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

Prof. Asimava Roy Choudhury
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 15
AJM- MCQs

Welcome to the 15th lecture of the course Non-traditional Abrasive Machining Methods. And today we are going to discuss some MCQs with respect to mainly AJM. So, let us have a look.

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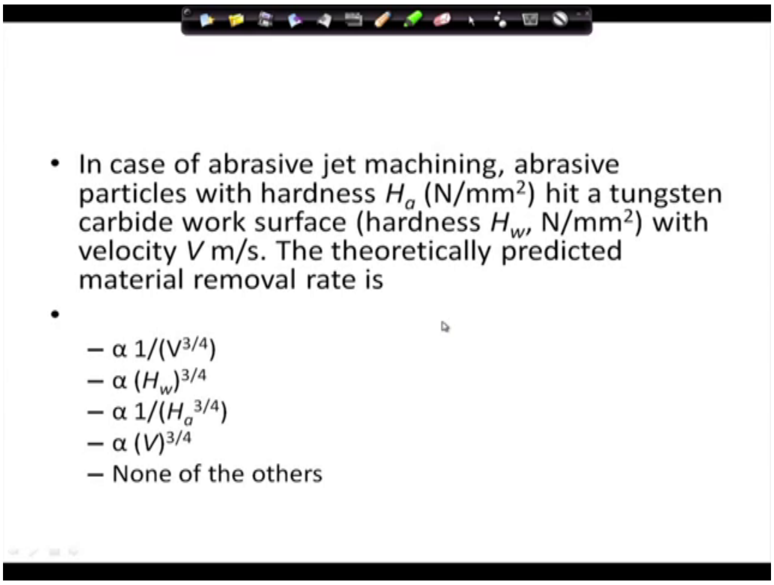

In case of abrasive jet machining, abrasive particles with hardness H a hit a tungsten carbide surface, hardness H w Newton's per millimeter square with velocity V meters per second. And in that case the theoretically predicted material removal is proportional to 1 by V to the power three-fourth proportional to H to the power three-fourth, proportional to 1 by H to the power three-fourth; H a sorry for second one was proportional to H w to the power three-fourth, proportional to 1 by H a to the power three-fourth, proportional to V to the power three-fourth and none of the others.

So, if you come across these expressions in that case if you remember the expression for material removal rate it is extremely simple, you can do that in one go. If you do not remember then also try to eliminate some of the cases by a common sense. For example:

the first one says that the material removal rate will be proportional to 1 by V to the power three-fourth, now how is that possible. Because, V to the power three-fourth you know if the velocity is increasing, in that case the denominator will increase and therefore M RR will come down; why should it you are apply you are providing more energy.

So, in these cases first of all we will assume that M dot the mass flow rate of the abrasive is not getting affected neither are the others changing. Why do we say that, because if you have a quick look.

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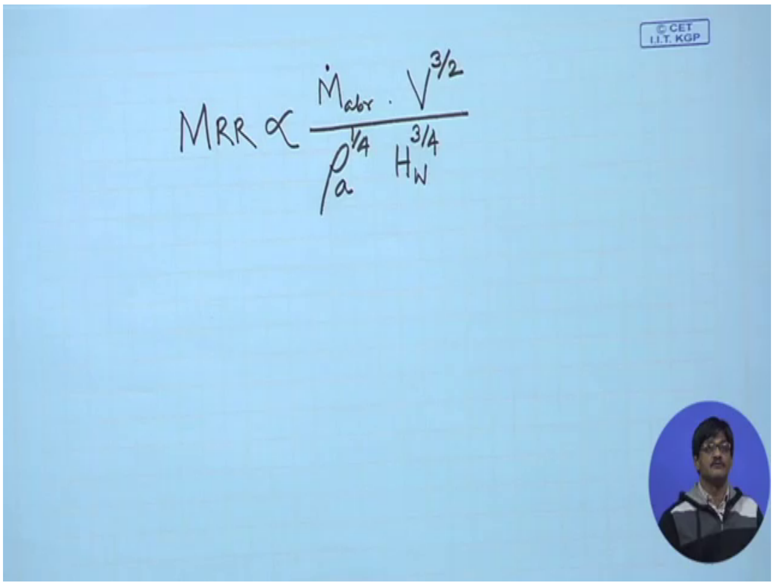

Once again we remember M RR is proportional to M dot abrasive into V to the power 3 by 2 divided by rho to the power one-fourth and H to the power 3 by 4. This one is work piece, this one is abrasive, this one is abrasive. So, in this case if V is being changed; V is being changed; obviously M dot is not change because nothing like that has been stated.

So, the first option can be removed the movement you apply your common sense that is if you increase velocity nothing else is changing; why should 1 by velocity become higher. So, the first is definitely not possible. Proportional to H w to the power three-fourth; now if the hardness of the work piece is increasing, if it is increasing what does it mean that the M RR will go on increasing definitely not.

[FL] here, you might say that suppose its shifting from the hardness is changing and then it shifts from the ductile regime to the brittle regime, in that case material removal rate will become higher. But no, we are talking about a definite type of work material which is tungsten carbide. So, that question does not arise. So, with common sense you can you know remove the second option also.

Now comes 1 by H a to the power three-fourth. Here also if you just remember hardness of the abrasive is not affecting the M RR in ultrasonic machining or abrasive jet machining or abrasive water jet machining. In none of the models that we have studied hardness of the abrasives are not brought into the picture.

Therefore this also is gone. So, what is left? V to the power three-fourth; now here if you remember it is V to the power 3 by 2 you can definitely say that this is not correct: there was the first one is wrong, the second one is wrong, the third one is wrong, the fourth one is wrong, none of the others.

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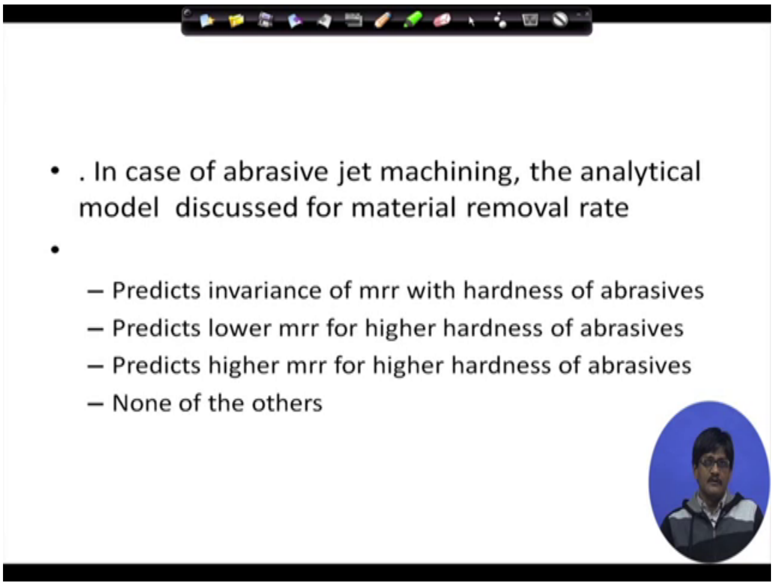

In case of abrasive jet machining the analytical model discussed for material removal rate. Ok, the analytical model the model that we have studied predicts invariance of M RR with high hardness of abrasives: predicts lower M RR for higher hardness of abrasives, predicts higher M RR for higher hardness of abrasives, and none of the others. Here we have discussed just now that if you have any of these processes; I will just repeat- if you have any of these processes ultrasonic machining, abrasive jet machining, and abrasive water jet machining the M RR has nothing to do with the hardness of the abrasives. It has an effect; I mean the hardness of the work piece has an effect because harder the work piece in the brittle regime less will be the material removal rate.

So, in this case none of these are correct. If you ask me that in reality is there any difference between the material removal rates of what we call it this say aluminium oxide and silicon carbide or boron carbide and silicon carbide. I will say yes, you can see some effect of the material that you are taking. You may say why should that be so, in that case why is it not in the model? Model has considered them to be you know just geometrical entities with perfect rigidity. That is why they are not coming into the model. But, in the actual case they might be harder bodies, might be having less compression of those they might be one which is you know more brittle; more brittle so that they breakup if they impact on the work piece. And if they breakup they might be taking part of the energy for themselves for producing more surfaces and therefore they do have an affect the hardness of the body.

But for these questions please understand for the analytical model there is absolutely no effect of hardness of the abrasives.

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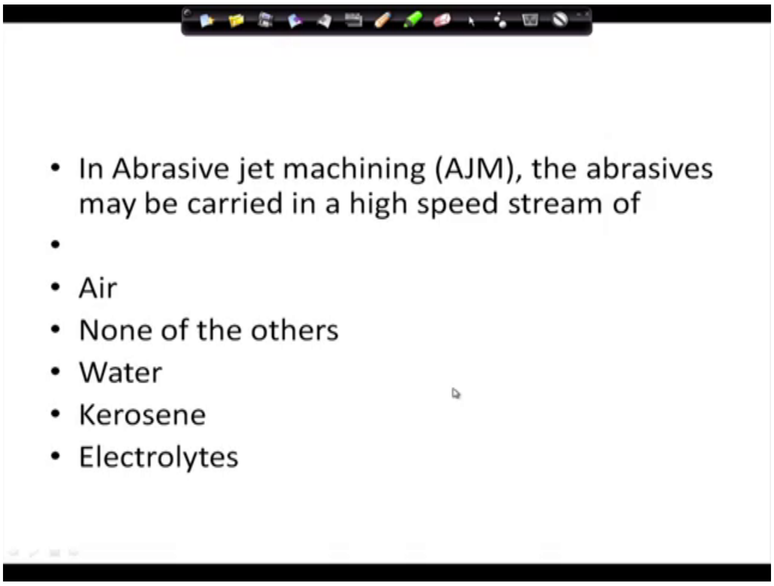

In abrasive jet machining, the abrasives may be carried in a high speed stream of air, none of the others, water, kerosene, electrolytes. Now whenever we talk of abrasive jet machining please understand that it is we are talking of basically of a gas. If it is abrasive flow machining then it might be a gas or a liquid fluid; abrasive flow means fluid. If it is water jet machining its essentially water. So, abrasive jet machining in this case they may be carried in a high speed steam of air.

Say had I asked you that in abrasive jet machining the abrasives have to be carried in a high speed stream of air none of the others etcetera; in that case it would have been none of the others. Have to be means that I am saying that it is this one and nothing other than this; so in this case as we have said maybe so its air. The correct answer is high speed stream of air [FL].

Coming back to our discussion.

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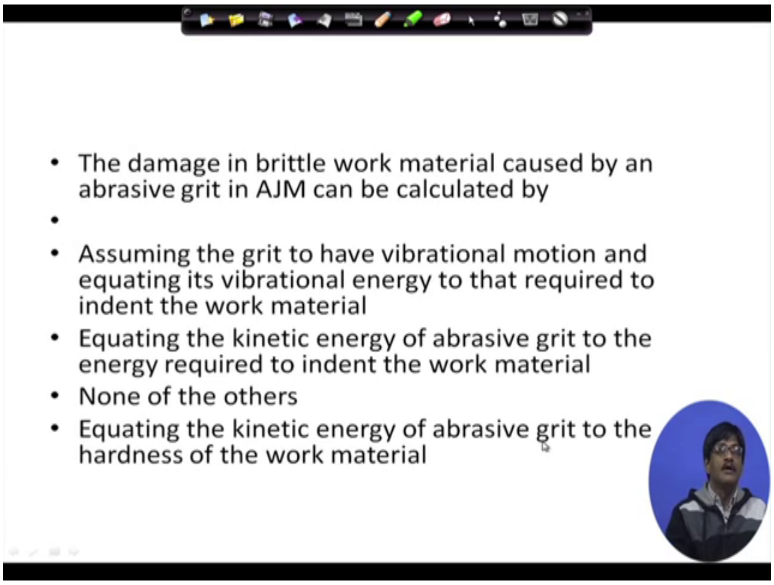

The damage in brittle work material caused by abrasive grit in AJM can be calculated by. So, what are we saying that damage in brittle work material caused by an abrasive grit; that means, we are talking of a single impact. By an abrasive grit in AJM can be calculated by assuming the great to have vibrational motion and equating its vibrational energy to that required to indent the work material. Equating the kinetic energy of the abrasive grit to the energy required to indent the work material, none of the others, equating the kinetic energy of abrasive grid to the hardness of the work material.

So, to some of you the answer has already become obvious and to all the others I mean to everyone. First of all assuming the grit to have vibrational motion no not at all; vibration does not come into the picture here. Second: equating the kinetic energy of abrasive grit to the energy required to indent the work material. This is the correct one. What about the others? None of the others, definitely not if we find one correct answer. And equating the kinetic energy of the abrasive grit to the hardness of the work material; now what does this mean? Hardness of the work material kinetic energy and hardness they are not compatible they do not have the same units. So, from that point of view obviously it is wrong.

So, we understand that here the correct answer is equating the kinetic energy of abrasive grit to the energy required to indent the work material: this one is the correct answer.

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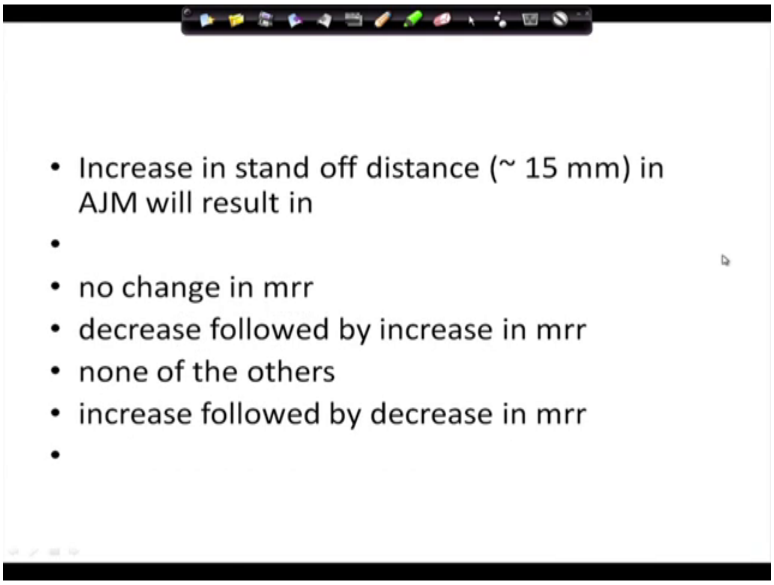

Increase in stand off distance this means up to 15 millimeters stand off distance upto 15 millimeters in AJM will result in no change in M RR, decrease followed by increase in M RR, none of the others, increase followed by decrease in M RR. So, here if you remember the material removal rate graph I mean plot of AJM against stand off distance in that case it first rows to a particular level maintain that plato region for some time and after that drooped off So, it is increase followed by decrease in M RR.

The last option: this reminds me if you look at this board I mean at the page.

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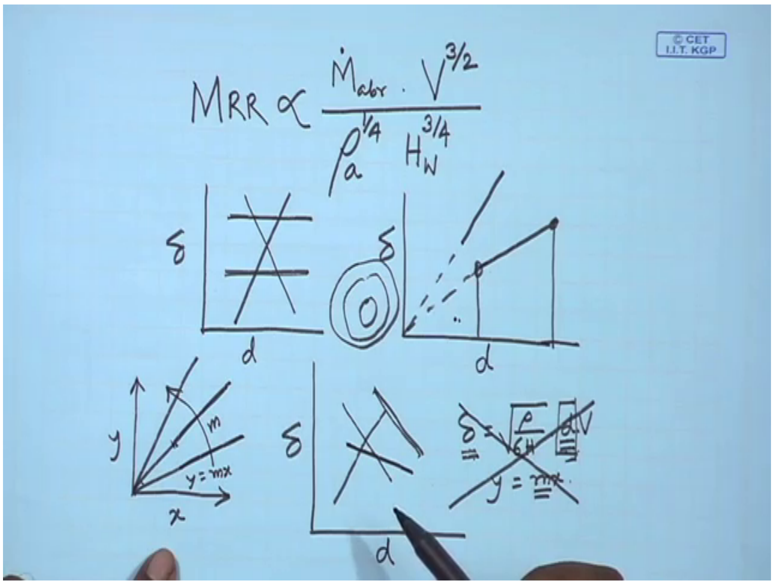

Suppose I give you three plots: this is say a right abrasive grit sorry and I give you certain graphs: this one is; what I say is that which one would represent correctly the value of delta in AJM against increase in grit size, I have drawn the increase in grit size and suppose I have drawn these graphs which one represents correctly the plot of indentation for impact.

So, here what you can say is that if you are good in studies and if you remember this expression: delta is equal to root over rho by, correct me if I am wrong rho by 6 H into d into V as far as I can recall. So, if this be, so if all the other things are remaining constant in that case this is d and this is delta and. So, you can see it has a relation as y is equal to mx, so that if you go on changing d you should get let me draw it here. If you go on sorry if you go on changing M what sort of relation will you get? If this is x and if this is y you will get this curve first of all and if you change M this is the way in which it changes. If M is changed y is equal to mx will give you this sort of graphs.

So, if you remember the relation between delta and grit diameter, I hope I have got this expression correct; in that case you can say that first of all they are going to have a relation y is equal to mx and if they are different plots they should look like these. Maybe not starting from the centre because you have not taken those very values, but what about these; these seem to be correct.

So, this way if you remember this it is not very difficult to follow. But suppose you are not that good in studies, and therefore you do not remember this one at all now comes a question can you crack this why common sense. You will say- diameter is increasing and it is not having any effect on delta; no, this is not possible and you scratch it out I mean not above question paper mentally you do not consider this as a possible correct option. Next diameter is increasing and your delta is coming down; absolutely not this is unacceptable and by the method of elimination this one will be your correct answer. And it matches with common sense you know understanding of a problem also. That is if you are increasing diameter that means the grit is becoming larger and larger actually in that case you it is expected that you will be producing higher and higher delta values ok.

So, this sort of questions if you do not know them at all; I mean even if you do not know the expression with which you can solve them you can still use a common sense and get it done. I tried that always to put in questions where everybody has a fair chance, you might not have had you know a lot of time to involve yourself in these studies, but you definitely all of you have common sense. So, that also you may be able to apply.

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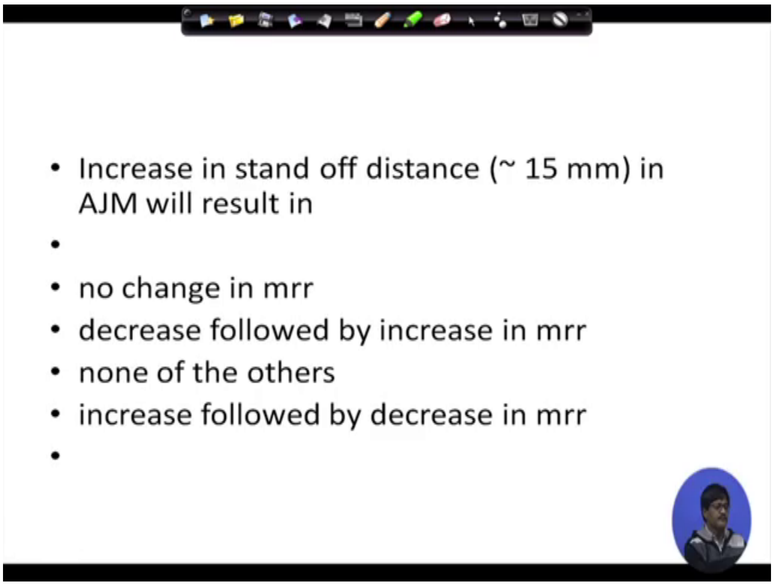

The speed of abrasive particles in abrasive jet machining would typically be in the range of 150 to 300 meters per second, 1000 to 2000 meters per second, none of the others 10 to 15 meters per second.

Now, if you have gone through the notes several times I have mentioned that it is in the range of 150 to 300 meters per second. Now comes the common sense approach: can we eliminate them, eliminate the incorrect answers. So, suppose you remember at least that you know the sonic velocity is around how much maybe 335 meters per second in air. So, 1000 to 2000 meters per second, that means you are travelling at supersonic speeds etcetera through basically air those grits are travelling a supersonic is most probably you know not correct. If you try to have a particular equip piece of equipment in through which you are going to have this velocity most probably it will re choked condition, and therefore you will not reach this particular velocity; choking velocity.

So, that one is gone. Now comes 10 to 15 meters per second: 10 to 15 meters per second is so less you know through air it will hardly cause a puff on the metallic surface no effect at all. What about 150 to 300? Now here if you remember the velocity of sound in air then I think you will be more or less agreeing with it, you may more or less agreeing with this. So, 150 to 300 meters per second is the correct answer.

You are getting a jet speed of 150 meters per second at the nozzle outlet of and AJM machine. Now what is this jet speed of 150 meters per second at the nozzle outlet of an AJM machine? Now, the nozzle outlet diameter is 0.5 millimeters without changing anything else you use another nozzle with outlet diameter 0.25 millimeters; that means, the nozzle outlet diameter is becoming less. The outlet velocity would be assuming no throttling 300 meters per second, 150 meters per second, 75 meters per second, and none of the others.

So, in this case let us see I we apply Bernoulli's theorem to the system starting from other cylinder where there is stagnation pressure, at the outlet of the nozzle buy these atmospheric pressure. So, the gas jet will be fully expanding to its highest possible velocity which has been stated here to be 150 meters per second at the nozzle outlet. Now if you are changing the outlet diameter unless some other effect is there the velocity should still be 150 meters per second.

Now let us see; what are the other effects which can cause a problem. One is throttling; that means the diameter become so low at it starts you know creating some head loss in it while the air is passing through it, but we have said that assuming no throttling ok. Second is that- whenever abrasives are getting entrained in the air one condition needs to be satisfied that is the nozzle I mean the outlet of the air inside the mixing chamber that generally should have a lower orifice diameter than the nozzle outlet diameter. In that case suction will occur of the abrasives into the air stream or gas stream.

So, if that is also valid in that case we can clearly write the answer is 150 meters per second, because in Bernoulli's relation the orifice diameter should not come. So, I will slightly if I ever give you this problem, I will slightly modified saying that no other effects will be dominating the condition. No other conditions will be dominating in this case. So, in that case you can simply apply Bernoulli's theorem.

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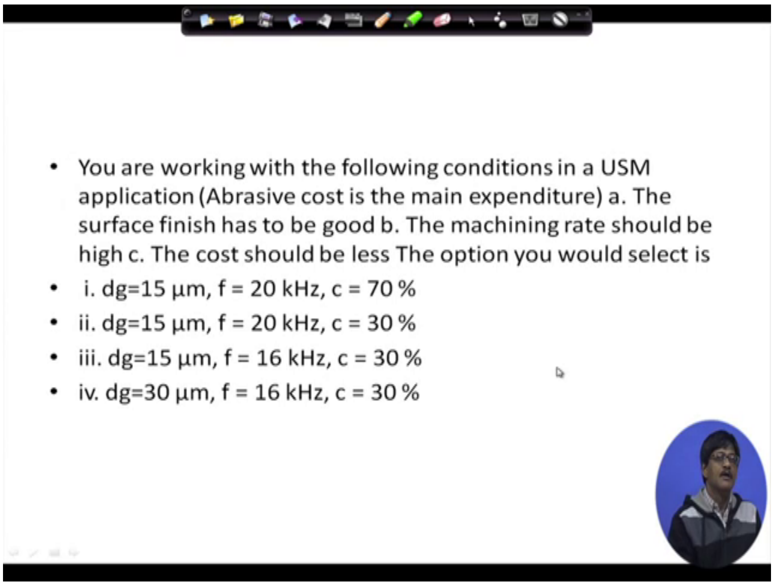

You are working with the following conditions: you know USM application abrasive cost- oh just a moment I have given one USM problem anyway that is not bad, final preparations. With you are working with the following conditions in a USM application and abrasive cost is the main expenditure. The surface finish has to be good, and b the machining rate should be high, and c the cost should be less. So, what are we bothered about, you are bothered about surface finish, you bothered about M RR, and we are bothered about the costs. The option you should select is; so there are four options given of these four options we have to choose that one which is going to give us surface finish, good surface finish, machining rate high, and the cost also should be less.

So, what is the deciding factor for surface finish? I would say grit size. So, first of all the last option is gone; the last option is gone surface finish has to be good. So, we have three options now: what about M RR? M RR is definitely going to be high if you use high frequency. So the third option is gone, and we have the first two options surviving. And cost has to be less, if the cost has to be less we can use the one with a lower concentration because we know at higher concentrations there is hardly any increase in M RR; why, because it is M RR is proportional to c to the power one-fourth and the graph flattens out after it has reached 30 percent.

So, the correct answer is the second one: grit size is 15 microns good surface finish, f is equal to 20 kilohertz higher M RR, and c is equal to 30 saving in abrasive cost.

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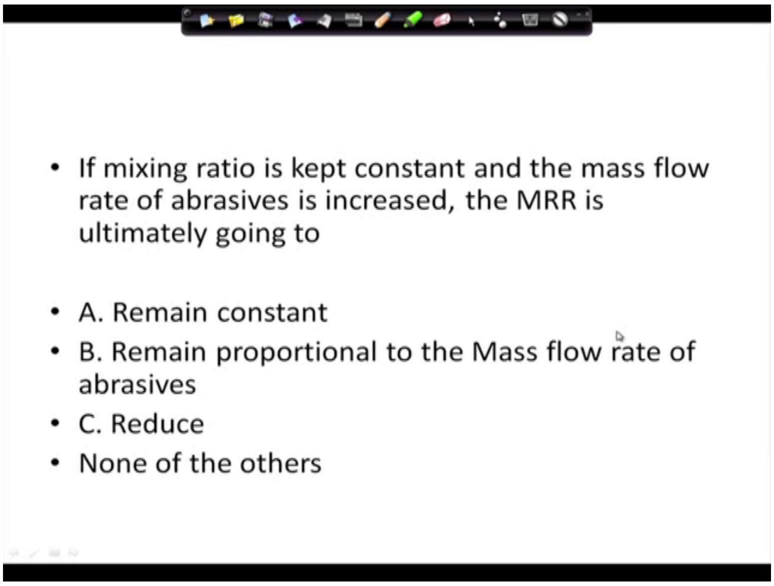

If mixing ration is kept constant and the mass flow rate of abrasives is increased the M RR is ultimately going to remain constant, remain proportional to the mass flow rate of abrasives reduce none of the others.

Now, once again if you recall the M RR is proportional to the mass flow rate of abrasives, but if and only if the mixing ratio remains constant because otherwise the velocity of the jet will come down and affect the results. Therefore, we have mixing ratio being kept constant what you call it M RR is going to remain proportional to the mass flow rate of abrasives. And therefore, we have the second option to be correct. The second option is therefore correct.

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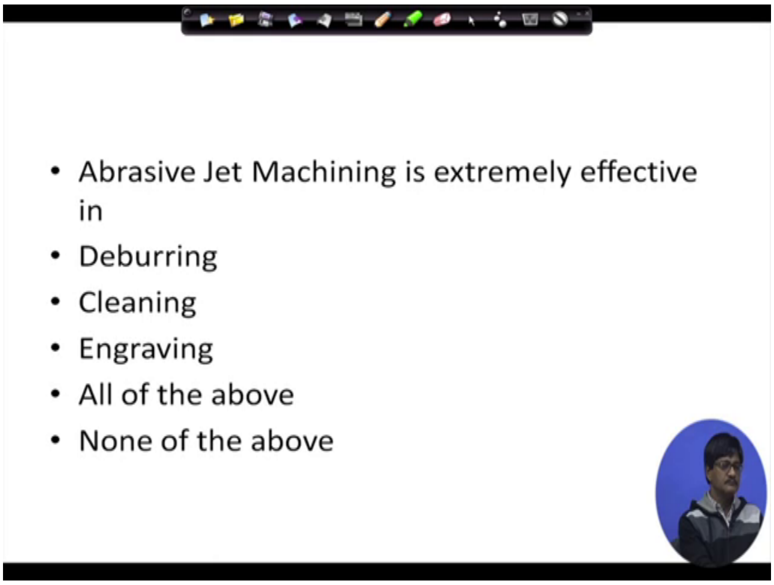

Abrasive jet machining is extremely effective in deburring, cleaning, engraving, all of the above, and none of the above. Abrasive jet machining: so deburring, cleaning, etcetera, these processes are you know finishing processes and abrasive jet machining is extremely effective in these cases. It can carry out deburring, it can carry out cleaning, it can give you a method math surface like appearance, it can give you a frosted glass appearance I mean in the work piece it can create it can do grooving it can remove material from inaccessible portions, it can remove oxide layer, it can remove what you call it stains, it can remove adherent coatings, and it can also do engraving.

So, the answer in this is case is all of the above [FL].

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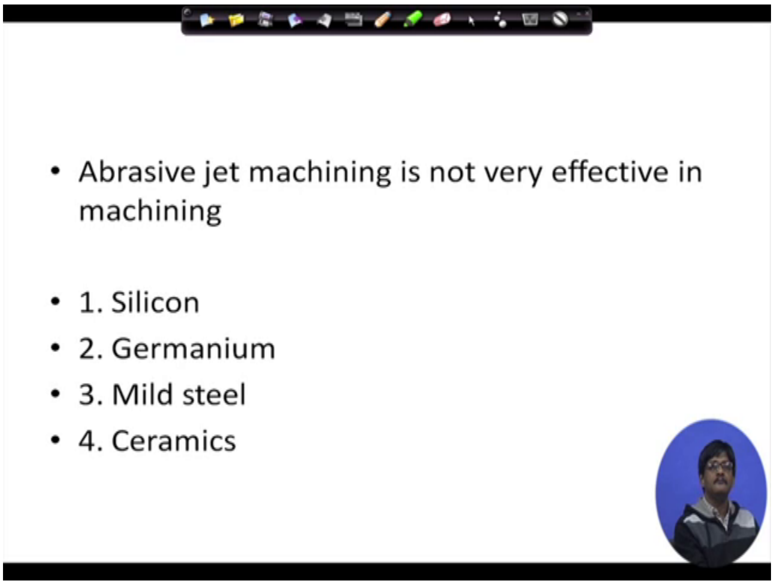

Abrasive jet machining is not very effective in the machining of silicon, germanium, mild steel, and ceramics. So, in this case first of all take silicon for example semiconductor: semiconductors, glasses and ceramics they are always you know highway machinable by these abrasive processes. So, silicon can be machine very effectively, germanium can be machine very effectively, ceramics can be machine very effectively; but not mild steel, mild steel is quite a ductile material, it is not undergo brittle fracture as such due to impacts. And only microchipping will take place by the removal of sectors; you know sectors of interference between the grits and the material. And therefore the one material in which abrasive jet machining is not very effective is mild steel.

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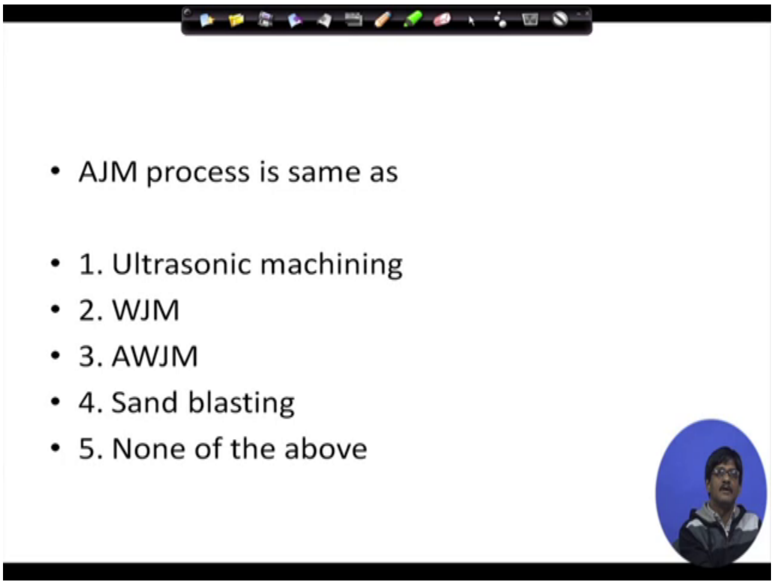

AJM process is same as ultrasonic machining, water jet machining, abrasive water jet machining, sand blasting, none of the above.

So, by up till now from the lectures that you have attended you surely know it is not ultrasonic machining, it is not water jet machining, it is not abrasive water jet machining, and what about sand blasting? You know sand blasting is does not have the finery finest neither does it have the control as is available in abrasive jet machining. So, abrasive jet machining cannot be reduced to the level of sand blasting, no not at all. It can carry out finishing processes as well as machining processes, while sandblasting is simply no by near it. There are you know more differences between AJM and sand blasting than similarities in fact. So, the correct answer is AJM is the same; a process is the same as none of the above.

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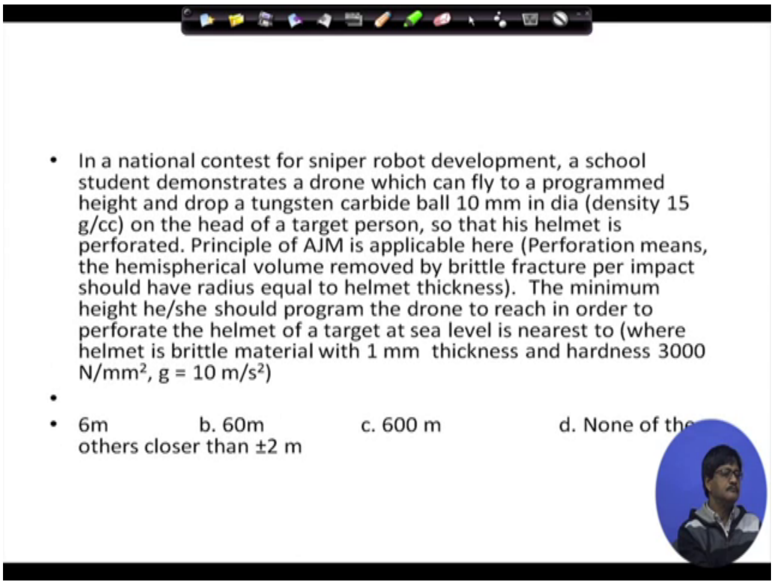

Now, this is a question which I would like to keep as take home assignment it is extremely simple, but I hardly have the time to you know discuss it and complete this lecture. So, I will share the answer with you after you have tried it out yourselves.

In a national contest for sniper robot development a school student demonstrates a drone which can fly to a programmed height and drop a tungsten carbide ball 10 millimeter in diameter, density 15 grams per cc on the head of a target person. Now that is not very you know that is not very nice dropping a tungsten carbide ball on the head of a person, but try to understand this is the sniper robot that too it is remotely controlled. So, it might be quite effective especially at night you are not able to see anything while this sniper robot might when we equate with you know infrared cctv. So, that if once it zeros in on the over a head of a person it can simply drop this tungsten carbide ball and God help the person who is underneath that particular robot.

So, what is the purpose of dropping this ball the helmet has to be perforated? If the helmet is perforated, we will consider that our job is done. So, principal of AJM is applicable here for finding out the perforation. And have a look at this.

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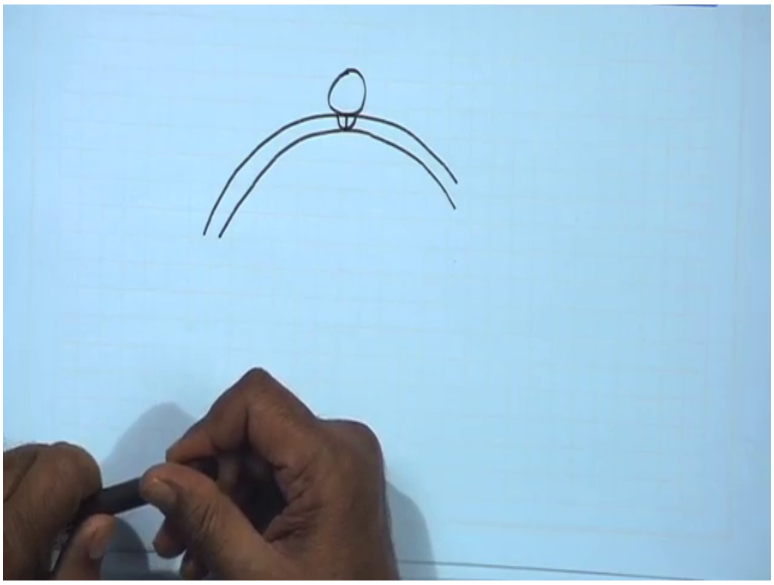

If this is the helmet body and if this is the ball, the ball should create you know hemispherical chunk whose radius will be equal to the thickness of the helmet. In that case we will consider the perforations to have been performed successfully. Radius of the indentation should be equal to the thickness of the helmet. So, what is given after that? The minimum height he or she should program the drone to reach in order to perforate the helmet of a target at sea level is nearest to, ok.

So, the minimum height to which the drone should go where helmet is brittle material with 1 millimeter thickness and hardness three 1000 Newton's per millimeter square and g is equal to 10 meters per second square. Do we need anything else? We have been given density of the ball, its diameter and we have been given the hardness of tungsten of the helmet material and its thickness. So, seems quite straight forward. So, please do this particular problem and share your answer with me, and I will tell you whether it is correct or wrong.

So, with this we come to the end of the 15th lecture and five lectures are left in which I will cover abrasive water jet machining and its associated processes.

Thank you very much.