Advanced Machining Processes
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Lecture 01

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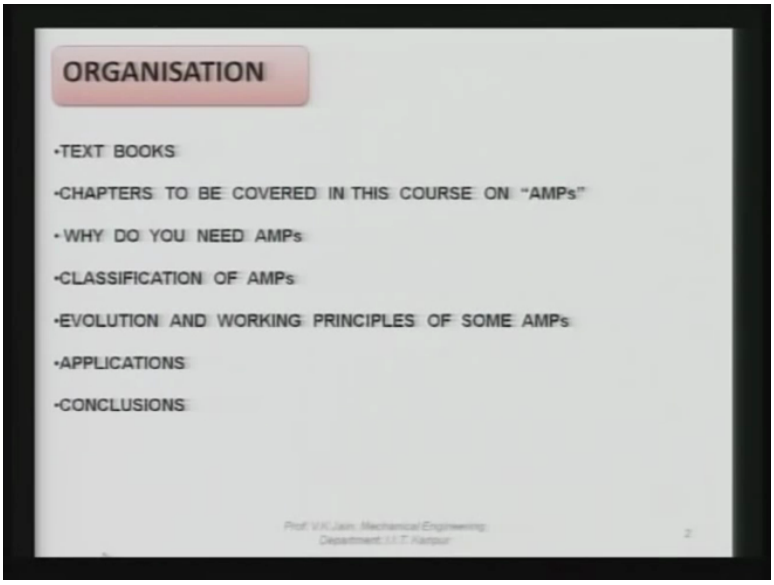

Welcome to the course on Advanced Machining Processes, the course organization or lecture organization is as follows, I will give you the names of the text books then I will tell you about the chapters to be covered in the course on Advanced Machining Processes that is AMPs. After that I will explain to you why do we need really advance machining processes.

Then we will discuss with the classification of various advanced machining processes, after that I will try to tell you some of the real life events from which researchers or inventors have taken inspiration and they evolved some of the advanced machining processes and then we will discuss with the principle of some of these advanced machining processes and after that I will give you some interesting applications of these advanced machining processes and this chapter will close with the conclusion.

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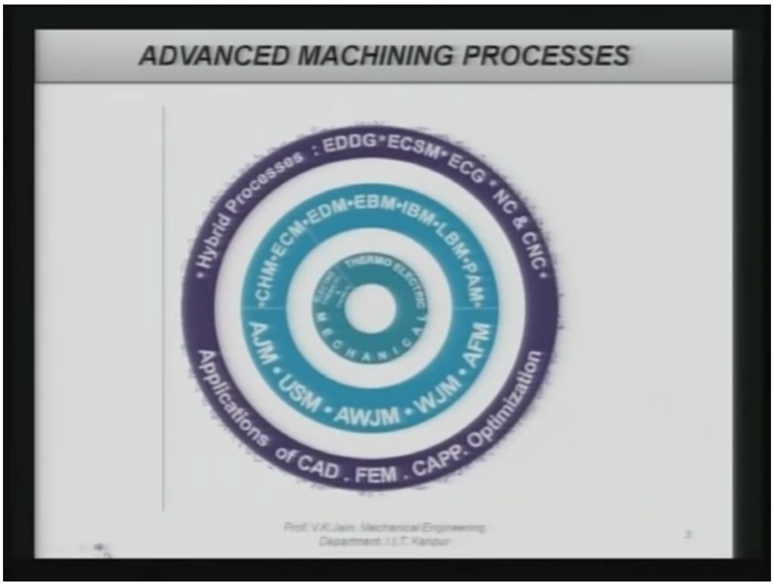

Now I am going to follow in this particular course the book on Advance Machining Processes written by V. K. Jain and this is the front page of the book.

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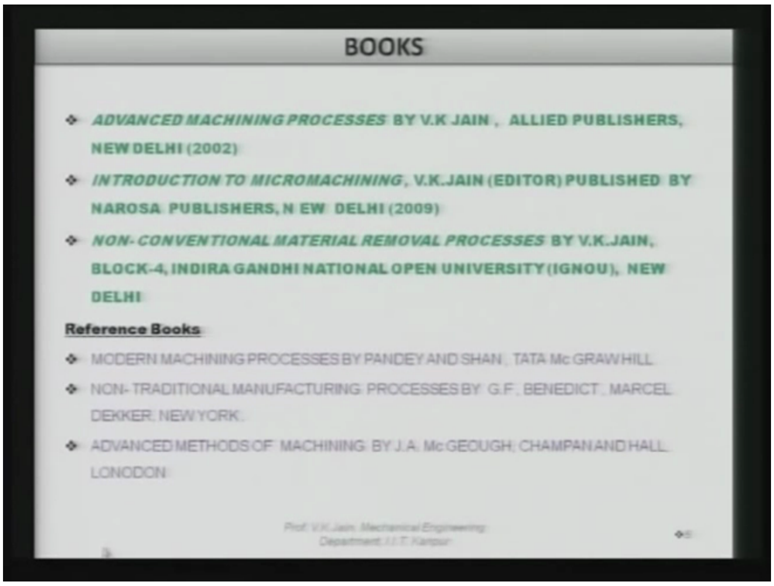

There are various text books available in the market as I just mentioned, one of them is the Advanced Machining Processes by V. K. Jain published by Allied Publishers, New Delhi in the year 2002. Second is the Introduction to Micromachining again by V.K. Jain editor and published by Narosa Publishers, New Delhi in the year 2009 and third is the Non-Conventional Material Removal Processes by V. K. Jain, Block-4, it was written for Indira Gandhi National Open University IGNU, New Delhi.

There are those reference books which I will be following often and whenever need arises, one of them is the Modern Machining Processes by Pandey and Shan, another is Non-Traditional Manufacturing Processes written by Professor G. F. Benedict and published by Marcel Dekker, New York. Next is Advanced Method of Machining by Professor J. A. Mc Geough of Edinburgh University and published by Chapman and Hall, London.

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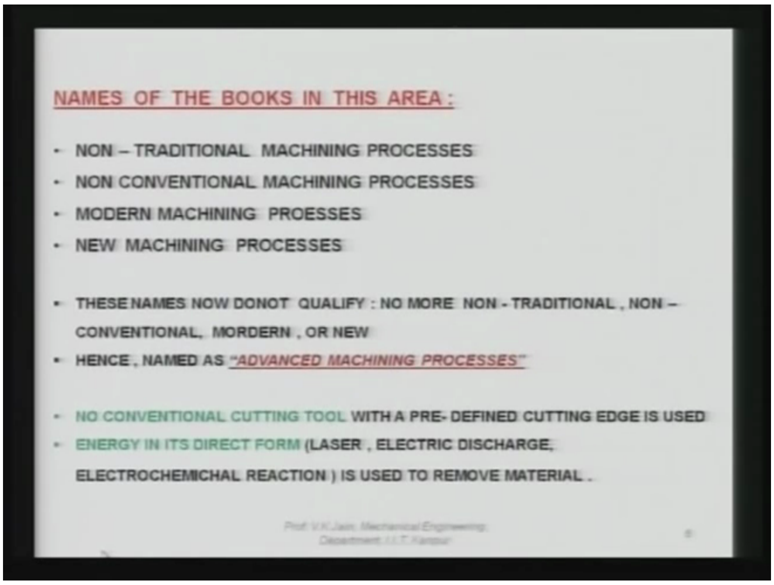

Now one of the things you must have seen that various others have given different names to these books, now the question arises why this different names, why not the same name given to various books over there? Some authors have written it as Non-Traditional Machining Processes then there are some authors who have given the name as Non-Conventional Machining Processes. Some have written it or named them as Modern Machining Processes or New Machining Processes.

Now these names nowadays do not qualify much, these processes which we are going to discuss in Advanced Machining Processes are no more non-traditional, they are no more non-conventional or no more modern or new. Many of these processes are so commonly used on the large scale and medium scale industries that they really do not qualify these various names given to this particular type of the course content book.

That is why I have named them as Advanced Machining Processes and Professor Mc Geough also had written it as Advanced Machining Methods rather than using the word non-traditional, non-conventional, new or modern.

Now this is not conventional in the sense that in these processes no tool is being used which has predefined tool nomenclature as we use in case of single point turning tool or multi point turning tool. In these processes energy in its direct form is used for the removal of the material that energy maybe laser energy or electric discharge in the form of the spark or the arc or electro-chemical reaction just like in case of electro-chemical machining processes. The energy is used in its direct form for the removal of material so that the work material or work piece is shaped and sized according to the design of that particular component.

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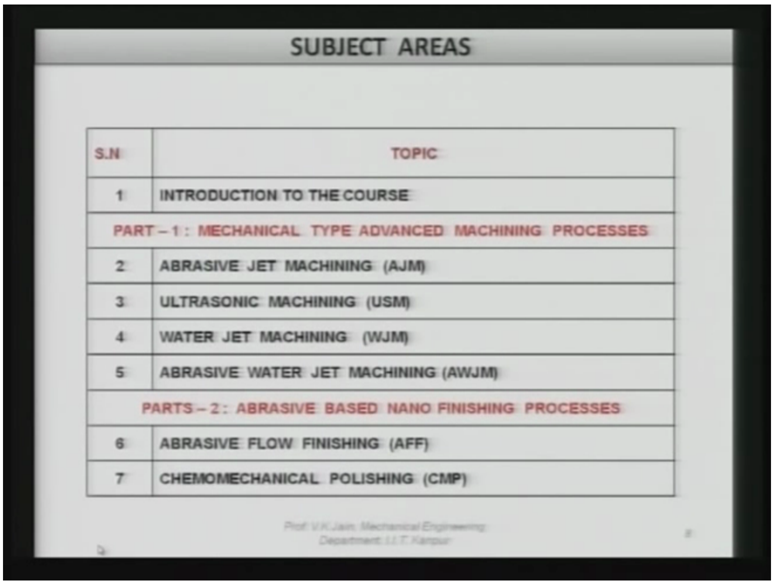
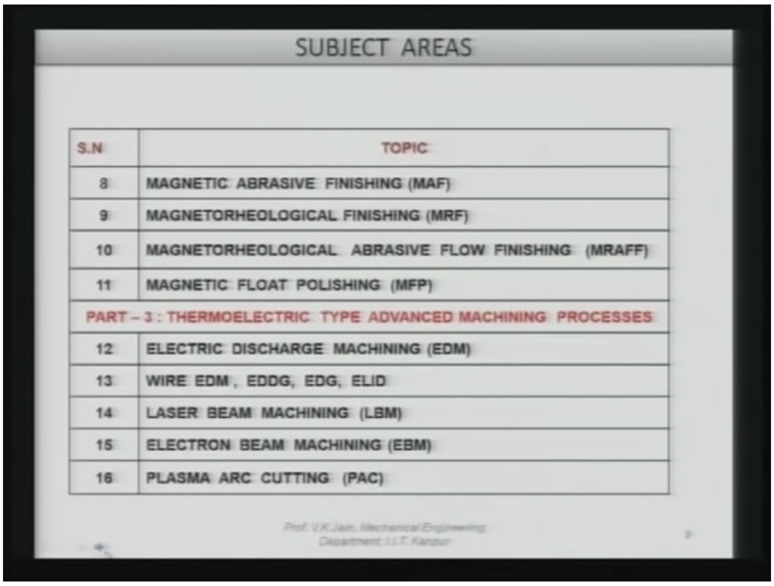


SUBJECT AREAS

S.N	TOPIC
1	INTRODUCTION TO THE COURSE
PART – 1 : MECHANICAL TYPE ADVANCED MACHINING PROCESSES	
2	ABRASIVE JET MACHINING (AJM)
3	ULTRASONIC MACHINING (USM)
4	WATER JET MACHINING (WJM)
5	ABRASIVE WATER JET MACHINING (AWJM)
PARTS – 2 : ABRASIVE BASED NANO FINISHING PROCESSES	
6	ABRASIVE FLOW FINISHING (AFF)
7	CHEMOMECHANICAL POLISHING (CMP)



SUBJECT AREAS

S.N	TOPIC
8	MAGNETIC ABRASIVE FINISHING (MAF)
9	MAGNETORHEOLOGICAL FINISHING (MRF)
10	MAGNETORHEOLOGICAL ABRASIVE FLOW FINISHING (MRAFF)
11	MAGNETIC FLOAT POLISHING (MFP)
PART – 3 : THERMOELECTRIC TYPE ADVANCED MACHINING PROCESSES	
12	ELECTRIC DISCHARGE MACHINING (EDM)
13	WIRE EDM , EDDG, EDG, ELID
14	LASER BEAM MACHINING (LBM)
15	ELECTRON BEAM MACHINING (EBM)
16	PLASMA ARC CUTTING (PAC)

Now what are the various areas or the topics that I am going to discuss in this particular course on Advanced Machining Processes, it consists first chapter today I am talking about the introduction to the course from the next class I will discuss about the mechanical types of advanced machining processes which will include Abrasive Jet Machining AJM, Ultrasonic Machining USM, Water Jet Machining WJM and Abrasive Water Jet Machining AWJM.

After this second part of this course will deal with the Abrasive Based Nano Finishing Processes, it will include Abrasive Flow Finishing AFF, Chemomechanical Polishing CMP, Magnetic Abrasive Finishing MAF, Magnetorheological Finishing MRF, Magnetorheoloical Abrasive Flow Finishing MRAFF or MRAFF and Magnetic Float Polishing MFP.

Third part of this course will deal with the Thermoelectric Type Advanced Machining Processes which includes Electric Discharge Machining EDM, Wire EDM, Electric Discharge Diamond Grinding EDDG, Electric Discharge Grinding EDG, Electrolytic in Process Dressing ELID. Then we will discuss about Laser Beam Machining LBM, Electron Beam Machining EBM, Plasma Arc Cutting PAC.

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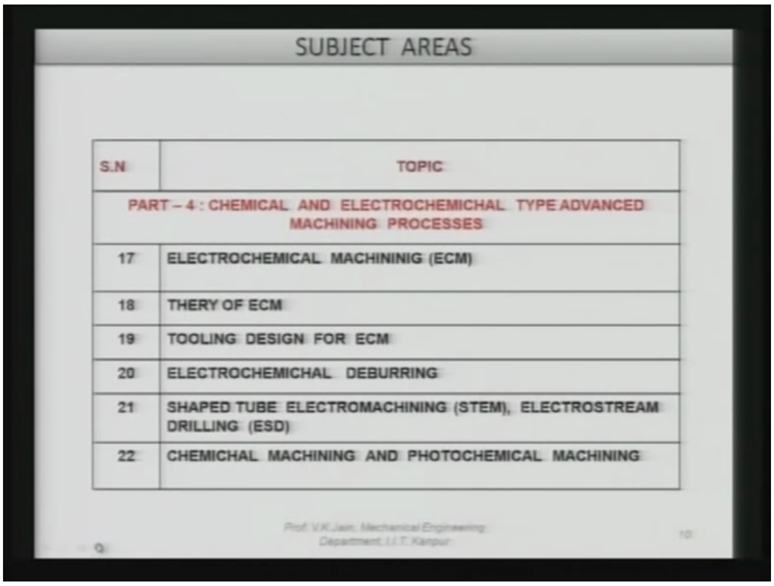
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S.N	TOPIC
	PART – 4 : CHEMICAL AND ELECTROCHEMICHAL TYPE ADVANCED MACHINING PROCESSES
17	ELECTROCHEMICAL MACHININIG (ECM)
18	THERY OF ECM
19	TOOLING DESIGN FOR ECM
20	ELECTROCHEMICHAL DEBURRING
21	SHAPED TUBE ELECTROMACHINING (STEM), ELECTROSTREAM DRILLING (ESD)
22	CHEMICHAL MACHINING AND PHOTOCHEMICAL MACHINING

The fourth part of this course will deal with Chemical and Electro-chemical type advanced machining processes, it includes Electrochemical Machining ECM, then I will deal with theory of ECM, Tooling design for ECM, Electrochemical Deburring as the application of ECM process, Shaped Tube Electromachining, Electrostream Drilling and some other allied processes then Chemical Machining and Photochemical Machining.

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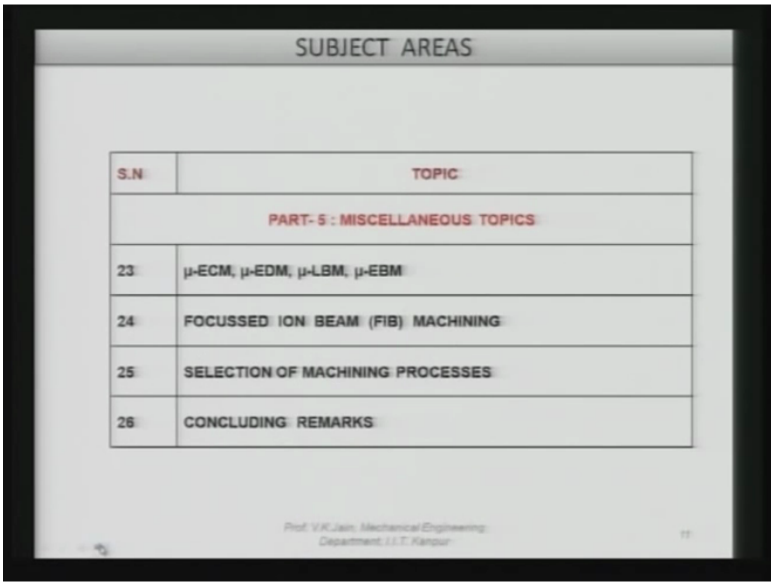

Fifth and last part of this course will deal with some introduction to Micro ECM, Micro EDM, Micro LBM and Micro EBM. After this a brief introduction will be given to Focused Ion Beam Machining that is FIB Machining and last section will be Selection of Machining Processes, this is very important to select a right kind of machining process. If it is not economical, if it is not with high productivity, probably an industrialist will not accept it. And finally I will give some concluding remarks about the total course.

Now first and foremost question arises is why do you need advance machining processes when there are so many types of traditional or conventional machining processes about which you already know for example turning, milling, grinding, shaping and so on. So now we all know that these age lot of research is going on in engineering materials and this is very important area.

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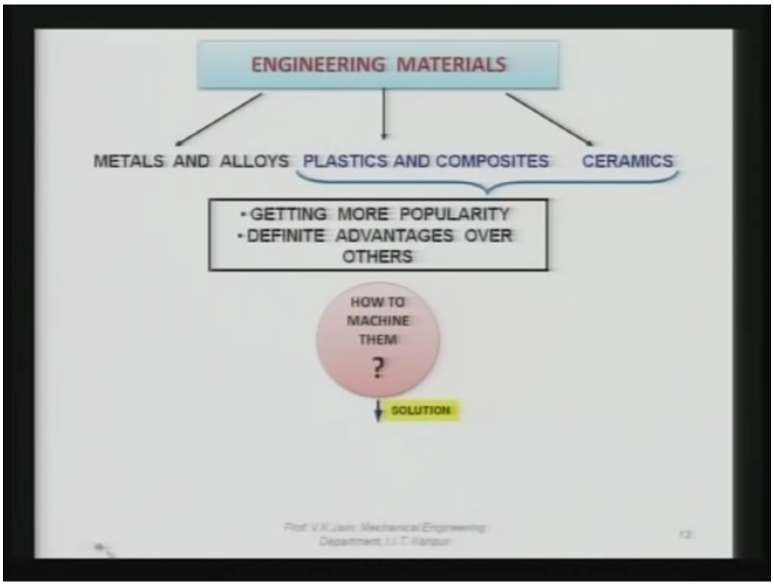

If you want to classify the engineering materials, you can classify them into three categories as you can see Metals and Alloys, Plastics and Composites and Ceramics. You know little bit about all these type of materials. These materials specially plastics and composites and ceramics, they are getting more popularity amongst the industry users. Definite advantages they have got over the other materials commonly used specifically metals and alloys.

Now question is how to machine these materials because if we see the ceramics, normally we use ceramic tools for cutting the metals and alloys or other material. Now when material or work piece material itself is made up of that hard materials like ceramics the question arises which material will you use for cutting ceramics because we know that tool should be much harder than the work piece material when work piece itself is hard or harder than the tool material, how to machine it?

So this was one of the regions that people or the researchers in the field of manufacturing started thinking to evolve or to come up with a new processes, new type of machining process where hardness is not the barrier and the solution they found nowadays is known as Advanced Machining Processes.

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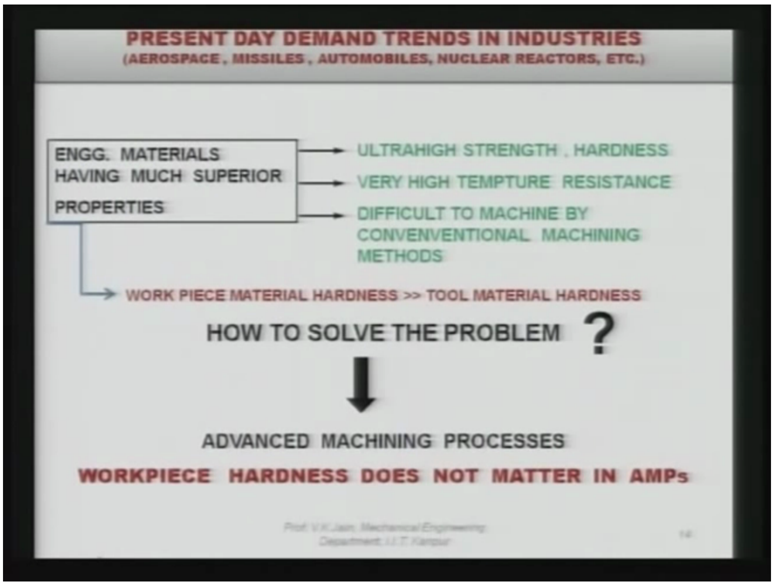

Now the question arises what is the present day demand trends in various kinds of industries, especially high tech industries just like aerospace industries, missiles, automobiles, nuclear reactors, etc. Now engineering materials which are in demand they should have much superior properties then the commonly used metals and alloys. And what should be the properties just as we see they should have ultrahigh strength, very high hardness, very high temperature resistance because there are certain components just like turbine blade. Yes turbine blades, they operate at 1100 or 1200 degree centigrade so at that temperature they should be able to retain their shape and size and other properties while in use.

Now when we use ultrahigh strong materials as work piece material then the question arises how to machine them, it becomes very difficult to machine by conventional methods where we know the work basic principle is that tool material hardness should be much higher than the work piece material hardness, and this principle is well known (())(12:41) manufacturing area started thinking or evolving new manufacturing processes, new machining processes and the result was as we all know that advanced machining processes were evolved over the period of time.

Here the important thing is work piece hardness does not matter in AMPs, Advanced Machining Processes as I just mentioned that hardness is the barrier in case of conventional machining processes. So when we are using advanced machining processes, hardness does not remain as a barrier for machining it.

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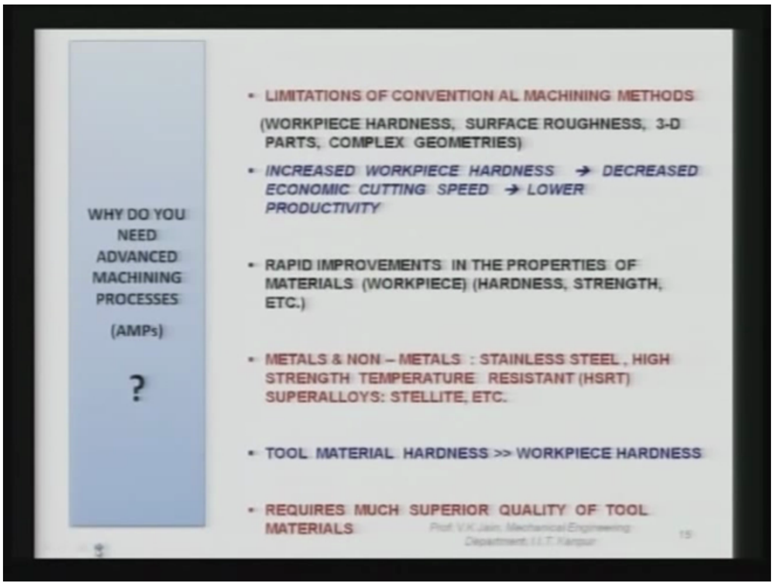

Now there are various reasons why we need to use advanced machining processes, so the question arises why do you need advanced machining processes and the basic answer for this is that there are various limitations with conventional machining methods or conventional machining processes just like I have already mentioned that work piece hardness should be smaller or lower, then the tool hardness. The present day industries they need very high level of surface finish that means surface roughness value should be very very low.

Even people are in the demand of nano level surface roughness value that is RA should be in the range of 1 nanometer to 999 nanometer. There are various components which are 3D in nature, 3 Dimensional just like turbine blades, the question arises how to make them by conventional machining method which is very very difficult because these 3D components many of these 3D components are made of super alloys which are very very hard or they have the hardness as good as that of cutting tool materials.

Single point or multi point cutting tool materials which we normally use in conventional methods and their geometry in many cases are complex and it is difficult to machine them by conventional methods so in most of the cases industry people use CNC machine that is Computer Numerical Control Machine.

Now Increased Work piece Hardness will lead to the decreased economic cutting speed because as the hardness of the work piece increases, the cutting speed at which in conventional methods you can machine this particular part keeps on decreasing that means productivity goes down or you get lower productivity that means more expensive component, more time consuming. And as we have already seen there are the rapid improvement in the property of the material which are used as the work piece material.

Now metals and non-metals are used as the work piece materials just like stainless steel, high strength temperature resistance super alloys. So the question arises how can you machine them and when we see these properties of these materials definitely we have to go for using the advanced machining processes. Now when tool material hardness is very close to the work piece material hardness then you require much superior quality of tool materials.

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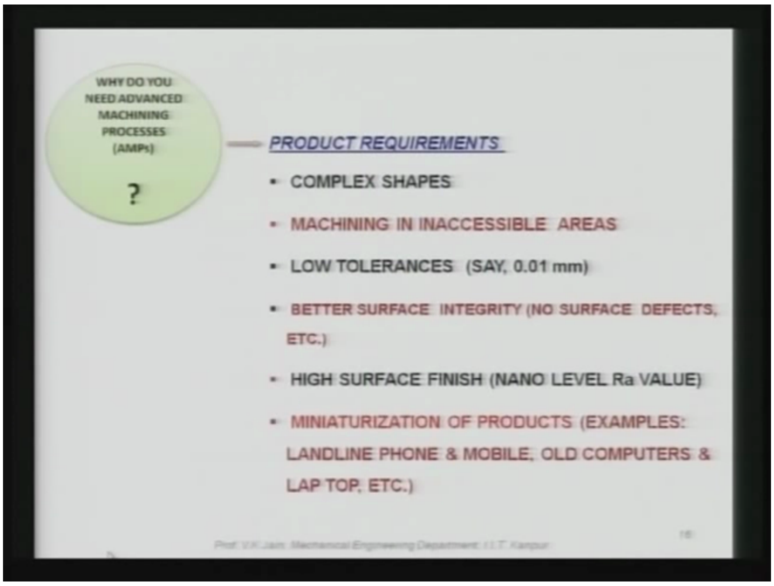

Now apart from the work piece material properties, there are the product requirement which are very complex in shapes, many products are very complex in shapes. Now many times you require, as I will give you some example to machine the component in inaccessible areas for the conventional cutting tools maybe single point cutting tools or multi point cutting tools. There you definitely require advanced machining processes to shape and size such components and tolerance is required these days are very very small, 10 micrometer or even smaller than 10 micrometer depending upon the requirement of the component.

You need better surface integrity, this is very important to understand the surface integrity means the surface after machining should not have any defect maybe micro cracks or poor surface finish or heat affected zone kind of the thing should not be there otherwise it may get rejected during inspection. High surface finish as I have already mentioned.

Now Miniaturization of Products is another thing which forces you to use the advanced machining processes. You can see in the olden days or even today we use the landline phone which are much larger in size as compared to the mobiles and these mobiles have much more capabilities than landline phones, you can internet with the help of these mobiles, you can send the e-mail with the help of these mobiles and everything is compacted in a very small size of the product that is the mobile.

Old computers and laptop, the old computer say if you see this room, this size of the room could not have much more memory than what you can have in the laptop which is very very small in the size. So this miniaturization requires very small size of the component with different capabilities and very different materials and for machining these components you definitely require the processes other than conventional machining processes.

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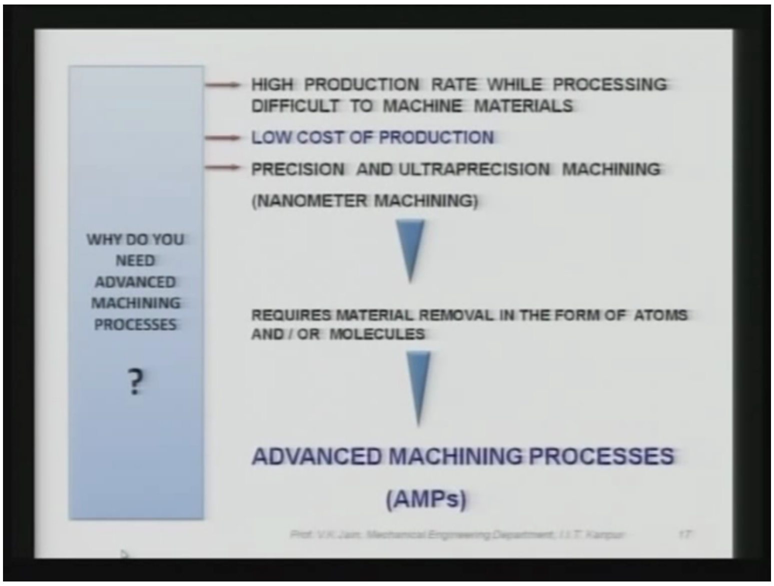

And industry people always talk of high production rate, they need the processes which can give high productivity while processing difficult to machine materials specially. Also they always demand that the cost of production should be as low as possible so that they can have higher profit.

Precision and Ultraprecision Machining or Nanometer Machining are the requirements of todays sophisticated high tech industries which you cannot fulfill with the help of conventional machining methods so you have to go for advanced machining processes. When we talk of nano level surface finish or tolerances less than 10 micrometer, definitely you cannot get these kind of the requirements on the component with conventional machining processes where you are removing material in the form of the chips, where the size of the chip itself is few 100 microns if you see on the lower side or sometimes in the form of few millimeters.

With these kind of the removal of the chip you cannot definitely get nano level surface finish or micro products so you need the processes where you are removing the material in the form of atoms or molecules and removal of the material in the form of atoms and molecules you can get through advanced machining processes only as we will see in various lectures. So the solution finally is the advanced machining processes.

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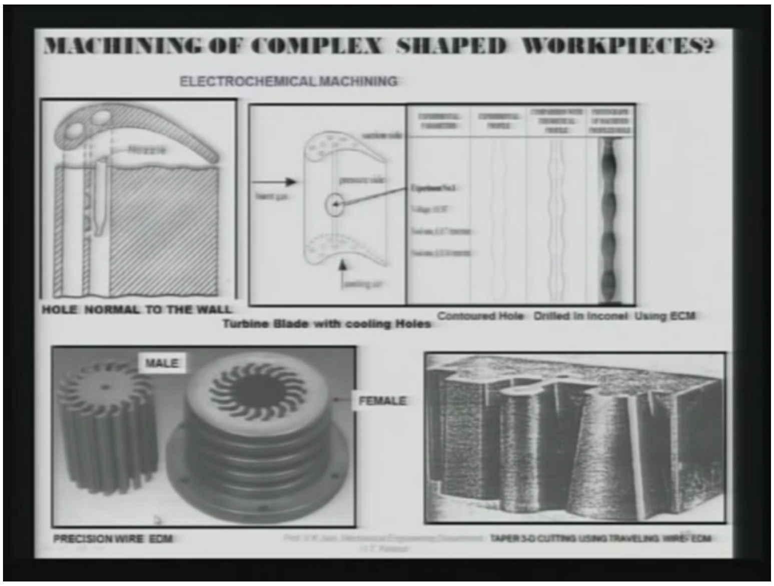

Now let us see some interesting examples which you cannot solve or machine by the conventional machining methods. If you see here the first part here, on the this one, here is a hole and here is the another hole in between these two holes there is a wall and you want to drill a hole perpendicular to this wall. The question arises which conventional machine method can do this to the best of my understanding, no conventional machining method can drill a hole like this in this particular component.

So here you can use only the process that can serve your purposes, electrochemical machining, we will discuss it later on and you can see this by electrochemical machining they are able to drill a whole, normal or at a 90 degree to the valve. Now here if you see in the second figure these are the cooling holes in the turbine blade and the dimensions of these cooling holes are very small, normally the size of the cooling hole is normally 1 to 2 millimeter and the length is quite large. So you get the high aspect ratio in the material of these turbine blades is super alloy.

So you cannot machine it by normal conventional methods. So the question arises how to machine them? So there is a process called shaped tube electro machining that is the only process which you can use for this purpose although there are competitive other processes also I will discuss them later on.

Now present a design of the turbine blades cooling hole, they do not require straight sided hole they need the turbulated hole as you can see here the wear, the diameter of the hole is continuously changing along its length, now the question is how to drill such kind of the holes where diameter of the hole itself is changing and the largest diameter of the hole is say around 1.5 to 2 millimeter and smallest is around 1 millimeter and that too with turbulated hole, you cannot use any conventional machining method for dealing such kind of the hole.

Rather you have to go or advanced machining processes and for that purpose again shaped tube electro machining method is being used and this is the hole that has been drilled at IIT Kanpur, you can see whose diameter is continuously changing along the length of the hole. Now if you see here, in this particular case you have the male part and you have the female part. This male part has been taken out from the female part and the difference in the features of this female part and male part is only few 100 microns.

So you can fit this male part into the female part and you can use it as a single product. Such kind of component you cannot make by any of the conventional machining method so definitely you have to go for advanced machining processes.

Here is the another example of a 3D component, now such kind of the 3D component you cannot make easily by conventional machining methods you have to go for advanced machining processes and this can be easily make by wire EDM process, wire electric discharge machining process and this component also can be easily made by electric, wire electric discharge machining method, we will discuss them later on.

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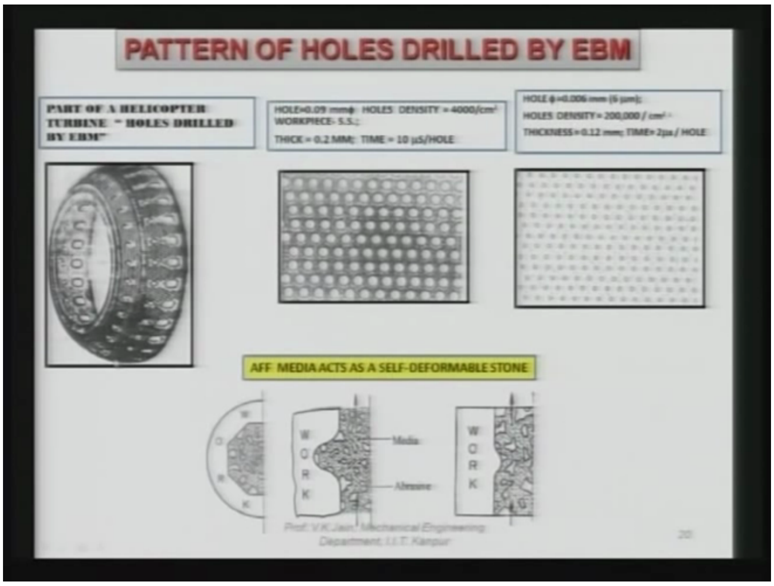

Now here are other examples where you really need to go for advanced machining processes, now see here there is a component, part of a helicopter turbine there are thousands of holes that have been drilled in this particular component the shape and size of these holes is very small, shapes are varying from location to location as you can see here this are very small hole these are the much bigger holes and thousands in number and the thickness in this particular component is very small maybe less than millimeter and very hard material.

Question arises how to make them, you cannot make by any of the conventional methods otherwise component itself will get warp out or it will get damaged so only process which can be used in this particular case is electron beam machining method. Now here is another requirement, hole diameter in this particular case is just 90 micrometer, hole's density is 4000 holes per (())(25:33).

Now the question arises how to make so large number of holes in such a thin sheet and such a hard material and that too with high productivity. So this is only possible through some of the advanced machining processes just like it has been made by electron beam machining method and you will be surprised to know that the time taken for dealing each hole is just 10 microsecond per hole and these kind of the holes are needed in the filters specially textile industries or juice industries, they need the filter of such a small size holes but people are not satisfied even with this requirement, they say no we want still smaller holes and still larger density of the holes.

And you can see here in this particular case the hole size is just 6 micrometer and the hole density is 2000000 holes per square centimeter and the thickness of the sheet in this particular case is just 120 micron size and the time taken for the drilling these holes is 2 microsecond per hole and in this particular case it is taking 10 microsecond per hole but this has reduced substantially by 5 times. So now you can see such kind of requirement cannot be made by conventional machining method in any way you have to go for advanced machining processes.

Now there is another example you see here this is a particular component where orthogonal kind of the component and you have to finish this internal surface to a nano level surface roughness value or here is a concave component where you gave to finish whole surface including this concave surface to a nano level surface finish or this is a convex surface, the question arises how to finish them? You cannot use grinding, you cannot use honing, you cannot use lapping, the only process or similar to this process that you can use are abrasive flow finishing or magnetorheological abrasive flow finishing processes which we are going to discuss later on in this particular course.

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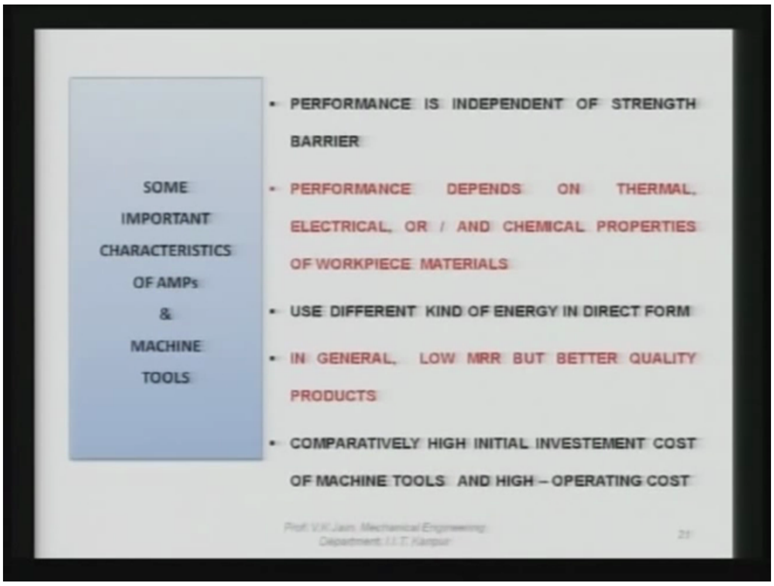

Now what are the some important characteristics of advanced machining processes in some advanced machining processes machine tools now as we will see later on that performance of these processes is independent of strength barrier that is the strength as well as hardness of these work piece component, the performance of this processes does not depend upon these two characteristics.

Performance of advanced machining processes depends on thermal properties of the component, electrical properties of the component whether it is electrically conducting or electrically non-conducting. Chemical properties of the component, what is the electro chemical equivalent of the component that will decide in some cases the material removal rate or performance of the process.

Now these advanced machining processes they are going to use different kind of energy in its direct form as I have already mentioned just like laser beam energy. Electron beam energy, focused ion beam energy or spark, electric spark or discharge energy and so on. In general material removal rate in these advanced machining processes is lower but definitely quality of the product is better than what you can achieve if at all you can machine them by conventional machining methods.

Here in these advanced machining processes, investment, initial investment is very high compared to your conventional machining machine tools. Say a lathe machine you can buy, a good lathe machine you can buy for about 10 lakhs or so but if you go to buy a simple ECM machine it will not cost less than 15 to 20 lakhs and if you go for electron beam machine it will cost you around 100 lakhs o rupees and if you go for focused ion beam machining it may cost you 600 lakhs of rupees or even more than that.

So initial investment is very high in case of some of the advanced machining processes and also the operating cost is also very high in case of some of the advanced machining processes as compared to conventional machining processes but the beauty is that you can solve your many many difficult to solve problems related to machining processes.

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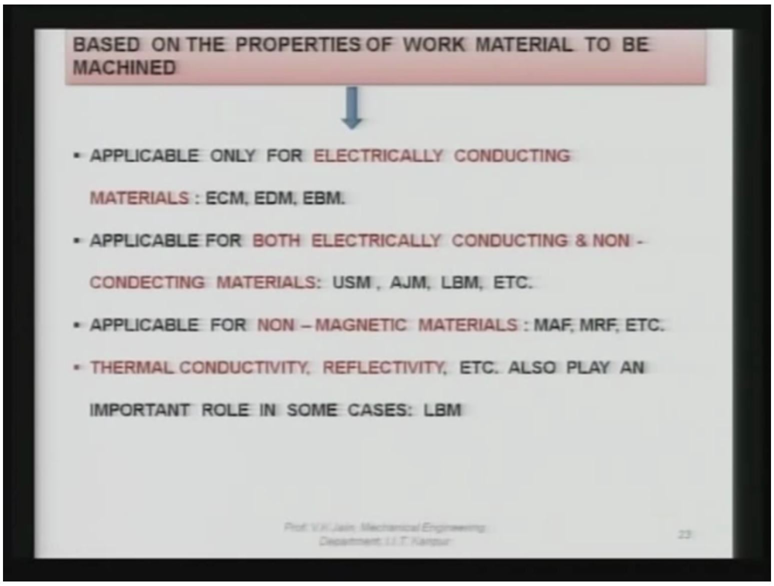

Now let us see in brief classification of these advanced machining processes, now classification you can do of these advanced machining processes based on different criteria. One of those criteria is work piece material to be machined. Applicable only for electrically conducting material, they are certain processes which are applicable only for electrically conducting material those processes are like electrochemical machining, electric discharge machining or even electron beam machining. They cannot be used for the materials which are electrically non-conducting.

There are certain processes which are applicable for both electrically conducting as well as electrically non-conducting materials just like ultrasonic machining processes, it can be applied for any kind of work piece material whether conducting or non-conducting materials, abrasive jet machining, laser beam machining, etc. Now there are certain processes which are very good for non-magnetic materials, while they are not so good for magnetic materials and those processes are like magnetic abrasive finishing, magnetorheological finishing, etc. where magnetic field is used for assisting the performance of the process.

There are certain processes whose performance depends upon thermal properties of the work piece material like thermal conductivity, reflectivity of the material used for making the part, those processes play an important role in some cases, these properties rather play an important role in certain processes specially in case of laser beam machining, if the component has high reflectivity, laser beam machining cannot work efficiently.

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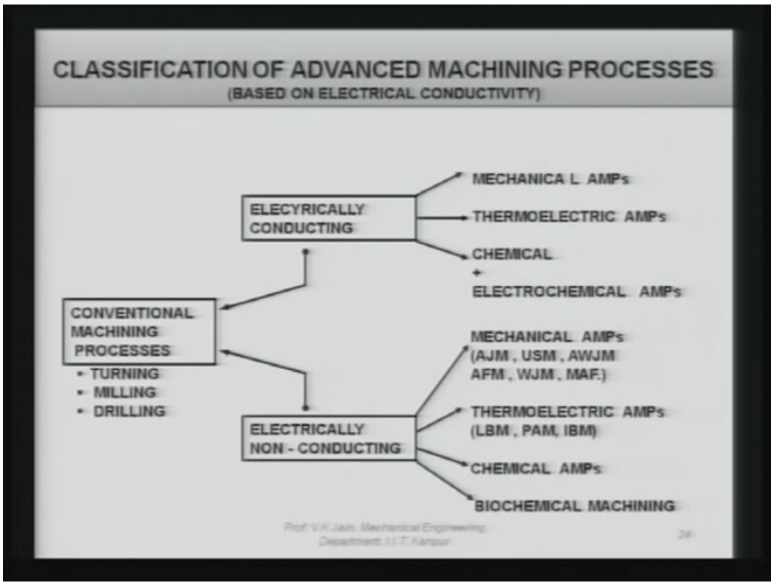

Classification of advanced machining processes based on electrical conductivity, I have just mentioned in brief. Now if you see the conventional machining processes like turning, milling, drilling, they really do not have any such kind of constrain. You can use it for electrically conducting material, all this conventional machining processes can be used. In case of advanced machining processes you can use mechanical type of advanced machining processes, any of the advanced machining processes and also mechanical type finishing processes can be used for electrically conducting all kind of materials even thermo electric advanced machining processes can be applied for electrically conducting material. Chemical and electro chemical advanced machining processes can also be applied for electrically conducting material.

But if you see electrically non-conducting materials, you can use all kind of conventional machining processes like turning, milling or drilling processes but if you see the advanced machining processes electrically non-conducting materials, you can use mechanical type of advanced machining processes like AJM, USM, abrasive water jet machining, abrasive flow machining, water jet machining, magnetic abrasive finishing, all of them can be used for electrically non-conducting material.

In case of thermo electric advanced machining processes you can use laser beam machining, plasma arc machining, ion beam machining. You can also use chemical advanced machining processes as well as biochemical machining processes can also be used for electrically non-conducting material.

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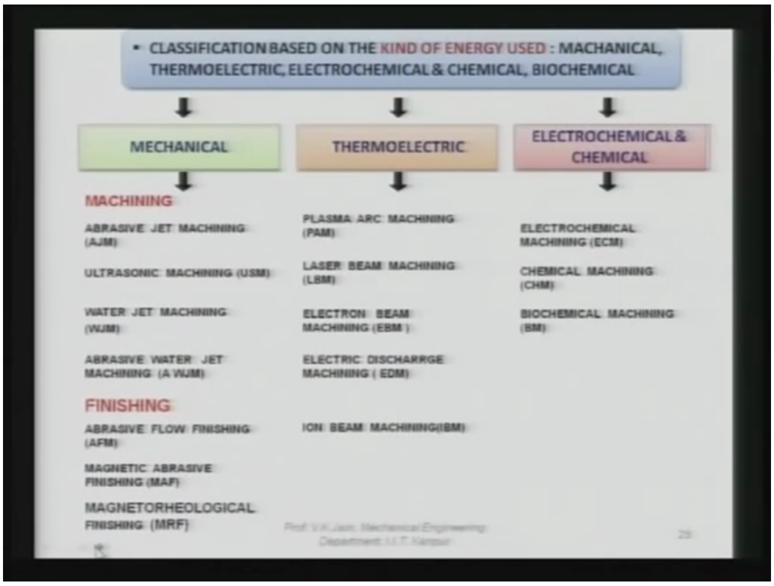

Now let us see how you classify various advanced machining processes based on kind of energy they are using just like mechanical, thermo electric, electro chemical and chemical and bio chemical machining processes.

Ok let us discuss about the classification based on the kind of energy used, we can classify them in mechanical thermo electric, electro chemical and chemical and biochemical machining processes. You can have various kind of machining processes that includes abrasive jet machining, ultrasonic machining, water jet machining, abrasive water jet machining then there is a different class of finishing processes using tools abrasive flow finishing, magnetic abrasive finishing and magnetorheological finishing processes.

Then there is another class that is known as thermoelectric type of machining processes, it includes plasma arc machining also known as plasma arc cutting processes, then laser beam machining, electron beam machining, electric discharge machining and ion beam machining processes and this ion beam machining also known as focused ion beam machining processes.

In case of electrochemical and chemical machining processes we have electrochemical machining and chemical machining, there is another very latest process which is also known as biochemical machining although I am not going to discuss it in this particular course but this is the latest development in the area of machining method.

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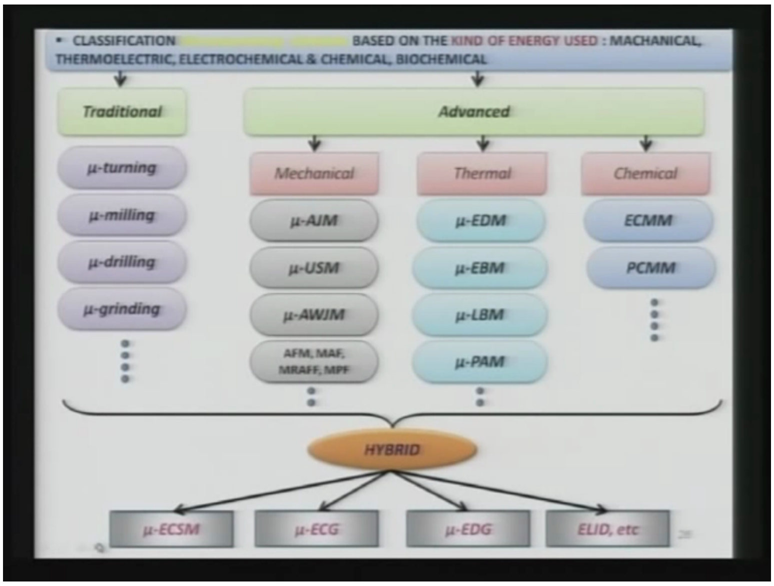

Now there are various, as I mentioned in the beginning that miniaturization is taking place and for miniaturization you need to go for micro machining in place of macro machining. So there are classification of various kind of advanced micro machining processes, let us just see the classification like traditional machining processes they have been classified as micro turning, micro milling, micro drilling, micro grinding, etc. All these are the conventional macro processes which have been scaled down to micro level and that is why they are known as you can see micro turning, micro milling, etc.

In case of advanced machining processes again you can have similar kind of classification as in case of conventional or traditional machining processes like micro abrasive jet machining, micro ultrasonic machining, micro abrasive water jet machining and then you have the nano finishing processes like advanced finishing methods or abrasive flow machining, magnetic abrasive finishing, magnetorheological abrasive flow finishing and magnetic float polishing, it is not MPF it is MFP.

Same way you have thermal processes or thermo electric micro machining processes like micro electric discharge machining, micro electron beam machining, micro laser beam machining, micro plasma arc machining, and so on. And in the last category you can have electro chemical micro machining, photo chemical micro machining and so on. So these are the various kind of micro machining processes.

Now there is another class which is known as Hybrid Micro Machining Processes. In case of hybrid what you are doing really that you are combining more than one that is two or more than two traditional machining and advanced machining methods or advanced machining method and taking advantage of both the processes.

As you can see here micro electro chemical spark machining process, now if you see here electrochemical machining is used for electrically conducting material, electric discharge machining is used for again electrically conducting material, but electrochemical spark machining is used for electrically non-conducting material and when you are scaling down its machining parameters to the micro level then you call it as electro chemical spark micro machining methods or micro electro chemical spark machining method. Same way you have micro electro chemical grinding, micro electric discharge grinding and ELID and other processes.

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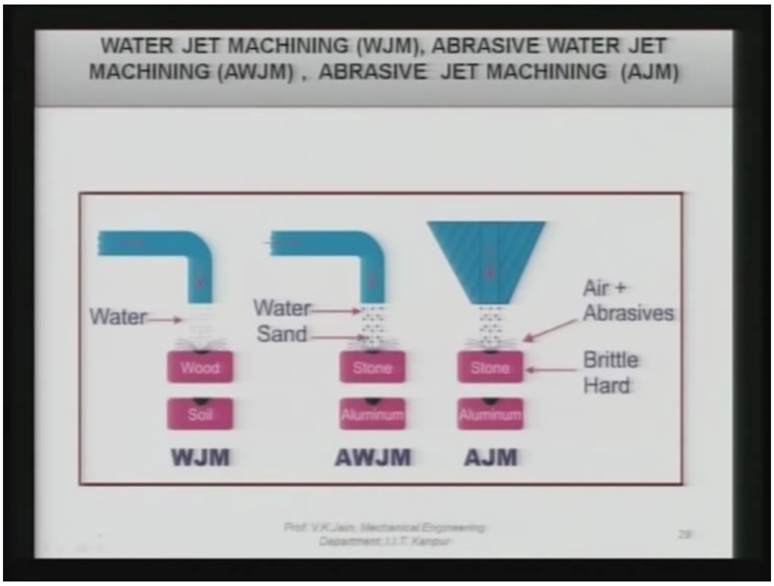

Now let us see the working principle of some of these advanced machining processes, now let us take some examples of events which we see in our everyday life. Now this particular figure is very interesting now here if you see this particular figure, water is coming from the tap and all of you have tap at your houses and the water is coming and if you put the wooden piece under the tap you will find that after few days a crate has been formed.

Now the question arises how water is able to cut the wood because we have just studied that tool material should be harder than the work piece material, there is nothing like a tool only water is coming falling on the woos and still it is able to create a crater over here or if you in place of wood if you place a lump of soil you will find that this crater is bigger than the crater that has been formed on the wood.

Now the question arises how water is able to remove the material from the wood or the soil? So keeping this in view this destructive feature in some sense, I just ask a question to all of you, could you think to make use of this destructive phenomena in some constructive purposes, for some constructive purposes, people took the inspiration from this phenomena and they developed a process what is known as water jet machining process.

Same way in rainy season, if you see that water coming out of the tap, you will find that some sand particles are there mixed with this and as shown over here. Now when this same particles along with water jet they come and hit the stone you will find after a few months a crater has been formed on the stone. Now the question arises how this jet of water and few sand particles is able to remove material from the work piece as hard as stone or if you place replace this stone by aluminium, you will find much bigger crater has been formed on the aluminium.

So what I mean to say here is that can you make use of this destructive phenomena for some constructive purposes, people have taken inspiration from such phenomena which they saw in their everyday life and they developed the process what is known as abrasive water jet machining process, which we will discuss in detail later on.

Now there is the third process, if you see here, here is the jet of air and abrasive particles coming out of the nozzle, now when this jet comes and hits the stone we will find a crater has been formed over here. In place of this stone if you place the aluminium, you will get the much bigger crater has been formed compared to what was formed on the stone.

Now such kind of destructive phenomena have been utilized for evolving or developing the machining processes very delicate sophisticated machining processes which we will discuss in this particular course.

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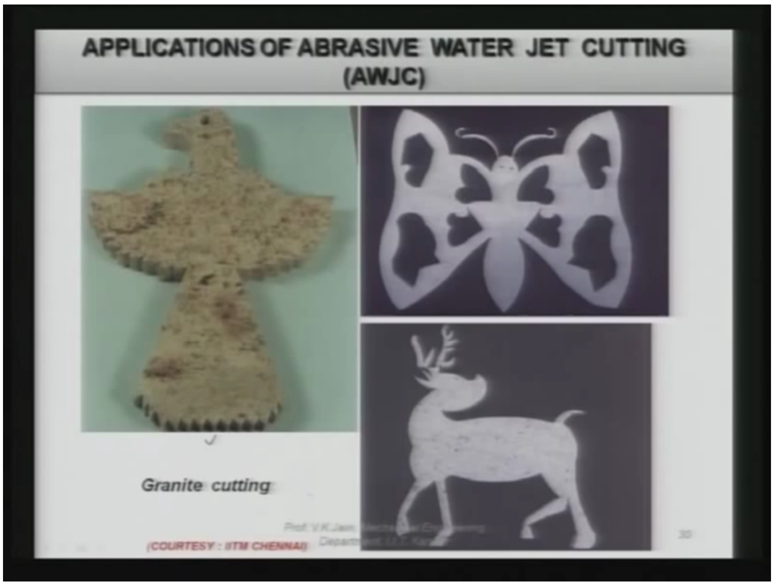

Now you can see the examples of the applications of these processes specifically abrasive water jet machining process, here a granite cutting has been done and you can see very beautiful shape has been formed. Again here there is another application of the abrasive water jet machining and there is a third application of abrasive water jet machining, these photographs are taken from Indian Institute of Technology, Madras, Chennai.

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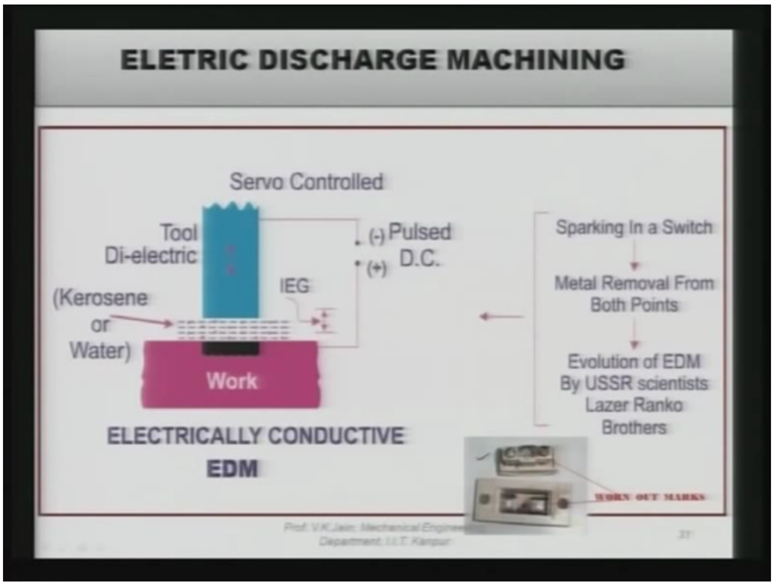

There is another process called electric discharge machining, let us see how it evolved, there were two brothers, Lazarenko brothers in the old USSR and one day they found that male and female parts of their switches. They were having the dark materials, dark spots over there like this and some material has been removed from male as well as female parts and both of them started thinking how to make use of this destructive phenomena of a sparking for some constructive purposes. They kept trying trying for years together and developed many machines but none of them worked, finally after a long time they were able to develop a machine which they named as Electro Spark Machining and today it is known as Electric Discharge Machining Machine.

And then they patented it and the working principle is very simple, you have a tool over here and you have the work piece in between the tool and the work piece you flow what is known as dielectric and you connect this tool and work piece to the pulsed power supply and when the potential gradient between the two electrodes is more than the breakdown voltage of the dielectric.

Then a plasma column is formed between the two and sparking takes place and because of that spark, the material is removed from the tool as well as from the work piece and finally you get the shape of the cavity on the work piece which is very very close to the shape of the tool but mind it here material is being removed from the tool as well as the work piece. But we want that the material should not be removed from the tool it should be removed from the work piece only.

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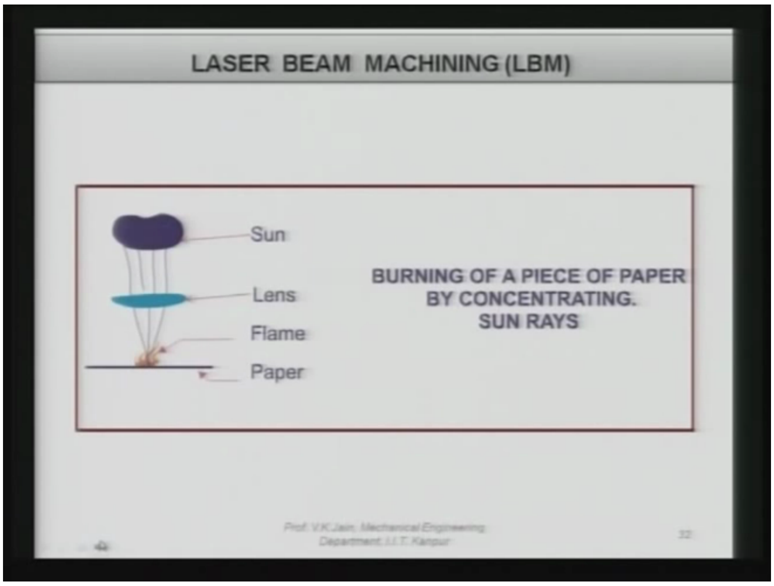

Now this is another interesting thing which children in their child age or young age they keep doing this magic, they take a lens, they concentrate the sun rays on a piece of paper and they burn and they enjoy this burning of the piece of paper and they call it as magic similar kind of concept has been utilized if you see here in case of laser beam machining but you are doing in laser beam machining, you are concentrating the laser light at very very small spot on the work piece to be machined or to be given a particular shape and size and the heat intensity of this laser light is so high that you can melt or vaporize any material known to you.

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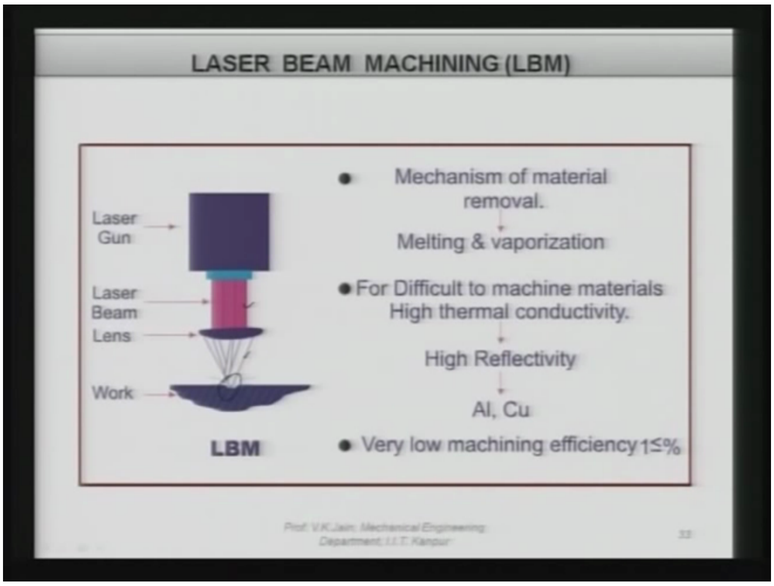

And you concentrate here laser beam and very small spot and temperature goes to very high value and you can machine or you can melt and vaporize any material you can get the desired shape and size.

Now there are certain problems with some materials which got high thermal conductivity and high reflectivity. They can be machined but performance of the process becomes very very poor specially in case of aluminium and copper. So very low machining efficiency this particular process in the beginning at very very low machining efficiency, machining efficiency was as low as less than 1 percent

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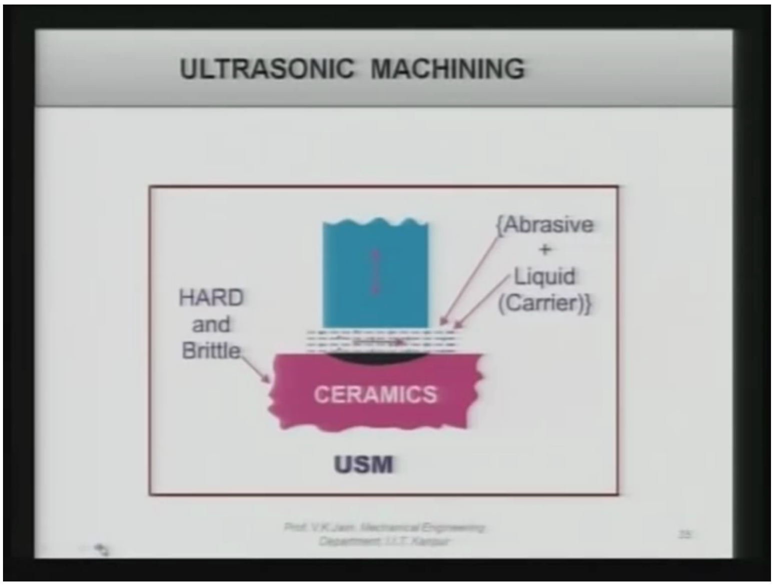

Now working principle of some other advanced machining processes, now there is another advanced machining process called ultrasonic machining process. Now in this ultrasonic machining here you have the tool which is vibrating at ultrasonic frequency that means near or more than 20000 hertz, means 20000 times per second it is vibrating with a certain amplitude of vibration and here if you see here there is a slurry which consists of liquid say water and abrasive particles.

And when this tool hearts a particular abrasive particle, it comes and strikes with the work piece say here ceramics is the work piece material and so 20000 times, thousands of abrasive particles are hit by the tool and they come and strike the ceramic or the work piece material and they remove very very fine crater or they create very very fine crater on the work piece and they keep removing the material and finally you get the shape of the crater form on the work piece very close to the shape of the tool and this is used or machining brittle and fragile materials we will discuss when we discuss the ultrasonic machining process.

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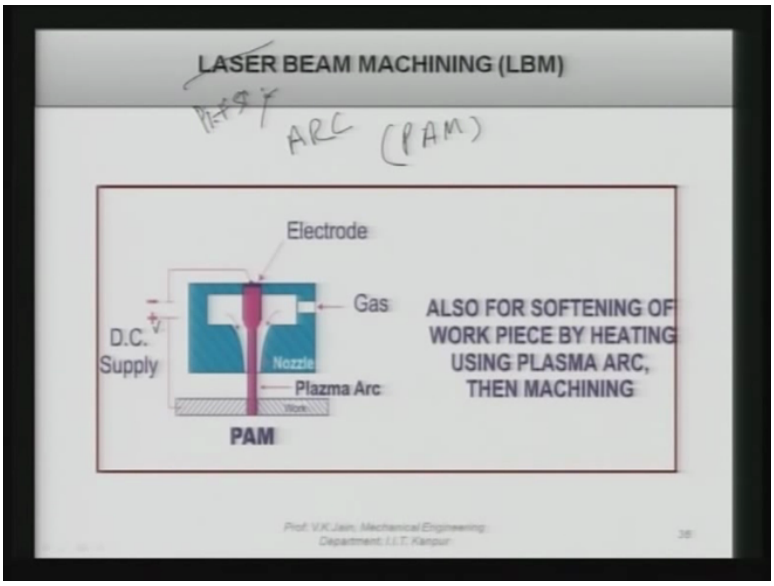

There is another process called, this is the Plasma Arc Machining not Laser Beam Machining so you can correct it this is plasma arc machining, PAM. Now in this particular as you see here you have the gas which is coming in and it is connected to the electrode which is connected to the negative terminal and here is the work piece which is connected to the positive terminal and very high potential is applied.

And when this gas comes then arc is formed and the gas gets ionized and plasma is formed and this plasma has very high heat intensity and you can cut any material that you have and when we want to cut very very thick materials where electric arc does not work at that place we use the plasma arc for cutting those thick materials into pieces. So this is very interesting very useful process but this process is used for rough machining or rough cutting not for finish machining or finish cutting.

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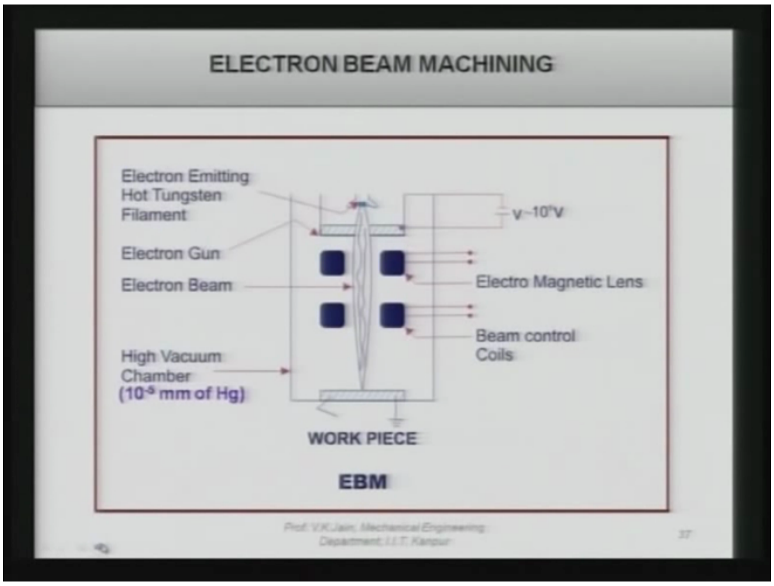

Now this is very interesting process Electron Beam I have shown already to you some of the examples of machining micro holes with the help of this process. Again very simple, here we have a hot tungsten wire filament or hot tungsten filament which is emitting electrons from this filament and here you can see electron gun is there we will discuss all these parts later on.

And here you have the electron magnetic lens and then beam control coil is there and you can see here this is the electron beam which is electrons in this particular beam are moving at the velocity which is close to the light and when such a high velocity electron, although they have got negligible mass but with such a high velocity half mv squared that is the kinetic energy becomes so large that they create a very high temperature at the point where they hit the work piece surface and the temperature is very very high.

But the condition is in this particular machining chamber it should have a vacuum if air is there then the molecules of the air will strike with the electrons and they will lose their energy and you will not get very fine cut on the work piece component so mostly the vacuum is created in the chamber and that vacuum can be 10 raise to power minus 5 millimeter of mercury. However there are certain versions of this electron beam machining machine where people are using air rather than the vacuum but the efficiency is comparatively lower.

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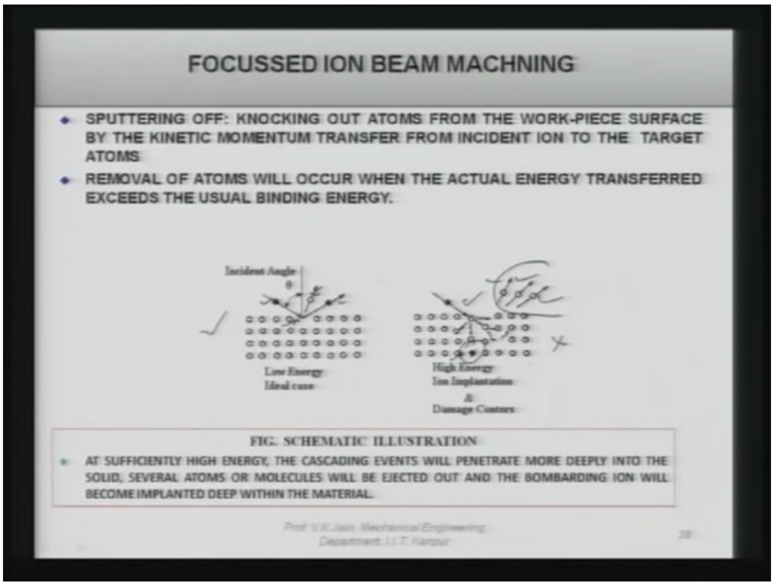

Now focused ion beam, here sputtering off or knocking out of atoms from the work piece surface by the kinetic momentum transfer from incident ion to the target atoms takes place. I will explain it here with the help of the figure as you can see this is the ion of some gas is coming and hitting the top surface of the work piece and you can see here it has displaced the atom from this particular point and you can see here is that atom and here is the ion.

So the energy with which the ion is hitting the work piece surface, top surface of the work piece is just sufficient to dissociate one atom from the top surface of the work piece and you can see one ion has dissociated or separated out one atom from the top surface but normally the energy of the ion is much more than what you really just needed to remove one single atom and you can see here in this particular case that the ion has much larger energy, so in place of one single atom many atoms are removed from the top surface.

And the ion gets implanted at the bottom of the below the top surface and this you can see over here and this is the situation which we really do not want in machining because surface gets damaged over here.

This is the ideal situation which we want but normally in practice in between these two the situation takes place. At sufficiently high energy the cascading events will penetrate more deeply into the solid as you can see over here several atoms or molecules will be ejected out and that is shown over here and the bombarding ion will become implanted deep within the material that is what you can see over here. So this situation we really do not want, we want this particular situation.

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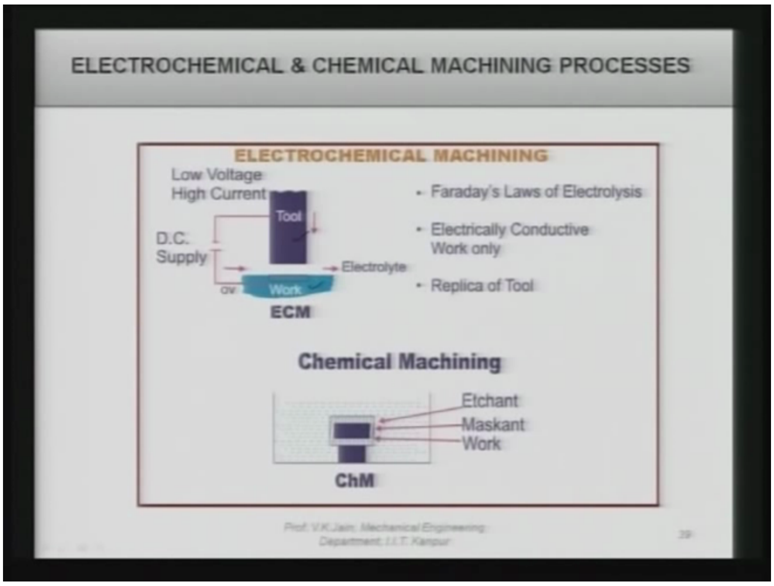

There is another process known as electrochemical machining and you must be knowing electroplating this process is just reverse of electroplating in this particular case you have the tool you have the work piece both are electrically conducting and then you use what is known as electrolyte. Electrolyte is nothing but the solution of normal salt in water there are other electrolytes also which we will discuss later on and when this electrolyte is flowing in this gap and you connect this tool to the negative terminal and work piece to the positive terminal then current starts flowing in the gap.

This gap is known as inter electrode gap and when this current is start flowing electrochemical reaction takes place and as a result of that material is removed from the work piece and you get the cavity formed in the work piece which is close to the shape of the tool and in this way you can machine any hard material.

It is the chemical property or metallurgical property of the work piece which affect the performance of the process rather than mechanical properties of the work piece that is the hardness is no more barrier in these kind of the processes as we find in case of conventional machining processes.

And there is another process called as chemical machining process, in this process you are using the etchant which reacts chemically with the work piece surface you use the maskant to hide the surface from where you do not want to remove the material and you immerse the work piece in the etchant which already has the mask and once you immerse it for the definite period of time, the material start dissolving chemically and after a certain period of time you take out the work piece and you will find the desired shape and size on the component.

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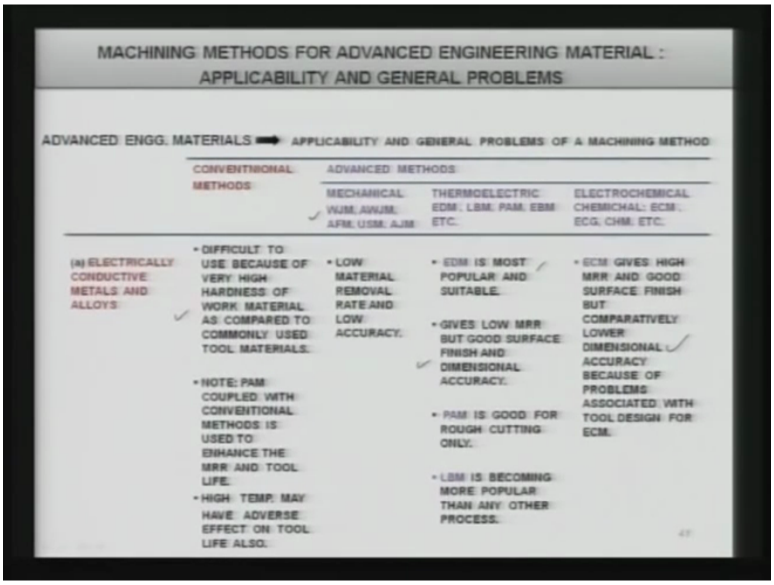

Now in brief I will just tell you the machining methods for advance engineering materials what are the applicability in general problems that you find. Now let us discuss them in these headings which we have already seen conventional methods, advanced machining methods.

If there are electrically conducting metals and alloys, by conventional methods difficult to use because of very high hardness of work material as compared to the commonly used tool materials. Once the hardness of the work-piece material increases commonly used tools materials for them it becomes difficult to machine them.

Note, plasma arc machining coupled with conventional method is used to enhance the material removal rate and tool life this particular pulse is when you are hitting the work piece material with the help of plasma arc and removing the material with the help of conventional cutting tool that is also known as hot machining.

Now in case of mechanical advance machining methods all these water jet machining, abrasive water jet machining, abrasive flow machining, ultrasonic machining and abrasive jet machining, they can be used but they give low material removal rate and low accuracy while thermoelectric method like EDM, LBM, PAM, EBM, etc. EDM is the most popular process amongst all of them and you will find that this process is used even small scale industries in India. It gives low material removal rate but good surface finish and good dimensional accuracy compared to other processes.

Plasma arc machining is good for rough cutting only. Laser beam machining is becoming more popular than any other process in case of thermo electric processes. Now in case of electrochemical and chemical machining processes ECM is the most popular process. It gives high material removal rate it gives the highest material removal rate in advance machining processes except plasma arc cutting and good surface finish.

But comparatively lower dimensional accuracy, this is one of the reasons why it is not so popular as compared to electric discharge machining processes because of problems associated with tool design we are not able to get good accuracy on the machine component.

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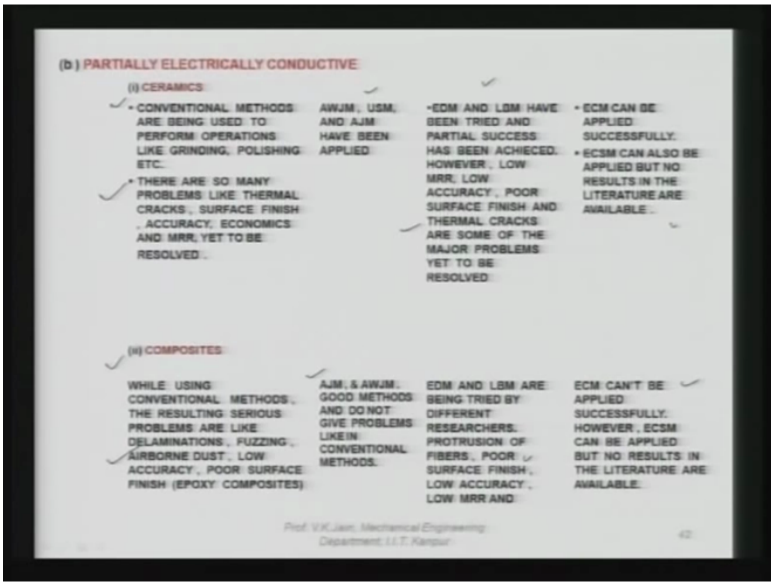

Now there are many materials which are partially electrically conductive like ceramics. Conventional methods are being used to perform operations like grinding, polishing, etc. There are so many problems like thermal cracks, surface finish is poor, accuracy is also poor, economics and MRR are the problems which are have to be resolved. In case of advanced machining processes you can use abrasive water jet machining, ultrasonic machining and abrasive jet machining, they have been applied for partially electrically conducting material.

In case of thermoelectric methods, EDM and LBM have been tried and partial success has been achieved. You know there are, people are engineering the materials such that they can be machined by thermoelectric advanced machining processes like EDM and ECM. So they are introducing deliberately partial electrical conductivity so that they can shaped and sized easily.

Surface finish and thermal cracks are some of the major problems yet to be resolved in case of thermoelectric advanced machining processes ECM can be applied successfully provided the work piece has some minimal electrical conductivity. Electrochemical spark machine can also be applied but no results in the literature are available with reference to partially electrically conducting material.

Now in case of composite materials while using conventional methods the resulting serious problems are like delamination, fudging, air borne dust, low accuracy, poor surface finish specially in case of epoxy composite material. AGM and abrasive water jet machining processes, they are the good methods and do not gave problems like in conventional machining methods that I have just told you delamination, etc. Thermoelectric methods EDM and LVM are being tried by different researchers provided they have partial electrical conductivity or full electrical conductivity.

Protrusion of fibers give a bit problem in case of thermoelectric methods, poor surface finish is obtained, low accuracy and low material removal rate in case of thermoelectric methods, ECM cannot be applied successfully however ECSM can be applied but no results in the literature are available now ECM can be applied only when it has certain minimum electrical conductivity.

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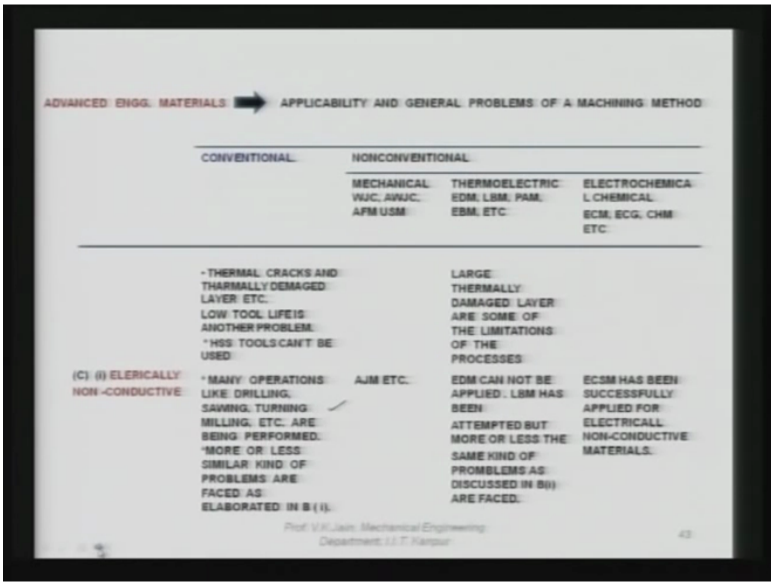

Now advanced engineering materials, it is applicable and general problems of a machining methods are like as follows. Now in case of thermal, conventional methods you get thermal cracks and thermally damaged layer are obtained and you get low tool life, high speed steel tools cannot be used in such cases of composite materials. Now in case of non-conventional or sorry, now electrically non-conducting materials you can apply conventional methods like many operations like drilling, sawing, turning, milling, etc. are being performed. More or less similar kind of problems are faced as elaborated earlier in case of B1.

Now for electrically non-conducting materials AGM, etc. they can be applied, but in thermoelectric processes you get large thermally damaged layer is obtained which creates some of the limitations of the processes to be applied. Now in case of non-conducting materials you cannot apply laser beam machining, although laser beam machining has been applied attempted but more or less same kind of problems as discussed in B1 are faced. ECSM has been successfully applied for electrically non-conducting materials.

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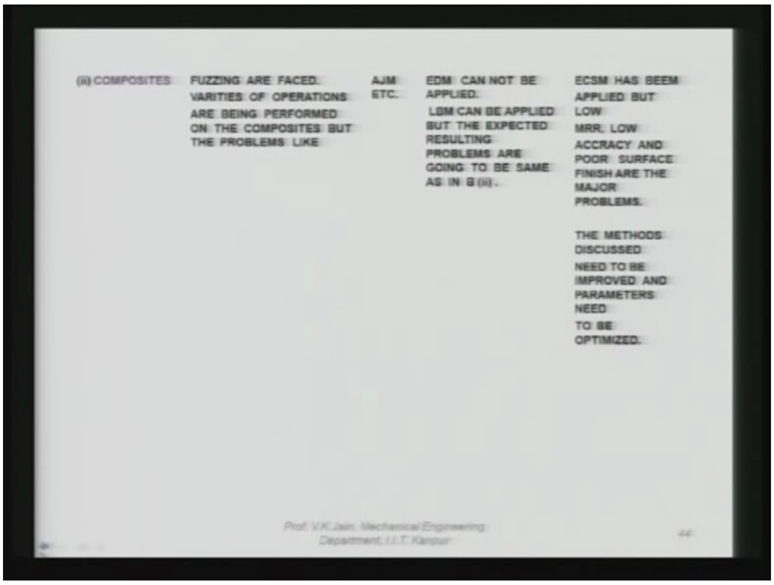

Now when we are talking of composite materials fudging are faced in case of conventional methods fudging is one of the basic problem that is being faced varieties of operation are being performed on the composite but the problems like AGM can be applied, EDM cannot be applied, LVM can be applied, but the expected resulting problems are going to be there as discussed earlier.

ECSM has been applied but low MRR, low accuracy and poor surface finish are the major problems, the methods discussed need not be improved in parameter need to be optimized. In conclusion from all this lecture we can conclude that advanced machining processes can be efficiently used for macro, meso, micro, and nano machining and finishing processes that we have seen.

Advanced machining processes should be used only when the traditional processes are incapable to perform the desired job efficiently, this is very important because the jobs which you can do by traditional or conventional machining methods you should not attempt by advanced machining processes because advanced machining machine tools are very very expensive their operating cost is also high and material removal rate is or the productivity also comparatively low. Hybrid processes normally perform better than the constituent individual processes.

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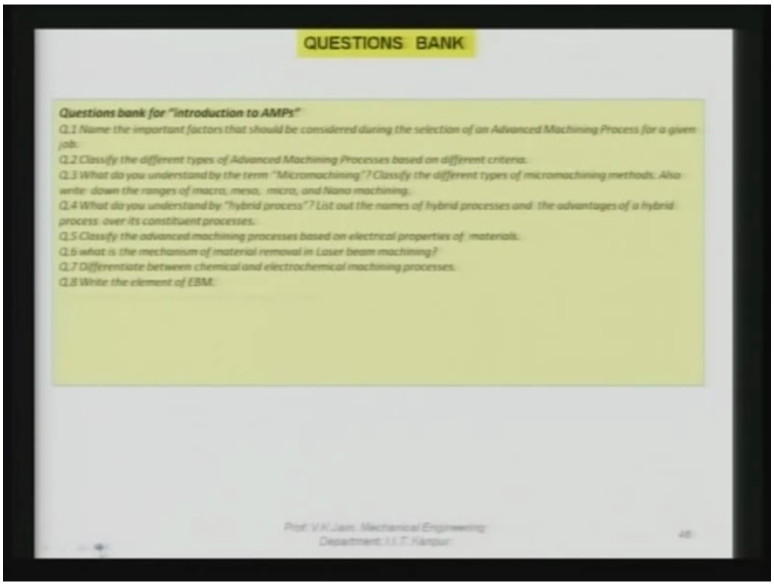

Now there is some exercise or question bank here you can try to attempt yourself and if you want you can find the solution for most of these questions in the todays lecture or in the book that I have already mentioned to you Advanced Machining Processes by V. K. Jain. Thank you very much.