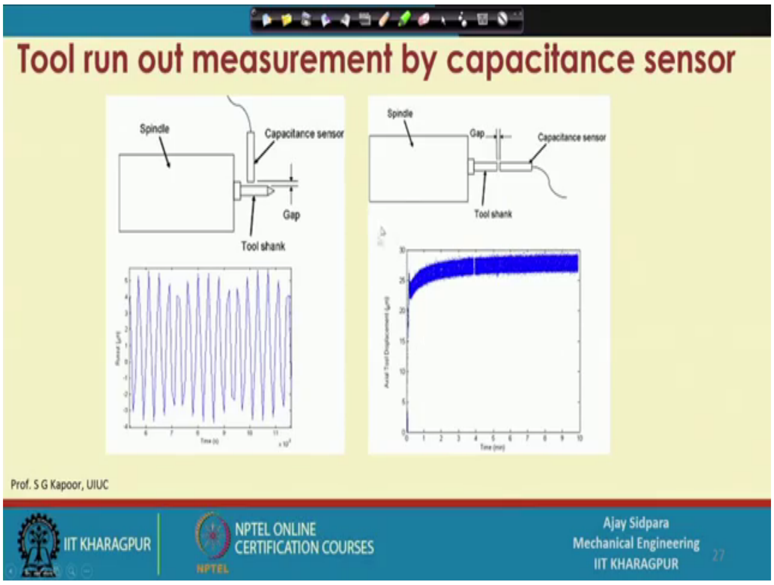
Introduction to Mechanical Micro Machining
Prof. Ajay M Sidpara
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 53
Micro tools (Contd.)

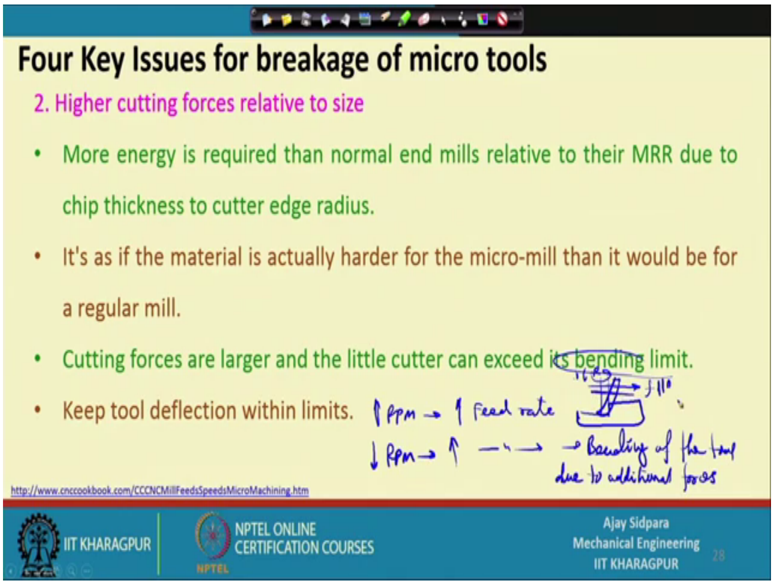
Let us continue our discussion on the different issue of the cutting tool break a tool brakeage. And we were started discussion about the tool run out, and we have seen that tool run out is one of the most important issue in the micro machining and we have seen that what are the different tool run out we are getting and what are the ways we can measure the tool run out also.

(Refer Slide Time: 00:35)



So, let us discuss this thing further.

(Refer Slide Time: 00:39)



So, we have seen that one of the reasons is the tool run out and another is the higher cutting forces related to the size. Now if you see that we have to we know that our specific cutting energy is very very high in the micro machining zone because we are cutting a material without any defect also sometimes we are do not encounter into any defect because the size is very very small.

And because of that our cutting has radius and cheap thickness are also different way playing important role in this case. Now we have seen that if you are doing machining of a one material by 2 different tool, one is the micro tool, one is the conventional tool, if the material is hard then it will actually hard for both the cases right whether you cut the micro machine micro cutting or macro cutting.

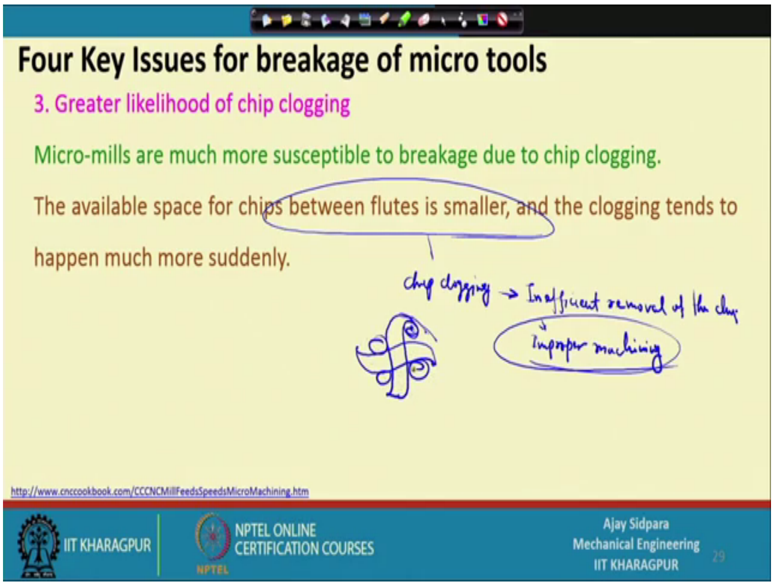
A problem is the macro micro cutting what is happening the number of defects are very very small that we have discussed in the specific cutting energy part and we are not consistently actually reducing the force when you are reducing the on cut chip thickness. So, after a certain level force will be very very high because of these material issues, and the cutting forces are larger in and the literal cutter can exceed its bending limit.

So, whenever you force your cutting tool into the work piece why without looking into this particular aspect that is the cutting forces related to as then what is happening that you are actually bending the cutting tool your material is your tool is not able to force the material to cut and because of that the material also play some resistance to the cutting tool and then it will reduce it will actually cross the bending limit and tool will be broken directly.

So, what is the thing that we have to keep the tool deflection within the limits; so whatever rpm and the feedback oscillating so those things are actually synchronized right. So, when you talk about the higher rpm then only you can go with the higher feed rate right because in this case if the rpm is low when rpm is low in a higher feed rate then there is a bending of the tool due to additional forces correct.

Because now your tool is here and this is the cut out material and you are moving in this reaction. So, your moving direction is f is very very high and your rpm is very very low so in that time what is about the tool will be bend completely because this tool is going down and down, but you are not removing the material. So, your tool will be something like this where there sometimes it will be something like this and once it cross this particular bending limit then there will be a fracture of the cutting tool right.

(Refer Slide Time: 03:44)



Third one is the greater likelihood of the chip clogging. So, what is that micro mills are much more susceptible to the breakage due to chip clogging because we know that when you are doing cutting operation at the time there is a formation of chip. But in conventional machining what happened that we are using a two fluid cutter or the four fluid cutter the fluids are very important to navigate this chips completely out from the machining zone, but here we know that a chip space is the fluid space is very very small.

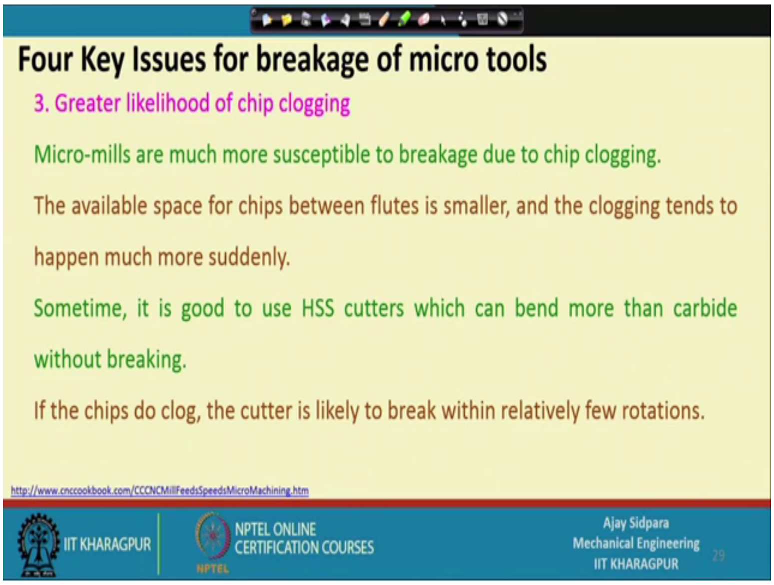
So, at that time the chip will be clogged in between the work piece and the cutting tool and that creates the problem that is available space for chips between the flute is smaller and the clogging tends to happen more much more suddenly. So, you do not have some time also to understand that thing the by that time your feed rate is high your rpm is very high you will suddenly get the clogging of the chip and once the chip clogged there further moment of the chip is not possible.

So, chip start accumulating at the same location and because of that you will get the chip breakage so that is what is happening. So, the because of that chip clogging, inefficient removal of the chip of the chip, and then you will get the then improper machining correct.

So, in that way your tool is fully loaded and once it is fully loaded we know that suppose your tool is something like this is the four fluid cutter then this whole thing is completely filled with the chips now your you are not able to remove that then what is happening that when it is trying to cut the phrase material then this particular chip will actually play very important role in actually isolating this particular sharp page with the cutting work piece surface so, in that case you will not get the efficient material removal right.

Sometime it is good to use HSS cutter with can bend more than the carbide without braking. Because now HSS is we know the carbide is very very hard material and it do not have so much of bending strength.

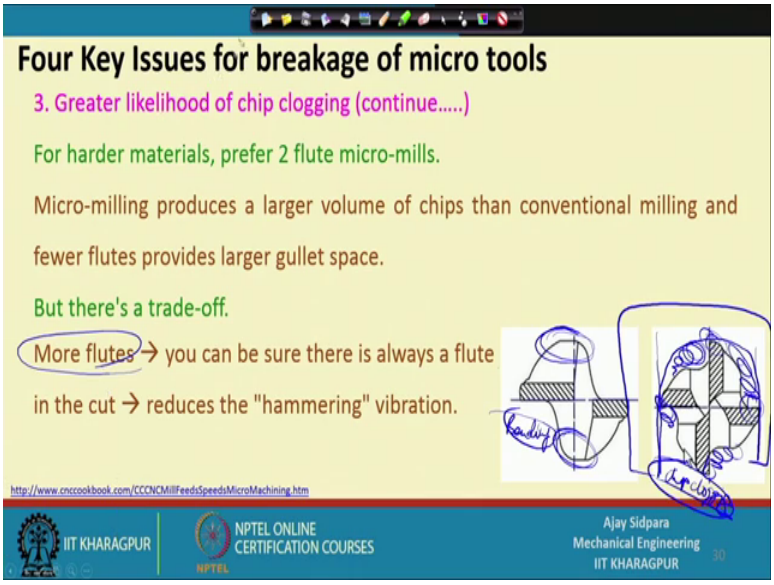
(Refer Slide Time: 05:47)



So, at that time if you use HSS cutter at a micro level then there is a high chance that you can actually increase the bending up to a certain level and if you can remove the clogging of the chip within that time then you can actually continue cutting with the HSS cutting tool than this one. So, this is sometime advantage, but you are actually sacrificing the hardness with the selection of HSS.

So, if the chips do clog the cutter is likely to brake within the relatively few rotations that is; obviously, because now you do not have space to accommodate phrase chip and the phrase chip if you not that then everything is actually jammed in between the work piece and the cutting tool.

(Refer Slide Time: 06:42)



For harder material what prefer that it is better to go with a 2 flute micro cutting tool because what is happening so this is the 2 flute cutting tool so, it has a 2 flute. So, micro milling produces a large amount of chip than convectional milling that is with respect to the size and the flutes will provide the larger gullet space.

Now you have a space this much of when it is cutting the surface now you can see this is the diameter and this much amount of space is available for actually evaluating this chip away from the machining zone correct. So, this is the way you can do that thing. But there is a trade off also right because every time this is not the solution why it is like that because more flutes you can sure that there is always a flute in the cut right. So, this is the four flute cutter how this thing is better in the some sense is now you can see that when you are rotating the cutting now if you see this is your this is your work piece, and you are going in to then and this is the rotational direction right.

And if you go with a high speed what is happening that in a one rotation only 2 places are there where your cutter is coming into contact remaining this particular portion when it is touching and when it is touching. Now if you see this is going continuously right it is not that intermittently. So, when it is going in continuously there is some instant where this portion actually comes into contact with the work piece. So, that is called the hammering vibration right your cutting edge is not coming because when it is a cutting edge cutting edge is very sharp and sharp edge can remove material efficiently, but here actually it is a something like a hammering that your work piece your tool is actually hammering the work piece surface.

And because of that here when it is touching the surface obviously material will not be removed because there is no surface or there is nothing which can remove the material. So, it is actually forcing the material inside and by second instant you are cutting edge is coming into contact. So, intermittently you will get a hammering effect in this particular case, but that can be minimized if you are using a 4 flute cutter right.

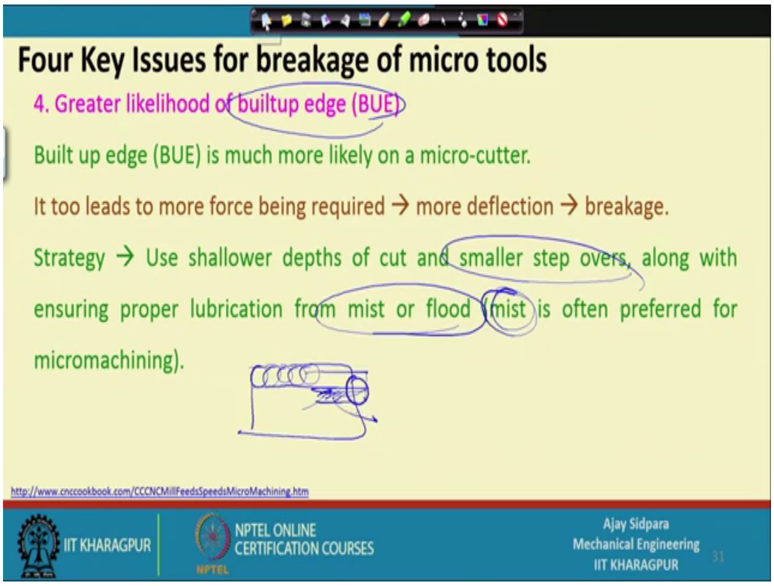
So, what is happening in 4 flute cutter that when it rotates in one rotation because now you can see that this is what is your situation now. So, work piece a that tool work pieces coming into contact at the 4 places where the sharpness is just in one rotation you can get that you are making sure that your cutting; that means, whatever your flute that cutting edge that is coming into contact so that is opening only 2 times here.

So, the hammering effect can be minimized mostly it may not happen also because when you are rotating at a 1050, 1000 1 lakh rpm you may not encounter this particular hammering action at this location. But it may happen at this location because now you have to pass through this particular location which is with which do not have any type of surface which can remove the material.

So, by more flute what you are making sure that you are making sure that there is always a cutting edge which removes the material, but problem is that now you are end up with less amount of space for the chip.

So, chip clogging is issue here, but if you want to ever the chip clogging you have to reduce the number of flute, but problem is the number of flute reduced then you will get the hammering action. So, here bending is high and here the chip clogging is high right. So, again there is a compromise now you have to see that for which particular occupation you go with the 2 flute and which application you go with the more number of flutes and fourth issue is the built up edge.

(Refer Slide Time: 10:32)



Now built up edge is very creating more creating problem because built up edge is much more likely on the micro cutter because it could leads to the more force being required more deflection finally, the breakage part. So, what is built up edge that you get some material deposit it on to the cutting edge of the work piece material tool.

And because of that that your tool will considered as a more amount of radius; that means, whatever cutting has radius of the cutting tool is there by built up edge it will be further more. And because of that we know that if it becomes dull whether by the wear also or by deposit of other material your force requirement will be very very high because now you are not consistent with the uncut chip thickness to the cutting edge ratio.

And then there is a more deflection and there is a breakage at the final stage. So, what is the strategy; that means, when you are doing machining better to go with the shallower depth because you do not give lot of amount of depth if you go more depth then what is happening the chip has to flow through over the flutes and then it will create a problem at the later stage and give the smaller step over; that means, once you want to cover more amount of surface.

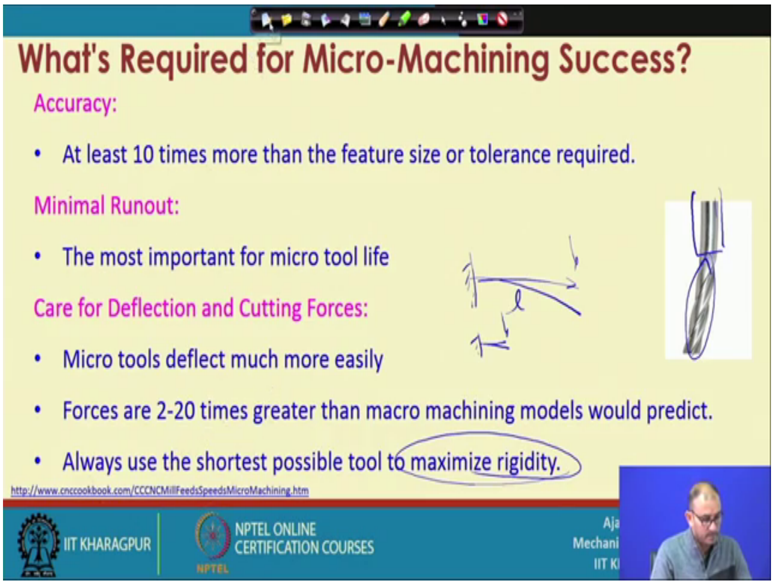
Now, consider that suppose this is the surface and this is your cutting tool. So, in a one go your cutting this much amount of material right so your cutting tool is coming like this and once it is over then you have to cover this part then give a small step over right. So, if you are giving a small step over then what happened in the next step suppose your cutting tool is here then only this much amount of extra material is it is cutting in the next step.

So, amount of material removal is you will take more time, but you are making sure that you are not coming across the built up edge because every time it is a compromised only you cannot get everything right at by setting all the parameters so some where you have to sacrifice here what we are sacrificing we are sacrificing time right.

So, in this way what we are doing the smallest step over will make sure that every cut has a less amount of material which is passing through the cutting tool. Shallower depth when diameter depth wise also you can go less at that time you also make sure the number of amount of material which is coming out of the work piece it less and the flute are enough to pass those material away from the machining zone.

And other than that you can actually use the mist coolant and flood coolant, but mostly in the micro machining mist coolant is preferred. Because mist coolant will not create this space more messy as well as the mist will make sure that when your impinging with a high velocity, or high pressure at that time it use actually spreading the chips and whatever other dots available which is away from the machining zone. So, that are the advantage then mostly people go with the mist coolant right.

(Refer Slide Time: 13:22)



So, now finally the complete summary that what is required for micro machining success what thing first thing is the accuracy required. Because we have seen that if your machine has very very high accuracy, but your feedback system has low accuracy then your machine actually you are working with a low accuracy only. So at least 10 times more than the feature size or tolerance required so that is 10 times is everywhere because we have seen the run out also in terms of 10 size in the machine accuracy with respect to the feedback accuracy also 10 times of something.

So, this is constraint as a sometimes of bench mark, but it is not same for every cases, but mostly people follow this particular bench mark so that you can get the required things done in very easily. Minimal run out because that is we have seen that this is creating lot of problem in the machining part, most important for the micro tool life, care for deflection and the cutting forces.

Because now we have seen that because of the run out then chip clogging and the in proper setting of the speed and feed at that time you will get the deflection of the work deflection of the cutting tool and you will get a very very high fluctuation of the cutting forces.

And the micro tool will deflect much more easily so that is mostly this is HSS so, it is bending little bit more. But if it is a carbide cutting tool then it will be broken from some location wherever there is a high stress concentration right. So, forces are 2 to 20 times greater than the micro machining with the model machining model would predict

So, in the when you do force modeling at that time you will encounter the forces are very very high in this particular. When you are talking about the work piece that particular zone I mean total force is very very less, but if you consider the amount of material which is removing with respect to force then it is very very high and always use the shortest possible tool to maximize the rigidity right.

Because do not give the over hell a lot of overhanging because sometimes what happened that suppose you have this much amount of cutting tool length you have a label. So, hold it form this location right. So do not, because we know that if it is a length is less than your bending will be less right.

So, if you see this thing and this thing then there is a less bending in this will this will be less. So, if you give more and more over load means over hanging portion then there is a chance of a bending or it is a breakage of the cutting tool. So, you can actually maximize the rigidity by giving a less amount of tools length right. Care for chip load and the feed rates now.

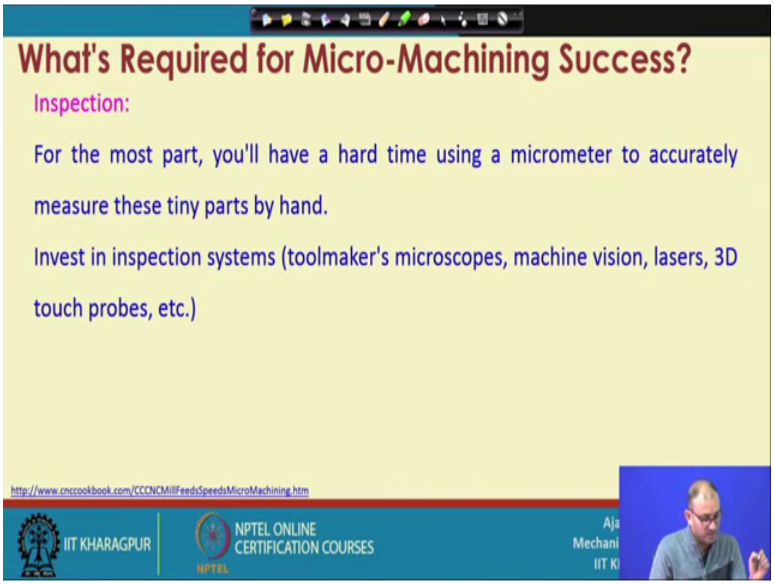
(Refer Slide Time: 15:57)

Because we know that cutting edge radius is same as the chip load. So, mostly we have seen that it will come across the negative rake angle in very narrow range of acceptable chip load before tool life and outright breakage become the problem.

So, when we know that how much is the amount metal you want to remove then accordingly you have to select the feed rate. Because feed rate will tell you that how quickly you are penetrating your work tool into the work piece. If you do not have high speed then actually you have to sacrifice the feed rate and finally, the production rate completely. So, in this particular case you have to make sure that you do a calculate chip load calculation based on the feed rate and the speed what you are using as well as the depth of cut also.

Higher speed spindle is required because only higher speed spindle will make sure that your machine is speed is high the only way to increase the machining speed in this case and allow the reasonable feed rate within the limitation of the tolerable chip load. Because if you are do not give high speed then you have a restriction on to the feed rate and if you are restriction the feed rate then you are restricting the total machining speed also that you cannot actually operate the machining at the tool capacity and the production rate will be very very low.

(Refer Slide Time: 17:11)

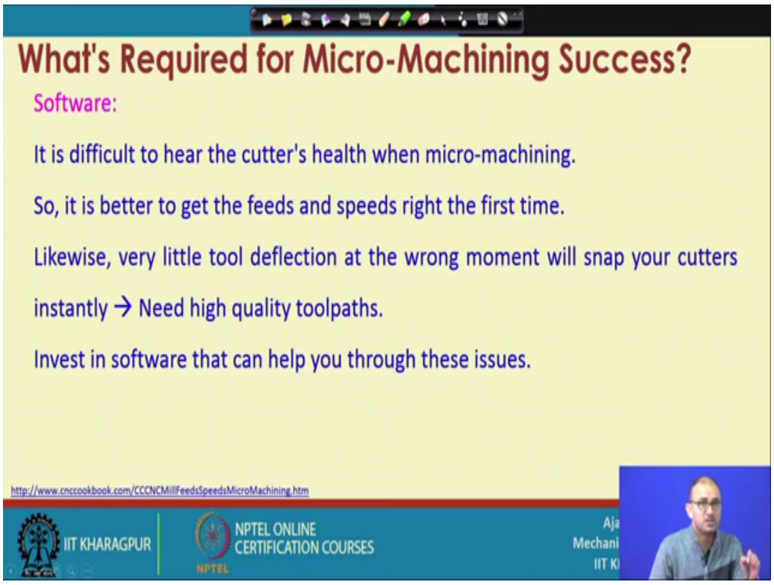


Inspection is very very important here because for the most part you have a hard time using a micro meter to accurately measure those tiny parts by hand. Because when you do micromachining your conversing machine you can use micro meter, you can use vernier caliper, or many things are there by which you can do the measurement.

But here nothing is possible because those parts are very very small and by putting this micro meter itself is a issue. So, you have to spend lot of money in the inspection system that tool maker microscope, machine vision, lasers, 3D touch probes. So, these are the different, different instruments are available some of the instrument you can directly mount on the machine itself so that you do not need to remove the work piece also or the tool also.

It will do measurement of all the thing that suppose you want to measure the dimension of the whole or something then there are probes available, there some of the things are infrared props, also some of the wired props are also there. By which do not remove the material you do the measurement on the machine itself because we know that once you remove the work piece from the table again putting at the same location with the same accuracy is very very problematic.

(Refer Slide Time: 18:11)



So, it is better that you do everything within the machine also machine only by or let it be on the tools side or the work piece side so that need the high all the things. So, here that is import touch probes are also machine vision is available because by which you are using some type of high magnification microscope and you can actually monitor the machining operation also and you can see that how the machining is being done.

Another thing is a software now how software is playing important role here because what is happening that it is difficult to here a cutter health when you are doing micromachining. So, when you are doing a machining with a high feed and high speed at the time you have to select those parameters in such a way that your machine or your tool is able to bear those things.

Because now whatever operation we do mostly we do by GNM code and GNM code is mostly created by some type of third party software's by which you created tool path and then give feed rate and the speed data or all the things.

So, if whatever software you are using and if their software is not able to capable to give that particular things correctly then what is happening that a little tool deflection is happened because your feed rate is very very high, your speed selection is there even though you have given everything to the software, but software has not software does not have that capability to handle those things.

So, likewise very little tool deflection at wrong moment will snap your cutter instantly, so, we have seen the geographical error similar way this is the error because of the wrong parameter setting and there that is the way you need a very very high quality tool pulse. So, generating of tool path with a one particular feed rate and speed that read some type of high resolution or the high quality of the tool path and that is possible by the software and in invest in software that will help you or through the different type of issue.

So, you have to select the software also in such a way that it will provide some type of things which are very very convenient to process this part. So, let me stop this particular thing here and let me show you one video here that how these tools are fabricated.

(Refer Slide Time: 20:29)

Now this is the things which are fabricated by a grinding operation.

(Refer Slide Time: 20:33)

Now, see these are the different, different tools are available.

(Refer Slide Time: 20:37)

Now, you can see these are this is the grinding will and this is the cutting tool. Now you can see the how it is indexing and it is creating flute on to the surface and once you can see that these are the 2 different processes right. So, this is the one grinding wheel, this was another wheel. So, this is the course one right first the tool was coming here that was sitting there and this is the final one we have also seen same thing into the slide also that how it is making the things.

So, now, this is animation by which you can see that how it is creating flute on to the surface. And this is the final say whether you want a bowl, and cutter value or you want a milling cutter depending on that you can see the things here.

(Refer Slide Time: 21:23)

Now, once you create this thing then you have actually using those tools in the machining process.

(Refer Slide Time: 21:28)

And this is you can see that it is showing what is the tool run out and this is the diameter of 500 micron. And you are cutting the pro machine this thing and this is at high speed.

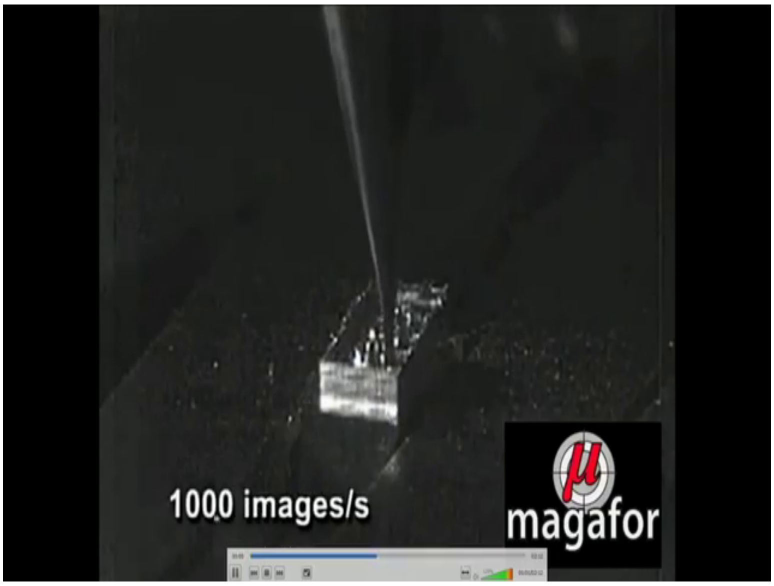
(Refer Slide Time: 21:32)

(Refer Slide Time: 21:36)

Machining operation; that means, you are using some high speed camera to see the things it is now 300 micron cutting tool.

(Refer Slide Time: 21:41)

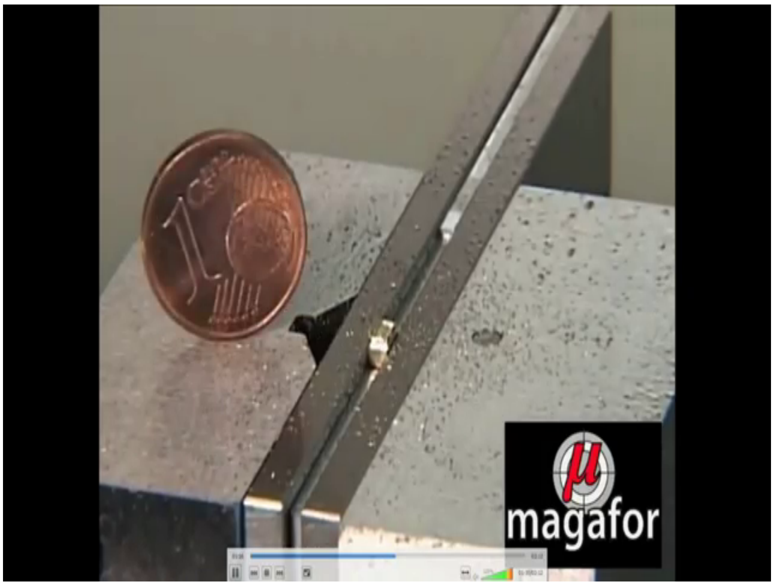
(Refer Slide Time: 21:45)



And this is the 1000 image per second high speed camera and now it is 100 micron n mill cutter right.

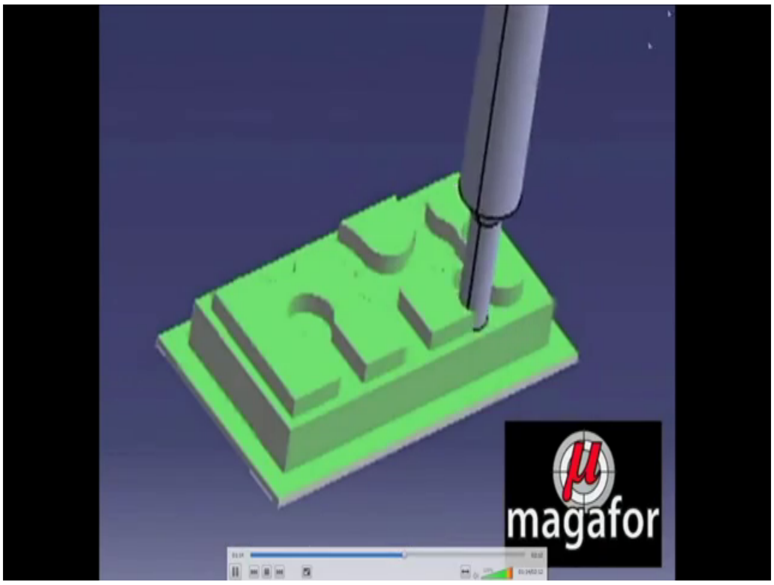
(Refer Slide Time: 21:50)

(Refer Slide Time: 21:54)



So, in this way you can see that; what are the different-different features you can create by different operations?

(Refer Slide Time: 22:00)



(Refer Slide Time: 22:14)

This is the one thing right so you need to spend some on that also camera and all the things also.

(Refer Slide Time: 22:20)

Because once you create those pictures then quickly you should have some system or by which you can measure the dimension and everything.

(Refer Slide Time: 22:30)

So, this is the vision system available by which you can do measurement of different, different features.

(Refer Slide Time: 22:37)

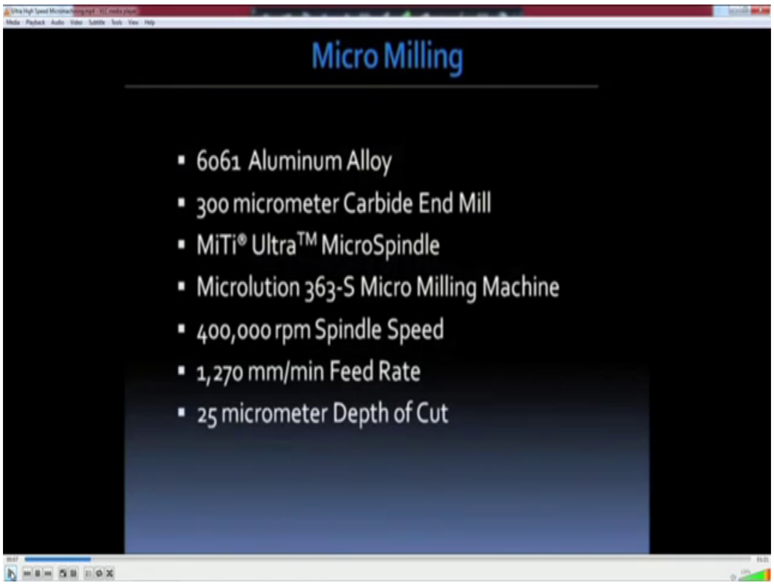
Now you can see it can easily get this particular thing see it is creating this radius and everything. So, micro inspection you can easily get this thing done.

(Refer Slide Time: 22:48)

(Refer Slide Time: 22:51)

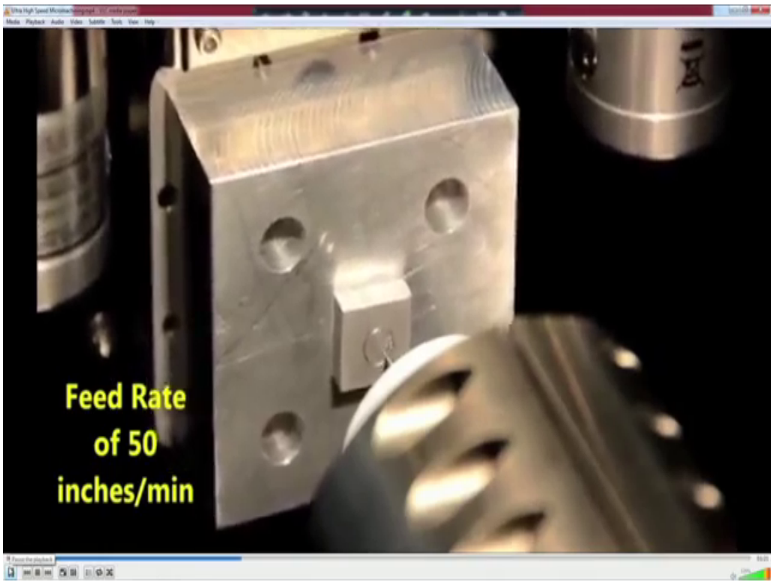
And this is the machining at a 4 lakh rpm. Now, you can see that at which this rpm that your spindle is rotating at a 4 lakh revolution per minute let us see that how it will do machining.

(Refer Slide Time: 23:00)



So, these are the different parameters of work piece aluminum alloy then work diameter is 300 micron tool diameter, spindle is one particular company spindle then it has a 4 lakh rpm and feed rate is 100 and 1270 millimeter per minute and depth of cut it is a 25 micron right.

(Refer Slide Time: 23:30)

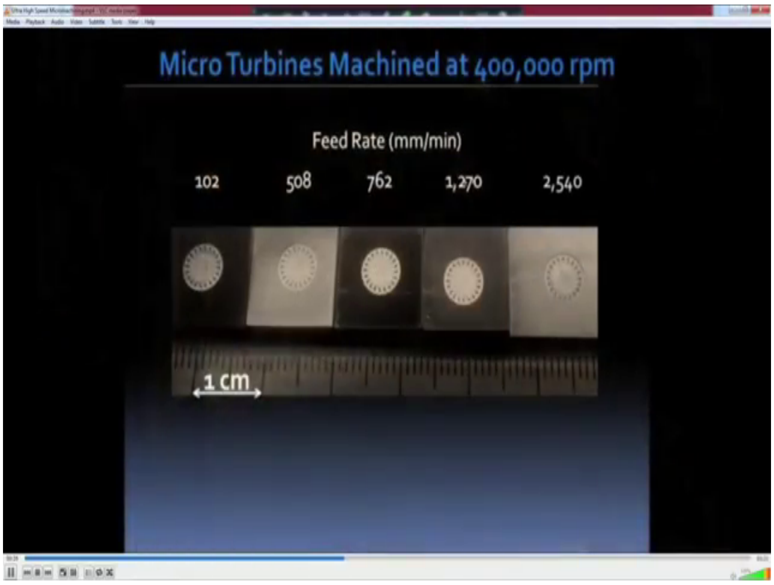


This is the work piece and this is the cutting tool and this is showing in the real life; that means, you are not using at high speed camera here. So, feed rate is 50 inches per minute, now you can see the way it is moving or it is doing cutting. So, it is showing in the real time.

(Refer Slide Time: 23:47)

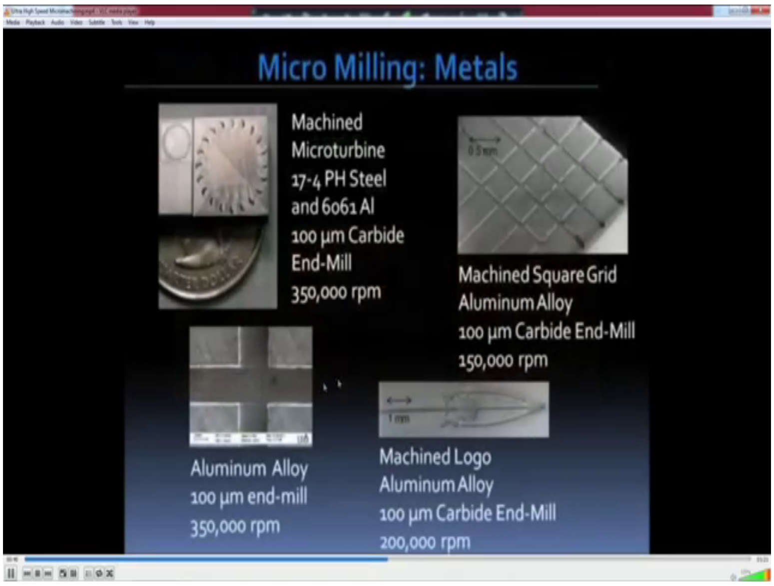
So, this is operating at a 4 lakh rpms.

(Refer Slide Time: 23:54)

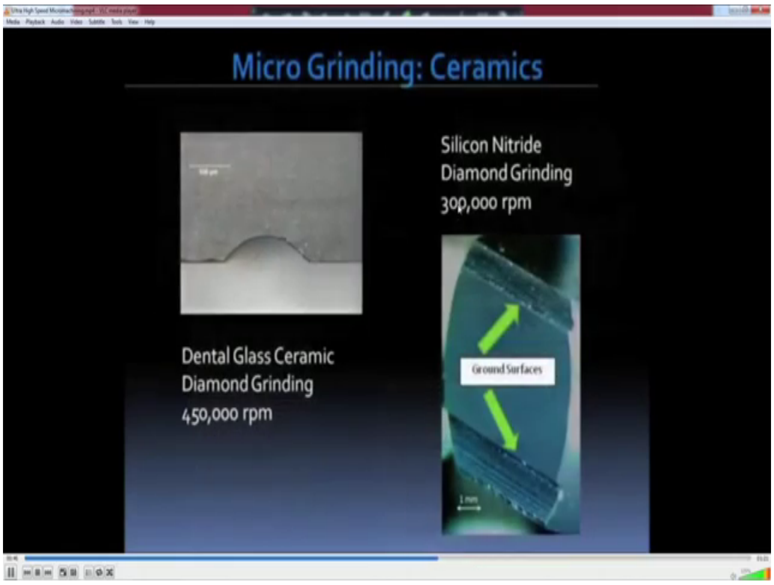


So, this are the different feed rate thing by which you can do study and see that which feed rate is showing you the better results here.

(Refer Slide Time: 24:00)

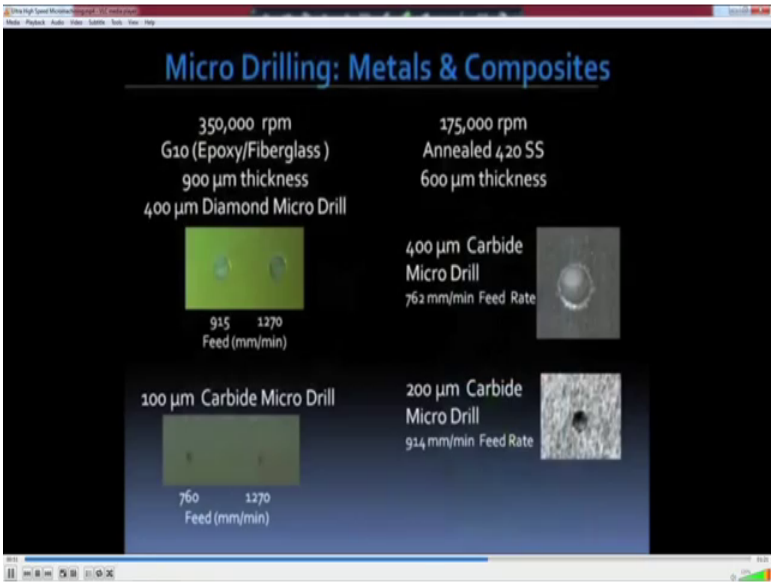


(Refer Slide Time: 24:05)



And these are the different, different work piece and different steps which are cut by the different, different rpm settings. Ceramic is the 4, 4.5 lakhs rpms, 3 lack rpm some other materials right.

(Refer Slide Time: 24:10)



(Refer Slide Time: 24:17)

So let me stop it here now, and we will continue new topics in the next class that is related to the micro factories.

Thank you very much.