it anyway, so 7000 more, 16,000 + 7000 is 23000. Add to that a profit of 1000 rupees that we would like to have that is 24,000 let us see, yes you win the purchase order because your price is going to be 24,000 and is going to be lower than any of the bids which are put forth by these 4 companies. Congratulation, so you have won the purchase order for this particular equipment.

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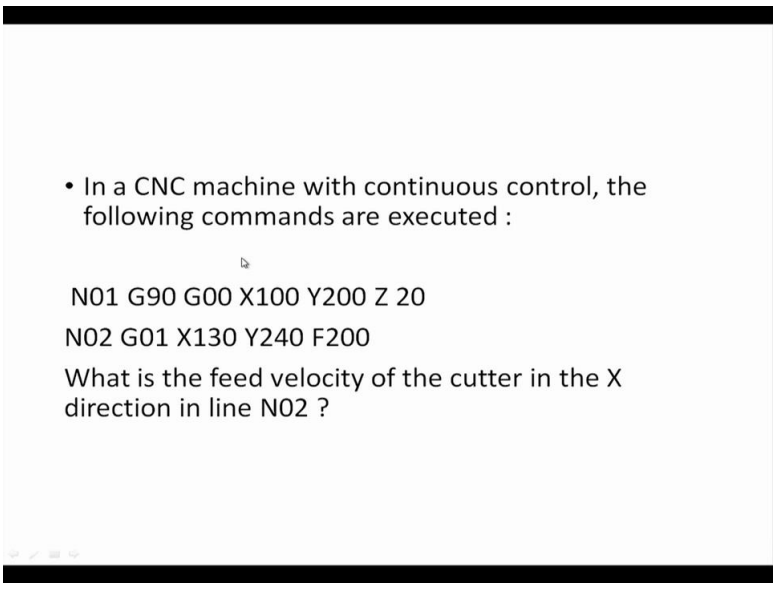

Last of all, we have just a few minutes to finish one small problem. In a CNC machine with continuous control, the following commands are executed. G90 G00 X100 Y200 Z20 and after that, so this is a rapid traverse command occurring at highest possible speed and after this, the tool is going to reside at 100, 200, 20. After that we have a G01 that means linear movement, where X is 130, Y is 240 and F is 200, so that means net X movement okay is 30

millimetres incremental and 40 millimetres along Y axis, so 30 and 40. What is the feed of the cutter in the X direction in line number N02? So let us have a quick calculation.

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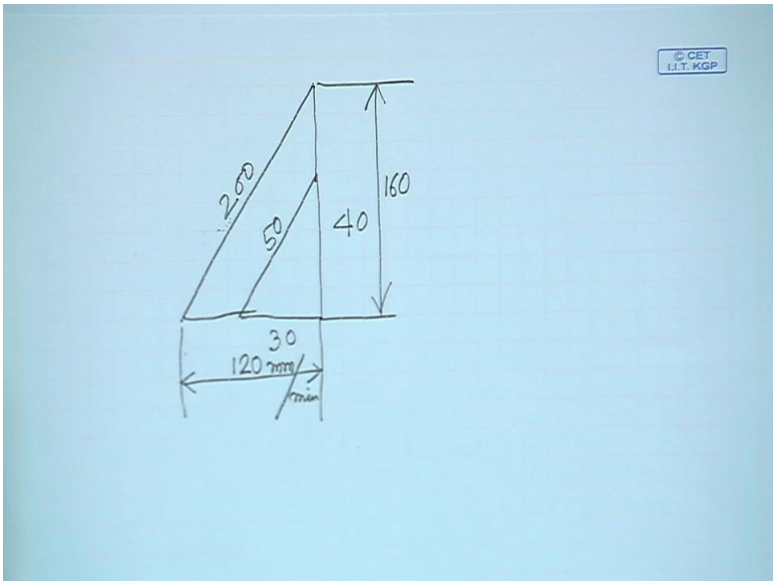

Y is 40, X is 30 and therefore, this must be 50 this is the displacement triangle and on top of that we are putting the velocity triangle. What is the velocity triangle? The velocity triangle says that this is 200, so proportionally we can place therefore this is the feed along X-axis. How much should this be? If it is 50, it is 30, so multiplied by 4 and therefore you have 120 here and here you have 160. So answer is, the feed should be 120 millimetres per minute along the X axis for this particular command block okay, 120 millimetres per minute.

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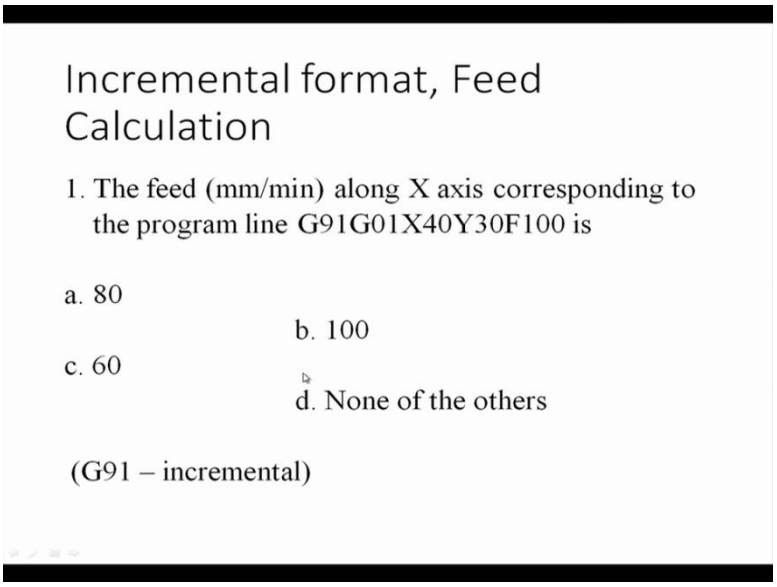

Last one, incremental format, the feed along X axis corresponding to program line G91, which means incremental, G01 X40 Y30 F100 is… is absolutely the same problem, only incremental means these are the actual movements, incremental movements along 40 and 30, so they will be just like the same problem, I am sure you can do this yourself, thank you very much