Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology-Part-2

Module 27

Introduction to Finishing Process

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Hello and welcome to the manufacturing process technology part 2 module 27. In the last module we had mainly looked into the system processes related to electro-chemical machining, the particularly discussing electro-chemical grinding, electro-scheme drilling and also just electro-chemical drilling or ECD, ECG and ESD. So we kind of left the discussion with the nodes that we will be looking at some of the system processes for the mechanical material removal.

You have already done two different processes with detail modeling aspects including EDM abrasive finishing machining as well as the USM or electronic machine. So there are many other processes which are particularly important when it comes to finish machining or surface finish.

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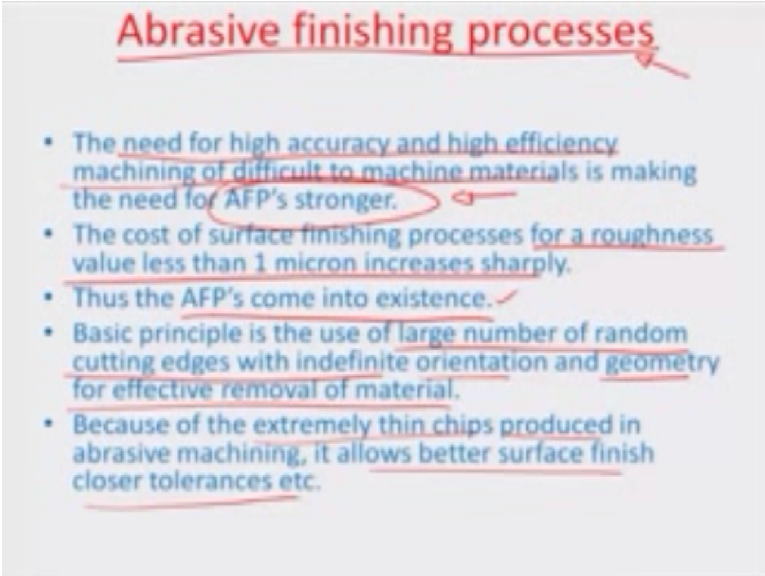

So these processes are in general known as abrasive finishing processes, these are all system processes of the mechanical way of, you know mechanical non-traditional way of removing material. Obviously, the need for high accuracy and high efficiency machining of difficult to machine materials is making the need for these abrasive finishing processes stronger and stronger.

For example, if you wanted to finish a piece of silicon to the level of plus the micron surface condition, it is very, very important that we deploy some processes apart from the routine CMP or chemical mechanical polishing which would be able to do with the high yield, you know the surface condition processes. So the cost of surface finishing processes for a roughness value in the sub micron range had increased quite sharply.

And therefore, you know all the more needs is AFP's or the abrasive finishing processes. And that is one of the reasons why they are in existence. So the basic principle is really the use of a large number of random cutting edges with indefinite orientation and geometry for effective removal of the material, that is similar to any other abrasive based finishing processes or the grain are all randomly oriented, they have sharp edges, and they have, they can be expand to overall different kind of geometries.

And because of the extremely thin chips which are produced in the abrasive machining it allows better surface finish closer tolerances so on so forth.

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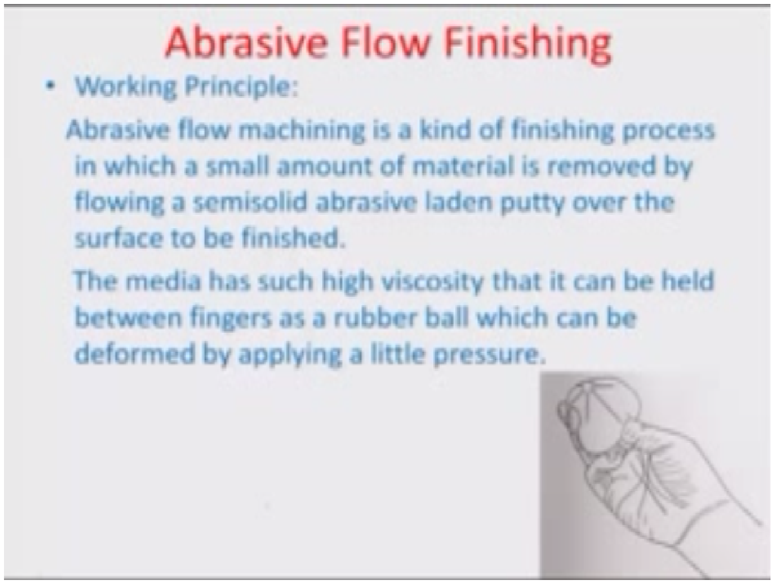

So the first process of the AFP's is actually abrasive flow finishing. And basically the working principle of such a process look at for example, lapping or honing processes which are again abrasive based. They have similar indefinite orientation with the grains or, you know basically in one case you have the possibility of a slurry of a grains or abrasives which is normally used in polishing operation where the slurry can be able to get into any of the surfaces and small gaps.

Thus, even being able to finish machine in rather inaccessible areas in complex geometries. So also because of the extremely thin chips which are produced in abrasive machining processes allows better surface finish. And that is why the question of sub micron really. So let us look at or compare some of these processes on, you know surfacing scale in terms of surface finish etc, and what are the capabilities.

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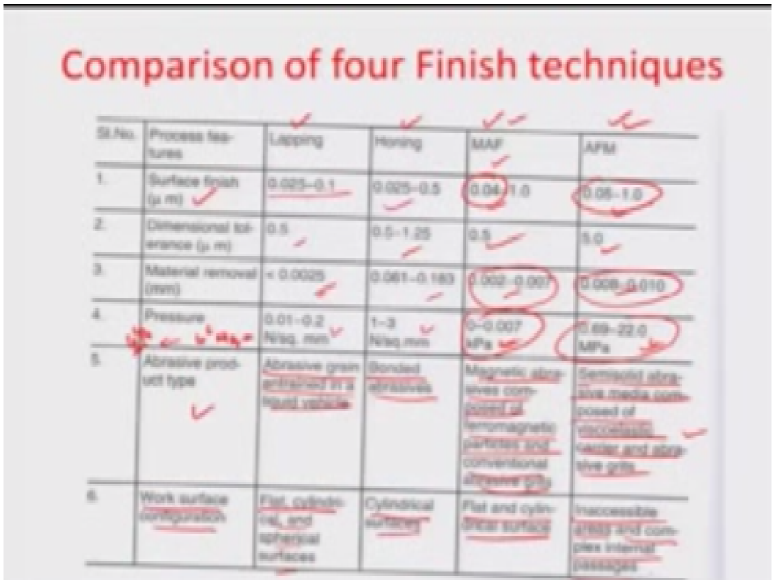

Sl.No.	Process features	Lapping	Honing	MAF	AFM
1.	Surface finish (μ m)	0.025–0.1	0.025–0.5	0.04–1.0	0.05–1.0
2.	Dimensional tolerance (μ m)	0.5	0.5–1.25	0.5	5.0
3.	Material removal (mm)	< 0.0025	0.061–0.183	0.002–0.007	0.008–0.010
4.	Pressure	0.01–0.2 N/sq. mm	1–3 N/sq.mm	0–0.007 kPa	0.69–22.0 MPa
5.	Abrasive product type	Abrasive grain entrained in a liquid vehicle	Bonded abrasives	Magnetic abrasives composed of ferromagnetic particles and conventional abrasive grits	Semisolid abrasive media composed of viscoelastic carrier and abrasive grits
6.	Work surface configuration	Flat, cylindrical, and spherical surfaces	Cylindrical surfaces	Flat and cylindrical surface	Inaccessible areas and complex internal passages

So let us look at four processes in general, two of them are the model or nonconventional, nontraditional abrasive flow processes like magnetic abrasive, finishing or abrasive flow shine and let us compare them with two conventional event able lapping and honing processes which are otherwise valuable as a variable kinding. So if we look at the surface finish range of the average process feature size left over after the finish machining has been carried out.

In case of lapping this where is between 0.25 to 0.1 micron, so that is about under autonomic those finish okay. So in honing as well it varies again between 0.025 and 0.5 micron of 100 nanometers finish, and if you have, you know the scope of getting into abrasive flow techniques, so this magnetic abrasive finishing is basically something where a finish which is not as good as lapping maybe, but at least turn out does move or turn not as less finishing up to a micron range, and probably delving down into the sub micron range, all the way up to above 40 nanometers finish is possible using MAF techniques.

And similarly abrasive flow machine you can go all the way from 0.05 to about 1.0 microns so basically it is about 1000 nanometers all the way about 50 nanometers finish so the domain of these two new nontraditional process as you can see is quite large similarly if we look at dimension tolerances the MAF process is kind of where I am into them with lapping and earning both whereas A from may have a slightly higher dimension tolerance.

Material removal in these process in comparison to let us say lapping or even horning or quite comparable and in fact in case of let us say MAF if we compare MAF directly to the lapping process in fact this is better you know so you have a higher elide possibility because of the higher amount material removal rate in the MAF process or AFM process compare to the conventional lapping and horning similarly if we look at the pressures which are deployed on to the surface b4ecaude of the operation we can see that in this case you know if we compare Newton per square mm or 10^{6} Newton per square meter or scales okay.

So the convectional process like lapping and horning again are able to work in the range of mega Pascal where as a technique like MAF could actually go ahead with almost a kPl level pressure which is lesser to the work piece in comparison to a lapping or earning process you may have to understand because it is a finish machining process typically the requirement may be on a surface which may not be that big for that high strength.

For example in silicon vapors when we need the polishing of a surface of silicon vapors generally the vapors are of all sort of thinness ranging from 300mircons all the way to 900 micros okay, so in for the vapor to handle a pressure in the range of mega Pascal it is some types becomes a problem and therefore lapping morning may not work or shatter the vapor base okay where as if not properly executed but in case of MAF and AFM you may find out that the process are comparatively better AFM of course as a higher amount of pressure in the mega Pascal range but at least the magnetic abrasive finishing methods could be deployed there where the sub states sizes are increasingly small or they lake strength so abrasive product types normally in the lapping process you have abrasive grains and trained in a liquid vehicle.

So the region which is need to be lapped is basically spade with this abrasive slurry and then there is a tool which comes and rubs the slurry against the surface for example in horning again you have bounded abrasive to a stick horning stick where you have abrasive put it all sides of the particular stick in MAF process you have magnetic abrasive composed of ferromagnetic particles and conversional abrasive grads and the idea is the magnetic field all the ferromagnetic particles would alien and trap with them or trap within the cervices the abrasive particles.

So that it is like a brush or it is virtual brush which has been formulated where the you know there is a possibility of having the abrasive pressed because of this alignment of the other ferromagnetic particles and squeezing the abrasive particles against the surface where you are wanting to carry out the finish similarly in the AFM process you have a sort of a semisolid abrasive medium something like you know may be a something like a put T where you have you know or may be τ you know here you have the abrasive bounded within the medium and you basically move this highly semisolid viscous elastic carrier medium with the abrasives using higher pressure and typically for internal surface finish etc of pipeline etc.

This is the best process that it could actually use two pressure cylinders on other side and move this highly viscous material think material with the abrasive in the internal portion of the pipe line that has to machine okay so that is how you have a process comparison further comparison for whatever the abrasive products are being used similarly if we look at work surface configuration in terms of accessibility of the work is etc typically lapping and horning process may find out applications in flat cylindrical.

And spherical surfaces horning you have probably horning cylindrical surfaces MAF again flat and cylindrical surfaces MAF can actually be if we can do the tool path planning in a right manner it could be over any kind of complex can do surfaces in fact groups working with the nomination is shown map to be carried out within complex knee joins or health joints earlier the one process again is related mostly to maximum areas and complex centers as just for a example if you wanted to find or do machining on the internal contour of a pipe line this is the best process to take it at the abrasive flow machining is the best process.

So take it that so let us now look into the different finishing process particular the, the abrasive flow finishing or AFF process, so in a abrasive flow machining or flow finishing.

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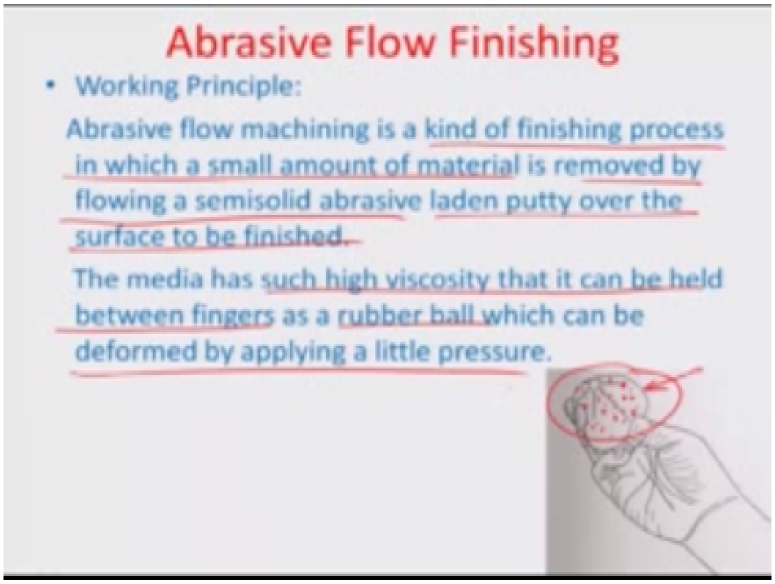

It is a kind of finishing process in which is small amount of material is removed by flow a semi solid abrasive latent put the over the surface to be finish, so this is how it looks like so it is a ball made out of this putty or highly last take it is a last kind of material where abrasive grains are all trapped within this particular medium the on the thing is that this medium can be under pressure expanded, and contracted and can change shape and basically the idea is to be a able to deploy this medium within contours where you want to do.

Finish machining particularly in this internal surface of those contours, the media as such high viscosity that it can be help between singles; it is like a rubber ball which can be deformed by applying a little pressure and now.

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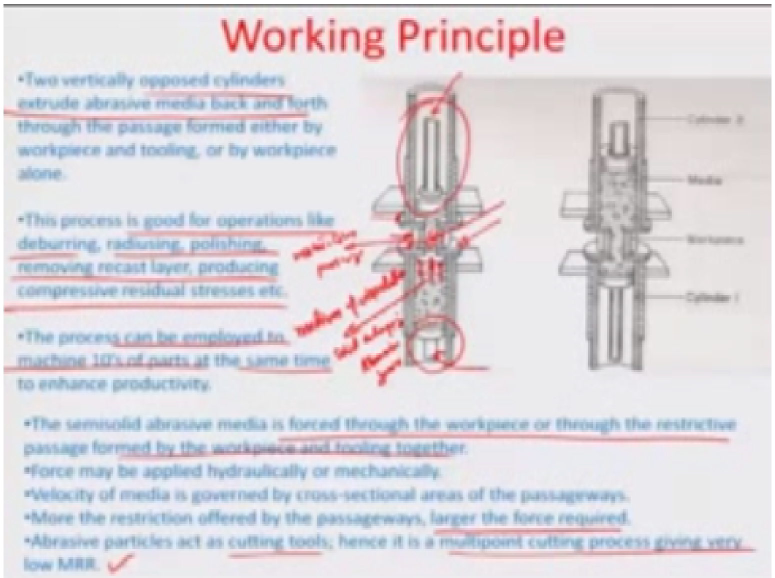

We can see here for example how the machining is been carried out, there are two vertically a above cylinders which x2 the abrasive medium back in forth so there is one cylinder and plunger on the opposite side here and similarly one of the down bottom here, and this is really the medium which we just worked talking about, so medium of viscous elastic solid and trapping abrasive grains and there is a motion of all these abrasive grains where you know finish, finishing can take this real.

On the internal contour of this particular element which is kept is a signed which in the sand which or initiation between both the cylinders vertically oppose cylinders so this process good for operations like debarring, radicing polishing and moving recast layers and using the abrasive compressive residual etc. The process is again can be employed to machine probably turns of parts of the same time because all unit to do is to have proper cylinder actuate at mechanism which is sand which all these parts together.

Under similar kind of a you know environment and so therefore it is highly productive and highly to process you can do many finishing operations together, the semi solid abrasive media is force to the work piece or through this message form by the work piece in the tool into gather this here is the state to passage that talking about restrict passage, force typically may be hydrloically applied particularly on both these cylinders or mechanically applied motors and you know.

Rank will kind of arrangements and the velocity of the media obviously would also depend on cross sectional area through which the you know media is transported particular the passage with cross sectional areas, and if you can reduce the area from the main cylinder portion do the work piece portion you always have a better flow resistance offered and more is a resistance more is the energy that is needed which can be distributed again, uniformly a cross the medium and that gives you.

Larger forces which are needed to plot the material so abrasive particles really act here as acting tool, where the abrasive particles are pulled or pushed against the internal contour at a certain normal force and are again made to move the vertical or parallel to the axis of the component so that there are scratches and you know of very small dimensions, and eventually where this we need to finish whatever decreased being generated in from the internal contour is again carried out by the viscous elastic media as such because this is sticky medium.

And you know once you have flow this medium through then probably if it is not magnetic medium we going to move the particles so magnetic are rather means and then read to ploy the back machines, so abrasive particles act is cutting tools and some multi points cutting process and it gives reasonably low MRR which is again another requirement for finish machining or grains.

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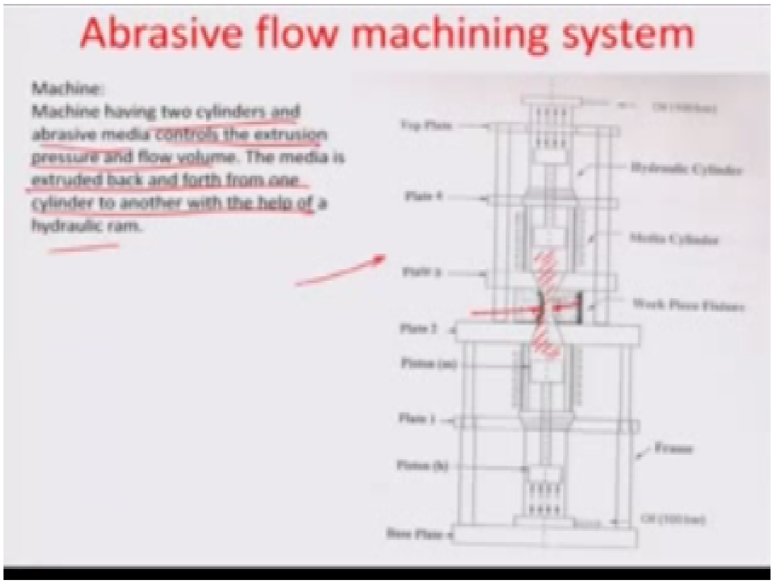

So a typically abrasive flow machining system is shown righty here the machine has to cylinders again and abrasive media control the extrusion pressure on flow volume media is extruded back and forth from one cylinder to another and with the help of hydraulic clam as you can see here and this leads to the flow of medium in this particular region here shown by the hatched section okay which goes into this internal contour where it has to finish machine.

So there is a reduction in area and an increase in the overall force resistance and these are really the valves which get finished because of the two and fro motion of the medium because of the motion initiated by the two hydraulic ramps on both sides.

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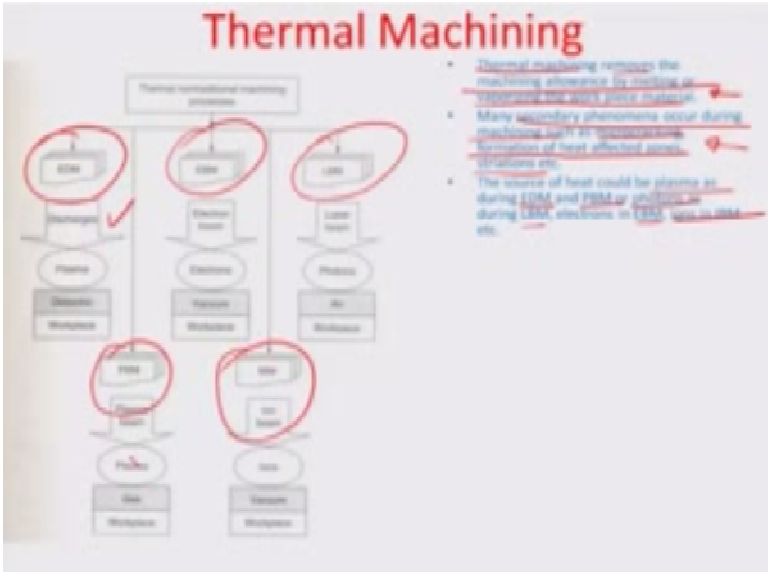

So that is how the flow finishing machine takes place today we would also try to look at another very important process which is actually related to thermal machining in fact we have been looking at mechanical machining and its associated or system process we have also looked at the electro chemical machining and system processes now we want to find out how material can be found or removed in a thermal manner.

So there are various modalities which are associated with again nontraditional processes with thermal removal is deployed one of them is discharges particularly DM or electro discharge machining another is through electron beams where the electron beam can expose a surface and try to create you know momentum transfer on to the latent atoms which relates to an increase in the kinetic energy overall kinetic energy.

And then again material removal or a laser beam where there is a photon to phonon conversion because of bond vibrations and also the absorption of the material sue to which there is a machining operation which is carried out there can be many other means of creating high temperature processes or high temperature zones on the work piece when is using of plasma beams another is iron beams.

So these can also be visualized as one of the many processes where thermal machining can be achieved number of pieces, so the basic principle behind thermal machining is basically removal of the machining allowance by melting or vaporizing the work piece okay. So you have to really increase the selfish kinetic energy too and extend that the materials starts melting, the many secondary phenomena which occur during a machining process such as micro cracking formation of the heat affected zones.

Or may be some striation because of reflow and recanalization so on so forth and we have to somehow be able to optimize the parametric of processes so that these secondary phenomena minimized, again the sources of heat as I just talked about could be many it could be DM sparks basically which is also known as electro spark machining or electro discharge machining it could be a plasma beam commonly known as plasma beam machining.

It could be photons commonly known as laser beam machining or electrons as an EB machine or even irons as an iron beam machining so on so forth.

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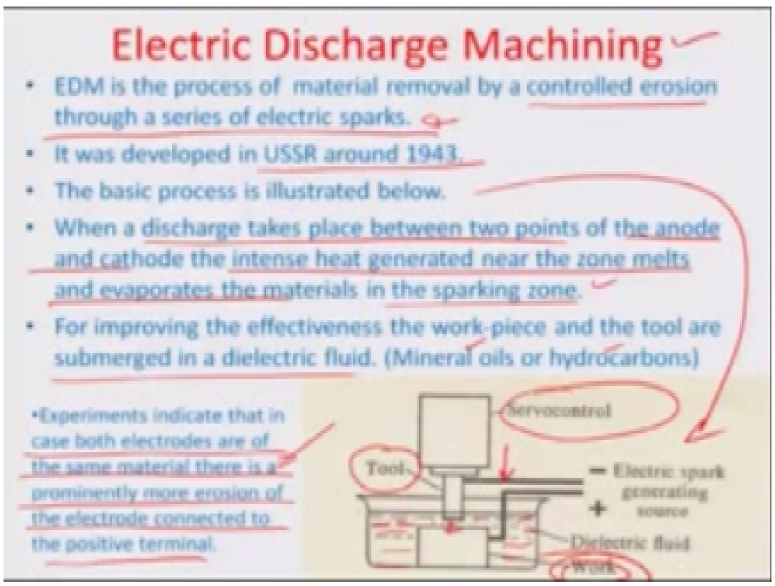

Let us look at the first of these processes which is the electro discharge machining process which was generated more due to I think wire war requirement in USSR in the year 1943 so IDIOM is a process of material removal by a controlled erosion and which can be obtained through a series of electric sparks the basic process illustrated here by here and you can see that there are two electrodes here one formulates the tool another is the work piece and there is a dielectric medium which is otherwise an insulator which is shown between the tool and the work piece in this particular region.

So this tank is actually full with that dielectric fluid in which all the surface emerse there is a server control which is used for giving a down feed to the tool so the tool can approach the work piece surface and you know there is a discharge that needs to occur between the surface the and up to which we can say that machining is not taking place but after the discharges happens there is obviously a local melt tool which is generated in the work material.

Because of the high pressure of the electrons which strike the surface here right here where the spark is generated and this melt pool can slowly be taken away by the dielectric which is flowing around in the zone between the tool and the work piece, so directly otherwise is a fluid in nature, So the discharge take place between two points of the anode and cathode and the intrinsic generated near the zone which melts and evaporates some material.

And the material is generally melted and evaporated due to a spark in this sparking zone okay. So obviously for improving the effectiveness of the work piece and the tool and the machining process you could submerged the whole thing in a insulating medium so that the spark power could control and there are several such insulating mediums which I used one of them has been a loyal another is hydrocarbons that can be idiom oil so on and so forth.

So the experiments indicate that in case both the electrodes are of the same material there is prominently more erosion of the electrode connected to the positive terminal and therefore normally the tool is made in this case the positive electrode. There is a reason for this to happen which I will explain in the following slides.

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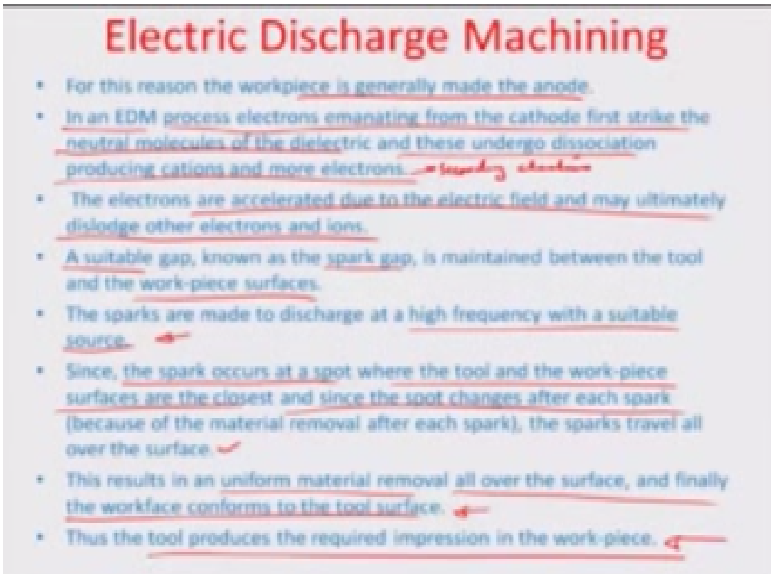

So let us now look at why these spark should be generated and how it should be generated and what is the physics behind the generation of the spark process, so basically if we make the work piece the anode and the tool the cathode there is going to a discharge primarily composed of electrons which reaches the anode , the anode being positively charged and if the discharges is made up of electrons the question that we should really ask is that what is the number of ions reaching the cathode verses what is the number of electrons which reaches the anode.

How are ions formulated that as soon as the spark is generated in the medium which is because you know medium has achieved is break down voltage of electron electric field which is a function of two things, one is applied voltage another is the distance between the two electrodes so obviously electric field is the voltage per unit distance, so if the distance is small and it becomes smaller and smaller the electric field increases to a level where the medium breaks down and the spark gets emanated.

So in this spark gets formulated obviously there are high velocity electrons and just in front of the electrons there is the dielectric medium which can be easily ionized so there are some secondary electrons and ions which are generated the moment this primary ions are sent in as a spark from one of the electrons the cathode. So the ions would move towards the cathode they are positively charged and the electrons would move towards the anode and obviously the electron density is much, much higher and comparison to the ion density.

And obviously also the electrons move because of their lower mass at higher velocity, so the amount of momentum delivery if we look at of the electrons which the ions the electrons would have overall much more momentum transfer in comparison to the ions and one of the reasons why the as I was just mentioning in the last slide if the tool and work piece are made of the same material anode has more depletion is mainly because the anode is a primarily hit with the electrons and the electrons of high momentum and high momentum transfer.

So if this principle can be deployed to appear of work pieces where the work piece or pair of materials where the work piece is made the anode obviously the same effects could be captured and the electron would be able to generate more damage on the surface rather than ion generating damage on the other surface, so therefore normally in all the cases the work pieces made the anode and any other material which is made the tool is made the cathode and the cathode does not have although it gets one down with time but may not be went down that significantly as the work piece does and therefore you know you can say that the tool is machining the work piece.

Because there is a relatively larger amount of dupery coming out of the anode than the cathode so obviously in an EDM process the electrons emanating from the cathode would first strike the neutral molecules of the electro light tool is normally made the cathode and the work pieces made the anode. One of the reasons why this is so is because you know when we talk about the whole idiom process it is about how the spark is generated so there is a cathode, there is an anode and there is some kind of a dielectric medium in between which is otherwise insulating in nature and then you are reducing the distance between the cathode and the anode.

So there is a possibility that the electric field between the anode and cathode makes C to the break down electric field which is needed for the dielectric to break down fully, and that is a point of time where you can have a discharge, okay. So there is a voltage which is applied a voltage signal which is applied across the cathode and anode and there is a reduction in the inter-electrode distance so the electric field goes up as a function of that you know lesser and lesser or lower and lower distance between the electrodes.

And it hits up on a point where there is a break down the moment there is a break down there is a release of electrons from the cathode. Remember, the tool is made the cathode in this case and these electrons which are released from the cathode they would actually come into the dielectric medium and start breaking down the dielectric fluid into ions and electrons, so there is some kind of a ionization process that is happening to the column which is trap between the anode and cathode in this case.

And there are positive irons which are created there are also some secondary electrons which are created by cause of the charge. So it is similar to may happen in case of welding but that happens with KR in between and obviously that happens for a longer amount of time here it is only a slow release or one step release so the charge get transparent completely at one go short span of time.

So here the process is related to sparking okay as suppose to may be welding process which I had talked earlier in weight details and manufacturing process technology one, where it was a longer time that this spark was being formulated and we call such spark actually arches not sparks. So here in this case it is a very short time discharge that we are talking about and that discharge once sort of generated from the tool actually create sanitations and more secondary electrons.

So obviously the electrons now would start going towards the anode the ions that are formulated in the columns would approach the cathode and if you look at the numbers of the electrons we have is number fans and the electrons are much more or much more outnumbered in comparison to the ions number two because the lighter and weight they can be moved at a higher velocity and overall they are impact momentum or the momentum that it delivers because of the local electron pressure near the surface of the anode is much higher.

And because of such high momentum transfer there is a possibility that the anode has more amount of you know thermal energy and more amount of melting and vaporization in comparison to the tool where may be the ions are fewer and also although there mass is heavy the velocity is may not be that high and therefore they may not overall in terms of numbers time of mass velocity product may be able to apply sufficient domatium momentum transfer for huge removal of the tool material through melting vaporization processes.

So overall it is seen that if in case is the materials are similar at both the anodes and cathodes the anode would repeat faster in comparison to the cathode and in fact in all other radium process if the tool material is changed as well. So in principle that is a reason why the configuration of the idiom tool is with the work piece at the anode side. So let us summarize.

So in this for this reason the work piece is generally made the anode in idiom process electron emanating from the cathodes first trying the neutral molecules of the dialectic and this under go to dissociation using producing cantons and more electrons, these are secondary electrons just is I was talking about the electrons are accelerated due to the electric field they are ultimately use for dislodging other electrons and ions and there is a suitable gap better known as a spark gap which is maintain between the tool and the work piece surfaces.

And sparks are many to discharge at very high frequency with suitable source I will just tell you little bit about the positioning of this spark and the way that the spark goes around the whole surface depending on what really is the inter electro distance as a function of the overall surface waviness and roughness of the electrodes. So since the spark occurs at spot where the tool and the work piece surface or the closest and since the spot changes after each path the spark travel all over the surface and this result in a uniform material removal all over the surface and finally the work piece conforms exactly to the tool surface. Thus the tool produces the required impression on the work piece.

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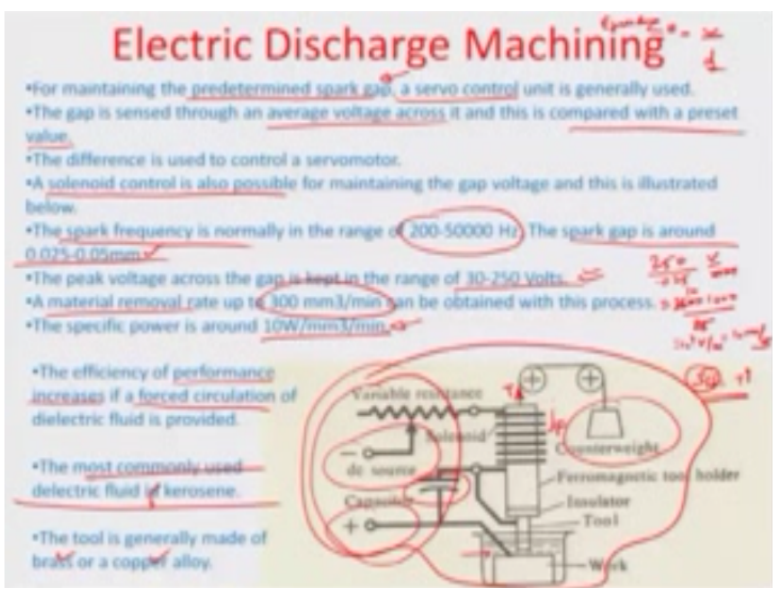

So there are certain important aspects in order to maintain the predictor mined spark gap because obviously you have to go for certain distances where the v / d should produce and electric field which is greater than the breakdown field ebric down okay of the medium, and generally disperser to our servo control in order to maintain that gap the gap is since 2 and average voltage across it and then it is compare to our pressure value and then there is a control based on a servo motor which would actually initiate the linear feed of the tool with respect to the work piece.

So that the voltage changes to the predict mined value or the present value. So there can be many other controls like a solenoid control is also possible for maintaining the gap voltage and some parametric associated with this process that the spark frequency is normally in the range of about 200 to 50, 000 watts, that means so many sparks for cycle per second and the spark gap which is maintain this almost around 0.025 to 0.05mm.

Okay so it is basically 5 to 2.5 microns the voltage of the cross gap is kept almost in the range of about 32 to 50 volts so you can understand what is the kind of the electric fields that is needed let us say 250 volts by .025 millimeters okay.

So that mixed about 10^4 volts per meter or about close to 10kv per meter so it is high field that we are talking about and approximate estimate of the material removal, material removal rates up to about 300cube millimeter per minute can be obtain on the specific energy or specific power that is need about 10 watt per unit of material removed in mm cube per minute.

So the efficiency of performance increases by manufactures one of them obviously is changing in nature of dialectic another is by force circulation so the idea is that the dialectic is also able to generate through efficiency process the medium there are the melt which is their locally available at the anode after the sparking process is happened.

After one such sparking process has to be refused so if there si a circulation over all and there is the flow velocity the process they take away or carry over the material okay and so therefore you would have lesser relaxation tine between this sparks because obviously the iron column once created has to be completely eliminated before an another column can be set and so therefore set in.

And therefore the frequency of the sparking process also would depend on how soon are able to get rate for going up to the next cycle so the most commonly used dialectic fluid is kerosene and the most commonly used tools are brass and copper alloys made up of brass and copper alloys this shows is sort of systematic of how you know we could control the through the servo the all sudden alloys the intro electro cap so there is a gap and capacitor here the cap volt capacitor is here.

And there is also solenoid were you know it controls the cap through relative difference between a reference voltage okay and this gap voltage the variable resistance and in order to control the upper motion of the tools supposing it has over voltage short up the perceive value there is always a count to rate which can be used to pull this back.

So the solenoid force and the force attention and you know our acting in the opposite directions to each other and add equilibrium obviously the solenoid forces same as retention force and the solenoid force which is also a function of this difference between the preset and gap voltage decreases the retention would be more dominated to low backwards.

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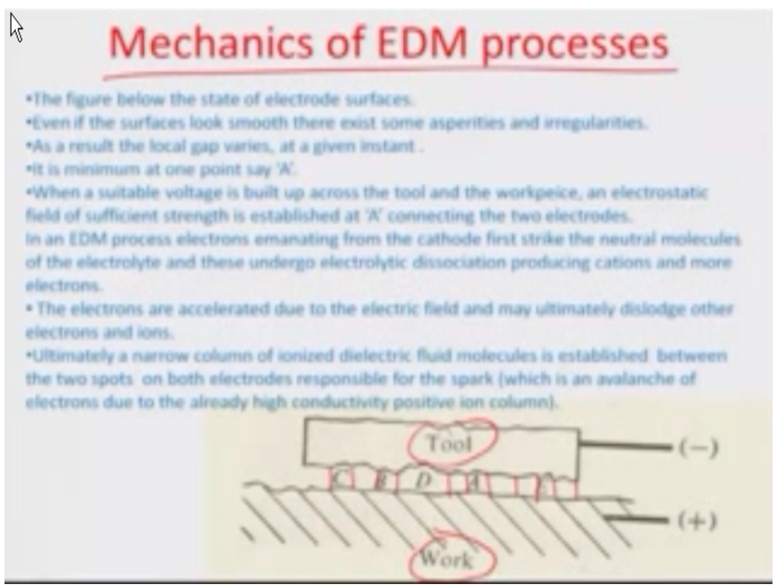

Similarly if we solenoid forces more the tool forces it would be forward or the tool would be forwarded into the work piece so that is how you can operate such tool so let us look a add a little bit into the mechanics the basic mechanics of EDM process so here the idea is that there is a highly rough surface and of the tool in the work piece and there are varying intro electro gaps that you can see there is a peak up to the valley and valley.

And so the field the different places within the tool surface also different we are actually looking forwarded to a distance which is actually the least distance okay may be a peak to appeal facing each other where the field would be higher for location of the spark so we will try to continue this in the next module I am closing this the interest of time and I would try to talk about the basic mechanics a little bit of how to estimate the material removal rate etc of the spark machining process in the next lecture module and till then goodbye and see you all thank you.

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