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

Lecture – 01
Introduction

Good morning everybody, myself Ajay Sidpara from Mechanical Department IIT Kharagpur.

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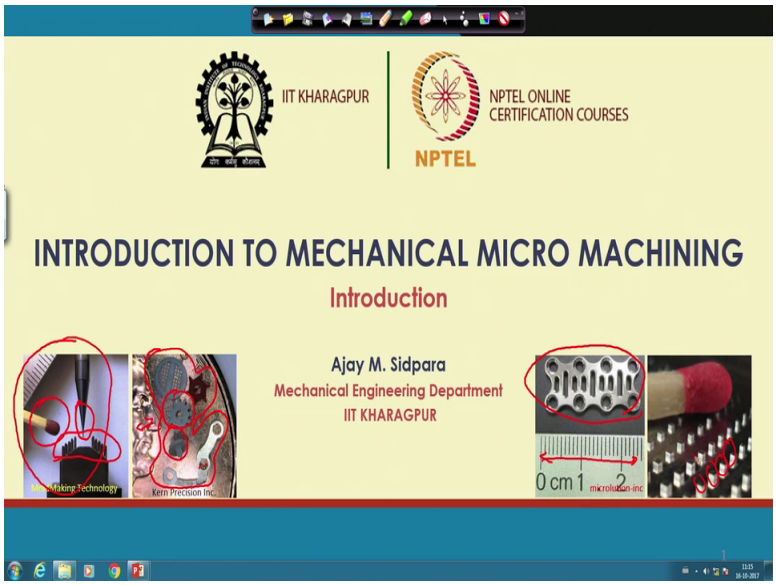

I am telling you about this particular course, explaining about this course is related to introduction to mechanical micro machining processes. And todays class we will be related to introduction of the processes. Now if you see this particular first slide then there are 4 images, this particular image is related to the fabrication of a micro mold using a micro anvil cutter. Now with reference to this match stick you can see that what is the dimension of this anviling cutter, and what is the dimension of the fabricated component. So, this is how this machining process works.

Second figure is the different type of components metallic, as well as non metallic on a different frequency that this is the gear and this is the one type of sprocket of this gear, and this is some type of joint where the gear will entered, and then you can get the part and this is the dollar point and you can see that how much is the size of this component.

Third component is a one type of plate which will bone plate which will go in your body to support the broken bone, and you can see the dimension is from here to here it is 2.5 centimeter. And you can see what are the different features which are created on this bone plate and you can a sense the what is the complexity of making this component.

Last one is the fabrication of a micro pillars at a particular pitch in an x and y direction and you can see the dimension with reference to the match stick. Now, you can see that there are different type of components which are very difficult to visually see. So, you always need a microscope for fabrication of this component.

So, introduction of this course is mostly related to the introduction of the different component processes, classification of the different micro machining processes, and see that whether miniaturization is important or good or not for different type of applications.

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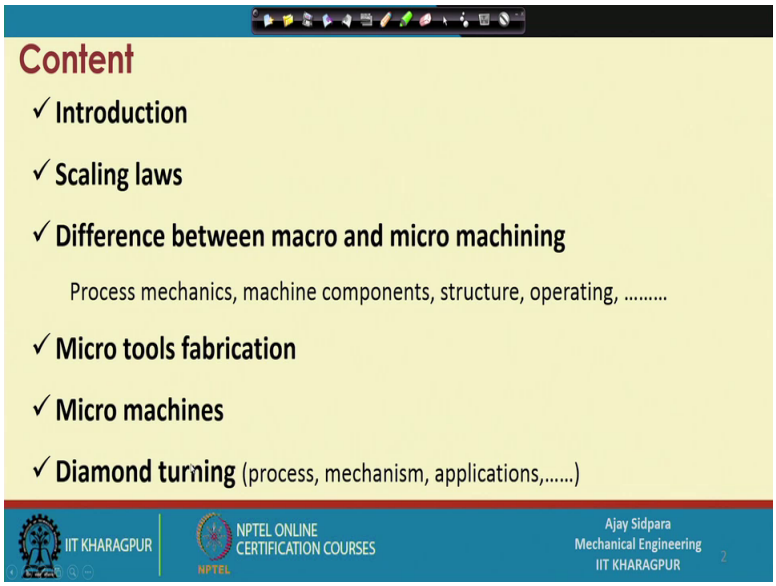

Now, content of this course is first is the introduction we will cover most of the processes, which are used for fabrication of the micro components not only related to the micro mechanical processes.

Because micro mechanical processes what we are going to discuss it is related to the milling operation, turning operation, and drilling operation, but apart from this there are many processes which are also can be used for making of different type of components those are called advanced machining processes, which consider the EDM process that is

electro discharge machining process, electro chemical machining process, laser beam machining process, iron beam machining process, electron beam machining process, as well as different type of hybridization of this processes to get the advantage of the two different processes.

And other than that there is one particular domain it is called etching in the deposition by which you can get the different micro scale component, but those processes mostly favorable or used for the fabrication of memes product, that is called micro electro chemical system component, but we will see the classification of different type of processes in this particular introduction.

Then second is the scaling law. Now, if you see that when you scale down a component, first you have to understand that whether it is a favorable or not, so you have to follow some type of physical law by which you can see that whether the dimension can be reduced or not, or whether it is a good or bad for the particular system. So, scaling law will tell you that whether you are going in right direction or you have to stop for. That thing or you cannot go at all in that particular reduction in the dimensions.

So, we will go with the different type of example, where see it will tell you that if you reduce the machine size from a bigger size to down side, what are advantage, what are the disadvantages, or what things you have to take care when you are designing a machine or the product or a component at a micro scale. So, those things will be covered in the scaling law.

Then the difference between the macro and micro machining, because we all know about that conventional machining processes, those are processes are milling drilling and turning operation. So, and we have also performed lot of operations. Here also we are going to do the all the same thing, but only difference is the size of the features or the component will be at a micro scale less than 1 millimeter or dimension. And those thing will make differences, because what are those difference is first thing is the process mechanics.

In process mechanics what happened the way the material is removed in macro machining; micro machines are different. So, we will see that how those things are different in terms of the uncut chip thickness, related to the feature or geometry of the cutting tool, RPM of the spindle, then we need something about the coolant, then

different type of others miscellaneous features which will be affecting these particular combination of macro machining and the micro machining.

Second thing is the machine component. Machine component means what things you need from the machine. So, if you are using a one particular micro cutting tool, considered end mill cutter of a diameter 500 micron. If you are using that particular cutter to a conventional machining is it possible to do machining or not, so first thing you have to ask that question to the machine. So, if you are getting those results or you are not getting those were that will be decided by the machine component, the how much precise is the machine that will tell you that whether it is a doable or not.

Then third one is the machine structure. The how this structure will help because we know that machine structure has some stiffness, so if machine structure stiffness; that means, all joints should be completely firmly gripped or firmly joined. So, if you are doing machining there are obviously, forces from the tool side as well as work piece side. So, if you are not holding the work piece properly, then you will get some type of vibration in the work piece, and that vibration will be propagated throughout the machine bare to the machine structure. Same thing will happen from the tool side, tool bare basin will transfer to the tool holder; tool holder to the spindle, and spindle to the main boarding.

So, stiffness will make the difference here. So, how much if your structure is there that will be decided by the different type of component and the structural part of the machine. Then operating is the 1 parameter, now you know that if you operate a macro machining of machine, and another one is the micro machining operation those things are different.

We will see that how these things are different because operator will not get any information from the machine which is very easy to get from the macro machining by means of sound, some type of visual confirmation, but those things are not available in the micro machining. And there are also available topics also available related to the habits or the environment of the machining operation where it is being done, and these things we will cover in detail.

Then micro tool fabrication because we know that we are using milling turning and drilling operation so; obviously, we need tools. So, if you see at macro operation that it is a conventional machining you can visually see the cutting tools, but here when you are

talking a dimension less than 100 micron or less than 500 micron visual location finding location of this tool is very difficult.

So, you have to fabricate micro cutting tools. So, we will discuss different type of processes here, which will be used for fabrication of a different type of micro cutting tools that we will discuss in detail. Then micro machine, so up to this 4 point whatever we are discussing here those 4 points will be covered related to the machines which are in the same scale of the micro machines tools.

Because here if you say that you are making a small component by you are utilizing a very big machine. So, whether it is a good to use a very large volume space of the machine to make a small component, or you should reduce the size of the machine itself to fabricate those components. So, we will see some advantage and disadvantage of this particular scaling down of the machine to fabricate the micro components. So, that will be covered in these components.

Then we will cover diamond turning operation. Diamond turning operation or the diamond turning machine is actually not the micromachining part, but it is a precision machine, but we are going to cover here because some aspects of these particular machining process is related to the micro machining parts. And it is also turning operation, so cutting tool will come into contact with the work piece; work piece rotates and physical contact will remove the material from the work piece. So, that also comes under the micro machining zone.

But the size of the component sometimes in a meter scale, but the roughness is at a very small scale it is a few tense of Nano meter. So, we will cover here the what are the different process is available, or the different classification of diamond turning process, mechanism at which it removes the material, and lot of application because mostly it is used for nonferrous material and fabrication of mirrors, and lens of the glass, and some type of polymer materials.

Then we will cover some aspect of the sensors, because we know that we are not able to see the machining operations tool, and the features which are created or which are being created on the work piece surface. So, we have to mount some sensors to monitor the process as well as the status of the tool, and we have use some cameras high magnification cameras. So, we can directly see what is happening inside machining zone.

So, those things we will cover that which type of sensors you require to sense the small amount of force is, as well as the status of the machine tool as well the tool. Then at the end we will cover some metrology, because once you go through the different type of operation ultimately you are getting one job out of the machining process.

So, then you have to see the dimensions because if the size of the components very big, then by naked eye also you can actually feel the surface roughness you can find different type of tool marks, whether roughness and the size is accurately machine or not, then you can go with a different type of tools which are very large in terms of fabrication of the component.

But when we are talking about the micro machining the components at the time size of the component is very small, you have to also say that tool we are what is the tool where whether we can use the same tool for the next operation, or you have to use the fresh tool.

So, those things you have to go through the metrology part, that there are different type of metrology or the equipment available which can do measurement at a micro scale, some type of things are contact type some things are non-contact types. So, we will cover some of the equipments which are routinely used for characterization of the machining components as well as the tool parts. So, this is the content of the particular course.

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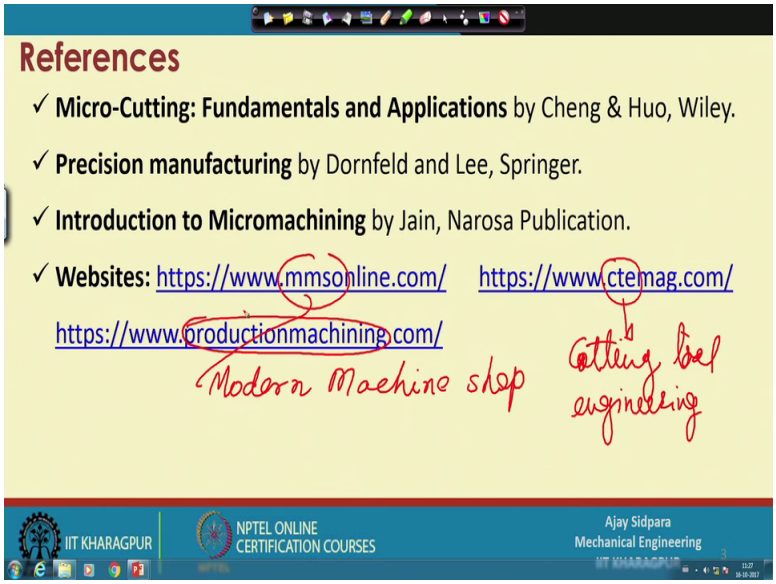

What are the references, so these are the references one is the micro cutting fundamental in application by Cheng and Huo. It is Wiley publication here you will get the information about the all the milling operations, turning operation as well as the diamond turning operation.

So, as well as the theory and some other parts, which will be very convenient to reference, then precision manufacturing Dornfeld and Lee, Springer publication here you will get all different type of structural part that what are the different errors, encounter in the precision machining.

Then how you can remove those errors, and how you can measure those errors. As well as same thing about the first fabric first reference, that is related to the conventional machining processes, compared to the micro machining process, decision machining processes, and some type of sensor that is mostly related to acoustic machine sensor, and some dynameters.

Then introduction to micro machining by Jain, Narosa Publication, here you will get different chapters in the micro machining domain compared to the other two references, this is more focused on the application point of view, and here you will get all advanced machining process is also, electro discharge machining, electro chemical machining, conventional meaning operation. As well as some type of metrology related chapters also. But more important are this three websites.

Now, you know that it is very fast moving technology related to micro machining. So, it is very difficult to incorporate all this particular advancement or the technological advancement in terms of books. Because the way websites and the technologies is updating you cannot update the books. So, this 3 website, so one is the mms online that is the machine.

So, this is the modern machine shop, machine shop online, then this is the cutting tool engineering, magazine dot com and this is the production machining part. So, here you will get lot of different type of magazine, as well as the broacher of the companies who are updating this micro machining domain. Because after every month or after every 6 months you will get one products which is very useful for fabrication of the different of micro components.

These three website will give you let us update about this particular course, which we are going to cover so many things I have covered from these three websites, which are routinely not available in the text books as well as some other reference books.

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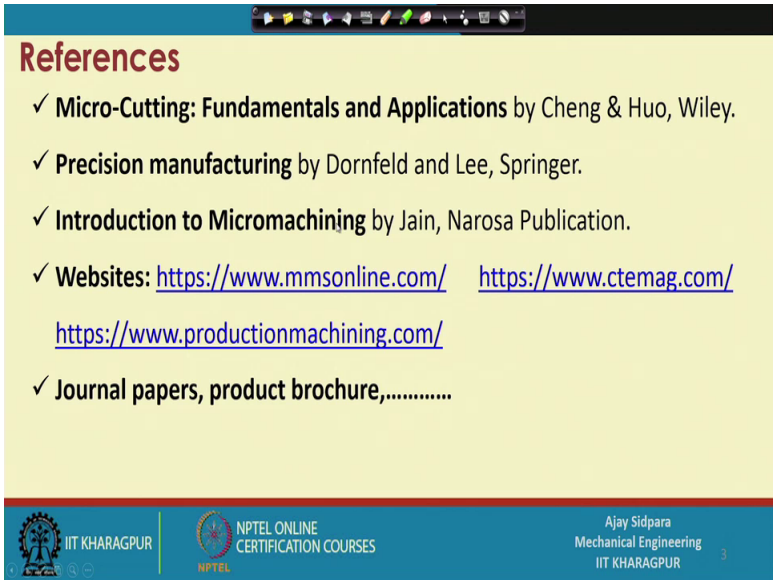

And then; obviously, journal papers product brochures from the different manufacturer, and this all things will give you the very reasonable amount of understanding about this particular course.

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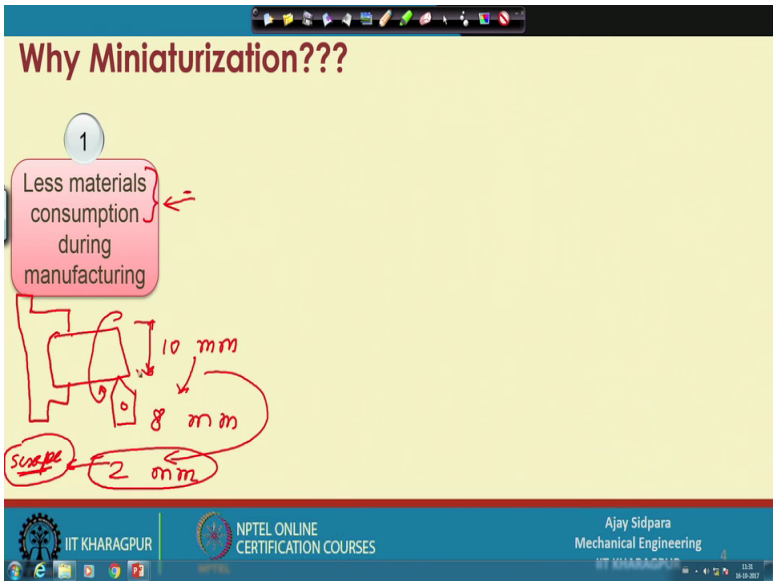

Now, let us start the course now first question you may ask that why we need miniaturization. Now if you see the different products, if you see our laptop, our computer, our tablets, our mobile phone, every things are sinking in size and weight. Now, if you say very light weight computers tablets available even mobile phone also, but we are not compromising with the functionality. Every time the thickness and the sizes reduce your functionality also increases, because that is both things are in a opposite manner.

If you are reducing something you have to compromise, but we are not compromising anything. So, what things are making this possible, so you might have seen that very thin even 5 centimeters, 7, 5 millimeter or 7 millimeter thick mobile phone and tablets, and still you will get the very large amount of response or the functionality from this things.

And other than that you have seen the different of a medical component the way, we are putting syringe in our body those things are also very small. Sometimes it is very difficult to sense pain also, when it is going or come in setting in our body to get some liquid or some liquid. So, in that case we have to understand that what things are driving this particular field. So, what are the advantage that why we need miniaturization.

So, first thing is a less material consumption during manufacturing. Now if you see the latest turned one component. So, this is the turning tool, and it is removing the material now considering the initial dimension is 100 mm, and you want to reduce it to 80 mm. So, how much you are removing you are removing 20 mm material. Now here you can see that you are removing 20 millimeter of material in terms of diameter and this will be the scrap.

So, here scrape material is very large. Now consider your diameter is 10 millimeter that you want to reduce to 8 millimeter, so how much you not really removing material of 2 millimeter. So, if you are compare these two example, you can understand that amount of material you are spending is very less and; that means, your input or the row material is very less in terms of volume.

So, you can get a large number of pieces from the same volume, if you consider a block of a 100 millimeter by 100 millimeter, you can get very small component consider 10 millimeter by 10 millimeter by 10 millimeter. So, in that case you can get a large or the

more amount of component from the same volume, which is difficult to get from the bigger size component.

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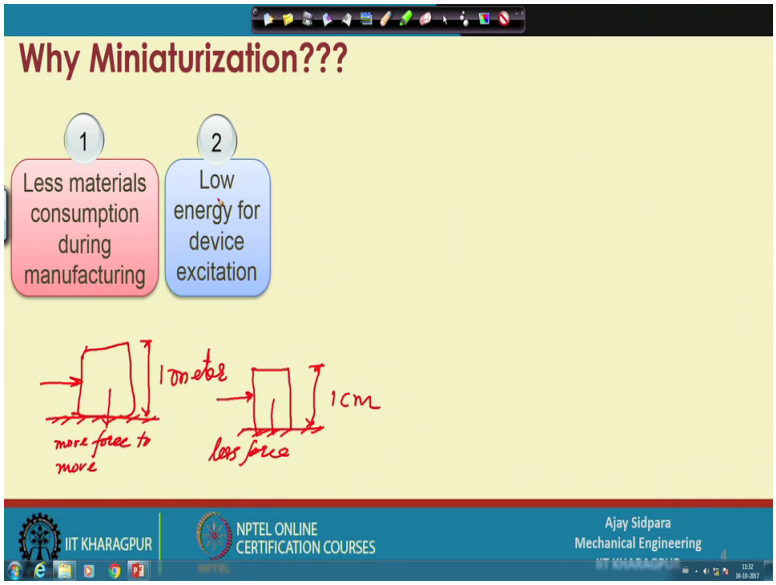

Second is the low energy device excitation. Now you can consider that suppose we have one block, this is considered 1 meter, and we have another block 1 centimeter. Now if you want to displays this particular component, then you have to give more force here.

And here less force, because the weight is very large here and here weight is very less. So, considering this example you can consider that if the component size is very small, you do not need large amount of force or the energy; that means, your input or input voltage, whatever you are using it will be very small. So, in that case you can actually save large amount of energy in a machine, in a operating or this particular machine, or the component when it is in the operation part.

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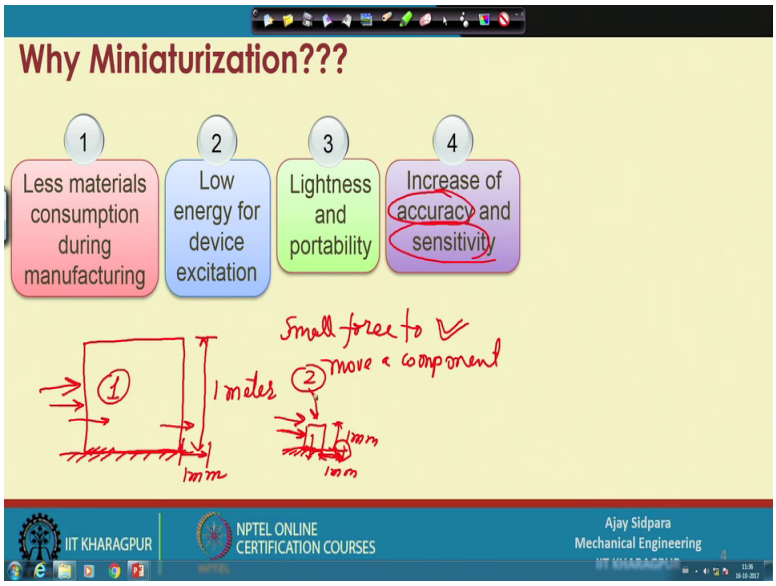

Now, third one is the lightness and portability, because here you can see that if your component is very small; obviously, it will be very light. So, this is obvious advantage, then portability what is portability; that means, if your component it is very small you can easily transfer or you can easily transport to another location, without utilizing very highly sophisticated material handling devices.

So, these are very portable in the sense suppose you have one machine, which you and some components are at a micro scale, you want to move to another machine by chance that machine component is not working properly. So, you do not need a crane, or you do not need some type of material handling device, you can easily pick and place to that location very conveniently. So, that is the obvious advantage.

Then increase of accuracy and sensitivity, now accuracy how do you increase the accuracy. Now suppose you have 1 block, consider this size is a 1 meter. And you want to move this thing only 1 mm. Now another component we have that is 1 mm component and that also you want to move 1 mm. Now if you see this particular first component and this is the second component.

So, in this case it is very difficult to move such a big component to a 1 millimeter, because it has a initial friction and that overcoming of initial friction; friction, sometimes what whatever it will give you a very jerk movement. So, it is very difficult to move smoothly of this particular big component, but it is very easy here because here the

weight or the friction is very less in this case, because you can give a very small amount of force and you can precisely move something like this. You consider a another simple example, that suppose you want to move big table to a 1 millimeter of displacement that is very difficult, but if you want to move 1 pen from 1 millimeter to second millimeter it is very easy because you can easily move it from one location to another location.

So, that is the advantage of increasing the accuracies, you can get a required displacement and it can raise to the exactly it is a dimension to the co part. So, that is the advantage of that then coming to the sensitivity. Now it is sensitive because now see the amount of load you required here, suppose it very high and here the amount of load which is required or the force required to move it is very less.

So, small force will give a displacement small force to move a component, so this is the advantage, because you do not need to give large amount of force. Now consider our live lively example suppose elephant and particular main available. So, if you put a syringe in our body it is we can get some pain at initial state, but if you put the same syringe into the elephant body it will not get that much amount of pain, because the body is very large. So, in that case the same thing happens here that sensitivity increase is with reduction in the size.

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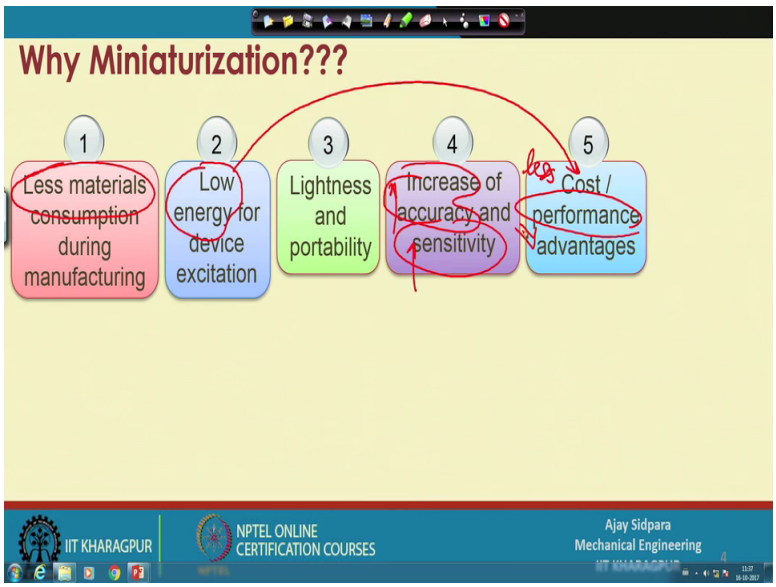

Then cost to performance advantage, now how this will matter because when you are spending less amount of material less amount of energy then; obviously, it will result in

the less cost right. And then we know that performance; that means, how to increase the accuracy, and sensitivity if you increase both the things high then; obviously, your performance will be very high. So, in that case if you reduce the component size obviously, you will get the cost to performance advantage.

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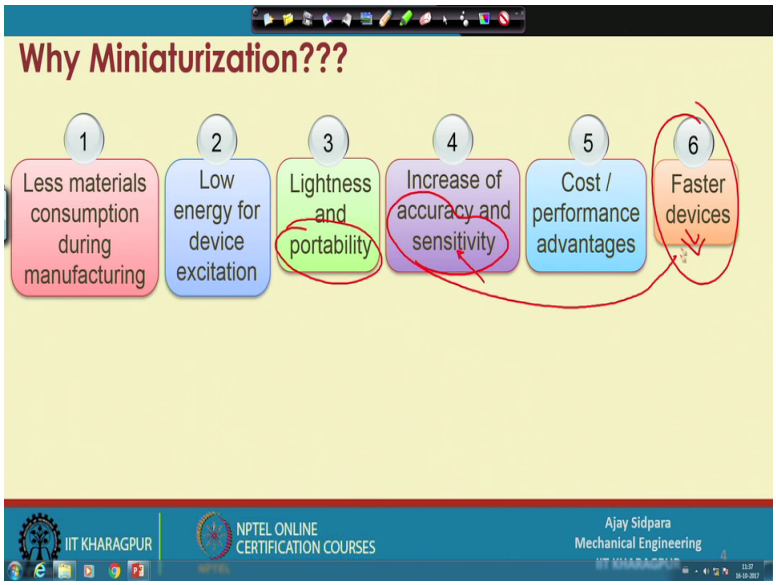

Then faster devices, so how devices are faster because we know that we have to give a less amount of energy to sensitize; sensitize, means that suppose you are pushing a small amount apart it will directly move does other location. As well as you if there are portable in the nature, so you can easily move also, so that is the obvious advantage we do not need much discussion on this particular point.

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Now, what are the trends in miniaturization, because we have seen in our daily life there are many components which are very small in the size, even some big components also very small features on the top. So, if you see our mobile phone and open the mobile phone you will find different type of screws available which are very difficult to join also there are specific screw driver also available, which will remove those thing if you open the your wrist watch.

Then if you see the base or the plate of the wrist watch, if you will find different type of gears available, different type of slot cutting, different type of threads, which are particularly useful for the fabrication of a micro components. So, these are the different type of trends available these are very old example. If you see the new example micro robots are available even the medical components, or surgical components, or the surgical tools are also very sharp and very small, so that you will get the less pain when it is under operation.

Now, what are the trends that makes systems and device more intelligent and autonomous, so let us see some examples, so this first example is the microbot medical. So, this is one robot. So, this robot is used to go in our body and then do some type of operation or do some time type of understanding about what is happening there.

So, these are wirelessly operated so, there must be some things which is getting the signal from the outside or from the remote. So, you can understand the what is the size of

this robots, and what are the size of the components which will be used for fabrication of this robots.

Another example is the quadrocopter. So, here you can see the dimension compared to our finger there are 4 routers available. So, you need a one 4 motor for that it has a light, it has a camera, so that you capture the different images, and everything is encompassed within a small dimension. Now as well as it is a remote control, it is wire wireless so, there must be some battery available. So, you can understand that how much is the system or the how many components are in built into this particular copter.

So, understanding those thing will make you realize that how much is the difficulty in making this component. Another medical related example is the endoscope because endoscope is used to insert in our body, and find out the location or see the what things are there by in terms of the live video or recording or well capturing the images, if you if the diameter is very large, so that when you are putting in our body it will give a pain to the patient also, and it will be difficult for the doctor also.

Now, how much you reduce the size of that tube. So, smaller the size smaller will be the pain to the patients as well as the easy for the doctor. So, that you can easily go into the body and get the required things done, but there are many things because this particular endoscope has a camera it has a flexible body. So, that you can move at some different location, it has light also because inside you may not get enough amount if brightness. So, that it can capture the images in a presence of light source.

So, everything is income and everything should be wired, because this cannot be remotely controlled because you need a wire. So that you can move here and there easily and you can get the required things done.

So, how to make this systems and devices more intelligent opposes this you have to put lot of sensors. And once you put the lot of sensors, now you see the and what size you are actually reducing the dimension, in other side you are talking about putting more and more device inside it. So, this is very difficult. Now if you consider a if just reducing the dimension no problem, but you are also incorporating some extra component that is in terms of sensor.

So, sensor side should also very less. So, in both the case you are end up with a shrinking of the system as well as the external component which should be even smaller than the size which is routinely used. So, in both the cases you are how to think about the processes which are used for that.

Now, another condition is that cost and energy consumption should not be exceed the acceptable limits. Now if you see the one component which is micro component and another is the macro component; macro component is the bigger size component, but if you are spending more money and time in making micro components compared to macro components, then it is not the right thing or it is justifiable that why we are moving in the this direction.

So, there is a limit somehow related to the time and energy, and the cost which you are putting in fabrication of the micro component. So, you have limit on that side also. So, from every side you have pressure one is the how to shrink the components, then you have to add more and more component inside it, and while fabricating or under operation the cost energy and time should not be large.

So, now how to do all these things that will create more challenge to the fabricator or to the engineer who is making and designing these components.

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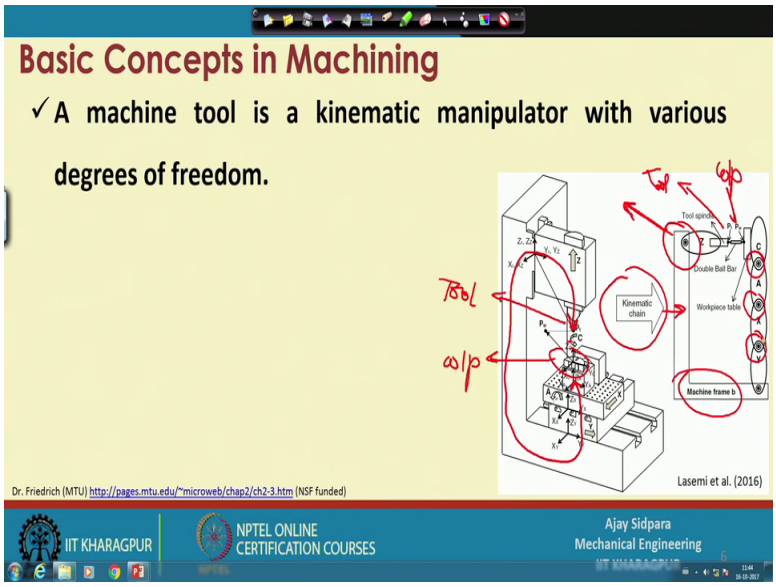

Now, what are the basic concept of the machining now see, machine tool is a one type of link yes that there are different type of links available which are joined with each other, and then you do a machining operation.

Now, if you see this particular thing so, this is the tool. This is the work piece, and then tool is connected in this direction, and then it will go. So, this is a one particular loop. And all loops if you transfer this all the things in a kinematics chain. So, this is the machine frame, this is the work piece, and this is the tool, and then everything is connected with each other.

Now, if any of this joint is not working as per the designed part then whole part, whether it is a micro components or the macro component it cannot be as per the dimension. So, you have to get a 100 percent work out of all this link that mean there should not be any type of loose fit or any things which will create a problem at the later stage on the fabrication of the component.

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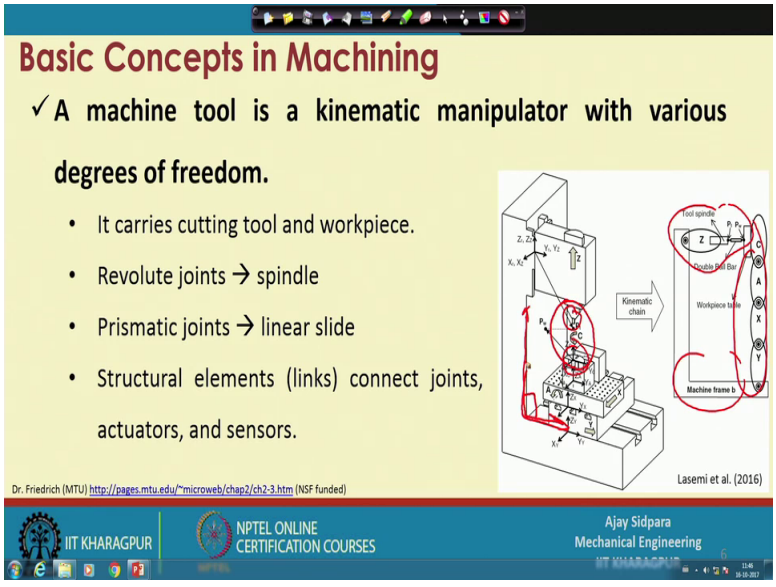

So, it carries the cutting tool and work piece that we have seen that, this is the work piece and cutting tool it is creating. Then there are joints because spindle is rotating. So, it is revolute joints then prismatic joints are spindle will move up and down that is called the translation motion. And then x and y motion is also there. So, this x and y motion it also considered as a translation motion.

Then there are structural elements. So, this is the 1 element, this is the second element, then the table x y then fixture then work piece fixture tool fixtures. So, this old things considered is link, which will connect the joint actuator and sensor and everything. So, now, if you consider all these components only thing you have to make sure here, that your contact point of the work piece and tool should be perfectly uniform, and it should constantly do operation of the part.

So, now making these things happen what you have to do the structure of stiffness would be very high, there should not be any type of loose joint or there should not be any type of aging of the component within a short duration. So, you have to also monitor the life of the machine also compared to the macro machining, because there the you can operate many hours of operation without looking at the structural deformation of the machine itself. As well as temperature variation, what is the temperature variation how different sensors are working, many times we do not care or do not give more importance to those things, because their things will not make much difference to the component which you are making it a big size, but when you are making those component a small scale at that time everything matters. You cannot ignore even a single parameter which was not affecting in the macro scale.

So, here what we have to see that if you are looking at these part any joint here over here, everything matters that you how to make sure that this is at the right angle. If those things are not right angle, then your part will be different even if you are using all the components same; that means, everything is working perfectly fine, but if you have some error in the kinematic point of view that 2 axis are not perpendicular to each other then you are end up with some type of (Refer Time: 33:08) So, let me finish this lecture here, we will continue from these particular slide in the next class.

Thank you very much.