Introduction to Mechanical Micro Machining
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Lecture – 02
Introduction (Contd.)

Good morning everybody, welcome to our course on Introduction to Mechanical Micro Machining Processes. Now, in the last class we have seen some of the view of the miniaturization, initially we have seen that why we need miniaturization.

So, here we have discussed about the amount of material which is consumed in the fabrication or the making of this components, then the energy requirement to operate this components, then the lightness and the portability of this component that these components are very small and you can move very easily. Increase the accuracy and sensitivity because smaller components are very sensitive to the external disturbances and cost and performance advantages and finally, the faster devices.

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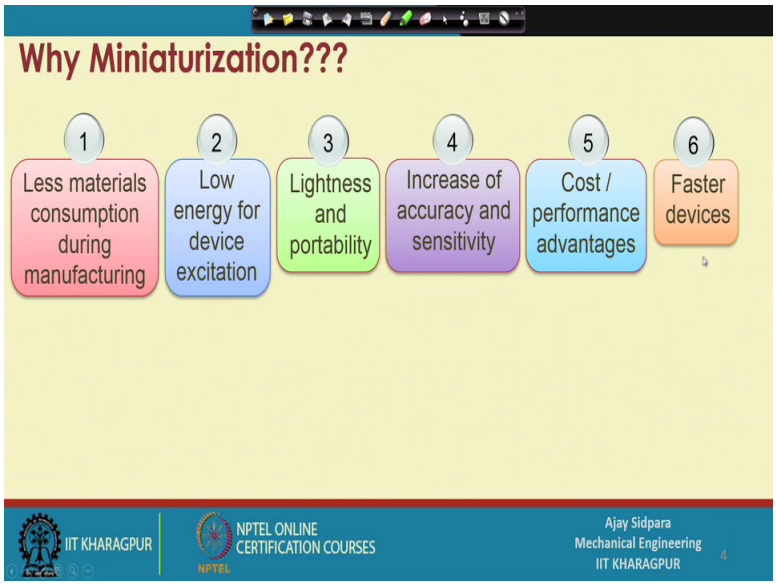

Then what are the trends in miniaturization, we have seen some examples, like the very small micro robots. One is the quadrocopter and with size is very very small comparing with this our finger and one medical example is the innovation in the endoscope.

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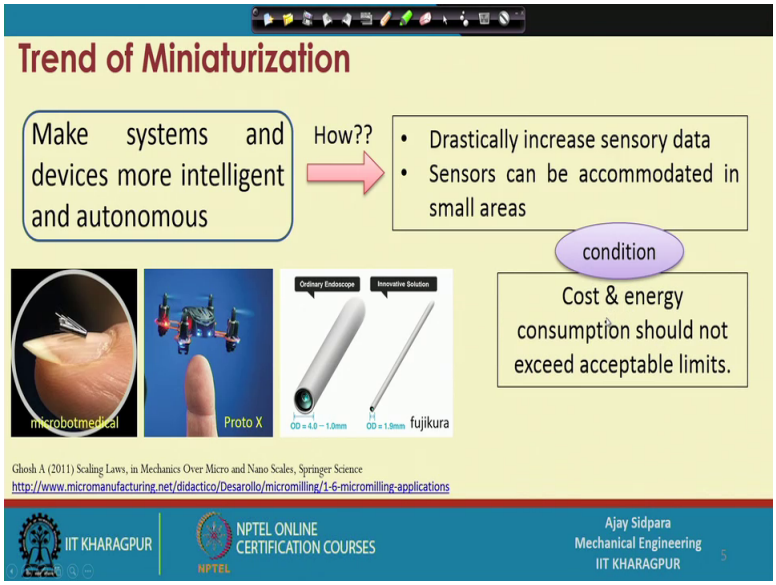

Now, we have also seen that how to make these component and what things are required that we have to increase the sensory data as well as we have to cramp lot of different type of sensors. And that is condition that which should not actually increase the cost and the energy requirement of this particular components.

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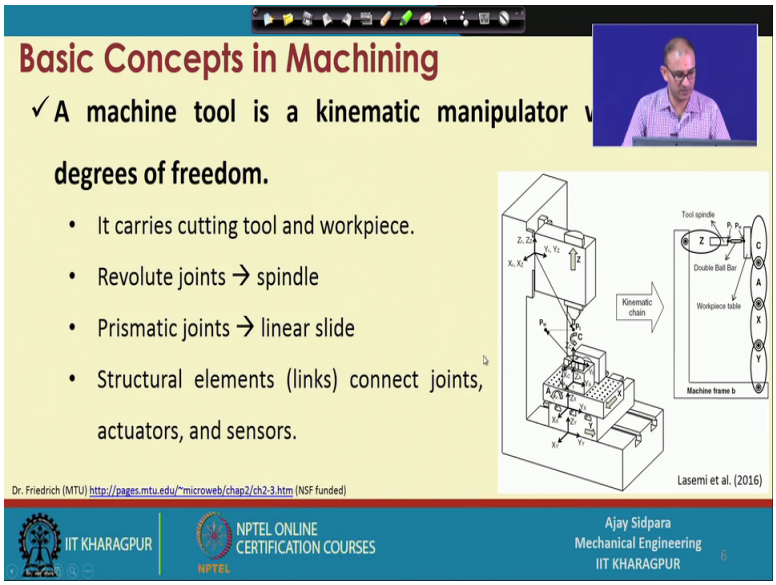

Then moving to the machining we have seen that machine tool is basically the kinematic linkage between the different components. Here is the tool and the work piece and then it is moving in the structural part of the machine tool and if you convert this machine tool

in terms of kinematic chains then there are lot of linkage, because work piece is connected with the work piece fixture then it is a table, then x y axis, then going into the machining frame and on the top tool side tool is connected with the spindle the spindle to the z axis and z axis to the machining frame.

Now, we have seen that you if one of this linkage is not performing as per their design requirement then you cannot get the component whether it is a micro domain or the micro domain. Component should perform its work which is assigned during the operation. And we have seen this, these are the different type of joints available prismatic joints revolute joints and all joints will give you a continuous motion, so that you can get the required dimension machine on the part.

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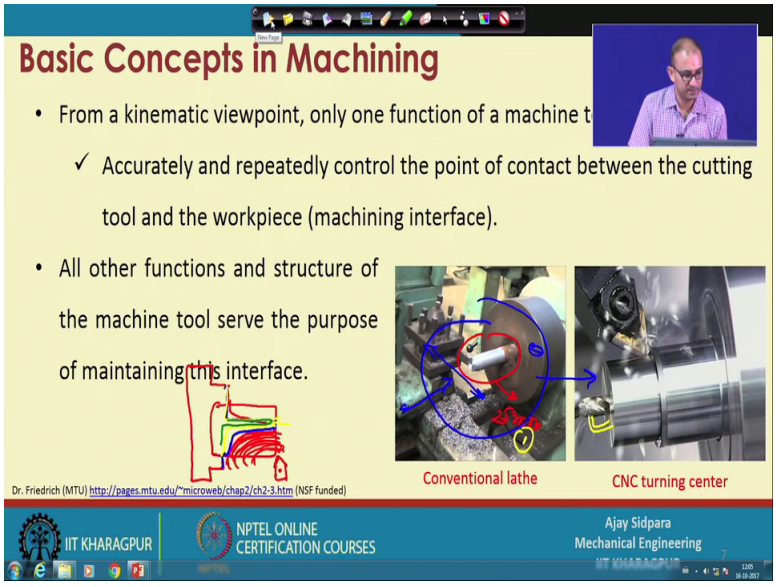

So, let us continue this particular topic. Now, if you, we have seen the machine tool is actually the kinematic joint between the different type of elements and finally, all joints will move with respect to each other and you can get the machining done in this case. So, what is the function in terms of kinematic point of view of this machine tool? That, accurately and repeatedly control the movement of this particular contact between that cutting tool and the workplace that is called the machining interface.

Now, if you see this particular slide. Now, this is the conventional lathe operation that is the turning operation. Now, here if you see when the tool is contacting the work piece

surface so that is called the machining interface, so this is the machining interface. Now, how accurately it is and repeatedly it is controlling this point. Now, see this particular carriage will move in this direction, this is in rotation and it is in physical contact. So, you will get some forces from the work piece to the tool and tool to the work piece. So, in that case under these forces how much is the movement of this particular slide in the straight line, so that particular things will decide that how much what is the function of this particular kinematic joint. So, what are the kinematic joints? So, if you see here, if you see this particular joint. So, here, this is the first joint. So, it is the interface between the tool holder and the cutting tool and then it is going in this direction, then it is moving on the carriage from the tool for work piece part. So, it this work piece to the chalk and then chalk to the spindle. So, in this way these are the old joints which was considered as a kinematic points. So, all points should perform their work very efficient to make this operation happen in this case.

Now, this is the same operation turning operation, but it is perform under the turning center. So, this is the CNC operation. So, now, how these things are different? Now, if you see here the accuracy of this moment in the z direction and this is in x direction. This everything will depend on how much is the accuracy of the guide ways. In this particular case now, it is a CNC machine. So, gripping will be very very accurate compared to this part. So, this is the gripping of the work piece in the truck and that will be much convenient and it will be more perfect compared to this operation. So, you have seen the what is the difference that, in this particular CNC machine it is very easy to get the required dimension as well as the required tolerance compared to the conventional machining process because here the operation will be taken care by the machine interface that is called the programmable interface where you operator does not need to do any type of operation manually. So, you have to feed the program and then this particular interface will take place according to the motion in terms of g and m code.

Now, all other function and the structure of the machine tools serve the purpose of maintaining this interface. Now, if you see this particular thing our objective is to maintain this interface for a continuous duration, so that you can get the required dimension on to the surface. Now, to maintaining this thing what will happen this structure of the machine tools; that means, all this linkage whatever is there, so those

linkage should perfectly perform all the operation without any type of deviation then only it is possible to move ahead in this case.

Now, how this operation is different in this case? Now, consider that this particular shaft diameter is considered there 25 mm and you want to reduce to the smallest component. Now, if you start continuously reducing. Now, suppose this is the diameter and then this is our tool which is used for machining of this part and then you are gradually reducing the diameter and then we want to see that at which location you are not able to reduce the diameter for that. So, now, that will decide by the structure of this particular lathe machine that what is the precision of this machine because ultimately you are going to cut material slowly slowly in this direction and at the end you are end up with the particular material which will be something like this.

Now, once you reach to this location why you are not able to reduce this further, that will be decided by many parameters one is the cutting tool geometry, another is the RPM of this particular spindle and then what is the rigidity of this particular x and y slides. So, those things will make it very difficult to reduce it further. Then it is, if it is not possible a let us move to this particular path. So, now, once you reach to this particular machine. Now, there is a chance that you can reduce it to for little bit more. So, now, suppose you are reaching to this particular location. So, now, that means, if you are reducing further; that means, this machine is more precise than this one. Now, you are reaching to because here many things are very very straight forward in terms of the x axis, y axis in the movement because the precision and the linear angular all the motions are very very strictly controlled in this case you can get this part.

Now, suppose we want to further reduce it. Now, we want to go to a very very small dimension then this machine will also fail. So, we have to go to one and the micro machining center where the precision of the machine components and the different type of other compliance mechanisms will play important role in the fabrication of this component. So, ultimately there is a limit of all the processes all the machine, but we will say the how far we can reduce the size of the component in the different parts.

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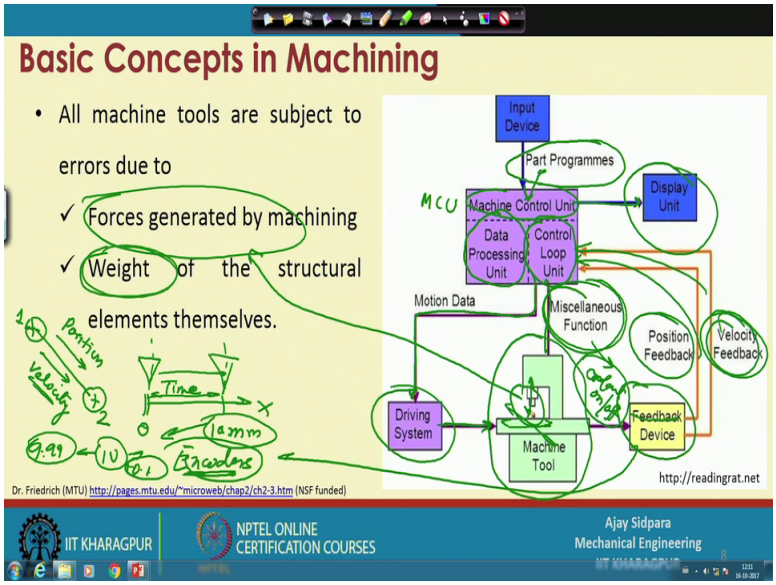

Because now you have seen that when it is interacting with the work piece, so there are different type of force occurs. So, these forces are generated by the machine and then there are the weight of the structure element also, because if you are making a small component even micron size error will be enough to destroy the geometry was over the required dimension of the components. So, you have to consider each and every aspects which you are actually ignoring when you are machining at the micro scale. So, temperature is there, vibration is another on the scale, the aging of the component you have to calibrate your machine continuously may be after every month after every 6 month, 100 percent. So, these things will create a problem.

So, now this particular diagram is showing that this is the machine tool. Now, if you are talking about the CNC machine; that means, everything is done by the part program. So, manually you are not operating the machine you write a part program and then part program is fade into the machine control unit that is called MCU and here you are doing a data processing; that means, it will execute this program and there is the control loop units. So, execution of program; that means, it will going all this motion to the motion data because ultimately how you perform the operation in the milling machine that your x y and z axis are moving with respect to each other and your tool is in contact with the surface and then it is removing, it is giving depth of cut then feed motion RPM is also there, so you are getting different type of motion. So, motion is done by the drive system.

So, drive system will rotate the tool it will rotate, it will translate the x and y motion as well as the movement of the z axis, once this thing is done then you will get the different type of geometry done, and control unit will give you miscellaneous functional also. What are this miscellaneous function? That is the coolant related on and off and some spindle on spindle off. So, these are clockwise direction anticlockwise direction. So, those are called the miscellaneous function that is also given by the tool. So, once this thing is done; that means, suppose you want to move one component or the x axis suppose this is the x axis this is your 0 position and you want to move to 10 millimeter and your tool location is here suppose this is the tool location and you want to know this tool location to here.

So, your drive will drive this particular x axis to the 10 millimeter. Now, you have to also make sure that is actually moving to the 10 millimeter. Now, how to make sure that thing; that means, we need one feedback device. So, this feedback devices are mostly the encoders. We will discuss more about this thing in detail, but this encoder will give you the actual position of this because everything is if you do not use encoder or feedback this is called the open loop control, because you are not getting any feedback from the system. So, this feedback will tell you that when you are going from 1 to 10 millimeter it is actually moving 10 millimeter or it is moving 9.99 or it is moving 10.1. So, it will tell you exact motion of that part and that feedback is given by two way.

Now, if you see you want to move this is the 0.1 and this is the 0.2. So, one is the position; that means, from here to here it is called position and how fast you are going that is called velocity. So, it has two control, one is the position feedback that whether it is moving from here to here 10 millimeter or 9.99 or 10.1, that is given by the position another thing is the velocity feedback, how much time it is required. So, this is called time.

So, how much is time required to move from 0 to 10 millimeter that is given by the velocity feedback. So, both this thing will go into the control unit and then it will tell you that machine organic control. So, this is in closed loop. So, whether it is a 9.99 or 10 and then it will give that feed back to the machine then it will correct this position, whether it is a translation motion or the rotation motion, and then everything will be displayed in to the display unit that is your computer screen of the machine tool. So, now, if you see all these thing. So, forces are generated at this particular location this is the 4th generation.

And then weight of the structure; that means, each and every machine has the limitation of the weight how much weight you can put on to the machine, because ultimately there is a limit of the weight of the weight bearing capacity of the machine. If you are talking about micro machining part then what happened the size of the component may be very very small and the axis which you want to use for moving in x y direction or the z direction it has very limited trance travel distance because in mostly the micromachining you do not do machining at a large component there is limit on the so obviously, there is a size limit or the travel distance is very small compared to the big machines. So, this weight also plays important role in this case if you are putting 10 kg of weight on to the micro machining center your bed itself may deform at a micro scale and that will create a problem in the later stage.

So, now before going into the machine mechanics and means how processor different from micro and macro scale, first let us see what are the different applications of the mechanical micromachining. We are not going to cover the application of electro discharge machining, electrochemical machining or laser beam, iron beam or the electron beam because those processes are not fitting in this particular. So, these application will give a sense that why we are going in this direction because this particular technology that is called micro mechanical machining, it is come up, it is taking very high phase in the last since last decades only or because earlier because this was the domain of the this advanced machining processes. But there are some particular disadvantage of each and every advanced machining processes and those processes require some additional skill this is not like routinely operating of this particular milling machine, drilling machine or the lathe machine.

So, if you convert those machines into the micro machining it is one advantage that you are familiar with the machine, because we know what is the milling machine, what is the drilling machine and what is the lathe machine. So, in that case conversion with the machine is very easy in that case. But only problem in this case that you have to understand that machine in a different concept because now, you are not making a big component, but you are making a small component. So, we let us see some example that where this particular micro mechanical machining processes are used to making different type of components.

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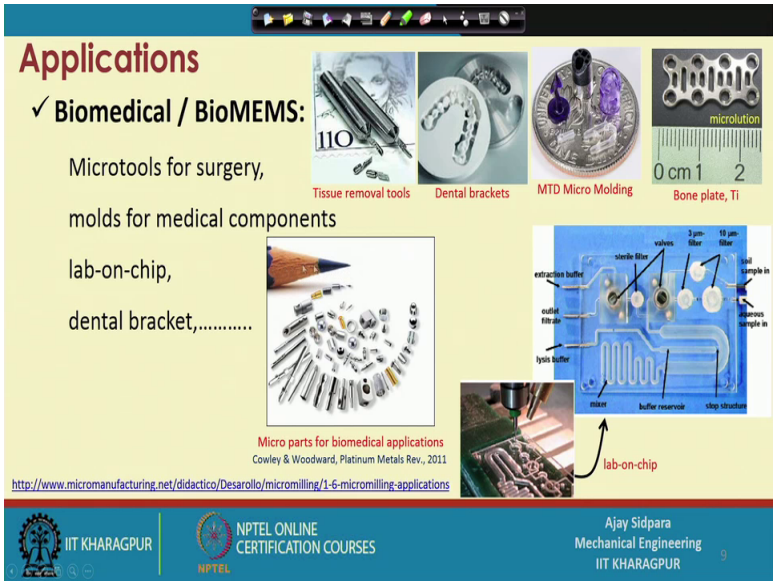

So, first one let us go with the biomedical or biomems. Now, see there are different type of surgery tools available. So, this surgery tools are very very sharp and very very fine, that fine means in terms of dimensions because we know that if you want to do one cut in our body and if you use a very very dull or the non sharp knife or something it will give lot of pain and the loss of the blood. But if you use a very very small and very sharp knife then it is very easy to give a cut without going in to much pain. So, smaller the tool it will be better for the doctor as well as for the patient.

Then the mold for the medical component because if you see the different type of small small components which are used for joining of the different components. So, if you see this particular part then you can see that here there are 4 or 5 different type of plastic components available which are used for clumping or some type of supporting element for other components then lab on a chip because. Now, if you have seen that for the measurement or testing of different type of blood sample or urine sample or some other liquid sample there are some point of care devices available. So, what are this point of care devices? That means you can diagnose what take do the testing right near the patient, you do not need to transfer the location of the samples to the laboratory or some other location. So, this is one of that example.

Now, if you see here this is the particular operation which is being done to fabricate this particular a micro lab on a chip example. So, now if you see here these are the two inputs

available soil inputs and aqueous input then these are the filters available you can see the 3 micron filters, so some very small amount of parts available at this is 10 micron then your sample will move in this direction this are the walls.

Now, consider lab on chip; that means, the size of this particular thing is similar to the credit card or the debit card. So, size is very very small. So, you can imagine that how to machine this particular component to make this thing done. So, this is the micro anvil cutter is used to cut all this particular features and you can see that these are the different buffer available extraction buffer; that means, once it is processing through all this there will be outlet and you can get the required result done here in this case. So, this is the mixing chamber, this both things will go here and then you it will do mixing and depending on the mixing time it will give some type of analysis at the end. So, you have to mix some two different type of chemical one is the our body fluid and some other chemical mixing rate mixing time will tell you the what is the problem in that sample.

So, these are the example related to the medical and bio medical field, but there are these are, but you will get lot of different type of example later also, but everything cannot be covered here. And this is the component you have seen that these are the very very small component all things are bio medical and compared to this you can see the what are the size of this thing. And mostly these things are done by the different type of micro turning operation that is Swiss lathe mostly it is done, earlier that was used for fabrication of the watch component that is why it is good Swiss component Swiss lathe and Swiss (Refer Time: 20:19). And this component you can see the dimensions how are they.

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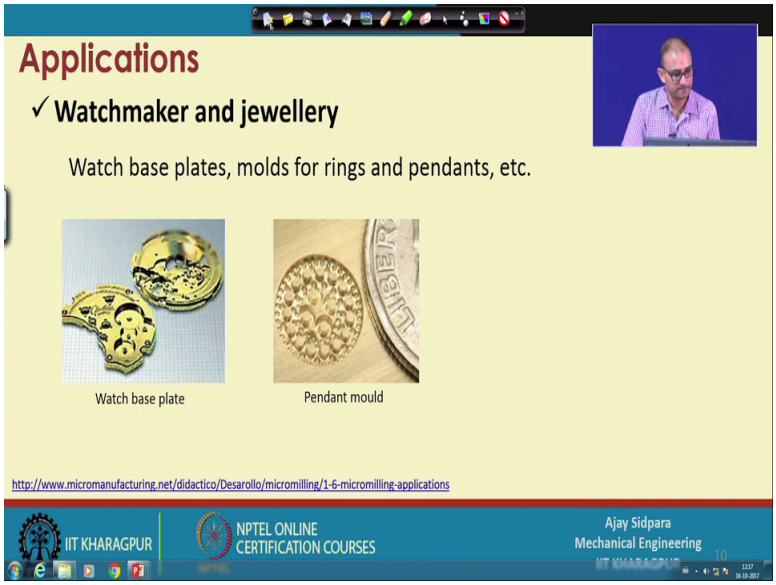

Then watch making and jewelers watch make. So, these are the two major applications. So, watch base plate is the very old age application because watches are available since the long time and you have seen that these are the different type of compound.

Now, you can see that this is the very small amount of projects available these are the kvt's available and then you have to drill very small small hole to incorporate the small amount of gears and some other mechanism. So, how to do all this things? So, this is the very old age example of the micro milling and the micro turning operation. And we have different type of ornaments and some type of jewelries where very fine amount of patterns and designs available. So, for that you always need a mould. So, this moulding is mostly done by this micro moulding nowadays, earlier it was done by the other processes advanced machining processes. So, this moulds served. So, you pour this precious metal in a molten stage and then it will be coming out as mould and you can use it for further usage.

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Then automotive application. So, now, we have seen the injection nozzles available. So, now, this is the injection nozzle for diesel engine. Now, there are small small holes available. So, if you have many holes at different different location spraying will be very uniform in all the direction. So, in that case you can get homogenous combustion inside the diesel. Now, this is the mould making. So, you have to make small small mould for the EDM operation also because if you want use electro discharge machining at micro scale then first you have to make to let micro scale. So, now for making the tool again you have to go with the micro ed micro milling operation or the micro turning operation, so that you can make the micro cutting tools, so that is also one application.

And now, if you have seen that our car that if car is mostly to be have a lot of sensor air bag is also, there you can measure the temperature inside the car outside the car also, it has different type of climate condition you can measure the pressure also if your car. Then there are a lot of different things available here if you have seen that these are the different sensor micro machine accelerometer is there, then micro nose cancellation is there, air bag is there from all the sides fuel sensor is there, how much fuel, fuel is available in your car and how much kilometer it will run. So, it is also coming giving as the distance to go. Then crash sensor is there exhaust gas sensor, then the pressure sensor is available. So, now, you have seen the car aerospace and a medical application has two limitation, one is that you cannot put so much of component in terms of volume and the weight also. So, volume or consider size and the weight are the two very restrictive

requirement of this particular aviation, auto mobile or the medical field because smaller is better in terms of weight and the size.

So, now, to put all these thing into the card then what you have to create, you have make a very small component because if you make big component the compatibility of the passenger inside the car will be reduced because you have to create a small small amount of part and the design should be also very lucrative. So, those things is only possible when you miniaturize all this sensors and the actuators which will be used in the car for comfort.

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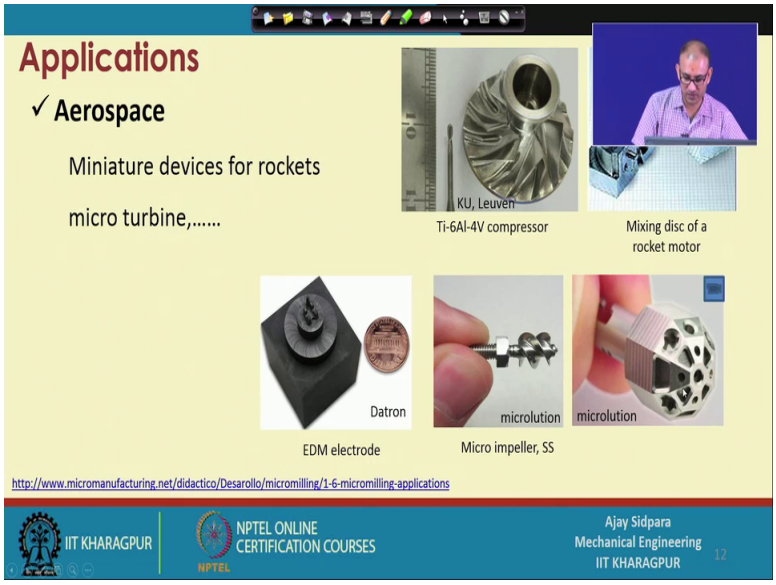

Another example is the aerospace example. Now, if you say miniaturize rocket devices then micro turbines. So, this is the one mixing disc for the rocket, rocket motors. So, where the size is not given, but this is hardly 10, 1 centimeter to 2 centimeter. So, in this particular case you can create a very small amount of features and that features is very difficult to fabricate by the other processes. So, here advantage of micro milling and micro turning is very high.

Now, if you see with respect to this dimension this is the micro compressor. Now, this particular dimension is 2 centimeter. So, the whole thing is within 2 centimeter and everywhere you have seen this particular curvature. So, this are called the free from surfaces and it is to be difficult to make on a conventional machine soyou have to go with the 5 axis milling machine 3 axis will not create this type of features then EDM

electrodes available. So, you have to create this EDM electrodes on the graphite material and you can get the things done for the later machining on the EDM.

Now, this is the micro impeller, if you see the size, its size is very very small in this case and here you have to use 4th axis of the milling machine or the other machine, so that you can get the curvature on this particular. So, you can get the helix angle.

Another example of a particular component is a very very small amount of features on this particular component and you can see that this is holding in our head. So, this is difficult to fabricate in this case. So, let me show you this particular video because we have one video which will be easy to explain all the thing.

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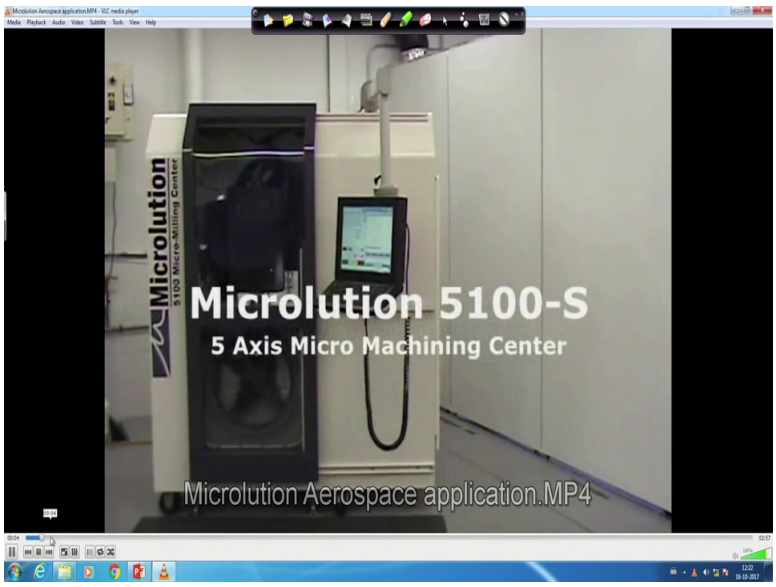

So, this is the 5 axis machining center.

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Now, see what things you need in this case how this machines are different compared to the conventional CNC machine. So, these are material base material is granite material. So, mostly we use the cast iron or some other material with a high damping capacity, but here the damping coefficient is very very damping coefficient is very very damping efficiency is very high, so force will not be transferred to the other components. So, natural granite is used. Tool is available, tool carousel; that means, the tool changer is available rotary axes, linear axes available in this direction.

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So, this is the size of the machine (Refer Time: 26:30), size is also comparatively small compared to the other part.

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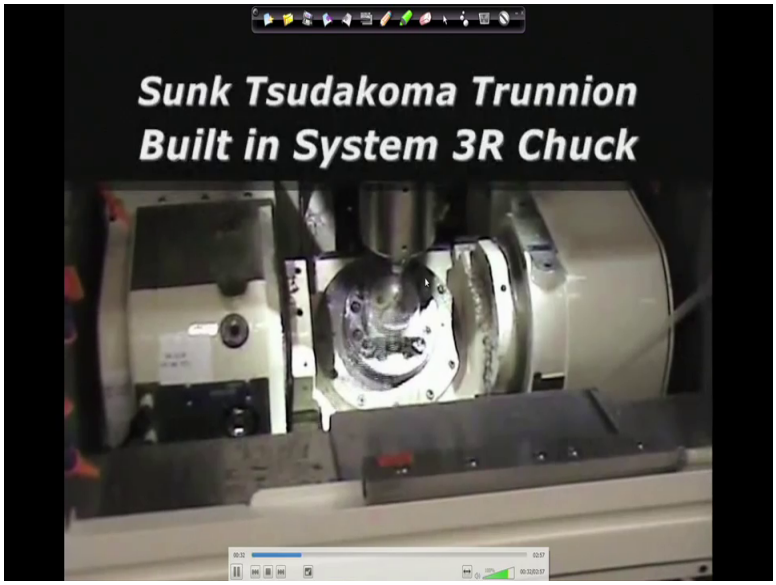

Now, this is that component which is we have seen in the earlier slide.

Now, see this is the z axis and this is the x axis and in this direction is y axis. Now, all component it is rotating around the x axis. So, this is called a axis. Now, we will see this, how they are making. Now, these are the small small features which has being created on the periphery of this component.

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So, this is the true 5 axis. Now, this, whatever is rotation, this rotation is actually along the z axis, but it is inclines, so we are not looking at the z axis, but if it is exactly per perpendicular to this table perpendicular to z axis then you can see that this rotation is along the z axis. So, this is called c axis.

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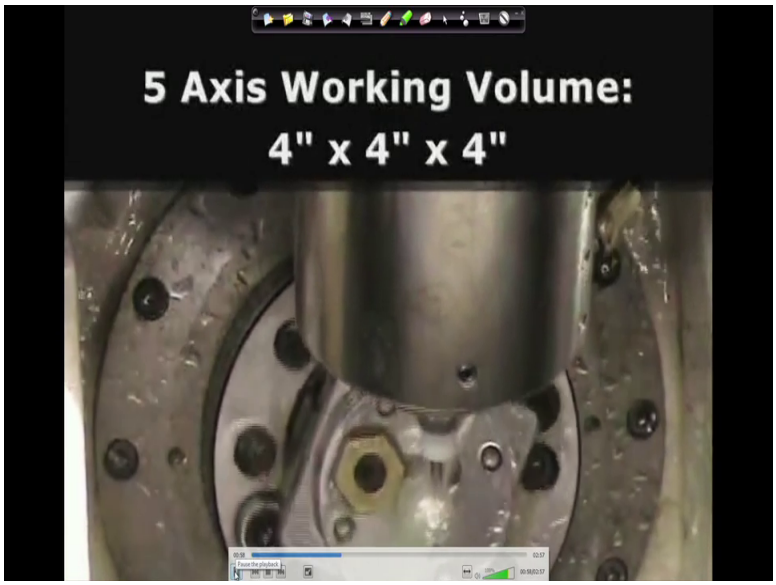

So, it is a continuous 360 degree and now, it is moving in the x in the rotation around the x is the rotation around the z axis.

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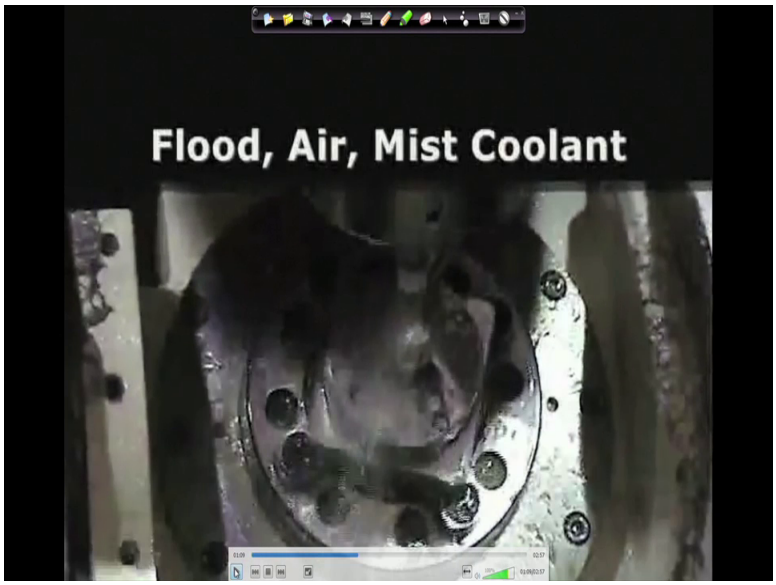

So, now what is the advantage of this thing? That if you have 5 axis machining center then you do not need to relocate the work piece, otherwise at the end what happens is once one operation is over you have to relocate the work piece or remount the work piece in other directions, so that other phase come into the contact with the tool. But 5 axis machining center will reduce this type of changing of this part and it will reduce the time requirement for the production of this. Only problem of this part that a program will be very very complex and you have to relocate this thing many times, so that finally, once you confirm the program is then only you can fade to the these particular machine and you can so the remaining part.

Now, this is the true 5 axis machining center and it is giving all the required geometry on the surface and RPM is very very high, we will discuss about why we need very higher RPM in micro machining at the later stage.

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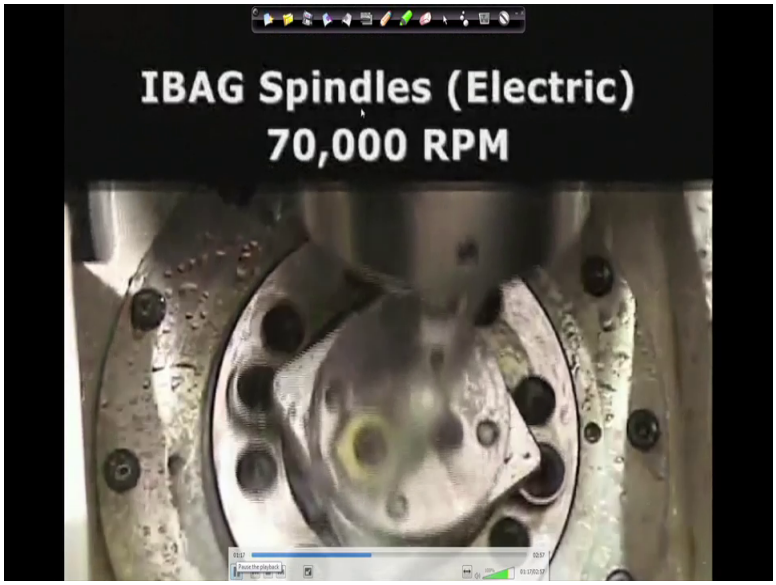

And now, this is the drilling from the top surface and this is the automatic tool changer you can change the tool also because many time what happens the same tool is not used for the all the operation, so you have to change the tool also.

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Again the tool and compensation is a problem other tool have many be have different type of length then everything will be consider were calculated before it is mounted on this part.

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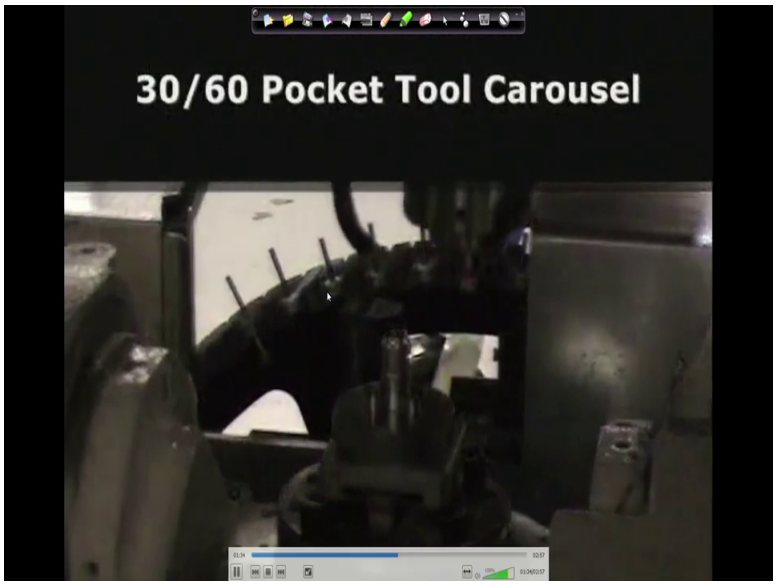

So, now this is automatic tool changer, tool is moved from one location and the tool is picked up by the by the spindle and then it is done by that.

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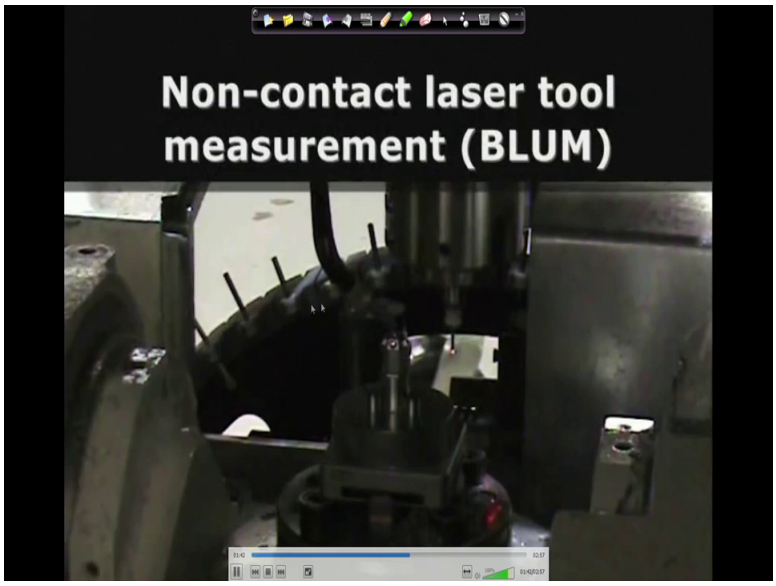

So, now, once the operation is over now, you have to confirm whether it has a required dimension machined or not. So, now, this is the non contact tool measurement sensor. So, this particular sensor will sense and it will measure the dimension of this particular machine or machine component and then once it is confirmed then only it will go to that particular part. So, that thing was done for measurement of the status of the cutting tool.

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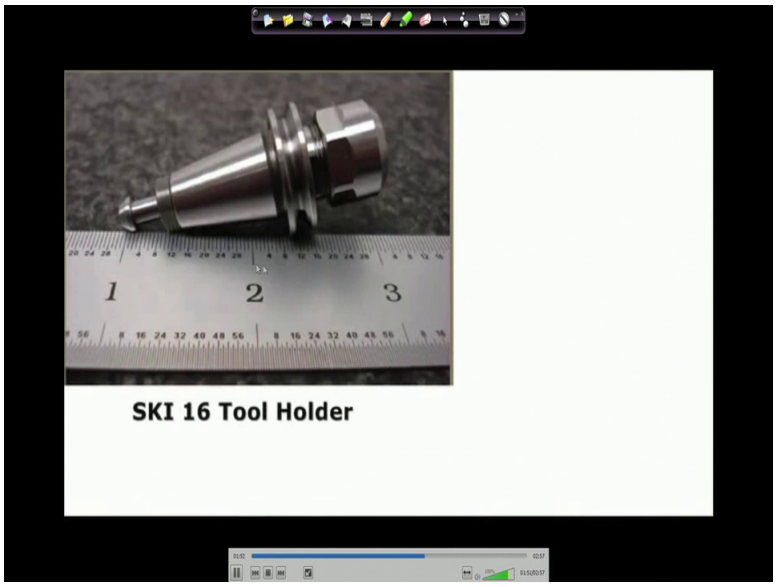

So, once that is done. Now, this is the component which is; this is the tool phase interface it is used for rotating at a 7000 RPM and now, in process measurement and compensation.

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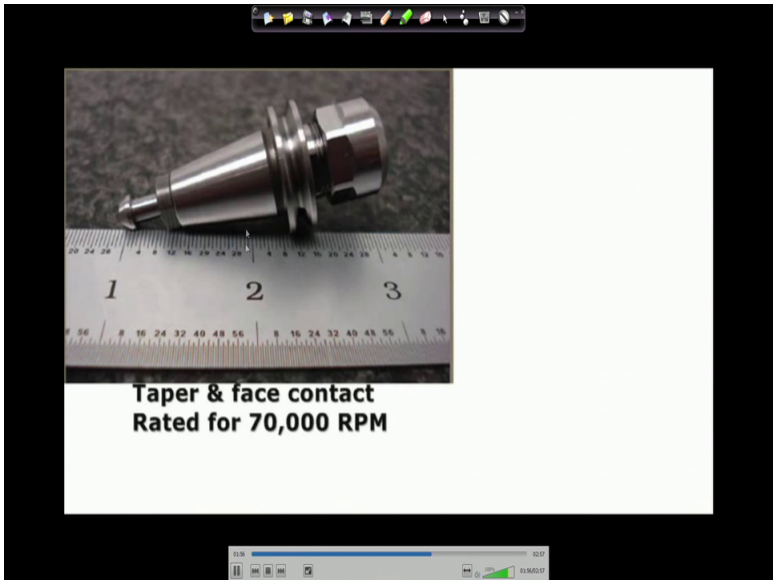

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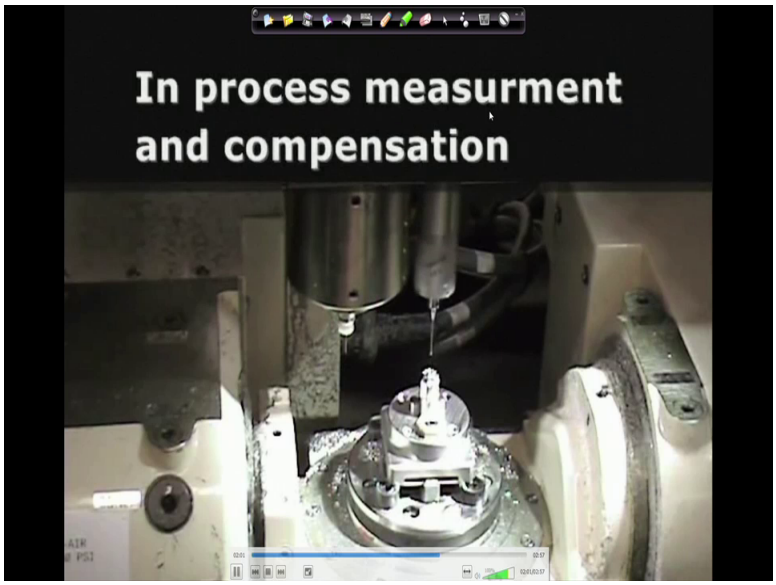

So, this is which is used for measurement of this particular component. Earlier one was used to measurement of the status of the cutting tool. So, it is a laser guided. So, this particular tool will move into that location and laser will confirm the edges and the length and this is used for measurement of the cutting.

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So, this sensor will give you all the dimensions. So, it is moving in other direction in this direction. Find out the what is the radius or the diameter of this part and then it will move. And this movement or the ficturing is also the pneumatic, so that you do not need to press anything very hard on the top it is a pneumatically operate or the vacuum fixture. So, clamping and declamping will be very very easy and convenient without giving any type of extra force. So, this is how this thing works.

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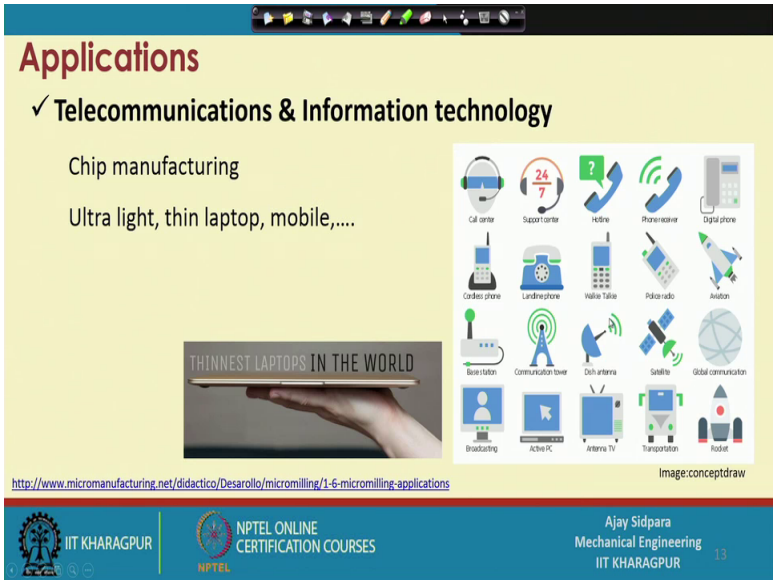

And telecommunication information there are chip manufacturing we have seen, we have also already discussed that what is the size of the laptop and the total components are coming. And these are the different type of related things in telecommunication and information technology because everything you may not see the wires and different type of components which are lying here and there because everything is in compact mode so you can increase the total space requirement as well as the efficiency of the component.

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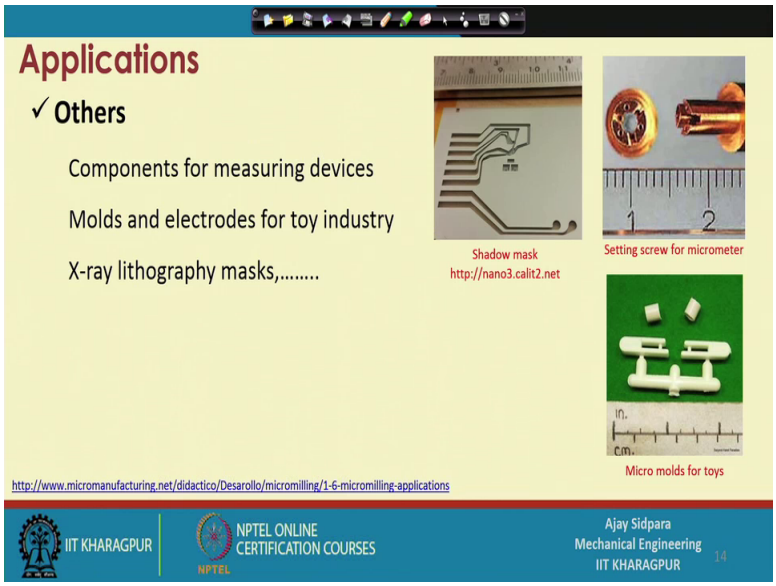

Then other applications are the components for measurement of devices, mold or electrode. So, this is the lithography mass, so lithography all together different operation which is used for fabrication of micro components itching and deposition. But for that you need a mask and the mask is fabricated by the micro milling operation these are the different settings tool for micro meter related to the measurement devices, and micro mold for toys and small small thing you have seen that micro screws and different joints in the small toys, this most of the things are made by micro milling operations.

So, let me finish this class here itself and from next class we will go with the classification of the micro machining operation and compared to the other domain of the parts.

Thank you very much.