Non-traditional abrasive machining process: Ultrasonic, Abrasive jet and abrasive water jet machining

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Lecture - 18
AWJM - Numerical Problems

Welcome viewers to the 18th lecture of the course Non-Traditional Abrasive Machining Methods, including Ultrasonic Machining, then Abrasive Jet Machining and Abrasive Water Jet Machining. And we have already completed ultrasonic machining and abrasive jet machining. We have completed I think 2 lectures on Abrasive Water Jet Machining also. And today we are going to proceed with some numerical problems in Abrasive Water Jet Machining.

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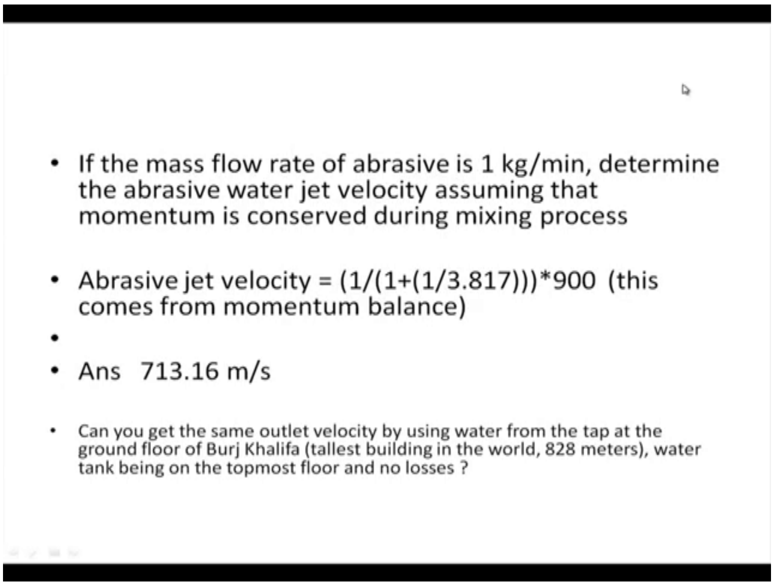

So, let us proceed this one we have already solved in the previous lecture. So, I am skipping this.

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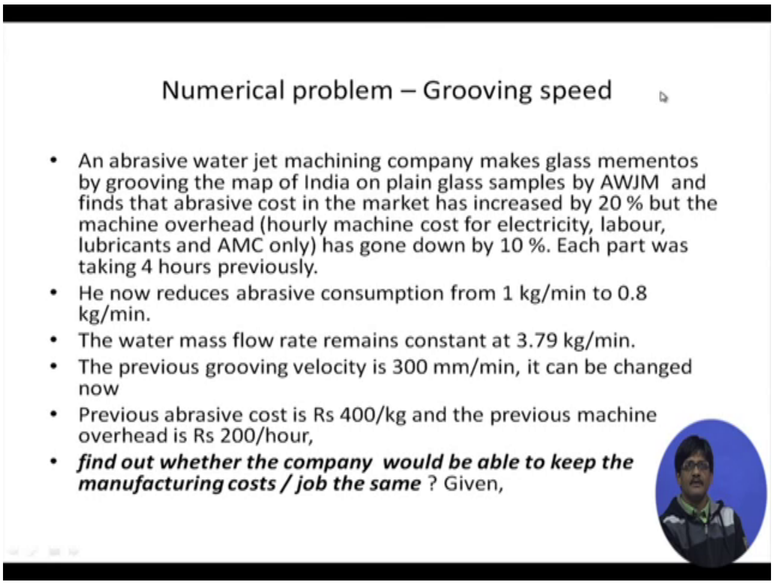

So, let see an abrasive water jet machining company makes glass mementos by grooving the map of India on plain glass samples by abrasive water jet machining and finds that abrasive cost in the market has increased by 20 percent, but the machine overhead; that means, hourly machine cost for electricity labor lubricants and AMC etcetera that has gone down by 10 percent, each part was taking 4 hours previously.

So, in response to this price hike and coming down of the overhead, now reduces abrasive consumption from 1 kg per minute to 0.8 kg per minute. So, that is quite you know unnatural prices of abrasive have gone up. So, it reduces the consumption of abrasive, the water mass flowing rate remains constant at 3.79 kg per minute. The previous grooving velocity is 300 meter millimeters per minute and it can be changed now.

Previous abrasive cost is 400 rupees per kg and previous machine overhead is rupees 200 per hour. That is understood. So, lot of data and first of all it is a question of grooving. Do we know anything about you know any relation between grooving and grooving depth and something else etcetera. So, let us have a quick look first at that.

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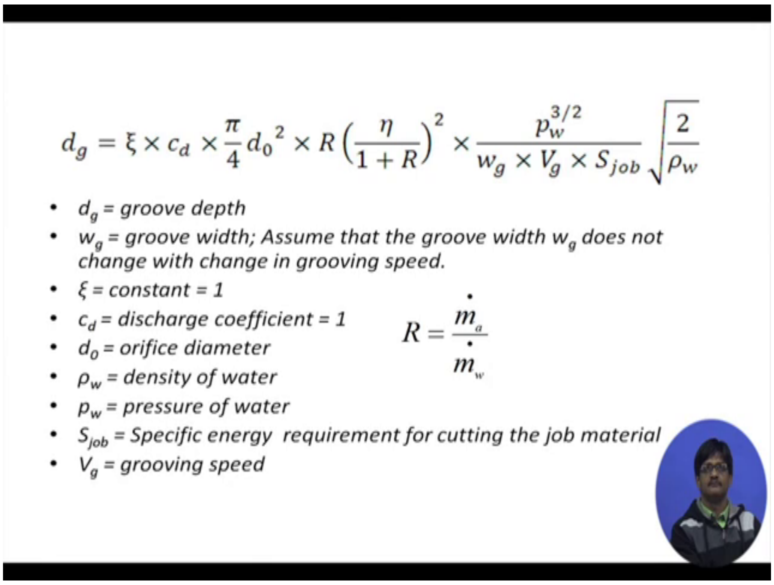

What was the question to find out whether the company would be able to keep the manufacturing costs per job the same. That is it. This expression is you know appears to be something that we have come across in the very recent past. What is that? I think you will recognize this particular expression R into eta square by 1 plus R. I mean eta by 1 plus R whole square into p to the power 3 by 2 into 2 by root over rho etcetera, ok.

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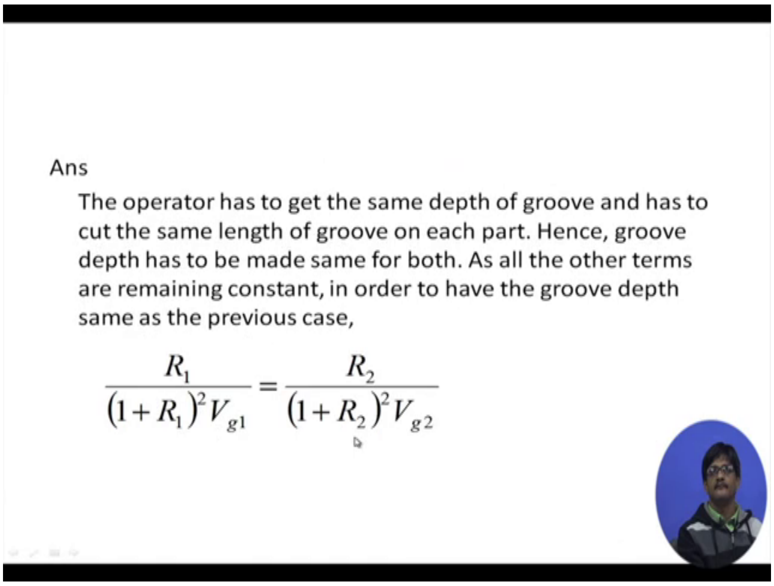

All these are constants for which we we will definitely find out what are the values to be taken. Then, 5 by 4 d square is a cross-sectional area etcetera. So, this is a well known expression that we are coming across, but these are the new comers.

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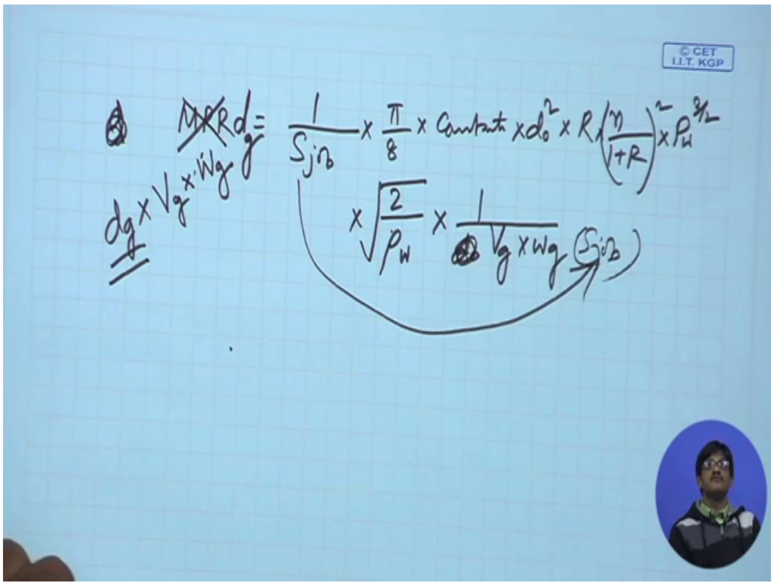

How are they coming in? So, probably it is because of this. Let us write down the previous expression that we had derived. MRR equal to 1 by specific energy of the job material into if I remember correctly it was pi by 8 in all sorts of constants which I am just you know putting it together like these constants and there was d 0 square multiplied by R into eta by 1 plus R whole square into p to the power E W to the power 3 by 2 multiplied by 2 by P W rho W root over etcetera.

Now, how does it compare with the grooving equation that we had written down? It comes in here. Instead of writing MRR, simply let us write down the volume of material removed multiplied by the density and after that you know, sorry we do not need to bring in a density. This is material removal rate volume metric and we first write down this must be equal to the grooving depth d g. Write down here d g multiplied by V g velocity of grooving depth of grooving cross-section of the groove, sorry width of groove. Let us write how much width of groove that is it once we write this and keep d g on this side.

Therefore, d g will be equal to we write d g equal to and put all these things underneath d g, sorry V g into W g and in order to keep them company, we bring it here S job. That is it and we get the expression for depth of groove. So, that is what let S come back to the screen. That is what is written here you know all sorts of equations, the cross-sectional area R by R into eta by 1 plus R whole square into comes out you know well known characters, the three characters.

W g V g S job and other things are you know as mentioned before. So, it is nothing you know very similar to what we have been discussing up till now. The depth of groove is related to the other terms in abrasive water jet machining in this particular form. So, our question has been given. Let us have a quick look once again at our question. What are you know stumbling blocks here? No problem. Abrasive cost is increased machine overhead has decreased. Now, the abrasive consumption has changed from 1 kg to 0.8 kg per minute and the water flow remains constant at 3.79 and the previous grooving velocity is given and can be changed now and the previous abrasive cost is 400 kg and the previous machine overhead is 200 per hour.

Now, the question is would the company be able to keep the manufacturing costs per job? Let us see how it can be done. The operator has to get the same depth of groove actually. If the part has to be same, the groove depth has to be the same and has to cut the same length of groove on each part, yes of course, if it is the identical job, the length of groove is the same and the depth of groove should be the same. Hence, groove depth has to be made same for both as for all the other terms remaining as all the other terms are remaining constant in order to have the same groove depth, we have this particular expression.

What are we doing here? All the terms which are changing from case 1 to case 2, you know we have written them down and all the other terms we are assuming they are canceling from the two sides. Pressure of the water jet are we changing it? No. So, it gets cancelled, density of water it gets cancelled from two sides, the same material is being cut. So, the specific energy gets cancelled. So, like that so on and so forth. We simply have these terms and they have to be equal. Why? It is because the group groove depth has to be the same.

So, R1 that means loading factor for the first one; that means, M dot abrasive by M dot water divided by 1 plus I etcetera. The first velocity is definitely going to be different from the second velocity. You may ask me why? Why do not I keep the velocity the same? You will get to know as we proceed. The velocity has to change. So, in fact from here itself we can understand if the groove depth has to be the same. I am sorry here itself we can find out if the groove depth has to be the same and R has changed. Velocity has to change in order to keep these two same. Why has R changed is because he has reduced the abrasive mass flow rate from 1 kg per minute to 0.8 kg per minute.

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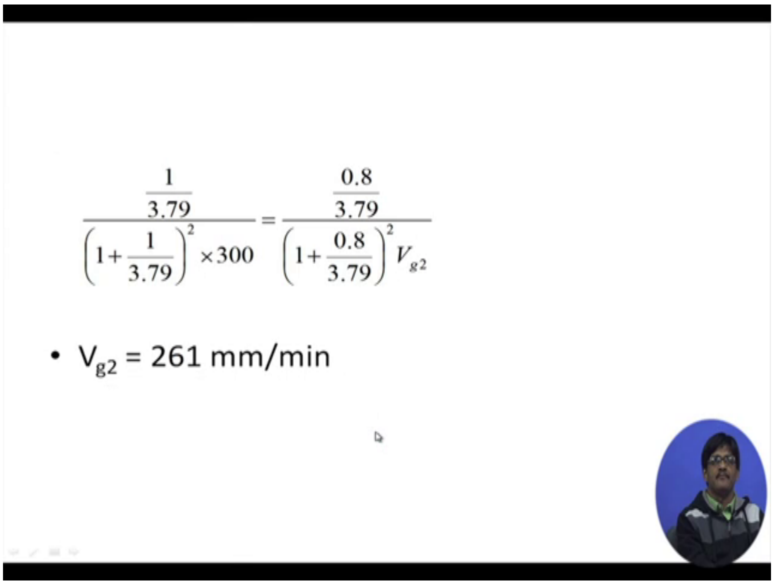

So, R is changing. So, naturally V has to change. So, let us have a quick look.

1 kg by 3.79 kg which is the water mass flow rate, abrasive mass flow rate divided by 1 plus 1 whole square which means 1 plus 1 by 3.78 whole square multiplied by the cutting speed of 300 meter millimeters per minute is speed of cutting. I am sorry. Speed of grooving must be equal to the second loading factor which is you know 0.8 divided by 3.79 divided by 1 plus r whole square into this is the unknown from which we find out that he has to employ this particular speed. He has no other option. So, this is understood. Everything else is known. We put in the values and we can get to know the velocity of grooving which he has to employ in order to attain the same depth of groove.

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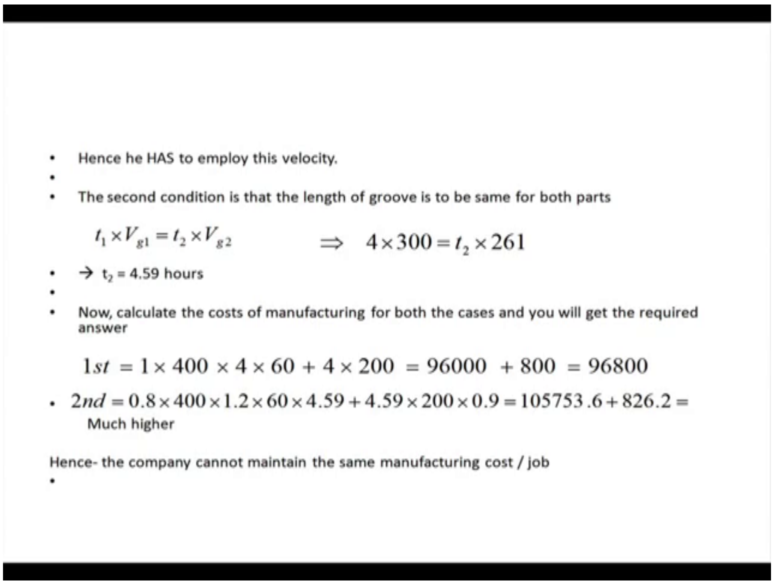

Once this is understood, so hence to employ this velocity, the second condition is that length of the groove is to be the same for both the parts. The length of groove is to be same for both the parts. So, we understand velocity of grooving in the first click, first case multiplied by the time of grooving must be equal to velocity of grooving in the second case multiplied by the time of grooving. That means, total length of groove is equal to total length of groove. That is understood. That is very good 4.9 hours. T 1 is known. How much was t 1? Each part was taking 4 hours previously.

So, we have putted here 4 multiplied by the grooving speed is equal to the second time and the second grooving speed having been solved before we get the time 4.59 hours and after that it is you know just you have to finish calculating the costs of manufacturing. Let us have a quick look how they are calculating it.

First of all this abrasive cost 1 kg of abrasive costs is 400 rupees and therefore, this is cost per minute. Costs per minute abrasive costs is 1 kg per minute multiplied by 4 hours because on part if taking 4 hours multiplied by 60 minutes plus 4 hours multiplied by machine overhead is equal to 96000 plus 800. Now, what is this 800 coming out from?

Let us see whether there are any other costs. Previous machine overhead is 200 rupees per hour and abrasive cost is 800. Are there any other costs? Let us see. I understand this one, first term is 96000, the second term is 800 and they add up to 96800.

Next one is abrasive cost per minute and abrasive consumption per minutes was 1 kg and that is why multiplied it by 60 to find out the cost per hour multiplied by the total number of hours. The second one in more tricky. The time is 4.59 hours and the cost of the consumption of abrasive is 0.8 multiplied by the cost of abrasive per kg multiplied by the increase in cost of 20 percent. So, 1.2 multiplied by 60 to make it per hour and then, multiplied by the total number of hours and next is the machine overhead, where the cost machine overhead cost come down by 0.90 percent and 10 percent and the total time of use of the machine is 4.59, otherwise much higher.

So, the answer to the question is where even if he has reduced abrasive cost to 0.8 of its previous value and even though the machine overheads have come down by 0.90 and by 10 percent, still he has to spend lot more in order to machine the second part. This is the answer because this cost is coming out to be much higher.

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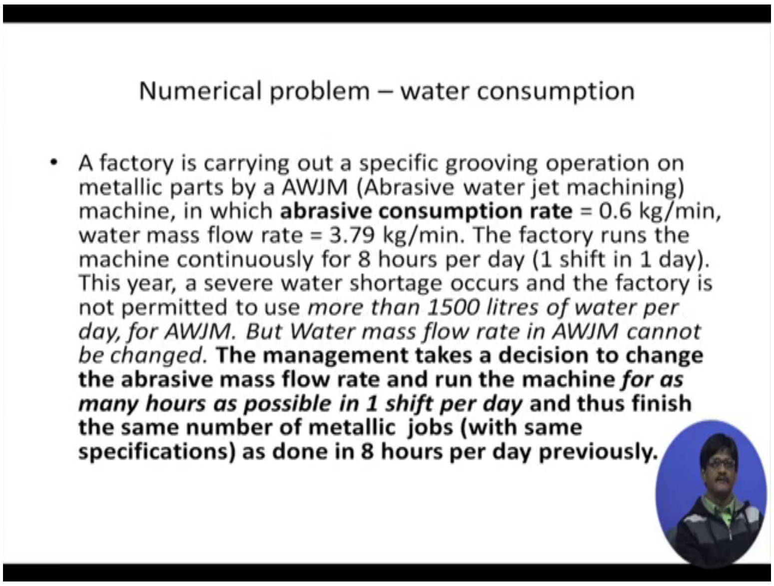

Let us take the next numerical problem on water consumption. This was what we were discussing. So, a factory is carrying out a specific grooving operation and metallic parts by abrasive water jet machining in which abrasive consumption rate is 0.6 kg per minute. That is understood. Abrasive consumption is 0.6 kg per minute, water mass flow rate is 3.79 kg per minute, the factory runs the machine continuously for 8 hours per day. This year a severe water shortage occurs and the factory is not permitted to use more than 1550 liters of water per day for abrasive water jet machining. So, the idea is very clear. 8

hours of work was being done previously and now, suddenly it is shortened because they cannot use water more than 1500 liters and therefore, the water flow rate, the number of hours of work it has to be shortened.

Why? It is because the water mass flow rate cannot be changed. If it is 3.79, even if you have a draft drought, you cannot reduce the water consumption. So, you can run the machine only perhaps for reduced number of hours that calculation will tell us.

The management, the decision to change the abrasive mass flow rate and run the machine for as many hours as possible in one shift per day and thus, finish the same number of metallic jobs as done in 8 hours of work per day previously. So, what they have planned is that previously with 8 hours in your hand, where 3.79 water flow, we were using 0.6 kg per minute. Now, we cannot use it for 8 hours; maybe we can use it for 5 hours. So, increase the abrasive mass flow rate, so that we have enhanced or increased machining rate. So, even if we have 5 hours, we can finish the job of 8 hours. In the previous case, in those 5 hours, this is the problem. It is very simple.

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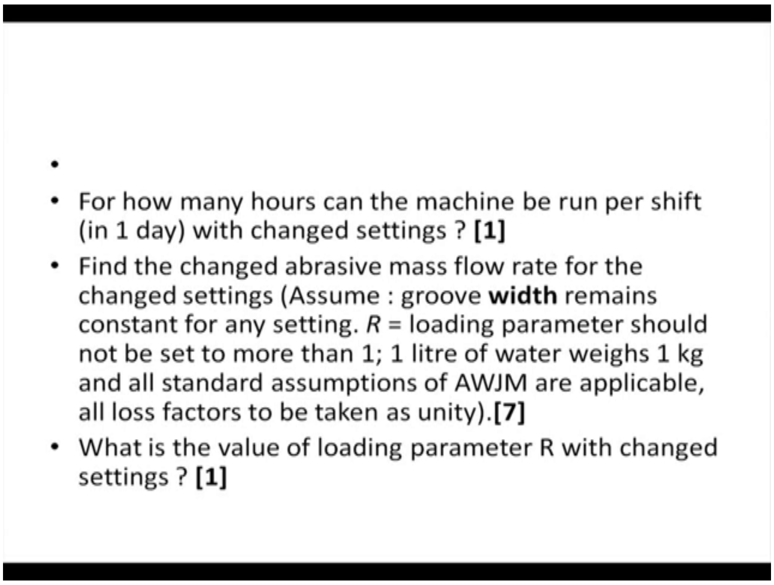

So, let us see how it can be done? Questions are for how many hours can the machine be run per shift with changed settings and find the changed abrasive mass flow rate for the changed settings and what is the value of the loading factor r with the changed settings? What is assumption? Assumption is that groove width remains constant for any setting which is not really true, but you know for all practical purposes, we can assume this and r is the loading factor and it should not be set more than 1.

Now, are we changing R? Yes, if water mass flow rate is not changing, but the abrasive mass flow rate is changing, R has to change and 1 liter of water weighs, 1 kg and all standard assumptions of abrasive water jet machine, they are applicable and all loss factors to be taken as unit.

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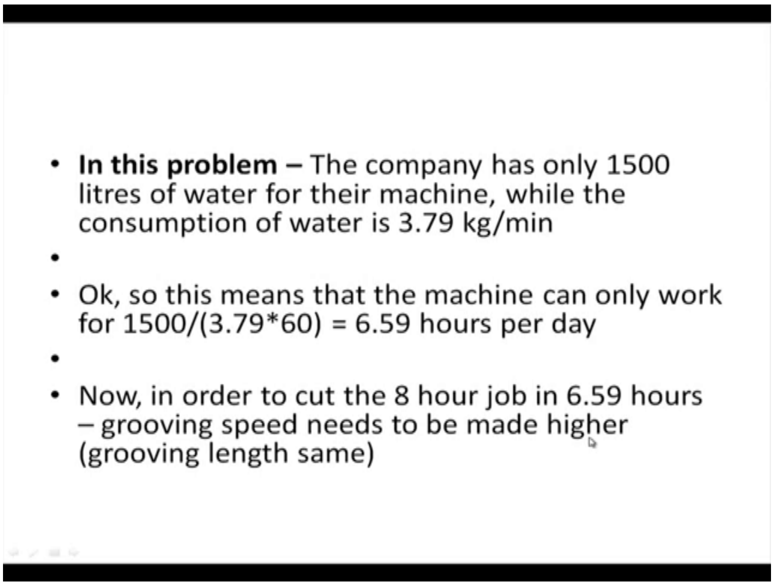

So, let us proceed on to the solved problem. In this problem, the company has only 1550 liters of water for their machine while the consumption of water is 3.79 kg per minute. So, this means that the machine can only work for 1500 liters which is your capacity per day divided by 3.79 into 60 which is the consumption per hour equal to 6.59 hours per day. So, you can use this machine for 6.59 hours per day. Now, you cannot use it for 8 hours.

Now, in order to cut 8 hour job in 6.59 hours, grooving speed needs to be made higher grooving speed. Naturally if you are cutting, if you are grooving and if this grooving is taking less time that means your speed is increasing. So, grooving speed needs to be made higher grooving length is the same. You are cutting the same job and mind you have to produce the same grooving depth also. So, we have two conditions to satisfy. We have a new velocity expression now and we have a new grooving, sorry and we have to maintain the same grooving depth.

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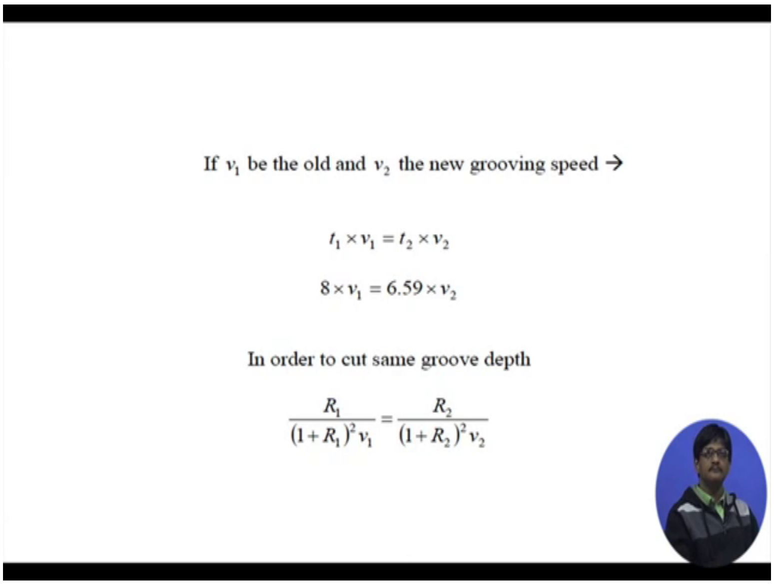

I hope you can read this. It has become smaller font. So, if v 1 being the old and v 2 be the new grooving speed, in that case we can say t 1 into v 1 which means the length of groove is being made the same. You are work outing the same job. The length of groove is the same and therefore, t 1 into v 1 is equal to t 2 into v 2. So, time for the previous one we already know its given to be 8 hours multiplied by the velocity of cut in the previous case.

Now, what was the velocity of cut in the previous case? Suppose I do not know that whatever. So, in the second case, the time of grooving was reduced to 6.59 and therefore, we have at least a ratio of the speeds available with us. What is that ratio v 1 by v 2 is equal to 6.59 by 8. Now, in order to cut this same groove depth, the job is remaining same. The groove depth has to be the same and once again we remember that in the expression for groove depth there were so many other terms, but none of them are changing. Just to remind you cross-section of the water jet is not changing. I mean water jet, jet of water is not changing, then pressure is not changing, density of water is not changing.

So, we absolutely do not have to bother about the other terms, but these terms are changing. Loading factor is changing, velocity is changing and therefore, groove depth has to be now kept the same.

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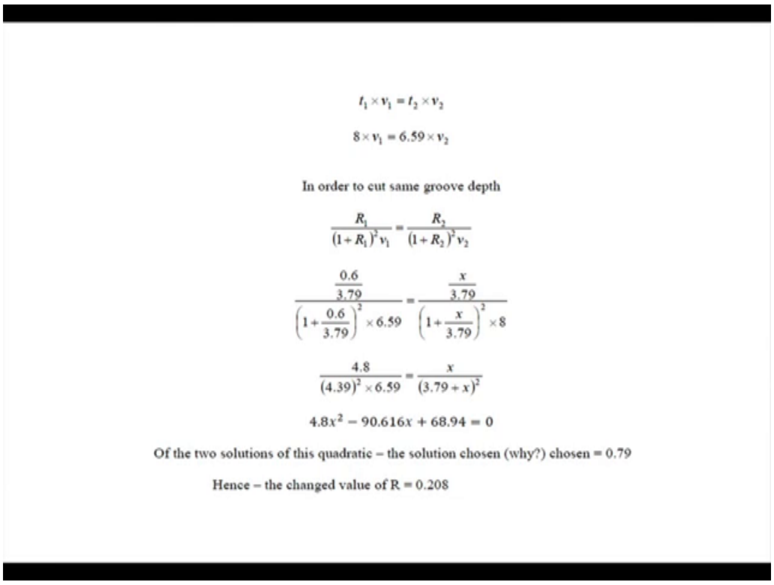

Let see it is becoming smaller and smaller, but hopefully up till this point, we have the same thing written down once again and I hope you can read this. It is written here you know we are simply putting the values. Let us quickly check whether the correct values have been kept. Yes, R 1 is equal to 0.6 by 3.79. 0.6 was the previous abrasive mass flow rate and water mass flow rate remains the same which is 3.79 and we are considering that x is the present mass flow rate of abrasives.

What about you know our velocities grooving velocities? We do not know, the grooving velocities none of them. Neither v 1 nor v 2, but we know the ratio v 1 by v 2 is equal to 6.59 by 8. So, v 1 and v 2, their ratio we are increasing by 6.59 by 8. 6.59 has been written on this side and 8 on the other side. That is 1 plus R whole square has also been written and since x is the abrasive mass flow rate. So, we have x by 3.79 equal to R and 1 plus R accordingly written here, so that after we crunch the numbers, that means we use our calculator, our excel file or whatever, we have 4.8 divided by 4.39 whole square in 6.79 equal to x by 3.79 plus x whole square.

So; obviously we are going to have a square term appearing and that means, we are left with a quadratic expression, a quadratic 4.8 x square minus 90.61 x plus 68.94 equal to 0. Shall we have a quick look. I internet connection is available, we can have solution to this one. Let see [FL]. We can do without this. We do not exactly need it because I have solved it here itself. So, coming back we see that if we solve this quadratic equation, we have 4.8 x square minus 90.61 plus 68.94 equal to 0 and if you have a quadratic equation solver, you can simply use that of course if you are permitted to do that in the exam. If you are not permitted to use that, you can simply use you know x is equal to minus b plus minus root over b square minus 4 a c divided by twice a.

So, with that sort of calculations, I have not included these calculations because you know you can do it yourself very easily and therefore, x in my case was coming out to be 0.79. That means, the consumption of abrasives will be increasing from 0.6 kg per minute to 0.79 kg per minute and if you find out the ratio of the new abrasive consumption rate to you know to the mass flow rate of water, you will find that R value will come out to be 0.208.

So, I hope that you will agree with me that the question. When you start with it looks quite formidable, but it is absolutely logical and it is based on our hard foundation of technological facts that is if you have to change over to from one setting to another, remember that groove depth has to be maintained. The same cutting velocity, sorry cutting total groove length has to be maintained the same. So, groove depth and groove length have to be the same and velocity as it affects the groove depth and what we call it as the loading factor affects the groove depth.

So, they have to be you know properly taken care of, so that you can maintain the same groove depth and the same length of groove, ok.

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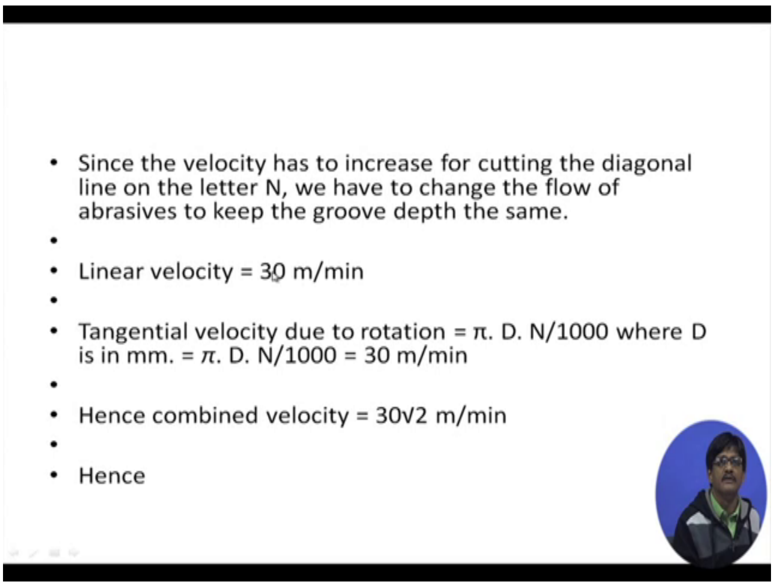

So, I will end this discussion with a small you know example from MCQS.

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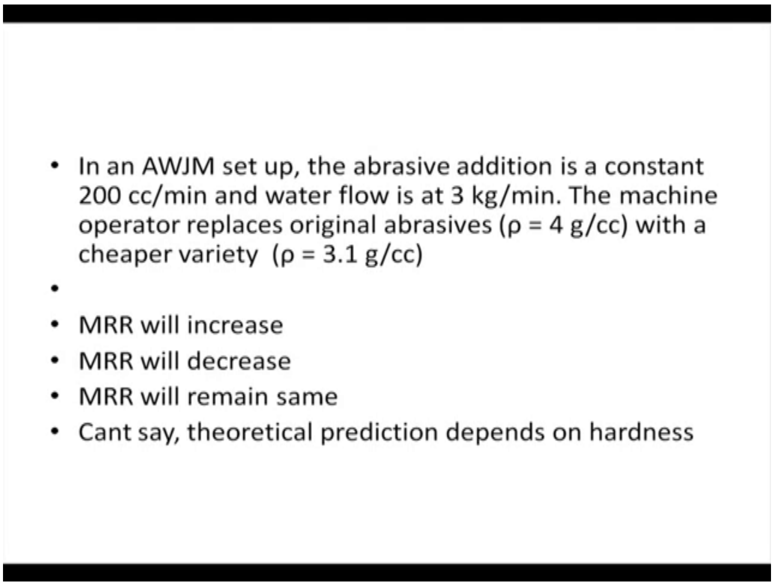

In an abrasive water jet machining setup, the abrasive addition is a constant 200 cc per minute and water flow is at 3 kg per minute. The machine operator replaces original abrasives of rho equal to 4 grams per cc with a cheaper variety. So, in that case MRR will increase, MRR will decrease, MRR will remain the same and we cannot say because theoretical prediction depends on the hardness. So, let us try to find out what is being talked about. You know if abrasive addition is at a constant volume rate, then mass flow rate is also at a constant rate, but the moment you are changing over from one abrasive to another, the rho is changing which means that the abrasive mass flow rate is going to change. So, you can quickly calculate what is you know changed mass flow rate and accordingly, we can find out where are the term R by 1 plus R whole square whether it is going down or going up.

If it goes up, then the power available for machining is higher and if it goes down, the power available for machining will be lower.

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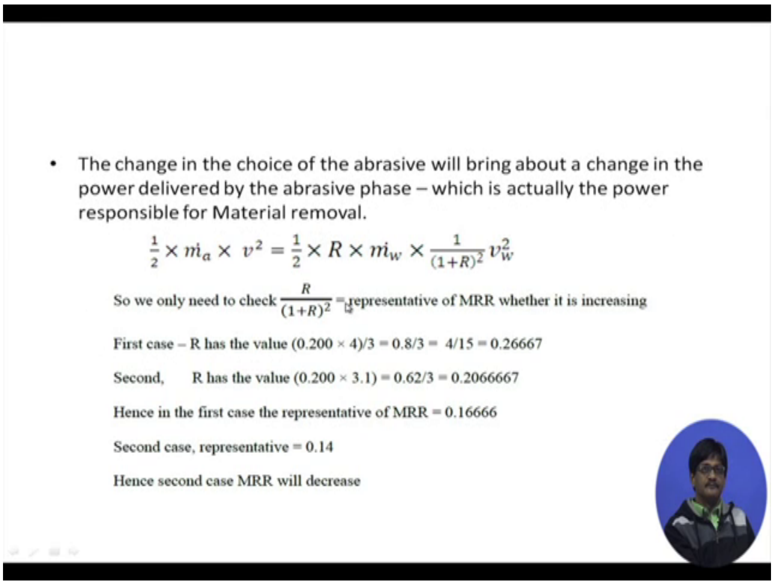

So, MRR will accordingly increase or decrease. The change in the choice of the abrasive will bring about a change in the power delivered by the abrasive phase which is actually the power responsible for material removal. So, half m v square is equal to half R into m dot w into 1 plus R whole square multiplied by velocity square. So, we have calculated this term because it is easy to calculate and because all the other terms are constants while R by 1 plus R whole square has to be calculated.

So, R has a value of you know 0.2 into 4 by 3 in the first case which is 0.26667 and in the second case, it is 0.20667. You might say how are we doing it? Well, you know in the first case, we can find out and multiply the density with the constant volume rate of addition and find out an expression of mass flow rate. In the second case also with the changed density, you can find out the mass flow rate and then, calculate R for the time being. I am leaving that to you. So, if you calculate R value, we find that you know the representative of R by 1 plus R whole square is coming out to be in the first case 0.166 and in the second case 0.14 and therefore, in the second case MRR will decrease, MRR will decrease.

So, I will stop here. If you are having doubts, you can definitely ask me while the lectures are going on. So, this is the end of our 18th lecture. We will continue with the next lecture next time.

Thank you.