Metal Cutting and Machine Tools
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Lecture-20
Numerical Problems

Welcome viewers to the last lecture of our course metal cutting and machine tools. So, let us move right away, so today we are going to have some discussion on the numerical problems which can be in these areas.

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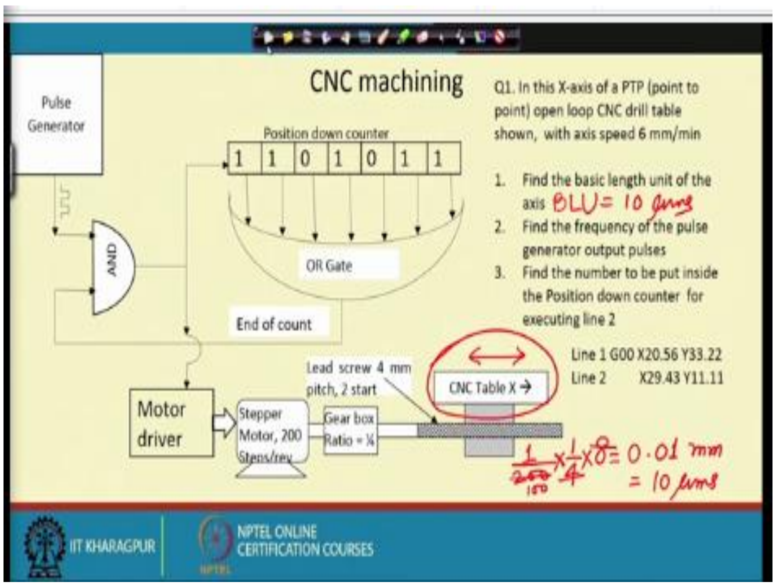

So, let us start right away with our figure that we have come across and the question reads in this X-axis of a point-to-point open-loop CNC drill table shown with axis speed of 6 millimeters per minute, find the basic length unit of the axis? Find the frequency of the pulse generator output pulses? And find the number to be put inside the position down counter for executing line number 2 of this particular couple of lines?

So, first of all which is the table, the table is this one, this is the CNC table X-axis, so it is capable of moving this way and that way who is moving it. The lead screw is moving it, the lead screw is connected to the motor through a gearbox, the motor is run by the pulse generator. So, the pulses which are emitted here they are moving through and for the timing let us assume that nobody is stopping these pulses from reaching the motor.

Basic length unit means the smallest distance that we can control or measure for movement. Here we are not measuring anything because this is working in open loop. But we are controlling the movement by our smallest controlling element is one pulse. So, let us see how much movement we are acquiring by one pulse and that is basically our basic length unit or BLU. So, first of all let us see whether we can have some calculation here.

Yes, first one pulse must be moving the motor shaft by 1 by 200th of a rotation, so let us write 1 by 200, this is the movement correspond to one pulse rotation. Gearbox further reduces it, gearbox multiplies it by a factor of one fourth, one rotation here is converted to one fourth of a rotation here and therefore this also is proportionately reduced. Lead screw however will be undergoing 8 millimeters per rotation of it is of the lead screw.

So, this one for these many rotations of the lead screw it will be moving the table by 8 millimeters into this. So, how much is this equal to? 4 cancels out with 8 and this 2 cancels out and we have left 100 and therefore this is equal to 0.01 mm, 10 μm, this is equal to 10 μm. So, we have this answer basic length unit is 10 μm, find the frequency of the pulse generator output pulses. Now we are given this information that axis speed is 6 mm/min, so let us consider a pulse generator frequency to be f, so f.

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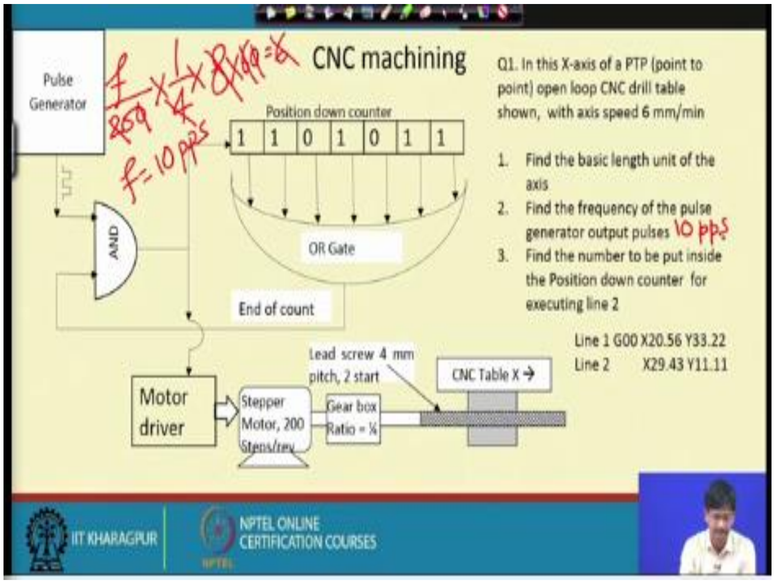

How many of these pulses will give us one rotation? 200 pulses, so these many rotations of the stepper motor will be obtained per second. Now these rotations will be reduced by the gearbox by a factor of one fourth and the amount of motion obtained will be multiplied by the lead of the lead screw and therefore this should be equal to when multiplied by 60 this should be equal to 6 millimeters.

Now here what will cancel out 6 with this 6 and this 0 with this 0, this 4 with this 8 and this 2 with rest of 8 and therefore we will have f = 10 pulses per second. So, this one is 10 pulses per second, find the number to be put inside the position counter for executing line number 2.

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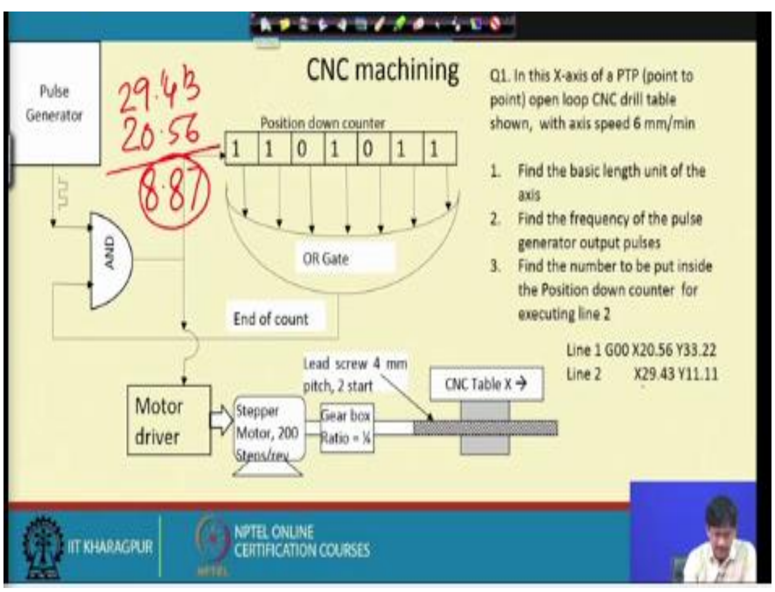

Line number 2 says that I want a movement of 29.43 millimeters, so let us subtract it 29.43 and it was already a 20.56 so this means 13 7 1 14 and this is 6, so this is 8 and 1 goes here 8, 8.87mm of movement are required. So, I have to put some number, so that this will get decremented and it will exactly become 0 when the required motion has taken place. Per pulse I am having 10μm of movement.

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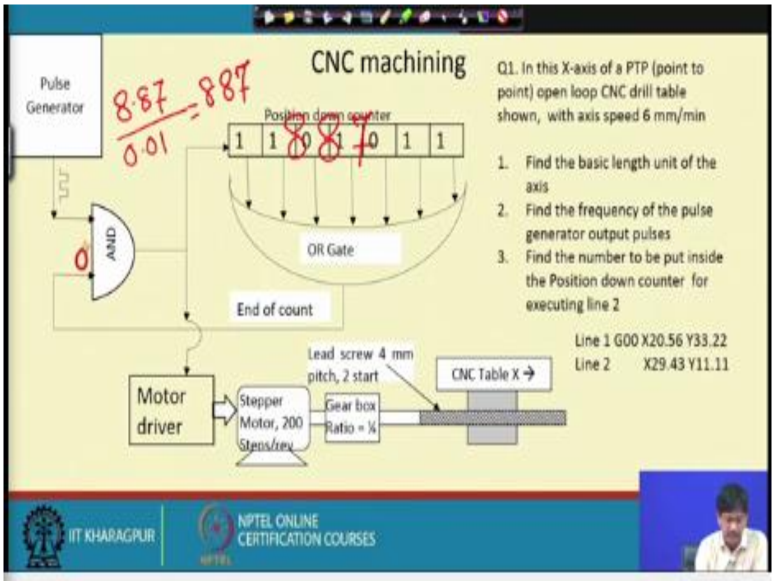

So, this means that if I want to have 8.87mm of movement, how many pulses would be required? 887 pulses will be required in order to get the stepper motor move the table through 8.87mm. So, if we put 887 in binary inside this position down counter, our job will be done. Because while 887 pulses are coming here, 887 pulses will be going there and it will be down counting the contents to 0 and OR gate will put out a 0 here and further pulses will be stopped. So, the number to be put inside is 887.

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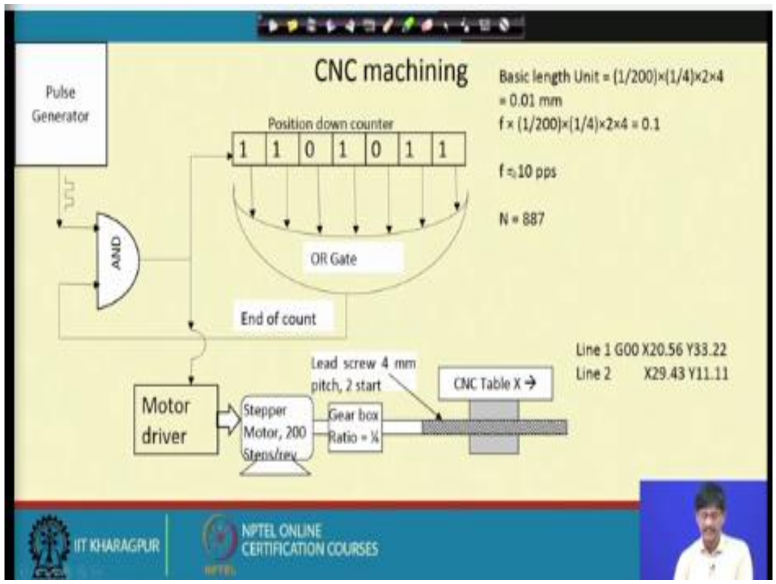

Let us see, these are the answers provided here, this was 0.1 and from here you can easily calculate f. So, having understood this one let us move on to the next problem.

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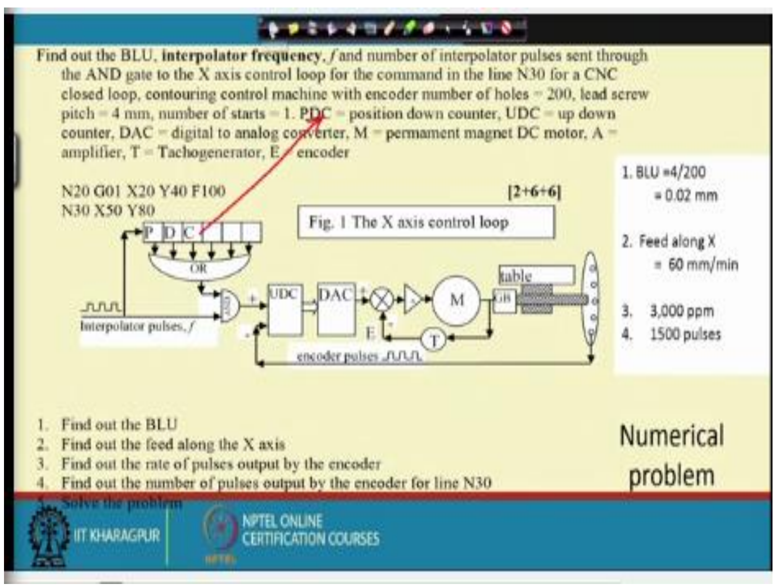

Find out the basic length unit, interpolator frequency f and the number of interpolator pulses sent through the AND gate to the X-axis control loop for the command line 30. For a CNC closed loop contouring control or continuous control, whatever with encoder number of holes 200 lead screw pitch 4 millimeters, number of starts = 1. And PDC stands for position down counter, so this is the thing position down counter.

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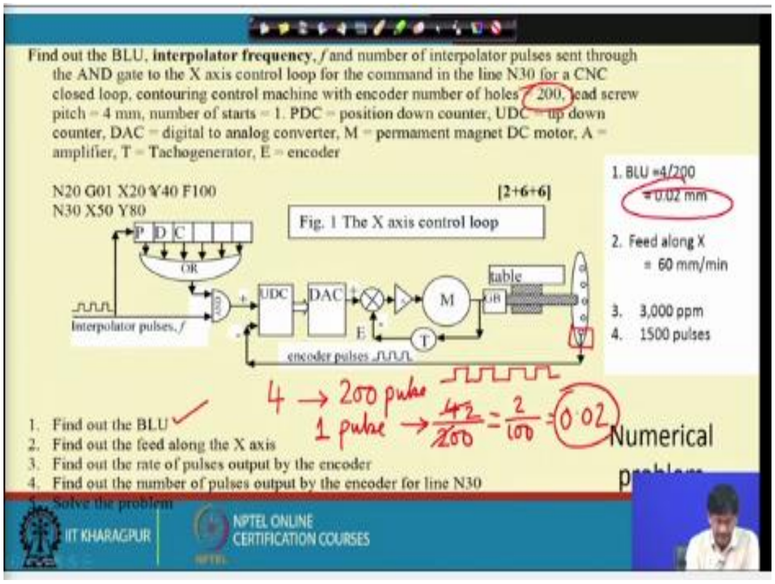

Next UDC up-down counter here, just as we have discussed this thing, so let us go into the problem directly. Find out the basic length unit, how is the basic length unit decided? This is a closed loop system in which we are keeping track of the movement which is taking place. And the encoder sends back pulses; each pulse is therefore our smallest unit of the actual movement carried out. What is this smallest unit?

So, how many holes does the encoder have? 200 holes, that is fine, so each rotation of the lead screw also causes 200 holes to pass through some there is a control circuit placed here which sends out pulses here corresponding to each such hole. Each hole when it passes through the control circuit sends out pulses like these. And these encoder pulses are the counting unit. So, let us find out what movement of the table corresponds to the passage of one encoder pulse to create one encoder pulse across this control circuit?

So, we understand the table moves by 4mm, 4mm of table movement is obtained for 200 encoder pulses. Therefore, one pulse of the encoder will be counting this much amount of movement and how much is this? 4 cancels with 2, so that a 2 remains upstairs 2 by 100 and therefore this must be equal to 0.02. And this must be the amount of distance kept track by the one encoder pulse, therefore this is the answer.

Next is what is the field along X-axis? now this seems to be difficult, feed is mentioned here but that is along a path which is not along x axis. You are at 20 and 40, so you are at this point, this is 20, 40.

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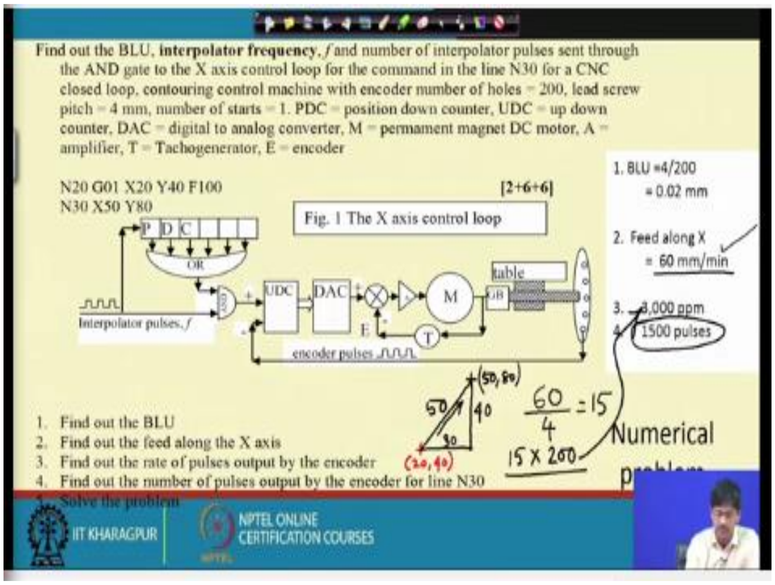

Now this red is which is difficult to this, you are at point 20, 40 and from there you are going to another point 50, 80 50, 80. So, we can easily compute these distances, 20 to 50, 30, 40 to 80, 40, so this must be 40 and therefore this must be 50. So, that means the feed of 100mm is along this path, 100. So, if 50 is here by Pythagoras theorem we can say this is 30, this is 40. So, if 100 is here since feed triangle and displacement triangle they are similar for linear movements.

So, if 100mm movement is there we must be having 60mm/min movement along X-axis, so that is why feed along X-axis 60. Next, find the rate of pulses output by the encoder, this must be easy we have done something like this very in the last slide itself, so let us find out. How much movement rate of pulses output by the encoder? Now this is X-axis, so we are having 60 mm/min.

If we are having 60 mm/min movement this corresponds to how many rotations of the lead screw per minute 60 divided by 4, 15 rotations of this shaft. So, 15 multiplied by 200 must be pulses coming out from the encoder, so that is equal to 3000. So, 3000 pulses are coming out, so this way I leave the last one to you, they are absolutely easy. Find out the number of pulses output by the encoder for the lime N 30, so for the line N 30 find out what is the total number of pulses corresponding to this movement. Just like we have done previously and find out whether is equal to 1500 or not, I leave that one to you.

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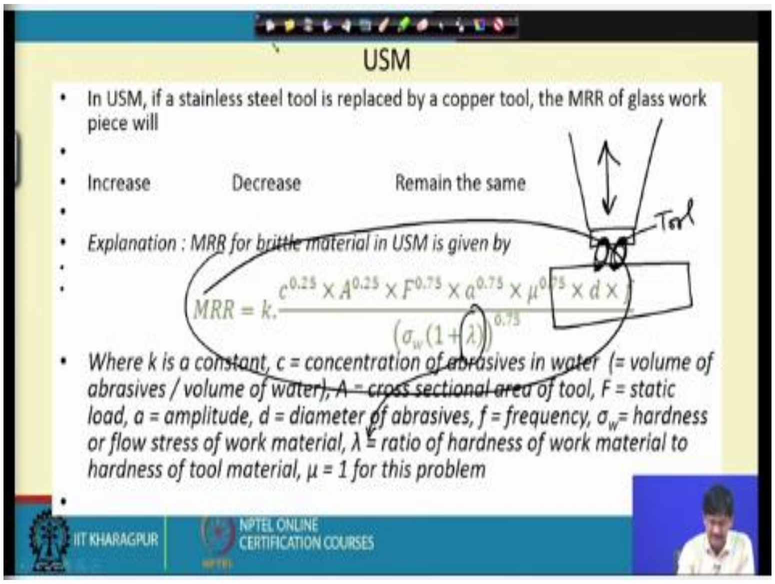

Next, ultrasonic machining. In ultrasonic machining if a stainless steel tool is replaced by a copper tool the MRR of glass workpiece will increase, decrease, remain the same. So, a tool is replaced, remember the tool which was vibrating against the workpiece. Now if steel tool is replaced by copper tool the tool is softer, I have worked it out through this formula but I will give you a physical idea also.

This is the last part of the horn and this is the tool, so this being the tool there are abrasive particles in between and this is the workpiece. So, if the workpiece if this is going on hammering from the top and if these abrasives are very hard, they will cause indentations on the workpiece side as well as the tool side. Now if the tool becomes softer these indentations will be higher on the tool side and workpiece will be getting a relief on their side the indentations will not be much.

Because most of the hammering action will be absorbed by larger indentations of the tool if it is softer copper tool and therefore material removal rate will definitely decrease. And we have given here an explanation based on this formula. Please study this yourself I will give you a hint, it is λ which is affected and work it out yourself.

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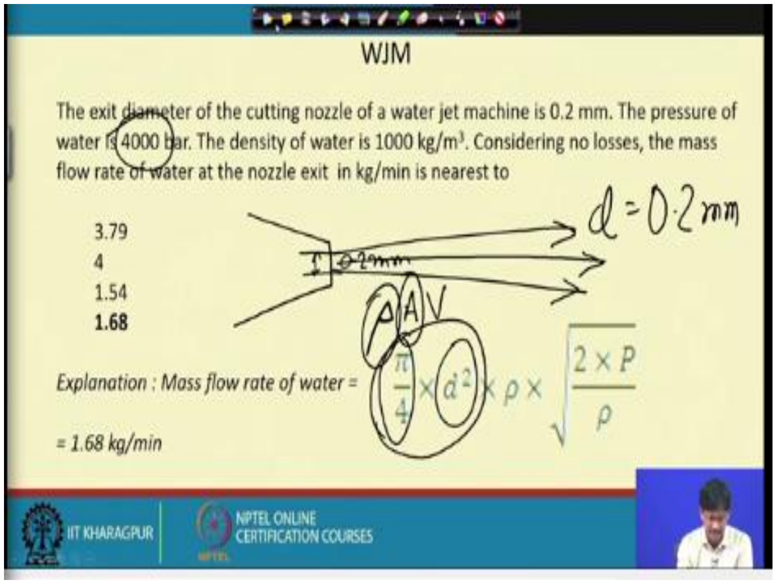

Next, the exit diameter of the cutting nozzle of a water jet machine is 0.2 millimeters, the pressure of water is 4000 bars, the density of water is 1000 kg per meter cube, considering no losses the mass flow rate of water at the nozzle exit in kg per minute is nearest to. These are the options and I am providing the answer 1.68 kg/min. So, let us first see what is the problem about?

The problem says that there is a nozzle from which water is emanating in water jet machining; water is coming out at high speed. Therefore, it is able to cut most of the nonmetals like leather, paper, meat, frozen meat etcetera. These things it can cut efficiently from 4000 bars and the nozzle diameter outlet here is only 0.2mm, just imagine 0.2mm so small. So, how can we find out the mass flow rate of water at the nozzle exit in kg/min?

So, I will just give you the basic idea and from there you can find out. First of all, we know that mass flow rate will be equal to ρ * A * V, where ρ is the density in this case 1000, A is the cross sectional area which is π/4 * d^2, where d is equal to d is given 0.2mm. And ρ comes here, so ρAV.

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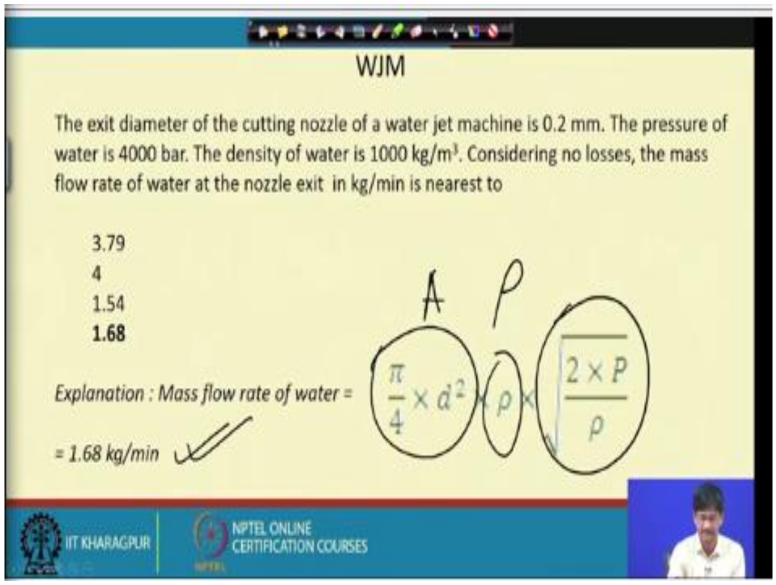

This is A, this is ρ and this is V, how is V found out? V is found out by converting the pressure energy completely to velocity energy. If you remember we have Bernoulli's equation where P by gamma = V square by 2G = z, so the same thing has been done here, I leave this calculation to you, I am sure you can solve it and this way the mass flow rate can be calculated to be 1.68 kg per minute.

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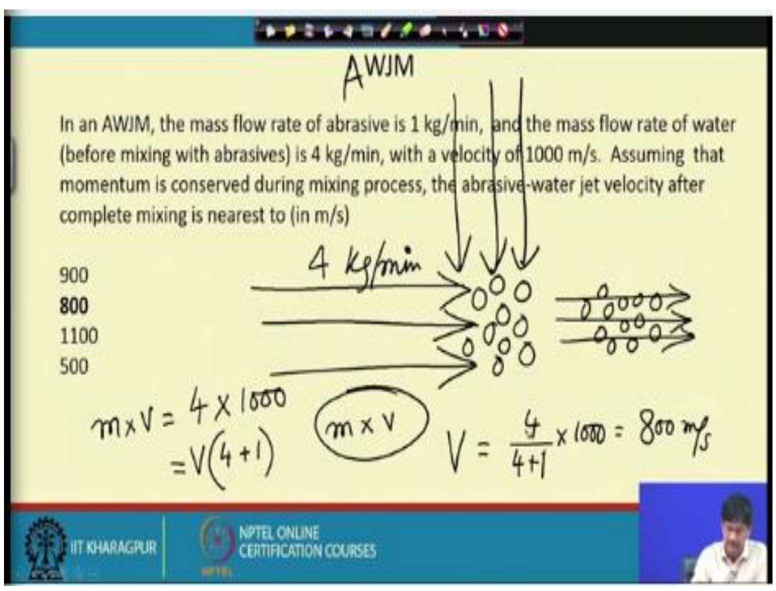

Next, so water jet machining? In case of abrasive water jet machining what are we working with? So, this will be abrasive water jet machining. In abrasive water jet machining the mass flow rate of abrasive is 1 kg per minute and the mass flow rate of water before mixing with abrasives is 4 kg per minute with a velocity of 100 meters per second. Assuming that momentum is conserved during mixing process, the abrasive water jet velocity after complete mixing is nearest to in meters per second, so what is this dealing with?

In abrasive water jet machining what happens is water is coming at high speed and it is having a definite mass flow rate, the mass flow rate is given to be 4 kg/min. And its speed is very high with a velocity of 1000 m/sec. So, we can immediately find out what is its momentum? How do we find it out? Mass into velocity, so here mass into velocity whatever momentum is carried by the water jet abrasives are put inside this particular stream, what is the abrasive velocity?

Practically zero, the abrasives have no velocity to contribute. So, ultimately if we are following this momentum is conserved we have to assume that whatever momentum is carried by the water into the mixing chamber, that is the only momentum available. So, m into V here means 4 multiplied by 1000. Now this one is ultimately giving us after the mixing chamber an abrasive water jet where both of them are sharing the same velocity.

That means the abrasives have got completely mixed inside and they are coming out. So, we are assuming that in this case momentum is conserved no other losses but energy is not conserved. Due to mixing some energy is lost, so we can only apply the momentum, conservation, relation and say that ultimately if the velocity is V, it is mass that is being carried in this stream it has become higher because abrasives have been added, so it is 5, 4 + 1.

And therefore the velocity comes out to be 4 by 4 + 1 into 1000 which is 800, 4 by 5 800 m/sec. This one is sometimes referred to as the loading factor, which one? This can be actually let me just remove this.

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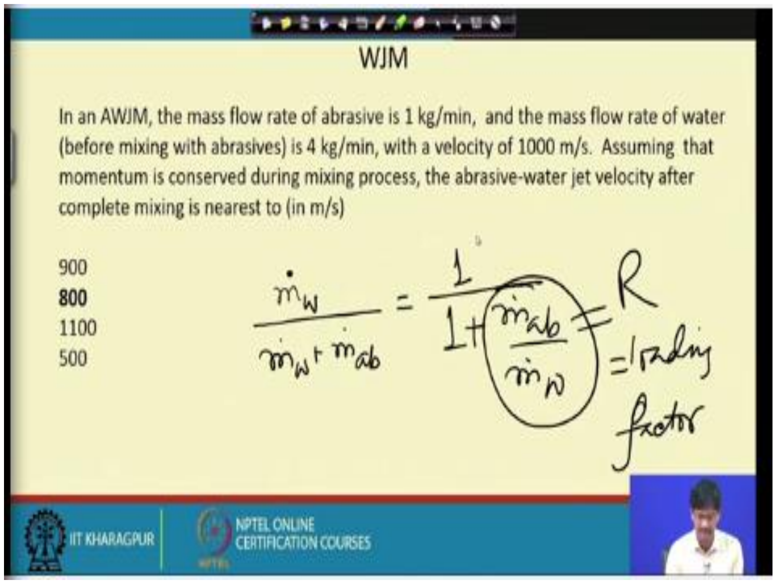

This can be referred to as $\dot{m}_w / \dot{m}_w + \dot{m}_{abr}$ equal to if you divide this by $\dot{m}_w$ it becomes $1 / 1 + (\dot{m}_{abr} / \dot{m}_w)$ and this one is called loading factor or R, loading factor. It is one of the most important parameters in abrasive water jet machining. I intend to include some solved problems and upload it for your use where you will come across the use of such parameters in abrasive water jet machining.

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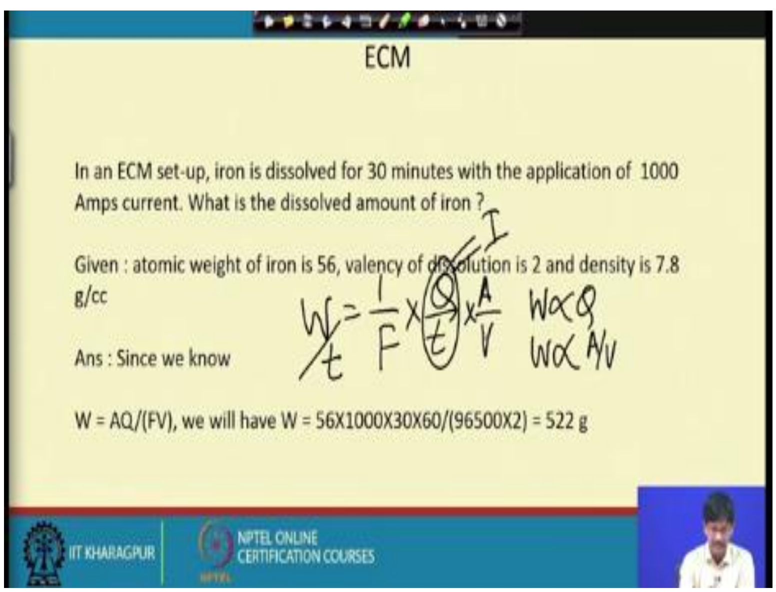

ECM, in an ECM setup iron is dissolved for 30 minutes with the application of 100A current, what is the dissolved amount of iron? So, in this case what we have given is atomic weight of iron is given to be 56, that means gram atomic weight is 56g, valency of dissolution is 2, I have 2 valencies, one is 2 and one is 3 and the density is 7.8 g/cc. What do we know from previous calculations as we did if you remember?

We had weight is proportional to Q, weight is proportional to A/V and therefore weight is equal to 1/F * Q * A/V. And if we take material removal rate and divide it by t and we divided by t here, so that this becomes current. MRR = 1/F * I * A/V, it is not so complex here, it is even simpler than that, let us see what we have been given. So, W this is what we have to find out, what is the dissolved amount of iron?

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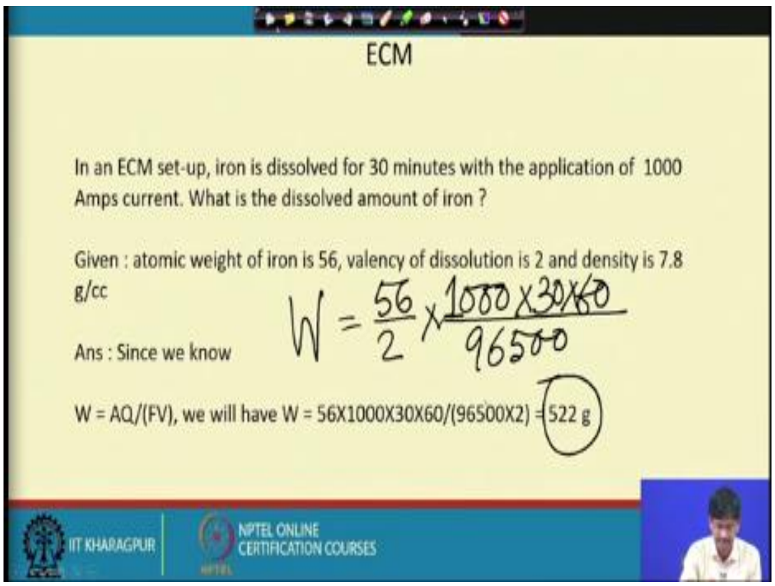

So, let us write W, it is already written here this must be equal to atomic weight by valency**.** So, we have multiplied by charge which is Amperes, Ampere is 1000A into time 30 minutes into 60 that gives the seconds. So, this is the total amount of charge in coulomb. Once we have this, so 56 by 2 into this thing divided by 96500 Faraday’s constant. So, this one after calculations will give you 522g of iron, just imagine you are able to dissolve about half a kg of iron by applying this current for 30 minutes.

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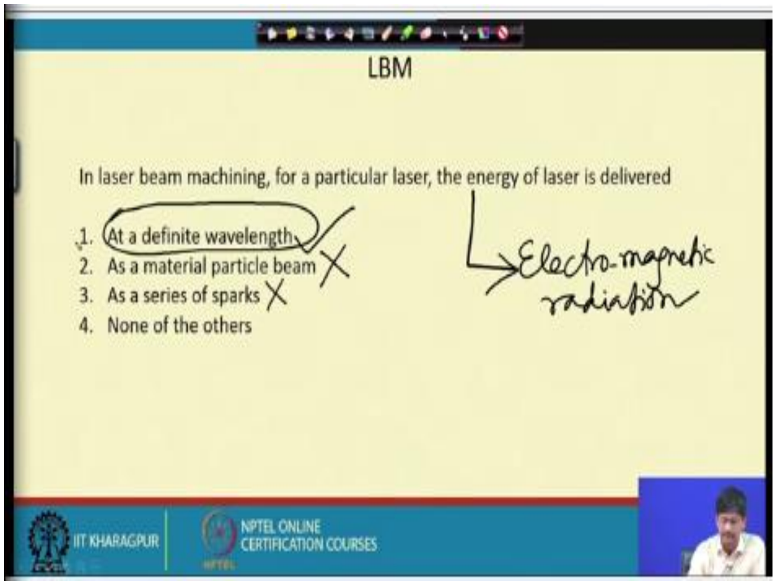

Next, laser beam machining, a laser beam machining for a particular laser the energy of laser is delivered at a definite wavelength as a material particle beam, as a series of sparks, none of the others. So, first of all at a definite wavelength, lasers always correspond to a definite wavelength or maybe a mixture of 2 wavelengths like that. But in general the concept is at a definite wavelength, so this first one is correct, we will term this as correct.

As a material particle beam, no, this is wrong, lasers are basically they are light or they might be light at frequencies which we cannot see, so they are basically electromagnetic radiation. As a material particle beam, no, as a series of sparks, no, sparks are pertaining to electrical discharge machining, so that people confused with that we will take this one, this is not correct. And therefore we have this as the correct answer. So, this gives us an opportunity to discuss a little more about some other methods which I have left behind but they are equally important.

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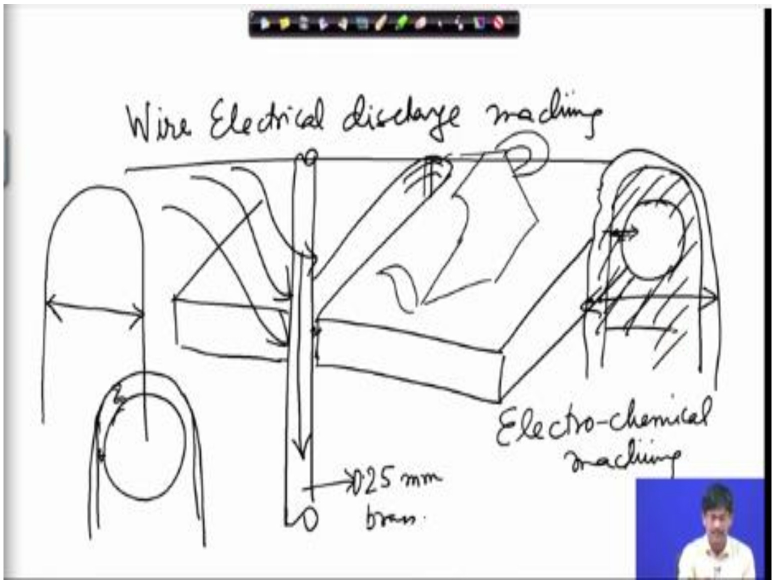

That is first I would like to just mention there is another method called wire EDM, wire electrical discharge machining which works on the same principle as EDM. Only difference is that there is a wire which is moving and it is used as the cutting element, that means if there is a material here say a sheet of metal and I want to cut this along this line, this way I want to cut it. If I want to cut such a piece of material then obviously if I make the wire move, so what is the diameter of the wire maybe say 0.25mm as a very thin wire, what material?

Say brass, it can carry current but that is all, it does not have such any cutting ability. But suppose I give electrical connection to this and I am providing voltage pulses and I am flooding the whole place with some dielectric fluid say deionized water or kerosene like that. So, if I am giving an electrical connection in between them the moment the wire comes close sparks will fly and if I make the wire move along a definite path accordingly material will be cut and two dimensional CNC control cuts can be taken very conveniently.

So, you can move and along any path that you want and have practically anything which you require. So, this all again learn so signifies whatever you want in two dimensions it is available from wire cut EDM. It has become very popular and surprisingly the other method electrochemical machining has not been able to produce a corresponding method, electrochemical machining why so?

There is no wire electrochemical machining process, no, why is this so? This is because wire electrical discharge machining is a method where sparks are deciding the material removal. If you have a definite distance existing between if you see the wire from the top between the wire and the other electrode. If the distance crosses a certain limit sparks will not fly. So, laterally the size of the cut is extremely well defined beyond the certain distance for the pulses will not occur and you have well defined cuts taking place of definite dimensions.

This dimension becomes extremely well defined. In electrochemical machining the problem is that electrochemical dissolution can take place over any distance practically and it is not by sparks but by electrochemical dissolution. So, if this place is filled up with dielectric fluid, you really do not have a choice but they are going to be totally uncontrolled cuts and you might be ending up with large over cuts.

And therefore it is not very well controlled and that is why wire electrical discharge machining has been widely accepted while this is not. So, with this we come to the end of our lecture series, so whenever you have any difficulty you can use our forum to get in touch with me and I will be ready to explain all your doubts. Wish you all the best, thank you very much.