Production Technology: Theory and Practice
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Lecture - 18
Non-Traditional Processes

Hello and welcome to the discussion sessions of production technology theory and practice. In our last session we have finished discussing the machining processes and we have discussed all machining processes, how they are performed what is the mechanics of the machining processes including the grinding, milling and so on. We will start discussing the non-traditional processes.

Let me give you a preamble on what we mean by the non-traditional machining. As the name says that this is not traditional machining. The traditional machining processes we have discussed during our discussions on the machining processes. There we have seen that there is a workpiece and a tool are interacting with each other having a mechanical contact between them and a mechanical force is imparted to the workpiece to create high strain rate of deformation.

Causing plastic deformation to occur in the machining zone and as a result the excess material from the workpiece is segregated. That we called as a conventional or traditional machining. What was the problem in that or why we have to think of some kind of a non-traditional machining? Wwhile discussing the machining, we have said probably only one disadvantage of the machining which is that there is a lot of material wastage.

But, along with that, what has to be considered also is that the metallurgist people are coming up with newer and newer material. Metallurgy people, material science people are specialists inventing those materials that are to be used in the industries like automobile industries, space industries, machine tool industries, making the parts for different machines and so on.

For machining those materials which obviously will have a different kind of characteristics in the sense that their properties are better than the existing materials in terms of hardness, in terms of toughness and so on. Making or fabricating the parts with those materials, the hardness of the tool that we need in the traditional machining has to be very very high, higher than the workpiece material that we are going to make.

That becomes very big problem because in that case, the tool becomes very expensive and in many cases those tools are not simply available, tool materials are not available. Other problems which we face in the traditional machining is that when the shape is very intricate, very complicated or for example, we have to drill very very thin very small holes in a very thin job or a very fragile job or the shaft that we have to machine is let us say the tool of a micro EDM or micro machining.

In those cases, tools are very very small in diameter they are very fragile and they are very slender. In that case, those kinds of slender tools are not possible to machine conventionally by imparting mechanical force, first of all you understand and I also discussed it while discussing machining that they cannot be held between centres for example, if you want to have the turning.

The other processes which can be used for that of course will be casting or metal forming. But again, in those cases the surface roughness is not adequate. There are problems overall in the conventional machining. Apart from that we have to waste a lot of material. So, that forced us to think of some non-traditional machining, it is not a new machining.

Authors claim in the books that this is the newer processes, I mean it used to be newer processes, but no more it is new because it has been invented long time ago. Those new processes are the non-traditional processes, where probably we can machine any material of any hardness, irrespective of the hardness of the material, irrespective of the intricacy of the shape and without wasting much of material.

That means we have to eliminate all the drawbacks that we had in the traditional machining so that these machines and these processes could benefit us. Those are the non-traditional machining, which will replace or which will be implemented in practice when the traditional processes do not work. Suppose, there is a very hard work piece material and we do not get sufficiently hard tool material for machining that material. In that case of course, we switch over to the non-traditional machining processes.

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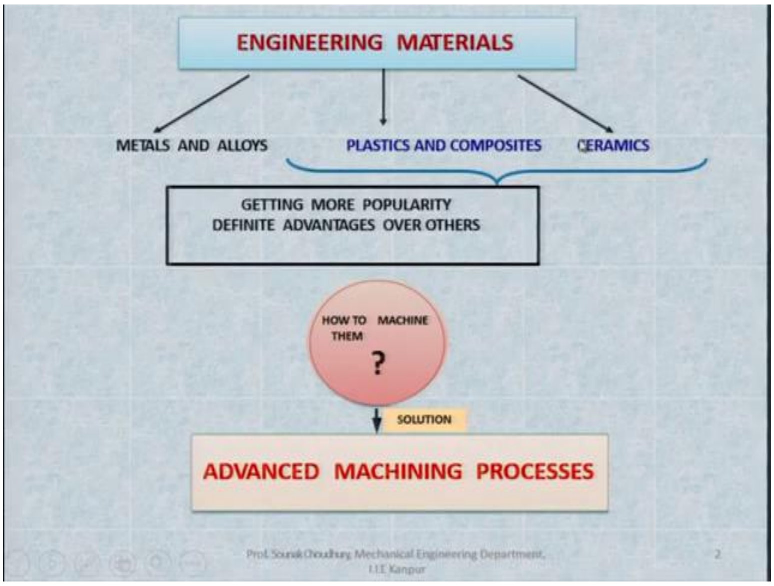

Let us look at these slides. This will be the introduction to non-traditional machining. It is also called the unconventional machining. The engineering materials overall and that also we have discussed during the discussion on the engineering materials that they are subdivided into metals and alloys, plastics and composites and ceramics.

Metals and alloys, we are familiar with. Plastics, composites, and ceramics are the materials which are getting more popularity because of many reasons, because of the adequate properties of those materials with respect to the metal or in comparison to the metal; metals many times become very heavy that is the probably one of the drawbacks of the metallic parts, but they are strong, they are rigid.

Their hardness is fine, but they may be very heavy. Particularly in case of aircraft industries, if you can save a bit of weight, it will be beneficial. The plastic and composites and the ceramics are getting more popularity and because they have the definite advantages over the metals and alloys particularly, but problem comes then how to machine them.

As you know that plastics cannot be machined like we do it for the metals and the alloys, they are the soft materials and they have to be handled in a different way. Composites for example, have the layers of materials. We have the glass composites or fibre composites.

So, in that case, when we try to drill, let us give an example of that drilling, when you try to drill in a conventional way, in that case, those fibres break and they fracture inside, they cannot be plastically deformed in that case the hole accuracy will not be good, the hole surface finish will not be good and so on. Ceramics, are very hard materials and very brittle materials.

So, machining these materials becomes very difficult. Then the solution is the advanced machining processes, the machining processes with some advanced technology or advanced concept of the machining, of the removal of the extra material. But, when you talk about the advanced machining processes, here also we are removing the excess material like in case of the conventional machining.

It is also a metal removal process, but in this there will not be any direct contact between the tool and the workplace. This is the basic characteristics of the advanced machining processes.That is one and the second basic characteristics is that it there could be different kinds of energies that we can use apart from the mechanical energy. Let us see it here.

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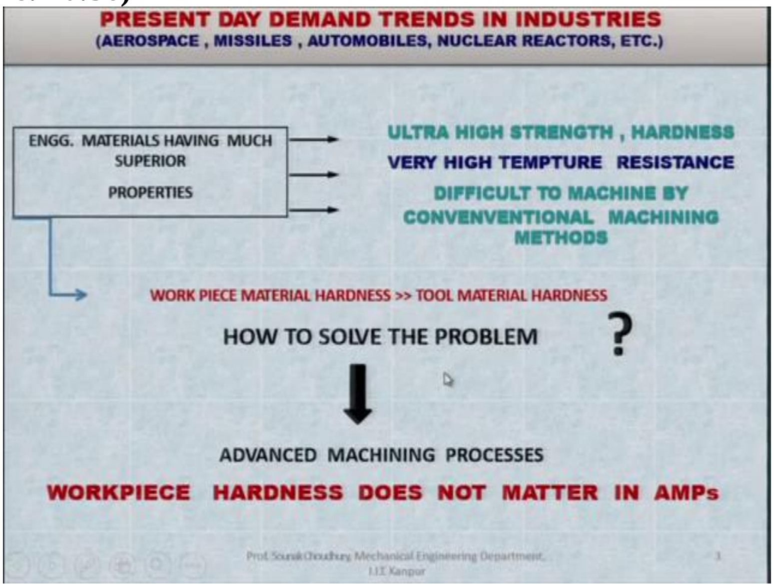

Present day demands trends in industries like for example aerospace, missiles, automobiles, nuclear reactors, etcetera, that engineering materials having much superior properties. For example, materials with ultra-high strength, hardness, very high temperature resistance, difficult to machine by conventional machining methods. Such materials having these kinds of properties are very difficult to machine.

Work piece material hardness in this case is becoming much more than the existing tool materials, we have the certain limitation in the tool material so far. When we have the materials with much superior properties, then the work piece material hardness becomes much more than the tool material hardness.

How to solve the problem? Problem can be solved by implementing the advanced machining processes and as I said that there we do not have any direct contact between the tool and the work piece like in case of the conventional machining and we use different other energies than the mechanical energy, mechanical energy is also used, but, apart from that mechanical energy other energies can be used which will be much superior and in that case the workpiece hardness will not be a matter.

In that sense that workpiece hardness does not matter in the advanced machining processes, whatever is the hardness of the workpiece irrespective of that the machining can be done because of the technology because of that particular technique that will be used in the advanced machining processes. Let us see what kind of energies are used.

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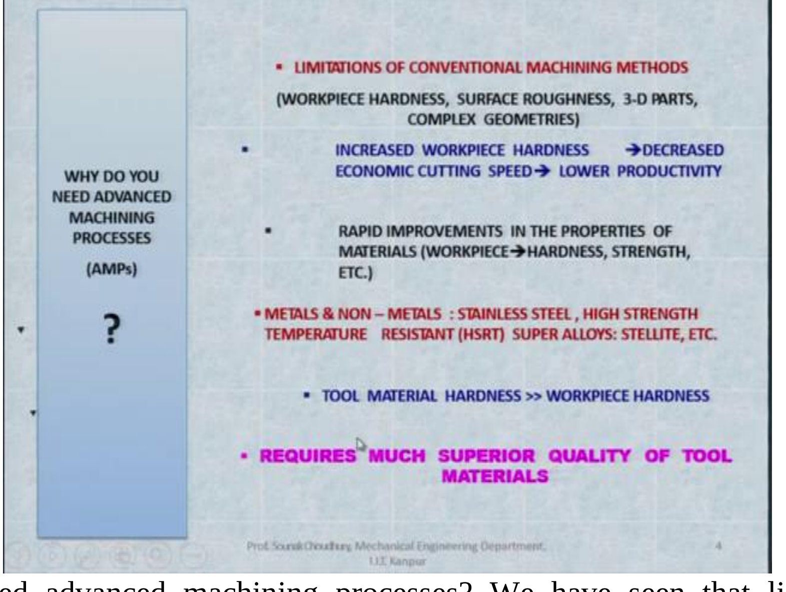

Why do we need advanced machining processes? We have seen that limitation in the conventional machining methods is the workpiece hardness, surface roughness, 3 dimensional parts are very difficult to machine complex geometries, intricacies the increased workpiece hardness that will decrease the economic cutting speed that we have seen in the machining.

As the hardness is increasing the cutting speed that has to be decreased will be lowering the productivity., The rapid improvements in the properties of material, that means the workpiece, hardness, strength etcetera, increasing; as I said that superior properties of the material that will be provided by the material science people or metallurgy people.

Metals and nonmetals like stainless steel, high strength, temperature resistant, super alloys like satellites etcetera are provided to us. In that case, the tool material hardness has to be more than the workpiece hardness this also we have discussed that the tool material hardness is 35 to 58% more than the workpiece material hardness then only we can have the interaction between the tool and the workpiece to remove the excess material from the workpiece surface.

That requires much superior quality of tool materials because we have to have the tool material hardness, much more than the workpiece hardness and that as I said that 35 to 58% more.

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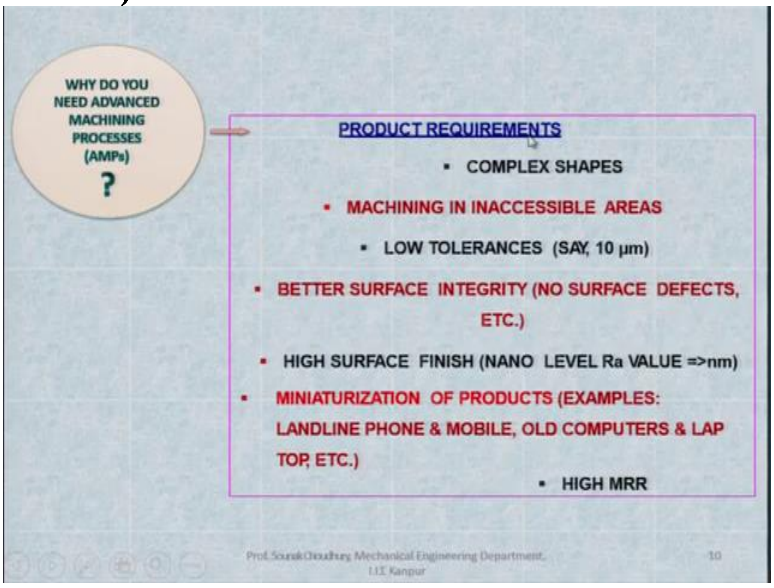

Why do you need advanced machining processes? Apart from what we have said that the hardness, superior properties, complex shapes, I told you earlier that we may also have very intricate shapes. I will give you some examples also of such kind of shapes which are very difficult to produce with the help of the conventional machining.

While discussing machining, I gave you examples of internal combustion engine cylinders. There internally when the two holes, with their axes perpendicular to each other, are meeting, there could be burrs. That means those small chips have to be removed. Removing those burrs by conventional machining process is very difficult and in many cases it becomes impossible.

Tolerances could be low, let us say 10 micrometer tolerance. Maintaining 10 micrometer tolerance is very difficult because in that case machine tool has to be very stable, there should not be any kind of vibration or any kind of relative movement between the tool and the workpiece rather than which is desired. In case there is any small vibration, you understand that its amplitude may be more than or even around 10 micron, in that case this kind of a tolerance of 10 micron cannot be accepted.

Next is the better surface integrity, that is no surface defect which means that there should not be any scratch, there should not be any fracture or anything there should not be any surface defect. That is difficult to achieve by the conventional machining because many times the chip entangles with the workpiece surface, the tool wears out and the flank face starts rubbing the already machined surface, spoiling the surface or tool when overall tool health is deteriorating as the cutting process goes on.

Therefore, as the cutting process goes on, the surface integrity may or may not have the desired one and surface defects may occur. High surface finish in the nano level for example, that is the Ra values are in the nanometre Ra value I will show you while discussing the surface roughness in the metrology section. There the high surface finish we have to obtain in many cases in the nano level, that is the Ra value of the asperities or undulations.

This is the property of the undulation that these values should be in the nanometer. It is very small. Miniaturization of the products for example, we have the landline phone and mobile, old computers and laptops. Just imagine from the landline phone we switched over to the mobile and the parts that we have in the landline phones are easier to make rather than the parts that we are having right now in mobiles.

So, we have miniaturized and if we compare the old computers with the laptops, laptop is much compact. It has been miniaturized in comparison to old big computers that we used to have earlier. We need also high material removal rate because we need to have the high production rate. All those requirements are not possible all the time to satisfy with the conventional machining that we have discussed.

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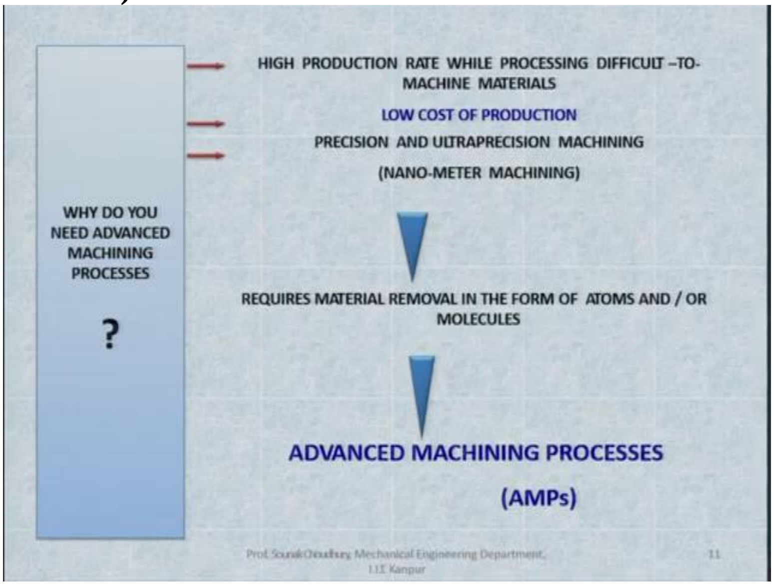

Therefore, we have to go for the advanced machining processes. This is the justification why the advanced machining processes came into picture. High production rate while machining difficult to machine material; anyway it gives the difficulty as the name says for machining because its hardness is very high, tool wears out very fast, you need to have the high force, high strain rate of deformation to be imparted and so on.

So then along with that for those materials, we need to also have the high production rate, low cost of production costs should not be very high precision and alter precision machining that is in the nanometre machining. These are all the increasing demands in the industry because we are progressing, we have to go faster, we have to have the miniaturization, we have to have more precision machines.

That requires material removal in the form of atoms and molecules. So, we are no more now limited to the we cannot limit ourselves in removing the chips although it says small chips these are not in nanometers these are in millimetre those are big chips I mean in comparison to when we talk about molecules and atoms. This is the solution which is the advanced machining processes that we have to come up with to solve these problems that we face in the conventional machining.

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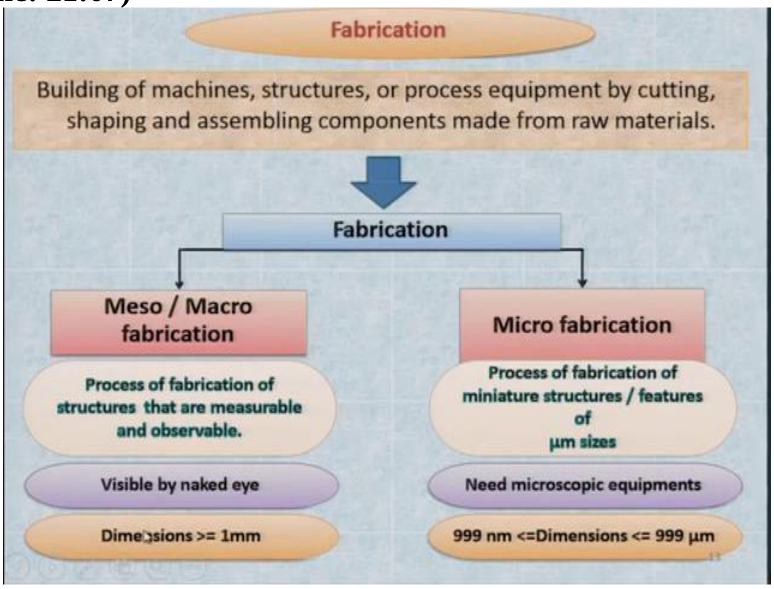

Some examples: When we talk about building of machines, structures or process equipment, by cutting, shaping and assembling components made from raw material, this is the fabrication. This fabrication may have the meso or macro fabrication or micro fabrication.

Now meso and macro fabrication, here the process of fabrication of structures that are measurable and observable, dimensions are bigger, is visible by naked eye, we can see them because they are bigger in diameter, dimensions and the dimensions are normally more than or equal to 1 millimetre. So, you can understand that this is quite big for us to see by naked eyes.

But in case of micro fabrication when you talk about that, the process of fabrication of the miniature structures, we talk about features of the micron sizes and that fabrication process needs microscopic equipment for the measurement because the dimension lies between 999 micrometre to 999 nanometre. Within that the dimensions are length and as you can see that this is less than 1 millimetre and some of them are not even visible with naked eyes. You have to have the microscope to see them because in that case as we said the material is removed in the atoms, in the size of an atom or molecule.

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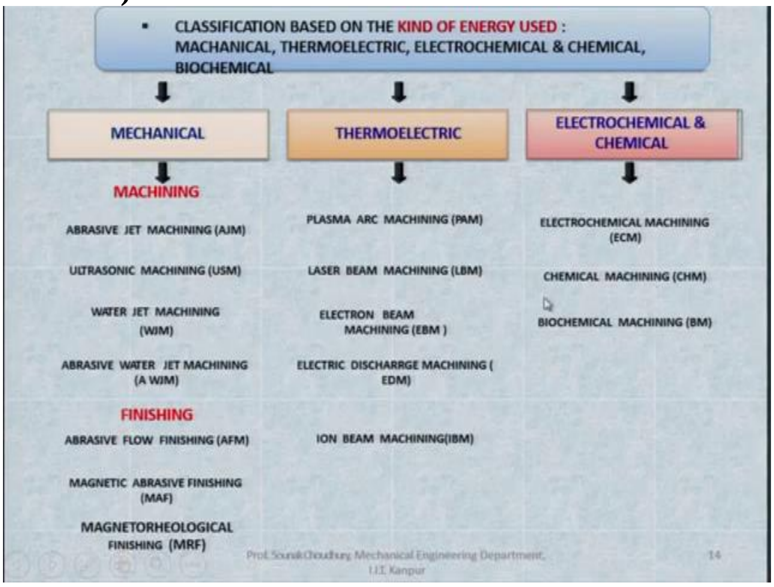

non-traditional machining processes can be classified based on the kind of energy used as I told you that here in contrast to the normal machining processes or conventional machining processes, we not only use the mechanical energy, but we can use different kinds of energy because as you understand that we have to now machine material of any hardness which was not possible with the help of the conventional machining.

Therefore, the kind of energy used are the mechanical energy, thermoelectric energy and the electrochemical and the chemical energy, these 3 basic groups of energy that are used in the case of the non-traditional machining processes. Now in the mechanical, this is abrasive jet machining, this is normal machining processes, abrasive jet machining, normal machining processes we mean to say that still it is non-traditional.

But then this is not the finishing process, it is a machining process. Abrasive jet machining is the process which uses the mechanical energy. Details of that we will talk about a little later. Ultrasonic machining where, as you can see by name, the ultrasonic frequency of vibration is used here; abrasive jet by name it says that the machining or the material removal is accomplished with the help of the abrasive jet that impinges the workpiece surface.

Water jet machining; again, the removal of the material from the surface by water jet again that will impinge the workpiece surface with very high force and I will show you the picture and I will show you the details. Abrasive water jet machining; abrasive water jet machining means that you are mixing abrasive here. It is abrasive water jet machining here, the water stream that we were using, water jet that we were using in the water jet machining; there the abrasive powders are mixed.

Therefore, it becomes the abrasive water jet machining. In the finishing, we have the abrasive flow machining or abrasive flow finishing. Here also you can see that the abrasive powders are used. But in comparison to this abrasive water jet machining if this is the rough machining, this can be used for the finishing. Magnetic abrasive finishing or magnetorheological finishing are the processes which have been in practice recently, not very long ago.

It has been started being used, now the thermoelectric energy using the thermoelectric energy the processes which are in practice are the plasma arc machining. There a plasma arc is used to remove the extra material from the workpiece surface. Laser beam machining: using the laser beam; electron beam is used in electron beam machining for removing material.

So, these are all the beam technology that means using different kinds of beams like plasma arc or laser beam, electron beam, we can remove the excess material. Electric discharge machining EDM is one of the very popular processes which is the thermal process and it is the thermo electric because electricity is used, a voltage is passed through ion beam machining which is another beam technology.

Here you can see that most of them are the beam technologies that means, we create the thermal energy, we create the temperature high temperature and that can melt and evaporate the workpiece material whatever is the hardness of the material. That means we are using thermo electric energy or electro chemical and the chemical dissolution. This is the electro chemical machining, this also very popular like the EDM, this is called the ECM - electro chemical machining.

Chemical machining: aging for example, kind of chemical machining, biochemical machining, also came into picture recently it was not so popular earlier but because we have different materials plus soft materials and nano scale when we have to machine then those biochemical machining are very popular nowadays.

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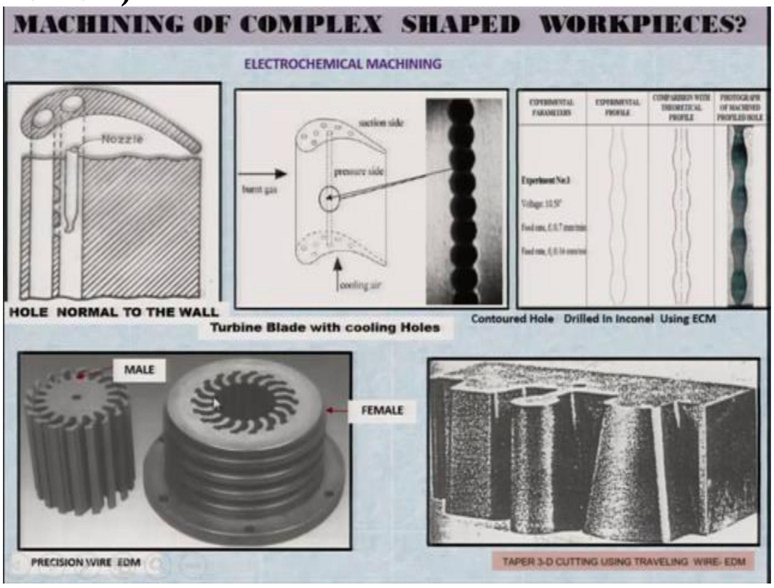

These are some of the complex shaped work pieces and you can see that these work pieces are really very intricate, for example, turbine blade, this is the cross section of a turbine blade and this is the turbine blade view and you know that in the turbine blade first of all that shape is very intricate, and hence machining of this kind of a shape is itself is a challenging job. Second aspect is that it works with the burned gas which is at a high temperature.

Overall, the turbine works in the environment of very high temperature and pressure. So, these blades are to be cooled down and therefore, cooling air is passed through the holes and those holes are very intricate holes, these holes are you klike this, this is the theoretical profile that has been designed and this is the machine profile, the hole is like this.

This is the experimental profile hole which is not a straight hole but it is a kind of like this. These are the kinds of machining that we have to do and that too in a material which is very hard, for example, it is an inconel material. Here is the example when such kind of hole is drilled, this is the actual profile, made by electrochemical machining or for example, this is a part where you can see that male part and this is the female part and you can see the interfaces.

This is also a turbine blade here also there are very small holes you can see that and through these holes the cooling is done and making these holes conventionally is almost impossible. Therefore, where electro discharge machining is used for making such kind of parts, the precision is maintained as well as such kind of intricacies can be obtained.

This is highly exaggerated view of the taper 3D cutting using the travelling wire electro discharge machining. You can see that the intricacies of the surfaces and theprecision has to be very high and overall, the material is very hard, it is very difficult to machine. Therefore, all these criteria have to be satisfied and the traditional machining many times they are notsuccessful in creating these jobs. So, non-traditional processes have to be used for that.

You can see that with the help of the wire EDM or with the help of the electrochemical machining or with the help of the wire EDM, normal wire EDM also like these kinds of intricate holes these kinds of intricate shapes can be machined.

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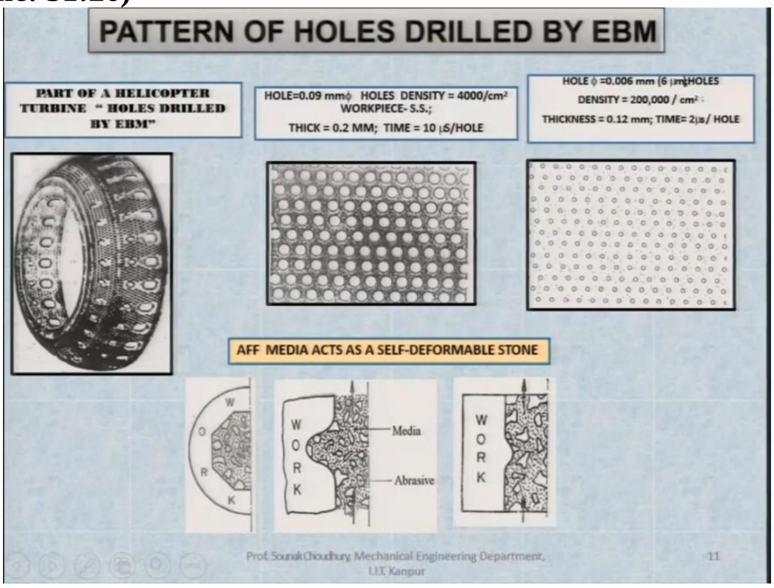

This is the part of a helicopter turbine. The holes here are also very complicated because the surface is not the straight cylindrical surface. They are drilled by the electron beam machining, EBM. Here this is exaggerated, amplified under the microscope. Here the diameter of each hole is 0.9 millimetre and here in 1 centimetre square there are 4000 holes.

So, hole density is 4000 per centimetre square. The workpiece is of stainless steel with a thickness of 0.2 millimetre. just imagine that how would it be possible to drill such holes in such a thin work piece of 0.2 millimetre in such a hard material like stainless steel and with such density of 4000 holes per centimetre square that means, the distance between the 2 holes is very very small.

This has been done by electron beam machining and the time taken is 10 millisecond per hole, it is 0.06 millimetre hole diameter and the hole density is 200,000 holes per centimetre square here it was 4000 and the thickness is 0.12 millimetre, and the time taken is 2 microsecond per hole.

So, these are the facts of the non-traditional machines which cannot be done using the conventional machines.

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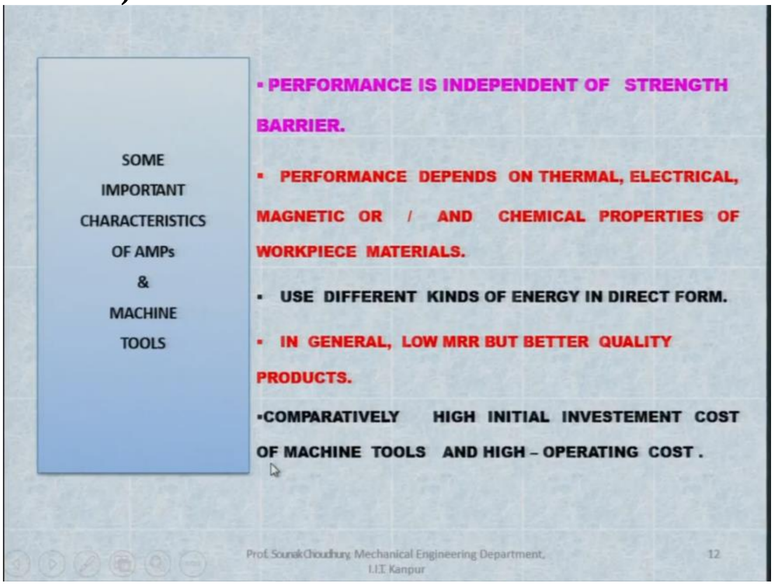

Some important characteristics of the abrasive machining processes and machine tools performance is independent of the strength barrier that I said. The performance depends on thermal, electrical, magnetic, or and chemical properties of the work piece material. So, depending on the work piece material properties, we will have the choice of a particular process and the performance.

Use different kinds of energy in direct form. All these energies that I have already told you earlier in general are used. Low material removal rate, but the quality is better quality of the product is better while we are comparing with the conventional machining. Comparatively high initial investment costs of machine tools and high operating cost.

This is the disadvantage because the cost will be more and of course, the production rate will be less because the material removal rate is very less and the time taken for making for example in case of the electro discharge machining or electrochemical machining time taken is very high in comparison to conventional machining, but here the quality is better the accuracy of the machining the overall quality and the surface roughness can be better.

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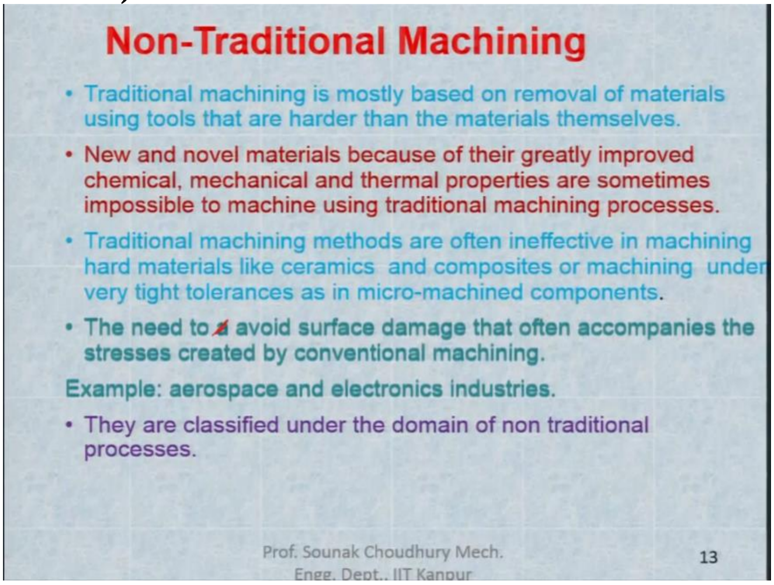

Traditional machining, by definition, is mostly based on removal of materials using tools that are harder than the materials themselves. New and novel materials because of their greatly improved chemical, mechanical and thermal properties are sometimes impossible to machine using the traditional machining processes. I am simply summing up whatever I have said earlier.

The traditional machining methods are often ineffective. Traditional is the one normal machining processes that we have discussed in machining hard materials like ceramics and composites, or machining under very tight tolerances as in micro machine components for example. Therefore, it is required to avoid surface damage that often accompanies the stresses created by conventional machining.

We have the surface damage in the conventional machining very often because of the entangling particularly of these chips or the high friction between the work piece and the tool and so on. That can be avoided in case of unconventional machining. Example is the aerospace and electronics Industries they are classified under the domain of non-traditional processes.

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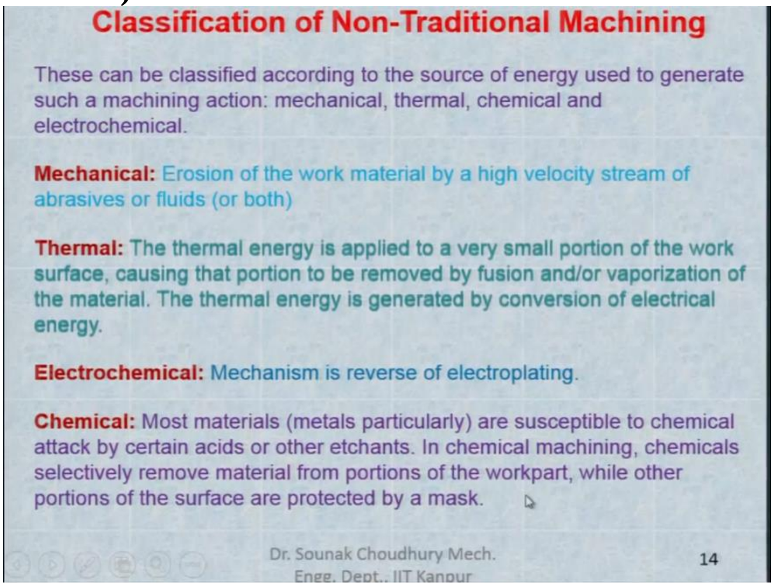

I will define the classification here in wordings that this can be classified according to the source of energy used to generate such a machining action mechanical, it can be thermal energy chemical and electrochemical I have shown it to you in a table. Mechanical is erosion of the work material by a high velocity stream of abrasives or fluids or both.

This is an example of the mechanical energy when we have the impinging of the abrasive materials, that means, the grains of aluminium oxide, silicon carbide grains or diamond grains which are very hard particles, can impinge the surface with a mechanical force and have an impact and then remove the material. It can be thermal energy, the thermal energy is applied to a very small portion of the work surface causing that portion to be removed by fusion and or vaporisation of the material.

The thermal energy is generated by conversion of electrical energy. I have given examples like electron beam machining, laser beam machining. There electricity is passed in a circuit and we convert this electrical energy to electron beam or to create the plasma arc and so on. Those beams are then used to create very high temperature in a very small area that can melt and evaporate the work material.

Electro chemical dissolution: as I said that mechanism is the reverse of electroplating, we know about electroplating; this is very famous process which you must have studied in class 10 and 11. Opposite to electroplating is used here. It is material removal instead of material deposition. Therefore, it is the opposite and we call it electro chemical dissolution.

Herethe material is dissolved in the solution and the chemical energy is used to dissolve the work material. Most metals are susceptible to the chemical attack by certain acids or other agents. In chemical machining, chemicals selectively remove material from portions of the work part while other portions of the surface are protected by a mask. So, the surface is masked first and that mask is such that it will not be affected by the acid or that or by certain chemical which is being used.

Those portions which you need to be attacked, need to be removed or machined, those are not masked. Then if it goes through the chemical or a chemical is poured on top of it, then those portions which are exposed will be only aged or marked and other portions are not because there is a mask. That is the process of the chemical machining and this is quite well known, this is very popular in even the household appliances.

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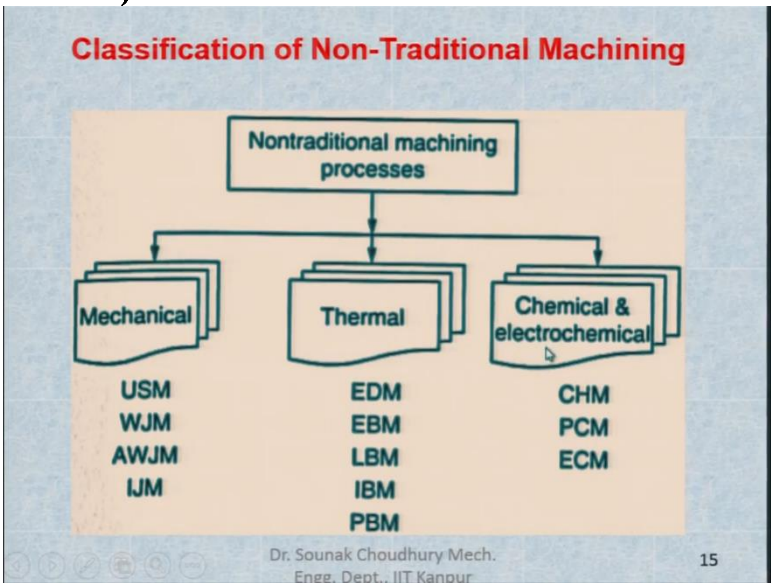

So, in one-word non-traditional machining processes can be classified into 3 categories where we are having different kinds of energies used such as mechanical, thermal, chemical and electro chemical etc. In mechanical, we have the ultrasonic machining, water jet machining, abrasive water jet machining and among the processes using thermal energy, we have the electro discharge, electron beam, laser beam, iron beam plasma arc and so on. Chemical energy is used in chemical machining and electro chemical machining.

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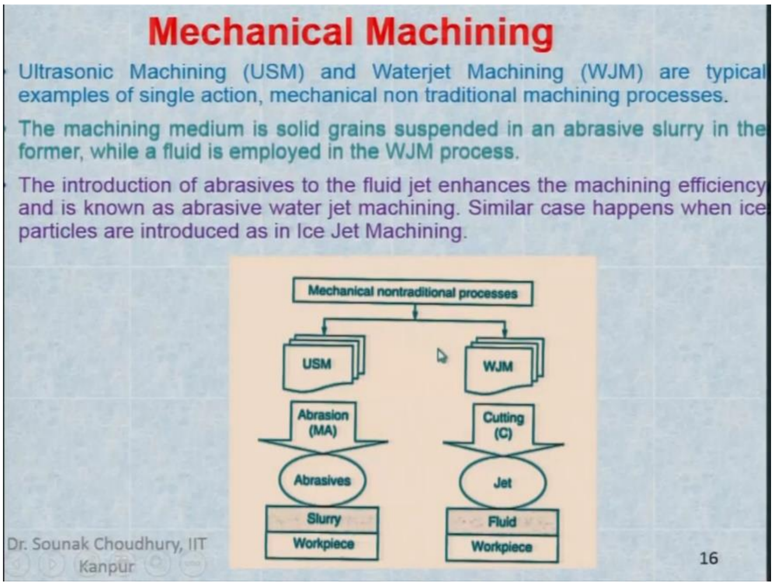

Mechanical machining that is ultrasonic machining and water jet machining, these are the examples of the mechanical machining. By mechanical machining we mean to say that non-traditional machining using the mechanical energy. They are typical examples of single action mechanical non-traditional machining processes ultrasonic machining and the water jet machining.

The machining medium is solid grains suspended in an abrasive slurry while a fluid is employed in the water jet machining. In the ultrasonic machining, solid grains are used suspended in an abrasive slurry. Abrasive slurry means that abrasive mixed with some kind of fluid. That fluidic material where we have the abrasive materials is flown in the gap between the tool and the work piece

There is no direct contact between the tool and the work piece like in the case of the normal machining processes or traditional machining processes. The machining media is solid grain suspended in an abrasive slurry and here in case of water jet machining a fluid is employed.

Now the introduction of abrasives to the fluid jet enhances the machining efficiency. I discussed water jet machining earlier. Here we are mixing with the abrasive powders that enhances the material removal rate. Therefore, it is known as the abrasive water jet machining. Similar case happens when ice particles are introduced in an ice jet machining.
Ice jet machining is also used rarely but these are used when the ice is included in place of the abrasive material, abrasive grains. You can see in this figure also the mechanical non-traditional machining processes, they are basically subdivided into ultrasonic machining and

water jet machining, ultrasonic machining is the abrasion. Mechanism of material removal is mechanical aberration and abrasives are used as particles in a slurry and we have the work piece here.

In case of water jet machining, the cutting process happens and the medium uses some jet which is the water jet and this is a fluid and the work interaction between the fluid and the work piece.

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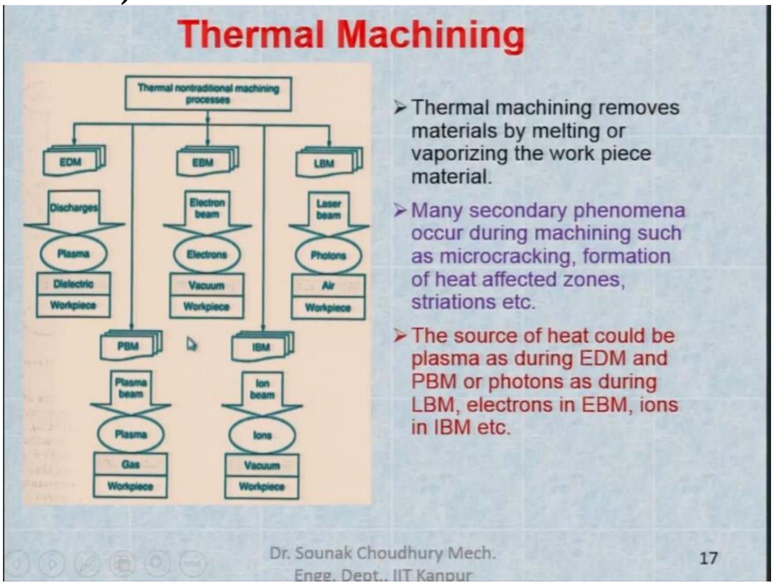

In case of thermal machining, thermal non-traditional machining processes remove material by melting or vaporising the work piece material. Many Secondary phenomena occur during the machining such as micro cracking, formation of heat affected zones, striations etcetera. These are the phenomena which happen during the machining.

In a photon beam machining, photons are used for machining as in laser beam machining. Electrons are used in the electron beam machining, ions in the ion beam machining and so on. So, you can see that there are different kinds of sources which we are using, heat source that we are usingcreates very high temperature in a very small area.

Therefore, that high temperature melts and evaporates instantaneously irrespective of the hardness of the work piece.

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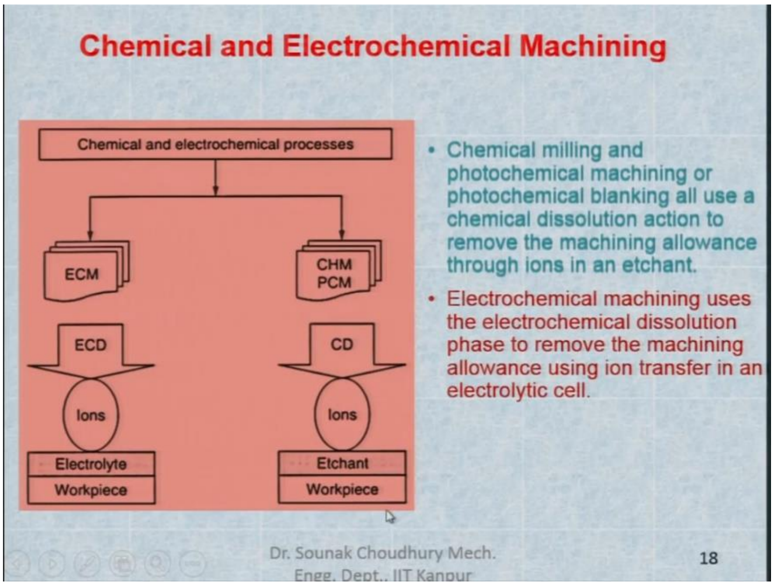

Chemical and electrochemical machining: here the mechanism is the following. These are the electrochemical machining processes. Here electro chemical dissolution is the mechanism and the ions are used as the source. Electrolyte is used and the interaction with the work piece chemical machining here the chemical dissolution is there, here also the ions are used to etch the work piece.

The interaction between this ion and the work piece by the etching. Chemical milling and photochemical machining: photochemical machining falls under the chemical machining. Here it is the chemical milling and here it is a photochemical machining or the photochemical blanking also it is called, all use a chemical dissolution action; this is the chemical dissolution; this is the electro chemical dissolution and chemical dissolution.

So, these are the mechanisms of material removal, how the material is removed using thermal energy. In thermal, we said that this is melting and evaporation; in case of electro chemical machining, it is electro chemical dissolution, in case of chemical milling or the photochemical machining, it is the chemical dissolution to remove the machining allowance through the ions in an etchant and the material from the work piece is removed. Electrochemical machining uses the electrochemical dissolution.

To remove the machining allowance using the ion transfer in an electrolyte cell: in the electrolyte cells, the ions are transferred, by help of the electrochemical dissolution the material from the work piece is removed.

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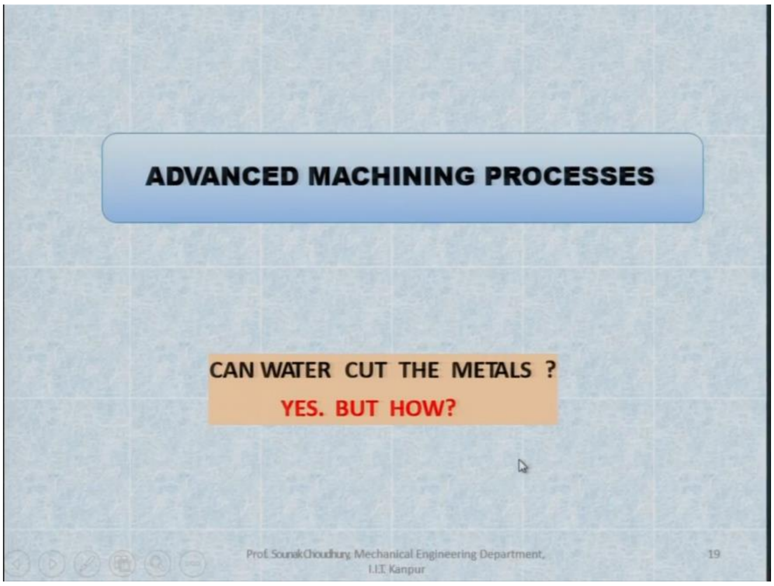

Therefore, in these advanced machining processes it is interesting to find out that can we use all kinds of sources for example, water, can water cut the metals? Answer is yes but how? Here is how.

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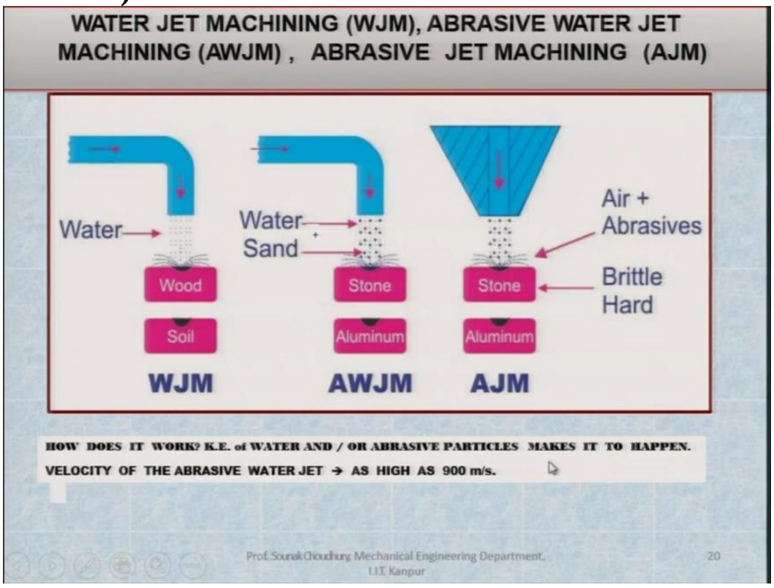

That is water jet machining, abrasive water jet machining, abrasive jet machining. We can see that if the water is forced at a very high speed through a very narrow nozzle with the less diameter in that case the wood, soil can be cut. Now if we use the sand and the water together, then of course harder materials like stone for example or aluminium can be machined.

In that case the material can be removed from the harder surfaces than the wood and the soil because we have the abrasive water jet machining and, in this case, the high force of water along with the impinging of the abrasive hard particles into the surface that helps in removing the material more, in the abrasive jet machining it is only the air and the abrasives.

Here it is water and sand, it is abrasive and sand, sand and air. Sand and air or water and sand they can create the brittle fracture. when the abrasive material impinges the work piece surface, the work piece surface can be fractured and when it is a brittle material this is easily fractured. It is convenient for removal of material from the brittle surfaces particularly.

Particularly the abrasive jet machining processes are popularly used for removing the material from the brittle surfaces because the material removal mechanism is the brittle fracture, it fractures the material and removes that way. Velocity of the abrasive water jet can be as high as 900 metres per second which is very high speed.

That jet if it comes on the on the human being, it can damage the skin and the flesh. It is of a very high speed and if you remember if you have seen that sometimes the riot police have a water gun. They also use the high-speed water jet to disperse people, of course to scare them, not to damage but the purpose is to scare them but nevertheless if it falls on the human being, human beings cannot sustain that force.

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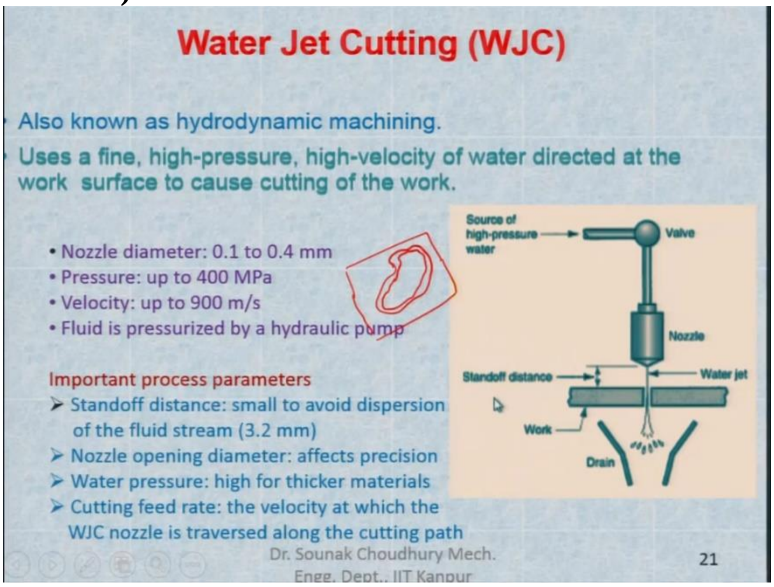

Water jet cutting in details: also known as the hydrodynamic, hydrodynamic machining, means, this is the machining process or removal of extra material excess material by the hydrodynamic force that uses a fine high pressure high velocity of water directed at the work surface to cause the cutting, to cause the material removal.

This is the work piece, now here is the nozzle and there is a valve to regulate the pressure of the water and here we have the source of high-pressure water coming from here the valve it regulates that pressure and it throws this water to the nozzle from the nozzle the water comes through a very tiny hole and the very fine water jet is directed towards the work piece from a distance between the nozzle and the workpiece.

This distance is called the standoff distance which is very important. In each of these unconventional machining processes or non-traditional machining processes, there the standoff distance should be maintained in a proper way and the standoff distance means that there is a particular distance between the tool and the work piece that should not fluctuate.

If the standoff distance fluctuates, it may create inaccuracy in the machining. As the standoff distance increases for example, then the value which has been calculated in that case the strength of the water jet falling on the work piece surface will be less and another aspect is that if the standoff distance is inappropriate in that case the tapering may happen here, here the diameter will be less or more.

They are not the same therefore, there could be a tapering and that tapering may vary which is called the overcut. The overcut can be of this type. It can happen because the energy is maximum on top and as it goes inside then it becomes less and the diameter becomes less.

Here the nozzle diameter here is the 0.1 to 0.4 millimetres and there is a pressure which is created by the high-pressure water and this is up to 400 mega Pascals, this is also a very high pressure, the velocity is 900 metre per second. Because of this pressure and the nozzle diameter which is up 0.4 millimetre, the velocity becomes 900 metres per second.

This speed of the water jet is very high and the fluid is pressurised by hydraulic pump there is a hydraulic pump here there is the source. Important process parameters are the standoff distance between the nozzle and the work piece which is about 3.2 millimetres.

As I was telling you that that standoff distance is very important and that can be optimised depending on the pressure that you are creating, depending on the velocity that you are creating and the work piece surface and the work piece material that has to be kept constant all the timeso that the accuracy is maintained. Here it is about 3.2 millimetre. Nozzle opening diameter affects the precision.

You understand as I told already water pressure high for thicker material, when the material is thick, that is the thickness of this work piece material is more then you need to have the high pressure because the force required to impinge by the water jet throughout the width of the work piece should be more.

As you understand that this is not only for the cutting or cutting of the material, but it can be used to make a contour for example, let us say we have a material like this or we have a plate like this and we have to have a contour shape cut from here like this. This can be cut through the nozzle and that is then the nozzle has to be traversed. This is called the cutting feed rate. This is the feed rate at which the nozzle will be moved to make this contour to cut this profile, this I will show it to you in more details later.

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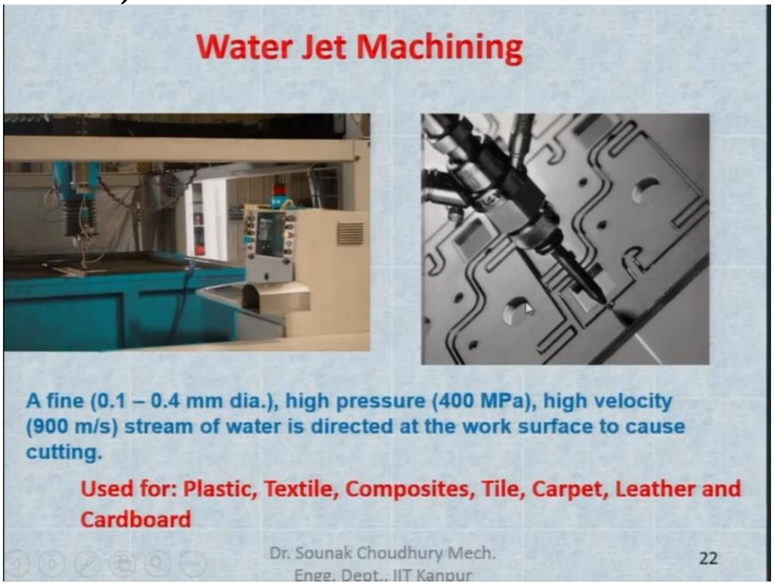

Here the water jet machines are here you can see that that this is the nozzle, and you can see that very high-pressure water jet coming through the nozzle and it is making a groove like this. This is the traverse that I was talking about the nozzle has to traverse like this along the path of the groove to make that.

These are the slots or the grooves made here it can also make a through hole like this. For that it has to impinge first, make the entire material cut in one place and then it will traverse like this and therefore the entire material will be removed or the hole will be obtained in that case.

The rest of the material in this section of the non-traditional machining, I will discuss in our next session. Thank you for your attention.