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

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Lecture – 10
Ultrasonic machining- Numerical and MCQs

Welcome to the 10th lecture in our series of a lectures on Non-traditional Abrasive Machining Processes. And today we are going to discuss about you know the last lecture on ultrasonic machining some numericals some MCQs and any other thing that we have left behind.

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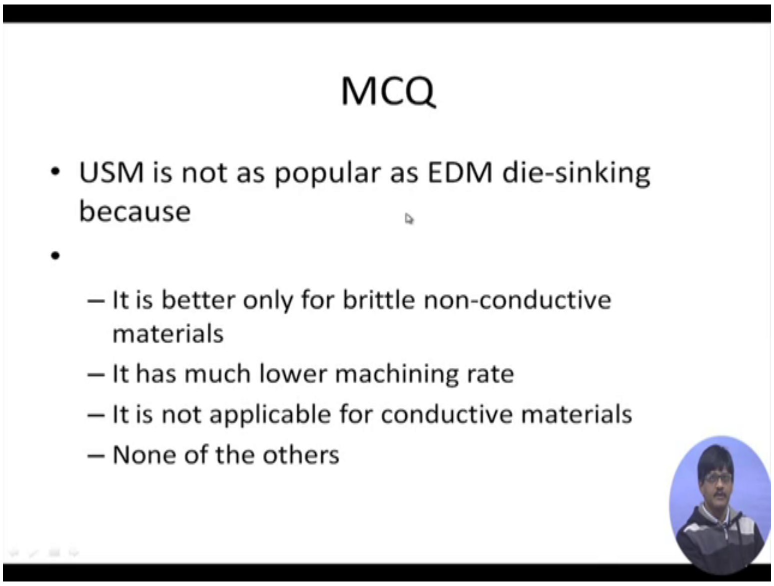

So, let us start right away. Ultrasonic machining is not as popular as EDM die sinking, because it is better only for brittle non conductive materials. It has much lower machining rate it is not applicable for conductive materials none of the others.

So, first of all the first one it is better only for brittle non conducting materials, for this one while it is true for that is this brittle it is better for brittle non conducting materials, should we say only. Is it better for some materials which cannot be machine very easily by others other methods; so for that we may make mention of say difficult to machine materials etcetera, but EDM also will not have those difficulties. Because conventional machining has many problems with difficult to machine materials, but EDM also well not have those problems. So, this one we should treat as correct. So, let us go back to this one it is better only for brittle non conductive materials, yes. We say that it is also better for difficult to machine materials which are conductive, but he is also good. In fact, it is better difficult to machine materials conventionally will be done by EDM quite well.

Next is it has much lower. So, first one is correct it is much lower machining rate this is also correct. Main problem in USM is you are not satisfied with the machining rate in most cases. It is not applicable for conductive materials are it is USM not popular and not as popular as EDM because it is not applicable for conductive materials. The sentence is not the statement is not correct. It is applicable for conductive materials, but it is generally not applied first of all if the conductive material is ductile then USM material removal rate will be not as high. And secondly, if it is conducts then why not why not go for EDM why not go for EDM?

So, it is not applicable for conductive materials it is not correct. It is not carried out for conductive materials mainly because EDM is the best better choice first choice. None of the others naturally is wrong. So, first and second both are correct here.

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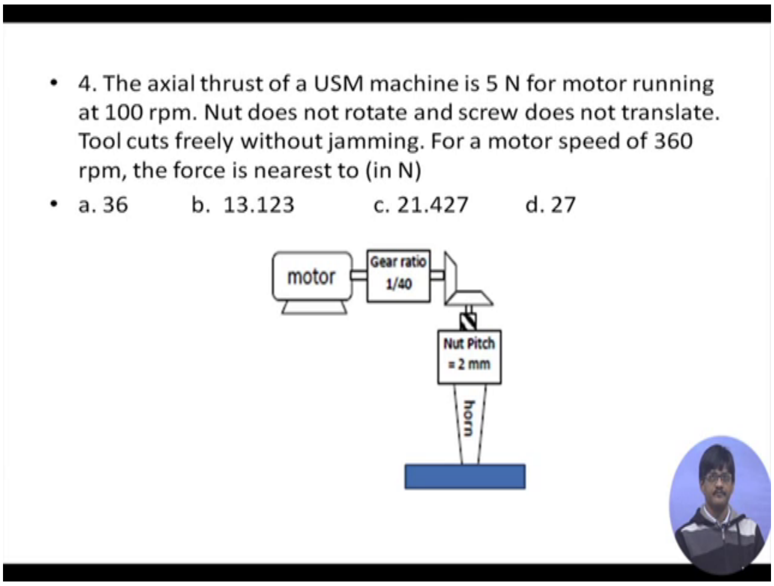

The axial thrust of a USM machine is 5 Newton’s for motor running at 100 rpm. So, first of all let us have a look at the setup. There is a motor which is rotating and you know giving input rpm to a gearbox which has a reduction ratio of 1 by 40, what is this mean? This means that the motor rpm is input an output will be an rpm read reducing this motor rpm by a factor of 40.

So, if motor rpm is 400 then 400 divided by 40 only 10 rpm will be output. So, this output rpm by means of bevel gears in it is the direction of rotation I mean it is not direction over here angle orientation of the shaft is changed to which is finally transmitted. And we can see a small thread protruding, so that thread rotates inside a nut which moves downwards and that is connected to a horn. So that means, that the whole acoustic head is moving downwards at a constant rate due to it is connection with the motor. So, unlike the case in which we are applying a constant load we have working here with a constant rate of feed. It is not very much you know used in case of ultrasonic machines because in ultrasonic machines they generally work on constant load because if I use a constant rate a machine might well not be able to you know remove material at that rate and they will be jamming.

But here it is stated in the problem, that considering a case where is no jamming and a tool cuts freely in that case, if such is the configuration and we are getting an axial thrust of 5 Newton's for motor running at 100 rpm in that case if the motor runs at 360 rpm, what will be the force: A 13.123 Newton's 20.427 Newton's or 27 Newton's, what can be the possible answer? So, here what we have to first decide is that what is you know what is exactly this the rule of the motor? The rule of the motor defines the rate of material removal, because if it is rotating an 100 rpm considering that there is no jamming correspondingly a certain amount of material will be removed proportionally.

So, if it rotates the third is 360 rpm, naturally instead of you know by unitary method. The read of material removal will increase. So, basically motor rpm corresponds to an increase in the proportional increase in the MRR. So, we can treat the problem in this manner, let us have a look MRR 1, Its proportional to motor rpm.

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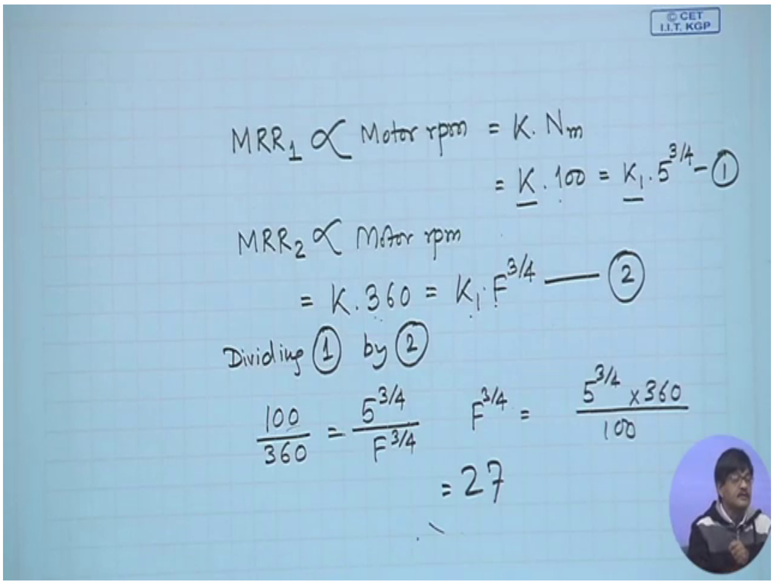

So, if we say it is equal to k into motor rpm it is k into 100 MRR 1. We can also say that this MRR 1 must be proportional to the normal react to the static load and; what is the static load it is given the axial thrust of a USM machine is 5 Newton's for motor running at 100 rpm. So, if it is 5 Newton's we can definitely say it is equal to k 1 into 5 to the power three-fourth. So, immediately this k 1 k 2 we are getting a relation between them. In the second case was happening MRR 2 is proportional to the motor rpm therefore, it must be equal to k into 360 equal to k 1 into f to the power three-fourth.

We do not know the value of f. So, let us see whether we can we can we can relate f 2 the previous equation. So, let us divide this one by this one. So, we have 100 dividing 1 by 2 what do we get? We will get 100 divided by 360 equal to what is above k 1 k etcetera, everything will cancel 5 to the power three-fourth divided by f to the power three-fourth. And therefore, we can say f to the power three-fourth must be equal to 5 to the power three-fourth into 360 divided by 100.

This is a po number you can solve it. And I have solved it and I found it to be 27. So, let us quickly have a logic once again if I am giving MRR to be proportional to motor rpm because it is working without jamming. Therefore, I can relate MRR is proportional to motor rpm. Secondly, if this is the rate of material removal I know it must be proportional to the static load. So, the first case static load has been given. So, I relate this 2 to k 1 into 5 to the power 3 4, next time when rpm is given, but force is not given I can still you know consider force to be f and therefore, I have the same relation existing between MRR motor rpm and static load. Then I divide 1 by 2 and I get this relation and f to the power three-fourth comes out to be this one I can solve very easily for this.

If you have just a calculator in hand just find out what is this f is equal to all this to the power minus three-fourth and that will your result will come, it comes out to be 27. So, let us see therefore, we must be having D to be correct D 27 is correct. So, let us move on to the next problem.

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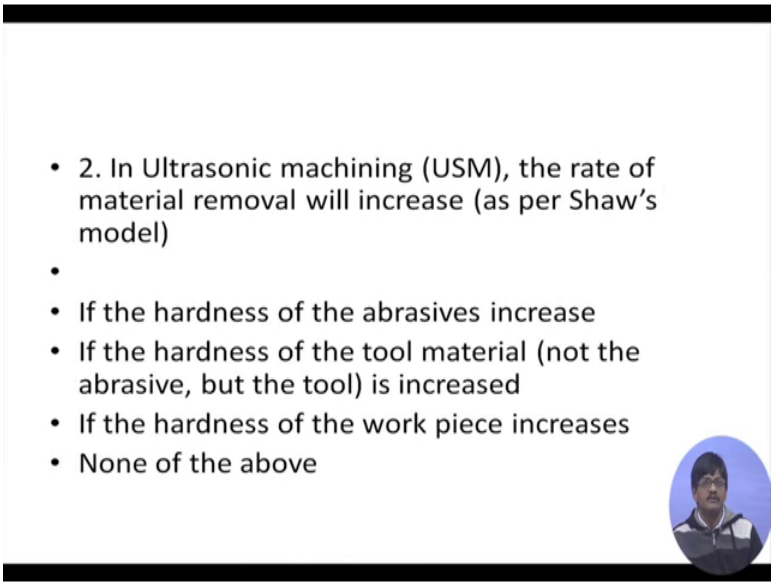

In ultrasonic machining the rate of material removal will increase as per shaws model shaws model is the model that we have studied. So, they are saying that MRR will increase. As per the model not by any other thing we have to if the move strictly by the observations made or rather the conclusions made as per that model, if the hardness of the abrasives increased if the hardness of the tool material not the abrasive, but the tool if the hardness of the tool material is increased, if the hardness of the work piece increases, none of the above.

So, let us see one by one, if the hardness of the abrasives increase. Interesting to note shaws model does not referred to does not take into consideration the hardness of the abrasives. So, the first one is not correct. Second, if the hardness of the tool material; that means, that particular element which is stuck at the end of the horn and which is carrying out the hammering on top of the work piece with the abrasive particles in between. So, if the hardness of the tool is increased, now what will happen if the hardness of the tool is increased? We can look at it in 2 ways, physically if tool material is harder then definitely delta t will be less and therefore, delta w has to be more delta t has to be less and therefore, delta w has to be more.

Or alternatively we can have directly have a look at the equation and in the equation we will find it is written lambda is equal to let me write down or we can find out this expression in one of the sums definitely let us ptc, yes that is it lambda.

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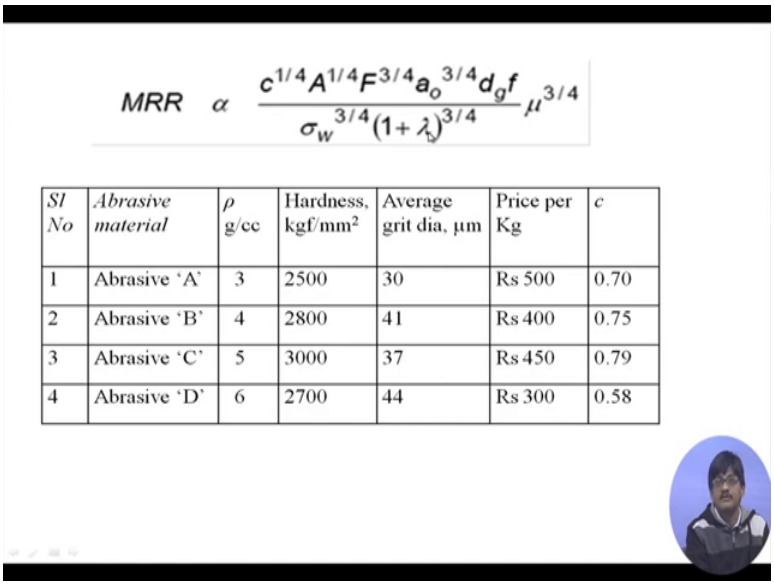

$$MRR \;\alpha\; \frac{c^{1/4} A^{1/4} F^{3/4} a_o^{3/4} d_g f}{\sigma_w^{3/4} (1+\lambda)^{3/4}} \mu^{3/4}$$

Sl No	*Abrasive material*	ρ g/cc	Hardness, kgf/mm^2	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

This is a different problem altogether do not worry about that lambda is the one which is having which is taking tool hardness into consideration. What is this equal to? This is equal to work piece hardness by tool hardness.

So, if the tool hardness if the denominator increases then this term will come down. In this term comes down the denominator will come down and therefore, MRR will increase. So, this is the mathematical way of looking at the answer. MRR will increase if the tool hardness goes up. So, let us quickly return, yes. So, if the second one is definitely correct. Now comes the third one if the hardness of the work piece increases, now this is a very interesting a situation. If the hardness of the work piece increases people will say oh, then definitely you will have less MRR because you know harder the material more difficult it is to remove, but there is a catch here.

The catch is that the mood of fracture or rather the mood of material removal; that means, the way in which the material is removed depends on the material properties. If it is a ductile material as per assumption of this model only a segment of the material gets removed let me just take the help of a drawing to make this clear.

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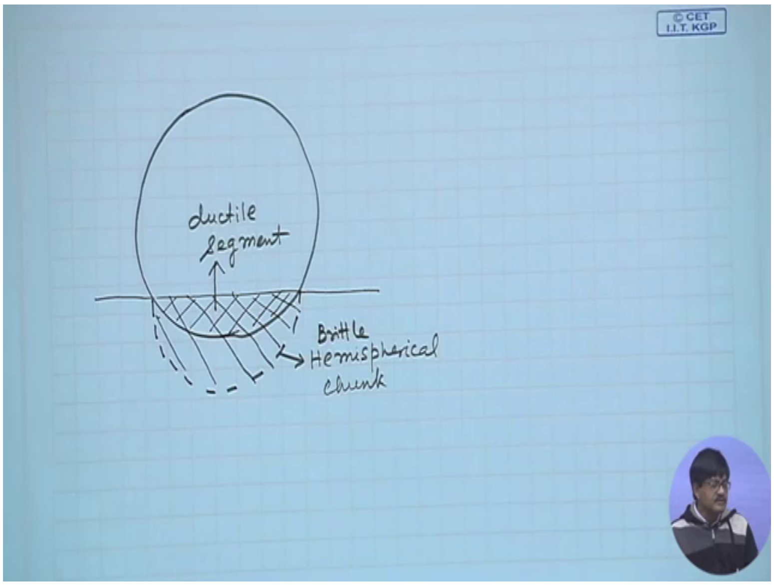

What I mean to say is that if this is the abrasive grit if this is the you know material and this is the amount of indentation, then for a ductile material ductile work piece material this is the material removed, this is a segment. But in case of brittle material this is the hemispherical chunk which is removed hemispherical. That means, the full thing let me use another type of hatching this whole material. So, this is brittle this one is removed if you have brittle material.

So, just noticed this if the hardness of the work piece increases, this every possibility that I mean this possibility that in some cases it might be shifting from the ductile regime to the brittle regime as we know if hardness increases in it has a correlation with brittleness; harder materials the frequently more brittle. So, if the hardness of the work piece increases is a possibility that it shifts from the ductile regime to the you know brittle regime and therefore, suddenly we will find that instead of in if you look at the figure, instead of this material getting removed. Now a larger chunk will start getting removed and the material MRR will rise. So, coming back to the option we will find the third case is also correct in certain cases. The second case is correct and a third case is also possibly correct in certain cases.

So, here both the second one and the third one they are correct.

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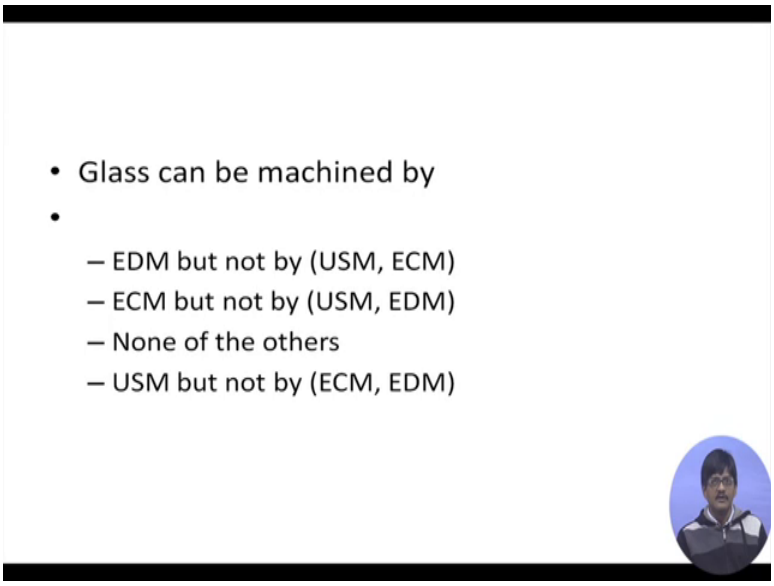

Glass can be machined by EDM, but not by USM and ECM glass is a non conductive material. So, straight away we can say it can be machine by USM and not by ECM or EDM. So, the forth answer is correct. I will just read out the options EDM, but not by USM or ECM ECM, but not by USM an EDM and USM, but not by ECM or EDM forth one is correct.

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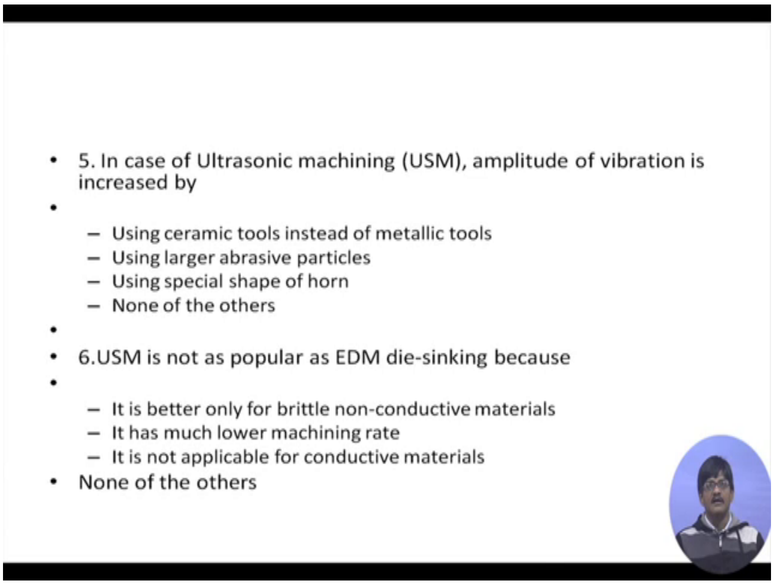

In case of ultrasonic machining amplitude of vibration is increased by using ceramic tools instead of metallic tools mind you tools; that means the one which is stuck at the end of the horn. This is not correct. This should not be any effect for using different material tool. Second one, using larger abrasive particles; larger abrasive particles have nothing to do with the amplitude of vibration. Using special shape of horn, this is correct.

If you use exponential horn any type of tapered horn, then stepped horn with the final step and the 2 line to be smaller than the larger diameter or larger cross section at the acoustic head and you will have amplitude of amplification in the amplitude of vibration. Next, So the answer is using special shape of horn. 6 I mean second one, USM is not popular as I think we did it before I am skipping this.

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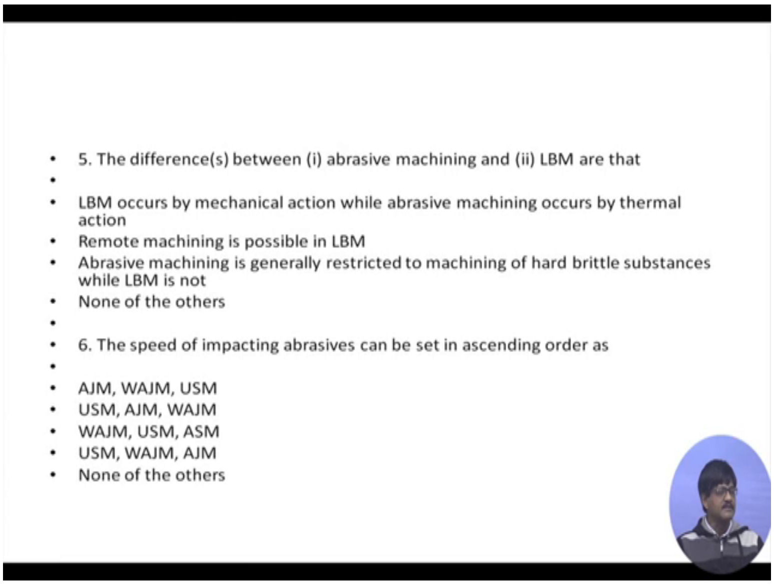

The difference between abrasive machining and LBM, LBM means laser beam machining or that. LBM occurs by mechanical action while abrasive machining occurs by thermal action, actually it is just the opposite. LBM basically means that there is a laser which is focused on the work piece surface and due to it is high energy density, it can heat melt and sometimes evaporate material so as to cause material removal.

So, it basically is a thermal process though, initially the laser beam is consisting of energy which is in the form of light. So, the first option is not correct it is just the opposite. Remote machining is possible in case of LBM, this is correct. You can weld or you can cut a material without contacting it by any physical device if you are having laser beam machining.

So, second point is correct. Abrasive machining is generally restricted to machining of hard brittle substances while LBM is not, this is also correct. LBM laser beam machining can machine practically any material, which response to thermal changes, none of the other. So, here we find that the second one is correct and the third one is correct. The speed of impacting abrasives can be set in ascending order has AJM work sorry water AJM. So, it is it reads as abrasive jet machining, water abrasive jet machining, ultrasonic machining. So, speed of impacting abrasives can be set in ascending order. So, is So the first one suggest that the ultrasonic machining abrasive particles have the highest speed.

This is not correct. Second one ultrasonic machining abrasive jet machining water abrasive jet machining this one is correct. This one is correct, next water abrasive jet machining ultrasonic machining this I am sorry this should be AJM. In the third option last term should be AJM. This one is also not correct. And USM etcetera. So, the only correct answer here is the second option, ultrasonic then abrasive jet and then water abrasive jet. Now why is this correct Let us have a quick look?

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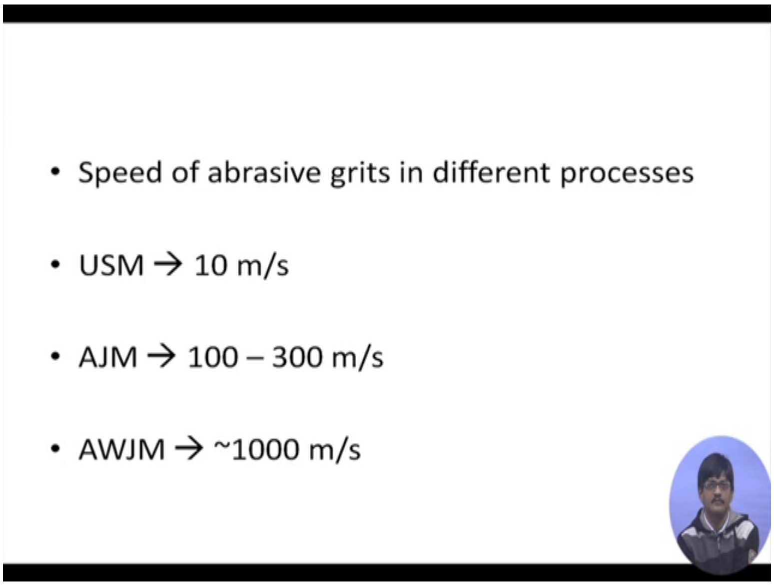

Speed of abrasive grits in different processes. In ultrasonic machining the maximum speed which is attained by the vibrating tool, it is equal to of it is of the order of 10 meters per second. In ultrasonic machining you can have a maximum possible speed of abrasive grits in the range of 10 meters per second. How you find it out? We have done it once to find out the velocity of free impact particles in ultrasonic machining and it was equal to twice pi frequency into amplitude 2 pi f a.

If you put in values 2 into pi into f say equal to 20,000 and a is equal to say 50 microns. You will quickly find out the value and you can check this out. Then abrasive jet machining, abrasive jet machining typically works in the range of 100 to 300 meters per second. What does this mean? This means that abrasive jet machining carries the abrasives in a gaseous medium. So, if this is a gaseous medium first of all it some particles are put into the gaseous medium which is at high speed, and it accelerates the particles abrasive grits to a particular velocity. And in the process it loses some of it is momentum and ultimately we will get some speed in within this particular range.

So, you will invariably ask that why I will restrict yourself to this particular range we can still you know accelerate the gaseous medium. The answer is that beyond the particular speed they will be choking flow and it would not be possible for us to further accelerate the medium in to a higher level. So, in AJM since you are using a gaseous medium, our the highest possible speed that we can apply is restricted to this particular range. Last of all in abrasive water jet machining the range of speed that we can attain is generally 1000 liters per second, what is this mean? This means that water is generally taken to a very high pressure from which it is released So that the pressure head or the pressure energy stored will be completely converted to kinetic energy. Might be having 4,000 bars 4,000 bar pressure when converted completely to kinetic energy ok.

That will give rise to a tremendously high speed of the abrasive jet sorry, abrasive water jet machining what you call it water street. And this frequencely frequently goes to the range of 1000 meters per second. And when this is mixed with static abrasive particles in a particular ratio in that case some momentum is lost, I mean some energy is lost. And ultimately after momentum balance we generally find that the velocity comes are comes down to around 900 meters per second of course, this varies depending upon the amount of abrasive you know abrasive particles that you put into the liquid I mean flowing water.

So, this way we have a typical speed range existing for different abrasive methods. Last of all let us quickly go through the preliminaries of solving a problem which I had set before you for solution.

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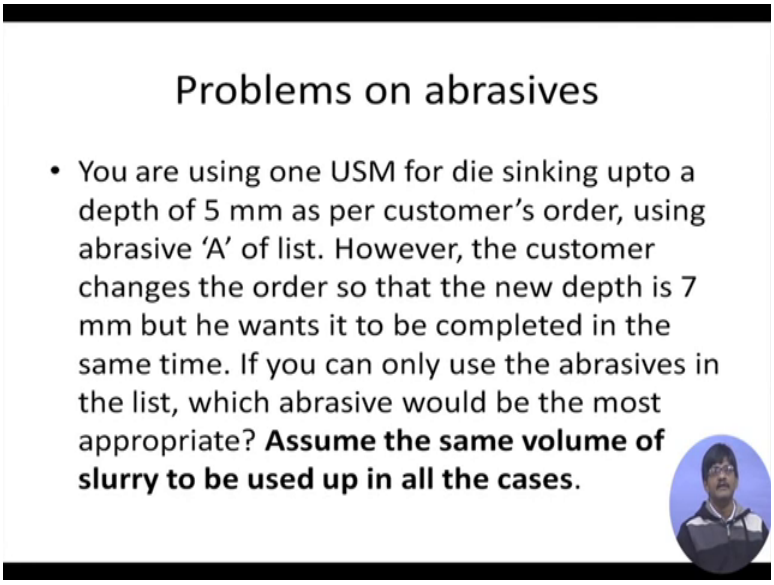

I hope you have tried out yourself. Let us have a quick look how it can be attempted.

The problem was this that you are doing a die sinking operation on a particular job. And grew a what you call it machining was to be done upto 5 millimeters, but the customer suddenly changes it and says that I want 7 millimeters depth. But I do not give you extra time for this. So, naturally you have to use different set of input factors in order to get a higher machining time. And what are those input factors which are you know which are which you are free to change? They are first of all given by this table.

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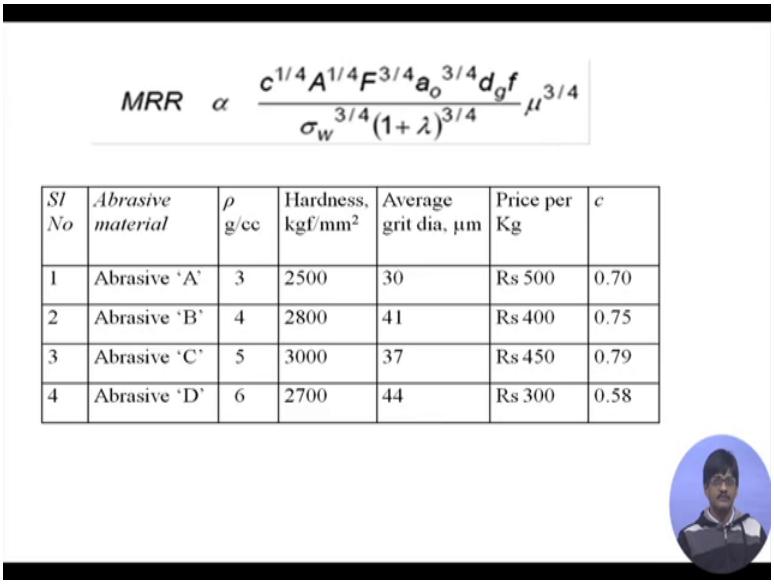

$$MRR \ \alpha \ \frac{c^{1/4} A^{1/4} F^{3/4} a_o^{3/4} d_g f}{\sigma_w^{3/4} (1+\lambda)^{3/4}} \mu^{3/4}$$

Sl No	*Abrasive material*	ρ g/cc	Hardness, kgf/mm^2	Average grit dia, μm	Price per Kg	c
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That is you can you are using abrasive A and you can use abrasive B C or D, which one would you choose? What are the things which are you know different for the abrasives the abrasive grit, dia is different the abrasive concentration that is recommended that is different. And the abrasive densities are different, and of course abrasive prices are different.

So, I had I have given you roughly a procedure by which you can solve it. And let us at least let us do the preliminary part to find out what exactly is you know focused upon in this particular work.

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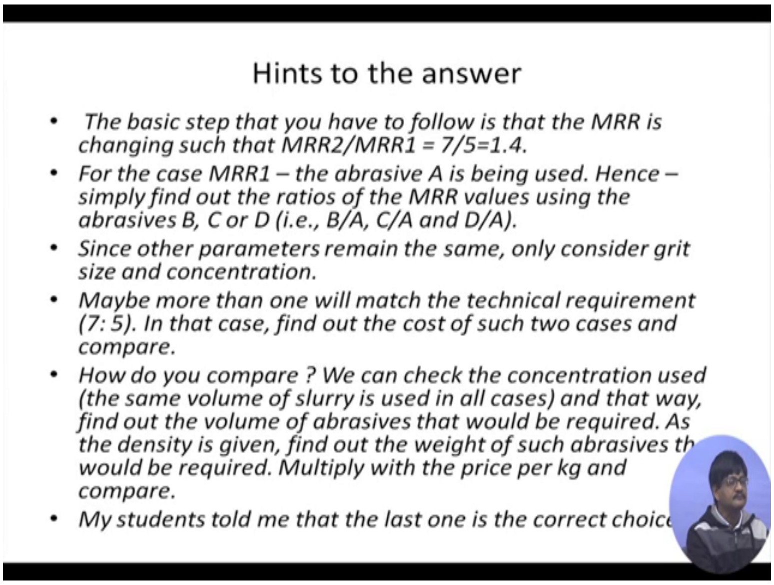

So, for that this is the way in which we were supposed to do it. So, what I will do is I will end the show and quickly go to the way of solution.

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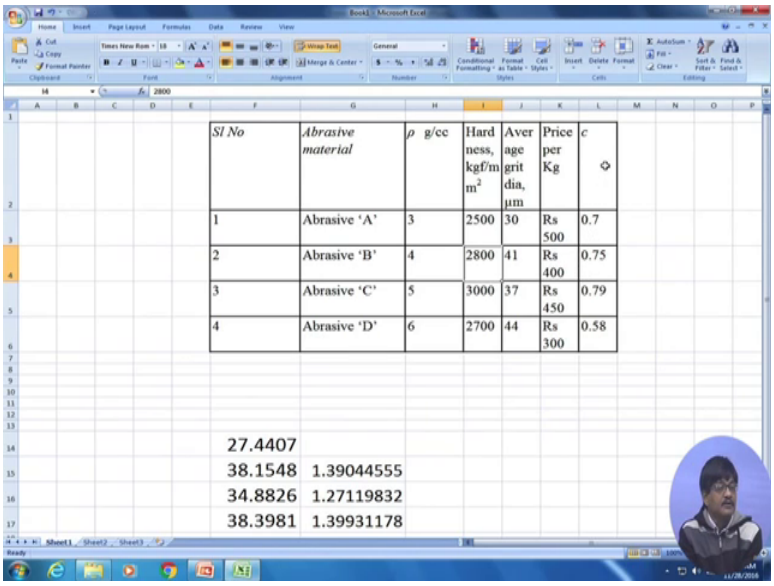

This is the place where I have kept the values of the abrasive grits. Let me make it a slightly larger So that it will be easier for you to see. Yes, this is good enough. So, first of all when you are trying to find out the rate of machining these abrasives would produce. The first one I have written down here, must be proportional to first one must be proportional to J 3; that means, the average grit size the average grit size is this one I hope you can read it on your respective screens, which is 30 microns diameter multiplied by c to the power one-forth and c happens to be 0.7.

So, that way L 3, L 3 this value. This value is being chosen for the first case and it is 27.4407. So, this is it is it is MRR will be proportional to this. So, in the other cases also I have found out corresponding terms to which the MRR will be proportional which is simply grit size into concentration to the power one-forth. And it is it is this list that we are obtaining. Let us quickly find out whether they have a ratio roughly equal to 7 5 is to 7 or not; that means, the material numerators in this case these cases should be I mean the one which is appropriate, it should be having 7 is to 5 material removal rate ratio. So, let us take how much will this be this is equal to this let us try f, f 15 by f 14; so f 15 by 27 point, 27.4407.

So, it is equal to 1.39. Let us see the others let us increase the size a bit, how much that is right. See these are the values that we are obtaining as the ratio of MRRs to the original MRR obtains in case of abrasive A. These ratio shows that it is roughly equal to 1.4 in this case as well as this case. Once again to check what is this value this is equal to f 15 which means this one, divided by 27.4407 which is this one; that means, the ratio of the MRRs in these 2 cases.

So, in this case and in this case it qualifies technically the technical specifications are such that it will give us the MRR that is required, but in these 2 cases, which one should I choose? Should I choose abrasive B? Or should I choose abrasive D? For that we have to take a decision as per the economy that those processes offer. What do you mean by this? I mean that the price per kg now has to be taken into consideration, in what way? We will say that from the concentration we will find out the amount of abrasive which is being used and we will make an assumption here. That is the same amount of slurry volume is used in all cases.

So, if it is one liter in case of this one 0.75 means that 0.750 liters of abrasive have been used here sorry, 750 one liter has been used 750 cc's of abrasive B have been used. And the density is given for cc. So, that if we multiply the row column if we multiply the third column with the last column we will find out the volume of material sorry, we will find out the weight of material which has been used weight or mass, whichever you say it is for this problem which is the same. So, last column multiplied by third column will give you the mass. Once you have got the mass price per kg; that means, price per unit mass is also provided. So, if you multiply the second last column with the product of the last column and the third column, you going to get actual price which will be used by you in order to machine this money.

So, once you have multiply these 3 columns it will immediately tell you, it will immediately tell you which one is the most appropriate one; that means, technical specifications and price requirements make it the best possible abrasive. I mean did that and found that abrasive D was the best. So, the last part I leave it to you. I am sure you can solve it. So, with that we come to the end of the tenth lecture.

Thank you very much.