**Introduction to Mechanical Micro Machining**
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**Lecture – 05**
**Introduction (Contd.)**

Good morning everybody, and welcome to our course on introduction to mechanical micro machining processes. In the last class we have seen the classification of different processes, and then we have a compared the 2-different domain of the micro machining or the micro fabrication processes. One is related to micro electromechanical system, and another one is the our course related to the mechanical micro machining processes. And we have seen that there are lot of differences between 2 processes, or the 2 domain of the processes.

Now, there is one more domain which is related to the ultra-precision machining. So, that ultra-precision machining is also consider is a one type of micro manufacturing processes or micro machining processes and where we also do some type of processing in terms of the micro mortality model.

So now, let us discuss about the differences between the micro mechanical machining processes and the ultra-precision machining processes.

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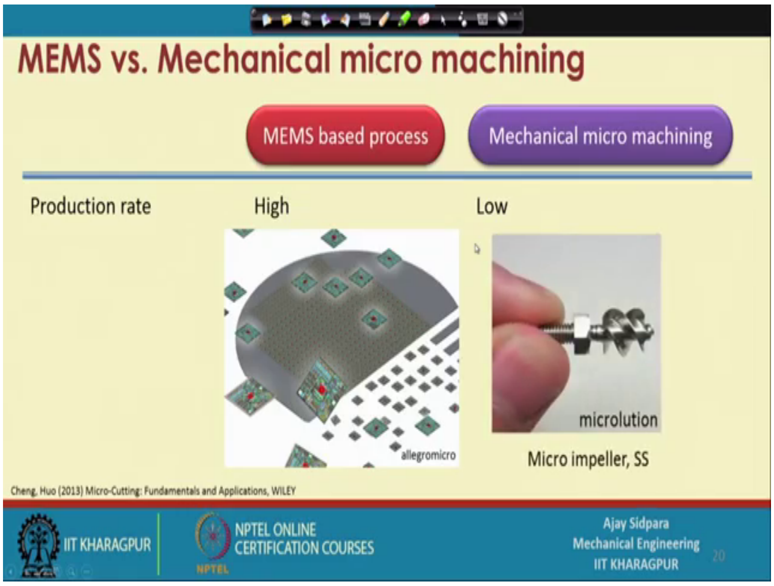

So, these are the things which we have discussed in the last class.

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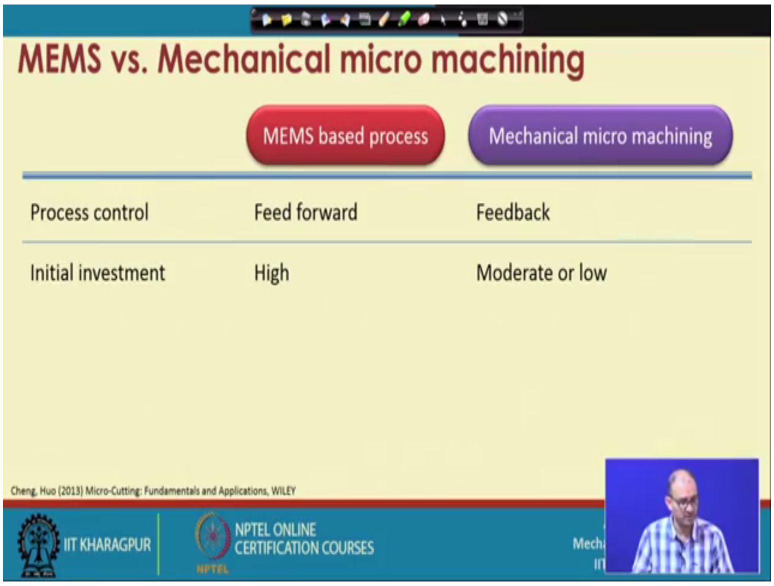


What are the different between the MEMS processes and the micro mechanical machining processes?

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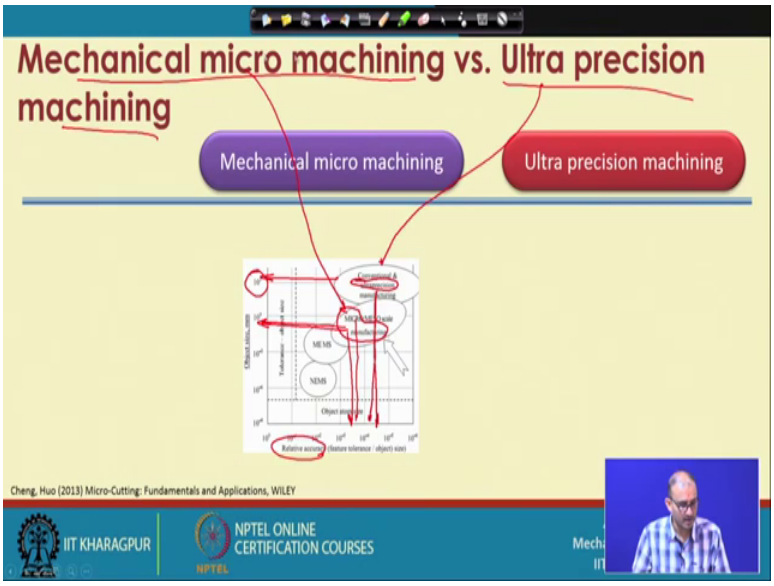


Now coming to the mechanical micro machining processes versus ultra-precision machining processes.

So, what are these ultra-precision machining processes? If you see this particular diagram, we have 2 distinction micro mechanical processes. So, this particular thing is here. And this ultra-precision part, that is here. So, this is the ultra-precision manufacturing, and this is what we are talking is the micro manufacturing processes. So, there is the difference. So, difference is in the size. So, this is the domain.

So now, if you see the size of the component for this is very, very large in this case. Apart from that not only large, but also you can get a very, very high relative accuracy in the ultra-precision manufacturing. But that is not the case of the micro mechanical machining processes, where the size of the component is one millimeter or less than one millimeter, and the relative accuracy is also less compare to the ultra-precision machining ultra-precision manufacturing.

So, let us see that what are these processes. So, what are the processes?

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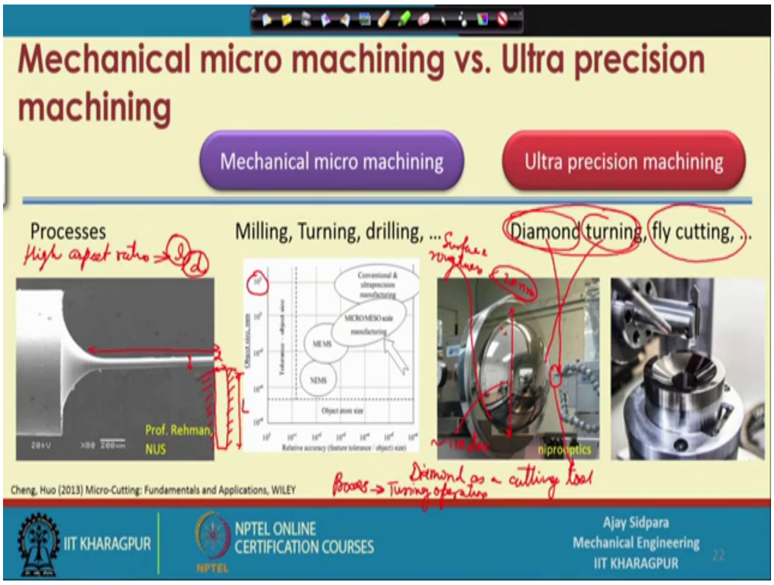


In this process, we know all the processes there milling process turning process drilling process. And in this particular this is the example that this is the soft fabricated by the mechanical turning process is and you can see the dimension is here, less than 50 or 20 micron of the dimension. And it is called high aspect ratio structure.

Now what is high aspect ratio structure? High aspect ratio means, it is a l by d. So, here length is very, very high and the diameter is very, very small. So, here you can say that length is very large, but if you see the diameter diameter is very, very small. So, that is in terms of the rod, but same thing can be applicable for the whole also. Now if you see this is the depth of the hole, and this is the diameter of the hole. So, in that case also it is call high aspect ratio hole, and here it is called high aspect ratio structure. So, that is the difference.

Now what is the process available here? There are 2 process is available, and one is call the diamond turning operation, another one is call the fly cutting. We will cover this process are in more detail when we cover this particular topic it is called ultra-precision machining. But for presence slide let us see that diamond turning. So, diamond turning operation there are 2 words one is a diamond in under on in determining operation. So, diamond is applicable for the tool and the turning is the processes which forces which we are using for that. So, here we use a diamond as a cutting tool, and the process is turning operation, right.

So now you know that how this size is meter. So now, see the size is in terms of meter. And now you can see there considering the size of this component this is the cutting tool. And this is the component. If you say this particular size, it is size is in a meter scale. Consider approximately one meter, right. And whatever roughness or the tolerance, you are getting the tolerance is very tight; that means, you can get the surface roughness in terms of nanometer. Surface roughness less than 20 nanometer, and this is about diamond turning.

Now, what the fly cutting operation, now fly cutting, now let us see here that this is the component.

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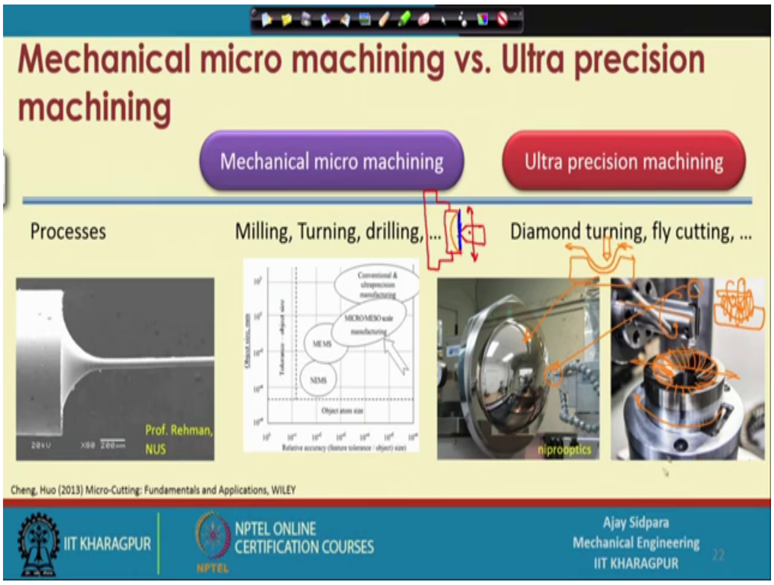


And this a chock, and then you are doing a facing operation. This is the cutting tool, and it is moving in this direction. And then it will do machining it this particular face. So, this is call the facing operation. So, we are using a cutting tool like this. But now suppose you want to create one cavity be here, now your surface is something like this, correct?

Now, there are 2 ways of doing this thing that you put this tool inside and then create a one cavity like that, then you move this along the curvature. There is another way that you mound this tool like, this now this is the cavity, this is what the same cavity, suppose you want to make. So, this is the features of this, cavity and if you see the cross section of this, you will get something like this surface, right? And now this is the single point cutting tool same as what we are using here.

But here difference between these 2 is that this will be rotation. So, this is the spindle on which it will rotate in this direction continuously. And then it will penetrate inside. So now, this is the way it is happening here. So, this is the cutting tool, and this is the spindle and then the spindle will rotate in this direction. So, it will rotate and it will remove the material continuously in this direction.

In other way here what we have to do suppose is this is the same feature here. And this is the same cutting tool, then what you have to do to move this cutting tool in this direction to cut the material? So, this is called the diamond turning operation, and this is called the fly cutting operation. Here the advantage is that you can get the required features here, because many times what I mean suppose, you want to create some type of features here that is some type of slot or some type of small small features here, that is possible by fly cutting operation. We will see everything in detail in the (Refer Time: 08:51).

Right now, difference is there the here tool can translate only in the diamond turning operation, but here tool can rotate at a high rpm, as well as it can move in this direction. So, this is the 4th axis. So, this rotate this will rotates, and this will move up and down. So, so, you can get the required cavity machine very easily in this case.

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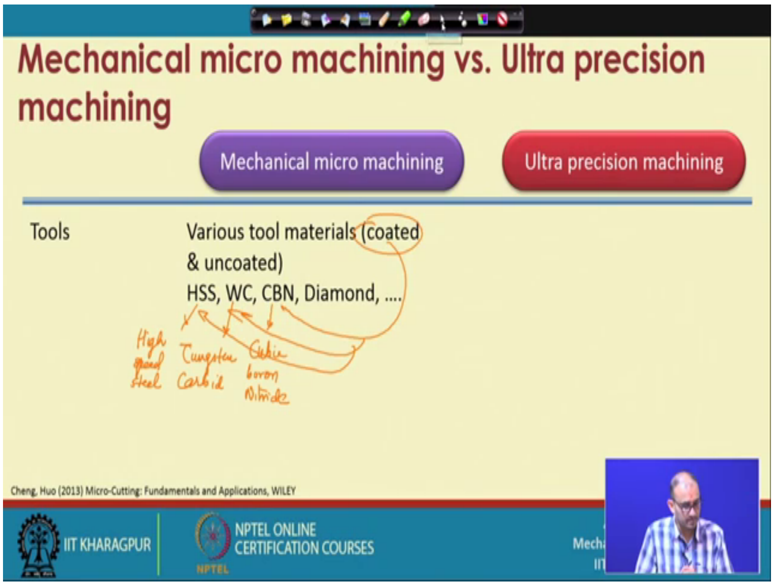


Now so, what are the different tools we can use, because we know this micro mechanical machining very easily. So, there are different type of cutting tools available quoted unquoted, and there are different materials also. So, this is called high speed steel. This is called tungsten carbide. This is called cubic boron nitride, and diamond is well known. So, we do some type of coating were. So, to increase the tool life of these particular cutting tools and so, that you can use the same tool for a longer period of time. And these are the cutting tools available.

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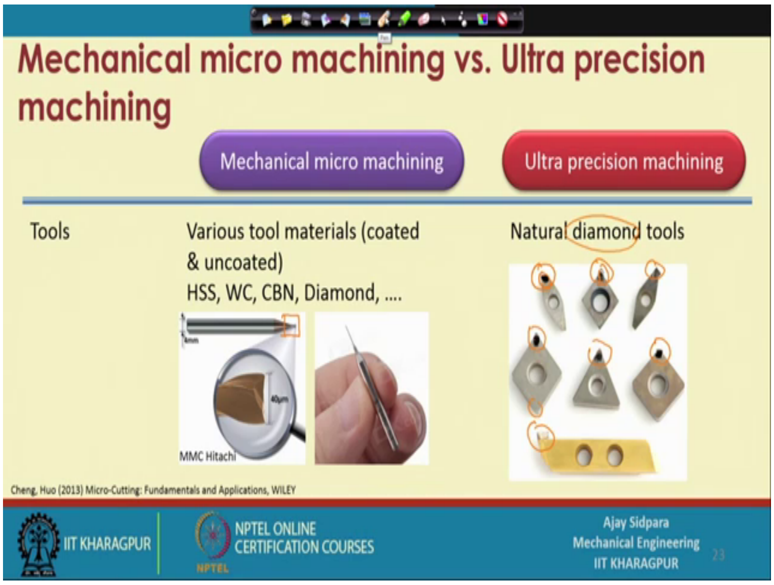


Now, if you see this is the n mill cutter, but only thing the dimensions are in micron size. So, this is the n mill the same diameter is 4 millimeter. And this is magnified and you can see here it is a 40 micron is the diameter of the cutting tool. And this is the drill available. So, here also you can do drilling operation briefly available tool is 100-micron drilli drill bit is available right now with a very reasonable price. And here what are the tools? The tool material is natural diamond that we have seen in the last slide that is why it is called the diamond turning operation. But here that whole tool is not made of diamond because remaining part here you are not utilizing for any type of machining.

So, here you can see that only a small tip of a diamond is solded with the surface, and then this particular bit is index or it will be hold with the particular tool holder. So, you once you use this particular thing, then after machining or once this tool is worn out then you put one another shoulder what you can use another tool.

So, here the part or the or the cutting tool dim geometry is very, very small in this case, and that is here you can see this really large amount of part is available for machining or the same material is because diamonds are very costly, and you are not utilizing the whole surface of the cutting tool or indexing tool for a machining. So, you it is better to distric our self where we actually do the contact with the work piece surface. So, these are the different natural diamond tools for machining under ultra-precision machining or the diamond turning operation.

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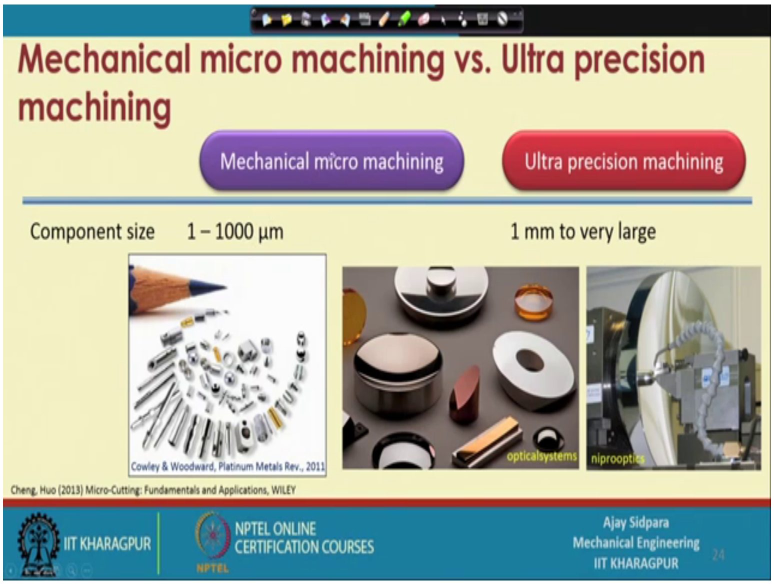


What are the component size here? You we have seen in that graph between the component size to the precision parts. So, here it is a one micron to the thousand micron that is up to the one millimeter. And these are the different component you have in see that many of thems are fabricated by the turning operation, many of them are for milling operation and some of them you can do drilling also was specimen of the component something like this.

And here it starts with the one millimeter to very, very large. Now most of the application of this diamond turning or the ultra-precision machining is the fabrication of mirrors and the lenses. Now if you see these are all highly polished and you can even see the reflection also be. So, roughness is extremely small as well as the tolerance are very, very high in this case. And this is a small component here, these are very small lens is available even you can appreciate the intraocular lenses also by diamond turning machine.

And here this is another operation or the another turning operation by diamond turning operation; where that size of the component is very, very large, and we can consider it a in a meter scale also. So, here to dimension range is very, very large, from one millimeter it can go up to milli meter size also even more than meter, but here the size of the components are very, very small because our objective is to machine this component, but at a lower pieces and lower the lower tolerance level.

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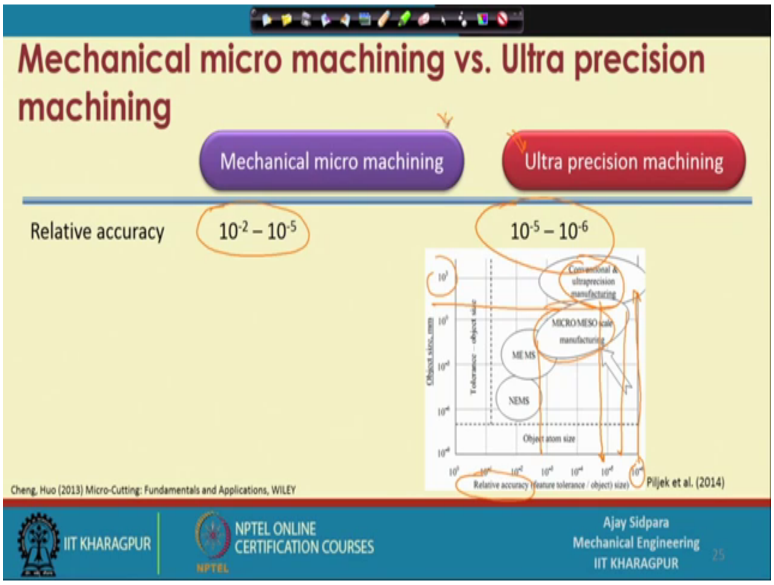


Relative accuracy that we have seen in earlier case that the from mems to the micromechanical machining the mems is the was relative accuracy, because you will not the get another chance of doing some type of correction by; that means, by grinding or lifting or some other finishing processes, you cannot reduce the size because the size of components very, very small and it cannot be a large amount of forces during machining.

But here it is possible to do little bit of machining, but it is even more tight in this case because the size of the component is very, very large. So, you have a chance of reducing the surface roughness or the tolerance level to a one more digit down to the required dimension. So, here whatever it is telling it suppose you want to make a diameter of 20-micron, 20 millimeter then you can go up to 20.601. So, up to that much precision is possible in the diamond turning operation that is the advantage, but another problem that you cannot do machining at a micro scale. That is in terms of component size.

Yes, so, same graph is here. So, our particular location of this part is here. And you can see the tolerance level, or the relative tolerance as here. And this particular thing is little bit expanded, but here you can see it can go more than 10 raise to minus 6 also in this case . But here the range is this much only. So, that is the advantage of going with the ultra-precision, if your requirement is with the high relative accuracy. You can go with this, but the dimension of the part is also very large you cannot do machining with a very, very small component, but here you have this part.

So, more processes have their particular domain of applications, where one process is useful another is not in other particular domain. This particular process is useful, but this one is not. So, that you have to select the process depending on the requirement and the accuracy.

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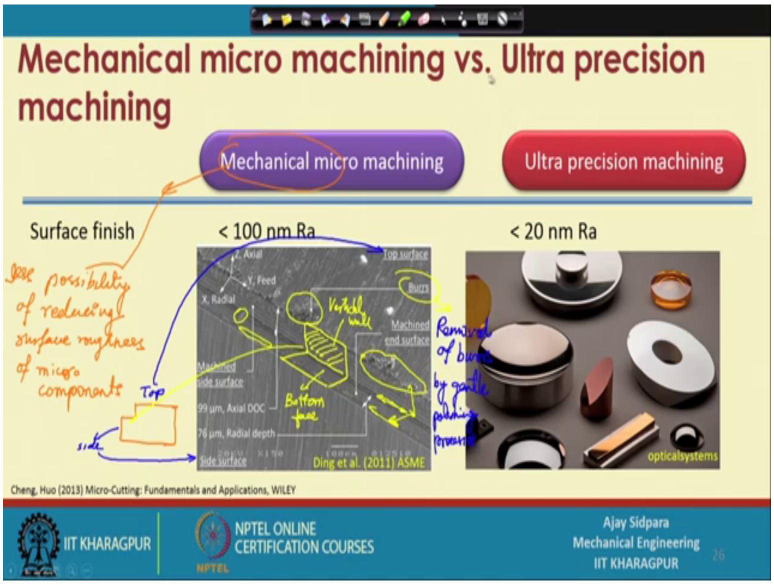


Now surface finish requirement now we know that once you complete the component machine by the micromachining process, by this particular process you do not have chance to reduce the surface roughness. No possibility reducing surface roughness, rather we can write something less because if the dimension very, very large suppose consider it is a 900 micron or something, then you can do little polishing by a gentle polishing processes.

So, let us light is a less possibilities reducing the surface roughness of micro component. Because now you can see this particular feature now it is a milled component, now where it is milling is done now this is the milling is done at this location. Now this is the top surface, this is the side surface, now this side surface is written here and top surface is written here, and this is the slot it is cutting. So, this particular surface is this one. And this is the edge of this part.

So now you can see that how this thing is visible. So now, this is the vertical surface, vertical wall and this is the bottom face, correct? And now you can see there are many things are here. First thing is the these type of things. So, these are called burrs, that is already written here. So, these are the bar and if you see the surface also, now surface is also not smooth here. You can see there are lot of inter surface inter debrises or many things are there burrs are locate on the top also some debrises are also available someone removed material which are loosely bonded with the surface that is also available.

Now, if you use this particular part for the later application, it is difficult to use it, because there are lot of join loose materials available that will create problem in assembly or the final operation. So, what we have to do that if the dimension is very large now, if you see it is a 100 micron. So, these particular dimension is probably 100 micron by 100 micron. And this is open; that means, you can actually see by the microscope it is not something inside the component. So, if you do some gentle polishing operation, there are many advance polishing operation available which can do some type of polishing. So, how to remove this burrs? So, it is removal of burrs by gentle polishing processes.

And so, if I mention is very large and you can actually access, that particular feature when you machine it, then there is a chance of doing that thing. But suppose you you have drilled one hole, and after drilling suppose you want to if you want to do some type of removal of the material or dimension of clearity inside the hole, then it is difficult because you came not in a produce inter inside something the something like a rimming tool over some type of other owning tool or something like that it is difficult to access that particular hole.

So, these are some of the way you can do polishing or some type of e regular to removal, but that depends on where those pictures and located on the surface. Now coming to the surface rough finishing in the precision, because now here surface is very, very large and the diamond there is the very, very stable component because here we are using diamond for fabrication of the nonferrous materials. So, it can retain it is geometry for a longer time, as well as sharpness and the other features of the cutting tool.

Then that is the reason that you can get a very, very fine polish surface is and many times you even do not need any type of post polishing operation, because many application need surface roughness around 20 nanometer or 10 nanometer, you can directly use this component for the final application. But again we know the diamond turning is a turning operation. So, ultimately it also creates some turning marks. So, those turning marks can be reduce or can be illuminated in the final finishing operations; that is, performed by the again this is gentle polishing processes. We will discuss some of the processes at later and the course will continue.

So, here these are the 2 different ways to distinguish between the roughness roughness is very, very large here comparatively, but it is very small here because components are very large and you have provision of polishing of this component further in the process.

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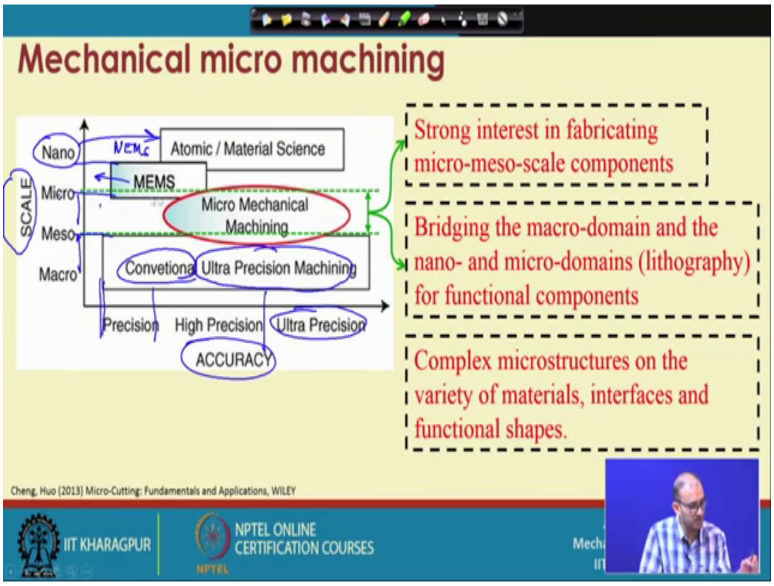


Now, where these micro mechanical processes are standing?

In between the other processes. Now, this is one another comparison. Now this comparison is with respect to the scale of the component this is the accuracy. We have seen earlier also, but here this is giving a overall about this thing. So, if you see this nano scale actually nano scale mostly it is atomic and material science, where we talk about the grain size and the dislocation density inside the material and support are the features within the grain. So, in some of the process, we have seen it is called nems nano electromechanical systems.

Now if you go down to the micron sized, than between the nanometer and micrometer we are working with the mems product. So, each dimensions are; obviously, smaller than the feature size which we can create by micro mechanical machining, then come something between the millimeter to the micrometer size. So, here we are working with the micro mechanical machining, then when the part size is very, very large from mean one millimeter to the meter scale then we have conventional machining processes and the ultra-precision machining processes.

Now, coming to the z scale so, these are the different zone of the precision high precision and the ultra-precision part. Now if you consider conventional machining processes and ultra-precision machining processes these 2 are combined here because both the dimensions are almost same. So, you can have a very large variation in the precision zone, that you can create a very, very less precise component also by normal cnc cutting milling operation or the turning operation. And if you want very, very fine feature then you can go with the diamond turning operation.

So, all these things are important here. Now if you see if this particular thing is not available. Suppose, micro mechanical machining process are not available. Then we are missing something between the one few of millimeter to few of micron. Because this is the domain of the conventional ultra-precision machining this is the domain of the mechanical electromechanical system. So, to bridge these particular things, we need something which can fulfill our requirement between the meso scale to micro scale.

So, that is the reason that we are more interested in fabrication of the component by mechanical micro machining. And it is bridging the gap between these particular domains, because one way it is a lithographic based processes available another way we have conventional machining process available. These are very costly processes, here it is a reasonable cost, but the problem is that you are not getting the required size neither in this mems product nor in the conventional machining process. So, it is very useful to bridge this particular gap between the mems and the processing. So, you can get the functional components.

Complex microstructures on the variety of material interfacing and functional shapes can be produced by the mechanical micro machining processes because when you would see the complexity of the structure, only possibility that you do this same operation at the macro scale or it a bigger size. But if you go on the upper side of this dimension; that means, on the smaller side of the dimension, complex structure cannot be fabricated. Because these processes are unable to fabricate the z dimension at a larger stage so, that is the problem of this mems protocol some other components.

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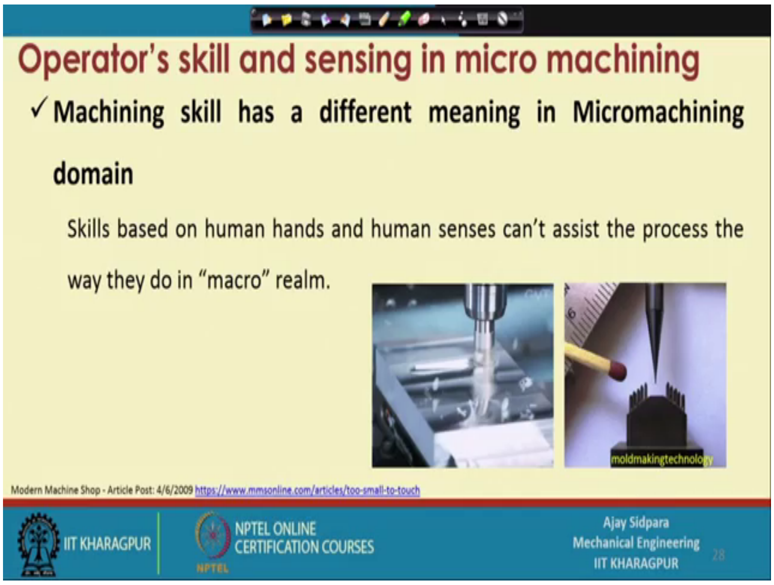


Now, how these things important now if you see a one operator who is operating a micro machine or the conversion machine came the same person can operate the micro machine or not. So, there are different aspects of doing this thing because operator gets some knowledge or expertise when you operate the machine at the micro scale suppose, one operator is operating a machine for a many years.

So now here some intrusion that if some particular noise is coming out of the machine he understands that this is what is going probably go hyphening there, you can control the machine very easily, because that is by some type of noise judgment. Because he does not might actually what is happening, but because of the large experience he can actually operate the things very easily in this case. So, that is different.

So, but problem here in micro mechanic machining, that those things will not help to this particular part; why not happening let us see their thing here. So, machining skill has a different meaning in the micro domain. How? That means this skill base on human hands and human sense cannot assist the process, the way they do in the macro realm. Because we know there how to operate the machine, because everything is visible all the things are very, very clear to our mind, but that thing is different in the micro domain.

Now, say this is the operation we know the how chips are moving tool is in contact with the surface that also we know, if tool is broken that is also visible, but when you go with this particular part it is very difficult to find that how things are going on. So, here there are 2 different way the even experienced person is also fail to make the judgment at the micro scale. So, what are those 2-different type of things, that how operated knowledge is not making any help or not making any sense in the micro domain. Or he has to develop some extra knowledge about the process by trial and error that we will see in the next class.

Thank you very much.