Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology-Part-2

Module 01
Introduction to Advanced Machining Processes

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Hello and welcome to this manufacturing process technology part 2.

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module one I am Shantanu Bhattacharya I am an associate professor at the mechanical engineer of technology at Kanpur so prior to this we had also done another series of you know courses related to manufacturing systems and then manufacturing process technology1 where we talked about the primary manufacturing process like casting and some of the joining processes secondary manufacturing processes like welding or machining technologies.

Here in this module it would focus on more towards the advanced machining techniques which have emerged because of you know a diverse amount of new materials which are emerged because of again the aerospace and the automotive industry requirements and also the requirements that have been generated to produce very complex parts you know with geometries which are very complex and otherwise cannot be achieved using conventional machining processes.

So this module would actually be an introductory module for advanced machining processes and then once we are able to cover all these processes and details which will include modules which will include you know the different applications of such processes we will delft into the metal forming area and try to do few modulating that particular area or domain. So let us look at a brief introduction of advanced manufacturing processes why they are needed.

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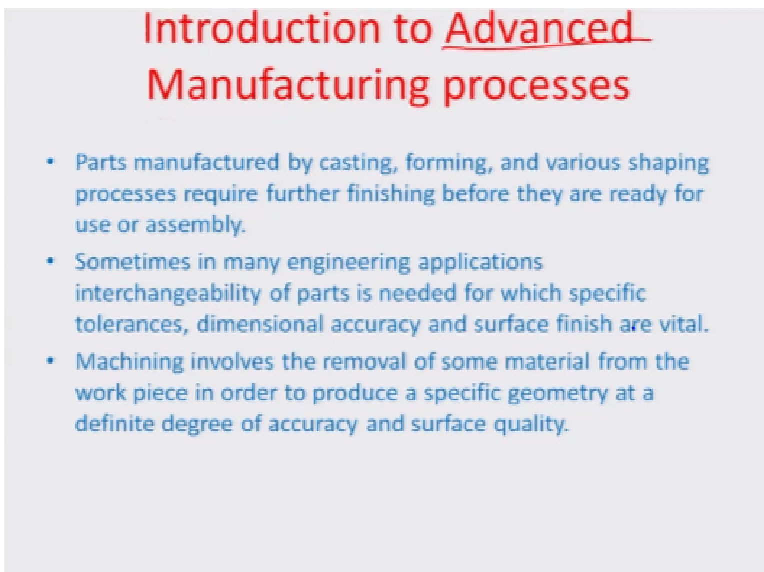

So parts which are manufactured by casting forming and various shaping processes require further finishing before they are ready for user assembly and that is one of the main reasons why these advanced manufacturing techniques were developed actually so in many engineering applications sometimes interchangeability of parts is a big requirement okay and this is needed we need specific tolerances dimensional accuracy surface finish so on so for.

And they are very vital for making a family of parts or a group of parts which are uniquely similar they have similar manufacturing processes and they can be used in a variety of area look at for example fasteners in automatic industries so therefore as the surface finish definitely becomes a very critical issue in such parts and we have to go for some non conventional type of material removal processes.

Which would enhance the surface finish or which could actually give dimensional accuracy or more tighter tolerances to let systems or part So machining involves the removal of some material from a work piece as you have done before in order to produce a specific geometry at a definite degree of accuracy and surface quality.

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And we will now try to look at some of the you know issues related to the history of how machining emerged as material removal processes emerged and if you look at historically the first kind of tools which were used by mankind were used mostly or made of my bones sticks and stones and there were hand tools you know and if you look at historically about 2.6 million years ago the first paralytic stone tool.

You know industry they all do one was developed by the earlier members of genus Homohabilis this contained things like choppers Buren is all these are two in stone implements which are formulated back in those days you know which can be considered to be the first tool our first machined tool so as gradually things move forward in the upper Paleolithic is there were little more advances to this simple choppers appearance.

And they were replaced by these nets or bolas which typically would be hurled around in the stone and it would be thrown off so that it would be typically used as a hunting tool for most of the you know food requirements that were present so this followed by development of the spear thrower bows and arrows so on so forth and that is how the historically significant stepping-stone towards material removal processes was met this followed by later on by is series of developments.

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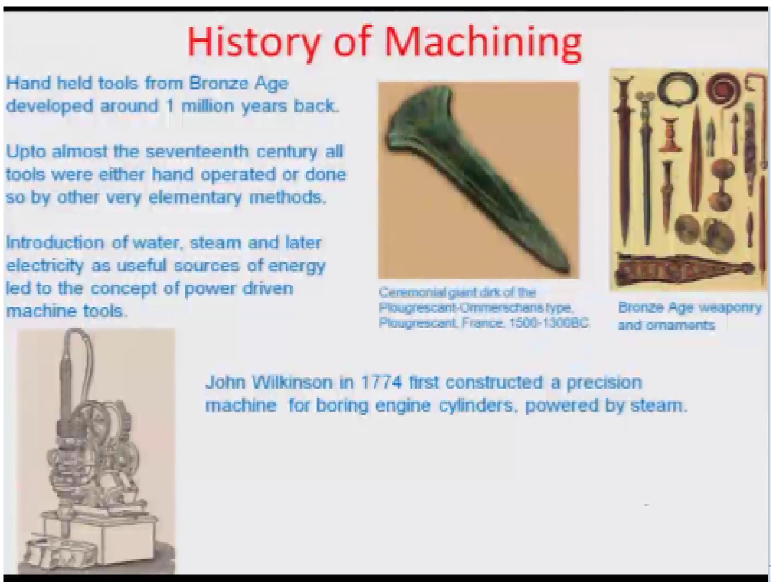

And if we really look at you know 1 million years back in the Bronze Age there were many tools and weaponry which were used from different shapes and sizes man now knew how to actually melt and cast then there was this ceremonial giant Dirk which was found in France and 1500 to 1300 BC belonged to this particular gene and all the tools up to almost about the 17thcentury were man-made or they were made using hands or handheld tools.

The first you know introduction of power tools came way back in 1774 which was basically in terms of a precision boring machine for engine cylinders as you can see right here and this was one of the first instances when but she started to be powered with alternate sources like of energy like steam okay or water and later on electricity as age progressed so there were many other examples during this time 23 years later.

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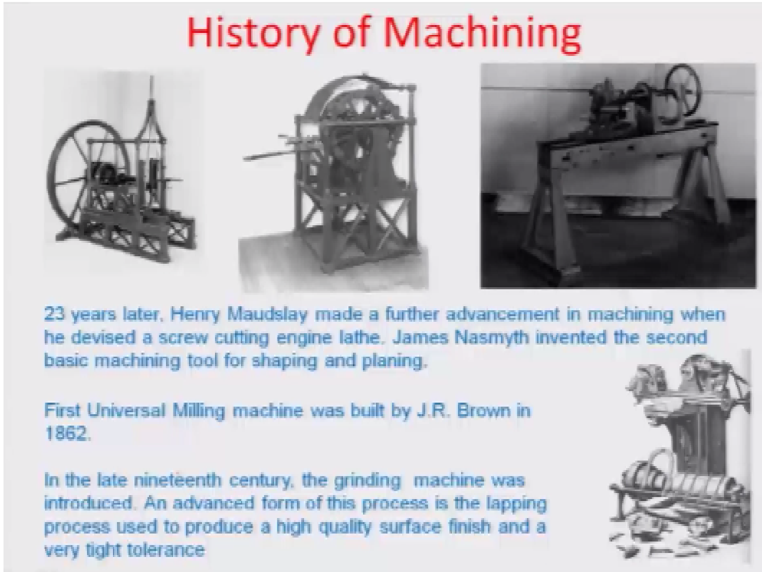

Hanley Mont sleigh further made advancement in machining when he revised his crew cutting engine late James Nasmyth invented the second basic machining tool for shaping and planning you can see some of the examples here lathe the shaping planning machine the first universal machine milling machine was built by J.R. Brown in 1826 this shows one of the you know very first models of such a machine.

And then late 19th century the concept of precision came into being because of the introduction of you know processes like grinding which would give a surface finish and a surface tolerance so that parts could now produce a function more appropriately in assembly of parts so an advanced form of this process now is lapping for example or horny and it is used to produce high-quality surface finish and very tight tolerance.

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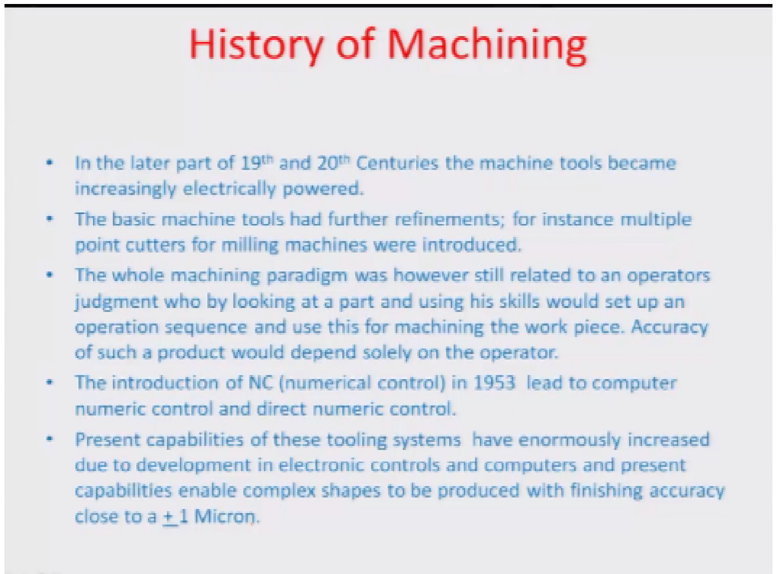

So that is how I would say machining progress and if we look at some of the current trends particularly towards the latter part of the nineteenth and twentieth century machine tools became increasingly electrically powered basic machine tools and further refinements for instance multiple point cutters for milling machines were introduced so this would make a high yield machining process.

The hole machining paradigm was controlled by you know skill set dependencies of the operators and therefore in order to make repeatability or of producing parts a mandate the first CNC machine was introduced which started with numerical control in 1953 so this led to a series of these computer numeric control machines and direct numeric control machines and then later on distributed numeric control machines.

Which were step by step improvement of the basic my NC machine which was generated the Traverse City by Parsons corporation in year 1953 so the present capabilities of these tooling is are enormous with you know almost the machining accuracy or you know finishing accuracy of close to about +/-1 microns and not only that they have huge capabilities of producing complex shapes of parts which makes this set of NC machines very useful a set of tools for the future machining aspects.

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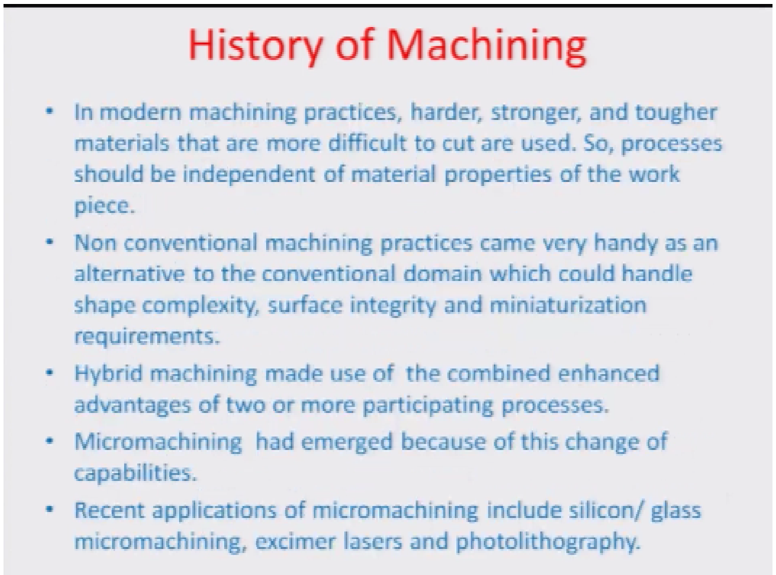

If we look at the modern machining practices they really emerged because of the increasing requirements of two different industries that is the aerospace in the automotive industry in terms of more stringent engineering requirements to be met by the parts harder stronger and tougher materials and a lot of research was invested in the area of materials engineering alone and it became very you know important to be able to finish our machine extremely tough and light weight materials.

So these were one of there is in which resulted into the formulation of the so-called advanced machining or non conventional machining practices and they were so very different from the traditional machining domain that now if we were talking mostly about applying energy in different forms like let us say mechanical packets of energy or thermal packets of energy you are probably packets of photons or quanta quantum of light using them or these different methods as or maybe even chemical energy there were a series of very highly complex shapes.

And integrated surfaces and also miniaturized elements which actually could be formulated by these novel conventional non-conventional or advanced machining practices so as a corollary of it micro machining also emerged and because of this change of capabilities obviously you could go at smaller sizes and be able to finish better at those sizes and so therefore the domain of engineering involved which is also known as the micro machining engineering.

Where a lot of parts of you know the size of less than in the sub millimeter zone could be realized very accurately so recent applications of micro machines involves silicon glass micromachining examined lasers for the lithography so on so forth.

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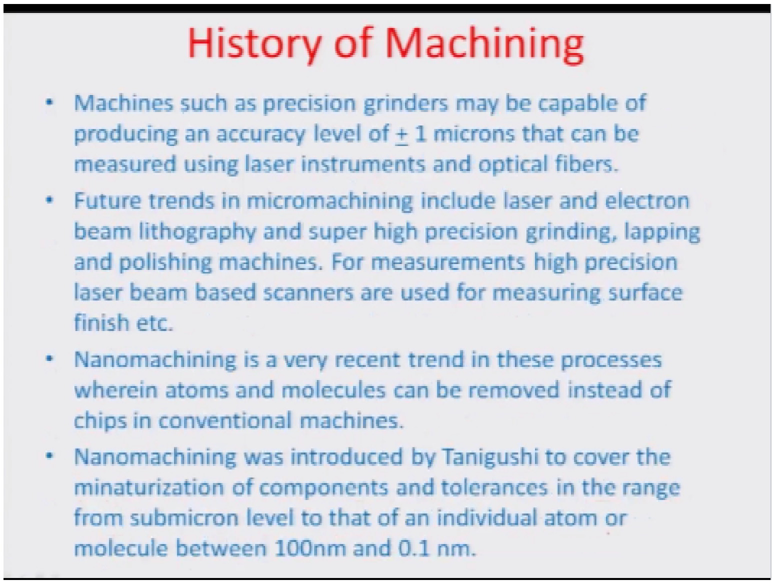

So if we really put together some of the modern forms of machines and historically look back we started with precision grinders with an accuracy level of almost +/- 1 micron of the surface finish generated a series of tools which were enabled to measure such kind of accuracies and mostly using lasers or optical fibers such tools were realized with different forms of you know flight patterns or interference of light through which we could actually produce reflections.

And try to correlate the topography of a surface with respect to the signal that was generated so on so forth. so we had a set of high precision metrological tools or advancements which came into picture and then finally this resulted in nano machining which is very recent trend in these processes and in this particular process it was more about the successful manipulation of atoms or molecules you know which could not be otherwise possible in a conventional machine.

So the precision that was needed was even much higher of movement or relative movement in comparison to what it would be when we talked about you know conventional machines so nano machining or nano finishing processes came towards the probably the beginning of you know19th century and it was 20th century and it was introduced by Tanigushi to cover the miniaturization of components and this would typically mean achievement of tolerances in the range sub micron level to that of individual atoms or molecules.

That is between 100 nanometers to 0.1nanometers or almost you know one Armstrong or one atomic spacing thick machining. so in fact starting from the Tanigushi he kind of mapped the different you know machining accuracies way back in 1983 where the scale.

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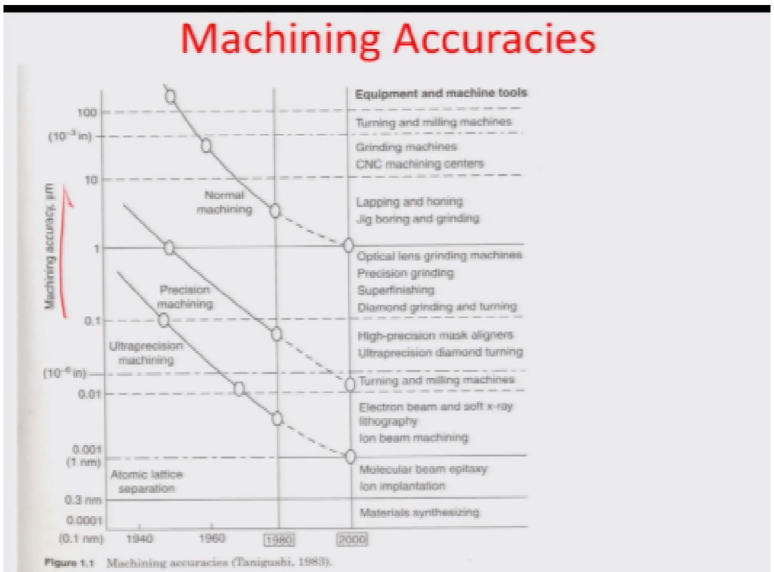

Here on the y-axis shows the machining accuracies and micrometers scale on the x-axis shows number of years as the machining technology has progressed and you can see here that accuracy is from100 microns to one micron typically comes within the normal machining range which includes typically machines like turning like machines grinding machine CNC machining centers lapping and honing jig boring and grinding mechanism so on so forth.

Then we have the precision machining domain which comes from one micron to 0.01 microns which actually includes optical lens grinding machines precision grinding super finishing diamond grinding turning high-precision mask aligners ultra position diametering tools turning and milling machine so on so forth and then finally the final ultra precision machining which varies between 0.1 microns all the way to 1 nanometer.

And even beyond where we talk about really some very interesting developments of the current century depending you know related to electron beam machining soft x-ray lithography I on being machining molecular beam epitaxial in implantation systems so on so forth this really is able to produce accuracies almost at the atomic lattice separation level that is how highly accurate the machining strategy can be in this particular kind of material.

And then of course you can actually have self assembly techniques of material synthesis technique with the bottom of approach which can even go further and be able to produce one atomic layer thick you know material uniformly over a surface to give that kind of a precision to that particular surface so that is how the machining accuracies proceeded on a year wise manner starting from 1942 2000.

Almost the current century and you can actually map in terms of different grades of machining and some of the accuracies the various technologies that have emerged or been formulated so let us now look at some of the classifications.

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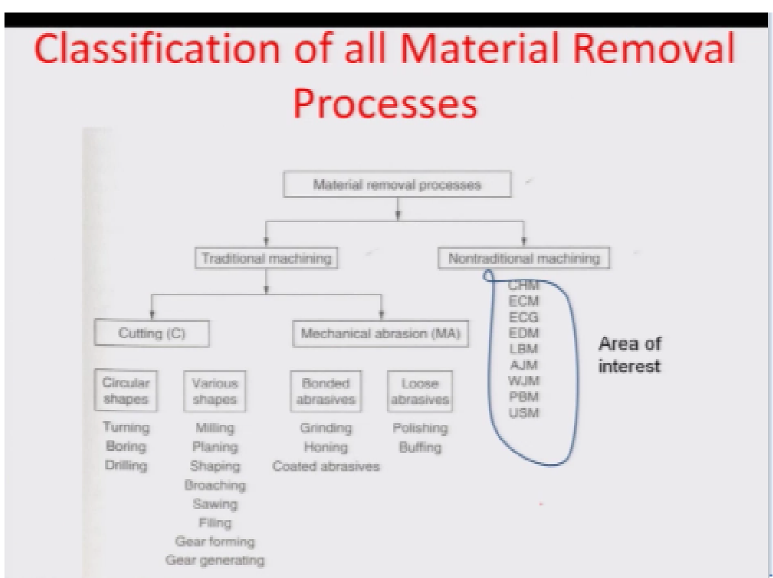

Which are you know involved in material removal processes and if you may recall earlier we had focused more in the part 1 of this course on the traditional machining domain where we talked about various cutting processes turning boring drilling so on so forth and then various shape making processes like milling shaping planning broaching sawing filing gear forming gear generation so on so forth.

The second part of traditional machining belongs to mechanical abrasion where you know we talked about bonded abrasives grinding horning coated abrasives lose abrasives polishing buffing etcetera and then in this particular module will be more focusing on to this non-traditional machining which is really going to be the area of interest for at least the first few modules when we talk about the various processes

Like chemical machining electro chemical machining electrochemical grinding electrode position machining laser beam machining abrasive jet machining water jet machining plasma beam machining ultrasonic machining so on so forth and also we will try to introduce some of these in context of micro systems engineering or Microsystems fabrication processes talking about a little bit of you know deposition of lithography driven you know process for doing small materials fabrication or small micron no fabrication so on so forth.

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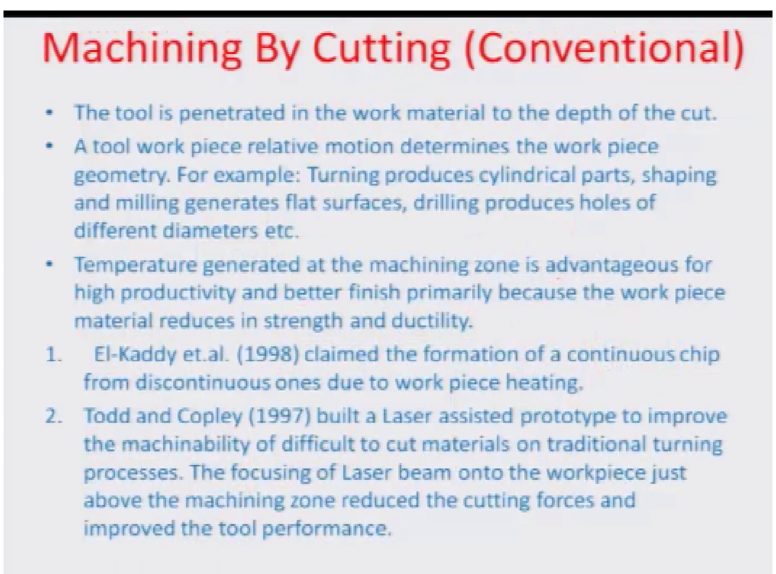

So that is going to be the Mandate of first part of this course manufacturing process technology part 2 and I would just like to just like to do a little more detail classification so as we have already realized in conventional machining processes the tool is penetrated in the work material particularly to the depth of cut and there is a relative motion between the work piece and the tool and that determines really the eventual geometry that the work piece is shaped.

And examples include things like turning processes particularly turning of cylindrical parts you know shaping and milling regenerates mostly flat surfaces drilling which produces holes of different diameters etcetera and the major important parameter here to be safeguarded as basically the temperature and temperature generated at the machining zone is really advantageous for higher productivity.

And better finish primarily because the work piece material reduces in strength and ductility because of the high temperature and comes into the plastic flow state so in fact if we look at literature back you know aEl-Kaddy et.al. In 1998 claimed the formation of a continuous chip from discontinuous ones due to the work piece prior heating and in Todd on Copley 1997 build in fact the laser assisted prototype to improve the machine ability of difficult to cut materials on traditional turning processes by focusing a laser beam on to the work piece.

Just above the machining zone so that heat could reduce the cutting forces and improve the tool performance okay so all these different you know couplings of the sort of you can say modern domain of nonconventional methods kept on carrying out throughout you know the 20th century.

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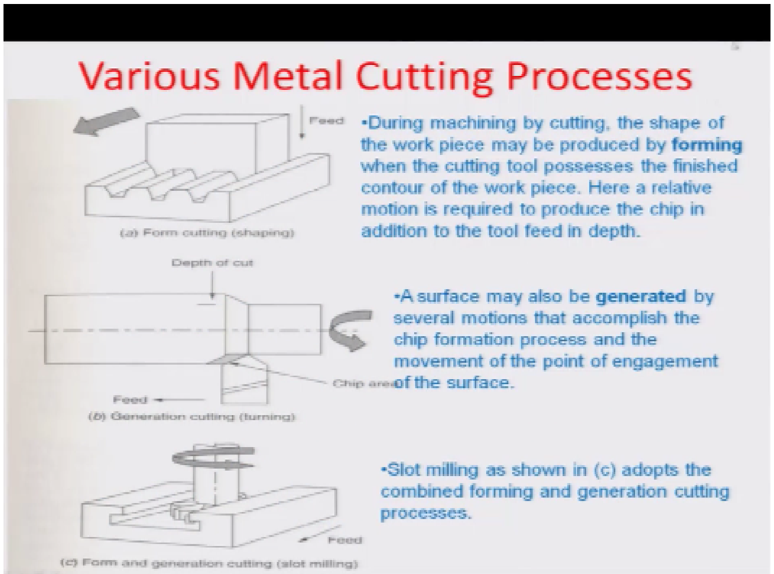

And typically if we look at all the metal cutting processes I think I had illustrated it earlier also in my lecture that you during machining by cutting the shape of the work piece maybe produced by forming when cutting tool possesses the finished contour of the work piece you can see exactly the negative of whatever you need to achieve on the on the surface here a relative motion is required to produce the chip in addition to the tool feed in depth.

And then there are generation processes okay so this is a shaping process where the invert of the tool inverse of the tool shape is impregnated onto the machining surface and generation where there are several motions that accomplish a certain geometry or a shape for example in the case of turning you realize that there is a linear motion of the tool in a rotator motion of the work piece we generate some kind of a cylindrical surface or you know things like frustum shapes or even you know symmetrical shapes which are symmetrical bout the axis of rotation of the work piece.

There are actually combinations of shaping and generating processes for example this process right here shows you know there is a form and generation cutting where there is actually a shaping operation going on and also a cutting operation the shaping actually is in terms of getting this shape which is exactly the reverse of the cutter and the cutting process of course is the chip removal process. In this particular case so that is how you classify all these material metal cutting processes.

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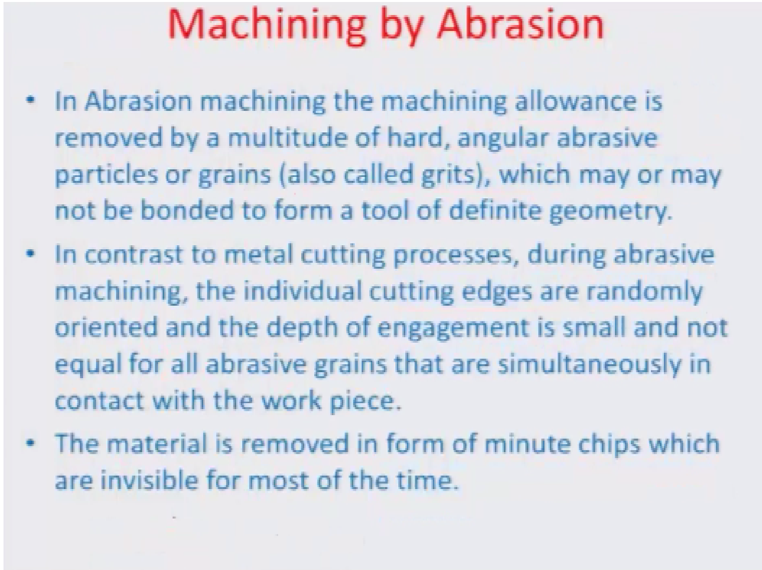

And when we talk about machining by Abrasion as we are aware that this is the machining where the machining allowances removed by multitude of hard angular abrasive particles or grains this was in fact invented at the beginning of 20th century and these grains are also known as abrasive grids which may or may not be bonded to in the in the shape or form of a tool of a different geometry.

And in contrast to metal cutting processes during a bracer machining the individual cutting edges are randomly oriented and the depth of engagement is small and not equal to the abrasive grains that are simultaneously in contact with the work piece one of the reasons why you can have more higher level of finishes because of this particular methodology of material cut so in fact the material in this case is removed in form of minute chip.

So minute that it almost gets immediately oxidized and goes up as splinters flames and the invisible for most of the time because of the high temperature and subsequent oxidation of the chip material which is dislodged from the surface.

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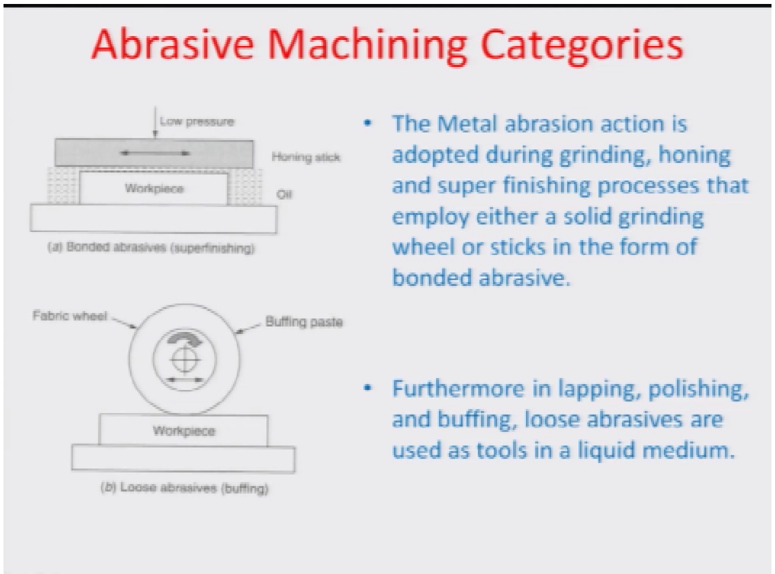

So various categories of abrasive machining are included where the measure the metal abrasion action is adopted during grinding horning and super finishing processes they employ either a solid grinding wheel or a stick in form of a bonded abrasive for example in this case you can see this morning stick and there is bonded abrasive on to the honing stick which actually rubs against the work piece in presence of machining oil.

And similarly you have one level further in terms of finishing capabilities the process of lapping and polishing and buffing where there is a in fact lose abrasive medium which actually is preyed on the work piece which is rubbed with a buffing tool or a lapping and polishing tool in fact these are processes typically used in the paint industry particularly automotive painting where there is a high level of polishing.

As well as you know dust removal and other defect removal mechanisms which are employed. so they use a lot of this lapping polishing and buffing techniques so that is how abrasive machining is categorized now let us look at non-traditional machining so in fact they are classified you know based on what is the kind of energy application mechanism which leads to the material removal and needless to say that because of the complexity requirements or material strength requirements.

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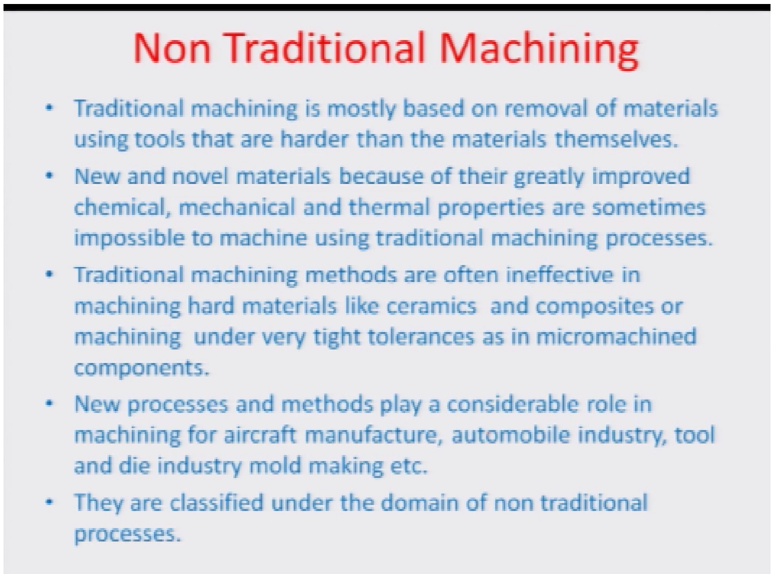

These came up so in general non-traditional machining process are classified into processes.

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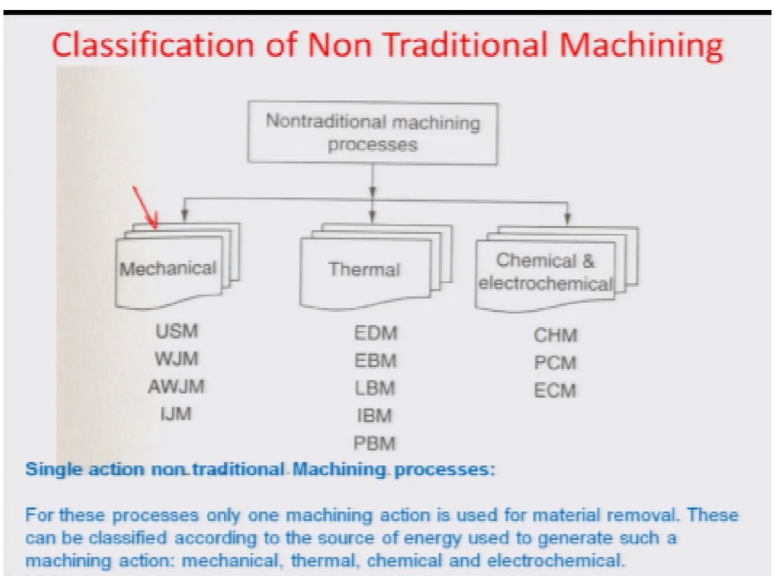

That would apply mechanical energy to remove the material the categories would involve machining methods like ultrasonic machining water jet machining abrasive water jet machining eyes jet machining so on so forth materials that are process that would employ thermal means to dislodge the material either as a melt or as a vapor for example electro discharge machining electron beam machining laser beam machining in beam machining or plasma machine.

And then there are processes which are either using chemical or electrochemical means to remove the materials where it could include chemical photo chemical machining electrochemical machining etcetera and is typically single action non-traditional machining processes where there is you know one of the strategies which are used for removal of material although in the current domain we have a combination of strategies called hybrid machining approaches.

Where more than one processes could be used simultaneously for obtaining a better surface accuracy or a better surface finish so this is going to be the domain now and we are going to look into the individual you know levels of the different processes starting with some modeling some approaches related to this and this will cover probably in the next module thank you.

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