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 - 16
AWJM – Introduction

Welcome viewers to the 16th lectures on Non-traditional Abrasive Machining Processes. And we have already covered Ultrasonic Machining and Abrasive Jet Machining. And today we are going to take up abrasive water jet machining. In abrasive water jet machining first we have to you know talk about water jet machining, what it is and after that we will be talking about abrasive water jet machining.

Water jet machining means that just like we were using pressurized gas in case of abrasive jet machining. We will be using water under pressure, and allow it to you know expand into not expand allow it to convert the pressure energy that is the pressure head to velocity or kinetic energy velocity head. And that way get a tremendously high speed of a jet of water emanating out of a nozzle. Now what can we do with this jet of water at high speed? Can we cut thick metal pieces? Not exactly, with only water we have to you know restrict our self selves to the machining of you know materials like say wood leather frozen meat etcetera etcetera, and metal foils also can be you know machined with water jet machining equipment.

Now, how much will be the speed of this water jet? It will be roughly you know around 1000 meters per second; that means, one kilo meter in one second, that is quite an abrasive speed. And what is the pressure generally that will be applied in order to you know get this particular speed attain this particular speed range. This will be around say 4,000 bars 4,000 bars.

So, in order to achieve such a velocity head, in order to achieve such a velocity head what we will be doing is we will be first of all attaining a very high pressure.

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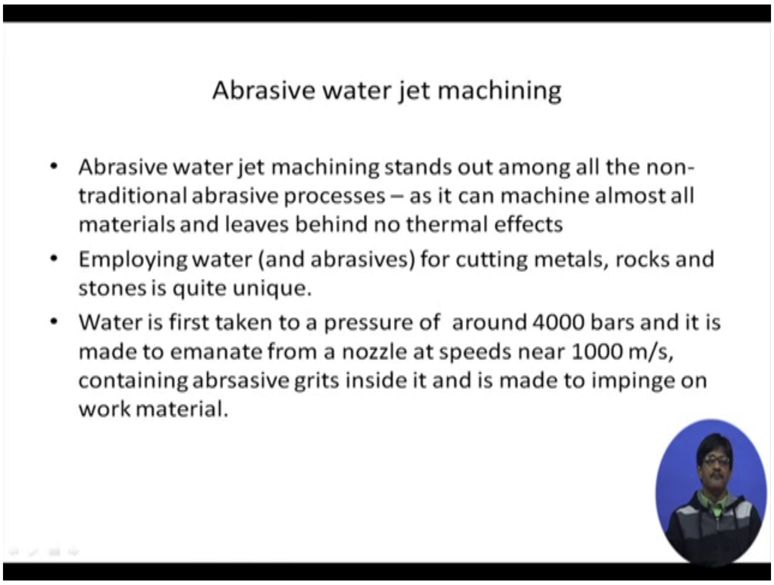

And after that so first of all comes the question that how do we attain this pressure. But before that just a few sentences in you know by way of introduction abrasive water jet machining stands out among all the non traditional machine abrasive machining processes, in what way? Abrasive water jet machining can machine almost all materials, while ultrasonic machining and abrasive jet machining they are rather restricted in the application to glasses ceramics brittle materials which are generally non conducting etcetera.

But for abrasive water jet machining just anything can be machined and the added advantage the plus point is that, it leaves behind no thermal effects. What do we mean by thermal effects? If we are using say wire electrical discharge machining or laser beam machining or oxygen cutting etcetera. In these cases in all these cases we will have quite a bit of thermal effects you know in the cut material in what way the laser will be using very concentrated you know high energy density beam So that large fraction of it will be absorbed by the work piece which will be which will be reaching quite high temperatures. And for that lot of thermal effects might be might be seen in the work piece.

In gas cutting also we are having as you know a burning of acetylene So that say in case of mild steel we form oxides which are liquid. At a lower temperature than that of the melting temperature of the material So that the oxide is created and it flows off due to gas pressure and that way cutting is achieved. So, naturally a very high temperature is attained there also there will be thermal effects. Thermal effects can be detrimental because it can change the properties locally near the cuts while the basic material has different properties. And wire electrical discharge machining can make can produce temperatures which are you know to the tune of 1000s of degree celsius and quite; obviously, we are going to have some thermal effects.

So, thermal effects are quite detrimental in the sense that they produce property differences with the basic material and it is really a very big advantage that we will have almost no thermal effects out of abrasive water jet machining, because the water itself serves as the cooler while we are cutting we are cooling. So, we will be you know employing water to cut metals rocks and stones which is quite unique this idea of course, we are using abrasives along with water, but it makes abrasive water jet machining quite a quite a unique tool.

So, as we discussed the battery is going to be taken up to a pressure of around 4,000 bars, and from where it will be emanating from a nozzle and attaining 1000 meters per second or so. And if it is if abrasives are put inside the velocity will be slightly less, but still of the same order ok.

So, what can be you know, why should we look for abrasive jet machine abrasive water jet machining or abrasive jet machining? In what way can we have it is applications? I can name one or 2 applications on the you know on the higher end. So, that is say for example, when we are thinking of rapid prototyping with, with you know first order approximation now what do we mean by that let us let us have a quick look. If you know If you if you look at this particular drawing.

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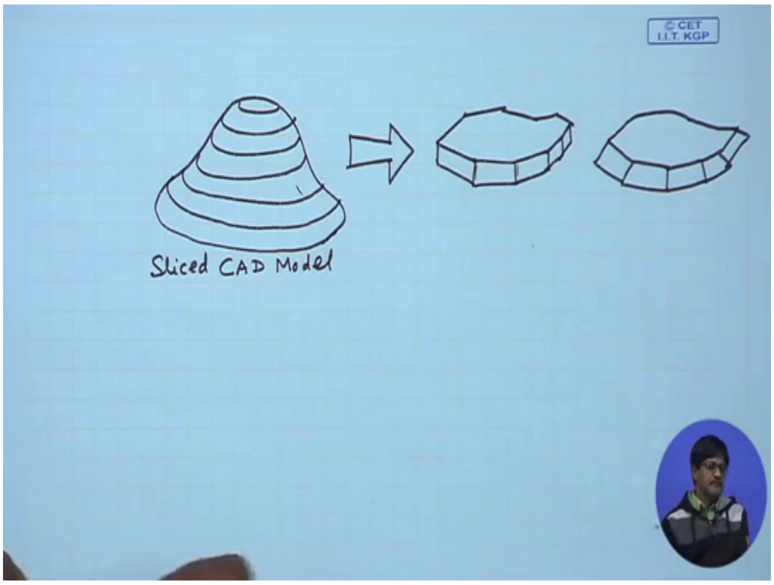

Suppose I am doing rapid prototyping by cutting out laminates; that means, layers of material and then I am sticking them together, in what case would I be doing it, I might be doing it for layers of material let me draw an example.

Suppose this is the particular body that I want to develop. So, I will be you know cutting it, into layers I mean I will make a cad model and I will cut it into layers. And then I will be forming I will be trying to physically realize these layers and stick them together and get this job.

So, this is you know virtual cad model, I will slice it. So, sliced cad model, these slices I now try to realize physically, how can I do it? Generally when they are realized they come with an approximation, what is that? That is called 0 order approximation. You know some cutter has been used to cut this out of a sheet of material or plate of material looks like this.

Now you can immediately point out 2 defects here, one is that these are straight cuts that really cannot be avoided in case of CNC technology, straight cut most of them. It might be able to you know what you call it? I will be able to remove some of them by curvy linear paths if they match, but some sort of approximation has to be tolerated. But yet another you know tolerance which we are proceeding here which we are seeing here is that these walls are vertical while these walls are inclined. Inclined and curved and these are straight and vertical. If we have a 5 axis water jet cutters in that case we can develop something of this type.

These will still perhaps we you know straight, but these can be inclined. So, water jet cutting will allow us to cut this sort of a layer in which we are simply using a 5 axis water jet cutter. Of course, in the same way we can use other cutting heads like laser cutter. And if you know technology is good enough we can use a wire EDM also, but these cutting technologies abrasive water jet cutting proves to be a very good member in this particular group. So, in the same way profile edge lamination tooling, where can also employ a water jet cutting device in order to realize these layers. So, this is by way of application.

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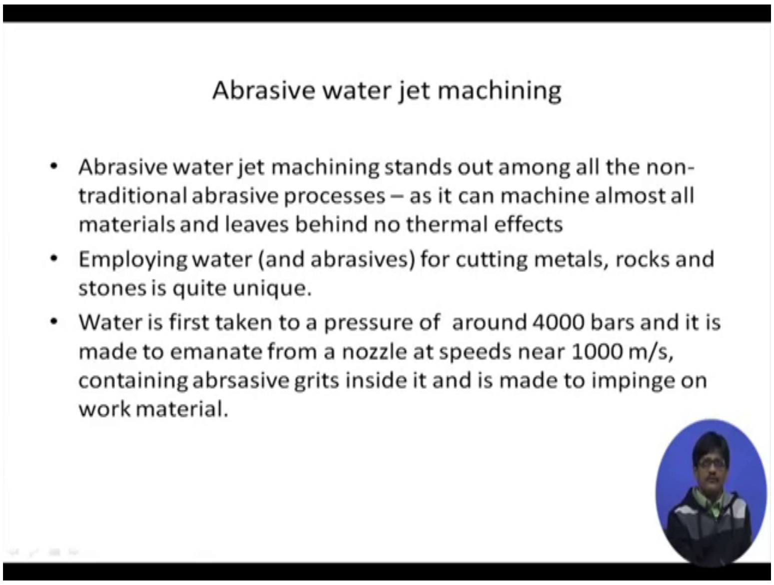

There are other applications also we will be going through a detailed discussion on the applications later on. Let us have a look at the machine, what does the machine consists of?

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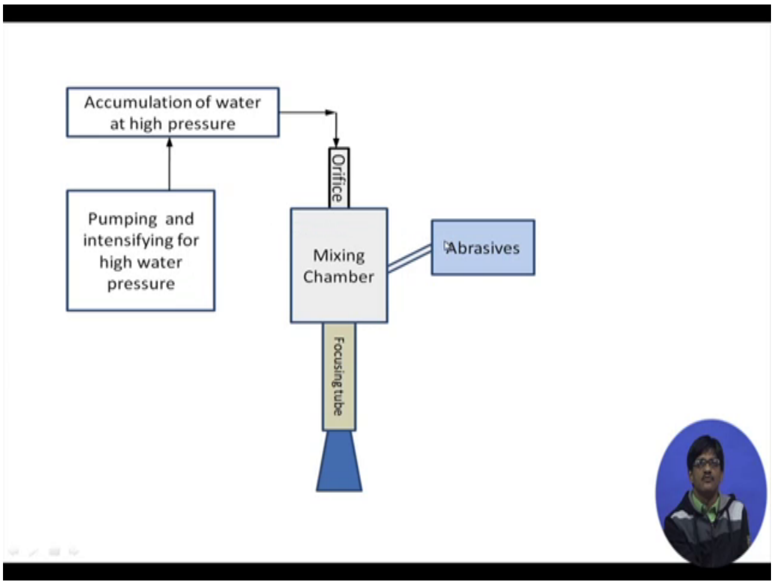

First of all it is understood that we have to have to develop a very high pressure very high pressure of water 40,000 sorry 4,000 bars. It is really not a very low pressure indeed. So, we pump and intensify the water to a very high pressure. How we do it we are going to come in the next slide, but let us first try to understand the overall idea. Once we have developed the pressure we accumulate the water at a very high pressure to remove pulsations and you know, pulsations in the pressure; that means, if we are using say a reciprocating device. This reciprocating device will develop the pressure recede develop the pressure so on and so forth.

So, that there will be pulses of high pressure in the supply line. In order to remove that just like a flywheel removes you know surges in energy. So, in the same way we can get the water to accumulate at high pressure in a reservoir, which will be removing such pulsations in pressure.

After sufficient pressure has been developed we can let it out through a very small orifice here. This orifice allows the water to come out at this particular point, what sort of diameter are you talking about? We are talking about a diameter of say 0.2 to 0.4 millimetres, 0.2 to 0.4 millimetres; that means, 200 microns to 400 microns such a small orifice will you know drilled into say some jewels. That means a very hard stone. Or so through that particular orifice water is allowed to the pressure is released and for all practical purposes we can assume that it comes out into the into atmospheric pressure So that the whole pressure head gets converted to velocity head. Mixing chamber means at the mixing chamber abrasives are entering into the water stream.

Why So? Because of the different types of water jet or abrasive water jet machines available we are here looking at the entrainment type; that means, abrasives are drawn into the water line at the mixing chamber. So, they are not pre mixed, but they get mixed up in the mixing chamber. So, in the mixing chamber what happens? A sort of you know vacuum is created vacuum is created by the ratio of the diameters of the orifice and a focusing tube So that a partial vacuum is created.

So, that the abrasives are entrained or drawn into the mixing chamber by this suction into vacuum. And they have a they have to pass through this abrasives and the water they have to pass through together through this focusing tube, where gradually the abrasives teacup the you know they are accelerated to the final outgoing velocity of the combined jet. And when it comes out the abrasives have reached the same velocity as that of the water coming out at the exit of the focusing tube ok.

So, essentially we are having abrasives coming in as the focusing tube is you know releasing the water into the atmosphere, atmospheric pressure is existing there and as the in the in a mixing chamber through the orifice water is coming out through a very small diameter. And abrasives are getting drawn into the particular stream of water and therefore, mixing is taking place. And finally, completely it is taking up the energy in the focusing tube the abrasives ultimately it is coming out together.

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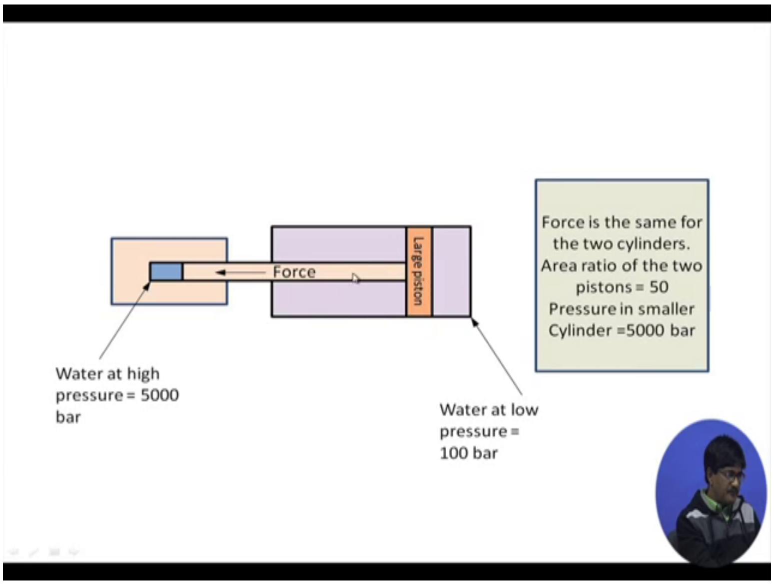

So, when this particular water is you know initially it has to be pressurized this sort of a device is used. What is this? Water is here in this small confined chamber, at present it is pressure is not very high, but pressure can be build up by this device what is this device? There is a large piston here and this large piston is connected to you know a rod, this shaft connects up connects up. These 2 cylinders this cylinder piston cross section area is very small. And their ratios might be 50 is to 1, 40 is to 1, like that.

So, suppose this sectional area is 50 times that of this particular section, water is filled inside and see at 100 bars pressure you know this piston is applying I mean we apply pressure on this side So that this piston is getting pushed towards this side. So, if there is 100 bars pressure multiplied with the area let us call it a 1. A 1 into 100 bar will give us the force which with which this piston is getting pushed. So, it transmits that force to towards this side and again this force is applied on this particular what you call it piston on this side.

So, when the pressure is being you know created at this end, the force which was developed it gets divided by a much smaller area 50 times less. And therefore, the force which was developed here I mean the pressure which was developed here ultimately it gives rise to a much higher pressure 50 times higher pressure due to this area difference, why because 100 into a 1 divided by a 2 is equal to 100 into a 1 by a 2 which is 50. So, 50 into 100 takes here occurs here, much higher pressure is created here by the simple system; and if we look at the full picture.

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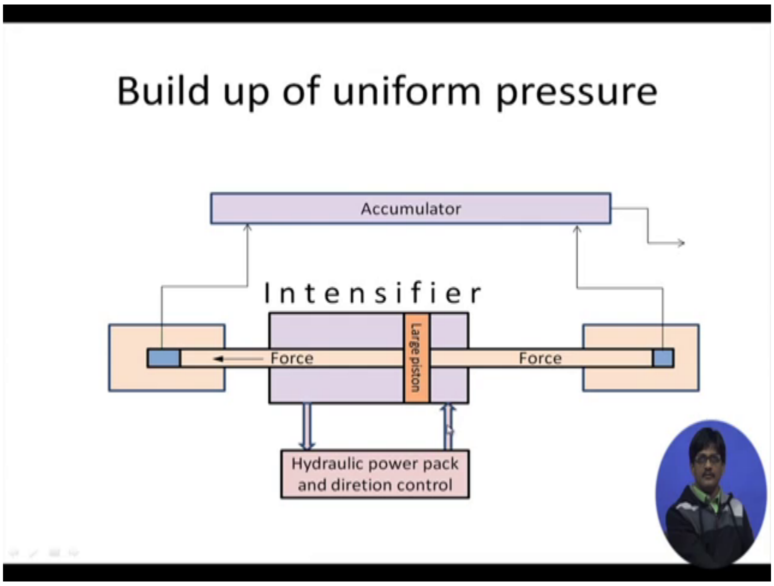

Let us now have a look at the base I mean schematic of the supply of high pressure water. So, first of all hydraulic power pack with a direction control valve it is responsible for putting in you know pressure at the I mean high pressure water; that means, which is coming out of the hydraulic power pack, say at 100 bars it is coming here.

And the same thing that we saw here with the difference is that, once it presses to this side and on the return stroke it presses upon this side and there are 2 similar cylinders or the 2 sides. And the power I mean the water which is at very high pressure now, that is delivered to a central reservoir called the accumulator. So, that it is not just you know pulses of high pressure occurring at a at regular intervals in time no.

Roughly we have more or less uniform pressure being developed with respect to time, once the stroke is taking place on this side. So, we are having a pressure surge increase in pressure and supply to the accumulator at high pressure we are having the return stroke occurring this way when the direction control valve has you know shifted the supply and you know discharge to the sum. When it has switched them then they starts moving towards the right hand side and water supply takes place at high pressure from this point.

So, this way we are removing the effect of surges or pulsations in the high pressure which is being developed and from the accumulator ultimately it is water is sent to towards the mixing chamber if you remember. So, from here we are going to the mixing chamber. So, as we discuss the high pressure head of the water. So, developed is ultimately converted to velocity head, this is done by passing the water through analysis etcetera we have discussed these things.

So, let us look quickly at the conversion; that means, velocity which can be developed is calculated, this way v square is equal to 2 P by rho why because from bernoullis equation if they have a quick look and the calculation.

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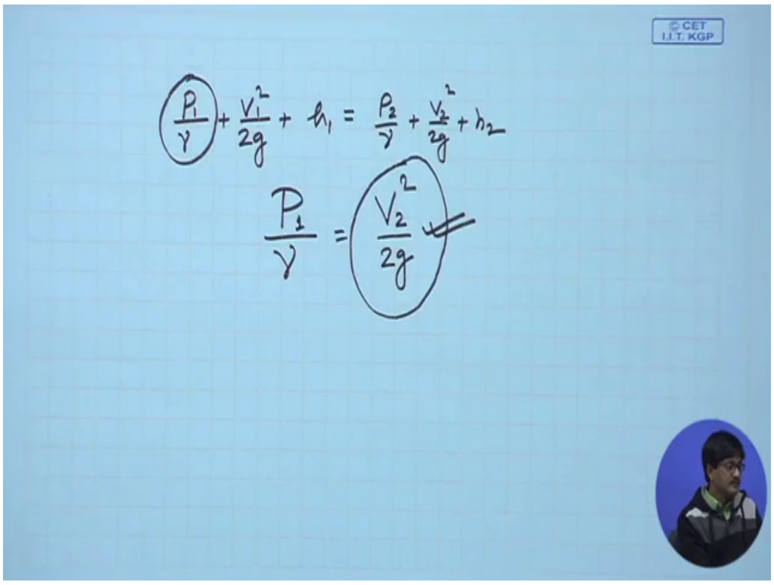

Let us say we have P by gamma plus v square by 2 g plus h velocity head pressure head and this is the height. So, this one will be equal to if we take another position P 2 by gamma v 2 square by 2 g plus h 2. We start from a place where there is absolutely no velocity, no height same height as the previous one. So, in that case it is called stagnation the water is starting from stagnation and only the pressure head will be existing.

So, in this case such a thing is happening when the accumulator is letting out the water for you know expanding to atmospheric pressure. So, in that case we have P by gamma where P is equal to that high pressure, that is equal to v square by 2 g P 1 by gamma is equal to v 2 square by 2 g, what is this? Atmospheric the velocity that is obtained when the water comes out at atmospheric pressure; what about the other terms? And in the atmospheric pressure we are considering gauge pressure to be 0.

So, this one is the velocity that we are going to get, and that is what we have written here.

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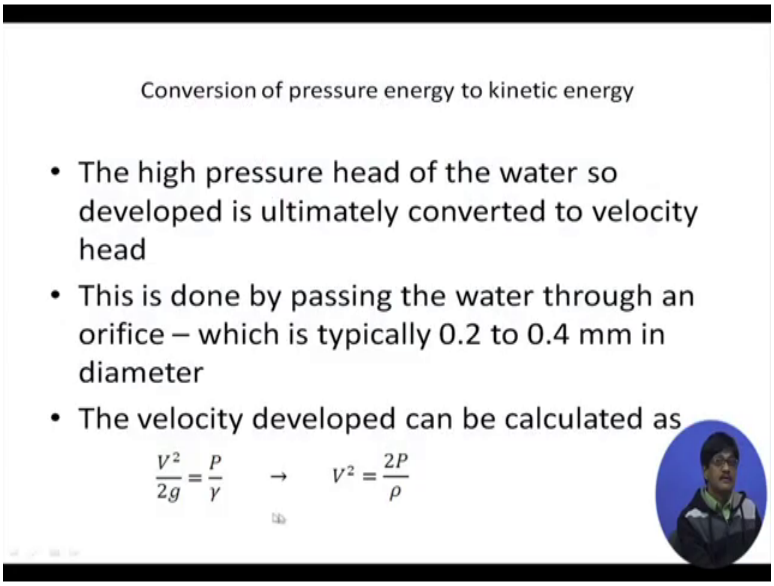

Let us look at this v square by 2 g is equal to P by gamma and therefore, if we remove the g from the expression we have v square is equal to 2 P by rho ok.

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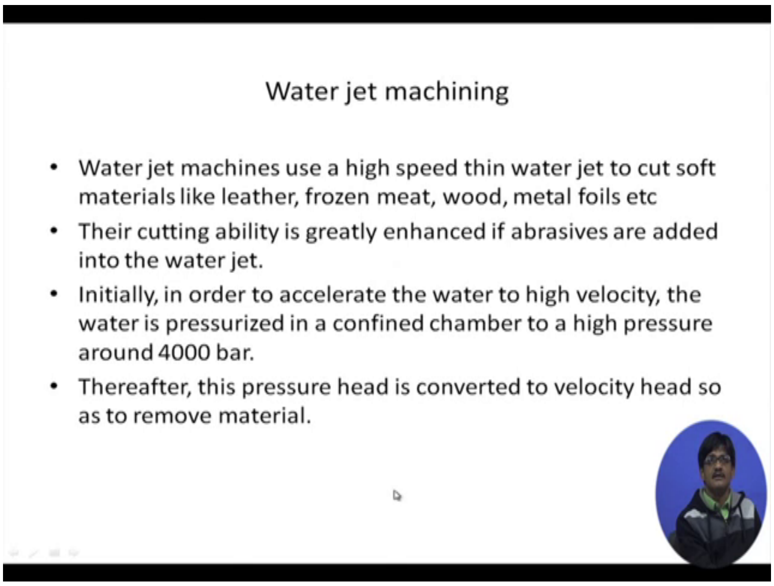

So, this thing we have already discussed. So, I am skipping this one.

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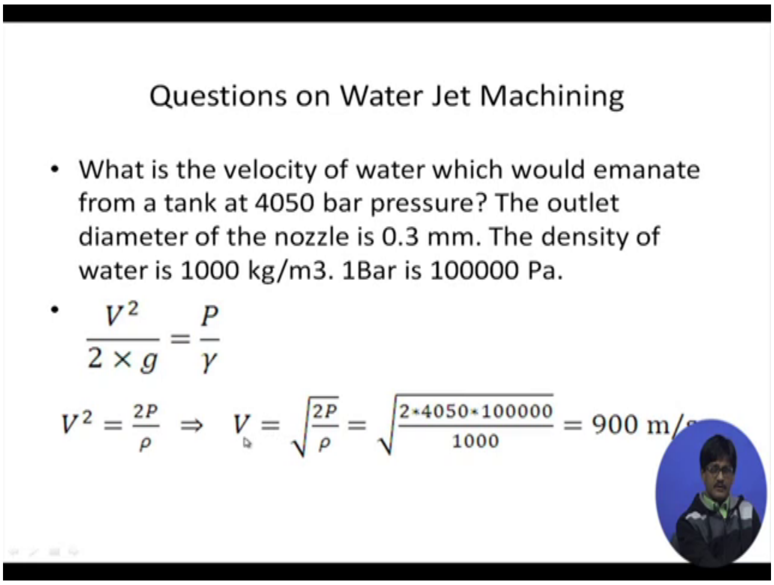

So, let us let us quickly have a look at the calculations. What is the read it is a problem in case of water jet machining. What is the velocity of water that would emanate from a tank at 4050 bar pressure? The outlet diameter of the nozzle is 0.3 millimeters the density of water is 1000 kg per meter cube, one bar is 10 to the power 5 pascals. One bar is given to be 10 to the power 5 pascals.

So, we start with our original expression what was that P by gamma is going to be square by 2 g or v square is equal to 2 P by rho. So once we put in the values we are going to get an estimate of the velocity, mind you up till this moment we have not put any abrasives inside the water stream.

So, let us see what we have done. First of all the pressure is 4050. And we then we have conceive converted into pascals. So, we have 10 to the power 5 here, divided by the density of water that is 1000 kg per meter cube. And after calculation the velocity of water is coming out to be 900 meters per second, 900 meters per second. So, with this velocity of water you can do a lot of cutting.

And I will just give you a corollary of this that is suppose you are standing at the basement of the tallest building in the world and you have come as a representative of a water jet machine selling company, and you want to demonstrate you have you have come with the intention of demonstrating the work of a water jet machine. And then you find that the consignment bringing your equipment it is not arrived from the airport due to some you know some confusion. So, at that moment you decide that in order to give a demonstration of water jet machining, you will use tap water and the tank is at the top floor say it is very tall building say burj khalifa in the middle east.

It is most probably around 900 meters high, if I am not wrong, hopefully I am correct. So, if you use tap water with the tank at the top floor, then find out whether you are going to attain the velocity in the range of typical water jet machining velocity So that you can you can go through go on with the demonstration find out. Let me anyway continue with since I have a few min minutes, I can continue with one or 2 points from the next lecture.

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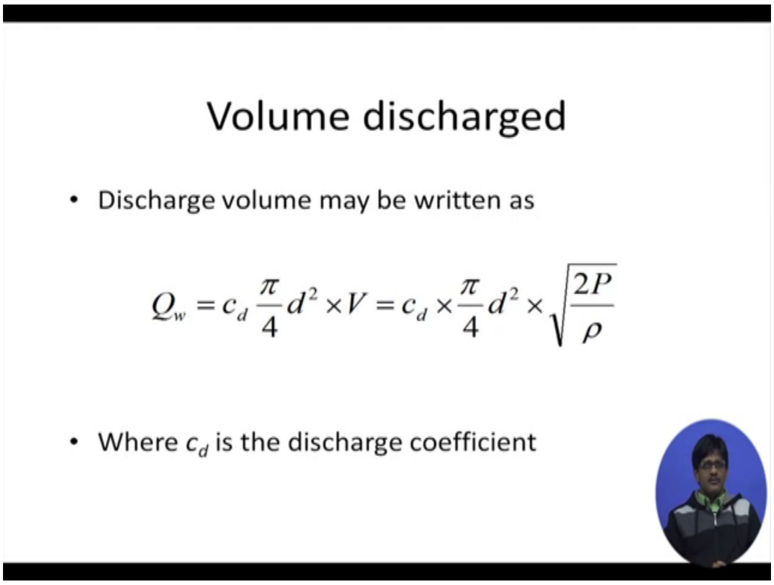

So, that particular problem you can find it out most probably you will come around you know speed will come around. So, first of all it is your duty to find out the height of the building I do not remember it might be 848 meters or I think So, 848 meters. So, you can put v square by 2 g is equal to h 1 and therefore, v square is equal to 2 g h and from that your velocity will be coming out. And In fact, we can we can have a quick try at calculating it ourselves give me one moment. So, let us have a do we have excel here, yes see quickly that is right.

So, let us try out the calculations ourselves and see what sort of results we are getting. So, this is equal to v square equal to 2 g h that is good. So, this is equal to root over square root of 2 multiplied by 10 multiplied by let us make it 900 sorry, and the velocity is only 134. So, therefore, it is absolutely impossible to demonstrate the effect of I mean demonstrate the working of water jet machining using tap water and the ground floor of the tallest skyscraper in the world you have to have some pressurizing equipment. And also we have not considered the tremendous amount of losses which will occur due to flow of water from the top floor through pipes up till the ground floor. That will take half of your energy away So that you cannot really carry out machining with tap water in any case ok.

So, let us go back to the yes, we will just have a quick look at this and then stop discharge volume now. Discharge volume means what? Since we are having water emanating at a particular velocity we can also estimate the discharge. The discharge is equal to simply velocity into cross sectional area into the discharge coefficient. So, this is the discharge coefficient and this one is the cross sectional area, and this is velocity it can be expressed in pressure head. And therefore, we can have very you know simple numerical problems based on these.

So, let us stop here, and we will continue in the next lecture.

Thank you very much.