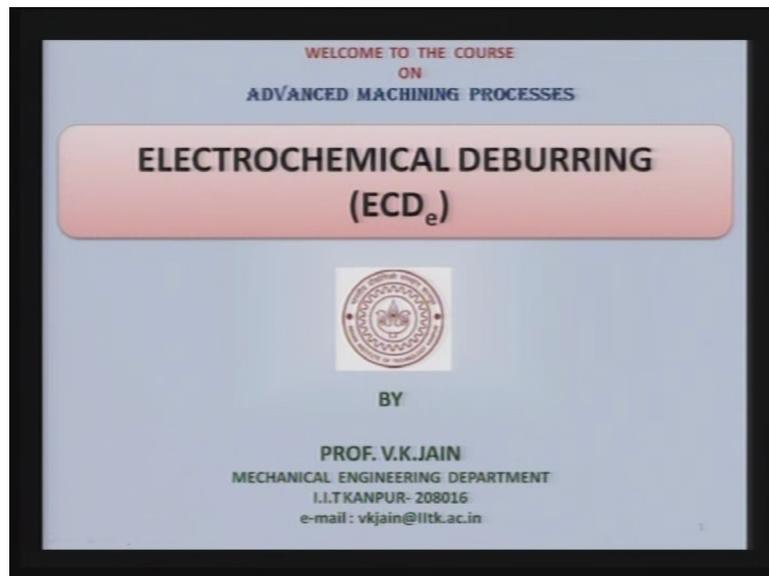


Advanced Machining Processes
Professor Vijay K Jain
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Lecture 22
Electrochemical Deburring

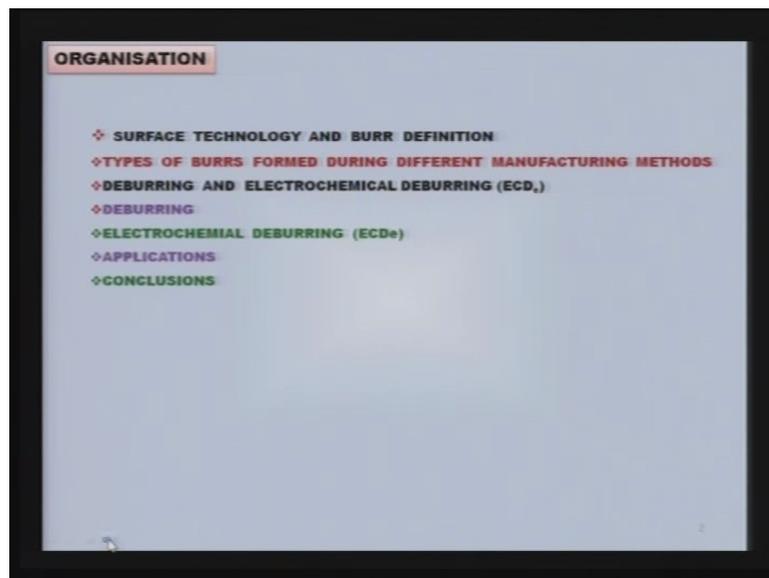
Welcome to the course on advanced machining processes. Today I am going to talk about electrochemical deburring processes and the principle of deburring.

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The organization of the talk is as follows. Surface technology burr definition, types of burrs formed during different manufacturing processes or methods, deburring and electrochemical deburring processes, deburring, electrochemical deburring, applications and then conclusions.

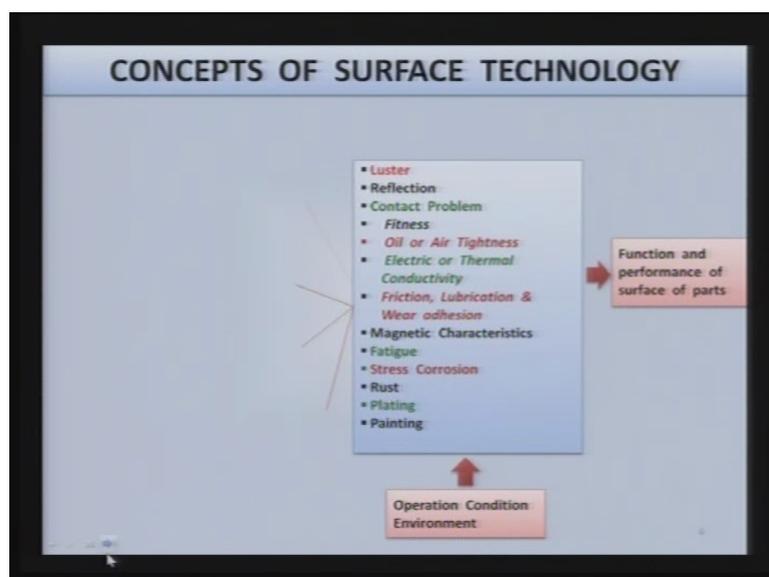
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Surface technology and burr definition. Now when we talk of surface technology, the surface should have a certain luster, it may have a reflection, it may not have reflection, there may be some contact problem with the surface, fitness.

When we talk of fitness we are concerned with oil and air tightness, electric or thermal conductivity of the surface or the component, friction, lubrication and wear adhesion, magnetic characteristics, fatigue, strength, stress corrosion, rust, plating. Now when we have these properties with the surface there are function and performance of the surface of different parts that are to be evaluated.

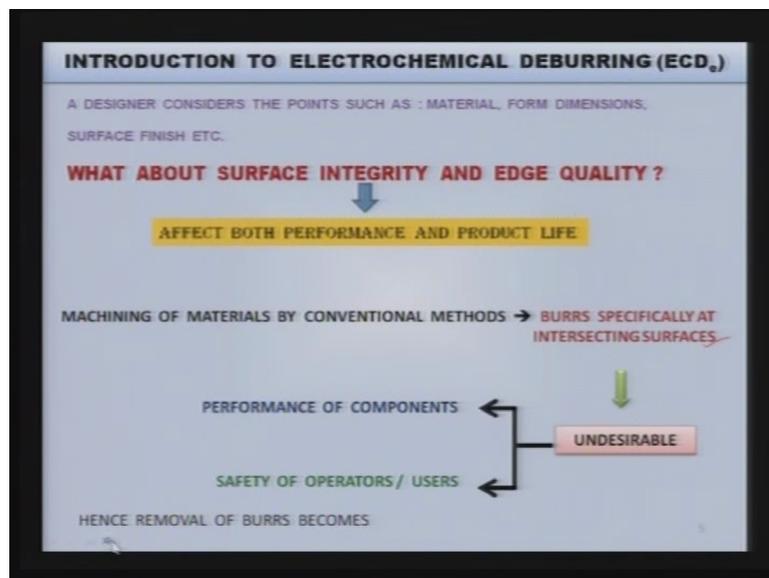
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includes drilling, milling, turning, shaping, etc. and all these components they produce the burrs which may be of micro size or macro size. And these burrs are formed mainly on the intersecting surfaces. These surfaces maybe two or more than two. Now these burrs are always undesirable from various point of use as I will show you later.

They affect the performance of the components and they also have bad effect as long as safety of operators or the users is concerned. So from different viewpoints burrs are not desirable and these burrs should be removed before the component is put into assembly of different systems. Hence removal of burrs becomes important.

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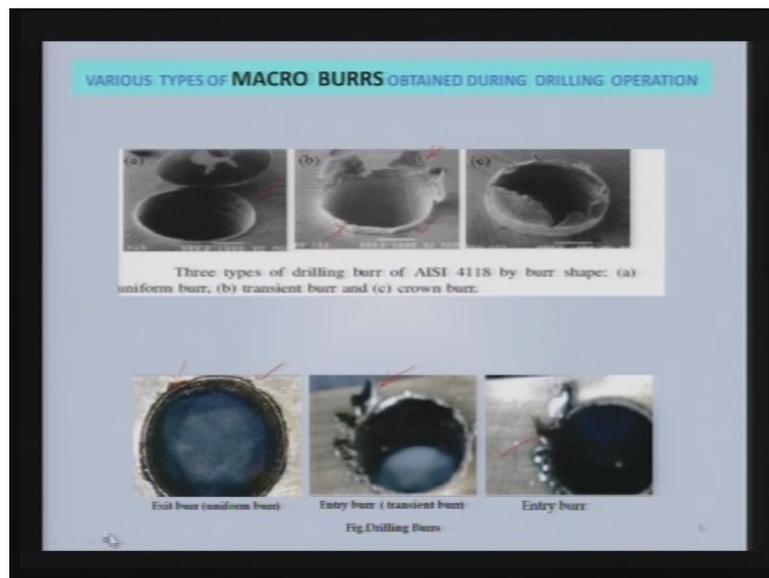


As you can see here they are some types of macro burrs which can be seen with the help of naked eye and these burrs are normally obtained in drilling operations. Three types of the drilling burrs on certain AISI 4118 material are shown. Uniform burr is there, then transient burr is there. Somewhere you can see bigger projecting part. Somewhere these are smaller ones and then you have that crown burr kind of the things.

Now when you are drilling a hole here the entry side of the hole and exit side of the hole that is entry means where the drill is entering into the workpiece for making a hole and where drill just crosses or exits or penetrates the whole thickness of the component.

So you can see two uniform burrs on the exit side and non-uniform burr on the entry side. And these burrs or these burrs both are undesirable and they should be removed or deburred. So you can see different kind of the burrs over here.

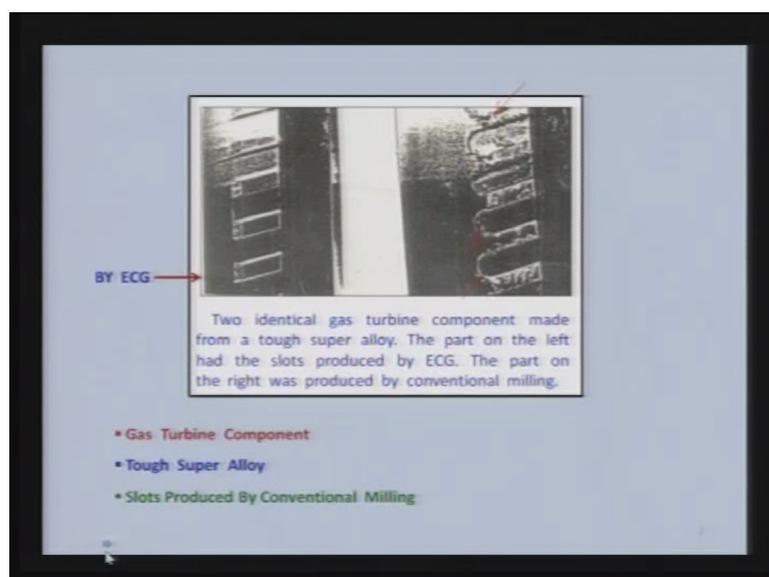
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Here is another example. Two identical gas turbine component made from a tough superalloy. The part on the left side had the slots produced by electrochemical grinding that we have already discussed. And the part on the right side was produced by conventional milling operation and you can clearly see the burrs on the different parts of this particular or different edges of this particular part.

And definitely these burrs have to be removed before this part is put for use. This is the gas turbine component made of tough super alloy. Slots produced by conventional milling over on the right side and electrochemical grinding on the left side.

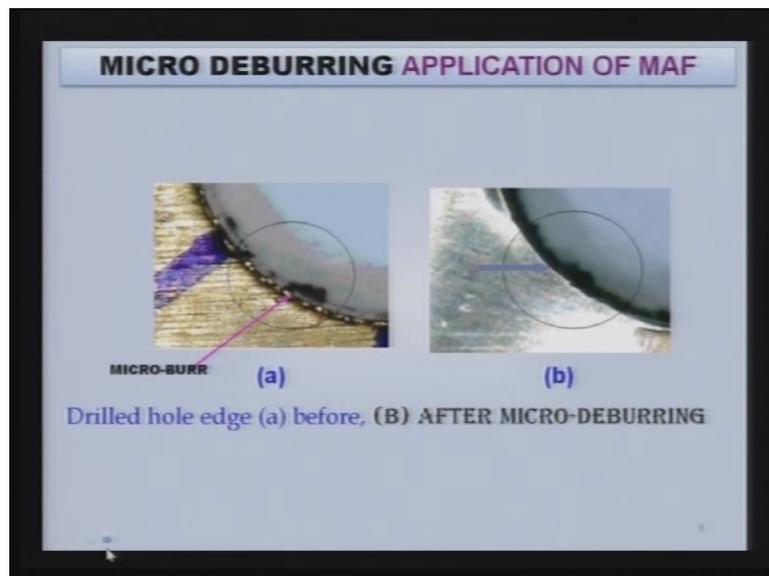
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Now these are the burrs that were obtained during verifying whole drilling and size of these are the zoomed view of the micro burrs as you can clearly see and these are discontinuous in nature. Now these micro burrs are also equally undesirable. So they should be removed before putting this part into assembly.

And you can see we have the component on the right side where these burrs have been deleted or rather removed or they have been deburred using an another process that is known as magnetic abrasive finishing. That is MAF process.

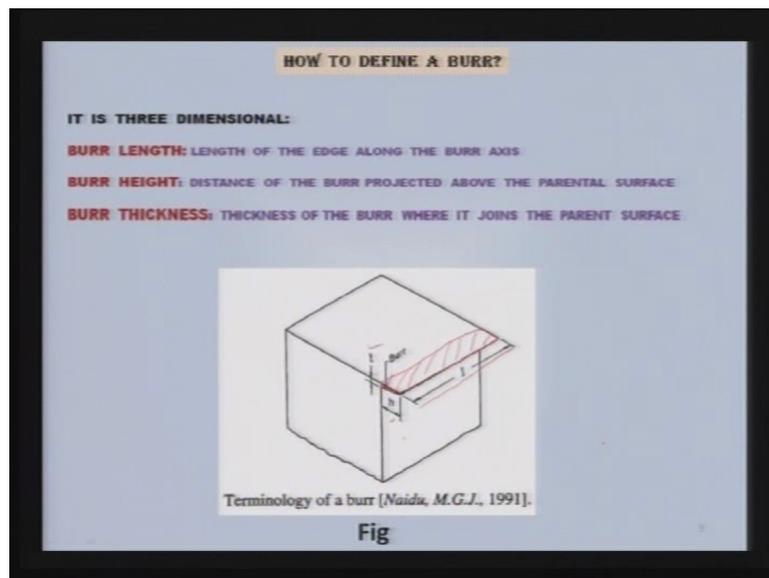
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Now the question is how to define the burr? Before deburring a component we should know the characteristics of the burr and to understand the characteristics of the burr we should be able to define the burr. Now here if you see the figure that is shown over here, it has three dimensional burr and the burrs are always three dimensional. They have the length of the edge along the burr axis as you can see here.

This is the length of the edge along the burr axis and you have burr height that is represented by h that you can see here. And I am just going to mark this red color this burr over here. You can see this is the burr if you see from the top side and this has the thickness also. Thickness is non uniform and it is shown by the symbol t as you can see here, this is t . So it has all the three dimensional length, height, as well as thickness.

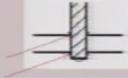
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Now once we know these three characteristics or three dimensions of the burr then only we can decide which is the most appropriate deburring method? So let us see what are the different kind of the burrs that are obtained during different kind of manufacturing operations? Now if you see the figure here the first one that is shown here compressive burr and this is the picture which is shown there with the arrow, the enlarged or the projected portion.

If you see this and if you draw this horizontal line then this part will form the burr and this should be removed. The produced in blanking and piercing operations in which slug separates from the parent material under compressive stresses. Compressive stresses are this is the punch which is going to blank it or pierce it and this is the part to be thrown out, not useful.

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TYPES OF BURR	FIGURE OF THE BURR	REMARKS
Compressive burr		The burr produced in blanking and piercing operations in which slug separates from the parent material under Compressive stress.
Cutting off burr		A projection of material left when the workpiece falls from the stock.
Corner burr		Intersection of three or more surface.
Edge burr		Intersection of two surface.
Entrance burr Exit burr		Cutting tool enters in the workpiece. Cutting tool exits in the workpiece.

Now cutting off burr. Now when we are cutting off the part you can see a projection of the material left and the workpiece falls from the stock and this is the kind of the burr you are going to get. Corner burr, now you can see here on the edges. This is the burr that you are getting on the component. It is on the intersection of three or more surfaces. You can see here the burrs on different intersection or different surfaces. Edge burr, now this is the edge burr and intersection of two surfaces you are getting the edge burr.

And entrance and exit burr as I showed in the earlier (trans) slides that when you are drilling a hole you get the burr at the entry side of the hole and you get the burr on the exit side of the hole. Cutting tool enters in the workpiece that gives you the entry burr and cutting tool exits in the workpiece that give you the exit burr as shown over here.

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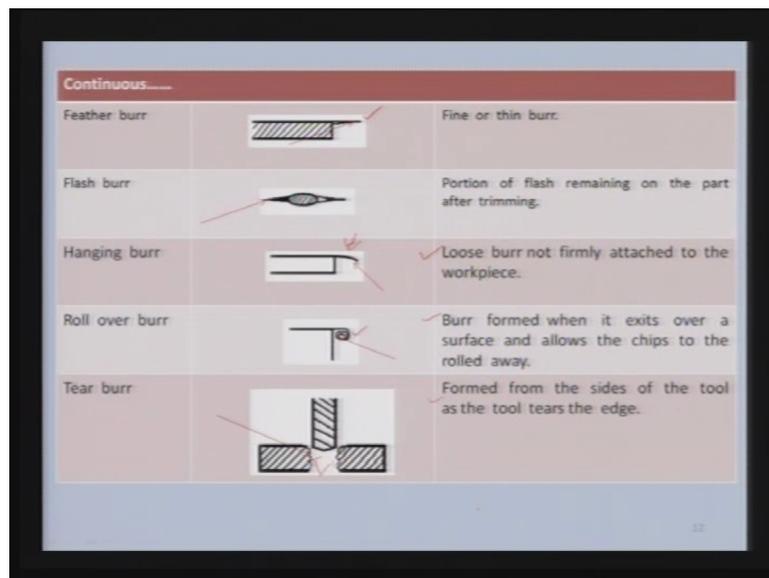
TYPES OF BURR	FIGURE OF THE BURR	REMARKS
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Source: Advanced Machining Processes By V.K.Jain, 2002, Allied Publishers, New Delhi

Here you see feather burr which is very clearly shown over here. Fine or thin burr is there. Flash burr, now portion of flash remaining on the part after trimming. So these burrs or this flash portion should be removed before putting it into assembly. Then there is a hanging burr, loose burr not firmly attached to the workpiece. A little force on this one will separate out the burr portion from the parent material or the workpiece. Roll over the burr, you can see a special shape of the rollover burr.

Burr formed when it exits over a surface and allows the chips to be rolled away and that is why it is known as roll over burr. And tear burr you can see formed from the sides of the cut as the tool tears the edges. You can see the irregular edges over here in there something like the burr and they should be straightened and smoothed before really putting this part into assembly purposes.

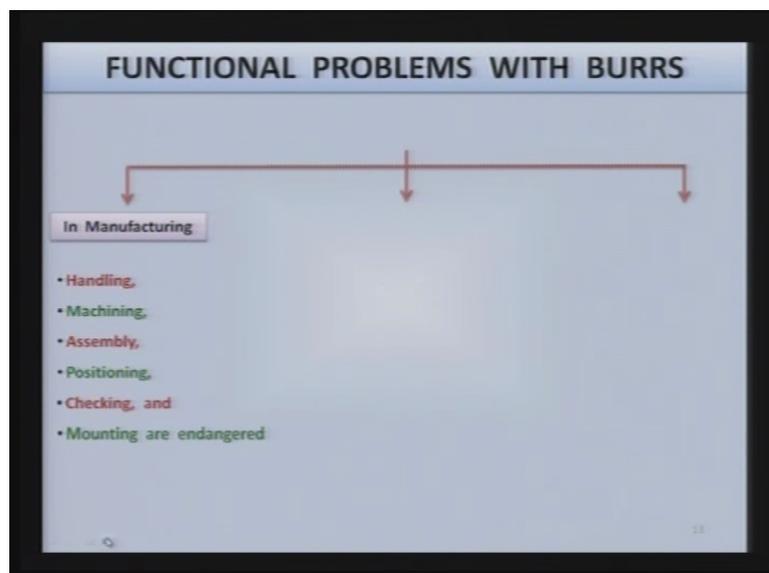
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Now functional problems with the burrs. Now definitely these burrs are hindrance in proper performance of the part. There are functional problems. You can have it while you are manufacturing and the parts with this burrs handling becomes difficult. Machining also becomes difficult. Then when you are assembling they may not assemble properly because in between the two assembling parts or matching parts, this burr will come into picture and this will not allow you to apply proper force or it will damage one of the two parts.

Positioning also becomes difficult because of the presence of the burrs. Checking or inspection and mounting are endangered when the burrs are present in the machined or the formed parts.

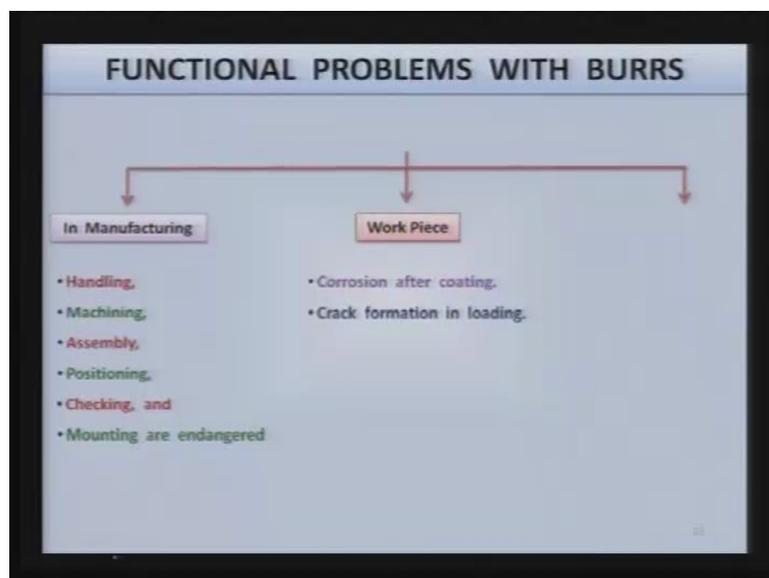
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Workpiece, now a burr are left and you have put the part into assembly then what will happen that after some time corrosion will take place on the part and even if you have applied the coating, the coating will peel off from the part wherever you have the burr. So corrosion is prone on the part where you have the burrs left. Crack formation in loading and whenever you apply the load burrs are sharp edges and large amount of pressure will react in on the burrs compared to the rest of the part.

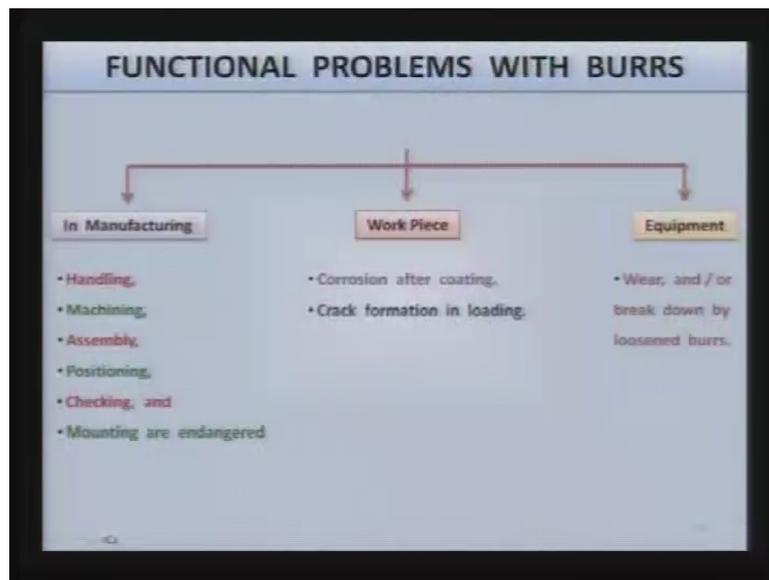
And when larger pressure is acting then will penetrate inside the component and a crack may develop during the loading of the part. And once the crack develop then it may propagate and fail a component.

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Wear and or breakdown by loosened burrs may take place. Breakdown of the component or breakdown of the system itself may take place. Even if one component fails the whole system may stop functioning. So it concludes from functional problems point of view that the component should be properly deburred before really it is used or it is put to the assembly.

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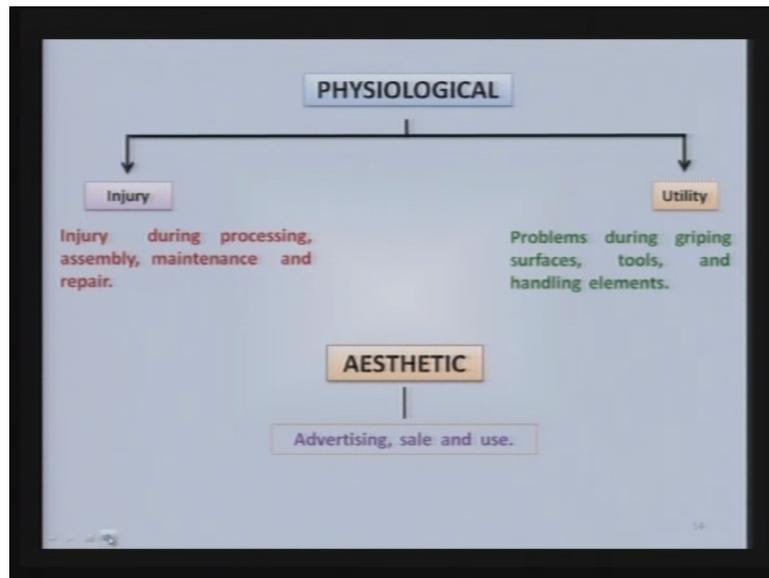


Now there are some physiological problems also. It is not only functional. Injury may take place during the presence of the burrs if you are by mistake knowingly or unknowingly you are touching it and fine burr is there then bleeding from your finger or thumb or some part of the body may start taking place. So injury during processing, assembly, maintenance and repair of the component with the burr may take place.

Then if we go to utility, problems during gripping surfaces is there because burrs are there so you will not be able to grip it properly even if you are gripping it with the help of the robot. It will not be very proper because of the presence of the burrs. Gripping of the tool and handling elements also becomes a problem. Now there are certain aesthetic aspects also. When you have the component with the burrs it always looks ugly although it may be performing functions properly but it will not look good.

So there are the problems in advertisement of such components or such products, in selling these products and in using these products which are not properly deburred. So it really forces you to do the deburring before putting these components into the use.

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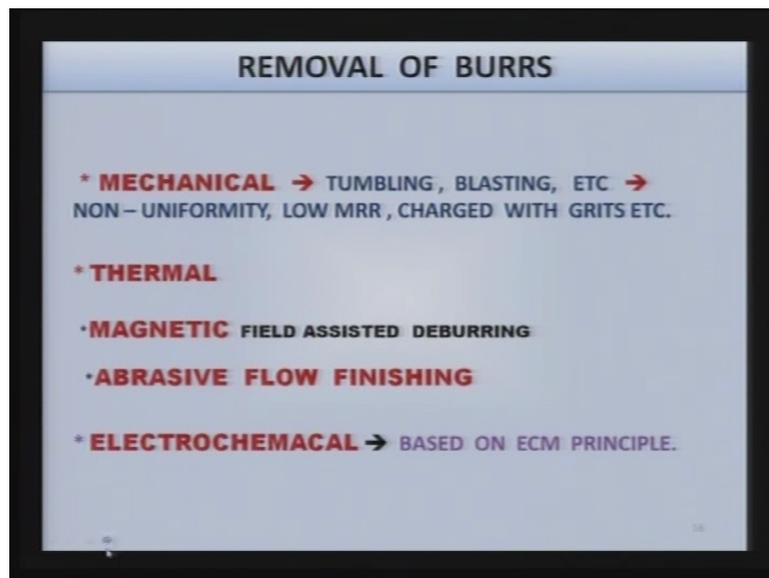


So deburring becomes an important operation of any manufacturing activity if the components are finally left with the burrs. Then there are various methods or various types of the methods which are used for deburring purposes. First category includes mechanical type of the methods. I am not going to discuss them in detail. I am basically going to concentrate in this lecture on electrochemical deburring but I will just mention the names of different types of the deburring methods.

Mechanical during methods include tumbling, blasting, etc. However mechanical methods after deburring do not give the component with uniformity. So you have non uniformity or non-uniform removal of the burrs. rate of the removal of the burrs is low and they may be charged with the grits if the workpiece material is soft. So that will add additional problems for removing these grits from the components. There are thermal methods which are quite effective but very expensive.

They are magnetic methods. One of them I mentioned earlier today itself. Magnetic field assisted deburring method that is the application of magnetic abrasive finishing process for deburring purposes. Then there is very important useful and effective method that is abrasive flow finishing where it performs the function of deburring a part from finishing operation. And then electrochemical deburring which is based on electrochemical dissolution principle which I am going to discuss in detail today.

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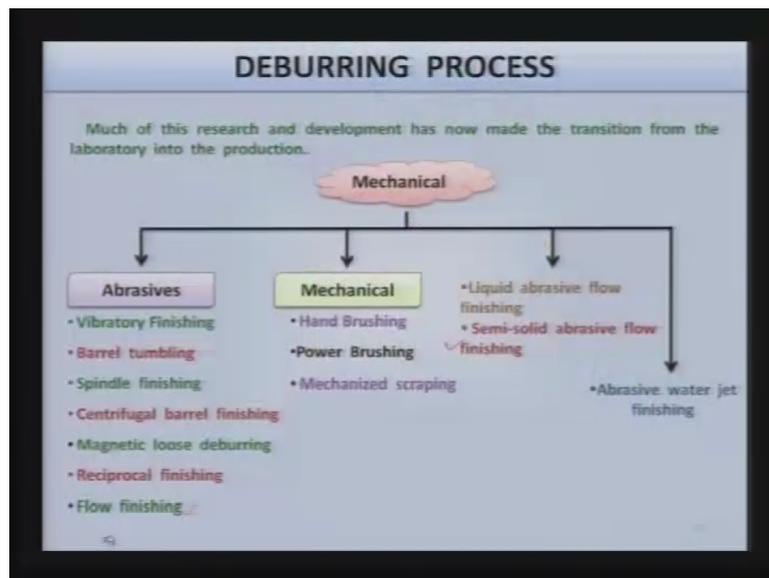


Deburring process, much of this research and development has now made the transition from the laboratory into the production and these processes are quite common in medium and large scale industries for deburring purposes. In mechanical you can have various methods where you are using abrasives for deburring purposes. You apply the mechanical force on the abrasives and these abrasives remove the burrs from the parent components.

You include them, one of them is vibratory finishing, barrel tumbling, spindle finishing, centrifugal barrel finishing, these are the components names, magnetic loose deburring, reciprocal finishing and flow finishing. Then there are other methods. Mechanical includes hand brushing, power brushing, mechanized scrapping, then liquid abrasive flow finishing, semi-solid abrasive flow finishing, this is what I had mentioned earlier also.

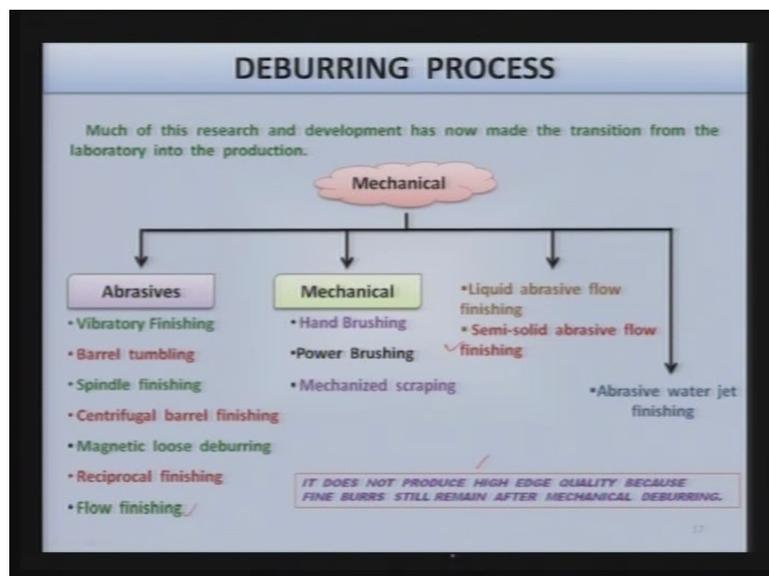
This is the same as flow finishing. In the end finally you have abrasive water jet finishing. All these methods are based on mechanical energy which you are applying for removal of the burrs that is known as deburring process.

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Now these mechanical methods including abrasives mechanical as such or liquid or semi-solid abrasive flow finishing, they have some problem. It does not produce high edge quality because fine burrs still remain after mechanical deburring. Especially in case of semi-solid abrasive flow finishing this does not hold very correctly but in other cases yes it does hold correct.

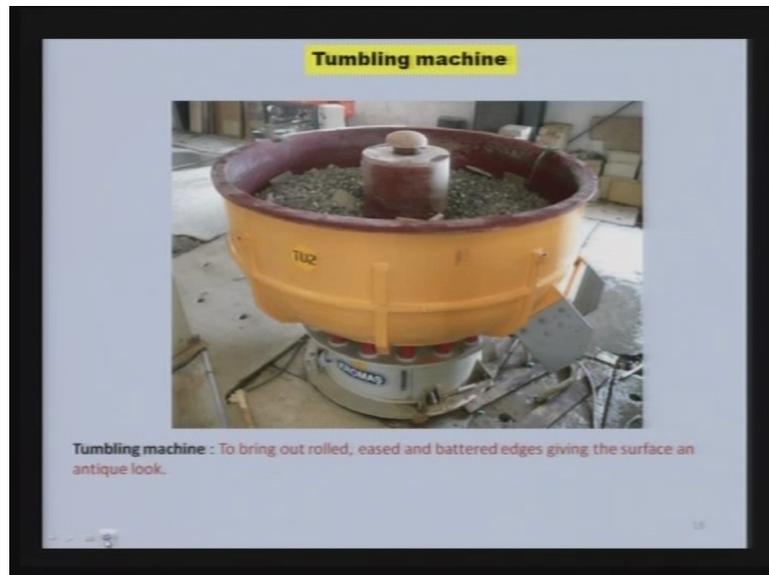
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Now tumbling you can see here. Here is the tumbler and you rotate this and you put the abrasive particles as you can see here and then put the component and rotate at high RPM. Then because of striking of these abrasive particles on the burrs they get separated out and you get deburring process performed. This is very good where do you not really look for very

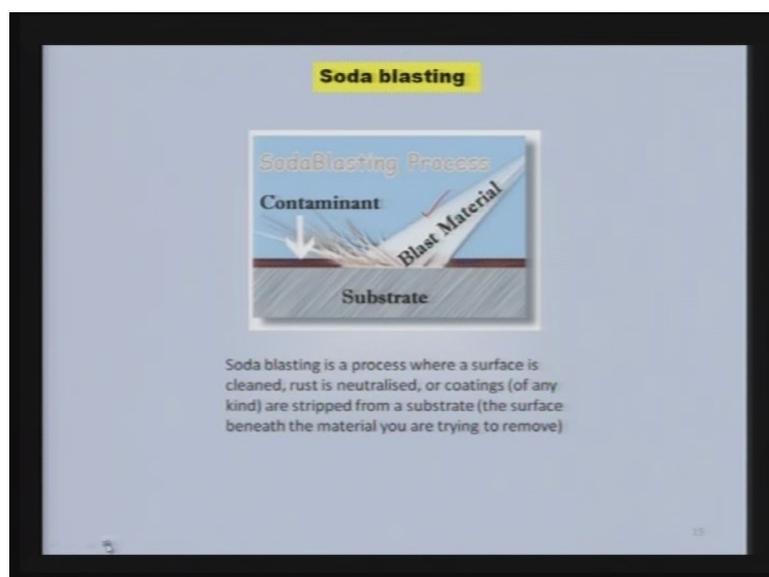
high accuracy and you do not mind even if micro burrs are left over there. Tumbling machine, to bring out the old, eased and battered edges giving the surface an antique look.

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Soda blasting, just like you can see here this is the contaminant surface where you want to clean it and you can blast a certain hard material. It can be blasting of abrasive particles just like in case of abrasive jet machining. You can use the abrasive jet machining for deburring purposes. similar kind of the thing is shown over here and you are able to remove the burrs. Soda blasting is a process where a surface is cleaned, rust is neutralized or coatings of any kind are stripped from a substrate, the surface beneath the material you are trying to remove.

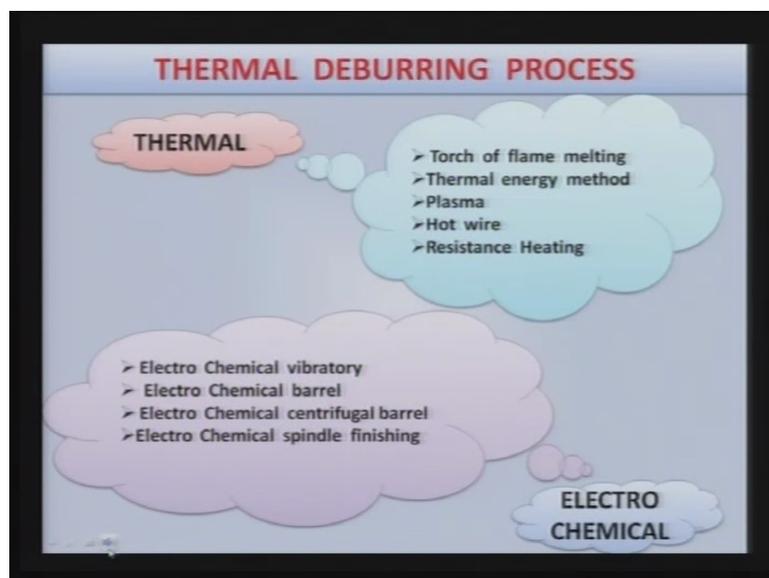
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Thermal deburring, there are various versions of thermal deburring. Torch of flame is used for melting out the burrs and then they get separated. Thermal energy method like plasma, hot wire, resistance heating, etc. can also be used for deburring purposes. Then there are electrochemical methods which we are going to discuss in detail. Electrochemical methods can be combined with vibratory, electrochemical barrel, electrochemical centrifugal barrel, electrochemical spindle finishing.

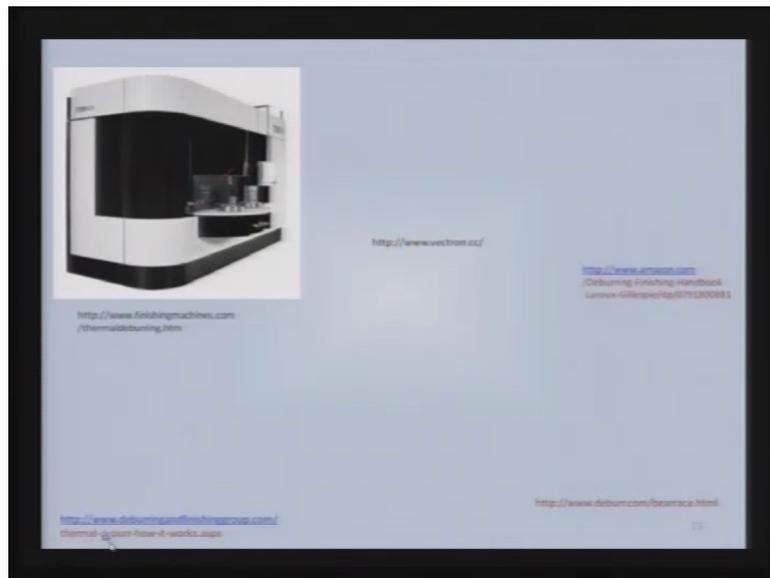
These are the various names which I have taken from some industries and they call these different versions of electrochemical deburring by these names depending upon kind of components and other details.

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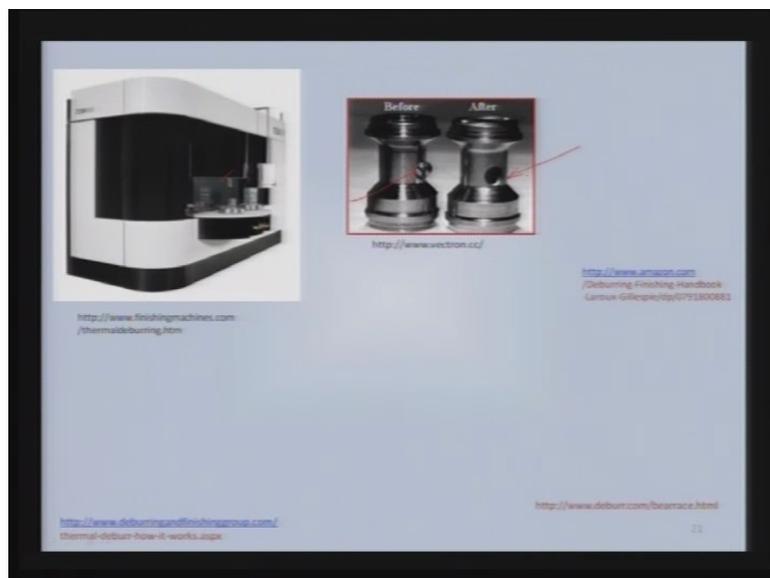
I will just show you, this is the chamber which is used for thermal deburring. Here you can see this is the chamber where you place the components to be deburred and then close the chamber and then ignite the gases. Combustible gases are filled in this chamber and you ignite them and then very high temperature reaches instantaneously and because of that high temperature, high heat content, the burrs which are very thin very small sections they get separated out from the parent material.

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Now you can see the component here. This is the component before thermal deburring and this is the component after thermal deburring and you can clearly see the difference in the quality of the component.

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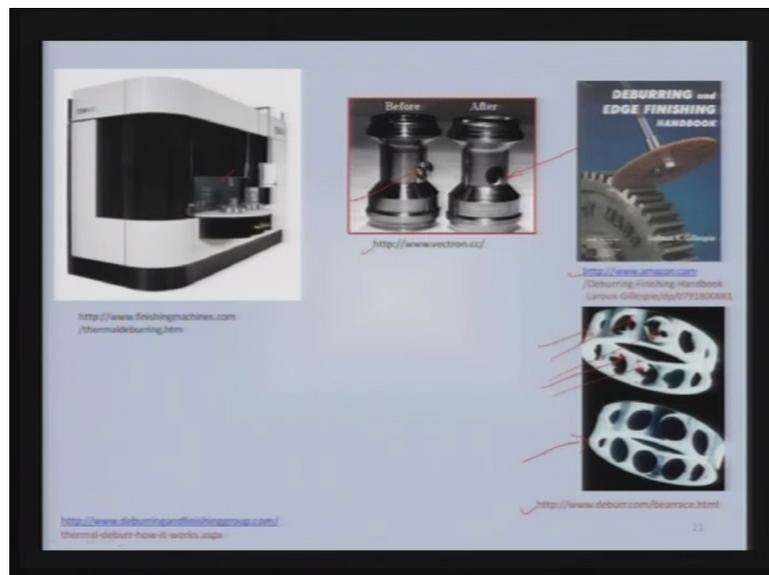
Now here it is shown deburring with the help of mechanical means. Here is something like a grinding wheel kind of the thing which is separating out the burrs or removing the burrs from each and every tooth of the gear and definitely as you can see it is going to take a lot of time. Although it may do quite well.

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Now again here you can see the component. This is before deburring. So you can easily see the burrs over there at different sections over here and this is the component after deburring and you can clearly see the difference in the quality of the component. And here are the sources from where these figures have been taken.

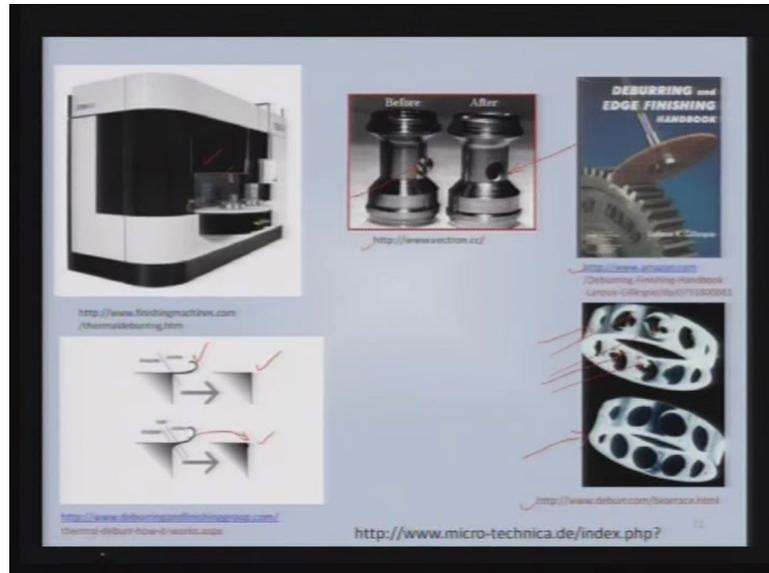
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Now you can clearly see these are the kind of the burrs when you put it in this particular (cha) chamber and these are being very small in section, very high temperature like 3000 to 4000 degree centigrade. They get separated out and you get this kind of the edge. After removal of these burrs you can see the difference in this as well as this. So this is such kind of surfaces or edges rather can be obtained after thermal deburring. This is quite effective but the initial

investment is very high and running expenses are also quite high because you are using combustible gases.

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Now how does it work more precisely? You can see here, deburring is done in the seconds with thermal deburring system and this system is available from the Rexroth Bosch. Thermal energy can quickly and easily remove cutting burrs produced by turning, as I mentioned in the beginning. You get the burrs after turning a component or after milling or broaching or grinding as well as burrs resulting from die-casting, they are also easily removed by thermal deburring process.

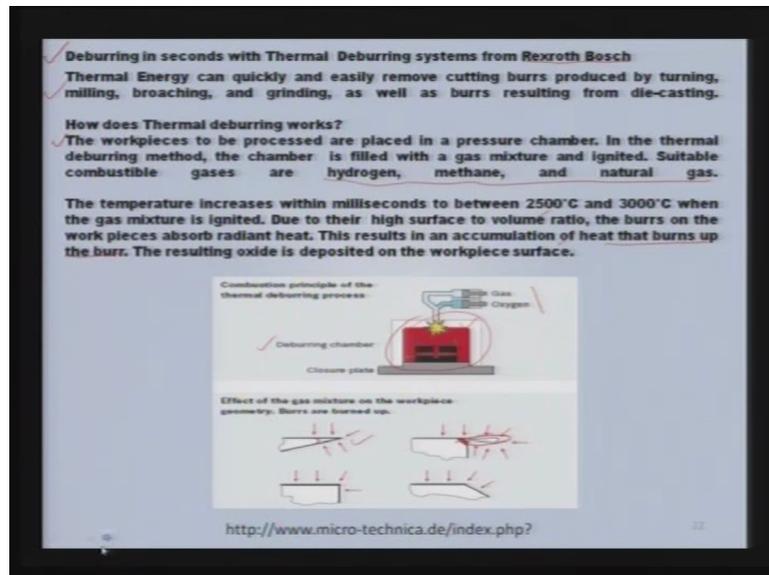
How does thermal deburring works? The working principle, pieces to be processed are placed in a pressure chamber as you can see also shown over here. In the thermal deburring method the chamber is filled with a gas mixture and then those gases are ignited by remote control. Suitable combustible gases are hydrogen, methane and other neutral gases which are filled in the chamber. The temperature increases within milliseconds between 2500 degree centigrade to 3000 degree centigrade when the gas mixture is ignited.

Due to their high surface to volume ratio the burrs on the workpiece absorb radiant heat. This results in an accumulation of heat that burns up the burr. Now so the burrs get burnt out, the resulting oxide is deposited on the workpiece surface. You can easily clean it.

So you can see here the gases are there and you are burning and this is the chamber where you place the component, you fill it with the combustible gases and this is known as deburring chamber. Now effect of gas mixture on the workpiece geometry burrs are burnt out

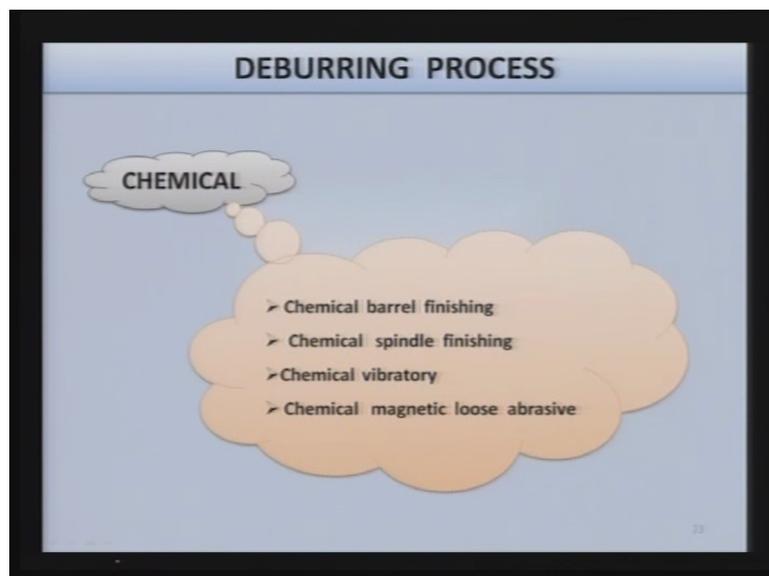
as you can see here. This is the one which will get burned out and you can get the edges like this.

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In case of chemical deburring, chemical barrel finishing, chemicals spindles finishing, chemical vibratory finishing and chemical magnetic loose abrasive finishing I mentioned earlier.

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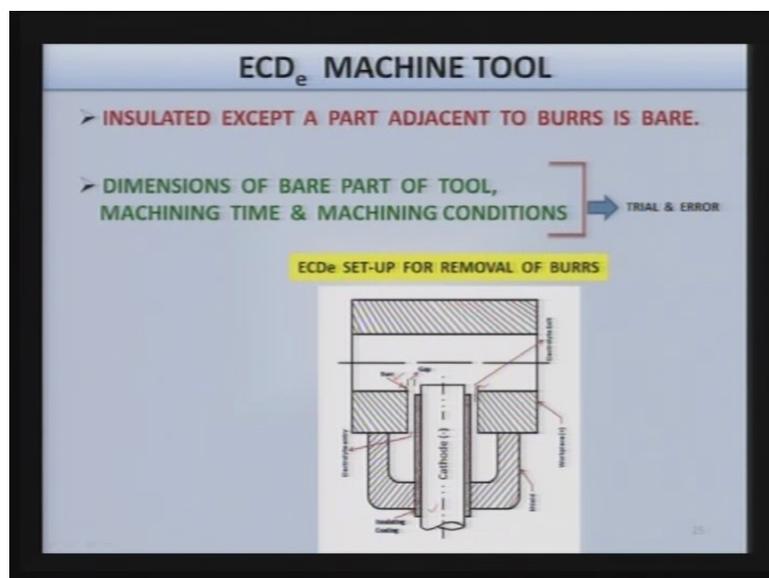


Let me see what is this working principle of electrochemical deburring? The electrochemical deburring machine tool, it has insulated part. I will show you the figure, insulated part is there except a part adjacent to the burr.

There you will see that I will show you the figure that a small part is bare, rest of the part is being insulated and from this bare part the current flows between the burr and the tool and electrolyte is flowing in between the two so that electrochemical dissolution of the burr takes place because at the burr this continuous surfaces you will have very high current density. And the first dissolution takes place of the burrs.

Dimensions of bare part of tool and machining time and machining conditions are decided by trial and error method. As you can see here clearly it shows the working principle as I just mentioned. See this is the burr as shown over here and this is the burr on the other side and this is the tool. Whole of this part is insulated.

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Now only this is the bare part when you supply make it the cathode as shown over here and this is made as anode. So what happens that here you have the electrolyte in this portion so the current starts flowing in this direction. And since high current density is there on the burrs, the burrs get dissolved in a couple of seconds or even less than a second sometimes and you get a very fine surface like this without any burr.

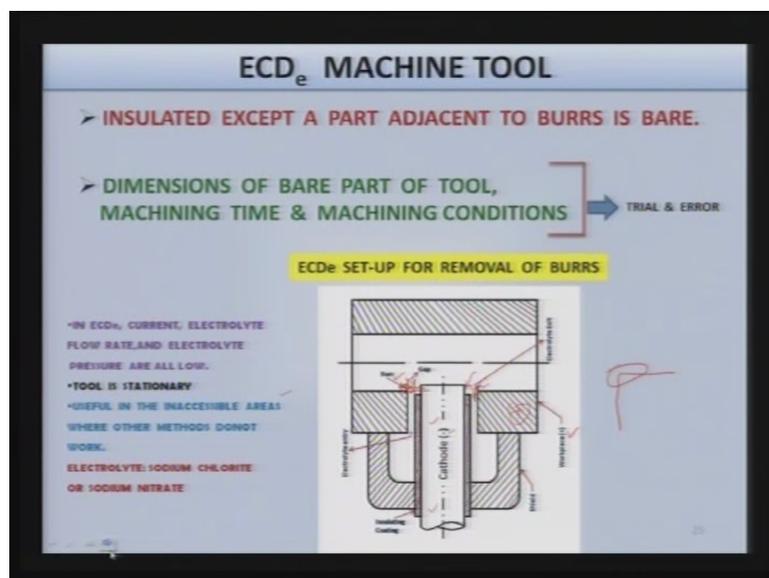
The burr has been removed from here and you can clearly see this is the workpiece which has been made as anode and this is the tool as the cathode and electrolyte is flowing through the gap like this and this is the gap between the burr and the tool and that decides the magnitude of the current to flow.

In electrochemical deburring current, electrolyte flow rate and electrolyte pressure are all low as compared to electrochemical machining because the amount of material that you are

removing is just a burr which has very small magnitude of material, very small amount of material. Tool is stationary as you can see there is no feed given to the tool and it is a matter of couple of seconds or less than couple of second. It is useful in inaccessible areas. Now this area where we have shown over here in inaccessible.

You cannot do the deburring mechanically so easily. You cannot use the tumbling method so easily. Even the thermal method may be difficult. So in such cases electrochemical deburring is the best method and it is useful in inaccessible areas where other methods do not work. Electrolyte normally use maybe sodium chloride NaCl or sodium nitrate depending upon the material properties or workpiece material properties.

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This electrochemical deburring machine tool consists various part system or subsystem, electrolyte supply system. Some of the things I have already discussed while I was discussing the electrochemical machining process. Here high velocity electrolyte flow takes place but definitely the electrolyte flow velocity is much lower than what you get in case of electrochemical machining. Then electrical power supply, again the current is smaller or rather much smaller as compared to electrochemical machining.

Mechanical structure for workpiece and tool mounting, you have to have the workpiece mounting, you have to have the tool mounting. So you need full mechanical structure just like ECM machine. You also have electrochemical deburring machine then you have to have sludge separator because electrochemical dissolution is taking place. So sludge is formed and

sludge should be separated out, the electrolyte should be properly filtered out before really it is recirculated.

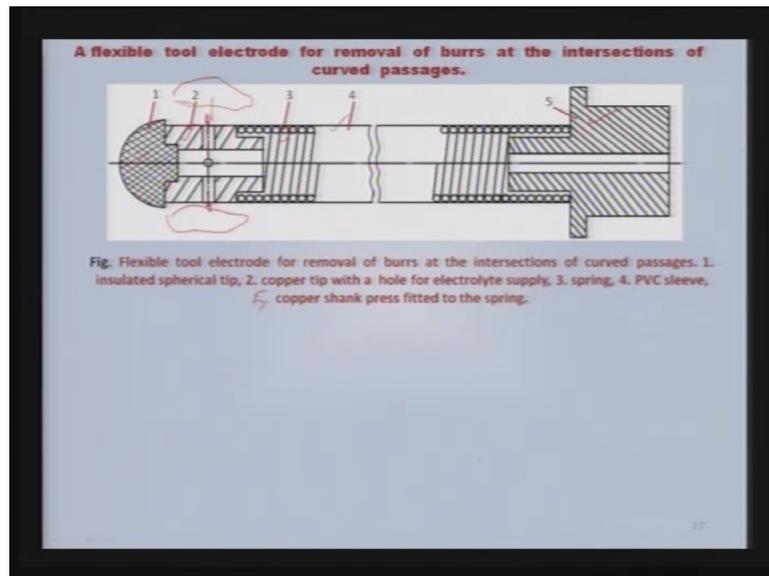
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A flexible tool electrode for removal of burrs at the intersection of curved passages. This is also important because as I mentioned that inaccessible areas are easily deburred as compared to other methods by this particular process. So let us see this is the kind of the tool, flexible tool electrode for removal of burrs at the intersection of curved passages. Here 1 is the insulated spherical tip and 2 is the copper tip with a hole for electrolyte supply. This is the one which is going to really remove the burr.

And you can see here the electrolyte supply is there and you will get the electrolyte supply all around so that there is the electrolyte between the tool and the workpiece gap. Then 3 is the spring and 4 is the PVC sleeve that is the electrically non-conducting material. So that current will be flowing only through this particular part and there has to be the part to be deburred somewhere here or somewhere here. And copper shank press fitted to the spring that is the number 5 over here. That is this one.

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Now for various types of the material you can use various kind of the electrolyte like carbon and low carbon steel. You can go for 5 to 15 percent sodium nitrate and 2 to 5 percent sodium nitrite. Copper alloys, 5 to 15 percent sodium nitrate. Aluminium alloys, 5 to 15 percent sodium nitrate and stainless steel you can go 5 percent sodium nitrate or plus NaCl.

So you can see here the electrolyte concentration is also comparatively low as compared to the cases of electrochemical machining. The applied voltage is in the same range as in case of ECM. Current density is also quite high and deburring time is much smaller as compared to the ECM process.

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A flexible tool electrode for removal of burrs at the intersections of curved passages.

Fig. Flexible tool electrode for removal of burrs at the intersections of curved passages. 1. Insulated spherical tip, 2. copper tip with a hole for electrolyte supply, 3. spring, 4. PVC sleeve, 5. copper shank press fitted to the spring.

MATERIAL	ELECTROLYTE	APPLIED VOLTAGE	CURRENT DENSITY	DEBURRING TIME
Carbon and low carbon steel	5 - 15 % NaNO_3 + 2 - 5 % NaNO_2	12 - 24 V	5 - 10 A / Cm^2	5 - 100 s
Copper alloys				
Aluminium alloys	5 - 15 % NaNO_3			
Stainless steel	5 % NaNO_3			
	+ NaCl			

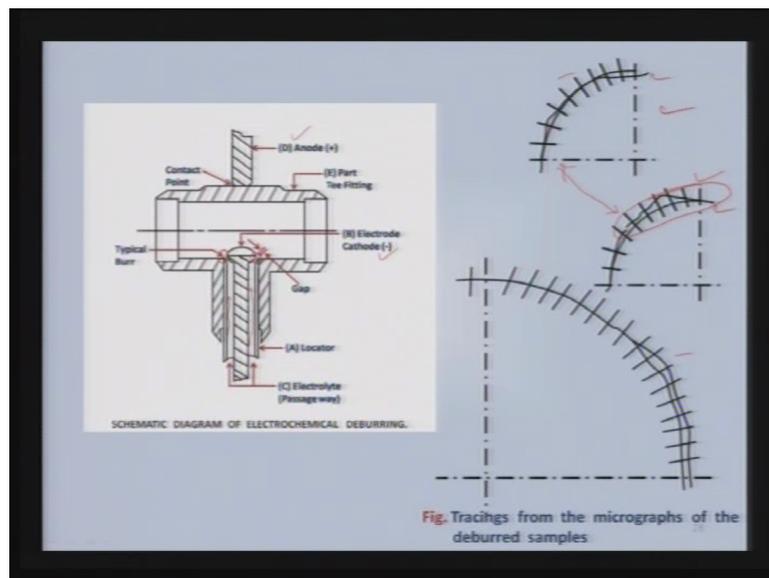
So let us say this is the another component which can be electrochemically deburred. It is not easily accessible also as we can see here that this is the burr and this is the burr. You cannot remove these burrs easily. So you have the tool and electrolyte is flowing all the way through this one as well as this one in here is the gap where gap is shown there. The gap between the burr and the bare part of the tool. And the current will flow and this will quickly dissolve the burrs from there and it will take only few seconds.

And this component has been made as anode as you can see here and the tool has been made as cathode that is shown over there. And there are locators and other things so that the tool is fixed at the right position for deburring purposes. If you see on the right side, these are the shapes of the edges obtained before deburring and after deburring and you can clearly distinguish the difference between before deburring. This is before deburring and this is after deburring.

And this is the enlarged view and for other kind of the edge and you can clearly see the difference between the deburred. Tracing from micrographs of the deburred samples as you can see here. Here this also maybe the deburred one. But the burr left or non-uniformity is more compared to this part as well as this part. But in some cases it can be treated as a micro burr.

Then this burr should be removed either by abrasive flow finishing process or magnetic abrasive finishing. So you can treat it as a micro burr even after electrochemical deburring. All this will depend upon how you select the tool? How select the time of deburring? And how you select the type of the electrolyte?

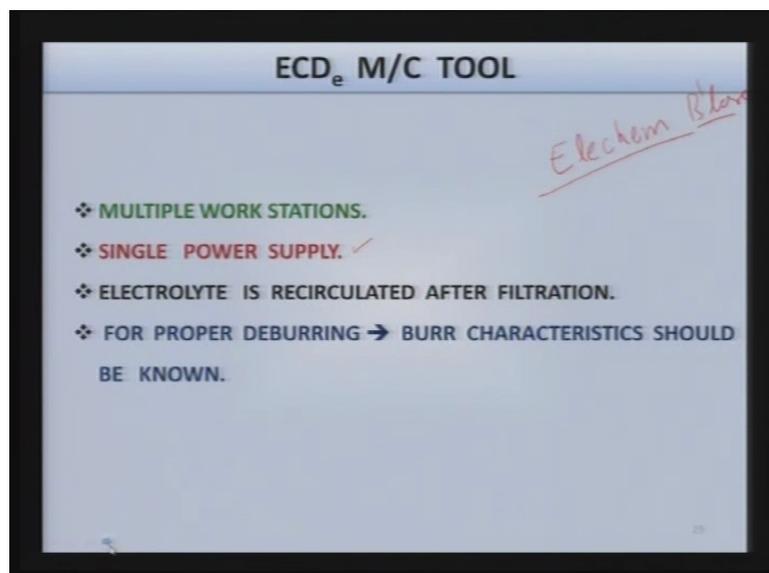
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Now in case of electrochemical deburring machine tools, in place of one component you can deburr many component at a time. This will help in increasing the productivity and same power supply and same electrolyte flow system can be used even for deburring many components at a time. And there is a company called EleChem in India and this is in Bangalore and this makes such kind of electrochemical deburring machines where many components can be deburred at a time.

You use a single power supply, electrolyte is recirculated after filtration, removal of the sludge, etc. For property deburring, burr characteristics should be known and I have already mentioned to you various features or various characteristics of the burrs.

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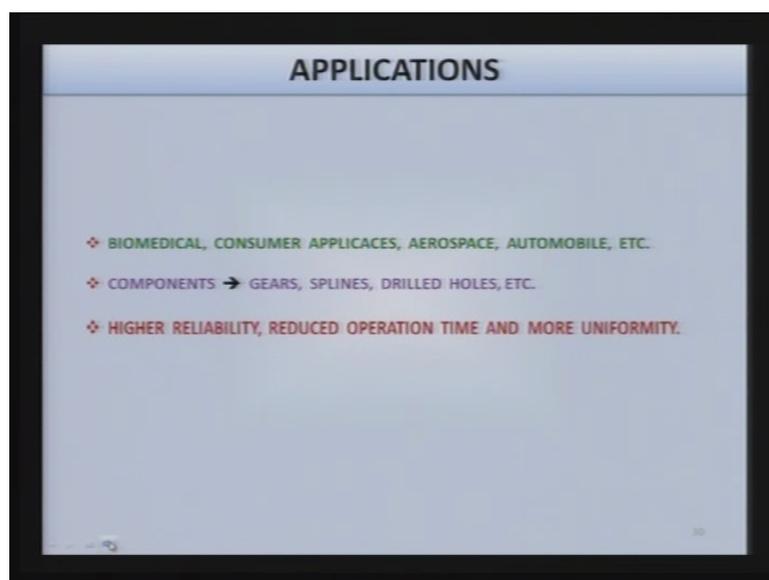


Now there are various applications of deburring processes. It is very important in biomedical component. Even a micro burr will make the component to fail. In case of biomedical application if that burr is left, it may start bleeding from the organs or the body of the human being and that will create a problem.

Now consumer appliances are again the components or the products where burrs cannot be tolerated because it will injure or hurt the users of those appliances and definitely they will not like such components which create these kind of the problem. Then there are aerospace components, automobile components, etc. where really deburring is very important.

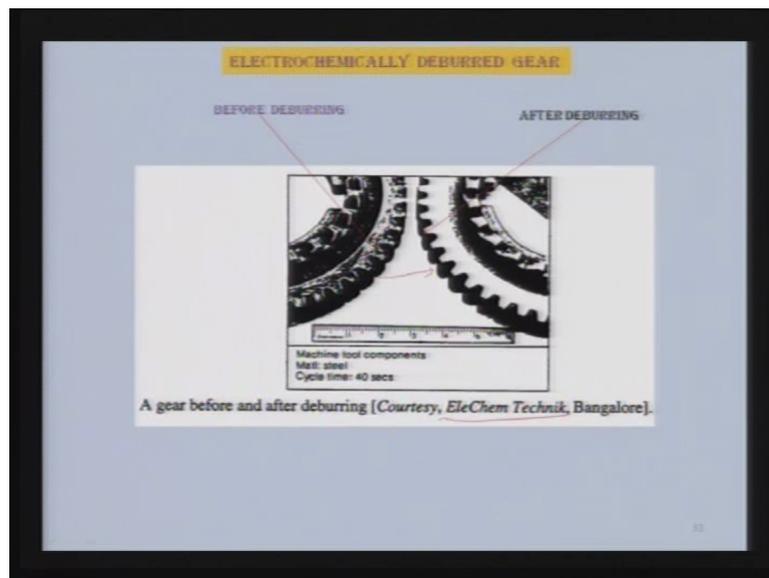
Like gears, components where deburring is done is gears, splines, drilled holes, etc. I have already shown some of the examples to you for deburring purposes. Now if component is deburred, it will have higher reliability, reduced operation time and more uniformity in the performance.

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You can clearly see the example here. This is the gear made on the gear making machine. This on the left side and you can see the kind of the burrs left over there and it is a common feature. Now after electrochemical deburring it was done with the help of the EleChem Technik Machine, Bangalore. You can clearly see the difference between the deburred component and the component which is having the burrs. So this clearly indicates the very useful application of the deburring process.

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From this talk we can conclude that electrochemical deburring is an accurate and comparatively fast deburring process and this is also less expensive as compared to many applications. Thank you very much.