Introduction to Mechanical Micro Machining
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Lecture - 21
Difference between macro and micro machining (Contd.)

Good morning everybody and let us discuss about this ongoing topic on the surface roughness. So, we started the topic in the last class and we have seen that different-different components available and there are many different instruments also available.

So, we have to select some components depending on the what is the requirement of that particular components which we are machine from the work piece and then we have seen that different machine instruments are available which can be use for measurement of the surface roughness and we also found that non contact type and the atomic force microscopy based instruments are good for the measurement of surface roughness of the micro components. So, let us go further on these things.

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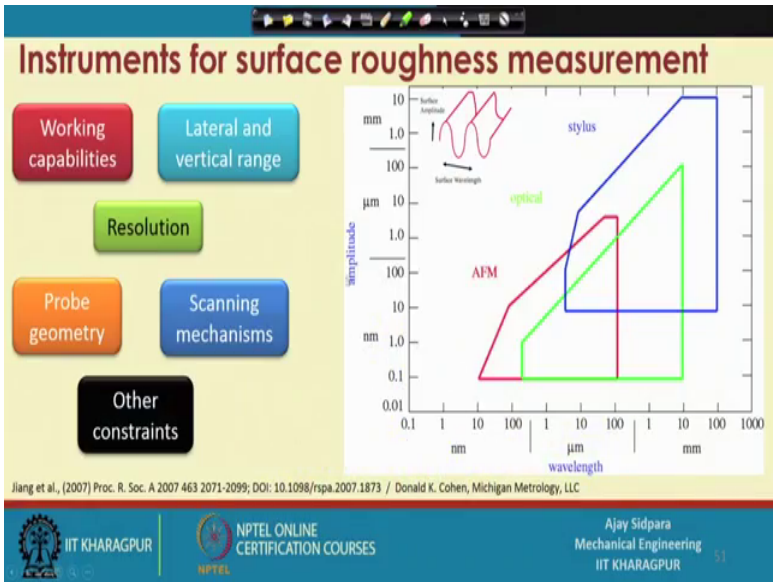

So, we have seen this particular slide in the last class and these are the different properties or the specification of the instruments.

So, depending on your requirement you have to select this particular specification and then select the instruments which we are going to use.

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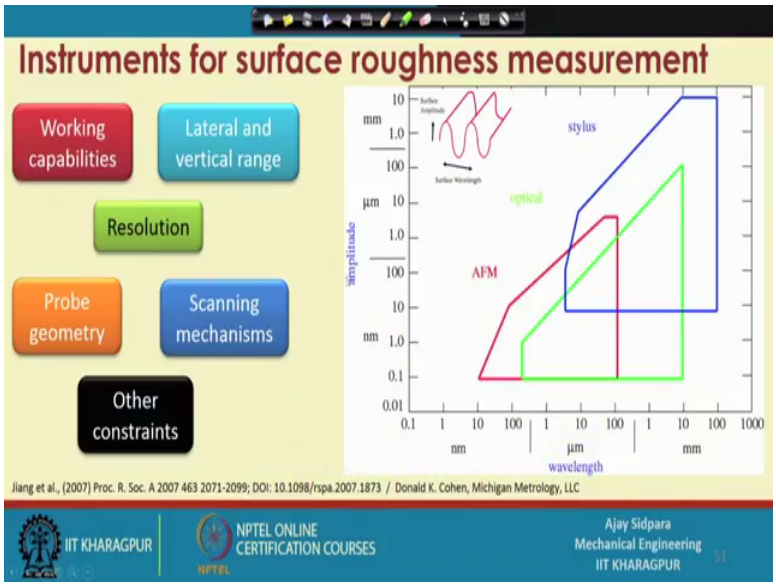

So, what things are there in the surface roughness the surface roughness damage is mostly done by the forces because if you see this particular figure here what is going to happen. So, here you are getting burr. So, these are the burr formation. So, this are the burr formation here this are the burr formation and this is the surface.

So, if you see this surface this surface you are actually getting some type of machine mark. So, this are the milling cutting mark and whatever the spacing is there that spacing will create a problem at the later stage what we need that we do not need those types of marks and we do not any type of project inverter.

So, this is the vertical hole. So, this is the vertical hole and this is the bottom surface this is the old surface and this is; what is the component of the un-machine surface side surface. So, in this way one is the forces if the forces are very very high or the fluctuating force is then you will get a different-different pattern and there is a burr formation also and there is a surface roughness increase also

Another thing is the vibration because if your force is your burr piece is not clamped properly or your tool is not clamped properly on the spindles spindle tool spindle at that time you are getting vibration and if your machining a some type of heterogeneous material then again there is the vibration in the machine.

So, this vibration also creates surface roughness very very high plastic deformation also creates a problem because what is going to happen that your material will be if you are machining a brittle material your roughness will be mostly sometimes very very smooth, but in machining of a ducktail material like a aluminum it is very difficult to maintain or getting a good surface finish and burr formation is; obviously, related to the surface higher the burr formation higher is the roughness. So, this both things are coupled with each other.

So, higher surface roughness are mostly due to elastic recovery because when you are cutting a material we have seen in that lecture where we have seen that what is the condition when you are machining with a low depth of cut, but the high cutting edge radius. So, at that can mostly it is elastic recovery your tool will pass through the surface without removing any material.

So, that is the problem with a high roughness elastic recovery is depending on the size of the cutting edge radius and the work piece material because we have seen that a you have to continuously monitor the status of the cutting edge radius with respect to the uncut chip thickness or the depth of cut materials also play important because the soft materials have the high elastic recovery compared to the brittle material large elastic. That is mostly when you are cutting edge radius is very very large at that time it will create a problem because it will just pass through the surface and you will not get any type of further improvement, right.

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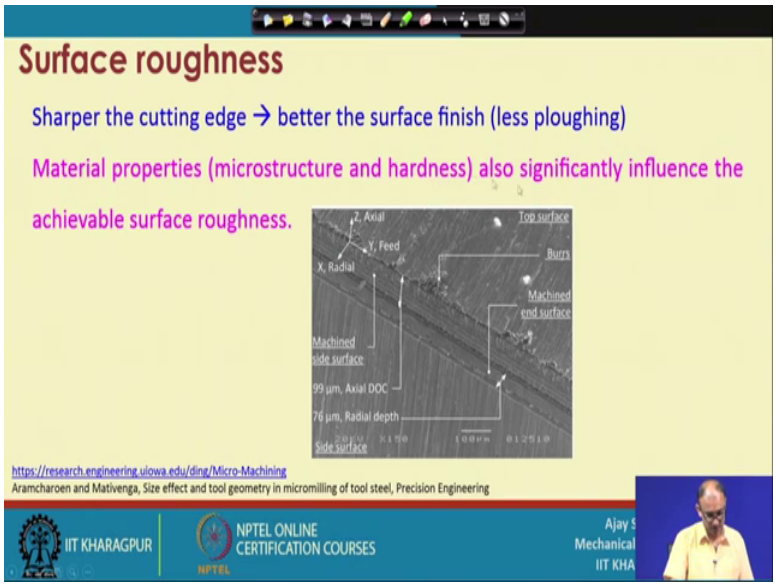

So, what is the general scenario the sharper the cutting edge is the better is the surface finish, right? So, because we want to avoid the flowing action if your surface or cutting edge is very very dull at that time we know that it is not maintaining its value with respect to the uncut chip thickness and because of that you can end up with rubbing and flowing type of mechanism and you are not getting the better surface finish in this case.

So, we have to maintain this sharpness of the cutting edge for a longer time. So, there are many where there are if you state a process parameter very very efficiently or optimize then you will retain those things there is the coating also available you can use cooling coolant also these are the different ways you can maintain that part. So, material properties microstructure and hardness that we have seen that if it is a soft material then your surface roughness is high and if it is a brittle material than you can get a good surface finish.

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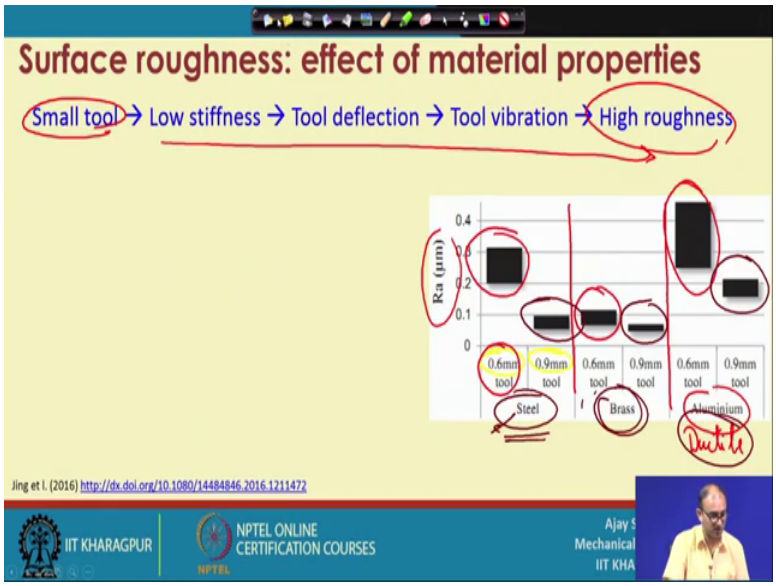

Then what is a material property that for a small tool; what is a problem that its stiffness is very very small; and the tool deflection is very very high; because when you are cutting a material; then you are end up with the high vibration and finally the high roughness. So, this is the problem with the small cutting tool if you use the bigger cutting tool what we are using in the micro machining at that time your stiffness is not a problem because material has a very large amount of volume available. So, which will make sure that it will not deflect to a certain level and you are not getting a vibration in them and this is the thing in terms of the surface roughness.

Now here what is the important is that there is a two different tools one is the 600 microns one there is a nine hundred microns and there are 3 different cutting tool materials that work piece material. So, this is the things. So, if you see these particular things 600 microns if you see this is the 600 micron; 600 micron for machining of brass and 600 micron for machining of a aluminum.

Now if you see that aluminum is a very very ductile material. So, its roughness is also very very high in this case and another thing that smaller the tool higher is the roughness because we know that the smaller the tool what is going happen that because of this sequence of this particular event you are getting a high surface roughness other than that we also know there are smaller the tool your means consistency with respect to the uncut chipness that is the relationship between these 2 are more and more tight. So, you to also

maintain this particular relation if you are going to a use very very small cutting tool so that is the reason that you can see that with a 600 microns all the region is giving or region are giving more surface roughness, but when you are going with a bigger size cutting tool and keeping all the perimeter constant, then you are end up with a small surface finish or the small small surface roughness

So, in this case you can see the brass is giving much better result compared to the other two materials because in the steel material removed because we know the harder the tool our tool wear is also very very high. So, it is not only case of material ducktail material, but we also see. So, in the brass is something in between these 2.

So, you are actually optimizing with respect to material that going to with a hard material your tool wear very very high at the end your material surface roughness is very high compared to brass compared to aluminum; aluminum is soft material. So, your tool wear is not a problem, but the cheap clogging is problem then the material removal is also problem you have a elastic recovery. So, those things play important role in the surface generation mechanism. So, this is diagram; what it is showing right.

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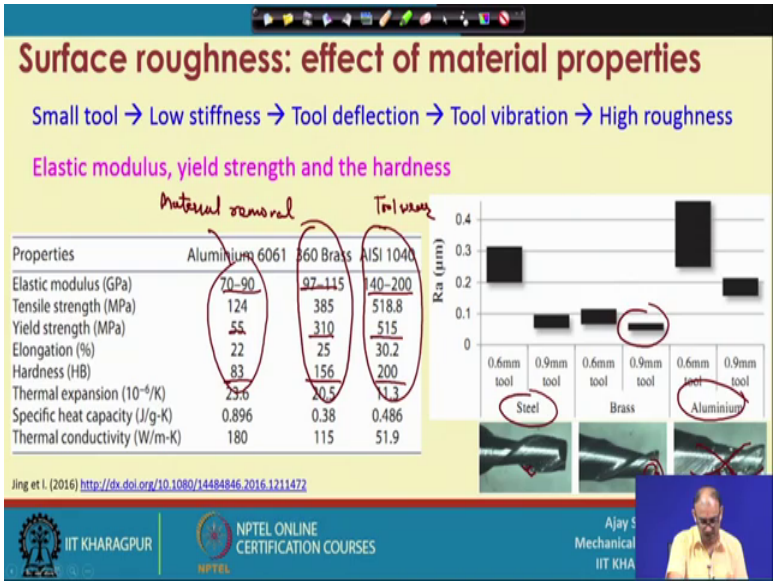

So, this is; what is the chip. So, now, if you see the condition on the cutting tool now when you cut a steel material you can see that there is no chip clogging on the flute of this cutting tool, but if you see aluminum there are many chips which are actually stick to the surface and these particular chips are creating the problem. So, now, if you use this

cutter these cutter will chip will not get the flow or the paces through which it come out of the socket or come out of this particular pocket which is going to cut in this.

And this is in between these two because if here you see very small amount of material is loaded in the flute, but this material may be removed if you rotate at a very very high appear, but nothing is here, but the tool wear may be very high in this compared to the other two material. So, this is the condition of the cutting tool after machining of 3 different type of work piece material right. So, these are the properties of these particular materials.

So, now, if you see in this elastic modulus is important yield strength is important and hardness is important if you see this particular material. So, this are the 3 particular things and then this is the hardness is here and this is the yield strength is here correct. So, depending on if it is very very low it is also a problem. If it is very very high also it is a problem in between it is giving a optimize region.

So, here the tool wear is a problem and here it is the material removal is a problem correct. So, this way because any way you have to cut the aluminum, but you have to finalize the process parameter in a such a way that you are not end up way, you use some type of mist coolant and you aid some type of a projector with a high pressure high pressure. So, that it will remove these things very easily right.

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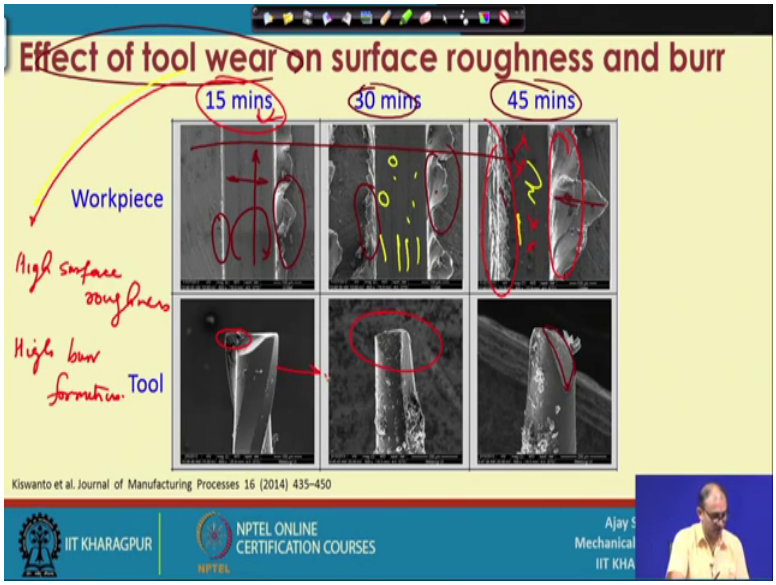

So, here it is a tool wear. So, now, if you see this particular thing; so, this is the tool condition after 15 minutes of use and this is after 30 minutes and after forty five minutes now if you see this is mostly the rotation in these direction of cutting tool and then it is moving in this direction.

So, now this is the up milling side and this is the down milling side you can consider; you can see that in earlier case also, we have seen that two chip formation; that means, burr formation on the down milling is high compared to the up milling. So, this is the condition after 15 minutes and after 30 minutes, what is going to happen? There, your cutting tool also getting worn and because of that you are end up with getting more and more top burrs on the both the surface. Now size of burrs on the bottom is down milling is high and you also getting burr in the up milling side. If you future increase that particular cutting tool for a operation, then you can see that there is a large amount of wear of the cutting tool and the size of the burr also very very large in both the cases.

So, now, you can see that by tool where you are getting worst and worst condition of the workpiece material. So, now, for a getting a surface finishing also important because here the surface if you see here in this location the surface is very very fine and now here you are getting some type of problems here. These are the residual material which are staying here and then you are getting marks also there this are the marks and then you are ending with this worn tool farther using this worn tool farther then you are roughness is also very very high correct. So, we are getting both the things there the higher the tool wear high surface roughness and the high burr formation.

So, you have to estimate the tool wear that is very very important in this particular case because if you could not look into tool wear and continuing the machining your work piece will not be acceptable at the end and sometimes what happen that here deburring operation very very conveniently, but here deburring is also very very difficult because size of the burr is.

So, high that you have to use some aggressive deburring operation and that aggressive deburring operation will actually create a problem here this finish surface also or at the machine surface also. So, it is better to limit the use of the cutting tool within a short period or you do some type of coating and use coolant. So, you can increase this particular life to a certain further duration.

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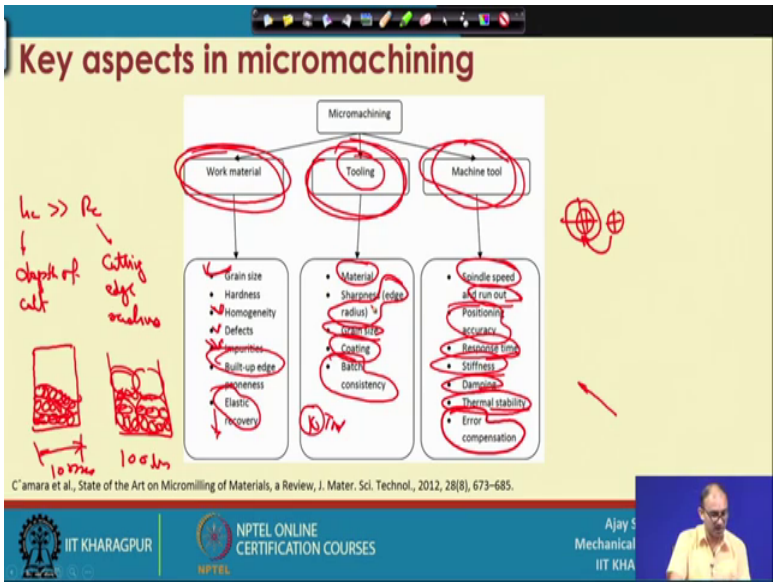

So, what are the key aspects of the machining that what we have learned that we have 3 different areas by which we can monitor or we can understand something first is the workpiece material and we have seen that grain size is important because smaller the grain size easy to remove material because the cutting tool will pass through the boundary of the grain hardness is playing important role because hardness you are getting a good surface, but you are tool wear is very very high homogeneity is important you will not get the fluctuation of the forces if the presence of defects is very very high material removal is easy, but what is going to happen that your work piece will not be acceptable at the end impurities that is same material with the different size, you will getting different parts built up edge is also a problem because if built up edge is there then your tool will not penetrate much and it will create some type of stick slip type of phenomena.

Elastic recovery is important because if it is a low then you will get a removal very very easily in some of tooling size because this are the 3 things which are very very important in our cases what material we are using that is important; that means, we have high speed steel. We have tungsten carbide we have ceramic tools.

So, those things are very very important and we are very more concerned about the edge radius because sharper the edge radius we can easily remove the material and now we

can give a small and small depth of cut depending on the sharpness of this part because we have to maintain that particular radius because the he should be higher than the Rc.

So, that is the uncut chip thickness or the depth of cut and this is the cutting edge radius, correct, grain size of that thing is important because we are using very very small tool, correct. So, this is considered very very big tool we are using in a micro machining. So, it is considering in a ten mm right. So, we are using a very very coarse grain of these cutting tool tungsten carbon let us consider it is so.

Now, you go from here to 100 micron, then if you same thing what is going to happen that is only 2 or 3 grains will come into this particular parts so; that means, its strength is also very less. So, you have to very very fine grain tungsten carbide particles in such a way that you will get a enough amount of particles to maintain that stiffness for a longer time coating is important batch consistency suppose that you are making 10 cutting tools, then all 10s are with a same quality or not because machining process is itself is creating a problem at the later stage, then coming to the machine tool that you cannot get the micro motion components from all the machines. So, you aspect some type of reasonable goods specification from the cutting tool machine tool.

So, that it can generate a micro machine. So, spindle speed is important you have to go with higher cutting speed. So, that you have reasonable amount of production rate run out is a very very problem because a cutting a material with a very higher run out of the spindle you are end up with a sudden failure of the cutting tool position accuracy that we have seen in the geometric accuracy or geometric error in the xyz and the other directions response time is important because when you give a command how much time it requires to act on that command by the cutting tool.

So, that is important stiffness is important because it should maintain your structure in a form where under the action of different type of cutting forces damping is important higher damping will reduce the vibration to propagate in to the different-different components. So, that is important thermal stability this things will discuss more in the spindle part. So, thermal stability is very important because if you are getting a large variation in the temperature all components have a different-different coefficient of thermal expansions.

So, material will expands in a different-different directions with a different-different magnitude and than your structure will be deformed completely error compensation is important because if your structure we have seen in that video also that there is a error compensation with a point one micron in a one machine tool company that is that if you can come calculate the error compensation.

Then if you are going to target this particle their tool is located here, then what is going to happen that once the temperature is different and different part your machine sensor temperature sensor will calculate those temperature difference is and that temperature difference will be transfer into the motion control and motion control will again target this particular part to the actual location. So, at that time error compensation that is related to temperature compensation other then the temperature compensation there are different sensors available which will do also position compensation even if there is some type of deviation

So, our focus is on the work piece material you cannot cut any material in the micro machining you cannot use any tool for the micro machining and you cannot use any machine tool for the micro machining. So, you have a specific combination of all the 3 components than only machining at micro scale is possible right.

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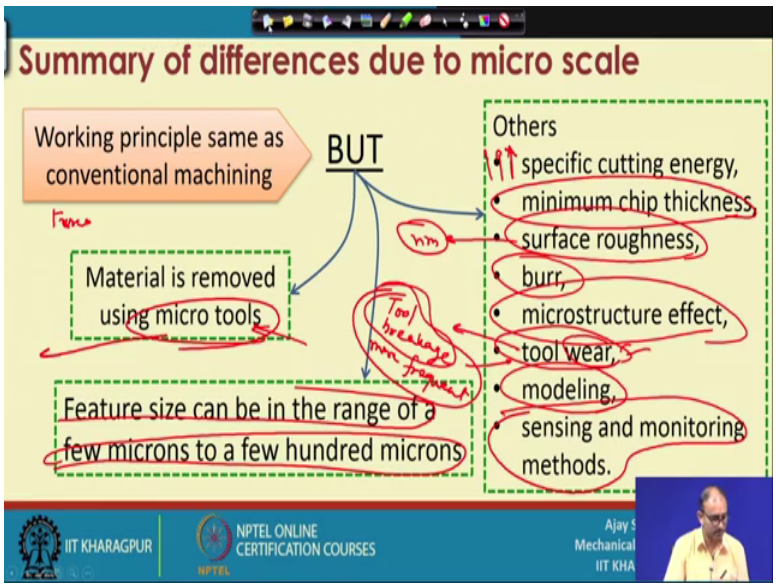

So, what are the summary of this difference is that work piece principle is mostly same material is removed, but there are differences are there one is removed by the micro

tools. So, you have to end up with or you have to fabricate these micro tools. So, that is also one of the process because when you are cutting at a micro tool you are using at a micro cutting tool, but you also find some processes which are fabricating this micro tools.

So, those process are against the machining process is. So, again the requirement is very very tight to these processes. So, that is the one thing feature size can be in the range of few microns to hundreds of microns. So, these things are different than the convention machining and very very important things are this specific cutting energy is very very high because at small scale you are getting very less amount of defects material strengthening is also very very high minimum uncut chip thickness.

This you have to maintain otherwise you will not get a clear material removal flowing rubbing those things are very very frequent in the micro machining surface roughness you have to play very impor[tant] you have to pay more attention to this because surface finishing application is very difficult here you can apply a deburring operation, but surface finishing operation is very difficult here because burr size is very very large compared to the roughness components.

If you are removing the burr it is very easy because still it has microns size or something, but if when you are looking at the surface roughness it always has a nanometer size micro-structural effect is important because what is the micro structure of the components which you are machining. So, it has different components tool wear is very important in micro machining what is mostly happen there is a tool breakage is more frequent breakage is more frequent than tool wear because even a slight amount of change in the force or diff other force other parameter your tool will suddenly break before it will reach to the wear.

So, calculation is wear is not important calculation is how to avoid the breakage that is more important if you can avoid the breakage then you can do some measurement of wear, but if your tool is break getting broken within one minute than there is a no way of paying a more attention to the tool wear modeling is very very difficult here.

Because whatever theory we have learned in the merchant circle diagram force measurement those things are not directly applicable to this because you have to do lot of modifications because this parameters are completely different sensing and monitoring

methods are very very important here because these particular things because everywhere we know the forces are very very low right forces are low.

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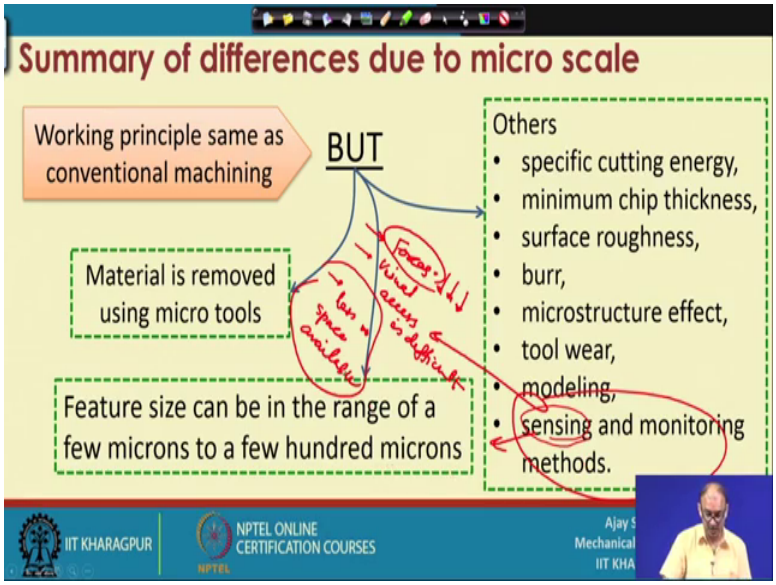

So, this is very very big problem and sometimes you will not get any type of voice out of that machine there is not any type of noise or some machine disturbance things from that visual conformation is difficult visual access difficult and other than that you do not have less space available because space also you do not have here because suppose you want to add some microscope or high speed camera or something how you can focus to that location that is also different because in the micro scale you can easily get the idea of the focus on to the chip and that workpiece and tool interface, but that interface access of that interface is very very difficult here.

So, you you need very very high sensitive instruments that is load cell or the dynamometer or different type of the acoustic emission sensors in such a way that it should it can able it can measure the small amount of forces or any type of other vibration signal or any time of tool wear signal. So, those things should be there and size should be also very small because you have to accommodate all this sensor or monitoring device is in a small locations.

So, this are the different-different problems or the different-different methodology by which you can successfully machine themicro components.

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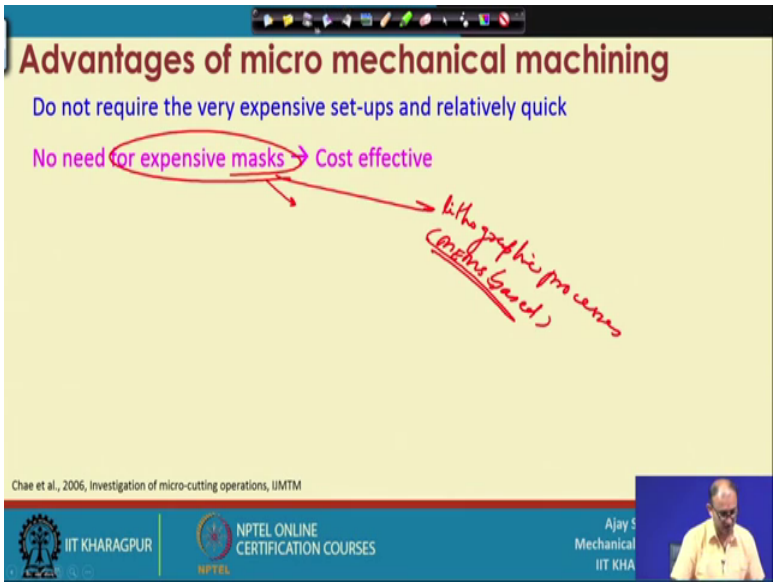

So, what are the advantages of this particular thing that after comparing this micro machining and the macro machining we can find out that what are the ways. So, here what is the good things that do not requires expensive set ups and relatively quick because we know the conventional machining.

So, is it just a skill down of the conventional machine we know that how to turning operation and how to do milling operation same operation is here, but we have to actually look into more detail. So, set ups are not expensive relatively quick because we know all the basic all the kinematic structure of the machining tool which are very same no need for expensive masks and cost effective. So, this is related to actually the lithographic processes lithographic process of that is MEMs based that we have seen in the probably first class or the second class comparison between the conventional this micro machining mechanical micro machining and the MEMs based the processes.

So, here you need a mask for passing the light through it. So, that it will actually remove some of the portion of that different-different type of surfaces than there is etching of the surface and you can get some types of futures. So, those things are called the MEMs based surfaces the suitable for the individual components rather than the batch sizes because.

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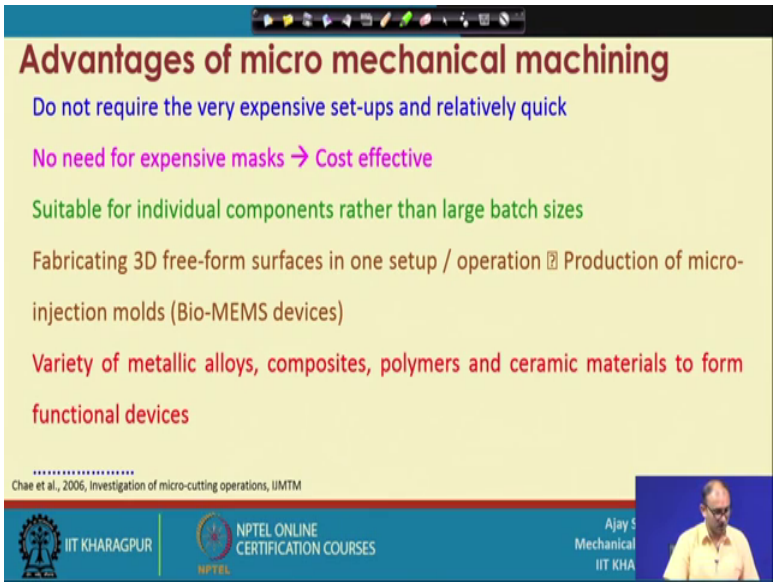

If you use these MEMs based surface it is for mass production because in a single silicon wafer you can create 100-1000 or more than 1000 lakhs of components in the single wafer, but this is mostly used for the individual components rather than the batch size and ad more advantage you can actually create the real 3 d free form surfaces in one setup and that is very very difficult or sometimes not possible by any other process let it be a lithography processes or any type of other advance machining processes like electro discharge machining electro chemical machining or the laser based machining.

So, production of the micro injection mold for bio medical implant is or the devices you can actually create a 3 d mold and then this injection molding or the some type of other casting micro castings are very very easy if you are getting a molded 3 d surface. So, that is the very very big advantage of this particular micro machining part and mostly you can do any type of machining of material.

Because only thing that you have at a right tool for a right material metallic material composites polymers ceramic materials anything can machined by this particular micro machining process because our if our tool is harder, then the workpiece then there is a no limit only we have to look into the tool wear of the part.

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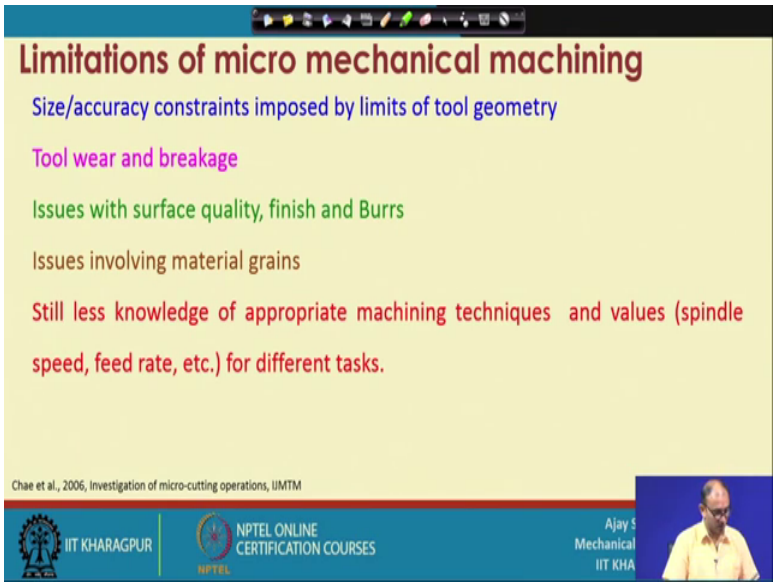

So, that is the advantages limitations are also there because nothing is perfect size and accuracy constraints by the tool geometry because what is the small feature you can create that depends on the tool geometry if smaller the tool smaller the features you can create the tool geometry is also important because we have to maintain the cutting edge radius smaller than the uncut chip thickness.

So, that is the first thing we have to look into the detail of the cutting edge tool wear and breakage is frequent in these case breakage is frequent compared to tool wear issue with the surface quality finish and burrs because if you are getting these particular things in the negative directions then it is very difficult to remove those art defects at the later stage material grains are also important here that is related to both the sides.

That means, not on to the workpiece side, but also on the tool side also, but still less knowledge of appropriate machining conditions and values available for a different task because if you see our convention machining there are different design data books are available you keep the work select the work piece and the tool material then there are specific speed feed and depth of cut calculations available for the optimum removable, but that is not available right now in the micro machining.

So, mostly you have to do trial and error and you have to create your own database. So, that later on that can be useful for others also.

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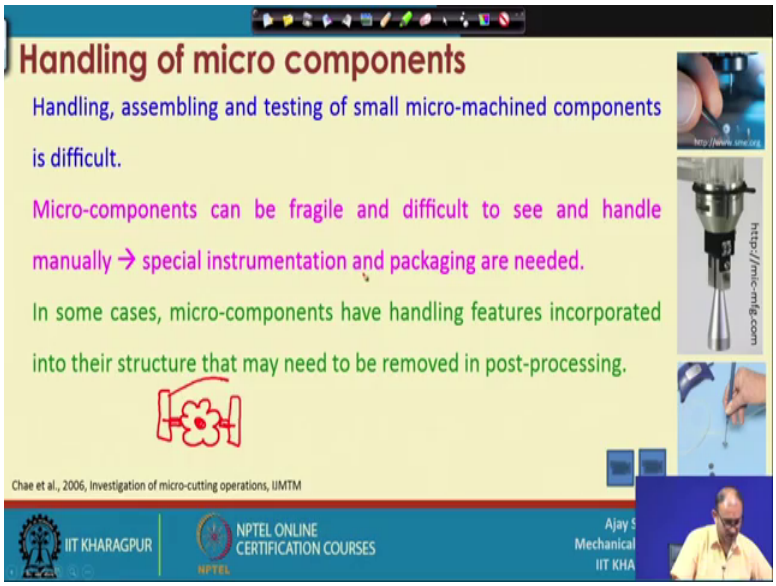

Now, this is also important how to handle these micro components once you machine all the components everything is in a how to transfer that components from one location to another location because size is very very small and then it is creating a problem.

So, handling assembling and testing of these small micro machining components is very very difficult. So, if you see this things that once you machining is over than you have to use some type of very very gentle pluckers to move this components and, but that also depended what are the size of these things and there are some components available which are piezoelectrically actuated that it will not create. So, much of force that it will actually damage the component or the machine components to a large extent then there are some vacuum type of tweezer available that it is a vacuum type. So, you just touch the surface it will pluck up that part completely and you do not require any type of forces.

So, micro components can be fragile and difficult to see and handle. So, special instruments and packages are required. So, this is the some of the ways of handling these components and in some cases the micro components have handling features incorporated into their structure that may needed to be removed in the post processing. So, this is similar to the adding that additional material for the burr removal process. So, you aid some extra material and that material will be helpful suppose now see when you

are doing a casting or molding of a plastic this particular thing suppose you consider this particular gear.

So, now this is a gear consider let me draw it further something like this and hole is at the centre now when you are making that what you provide that you provide one extra feature here yes you create this features here then you mold it then what is happened the molded components will be completely this part and then this contact zone is very very small.

So, you just if you bend this part [FL] it will completely come out of this part. So, this are the additional features you have to create just for handling of this part now if you see this videos let me show you this part. So, there are 2 different ways; now if you see, this is one of the vacuum holder.

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This are the different-different nozzles available it depending on the size now if you see.

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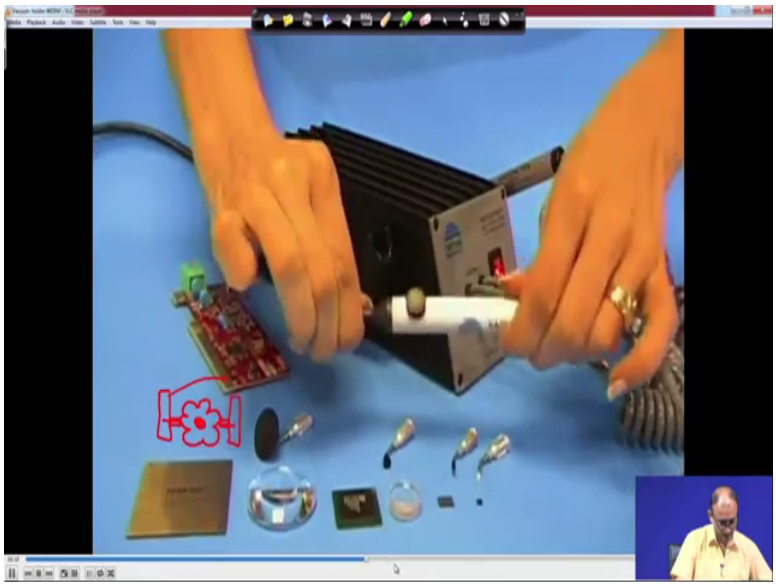

So, you can change these particular nozzles depending on the what is the size of the component you want to pickup.

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And then because of this air then it will just suck and if you press this button it will release this particular part. So, that is the advantage of using this part this is about the small components, but if you have large component area then you can also use a similar way.

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But now the area of this particular part is large.

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So, this is again the same vacuum type of things, but it area is large. So, this is the way you can actually move this components and you can move to them different location advantage of here is also one of the thing that you can actually change the pressure of this particular parts how much pressure is required.

So, this is the vacuum level maximum minimum is there. So, depending on the delicacy of these components if it is very very delicate, then what you can do you can actually

minimize the pressure. So, that it will not damage the component here and this way you can move the components. So, these are vacuum based components and these vacuum based components are very very handy in the fabrication of these particular parts.

So, this is all about the machining or comparison between the micro machining zone and the macro machining we have seen about all the things on the mechanics points of view we have seen about the how to handle this components and we have also seen that how the errors and others things are generated.

So, let me finish this lecture here and we will continue about the components of the machine tools in the next class.

Thank you very much.