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

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Lecture – 19
AWJM - Application Equipment details

Welcome viewers to the 19th lecture of the online course Non-traditional abrasive machining processes like USM, EJM and AWJM. So, we have finished almost all the you know different items like USM and EJM has been completed and AWJM which means abrasive water jet machining that we are almost on the way to completion sorry.

So, today in this lecture we will be learning about some of the applications and equipment details of abrasive water jet machining that we have not completed in the previous lectures. We have had quite a lot of discussion about some of the equipment the working principle the analytical derivations and the mathematical some numerical calculations also. And today lets tie up the loose ends, so that we will be ready for the last lecture in which we will be extensively discussing some MCQs because after all MCQs other ones through which you interact with the system. So, let us move on right away with our discussion.

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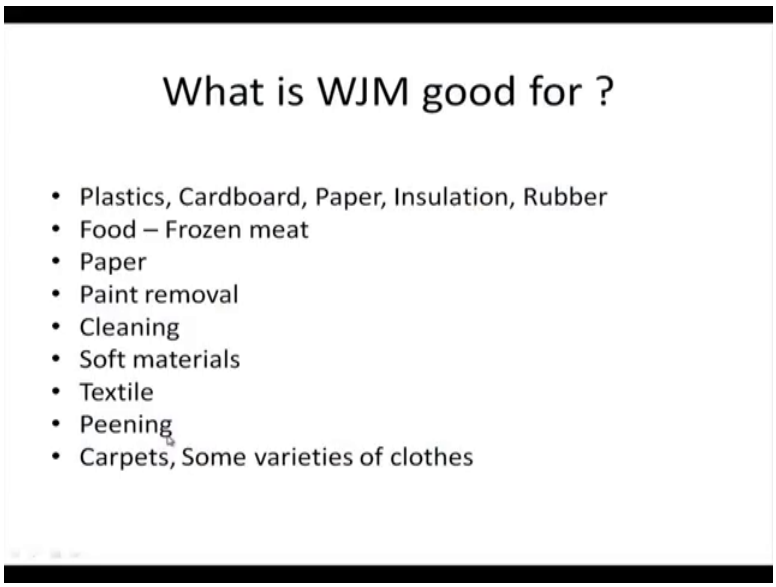

So, these things we have roughly discussed in case there are some points that we have left behind we will quickly go through these points like what is water jet machining good for? Water jet machining and abrasive water jet machining there is a distinction because a water jet machining does not contain abrasives, but it is you know the velocity range of water jet is same as abrasive water jet maybe a bit higher because it is not decelerated by the abrasive content as in abrasive water jet machining. So, plastics, cardboard, soft materials, paper, insulation, rubber food, so in case of food like frozen meat leather etcetera, there is no you no risk of contamination due to abrasives being present. So, water jet machining is extremely suitable for these. So, paper, paint removal, cleaning soft materials then textiles peeling that means, a sort of hardening and carpets some varieties of cloth etcetera. So, in all these cases, water jet machining is quite suitable.

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And what is abrasive water jet machining good for? We have already discussed some of the materials, let us see whether there are some additions which we had not mentioned before like glass, ceramics, composites, semiconductors, polymers, MMCs - metal matrix composites, ceramic matrix composites. Titanium and titanium alloys nickel and nickel alloys, brass, aluminum steel that means, almost every each and every metal. Wood, stone, granite, rocks this is one in which you know it excels over other methods like say EDM, ECM etcetera. Concrete, then a glass fiber metal laminates, turning, drilling, pocket milling etcetera.

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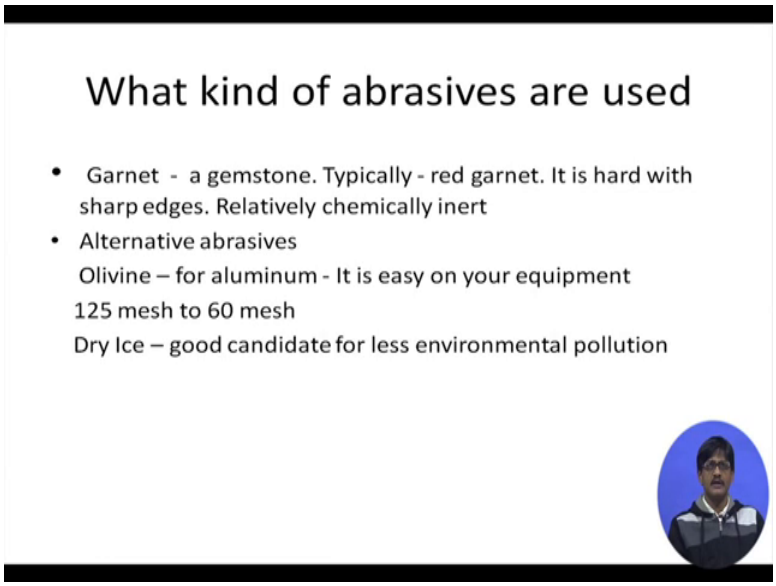

So, what kind of abrasives are used, do we use silicon carbide aluminium oxide, generally not. We use garnet which is generally a gemstone and there can be different compositions of garnets, so we are not putting in any specific composition here. And typically red garnets are used. Why is this garnet used because first of all its available in abundance, it can be found in mines in the sediment you know alluvial deposits, but from the mines the ones which are available they can be very sharp and hard etcetera, and therefore, they are an obvious choice from the mines.

So, if you ask me what is the reason because of which is being chosen because it is hard and it has sharp edges and it is available in abundance and its relatively chemically inert. There are some alternative abrasives like olivine for aluminium and it is you know advantage is that if you are not cutting some very hard very tough material say aluminium, you are cutting aluminum in that case you can do with olivine which is not as hard or sharp as garnet. And it will be easy on your equipment that is your equipment would not be worn down as much as in case of the use of garnets. And generally it is from 125 mesh size to 60 mesh size. And dry ice could be a good candidate because dry ice you know disappears after use and therefore, it will be causing less environmental pollution and contamination.

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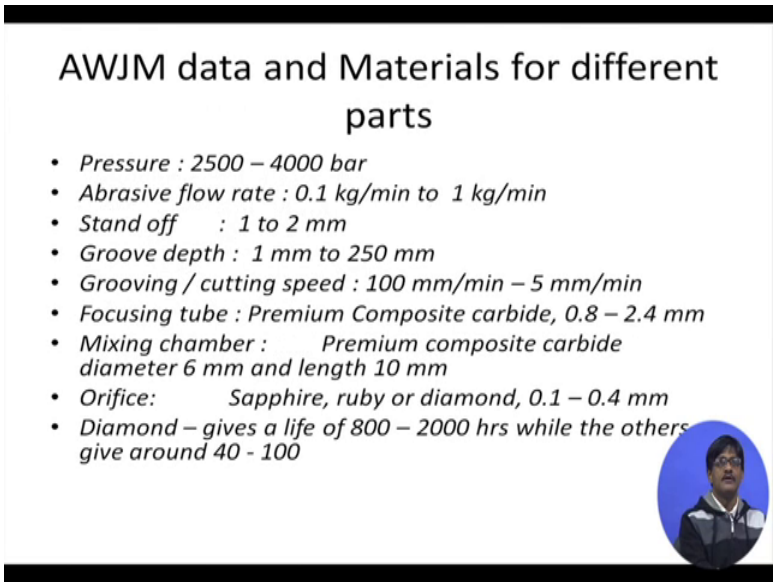

So, some of the data that could be that could prove to be useful to us you know some of the points minor finer points that we have we might have you know missed out. What is the pressure range we have done so many problems with you know 4000 bar generally the pressure range is 2500 to 4000 bar give or take a few hundreds of bars. So, that generally defines you know velocity range that you are going to achieve because as we know v square is equal to 2 p by rho. So, if pressure is fixed and if you are considering water then the initial velocity of water is fixed by the pressure. So, you can immediately say this is the velocity range.

Abrasive flow rate, abrasive flow rate can be as low as 0.1 kgs per minute and as high as 1 kg per minute. In the numerical problems, that we have solved you might find you know reference to abrasive flow rates of 0.6, 0.8 etcetera, etcetera and in some cases we might have crossed it. For the sake of mathematical problems to you know formulated on you know some basic principles we might be going slightly away from it, it does not really matter for mathematical problems, but generally when you are working in for all practical cases when we try to be within this particular limit.

Sstandoff, standoff is generally 1 to 2 millimeters. If you go for higher standoff the you know MRR will fall; if you go for lower standoff the jet might not be able to come out properly. And generally as the jet moves outwards, it will be flaring that means, its diameter will be increasing. So, some long chain polymers are generally added to the

water to stop it from fragmenting and flaring etcetera. So long chain polymers called stabilizers generally might be added.

Groove depth we can handle groove depths between 1 millimeter to 250 millimeters, of course, it must be depending upon the particular material you are cutting. And grooving or cutting speeds can be and you know as low as 100 millimeters from in it and you can go as high as I think it should be 5 meters per minute sorry, so 100 millimeters per minute to 5 meters per minute. The focusing tube the focusing tube is made up of you know premium composite carbides ordinary carbides tube it is 0.8 to 2.4 millimeters.

So, it is interesting to notice that the focusing tube which ultimately you know sends the abrasive water jet into the atmosphere its diameter is 0.8 to 2.4 millimeters while the orifice is 0.1 to 0.4 millimeters. It is through the orifice that the water first comes out from high pressure and enters a mixing chamber the mixing came generally of the diameter of 6 millimeters and the length of 10 millimeters that is also made of premium composite carbide. Mind you the focusing tube and the mixing chamber, they are you know they have to withstand quite a lot of wear and tear because of the abrasives entering into the water stream.

And the orifice is generally made out of you know some very hard and resistant and you know tough material. Common choices might be jewels like sapphire, ruby, diamond etcetera. And diamond gives a like life of say 800 to 2000 hours, but the others do not gets that amount of life. So, this is some typical data about the abrasive water jet machine and as you can well understand. So, it is going to be quite costly from the maintenance side because many parts are going to wear off after several hours of use and have to be replaced.

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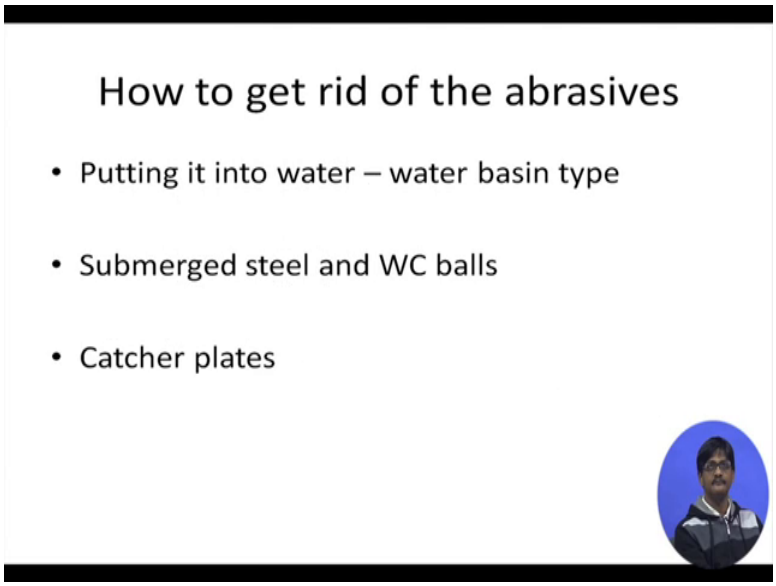

How do we get rid of the abrasives because you know so much abrasive coming out with so much so high velocity if it is open to the atmosphere we will definitely have some environmental your pollution and contamination problems. So, generally it might be put into water, the easiest way put have a water basin into which the abrasives will be put in. And then once it is trapped inside water, it cannot go out into the open atmosphere or there might be some submerged steel and tungsten carbide balls and it gets strapped inside in between these and cannot escape. Or we might have catcher plates, which are so angled that once these abrasives come inside they get reflected multiple times in these catcher plates and ultimately they cannot escape outside.

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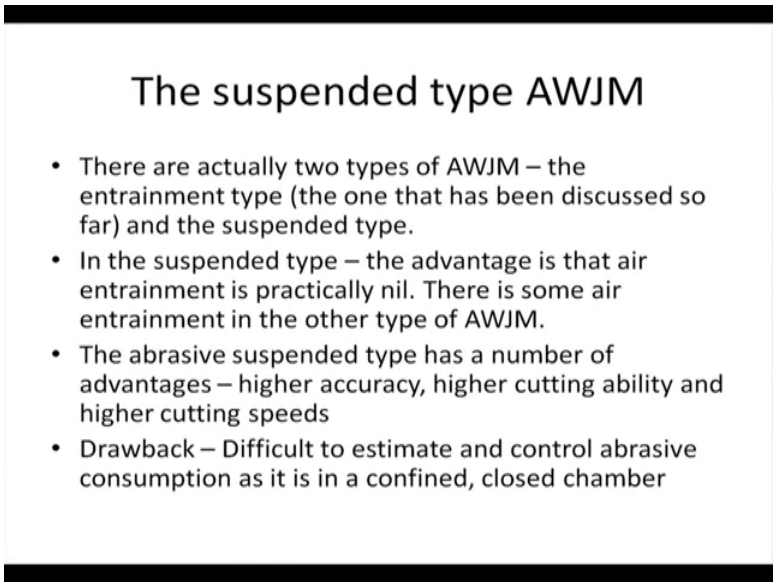

So, it is very important point to you know take care that the abrasives do not get exposed and you know get into the outer environment. Well, all the abrasive or water jet machines that we have been referring to during our analysis mathematical problems etcetera. They for particular type called entrained abrasive jet machines which simply means that when water is coming out through the orifice and entering the mixing chamber, and ultimately going out through the focusing tube into the atmosphere. Inside the mixing chamber we produce a sort of a vacuum, due to its sudden flare in diameter and into this vacuum the abrasives get sucked in and they are entrained into the jet, some air also gets entrained, but this is the way in which we are doing it. Now, obviously, this has its advantages and also its problems.

Determining the amount of you know consumption of abrasives is very easy in this case and the problem is that it is not possible to completely stop the entrainment of air. The more is the amount of air entrained the less will be the efficiency of the machine, but it is possible to you know make a have a machine in which have some equipment in which entrainment of air can be completely avoided. So, as a decision here you the suspended type abrasive suspension jet - ASJ sometimes its referred to in this kind of abrasive water jet machine we have the abrasive water slurry already created and put inside some pressure vessel. So, once again the high pressure water comes in pressurizes this abrasive water slurry to come out and carry out machining operation.

Now, there are obviously, some problems with either system and the problem with this abrasive suspension jet is that it is difficult to control the first of all difficult to monitor the consumption of abrasives in the system and it is difficult to introduce the abrasives into a confined chamber which is under very high pressure. So, let us have a quick look at this. So, otherwise it is very good because we can get higher accuracy, higher cutting ability, higher cutting speeds is absolutely no air entrainment and therefore, it should be; obviously, the better choice but due to this problem that is introduction of abrasives into the system being a problem, it is not that popular.

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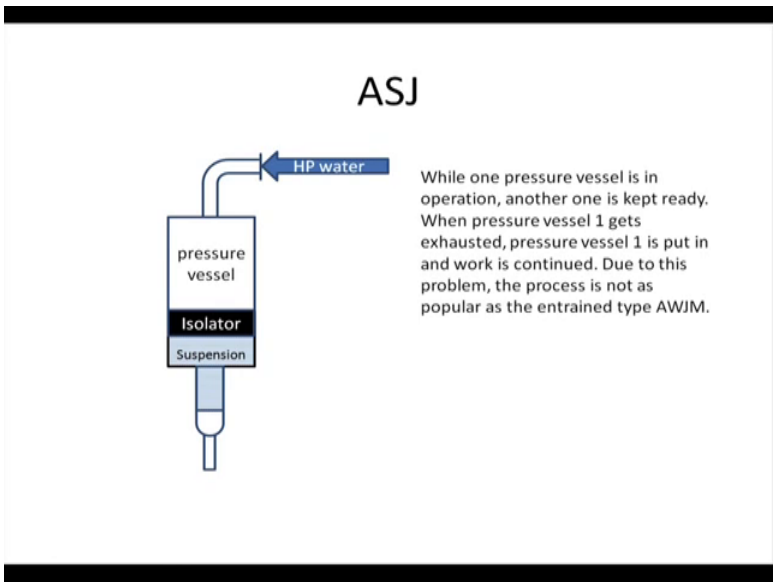

So, in this case what we have high pressure water is still used here, and we have a pressure vessel there is an isolator, and here is the suspension of abrasives in water. And it has an outlet through which ultimately it is led to the machining zone. So, when the suspension is gradually getting depleted it starts from here; when it is full and it is gradually getting depleted it is sometimes difficult to estimate when a replacement is required. So, generally we have a two vessel system, there will be in parallel yet another vessel which is full the moment this is emptied up we have the provision of machining I mean abrasives getting sucked in from the second pressure vessel and this is removed and replaced by a fresh one. So, this way by alternatively taking the abrasive slurry from this vessel and second vessels, the system can be continued you know without any pause, but this is not as popular as the previous one that we have discussed which is entrainment.

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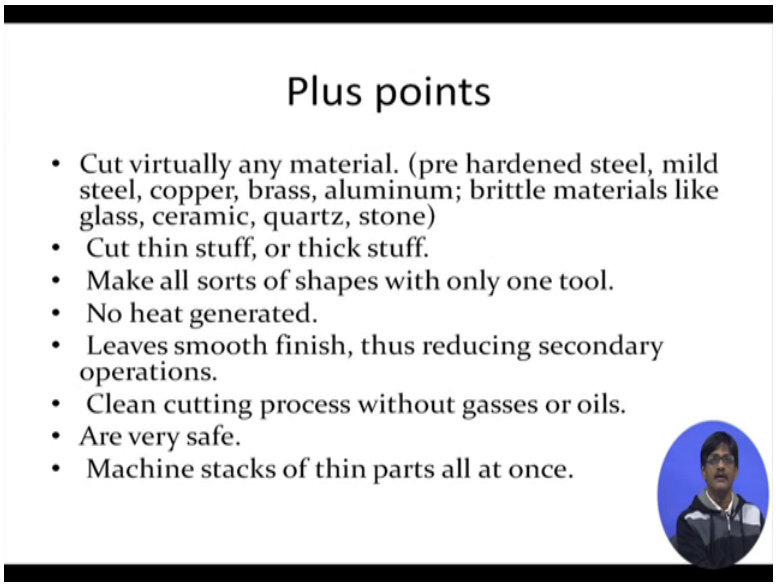

So, before completing this course, we should definitely look at the plus points and the drawbacks of the system. Plus points, as we have discussed before abrasive water jet machines can cut virtually any material like pre hardened steel, mild steel, copper etcetera, etcetera. It can cut thin material, it can cut thick material and it can make all sorts of shapes only with one tool.

There is no heat generated and it leaves the smooth finish. And sometimes secondary operations might not be required at all. And it is a clean cutting process without gases, oil, dust free, debri of material I mean debri of the cutting process this is minimal its quite safe. And last of all it can machine stacks of thin parts all at the same time; and if some material is non homogeneous it would not cause a problem. It might cause a problem in other cases; it might cause a problem then say thermal properties of a body they are varying drastically from one point to the other, it might cause a problem in case of laser beam machining. But any properties even if they be different in this case does not pose that much of a problem in case of abrasive water jet cutting.

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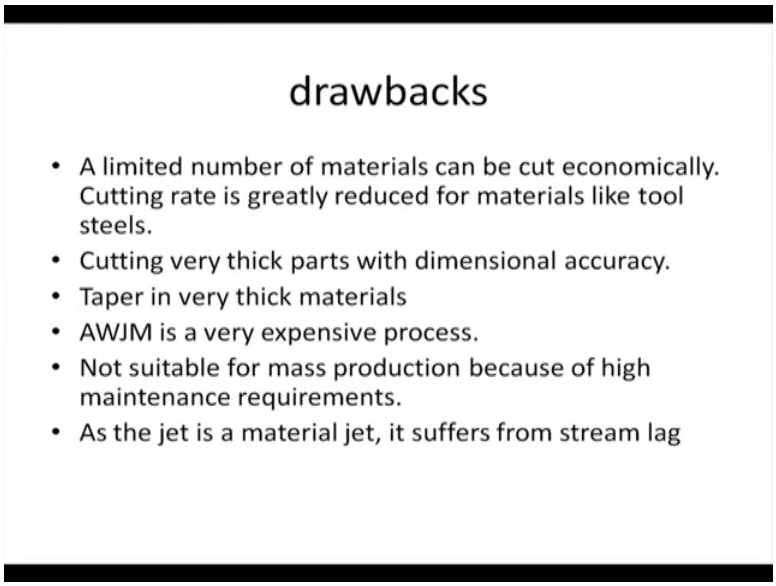

Let us look at some of the drawbacks, because there must be some drawbacks, otherwise abrasive water jet cutting would have replaced laser beam cutting, it would have replaced wire electrical discharge machining process, it would have you know replaced gas cutting where you use excess of oxygen with acetylene to you know burn and remove material. And it would have removed plasma cutting, it would have removed replaced you hacksaw, power saw, band saw and all sorts of slitting solves every cutting operation would have been replaced by water jet cutting because of its obvious advantages that we have discussed previously, but it is not so.

Do you see a water jet machine in just every shop that you have visited perhaps for your industrial training for industrial visits? And if you are associated with some you know mechanical workshop etcetera, do you see abusive water jet machine, is extremely rare. So, there must be some drawbacks. The drawback is that a limited number of materials can be cut economically costs are high I mean rather we will say that for a limited number of materials costs are low, and costs are generally. High cutting rate is greatly reduced for materials like tools steels that means, hard, tough materials etcetera; immediately you will find yes you can cut it, but at a very slow rate. So, this is the main problem. It can cut any material, but it does not cut them either economically or you know at a reasonably fast pace that is one of its main drawbacks because of which it has not got a you know blanket acceptance in the industry.

Cutting of very thick parts with dimensional accuracy it is you know except problem because sometimes what happens is the cut starts you know moving towards one side inside the thick material, it moves to one side, so that you would not get a straight cut. If it is very thick material because we are claiming that it can cut any thickness 120 millimeters, 250 millimeters, but the cut will start moving may you know shift in an angular manner in a curvedly manner to one side. So, taper in very thick materials is also a particular feature which is a drawback and it is expensive already discussed. So, as it has high maintenance requirements generally it is not suitable for mass production and as the jet is a material jet, it suffers from stream lag. So, we have some material moving through. What is the stream lag let us have a quick look.

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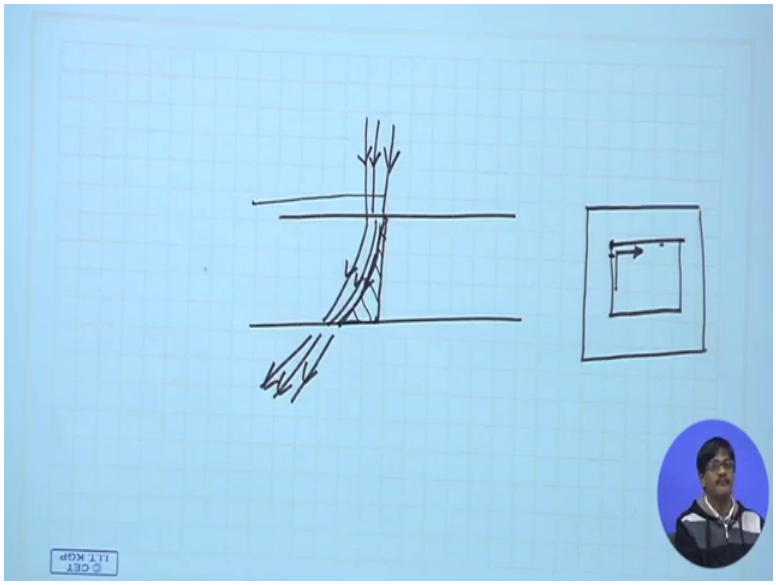

Let us say these are some of the abrasive jets which are coming in, it is cutting this material this part has already been cut and this is the particular pathway of these tools, I mean of these abrasives. Now, this is a problem because when you are cutting the operator or the machine and you know machinist expects that I have cut up till this point, but this material is uncut. Now, what is that, what problem does it create, whenever you are cutting say a corner say this is one part and you intend to cut like this, you will have a big problem when you are turning. So, you are cutting this way you are moving this way, you are moving this way etcetera. You are thinking that you have cut up to this corner when the you know when the cutter reaches like this, but actually it is it is left behind this particular uncut material may be on the bottom, it has cut only up till this point while

you have reached up till this point that is the problem. Because at this point you are going to take a turn and immediately this part is going to remain uncut.

So, the cutting jet water jet is proceeding this way and then say it takes a turn and it starts moving up I mean takes right angle turn. So, it is moving this way and every time it takes a turn it will be leaving behind this material uncut. So, stream lag is unavoidable and it creates you know defects geometrical defects in the work piece, and we have to have some method by which we can remove it. So, this is listed as one of the drawbacks.

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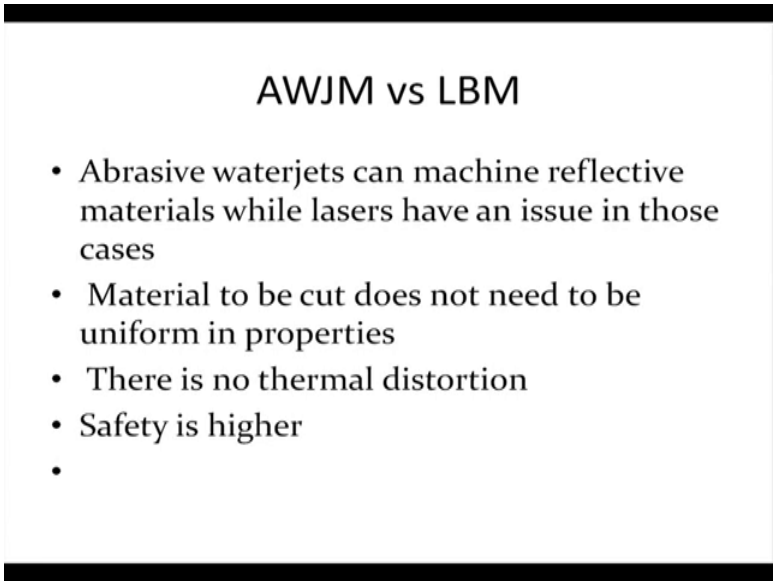

A quick look at a comparative study of abrasive water jet machines and say laser beam machining. Abrasive water jet machines can machine reflective materials, this is a very you know strong point in support of abrasive water jet machines while laser lasers do have an issue in these cases. For example, if you have a very shiny surface of say aluminium silver or some such material, which is you know the surface is very polished and it is having a high reflectance. For example, if you have metals and if you have a carbon dioxide laser at 10.6 microns wavelength you will find most of it is getting reflected. How much is reflected say if I say more than 90 percent would you be very much surprised it can be as high as 95 to 96 percent also in some cases. So, even if you have a laser with kilowatts of energy kilowatts of power would it make any difference if half of it is reflected.

So, lasers have an issue with materials which are highly reflective or rather they are polished to a level, so that most of the power is getting reflected. Lasers might be rendered ineffective, but this is not the case with abrasive water jet machines. They can machine reflective materials. Materials to be cut, material to be cut does not need to be uniform in properties this we have already discussed. And there is no thermal distortion, this also we have discussed because as we know what abrasive water jet machine is essentially having water in it, so that cooling is automatically achieved.

In laser beam machining, in electron beam machining, in electrical discharge machining, in all these cases, you know heating up is definitely one of the issues which has to be addressed, because heating will cause thermal changes and associated property changes, and therefore, material properties will also start vary. And in abrasive water jet machining since we are using very simple system with mechanical components you know safety is definitely higher.

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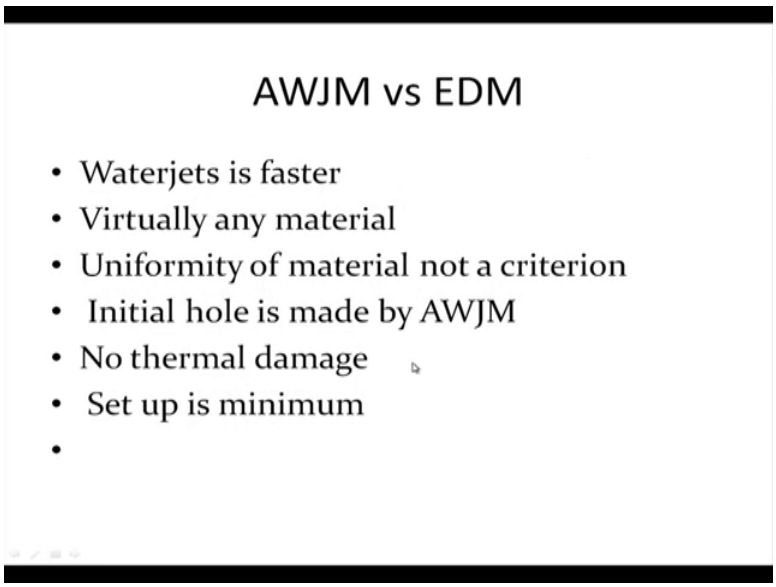

Now, look at say abrasive water jet machines and electrical discharge machining water jets can act faster in what way. Suppose you are cutting and you are using abrasive water jet machines and you are using wire electrical discharge machines, what is the problem with wire cut electrical discharge machines. The problem is essentially you have to carry the current, essentially you have to carry the current through what you call it the wire. And the wire as you know is I am going to have a diameter how much 250 microns and a

250 microns thickness wire can hardly carry the current that you would have liked it to carry and therefore, cutting speeds are generally restricted by this. But with an abrasive water jet cutter you can well reach speeds of 5 meters per minute that is considerably higher than what you can reach with wire electrical discharge machines.

So, you might I will supply as much current as would be required for that sort of speeds, but you are restricted by the wire. So, wire will be having a maximum capacity to carry current that restricts it. Abrasive water jet machines are not restricted by you know requirement of electrical conductivity of the material, and therefore, virtually any material can be cut. And uniformity once again these points they are already known to us. Initial hole is made by abrasive water jet machines itself while initial hole might have to be you know made in case of cutting methods in electrical discharge, wire electrical discharge machining. No, thermal damage and setup is also minimum.

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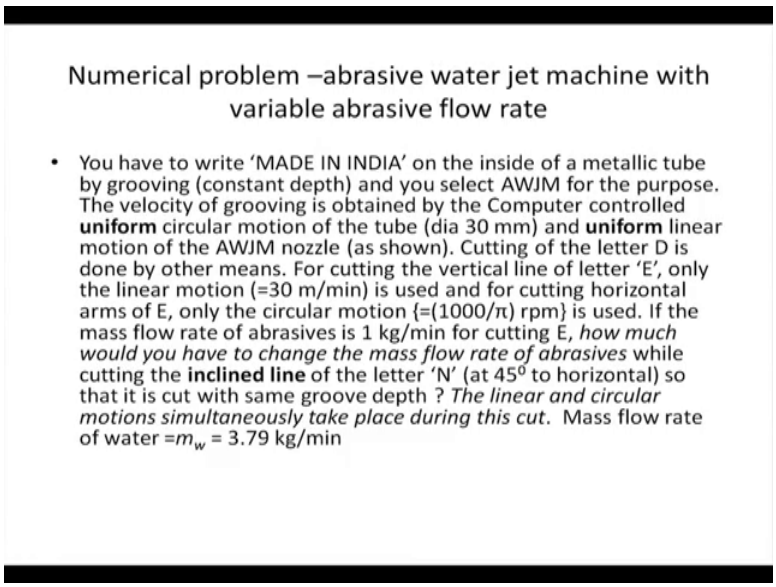

To end it, I just like I am giving you take home problems take home assignment. This is one take home assignment and if you want you can answer it; if you do not want you need not answer it. So, it is just for those students who feel interested to proceed a bit more. So, this has as I said this has all take home assignments are going to have different flavor not the run of the mill problems. So, what do we have here you have to write MADE IN INDIA inside a metallic tube by grooving and these grooves have to have constant depth and you select abrasive water jet machine for the purpose. The velocity of

grooving is obtained by the computer controlled uniform circular motion of the tube where whose diameter is 30 millimeters and uniform linear motion of the abrasive water jet nozzle as shown.

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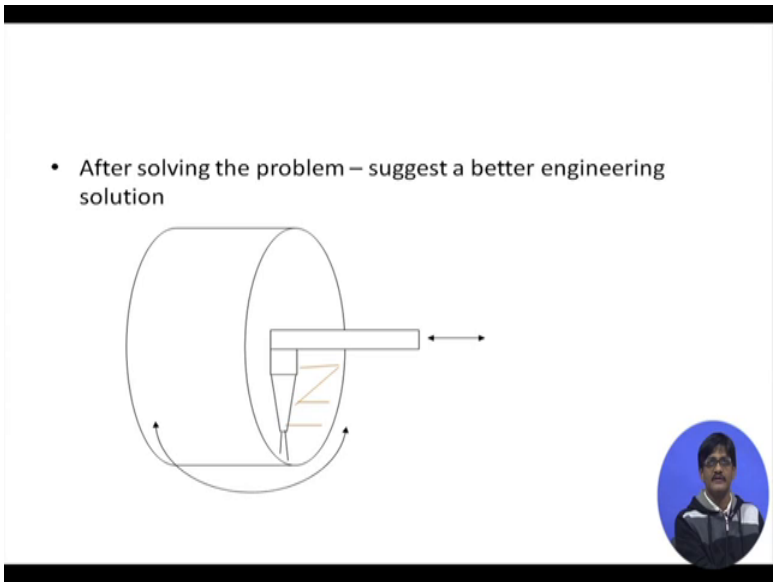

So, let us see what is shown. This is it this is the tube; this is the end and inside you are going to write MADE IN INDIA. So, if you want to write MADE IN INDIA, this is your nozzle which has you know a squarely bench neck this is the jet coming out. So, the motions which are provided here to write all the letters is straight line axial motion of the abrasive water jet machine nozzle, and circular motion of this tube. What is the diameter of this tube, 30 millimeters. What is the speed of this particular nozzle, 30 millimeters per minute. And what is the rotational speed, it is a constant rotational speed either on or off that is let us read it up. Yes, the velocity of grooving is obtained by the computer control uniform circular motion of the tube whose diameter is 30 millimeters and uniform linear motion of the abrasive water is nozzle as shown. What is that uniform linear motion is 30 meters per minute mentioned later.

Cutting of the letter D is done by other means because you know it has second interpolation and that is going to cause problems and we are we should not bother ourselves with the writing of D, but for the cutting of the vertical line of the letter E ok. The vertical line of the letter E only the linear motion 30 meters per minute is used and for cutting the horizontal arms of E only the circular motion equal to rpm 1000 by pi is

used. If the mass flow rate of the abrasive is 1 kg per minute for cutting E, how much would you have to change the mass flow rate of abrasives while cutting the inclined line of the letter n at 45 degrees to horizontal, so that it is cut with the same groove depth. The linear and circular motions simultaneously takes place during this cut mass flow rate of water is 3.79 kgs per minute, let us see.

So, now this makes more sense this is going to move this way thirty meters per minute this has 30 millimeters diameter and this rotates at thousand by pi rpm. And in case of the writing of this inclined and you know line of n both these motions will be taking place together. And at that time obviously, the speed of cutting I mean speed of grooving will be increasing because these two things have to take place simultaneously. So, if speed of grooving increases in that case if the abrasive flow rate is kept constant you will have a problem because in that case the groove depth will reduce. So, in that case what should be increase in abrasive flow rate, so that this groove depth will be maintained in this case. So, try to solve the problem yourselves. I will provide I will disclose the correct answer after the last date of submission of this assignment, this assignment is not compulsory.

One last word, do we face this problem you know in ordinary abrasive water jet cutting, generally not. Generally, in abrasive water jet cutting if it is a simple cutting of a profile we will always try to keep the abrasive flow rate same and the cutting speed same. So, that the cutting characteristics if you are grooving the groove depth if you are cutting in every case everything is uniform. So, this is just a special case to hone your you know mathematical skills in this particular problem solving exercise. So, the solution is here. So, now we come to the end of the 19th lecture. I will meet you for the last time in the twentieth lecture to end up our course.

Thank you very much.