Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title

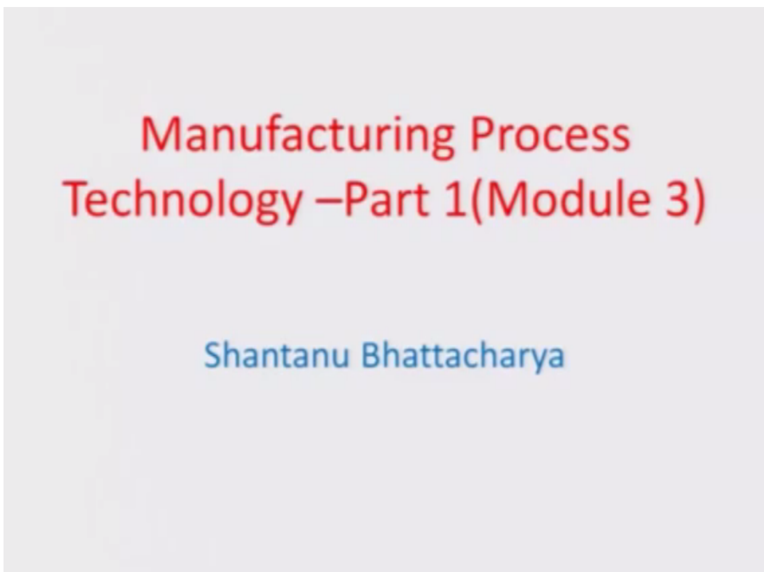
Manufacturing Process Technology -Part-1

Module-03

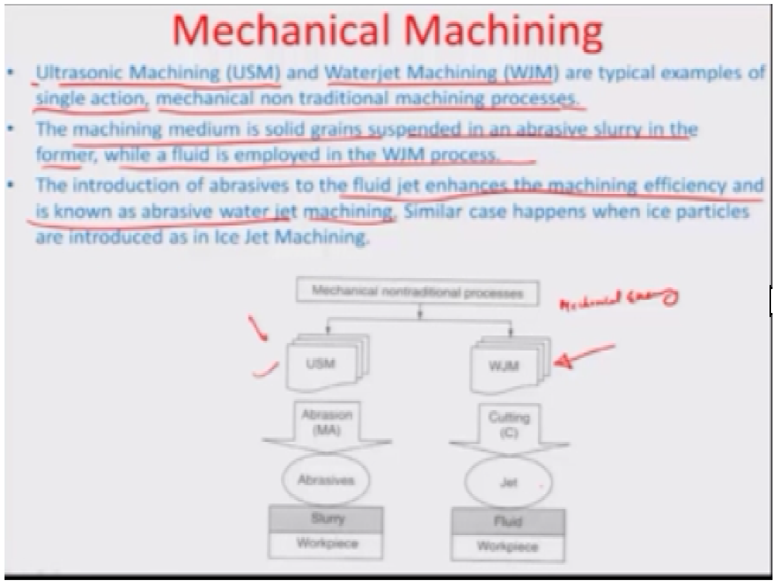
by
Prof. Shantanu Bhattacharya

Hello, and welcome to this manufacturing process technology, part 1 module 3, we are going to discuss little more and the nontraditional machining processes, and how they evolved.

(Refer Slide Time: 00:22)



(Refer Slide Time: 00:23)



So let us look at, you know as I discussed last time, the nontraditional machining processes emerged because of the increasing requirement of the manufacturing industry to machine new and novel materials which would be applied to the aerospace or the, you know the automotive sector and they would typically be high strength, high ductility, high hardness, stronger, and tougher, kind of materials.

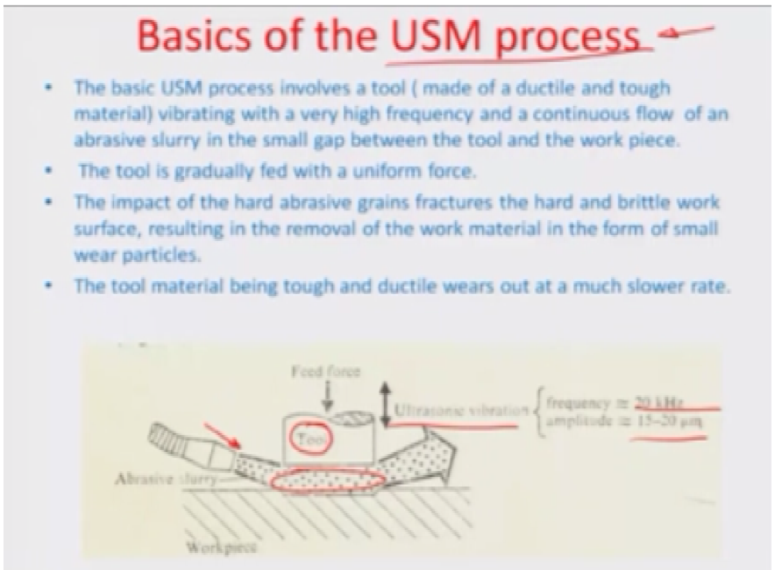
And sometimes the nonconventional domain would be necessitated because the conventional would not work for such materials. So let us look at some of these processes which has been figured out or, you know the first process that I would like to give you an illustration is the ultrasonic machining or the, you know where there is a abrasive particle which is involved typically.

And so, it can be either a ultrasonic machining process or a water jet machining process which are typical examples of single action mechanical nontraditional machining processes. The machining medium is solid grains suspended in a abrasive slurry in the former while a fluid is employed in WJM process. The introduction of abrasive to the fluid jet enhances the machining efficiency and is known as abrasive water jet machining.

And basically it means mechanical energy that is number one, it also means in one sense, you know you use ultrasonic components which I am going show later in great details, and how this ultrasonic machining is going to work. And so, there is a sort of a vibrating head here which comes and presses on these abrasive which is on the slurry form and it activates on the work piece by other freely throwing the grain or pressing the grain against the work piece.

In the second domain is the AJM or the, you know the water jet machining where the jet of water at a certain presser with abrasive loaded with presser was used for a work piece which is submerged, and it is used for the purposes of taking of the material.

(Refer Slide Time: 02:23)



So let us talk about the first mechanical material removal process which is the abrasive jet machining process. So in the AJM the material removal takes place due to impinging of the fine abrasive particles, so you can see here for example is a nozzle, and this nozzle is basically, you know made up of tungsten carbide or some other hard and tough material, which can withstand the abrasion of moving abrasive particles.

There is a high speed air at a velocity of about 150 to 300 meter per second, and there is a loading of the abrasive particles into the air. So the way that it mandates out from the nozzle is the combination of the high speed air and the abrasive particles, and these particles are thrown at a certain nozzle tip distance which is about 800 microns to the machine surface and this abrasive particle come out.

And they generate a mechanical action within the work piece surface which results in, you know brittle fracture of the surface. So basically what is going to happen here is that the abrasive particles typically about 25 microns in diameter, and they are forced by air discharges which are at a pressure of several atmospheric pressures and it causes brittle fracture, you can see here abrasive grain coming and striking the work piece at a certain velocity.

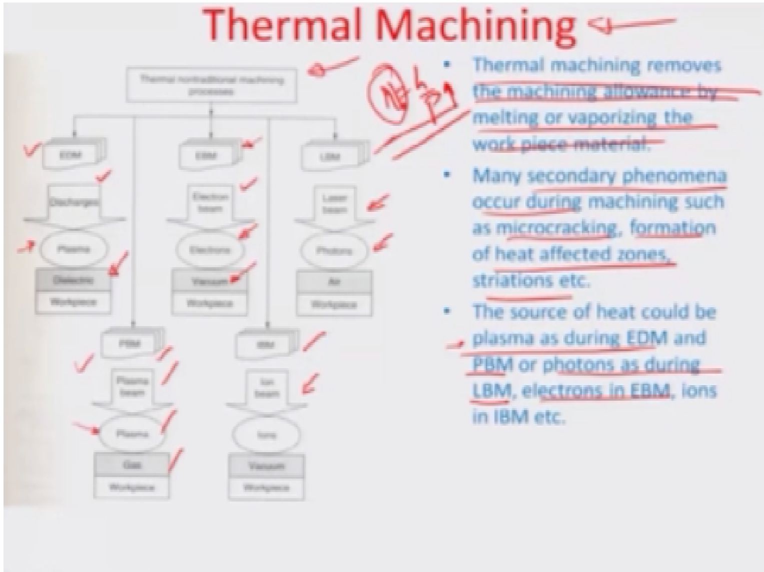
And therefore, a fracture is created in the work pieces you can see here and the fractured particle is now moving by the flowing air out of this cavity. So that is how the fracture of the work surface and the formation of the cavity comes out. So the abrasive particle impinging on the work surface at a high velocity at this impact causes a tiny brittle fracture, and the following air or gas carries away the dislodged small work piece particles.

So that is how the abrasive jet machining processes are individual. The other processes which are of concern is as I told ultrasonic machining process again a mechanical process where you can see there is a slurry of the grain and the abrasive powder. And this slurry is actually applied by shooting the slurry into the work piece surface through a nozzle, and then there is a vibrating tool head which basically is in a ultrasonic frequency which is frequency over and about 20 kilohertz.

The amplitude of motion of such a tool is about 15 to 20 microns which is similar to the grain diameter which is there, and the purpose of this tool is to sort of apply a feed force, so there are two cases, one where the particle get deflected from the moving surface at a high velocity. So it is called the free grain case where this would cause some mechanical action on the work piece, the other case would be where the particles is entrapped between the vibrating head and the work piece which would actually create again a tiny brittle fracture on a surface.

So both these combine together would result in MRR or material removal rate, we are going to model extensively when we do this process in the details later on. So therefore, you know you will have the grain hammering as well as the free throw grains is the main cause of the material removal here.

(Refer Slide Time: 05:47)



The other technique that I would like to illustrate is thermal machining where thermal energy is applied. So this energy could be in form of short dischargers, which is done in the EBM. So it could be in case of electron beam rastering and scanning over the surface, where you can super focus the energy to the very small area, so that you can directly penetrate through a few layers and go into and create wiper pocket which comes out okay.

And then you have laser beam machining where again the energy is much more intensified and it is a direct vaporization on the surface, because of the photon to phonon conversion. So you can see here the EDM case has a dielectric fluid deployed because the idea is the spark would not be formulated unless there is a dielectric. And, you know it has to break down the dielectric and formulated a spark.

So in case of, you know electron beam there is a accelerated electron beam which is created by a perforated anode and a thermally heated filament which is also the cathode, and by thermionic emissions the beam is generated and is focused the magnetic fields into very, very small area which can induce the flux density of the beam to be very high and this creates some kind of a thermal imprint on the material.

You have plasma beam machining where the same thing is done by plasma which is the hot ions and electrons combination. And, you know the two here PBM and EDM are really media based, so you either in one case gas plasma and other case there is a dielectric break down which is happening. The one which carries the electrons on the EBM is actually typically done vacuum because of their ion molecules they will again get ionized and they may not have the same impact as the EBM machine.

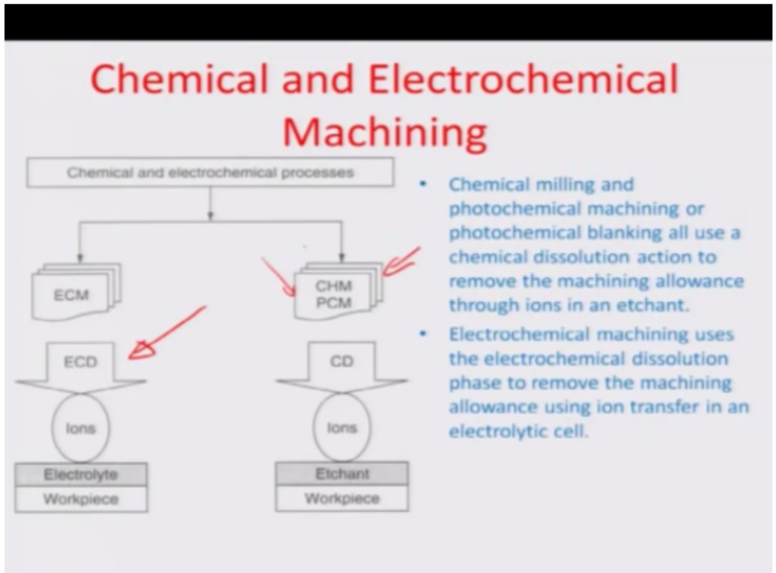
And there may be in particularly small writing cases where you need a consistency of the momentum delivery, and also a high momentum where the wavelength would reduce you remember the famous $\lambda i = h/p$ formulation. So the momentum is high and the wave length is low, so one of the reasons why more momentum is gathered together by EBM is also to sort of reduce this wavelength, so you can write at a higher resolution using E-beam.

So they have constructed EBM lithography for example, other processes where very small scale writing can be done with this particular method. But here the idea is that is has to be done without a medium, so it should typically be a vacuum column and therefore it limits the sizes of the work piece that you are wanting to machine using these process. Then there is a ion beam machining again similar to the principle of more or less similar to the EBM only thing in this case it are ions generated heavy ions generated through a vacuum chamber, and striking on the surface.

The ions can either be a accumulated on the surface, so that you can have a additive micro machining or they can be used for taking off the material from the surface. So that can be subtractive micro machining so on so forth. And then you have laser beam machining where there is a photon to phonon conversion leading to a local melting of a work piece. So thermal machining removes the machining allowance by melting or vaporizing the work piece material many secondary phenomenal occur during the machining, these are micro cracking formation of heat effective zones, striations, etc.

And the source of heat could be either a plasma as either a discharge as, you know EDM or plasma in case of PBM, or photons as during LBM, electrons in EBM, machining and ions in the IBM machining etc. So that is the thermal machining process, so you did mechanical and thermal.

(Refer Slide Time: 09:57)



The other important process is the chemical and electrochemical machining process where either you use the, you know Faraday's laws to either deposit material electro chemically on a surface or take off machine subtract material away from a surface. And here what you do is typically you take an electrolyte which has a certain level of conductivity and you dip or insert two electrodes one of them gets coated up and another get material subtracted from its surface.

So immediately when you do that there is a formation of a dual layer between the electrode which comes in, and the electrolyte which is there. And there is charge transport across this dual layer, and this charge transport is what is the cause of either taking away the material from one of the electrodes, and depositing the material on another electrode. So you can either use it as a machining or a building up process if you just reverse the polarity or reverse the electrodes.

And here what it is going on is that if you want to use it as a machining process, you need to ensure that whatever comes out of the one of the electrodes, which is suppose to get machine, the ions which come out thereby interact with the solution or the medium, which they come out into and they convert into a chemical which otherwise get precipitated. So therefore, without depositing it on the other electrode you are generating a mechanism through which the material that comes out gets precipitated.

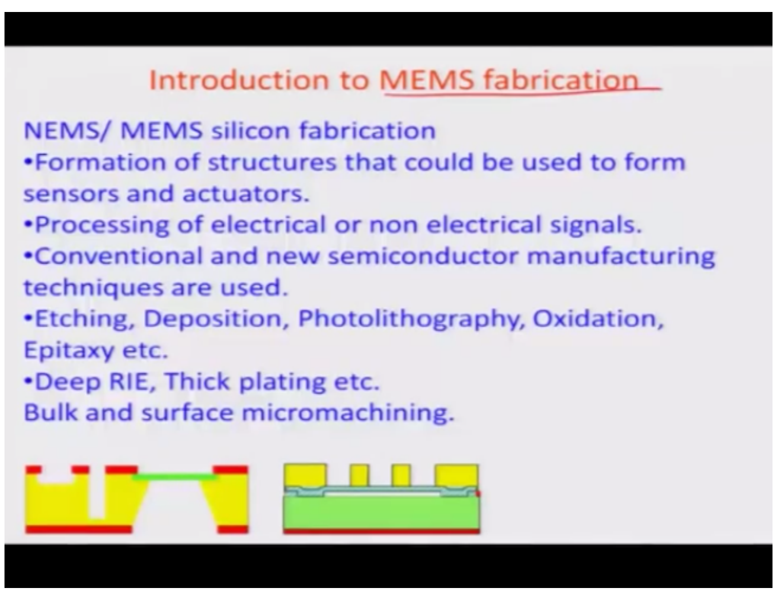
And precipitated means, it does not dissolve in the electrolyte solution per se, and its goes down okay. So in case of machining steels or irons, there is a tendency of ferric ions to form ferrous hydroxide. And ferrous hydroxide is something which can be precipitated, so therefore the idea is that, if I flow the electrolyte now very close to this electrode and apply a potential whatever is coming out of the electrolyte is getting carried away as precipitates, and you can re circulate that electrolyte by filtering that precipitate off okay.

And so that the machining process, that is the how you do ECM, electro chemical machining. You also have processes of chemical or photo chemical machining, where obviously there is going to be either a chemical deposition or a chemical etching which happens because either there is a plasma for example, of ions, you know which can create some chemistry on the surface it can go beyond the surface, and also be able to influence the bonds.

And there you can either use a gas like medium as a plasma as I told, or even non plasma which is like a gas etching gas or etching environment, you can also use a etching liquid, and these process are more so generated, because of the requirements of the semiconductor industry. Because these are systems were very accurately you can control the etch depth for example or even the etch geometry, and there are many process associated with this, we will do some great detail investigation in this chemical and electro chemical processes as well when we talk about the traditional, the nontraditional machining domain.

So we have covered now three different domains the mechanical abrasion based machining, the thermal machining, and the chemical, electro chemical machining.

(Refer Slide Time: 13:31)



So that leads us to the utility of all this micro fabrication particularly MEMS fabrication. And so we will have a small module towards the end if time permits to study about this area of how some of these processes can be utilized for fabricating MEMS structures. So in micro machining or let us say MEMS machining, MEMS grade machining you do various techniques like etching deposition, photolithography, oxidation, epitaxy, etc.

You do deep RIE, thick plating, and these techniques would discuss in great details, and then the idea is that either you do bulk or surface micromachining where in one case, you subtract the material away, you can see here the material is been subtracted away by the etching processes. And here you can see the same thing been deposited into. So there is a subtractive machining which is either the, which is also known as the bulk micro machining, or there is additive machining here, where you can actually build on.

So this additive process and that is how you basically, able to generate micro features and structure on the surface. So whatever we would be doing in nontraditional would actually end up into may be generating some of these MEMS based process also which can do micro machining on surfaces. So that is going to be the brief overview of what is going to be taught in this course, and I would like to start with the engineering materials in the next lecture, where we start discussing with some of the mechanical properties of the engineering materials, some of the properties related to how solidification process would happen.

And some of the properties related to post solidification how we can do the treatment, so that their strength, or ductility improves, and you can actually tailor the engineering properties for a certain application for that particular material. So with that I am going to close this particular module, thank you so much.

Acknowledgement

Ministry of Human Resources & Development

Prof. Satyaki Roy
Co – ordinator, NPTEL IIT Kanpur

NPTEL Team
Sanjay Pal
Ashish Singh
Badal Pradhan

Tapobrata Das
Ram Chandra
Dilip Tripathi
Manoj Shrivastava
Padam Shukla
Sanjay Mishra
Shubham Rawat
Shikha Gupta
K.K Mishra
Aradhana Singh
Sweta
Ashutosh Gairola
Dilip Katiyar
Sharwan
Hari Ram
Bhadra Rao
Puneet Kumar Bajpai
Lalty Dutta
Ajay Kanaujia
Shivendra Kumar Tiwari

an IIT Kanpur Production