Advanced Machining Processes
Professor Vijay K. Jain
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur
Lecture 02

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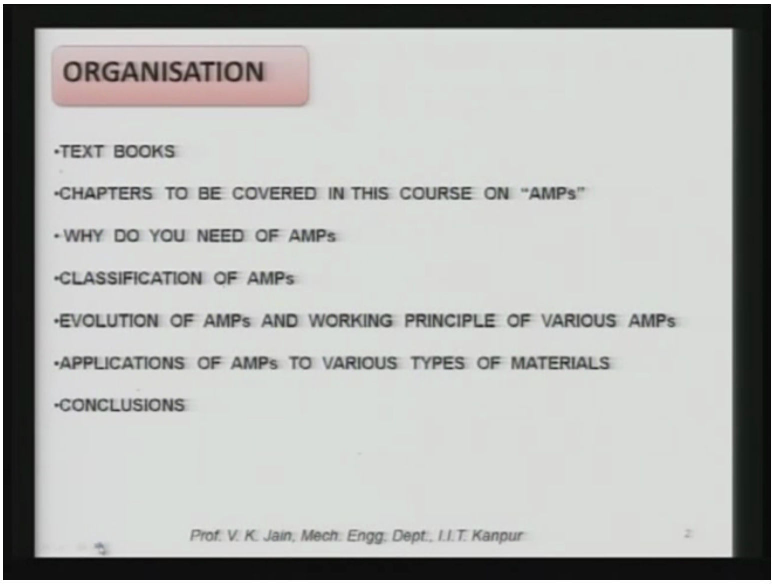

Welcome to the course on Advanced Machining Processes, now organization of the course is as follows, I will tell you about the textbooks available in the market then we will move to the chapters that are to be covered in this particular course on AMPS that is Advanced Machining Processes.

The first and foremost question that arises is why do you need advanced machining processes, then we will deal with the classification of various advanced machining processes that are in use, afterwards I will tell you about the evolution of advanced machining processes and working principle of various advanced machining processes.

Then I will deal with applications of advanced machining processes to various types of the materials, various types of the operations and various types of the industries and finally we will derive some conclusions from this particular talk.

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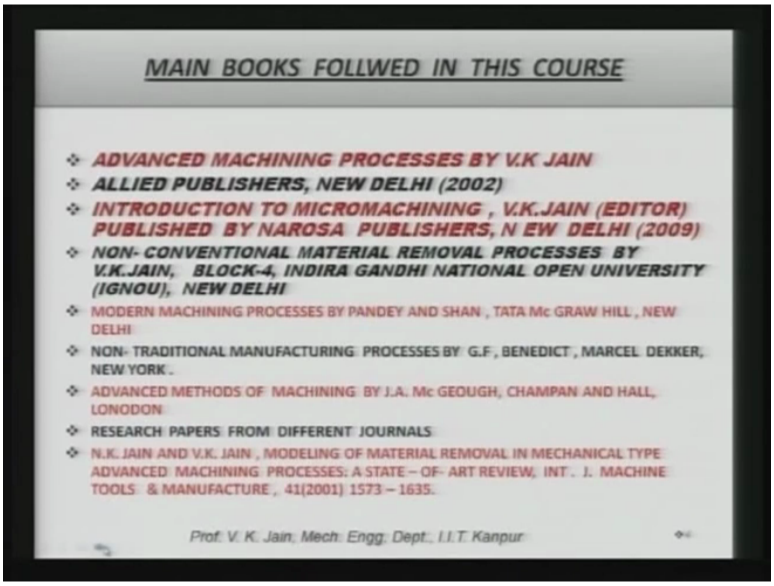

What are the various textbooks that are available in the market related to this particular course, you can see here first one is the Advanced Machining Processes by V. K. Jain, it has been published by Allied Publishers in the year 2002, second one is Introduction to Micromachining again by V. K. Jain editor published by Narosa Publishers, New Delhi, 2009.

There are various names of this particular subjects on which the books have been written just like Non-Conventional Material Removal Processes by V. K. Jain that was written for Indira Gandhi National Open University, New Delhi. Then there is a book on Modern Machining Processes by P. C. Pandey and H. S. Shah published by Tata Mc Graw Hill, New Delhi, another one is Non-Traditional Manufacturing Processes by G. F. Benedict published by Marcel Dekker, New York.

The book on Advanced Methods of Machining has been published by Chapman and Hall, London and it has been written by well known researcher Professor J. A. McGeough of Edinburgh University. Then there are various research papers available in International Journals related to Advanced Machining Processes. A very well accepted and a relevant research paper which I will be referring in this particular course is by N. K. Jain and V. K. Jain, the title is Modeling of Material Removal in Mechanical Type Advanced Machining Processes, a state of art review, published in International Journal of Machine Tools and Manufacture, it was published in the year 2001.

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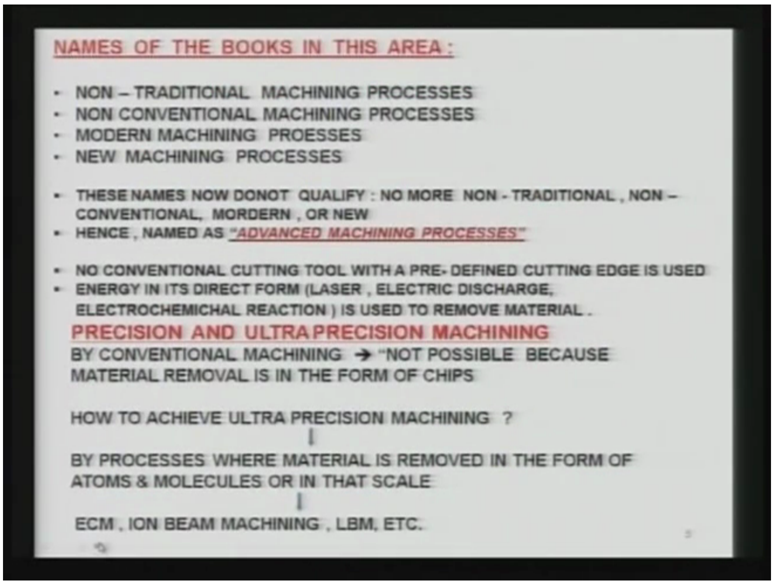

So you can see from the titles of the various books that this particular subject is named in a different ways like non-traditional machining processes, non-conventional machining processes, modern machining processes, new machining processes. However the contents covered in all these books are more or less the same, these names now do not qualify because most of these processes that are discussed in this particular subject, they are no more non-traditional, no more non-conventional, no more modern or new. Most of this processes are nowadays very commonly used in medium scale industries and large scale industries and to some extent in small scale industries as well.

And that is why these processes nowadays are known as advanced machining processes which are different from traditional machining processes like turning, milling, grinding, shaping, etc. In these processes no conventional cutting tools with a pre-defined cutting is edge is used just like we all know that single point turning tool or milling cutter, etc.

In these processes energy in its direct form is used just like laser energy, electric discharge energy, electrochemical reaction, etc. are used for the removal of the material. Precision and Ultra Precision machining, by conventional machining methods it is not possible to achieve precision and ultra precision machining because material removal is in the form of the chips and normally the chip size is quite large, however with present day technology developments, you can achieve the microchips also but these conventional machining method have their constraints, limitations, specifically of the shape and size which I will discuss in different lectures.

Now the question arises how to achieve ultra precision machining by processes where material is removed in the form of atoms and molecules or at that particular scale will be possible to achieve precision or ultra precision machining. It is very difficult to achieve ultra precision machining with the help of conventional machining processes where material is removed in the form of the chips. Electrochemical Machining, ion beam machining, laser beam machining are some of the examples where material is being removed in the form of atoms or molecules.

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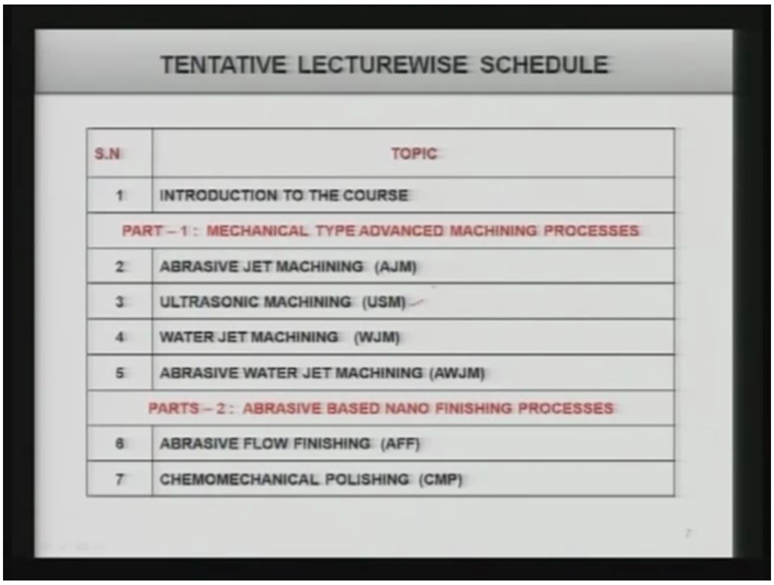

Now what are the various chapters that are going to be covered in this particular course on Advanced Machining Processes, first one is the introduction to the course, part one will deal with the mechanical type of advanced machining processes which includes abrasive jet machining which is abbreviated as AJM, second is ultrasonic machining as USM, water jet machining WJM, abrasive water jet machining AWJM. Part two of this course deals with abrasive based nano finishing processes, abrasive flow finishing, chemomechanical polishing.

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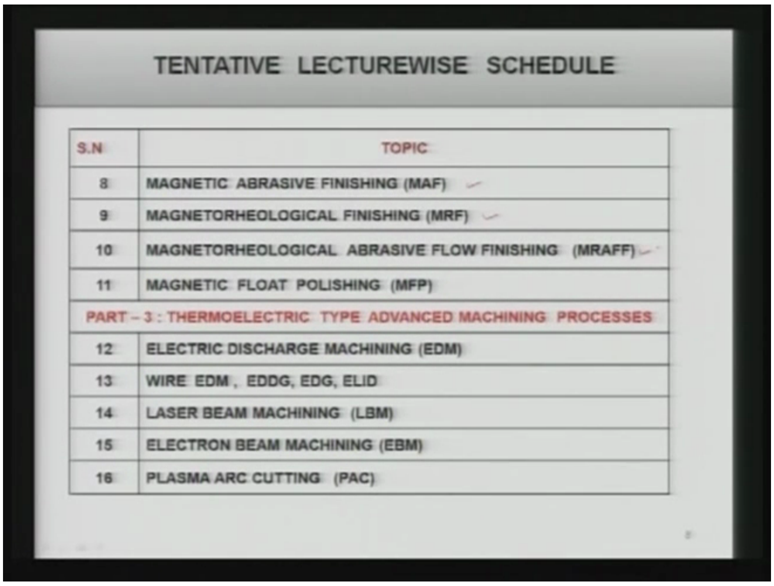

Magnetic abrasive finishing, magnetorheological finishing MRF, magnetorheological abrasive flow finishing MRAFF and magnetic float polishing. These are some of the processes which are used for nano finishing of different shapes and sizes.

Part three deals with thermoelectric type advanced machining processes which includes electric discharge machining, wire electric discharge machining, electric discharge diamond grinding that is EDDG, electric discharge grinding EDG, electrolytic in process dressing ELID. Next chapter that we will deal with is laser beam machining that is LBM, electron beam machining EVM and plasma arc cutting that is PAC.

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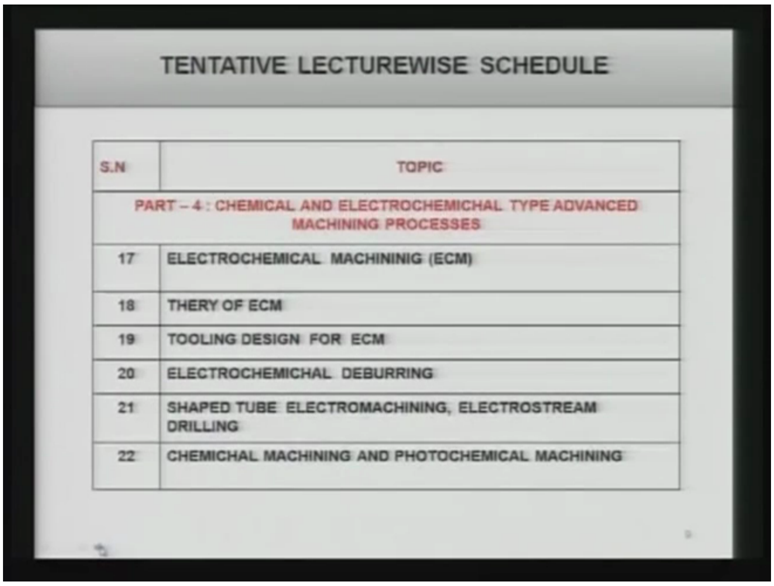

The next part of this course deals with chemical and electrochemical type advanced machining processes which includes electrochemical machining, this will be the introductory section, then we will deal with the theory of electrochemical machining, tooling design for electrochemical machining, electrochemical deburring, shaped tube electrochemical machining, electrostream drilling, then chemical machining and photochemical machining.

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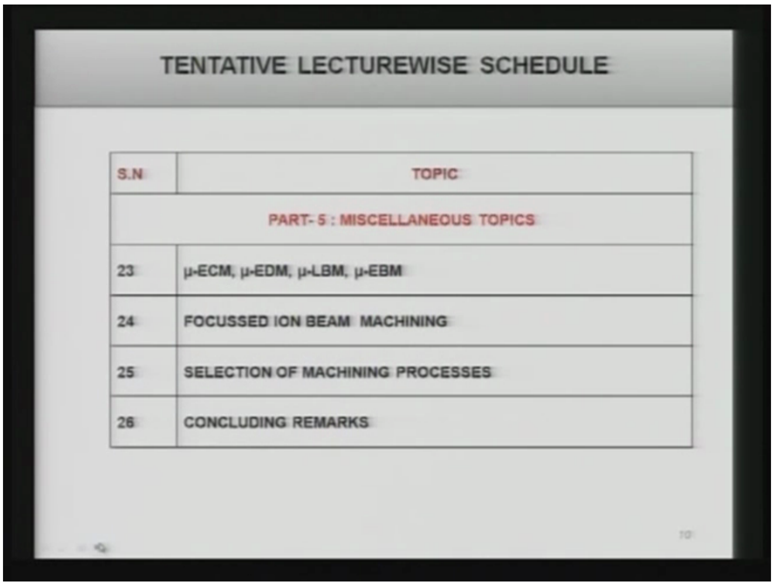

Last part of this course will deal with miscellaneous topics which includes micro electrochemical machining, micro electro discharge machining, micro laser beam machining, micro electron beam machining, focused ion beam machining and then it deals with selection of machining processes which is very important to select a right kind of machining process.

It should be economical, it should serve the functions of the parts which are to be machined and finally some concluding remarks about this particular course will be made. Now the basic question that arises here is why do you need these advanced machining processes when you already had many types of traditional machining processes? Now the question arises why do we need this advanced machining processes when we already have many traditional machining processes like turning, milling, grinding, etc.

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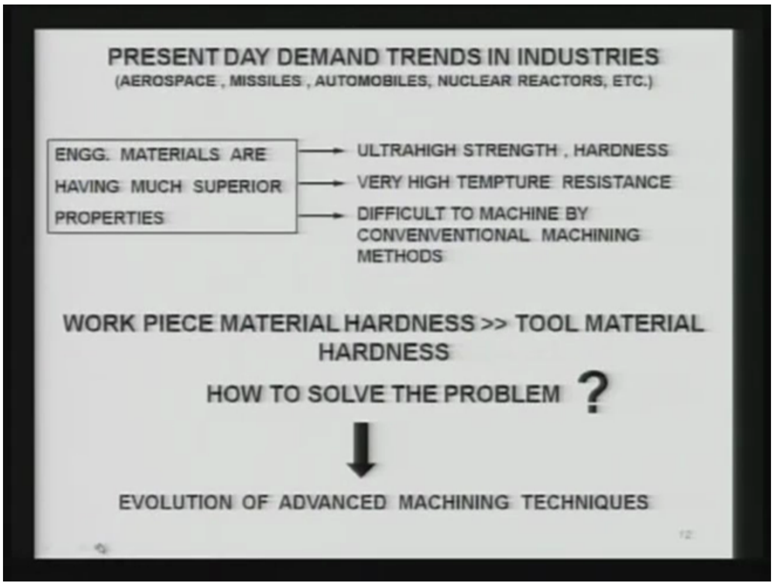

Now if you see present day demand trends in various industries, high tech industries specially like aerospace industries, missiles, automobiles, nuclear reactors, etc. The basic requirement of these industries is that they need the engineering materials that are having superior properties just as ultrahigh strength hardness, very high temperature resistance, difficult to machine by conventional machining methods, because they are very very hard high strength so they are difficult to machine by these conventional methods like turning, milling, grinding, etc.

Now because there is a basic principle of these conventional machining processes one has to follow that is work piece material hardness should be smaller than the hardness of the tool material but in these high tech materials, the work piece hardness is much much harder or much much larger than the tool material hardness, so it will be difficult for the conventional tool to machine these work piece materials.

So the question arises how to solve this problem so this led to the evolution of advanced machining techniques that is what we are going to discuss or that is what we have named as advanced machining processes.

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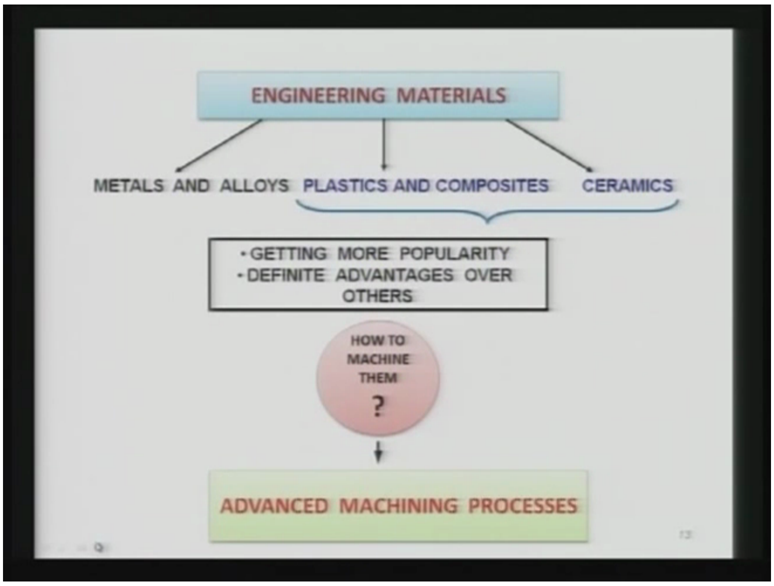

Now engineering materials they can be divided into three categories like metals and alloys, plastics and composites and ceramics. Now plastics and composites and ceramics they are getting more popularity because they have got definite advantages over other materials but these specially the ceramics are much much harder than the conventional tool material.

So the question arises how to machine the materials which are harder than the traditionally used tool materials? So the only solution is that we have to go for advanced machining processes.

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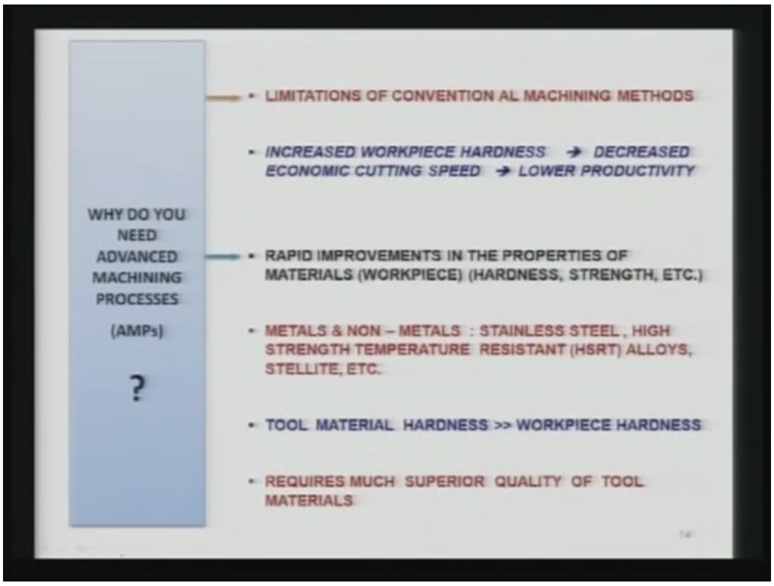

So the question arises what are the limitations of conventional machining methods as we have seen that 3 dimensional, high precision components cannot be machined easily by the conventional methods. Second point is that the work piece hardness is increasing day by day, so the tool hardness is not able to match with the work piece hardness so you cannot use conventional tools for that purpose and as the work piece hardness increases, the economic cutting speed keep decreasing which leads to the lower productivity.

Another problem is rapid improvement in the properties of the materials that is the work piece hardness, strength, etc. they also force for using new techniques for machining newly developed materials. Metals and non-metals such as stainless steel, high strength temperature resistant, alloys or super alloys, stellite, etc. How to machine them is again a problem by conventional methods.

So the basic requirement of conventional methods is tool material hardness should be much higher than the work piece hardness, so requirements of much superior quality of the tool material comes into picture.

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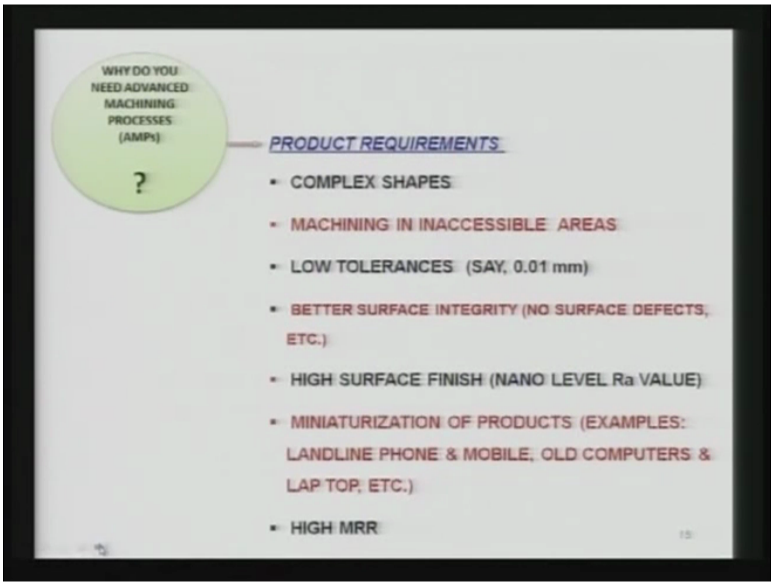

So why do we need advanced machining processes another is the apart from the material which are much superior than in the past there are the stringent requirements of the products also, the complex shape of the component again forces to evolve new techniques for machining these complex shaped component.

Another requirement may be machining inaccessible areas as some of the examples I will quote when I deal with different kind of the machining processes. Low tolerance requirement that is the 10 micrometer or even less than 10 micrometer. Better surface integrity that is the surface after machining should not have surface defects, high surface finish, these days various many components they require nano level surface finish. This you cannot achieve easily with the conventional machining or finishing techniques.

Another important point is miniaturization of the products for example landline phone and mobile. Mobile shape and size has considerably changed as compared to the landline telephones. Old computers and new laptops, again the miniaturization has taken place substantially, etc.

And also we need a higher productivity or higher material removal rate, so high production rate while processing difficult to machine material is another requirement, not only the high productivity also the low cost of production is also very important, there is a very tough competition globally so unless your product quality is high, cost is low you cannot compete in the market.

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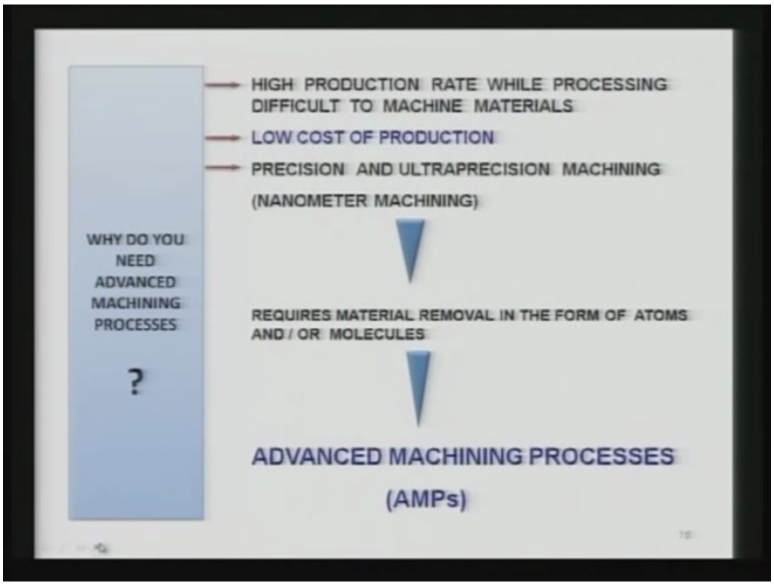

Precision and ultraprecison machining of nanometer level is another requirement, all these requirements lead to the use of new techniques, new methods for machining, finishing of these materials and when we talk of nano level surface finish or micro level tolerances, definitely we require the processes or the methods which can remove material in the form of atoms or and molecules. Then only that kind of tolerances and surface finish can be achieved and for this purpose we have no other solution except to use advanced machining processes that are named as AMPS.

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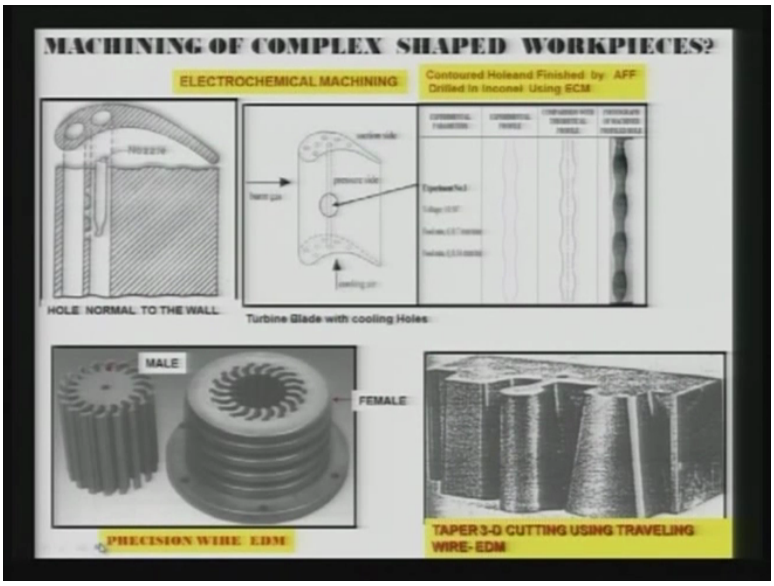

Here we can see some of the very important examples where by which we can say that yes we need some new type of machining processes for solving these problems. Just let us see this example work, here they are the two holes, hole 1 and hole 2 in a turbine blade, now suppose we want the hole which is perpendicular to the access of these holes as you can see here one hole is needed here another hole is needed here third is needed here.

Now the question is how to machine these holes perpendicular to the wall and the size of these holes, two main holes is very small, maybe 1 millimeter to 2 millimeter, now the question arises which process can do? You cannot use drilling process, you have to use some new technique which can drill the hole perpendicular to this wall that is shown over here and these kind of the holes are requirement in some of the special type of the products.

We will discuss when we discuss electrochemical machining, how to machine these kind of the holes, another requirement is here like a turbine blade. In turbine blades we need the cooling holes and thousands of such cooling holes are needed in the turbine blades and the size of these cooling hole is very small maybe 1 millimeter or 1.5 millimeter and the aspect ratio becomes quite high because in some cases aspect ratio may go more than 100.

So now the question arises so small diameter and so big holes in the super alloy, how to make them? Now this is not the only requirement because these are the holes which are shown as straight sided hole but if you see present day requirement of these turbine blades, they do not require straight sided hole rather they require contoured hole or turbulated hole as shown over here and these turbulated hole, how to make them?

Because you can see here the diameter of the hole is continuously changing along the axis of the hole and these type of the holes are very well required in the turbine blades because if such holes are there then the cooling efficiency goes high when dealing with the electrochemical machining or abrasive flow finishing, I will explain in detail. But these holes cannot be made by any process other than shaped tube electro machining which is a version of electrochemical machining; we will deal with this while dealing with the electrochemical machining process.

Now another example, peculiar example you can see over here that a part has been machined and you can see here, here is the male part and here is the female part now this male part can be fitted in the female part and both of them can be used simultaneously. Now this has been machined and taken out from this female part itself, now the question arises how to do it? So for that purpose there is a process called wire EDM process, wire electro discharge machining process, we will discuss it in detail later on.

And this is another 3D component which has been cut by traveling wire electro discharge machining process, such kind of the complex shape component cannot be machined by processes other than advanced machining processes and this very clearly indicates that there is a need of new techniques of machining other than conventional machining processes.

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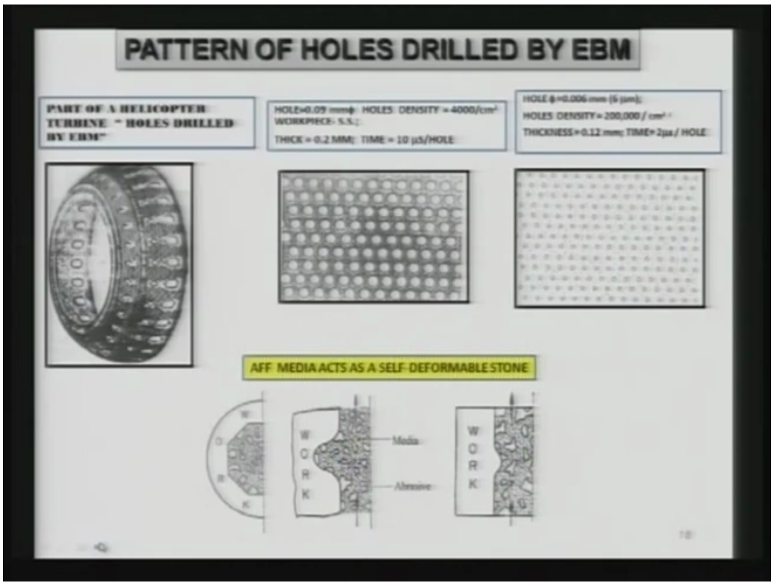

Now here are some other examples of need of non-conventional or advanced machining processes, you can see here, here is a part that is the part of helicopter turbine and you can see here thousands of holes are there and these holes have been made in a very thin sheet of this helicopter part, now how to drill these holes at accurate places of accurate size of certain shapes now you cannot do it by many processes, the process which is capable of doing all this is known as electron beam machining process.

Now in the filters many times we need filters for textile industries or for making juice etc. or filtering the juice etc. Now the question arises, these are the very fine holes of few micron size and they are thousands and thousands in numbers. As you can see example over here, there is one hole density in this particular case is 4000 holes per square centimeter and the diameter of the whole is just 90 micron and the material of the component is stainless steel and the thickness of the sheet is 0.2 millimeter.

Now how to drill these kind of the holes, they can be drilled only by electron beam machining process, but if you require the holes of even smaller size then you can go or 6 micron size holes where the density in this particular case is 200000 holes per square centimeter and the thickness of the sheet is just 0.12 millimeter and the time taken for drilling each hole is 2 microsecond per hole.

So you cannot use many processes for such kind of application, apart from this drilling the holes many times you need surface finish, controlled surface finish in various kind of the component. Now if you see here, this is a particular shape and you want to finish all the sides of this particular hole or here is a concave shape of the hole and here is the convex shape of the hole.

Now you want to finish the hole along with this concave and convex shape, now the question arises which conventional machining or finishing processes can be used? You cannot use grinding process, you cannot use lapping process, you cannot use honing process. In such cases the process which can be conveniently used and successfully used is known as abrasive flow finishing process, we will discuss it later on in detail.

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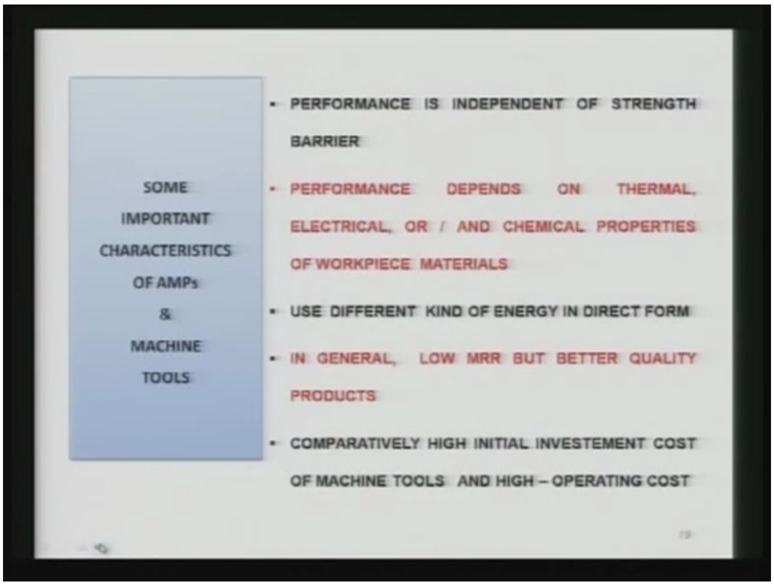

So let us see what are the important characteristics of these advanced machining processes, now in these advanced machining processes as I have mentioned, performance is independent of strength barrier as we have seen that the basic requirement of conventional machining processes is that the tool hardness should be much higher than the work piece hardness, but in these advanced machining processes like laser beam machining, electron beam machining, electrochemical machining that constrain is relaxed.

Because there you are not going to use a well defined cutting edge tool as we do in case of traditional machining processes. Second is performance depend on thermal properties of the work piece material, electrical properties of the work piece material, chemical properties of the work piece material, one of these can be the performance deciding factor rather than the hardness or the physical properties of the work piece material.

Use different kind of energy in direct form in case of advanced machining processes just like laser energy, electron beam energy or spark energy. In general low material removal is obtained in case of advanced machining processes compared to traditional machining processes but you obtain better quality of the products and comparatively high initial investment cost of machine tools and high operating cost is there as compared to traditional machining processes.

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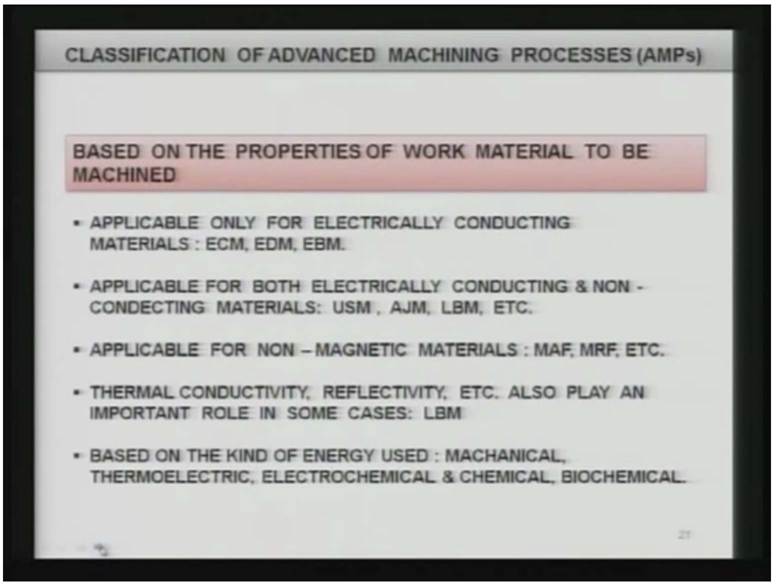

Next is the classification of advanced machining processes, you can classify these advanced machining processes based on the properties of work piece material to be machined. Some of the processes which are applicable for electrically conducting materials like electrochemical machining, electric discharge machining, electron beam machining, etc. Some of the processes are applicable for both electrically conducting as well as electrically non-conducting material like ultrasonic machining, abrasive jet machining, laser beam machining, etc.

Now certain processes are applicable for non-magnetic materials more effectively than magnetic materials like magnetic abrasive finishing, magnetorheological finishing, etc. Now thermal conductivity, reflectivity of the work piece material also make difference in the performance of the process especially in case of laser beam machining, based on the kind of energy used you can classify various advanced machining processes like mechanical type of advanced machining processes, thermo electric type of advanced machining processes, electrochemical and chemical type of advanced machining processes.

There is a recent process that is known as biochemical machining which can be placed, which can be put together along with the electrochemical and chemical machining processes as long as classification is concerned.

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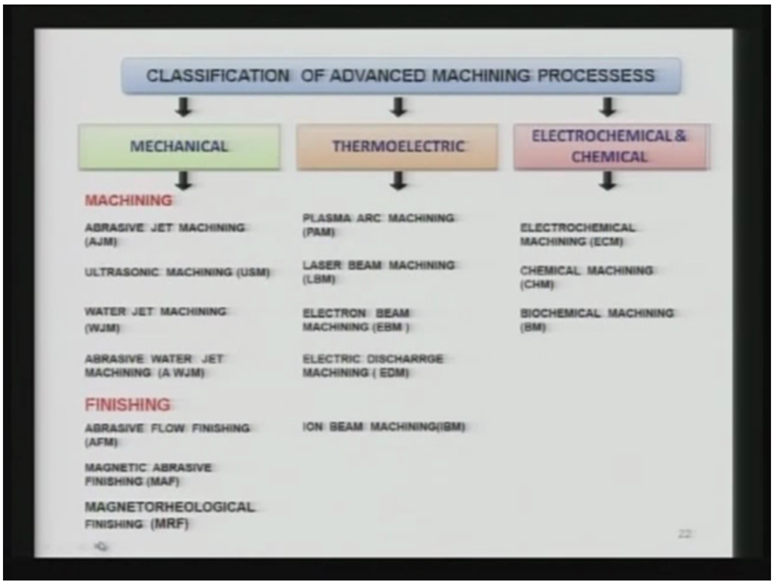

So it shows the classification of advanced machining processes, mechanical type of advanced machining processes, it includes abrasive jet machining, ultrasonic machining, water jet machining, abrasive water jet machining.

Now finishing techniques includes abrasive flow finishing, magnetic abrasive finishing, magnetorheological finishing and there are various allied processes. Thermoelectric includes plasma arc machining, laser beam machining, electron beam machining, electric discharge machining, ion beam machining and there are various hybrid processes as we will see later on and then finally electrochemical and chemical machining processes includes electrochemical machining, chemical machining and biochemical machining.

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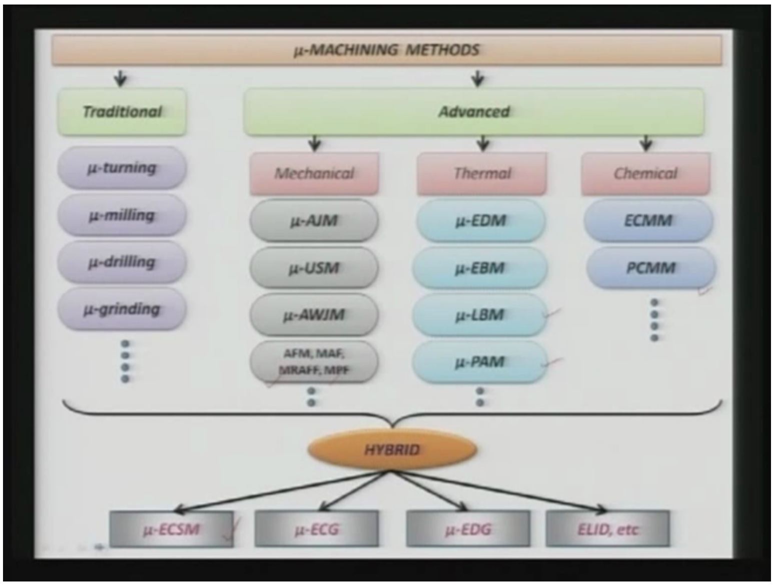

Now there are various micro machining methods which use traditional as well as advanced machining processes, now if we see the traditional micro machining processes it includes micro turning, micro milling, micro drilling, micro grinding, etc. Then there are advanced micro machining processes, again they can be classified into mechanical type of micro machining processes which includes micro abrasive jet machining, micro ultrasonic machining, micro abrasive water jet machining, then micro nano finishing processes like abrasive flow finishing, magnetic abrasive finishing, magnetorheological abrasive flow finishing, magnetic float polishing and so on.

Then we have thermal micro machining processes which includes micro electric discharge machining, micro electron beam machining, micro laser beam machining, micro plasma arc machining and so on, and then we have chemical micro machining processes, then we have electrochemical micro machining processes and then also photochemical micro machining processes.

So you have the large classification or large type of the, or large number of the machining methods which can used for micro machining purposes. Now there are certain hybrid machining processes where if you find that one particular type of the machining processes cannot perform to your satisfaction then what you can do you can combine two or more than two traditional and advanced machining processes, or two advanced machining processes to make use of the merits of both the machining processes.

Just like micro electrochemical spark machining processes, here electro, micro electrochemical machining and micro electrical discharge machining, both have been combined and you get the process that is micro electrochemical spark machining processes, this particular process can be used for machining of electrically non-conducting material while its original processes like ECM and EDM, they are applicable only for electrically conducting materials.

Same way you have micro electrochemical grinding process, here electrochemical machining and grinding processes has been combined together to achieve micro electro chemical grinding process, micro electric discharge grinding process again EDM and grinding have been combined to make this particular process workable then you have electrolytic in process dressing, etc. where in electrolytic in process dressing again electrochemical machining and grinding have been combined together.

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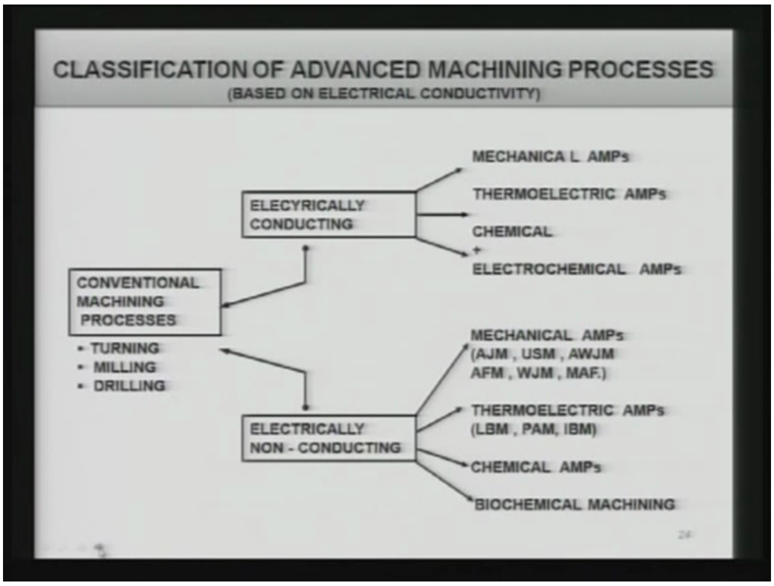

So you can have the classification of the advanced machining processes based on type of the work piece material as I have already mentioned that conventional machining processes which includes turning, milling, drilling, etc. Electrically conducting materials can be machined with the help of, electrically conducting materials can be machined by mechanical advanced machining processes, thermoelectric advanced machining processes, chemical and electrochemical machining processes.

Electrically non-conducting material can be machined by only limited number of the machining processes just like abrasive jet machining, abrasive water jet machining, ultrasonic machining, abrasive flow finishing, water jet machining, and so on. Thermoelectric advanced machining processes just like laser beam machining, plasma arc machining, ion beam machining then chemical advanced machining processes and biochemical machining processes they can be used for electrically non-conducting materials.

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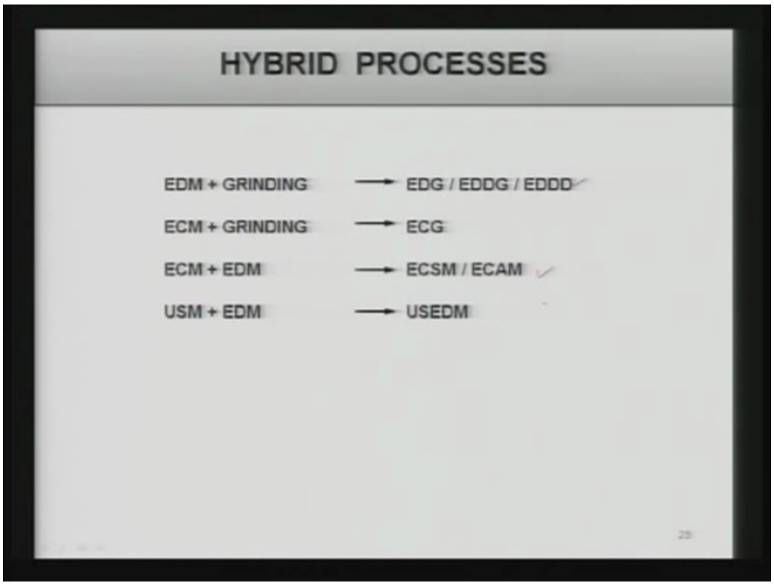

Now hybrid processes as I have mentioned a bit earlier these are the processes like EDG, EDDG, Electric Discharge Diamond Drilling. Electrochemical grinding which is a combination of ECM plus grinding, electrochemical machining combined with electric discharge machining give you what is known as electrochemical spark machining.

There is another process named as electrochemical arc machining, this process was developed at Edinburgh by Professor J. A. McGeough and it combines electrochemical machining as well as electric discharge machining. Here in place of spark, arc is created between the electrically conducting work piece material and the process tool so that you can enhance the productivity or the material removal rate from the work piece. Then you have another hybrid process that is known as ultrasonic machining and electric discharge machining process.

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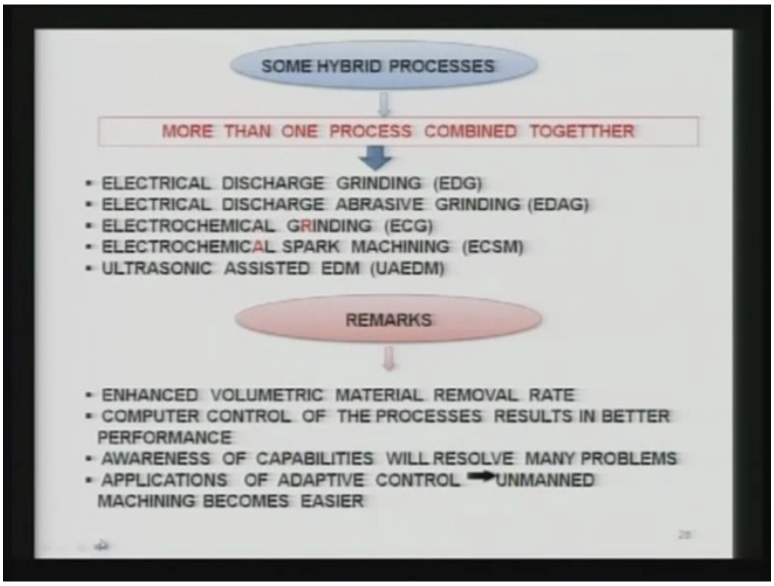

So some hybrid process is more than one process combined together as I have already told you I have mentioned all these EDG, EDAG, electrochemical grinding, electro chemical spark machining and ultrasonic assisted electric discharge machining process. Some of the remarks which I can make based on the discussion in this particular lecture are as follows that enhanced volumetric material removal rate can be achieved computer control of the processes results in better performance with all this advanced machining processes, if you are using CNC machine, then you get much better performance than manually operated machining processes.

One should be aware of capabilities of these various kind of processes then only you can resolve, you can solve the shop floor problems much easier way. Applications of adaptive control will make these machines unmanned machining processes and which will be a step in the automated factories.

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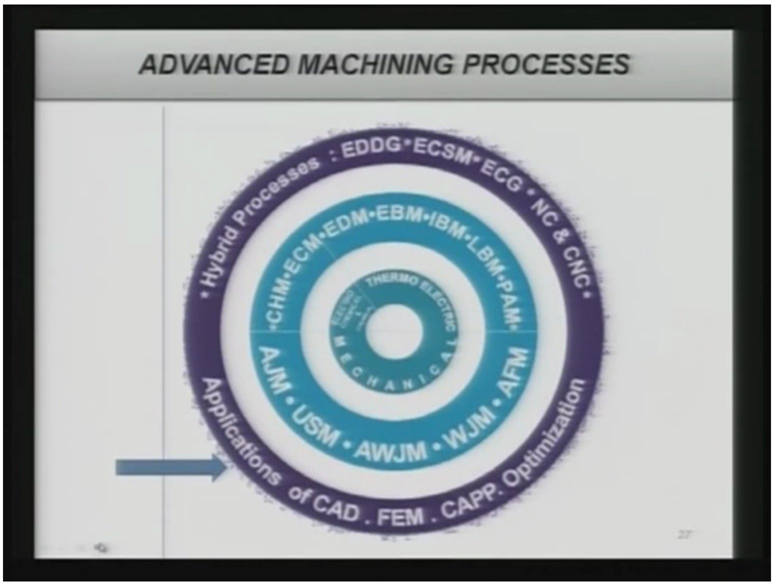

Now this is the Advanced Machining Circle where various kind of the machining processes are shown as you can see here these are the mechanical advanced machining processes, thermoelectric advanced machining processes, electrochemical and chemical advanced machining processes. Now if you see next circle, here they have been again classified like according to the classification which I have already discussed.

You can see here these are the mechanical type advanced machining processes like abrasive jet machining, ultrasonic machining, abrasive water jet machining, water jet machining and abrasive flow machining processes while thermoelectric machining processes are shown over here which includes electric discharge machining, electron beam machining, ion beam machining, laser beam machining and plasma arc machining processes and chemical and electrochemical machining processes includes over here.

Now the outer circle shows the applications of various techniques for enhancement and analysis of these processes as you can see here you can use CAM computer aided designing, finite alignment analysis can be carried out of all these processes. Process planning has to be done for all this kind of the processes and you have to optimize the parameters for all these kind of the processes to get best out of it and various kind of hybrid processes we have already seen.

Now the question arises, how the evolution of various kind of advanced machining processes has taken place. Evolution of advanced machining processes to understand the working principle of these advanced machining processes let us take some examples which we see in our everyday life.

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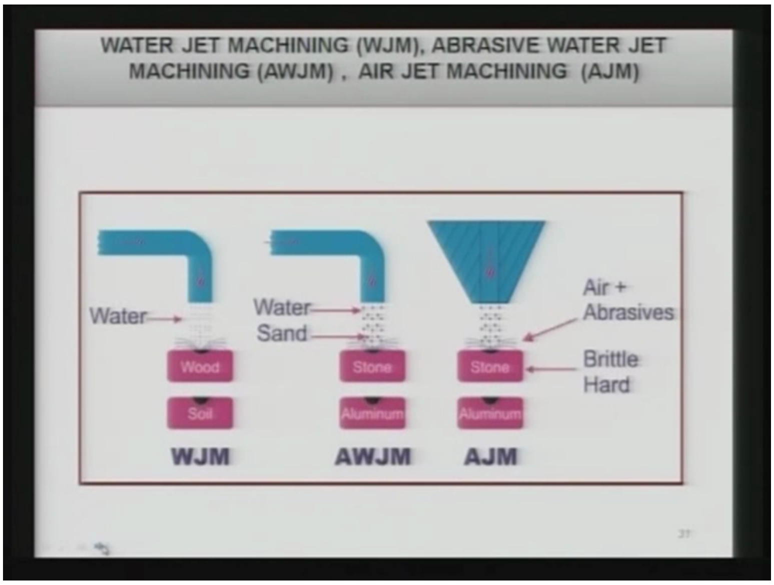

Mechanical type advanced machining processes, now as you can see here with the help of very simple example it has been shown that how one can think of evolving these kind of processes with the help of understanding simple phenomena which take in everyday life.

Just let us take the water is coming from the water tap at home or in the hostels now when you put a wooden piece under this water tape what happens you will find that after some days a fine some material has been removed and a small crater has been formed over there and this is here you can see the water is hitting the wooden piece or if you put the soil piece then you will find that the crater size is much bigger than what has been formed at the wood so this is because the question arises here water is very very soft compared to the wood or compared to the soil, how it is able to remove the material from the wood.

Because our basic principle if you remember was the tool material hardness should be much larger than the work piece material hardness. Now here water is able to remove the material, so it is really as we will see later on it is the kinetic energy of the water which is able to remove the material from the wood or the soil. Now if there are the abrasive particles mixed with the water as we can see here water is able to remove the material from the wood or the soil, same way if there are some abrasive particles with the water coming out of the tap.

You will find that the material is being removed even from the stone and you will find after a couple of weeks or so you will find that the crater has been formed on the stone. Now in place of stone you place there aluminium then you will find a larger crater has been formed on the aluminium. Now the question arises how water is able to remove the material from the stone or from the aluminium.

Same way if the air is mixed up sorry air is carrying the abrasive particles along with it and if it is hitting the stone or the aluminium it will also be able to remove the material and form crater. Now the question arises here in these last two cases abrasive particles are acting as the tool and they are able to remove the material but when we are taking water and water and sand particles, the question arises how they are able to remove the material so by taking the philosophy the idea from these two phenomena one could think can we make constructive use of these phenomena to remove the material from the engineering materials.

So keeping this kind of idea taking this kind of idea from these kind of processes quite possible people must have developed the process that is known as water jet cutting or abrasive water jet cutting or abrasive jet cutting processes.

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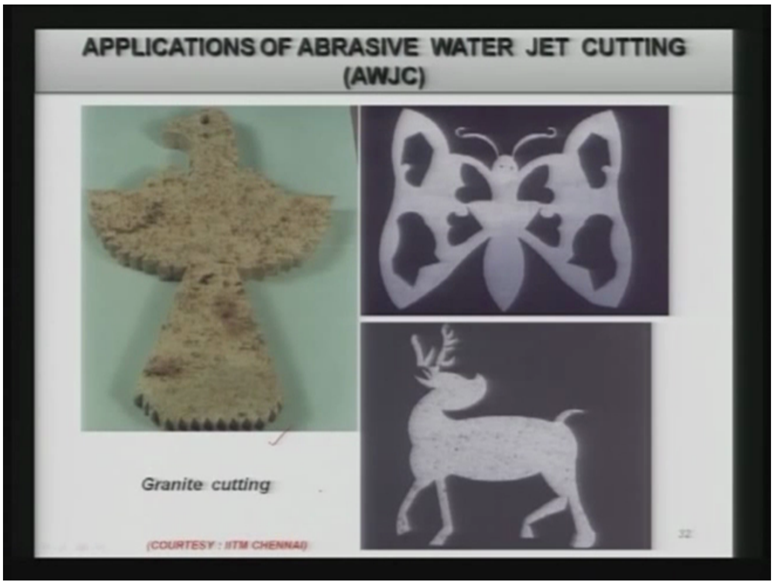

Now using this abrasive water jet cutting processes you can see here that the granite has been cut in a very beautiful shape as shown over here or various other kind of the shapes have been cut at IIT Madras, Chennai using the abrasive water jet cutting machine.

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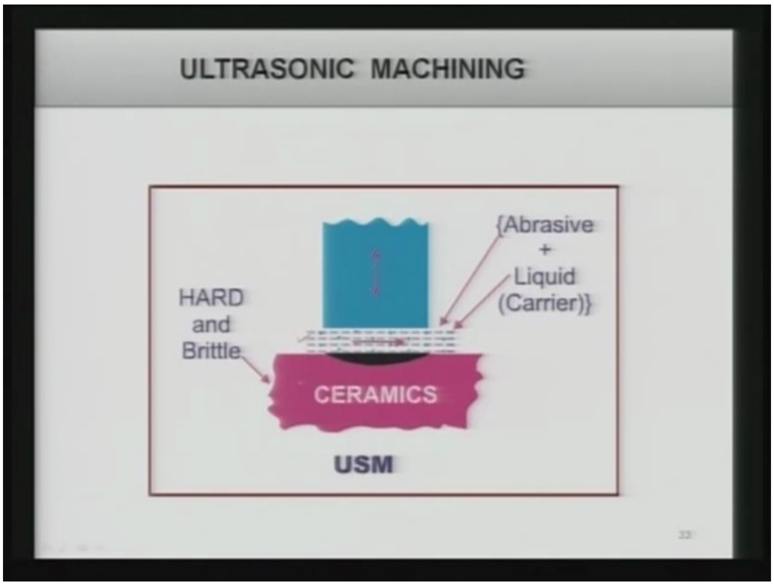

Now similar way there is a process called ultrasonic machining process, now in this particular process you have the slurry which is having the water or other liquid mixed with abrasive particles and there is a tool which is vibrating at ultrasonic frequency that frequency may be 20000 kilohertz or sorry 20000 hertz that means the tool is vibrating 20000 times in 1 second and they are hundreds or thousands of the abrasive particles which are being hit by the tools and all these abrasive particles they hit the ceramic work piece material over here and each particle, each time is removing some amount of material as a result of that you get the crater formed over there and this crater is more or less of the same shape as a shape of the tool. So you can use this phenomena for removing the material from very difficult material just like ceramics.

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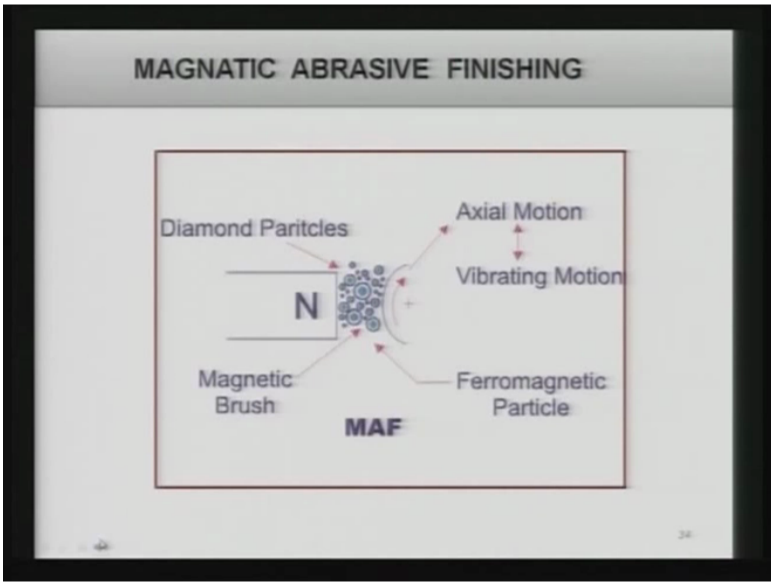

Now there is another process known as magnetic abrasive finishing we can understand this, in this particular process what you have is the diamond particles which have been centered with the ferromagnetic particle and once this ceramic particles have been centered with the ferromagnetic particle they form what is known as magnetic abrasive particles and that is shown over here.

Now when there is a north pole here and somewhere here will be the south pole and it is the work piece which is rotating now the gap between the north pole and the work piece is filled up with magnetic abrasive particles and this magnetic abrasive particles they align along the magnetic lines of force and they form what is known as ferromagnetic abrasive brush.

Now when this work piece rotates in this particular direction and this brush is held by the magnetic field so abrasive particle they come in contact with the work piece surface and they remove because all this work piece surfaces are having peaks and valleys and these abrasive particles they remove the peaks slowly and you can get very good surface finish and that surface finish is as good as 7.8 nanometer that has been achieved at Oklahoma State University by Professor (())(39:53)

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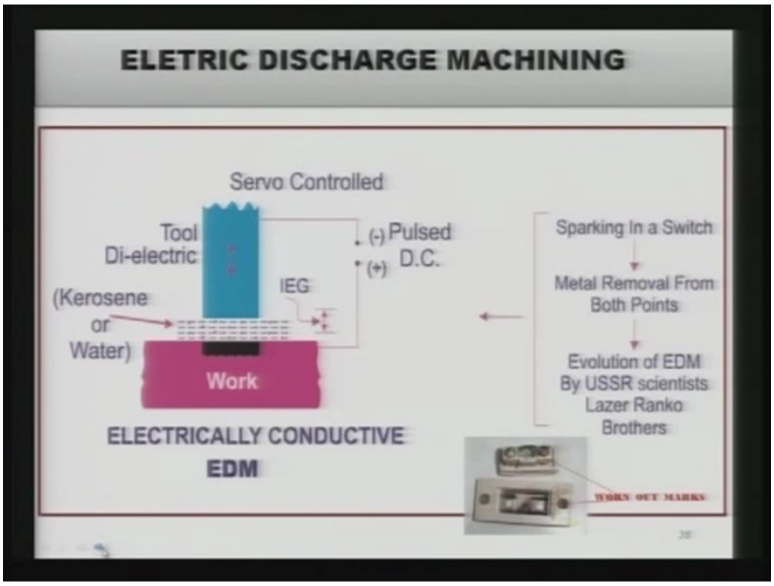

Thermoelectric advanced machining processes, now there (())(39:59) is the process which is very very commonly used. Now the question arises how it came into picture, now there were the Lazer Ranko brothers who saw in their male and female part of the switches as you can see on the wall they are the switches which have male part as well as the female part and when they opened it they found that both of them have some black spots over there where from some materials has been removed.

Now they started thinking why this material has been removed from here, due to sparking the material has been removed and this was the destructive phenomena which they observed on it and both the brothers started thinking can we make some constructive use of this destructive phenomena and they thought of making a machine where they can remove the material by this particular phenomena from the work piece in the manner they wanted.

So they started making electro spark machining and they failed many times and finally they were able to develop a EDM machine and patent it and initially they called this machine as electro spark machining machine and that is how EDM machine was evolved.

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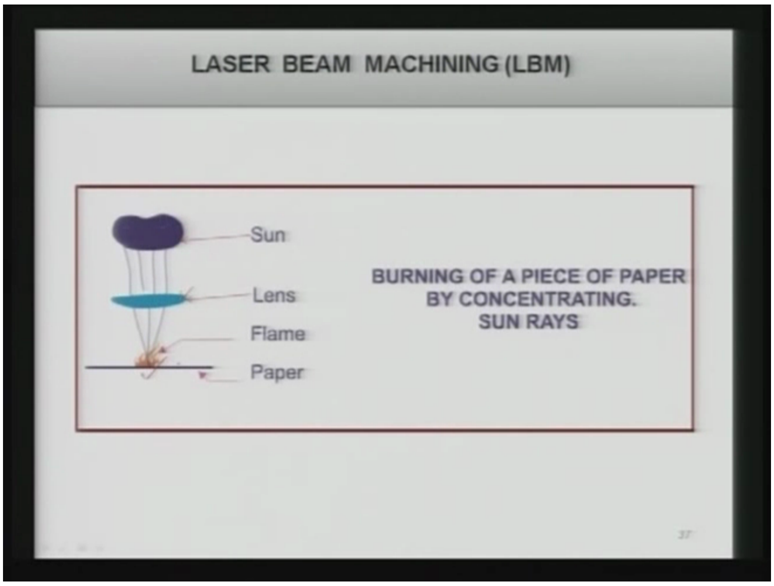

Now you must have seen or experienced a very simple experiment which children use to do that they take a lens and they try to concentrate the sunlight on a piece of paper and when that sunlight concentrates on a piece of paper it starts burning and they use it as a magic. Now this kind of phenomena can you think of using this phenomena for some constructive use for removal of the material similar kind the method has been developed that is known as laser beam machining process.

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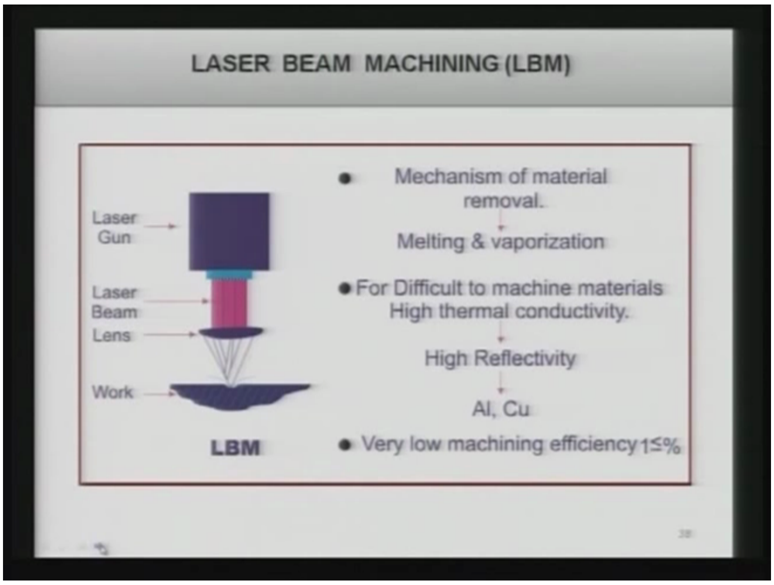

Now in laser beam machining process what you are doing is you are concentrating the laser light on a very small area and in that small area the heat intensity is so high that the it may be as high as that at the sun and you are able to machine or remove material from the work piece of having any hardness and very high temperature resistance material RA can be machined by this particular process very easily.

Now only limitation is that if the work piece material is having high reflective then machining efficiency is poor in that particular case, another very important point of this particular process is that the machining efficiency in case of laser beam machining is very low compared to other type of machining processes.

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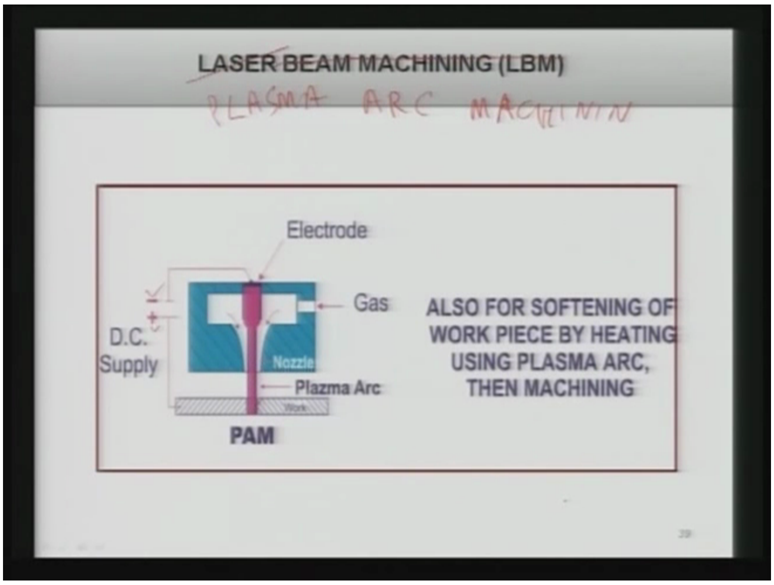

Then there is another process called as plasma arc machining process, this is not laser rather it is a plasma arc machining and in this particular plasma arc is created, air goes from this side and here is the electrode and work piece also work as one of the electrodes which is connected to the positive terminal and this is connected to the negative terminal and here is the gas and the plasma is formed and that plasma has very high temperature and because of that very high temperature any material can be cut. This particular process is basically used for rough cutting rather than for very fine cutting.

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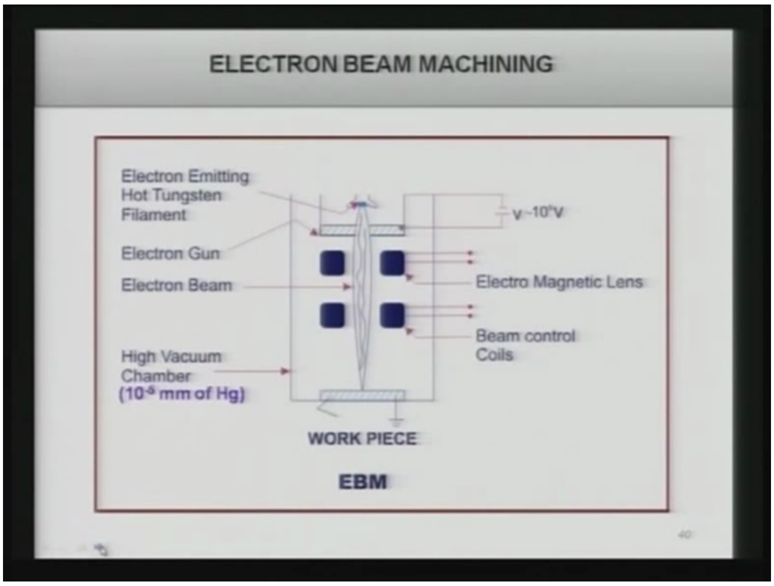

There is another process known as electron beam machining process where there is the filament which is emitting the electrons and these electrons are attracted by the anode and they start moving towards the work piece and you have electromagnetic lens and you have the beam control coils over there which can concentrate this electron beam at a very small point over here and when this electrons they come at the velocity which is more or less close to the velocity of the light and when they hit the work piece they increase the temperature of that particular area to a very high value as a result of that any material can be evaporated rom there and you can machine the materials.

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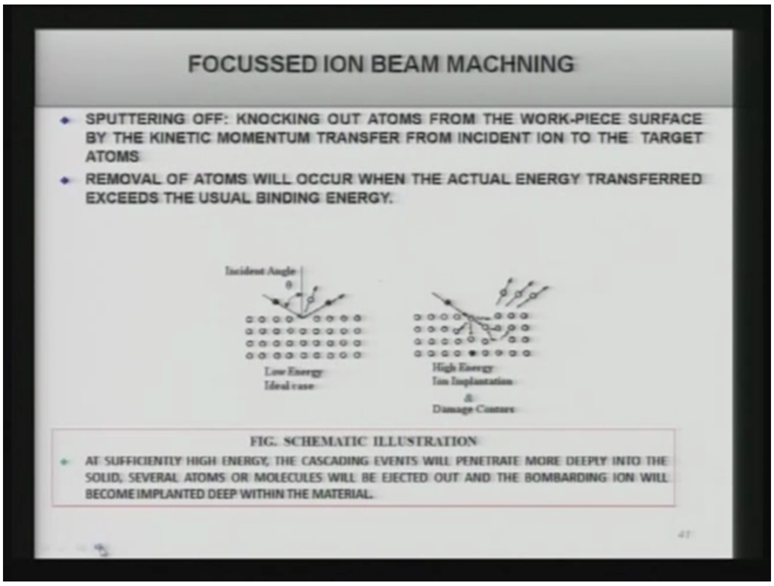

There is another process known as focused iron beam machining processes, now in this particular process sputtering off or knocking out of atoms from the work piece surface takes place because of the kinetic momentum transfer from the incident ion to the target atoms. As you can see here in this particular case, now there is the incident ion, it is coming at a very high velocity and it hits the top surface of the work piece and it hits the particular atom.

Now if the energy of this ion is larger than the bonding energy of these atoms on the top surface then a particular atom will be sputtered off and this ion will also go away from here. But normally what happens that the energy contained in the ion is much larger than the bonding energy of these atoms as a result of that in place of one single atom, it removes many atoms rom the top surface and it penetrates inside the surface and sit over there and this is not a desirable phenomena.

So the energy of the ion should be more or less the same which can break the atoms from the top surface and remove them one by one, however it does not happens so. So at sufficiently high energy the cascading events will penetrate more deeply into the solid several atoms or molecules will be ejected out and the bombarding ion will become implanted deep within the material and this is not a desirable phenomena.

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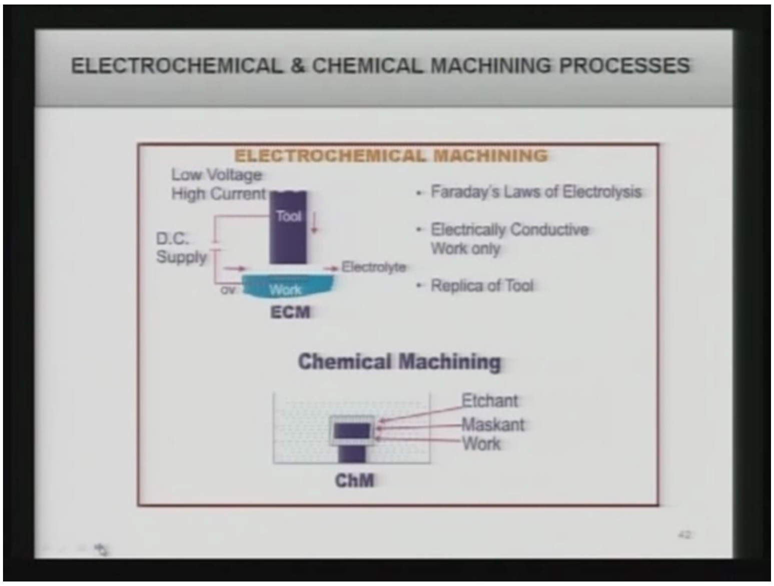

Now there is electrochemical machining processes which works on the Faraday's Laws of Electrolysis which is nothing but reverse of what we already know is the electroplating. Here tool acts as the cathode and work piece acts as the anode and you make the electrolyte to flow between these two and once the electrolyte flows, electrical circuit is completed and electrochemical reaction starts taking place and anodic dissolution of the work piece start taking place and you get the cavity on the work piece which is replica of that, approximately replica of the tool.

And then they there is another process which is known as chemical machining process, here a work piece is coated with the mask and where from material is not to be removed and it is kept where from the material is to be removed and then you use the etchant and once etchant reacts with the work piece material it start dissolving the material and you get the desired cavity or the desired shape and size of the work piece.

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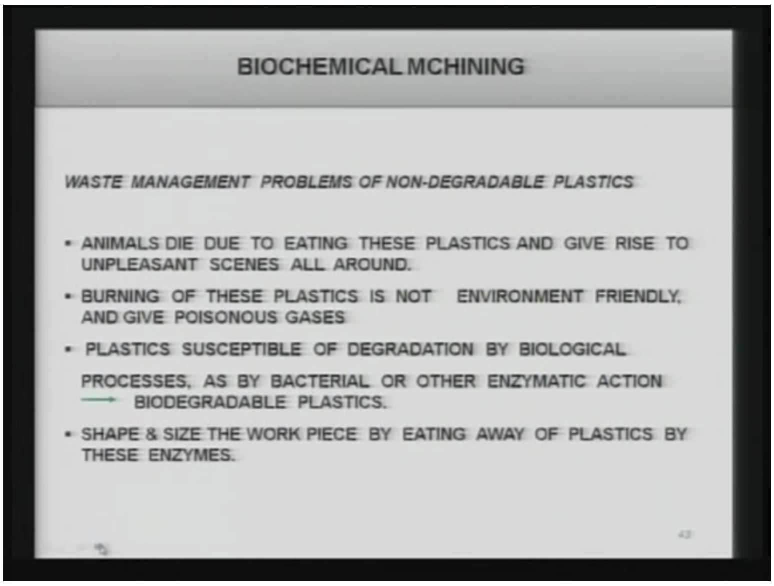

Now there is another finally the last process that is known as biochemical machining process now there is a problem of waste management when we have non-degradable plastics now animals die due to eating these plastics and give rise to unpleasant scenes all around in the various cities across the globe.

Burning of these plastics is not environment friendly and give poisonous gases, plastics susceptible of degradation by biological processes and by bacterial or other enzymatical action and they are known as biodegradable plastics and these plastics are being developed so that these environment, they are environment friendly and these problems of waste disposable waste management is solved so shape and size, the work piece by eating away of plastics by this enzymes some work is being done in the western world on this particular process.