Advanced Machining Processes
Prof. Vijay. K. Jain
Department of Mechanical Engineering
Indian Institute of Technology Kanpur
Lecture No 19

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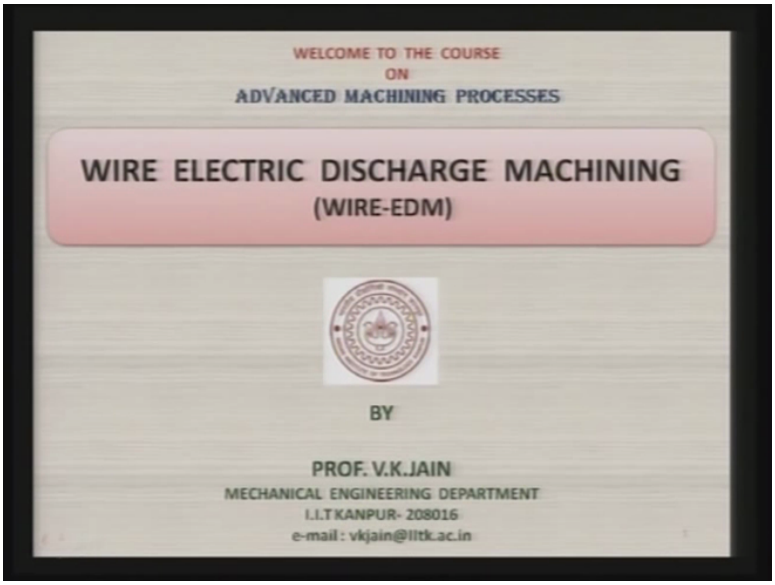

Welcome to the course on advanced machining processes, today I am going to talk about an aligned EDM process that is wire electric discharge machining which is abbreviated as wire EDM.

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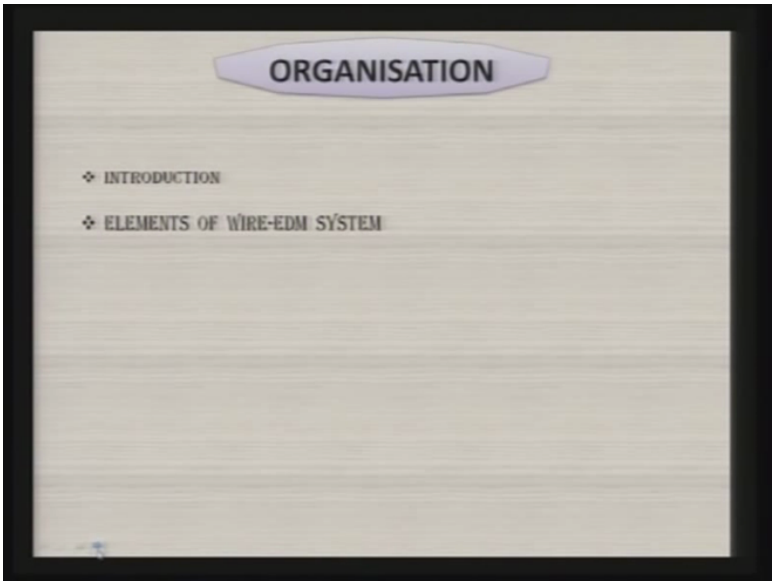

The organization is like this first I will give the introduction to the aligned processes specially EDM then I will tell you the elements of a wire EDM system.

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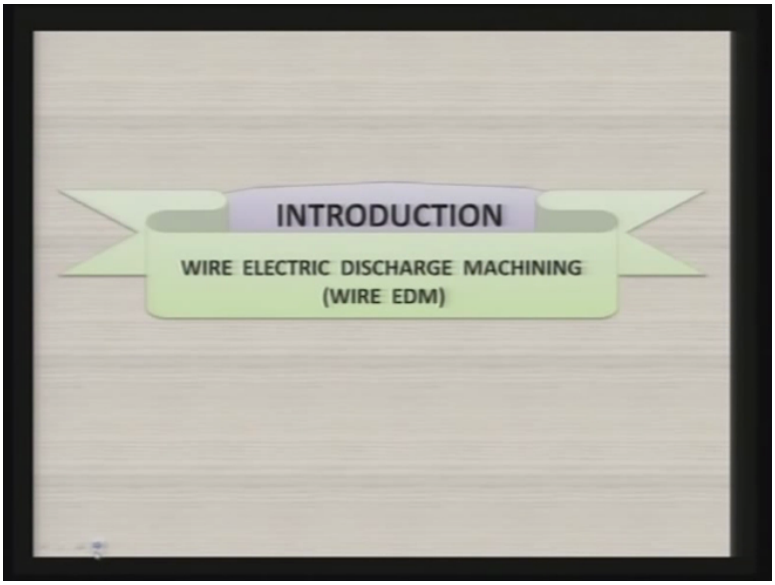

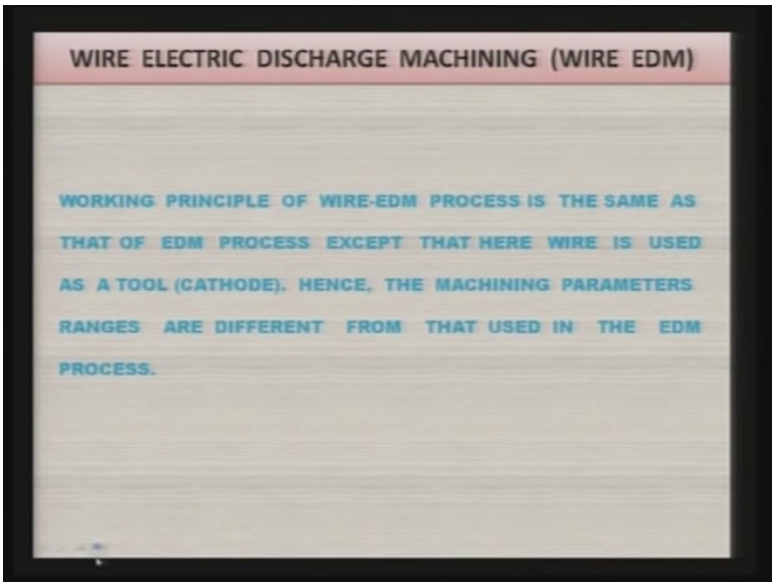

Introduction to the wire electric discharge machining process, working principle of wire electric discharge machining process is the same as that of electric discharge machining process which I have already discussed in the last 2 lectures except that here in wire EDM, wire is used as a tool that is the cathode instead of using solid large size tool or cathode in EDM process. Hence, the machining parameters ranges are different from that used in EDM process.

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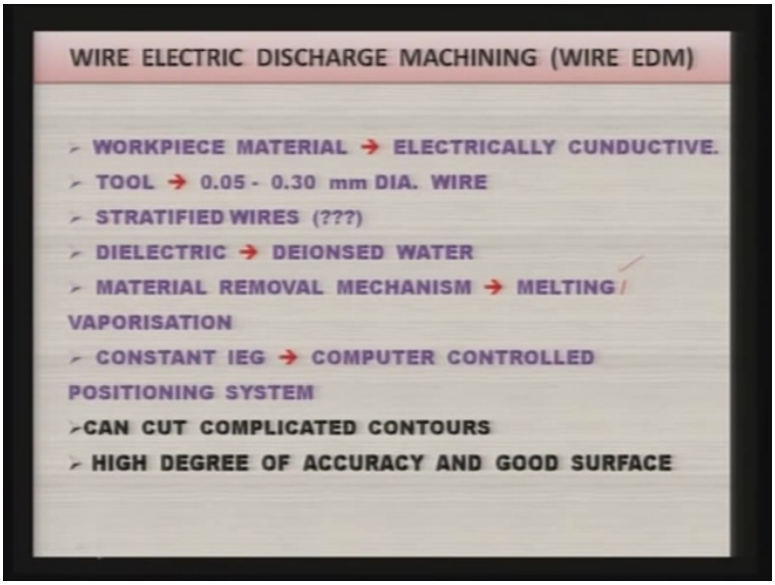

Definitely the conditions basic conditions of EDM process remains the same that is workpiece material should be electrically conducted because in this process also you are making workpiece as anode in normal polarity which we use in case of wire EDM process. The tool diameter that is the wire diameter is normally 50 micron to 300 micron depending upon the requirement and the availability of the wire and type of the wire. Now in the beginning most of the manufacturers of wire EDM machines were using bare copper wires or other materials wires but lately Charmille's Incorporation developed a new type of wire that is named as stratified wire.

The question arises what is stratified wire and why we should use stratified wire? We will see after a few slides. Here in this case the dielectric use is mostly deionised water while in case of EDM process it is kerosene, paraffin oil or the dielectric developed by individual manufacturer which are which composition is normally kept secret but in wire EDM invariably deionised water is used as the dielectric. Material removal mechanism in case of wire EDM remains the same as in case of electric discharge machining that is melting of the material by the heat produced by spark between the tool and workpiece, in this case wire and the workpiece and many a times the temperature of the localised area where sparking is taking place is so high that it is not only the melting rather a part of the material gets vaporised from tool as well as workpiece both.

So the mechanism what we had in case of EDM process remains the same in case of wire EDM process also. Now as in case of EDM process this case also the gap between the wire and the workpiece should be maintained constant that is the constant interelectrode gap IEG

and this is done or this is achieved by the computer controlled positioning system which every wire EDM process, wire EDM machine uses and wire EDM machines are CNC Numerically, computer numerically controlled machines. Now the beauty of this particular process is that wire EDM process can be used for cutting complicated contours, even three-dimensional for cutting three-dimensional contours wire EDM is very suitable and very economical and important another important point is that you really do not melt and vaporise all of the material to be removed rather you can get solid piece from the area where from you want to machine the material.

You can achieve high degree of accuracy and good surface finish in this particular case surface finish is much better than what you get in case of normal EDM process. The reason is very simple, in case of wire EDM process the current supplied or the current that flows between tool and workpiece is very small compared to normal EDM process and frequency of pulsed power supply in wire EDM is much larger than the frequency that you have in case of EDM process that is why as we have seen in the past in the while discussing EDM process, the effect of current and effect of frequency both very small current and very high frequency will lead to very small size of the crater and if the size of the crater is small definitely the surface roughness value that you are going to get is going to be small or you can say a much better surface finish.

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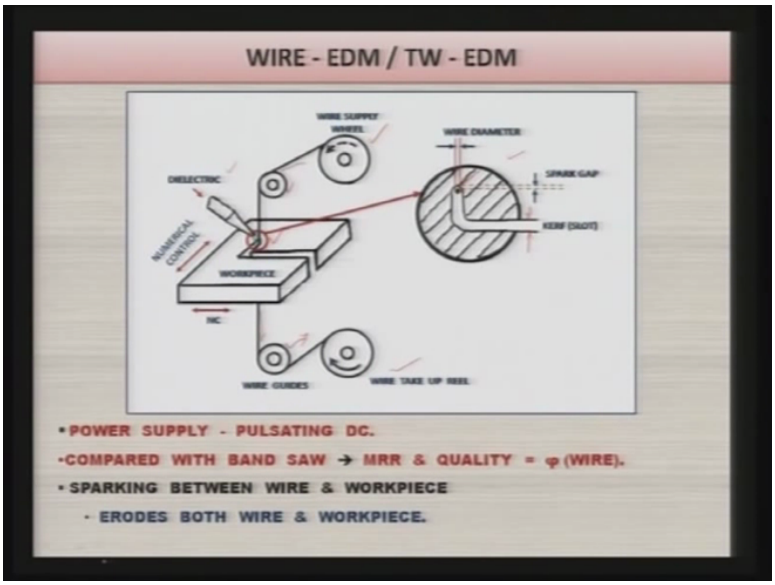

This is also known as travelling wire electric discharge machining process whose schematic diagram is shown over here which is simple you can see here this is the wire supply wheel where from the wire is coming and this wire moves on the pulley and from the pulley it

comes to the area where material removal is taking place, there is a nozzle which is supplying the dielectric between the tool that is the wire and the workpiece kept that is the interelectrode gap. Now when this wire is moving this is being pulled by the other pulleys and that you can take here and see here while take-up reel of pulley which is pulling the wire to the wire guide pulley and this way the wire is moving.

Now here if you see the enlarge view of the area where from material is being removed on the right side you can see it clearly that kerf is being produced and the size of the kerf or width of the kerf depends upon the wire diameter, it is slightly larger than the diameter of the wire and that is that enlarged size of the kerf compared to the wire it is known as over cut as you can see over here. Here is not shown I will show you in the next slide that is the over cut and the gap between the workpiece and the wire outer periphery that is known as sparking gap or interelectrode gap and the slot that is being formed is known to as kerf or the slot as you can see on the right-hand side of the picture of the figure.

Power supply is pulsating power supply, you can compare it with the band saw where material removal rate and quality of the cut surface depends upon the wire parameters also, the size of the wire and other cutting parameters that is the current. As we have seen sparking takes place between the wire and the workpiece as you can clearly see here on the right side of the figure wire diameter shown their and the gap between the wire and the workpiece is there and that is known as sparking gap where spark is taking place. Now when sparking takes place as we have seen in the earlier lectures plasma channel is form and that plasma channel erodes the material from both in this particular case from the wire as well as the workpiece and that is why you create the kerf and cut the workpiece either in 2 pieces or you shape it and size it depending upon your requirement.

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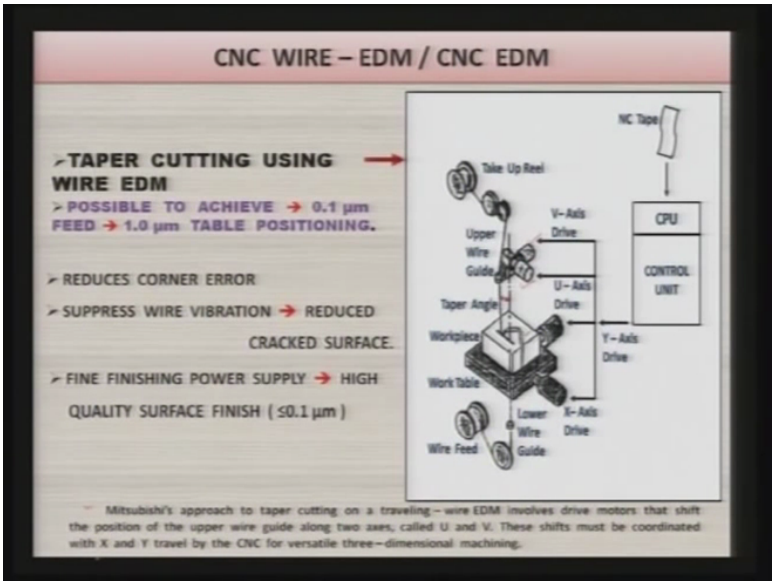

Here you can see a better version of the CNC wire EDM process, now here you can see V axis is given over there and there is a motor for giving the or moment in the V and U both where as you can see here in the note that Mitsubishi approach to taper cutting on a travelling wire EDM involves drive motors that shift the position of the upper wire right along 2 axis called U and V as you can see here I have marked with the mark yes mark or correct mark. These shifts must be coordinated with X and Y travel by CNC or versatile three-dimensional cutting. So this particular version of CNC wire EDM process is useful for cutting three-dimensional on end.

Rest of the things remains the same as we have seen in the earlier figure and you can see a complicated shape is being machined here by moving the workpiece in X and Y direction and the wire moment is given in U and V axis and you can cut the surface at a particular angle and that angle you can control with the help of the taper angle of the wire with reference to the axis of the wire without taper and that has in cutting making three-dimensional cutting.

Here in case of wire EDM it is possible to achieve 0.1 micron feeds rate and 1 micron table positioning accuracy all this depends upon the type of the system you have and the kind of the money you are investing with the different kind of features in the machine. Another point is it reduces corner error and it suppresses wire vibration and here wire vibration is suppressed then you get reduced crack surface. Fine finishing power supply you get high quality of surface finish, the surface finish that you can obtain by wire EDM process is less than or equal to 0.1 micron which is a very good surface finish and we have to controller the

machining parameter accurately to get such kind of the surface finish on the on the machine component.

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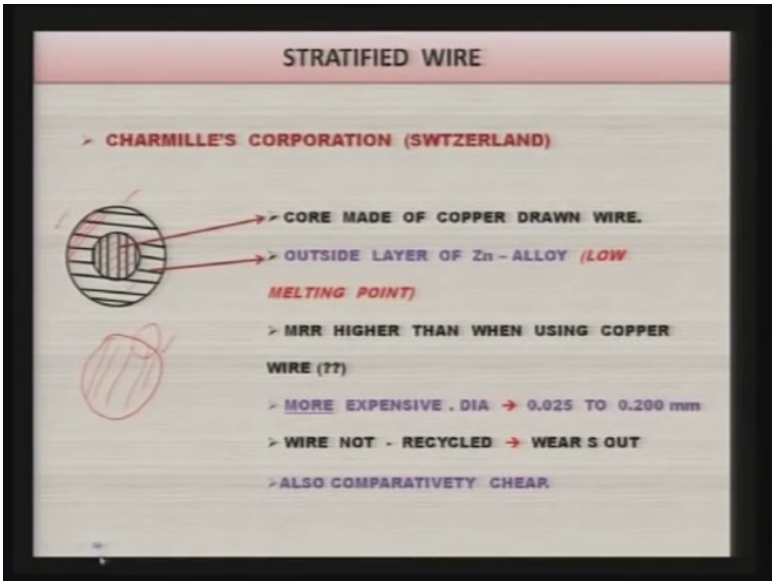

As I mentioned a few minutes back stratified wire was developed by Charmille's Corporation of Switzerland, now we can try to understand what this stratified wire is? Now here if you see this is the picture on the left side of a schematic picture, schematic diagram of the stratified wire, the core of this wire as you can see here is made of copper drawn wire, now outside layer of this is made of zinc alloy. Now here point to be noted is that whatever is the coating made of, it should be having melting point much lower than the core of the wire that is a copper in this particular case, so that MRR is higher than when using copper wire alone in case of stratified wire, I will explain how you get higher MRR in case of stratified wire as compared to the naked or bare copper drawn wire as the wire EDM process.

However, this wire stratified wire is comparatively more expensive and its diameter normally ranges between 25 to 200 micron size. Another important point to note here is that the wire if used once it is normally not recycled because the wire wears out and when you are trying to reuse it indefinitely wire will break during the use and if it breaks it takes enough time for rewinding it on the pulleys and the productivity goes down and these wires are not very expensive, so one can afford to use them only once, also the wires are comparatively cheap.

Now let me…what happens here that when you supply the current in the say naked wire only say this is the only copper wire which you are using then when you supply high current then sparking takes place between this wire copper wire and the workpiece and melting and

vaporisation of the material from the copper wire start taking place and wire me break or it cannot carry very high current but when you are using stratified wire and what happens when you are using very high current the most of the heat that is supplied by sparking is equalise in melting and vaporisation of this outside layer of zinc because when it is vaporising or when it is melting lot of energy is consumed for you know latent heat of melting and latent heat of vaporisation, so most of the heat that is created is taken by the outer layer of zinc alloy or low melting alloy that is why you are able to supply much larger current in case of stratified wire as compared to the naked wire or bare wire and if you are able to supply much larger current then it means your energy per spark will be more and if energy per spark is more and material removal rate is also going to be higher compare to the case when current being supplied is lower.

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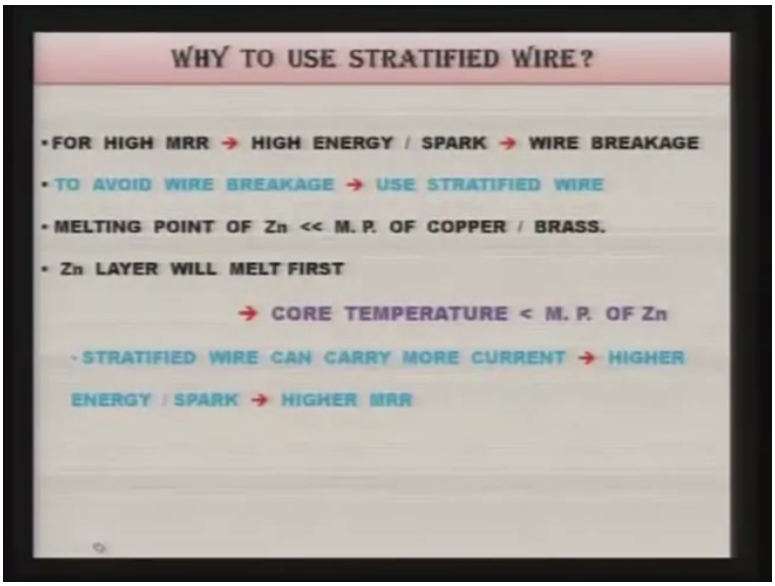

That is what is explained over here for high material removal rate you need high energy per spark but if you are supplying high energy per spark then wire will break, if it is the bare wire as I showed to you in the earlier slide only of copper, so to avoid this breakage of the wire, stratified wire use is recommended. In this particular case melting point of zinc is much lower than the melting point of copper or brass of which the core wire is made of, so zinc layer will melt first because of the heat supplied by the sparking on the wire as well as on the workpiece, so core temperature of the wire will be lower than the melting point of the zinc, so the chances of the breakage will be minimal. Stratified wire can carry more current that means higher energy per spark and higher material removal rate without breakage while if it

is just bare wire then at that particular temperature wire may break which is not the case with stratified wire.

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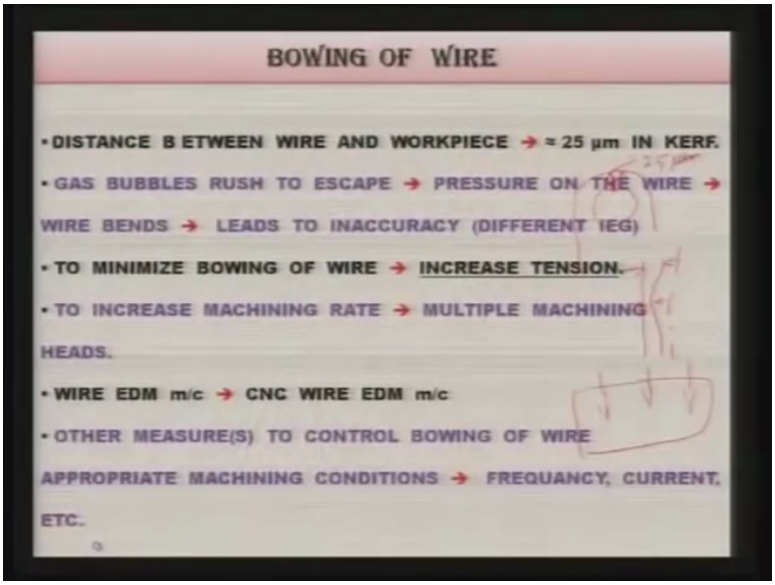

Now another problem that we normally face during wire EDM is distance between wire and workpiece is approximately 25 micron in the kerf that is the, suppose this is the wire and this is the area which being cut on the workpiece then this gap is normally 25 micron which is quite small. So gas bubbles rush to escape because of very high amount of heat the dielectric gets vaporised and the gases that are evolved during vaporisation it try to rush and escape out of the machining zone and pressure and as a result of that they apply pressure on the wire and once that pressure is being applied on the wire, the wire bends and it leads to inaccuracy because once the wire bends then the…if this is the site being machine and this is the wire and when wire bends as you can see here then the gap between the wire and the workpiece will be different at different locations and that will result in the inaccuracy of the machine component and this is not desirable feature because interelectrode gap is different, so it is going to create shallower and deeper crater at means surface finish also will not be good.

So to minimise the bowing of wire, what one can do? You can increase the tension on the wire because these wires are being pulled by the guiding or by the pulleys and so tension is increased and if tension is too much increased then the wire itself may break, so to increase machining rate, now another point is that in we want to increase the machining rate by wire EDM instead of one, you can use multiple machining heads that means suppose you are cutting workpiece into more than one pieces then you can use different machining heads and at all the 3 machining heads it is cutting at the same time, so in the same time which you

utilise for cutting one-piece into 2 pieces, you can use 3 heads to cut it into 4 pieces, so that way the productivity of wire EDM process can be increased and wire EDM machines are always CNC wire EDM machines. Other measures to control bowing of wire appropriate machining conditions, frequency, current, et cetera, so you should use appropriate machining conditions, so that the bowing of wire can be minimized specially the frequency of power supply, pulsed power supply, current that are that is flowing and some other parameters.

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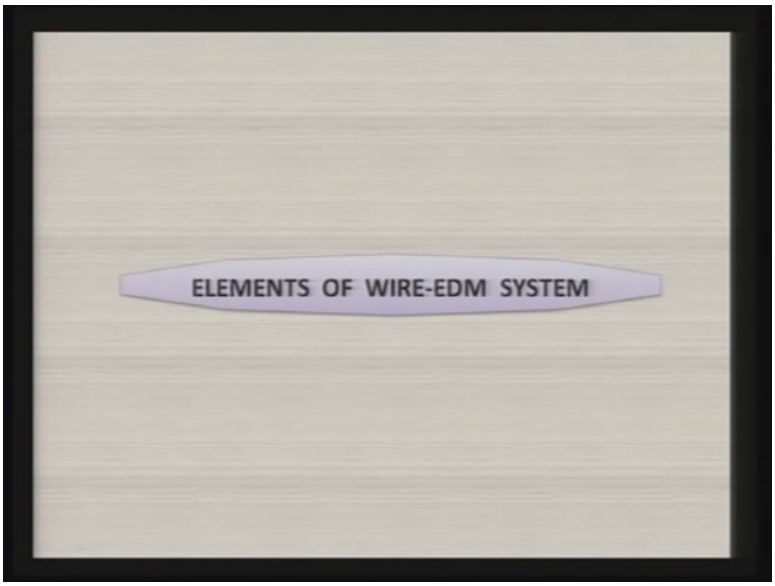

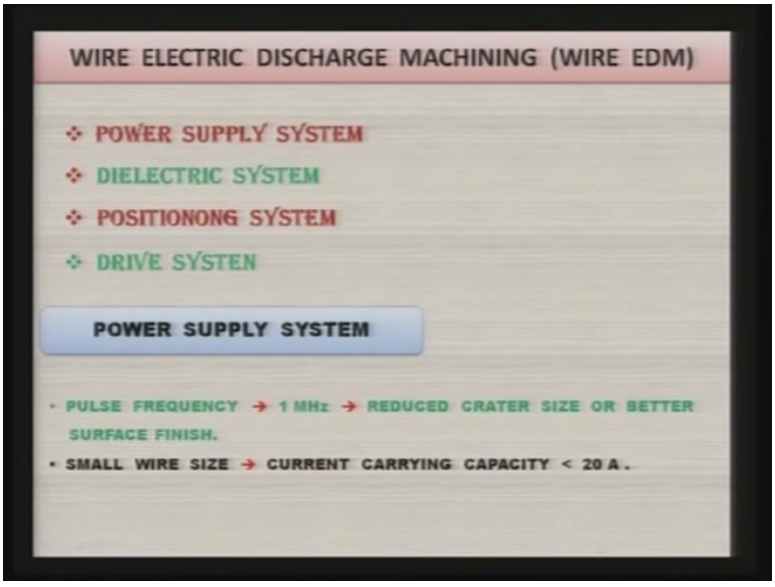

Now let us see what are the major elements of wire electric discharge machining system? Power supply, dielectric system, positioning system and drive system let us see very brief description of all these elements. Power supply system, you use pulsed power supply and the frequency is very high in the range of megahertz and if the frequency is high as we have seen

earlier the crater size is going to be much lower than what you get in case of EDM process and if crater size is lower then you are going to get much better surface finish as compared to normal EDM process. Also you can use a small wire size, so that the current carrying capacity is much lower and you cannot use very high current.

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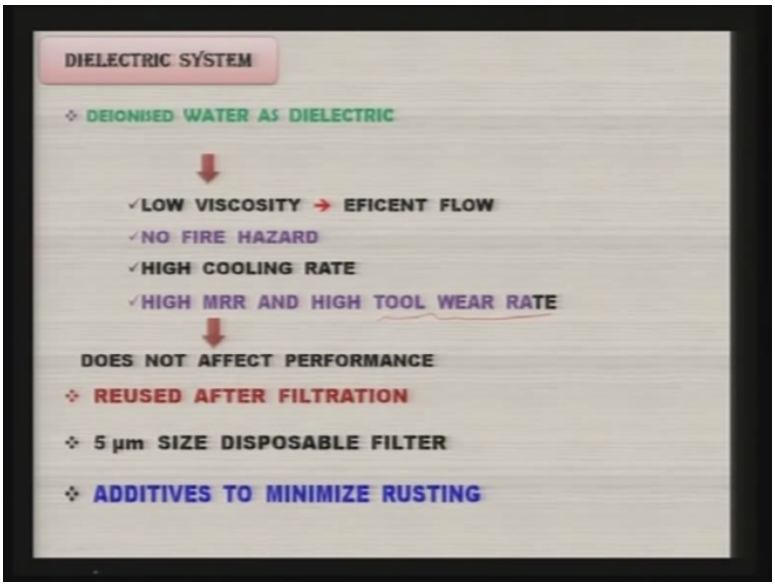

There is a dielectric system which utilises deionised water as the dielectric. Deionised water as low viscosity so that it is able to flow in the integrated shapes or the zones between the wire and the workpiece and if it can flow there then sparking will take place in that particular complicated zone and machining will take place. Since wire is used as the dielectric there is no fire hazard as is the case with the kerosene as the dielectric and wire is very high coolant, very good coolant, so high cooling rate is quite high in case of water. High material removal rate and high tool wear rate is also there, so this is undesirable feature in case of deionised water as dielectric, tool wear rate is high, so the probability of breakage of the wire becomes longer larger rather compared to other dielectrics.

It does not affect performance, reuse after filtration the dielectric that is the deionised water and be reused after proper filtration. You have to use very fine filters, you can use the filters of 5 micron size with which are disposable, you should not keep reusing it or a very long time. Now water has a property that corrosion or rusting of the machine component will take place, so what manufacturers do? They suggest certain additives to add it to the deionised water, that will or that minimises the rusting of the machine component and that is very important to safeguard the machine component for a long period.

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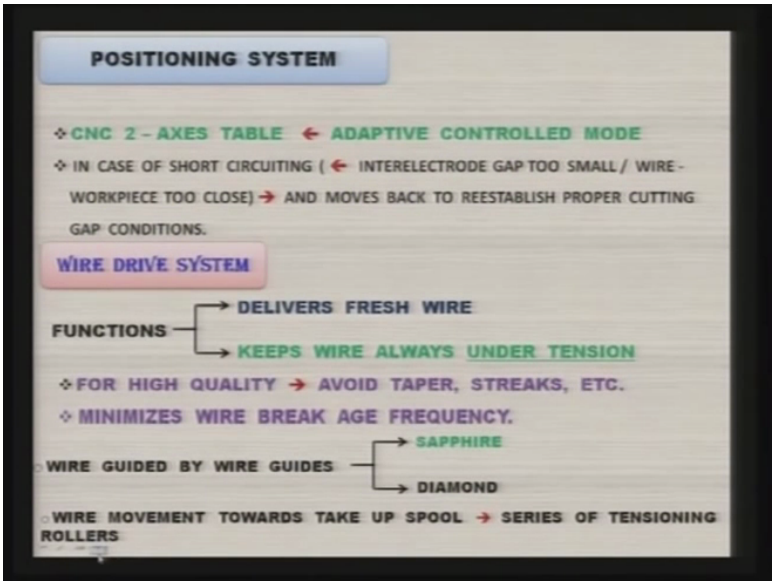

Positioning system, CNC has 2 axes table which can be controlled with the adaptive mode. In case of short-circuiting interelectrode gap is too small then short-circuit may take place or wire workpiece are too close then short-circuit may take place because whatever material is being removed in the form of debris that passes through the machining zone or the gap between the wire and the workpiece and they may bridged the gap as a result of that short-circuit may take place in short-circuit should always be avoided, so there are certain devices inbuilt in the wire EDM in the wire EDM machine which provide which avoid the short-circuiting of the workpiece and the wire otherwise the workpiece may get damage due to the short-circuiting and it is so then it moves back to re-establish proper cutting gap conditions.

Once the power supply is stopped because of the apprehension of the short-circuiting then inbuilt devices are there they will stop the power supply and then again they will before restarting they will adjust automatically in case of CNC adaptive control devices to the correct position, so that machine can restart automatically. Wire drive system, it has 2 functions it delivers the fresh wire all the time it keeps wire always under tension and I have already mentioned that it is recommended not to reuse the wire once used. For high-quality avoid taper, streaks, et cetera.

Minimises wire breakage, wire guided wire is guided by wire guides as we have seen in the earlier figures, wire guards guides may be made of sapphire or diamond. Wire moment towards take-up spool, they are series of tensioning rollers which provide or which create the tension in the wire when it is being pulled and that tension should be controlled. If it is too high wire will break, if it is too small then bowing of the wire will take place in the

machining gap and short-circuit may take place it will result in inaccurate machine surface also.

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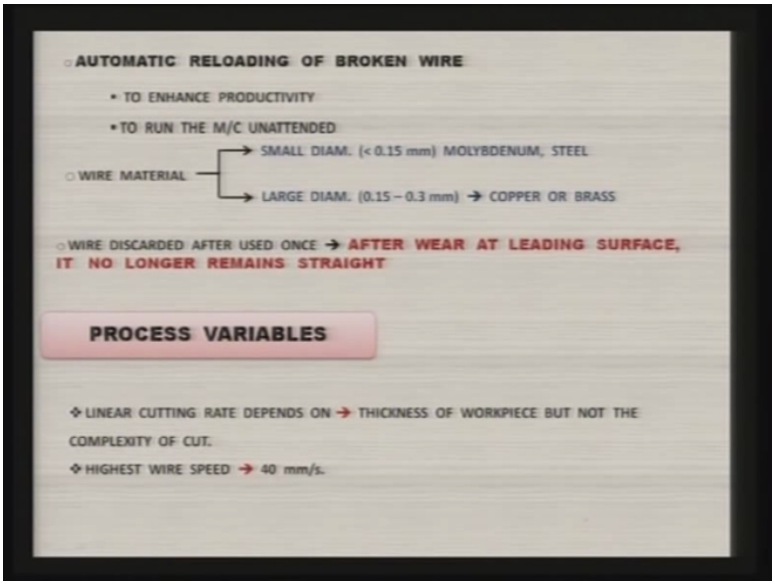

Then in modern machines there is automatic reloading of broken wire devices are there and if this automatic reloading broken wire if devices are there then it will enhance the productivity and especially unmanned factories they need such kind of the devices, so that before leaving the factory in the night some operators will start the machine and that machining will keep working throughout the night, in those cases you need automatic reloading of a broken wire that should be done either by the robot or by the devices inbuilt in the machine.

Then wire material, this has small diameter and the diameter and the material that you can use is molybdenum, steel or some other wires. Large diameter is it can be as large as 0.3 millimetre diameter, you can use copper or brass also as the material. Wire is discarded after used once, after wear at leading surface it no longer remain straight and it should not be reused. There are various process variables in wire EDM process, linear cutting rate depends on thickness of workpiece but not the complexity of the cut, complexity of the cut does not affect the cutting rate but thickness of the workpiece does make a difference. Highest wire speed is normally 40 millimetres per second which is quite high.

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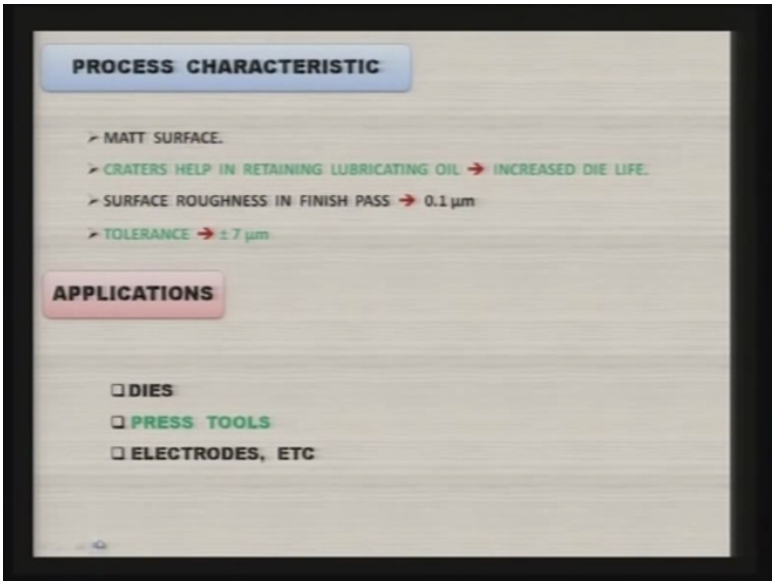

Now by wire EDM process the surface that you obtain is Matt surface that means you have thousands and thousands of the craters created on the machine surface and these craters are overlapping craters, so that you have the machine surface as the matt surface and this is good for retention or the lubricating oil and it increases the life of the dye. Surface roughness in finish pass may be achieved as good as 0.1 micron. Tolerance is normally expected by wire EDM process are plus minus 7 micron. There are various applications of this particular process some of the applications I have already shown to you in the introductory lecture, you can make the dies, press tools, electrodes, et cetera can be made by this particular process.

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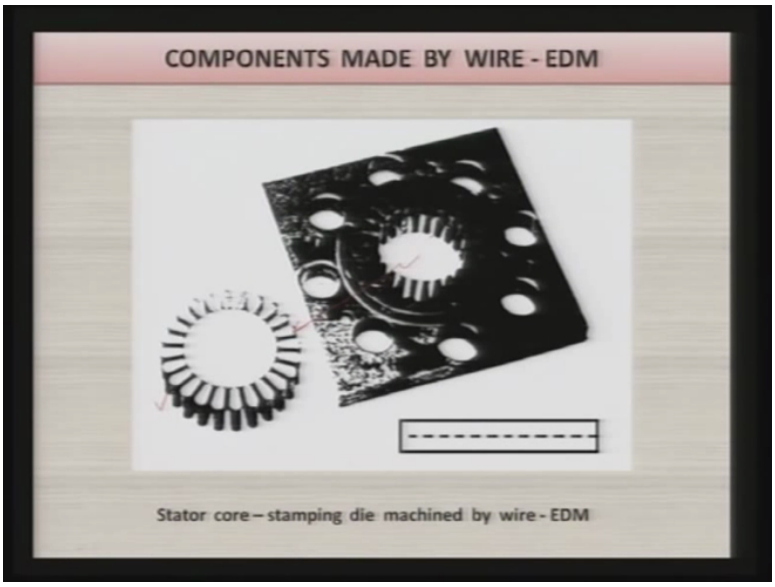

As you can see here stator core stamping die machine by wire EDM, here is the male component here is the female component. This has been taken out here, now both these components after assembling you can use as the subassembly or the assembly of this. Now the difference in the dimensions of this and this will depend upon the thickness of the wire that has been used to cut it and it is slightly larger than the thickness of the wire.

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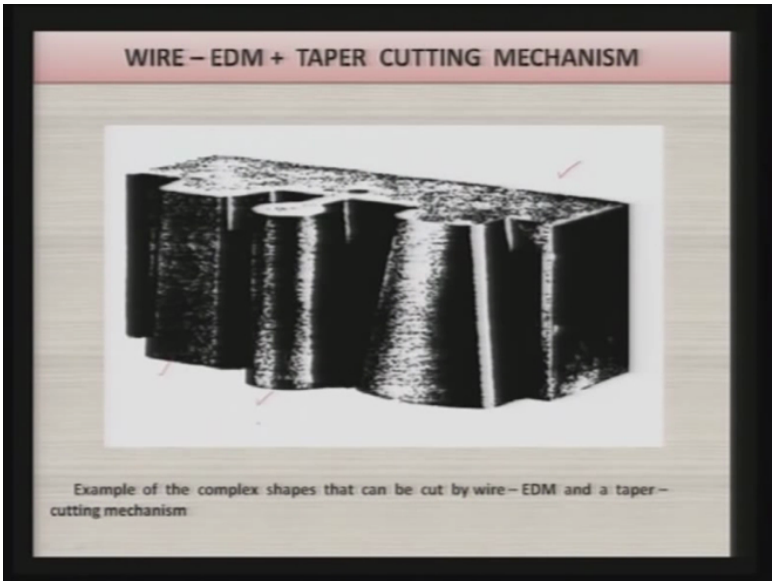

Now this is another interesting example this three-dimensional tapered component you cannot machined by other processes as it can be easily machined with the help of wire EDM process. Example of the complex shape that can be cut by wire EDM and a taper cutting mechanism as you can see here the there is a clear-cut taper in the vertical direction and again it is a 3-D component here the shape is different than this particular case, so this can be easily cut by wire EDM process.

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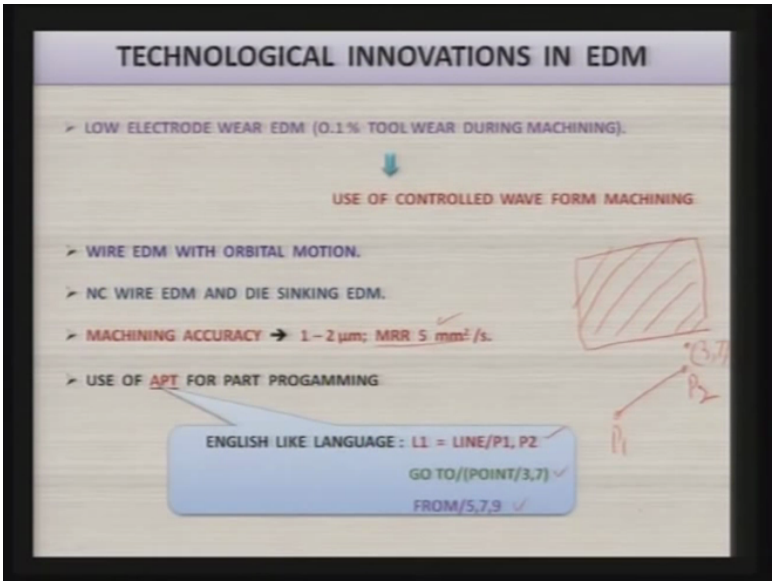

Now technological innovation in EDM process, low electrode wear EDM normally people are trying to develop the to select or to choose the material and the power supply system, so that electrode wear is minimise that is true for EDM process as well as for wire EDM process and the attempt is being made to achieve 0.1 percent tool wear during EDM process and for this purpose use of controlled wave form during EDM and wire EDM process are being made. Wire EDM with orbital motion is the system that has been developed by Electronica Pune. NC wire EDM and die sinking EDM are other examples.

Machining accuracy in case of NC EDM 1 to 2 microns, material removal rate 5 millimetre square per second. In this particular case it is very important to understand here the material removal rate is given in terms of millimetre square per second here actually with the help of the wire you are creating a surface rather than really removing material in the form of large quantity. When the surface is being created then one is solid part taken out from the machine as the machine component that is why the material removal rate is specified in terms of millimetre square per second rather than cubic millimetre per second as you have seen earlier whatever surface is being created say by wire EDM this is the kind of the surface that will be created, so whatever is the area of this particular surface divided by the total time taken to will give you the millimetre square per sec and as the cutting speed.

Now for preparing part program you can use various languages one of them is the APT automatic programming tool that is quite simple, in this particular case you use English like language like L1 is certain line which you are able to define by line P1, P2. P1 and P2 are the points like this as a can see here P1 and P2 and by this statement and define this. Now go to

point 3, 7 there is some point 3, 7 over here which we are X coordinate is 3, Y coordinate is 7, so you are giving the instruction to move the tool that particular point or to move from 5, 7, 9 this is 3-D where X is 5, Y is 7, Z is 9 coordinate point and from there tool is to move, so this kind of the language where you are using that is known as APT language you can use it and it becomes quite simple.

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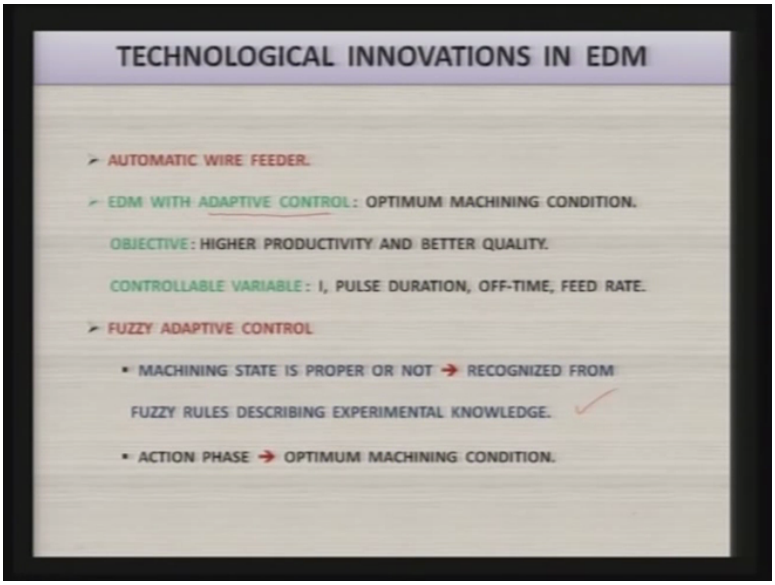

There are automatic wire feeder, EDM with adaptive control there where you can run the machine most of the time under optimum cutting conditions. Objective is higher productivity and better quality when you are using the adaptive control because most of the time you are running the machine under the optimum conditions and controllable variables are current, pulse duration, off time of the pulse and feeds rate. Fuzzy adaptive control also has been used in EDM and wire EDM, machining state is proper or not that can be recognised from the fuzzy rules describing experimental knowledge and action phase optimum machining conditions.

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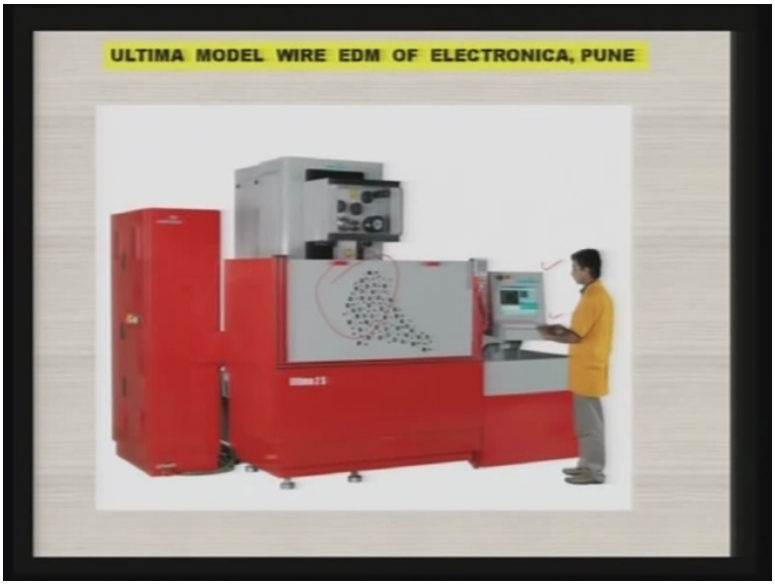

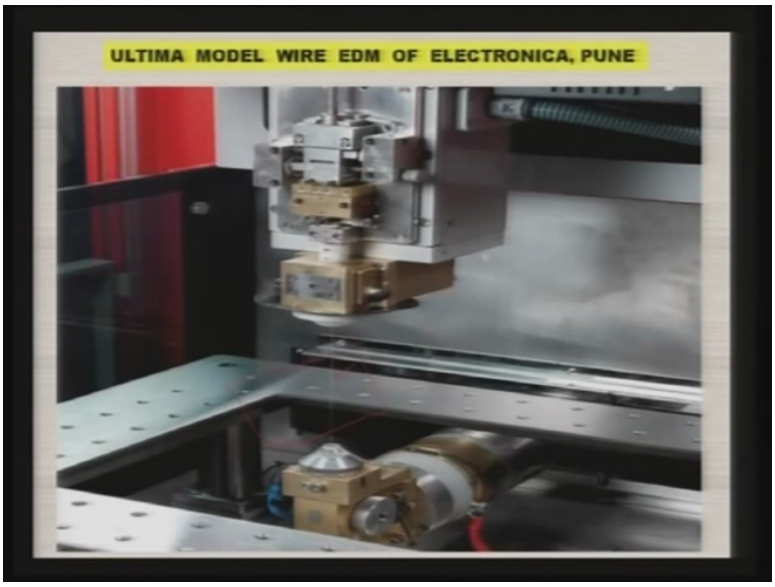

Here is the machine which has been developed by Electronica, Pune. It shows a picture or photographs of the ultima model, wire EDM machine developed by the Electronica as it can see here is the screen and inside this there is the machining area and all parameters or other various things you can control from the screen and the panel given over there and here not visible clearly as you can see in the next picture wire is clearly visible over here, this is the wire, this is the holder and you will keep the workpiece over here, so that it can be cut in the moment of the workpiece in X, Y direction and if the slides are given for tilting the wire in you can tell me why you to get the 3-D component. Thank you very much.