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

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Lecture – 05
Ultrasonic Machining- Problems & MCQ

Welcome to the fifth lecture of the course on Non-traditional Abrasive Machining Methods. And at present we are dealing different problems of Ultrasonic Machining. We have deal with problems of concentration, problems of work is hardness variation, etcetera, etcetera. So, in a fifth lecture let us quickly move on through other aspects of ultrasonic machining. You just now solved a problem on concentration and after solving that I am sure that you will feel interested to solve this particular corollary.

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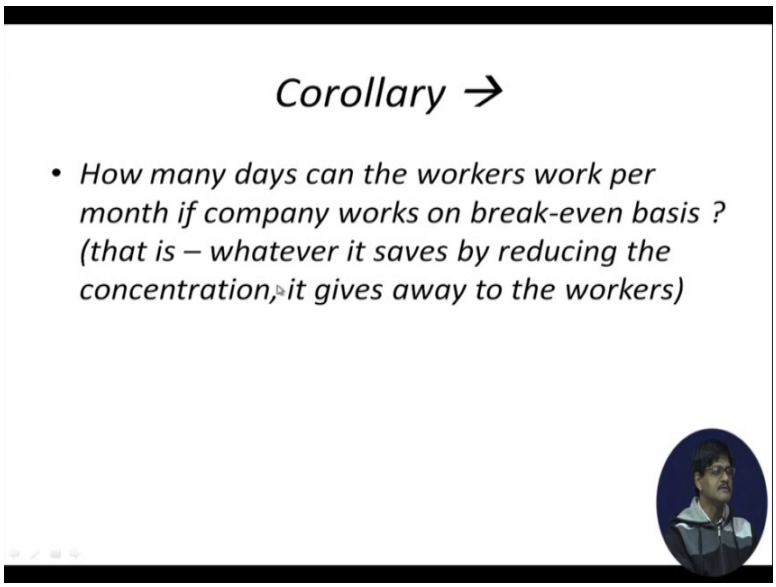

This corollary is how many days can the workers work per month if company works on break even basis? That means whatever it saves by reducing the concentration it gives away to the workers. In my case it came out be something like 24.7 days; that means, you reduce the abrasive concentration to such an amount that you save money enough to pay the workers for exactly those many days. That is you reduce the abrasive concentration for that you require x number of days extra and you also save money to pay the workers for x number of days.

So, what is x in that case, you can try it out of your interest and see whether it comes out be 24.7, ok.

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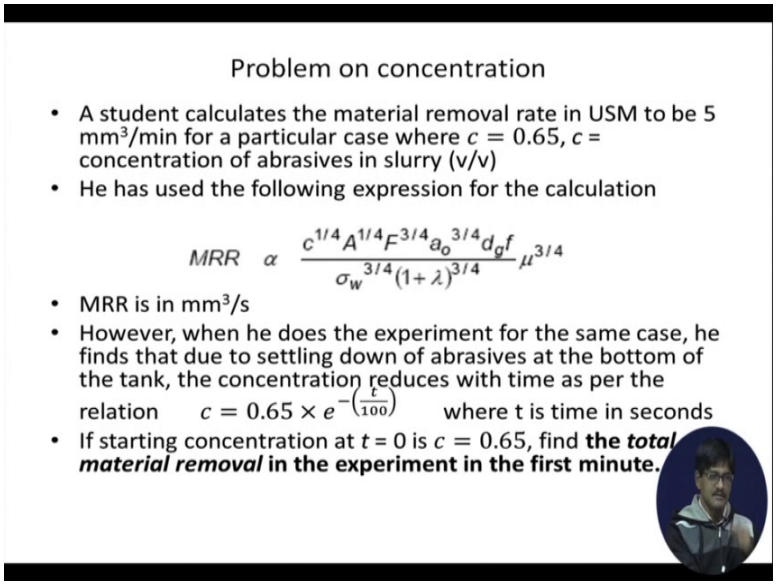

So, let us take this problem, another problem on another aspect of concentration. A student calculates the material removal rate in ultrasonic machining to be 5 millimeter cube per minute for a particular case when c is equal 0.65 and he has used the following expression which we are already conversion today.

So, what is the important point to note? Important point to note is that he has calculated c to be sorry he has calculated ultrasonic machining material removal rate to be 5 millimeter cube per minute when concentration is 0.65. Now what calculation has he made? That you do not know we only know that is you know concentration is 0.65 and he has put in some other values. So, that it comes out to be 5 millimeter cubes per minute; however, when he does the experiment for the same case. So, he is not doing the experiment.

So, in the experiment he express that yes I should get 5 millimeters cube per minute, but when he does the experiment he finds that due to settling down of abrasives at the bottom of the tank. This when I have carried out experiments on ultrasonic machining I have notice this the abrasives invariably since they are having a specific gravity around 3, 3.1, 0.8 etcetera.

They have a tendency to settle down in the tank unless you create a lot of turbulence. So, he finds that due to settling down of a abrasives at the bottom of the tank, the concentration reduces with time as per the relation c is equal to 0.65 into e to the power minus t by 100. So, exponentially it decay the concentration becomes less and less with time, where time is in seconds. If starting concentration at t is equal to 0 is c is equal to 0.65 find total material removal in the experiment in the first minute. So, we are still interested in the material removal rate for 1 minute; that means, the first minute after you just start the experiment and the concentration is just 0.65 at that moment. After that we are interested to find out how much is the material removal in 1 minute in the first minute.

What is the difference with the theoretical you know calculations? In theoretical calculations there is no decay of the concentration, no decay. But here there is decay and we have to find out that you know what you what you call it find out how much will be the material removal rate how much less will be the material removal rate let us find out.

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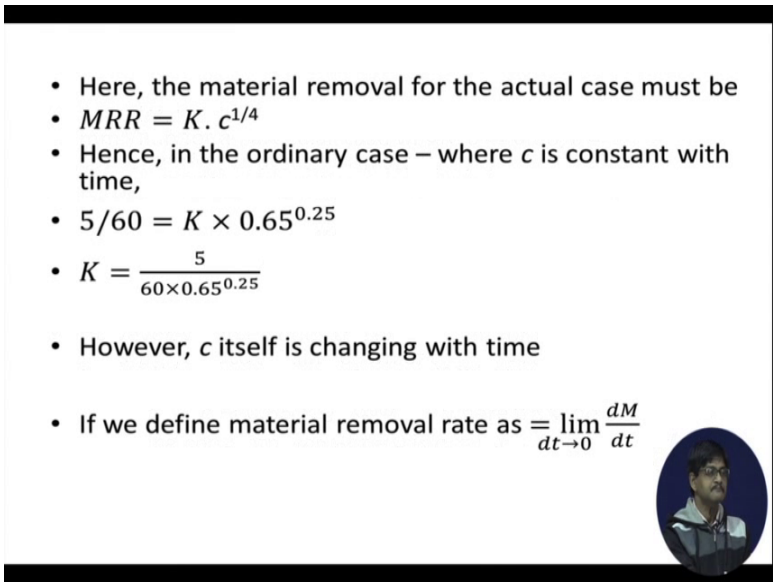

So, in the relation we have had there been no you know no reduction of concentration then we would have resorted to the relation MRR is equal to k into c to the power one-fourth this we are just shortening up the other terms k into c to the power one-fourth. Hence in the ordinary case where c is constant with time we can apply the known values which the student has used 5 by 60. That means, he has found out that in 1 minute the

material removal rate is 5 millimeter cube. So, first secondary is 5 by 60 is equal to k into 0.65 to the power one-fourth, straight cut calculation. From which we can find out the value of k to be 5 divided by 60 into 0.65 to the power 0.25 e to the power 0.2 sorry 0.25.

However, up till this point it is all right, but now we go now we have a look at reality where c is changing with time. And therefore, we bring in the idea of calculus that is if we define material removal rate as limit of dt tending towards 0 dM dt.

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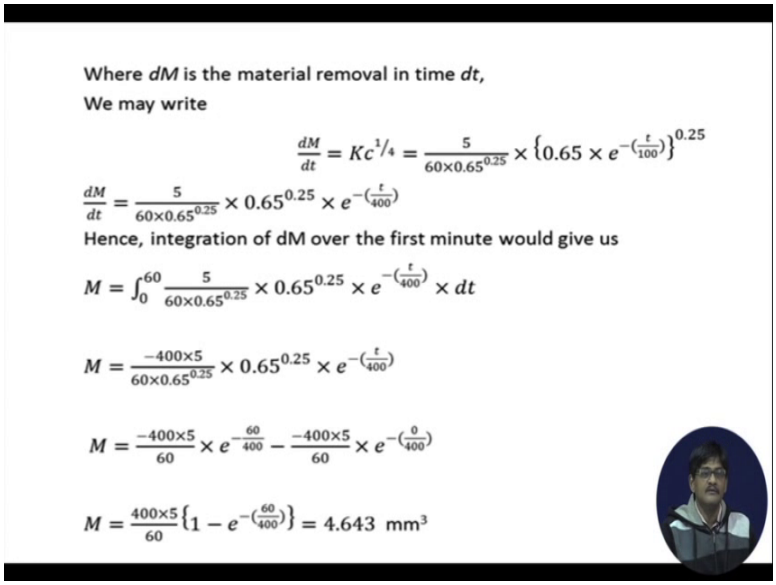

I hope you can read the small script on the screen dM dt is equal to k into c to the power one-fourth So that instantaneously we can write that it is equal to 5 divided by that is basically we are putting in the value of k now, this is the value of k. This is the value of k, and this is 0.65 into e to the power minus t by 100 into 0.25. Now what is this part? This part is nothing but the instantaneous value of concentration.

So, at any point in time t dM dt which basically means the material removal rate it is equal to constant I have written the value of a constant. And this is the value of the instantaneous concentration of the function of t. So, instantaneously this is always valid instantaneous at some point in time it is a function of time. So now, what we do is if dM dt is known to be this value let us find out what it contain.

This is the this is the constant term we do not have to bother about it this is also constant term, but we have a problem with this one e to the power minus t by 400 that is 0.25 now it is you know brought in side it is t by 400 now what do we do with that. So, we will be integrating to find out the total material which is removed over the first minute. So, integrate 0 to 60 and this is the constant etcetera.

Now, comes the e to the power term and therefore, after p after we integrate it we get this particular expression. We apply the initial condition that t at t equal to 0 at equal to 0 the value of concentration is 0.65 and there is no material which is removed at that time and we apply sorry, we are given 2 limits. So, we apply that definite integral and therefore, this constant comes out, let us see what we have done 60 into 0.65 0.255 this part is alright and this minus 400 has come out here and e to the power t by 400 has remained here and this constant is remained here fine.

Straight away you know integration of exponential function has been done and therefore, we sorry I have forgotten to write down the limits here we apply the limits and these are the 2 limits and therefore, we get 400 into 5 by 60 multiplied by 1 minus e to the power minus 60 by 400. This one is going to be one and therefore, it should be 1 minus this comes forward and this goes back and this is the final expression. So, instead of 5 millimeter cube the material removed is 4.643 millimeters cube in the first minute due to reduction of exponent a reduction concentration in an exponential manner with time.

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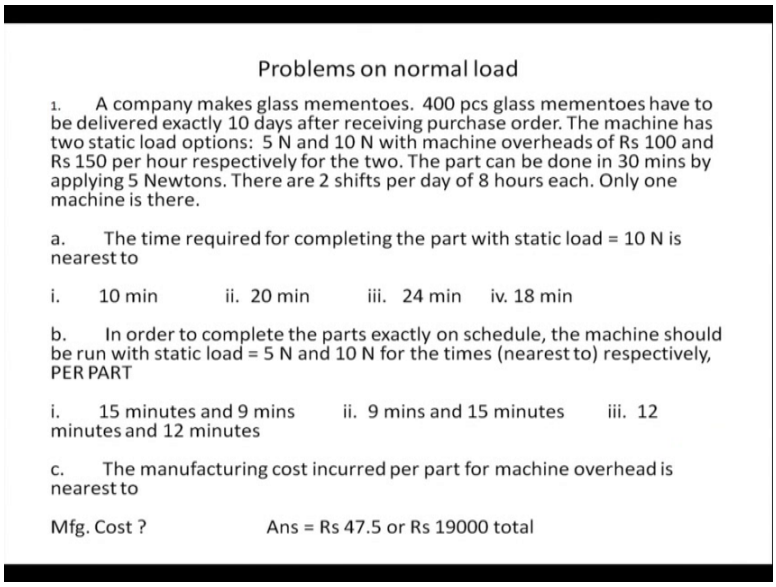

Now, let us have a problem on normal load and this is in the MCQ form. Let us see what it says a company makes glass mementoes. 400 pieces of glass mementoes have to be delivered exactly 10 days after receiving the purchase order now do we have systems like that? Yes, if you cannot you know delivered within say 10 days your order is cancelled, but what about those workers in that particular problem well it varies from problem to problem. So, in this problem it is 10 days or it is cancellation of order the machine has 2 static load options. So, in this machine you can either put 5 Newton's or you can put 10 Newton's. Now is it a realistic case yes it is discrete values can be applied like if we are having deadweight maybe you have 5 Newton load and 10 Newton load just like that.

With machine overheads of rupees 100 and 150 per hour respectively for the 2 now if you if you are interested in applying higher load. Maybe you will be incurring more current loss I mean current consumption etcetera etcetera, and for that the machine overheads are different higher load higher pay the part can be done in 30 minutes by applying 5 Newton's. So, if 5 Newton's are applied the work can be done in 30 minutes that is provided this information will be very useful there are 2 shifts per day of 8 hours each only one machine is there. So, what is the problem? Problem is the time required for completing the part with static load of 10 is nearest to this 10 minutes 20 minutes 24 minutes and 18 minutes.

Now, you might say first because many of my students do that I also used to do this, how is it going to be done? Or whatever is suppose to do? So, let us see first of all what is provided 30 minutes for applying 5 Newton's. So, immediately we can say I know that MRR is related to the applied static load in what way we can say MRR is equal to k into f to the power three-fourth. So, immediately I have starting point I can say I can relate MRR to the; you know what you call it to the load and that way I can also find out what will be the MRR for 10 Newton's.

So, let us quickly do that.

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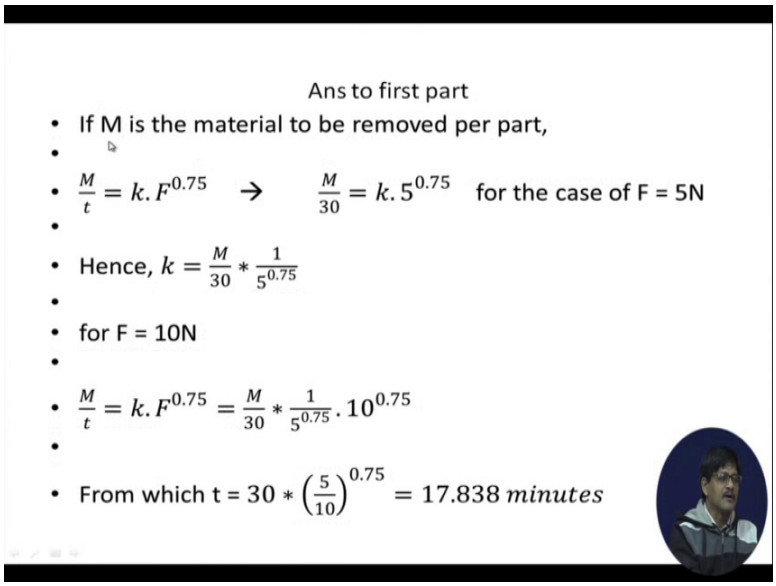

So, the first part says if M is the material to be removed per part M is the total amount of material it has to be removed in order that the part is finished. So, what we say is if M is the material to be removed therefore, material removal rate must be M by t where t is the time required that is good. So, M by t must be equal to k into f to the power three-fourth if that be so we apply the keys in which we are using a load of 5 Newton's. So, the material by 30 minutes we were working in minutes, if we are always sticking to minutes I hope it would not matter M by 30 is equal to k into 5 to the power three-fourth. For the case where f is equal to 5 Newton's and therefore, you can find out the value of k the value of k can be found out this way M by 30 into 5 to the power three-fourth.

So, if f is changing constant cannot change k cannot change and therefore, M is going to change or t is going to change M is M cannot change I am sorry, M cannot change k cannot change only t can change. And therefore, we put in the place of f we put 10 here in the place of k we put it is known value and we have M by t on this side. So, that M and M will cancel out and we will have a value of t equal to 5.75 divided by 10 to the power 0.75 and this is multiplied by 30 and therefore, we a value straight cut answer is 17.838. So, this is understood not very difficult let us have a quick look 10 minutes, 20 minutes, 20 minutes, 18 minutes this is the nearest one. Have we mention? Yes, is nearest time required for completely the part with static load 10 Newton's is nearest to.

So, the correct answer is 18 minutes. In order to complete the part exactly on schedule the machine should be run with static load 5 Newton and 10 Newton's for the times nearest to respectively per part. Now what does this mean? This means that I am using it with 5r Newton's load I cannot finish it by 10 days. If I am using it with 10 Newton's load I can finish it before 10 days are over.

So, you say what is wrong with that finish it before 10 days have fun for the rest of the days and then deliver at the end of 10 days. Problem is if you do that perhaps you are going to incur more costs I have not checked it, but common sense tells me if you are using a costly you know facility 150 per hour definitely ultimately your cost will be higher. So, maybe you have you know hired the machine you have taken it on a contract that I will use it for 10 days and you are trying to reduce your costs by utilizing the 5 Newton facility to the maximum, but 10 days is the limit. So, let us see how it can be done.

So, what is the question in order to complete the parts exactly on schedule, the machine should be run with static load 5 Newton's and 10 Newton's for the times nearest to respectively per part 15 minutes and 9 minutes, 9 minutes and 15 minutes, 12 minutes and 12 minutes. So, let us see what the answer is.

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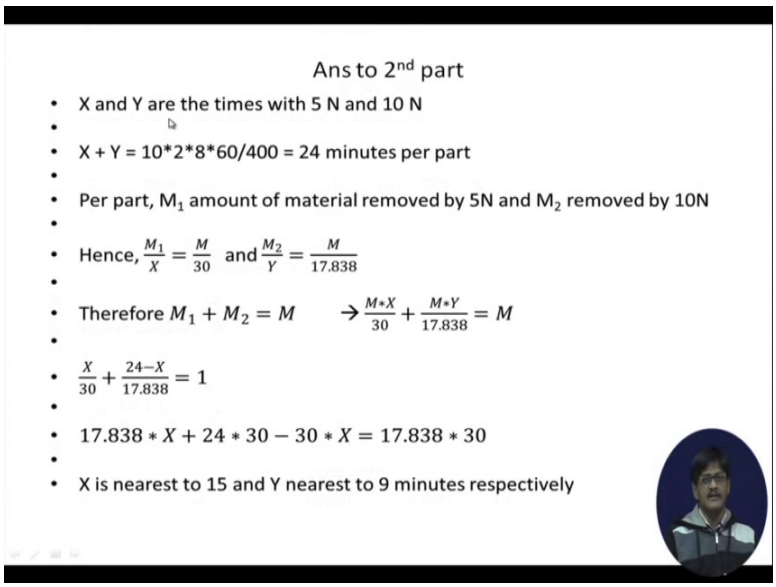

So, first of all we assume that the let the time is be x and y for 5 Newton's and 10 Newton's. So, x and x plus y I can I can tell you exactly what it is because I know that I

have 10 days of work in my hand and therefore, 10 days will mean 2 shifts 10 into 28 hours into 8 and that multiplied by 60 will give me the total number of minutes this I divide by the number of parts to be made 400 and I get 24 minutes per part. So that means, by (Refer Time: 17:49) you have to get 24 minutes allotted to every part that you are making that is good.

So, per part let M 1 amount of material we remove sorry per part let M 1 amount of material be removed by 5 Newton's application, and M 2 part 2 amount of material be removed by 10 Newton's application. So, that M 1 plus M 2 is equal to M that fine that we know for sure. And we can also say M 1 divided by x let me just point it out M 1 divided by x must be equal to M by 30, because it must be proportional if you are spending 100 rupees to buy say for 4 cricket balls, then you must be spending 25 rupees to buy one cricket ball.

So, if you are if you are removing M 1 amount of material for x amount of time it must be proportional to M amount of material having been removed in 30 minutes of time same thing with 2. So, M 1 by x is equal to M by 30 and M 2 by y is equal to M by 17.838 remember this is the value of you know time. Having understood this first of all M 1 plus M 2 must be equal to M and therefore, we add up M 1 by x plus M 2 by x M 2 by y, what do we do exactly? Sorry M 1 plus M 2 is equal to M and therefore, you find out the values of M 1 and M 2 and add them up and equate it to M.

What is M 1 equal to? M 1 is equal to M into x by 30. So, we write a M into x by 30. And what is the M 2 equal to? M 2 is equal to M into y by 17.838 M into y by 17.838, there sum must be equal to M that is good because M cancels out. We will find in mathematics equations etcetera, cancellation will always make you happy because things are becoming simpler. And in our case it is x by 30 M has M has gone out and in case of y which was left we have written it be 24 minus x. So, that yet another term is gone 24 minus x divided by 17.838 must equal to 1, and from this we can draw up one solution So that x comes to be nearest to 15 and y comes to the nearest to 9.

From here we can solve for x and then you can go and find out why using this equation and they come to be why x is nearest to 15 and y is nearest to 9, this you can definitely solve from here and find out.

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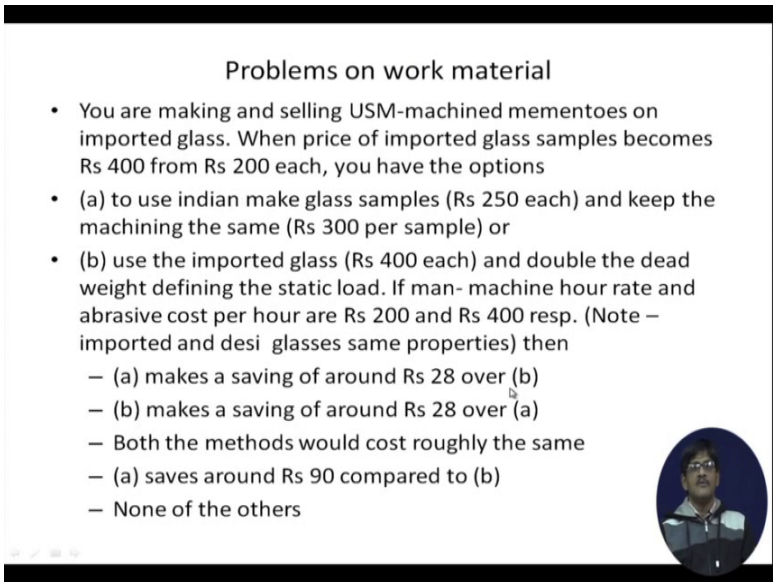

So, this option is correct. Now come a question on work material, did you do a question on work material yes we did. We did do that, but maybe it was connected with work material hardness. Let us see what this has say you are making and selling USM machined mementoes, USM machined mementoes are being sold on imported glass. When price of imported glass samples becomes rupees 400 form rupees 200 each. So, wait a minute there is a price rise which always makes you nervous there is a price rise imported glasses become of double the costs, and therefore you are making small mementoes.

You have the following options before you. So, some sort of design was being you know ultrasonically machine on top of them. You can use Indian make glass samples and they can also be used and they are cheaper In fact, rupees 250. And keep the machining the same rupees 300 per sample, what is the meaning of this one keep the machining the same? It means that you are basically keeping everything the same all the conditions are kept to same. Or you can go for the imported glass, why she will go for the imported glass? Because some people like them more than Indian make glass you cannot you know you cannot control everyone, if someone likes it that is it they will try to buy imported class.

So, if you are if you are in a business you have to see whether you can you can make profits by selling them imported glass mementoes. So, you can have the option that you

can use imported glass and double the dead weight defining the static load. So, we are doubling the dead weight that is the difference. So, rate of machining will rise what you what you gain for that if man machine hour rate and abrasive cost per hour are rupees 200 and rupees 400 respectively.

So, it means that static load increase in this particular problem is not incurring extra cost. It is not incurring extra cost. So, that is good note that imported and Indian; that means, desi glasses have same properties. So, they will have the same hardness. So, in that case the 4 options which I have given is that a makes saving of around rupees 28 over b, b makes a savings of around rupees 28 over a. Both the methods would cost roughly the same etcetera etcetera. And a saves around rupees 9 compared to b.

So, let us quickly note what is the difference in the 2 cases. Simply in one case you are having double the load double the static load everything else is the same. So, you have to be alert about the costs which are different and quite complex because they have changed over time overnight. So, let us see how it is solved.

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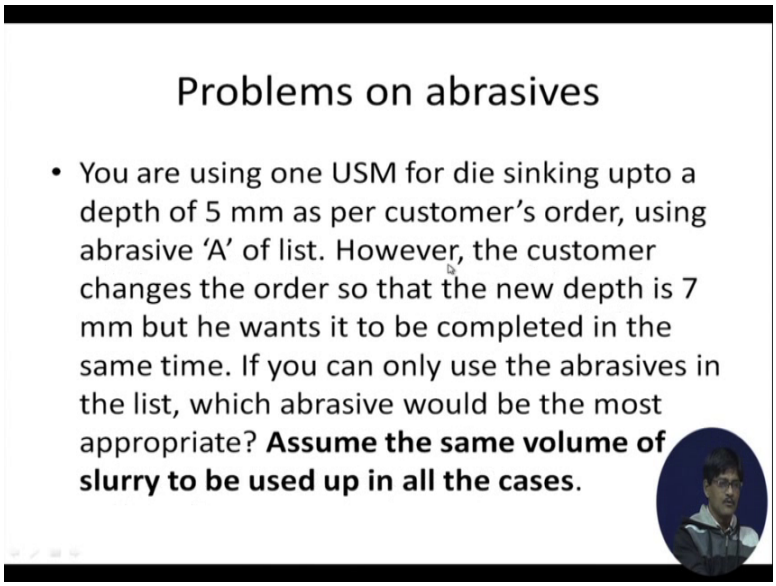

Just a minute, I am sorry, I think what has happened is I have set this as a practice problem. Take home assignment, because if we solve all the problems in the class you wouldnt be having any problem to solve for yourself. When you when you want to make some preparation. So, with that in mind I had included some problems which you can

solve yourself and you can intimate to me your correct answer and then you will understand whether you have done it correctly or not.

So, this problem is you know take home assignment (Refer Time: 25:19) let me see quickly yes this is also a sort of take home assignment because take home assignments only will be increasing your confidence on yourselves, but I have given you a hint how this is to be done. You are using. So, this is an abrasive. So, we are covering different aspects called work material normal load concentration etcetera etcetera and now come abrasives.

You are using one USM for die sinking upto a depth of 5 millimeters as per customers order. So, the customer has ordered 5 millimeters depth, in a particular part. That is good? Using abrasive a of the list where is the list it is in the next page; however, the customer changes the order So that the new depth is 7 millimeters. So, the problem is understood, 5 millimeters of depth was recommended first and then 7 millimeter of depth in the second case, but you wants to be, but you wants it to be complete in the same time that is the difference now; that means, I want a difference I want higher depth, but I wanted to be done in the same time. So, somehow you have to speed up the rate of machining. So, either rate of machining has to be increased you can only use the abrasives in the list. If you can only use the abrasives in the list which abrasive would be the most appropriate? As shown the same volume of slurry to be used up in all the cases.

So, the abra abrasive slurry volume is the same; that means, if you are using 5 liters you are using 5 liters in all the cases.

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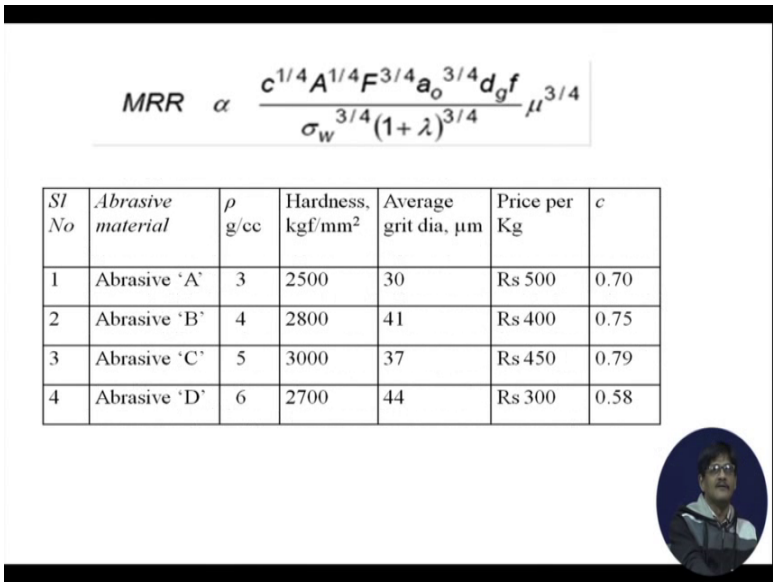

Sl No	*Abrasive material*	*ρ* g/cc	Hardness, kgf/mm²	Average grit dia, µm	Price per Kg	*c*
1	Abrasive 'A'	3	2500	30	Rs 500	0.70
2	Abrasive 'B'	4	2800	41	Rs 400	0.75
3	Abrasive 'C'	5	3000	37	Rs 450	0.79
4	Abrasive 'D'	6	2700	44	Rs 300	0.58

So, there is the list let us see you are using at present abrasive A. What is abrasive A? Abrasive A says that the rho; that means, density is 3 grams per cc hardness is 2500 hardness of what; hardness of abrasive. Average grit size in microns is 30, 41 etcetera. Price per kg is rupees 500. What is price per kg? Of the abrasives and c is, c is concentration sorry. C is the concentration which is different for the different abrasives, but how a c specified if I add more water that will be changing the concentration reducing it.

So, it is recommended that use you use this particular concentration for these abrasives respectively if you are using first one 0.7 like that. So, in this case it is a take home assignment and you have to choose which one abrasive will give you 7 millimeters depth in the same time as 5 millimeters previously.

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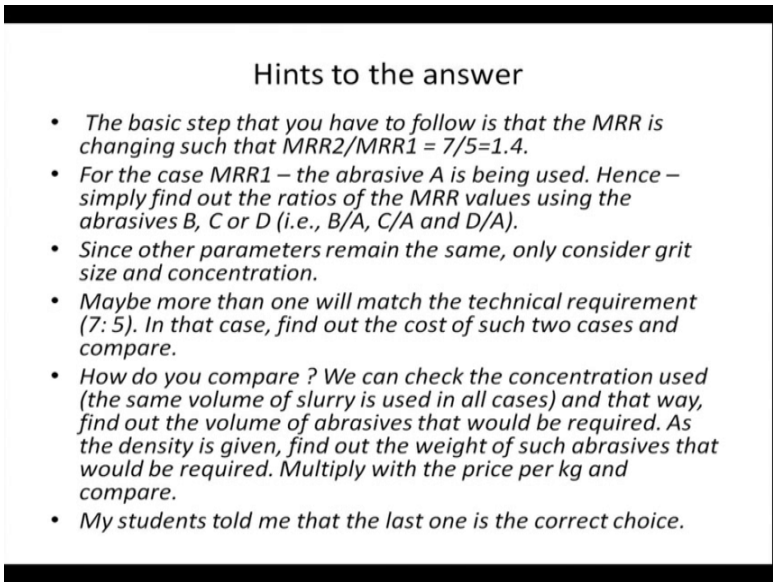

So, hints to the answer.

The basic steps that you have to follow are that MRR is changing such that MRR 2 by MRR one is equal to 1.4. And for the case of MRR one abrasive one A has been used and hence simply find out the ratios of the MRR values using abrasives B C or D which satisfies this particular MRR ratio. So, you want finding out which MRR which abrasive is full filling it.

Since other parameters remain the same only consider grit size and concentration that is interesting. Only grit size and concentration other ones which are listed in that table they are going to affect this particular you know process. Maybe more than one will match the technical requirement of 7 is to 5. Suppose you find 7 is to 5 more than one they are matching, in that case what do you do? In that case you go and look at the costs because as an engineer you are expected to understand that we have to go for the cheapest one ok.

How do you compare we can check the concentration use the same volume of slurry is used in all cases and that way find out the volume of abrasives that would be required. As a density is given find out the weight of such abrasives that would be used and multiply with the price per kg and compare. And my students told me that the last one is the correct choice.

So, please do it yourselves and after the first week of lectures are over then I will share the answer with you this is the take home assignment. Where I will share the answer with you, in the meantime if some of you have solved the problem then send me the answer and I can check it up and tell you whether it is correct or not.

Thank you very much.