Non-traditional abrasive machining process: Ultrasonic, Abrasive jet and abrasive water jet machining
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Lecture - 14
AJM - Process Parameters and Response characteristics take-home assignment discussing

Welcome to the 14th lecture of the course Non-traditional Abrasives Machining Processes including Ultrasonic Machining, then Abrasive Jet Machining, and Abrasive Water Jet Machining. So, today we will discuss something about the process parameters and their effects on the response characteristics and also if time permits we will have a quick look at the take home assignments that we will be you know sharing between us.

So, first of all let us move on to the subject directly.

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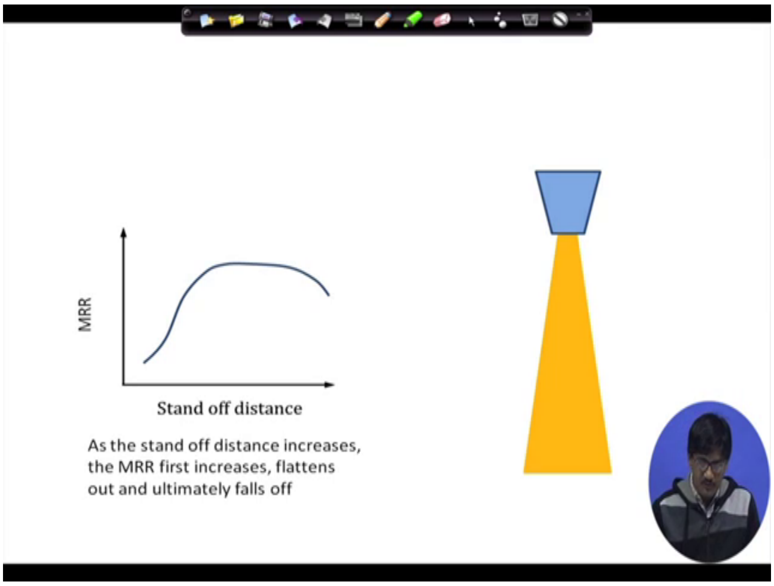

Standoff distance, what the standoff distance mean? Standoff distance means that whenever we are having the end of the tool as a nozzle. And from the nozzle abrasives are coming out at high speed, then the distance between the tool sorry the nozzle tip and the work piece surface that is called the stand of distance. And this is generally of a very low dimensional value say, 0.5 millimetres by common. So, a very small distance is there.

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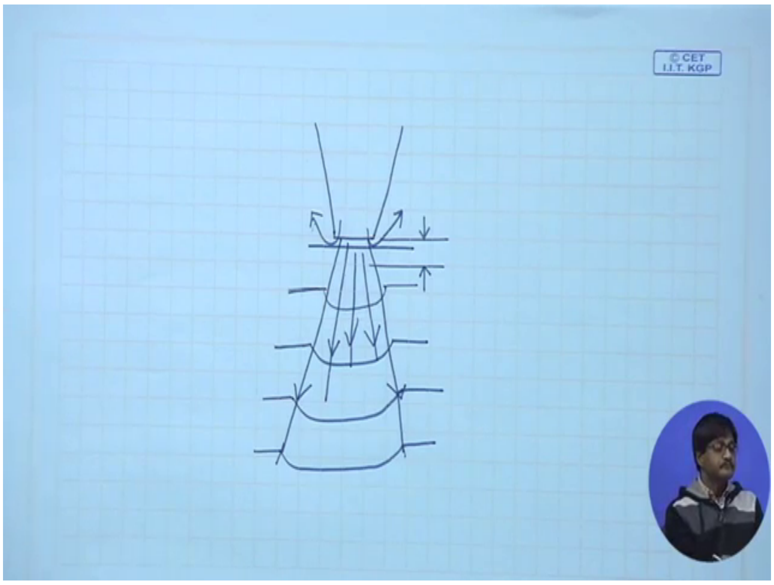

Let me draw a figure So that it is clear to everyone. This is the nozzle, and this is typically standoff distance. This can well be below one millimetre, as we go on increasing it up to say 15 millimetres we will see that consequently this becomes larger in lateral size. A very circular output it becomes you know larger and larger in diameter, why, because due to viscous effects as this becomes slower and slower of the expansion, slower and slower. Therefore, due to continuity it becomes larger and larger in diameter. So, first of all if you are interested in cutting very precise thin narrow lines; if you want to groove may grooves of very narrow curve width, if you go on moving away from the nozzle tip; that means, if the standoff distance becomes higher if it becomes higher and higher.

First of all this is going to give you a wide cut which might not be your requirement at all. Secondly, initially you will find that the MRR will rise why because it is you know it larger and larger area is coming under the affect of the you know of the jet. And therefore, more and more material can well be removed, but after some time you will find that the velocity of the particles becomes so less that they cannot create plastic deformation on the body they will simply bounce off in effectively. So, after some time material removal rate will come down. So, if the if the distance is very small, in that case back pressure will be created nozzle the what you call it the abrasives will not be able to come out at all and therefore, material removal rate will be very low.

So, let us have a quick look at the figure, standoff distance as it increases MRR is increasing, why? Because if you are putting it very close the there will be back pressure and there would not be full expansion of the gases and it would not be reaching you know, reaching it is full velocity. Therefore, if it is very close you do not have full expansion of the jet. But if you are reasonably away from it in that case you will have quite a high MRR, and this MRR will go on increasing. As the jet becomes wider and wider as we move more and more away from the nozzle tip that is why with standoff distance it first rises.

And then becomes steady when you know material removal is being closed. And however, it is becoming less and less with reduced velocity and, but still material removal is has reached the plateau region because it is encompassing more and more of the surface area and causing damage, but after some time it ceases to cause any material removal because the velocity has become So reduced. Say at around 15 millimetres it has become so reduced due to viscous drag from the atmosphere that it does not cause any plastic deformation of the work piece material.

So, this is the way we find is the variation of MRR with standoff distance.

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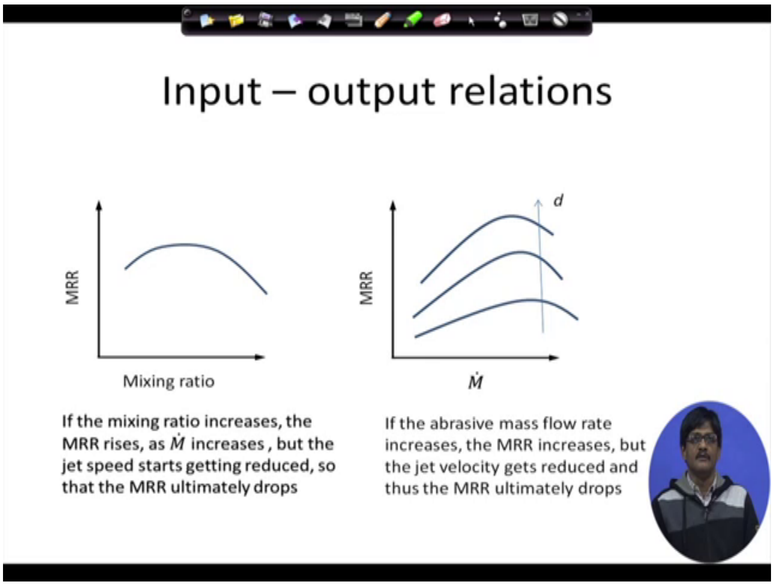

Next the change of mixing ratio causes a change in MRR. Now what is mixing ratio? Now if you remember we have defined mixing ratio according to our definitions and it is I mean according to our conceptions. And as per our definition it is mixing ratio is simply mass flow rate of abrasives divided by mass flow rate of the carrier gas. Hence mixing ratio if it is remaining if it is becoming higher and higher, it means that mass flow rate is become mass flow rate of abrasive is increasing at the expense not at the expense. It is increasing with respect to the mass flow rate of the gas.

Now, if you remember the expression of material removal in case of what you call it.

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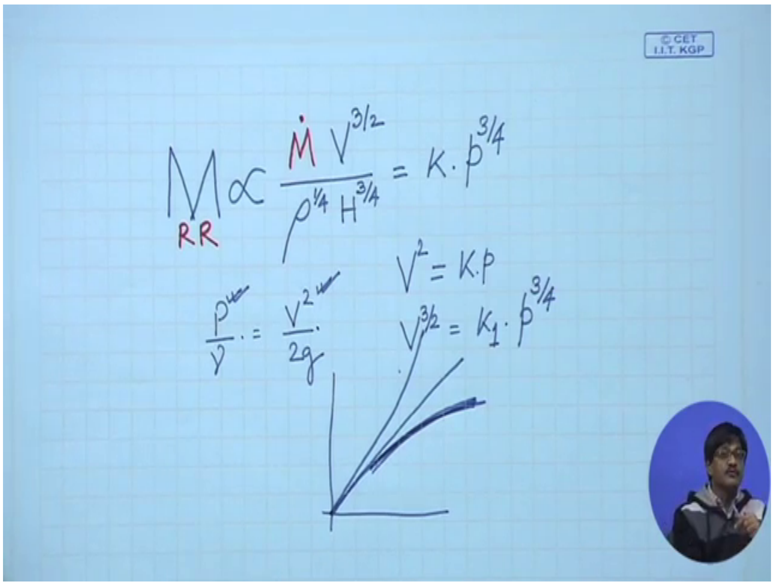

In case of abrasive jet machining if you have a quick look at this one, M is proportional to just one moment, it is proportional to sorry, MRR that looks quite good looks like a company logo. MRR is proportional to M dot. Abrasive mass flow rate, divided by v to the power sorry v to the power 3 by 2 rho to the power one-fourth and h to the power how much I have forgotten 3 by 4.

So, if you have a relation like this and if you keep the others constant, in that case if mass flow rate increases you will expect that MRR will increase proportionately and therefore, it will be a linear relationship mass flow rate increases of the abrasives and MRR increases linear to it. Because there is no power it is to the power 1. So, if we come back to the figure and have a look once again then why is the change of MRR initially you know increasing and after that in grooves.

This is because if mixing ratio is changing no doubt the mass flow rate of abrasive is increasing, but it takes it is toll on the velocity of the gas jet. Why, because velocity of the gas jet will go on decreasing if we consider if we recall that momentum balance. Momentum balance between the you know gas jet and steady abrasives I mean abrasives which are in steady state not moving, in that case the gas jet velocity gets sufficiently reduced due to the momentum you know, transfer. The abrasives have to be accelerated up to the final velocity of the abrasives of the abrasive and gas jet combined.

So, as we are going on increasing M dot; that means, abrasive mass flow rate the velocity of the of the jet will come down and that will have it is telling effect on MRR, MRR will start drooping. If you come back to the equation once again let us have a look. Velocity to the power 3 by 2 and this is now going down. If velocity goes down velocity to the power 3 by 2 will affect MRR in the sense that MRR will go down. So, that is why even if mixing ratio is bringing in more abrasives their velocity is reducing and therefore, MRR is ultimately going to drop increase initially and then drop later on. If we come to the affect of mass flow rate on MRR it is roughly going to be the same why because mass flow rate is increasing of the abrasives.

And therefore, MRR increases, but as it as jet becomes heavier and heavier with more and more abrasive particles, ultimately MRR comes down, because the velocity is going to go down and if the velocity goes down as you have seen MRR will go down.

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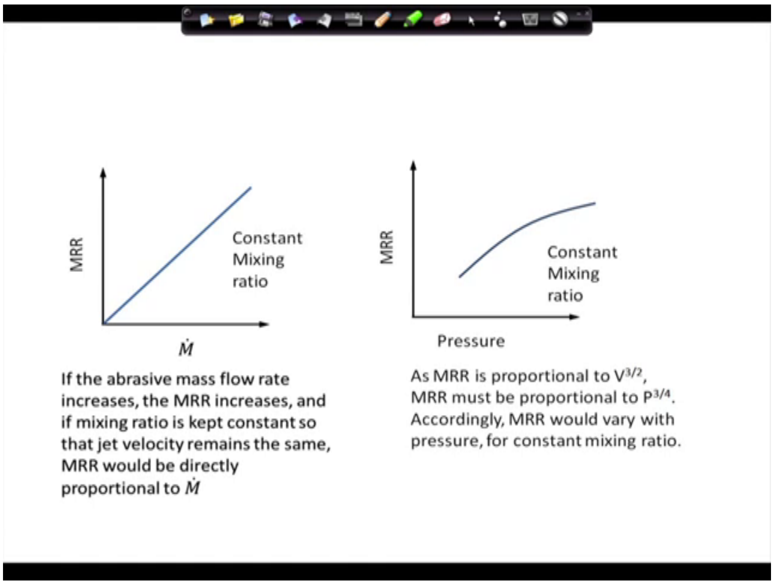

Now, we have an interesting graph. The graph is suggesting that if constant mixing ratio is maintained in that case M dot and MRR will have a directly proportional relationship, that is interesting let us see what is constant mixing ratio. It means that if you are increasing M dot simultaneously you go on increasing the gas flow rate so that, So that the ratio of the mass flow rates of the 2 phases always remain constant. So that means, if this particular ratio is constant, velocity of the gas jet would not decrease as previously, but will remain constant and therefore, M dot will you know linearly increase MRR as per the equation. So, v remains constant because constant mixing ratio is going to ensure that the flow of the you know flow of the gas jet remains constant and therefore, M dot directly affects MRR.

Now, another interesting graph that is pressure, how is pressure going to affect MRR. Now what is pressure? Pressure means that see initially we are having a cylinder gas cylinder or we are having a compressor, with the help of which we are inputting the gas at very high pressure and this pressure head ultimately is going to be converted to velocity head. So, if pressure head is getting converted to velocity head, we can easily write here P by gamma is equal to v square by 2 g. What does this mean? It means increasing the pressure is the same as increasing the square of the velocity all right. So that means, that if we are increasing pressure square of the velocity is increasing; that means, quite a lot of affect is taking place.

Now, let us look at this expression with in terms of pressure. Once we know that you know velocity square is equal to a constant into pressure, we can say therefore, velocity to the power 3 by 2 must be equal to whatever say k 1 into P to the power. First of all you take away the root it gets to the power half you get give it 3 by 2 it gets 3 by 2 into half; that means, 3 by 4. This is the relationship equal to constant into what you call it P to the power 3 by 4. So, if you have P to the power 3 by 4 after you know after studying about ultrasonic machining you can very well say that this is to the power 1, this is this is to the power more than 1 this is to the power less than 1. So, it must be having something of this type, and that is it if you look at the graph now this is the change of MRR with respect to pressure.

My new here also constant mixing ratio has to be maintained otherwise what will happen is if the amount of abrasives flowing in the you know carrier gas it is mass flow rate will decrease as more and more gas is flowing in it is mass flow rate will decrease, and therefore, you are going to have a different MRR. So, constant mixing ratio is maintained here as well. So, this is the affect of pressure on MRR, pressure to the power three-fourth is you know MRR is equal to constant into pressure to the power three-fourth.

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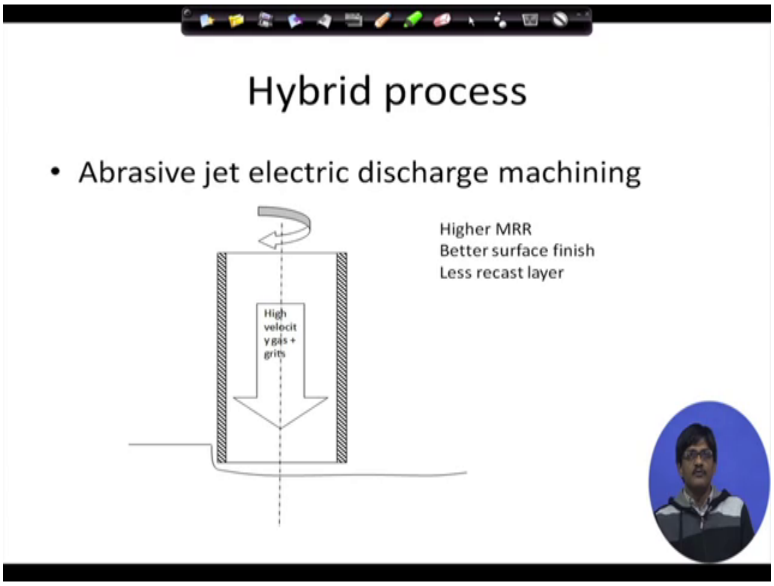

So, we have been looking at abrasive jet machining from so many angles.

So, let us look at it from the point of view of hybrid processes which have developed with respect to abrasive jet. So, we will be talking about abrasive jet electric discharge machining. So, first of all as we have discussed previously, before discussing about anything new first of all we have to check whether it is a purely academic exercise or whether it has any you know any meaningful implication on the industry. You might me might ask me why electric discharge machining is quite good by itself, why do we intend to add some of the abrasives?

So, when electric discharge is dealing with you know charges etcetera by bringing physical bodies like abrasives what are we are going to do in the first place. So, here we have you know a rotating annular cylindrical tool, hollow cylindrical tool where we are giving electrical connection to the tool and the work piece pair. And additionally we are also pre providing a very high velocity gas; that means, gas at high pressure is being given with abrasive grits.

Now what is it going to do? First of all as the medium is a gaseous medium therefore, sparks will be flying from the between the tool and the work piece you know across gaseous medium and this is called dry EDM. Dry EDM has a number of advantages like it might give us higher MRR etcetera etcetera, but mind you dry EDM the distance between the work piece of the tool has to be controlled very precisely, because in almost in many cases the distance is much less than that in EDM with you know liquid medium, it might be as low as 5 microns. So, coming back to this.

So, first of all if you draw figure here and have a look what is going on in this particular process.

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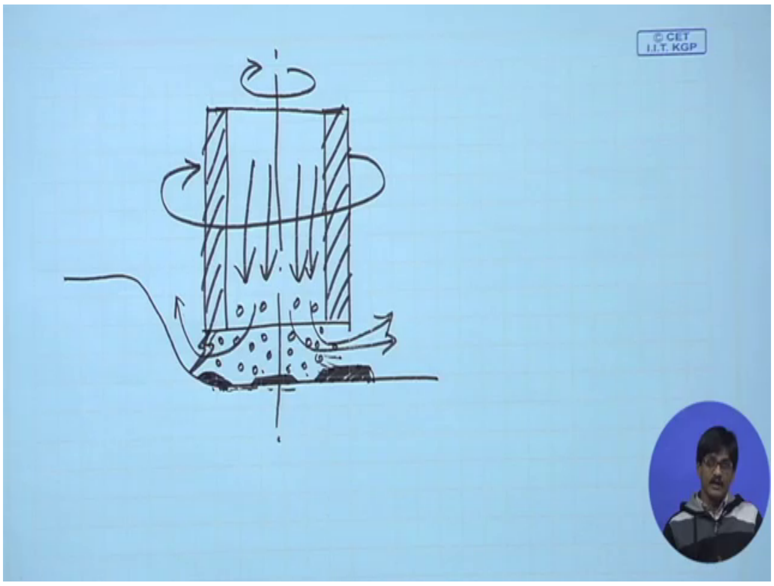

So, this is the tool, these are the sparks which are flying between the tool and the work piece. And they remove material by EDM this one is rotating. This sorry, this is the axis of rotation. Now so, this particular tool and here high pressure gas with abrasive particles they are coming in. So, there must be some problem with EDM alone because of which this is being employed what is that? EDM, generally almost always covers the surface with recast layer. And if this recast layer is there if you look at it under the microscope you will find a lot of cracks and a complete layer sometimes on top of the actual surface which will detrimentally affect it is you know performance as for as surface is concerned; that means, surface integrity will not be of very high quality.

So, if these abrasives are coming, it will find that at this edge EDM has taken place and maybe you know recast layer is formed on the surface which we call the finished surface recast layer. Abrasives will hit impact this recast layer and be able to remove it. This has a twofold advantage. The twofold advantage is first of all the abrasives will be you know removing recast layer which is detrimental for surface quality.

And secondly, material removal rate will rise and it has a 3 fold. In fact, 3 fold advantage the surface finish which was you know; obviously, rough because some places you have recast and some places you do not therefore, the roughness would have been quite appreciably high, but once abrasives have acted on that and all metal debri which was sticking to the surface they are driven off by the abrasives and the flushing action of the high pressure gas, we will find much better roughness will be obtained. So, higher MRR lower amount or elimination of recast layer and better surface finish. We can expect these 3 points from this particular hybrid process ok.

Now, next is a small discussion about what you call it, the take home assignments that I am going to give you.

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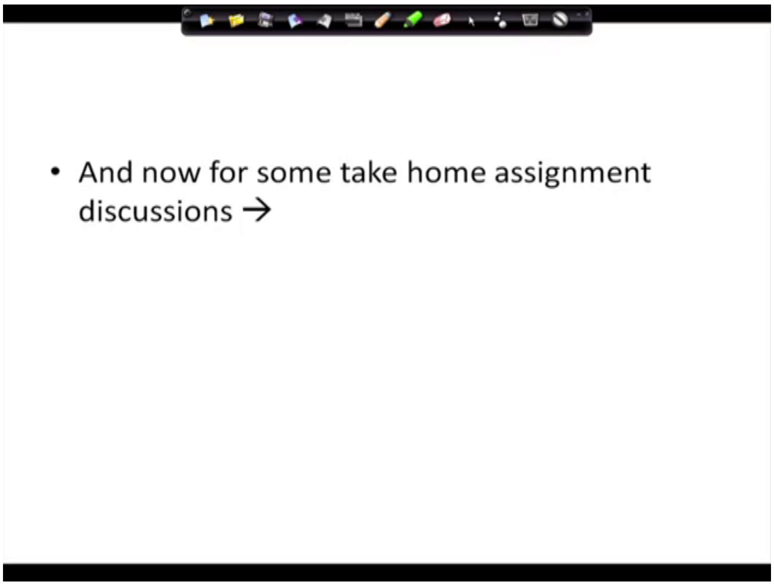

What are take home assignments they are not part of the actual assignments which carry marks, but they are for your conception they are for your interest and therefore, your you know pass time recreation if you call this recreation at all.

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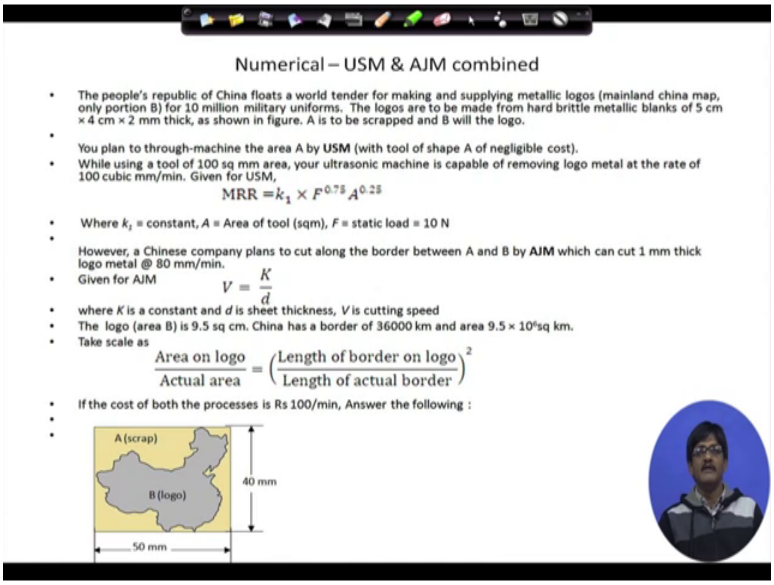

Let us see what does this particular numerical example say, the peoples republic of china floats the world tender for making in a and supplying metallic logos you know emblems symbols, logos etcetera which has a mainland china map, only portion B I have shown it in a small figure at the bottom. Only the portion which is shaded and shaded with a dark colour and with ash colour ashen colour and it is given A name B. Only this part is ultimately going to remain and the other parts are going to go away.

So, in that case what the people is republic of china intending to do it is planning to make 10 million such pieces. 50 millimetre by forty millimetre looks like a small badge. So, these are going to be may are going to be put into military uniforms and the logos that we made from hard brittle metallic clanks of 5 centimetre 4 centimetre 2 centimetre thick as shown in figure [FL]. So, a goes away and b will be the logo b is what we want and a is going to be removed.

You plan to through machine the area a by ultrasonic machining. So, you want to respond to the world tender by you know hoping, for you say that I will make it and this will make cost. What will be A cost? First of all what is your technical details for making it you will be using ultrasonic machining to remove part A. So, if you remove part A; that means, you have to have a tool exactly of the shape A with the B part not there hollow. So, while using. So, you want to use USM and some data is given about USM, if there is a tool of 100 square millimetres mind you this particular tool is not 100 square millimetres it will having some other area of itself.

So, while using a tool of 100 square centimetre square millimetre area, your ultrasonic machining is capable of removing logo metal at the rate of 100 cubic millimetres per minute given for USM MRR is equal to k 1 into f to the power 0.75 into a to the power 0.25, where k is a constant k 1 is a constant a is the area of the tool in square meters. And f is the static load equal to 10 Newton's that I am providing; however, you have a competitor a Chinese company plans to cut, along the border between A and B Chinese company says, says that I am not going to use USM and say why they will say we are free to use whatever process that we want to imply. Yes ultimately we are you know suppose to give only the end product whether I use USM or AJM or whatever it does not really matter.

So, Chinese company plans to cut along the border cut along the border between A and B by abrasive jet machining which can cut one millimetre thick logo metal at rupees as sorry as the speed of 80 millimetres per minute. That and if the relation is given as v is equal to k by d, where k is a constant and d is a sheet thickness and v is the cutting speed. And so, some data is given and the relation is given where and the logo of area B is of 9.5 square centimetres and china has a border of 3600 kilometres and an area of 9.5 into 10 to the power 6 square kilometres.

These are you know actual about china as you see on the internet these data. And take the scale as area on logo by actual area is equal to length of border and logo by length of actual border square. So, if the cost of both the processor is rupees 100 per minute answer the following. So, I hope the question is quite clear, you want to use USM Chinese company wants to use AJM and now you have to find out which one is going to be more costly. The one which is less costly will win the world tender.

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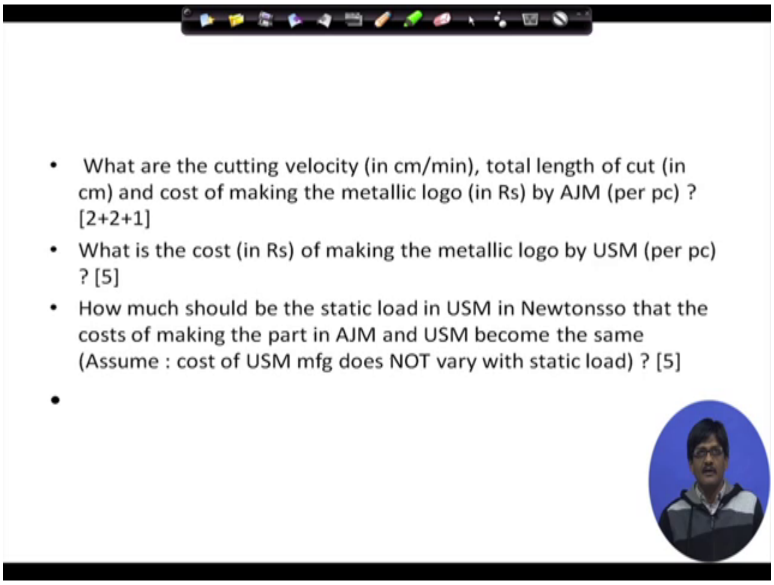

What are the cutting velocity total lengths of cut and cost of making the metallic logo by AJM, you have to find out what will be the cutting velocity what will be the total length of cut and the cost of making the metallic logo [FL] it should be. What are the maximum cutting velocities? When we cutting and slowly. So, what is a maximum? Next what is the cost in rupees of making the metallic logo by USM?

How much should be the static (Refer Time: 26:34) in load in USM in Newton's. So, that the costs of making the parking AJM and USM become the same. Assume that cost of USM manufacturing does not vary with static load. So, you can increase static load, but you have to use that static load So that AJM cost and USM cost become the same. This is take home assignment and you may or may not do it if you do it, you will come up with an answer you can send it to me and I will disclose the correct answer at that time, there will be a time given. So, I am not disclosing the answer, if you feel that I should disclose the answer because there is no marking I am ready to do it, there is absolutely no problem.

Next we have another problem.

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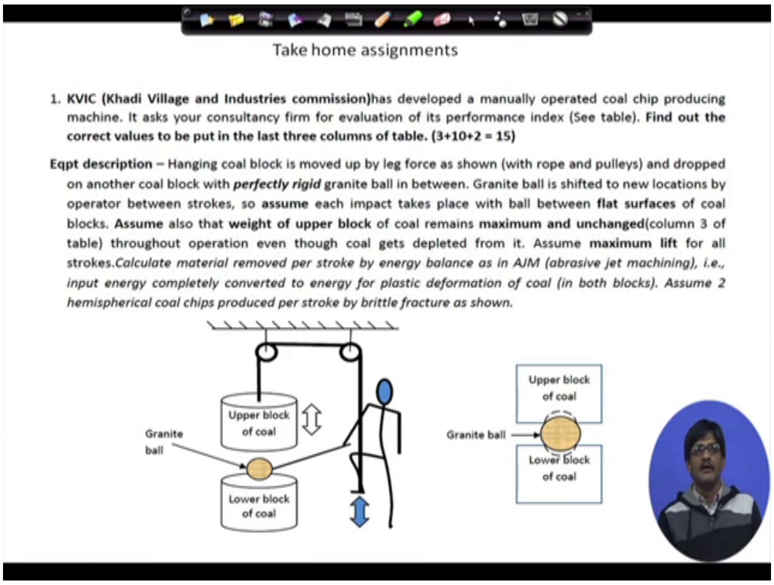

All these take home assignments will be you know for your interest. And therefore, they will not be conventional you know run off the mill experiment run off the mill questions, KVIC, which reads as kadhi village in industries commission has developed a manually operated coal chip producing machine. So, for the villages it says that you can produce chips of coal from a huge piece of coal and that you can sell in the market for that they are they have designed a very simple machine. And they want to give it to those people needy people so that they can make a living out of it. It asks your consultancy form for evaluation of it is performance index find out the correct values to be put in the last 3 columns of the table the table is in the next page.

Let us see how it runs equipment description hanging cold block. So, there is an upper block of coal, hanging coal block it is moved, but up by leg for see there is a rope and there is a there are 2 pulleys and this is the person you know putting his foot down. Literally he is putting his foot down and putting his foot up and this is going up going down and in between he has put a granite wall, which he can shift and place at different locations and therefore, there are 2 just like ultrasonic machining There are 2 chips coming out one from the upper coal and one from the lower coal.

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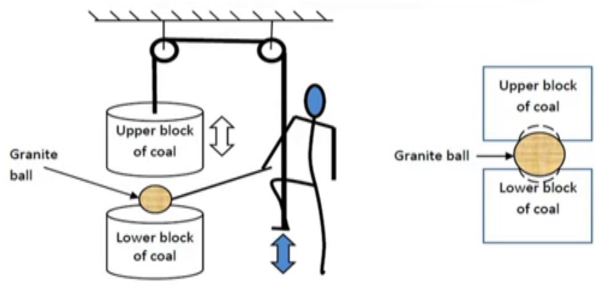

Number of full strokes per minute	Maximum lift of upper block of coal in every stroke (mm)	Maximum weight of Upper block of coal (N)	Hardness & density of Coal in GPa, kg/m^3	Diameter of granite ball (m)	Maximum energy input per stroke (joules)	Maximum Material removed in kg of coal chips created, per stroke (2 hemispheres)	Performance index = Maximum weight in kgs of coal chips removed per unit Energy input in Joules for 1 shift of 8 hours
30	600	400	0.25 & 750	0.150	??	??	??

And in that case these are the chips getting formed and what has been said is that, assume that the weight of the upper block remains maximum and unchanged, naturally if these chips are coming out it is weight will increase decrease.

But assume for the sake of the sum that is remaining same. And an even sorry assume maximum lift for all strokes calculate material removed per stroke by energy balance as in AJM. So, if you are lifting the coal to a particular level it gains in energy and when you bring it down it will give up this energy and this energy just like in AJM will cause these 2 indentations and you have to calculate how much are these indentations from there you have to find out the volumes of those coal chips. Assume 2 hemispherical coal chips produced for stroke by brittle fracture as shown.

And this is the table the table reads number of full strokes per minute will be 30 maximum lift of the upper block of the coal in every stroke is 600 millimetres. Maximum weight of the upper block of coal is 400 Newton's. Hardness and density of coal in GPA giga pascal and kg per millimetre cube is 0.25 and 750 diameter of the drainage ball is 150 at 0.15015 millimetres. The meters maximum energy input per stroke you have to find out, maximum material removed in kgs of coal chips you have to find out, and performance index you have to define, ok.

This is the second assignment take home assignment question. So, with this we come to the end of the 14th lectures. So, we will meet for the 15th lecture after some time.

Thank you.